PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
O'BRIEN ROAD OVERPASS
HIGHWAY 17 TWINNING, ARNPRIOR TO RENFREW
ONTARIO
G.W.P. 647-92-00

Geocres Number:

31F - 128

Report to

National Capital Engineering

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a preliminary foundation investigation at the proposed O'Brien Road structure beneath Highway 17 near Renfrew, Ontario.

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 based on the data obtained in the course of the present investigation.

Thurber carried out the investigation as a sub-consultant to National Capital Engineering, under the Ministry of Transportation Ontario (MTO) Agreement Number 4005-A-000157.

2 SITE DESCRIPTION

The site is located at the intersection of the existing O'Brien Road and Highway 17 in the Geographical Township of Horton, County of Renfrew, Ontario. This location is near the northeast municipal boundary for the Town of Renfrew.

The area to the south of Highway 17 consists of relatively low density commercial development within the Town of Renfrew. North of Highway 17 , the land is predominantly rural with heavily wooded terrain on the Bonnechere valley slopes.

The regional setting in this area is controlled by a large-scale bedrock graben structure containing the Ottawa Valley. The bedrock graben structure exhibits several northwest trending faults, and has been infilled with glaciofluvial and fine-grained marine sediments to form the Ottawa valley Clay Plain.

The site is located on relatively level terrain which is dissected by the gullies and valleys of nearby water courses. The most prominent feature is the 40 m deep valley of the Bonnechere River located approximately 200 m north and northeast of the proposed interchange. A small tributary gully to the Bonnechere River crosses O'Brien Road approximately 200 m southwest of the proposed interchange and flows in a northerly direction towards the Bonnechere River. The site is moderately well drained owing to the presence of the nearby valley and tributary gully.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between October 1 and October 7, 2003, on December 2-3 and on December 17, 2003. The site investigation consisted of drilling and sampling a total of five boreholes extending from 12.8 m to 28.2 m depth. The boreholes are labelled BRN-1 through BRN-5. The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing.

Prior to drilling, the borehole locations were marked in the field by surveyors from J.D Barnes of Ottawa, and utility clearances were obtained by Thurber at each borehole location.

A CME 75 track-mounted drill rig was provided by George Downing Estate Drilling to advance the boreholes and obtain samples. Hollow stem auger drilling techniques were used to advance the upper portion of the boreholes through the cohesive portion of the deposit. In the lower portion of the boreholes where saturated sand was encountered, the boreholes were advanced using casing and wash boring methods. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in overburden materials. In soft to firm cohesive soils, insitu vane shear tests were conducted using an MTO N-vane to measure peak and remolded shear strength. At each foundation element a single borehole was advanced approximately 3 m into bedrock by diamond coring.

Groundwater conditions were observed during the drilling operations and standpipe piezometers were installed in 4 of the boreholes to measure groundwater levels. The piezometers consisted of 19 mm diameter Schedule 40 PVC pipe with 1.52 m to 2.13 m long slotted screens installed in the bedrock or in the granular soils overlying the bedrock. Sand filter pack was placed around the pipe and extended at least 0.3 m above the top of the screen. Bentonite was placed above the filter sand.

On completion of drilling and sampling, all boreholes were appropriately backfilled.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes, recovered samples and transported the samples to Thurber's Oakville office.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The bedrock core samples were logged and subjected to point load tests to obtain strength parameters. The results of this testing are shown on the Record of Borehole sheets in Appendix A.

Selected samples were subjected to gradation analysis (sieve test) and Atterberg Limit determination. The results of these tests are included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

A general description of the stratigraphy encountered at the site is given in the following paragraphs and on the "Borehole Locations and Soil Strata" Drawing, inserted at the end of the report. For a detailed summary of the subsurface conditions at a particular location, reference should be made to the borehole logs and laboratory test results included in the Appendices.

In general terms, the site was found to have a thin surficial layer of topsoil or asphalt overlying fill. These units were underlain by a Clayey Silt to Silty Clay unit overlying an extensive layer of glaciofluvial sand. Beneath the glaciofluvial sand, at BRN-1, BRN-4 and BRN-5, a basal layer of silty sand till or boulders was encountered overlying marble bedrock.

5.1 Topsoil

Topsoil was encountered at boreholes BRN-2 through BRN-4, drilled north of the westbound lane. The thicknesses of topsoil encountered are summarized in the following table.

TABLE 1: TOPSIL THICKNESS

Borehole	Topsoil Thickness (mm)
BRN-2	50
BRN-3	180
BRN-4	100

Topsoil thickness may vary away between or beyond the boreholes locations.

5.2 Fill

Boreholes BRN-1 and BRN-5 were drilled through the pavement in the median of the existing intersection of O'Brien Road and Highway 17. Approximately 150 mm of asphalt surfacing was encountered at both locations. Beneath the asphalt at BRN-1, sand and gravel fill was encountered to 0.8 m depth or 129 m elevation. At BRN-5 sandy clayey silt fill with some gravel extending to 0.8 m depth (129 m elevation) was encountered beneath the asphalt.

5.3 Clayey Silt to Silty Clay

Beneath the topsoil and fill described in the preceding section, an extensive deposit of clayey silt to silty clay was encountered across the site in all boreholes. The thickness of the Clayey Silt to Silty Clay unit varies from 9.2m to 12.2 m at the borehole locations. The deposit contains numerous horizontal sand laminations and silty sand layers which become more frequent with depth. The thickness of thesand layers vary from a few millimetres to about 0.3 m.

The clay is generally brown changing to grey in colour with increasing depth. The SPT-N values generally decrease with depth ranging from a maximum of 14 to a minimum value of 1. The average SPT-N value is 7. Vane shear tests using MTO N-vane result in undrained shear strengths of 50 to 60 kPa indicating stiff conditions but becoming firm to soft with depth. The upper portion of the Clayey Silt to Silty Clay is in a moist condition and becomes wet below 6.5 to 8 m depth.

The Atterberg limit tests indicate liquid limit values ranging from 41 to 49 % in the upper 6 m of the deposit, and decreasing to a range of 22 to 28 % below this depth. These indices show the upper 6 m of the deposit to be medium plastic, and the lower portion to be low plastic. The moisture content of Clayey Silt to Silty Clay varies from 47 to 21% generally decreasing with depth, except in the upper 2 m where the deposit is desiccated and overconsolidated. Within this 2m thick desiccated crust, the moisture content is about 10% less than the liquid limit. Below this depth, the deposit has moisture contents equivalent to the liquid limit indices and is considered normally consolidated.

5.4 Glaciofluvial Sand

A glaciofluvial sand unit was encountered beneath the Clayey Silt to Silty Clay described above. The contact between the Clayey Silt to Silty Clay and the underlying glaciofluvial sand is not planar and varies from Elevation 114.9 m at BRN-3 to Elevation 119.8 m at BRN-1 The thickness of the sand deposit ranges from 11.8 to 13.4 m. The sand is predominantly fine to medium grained, with trace to some silt and occasional gravel. Occasional silt and silty sand layers were encountered in borehole BRN-2. The deposit is brown in colour. The sand is moist to about 20 m depth. Below this depth the deposit is described as wet. The moisture content of the samples from this unit varied from 5 to 24% with an average value of 15%. The SPT – N values in this deposit range from 10 to 76 with an average value of 39, indicating that the deposit is in a compact to very dense condition.

5.5 Basal Till Layer

Beneath the glaciofluvial sand, a basal till layer was encountered at between 105.7 m and 106.9 m elevation. This layer was variable in composition varying from silty sand till with trace gravel and occasional cobbles to a mixture of cobbles and boulders. Boulders up to 500 mm in size were encountered in the core samples taken at borehole BRN-2. The thickness of the basal till layer varies from 1m to 2.7 m. The SPT-N values recorded in this unit ranged from 25 to 34 indicating compact to dense conditions. The moisture content of the silt sand component varied from 15% to 20%.

5.6 Bedrock

The soils described above were found to be underlain by Pre-Cambrian marble bedrock. The bedrock was proved by coring in Boreholes BRN-1, BRN-2, BRN-4 and BRN-5. The depth and elevation of the bedrock surface measured at the borehole locations is summarized in the following table.

TABLE 2: BEDROCK ELEVATION

Borehole No.	Depth of bedrock below existing site grade (m)	Top of bedrock Elevation (m)
BRN-1	23.9	105.9
BRN-2	23.9	104.5
BRN-4	24.5	103.9
BRN-5	25.3	104.5

The rock is described as slightly to moderately weathered, white to light grey, coarse grained crystalline marble with light and dark banding. Occasional vugs infilled with calcite crystals were present.

Core recovery in the bedrock was generally 96 to 100%. The RQD values ranged from 19% to 100% and had an average value of 71%. With the exception of the RQD value of 19% measured near the bedrock surface in BRN-1, the bedrock quality can be described as fair to excellent. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, varied from 0 to greater than 5, with a mean value of 2 indicating moderate joint spacing. The condition of the joints was planar and rough.

The unconfined compressive strength of the intact rock, based on point load tests, varies from 46 to 95 MPa and has an average value of 72 MPa , indicating strong rock.

5.7 Water Levels

Observations of groundwater levels and soil moisture conditions during drilling and in the shallow piezometer at BRN-3 indicate that a perched water-table is present at about 0.6 to 6.7 m depth within the Clayey Silt to Silty Clay unit. Groundwater levels recorded in the deeper piezometers indicate that the upper portion of the glaciofluvial sand deposit is not saturated. The depths to the water-table recorded at various times are summarized in Table 3 below. The groundwater levels are expected to vary seasonally.

TABLE 3: GROUNDWATER LEVELS

	Piezometer completed In	Depth below ground surface (m)			ELEVATION (m)		
		Oct 22/03	Dec 16/03	Feb 4/04	Oct 22/03	Dec 16/03	Feb 4/04
BRN-1	Glaciofluvial Sand	19.7	19.4	19.4	110.1	110.4	110.4
BRN-2	Glaciofluvial Sand	19.3	19.1	18.9	109.1	109.3	109.5
BRN-3	Clayey Silt to Silty Clay	6.7	0.6	1.5	120.6	126.8	125.8
BRN-4	Glaciofluvial Sand		18.9	18.7	128.4	109.5	109.7

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 INTRODUCTION

This report presents interpretation of the geotechnical data in the preceding section and presents preliminary geotechnical design recommendations to assist the design team to select and design a suitable foundation system for the proposed structures.

The proposed grade separation structures will consist of twin reinforced concrete rigid frame structures carrying the westbound and eastbound lanes of the proposed Highway 17 alignment. The proposed alignment for O'Brien Road will consist of a two-lane section with curb and gutter passing beneath Highway 17. Reinforced concrete retaining walls are proposed to support the cutslopes on either side of rigid frame structures. The proposed intersection of the alignments of Highway 17 and O'Brien Road are skewed by about 20 degrees from the perpendicular.

We understand that the proposed design will maintain the approximate grade of Highway 17 and will result in the lowering of O'Brien Road by about 5.8 m. The preliminary design indicates that the proposed Highway 17 lanes will be at about Elev 130 m and the proposed grade of O'Brien St. will be at about Elev. 124.2 m.

Since the proposed structures will be located at the existing O'Brien Street, construction staging and detours will presumably be required to construct the proposed structures.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of this preliminary investigation.

7 STRUCTURE FOUNDATIONS

The proposed rigid frame structures will require 2 foundation elements at each structure. An additional eight foundation elements will be required to support the retaining walls. This section presents foundation recommendations for both retaining walls and the proposed rigid frame structures. The founding elevation based on the preliminary General Arrangement drawings (GA) will be up to approximately 7 m below existing grade and within the Clayey Silt to Silty Clay deposit.

7.1 Foundation Alternatives

This section discusses the feasible foundation alternatives, provides geotechnical design parameters and recommends a preferred foundation scheme. Consideration was given to the following foundation types:

- Spread footings on native soils
- Spread footings on engineered fill
- Driven piles extending to bedrock
- Caissons (drilled shaft piles) bearing within the dense sand.

The relative advantages and disadvantages of each foundation type are compared in tabular form in Figure 1, Appendix C. Preliminary design values for each foundation option are provided in the following sections.

7.2 Spread Footings on Native Soils

The calculated geotechnical bearing resistance for 5 m wide by 15 m long spread footing bearing on firm, saturated Clayey Silt to Silty Clay at 7 m below the existing Highway 17 grade, with concetric vertical loading would be:

ULS (factored)	115 kPa
SLS (for s= 25 mm)	75 kPa

The calculated bearing resistance for spread footings on native Clayey Silt to Silty Clay soils is relatively low. There will also be differential settlement associated with placement of backfill material adjacent to the proposed structures, and therefore the geotechnical conditions are not considered suitable for spread footing foundations at the proposed rigid concrete structure or the retaining walls.

7.3 Spread Footings on Engineered Fill

Higher bearing resistances could be achieved if all the firm Clayey Silt to Silty Clay was subexcavated from beneath the foundation footprint down to the sand layer and replaced with engineered fill. The recommended subexcavation elevations are 117.4 m at the WBL and 117.8 at the EBL. This option would require excavation up to 10 to 13 m below the existing grade, or approximately 3 to 6 m below the elevation required for spread footings on native soils. This will be a major excavation requiring temporary support and dewatering.

This option will require excavation and replacement of approximately 2250 m^3 of silty clay per footing and is therefore not considered as economical as the other foundation options.

However, preliminary geotechnical design parameters are provided below if required for preliminary design purposes.

Prior to constructing the engineered fill pad, all native Clayey Silt to Silty Clay should be removed within a volume contained within 1H:1V slope from the bottom edges of the footing, and extending down to the underlying native sand as shown in Figure 2, Appendix C. The volume should be backfilled with engineered fill consisting of OPSS Granular "A" placed in thin lifts and compacted to 100% of its Standard Proctor maximum dry density (SPMDD) at ±2% of optimum moisture content.

Provided a minimum footing width of 4 m is maintained, a footing bearing on the engineered fill may be designed for the following concentric, vertical geotechnical resistance:

Factored ULS	900 kPa
SLS (for 25 mm total settlement)	350 kPa.

In the case of eccentric or inclined loading, the geotechnical resistance must be calculated as illustrated in the CHBDC Clause 6.7.3 and Clause 6.7.4.

The sliding resistance of mass concrete poured on a compacted Granular "A" pad may be computed on the basis of an ultimate friction factor of 0.7.

7.4 Driven Steel Piles

Driven steel H-piles are considered a feasible option for foundations of the rigid frame structure and for the proposed retaining walls. This method will also allow the use of integral or semi-integral abutments.

The piles should be driven to bedrock. The expected elevation of bedrock at each of the foundation elements is shown in Table 4.

TABLE 4: BEDROCK ELEVATION

Borehole	Ground surface Elevation (m)	Depth to Bedrock (m)	BEDROCK ELEVATION (m)
BRN-1	129.8	23.9	105.9
BRN-2	128.4	23.9	104.5
BRN-4	128.4	24.5	103.9
BRN-5	129.8	25.3	104.5

7.4.1 Geotechnical Resistance of Driven Piles

The geotechnical resistance of steel H-piles driven to bedrock at the site is greater than the recommended axial structural resistance recommended by MTO-Structural Office in their April15, 1998 memo. It is therefore recommended that the piles be designed based on their structural capacity for the following vertical, factored compressive loads at Ultimate Limit State (ULS) as summarized below:

HP 310 x110	2000 kN
HP 310 x 132	2400 kN

The serviceability limit state (SLS) for end-bearing piles on bedrock will not govern.

The group resistance should be in accordance with the recommendations in the Canadian Highway Bridge Design Code(CHBDC).

The minimum recommended pile spacing, measured centre to centre at the underside of the footing, should be 2.5b (where b is the pile width or diameter) or 750 mm, whichever is greater.

7.4.2 Pile Installation

It is recommended that all piles be reinforced with rock points such as Titus Steel Co. "H" bearing pile point, Rock Injector design or equivalent, to protect the web and flanges from boulders that may be encountered overlying the bedrock.

Pile installation should be in accordance with Special Provision 903S01.

Some piles may encounter substantial resistance on boulders at higher elevations than the bedrock. If boulders are encountered, the piles shall be driven in accordance with Standard SS103-11 using the required ultimate geotechnical resistance (must exceed 2 x Design Load at ULS).

7.4.3 Lateral Pile Resistance

Lateral soil resistance against 310 mm wide piles can be calculated based on the CHBDC method. The coefficient of subgrade reaction, ks, and the ultimate lateral resistance is given by the following expressions:

Clayey Silt to Silty Clay :

$$Ks = 120 \cdot Cu/D \qquad \text{(kPa/m)}$$

$$Pult = 9 \cdot Cu \qquad \text{(kPa)}$$

Cohesion-less deposits:

$$Ks = n_h \cdot z/D \qquad \text{(kPa/m)}$$

$$Pult = 3 \cdot \gamma \cdot z \cdot Kp \qquad \text{(kPa)}$$

where Cu = 40 kPa, undrained shear strength of clay

z = depth below pile cap or abutment in metres

D = pile diameter or width in metres

N_h = 6600 kPa/m

γ = Average unit weight of sand, 21 kN/m^3

Kp =3.3 (passive earth pressure coeffiecient)

To account for reduced resistance resulting from group effects, the horizontal subgrade reaction values, obtained from the values above, should be modified using the multipliers shown below. The reduction factors will vary with the pile spacing expressed as a multiple of the pile breadth, 'b'.

For a pile group oriented *perpendicular* to the direction of loading:

Pile Spacing	Horizontal Subgrade Reaction Reduction Factor
4b	1.00
3b	0.8

For pile groups orientated *parallel* to the direction of loading the following reduction factors are recommended:

Pile Spacing	Horizontal Subgrade Reaction Reduction Factor
8b	1.00
6b	0.7
4b	0.4
3b	0.25

7.5 Drilled Caissons

The compact to dense sand underlying the Clayey Silt to Silty Clay unit on which the structure is founded could provide significant bearing resistance for large diameters caissons. Drilling and installation of caissons is considered feasible in the firm Clayey Silt to Silty Clay. However, sloughing and sidewall instability would likely be encountered in the compact to very dense sand unit underlying the Clayey Silt to Silty Clay, and may result in construction difficulties. The sidewall instability may be controlled with temporary liners and/or stabilizing fluids, thereby increasing the difficulty and cost of this option. Caissons are therefore not recommended for the structure and retaining wall foundations.

7.6 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. The recommended foundation type is steel H-piles driven to bedrock, making integral abutments a feasible option.

The integral abutment design requires that the piles be flexible in the upper 3 m of the pile length. At this site the upper 3 m of the piles will encounter soft to stiff, clayey silt to silty clay and the underlying sand to silty sand unit. 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 or concentric CSP's in accordance with standard integral abutment design procedures.

False abutment walls are not considered feasible at this site because of the presence of soft to firm cohesive silts and clays at the proposed subgrade level.

7.7 Frost Cover

Pile caps and footings should be provided with frost protection. This may take the form of a minimum 1.9 m of earth cover from any exposed surface grade.

8 EXCAVATION AND BACKFILL

8.1 General

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native Clayey Silt to Silty Clay at this site is classed as Type 2 soil above the water table and Type 3 soil if below the water table.

8.2 Earth Excavation

Earth excavation should carried out in accordance with SP 902S01.

An effective stress analysis for global stability of the permanent cutslopes was carried out using GSLOPE software developed by Mitre Software Inc.. Details of the soil model, soil parameters are summarized in Figure 3 in Appendix C. The preliminary stability analysis indicates that cutslopes inclined at 2H:1V and up to 6 m in height in the Clayey Silt to Silty Clay will have a Factor of Safety exceeding 1.5. The maximum recommended cutslope inclination is 2H:1V.

Permanent cutslopes higher than 8 m should be stepped at mid height to reduce potential erosion. The step should be 2 m wide and sloped at 3%. Vegatative covering should be provided for final cut slopes as soon as possible after excavation in accordance with SP 572SO1. If continual seepage or surficial instability is evident, remedial measures such as interceptor ditches, toe drains, gravel sheeting or rip rap may be required.

8.3 Abutment Structure Backfill

False abutment walls are not considered feasible at this site because of the presence of soft to firm cohesive silts and clays at the proposed subgrade level.

The backfilling for foundations and structures must be carried out in accordance with OPSD 3501.000 for granular backfill. Granular backfill is recommended for backfill of structures. MTO Granular B Type II should be used as abutment backfill. 150 mm diameter subdrains should be provided behind the abutments as per OPSD 3501.000.

Backfill should be carried out in accordance with Special Provision No. (SSP) 092S01 dated September 2003. A copy of this SSP is included in Appendix D.

Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.06.

9 GROUNDWATER CONTROL

Perched groundwater is present within the Clayey Silt to Silty Clay unit and groundwater flow is expected to be encountered from the sand layers within this unit. Excavation for the structure foundations and for the O'Brien Road approach cuts are expected to encounter low rates of groundwater inflow. Temporary dewatering measures will be required during excavation for the structures. It is expected that conventional dewatering methods using trenches, sumps and pumps will be required.

Permanent drainage of the structure backfill should be provided. Subdrains will also be required to provide drainage of the subgrade through the length of the cut along O'Brien Road.

10 EARTH PRESSURE

For cases where backfill to the rigid frame structure or retaining walls is placed in accordance with OPSD 3501.000, the lateral earth pressure will be governed by the properties of the material within the backfill limits as shown in the respective OPSD.

If the support system allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the support system does not allow yielding (restrained system), at-rest horizontal earth pressures should be used. In the case of an integral or semi-integral abutment design, the pressure on the ballast wall may be interpreted using Figure C6.9.1(a) in the Commentary to the CHBDC.

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

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

where P_h = horizontal pressure on the wall (kPa)
K = earth pressure coefficient (see below)
γ = unit weight of retained soil (see 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. For light compaction equipment, the magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or at a depth of 1.7 m for Granular A or Granular B Type II.

Earth pressure coefficients for backfill to the abutment and retaining walls are dependent on the material used as backfill. Values for typical materials are shown in the following table.

TABLE 5: LATERAL EARTH PRESSURE COEFFICIENTS

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°$, γ=22.8 kN/m^3		OPSS Granular B Type I $\phi = 32°$, γ=21.2 kN/m^3		Rock Fill $\phi = 42°$, γ=19.0 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	0.30*
At rest (Restrained Wall)	0.43	-	0.47	-	.33	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	5.0	-

* For retaining walls or 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.

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

11 SEISMIC CONSIDERATIONS

The site is treated as lying in Acceleration Zone 4. A peak horizontal acceleration factor $k_h = 0.18g$ on firm ground has been used in analysis. Structures should be designed in accordance with the CHBDC.

The foundation conditions consist of firm to stiff fine-grained soils and compact to dense coarse-grained soils with a depth greater than 15 m. A site response factor, S, of 1.5 is considered appropriate for these conditions. Liquifaction or significant loss of foundation shear strength under seismic loading is not expected to occur based on the stiffness and cohesive nature of the shallow deposits and the low water-table elevation in the underlying sand unit.

Design of the retaining structures should be carried out using the lateral earth pressure coefficients (K_{AE} and K_{PE}) that include both the combined static and dynamic loading, in accordance with Clause 4.6.4. The following parameters are recommended for use in design of lateral structures.

TABLE 6: LATERAL PRESSURES FOR SEISMIC CONDITIONS

Condition	Height of Application From Base as Percentage of Wall Height	Earth Pressure Coefficient (K) for Earthquake Loading			
		Granular A or Granular B Type II $\phi = 35^\circ$, $\delta = 17.5^\circ$		OPSS Granular B Type I $\phi = 32^\circ$, $\delta = 16^\circ$	
		Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (K_{AE})*	41%	0.39	0.93**	0.43	0.56
Passive (K_{PE})*	33%	3.3		2.9	
At Rest (K_{OE})**	47%	0.80		0.84	

* After Mononobe and Okabe, passive case assumes no wall friction.

** Slope may undergo movement for short durations during seismic event

12 CONSTRUCTION CONCERNS

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

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

- The Contractor's proposed dewatering measures should be reviewed and approved prior to commencing excavation.
- Installation of drilled caissons or placement of engineered fill, if carried out, will require full time geotechnical inspection to confirm that conditions are consistent with those used in design.
- Installation of H-piles driven to bedrock should be monitored to confirm that suitable capacities can be achieved. Piles may reach refusal on boulders above the bedrock surface.

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Appendix A

Record of Borehole Sheets

SYMBOLS AND TERMS USED ON TEST HOLE LOGS

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	Less than 10	Less than 2
Soft	10 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 TEST HOLE LOGS

SYMBOLS FOR SAMPLE TYPE	■ Shelby Tube	A - Casing
	⧄ SPT	▥ Grab/Auger sample
	☒ No Recovery	◫ Core

- MC – Moisture Content (% by Weight) as determined by sample

▼ Water Level

C_{vane} Shear Strength Determination by Field Insitu Vane

C_{pen} Shear Strength Determination by Pocket Penetrometer

C_{lab} Shear Strength Determination using a Laboratory Vane Apparatus

C_U Undrained Shear Strength determined by Unconfined Compression Test

(1) SPT Standard Penetration Test – refers to the number of blows from a 63.5kg hammer falling through 0.76m to advance a 60 degree truncated cone 0.3m.

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**		**Field Estimation of Hardness***
	(MPa)	**(psi)**	
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

RECORD OF BOREHOLE No BRN-1

1 OF 3

METRIC

W.P. 647-92-00
LOCATION N 1.0 E 1.0 (N 5 038 049.1 E 293 357.3) O'Brien Road
ORIGINATED BY JL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring
COMPILED BY SS
DATUM Geodetic
DATE 06.10.03 - 07.10.03
CHECKED BY AEG

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
129.8					
129.6 0.0	**ASPHALT** (150mm)				
0.2	**SAND and GRAVEL** Brown (FILL) (SP)	1	GS		
129.0 0.8	Silty **CLAY** to Clayey **SILT** Stiff Grey - Brown Moist (CI)	1	SS	6	
		2	SS	13	
		3	SS	7	
		4	SS	6	
	occasional sand lenses, wet	5	SS	7	0 2 50 48
124.2 5.6	Silty **CLAY**, with numerous sand laminations and layers to 300mm Firm Grey Wet (CL)	6	SS	7	
		7	SS	8	
	sand layer from 9.0m to 9.3m	8	SS	23	
119.8					

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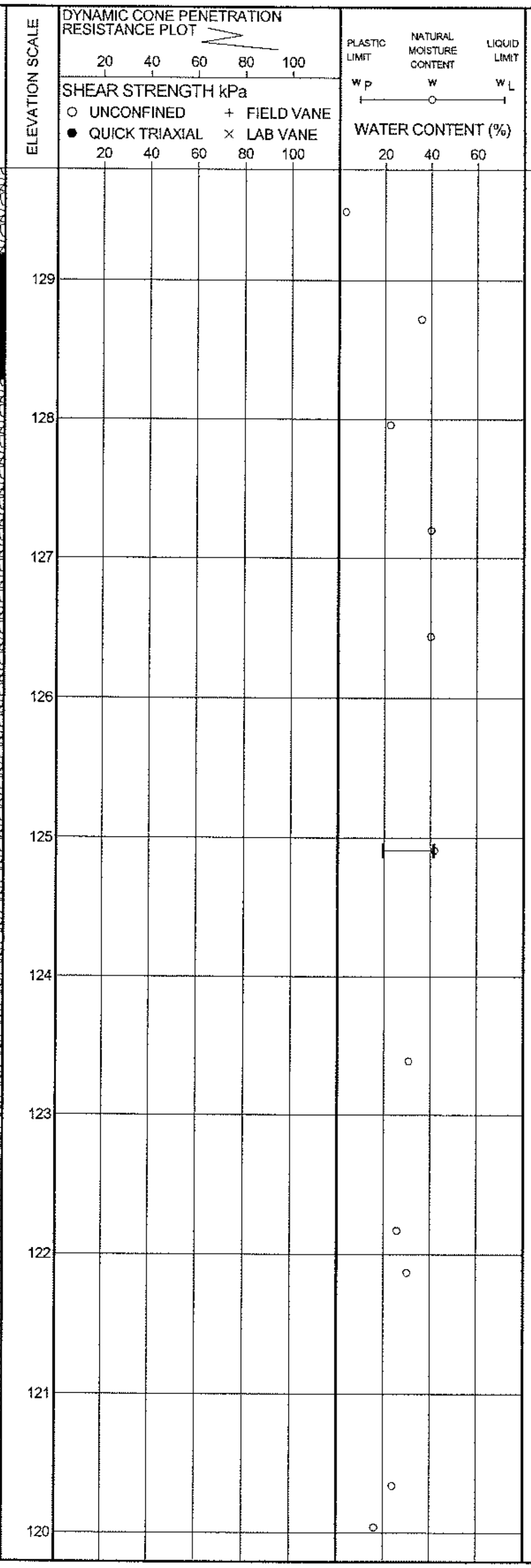


+³, ×³: Numbers refer to Sensitivity

15 ⊕ 5 (20, 10) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

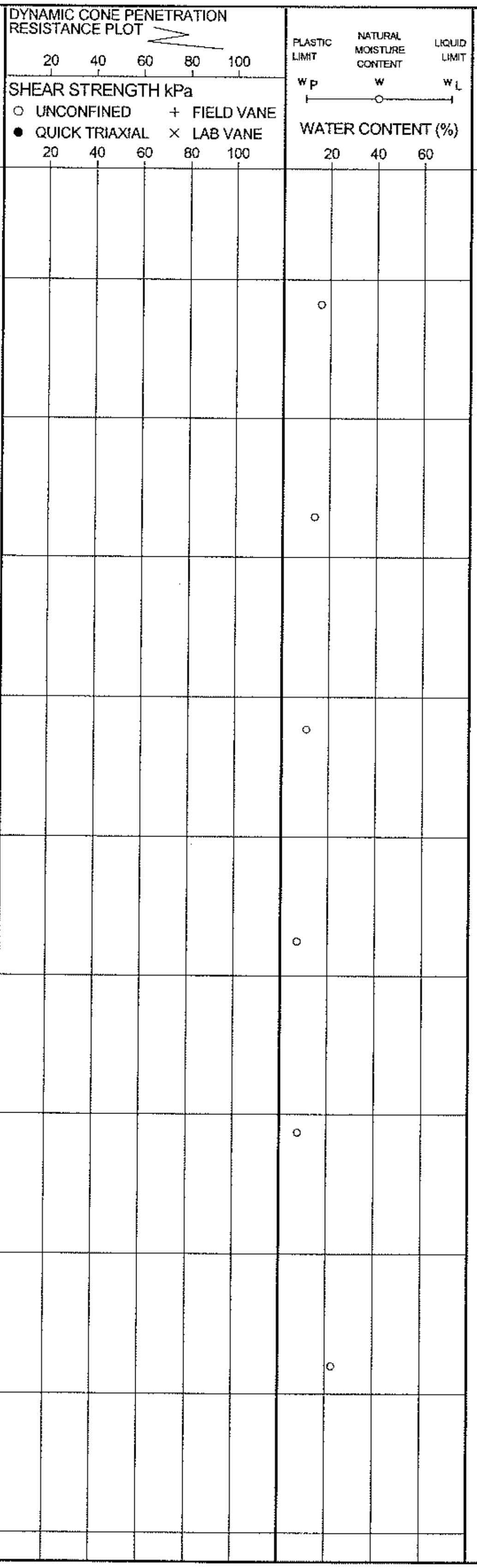
RECORD OF BOREHOLE No BRN-1

2 OF 3

METRIC

G.W.P. 647-92-00
LOCATION (N 5 038 049.1 E 293 357.3) O'Brien Road
ORIGINATED BY JL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring
COMPILED BY SS
DATUM Geodetic
DATE 06.10.03 - 07.10.03
CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
10.0	**SAND**, trace silt, trace to some gravel Dense Brown Moist to Wet (SP)								
		9	SS	47	119	18	56	26 (SI+CL)	
					118				
		10	SS	42	117				
		11	SS	40	116				
					115				
		12	SS	31	114				
		13	SS	44	113				
					112				
	Compact, wet	14	SS	29	111				
					110				



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

$15\text{-}\oplus\text{-}5$ (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

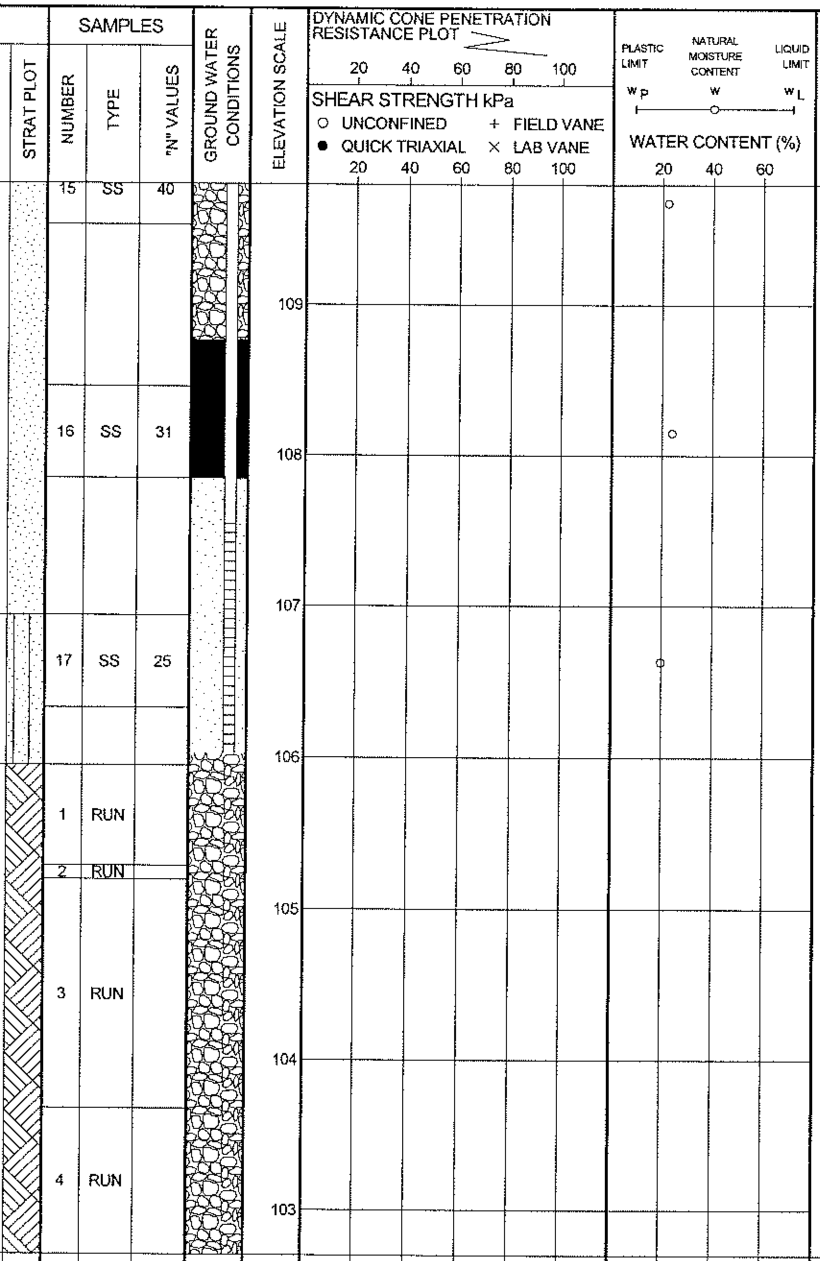
THURBER

RECORD OF BOREHOLE No BRN-1

3 OF 3 **METRIC**

G.W.P. 647-92-00
LOCATION (N 5 038 049.1 E 293 357.3) O'Brien Road
ORIGINATED BY JL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring
COMPILED BY SS
DATUM Geodetic
DATE 06.10.03 - 07.10.03
CHECKED BY AEG

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		15	SS	40			
					109		
		16	SS	31	108		
106.9 22.9	Silty **SAND**, trace gravel Compact Grey Wet (SM)	17	SS	25	107		
105.9 23.9	**MARBLE (BEDROCK)** Fresh to slightly weathered, light grey, moderately strong	1	RUN		106	FI 6 2	RUN 1# TCR=100%, SCR=81%, RQD=19%, UCS=46.4MPa
		2	RUN				
		3	RUN		105 104	3 4 1 1 1	RUN 2# TCR=100%, SCR=57%, RQD=0%, UCS=MPa RUN 3# TCR=97%, SCR=83%, RQD=95%, UCS=56.5MPa
102.7		4	RUN		103	>5 3 3	RUN 4# TCR=100%, SCR=89%, RQD=55%, UCS=73.7MPa
27.1	END OF BOREHOLE AT 27.09m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.						



WATER LEVEL READINGS

DATE	DEPTH (m)
22/10/03	19.72
16/12/03	19.38
04/02/04	19.41

ONTMT4 7450BRN.GPJ 19/08/04

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BRN-2

1 OF 3

METRIC

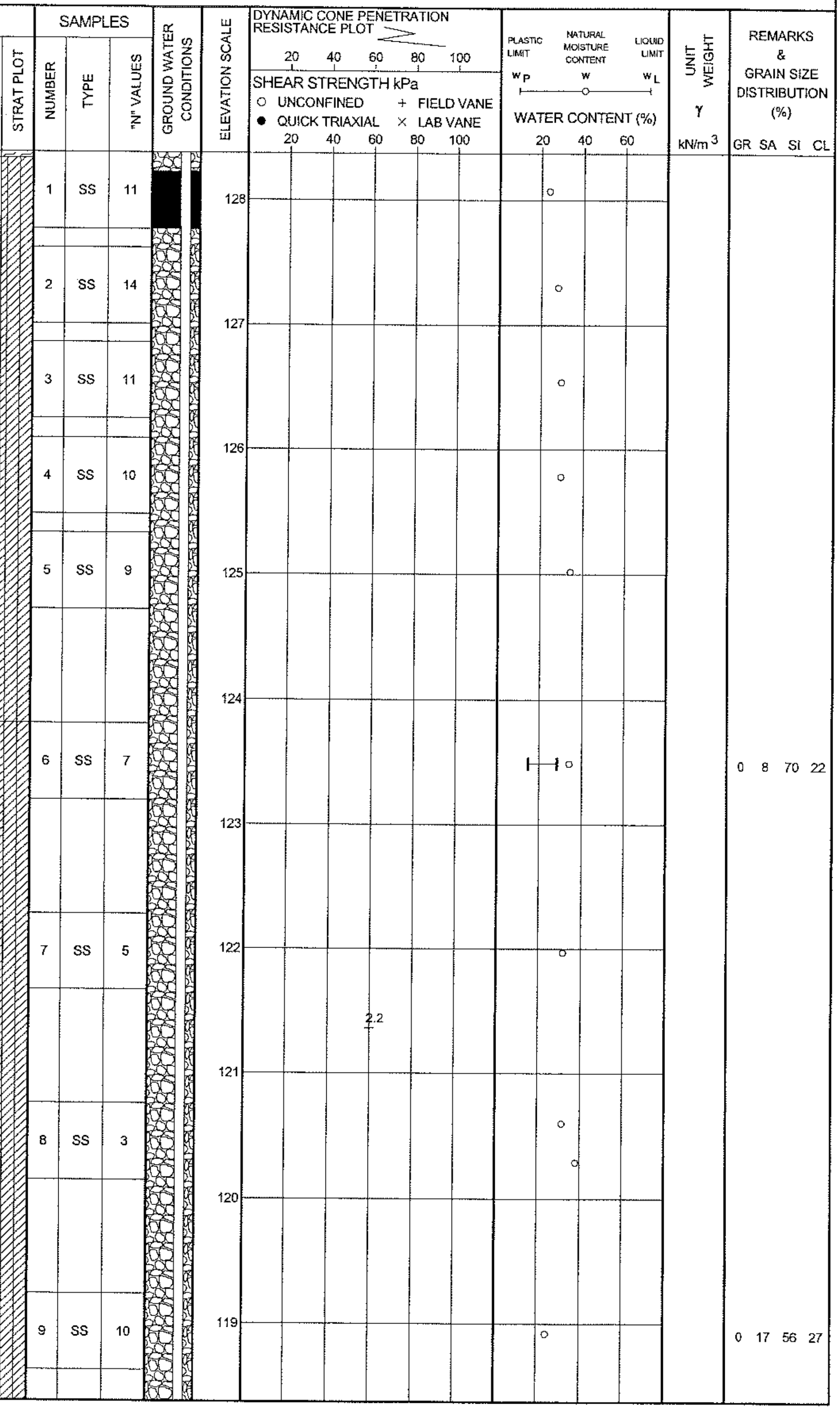
G.W.P. 647-92-00	LOCATION (N 5 038 074.4 E 293 421.5) O'Brien Road	ORIGINATED BY SL
HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring	COMPILED BY SS
DATUM Geodetic	DATE 01.10.03 - 02.10.03	CHECKED BY AEG

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
128.4	
128.3 0.0	**TOPSOIL** (50mm)
0.1	Silty **CLAY**, trace rootlets to 1.4m Very Stiff to Stiff Brown Moist to Wet (CI) with sand laminations
123.8 4.6	Silty **CLAY** with interbedded silty sand Firm Brown Wet (CL) becoming grey below 6.1m

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	11				
2	SS	14				
3	SS	11				
4	SS	10				
5	SS	9				
6	SS	7	0	8	70	22
7	SS	5				
8	SS	3				
9	SS	10	0	17	56	27



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+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

ONTMT4 7450BRN.GPJ 19/08/04

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BRN-2

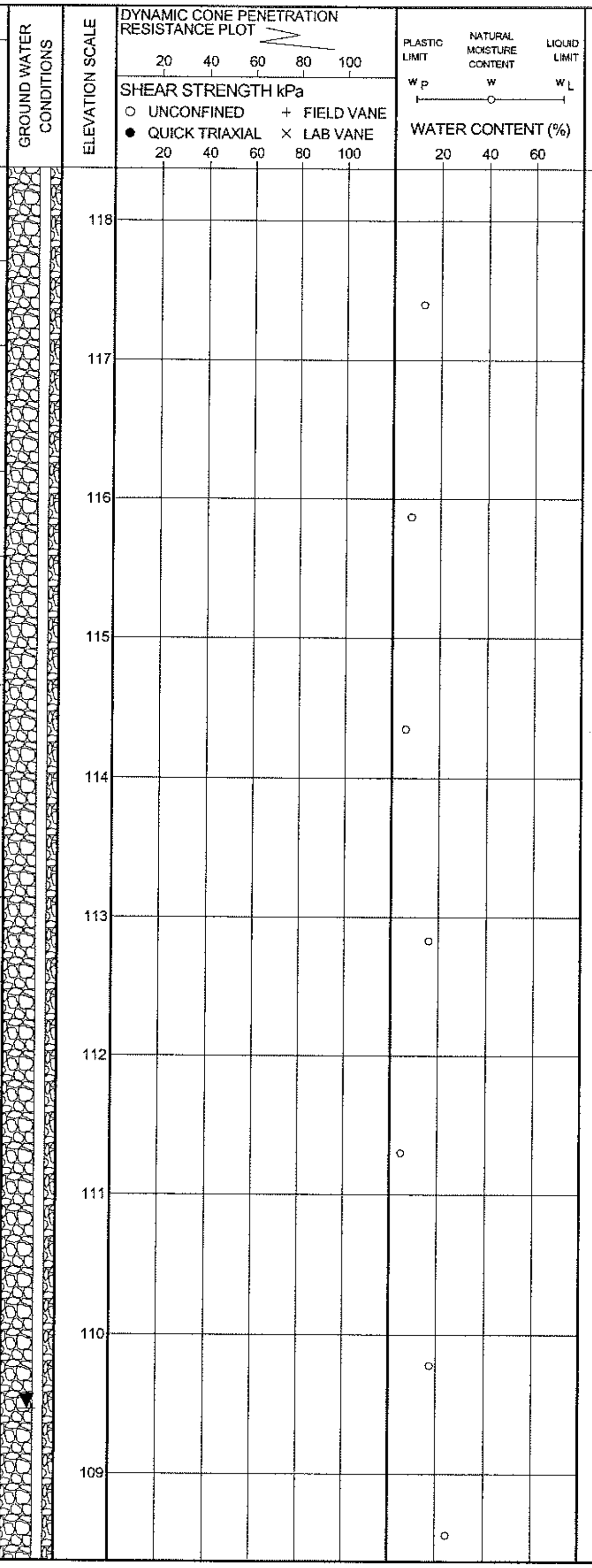
2 OF 3

METRIC

G.W.P. 647-92-00
LOCATION (N 5 038 074.4 E 293 421.5) O'Brien Road
ORIGINATED BY SL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring
COMPILED BY SS
DATUM Geodetic
DATE 01.10.03 - 02.10.03
CHECKED BY AEG

ELEV DEPTH	SOIL PROFILE DESCRIPTION
118.2	
10.2	**SAND**, fine grained, trace silt, trace gravel Very Dense to Dense Brown Moist to Wet (SP)
	some silt (SM) Compact
110.1 18.3	**SAND**, trace silt, occasional silt and silty sand layers Dense Brown Wet (SP/SM)

SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
10	SS	76				
11	SS	57				
12	SS	70	0	90	6	4
13	SS	10				
14	SS	74				
15	SS	40	0	60	33	7
16	SS	42				



UNIT WEIGHT γ kN/m³

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+³, ×³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

ONTMT4 7450BRN.GPJ 19/08/04

Ministry of Transportation
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THURBER

RECORD OF BOREHOLE No BRN-2

3 OF 3

METRIC

G.W.P. 647-92-00
LOCATION (N 5 038 074.4 E 293 421.5) O'Brien Road
ORIGINATED BY SL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring
COMPILED BY SS
DATUM Geodetic
DATE 01.10.03 - 02.10.03
CHECKED BY AEG

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

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
					108		
	medium grained, with silty fine sand seams	17	SS	35	107		
	Auger refusal at 22.4m.						
106.0 22.4	**Cobbles and Boulders**, some gravel, maximum size 500mm	1	RUN		106		
		2	RUN		105		
104.5 23.9	**MARBLE (BEDROCK)** Fresh to slightly weathered, light grey, strong	3	RUN			FI 1 >5	RUN 3# TCR=100%, SCR=100%, RQD=100%, UCS=60MPa
		4	RUN		104 103	2 >5 >5 >5	RUN 4# TCR=100%, SCR=100%, RQD=55%, UCS=70.9MPa
		5	RUN		102	>3 2 2 1 3	RUN 5# TCR=100%, SCR=100%, RQD=78%, UCS=86.4MPa
101.0 27.4	END OF BOREHOLE AT 7.57m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 2.13m slotted screen. WATER LEVEL READINGS:				101		

DATE	DEPTH (m)
22/10/03	19.30
16/12/03	19.08
04/02/04	18.91

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

20 15-⊕-5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

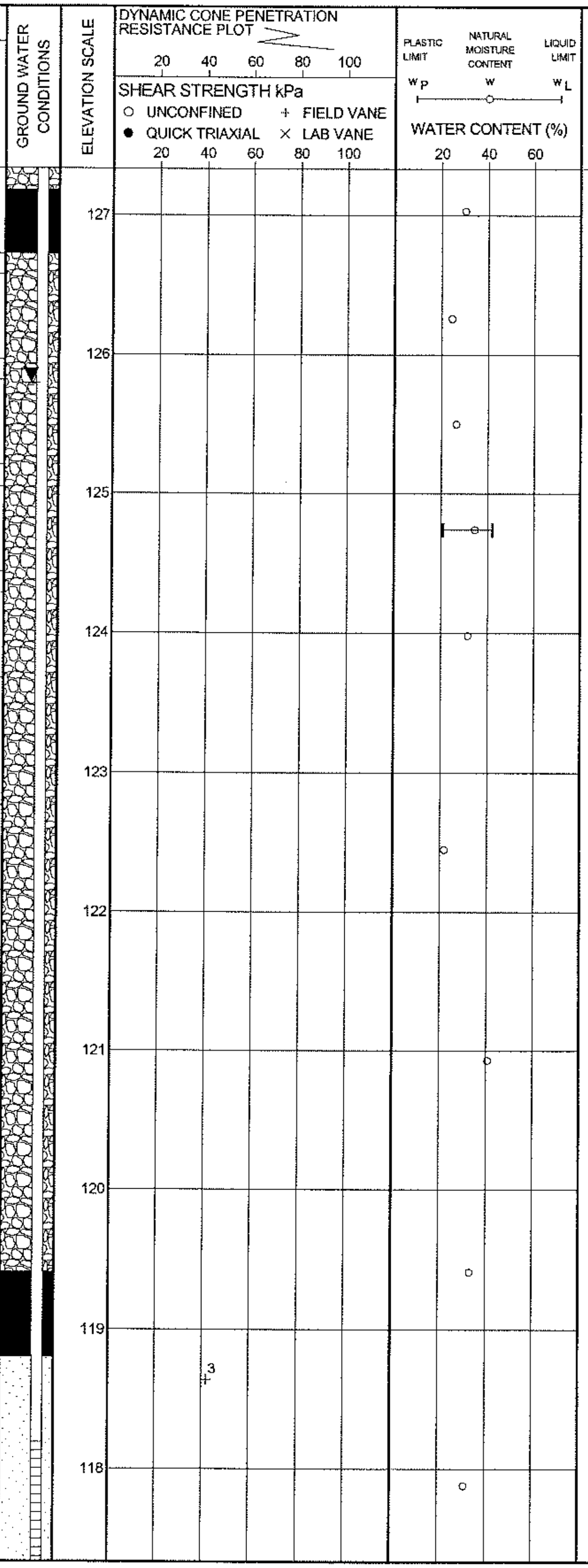
RECORD OF BOREHOLE No BRN-3

1 OF 2

METRIC

G.W.P. 647-92-00	LOCATION (N 5 038 163.5 E 293 603.5) O'Brien Road		ORIGINATED BY SL
HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers		COMPILED BY SS
DATUM Geodetic	DATE 06.10.03 - 06.10.03		CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
127.3								
127.2 0.0	**TOPSOIL** (180mm) Black							
0.2	Silty **CLAY** Stiff Brown Moist to Wet (CI)	1	SS	11				
		2	SS	11				
		3	SS	6				
	occasional sand seams/ partings below 2.3m	4	SS	8	0	1	58	42
		5	SS	6				
		6	SS	6				
120.9 6.5	Silty **CLAY**, occasional silty sand seams to 150mm thick Firm Grey Wet (CL)	7	SS	5				
		8	SS	4				
		9	SS	4				



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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+³, ×³: Numbers refer to Sensitivity

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

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THURBER

RECORD OF BOREHOLE No BRN-3

2 OF 2

METRIC

G.W.P. 647-92-00
LOCATION (N 5 038 163.5 E 293 603.5) O'Brien Road
ORIGINATED BY SL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY SS
DATUM Geodetic
DATE 06.10.03 - 06.10.03
CHECKED BY AEG

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
							117				
	Interbedded sand layers to 150mm thick		10	SS	3						0 15 57 28
							116				
							115				
114.9 12.4	**SAND**, some gravel Dense Brown Moist (SP)		11	SS	41						
114.5 12.8	END OF BOREHOLE AT 12.8m. BOREHOLE WET AND CAVED AT 11.13m ON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.83m slotted screen.										

WATER LEVEL READINGS:

DATE	DEPTH (m)
22/10/03	6.68
16/12/03	0.55
04/02/04	1.54 (frozen)

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

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

Ministry of Transportation
Ontario

THURBER

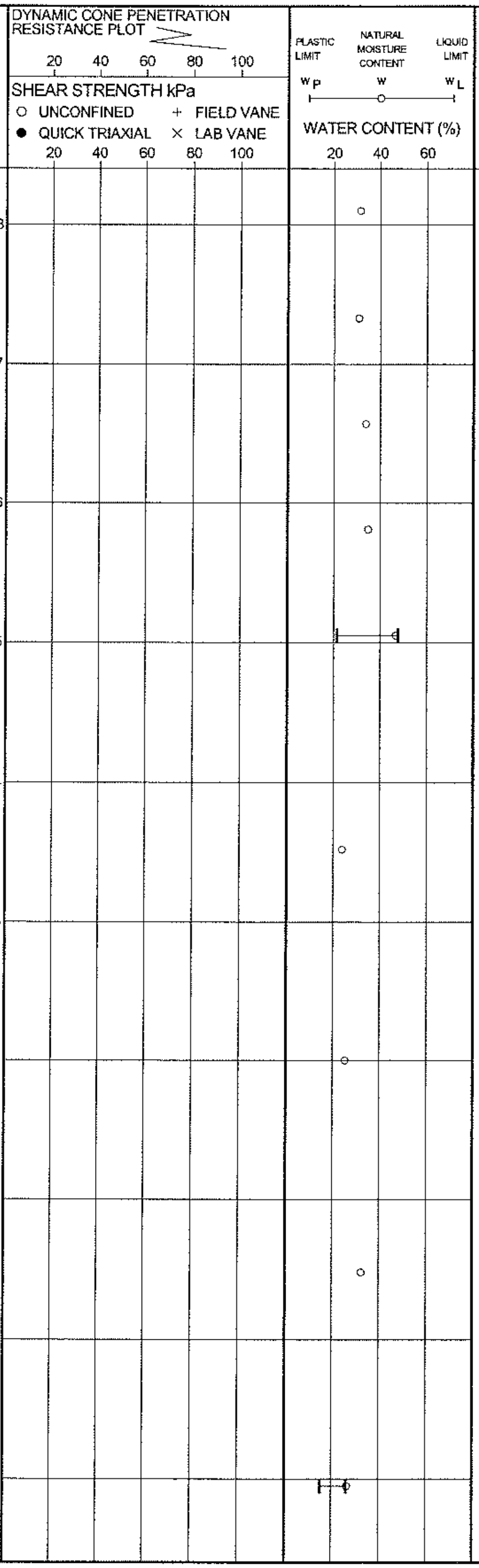
RECORD OF BOREHOLE No BRN-4

1 OF 3

METRIC

G.W.P.	647-92-00	LOCATION	(N 5 038 084.7 E 293 399.3) O'Brien Road	ORIGINATED BY	SL
HWY	HWY 17	BOREHOLE TYPE	Hollow Stem Augers, Casing and Washboring, NQ Coring	COMPILED BY	SS
DATUM	Geodetic	DATE	02.12.03 - 03.12.03	CHECKED BY	AEG

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
128.4						
0.0	**TOPSOIL** (100mm)	1	SS	6	128	
128.1 0.3	Silty **CLAY**, trace sand Firm Brown Moist (CI)	2	SS	8		
	Stiff below 1.5m depth	3	SS	9	127	
		4	SS	11	126	
	occasional oxide staining	5	SS	10	125	0 0 54 45
		6	SS	10	124	
		7	SS	10	123 122	
121.2 7.2	Silty **CLAY**, trace sand Stiff to Firm Brown Moist (CL)	8	SS	9	121	
	with thin sand seams below 9.1m	9	SS	6	120 119	0 10 57 33



UNIT WEIGHT γ kN/m³

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+³, ×³: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

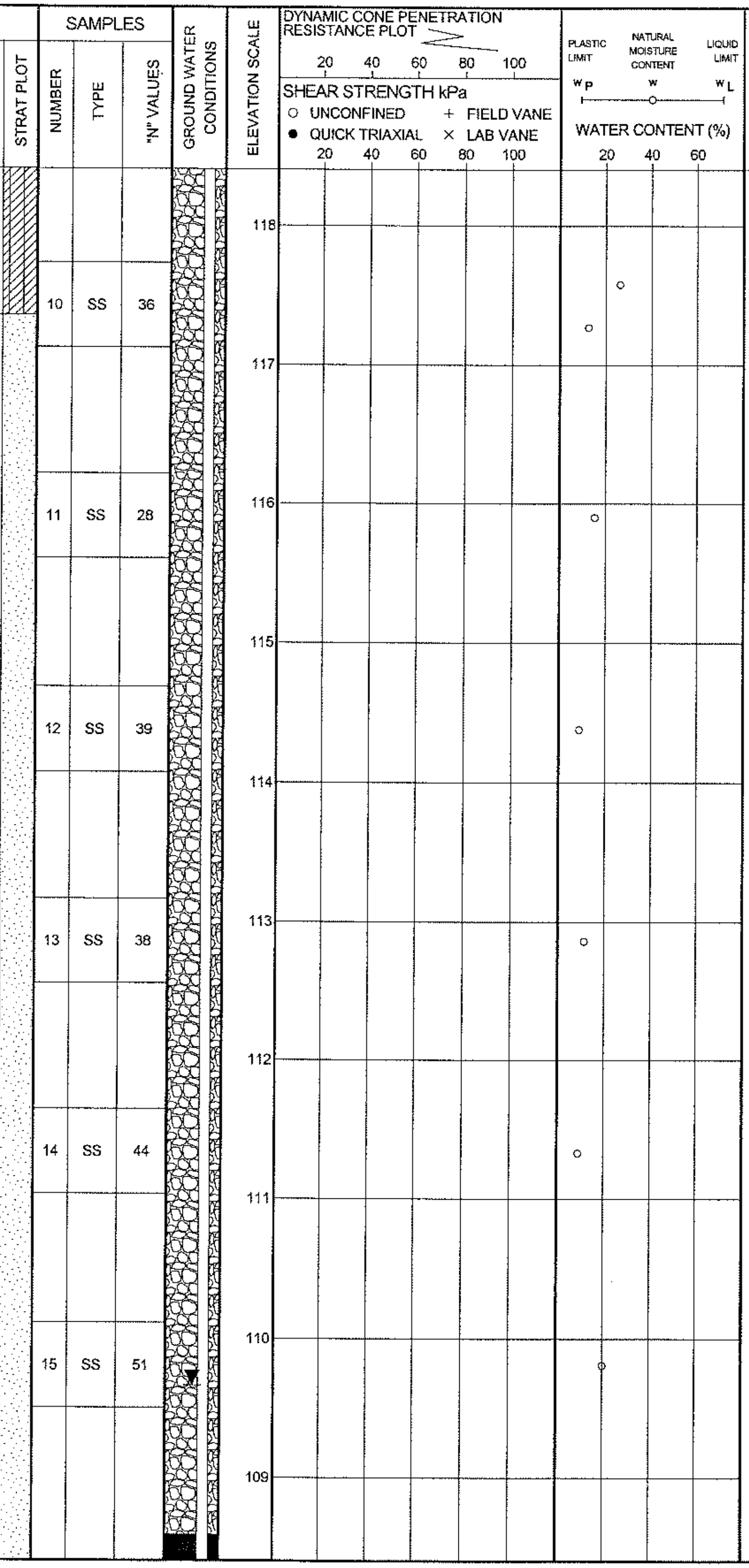
Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BRN-4 2 OF 3 METRIC

G.W.P. 647-92-00
LOCATION (N 5 038 084.7 E 293 399.3) O'Brien Road
ORIGINATED BY SL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring
COMPILED BY SS
DATUM Geodetic
DATE 02.12.03 - 03.12.03
CHECKED BY AEG

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
117.4 11.1	**SAND**, fine grained, some silt Compact to Dense Brown Moist (SM)	10	SS	36	
	with silty clay lenses Compact	11	SS	28	
		12	SS	39	0 82 18 (SI+CL)
		13	SS	38	
		14	SS	44	
					Casing with washboring
	Very Dense	15	SS	51	



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

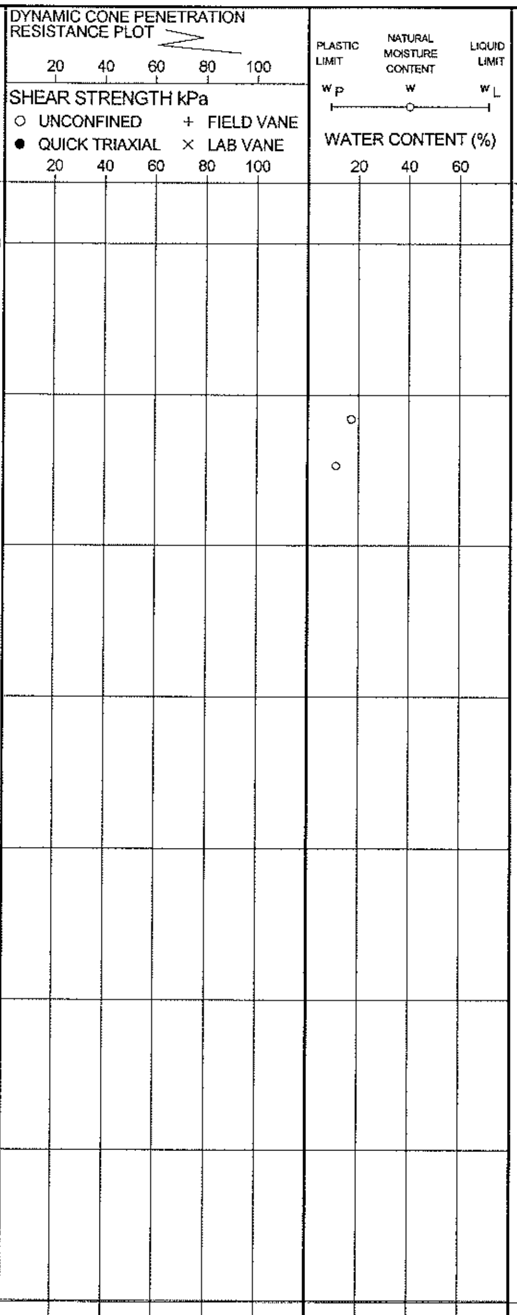
$15 \overset{20}{\underset{10}{\oplus}} 5$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BRN-4 3 OF 3 METRIC

G.W.P.	647-92-00	LOCATION	(N 5 038 084.7 E 293 399.3) O'Brien Road	ORIGINATED BY	SL
HWY	HWY 17	BOREHOLE TYPE	Hollow Stem Augers, Casing and Washboring, NQ Coring	COMPILED BY	SS
DATUM	Geodetic	DATE	02.12.03 - 03.12.03	CHECKED BY	AEG



ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
					108 107		
106.6		16	SS	34			1 86 13 (SI+CL)
21.8	Silty **SAND**, trace gravel, occasional cobbles Dense Grey Moist				106 105 104		
103.9						FI	
24.5	**MARBLE (BEDROCK)** Fresh to slightly weathered, light grey, strong	1	RUN		103	4 3 1 0	RUN 1# TCR=96%, SCR=81%, RQD=78%, UCS=92.7MPa
		2	RUN		102	3 2 1 1 1	RUN 2# TCR=100%, SCR=100%, RQD=90%, UCS=80.1MPa
101.0					101		
27.4	END OF BOREHOLE AT 27.41m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 2.13m slotted screen.						

WATER LEVEL READINGS:

DATE	DEPTH (m)
04/02/04	18.74
16/12/03	18.90

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

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

Ministry of Transportation
Ontario

THURBER

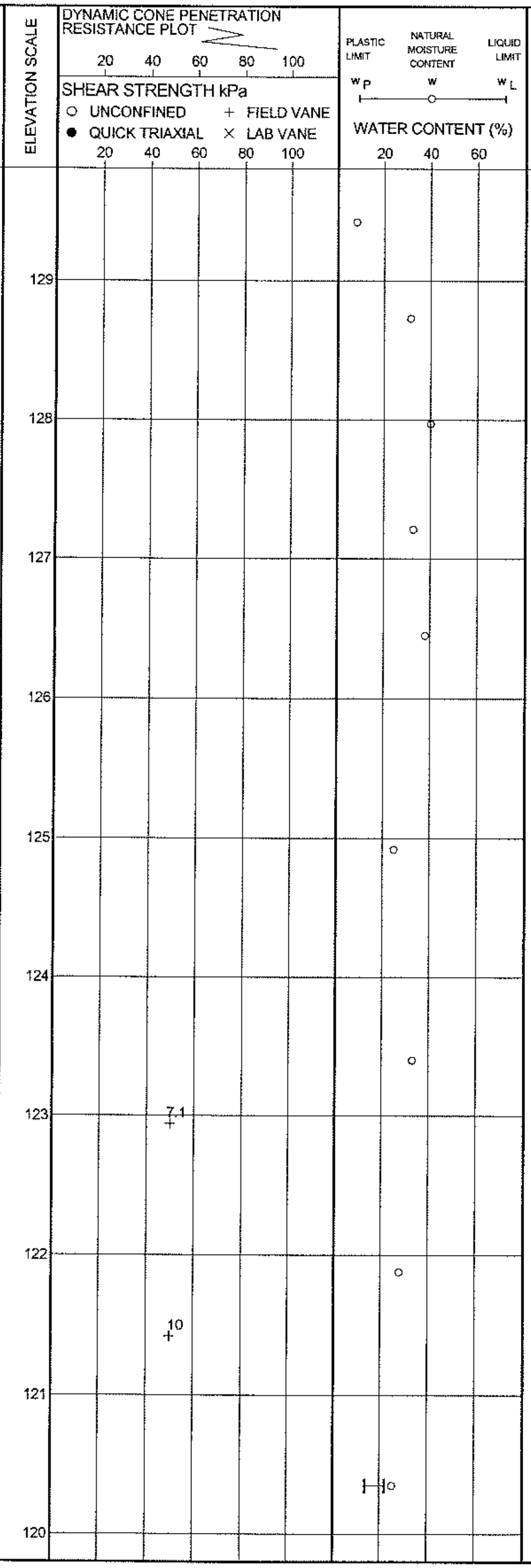
RECORD OF BOREHOLE No BRN-5

1 OF 3

METRIC

G.W.P. 647-92-00	LOCATION (N 5 038 028.3 E 293 364.2) O'Brien Road		ORIGINATED BY JL
HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring		COMPILED BY SS
DATUM Geodetic	DATE 17.12.03 - 17.12.03		CHECKED BY AEG

ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
129.8												
129.7		**ASPHALT** (150 mm)	■									
	0.2	Clayey **SILT**, sandy, some gravel Dark Brown (FILL)	▨	1	GS							
129.0	0.8	Silty **CLAY**, occasional oxide staining Stiff to Firm Brown (CI)	▨	1	SS	10						
			▨	2	SS	8						
			▨	3	SS	4			0	1	52	47
		some sand seams/ partings below 3.0m	▨	4	SS	4						
			▨	5	SS	4						
123.7	6.1	Silty **CLAY**, some sand to sandy, occasional sand seams Firm to Soft Brown-Grey (CL)	▨	6	SS	4						
			▨	7	SS	3						
			▨	8	SS	1			0	12	54	34



Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

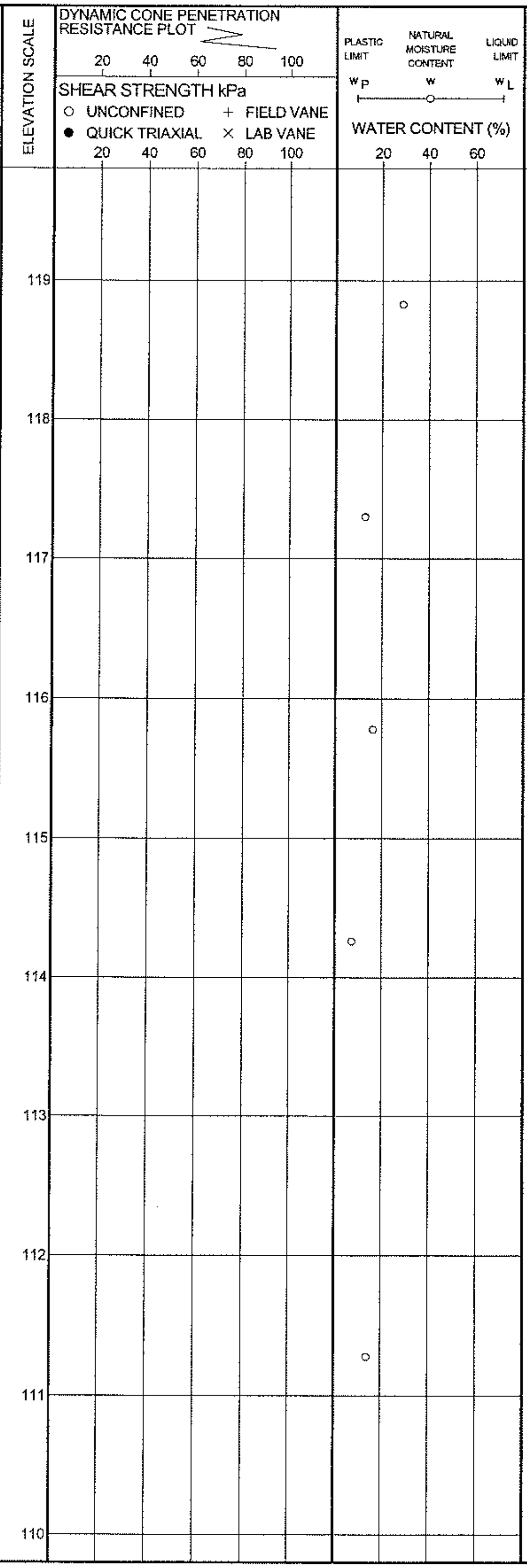
RECORD OF BOREHOLE No BRN-5

2 OF 3

METRIC

G.W.P. 647-92-00	LOCATION (N 5 038 028.3 E 293 364.2) O'Brien Road		ORIGINATED BY JL
HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring		COMPILED BY SS
DATUM Geodetic	DATE 17.12.03 - 17.12.03		CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			9	SS	5			
117.8 12.0	**SAND**, fine to medium grained, trace to some silt Compact Brown (SP)							
			10	SS	14			
			11	SS	24			0 80 20 (SI+CL)
			12	SS	21			
	occasional gravel		13	SS	49			Casing with washboring



Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

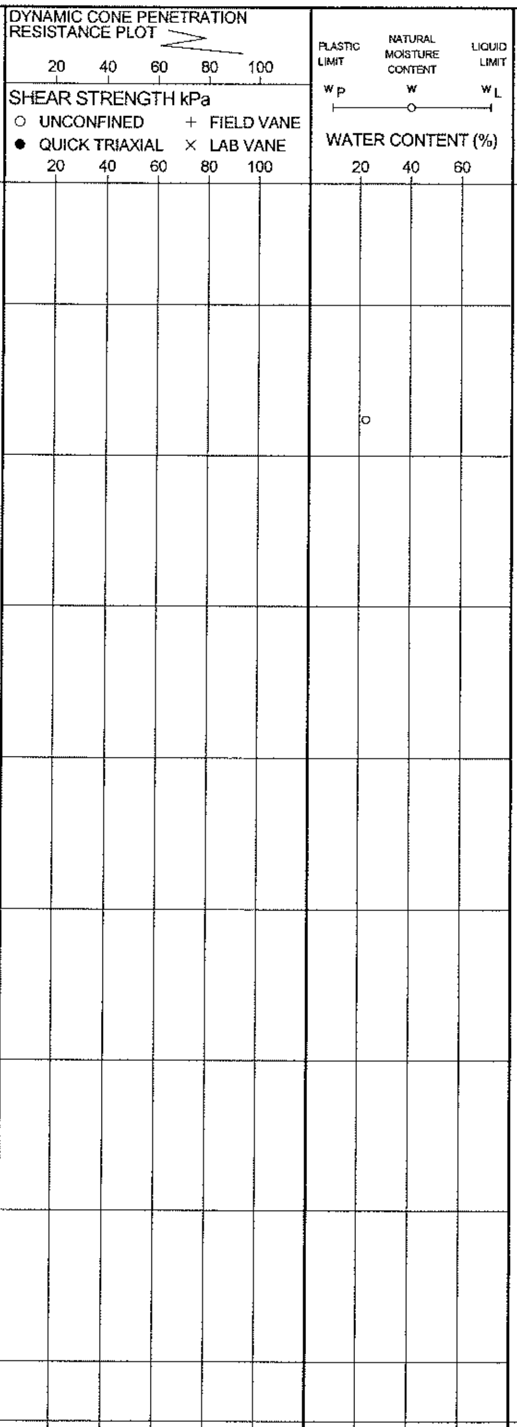
RECORD OF BOREHOLE No BRN-5

3 OF 3

METRIC

G.W.P. 647-92-00
LOCATION (N 5 038 028.3 E 293 364.2) O'Brien Road
ORIGINATED BY JL
HWY HWY 17
BOREHOLE TYPE Hollow Stem Augers, Casing and Washboring, NQ Coring
COMPILED BY SS
DATUM Geodetic
DATE 17.12.03 - 17.12.03
CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
						109		
		14	SS	20		108		
						107		
						106		
105.7 24.1	**Cobbles and Boulders**, some gravel Start coring at 24.97m.					105		
104.5 25.3	**MARBLE (BEDROCK)** Fresh to slightly weathered, light grey, strong	1	RUN			104	FI 1 3	RUN 1# TCR=100%, SCR=92%, RQD=68%, UCS=70.6MPa
		2	RUN			103	1 2 1	RUN 2# TCR=96%, SCR=94%, RQD=60%, UCS=55.8MPa
		3	RUN			102	1 0 0 2	RUN 3# TCR=98%, SCR=98%, RQD=94%, UCS=95.2MPa
101.6 28.2	END OF BOREHOLE AT 28.19 m.						1	



+ ³, × ³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Appendix B

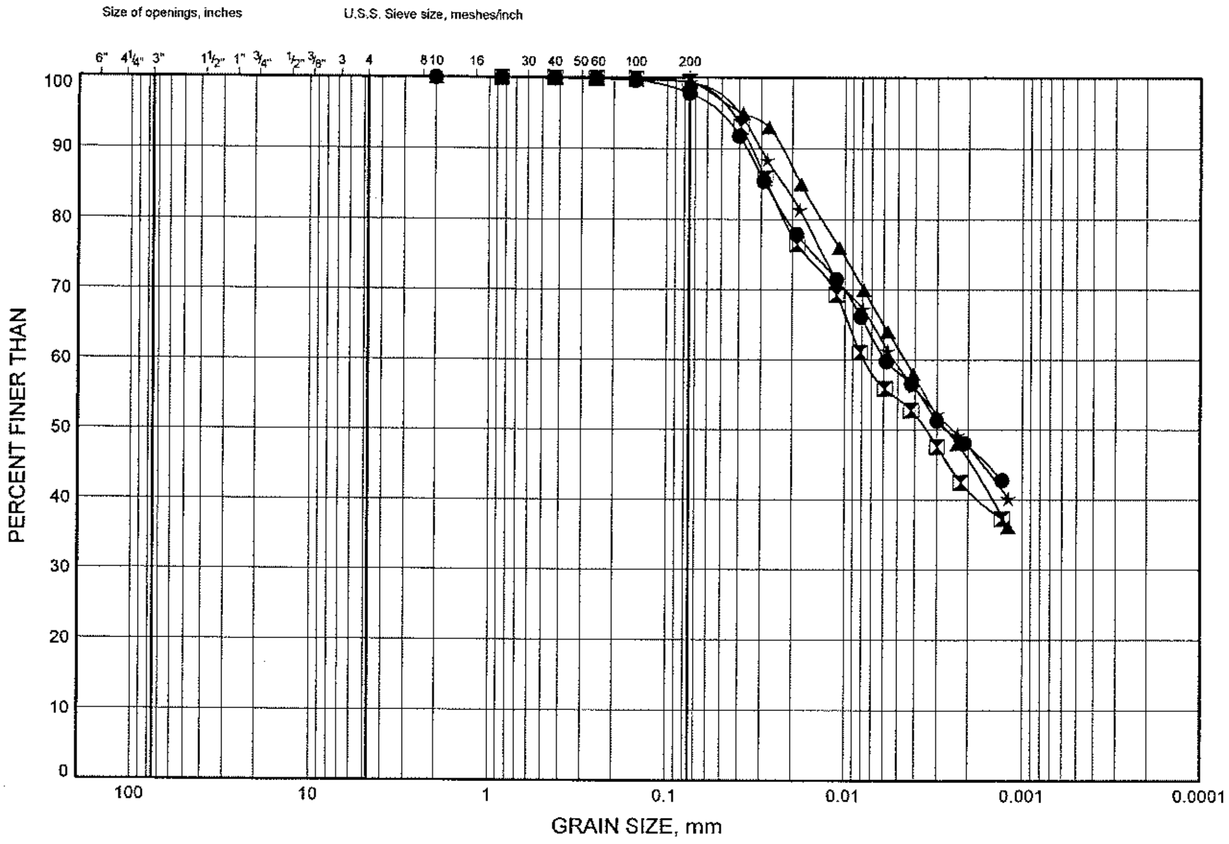
Laboratory Test Results

HWY 17 Twinning, Arnprior to Renfrew

GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY CLAY (CI)



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BRN-1	4.88	124.91
☒	BRN-3	2.59	124.74
▲	BRN-4	3.35	125.05
★	BRN-5	2.59	127.21

Date March 2004

Project 647-92-00

THURBER

Prep'd SS

Chkd. SMS

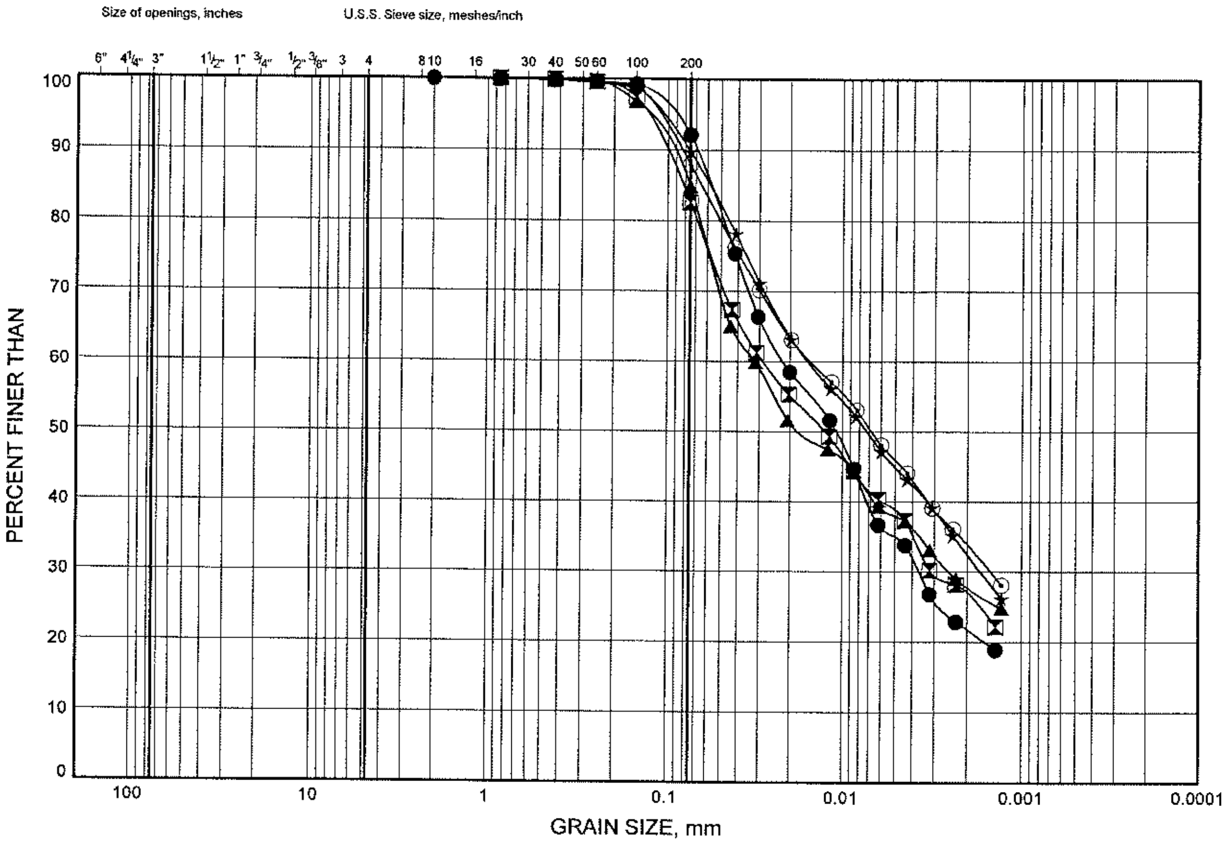
THURBGSD 7450BRN.GPJ 15/03/04

HWY 17 Twinning, Arnprior to Renfrew

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY (CL)



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BRN-2	4.88	123.49
⧗	BRN-2	9.45	118.92
▲	BRN-3	10.97	116.36
★	BRN-4	9.45	118.95
⊙	BRN-5	9.45	120.35

THURBGSD 7450BRN.GPJ 15/03/04

Date March 2004

Project 647-92-00

THURBER

Prep'd SS

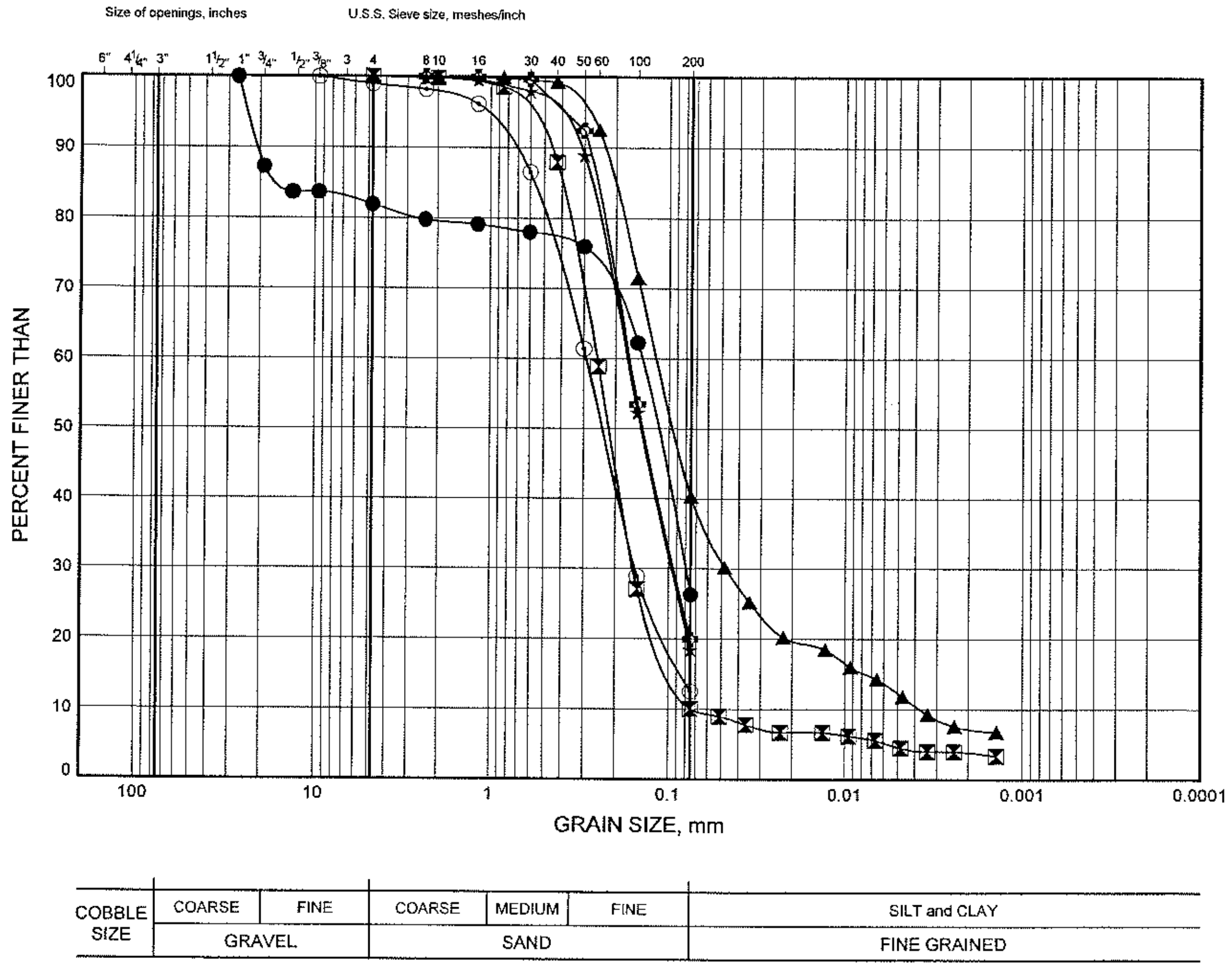
Chkd. SMS

HWY 17 Twinning, Arnprior to Renfrew

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BRN-1	10.97	118.82
⧗	BRN-2	14.02	114.35
▲	BRN-2	18.59	109.78
★	BRN-4	14.02	114.38
⊙	BRN-4	21.56	106.84
✪	BRN-5	14.02	115.78

Date March 2004

Project 647-92-00

THURBER

Prep'd SS

Chkd. SMS

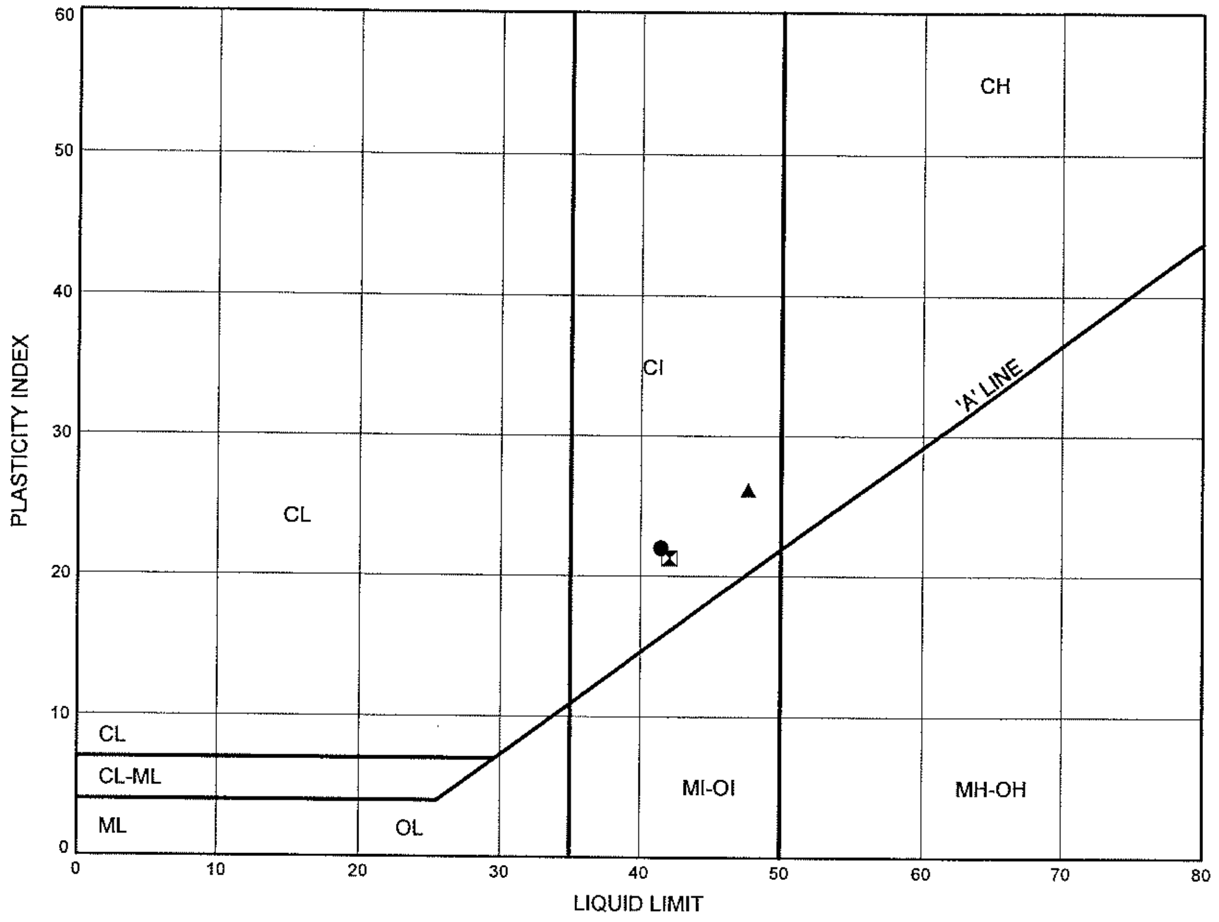
THURBGSD 7450BRN.GPJ 15/03/04

HWY 17 Twinning, Arnprior to Renfrew

ATTERBERG LIMITS TEST RESULTS

FIGURE B4

SILTY CLAY (CI)



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BRN-1	4.88	124.91
☒	BRN-3	2.59	124.74
▲	BRN-4	3.35	125.05

Date March 2004

Project 647-92-00

THURBER

Prep'd SS

Chkd. SMS

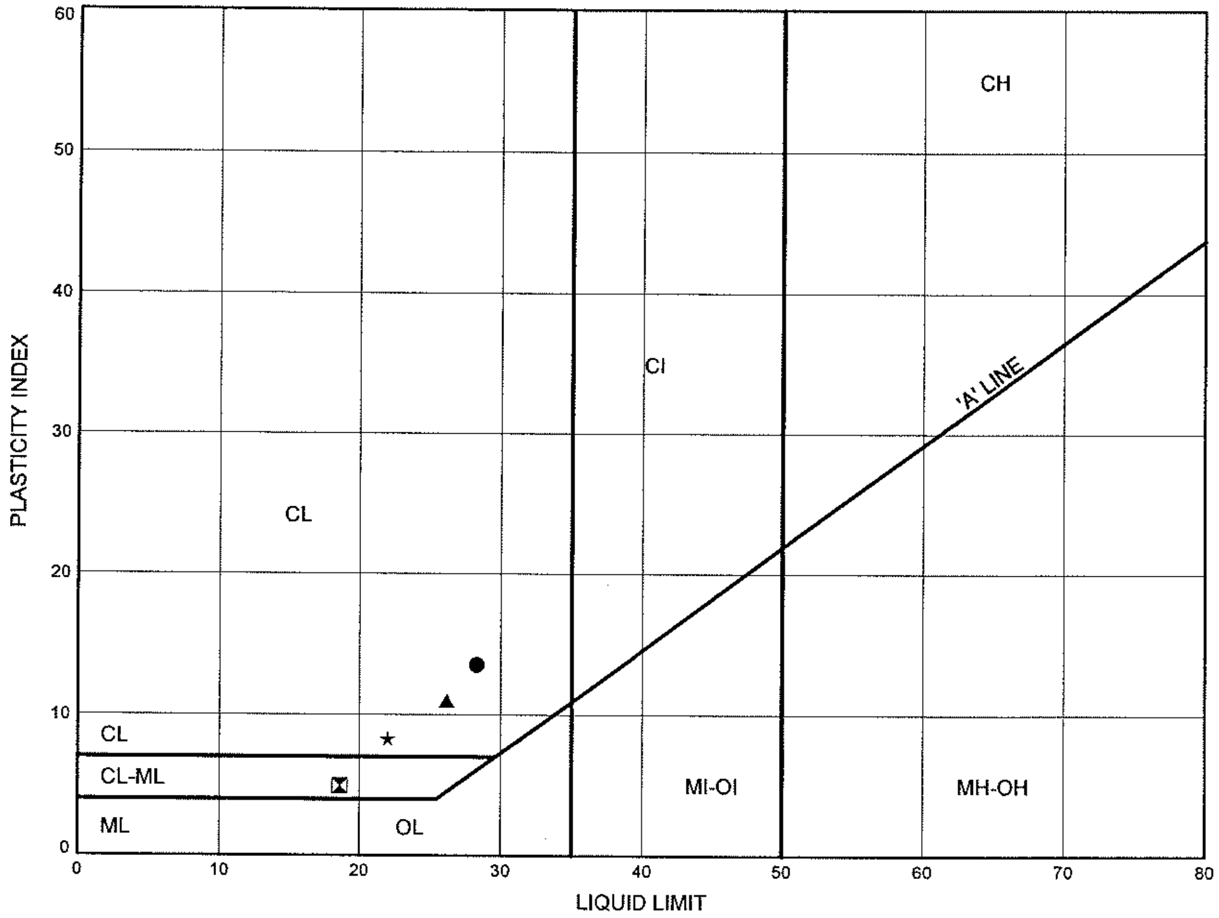
THURBALT 7450BRN.GPJ 15/03/04

HWY 17 Twinning, Arnprior to Renfrew

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

SILTY CLAY (CL)



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	BRN-2	4.88	123.49
⧗	BRN-3	10.97	116.36
▲	BRN-4	9.45	118.95
★	BRN-5	9.45	120.35

Date March 2004

Project 647-92-00

THURBER

Prep'd SS

Chkd. SMS

THURBALT 7450BRN.GPJ 15/03/04

Appendix C

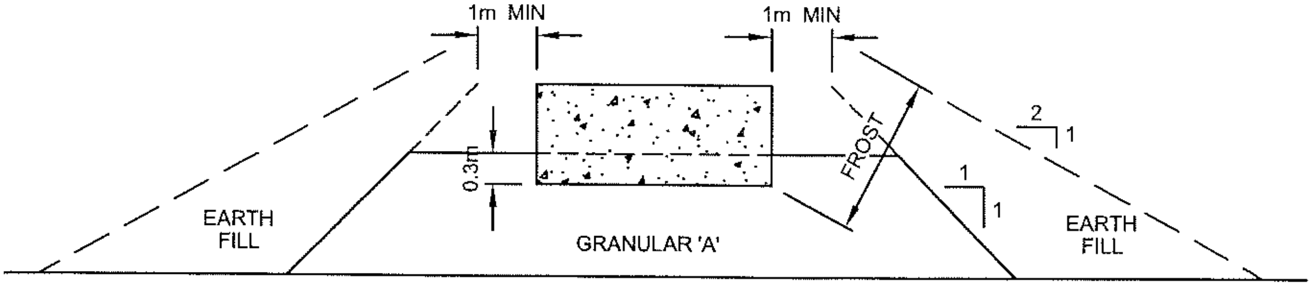
Figures

COMPARISON OF FOUNDATION ALTERNATIVES FOR RIGID FRAME STRUCTURES

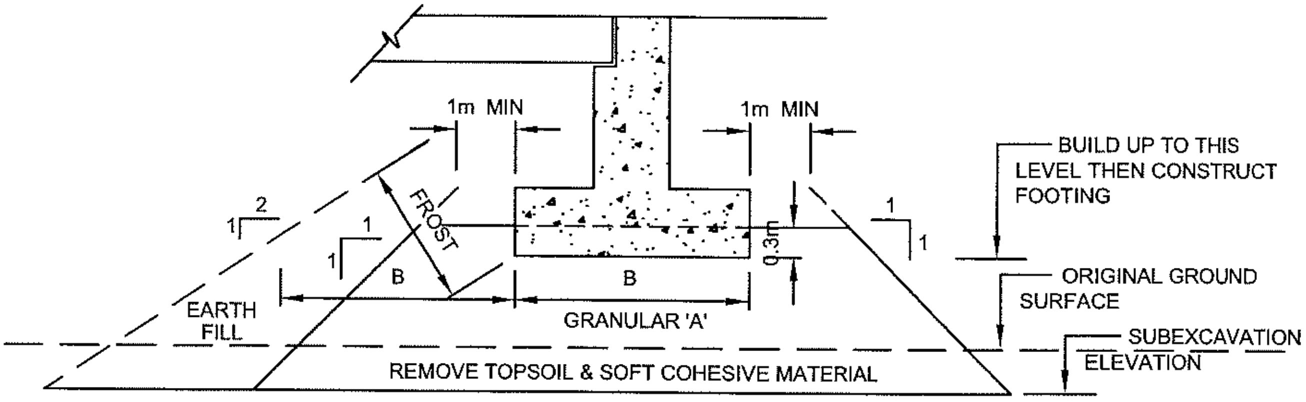
	Spread Footings On Native Soils	**Spread Footings on Engineered Fill**	**Steel H-Piles Driven to Bedrock**	**Drilled Caissons**
Advantages:	▪ Simple and cost effective foundation option if feasible	▪ Higher geotechnical resistance than footings on native deposits	▪ Bedrock is <25 m depth below existing grade ▪ High axial geotechnical resistance possible	▪ Moderate axial geotechnical resistance may be obtained using 0.9 to 1.5m diameter by 11 m long caissons ▪ Improved lateral resistance resulting from large diameter
Disadvantages:	▪ Very low geotechnical resistance at ULS	▪ Requires subexcavation and replacement of silty clay extending 3 to 5 m below footing elevation	▪ Presence of silty clay reduces lateral resistance of the piles.	▪ Cohesion-less sand may require side support such as a temporary liner or stabilizing fluid ▪ More difficult to install then H-piles
Recommendations	▪ Not suitable due to low resistance	▪ Costs for dewatering and excavation to 10 to 12 m below existing grade may be prohibitive	▪ Considered the most feasible option based on capacity, costs and ease of installation	▪ Considered more costly and has more risk of construction difficulty then H-piles

FIGURE 1

March , 2004



CROSS-SECTION



LONGITUDINAL SECTION

NOT TO SCALE

NOTES:

1. REMOVE TOPSOIL AND SOFT SILTY CLAY SUBSOIL UNDER FOOTPRINT OF COMPACTED GRANULAR 'A'.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

ENGINEER	AEG
DRAWN	SS
DATE	April , 2004
APPROVED	PKC
SCALE	NTS

ABUTMENT ON COMPACTED FILL SHOWING
GRANULAR A CORE

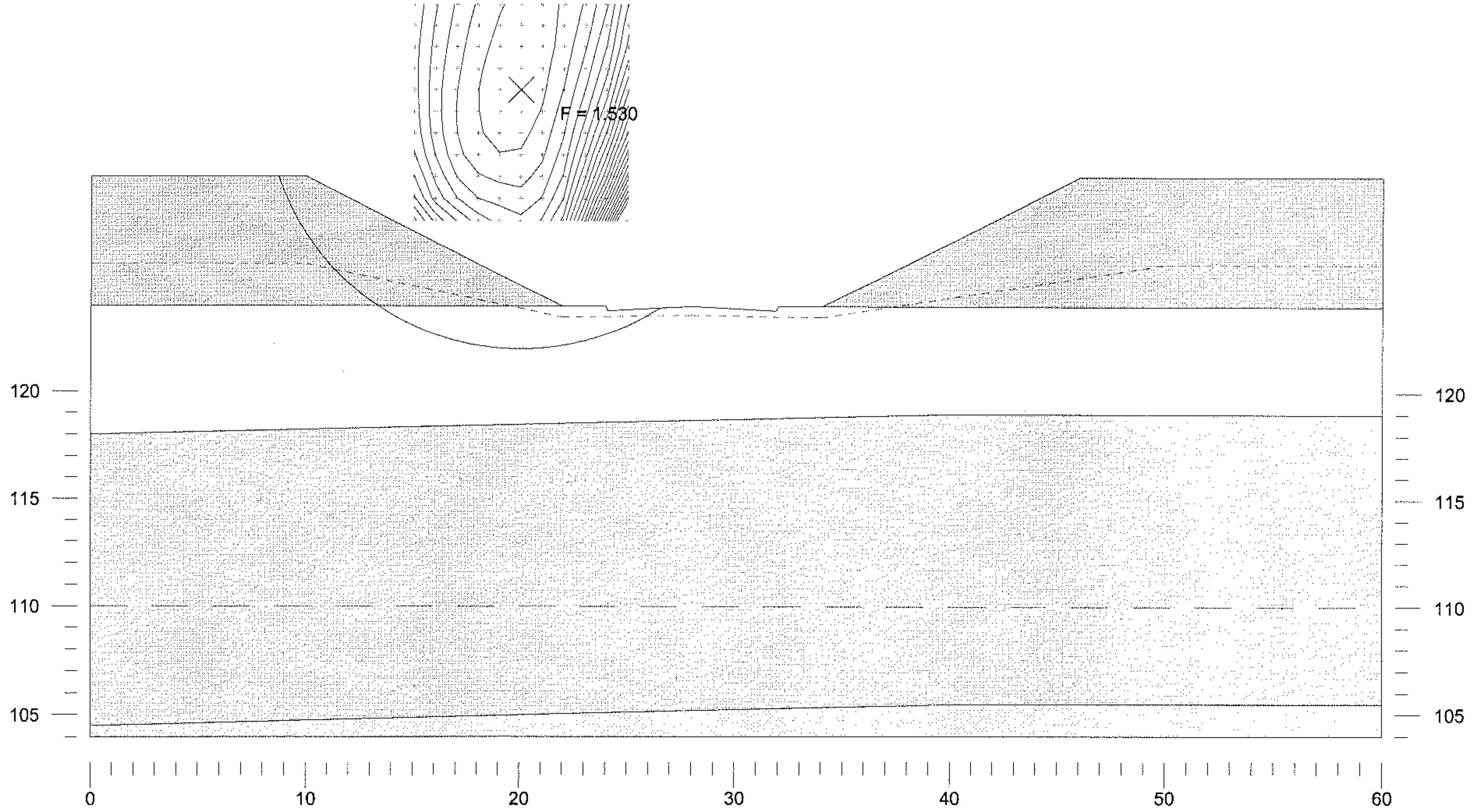
THURBER

DWG. NO. FIGURE 2

TED35146.DWG

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Firm to Stiff Cl	19	6	29	2
Firm to Soft CL	19	0	30	2
Compact Sand	20	0	32	1
Bedrock	27	500	32	1

Thurber Engineering Ltd. - Toronto
19-3745-0
Hwy 17 and O'Brien Road int
March 2004
Effective Stress Analysis



24/08/2004 11:34:14 AM C:\DATA\ENGINE~1\19-374~1\OB3.GSL Thurber Engineering Ltd. - Toronto F = 1.530

FIGURE 3

Appendix D

Special Provisions

EARTH EXCAVATION FOR STRUCTURE - Item No.
ROCK EXCAVATION FOR STRUCTURE - Item No.
UNWATERING STRUCTURE EXCAVATION - Item No.
CLAY SEAL - Item No.

Special Provision No. 902S01 September 2003

Excavation and Backfilling-Structures

902.02 REFERENCES

Section 902.02 of OPSS 902, December, 1983, is amended by the addition of the following:

OPSS 510

902.03 DEFINITIONS

Section 902.03 of OPSS 902, December, 1983, is amended by the addition of the following:

Quality Verification Engineer: means an Engineer with a minimum of five (5) years experience related to excavation and backfilling of structures, or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the Contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and issue of certificate(s)of conformance.

902.04 SUBMISSION AND DESIGN REQUIREMENTS

Section 902.04 of OPSS 902, December, 1983, is deleted and replaced with the following:

902.04.01 Site Survey

Prior to commencing the work, the Contractor shall submit to the Contract Administrator a condition survey of property and structures that may be affected by the work. The survey shall include, but not be limited to, the locations and conditions of adjacent properties, buildings, underground structures, utility services and structures such as walls abutting the site.

902.04.02 Working Drawings

Working drawings for protection systems shall be according to OPSS 539.

Where unwatering is required, the Contractor shall be responsible for the design of the unwatering scheme for the intended purpose. The design of temporary structures or protection system for unwatering shall be according to OPSS 539.

902.04.03 Submission of Certificate of Conformance

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation:

- Excavation for Foundation
- Excavation for Backfill and Frost Tapers
- Use of Excavated Material
- Unwatering of Excavation for Structure
- Backfilling

The Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

902.05.03 Backfill

Subsection 902.05.03 is amended by the addition of the following:

The Contractor shall be responsible for ensuring the quality of the material used for backfill. The quality of the material shall be verified by test results from a qualified and recognized testing laboratory. The frequency of sampling and testing shall be according to ASTM D75-87 and D3665.

902.05.04 Protection System

Section 902.05 of OPSS 902, December, 1983, is amended by the addition of the following:

Protection systems shall be according OPSS 539.

902.07.01 Protection Schemes

Subsection 902.07.01 of OPSS 902, December, 1983, is amended by replacing the word "Engineer" in the last paragraph with the words "Contract Administrator".

902.07.02 Excavation

Subsection 902.07.02 of OPSS 902, December, 1983, is deleted and replaced with the following:

902.07.02.01 General

For excavation, the Contractor shall be responsible for preventing any deterioration of the foundation soil or rock, surface water from entering and eroding the face of the excavation, and build up of hydrostatic pressures which may have harmful effects upon the temporary or permanent structures.

902.07.02.02 Excavation for Foundation

The excavation for foundation shall be inspected and approved by the Quality Verification Engineer prior to construction of the footing. Immediately after the inspection and prior to commencement of subsequent activity, a certificate of conformance shall be submitted to the Contract Administrator.

The Contractor shall be responsible for maintaining the stability of the excavation if any excavation below stream or channel bed is carried out.

The Contractor shall be responsible for restoring the over excavated area to its original conditions. For over excavation in earth, the backfill material shall be granular material such as Granular A or B compacted according to OPSS 501. For over excavation in rock, concrete shall be placed to achieve the original excavation limits. The concrete shall be of the same class concrete as the element it supports.

The Contractor shall be responsible for all additional costs due to excavation beyond the required tolerance limits, including but not limited to additional structure design, granular materials, concrete, reinforcing steel and retention of the services of a blasting consultant.

902.07.02.03 Excavation for Backfill and Frost Tapers

Excavation for backfill and frost tapers shall be carried out according to the specifications and details shown on the contract drawings. The Contractor shall be responsible for restoring the over excavated portion with backfill and shall be compacted according to OPSS 501.

The excavation for backfill and frost tapers shall be inspected and approved by the Quality Verification Engineer prior to placement of fill material. Immediately after the inspection and prior to commencement of subsequent activity, a certificate of conformance shall be submitted to the Contract Administrator.

902.07.02.04 Preservation of Channel

The Contractor shall be responsible for restoring the channel back to its original conditions unless otherwise specified in the contract.

902.07.02.05 Removals

Removal of pavement, curb and gutter, and sidewalks shall be according to OPSS 510.

902.07.03 Unwatering Structure Excavation

Subsection 902.07.03 of OPSS 902, December, 1983, is amended by replacing the first paragraph with the follows:

The Contractor shall carry out all work necessary to prevent disturbance to the founding material. Concrete shall be placed in the dry, unless otherwise specified in the contract.

After the unwatering, the excavation shall be inspected and approved by the Quality Verification Engineer prior to construction of the footing. Immediately after the inspection and prior to commencement of subsequent activity, a certificate of conformance shall be submitted to the Contract Administrator.

902.07.04 Backfilling

Subsection 902.07.04 of OPSS 902, December, 1983, is deleted and replaced with the following:

The Contractor shall ensure that the concrete has reached at least 70 percent of its design strength before placing the backfill against an abutment, wingwall, retaining wall or concrete culvert.

Backfilling shall be according to OPSS 501.

The backfilling operation shall be inspected and approved by the Quality Verification Engineer. Immediately after the inspection and prior to commencement of subsequent activity, a certificate of conformance shall be submitted to the Contract Administrator.

902.09 Measurement for Payment

902.09.01 Structures

Subsection 902.09.01 of OPSS 902, is amended by deleting the first five paragraphs and replacing them with the following:

"Earth Excavation for Structure" and "Rock Excavation for Structure" applies to the specific structure(s) designated, i.e., Bridge, Retaining Wall or Concrete Culvert, and is measured by Plan Quantity, as may be revised by Adjusted Plan Quantity, of the volume in cubic metres below the designated payment surface.

The above measurement also includes, where applicable, the excavation quantities, below the designated payment surface, for placing granular backfill and for placing the granular frost tapers.

For open footing culverts, the above measurement also includes the excavation quantities below the designated payment surface but between the plan areas of the footings and above the stream bed or the top of the footings, whichever is higher.

Where the structure excavation overlaps excavation required for other work, deductions will not be made to the structure excavation measurement.

902.10 Basis of Payment

902.10.01 Excavation and Backfill

Subsection 902.10.01 of OPSS 902 is amended by deleting the first paragraph and replacing it with the following:

Payment at the contract price(s) for the tender item(s) "Earth Excavation for Structure" and "Rock Excavation for Structure" shall be full compensation for all labour, equipment and material for all excavation required, for removal of pavement, curb and gutter and sidewalk except where there is a separate item for removal of pavement, curb and gutter and sidewalk which overlaps pavement, curb and gutter and sidewalk removal required for structure excavation, protection of adjacent works, unwatering, backfilling and compacting around the footing according to subsection 902.07.04, placing and compacting of suitable material in fill in accordance with OPSS 206 and management of any surplus or unsuitable excavated material, including the cost of disposal areas, all according to the requirements of this specification.

WARRANT: Always with these tender items.

SUPPLY EQUIPMENT FOR DRIVING PILES - Item No.
SUPPLY EQUIPMENT FOR INSTALLING CAISSON PILES - Item No.
SUPPLY EQUIPMENT FOR INSTALLING DISPLACEMENT CAISSON PILES - Item No.
SHEET PILES - Item No.
H-PILES - Item No.
TUBE PILES - Item No.
WOOD PILES - Item No.
PRECAST CONCRETE PILES - Item No.
CAISSON PILES - Item No.
DISPLACEMENT CAISSON PILES - Item No.
DRIVING SHOES - Item No.
ROCK POINTS. - Item No.
RETAPPING PILES – Item No.

Special Provision No. 903S01 October, 2002

Piling

OPSS 903, December 1983, is deleted and replaced with the following:

903.01 SCOPE

This specification covers the requirements for the supply and installation of deep foundation units comprised of wood, steel, concrete or a combination of these materials.

903.02 REFERENCES

This specification refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, General:

OPSS 180	Management and Disposal of Excess Materials

Ontario Provincial Standard Specifications, Construction:

OPSS 904	Concrete
OPSS 905	Steel Reinforcement
OPSS 909	Prestressed Concrete - Precast
OPSS 911	Coating Structural Steel Construction

Ontario Provincial Standard Specifications, Material:

OPSS 1302	Water
OPSS 1350	Concrete (Materials and Production)
OPSS 1440	Steel Reinforcement for Concrete

Canadian Standards Association Standards:

CAN/CSA 3-G40.20/G40.21-M92 - General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Sheets

CAN3-056-M79 - Round Wood Piles

CSA 080 Series-M97 - Wood Preservation

W47.1-92 - Certification of Companies for Fusion Welding of Steel Structures

W48.1 - M1991 - Carbon Steel Covered Electrodes for Shielded Metal Arc Welding

W59 - M1989 - Welded Steel Construction (Metal Arc Welding)

American Society for Testing and Materials Standards:

ASTM A 252-93 Welded and Seamless Steel Pipe Piles

ASTM A 328/ A 328M-93A Steel Sheet Piling

American Petroleum Institute:

API 13A-86 Oil Well Drilling Fluid Materials

API 13B Standard Procedures for Field Testing Drilling Fluids

903.03 DEFINITIONS

For the purposes of this specification, the following definitions apply:

Anvil: means the component of a diesel hammer that acts as an impact block for the ram

Bedrock: means a natural solid bed of the hard, stable, cemented part of the earth's crust, igneous, metamorphic or sedimentary in origin which may or may not be weathered. The actual surface of the bedrock, weathered or unweathered, exists immediately below the overburden.

Casing: means open ended enclosing cylindrical steel tubing or pipe permanently installed in the ground with caisson piles that is structurally required and can be used to render a stable excavation hole.

Caisson Pile: means a cast in place deep foundation unit with or without an enclosing liner formed by placing concrete in a bored or excavated hole.

Cap Block: means a material placed on top of the helmet to cushion the blow of the hammer and to attenuate the peak impact energy without causing excessive loss of the impact energy.

Deep Foundation Unit: means a structural member, driven or otherwise installed in the ground to transfer the loads from a structure to soil or rock and derives supporting resistance from the surrounding soil or rock or from the soil or rock strata below its tip or a combination of both.

Displacement Caisson Pile: means a pile formed in the ground by driving a casing or liner by means of a concrete plug or an expendable metal plate and replacing the displaced soil with plain or reinforced concrete.

Driving Shoe: means a reinforcement attached to the bottom of the pile and designed to protect the pile during driving or to penetrate into a hard stratum.

Driving to a Set: means driving the pile to a penetration that satisfies pile driving criteria correlated to a required pile resistance

Follower: means a removable extension which transmits the hammer blows to the head of the pile.

Helmet: means a formed steel cap that fits over the top of a pile head to retain in position a resilient cap block.

Jetting: means the use of a jet of water at high pressure directed into the ground below the pile tip to assist its penetration

Liner: means open ended enclosing steel tubing or pipe temporarily installed in the ground to facilitate the construction of caisson piles

Pile: means a relatively slender structural element which is installed, wholly or partly in the ground by driving, drilling, auguring, jetting or other means.

Pile Cap: means a footing or some other structural component used to transfer the load to the piles as well as maintaining them in position.

Pile Cushion: means a pad of resilient material placed between the helmet and the top of a reinforced concrete or timber pile to minimize damage to the head during driving.

Pile Group: means the piles supporting a pile cap.

Pumped Concrete: means a method of transporting concrete through hose or pipe by means of positive and continuous pressure.

Quality Verification Engineer(QVE): means an Engineer who has a minimum of five (5) years experience in the field of installation of piling or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the Contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s)of Conformance.

Retapping: means verifying that the specified resistance previously attained has been sustained by imparting appropriate hammer energy to the pile and monitoring pile penetration.

Rock Points: means a specially designed steel tip, fitted to piles to enable them to be driven into hard, sound sloped bedrock.

Sheet Pile: means a pile that is designed to interlock with adjacent piles and form a continuous wall for the purpose of resisting mainly lateral forces and to reduce seepage.

Slurry: means a drilling fluid, consisting of water mixed with one or more of various solids or polymers, used to maintain the stability of the side walls and bottom of an excavation.

Stamped: means drawings or details that have been reviewed and stamped "Conforms With Contract Documents". The stamp shall include the date and signature of the Quality Verification Engineer.

Tremie: means a hopper with a vertical pipe leading out of the bottom of it, used for placing concrete under water. The foot of the pipe is always submerged in concrete except during commencement of concreting and the upper level of the concrete is always above water level.

903.04 SUBMISSION AND DESIGN REQUIREMENTS

All submissions shall bear the seal and signature of an Engineer experienced in this field. This Engineer, under this section , will not be permitted to carry out the work of the Quality Verification Engineer.

The Contractor shall submit to the Quality Verification Engineer for review and stamping, the equipment and installation procedure and the procedure for monitoring installation.

903.04.01 Site Survey

Prior to commencing the work, the Contractor shall submit to the CA, a condition survey of property and structures that may be affected by the work. The survey shall include, but not be limited to, the locations and conditions of adjacent properties, buildings, underground structures, utility services and structures such as walls abutting the site.

903.04.02 Materials

903.04.02.01 Mill Certificates

The Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for H-piles, tube piles, casings and sheet piles.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the

Canadian testing laboratory.

903.04.02.02 Concrete

Concrete and concrete work shall conform to OPSS 1350 and OPSS 904. The Contractor shall submit a suitable, site specific concrete mix design that meets the requirements of the hardened concrete specified. The Contractor is responsible for providing plastic concrete with suitable characteristics for installation. The concrete shall be flowable, non segregating concrete that does not exhibit rapid slump loss. The concrete mix design shall be submitted to the Contract Administrator for information purposes only, one(1) week prior to construction.

903.04.02.03 Slurry

The Contractor shall submit, for information purposes only, one(1) week prior to construction:

1. The type, source, physical and chemical properties of the bentonite or polymer.
2. Slurry mix proportions and procedure.
3. Quality Control Plan to control properties of slurry mix.
4. Method of disposal.

903.04.03 Installation

903.04.03.01 Driven Piles

The Contractor shall submit, for information purposes only, one(1) week prior to construction:

1. Type of equipment and hammer details including Contractors stated potential energy(rated energy) of the hammer, operating efficiency, weight of ram, anvil and helmet.
2. Procedure including sequence for pile installation.
3. Procedure for monitoring installation

903.04.03.02 Caisson Piles

The Contractor shall submit, for information purposes only, one(1) week prior to construction:

1. Shop drawings that describe and illustrate equipment, materials.
2. Procedure for caisson excavation and construction.
3. Procedure for monitoring installation and caisson inspection.

903.04.03.03 Displacement Caisson Piles

The Contractor shall submit, for information purposes only, one(1) week prior to construction:

1. Equipment to be used for installation.
2. Procedure for installation
3. Procedure for monitoring installation.

903.04.03.04 Certificate of Conformance

Upon completion of the deep foundation work, the Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer. The certificate shall state that the work has been carried out in general conformance with the contract documents, specifications and stamped working drawings.

903.05 MATERIAL

903.05.01 Wood Piles

Wood piles shall be according to CSA CAN3-056 and shall be clean and peeled. Treated piles shall be pressure treated with creosote according to CSA 080.

Wood piles shall not be spliced.

903.05.02 Steel Piles

903.05.02.01 Steel H Piles

Steel H piles shall be according to CSA G40.20/G40.21 and shall be 350 W grade.

903.05.02.02 Steel Tube Piles

Steel tube piles shall be according to ASTM A252 minimum Grade 2.

903.05.02.03 Steel Sheet Piles

Steel sheet piles shall be according to ASTM A328. Steel sheet piles shall not be spliced.

903.05.02.04 Straightness Tolerance for Steel Piles

All steel piles shall conform to a straightness tolerance of 1.5 mm maximum per metre of length.

903.05.03 Driving Shoes and Rock Points

Rock points and driving shoes shall be as specified. Driving shoes shall transfer the driving stresses to the pile over the full cross-sectional area of the pile.

Where the contract shows details of "Splice and Driving Shoe Details for Steel 'H' Piles, the Contractor may substitute the Titus "H" Bearing Pile Point, Standard model, in place of the driving shoe details shown.

Where the contract shows details of "Oslo Points for HP310 H-Piles" the Contractor may substitute the Titus "H" Bearing Pile Point, Rock Injector model in place of the pile point details shown.

Welding of Titus Points shall conform to the manufacturer's specifications.

Where the Contractor elects to use any of the above substitutions, the cost shall be deemed to be included in the contract price for the appropriate item.

903.05.04 Casing for Caissons

Casings shall be according to ASTM A252 Grade 2. If welded they shall be welded by the electric arc method according to CSA W59.

The wall thickness specified is the minimum that shall be supplied. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation.

903.05.05 Steel Reinforcement

Steel reinforcement shall be according to OPSS 1440.

903.05.06 Concrete

903.05.06.01 General

Concrete shall be according to OPSS 1350.

903.05.06.02 Tube Piles

Concrete shall have a slump of 150 to 180 mm.

903.05.08.03 Caisson Piles

Concrete shall have a slump of 150 to 180 mm. When approved by the Contract Administrator in writing, admixtures may be used. Where the liner is to be withdrawn, sufficient retarder shall be added to prevent arching of concrete during liner withdrawal, and to prevent setting of concrete until after the liner is withdrawn.

903.05.07 Slurry

903.05.07.01 Solids

Bentonite and polymers shall be according to API 13A.

903.05.07.02 Slurry Composition

Slurry shall be according to API 13B

903.05.08 Helmets and Striker Plates

The head of piles shall be protected by a striker plate or a helmet. Helmets shall have adequate and suitable cushioning material. Helmets and striker plates shall distribute the blow of the hammer evenly throughout the cross-section of the pile head.

903.06 EQUIPMENT

The hammers shall be capable of driving the piles and liners/casings to the prescribed depth or to the specified resistance without damage to portions that are not cut off.

903.07 CONSTRUCTION

903.07.01 Subsurface Conditions

A Foundation Investigation Report that describes the subsurface conditions for the project is available, as specified elsewhere in the Contract. The Ministry warrants that the information provided in the Foundation Investigation Report can be relied upon with the following limitations and exceptions:

1. Any interpretation of data or opinions expressed in the report are not warranted.
2. Regarding the data presented in the report, although the raw measured data presented is warranted, the Contractor must satisfy itself as to the sufficiency of the information presented

for the intended construction purpose and obtain any updating or additional information as required to facilitate the deep foundation works.

903.07.02 Transportation, Handling, Storage

Piles, casings and reinforcing steel cages shall be transported, stored and handled in such a manner that damage and distortion is prevented and that the strength and integrity are maintained.

903.07.03 Driven Piles

903.07.03.01 Pile Driving Requirements and Restrictions

Piles shall be installed at the locations indicated and to the set or depth specified without being damaged.

Damage to adjacent structures, utilities and fresh concrete shall be prevented during pile installation. Piles shall not be driven within a radius of 7.5 m of concrete which has been in place for less than 72 hours.

The tops of all piles shall be either square to the longitudinal axis of the pile or horizontal as indicated on the Contract Drawings.

Piles shall not be forced into their proper position by the use of excessive manipulation. Pile damage due to excessive driving shall be avoided.

903.07.03.02 Splicing

903.07.03.02.01 General

Splices within 6 m of the pile cut-off shall be certified by the Quality Verification Engineer as being equal to the full strength of the pile. Any damaged material shall be cut-off prior to splicing. The certificate shall be sealed and signed by the Quality Verfication Engineer and shall be submitted to the Contract Administrator.

903.07.03.02.02 H Piles, Tube Piles and Sheet Piles

Welding shall be according to CSA W59 and shall be done by a qualified welder employed by a firm certified according to CSA W47.1, Division 1 or Division 2.1.

Steel H piles and steel tube piles may be spliced providing the pieces being spliced are not less than

3 m long. Splices in marine structures shall be located below the low water level unless otherwise encased in concrete.

Sheet piles shall not be spliced without approval by the Contract Administrator.

903.07.03.02.03 Precast Piles

Precast piles shall only be spliced when specified and the splices shall only be made with approved mechanical splicing devices.

903.07.03.03 Concrete in Steel Tube Piles

Concrete in steel tube piles shall be placed according to the OPSS 904 requirements.

903.07.03.04 Cutting Off Piles

903.07.03.04.01 General

Driven piles shall be cut to the elevation as specified in the contract.

The length of pile supplied shall be sufficient to ensure there is no damaged material below the cut off. Damaged material at the pile head shall be cut off.

903.07.03.04.02 Wood Piles

Where wood piles are broomed, splintered or otherwise damaged below the cutoff elevation, the pile shall be considered defective and shall be replaced.

903.07.03.05 Protective Coating for Steel H and Steel Tube Piles

Exposed steel H and steel tube piles shall have a protective coating applied from an elevation 600 mm below the low water level or finished ground surface up to the top of the exposed steel.

The steel surfaces shall be cleaned according to SSPC-SP10 prior to application of a coal tar epoxy system which shall be according to OPSS 911.

903.07.03.06 Reinforcing Steel

Reinforcing Steel shall be installed according to OPSS 905.

The reinforcing steel cage shall be fabricated in one piece.

Welding of reinforcing steel and use of splices shall not be done unless specified in the contract.

903.07.04 Caisson Piles

903.07.04.01 Installation - General

Caissons shall be constructed as specified in the contract.

The final bearing elevation shall be as specified in the contract or shall be an elevation determined by the Contract Administrator. When permanent casings are not specified the caisson shall be constructed in a drilled hole with or without the use of a temporary liner or slurry as determined by the Contractor.

903.07.04.02 Excavation

Sidewall stability shall be maintained throughout the excavation and concrete placement operation. Soil cave-in into the excavation hole shall be prevented.

Excavation methods shall be such that the sides and bottoms of the hole are straight and free of loose material.

Except when founded on sloping rock, the caisson bottom shall be level. On sloping rock, the caisson bottom may be stepped with each step not greater than ¼ the diameter of the bearing area.

903.07.04.03 Unwatering

Where unwatering is required, the Contractor shall effect a dewatering scheme in such a manner as to prevent any disturbance to the base founding material, or prevent subsidence or ground loss that may adversely affect the work of adjacent structures.

903.07.04.04 Backfilling Liners Left in Place

The annular space between a liner permanently left in place and shaft excavation shall be filled with concrete or fluid grout.

903.07.04.06 Concrete

903.07.04.06.01 General

Concrete shall be placed in the caisson according to OPSS 904. Concrete shall be placed immediately following acceptance of the caisson hole by the QVE.

The reinforcement shall not be displaced or distorted during the construction of the caisson. Arching of concrete during casing withdrawal shall be prevented.

The QVE shall provide inspection throughout the concreting operation.

903.07.04.06.02 Concrete Placed in the Dry

The concrete may be placed free fall provided the fall is vertically down the centre of the opening and transverse ties, spacers or other do not impede the free fall. In the event of interference with the concrete free fall, an elephant trunk or other means shall be used to prevent concrete segregation.

Concrete shall be placed in a continuous operation from the bottom to the top of the caisson, or where columns are cast integral with the caisson, to the elevation of the bottom of the column reinforcing cage. The concrete shall be vibrated for the last 1.5 m of the pour.

903.07.04.06.03 Concrete Placed Under Water or Under Slurry

Tremie or pumped concrete shall be carried out in one continuous operation. The Contractor shall carry out the tremie or pumping operation to ensure a continuous flow of concrete that prevents the inflow of water or slurry.

903.07.04.07 Reinforcing Steel

The reinforcing steel cage shall be checked to ensure conformance to the approved shop drawings prior to installation and during concrete placement.

903.07.05 Displacement Caissson Piles

903.07.05.01 General

Work shall be carried out in accordance with displacement caisson pile suppliers installation procedures. A permanent liner shall be used when specified.

The pile shall not be extended below the specified pile tip elevation without approval in writing from the Contract Administrator.

903.07.06 Tolerances

903.07.06.01 Driven Piles

1. cut off ± 25 mm
2. deviation from vertical not more than 1 in 50, except in the case of a pile cap or footing supporting only a single row of piles the deviation shall not be more than 1 in 75 in the direction of the span
3. the deviation from the specified inclination for battered piles shall not exceed 1 in 25
4. the centre of the pile at the junction with the pile cap shall be within 150 mm of that specified (measured horizontally) except in the case of a pile cap or footing supported on a single row of piles the deviation shall not be more than 75 mm(measured horizontally) in the direction of the span.

903.07.06.02 Caissons

1. Cut off elevation ±25 mm
2. Horizontal location at cut-off not more than 5% of shaft diameter nor 75 mm
3. Vertical alignment not more than 2% of the caisson length from vertical for vertical caissons, nor 2% of the caisson length from the specified inclination for battered caissons

903.08 QUALITY CONTROL

903.08.01 Monitoring Driven Piles

903.08.01.01 General

The driving of piles shall be carefully monitored and controlled and pile driving records produced for each pile. All driving records shall be certified by the Quality Verification Engineer and submitted to the Contract Administrator.

903.08.01.02 Driving to a Set

The founding elevation shall be established by driving to a set determined in accordance with the dynamic formula specified or by the application of the wave equation analysis procedure that verifies the pile resistance. This set shall be established on the first pile of every ten piles driven in a pile group.

The other piles shall be controlled by the pile penetration rate in blows per mm that correlates to the set.

When new conditions such as change in hammer size, change in pile size or change in soil material occur, new sets shall be determined.

903.08.01.03 Driving to Bedrock

When driving piles to bedrock, the Contractor shall adequately seat the pile on bedrock without damaging the pile.

Where rock points are used the rock points shall penetrate into the rock. Piles driven using rock points shall be driven to ensure adequate seating on the bedrock without damaging the pile.

903.08.01.04 Hammer Performance

When requested by the Contract Administrator, the Contractor shall verify the hammer performance using the Pile Driving Analyzer or other approved equivalent. The Contractor shall provide all instrumentation, related access and assistance for the testing and monitoring as directed by the Contract Administrator.

Hammer performance shall be verified to ensure that the actual potential energy is not less than 90% of the stated potential energy.

903.08.01.05 Retapping Tests on Piles

In each pile group, 10% of the piles (actual number of piles to be rounded off to higher number) but no fewer than two piles shall be retapped no sooner than 24 hours *after installation of the individual pile* to confirm the bearing resistance has been sustained.

Retapping of piles driven to bedrock is not required.

903.08.01.06 Retapping/Redriving Piles

Where the retapping tests indicate the bearing resistance has not been sustained, all piles in the group shall be retapped.

Where the retapping reveals that the bearing resistance of the piles has not been achieved, the piles shall be redriven to the specified resistance. Where piles have risen, the piles shall be redriven to the original depth.

903.08.02 Inspection of Caisson Holes

The caisson holes shall be inspected and approved by the QVE.

903.09 MEASUREMENT FOR PAYMENT

903.09.01 H Piles, Tube Piles, Wood Piles and Precast Concrete Piles

Measurement is in metres of the piling left in place after cut-off.

903.09.02 Sheet Piles

Measurement is in square metres based on the driving lines specified and the length of piling left in place after cut-off.

903.09.03 Driving Shoes and Rock Points

Measurement is for each driving shoe and rock point specified and used.

903.09.04 Caissons and Displacement Caisson Piles

Measurement is in metres of the depth along the centre line between the approved bearing surface at the bottom and the specified elevation at the top.

903.09.05 Retapping Piles

Measurement is lump sum for retapping the piles above and beyond the minimum 10% but no fewer than two piles requirement for the pile group.

For measurement purposes a count will made of the number of piles retapped above and beyond the minimum 10% but no fewer than two piles requirement and the number of piles in the pile group and a ratio will be determined.

Where retapping is not required above and beyond the minimum, no measurement for payment will be made for this item.

903.10 BASIS FOR PAYMENT

903.10.01 Supply Equipment for Installing Driven Piles - Item
Supply Equipment for Installing Caisson Piles - Item
Supply Equipment for Installing Displacement Caisson Piles - Item

Payment at the contract price for the above items shall be full compensation for all labour, testing, equipment and material required to do the work.

It will be assumed, for payment purposes, that 50% of the work under this item has been completed when the satisfactory performance of the equipment has been demonstrated to the Contractor Administrator by the installation of one(1) pile. The remaining 50% will be paid on the satisfactory completion of the installation.

When the hammer performance is requested to be verified, all costs associated with this work will be included in the contract price when the energy delivered is less than 90% of the stated potential energy(rated energy) specified in the submission.

When the energy is greater than 90% of the stated potential energy(rated energy) stated in the required submission, the cost will be paid as extra work.

903.10.02 H-Piles – Item
Tube Piles – Item
Precast Concrete Piles - Item
Wood Piles - Item
Displacement Caisson Pile - Item
Caisson Piles - Item
Driving Shoes - Item
Rock Points - Item
Sheet Piles - Item

Payment at the contract price for the above items shall be full compensation for all labour, equipment and material to do the work

Payment for redriving piles shall be at the contract price for the applicable item(s) above.

903.10.03 Retapping Piles – Item

Payment for retapping the minimum specified number of piles is included in the Pile Item. Where additional retapping is required, payment will be made based on the ratio of the number of piles retapped in a pile group above the minimum requirement, to the total number of piles in that pile group, times the tender price for retapping all piles for that pile group.

WARRANT: Always with these tender items.

HWY.17

WP NO. 647-92-00

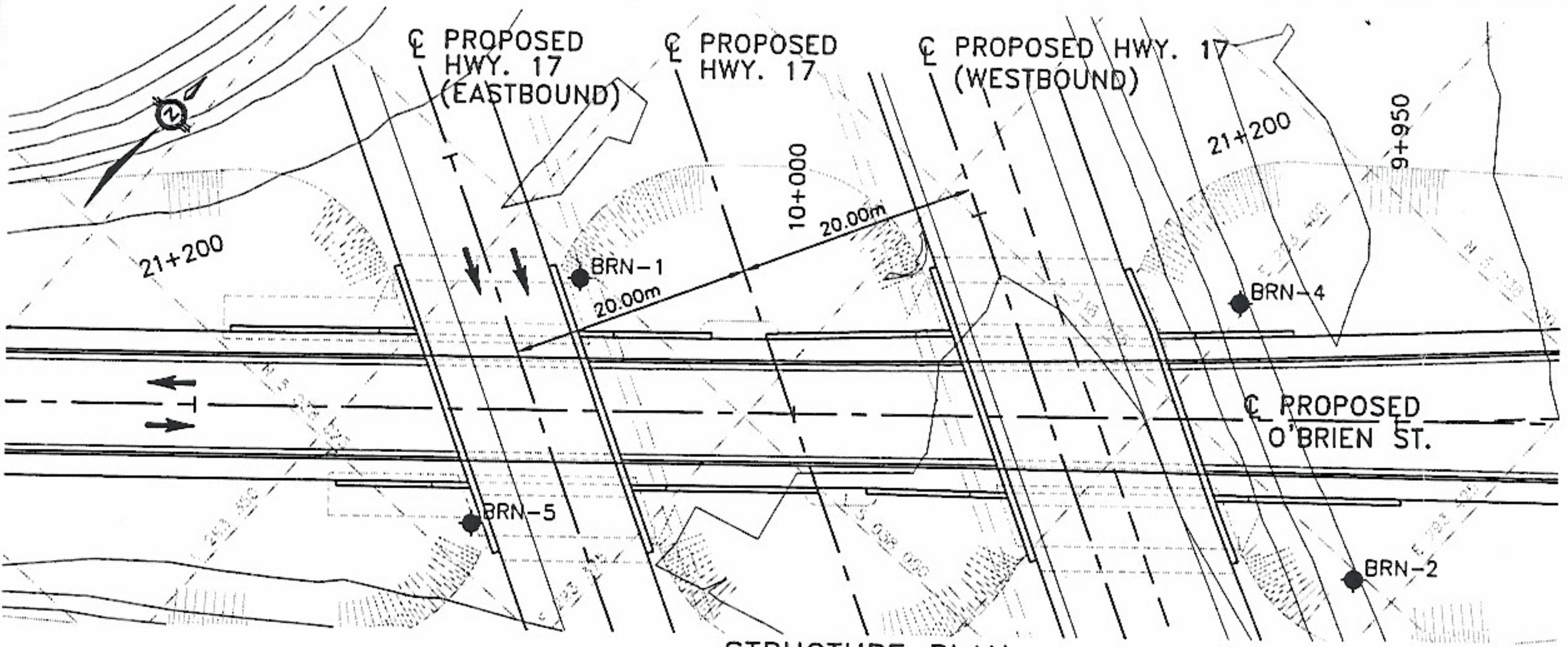
SHEET

HIGHWAY 17 TWINNING
O'BRIEN STREET
BORHOLE LOCATIONS AND SOIL STRATA

TSH engineers architects planners

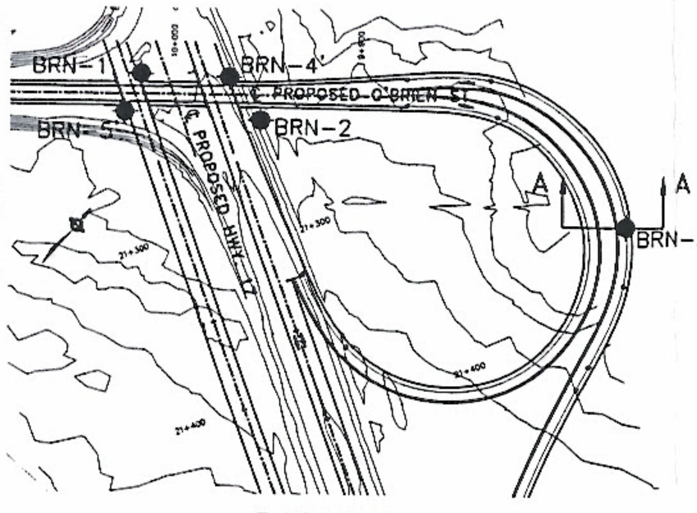
THURBER ENGINEERING LTD.

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



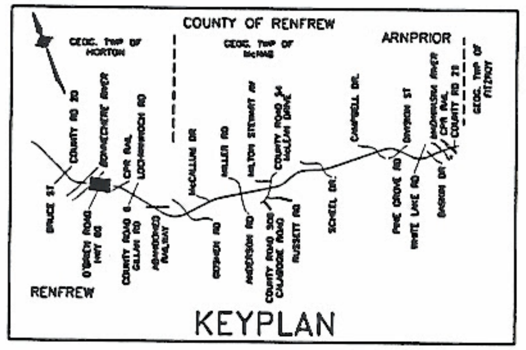
STRUCTURE PLAN

SCALE: 1:300

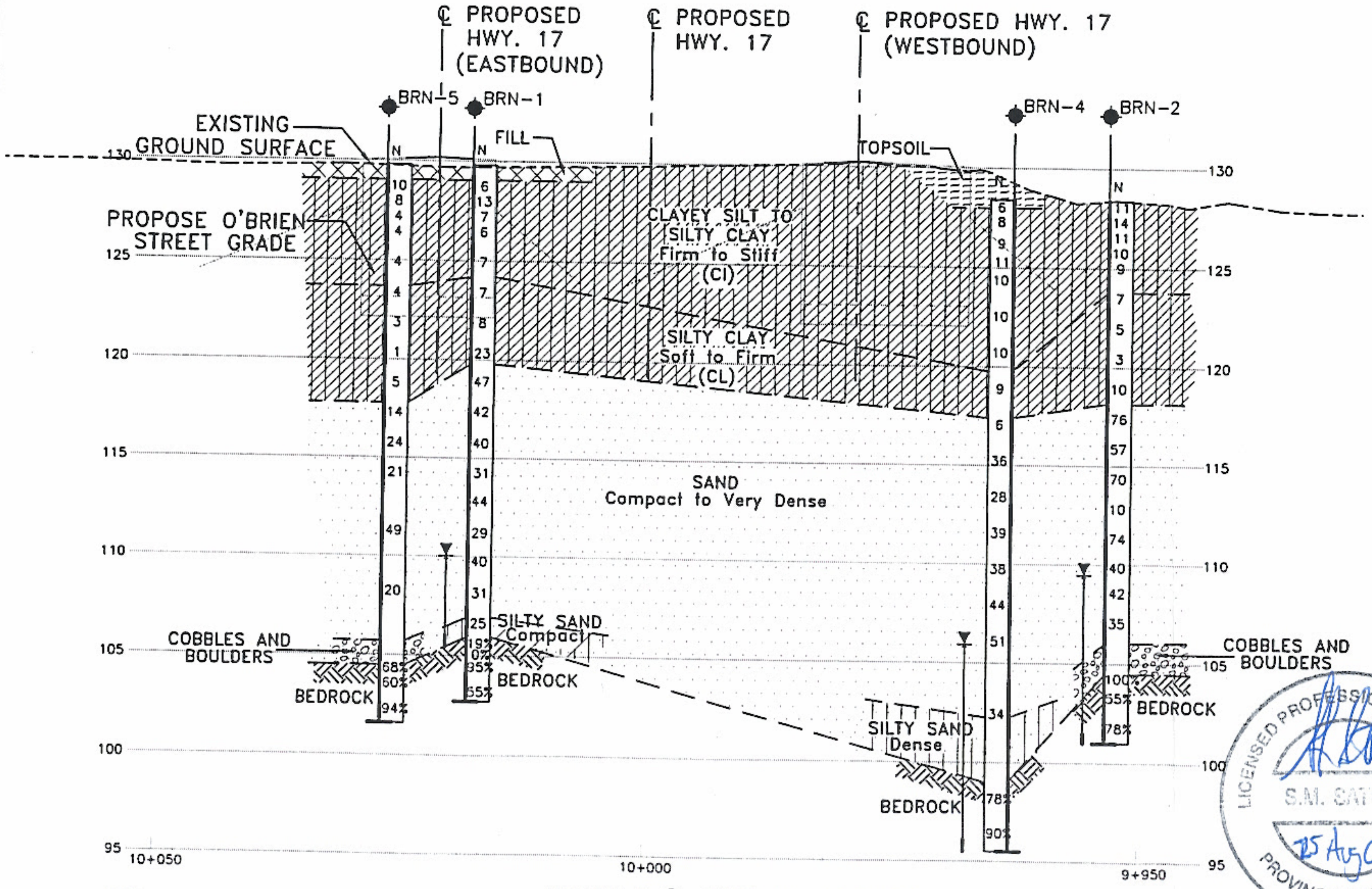


BOREHOLE PLAN

SCALE 1:2,000



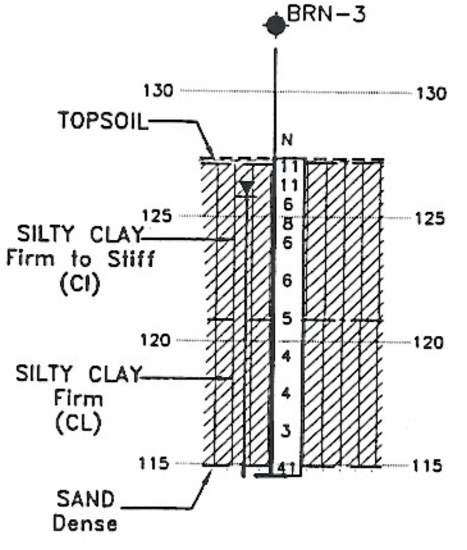
KEYPLAN



PROFILE ℄ O'BRIEN STREET

HOR: 1:300 VERT: 1:150

NOTE:
BRN-4 and BRN-5 locations are approximates



SECTION A-A

HOR: 1:300 VERT: 1:150

	LEGEND
●	Bore Hole
⊕	Dynamic Cone Penetration Test (cone)
⊕	Bore Hole & Cone
N	Blows/ 0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/ 0.3m (60° Cone, 475 J/blow)
PH	Pressure, Hydraulic
▼	WL at Feb 4/04
⊤	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BRN-1	129.8	5 038 049.1	293 357.3
BRN-2	128.4	5 038 074.4	293 421.5
BRN-3	127.3	5 038 163.5	293 603.5
BRN-4	128.4	5 038 084.7	293 399.3
BRN-5	129.8	5 038 028.3	293 364.2

— NOTE —

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

S.M. SATHER 25 Aug 04

P.K. CHATTERJI Aug 25/04

DATE	BY	DESCRIPTION
AUG. 04	SMS	FINAL
MAR. 04	SMS	ISSUED AS DRAFT FOR REVIEW

REVISIONS

DESIGN SMS | CHK PKC | CHBDC 2000 | LOAD | DATE AUG.2004
DRAWN SS | CHK SMS | SITE | STRUCT | DWG.