THURBER ENGINEERING LTD.

DRAFT
FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF CULVERT No. CV-0252-0400-0076
HIGHWAY 400 SOUTHBOUND
TOWNSHIP OF SEVERN
G.W.P. 2041-13-00
ASSIGNMENT NUMBER: 2013-E-0053

GEOCRES NUMBER: -

SUBMITTED TO

MCINTOSH PERRY CONSULTING ENGINEERS

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of Culvert No. CV-0252-0400-0076 (Site) located on Highway 400 southbound, within the Township of Severn. Thurber carried out the investigation as a sub-consultant to McIntosh Perry Consulting Engineers (MPCE) as part of a change order to Agreement No. 2013-E-0053.

No previous foundation investigation information for the subject culvert was available. Base plan mapping and survey data was provided by MPCE for the preparation of this report.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

2 SITE DESCRIPTION

The Site is located on Highway 400 within the southbound lanes, approximately 1.2 km south of Highway 400 / Vasey Road interchange. It is noted that for project orientation purposes, Highway 400 within the project limits, will be assumed to run north-south. The location of the twin culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

Highway 400 at this location has two through lanes in each direction with granular shoulders. The northbound and southbound lanes are separated by a wide median that is vegetated with brush and small trees. Based on the 60% Design Complete Package, Highway 400 southbound lanes consists of two, 4.0 m wide lanes with a rural cross-section, and granular shoulders that are approximately 1.5 m and 3.0 m wide on the east and west side of the highway respectively. The highway alignment is on a curve at this site. Based on the information provided by MPCE the existing twin CSP culverts have an internal span of 1.4 m and a length of 25.8 m and water flows through from west to east.

The slopes of the road embankment were observed to be grass and brush covered and graded at approximately 4.3H:1V (Horizontal:Vertical) and 3.2H:1V near the east and west ends of the culvert respectively. The elevation at the centreline of the highway was surveyed by MPCE at Elevation 182.82 m. The elevation of the top of the culvert was surveyed by Thurber at Elevation 181.29 m and Elevation 181.08 m at the inlet and outlet respectively. The maximum height of the road embankment from shoulder to the top of the culvert is approximately 1.8 m. The invert was measured at an elevation ranging from 179.86 m and 179.64 m at the inlet and outlet respectively.

The lands surrounding the project limits are mainly forested and partially developed with some residential and commercial developments. The terrain in the vicinity of the inlet and outlet of the culvert is generally flat. Select site photographs illustrating existing conditions at the site are presented in Appendix D.

3 SITE INVESTIGATION AND FIELD TESTING

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to provide utility locate clearances for the intended borehole locations.

The field investigation for this site included advancing four boreholes drilled between April 11, 2016 and April 19, 2016. The location and ground surface elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A and are summarized in Table 3-1.

Table 3-1: Borehole Summary

Borehole	Location	Drilling Equipment	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Depth (m)
16-1	Inlet	ATV mount CME55 / HAS	4 950 954.9	292 931.5	180.5	15.8
16-2	West shoulder	ATV mount CME55 / HSA	4 950 948.4	292 944.0	182.4	18.9
16-3	East shoulder	Truck mount CME75 / HSA	4 950 957.4	292 950.4	183.0	18.9
16-4	Outlet	ATV mount CME55 / HSA	4 950 952.0	292 966.4	180.3	15.8

The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes via the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. In-situ shear vane testing was carried out within cohesive strata. A DCPT cone was also advanced to refusal in Borehole 16-2. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing.

A 25 mm inside diameter PVC piezometer was installed in Borehole 16-1 to measure the groundwater level at the site. Construction details for the piezometer are illustrated on the Record of Borehole sheet for Borehole 16-1, provided in Appendix B.

The boreholes without a piezometer were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903. The piezometer was decommissioned April 19, 2016.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber between April 14 and 19, 2016. The vertical datum used was temporary benchmark (TBM) BM1484 provided by MPCE and had a geodetic elevation of 180.448 m. The location of the TBM is indicated on Drawing No. 1 in Appendix A.

3.1 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses, and Atterberg Limits testing were also carried out on selected samples to MTO and ASTM standards.

The laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures provided in Appendix C.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the culvert area is presented on Drawing No. 1 in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

For reference, the stratigraphy in the area of the boreholes through the embankment is generally characterized by sand fill with varying amounts of silt and gravel, overlying organic clay, overlying clay, overlying silt and underlain by probable bedrock.

More detailed descriptions of the individual strata are presented below.

4.2 Topsoil

A 50 to 75 mm thick topsoil layer was encountered in the inlet and outlet boreholes respectively.

4.3 Embankment Fill

A fill layer consisting predominantly of sand, with varying amounts of silt and gravel was encountered from surface in both embankment boreholes. This layer has a top elevation of 183.0 m and 182.4 m and has a thickness of 4.3 m and 3.7 m. The SPT ‘N’ values ranged from 1 to 45 blows per 0.3 m of penetration; indicating a very loose to dense condition; but typically loose to compact. Occasional cobbles were noted in this layer.

The moisture content for the samples tested ranged from 2% to 13%. The results of two grain size analysis conducted on samples of this material are summarized in Table 4-1 and are illustrated on Figure 1 in Appendix C.

Table 4-1: Gradation Results for Embankment Fill

Soil Particles	%
Gravel	9 to 11
Sand	74 to 77
Silt and Clay	14 to 15

4.4 Clay Fill

A clay fill layer with varying amounts of organics was encountered just below the ground surface in both the inlet and outlet boreholes. This layer has a top elevation ranging from 180.4 m to 180.2 m and has a thickness 0.7 m. The SPT ‘N’ values ranged from 3 to 6 blows per 0.3 m of penetration, indicating a soft to firm consistency.

The moisture content for the samples tested ranged from 32% to 55%.

4.5 Organic Silt (MH-OH) to Organic Clay (CH-OH)

A dark grey organic silt to clay layer was encountered below the clay fill in Boreholes 16-1 and 16-4 and below the embankment fill in Boreholes 16-2 and 16-3. This stratum has a top elevation ranging from 178.7 m to 179.7 m and a thickness ranging from 2.4 m to 2.7 m. In-situ shear vane test results indicated undrained shear strengths ranging from 22 kPa to 77 kPa; indicating a soft to stiff consistency; but typically soft to firm. A 50 mm thick peat layer was observed within this unit in Boreholes 16-2 and 16-3.

The moisture content of the samples tested ranged from 25% to 87%. The results of grain size analysis including hydrometer analysis conducted on three samples of this material are summarized in Table 4-2 and are illustrated on Figure 2 in Appendix C.

Table 4-2: Gradation Results for Organic Silt and Clay

Soil Particles	%
Gravel	0
Sand	1 to 3
Silt	51 to 57
Clay	41 to 46

The results of Atterberg Limits testing completed on three samples of this material are summarized in Table 4-3 and are illustrated on Figure 6 in Appendix C. The results indicate an organic silt to clay of high plasticity.

Table 4-3: Atterberg Limits Test Results

Liquid Limit	65 to 75
Plastic Limit	30 to 36
Plasticity Index	35 to 41

4.6 Clay (CL to CI) with Interlayered Silty Clay (CL-ML)

A clay layer was encountered below the organic silt to clay layer in all boreholes. This stratum has a top elevation ranging from 176.0 m to 177.1 m and has a thickness ranging from 9.6 m to 11.4 m. In-situ shear vane test results indicated undrained shear strengths ranging from 15 kPa to 50 kPa; indicating a soft to stiff consistency; but typically firm. A silty clay layer 1.9 m to 3.4 m thick was noted interlayered within the clay layer.

The moisture content for the samples tested ranged from was 32% to 64%. The results of grain size analysis conducted on five samples of this material are summarized in Table 4-4 and are illustrated on Figures 3 and 4 in Appendix C.

Table 4-4: Gradation Results for Clay

Soil Particles	%
Gravel	0
Sand	1 to 35
Silt	43 to 67
Clay	14 to 53

The results of Atterberg Limits testing completed on five samples of this material are summarized in Table 4-5 and are illustrated on Figures 6 and 7 in Appendix C. The results indicate a clay of low to intermediate plasticity.

Table 4-5: Atterberg Limits Test Results

Liquid Limit	17 to 47
Plastic Limit	13 to 21
Plasticity Index	4 to 27

4.7 Silt (ML)

A silt layer was encountered in all boreholes. This stratum lies below the clay layer and has a top elevation ranging from 165.5 m to 166.7 m. All boreholes were terminated within this layer. A dynamic cone was driven in Borehole 16-2. It reached refusal at a depth of 22.5 m (elevation 159.9 m). The SPT 'N' values were all weight of hammer per 0.3 m of penetration; indicating a very loose condition. This may indicate hydraulic disturbance of the silt layer.

The moisture content for the samples tested ranged from 20% to 30%. The results of grain size analysis conducted on four samples of this material are summarized in Table 4-6 and are illustrated on Figure 5 in Appendix C.

Table 4-6: Gradation Results for Sandy Silt to Silt

Soil Particles	%
Gravel	0
Sand	1
Silt	89 to 93
Clay	6 to 10

Based on the results of Atterberg limit testing, this material was classified as non-plastic.

4.8 Refusal on Probable Bedrock

Refusal on probable bedrock was encountered at 22.5 m in Borehole 16-2

4.9 Groundwater

The groundwater level in the piezometer installed in Borehole 16-1 was recorded on April 19, 2015, at least 0.85 m above existing grade indicating an artesian condition and corresponding to an elevation of 181.35 m.

Immediately after this reading the well was decommissioned by packing the well full of bentonite pellets to seal off the artesian flow at the source and decommissioned in accordance with Ontario MOE Regulation 903.

Slight artesian conditions were also noted during drilling of Borehole 16-3 at a depth of 7.6 m to 11.0 m. Additional drilling depth cut off the artesian flow and the water level completion of drilling was noted to be 11.3 m (elevation 171.7 m). Free water was noted at 7.6 m and 0.6 m depth within Boreholes 16-2 and 16-4 respectively at completion of drilling, corresponding to elevation 174.8 m and 179.7 m.

The water level in the culvert was measured at the time of Thurber’s field investigation at an elevation ranging from 179.7 m to 180.1 m. The groundwater level in the area of the culvert is expected to reflect the creek water level.

These observations are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level and/or artesian conditions may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and determined the ground surface elevations based on contract drawings provided by McIntosh Perry Consulting Engineers. Terex Drilling Solutions of Concord, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full time basis by Mr. Christopher Murray of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa, Ontario.

Overall project management and direction of the field program was provided by Kenton Power, P.Eng. Interpretation of the field data and preparation of this report was completed by Christopher Murray. The report was reviewed by Fred J. Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of Culvert No. CV-0252-0400-0076 (Site) located on Highway 400 southbound, within the Township of Severn. Geotechnical assessment and recommendations are provided to assist the design team in designing a suitable foundation for the proposed replacement culvert.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

No previous foundation investigation information for the subject culvert was available. Base plan mapping and survey data was provided by McIntosh Perry Consulting Engineers (MPCE) for the preparation of this report.

The frost penetration depth at this site is 1.6 m as per OPSD 3090.100.

The following sections address the foundation aspects of the replacement of the exiting twin CSP culverts. The discussions and recommendations presented in this report are based on the information provided by MPCE and on the factual data obtained during the course of this investigation.

6.1 Proposed Structure

Based on information provided by MPCE, it is understood that the proposed replacement of the existing twin CSP culverts will be carried out along the existing alignment with stage construction using a single lane closure and roadway protection. The technically preferred replacement option is to replace the existing culverts with, twin CSP culverts each with an internal diameter of 2.2 m. The proposed culvert invert elevation ranges from 179.53 m and 179.38 m at the inlet and outlet respectively. It is also understood that based on dimension of the culverts and the spacing between the cells the culverts are being classified as structural.

7 GEOTECHNICAL ASSESSMENT

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-14.

It is understood that the culvert structure have a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment will need to be reviewed and revised.

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values (Sa(T)) for the reference ground condition for a range of periods (T) and for a range of return periods including the 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is presented in Appendix G.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the reference peak ground acceleration (PGA).

8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy.

In the case where the soil stratigraphy consists of both cohesive (S_u criteria) and non-cohesive (SPT 'N' criteria) strata and the resulting seismic site classification differ the stratum with the lower site class would govern the site.

The following soil stratigraphy was encountered at this site:

- Layer 1: Thickness = 2.5 m Typical S_u = 55 kPa Organic Silt/Clay
- Layer 2: Thickness = 9.5 m Typical S_u = 25 kPa Clay/Silty Clay, Sandy
- Layer 3: Thickness = 6.0 m Typical N_{60} = 3 Silt/Sand
- Layer 4: Thickness = 12.0 m Typical N_{60} = 100 Inferred Bedrock

The seismic site classification for this is site is based on the N_{60} criteria. The harmonic mean of the typical N_{60} listed is 8 which corresponds to a Site Class E in accordance with Table 4.1 of the CHBDC.

8.3 Seismic Liquefaction

Based on the combination of low plasticity index and high water content to liquid limit ratio within the Silty Clay to Clay layer, this layer is classified as susceptible to liquefaction. However, based

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on the low PGA value (0.061g) for the site, this layer presents a reasonably low risk of liquefying during the design earthquake event. Furthermore, the consequences of liquefaction would be limited to minor settlement of the embankment, which would be readily repaired.

9 DESIGN OPTIONS

9.1 Culvert Foundations

For reference, the stratigraphy in the area of the boreholes through the embankment is generally characterized by sand fill with varying amounts of silt and gravel, overlying organic clay, overlying clay, overlying silt and underlain by probable bedrock.

The invert elevation of 179.5 m and 179.4 m of the new structural culverts is within the organic silt to organic clay strata or silty sand fill.

Artesian groundwater conditions were observed in Borehole 16-1 located at the culvert invert during the investigation with the ground water level observed to rise to elevation 181.35 m.

Further discussion regarding these design considerations from a foundations perspective, evaluation of design options and foundation recommendations for the installation of the new structural culverts are provided in the sections that follow.

9.2 Culvert Replacement Alternatives

This section presents discussions on the alternate options, and foundation alternatives, and provides recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below and a comparison of these alternatives, based on their respective advantages and disadvantages are outlined below, and are summarized in the table provided in Appendix E.

9.2.1 Corrugated Steel Pipe (CSP) Culvert

From a foundation perspective, twin 2.2 m diameter, corrugated steel pipe (CSP) culverts could be installed at the site with 179.5 m and 179.4 m

Assuming a bedding layer thickness of 1,000 mm due to the presence of organic silty / clay, and the proposed invert elevations, the base of excavation is expected to be at an approximate elevation between 178.7 m and 178.5 m.

Design and installation of CSP culverts should be carried out in accordance with height of fill tables of the OPSD 800 series drawings.

It is noted that construction will extend below the creek water level. Creek diversion and dewatering will be required to prepare the subgrade and to place the bedding material and install the culvert in the dry. It will also be necessary to lower the artesian head in the Silty Clay to Clay stratum to reduce the risk of basal instability during excavation for the bedding layer.

9.2.2 Concrete, Rigid Frame Closed Bottom

It is anticipated that that proposed invert elevation is to remain at the same elevation as the existing culverts. The proposed, twin rigid frame, close bottom (RFCB) culverts would each have an internal height and span of 1.8 m. Assuming an internal substrate layer thickness of 300 mm, a base slab thickness of 250 mm, the underside of the concrete culvert would be at an approximate elevation between 179.25 m and 179.05 m. The organic silt to organic clay layer will need to be subexcavated to approximately 176.0 m.

An assessment of the factored geotechnical resistances for the RFCB culvert based on a settlement analysis in Rocscience's Settle3D modelling software in conjunction with current analysis methods indicates the following:

- Factored geotechnical resistance at ULS 100 kPa
- Factored geotechnical resistance at SLS 60 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - ϕ_{gu} = 0.5 (static analysis; typical degree of understanding)
  - ϕ_{gs} = 0.8 (static analysis; typical degree of understanding)

The geotechnical resistances are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC 2014 Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces and sliding resistance between concrete and bedding material should be evaluated using an unfactored coefficient of 0.45 for pre-cast concrete.

It is noted that construction will extend below the creek water level. Creek diversion and dewatering will be required to prepare the subgrade and to place the bedding material and install the culvert in the dry. It will also be necessary to lower the artesian head in the Silty Clay to Clay stratum to reduce the risk of basal instability during excavation for the bedding layer.

9.3 Construction Methodology Alternatives

This section presents discussions from a foundation perspective on alternative construction methods for the replacement of Culvert CV-0252-0400-0076. Further comparison of these options is summarized in the table provided in Appendix E.

In preparation of these recommendations the following options have been considered.

1. Trenchless techniques
2. Open cut with full road closure
3. Open cut with staged construction and roadway protection

9.3.1 Trenchless Techniques

Although trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment, the cover over the existing culvert is less than one culvert diameter at some locations. This geometry is not conducive to tunnelling. Trenchless techniques are not considered suitable for the existing site conditions.

9.3.2 Open Cut with Full Road Closure

Installation of a new culvert using open cut techniques during a full road closure via median crossovers is one alternative. This option would allow for an expedient construction schedule and reduced costs associated with roadway protection, however, it is understood that a road closure is not feasible from a traffic operations perspective.

9.3.3 Open Cut with Staged Construction and Roadway Protection

The proposed twin culverts could be installed using open cut techniques with staged construction (half and half) and roadway protection in order to keep one lane of traffic open throughout the construction period.

9.4 Recommended Approach for the Culvert Replacement

If a full road closure is not possible due to other considerations, then open cut techniques with staged construction with roadway protection is considered the preferred alternative from a foundation perspective.

The existing culverts could then be replaced with twin, 2.2 m diameter, CSP culverts.

10 GENERAL RECOMMENDATIONS

Construction for installation of new culverts should be carried out in accordance with OPSS.PROV 421.

10.1 Excavations

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills at the site should be classified as Type 3 in accordance with OHSA. The underlying silts and clays should be considered to be Type 4 soils.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

10.2 Dewatering

Subgrade preparation and placement of culvert bedding must be carried out in the dry.

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the proposed culvert replacement to be constructed in a dry and stable excavation. It is recommended that the culvert replacement be conducted during a drier season such as after the spring freshet or prior to the fall season.

Artesian groundwater conditions were noted during the investigation. An NSSP alerting the contractor to this condition should be included in the specifications. A draft version is provided in Appendix F.

Temporary watercourse diversion will be required to install the new culvert in the dry. Water from either surface flow and/or groundwater must be diverted away from the excavation at all times.

Groundwater perched within the embankment fill, surface runoff and/or the water from the ditch will tend to seep into, and accumulate in proposed excavations.

Excavations below the groundwater level are anticipated, and water flow diversion may be required to control inflow of water into the excavation. Dewatering and surface water diversion must remain operational and effective until the new culvert is installed. The Contractor must carry out the design of an effective dewatering system.

To lower the groundwater table and to facilitate the removal of the organic silt / organic clay layer, a temporary sheet pile enclosure around the excavation, would be required to cut off the artesian flow and support the surrounding soils. The groundwater must be lowered at least 0.5 m below the final subgrade level to prevent the subgrade from boiling. A vacuum well point system may be required.

The Contractor must engage an experienced geotechnical engineer licensed to practice in Ontario to carry out the cofferdam and dewatering design.

10.3 Subgrade Preparation

Subgrade preparation for the culvert replacement should include the removal of the existing fill and any soft or deleterious materials. The native subgrade within the footprint of the culvert is expected to consist of native organic clay or silty sand fill.

In order to protect the clay subgrade and provide a proper working surface the use of a 100 mm concrete mud-slab is recommended. With a bedding layer thickness of 1,000 mm for the twin CSP culverts due to the presence of organic silty / clay, and invert elevations ranging from 179.5 m and 179.4 m, the base of excavation is expected to be at an approximate elevation of 178.3 m.

The final subgrade should be inspected by a geotechnical inspector prior to installing the new culverts in order to confirm that the founding conditions are uniformly competent consistent with the recommendations described herein, and to ensure that there is no disturbance of the subgrade soil along the culvert alignment. Any deleterious materials, organics, or loose/soft or wet conditions observed, should be sub-excavated and removed and the excavations backfilled with OPSS Granular B Type II, placed and compacted in accordance with OPSS.PROV 501.

10.4 Culvert Bedding and Backfilling

Bedding and backfill should be in accordance with OPSD 802.010. Backfill for the culvert must consist of free draining granular material conforming to OPSS Granular A or B Type II material specifications. The bedding layer should be 1,000 mm in thickness as outlined in Section 9.2.1. Excavated granular fill materials must not be used as culvert bedding or backfill.

Frost treatment should be in accordance with OPSD 803.030 or 803.031.

Compaction should be carried out in accordance with OPSS.PROV 501.

10.5 Embankment Design and Reinstatement

The existing embankments are sloped at approximately 4.3H:1V and 3.2H:1V on at the east and west ends of the culvert respectively. Embankment reconstruction, after culvert replacement, should be carried out in accordance with OPSS.PROV 206. The embankment material should consist of imported OPSS Select Subgrade Material. Excavated fill may be reused as embankment fill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction.

Provided the subgrade is prepared as outlined in Section 10.3 and embankment fill is placed as recommended herein, an embankment slope inclined to match existing will be stable.

10.6 Cement Type and Corrosion Potential

Two samples of the native soils were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water-soluble sulphate and chloride concentrations, and resistivity. The analysis was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in the Table 10-1.

Table 10-1: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
16-3	SS3	1.8	7.7	3890	64	21
16-4	SS3	2.6	6.9	1840	235	56

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU Portland Cement should therefore be suitable for use in concrete at this site.

The remaining properties in Table 10-1 provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in the Table 10-1 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

10.7 Erosion Protection

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. Normal slope vegetation should be established as soon as possible after completion of the embankment fills in order to control surficial erosion. The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805.

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

Typically, rock protection should be provided over all surfaces with which culvert water is likely to be in contact. Treatment at the outlets 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 general accordance with OPSS.PROV 804.

It is recommended that a clay seal be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

10.8 Roadway Protection

Roadway protection will be required to allow for staged construction and groundwater control. It should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2.

The design of roadway protection is the responsibility of the Contractor. All shoring systems should be designed by a Professional Engineer experienced in such designs.

11 EARTH RETAINING STRUCTURES

11.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC but generally are given by the expression:

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

where:

P_h = horizontal pressure on the wall (kPa)
K = earth pressure coefficient
γ = unit weight of retained soil (kN/m^3)
h = depth below top of fill where pressure is computed (m)
q = value of any surcharge (kPa)

Note that the unit weight of retained soil should be adjusted to account for the groundwater elevation. The recommended lateral earth pressure parameters for use in the design for a horizontal back-slope are provided in Table 11-1.

Table 11-1: Static Lateral Earth Pressure Coefficients

Parameter	OPSS Granular A & OPSS Granular B Type II	Existing Fill	Native Clay
Soil Unit Weight, kN/m^3, γ	21	18	16
Angle of Internal Friction, ϕ	35°	30°	27°
Coefficient of at Rest Earth Pressure, K_o (Non-Yielding Wall)	0.43	0.50	0.55
Coefficient of Active Earth Pressure, K_a (Yielding Wall)	0.27	0.33	0.38
Coefficient of Passive Earth Pressure, K_p (Yielding Wall)	3.69	3.00	2.66

For rigid structures, it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls. The ratio of wall movement to wall height required to mobilize the active condition would be approximately 0.002.

For static analysis, passive earth resistance in front of the walls should be ignored, and has been provided solely for use in roadway protection design. A lateral pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC.

11.2 Combined Static and Seismic Lateral Earth Pressure Parameters

The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

- k_h = ½ F(PGA)•PGA for structures that allow lateral yielding, and
- k_h = F(PGA)•PGA for non-yielding walls

The ratio of wall movement to wall height required to mobilize the active condition would be approximately 0.002 for a yielding structure with respect to the assessment of seismically induced lateral earth pressures.

The recommended seismic lateral earth pressure parameters for use in the design that are provided in Table 11-2 assume the following:

- Horizontal back-slope behind the wall
- Seismic Site Class of E, and a PGA with a 2% probability of exceedance in 50 years of 0.061g; as outlined in Section 8.2

Table 11-2: Lateral Earth Pressure (Under Seismic Loads)

Parameter	OPSS Granular A & OPSS Granular B Type II	Existing Fill	Native Clay
Soil Unit Weight, kN/m^3, γ	21	18	16
Angle of Internal Friction, ϕ	35°	30°	27°
Non-Yielding Wall			
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.33	0.40	0.45
Yielding Wall			
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.30	0.37	0.41

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall may be determined using the following equation that includes consideration of material properties and the soil profile:

$$\sigma_h = K_a \gamma d + (K_{AE} - K_a)\, \gamma\, (H - d)$$

where:

σ_h = lateral earth pressure at depth, d (kPa)
d = depth below the top of the wall (m)

K_a = static active earth pressure coefficient
γ = unit weight of the backfill soil (kN/m^3)
K_{AE} = combined static and seismic earth pressure coefficient
H = total height of the wall (m)

Note the unit weight of the retained soil should be adjusted to account for groundwater elevation.

12 CONSTRUCTION CONCERNS

The planned construction methodology includes an open cut excavation for the installation of a new culvert.

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

- Impact of the excavation on the existing pavement surface. Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert construction. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the C.A. for determining the level of remedial action that is required.
- An organic silt to organic clay layer is anticipated near the underside of the culvert. A 1.0 m thick granular pad should be constructed below the twin CSP.
- Artesian conditions were observed at this site. Construction will likely extend below the surface water level. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert and subgrade in the dry.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the subgrade soils to support the proposed construction equipment and any temporary structures or fill (i.e. as a pad for crane support). Site conditions may limit the type of equipment suitable for use. The design and safety of any temporary works is the responsibility of the Contractor. Recommended wording for an NSSP addressing this issue is provided in Appendix G
- Confirmation that the backfill is adequately placed and compacted to specifications.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

13 CLOSURE

Overall project management and direction of the field program was provided by Kenton Power, P.Eng. Interpretation of the field data and preparation of this report was completed by Christopher Murray. The report was reviewed by Fred J. Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.

Christopher Murray, M.A.Sc.
Geotechnical Engineer in Training

Fred J. Griffiths, P.Eng.
Senior Associate, Senior Geotechnical Engineer

P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

APPENDIX A

BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

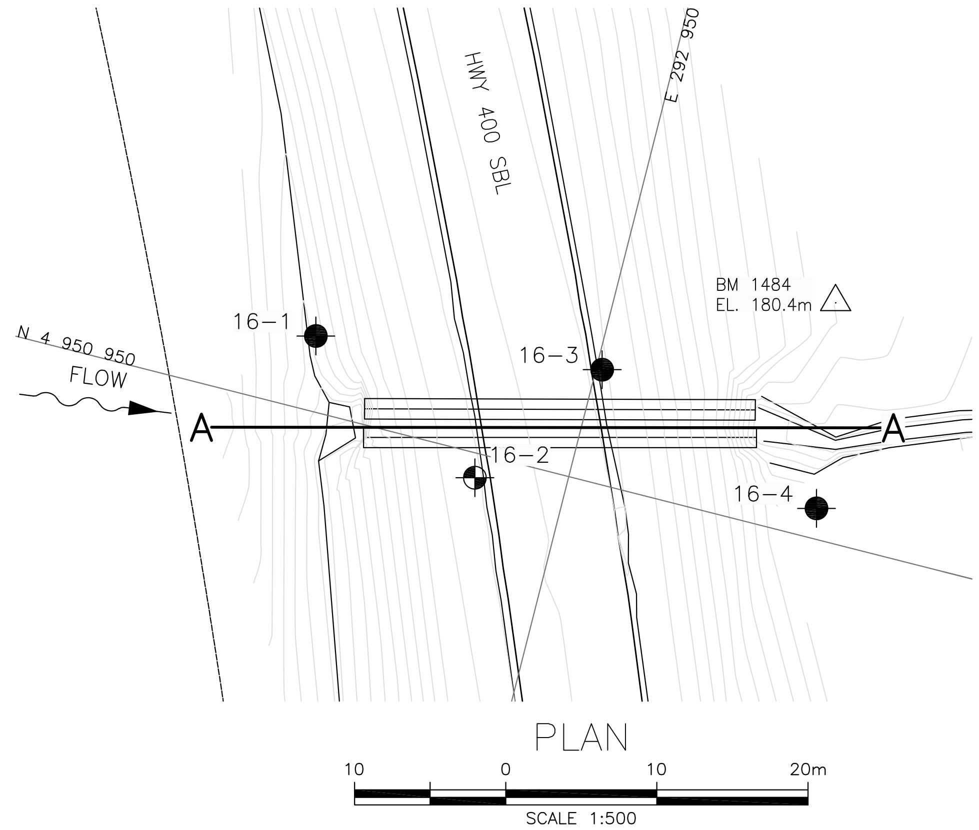
CONT No
WP No 2183-13-00

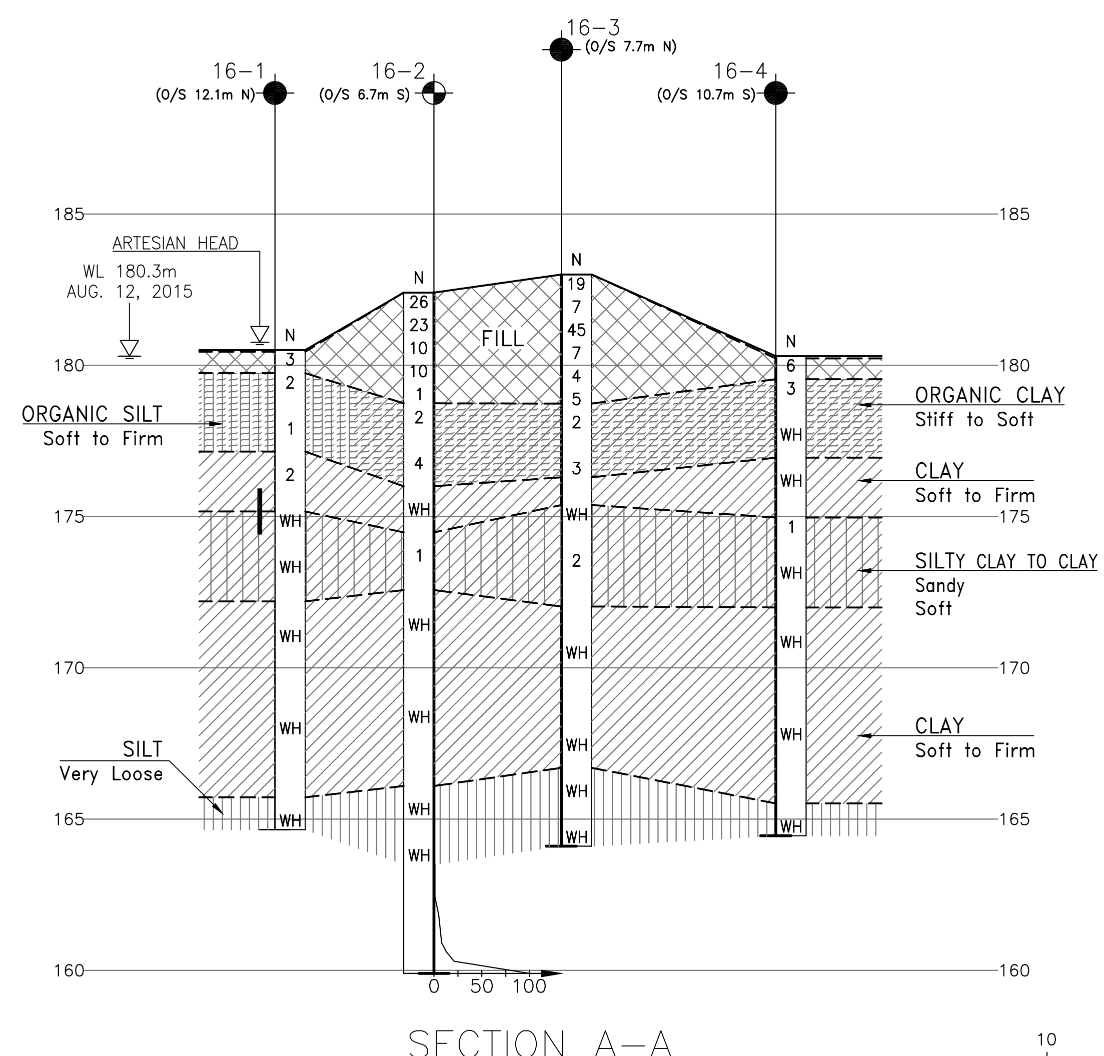
HIGHWAY 400 SB
COLDWATER CULVERT
CV-0252-0400-0076
BOREHOLE LOCATIONS AND SOIL STRATA

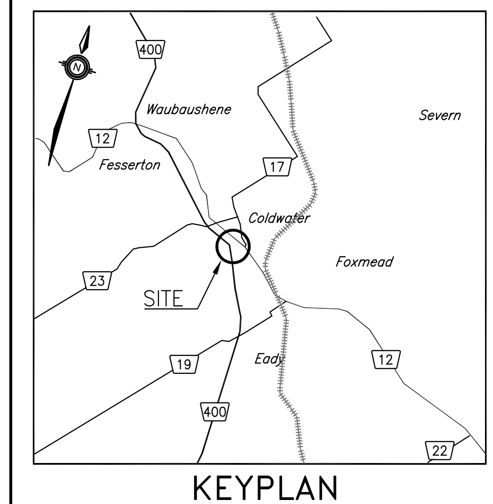
SHEET

McINTOSH PERRY

THURBER ENGINEERING LTD.







LEGEND

●	Borehole
⊕	Borehole & Cone
△	Benchmark
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
WH	Weight of Hammer
▽	Water Level
▼	Head Artesian Water
ǀ	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-1	180.5	4 950 954.9	292 931.5
16-2	182.4	4 950 948.4	292 944.0
16-3	183.0	4 950 957.4	292 950.4
16-4	180.3	4 950 952.0	292 966.4

-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.

3) Borehole locations are shown in MTM Zone 10 coordinates.

GEOCRES No.

10	0	10	20m	H 1:500
5	0	5	10m	V 1:250

REVISIONS

DATE	BY	DESCRIPTION		
DESIGN CM	CHK PC	CODE	LOAD	DATE JUN 2016
DRAWN MFA	CHK FG	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\19\3405\5\ted4055-Plan&Profile(Culvert).dwg
PLOTDATE: 6/1/2016 11:11 AM

APPENDIX B

SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS
RECORD OF BOREHOLE SHEETS

THURBER

SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

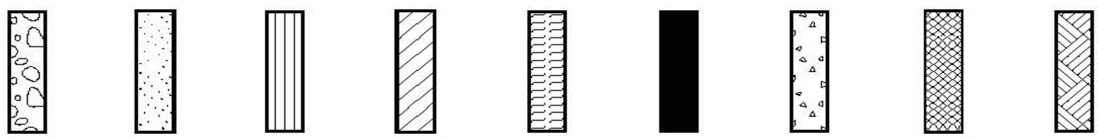
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an “A” size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders Cobbles Gravel | Sand | Silt | Clay | Organics | Asphalt | Concrete | Fill | Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

THURBER

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	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	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, 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.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L= Liquid Limit

THURBER

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
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 structures are preserved.

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 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

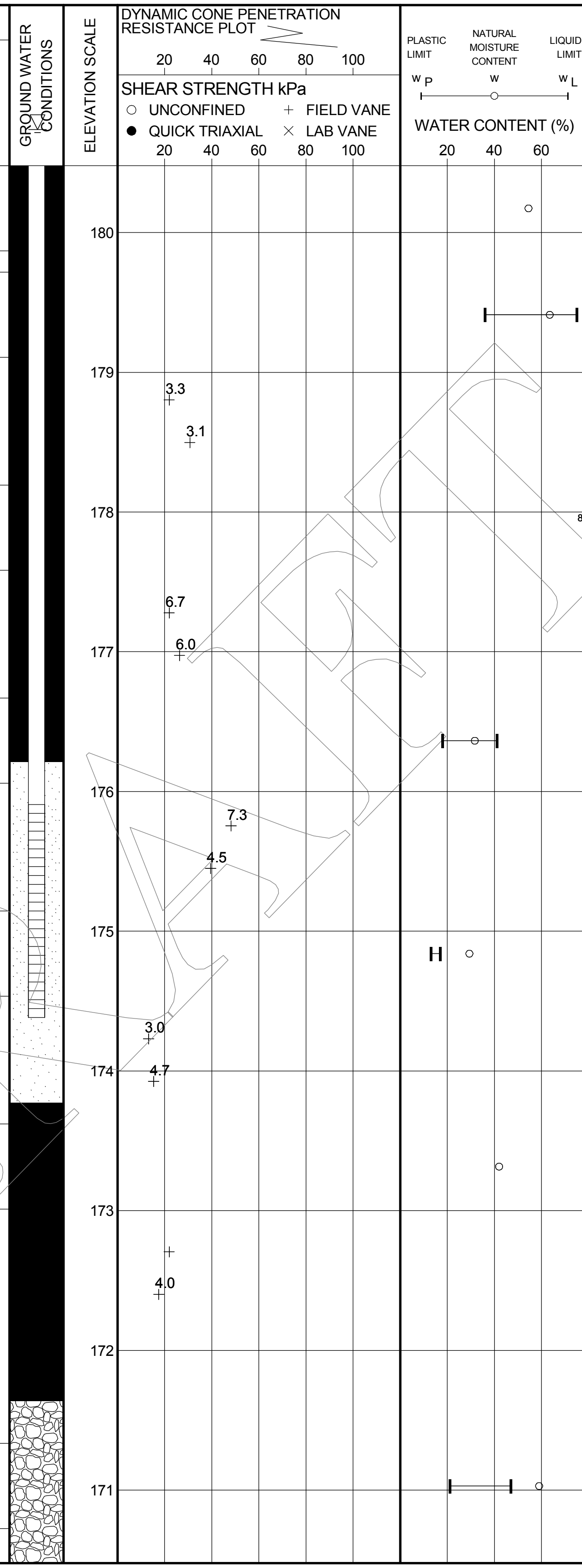
Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-1 METRIC

GWP# 2013-E-0053	LOCATION Highway 400 SB near Coldwater, ON N 4 950 954.9 E 292 931.5	ORIGINATED BY CAM
HWY Highway 400	BOREHOLE TYPE Hollow Stem Auger	COMPILED BY CAM
DATUM Geodetic	DATE 2016.04.18 - 2016.04.18	CHECKED BY KCP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
180.5								
0.0 / 0.1	**Rootmat (50mm)**							
	CLAY, trace wood **FILL** Stiff Brown	1	SS	3				
179.7 / 0.8	**ORGANIC SILT (MH-OH)** Soft to Firm Dark Grey	2	SS	2	0	1	55	44
	-Thin Topsoil / Silty Sand Layers around 2.4 m	3	SS	1				
177.1 / 3.4	**CLAY (CI)** Firm Grey	4	SS	2	0	2	60	38
175.1 / 5.3	**SILTY CLAY (CL-ML) to CLAY (CL)**, Sandy Soft Grey **Artesian**	5	SS	WH	0	35	51	14
		6	SS	WH				
172.2 / 8.3	**CLAY (CI)** Soft to Firm Grey	7	SS	WH	0	1	46	53



UNIT WEIGHT γ kN/m3

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

ONTMT4S 19-3405-5 HWY 400 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 2/6/16

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-1

METRIC

GWP# 2013-E-0053 | LOCATION Highway 400 SB near Coldwater, ON N 4 950 954.9 E 292 931.5 | ORIGINATED BY CAM

HWY Highway 400 | BOREHOLE TYPE Hollow Stem Auger | COMPILED BY CAM

DATUM Geodetic | DATE 2016.04.18 - 2016.04.18 | CHECKED BY KCP

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (Field Vane)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	CLAY (CI) Soft to Firm Grey				170							
						4.4						
						6.4						
					169							
		8	SS	WH	168		~59					
					167							
						3.0						
						4.4						
					166							
165.7 14.8	**SILT (ML)** Very Loose Grey											
		9	SS	WH	165		~25		0	1	93	6
164.6 15.8	End of Borehole at 15.8 m A water level of at least 0.85 m above ground level was measured on 19/04/16 just prior to decomissioning											

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

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 19-3405-5 HWY 400 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 2/6/16

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-2

METRIC

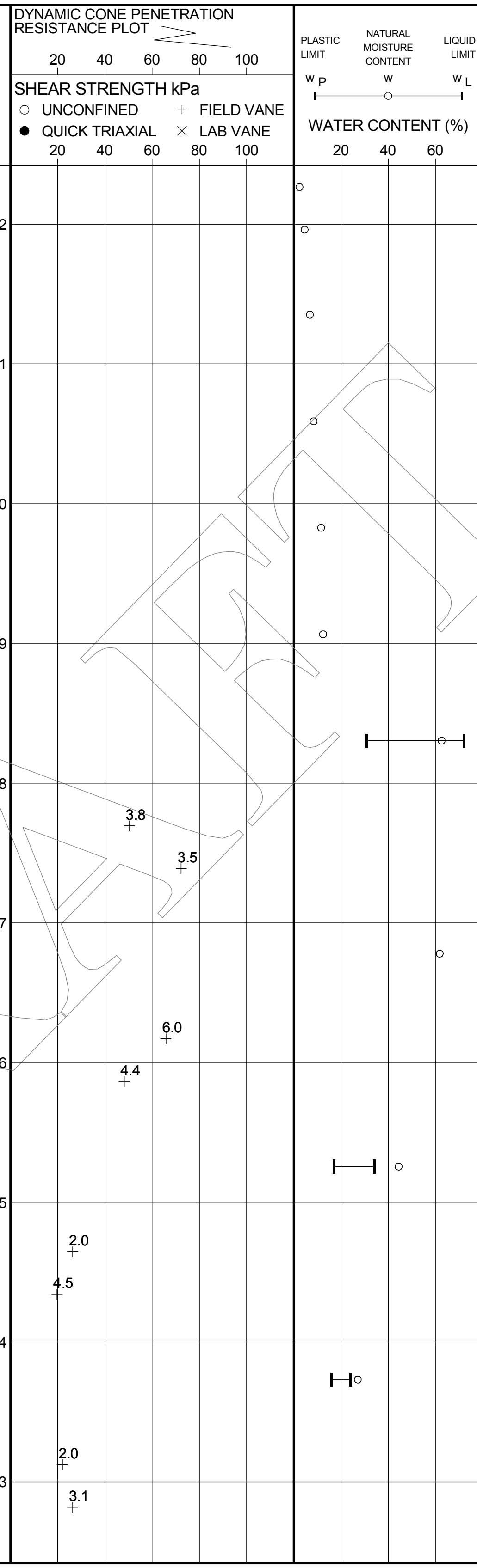
GWP#	2013-E-0053	LOCATION	Highway 400 SB near Coldwater, ON N 4 950 948.4 E 292 944.0	ORIGINATED BY	CAM
HWY	Highway 400	BOREHOLE TYPE	Hollow Stem Auger	COMPILED BY	CAM
DATUM	Geodetic	DATE	2016.04.18 - 2016.04.18	CHECKED BY	KCP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
182.4	
0.0	SAND with Gravel **FILL**, Compact, Grey
182.1 / 0.3	SILTY SAND **FILL**, Compact to Very Loose, Brown; -with Gravel
178.8 / 3.7	**ORGANIC CLAY (CH-OH)**, Stiff, Dark Grey; -50mm Peat Layer around 5.6 m
176.0 / 6.4	**CLAY (CL)**, Firm, Grey
174.5 / 7.9	**SILTY CLAY (CL-ML) to CLAY (CL)** with Sand, Soft to Firm, Grey, **Artesian**
172.6 / 9.8	

SAMPLES

NUMBER	TYPE	"N" VALUES	GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	26				
2	SS	23				
3	SS	10				
4	SS	10	9	77	14 (SI+CL)	
5	SS	1				
6	SS	2	0	2	57	41
7	SS	4				
8	SS	WH	0	5	63	32
9	SS	1	0	15	67	18



GROUND WATER CONDITIONS | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 16-2

METRIC

GWP#	2013-E-0053	LOCATION	Highway 400 SB near Coldwater, ON N 4 950 948.4 E 292 944.0	ORIGINATED BY	CAM
HWY	Highway 400	BOREHOLE TYPE	Hollow Stem Auger	COMPILED BY	CAM
DATUM	Geodetic	DATE	2016.04.18 - 2016.04.18	CHECKED BY	KCP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	FIELD VANE (Sensitivity)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY (CI) Soft to Firm Grey				172		
		10	SS	WH	171		
					170	2.7, 3.4	
					169		
		11	SS	WH	168		0 4 45 51
					167	2.4, 4.2	
166.1 / 16.3	**SILT (ML)** Very Loose Grey				166		
		12	SS	WH	165		0 1 92 7
		13	SS	WH	164		
163.5 / 18.9	End of Borehole at 18.9 m DCPT driven from 18.9 m to refusal on probable bedrock at 22.5 m Free Water at 7.6 m on completion of drilling				163		

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

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

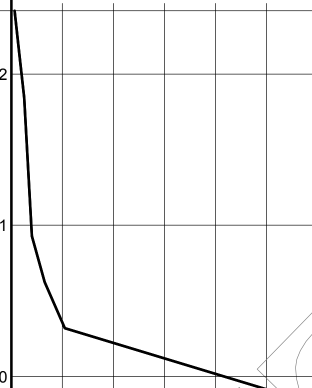
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-2

METRIC

GWP#	2013-E-0053	LOCATION	Highway 400 SB near Coldwater, ON N 4 950 948.4 E 292 944.0	ORIGINATED BY	CAM
HWY	Highway 400	BOREHOLE TYPE	Hollow Stem Auger	COMPILED BY	CAM
DATUM	Geodetic	DATE	2016.04.18 - 2016.04.18	CHECKED BY	KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
	Continued From Previous Page						162							
							161							
							160							



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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-3

METRIC

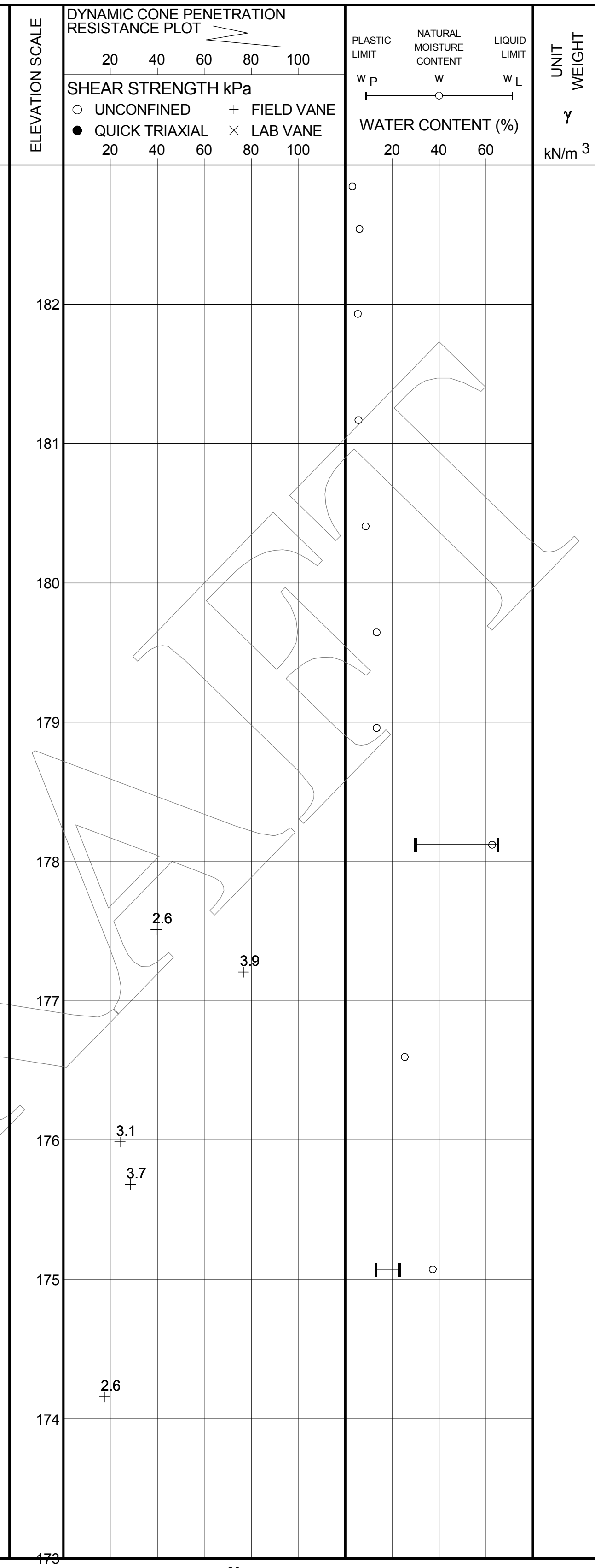
GWP# 2013-E-0053	LOCATION Highway 400 SB near Coldwater, ON N 4 950 957.4 E 292 950.4	ORIGINATED BY CAM
HWY Highway 400	BOREHOLE TYPE Hollow Stem Auger	COMPILED BY CAM
DATUM Geodetic	DATE 2016.04.19 - 2016.04.19	CHECKED BY KCP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
183.0	
0.0	SAND with Gravel **FILL**, Compact, Grey
182.7 / 0.3	SILTY SAND **FILL**, Loose to Dense, Brown
178.7 / 4.3	**ORGANIC CLAY (CH-OH)**, Firm to Stiff, Dark Grey; -50mm Peat Layer around 6.2 m
176.3 / 6.7	**CLAY (CL)**, Soft to Firm, Grey
175.4 / 7.6	**SILTY CLAY (CL-ML) to CLAY (CL)**, with Sand, Soft, Grey, **Artesian**

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	19	
2	SS	7	
3	SS	45	
4	SS	7	
5	SS	4	11 74 15 (SI+CL)
6	SS	5	
7	SS	2	0 3 51 46
8	SS	3	
9	SS	WH	0 24 43 33
10	SS	2	



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

ONTMT4S 19-3405-5 HWY 400 CULVERTS.GPJ 2012TEMPLATE(MTO).GDT 2/6/16

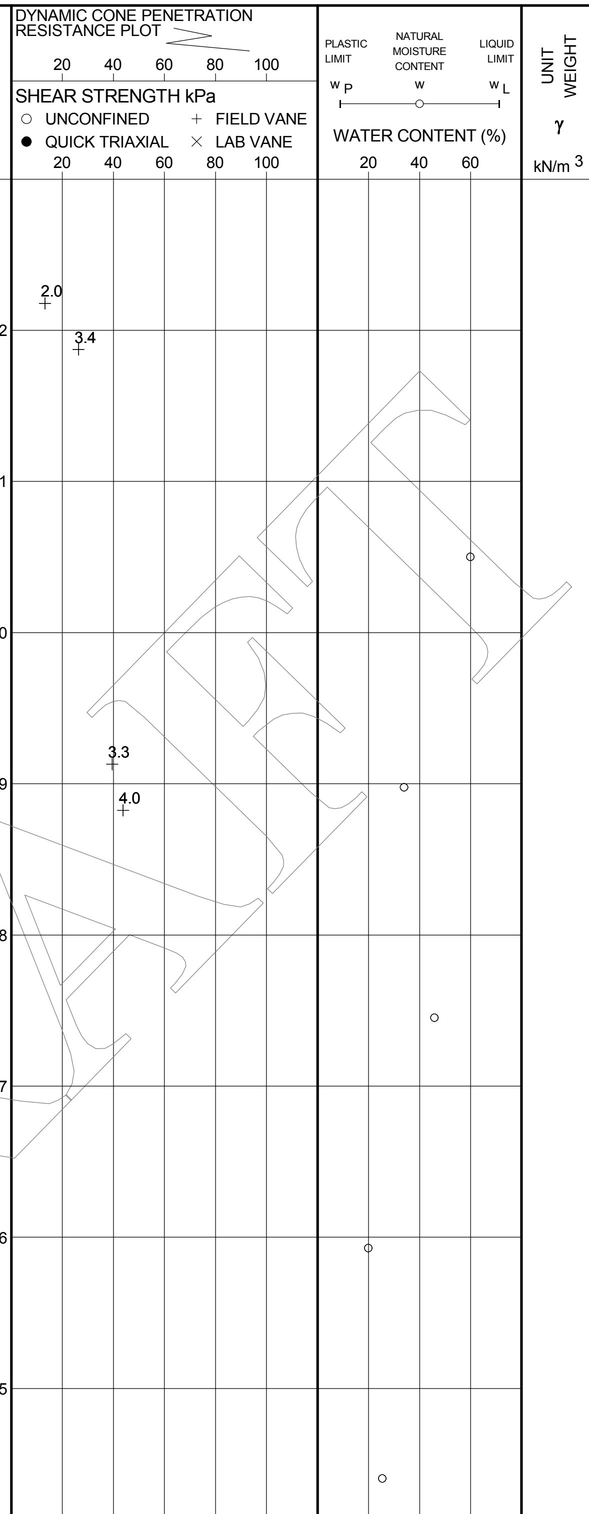
RECORD OF BOREHOLE No 16-3

METRIC

GWP#	2013-E-0053	LOCATION	Highway 400 SB near Coldwater, ON N 4 950 957.4 E 292 950.4	ORIGINATED BY	CAM
HWY	Highway 400	BOREHOLE TYPE	Hollow Stem Auger	COMPILED BY	CAM
DATUM	Geodetic	DATE	2016.04.19 - 2016.04.19	CHECKED BY	KCP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
172.0 / 11.0	**CLAY (CI)** Soft to Firm Grey						
			11	SS	WH		
			12	SS	WH		
166.7 / 16.3	**SILT (ML)** Very Loose Grey						
			13	SS	WH		0 1 89 10
			14	SS	WH		
164.1 / 18.9	End of Borehole at 18.9 m Free Water at 11.3 m on completion of drilling						



+ 3, × 3: Numbers refer to Sensitivity

15 ⊕ 5 (20, 10) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-4

METRIC

GWP# 2013-E-0053	LOCATION Highway 400 SB near Coldwater, ON N 4 950 952.0 E 292 966.4	ORIGINATED BY CAM
HWY Highway 400	BOREHOLE TYPE Hollow Stem Auger	COMPILED BY CAM
DATUM Geodetic	DATE 2016.04.14 - 2016.04.15	CHECKED BY KCP

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

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.3					
0.0 / 0.1	**Rootmat (75mm)**				
	CLAY **FILL**, Stiff, Grey	1	SS	6	
179.6 / 0.8	**ORGANIC CLAY (CH-OH)**, Stiff to Soft, Dark Grey	2	SS	3	
		3	SS	WH	
177.0 / 3.4	**CLAY (CL)**, Soft to Firm, Grey	4	SS	WH	0 4 63 33
175.0 / 5.3	**SILTY CLAY (CL-ML) to CLAY (CL)**, Sandy, Soft, Grey, **Artesian**	5	SS	1	0 30 54 16
		6	SS	WH	
172.0 / 8.3	**CLAY (CI)**, Soft to Firm, Grey	7	SS	WH	

Field vane sensitivity values plotted: 4.0, 3.0, 4.0, 7.0, 7.3, 5.2, 2.0, 2.0, 3.8, 5.0

Elevation scale: 180, 179, 178, 177, 176, 175, 174, 173, 172, 171

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 16-4

METRIC

GWP# 2013-E-0053	LOCATION Highway 400 SB near Coldwater, ON N 4 950 952.0 E 292 966.4		ORIGINATED BY CAM
HWY Highway 400	BOREHOLE TYPE Hollow Stem Auger		COMPILED BY CAM
DATUM Geodetic	DATE 2016.04.14 - 2016.04.15		CHECKED BY KCP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (+ FIELD VANE)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	CLAY (CI) Soft to Firm Grey						170							
								2.0						
								3.5						
							169							
			8	SS	WH		168		○					
							167	1.9						
								1.8						
							166							
165.5 / 14.8	**SILT (ML)** Very Loose Grey						165							
			9	SS	WH				○		0	1	91	8
164.5 / 15.8	End of Borehole at 15.8 m. Free Water at 0.6 m on completion of drilling													

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ ³, × ³: Numbers refer to Sensitivity

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

APPENDIX C

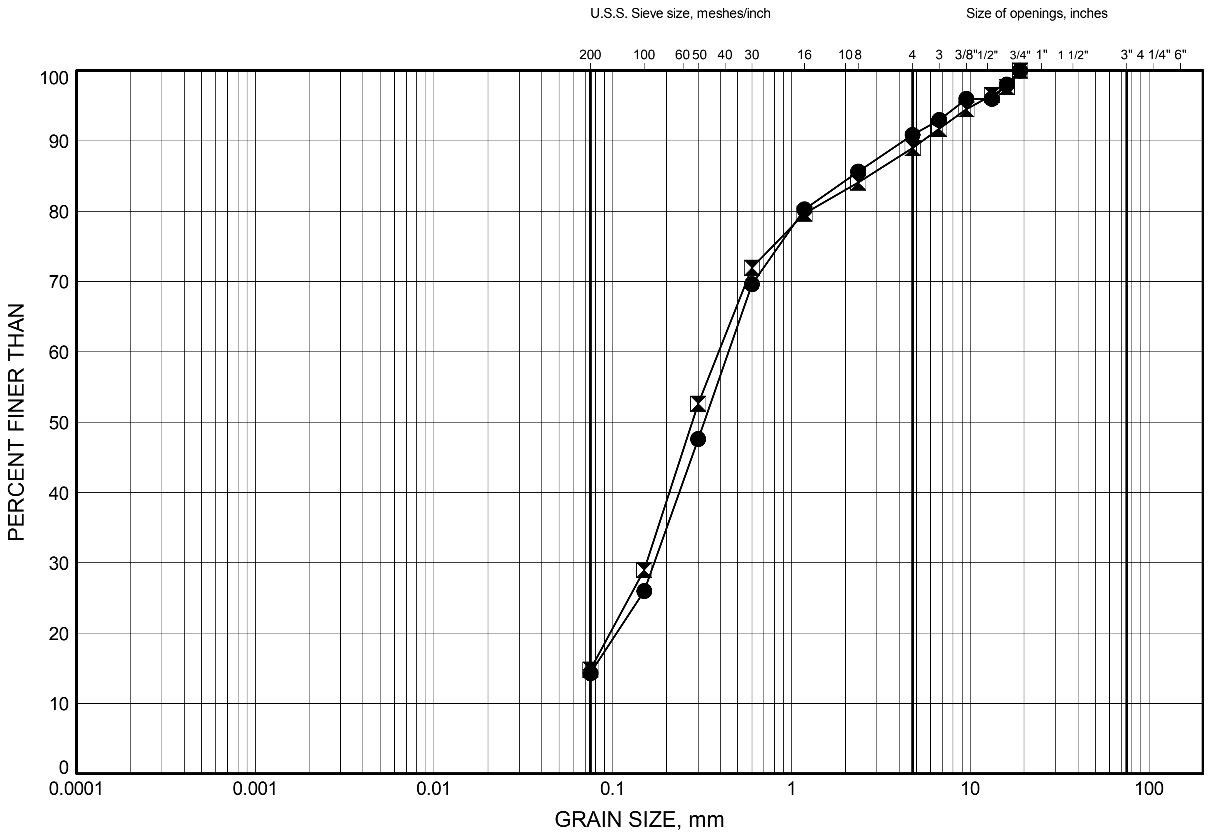
LABORATORY TEST RESULTS

Highway 400 SB near Coldwater, ON

GRAIN SIZE DISTRIBUTION

FIGURE 1

Embankment Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-2	2.59	179.83
⧗	16-3	3.35	179.65

Date May 2016

GWP# 2013-E-0053

THURBER

Prep'd CM

Chkd. FJG

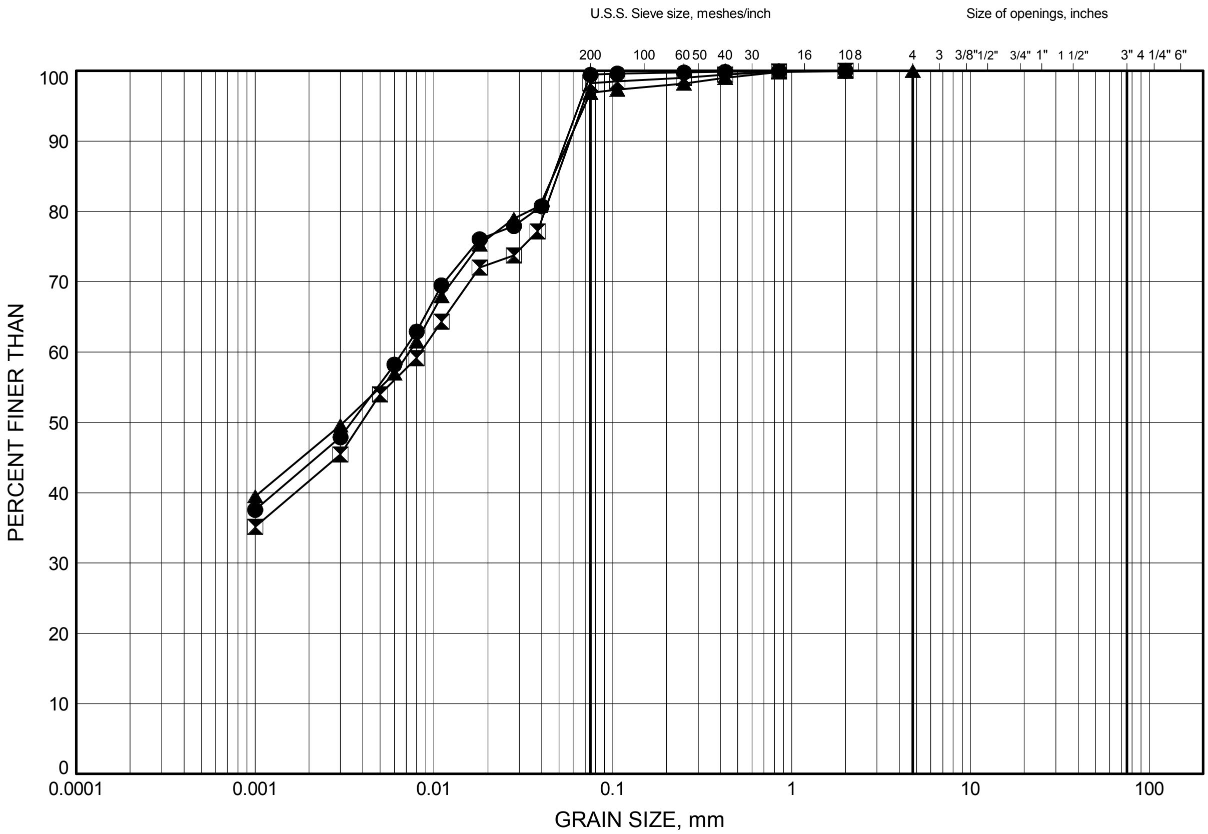
GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5 HWY 400 CULVERTS.GPJ 17/5/16

Highway 400 SB near Coldwater, ON

GRAIN SIZE DISTRIBUTION

FIGURE 2

Organic Silt (MH-OH) to Organic Clay (CH-OH)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	1.07	179.41
⧗	16-2	4.11	178.30
▲	16-3	4.88	178.12

GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5 HWY 400 CULVERTS.GPJ 17/5/16

Date May 2016

GWP# 2013-E-0053

THURBER

Prep'd CM

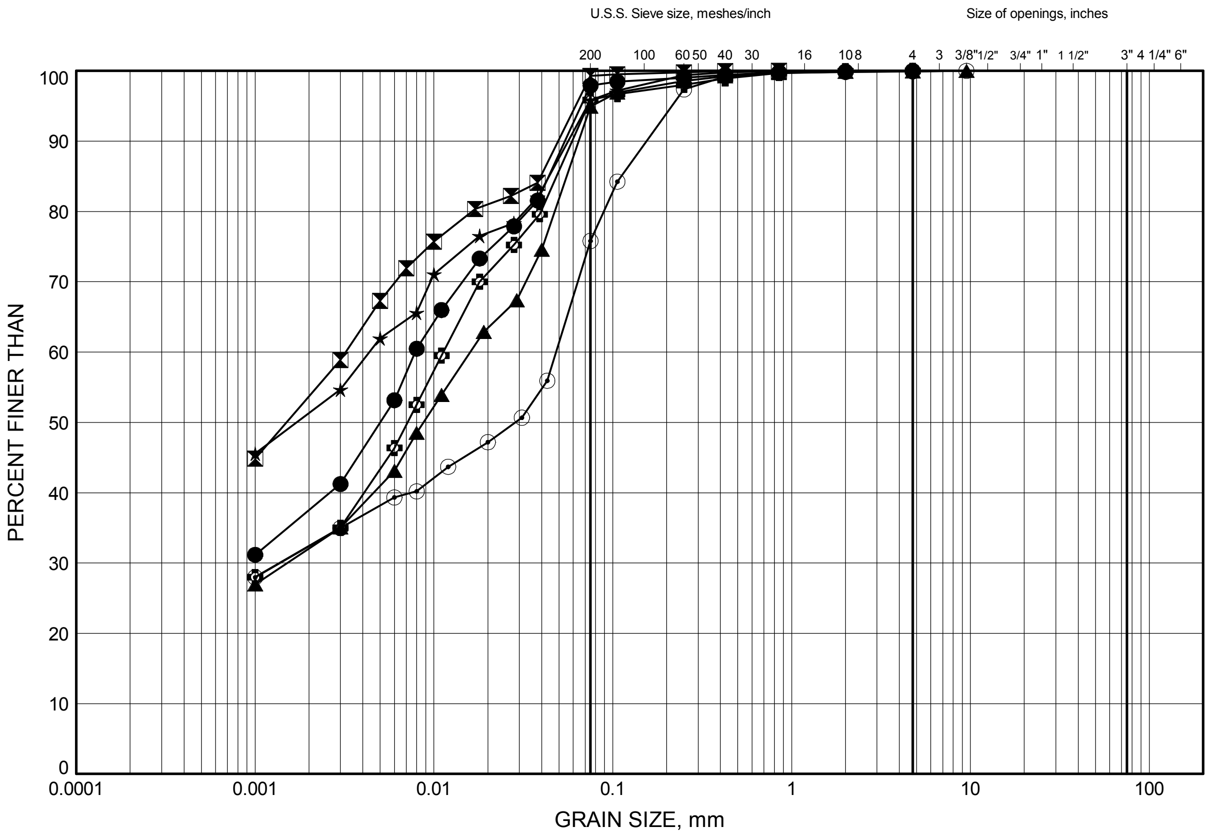
Chkd. FJG

Highway 400 Southbound Culvert Replacements

GRAIN SIZE DISTRIBUTION

FIGURE 3

Clay



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	4.11	176.36
⧗	16-1	9.45	171.03
▲	16-2	7.16	175.26
★	16-2	14.02	168.40
⊙	16-3	7.92	175.07
✿	16-4	4.11	176.21

Date June 2016

GWP# 2013-E-0053

THURBER

Prep'd KCP

Chkd. FG

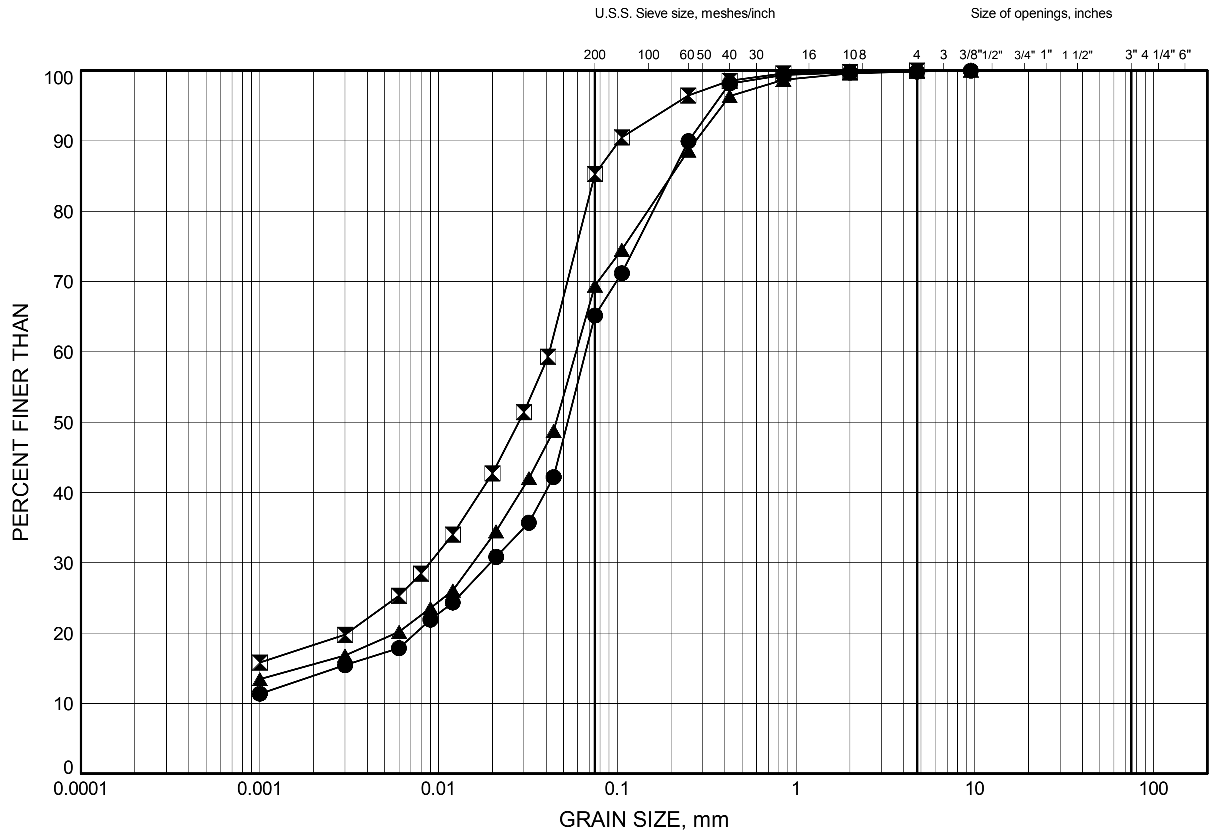
GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5 HWY 400 CULVERTS.GPJ 2/6/16

Highway 400 Southbound Culvert Replacements

GRAIN SIZE DISTRIBUTION

FIGURE 4

Clay



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	5.64	174.84
⧗	16-2	8.69	173.73
▲	16-4	5.64	174.68

Date June 2016

GWP# 2013-E-0053

THURBER

Prep'd KCP

Chkd. FG

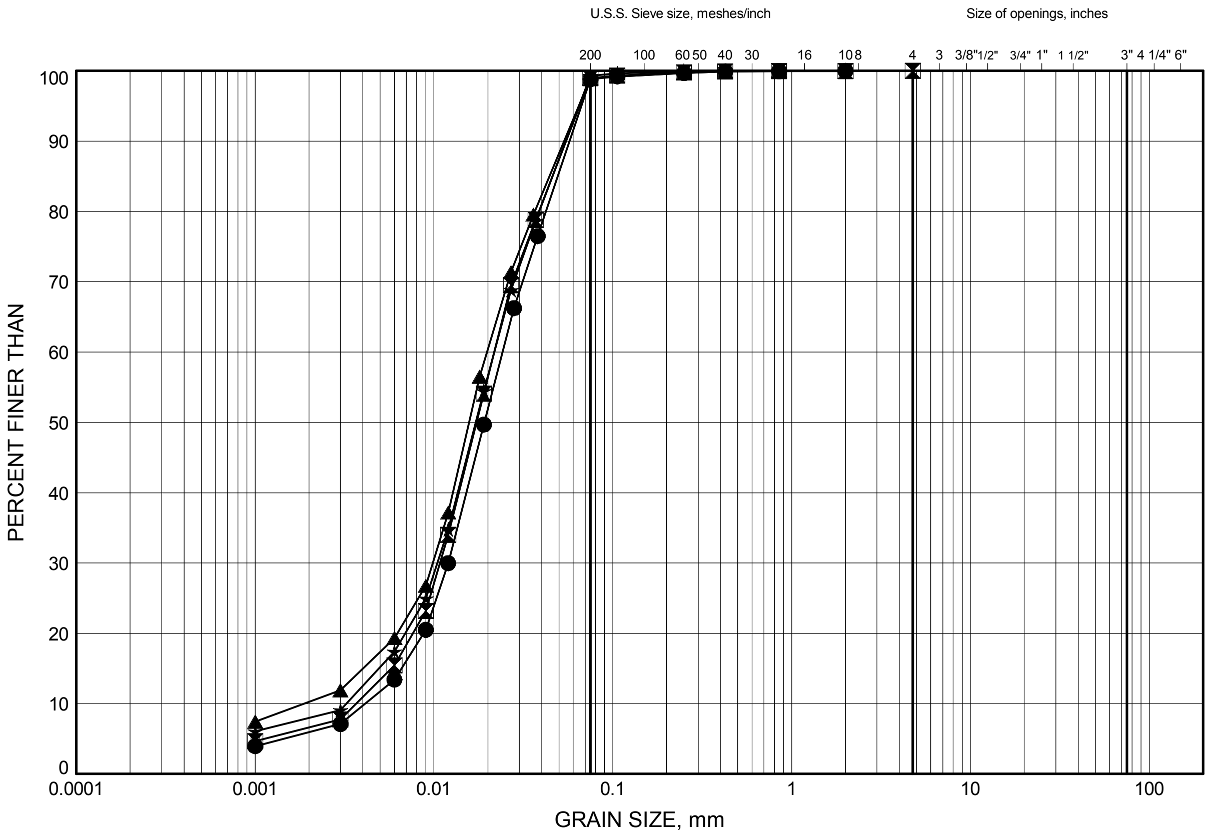
GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5 HWY 400 CULVERTS.GPJ 2/6/16

Highway 400 SB near Coldwater, ON

GRAIN SIZE DISTRIBUTION

FIGURE 5

Silt (ML)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	15.54	164.93
⧗	16-2	17.07	165.35
▲	16-3	17.07	165.93
★	16-4	15.54	164.78

Date May 2016

GWP# 2013-E-0053

THURBER

Prep'd CM

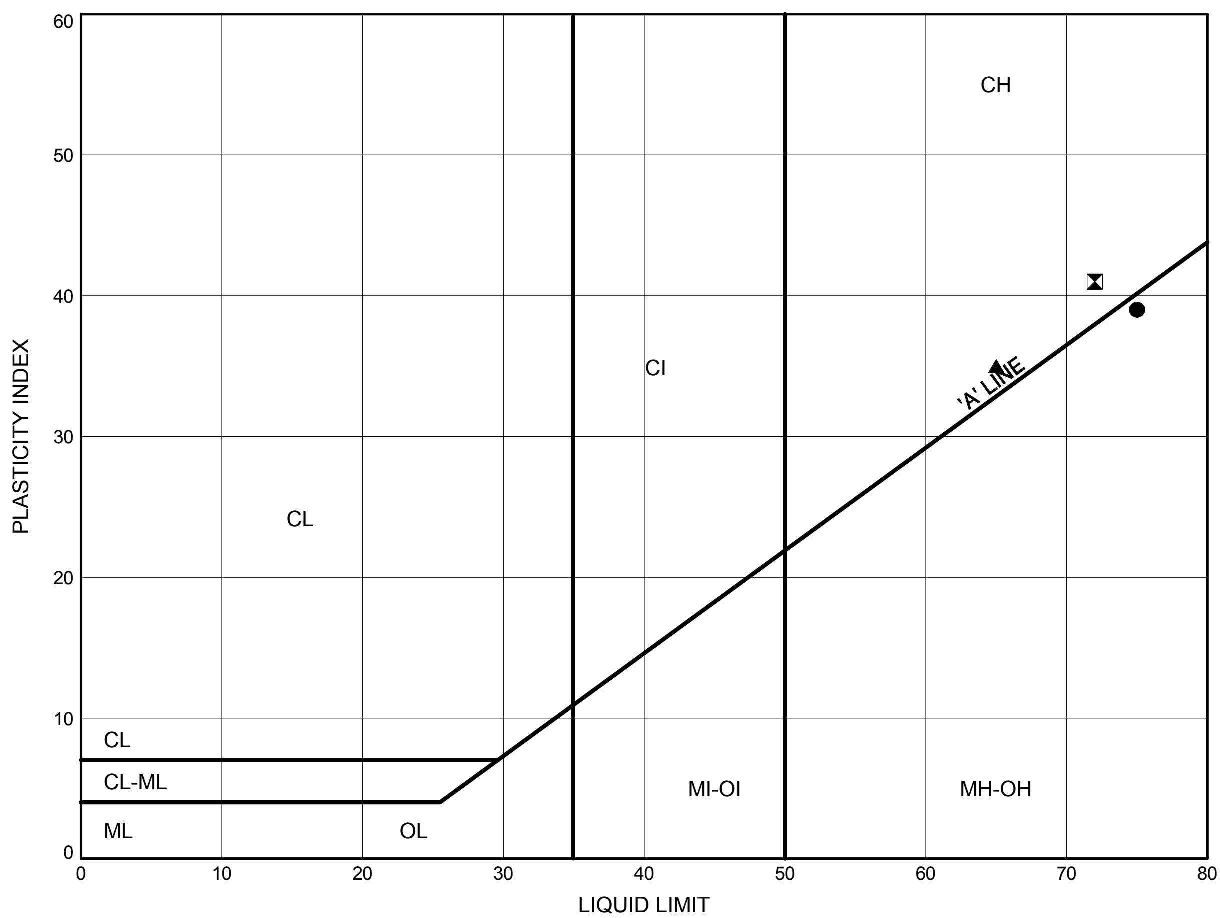
Chkd. FJG

Highway 400 SB near Coldwater, ON

ATTERBERG LIMITS TEST RESULTS

FIGURE 6

Organic Silt (MH-OH) to Organic Clay (CH-OH)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	1.07	179.41
⧗	16-2	4.11	178.30
▲	16-3	4.88	178.12

THURBALT 19-3405-5 HWY 400 CULVERTS.GPJ 17/5/16

Date May 2016

GWP# 2013-E-0053

THURBER

Prep'd CM

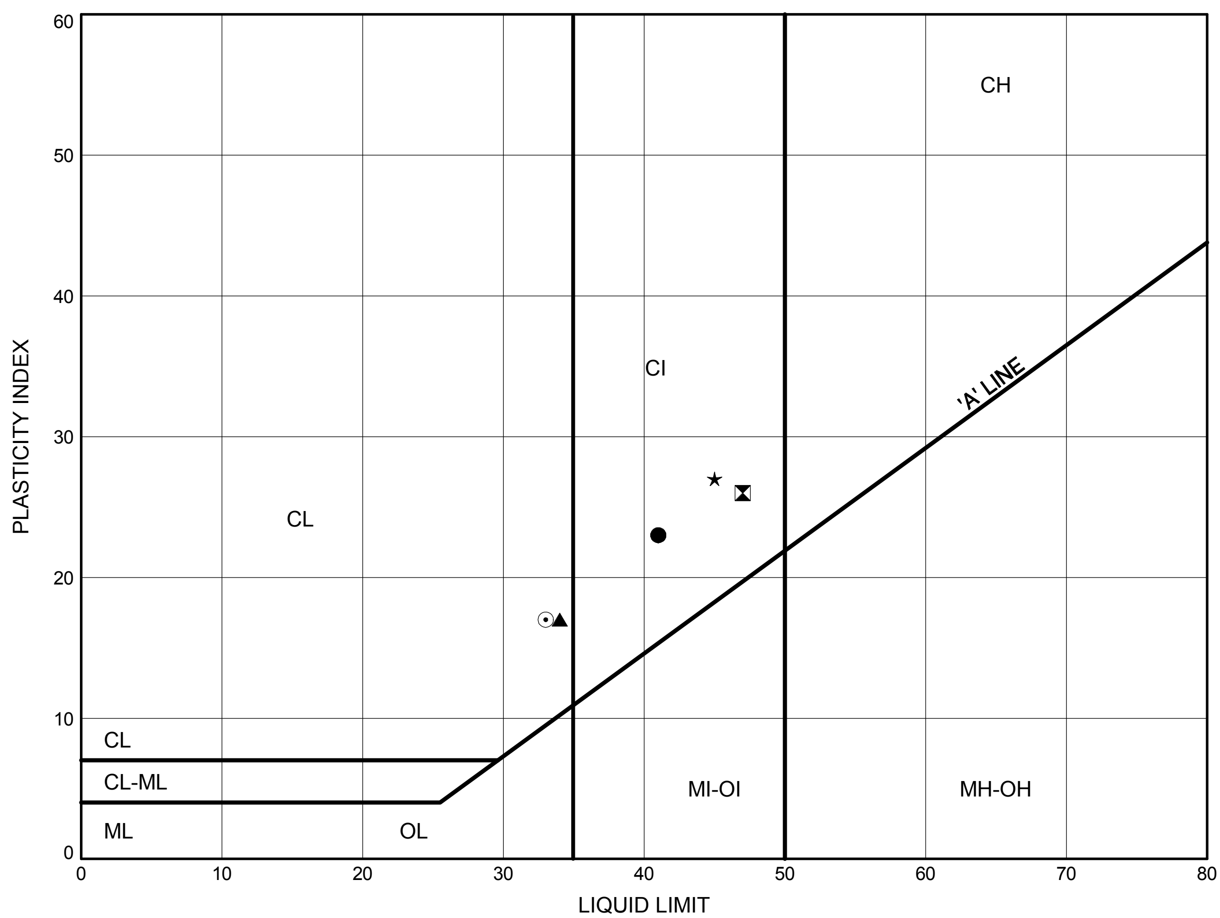
Chkd. FJG

Highway 400 SB near Coldwater, ON

ATTERBERG LIMITS TEST RESULTS

FIGURE 7

Clay (CL) to Clay (CI)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	4.11	176.36
⧗	16-1	9.45	171.03
▲	16-2	7.16	175.26
★	16-2	14.02	168.40
⊙	16-4	4.11	176.21

THURBALT 19-3405-5 HWY 400 CULVERTS.GPJ 17/5/16

Date May 2016

GWP# 2013-E-0053

THURBER

Prep'd CM

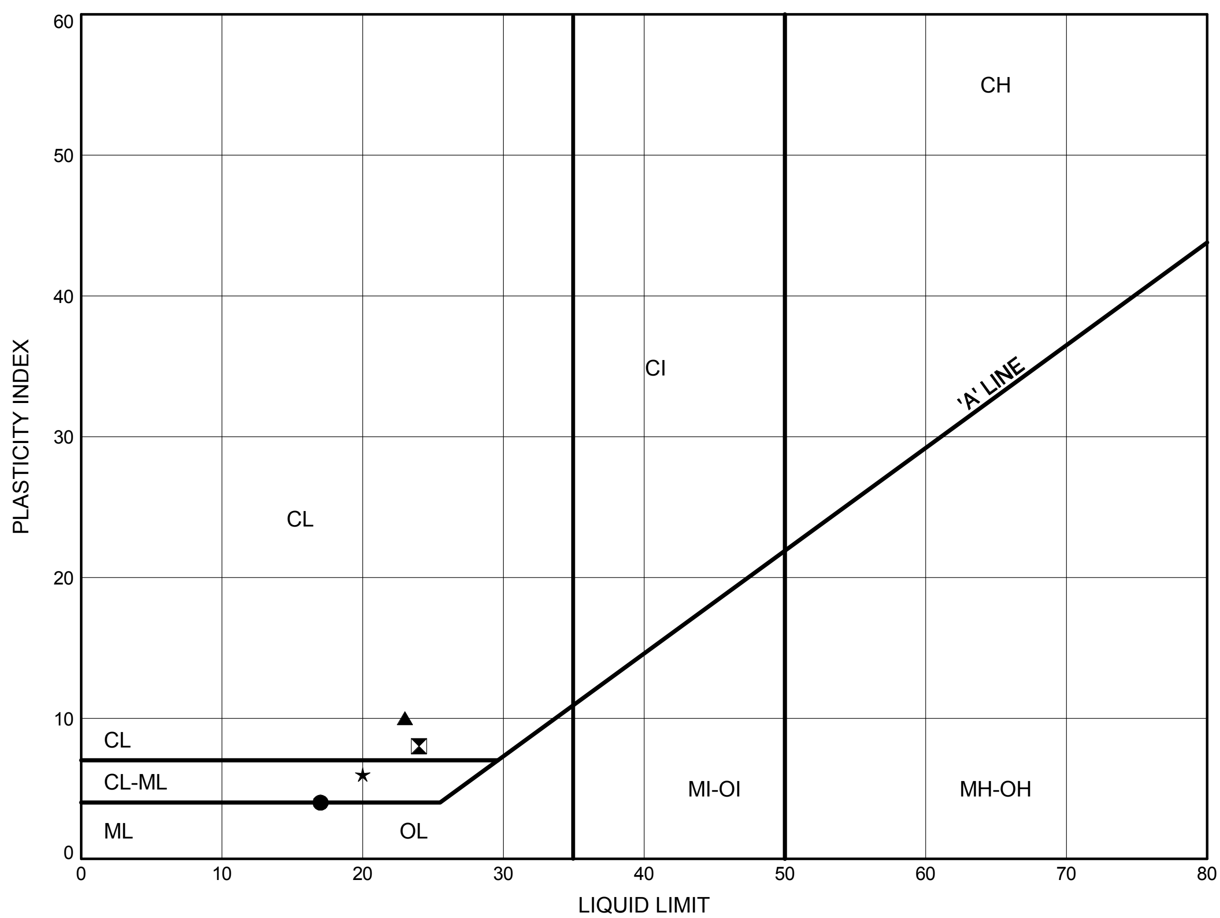
Chkd. FJG

Highway 400 SB near Coldwater, ON

ATTERBERG LIMITS TEST RESULTS

FIGURE 8

Silty Clay (CL-ML) to Clay (CL)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	5.64	174.84
⧗	16-2	8.69	173.73
▲	16-3	7.92	175.07
★	16-4	5.64	174.68

Date May 2016

GWP# 2013-E-0053

THURBER

Prep'd CM

Chkd. FJG

APPENDIX D

SELECTED PHOTOGRAPHS OF CULVERT LOCATION

Figure 1: Roadway Platform at southbound Culvert Site looking north

Figure 2: Looking east downstream from culvert outlet

Figure 3: Existing condition of culverts and embankment at outlet

Figure 4: Looking towards the west upstream from culvert inlets

Figure 5: Existing condition of culverts and embankment at inlet

APPENDIX E

FOUNDATION ALTERNATIVES COMPARISONS
COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS

Comparison of Culvert Alternatives

Comment	Corrugated Steel Pipe (CSP) Culvert	Concrete Box (closed) Culvert
Advantages	Relatively rapid installation Excavation depth reduced. Roadway protection and dewatering concerns are less erroneous due to shallower excavation More flexible.	Quick installation procedure due to use of pre-cast sections Durability
Disadvantages	Requires roadway protection during stage construction	Requires roadway protection during stage construction Deeper excavations required to remove organic material
Risks / Consequences	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays
Relative Cost	Low	Moderate
	RECOMMENDED	**FEASIBLE**

Comparison of Construction Methodology Options

COMMENT	TRENCHLESS: HORIZONTAL DIRECTIONAL DRILLING	STAGED, WITH ROADWAY PROTECTION	OPEN CUT WITH FULL ROAD CLOSURE
Advantages	Avoids open cut. Does not require staging – minimal traffic impact Relatively well known technology and readily available.	Quick installation particularly with a CSP. Simple construction	Quicker installation than with staged construction
Disadvantages	High mobilization costs Requires water/groundwater control at entry and exit pits.	Traffic impacts reduced Requires water/groundwater control	Traffic impacts Requires a long detour around project site to be setup and maintained throughout construction Requires water/groundwater control
Risks/ Consequences	Limited cover over installation could result in heave or settlement of roadway		
Relative Cost	**High**	**Moderate**	**Moderate**
	NOT FEASIBLE	**RECOMMENDED**	**FEASIBLE**

APPENDIX F

LIST OF REFERENCED SPECIFICATIONS
NON-STANDARD SPECIAL PROVISION

LIST OF REFERENCED SPECIFICATIONS

OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 803.030	Frost Treatment – Pipe Culverts Frost Penetration Line Below Bedding Grade
OPSD 803.031	Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut.
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

DEWATERING NSSP

The Contractor is advised that the soils underlying this site include varying cohesive strata and the observed groundwater table lies close to the surface at the embankment base. Furthermore, artesian groundwater conditions were noted. Excavation below the groundwater level is expected to lead to instability and slough of the sides of the excavation and boiling of the base, accompanied by loss in geotechnical resistance of the soils. Basal heave due to unbalanced hydrostatic forces is also possible. Appropriate means of dewatering must be implemented to depress the groundwater level sufficiently far below the base of the excavation to prevent any instability, sloughing, heave or boiling and so as to preserve the stability of the excavation and to allow the work to proceed in the dry."

APPENDIX G

GSC SEISMIC HAZARD CALCULATION

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

May 12, 2016

Site: 44.6985 N, 79.6491 W User File Reference: Severn, Ontario

Requested by: , Thurber Engineering Ltd.

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.075	0.105	**0.105**	0.091	**0.077**	**0.047**	**0.025**	**0.0062**	**0.0028**	**0.061**	**0.064**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.011	0.031	0.047
Sa(0.1)	0.017	0.046	0.068
Sa(0.2)	0.019	0.049	0.071
Sa(0.3)	0.017	0.044	0.062
Sa(0.5)	0.013	0.036	0.052
Sa(1.0)	0.0066	0.021	0.032
Sa(2.0)	0.0028	0.010	0.016
Sa(5.0)	0.0006	0.0023	0.0038
Sa(10.0)	0.0004	0.0011	0.0016
PGA	0.0095	0.027	0.039
PGV	0.0079	0.026	0.041

References

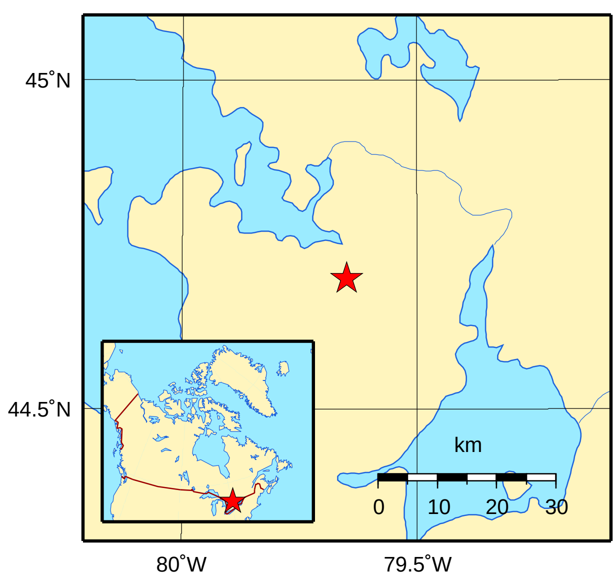
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



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