FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT EXTENSIONS
RECONSTRUCTION AND WIDENING OF HIGHWAY 8
FROM 1.0 KM NORTH OF GRAND RIVER, SOUTHERLY
TO SPORTSWORLD DRIVE, KITCHENER, ONTARIO
G.W.P. 277-97-00

Geocres Number: 40P8-146

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the locations of proposed culvert extensions along Highway 8 in Kitchener, Ontario.

Highway 8 will be widened from four to eight lanes from 1 km north of the Grand River southerly to Sportsworld Drive. The project will include construction of new southbound lanes and requisite extension of existing concrete culverts at Stations 13+298 and 14+093.

The purpose of the investigation was to explore the subsurface conditions at the proposed culvert extension locations and, based on the data obtained, to provide borehole logs, borehole location plans, stratigraphic profiles, and written descriptions of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to Morrison Hershfield Limited, under the Ministry of Transportation Ontario (MTO) Agreement Number 3005-E-0035.

2 SITE DESCRIPTION

The site is located along existing Highway 8 in Kitchener, Ontario. Within this section, existing Highway 8 descends through a cut section in an elevated land area on the north side of the Grand River, bridges over the Grand River, and crosses the remainder of the river floodplain to the south of the current river alignment on a fill embankment.

The existing culvert at Station 13+298 consists of a 1500 x 1220 non-rigid frame open (NRFO) concrete culvert. Based on existing ETR drawings, the culvert is located in a depressed area to the north of a highway cut section. Grades on Highway 8 slope downwards to the south. Contours shown on the ETR plates indicate that the culvert invert is near elevation 303.5 m and road grade above the culvert is near elevation 306.5 m. Flow in the culvert is towards the east.

The existing culvert near Station 14+093 consists of a 1.22 x 1.22 m, open frame concrete culvert. Based on existing ETR drawings, the culvert is located in a fill embankment area crossing the Grand River floodplain. Grades on Highway 8 are relatively flat in this area, near elevation 288.3 m. The ETR profile indicates that the culvert invert is near elevation 284.5 m. Flow in the culvert is towards the Grand River to the west.

Geologically, the site area is located within the physiographic region known as the Waterloo Hills, which is characterized by sandy hills consisting of ridges of sandy till as well as kames and kame moraines, with outwash sands occupying the intervening hollows. Locally, the Grand River spillway system contains alluvial terraces of uniform sandy and gravelly materials. The soils overlie Silurian limestone bedrock of the Guelph Formation.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out on May 30, August 9 and September 18, 2006 and consisted of drilling and sampling two boreholes at each culvert location. The boreholes were terminated at depths of 6.4 to 11.1 m. The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing in Appendix C.

Prior to commencement of drilling, utility clearances were obtained for all borehole locations. Road occupancy and lane closure permits were also obtained.

Hollow stem augers were used to advance the boreholes. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A member of Thurber's engineering staff supervised the drilling and sampling operations on a full time basis. The inspector logged the boreholes, visually examined the recovered samples, and transported them to Thurber's laboratory for further examination and testing.

Standpipe piezometers, consisting of 19 or 25 mm PVC pipes with slotted tip, were installed in the boreholes to monitor groundwater levels. The completion details are shown in Table 3.1. The remaining boreholes were grouted in accordance with the requirements of MOE Reg. 903.

Table 3.1 – Piezometer Installation Details

Piezometer Location	Tip (Sand Filter) Details			Backfill
	Depth	Elevation	Stratum	
06-70	10.7 – 8.8	295.1 – 297.0	Silty clay till	Bentonite seal to 8.2 m, grout to 0.9 m, bentonite to 0.3 m, concrete to surface
06-71	7.5 – 5.5	296.5 – 298.5	Silty clay till	Bentonite seal to 4.9 m, grout to 0.2 m, cuttings to surface
06-72	10.7 – 8.8	277.6 – 279.5	Silty clay till	Bentonite seal to 8.2 m, grout to 0.9 m, bentonite to 0.3 m, concrete to surface
06-73	5.9 – 3.8	279.2 – 281.3	Silt and sand till	Bentonite grout to ground surface

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A. Approximately 25% of the recovered samples were also subjected to grain size distribution analyses (sieve and hydrometer) and Atterberg Limits testing. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets in Appendix A and on the Borehole Locations and Soil Strata Drawing in Appendix C. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general terms, the stratigraphy encountered near Station 13+298 (boreholes 06-70 and 06-71) consists of a pavement structure or topsoil layer overlying sand to sandy silt deposits, underlain by glacial till. Near Station 14+093 (boreholes 06-72 and 06-73), the stratigraphy comprises a pavement structure, fill, topsoil and/or alluvial deposits underlain by a layer of sand and gravel, overlying glacial till.

More detailed descriptions of the individual strata are presented below.

5.1 Pavement Structure

Boreholes 06-70 and 06-72 were drilled on the shoulder of Highway 8. The pavement structure encountered in these boreholes consisted of 75 and 100 mm of asphalt overlying sand and gravel fill to depths of 1.5 and 1.4 m. SPT N-values obtained in the fill ranged from 38 blows/0.3 m to 50 blows/0.15 m, indicating a dense to very dense condition.

The results of grain size distribution analyses conducted on the granular fill, presented on Figure B1 of Appendix B, indicate a fines content (silt plus clay) of 11 to 13%. Moisture contents ranged from 3 to 8%.

5.2 Silty Clay Fill

A 1.6 m thick layer of silty clay fill was encountered below the pavement structure in borehole 06-72 drilled on the highway embankment through the floodplain. An N-value of 24 blows/0.3 m was encountered in the fill, indicating a very stiff consistency. A moisture content of 11% was measured. The lower boundary of the fill was encountered at 3.0 m depth (elevation 285.3 m).

5.3 Topsoil and Alluvial Deposits

Topsoil was encountered surficially in boreholes 06-71 and 06-73 drilled near the toe of the highway embankment. The topsoil layer was 375 and 150 mm thick in boreholes 06-71 and 06-73, respectively.

Alluvial deposits with trace organics were encountered below the fill and topsoil in boreholes 06-72 and 06-73 drilled in the Grand River floodplain. This material comprised brown sand and silt in borehole 06-72, and dark brown sand overlying clayey silt in borehole 06-73. The lower boundary of the alluvium was encountered at depths of 4.3 and 3.0 m (elevation 284.0 and 282.2 m).

N-values in the alluvium typically ranged from 3 to 7 blows/0.3 m, indicating a soft/loose to very loose condition. One value of 17 blows/0.3 m (very stiff) was obtained in the lower SPT in borehole 06-73. Grain size distribution results for a sample of the sand and silt are presented on Figure B2 of Appendix B. Moisture contents ranged from about 17 to 41%.

5.4 Sand to Sandy Silt

Native deposits of brown sand to sandy silt were encountered below the granular fill and topsoil in boreholes 06-70 and 06-71. The upper boundary of this layer was encountered at depths of 1.5 and 0.4 m (elevation 304.3 and 303.6 m), and the lower boundary was encountered at depths of 6.1 and 3.5 m (elevation 299.7 and 300.5 m).

SPT N-values in the sand/sandy silt generally ranged from 24 to 42 blows/0.3 m, indicating a compact to dense relative density. Localized loose zones were indicated by N-values of 8 and 9 blows/0.3 m obtained near 4.9 m depth (elevation 300.9 m) in borehole 06-70 and 1.1 m depth (elevation 302.9 m) in borehole 06-71. Grain size distribution results for one sample of the sand are presented on the Record of Borehole sheets and Figure B2 of Appendix B. Moisture contents ranged from 3 to 18%.

5.5 Sand and Gravel

A layer of brown sand and gravel with cobbles was encountered below the alluvial material in boreholes 06-72 and 06-73 at depths of 4.3 and 3.0 m (elevation 284.0 and 282.2 m). This layer was 3.0 m thick in borehole 06-72 and 1.0 m thick in borehole 06-73.

SPT N-values obtained in the sand and gravel ranged from 18 blows/0.3 m to 50 blows/0.15 m penetration, indicating a compact to very dense condition. Moisture contents from this deposit ranged from 10 to 17%.

5.6 Heterogeneous Glacial Till (Silt and Sand to Silty Clay)

A deposit of heterogeneous till was encountered below the sand and sandy silt in boreholes 06-70 and 06-71 at depths of 6.1 and 3.5 m (elevation 299.7 and 300.5 m), and below the sand and gravel in boreholes 06-72 and 06-73 at depths of 7.3 and 4.0 m (elevation 281.0

and 281.2 m). This deposit varies in gradation from cohesionless silt and sand, trace clay, to cohesive silty clay, trace sand. The results of sieve and hydrometer analyses conducted on three samples of this unit, presented on the Record of Borehole Sheets and Figure B3 of Appendix B, indicate the following particle size distribution:

Gravel	0 – 4 %
Sand	2 – 52 %
Silt	34 – 47 %
Clay	7 – 62 %

SPT N-values obtained in the till deposit typically ranged from 27 blows/0.3 m to 50 blows/0.15 m penetration, indicating a compact to very dense or hard condition. An N-value of 10 blows/0.3 m (stiff) was obtained locally at 4.9 m depth (elevation 299.1 m) in borehole 06-71. Moisture contents ranged from 9 to 22%. Atterberg Limits testing conducted on one sample of silty clay till (Figure B4) indicates medium plasticity.

The boreholes were terminated in the till deposit at depths of 6.4 to 11.1 m. Although not encountered in the boreholes, glacial till may contain cobbles and boulders.

5.7 Groundwater Conditions

Standpipe piezometers were installed in the boreholes to monitor groundwater conditions after completion of drilling. The water levels measured in the piezometers are summarized in Table 5.1.

Table 5.1 – Measured Groundwater Levels

Borehole	Date	Water Level (m)	
		Depth	Elevation
06-70	29-May-2006	7.3	298.5
	26-Sept-2006	10.4	295.4
06-71	19-Sept-2006	0.9	303.1
	20-Sept-2006	1.2	302.8
	21-Sept-2006	1.5	302.5
	22-Sept-2006	2.0	302.0
	25-Sept-2006	2.8	301.2
	29-Sept-2006	4.6	299.4
06-72	31-May-2006	6.0	282.3
	26-Sept-2006	3.9	284.4
06-73	10-Aug-2006	1.9	283.2
	11-Aug-2006	1.9	283.2
	14-Aug-2006	2.0	283.1
	15-Aug-2006	2.0	283.1
	16-Aug-2006	2.0	283.1
	29-Sept-2006	1.5	283.6

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall. Further, perched water may be encountered at higher levels in pockets or zones of more permeable soils above or within the heterogeneous tills. Of note are the wet conditions encountered in the sandy silt and sand and silt till below elevation 301.2 m in borehole 06-70.

6 MISCELLANEOUS

Thurber Engineering Ltd. selected the borehole locations in the field relative to existing site features and chainages along Highway 8 marked by Callon Dietz Inc., with consideration of access restraints, terrain conditions, and utility locations. Callon Dietz, retained by Morrison Hershfield, subsequently established the co-ordinates and ground surface elevations at the staked off-road borehole locations. For the highway shoulder boreholes, the approximate geodetic co-ordinates and elevations were interpreted from the digital base plan and profile information provided by Morrison Hershfield.

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

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

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations for design of the culvert extensions.

Widening of Highway 8 will include construction of new southbound lanes and require extension of existing concrete culverts at Stations 13+298 and 14+093. A description of the existing culverts at the proposed extension locations, taken from previous ETR plates, is presented in Table 7.1.

Table 7.1 – Existing Culvert Details

Approximate Location	Existing Culvert Type	Approximate Invert Elevation (m)	Height of Fill above Culvert (m)
Sta. 13+298	1500 x 1220 x 51.86 Open Frame Concrete	303.5	1.8
Sta. 14+093	1220 x 1220 x 62.8 Open Frame Concrete	284.5	2.6

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

8 FOUNDATION DESIGN

Details regarding the foundations supporting the existing culverts were not available at the time of report preparation. The subsurface conditions at the culvert sites are generally favourable for support of shallow foundations and, considering the small size of the culverts, the existing culverts are likely supported on spread footings. It is recommended that the culvert extensions also be supported on spread footings to provide consistent performance with the existing foundation system. Recommendations for spread footing design are presented below.

Consideration was also given to the use of driven piles or augered caissons (drilled shafts) to support the culvert extensions. However, the use of deep foundations will increase costs and will not match the performance of the existing footings. Therefore, use of deep foundation types is not recommended from a geotechnical perspective, and detailed design recommendations for these foundation types are not presented.

The assumed founding level of spread footings supporting the existing culverts is approximately 1.4 m below the invert level based on the frost penetration depth for the project area. The subsurface conditions anticipated at these levels, based on the borehole information, are as follows:

> Station 13+298: Borehole 06-71 is located nearest to the culvert end to be extended. The anticipated subgrade at the inferred founding level (elevation 302.1 m) consists of dense sand overlying compact sandy silt, underlain by stiff to hard silty clay till. The dense sand is considered suitable for support of spread footings.
>
> Station 14+093: The anticipated subgrade at the inferred founding level (elevation 283.1 m) consists of very dense gravel in borehole 06-72 and soft to very stiff clayey silt over compact sand and gravel in borehole 06-73. The soft alluvial material encountered above elevation 282.8 m in borehole 06-73 is not considered suitable for support of culvert footings. It is recommended that the culvert footings at this location be extended down to the very stiff clayey silt encountered at elevation 282.8 m, or alternatively the clayey silt should be subexcavated to the upper boundary of the sand and gravel (elevation 282.2 m) and replaced with engineered granular fill or mass concrete.
>
> The engineered fill must consist of OPSS Granular "A" placed in 150 mm lifts, compacted to 100% of its SPMDD at ±2% of optimum moisture content. The engineered fill should extend beyond the edge of footing a distance of least 1 m plus the thickness of fill below the footing. If mass concrete is employed, the concrete should extend at least 0.5 m beyond the edge of footing and be of the same class as the footing concrete.

The following geotechnical resistances are recommended for design of the spread footings:

Table 8.1 – Recommended Geotechnical Resistances

Location	Founding Level (m)	Reference Borehole	Founding Material	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Resistance at SLS (kPa)
Sta. 13+298	302.1	06-71	Dense sand	400	250
Sta. 14+093	283.1	06-72	Very dense gravel	400	200
		06-73	Engineered fill/mass concrete over compact sand and gravel		
	282.8	06-73	Very stiff clayey silt	225	150

The resistance values are for vertical, concentric loads, assuming a minimum 0.9 m wide footing. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clauses 6.7.3 and 6.7.4.

The geotechnical resistance at SLS was computed on the basis of limiting the settlement of an individual culvert footing to 25 mm under the applied load. The actual settlement of the culverts will be governed by compression of the foundation soils under the weight of the road embankment fill. In this regards, a camber should be applied along the culvert to accommodate a potential differential settlement of 25 mm between the crest and toe of the new embankment fill required for widening.

All foundation excavation should be carried out in accordance with SP 902S01. Following excavation to the design founding level, any remaining fill, topsoil, peat, streambed deposits or soft soils on the bearing surface should be subexcavated and replaced with mass concrete or compacted Granular A material. A 100 mm thick mat of concrete should be placed over the founding surfaces within 24 hours of excavation, inspection and approval. The mat concrete should be of the same class as the footing concrete.

A frost penetration depth of 1.4 m should be used during foundation and backfill design to provide protection against frost action on the culvert foundations.

The lateral resistance developed along the base of cast-in-place footings may be computed using an ultimate friction coefficient of 0.6 where founded on the dense sand, 0.5 on very stiff clayey silt, and 0.7 where founded on very dense gravel and engineered granular fill. These are "ultimate" values and require a degree of sliding movement (typically less than 5 mm) to occur to fully mobilize the resistance.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culverts should consist of free-draining granular material conforming to OPS Granular A or B specifications. The granular material should be placed to the extents shown in OPSD 803.010.

Backfill should be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be within 400 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction should be carried out in accordance with SP 105S10.

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

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

where:

p	= horizontal pressure on the wall at depth h (kPa)
K	= earth pressure coefficient (see table below)
γ	= unit weight of retained soil (see table below)
h	= depth below top of fill where pressure is computed (m)
q	= value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert are dependent on the material used as backfill. Recommended unfactored values are shown in Table 9.1. The at-rest coefficients should be employed for rigid frame culvert walls. Active pressures should be used for any wingwalls or unrestrained walls.

Table 9.1 – Earth Pressure Coefficients (K)

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

* For wing walls, if employed.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.9.1 (a) of the Commentary to the CHBDC.

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

The design of the culvert must incorporate measures such as weepholes to permit drainage of the culvert backfill and avoid the potential build-up of hydrostatic pressures behind the walls.

10 EROSION CONTROL

Erosion protection should be provided at the culvert inlet and outlet areas as applicable. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rip-rap should be provided over all surfaces with which stream flow is likely to be in contact. Treatment at the outlet (Sta. 14+093) should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in accordance with OPSS 572.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for erosion near the inlet area (Sta. 13+298). The clay seal should extend above the high water level, have a minimum thickness of 0.5 m, and extend laterally the width of the granular backfill material. The material requirements should be in accordance with OPSS 1205.

11 EXCAVATION AND GROUNDWATER CONTROL

Temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario. For the purposes of assessing excavation slope requirements in compliance with the OHSA, the following soil classifications are recommended:

- The existing fill, loose sandy silt and compact to dense sand in boreholes 06-70, 06-71 and 06-72 are classified as Type 3 soil.
- Although the SPT N-values indicate that the gravel in borehole 06-72 is very dense, a Type 3 classification is recommended based on the lack of cohesion in the soils, the depth below the water table, and the resulting possibility that excavation slopes will collapse if excavated vertically for the lower 1.2 m.
- The very loose sand and soft clayey silt above the water table in borehole 06-73 are classified as Type 3 soils. Below the water table, the soft clayey silt is classified as a Type 4 soil above elevation 282.8 m and Type 3 below this level.

Where space restrictions preclude excavation of trench sidewalls using inclined slopes, installation may be carried out using a trench box or temporary shoring. Where excavation for culvert installation is located in close proximity to live traffic lanes, an item titled "Roadway Protection" as per SP105S19 should be included in the contract documents. Performance Level 2 is recommended as per Clause 539.04.02.01.

Selection of the appropriate excavation procedures and dewatering system is the responsibility of the Contractor. The Contract documents should alert him to the requirement to maintain a stable excavation and a dry, sound base on which to work. Any shoring system should be designed by a shoring specialist, taking account of the need to maintain the integrity of the existing structure foundations, and the potential for groundwater seepage.

From a design viewpoint, it is anticipated that pumping from properly filtered sumps will be adequate to handle groundwater during culvert installation at Station 13+298. Excavation for culvert footing construction at Station 14+093 may extend up to 1.4 m below the groundwater level measured in the piezometers and require means to lower the water level, reduce seepage rates and maintain stability of the excavation. Pumping from filtered sumps may be suitable. A Permit to Take Water (PTTW) from the Ministry of Environment will be required prior to construction of the culvert extension at Station 14+093.

Temporary stream diversion measures such as impervious dykes should be provided to divert surface water runoff and stream flow away from the culvert excavations at all times during construction.

12 CONSTRUCTION CONCERNS

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

- Excavation may encounter existing approach fill or soft, loose, organic, wet or otherwise deleterious materials requiring flattening of excavation sideslopes or installation of temporary shoring. Soft organic alluvial material may be present in the stream channels extending to greater depths than encountered at the borehole locations.
- The sand and gravel and till soils may contain cobbles and boulders which will require removal if encountered during excavation, and may impact sheeting installation if employed.
- Care must be taken during footing excavation to avoid disturbing the founding subgrade and undermining the existing structure foundations.
- Temporary stream diversion, in conjunction with dewatering as required, is essential to maintaining a reasonably dry excavation. At Station 14+093, groundwater control techniques such as filtered sumps will be required.

13 CLOSURE

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

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

UNIFIED SOILS CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 06-70

METRIC

G.W.P. 277-97-00 LOCATION Hwy 8 Widening, Grand River to Sportsworld Dr N 4 809 565.36 E 230 184.39 ORIGINATED BY GA

HWY 8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM

DATUM Geodetic DATE 30.05.06 - 30.05.06 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
305.8					
0.0 / 0.1	ASPHALT: (75 mm)				
	SAND and GRAVEL, some silt, Dense to Very Dense, Brown, Dry (FILL)	1	SS	40	42 47 11 (SI+CL)
		2	SS	50/.150	
304.3 / 1.5	**SAND**, trace to some silt, trace to some gravel, Dense to Compact, Brown, Dry	3	SS	42	
		4	SS	24	
301.2 / 4.6	Sandy **SILT**, trace clay, Loose, Brown Mottled, Wet	5	SS	9	
299.7 / 6.1	**SAND and SILT**, some clay, trace gravel, Compact, Brown, Wet (TILL)	6	SS	28	
		7	SS	27	4 52 34 10
296.7 / 9.1	Silty **CLAY**, some sand, trace gravel, Hard, Brown (TILL)	8	SS	36	

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; ELEVATION SCALE 305, 304, 303, 302, 301, 300, 299, 298, 297, 296.

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 06-70

METRIC

G.W.P.	277-97-00	LOCATION	Hwy 8 Widening, Grand River to Sportsworld Dr N 4 809 565.36 E 230 184.39	ORIGINATED BY	GA
HWY	8	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	WM
DATUM	Geodetic	DATE	30.05.06 - 30.05.06	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
						▼					
294.7			9	SS	100/ 250		295		○		
11.1	END OF BOREHOLE AT 11.07 m. BOREHOLE OPEN TO 11.07 m AND WATER LEVEL AT 7.92 m UPON COMPLETION. Piezometer installation consists of 25 mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.										

WATER LEVEL READINGS:

DATE	DEPTH(m)	ELEV.(m)
29.05.06	7.28	298.52
26.09.06	10.45	295.35

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 06-71

METRIC

G.W.P. 277-97-00
LOCATION Hwy 8 Widening, Grand River to Sportsworld Dr. N 4 809 552.60 E 230 168.67
ORIGINATED BY SLL

HWY 8
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY MFA

DATUM Geodetic
DATE 18.09.06 - 18.09.06
CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
304.0 / 0.0	**TOPSOIL**: (375mm), trace roots, black				304	
303.6 / 0.4	Sandy **SILT**, trace organics Loose Brown Moist	1	SS	8	303	
302.4 / 1.6	**SAND**, some silt, trace gravel Dense Brown Moist	2	SS	30	302	10 70 20 (SI+CL)
		3	SS	32		
301.2 / 2.8	Sandy **SILT**, some clay Compact Brown Moist	4	SS	28	301	
300.5 / 3.5	Silty **CLAY**, trace sand Stiff to Hard Grey (TILL)(CI)				300	
		5	SS	10	299	
		6	SS	33	298	0 2 36 62
					297	
		7	SS	64/250		
296.0 / 8.0	END OF BOREHOLE AT 8.03m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

WATER LEVEL READINGS:

DATE	DEPTH(m)	ELEV.(m)
19.09.06	0.88	303.12
20.09.06	1.19	302.81
21.09.06	1.51	302.49
22.09.06	1.96	302.04
25.09.06	2.79	301.21
29.09.06	4.63	299.37

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

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

ONTMT4S 7938.GPJ 02/03/07

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 06-72

METRIC

G.W.P. 277-97-00 LOCATION Hwy 8 Widening, Grand River to Sportsworld Dr N 4 809 160.74 E 230 842.65 ORIGINATED BY GA

HWY 8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM

DATUM Geodetic DATE 30.05.06 - 30.05.06 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.3						
0.0	ASPHALT: (100 mm)					
0.1	SAND and GRAVEL, some silt; Dense; Brown; Dry; (FILL)	1	SS	42	288	41 46 13 (SI+CL)
		2	SS	38		
286.9 / 1.4	Silty CLAY, some sand, trace gravel; Very Stiff; Brown; (FILL)	3	SS	24	287, 286	
285.3 / 3.0	SAND and SILT, trace clay, trace gravel, trace organics, occasional cobbles; Loose; Brown; Moist	4	SS	7	285	1 56 36 7
284.0 / 4.3	GRAVEL, some sand, trace silt; Very Dense; Brown; Wet	5	SS	52	284, 283	
		6	SS	50/ .150	282	
281.0 / 7.3	Silty CLAY, some sand, trace gravel; Hard; Brown; (TILL)	7	SS	62/ .150	281, 280	
		8	SS	59	279	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 06-72

METRIC

G.W.P. 277-97-00 LOCATION Hwy 8 Widening, Grand River to Sportsworld Dr N 4 809 160.74 E 230 842.65 ORIGINATED BY GA

HWY 8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM

DATUM Geodetic DATE 30.05.06 - 30.05.06 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT
					278	
277.2		9	SS	93		o
11.1	END OF BOREHOLE AT 11.13 m. BOREHOLE OPEN TO 10.67 m AND WATER LEVEL AT 9.87 m ON COMPLETION. Piezometer installation consists of 25 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen.					

WATER LEVEL READINGS:

DATE	DEPTH(m)	ELEV.(m)
31.05.06	6.01	282.29
26.09.06	3.90	284.40

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

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 06-73

METRIC

G.W.P. 277-97-00	LOCATION Hwy 8 Widening, Grand River to Sportsworld Dr. N 4 809 157.57 E 230 802.08	ORIGINATED BY SLL
HWY 8	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY JHL
DATUM Geodetic	DATE 09.08.06 - 09.08.06	CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
285.1						
0.0 / 0.1	TOPSOIL: (150 mm)					
	SAND, trace organics; Very Loose; Dark Brown; Moist	1	SS	3	285	
284.4 / 0.7	Clayey SILT, some sand, trace organics; Soft; Dark Brown	2	SS	4	284	
		3	SS	3		
	Becoming Very Stiff	4	SS	17	283	
282.2 / 3.0	SAND and GRAVEL, some silt, occasional cobbles; Compact; Brown; Wet	5	SS	18	282	
281.2 / 4.0	SILT and SAND, trace clay, trace gravel; Dense to Very Dense; Brown to Grey; Moist; (TILL)	6	SS	31	281, 280	2 43 47 7
		7	SS	50/ .125	279	
278.7 / 6.4	END OF BOREHOLE AT 6.37 m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

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

WATER LEVEL READINGS:

DATE	DEPTH(m)	ELEV.(m)
10.08.06	1.95	283.18
11.08.06	1.92	283.21
14.08.06	2.02	283.11
15.08.06	2.00	283.13
16.08.06	2.00	283.13
29.09.06	1.52	283.61

ONTMT4S 7938.GPJ 02/03/07

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

Appendix B

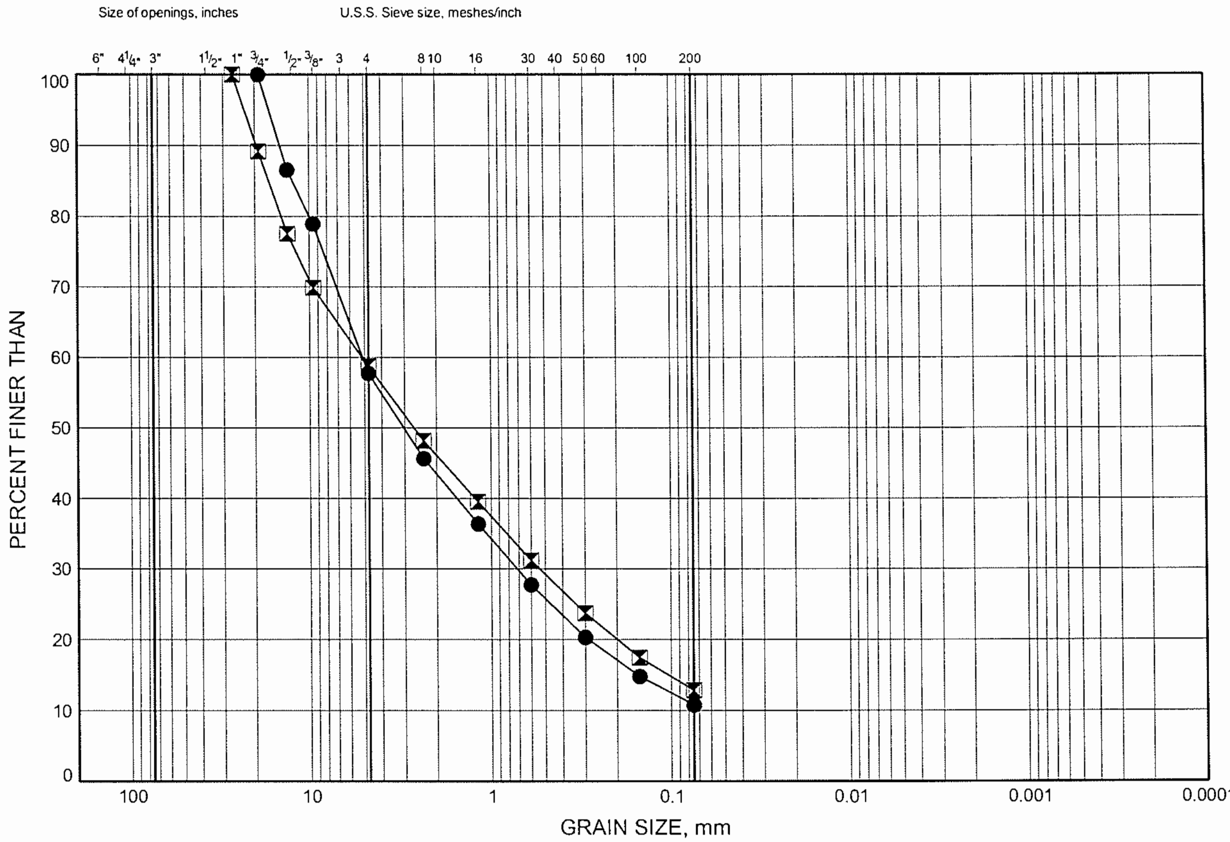
Laboratory Test Results

Geotechnical Investigation

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND AND GRAVEL FILL



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	06-70	0.46	305.34
⧗	06-72	0.46	287.84

THURBER

Date February 2007

Project 277-97-00

Prep'd JHL

Chkd. MRA

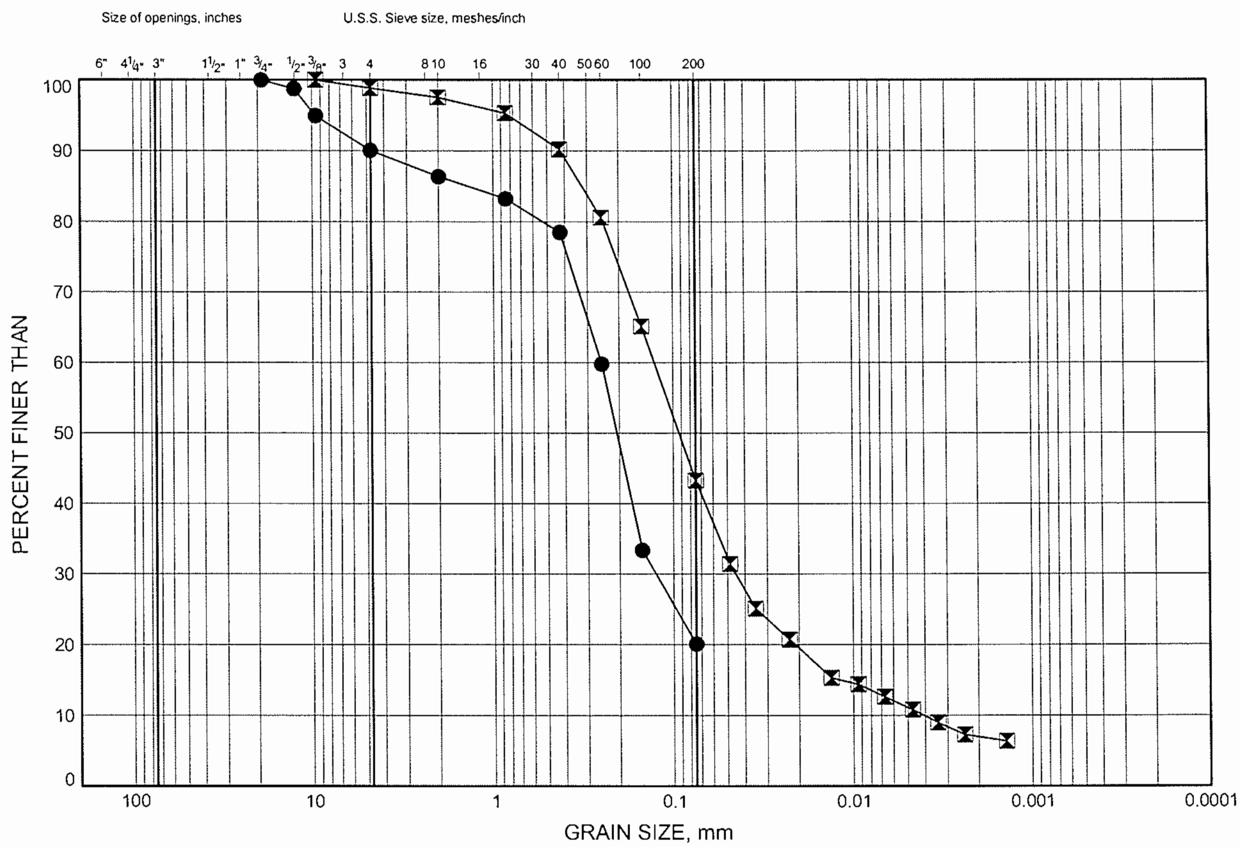
THURBGSD 7938-2.GPJ 12/02/07

Highway 8 Widening Over Grand River

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND, SAND AND SILT



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	06-71	1.83	302.17
⧗	06-72	3.35	284.95

THURBGSD 7938.GPJ 12/02/07

Date February 2007

Project 277-97-00

THURBER

Prep'd JHL

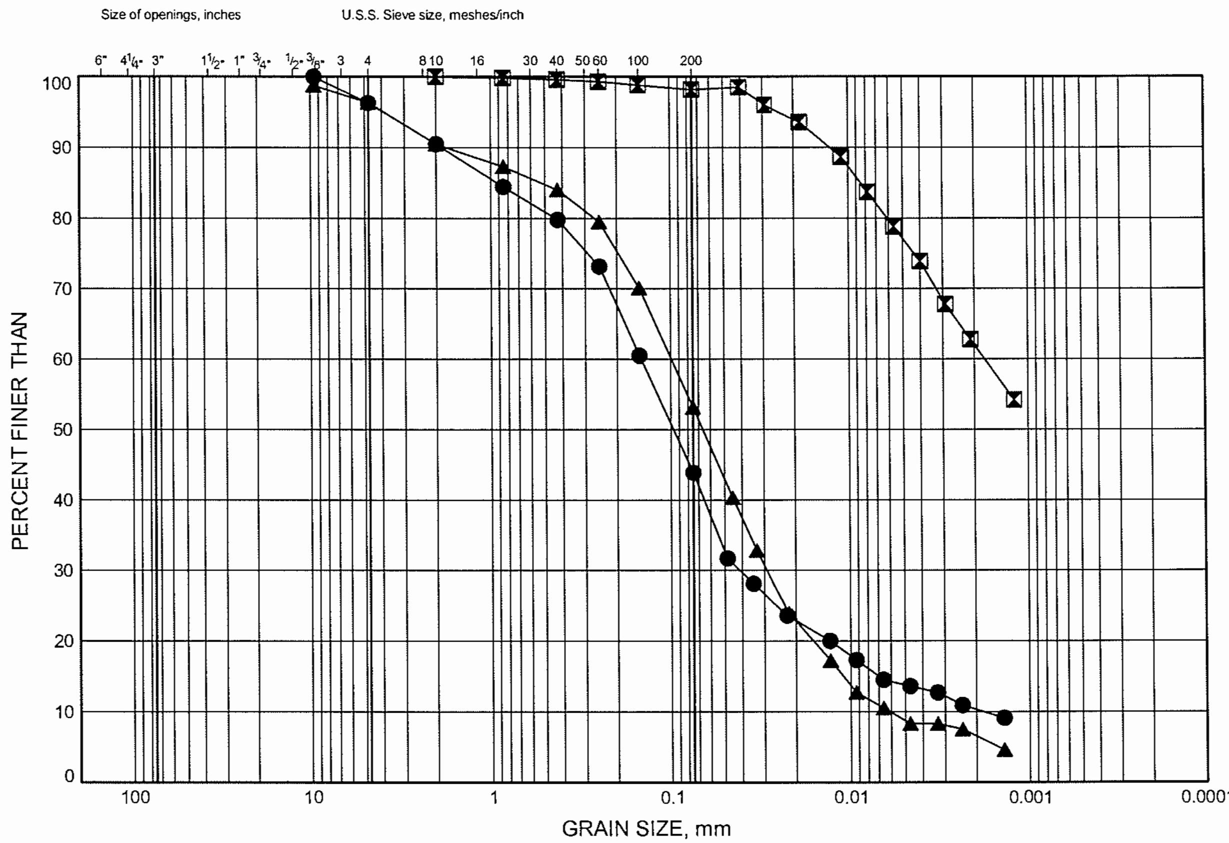
Chkd. MRA

Highway 8 Widening Over Grand River

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND AND SILT TILL TO SILTY CLAY TILL



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	06-70	7.85	297.95
⊠	06-71	6.40	297.60
▲	06-73	4.88	280.25

Date May 2007

Project 277-97-00

THURBER

Prep'd MFA

Chkd. MRA

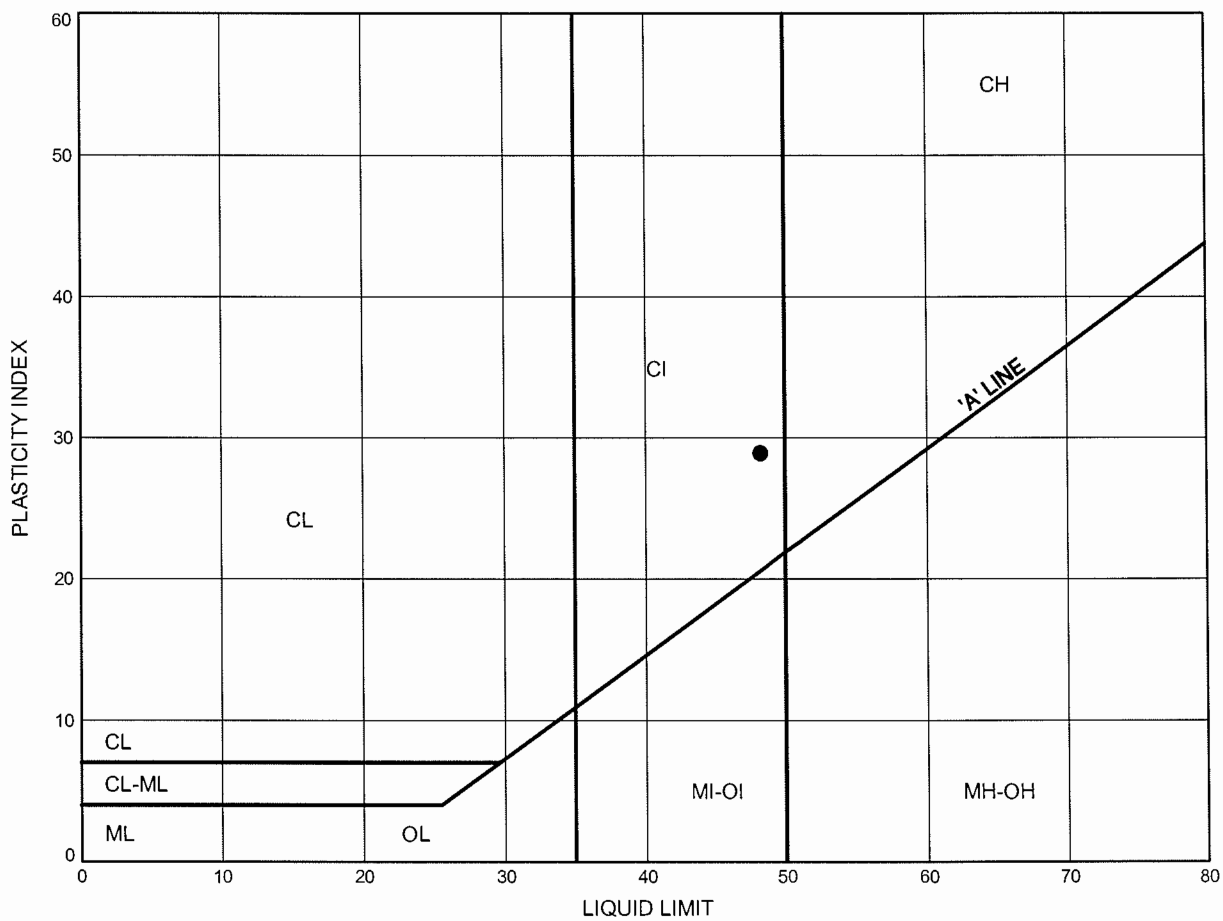
THURBGSD 7938.GPJ 5/28/07

Highway 8 Widening Over Grand River

ATTERBERG LIMITS TEST RESULTS

FIGURE B4

SILTY CLAY TILL



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	06-71	6.40	297.60

Date May 2007

Project 277-97-00

THURBER

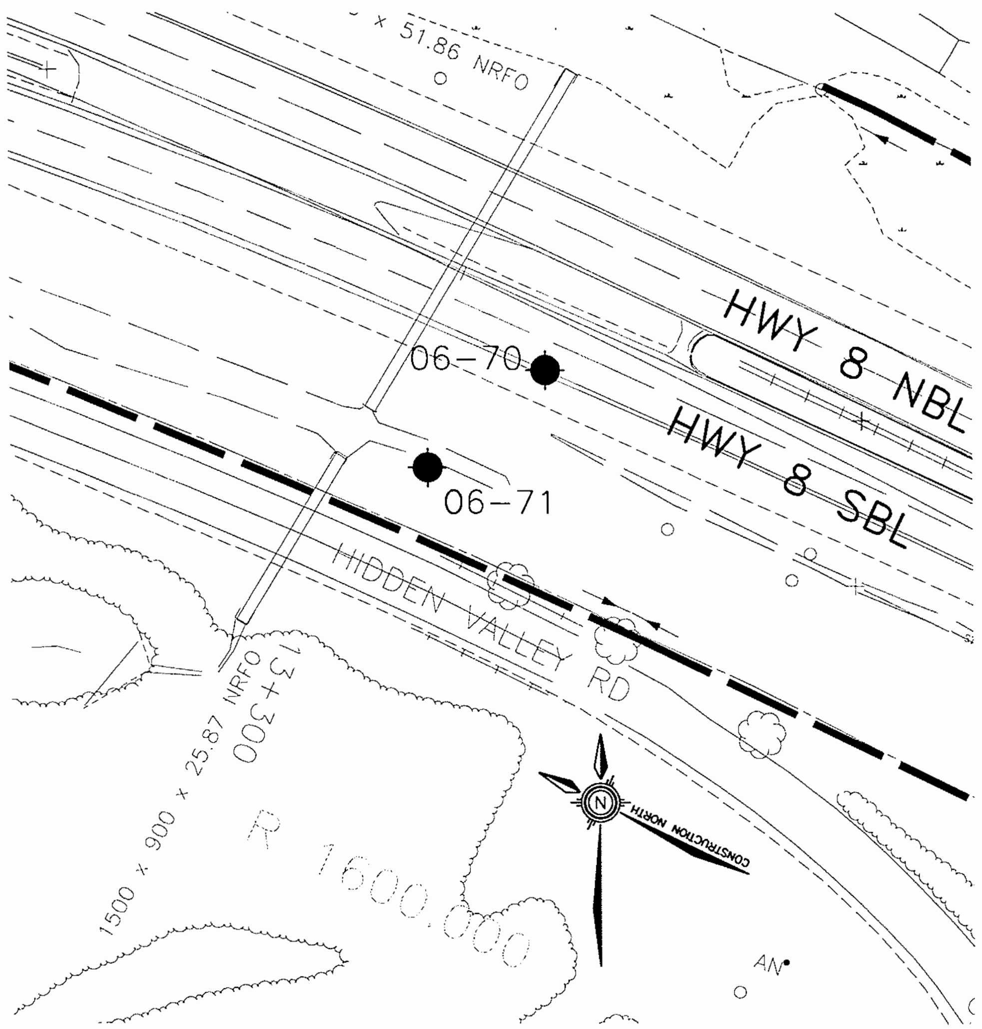
Prep'd MFA

Chkd. MRA

THURBALT 7938.GPJ 5/28/07

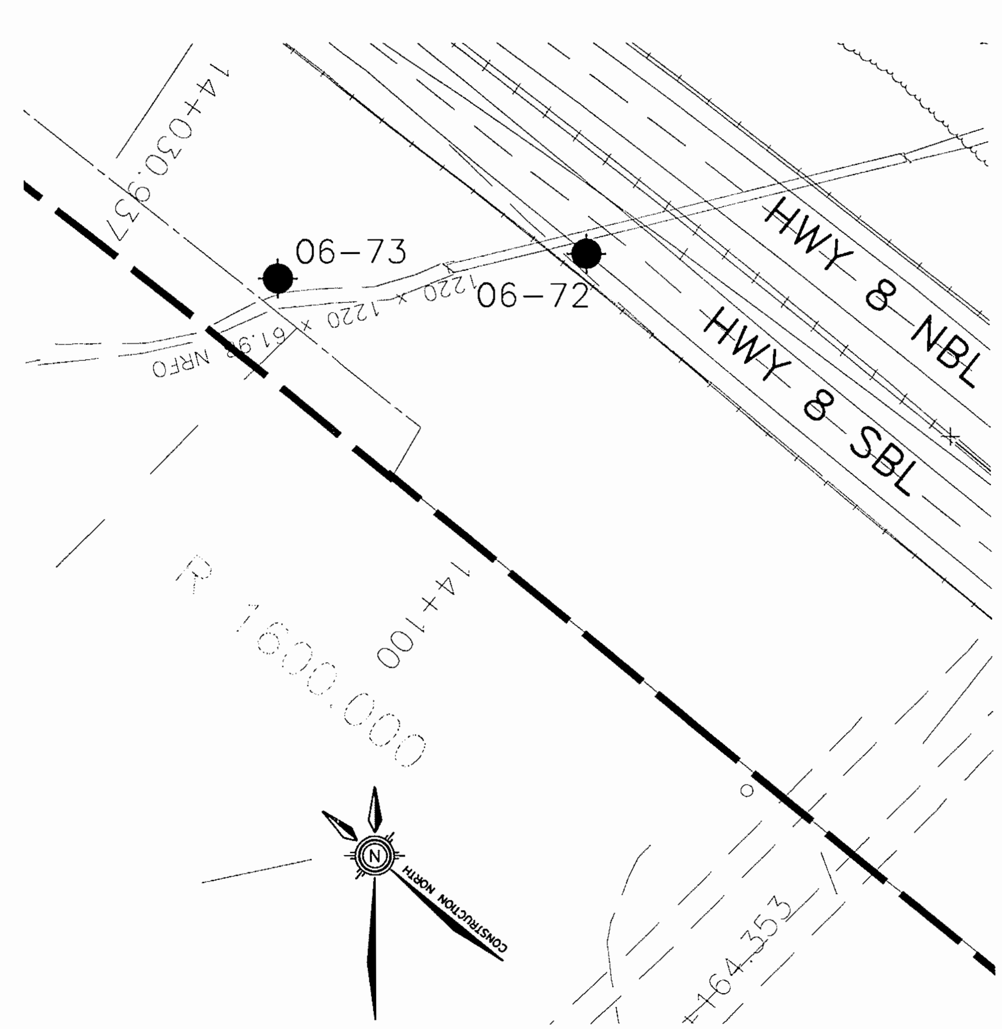
Appendix C

Borehole Locations and Soil Strata Drawing



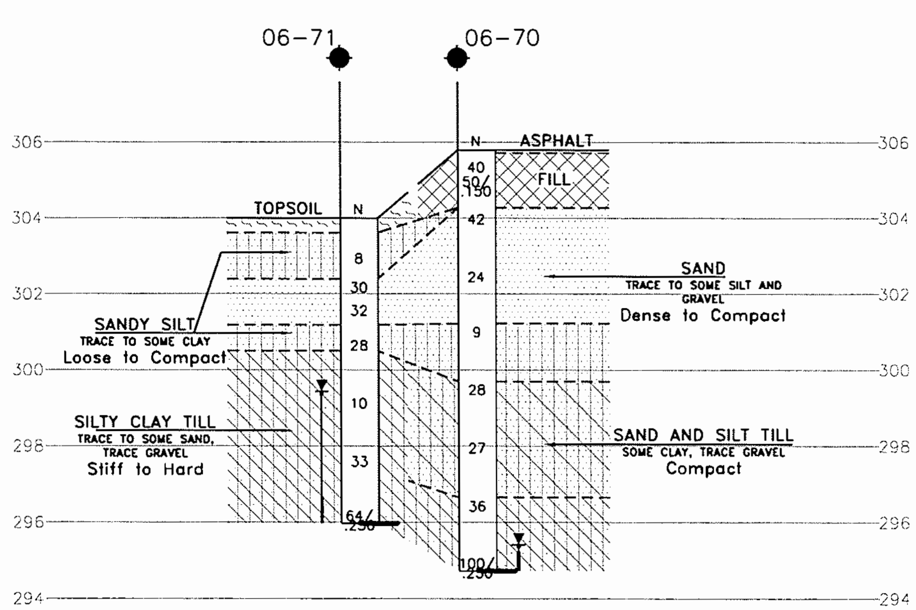
PLAN

SCALE: 1:1,000



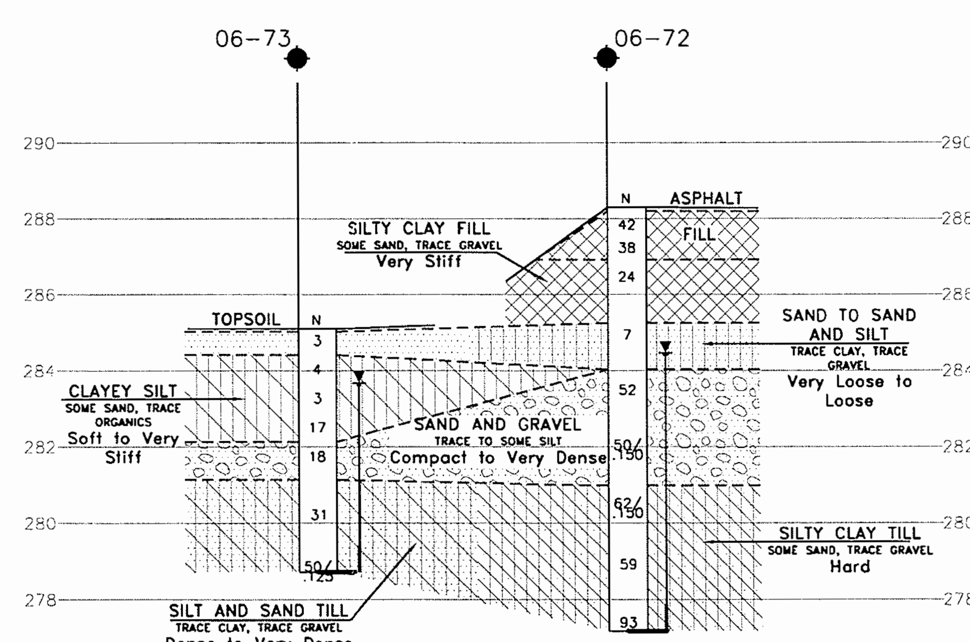
PLAN

SCALE: 1:1,000



PROFILE

HOR 1:1000
VER 1:200



PROFILE

HOR 1:1000
VER 1:200

DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

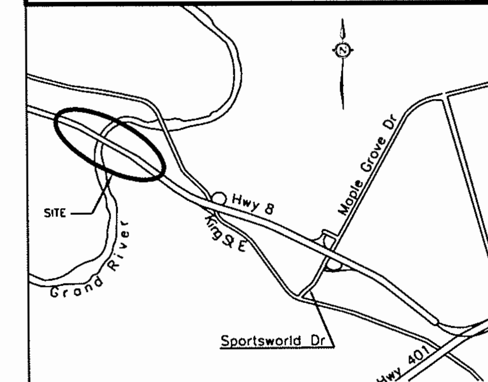
CONT No
GWP No.277-97-00

SHEET

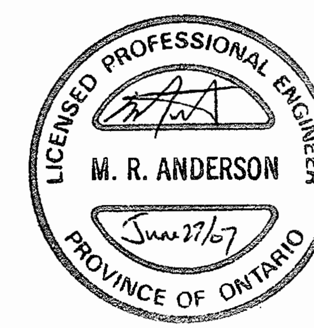
CULVERTS
HWY 8 WIDENING
BOREHOLE LOCATIONS PLAN

MORRISON HERSHFIELD

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



KEYPLAN



LEGEND

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

NO	ELEVATION	NORTHING	EASTING
06-70	305.8	4 809 565.4	230 184.4
06-71	304.0	4 809 552.6	230 168.7
06-72	288.3	4 809 160.7	230 842.7
06-73	285.1	4 809 157.6	230 802.1

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 40P8-146

REVISIONS		
MAY07	MFA	ROTATE VIEWS
DATE	BY	DESCRIPTION

DESIGN MRA	CHK PKC	CODE	LOAD	DATE JAN 2007
DRAWN JHL	CHK PKC	SITE	STRUCT	

FILENAME: O:\Job Files\19\4791.38 Hwy 8\1ED79381Culvert.dwg
PLOTDATE: May 28, 2007 - 9:36am

MINISTRY OF TRANSPORTATION, ONTARIO   PR-D-707   88-05   PLOT SCALE 1:1