REVISION 1

FOUNDATION INVESTIGATION AND DESIGN REPORT

MAGNETAWAN RIVER NORTH CROSSING, SBL

HIGHWAY 11, HIGHWAY 518 WEST to HIGHWAY 520

G.W.P. 480-93-00, W.P. 478-93-01, SITE 44-396S

Geocres Number: 31E-213

Report to

Marshall Macklin Monaghan

Thurber Engineering Ltd.
2010 Winston Park Drive, Suite 103
Oakville, Ontario
L6H 5R7
Phone: (905) 829 8666
Fax: (905) 829 1166

October 5, 2005
File: 19-1423-16
AEG\C:\Projects\19\1423\16 Hwy 11 Katrine\Bridges\Mag North\Mag N -
SBL\Mag Riv SBL FIDR UPDATED.doc

TABLE OF CONTENTS

THURBER

Appendices

THURBER

REVISION 1
FOUNDATION INVESTIGATION AND DESIGN REPORT
MAGNETAWAN RIVER NORTH CROSSING, SBL
HIGHWAY 11, HIGHWAY 518 WEST to HIGHWAY 520
G.W.P. 480-93-00, W.P. 478-93-01, SITE 44-396S

Geocres Number: 31E-213

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 the South Bound Lanes of the realigned Highway 11 over the Magnetawan River at the village of Katrine, Ontario. A previous, preliminary investigation had been carried out in the vicinity of the south abutment 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 bridge and the stability of the river banks.

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 lies across the Magnetawan River at a location where it is proposed that Highway 11 will cross the river. The site lies in the Village of Katrine, Armour Township, approximate 160 m east of existing Highway 11 and 220 m north of Three Mile lake Road.

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 glacio-fluvial and glacio-lacustrine soils.

The river has a broad, poorly defined flood plain at the site. The river channel is approximately 45 m wide and the maximum channel depth, based on May 2003 data, is 6 m. The river banks are low and no global stability problems were observed.

THURBER

The area immediately to the south of the river is occupied by a seasonal campground. The active portion of the campground, nearer to the river, is open and grassy while closer to Three Mile Lake Road the ground is covered by bushes and scrubby trees. Some permanent buildings related to the campground are located close to the site.

To the north of the river, the land is wooded. It is low-lying and wet near the river but rises to the north. There is one residential building approximately 500 m north of the river crossing.

3 SITE INVESTIGATION AND FIELD TESTING

Thurber carried out site investigation and field testing for this project on the north bank of the Magnetawan River between November 18 and December 8, 2003. Investigation was carried out on the south bank between March 6 and March 9, 2001, as part of the preliminary investigation by Shaheen & Peaker Limited.

The current site investigation consisted of drilling and sampling two boreholes (Boreholes 396S-1 and 396S-2) to depths of 28.9 and 6.7 m at the north abutment and north approach, respectively. Both boreholes were supplemented by dynamic cone penetration tests. The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix G.

Field layout for the site investigation was carried out by surveyors from Marshall Macklin Monaghan, who provided the coordinates and ground surface elevation data to Thurber.

All-Terrain Drilling supplied and operated the drilling and sampling equipment used for the investigation. A combination of hollow stem auger and rotary drilling techniques were used to advance the boreholes and samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Where bedrock was encountered, it was proved by coring into it for a distance of at least 3 m.

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
North Approach	396S-2
North Abutment	396S-1
South Abutment	MRS 1*, MRS 2*
South Approach	MRS 3*

* 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.

THURBER

A standpipe piezometer, consisting of 19 mm PVC pipe with slotted tips, was installed in the borehole at the north abutment to monitor the groundwater level. Piezometers were installed at the south abutment in the course of the preliminary investigation.

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

Table 3.2 – Piezometer Details

Piezometer Location	Piezometer Details	
	Tip Depth/ Elevation	Completion Details
BH	28.9/265.4	Piezometer with 1.5 m tip installed at bottom of borehole. Sand filter to 23.8, caved soil to 10.1, 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 the results are shown on the Record of Borehole sheets in Appendix A and on the charts in Appendix B. A total of five 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. The bedrock is mantled by sand and gravel containing cobbles and boulders that 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.

THURBER

In general terms, the site was found to be underlain by a thin veneer of topsoil; fill; a layer of sandy silt, silty clay; silty sand, sand and gravel and bedrock.

More detailed descriptions of the individual strata are presented below.

5.2 Topsoil

Topsoil thicknesses were established only at the borehole locations and ranged from 75 to 200 mm.

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

5.3 Fill

Some fill may be encountered overlying the topsoil in the area of the south approach, particularly under the driveways of the campground. Fill encountered in the south approach consisted of gravelly sand.

5.4 Silty Clay

A layer of silty clay was encountered in the S&P borehole at the south approach only. This layer partially replaces the silt encountered elsewhere on the site and is described by S&P as soft to very stiff silty clay.

Grain size distribution test results for this soil are reported on the Record of borehole sheets and are plotted in Fig. No. 1 in Appendix C. Plasticity data from boreholes drilled on the south river bank for other structures, and included in Appendix C, shows that the silty clay in fact lies at the boundary of CL and ML soils.

5.5 Sandy Silt

Below the topsoil, a layer of sandy silt was identified at both abutments and both approaches. This layer is described as silt, sandy, trace clay.

At the south abutment and south approach, the sandy silt extends to depths of 6.7 m (Elevation 288.4) and 7.3 m (Elevation 288.5), respectively. At the north abutment and north approach, the sandy silt extends to depths of 5.7 m (Elevation 288.6) and 2.3 m (Elevation 292.2), respectively.

The sandy silt layer is classified as very loose, based on maximum SPT values of 6 blows for 0.3 m of penetration and several cases where the sampler sank under the weight of the drill rods. The low SPT values recorded in this material are believed to be due, in part, to soil disturbance in the bottom of the borehole.

Natural moisture contents generally ranged from 20 to 30% with some higher values that are attributed to the presence of organic inclusions. The silt is described as wet and it is dark brown to grey in colour and lies mostly below the water table.

THURBER

Grain size distributions for this soil are reported on the Record of Borehole sheets and are plotted in Figure B1 in Appendix B.

5.6 Sand

The sandy silt is underlain by a stratum of fine grained sand that forms the main stratum underlying the site.

At the south abutment, the sand extends to depths of 17.5 to 20.7m (Elevation 277.6 to 274.1). At the south approach, the sand was not fully penetrated but extends the termination depth of the borehole at 9.6 m (Elevation 286.2). At the north abutment, the sand extends to depths of 22.8 to 24.5 m (Elevation 272.1 to 269.8). At the north approach, the sand was not fully penetrated but extends at least to a depth of 6.7 m (Elevation 287.7) and dynamic cone penetration testing indicates that the very loose to compact conditions extend to a depth of 12.2 m (elevation 282.3).

At the south abutment, the sand is described as very loose near the top of the layer, becoming compact with increasing depth. At the north abutment, the sand is described as very loose near the top of the layer, becoming compact then dense with increasing depth.

The measured natural moisture contents ranged from 20 to 30%. The soil is described as grey in colour and wet and lies below the water table.

Grain size distributions for this soil are reported on the Record of Borehole sheets and are plotted in Figures B2 and B3 in Appendix B.

At the north abutment, this sand layer was found to contain cobbles and boulders below Elevation 274. The cobbles and boulders were inferred from the grinding behaviour of the drill string at certain locations and the refusal to penetration of the sampling spoon when SPTs were attempted.

5.7 Gravelly Sand

A layer of gravelly sand was identified underlying the sand at the south abutment. This layer is described as gravel and sand, trace to some silt, with cobbles and boulders.

At the south abutment, the gravelly sand was found to extend to a depth of 21.3 to 22.5 m (Elevation 273.8 to 272.3).

The SPT values in the gravelly sand ranged from 36 to more than 100 blows for 0.3 m of penetration, indicating dense to very dense conditions.

The measured moisture contents generally ranged from 8 to 12%. The soil is described as grey and wet and lies below the water table.

Grain size distributions for this soil are reported on the Record of Borehole sheets and are plotted in Fig. No. 10, both in Appendix B.

THURBER

5.8   Bedrock

The soils described above were found to be underlain by bedrock of the Pre-Cambrian Canadian Shield. The bedrock was proved by coring 3.0 m at the south abutment and 4.4 m at the north abutment.

The rock is described as grey gneiss at the south abutment and as granitic gneiss at the north abutment.

At the south abutment, the core recovery was 100% and RQD values ranged from 100% at the rock surface to values as low as 10% in the lower portion of the core run. At the north abutment, total core recovery, solid core recovery and RQD were all 99 to 100% for the full depth of coring. Based on the RQD values, the rock mass is described as excellent quality at the north abutment and at the top of the rock at the south abutment. A possible poorer quality zone exists within the rock mass at the south abutment. The Fracture Index at the north abutment was generally 0 to 5, except between Elevation 297 and Elevation 296 where a value of greater than 10 was noted.

Based on Point Load Testing, the unconfined compressive strength of the bedrock at the north abutment was estimated to range from 145 MPa to over 158 MPa. Based on these strength values and the classification system given in the Canadian Foundation Engineering Manual, the rock was classified as very strong.

5.9   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 (m) (Elevation)	Material
North Abutment	396S-1	24.5 (269.7)	Bedrock
	396S-3	22.8 (272.1)	
South Abutment	MRS2	21.3 (273.8)	Bedrock
	396S-4	22.5 (272.3)	

THURBER

5.10   Water Levels

The initial and final groundwater depths and elevations are shown in Table 5.2.

Table 5.2 – Groundwater Depths (in metres) and Elevations

Date	South Abutment		North Abutment	
	Depth	Elevation	Depth	Elevation
March 6, 2001	2.3	292.8	-	-
April 1, 2001	0.2	294.9	-	-
January 19, 2005	0.3	294.8	-	-
February 9, 2005	1.3	293.8	-	-
February 17, 2005	-	-	0.4	293.9
February 23, 2005	-	-	+0.2*	294.5

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level will be influenced by the river level and may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

6   MISCELLANEOUS

Surveying of the locations of the boreholes was carried out by staff from Marshall Macklin Monaghan.

The drill rig and sampling equipment used in the investigation were supplied and operated by All-Terrain Drilling of Waterloo, Ontario.

Full time supervision of field activities, including obtaining utility clearances was carried out by Mr. Donald Parent, B.Sc. of Thurber.

Overall supervision of the field program, interpretation of the data and preparation of the report were carried out by Mr. Alastair E. Gorman, P.Eng..

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

Thurber Engineering Ltd.

Alastair E. Gorman, P.Eng., M.Sc.
Senior Foundations Engineer

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

THURBER

REVISION 1

FOUNDATION INVESTIGATION AND DESIGN REPORT

MAGNETAWAN RIVER NORTH CROSSING, SBL

HIGHWAY 11, HIGHWAY 518 WEST to HIGHWAY 520

G.W.P. 480-93-00, W.P. 478-93-01, SITE 44-396S

Geocres Number: 31E-213

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 single-span, 67 m long, welded steel plate girder structure is proposed at this site and integral abutments are under consideration. Both approaches will lie on comparatively flat, low-lying land of the river flood plain. The undersides of the abutment stems will lie approximately 1 to 2 m above the river level.

At the north abutment, the finished grade will be about Elevation 301.4 and the original ground lies at Elevation 294.3±, resulting in an approach fill approximately 7 m high.

At the south abutment, the finished grade will be about Elevation 302.0 and the original ground lies at Elevation 295.1 ±, resulting in an approach fill approximately 7 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 from a foundations perspective is recommended.

Based on the results of the exploratory boreholes drilled at the proposed abutment locations, the stratigraphy consists of approximately 18 m of generally very loose to compact sandy silt and sand overlying dense to very dense gravelly sand with cobbles and boulders followed by bedrock.

THURBER

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.

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 a depth of 16 m at the south abutment and 9 m at the north abutment. 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.

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 layer of sand containing cobbles and boulders lying immediate above the bedrock. In some cases, a pile may penetrate this layer without being obstructed by boulders and will meet refusal on the bedrock.

The piles should be designed on the basis of the axial geotechnical resistances given in Table 7.2.

THURBER

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 | |
			N. Abutment	S. Abutment
HP 310 X 110	1,800 kN	1,600 kN	273	276 to 274
HP 360 X 132	2,100 kN	1,800 kN	273	276 to 274
HP 360 X 174	2,200 kN	1,900 kN	273	276 to 274

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 8.2.3 Pile Driving.

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 Pruyn Points 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

- Some piles may fully penetrate the zone of cobbles and boulders and achieve refusal on the bedrock.

- In the case of partial bearing on bedrock, the cast steel point will provide better stress redistribution without failure than would be achieves in a pile tip reinforced with a driving shoe.

8.2.2   Pile Installation

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

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

- The presence of cobbles and boulders in the sands just above bedrock.

- 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.

THURBER

- The possibility that some piles may fully penetrate the zone of cobbles and boulders and achieve refusal on the bedrock.

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 Driving

Pile driving should be controlled by the Hiley Formula and an ultimate pile resistance to be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The Hiley formula need not be used until the piles are approaching the bearing stratum below Elevation 277. 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 310X110	3,600 kN
HP360X132	4,200 kN
HP 360X174	4,400 kN

The Contractor should be alerted to the fact that the piles may penetrate through the cobble and boulder layer and may contact the bedrock. If this happens, the Hiley formula is not applicable and a site decision must be made that bedrock has been encountered and that further pile driving must be controlled to adequately seat the pile in the bedrock without overdriving and damaging the pile. A suitable criterion for deciding that bedrock has been contacted is: 10 blows at full energy for 12 mm penetration, for two consecutive sets of 10 blows. The geotechnical resistances given in Table 7.2 remain valid in this situation.

8.2.4   Downdrag

The soils at the abutments are 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 and post-construction downdrag on the piles is 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 underside of the abutment and from the forward slope back sufficiently far to allow for the access and operation of construction equipment. Beyond that distance, the embankment should be constructed to full height.

THURBER

8.2.5   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:

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

$$p_{ult} = 3 \cdot \gamma \cdot z \cdot K_p \qquad (kPa)$$

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

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

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

Table 8.3 – Parameters for Lateral Pile Resistance

Location	Elevation	n_h (kN/m^3)	Unit Weight (kN/m^3)
South Abutment	OGL to 288	1,000	19
	288 to 279	1,200	19
	279 to 277	4,000	20
	277 to 274	6,000	20
North Abutment	OGL to 288	1,000	19
	288 to 285	1,200	19
	285 to 280	4,000	20
	280 to 275	5,000	20
	275 to 270	6,000	20

The total horizontal passive resistance of a single pile should not exceed the value shown in Table 8.4.

THURBER

Table 8.4 – Maximum Horizontal Passive Resistance of Piles

Pile	Maximum Passive Resistance	
	Factored ULS	SLS
HP 310X110	120 kN	50 kN
HP360X132	160 kN	60 kN
HP360X174	160 kN	60 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

Intermediate values may be obtained by linear interpolation.

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

8.3   Caissons

The soil conditions, and more particularly the 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 on bedrock, or possibly in very dense gravelly sand.

When attempting to found on bedrock, there could be difficulties sealing the liner to allow unwatering of the caisson and placement of concrete in the dry.

In the case of caissons founded in the very dense gravelly sand, it would be impossible to achieve a seal and slurry excavation and tremie concreting would be necessary.

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.

THURBER

8.4   Recommended Foundation

The recommended foundation system for both abutments at this site is steel H-piles driven to effective 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 posses flexibility in the upper 3 m of the pile length. At this site, the upper 3 m of the pile length will lie in very loose sandy silt which, in its original state, would provide sufficient flexibility. However, if the upper 3 m of the piles lies in compacted fill or if the native soil became compacted by the construction processes, 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 one of the following systems:

- For a "true abutment" supported on top of the piles - a 600 mm diameter CSP filled with sand, or

- For "false abutment" - concentric CSPs in accordance with standard integral abutment design procedures.

The sand must be placed in the CSP after the pile has been driven to avoid the danger of the sand being densified by pile driving.

Backfill sand should meet the gradation shown in Table 7.3.

Table 7.3 – Integral Abutment Sand Grading

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

THURBER

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, with 25 mm of rigid, extruded polystyrene insulation being equivalent to 600 mm of earth cover. Synthetic insulation must be covered to provide protection where it is used.

The forward slope for the structure must be constructed of rock fill to satisfy the assumptions made in the stability analysis. Frost penetrates deeper through rock fill than through earth fill and there is a possibility of freezing conditions developing below the pile cap.

At this site, it is considered acceptable to construct the forward slope of rock fill provided that the pile driving pad within the rock fill is specified to consist of free-draining, non-frost susceptible material. Granular fill specified to have less than 5% particles by mass finer than 75 μm is considered to be a suitable material.

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 to a level below the deepest excavation level sufficient 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 consideration may have to be given to excavating inside a cofferdam. The design of the cofferdam is the responsibility of the Contractor. The Contract Documents should alert him to the requirement to maintain a stable excavation and to the fact that any shoring system should be designed by a specialist, taking account of the need to control groundwater and prevent basal instability within the excavation.

THURBER

10   UNWATERING

Based on the preliminary GA for the bridge structure, it is not expected that work at the abutments will require excavation below the groundwater level. However, the Contractor should be prepared to pump from sumps to remove any seepage water or surface water collecting in an excavation.

The design of the dewatering system that may be required should be 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.

The design of the dewatering system should be coordinated with the design of the sheet-pile cofferdam, where required.

11   APPROACH EMBANKMENTS

The global and internal stability of the approach embankments was analyzed for both the side slopes and the forward slope. The required minimum setback of the abutments from the river has been determined on the basis of the results of the stability analysis of the forward slope.

11.1   South Approach Forward Slope

The computer output for the stability analysis of the south approach forward slope is shown in Figure F1 in Appendix F.

Various conditions were analysed to select an appropriate setback from the river's edge. Based on these analyses, it has been determined that:

- The immediate approach fill and forward slope must be constructed of rock fill, at a maximum slope of 1.25H:1V.

- The minimum recommended distance from the bearing centreline to the edge of the river is 8.5 m, for a minimum factor of safety of 1.5

The edge of the river has been defined, for the purpose of this analysis as the edge of water when the river level is at Elevation 294.1.

11.2   South Approach Lateral Stability

The global and internal stability of the approach embankment side slopes was analysed on the basis of a rock fill embankment, as determined in Section 10.1.

The computer output for the stability analysis of the south approach side slope is shown in Figure F2 in Appendix F. This analysis shows that a 1.25H:1V side slope constructed of rock fill has a factor of safety of 1.9 against failure.

THURBER

11.3   North Approach Forward Slope

The computer output for the stability analysis of the north approach forward slope is shown in Figure F3 in Appendix F.

Various conditions were analysed to select an appropriate setback from the river's edge. Based on these analyses, it has been determined that:

- The immediate approach fill and forward slope must be constructed of rock fill, at a maximum slope of 1.25H:1V.

- The minimum recommended distance from the bearing centreline to the edge of the river is 6.0 m, for a minimum factor of safety of 1.5

The edge of the river has been defined, for the purpose of this analysis as the edge of water when the river level is at Elevation 294.1.

11.4   North Approach Lateral Stability

The global and internal stability of the approach embankment side slopes was analysed on the basis of a rock fill embankment, as determined in Section 10.1.

The computer output for the stability analysis of the north approach side slope is shown in Figure F4 in Appendix F. This analysis shows that a 1.25H:1V side slope constructed of rock fill has a factor of safety of 1.9 against failure.

11.5   Settlement

The soils 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 175 mm.

11.6   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 14 Seismic Considerations.

11.7   Forward Slope Protection

The analysis of the forward slopes and the resulting recommendations are based on:

- The river channel remaining in its present location

- The forward slope being constructed of rock fill.

From a foundations perspective, no further protection of the forward slope is required. However, other factors may have to be considered and if the hydraulic analysis indicates

THURBER

that scour can occur at the river edge then the rock fill must be embedded into the river bank to a depth equal to the maximum scour depth.

11.8   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 included 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". The foundation soils are not considered suitable for the support of "High Performance" walls and this option is not recommended for retaining structures at this site.

13   BACKFILL TO ABUTMENTS

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

In the case of a conventional abutment, granular backfill is recommended but rock backfill can be permitted. 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.

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 OPSS 501.06.

THURBER

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 below)

γ = unit weight of retained soil (see table below)

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

q = value of any surcharge (kPa)

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

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

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall. In the case of integral abutments, material with a lower passive pressure coefficient (e.g. Granular B Type I) might be preferred as it results in lower forces acting on the ballast wall as the wall moves toward the soil mass.

The factors in Table 14.1 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.

THURBER

Table 14.1 – Earth Pressure Coefficient (K)

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°$, $\gamma = 22.8$ kN/m³		OPSS Granular B Type I $\phi = 32°$, $\gamma = 21.2$ kN/m³		Rock Fill (Limited to 300 mm size) $\phi = 42°$, $\gamma = 19$ kN/m³	
	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.

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.

THURBER

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.

In calculating the values of (K_{AE}) and (K_{PE}), the following geotechnical parameters were used:

ϕ = 35° for OPSS Granular A or Granular B Type II

ϕ = 32° for OPSS Granular B Type I

ϕ = 42° for rock fill

δ = 50% of ϕ

Where ϕ = the angle of internal friction of the backfill and δ = the angle of friction between the wall and the backfill.

The seismic earth pressure coefficients to be used in design at this site are shown in Table 14.1 at the end of the text.

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 or bedrock. 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.

---

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

THURBER

- The potential variability of pile lengths at refusal.

- The nature of the fill used to construct the approach fills. Certain recommendations in the report regarding stability and the set back from the river's edge are based on construction with rock fill. If other material is substituted, these recommendations are no longer valid.

- Excavation and unwatering close to the river.

17   CLOSURE

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

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

Thurber Engineering Ltd.

Alastair E. Gorman, P.Eng., M.Sc.
Senior Foundations Engineer

Report reviewed by:
P.K. Chatterji, P.Eng., Ph.D.
Review Principal

Table 15.1

Earth pressure Coefficients for Seismic Design

Condition	Earth Pressure Coefficient (K) for Earthquake Loading					
	Granular A or Granular B Type II $\phi = 35°$, $\delta = 17°$		OPSS Granular B Type I $\phi = 32°$, $\delta = 16°$		Rock Fill $\phi = 42°$, $\delta = 21°$	
	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})*	0.28	0.46	0.31	0.58	0.21	0.30
Passive (K_{PE})*	7.0	-	5.5	-	14.1	-
At Rest (K_{OE})**	0.53		0.58		0.44	

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

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.
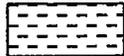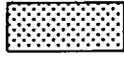
SYMBOLS

Symbol	Material
(hatched)	CLAYSTONE
(dashed)	SILTSTONE
(dotted)	SANDSTONE
(black)	COAL
(cross-hatched)	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

W.P.	478-93-01	LOCATION	N 5048585.9 E 316317.2	Magnetawan River SBL, ST. 12+309.5, CL	ORIGINATED BY	DP
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NW Casing/NQ Core		COMPILED BY	SS
DATUM	Geodetic	DATE	18.11.03 - 20.11.03		CHECKED BY	AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT wP	NATURAL MOISTURE CONTENT w	LIQUID LIMIT wL	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE		WATER CONTENT (%)				GR SA SI CL
294.3								20 40 60 80 100		20 40 60 80 100			kN/m³	
294.2	Silty, sandy TOPSOIL													
0.1	Sandy SILT						294							0 16 73 11
	Very Loose													
	Grey													
	Wet													
			1	SS	1						○			
							293							
			2	SS	3						○			
							292							
			3	SS	2						○			6 33 54 7
	with organics to 5.6m													
	Black													
	Soft		4	SS	3		291					○			
	Very Loose						290								
	Dark Grey														
			5	SS	2							○			0 30 64 6
							289								
288.6															
5.7	SAND, very fine grained, some silt													
	Very Loose													
	Grey													
	Wet		6	SS	4		288				○				
							287								
			7	SS	3						○			0 64 36 (SI+CL)
							286								
	Compact														
	Brown														
							285								
			8	SS	19						○			0 90 10 (SI+CL)

Continued Next Page

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

15 $\overset{20}{\underset{10}{\diamond}}$ 5   (%) STRAIN AT FAILURE

ONTMT4 MAGENTAWAN RIVER.GPJ 20/07/04

Ministry of Transportation Ontario

THURBER

W.P.	478-93-01	LOCATION	N 5048585.9 E 316317.2	Magnetawan River SBL, ST. 12+309.5, CL	ORIGINATED BY	DP
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NW Casing/NQ Core		COMPILED BY	SS
DATUM	Geodetic	DATE	18.11.03 - 20.11.03		CHECKED BY	AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa		UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						

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 wP — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wL
WATER CONTENT (%) 20 40 60

Description	Number	Type	N Value	Elevation	Remarks
				284	
Loose	9	SS	20		
				283	
	10	SS	8		
				282	
	11	SS	25	281	
				280	
becoming dense	12	SS	30		
				279	
	13	SS	39	278	
				277	
	14	SS	32		
				276	
	15	SS	32	275	3 76 21 (SI+CL)

Continued Next Page

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

$15 \frac{20}{\Phi} 5$ (%) STRAIN AT FAILURE

ONTMT4 MAGENTAWAN RIVER.GPJ 20/07/04

THURBER

W.P.	478-93-01	LOCATION	N 5048585.9 E 316317.2 Magnetawan River SBL, ST. 12+309.5, CL	ORIGINATED BY DP
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NW Casing/NQ Core	COMPILED BY SS
DATUM	Geodetic	DATE	18.11.03 - 20.11.03	CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH / WATER CONTENT	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Boulder encountered at 20.88m to 21.34m.		1	GS			274 – 273	o (water content ~25%)		
			16	SS	50		272			
	Cobble encountered at 22.25m to 22.4m. Cobble encountered at 22.56m to 22.71m. Boulder encountered at 22.91m to 23.16m. Boulders encountered at 23.24m to 23.93m, 24m to 24.54m.		2	GS	50/ .00		271			
							270			
269.7 24.5	**BEDROCK**									
	start of coring		1	RUN			269 – 268			RUN 1# TCR=100%, SCR=100%, RQD=100%, UCS=156.4MPa,
			2	RUN			267			RUN 2# TCR=99%, SCR=99%, RQD=99%, UCS=145.2MPa,
			3	RUN			266			RUN 3# TCR=100%, SCR=100%, RQD=100%, UCS=158.7MPa,
265.4 28.9	END OF BOREHOLE AT 28.93m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.									

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

ONTMT4 MAGENTAWAN RIVER.GPJ 20/07/04

Ministry of Transportation Ontario

THURBER

W.P. 478-93-01	LOCATION N 5048602.7 E 316306.1 Magnetawan River SBL, ST. 12+330, O/S 17.75L ORIGINATED BY DP
HWY 11	BOREHOLE TYPE Hollow Stem Augers COMPILED BY SS
DATUM Geodetic	DATE 08.12.03 - 08.12.03 CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa / DYNAMIC CONE 20 40 60 80 100	WATER CONTENT wP w wL 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.5 0.0 294.3	TOPSOIL										
0.2	Sandy SILT, some organics Very Loose Brown Wet						294				
			1	SS	1			o		
			2	SS	1		293	o		
292.2 2.3	with organics from 2.2m to 3.0m Dark Brown						292				
	SAND Very Loose Grey Mottled Brown Wet		3	SS	1			o		0 72 25 3
			4	SS	1		291	o		
	Grey		5	SS	0		290	o		
			6	SS	1		289	o		1 80 19 (SI+CL)
			7	SS	1		288	o		
287.7 6.7	END OF SAMPLE AT 6.71m. Dynamic cone penetration testing from 6.71 to 12.19m.						287			
							286			
							285			

DYNAMIC CONE PENETRATION RESISTANCE PLOT
PLASTIC LIMIT | NATURAL MOISTURE CONTENT | LIQUID LIMIT
SHEAR STRENGTH kPa
O UNCONFINED   + FIELD VANE
● QUICK TRIAXIAL   × LAB VANE
WATER CONTENT (%)

ONTMT4 MAGENTAWAN RIVER.GPJ 20/07/04

Continued Next Page

+³ , ×³ : Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of
Transportation
Ontario

THURBER

W.P.	478-93-01	LOCATION	N 5048602.7 E 316306.1	Magnetawan River SBL, ST. 12+330, O/S 17.75L	ORIGINATED BY	DP
HWY	11	BOREHOLE TYPE	Hollow Stem Augers		COMPILED BY	SS
DATUM	Geodetic	DATE	08.12.03 - 08.12.03		CHECKED BY	AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT — NATURAL MOISTURE CONTENT — LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	w_P w w_L WATER CONTENT (%)	γ kN/m³	GR SA SI CL

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
WATER CONTENT (%): 20 40 60

Elevation scale markings: 284, 283

| 282.3 / 12.2 | END OF DYNAMIC CONE AT 12.19m. WATER LEVEL IN OPEN BOREHOLE AT 2.7m DEPTH UPON COMPLETION. BOREHOLE OPEN TO 4.88m. BOREHOLE BACKFILLED WITH DRILL CUTTINGS TO SURFACE. |

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

$\begin{smallmatrix}20\\15-\oplus-5\\10\end{smallmatrix}$ (%) STRAIN AT FAILURE

ONTMT4 MAGENTAWAN RIVER.GPJ 20/07/04

Ministry of Transportation
Ontario

THURBER

W.P.	478-93-01	LOCATION	N=5 048 593.2 , E=316 321.3 Magnetawan River Bridge NC-S	ORIGINATED BY	GA
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	WM
DATUM	Geodetic	DATE	16.02.05 - 22.02.05	CHECKED BY	MA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV/DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60	γ	GR SA SI CL
294.9 / 0.0	Sandy **SILT**, occasional organics, occasional iron oxide staining Loose Dark Brown to Brown Wet		1	SS	5				o (~58)		
							294				
							293				
291.9 / 3.0							292				
	SAND, fine grained, some silt Loose to Compact Grey Wet		2	SS	8				o (~35)		
							291				
							290				
							289				
			3	SS	11				o (~38)		
							288				
							287				
							286				
	Becoming Loose, Brown		4	SS	6				o (~40)		0 89 11 (SI+CL)
							285				

Continued Next Page

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

ONTMT4S 2316(396, 400).GPJ 05/10/05

Ministry of Transportation
Ontario

THURBER

W.P. __478-93-01__   LOCATION __N=5 048 593.2 , E=316 321.3 Magnetawan River Bridge NC-S__   ORIGINATED BY __GA__

HWY __11__   BOREHOLE TYPE __Hollow Stem Augers/NQ Coring__   COMPILED BY __WM__

DATUM __Geodetic__   DATE __16.02.05 - 22.02.05__   CHECKED BY __MA__

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa / WATER CONTENT (%)		UNIT WEIGHT γ kN/m³		GR	SA	SI	CL
282.7 12.2	**SAND**, fine to medium grained, some silt						284								
	Loose to Compact		5	SS	8		283	o (282.x)							
	Brown						282								
	Wet						281								
			6	SS	11		280	o				0	82	18 (SI+CL)	
							279								
							278								
276.6 18.3	Borehole moved 2 m east and 1 m north, augered to 18.29 m		7	SS	16		277 276	o							
							275								

Continued Next Page

ONTMT4S 2316(396, 400).GPJ   05/10/05

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

$15\begin{smallmatrix}20\\ \phi\\ 10\end{smallmatrix}5$ (%) STRAIN AT FAILURE

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L

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

WATER CONTENT (%)
20 40 60

Ministry of
Transportation
Ontario

THURBER

W.P.	478-93-01	LOCATION	N=5 048 593.2 , E=316 321.3 Magnetawan River Bridge NC-S	ORIGINATED BY	GA
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	WM
DATUM	Geodetic	DATE	16.02.05 - 22.02.05	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
274.2											
20.7	**SAND**, fine to medium grained, trace silt, occasional cobbles and gravel Compact Brown Wet						274				
			8	SS	26		273		o		0 82 18 (SI+CL)
272.1										FI	
22.8	Slightly weathered to fresh, medium to coarse grained, massive, black, grey/white, strong to very strong **GRANITE**						272			1	RUN 1# TCR=100%, SCR=83%, RQD=69%
										2	
			1	RUN						>5	
							271			1	
										0	
										2	RUN 2# TCR=100%, SCR=22%, RQD=22%
										3	
			2	RUN			270			2	
										>5	
269.2										4	
25.7	END OF BOREHOLE AT 25.73 m. BOREHOLE GROUTED TO SURFACE.										

+ ³ , × ³ : Numbers refer to Sensitivity   15 $\overset{20}{\underset{10}{-\diamond-}}$ 5   (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

W.P.	478-93-01	LOCATION	N=5 048 535.5 , E=316 359.8 Magnetawan River Bridge NC-S	ORIGINATED BY	GA
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	WM
DATUM	Geodetic	DATE	13.01.05 - 19.01.05	CHECKED BY	MA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT — NATURAL MOISTURE CONTENT — LIQUID LIMIT / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			GR SA SI CL
294.8											
0.0 / 0.1	TOPSOIL (75 mm)										
	Silty **SAND**, fine grained										
	Loose										
	Brown										
	Wet						294				
							293				
							292				
291.8 / 3.0	**SAND**, fine grained, some silt, trace clay		1	SS	6				o		
	Loose										
	Brown						291				
	Wet										
							290				
							289				
			2	SS	5				o		
							288				
							287				
							286				
			3	SS	5				o		
							285				

Continued Next Page

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

15 ⊕ 5 (20/10) (%) STRAIN AT FAILURE

ONTMT4S 2316(396, 400).GPJ 05/10/05

Ministry of Transportation
Ontario

THURBER

W.P.	478-93-01	LOCATION	N=5 048 535.5 , E=316 359.8 Magnetawan River Bridge NC-S	ORIGINATED BY	GA
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	WM
DATUM	Geodetic	DATE	13.01.05 - 19.01.05	CHECKED BY	MA

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

ELEV/DEPTH	DESCRIPTION	N value	sample	water content	grain size
				284	
				283	
282.6 / 12.2	**SAND**, fine to medium grained, trace silt	4 SS 12		o (≈282.4)	0 69 31 (SI+CL)
	Compact to Loose			282	
	Grey				
	Wet			281	
				280	
		5 SS 5		o (≈279.5)	
				279	
				278	
				277	
		6 SS 5		o (≈276.5)	0 71 29 (SI+CL)
				276	
				275	

Continued Next Page

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

ONTMT4S 2316(396, 400).GPJ   05/10/05

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 396S-4   3 OF 3   **METRIC**

W.P. 478-93-01	LOCATION N=5 048 535.5 , E=316 359.8 Magnetawan River Bridge NC-S
HWY 11	BOREHOLE TYPE Hollow Stem Augers/NQ Coring
DATUM Geodetic	DATE 13.01.05 - 19.01.05

ORIGINATED BY GA
COMPILED BY WM
CHECKED BY MA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			GR SA SI CL

Column header notes: DYNAMIC CONE PENETRATION RESISTANCE PLOT scale 20 40 60 80 100; SHEAR STRENGTH kPa — ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — scale 20 40 60 80 100; WATER CONTENT (%) scale 20 40 60.

ELEV/DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEV SCALE	UNIT WEIGHT	REMARKS
274.1 / 20.7	**GRAVEL and SAND**, occasional cobbles and boulders. Very Dense. Grey. Wet	7	SS	100/ .125	274 / 273		
272.3 / 22.5	END OF SOIL SAMPLING AT 22.53 m. CORING STARTED AT 22.53 m. Fresh, coarse grained, massive, grey, white/black, strong to very strong **GNEISS**	1	RUN		272	FI 0 / 0	RUN 1# TCR=100%, SCR=100%, RQD=100%
		2	RUN		271	2 / 3 / 4 / 2	RUN 2# TCR=100%, SCR=82%, RQD=82%
		3	RUN		270 / 269	1 / 0 / 0 / 5 / 2 / 0	RUN 3# TCR=100%, SCR=100%, RQD=90%
268.6 / 26.2	END OF BOREHOLE AT 26.21 m. BOREHOLE OPEN TO 26.21 m AND WATER LEVEL AT 0.30 m UPON COMPLETION. BOREHOLE GROUTED TO SURFACE.						

Water content point (○) plotted near sample 7 at approximately 35%.

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

Appendix B

Laboratory Test Results
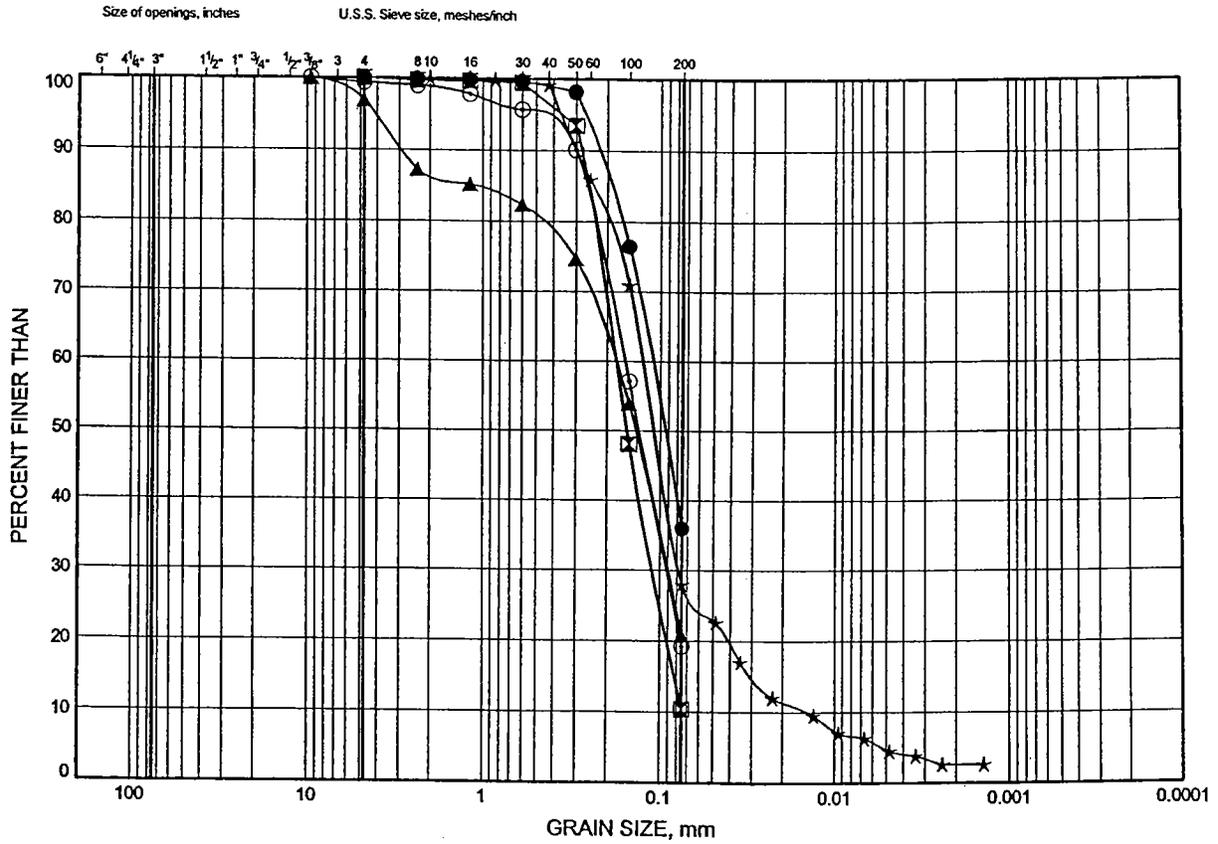
THURBER

SANDY SILT

Size of openings, inches   U.S.S. Sieve size, meshes/inch

GRAIN SIZE, mm

PERCENT FINER THAN

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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	396S-1	0.30	293.98
⊠	396S-1	2.59	291.69
▲	396S-1	4.88	289.40

GRAIN SIZE DISTRIBUTION

SAND

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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	396S-1	7.92	286.36
⊠	396S-1	9.45	284.83
▲	396S-1	19.35	274.93
★	396S-2	2.59	291.86
⊙	396S-2	4.88	289.57

Date June 2004

Project 478-93-01
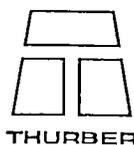
Prep'd SS

Chkd. AEG
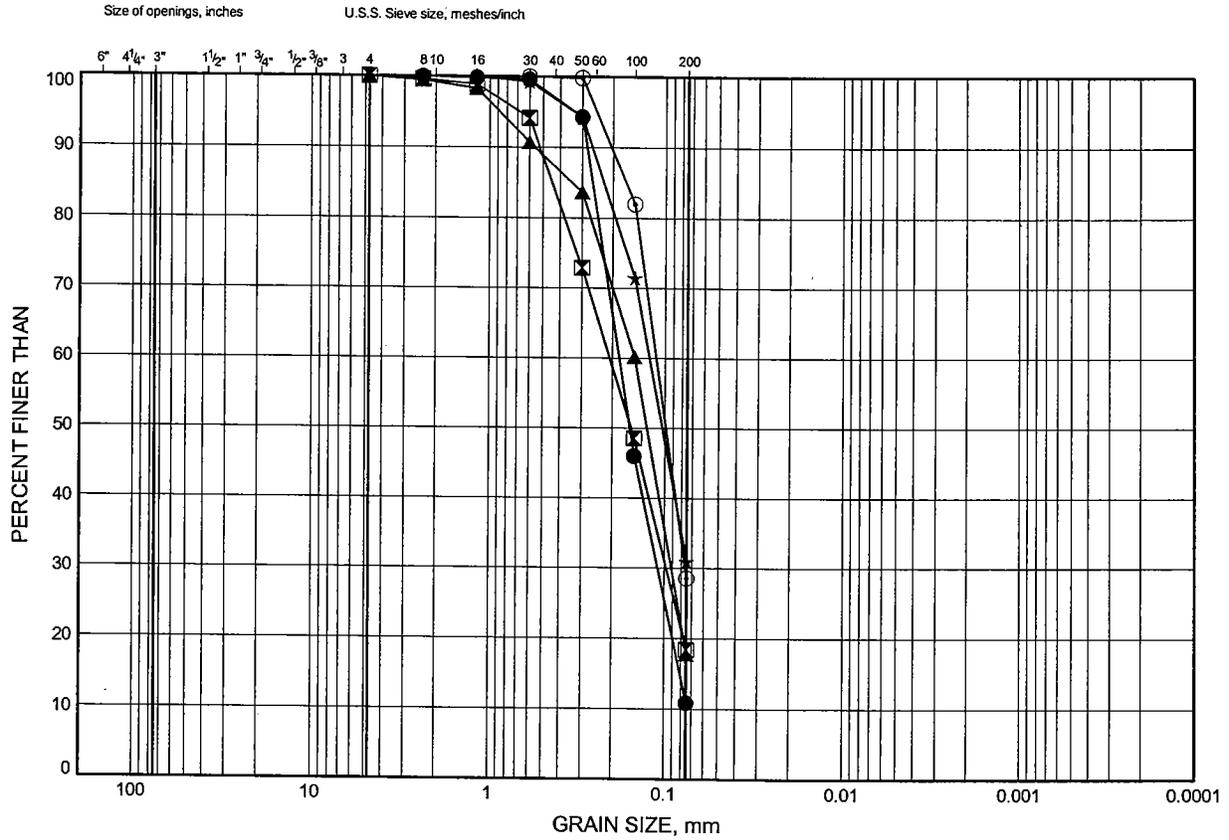
THURBER

SAND

Size of openings, inches

U.S.S. Sieve size, meshes/inch

PERCENT FINER THAN

GRAIN SIZE, mm

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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	396S-3	9.45	285.45
⊠	396S-3	15.54	279.36
▲	396S-3	21.64	273.26
★	396S-4	12.50	282.30
⊙	396S-4	18.59	276.21

Date   October 2005

Project   478-93-01

THURBER

Prep'd   HS

Chkd.   AEG

THURBGSD 2316(396, 400).GPJ 05/10/05
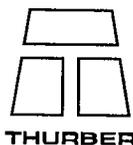
Appendix C

Data From Shaheen & Peaker Report

Ministry of Transportation Ontario

RECORD OF BOREHOLE No MRS1   1 OF 2   METRIC

W.P. 314-99-00	LOCATION Hwy 11 SBL over Magnetawan River Co-ords: N 5 046 539.9; E 316 348.9	ORIGINATED BY G.I
DIST 52 HWY 11	BOREHOLE TYPE Solid and Hollow Stem Augers, Washborig & Casings, NQ Rock Core	COMPILED BY G.T
DATUM Geodetic	DATE 07.03.01 & 08.03.01	CHECKED BY Z.O

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION / SHEAR STRENGTH	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.6 / 0.0	Ground Surface / 75 mm Topsoil		1	SS	2				o		
	brown						294				
	-----		2	SS	1				o		0 47 51 2
	SANDY SILT TO SILTY SAND		3	SS	1		293		o		
	trace of organics,										
	occasional organic pockets/lenses,					▽					
	grey to dark grey,		4	SS	2		292		o		
	very loose, wet										
			5	SS	2				o		
							291				
			6	SS	2				o		Commenced using drill mud
							290				
			7	SS	1				o		
			8	SS	2		289		o		
288.6 / 6.0			9	SS	2		288		o		0 85 15 0
	brown -----		10	SS	1				o		
	----- trace						287				
	grey organics		11	SS	1				o		
	-----						286				
			12	SS	5		285		o		
	FINE SAND										
	very loose to 8.5 m										Commenced washboring
	loose below, wet						284				
			13	SS	9				o		0 84 (16)
							283				
			14	SS	10		282		o		
	-----						281				
	brown		15	SS	8				o		
279.6 / 15.0	Continued Next Page						280				

+³ . x³ : Numbers refer to Sensitivity   15 ⊕ 5 / 20 / 10   (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRS1   2 OF 2   METRIC

W.P. 314-99-00	LOCATION Hwy 11 SBL over Magnetawan River Co-ords: N 5 048 539.9: E 316 348.9	ORIGINATED BY G.I
DIST 52 HWY 11	BOREHOLE TYPE Solid and Hollow Stem Augers, Washborig & Casings, NQ Rock Core	COMPILED BY G.T
DATUM Geodetic	DATE 07.03.01 & 08.03.01	CHECKED BY Z.O

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE • QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) PLASTIC LIMIT wP — MOISTURE CONTENT w — LIQUID LIMIT wL	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH 279.6	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100 / 20 40 60 80 100	20 40 60		
15.0	FINE SAND grey, compact, wet		16	SS	26		279		o		0 91 (9)
278.1											
16.5	GRAVEL AND SAND frequent cobbles and boulders grey, dense, wet		16A	RC			278				
			17	SS	35				o		March 07 ------ March 08
							277				
			18	SS	60/14**		276		o		** possible cobble
275.6											
19.0	GNEISS BEDROCK grey unweathered --------- moderatly to slightly weathered -------- unweathered		19	NQ RC	Rec. 100%		275				RQD=100%
			20	NQ RC	Rec. 100%						RQD=100%
			21	NQ RC	Rec. 86%		274				RQD=60%
272.5			22	NQ RC	Rec. 100%		273				RQD=100%
22.1	End of borehole *Water level at 2.3 m (not stabilized) on completion										

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

W.P.	314-99-00	LOCATION	Hwy 11 SBL over Magnetawan River Co-ords: N 5 048 527.9: E 316 348.2	ORIGINATED BY	G.I
DIST 52 HWY 11		BOREHOLE TYPE	Solid Stem Augers, NQ Rock Core & D.C.P.T	COMPILED BY	G.T
DATUM Geodetic		DATE	06.03.01 & 07.03.01	CHECKED BY	Z.O

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT Wp — NATURAL MOISTURE CONTENT w — LIQUID LIMIT WL WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100 / 20 40 60 80 100	20 40 60	kN/m³	GR SA SI CL
295.1 0.0	Ground Surface 100 mm Topsoil		1	SS	2		295		o		
	brown -----		2	SS	1		294		o		
	SANDY SILT TO SILTY SAND		3	SS	0				o		
	trace of organics, occasional organic pockets/lenses,		4	SS	0		293		o		
	grey to dark grey, loose to very loose, wet		5	SS	1		292		o		
			6	SS	0		291		o		
			7	SS	0		290		o		
			8	SS	6				o		
268.4			9	SS	4		289		o		Commenced using drill mud 0 40 60 0
6.7			10	SS	3		288		o		
			11	SS	4		287		o		
	FINE SAND occasional silty zones loose to very loose, wet		12	SS	4		286		o		
	grey ----- brown		13	SS	8		285 284		o		Commenced washboring
	----- grey		14	SS	6		283 282		o		0 86 (14)
280.1 15.0			15	SS	4		281		o		

Continued Next Page

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

RECORD OF BOREHOLE No MRS2 2 OF 2 METRIC

W.P. 314-99-00	LOCATION Hwy 11 SBL over Magnetawan River Co-ords: N 5 048 527.9; E 316 348.2	ORIGINATED BY G.I
DIST 52 HWY 11	BOREHOLE TYPE Solid Stem Augers, NQ Rock Core & D.C.P.T	COMPILED BY G.T
DATUM Geodetic	DATE 06.03.01 & 07.03.01	CHECKED BY Z.O

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
280.1 15.0	FINE SAND some silty zones, loose to compact, grey, wet		16	SS	3		280		o		0 65 35 0
							279				
			17	SS	18		278		o		
277.6 17.5	GRAVEL AND SAND trace to some silt, boulders below 19.0 m, dense to very dense, grey, wet		18	SS	36		277		o		43 42 15 0
							276				
			19	SS	52		275		o		
273.8 21.3			20	SS	49		274		o		
	GNEISS BEDROCK grey		21	NQ RC	Rec. 100%						RQD=100%
			22	NQ RC	Rec. 100%		273				RQD=100%
	unweathered ------ slightly to moderatly weathered		23	NQ RC	Rec. 93%		272				RQD=46%
270.8			24	NQ RC	Rec. 100%		271				RQD=10% March 06 March 07
24.3	End of borehole Hole open to 24.2 m on completion Dynamic Cone Penetration Test performed from 0 to 15.0 m Piezometer installed at 21.3 m on completion Water level in piezometer at: March 06/2001 - 2.30 m March 07/2001 - 1.20 m March 08/2001 - 0.90 m March 12/2001 - 0.80 m March 13/2001 - 0.75 m March 20/2001 - 0.75 m March 21/2001 - 0.70 m March 26/2001 - 0.70 m March 27/2001 - 0.65 m March 28/2001 - 0.60 m April 02/2001 - 0.60 m April 04/2001 - 0.55 m April 06/2001 - 0.45 m April 09/2001 - 0.35 m April 11/2001 - 0.20 m										

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

$15 \diamond 5$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No MRS3   1 OF 2   **METRIC**

W.P. 314-99-00	LOCATION Hwy 11 SBL over Magnetawan River Co-ords: N 5 048 513.8: E 316 362.6	ORIGINATED BY G.I
DIST 52 HWY 11	BOREHOLE TYPE Hollow Stem Augers & D.C.P.T.	COMPILED BY G.T
DATUM Geodetic	DATE 09.03.01	CHECKED BY Z.O

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (O UNCONFINED + FIELD VANE / ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT wP / NATURAL MOISTURE CONTENT w / LIQUID LIMIT wL — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60		
295.8 / 0.0	Ground Surface										
	FILL: Gravelly Sand		1	SS	35*				o		* frozen
294.9							295				
294.7 / 1.1	TOPSOIL-Clayey		2	SS	5				o	16.8	
	SILTY CLAY with Clayey Silt & Silt layers		3	SS	14	▼**	294		o	18.8	
	trace of organics, some organic zones		4	SS	8		293		o	19.2	0 10 63 27
	grey to dark grey, soft to very stiff		5	SS	2			>>	o	18.5	
292.2 / 3.6	SILT loose, grey, wet		6	SS	6		292	+²	o		0 4 96 0
291.3 / 4.5			7	SS	4		291		o		Commenced using drill mud
	SANDY SILT TO SILTY SAND loose, grey to dark grey, occasional organics and organic zones		8	SS	5		290		o		
			9	SS	4		289		o		
288.5 / 7.3											
	FINE SAND very loose to compact, grey, wet		10	SS	1		288		o		
							287				
286.2 / 9.6			11	SS	19				o		
280.8 / 15.0	End of borehole Dynamic Cone Penetration Test performed from 9.1 m to 15.3 m **Water level on completion at 2.1 m (not stabilized)						286 285 284 283 282 281				
	Continued Next Page										

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of
Transportation
Ontario

RECORD OF BOREHOLE No MRS3   2 OF 2   METRIC

W.P.   314-99-00   LOCATION   Hwy 11 SBL over Magnetawan River Co-ords: N 5 048 513.8: E 316 362.6   ORIGINATED BY   G.I

DIST   52   HWY   11   BOREHOLE TYPE   Hollow Stem Augers & D.C.P.T.   COMPILED BY   G.T

DATUM   Geodetic   DATE   09.03.01   CHECKED BY   Z.O

SOIL PROFILE		SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60 80 100	20 40 60	kN/m³	GR SA SI CL
280.8 15.0								20 40 60 80 100				
280.5 15.3	End of Dynamic Cone Penetration Test											

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

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM

| CLAY & SILT | SAND | | | GRAVEL | |
| | Fine | Medium | Coarse | Fine | Coarse |

MINISTRY SIEVE DESIGNATION (Metric)

MINISTRY SIEVE DESIGNATION (Imperial)

GRAIN SIZE IN MICROMETERS

PERCENT RETAINED

PERCENT PASSING

LEGEND

BH	SAMPLE	SYMBOL
MR3	2	
MR3	4	
MRS3	4	

GRAIN SIZE DISTRIBUTION
SILTY CLAY

Ministry of
Transportation
Ontario
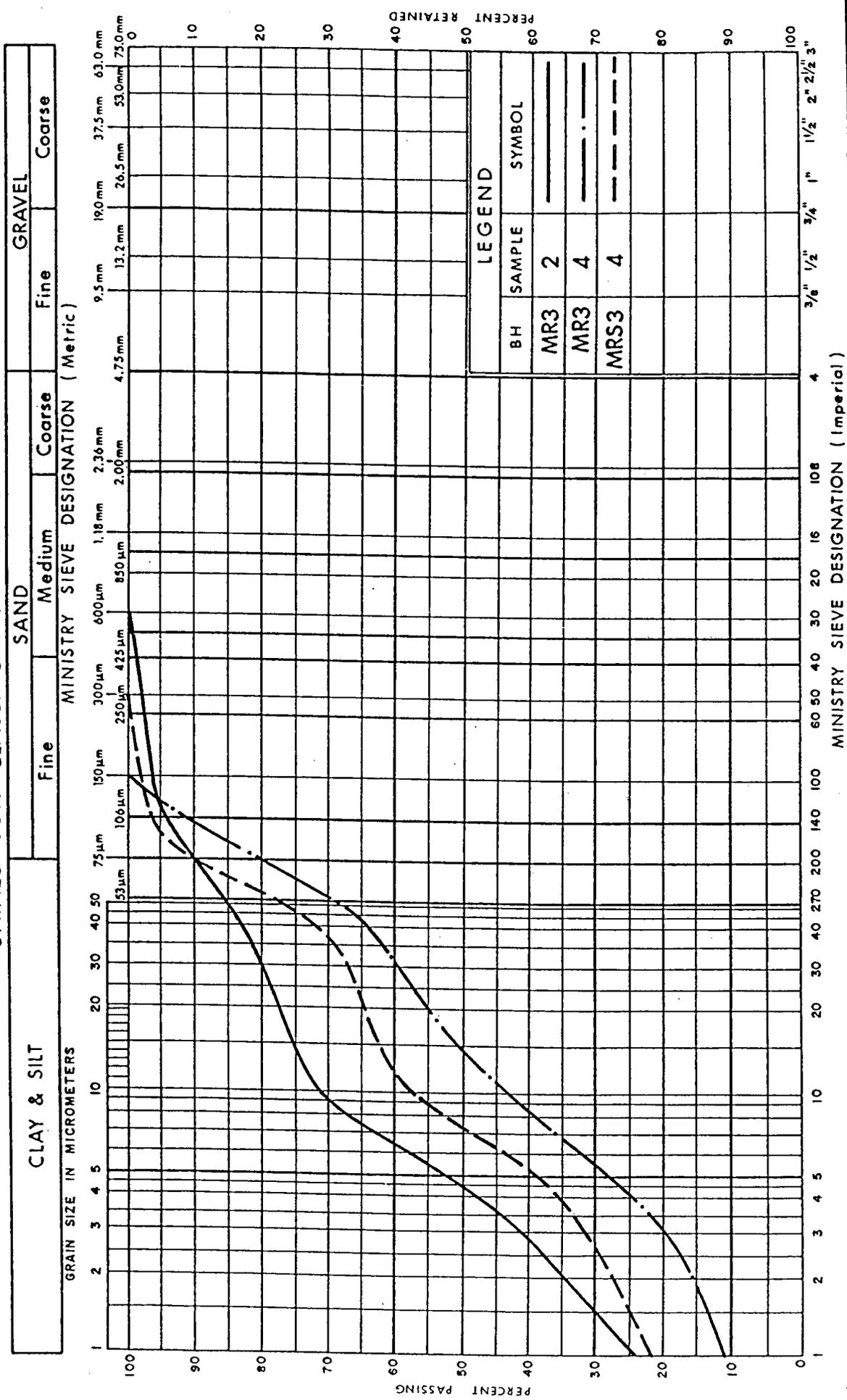
FIG No 1

W P 314-99-00

SPT 1010 B

7812 M

UNIFIED SOIL CLASSIFICATION SYSTEM

	CLAY & SILT	SAND			GRAVEL	
		Fine	Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

MINISTRY SIEVE DESIGNATION (Metric)

PERCENT RETAINED

PERCENT PASSING

LEGEND

BH	SAMPLE	SYMBOL
MRS 3	6	

1 2 3 4 5 10 20 30 40 50 75μm 106μm 150μm 250μm 300μm 425μm 600μm 850μm 1.18mm 2.00mm 2.36mm 4.75mm 9.5mm 13.2mm 19.0mm 26.5mm 37.5mm 53.0mm 63.0mm 75.0mm

53μm

MINISTRY SIEVE DESIGNATION (Imperial)

3" 2½" 2" 1½" 1" ¾" ½" ⅜" 4 8 16 20 30 40 50 60 100 140 200 270

GRAIN SIZE DISTRIBUTION

SILT

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

Ministry of
Transportation

Ontario

UNIFIED SOIL CLASSIFICATION SYSTEM

GRAIN SIZE DISTRIBUTION
SANDY SILT TO SILTY SAND

Ministry of Transportation
Ontario

FIG No 4
WP 314-99-00
SPT 1010B

7812 M

BH	SAMPLE	SYMBOL
MR1	2	
MR3	8	
MRS1	2	
MRS2	9	
MRN3	6	

LEGEND

ENVELOPE

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

MINISTRY SIEVE DESIGNATION (Metric)

MINISTRY SIEVE DESIGNATION (Imperial)

PERCENT RETAINED

PERCENT PASSING

LEGEND

BH	SAMPLE	SYMBOL
MR1	14	
MRS1	9	
MRS1	13	
MRS1	16	
MRS2	14	
MRN1	6	
MRN1	15	

ENVELOPE

GRAIN SIZE DISTRIBUTION
FINE SAND

FIG No 6

W P 314-99-00

SPT 1010B

Ministry of Transportation

Ontario

UNIFIED SOIL CLASSIFICATION SYSTEM

GRAIN SIZE DISTRIBUTION
SILTY FINE SAND

Ministry of Transportation
Ontario

FIG No 7
W P 314-99-00
SPT 1010B

LEGEND

BH	SAMPLE	SYMBOL
MRS 2	16	——

7812 M

Appendix D

Foundation Comparison

THURBER

Magnetawan River North Crossing, SBL

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 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**

THURBER

Appendix E

Special Provisions

Magnetawan River North Crossing, SBL

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 overlying the bedrock contains cobbles and boulders, particularly below Elevation 275. The presence of cobbles and boulders will potentially have an impact on the installation of piles at the site. Some possible impacts that must be taken into consideration include, but are not necessarily limited to:

- *The 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 to reach bedrock*
- *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.*

Magnetawan River North Crossing, SBL

Appendix F

Selected Slope Stability Output

Thurber Engineering Ltd. - Toronto

19-1423-16

Hwy11 - Katrine

December 2003

North Crossing - SBL - South Bank

Setback from May 2003 Water Level: 8.5m

F = 1.574

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	9.81	0	0	0
Backfill	21	0	30	1
Rockfill	20	0	42	1
Silty Sand	19	0	28	1
Fine Sand	20	0	30	1
Gravel and Sand	21	0	32	1
Hard Bottom	(Infinitely Strong)			

Figure F1

06/21/2004 4:07:11 PM C:\WINDOWS\PROFILES\AGORMAN\TEMPOR~1\OLKA1A2\NCSBLS1.GSL Thurber Engineering Ltd. - Toronto   F = 1.574

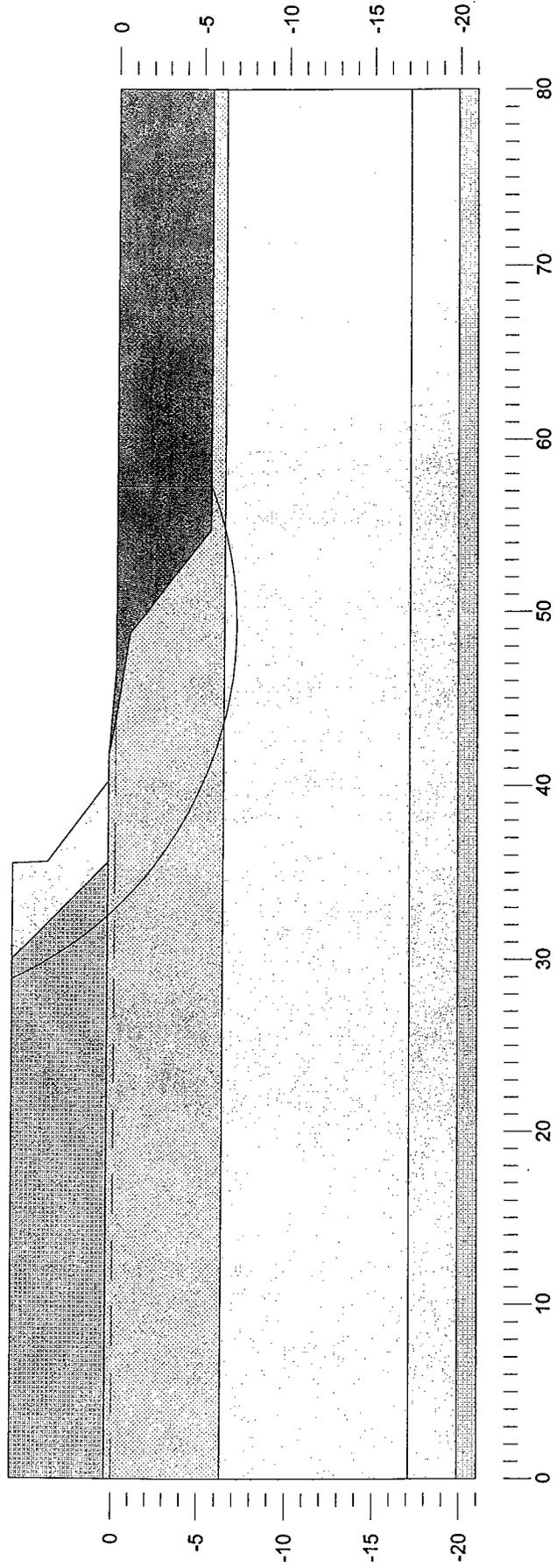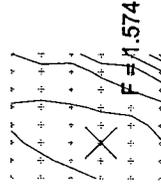|	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Rockfill	20	0	42	1
Silty Sand	19	0	28	1
Fine Sand	20	0	30	1
Gravel and Sand	21	0	32	1
Hard Bottom	(Infinitely Strong)			

Thurber Engineering Ltd. - Toronto
19-1423-16
Hwy11 - Katrine
June 21, 2004
North Crossing - SBL - South Bank
lateral stability

Figure F2

06/21/2004 4:21:03 PM C:\PROJ\19\1423\16\HWY1~1\1BRIDGES\MAGNOR~1\MAGN-S~1\NCSS1SS.GSL Thurber Engineering Ltd. - Toronto F = 1.930
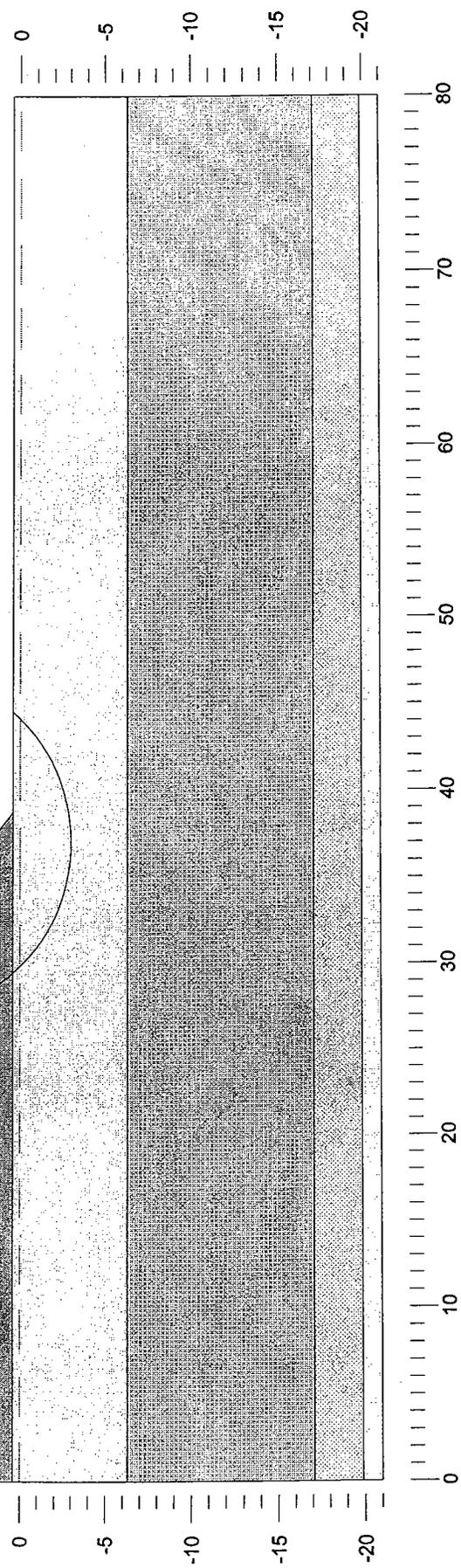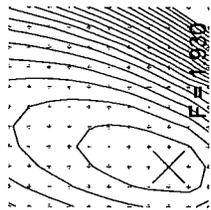
Figure F3

Thurber Engineering Ltd. - Toronto
19-1423-16
Hwy11 - Katrine
December 2003
North Crossing - SBL - North Bank
Setback from May 2003 Water Level: 6.0m

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	9.81	0	0	0
Backfill	21	0	30	1
Rockfill	20	0	42	1
Silty Sand	19	0	28	1
Fine Sand	20	0	30	1
Gravel and Sand	21	0	32	1
Hard Bottom	(Infinitely Strong)			

F = 1.669

06/21/2004 4:35:09 PM C:\PROJ\19\1423\16\HWY1~1\BRIDGES\MAGNOR~1\MAGN-S~1\NCSBLN1.GSL Thurber Engineering Ltd. - Toronto   F = 1.669
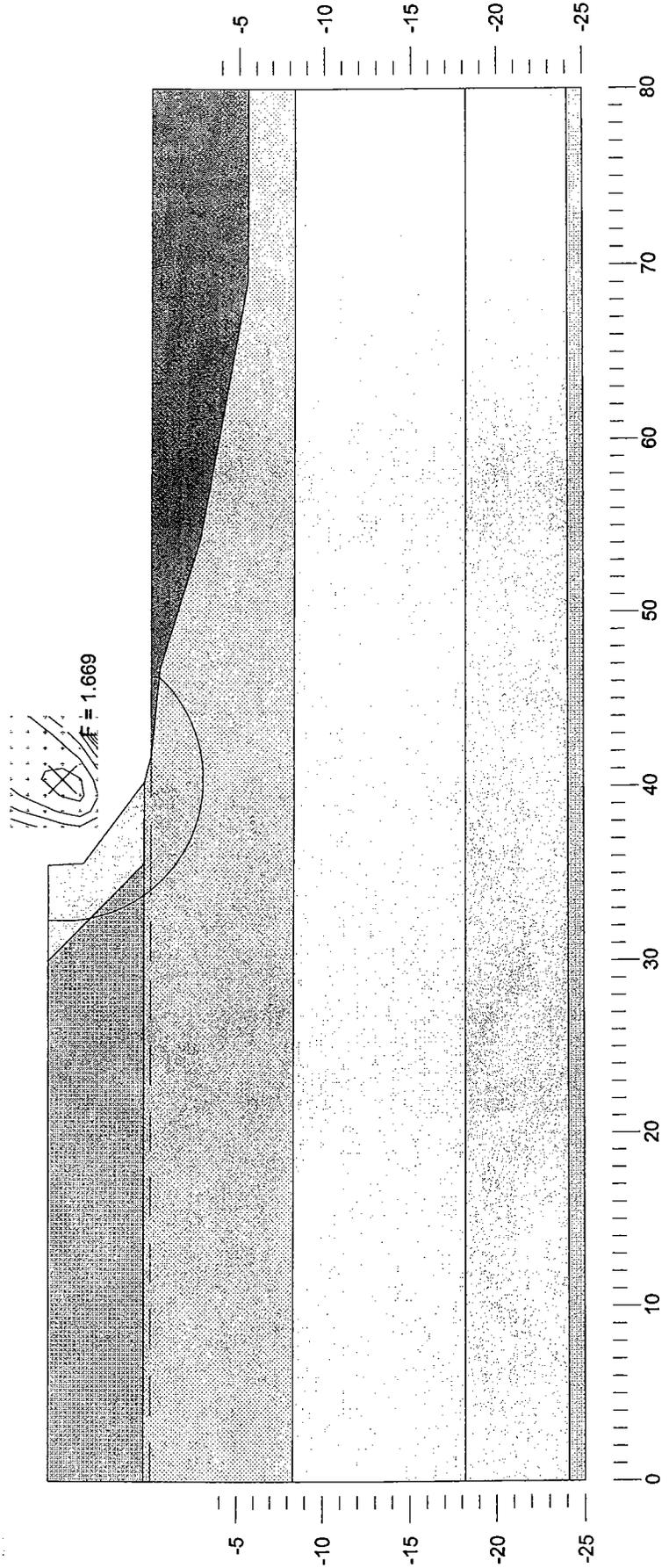
Figure F4

Thurber Engineering Ltd. - Toronto
19-1423-16
Hwy11 - Katrine
June 21 2004
North Crossing - SBL - North Bank
Lateral stability

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Rockfill	20	0	42	1
Silty Sand	19	0	28	1
Fine Sand	20	0	30	1
Gravel and Sand	21	0	32	1
Hard Bottom	(Infinitely Strong)			

F = 1.931

06/21/2004 4:41:54 PM C:\PROJ\19\1423\16\HWY1~1\BRIDGES\MAGNOR~1\MAGN-S~1\NCSN1SS.GSL Thurber Engineering Ltd. – Toronto   F = 1.931

Appendix G

Drawings

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

HWY 11
CONT No 2006-5148
WP No 478-93-01

MAGNETAWAN RIVER BRIDGE NORTH CROSSING SBL
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 751

Marshall Macklin Monaghan
PROJECT MANAGERS • ENGINEERS • SURVEYORS • PLANNERS
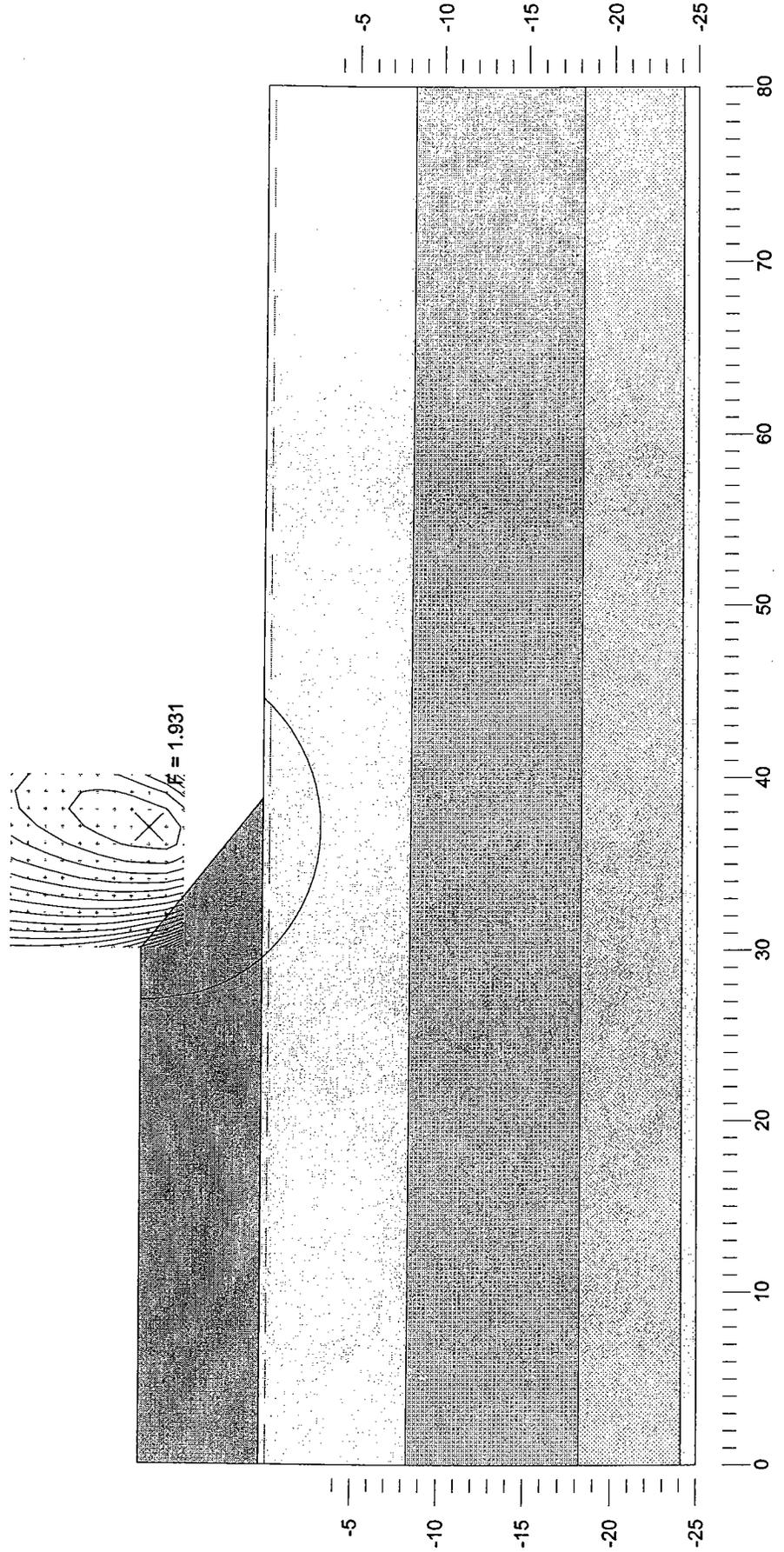
THURBER ENGINEERING LTD.
THURBER

KEYPLAN
DISTRICT OF PARRY SOUND
GEOG TWP ARMOUR

PLAN

CONSTRUCTION NORTH
FLOW MAGNETAWAN RIVER
℄ SOUTH ABUTMENT BRIDGE
℄ NORTH ABUTMENT BRIDGE
TO KATRINE
FROM NORTH BAY
℄ HWY 11 SBL
℄ HWY 11 MEDIAN
MRS2 MRS1 MRS3
396S-1 396S-2 396S-3 396S-4

SCALE: 1:250

SECTION A-A

MRS2 MRS1 396S-4
℄ HWY 11 SBL
PROPOSED GRADE
ORIGINAL GROUND
TOPSOIL
SANDY SILT TO SILTY SAND — Very Loose to Loose
SAND — Very Loose to Compact
GRAVEL AND SAND — Dense to Very Dense
BEDROCK
SCALE: 1:250

PROFILE ℄ HIGHWAY 11 SBL

MRS3 MRS2 MRS1
℄ SOUTH ABUTMENT BRIDGE
℄ NORTH ABUTMENT BRIDGE
396S-1 396S-3 396S-2
PROPOSED GRADE
H.W.L. 295.9m (REGULATORY)
100 YEAR FLOOD LEVEL EL. 295.95
ORIGINAL GROUND
W.L. 294.1m (MAY 2003)
SILTY CLAY — Soft to Very Stiff
FILL
SANDY SILT TO SILTY SAND — Very Loose to Loose
SILT — Loose
SAND — Very Loose to Compact
SANDY SILT — Very Loose
TOPSOIL
SAND — Very Loose to Dense
GRAVEL AND SAND — Dense to Very Dense
BEDROCK
COBBLES AND BOULDERS
BEDROCK
SCALE: 1:250

SECTION B-B

396S-1 396S-3
℄ HWY 11 SBL
PROPOSED GRADE
ORIGINAL GROUND
TOPSOIL
SANDY SILT — Very Loose
SAND — Very Loose to Dense
COBBLES AND BOULDERS
BEDROCK
SCALE: 1:250

LEGEND

Symbol	Description
	BoreHole by THURBER
	Dynamic Cone penetration Test (cone)
	BoreHole by SHAHEEN & PEAKER LIMITED
N	Blow/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
PH	Pressure, Hydraulic
WL	WL
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)

NO	ELEVATION	NORTHING	EASTING
MRS1	294.6	5 048 539.9	316 348.9
MRS2	295.1	5 048 527.9	316 348.2
MRS3	295.8	5 048 513.8	316 362.6
396S-1	294.3	5 048 585.9	316 317.2
396S-2	294.5	5 048 602.7	316 306.1
396S-3	294.9	5 048 593.2	316 321.3
396S-4	294.8	5 048 535.5	316 359.8

-NOTE-
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.
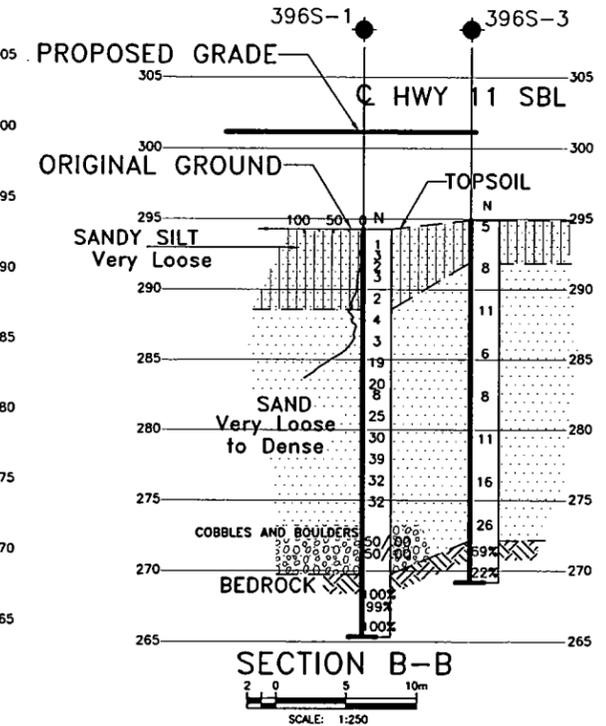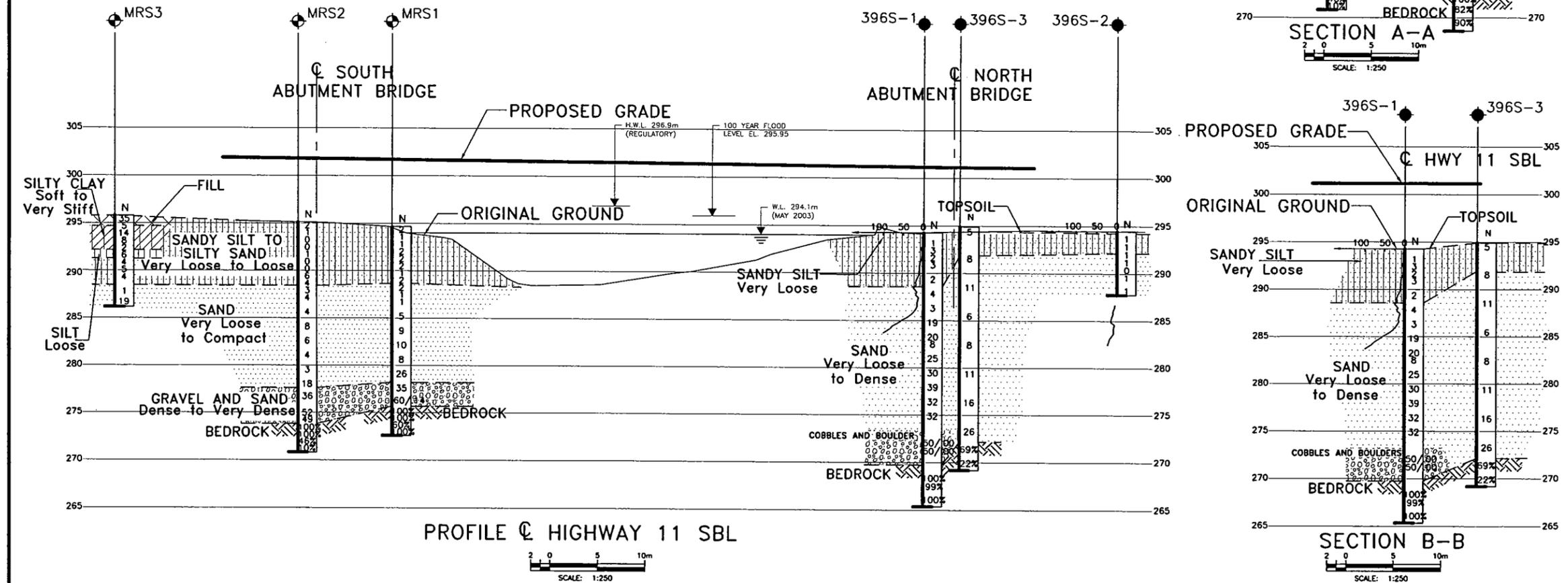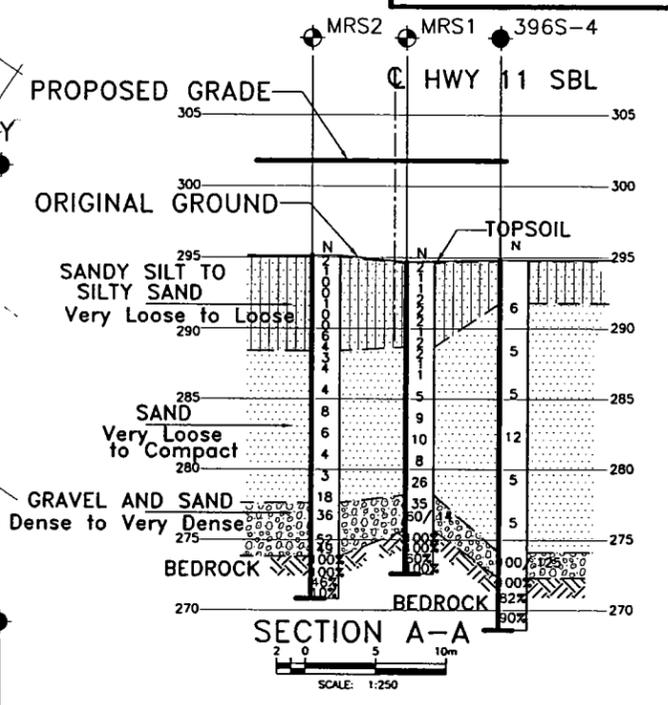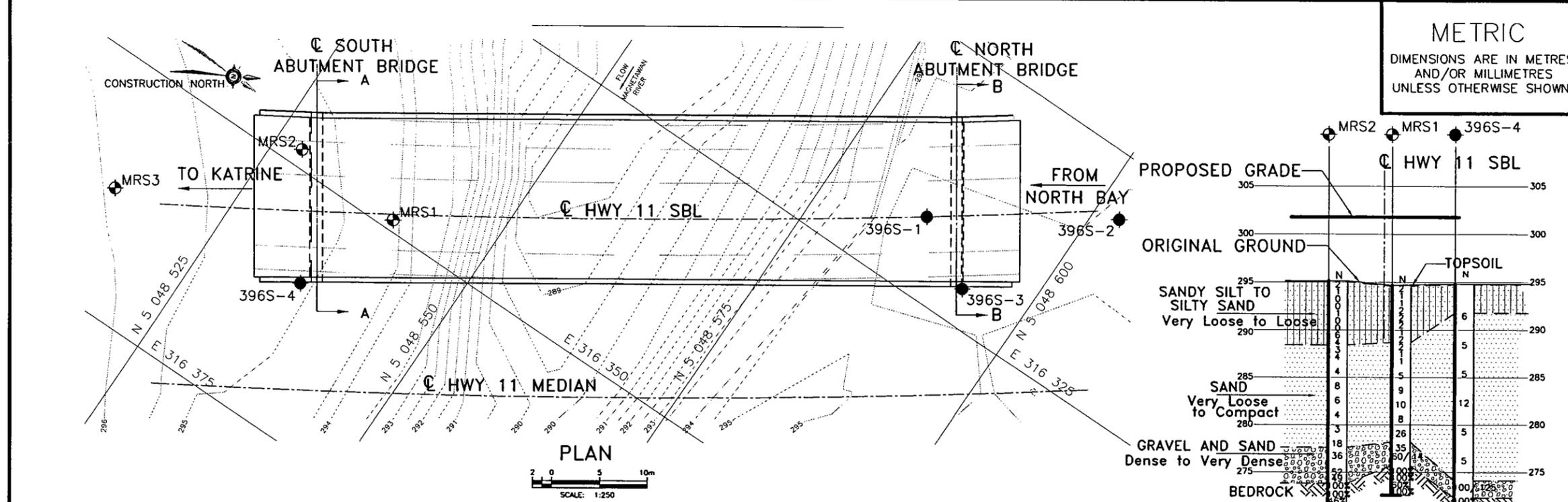
DHO BENCHMARK 333-67
EL. 307.808
TABLET SET VERT. IN ROCK CUT
21.3 LT 2.4km N OF HWY 518
40.057 LT 10+706.020

DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

REVISIONS
DATE BY DESCRIPTION
DESIGN AEG CHK PKC CODE CHBDC 2000 LOAD CL-625-ONT DATE JUNE 2004
DRAWN SS CHK AEG SITE 44-396 STRUCT. SCHEME. DWG 2