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FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT - SITE 39E-233/C
HIGHWAY 11 – 2.3KM WEST OF HIGHWAY 636

GWP 5129-13-00

5016-E-0007

Report to:

McIntosh Perry Consulting Engineers Limited

Latitude: 49.32912
Longitude: -81.112169

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for the proposed culvert rehabilitation at the Highway 11 crossing of an unnamed creek. The culvert is located approximately 2.3 km west of Highway 636 within the Township of Fournier. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (MPCE) under Agreement No. 5016-E-0007.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation. No previous foundation investigation reports were available for the subject culvert site within the Geocres library.

2 SITE DESCRIPTION

The existing culvert is a twin cell timber box culvert reported to have a height of 1.8 m, a span of 2.1 m per cell, a length of approximately 22 m and a generally north to south alignment. The flow through the culvert is to the north.

At the location of the culvert (Linear Highway Referencing System Base Point: 17580, Offset: 2.3), Highway 11 is a two-lane highway with a rural cross-section and gravel shoulders. The Highway 11 fill height above the culvert is approximately 1.6 m with the road surface at approximate elevation 268.6 m. The existing embankment slopes are inclined at approximately 3H:1V. The land adjacent to the highway consists of occasional residential and agricultural properties and is sparsely vegetated with shrubs and trees. Traffic volumes on this section of Highway 11 are understood to be 2350 AADT (2012). Standing water was observed at both the inlet and outlet of the culvert.

Select photographs showing the existing conditions in the area of the culvert are included in Appendix D for reference.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between April 19th and June 9th, 2017. The field investigation consisted of advancing six boreholes identified as 17-01 through 17-06. The drilling was carried out using portable equipment for off-road boreholes 17-01, 17-02, 17-05 and 17-06 and a truck mounted CME 75 drill rig for the on-road boreholes 17-03 and 17-04. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Boreholes 17-01, 17-02, 17-05 and 17-06, which were drilled with portable equipment, also utilized a full-weight hammer for SPT testing. In-situ vane shear testing was completed in the cohesive soils deposits. One Thin Walled (Shelby) Tube sample of clay was retrieved from Borehole 17-04 to obtain a relatively undisturbed soil sample. The boreholes were sampled to depths ranging from 8.5 to 14.3 m (elev. 253.9 to 260.1 m) below the existing ground surface. Borehole 17-04 was extended below the base of the sampled borehole with a Dynamic Cone Penetration Test (DCPT) to a base elevation of 247.3 m.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport for further laboratory examination and testing.

A 32 mm diameter standpipe piezometer was installed in Borehole 17-01 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the respective Record of Borehole sheet, provided in Appendix B. Following completion of the field investigation the boreholes were backfilled in general accordance with MOEE requirements (O.Reg. 903). Boreholes 17-03 and 17-04 were capped with 150 mm of cold patch asphalt to reinstate the traveling surface.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevation of the boreholes are provided on this drawing and on the individual Record of Borehole sheets.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. Five samples recovered from within Boreholes 17-01, 17-02, 17-05 and 17-06 were selected and submitted for organic content determination. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Two samples of soil recovered from Boreholes 17-02 and 17-06 were selected and submitted for analytical testing of corrosivity parameters and sulphate content. One Shelby Tube sample was recovered from Borehole 17-04 and submitted for extraction. All laboratory test results from the field investigation are provided in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by a pavement structure and granular fill overlying a deposit of native clay. A fairly thick organic layer with peat was present at the surface of the off-road boreholes. Bedrock was not encountered within the depth of investigation.

5.1 Embankment Fill

5.1.1 Asphalt

Boreholes 17-03 and 17-04 were drilled through the existing Highway 11 embankment and encountered a layer of asphalt with a thickness of 120 mm.

5.1.2 Fill: Silty Sand with Gravel

Below the asphalt in Boreholes 17-03 and 17-04 was a layer of fill consisting of sand with silt and gravel. The underside of the fill was at 2.3 to 2.6 m depth (elev. 266.1 to 266.4 m) below the existing roadway surface.

The SPT tests conducted in this fill gave N-values ranging from 79 blows per 300 mm of penetration to more than 100 blows per 300 mm of penetration indicating a relative density of very dense. The higher SPT tests results may reflect the presence of frozen material and/or cobbles within the fill material.

Recorded moisture contents ranged from 8 to 10%. The results of grain size analyses conducted on two samples of the fill materials are summarized below and are illustrated on Figure C1 in Appendix C.

Soil Particle	Percentage (%)
Gravel	32 – 55
Sand	39 – 57
Silt	6 – 11
Clay	

5.2 Organic Material

5.2.1 Organic Silt with Sand

A layer of organic silt with sand was encountered at surface in Boreholes 17-01 and 17-02 with a thickness of 4.2 m. An organic silt interbedded with sand and coarse fibrous peat was also encountered in Borehole 17-06 from ground surface to a depth of 4.7 m (elev. 262.2 m), however, a 1.5 m thick peat layer was present within this layer (Section 5.1.2). A 1.3 m thick layer of organic silt was also encountered below a surficial peat and sand deposit (see Section 5.1.2 and Section 5.1.3, respectively) in Borehole 17-05. The underside of the organic silt with sand across site ranged from 4.2 to 4.7 m (elev. 262.0 to 262.9) below the ground surface. Wood fragments were observed in Borehole 17-01 and 17-02.

The SPT tests conducted in the organic silt material gave N-values ranging from the weight of the hammer to 8 blows per 300 mm penetration indicating a relative density of very loose to loose.

Recorded moisture contents typically ranged from 62 to 345% with one value of 38% near the ground surface. The organic content within the organic silt was measured at Boreholes 17-01, 17-02, and 17-05 and ranged from 15 to 34%. The results of grain size analyses conducted on three samples of the organic silt material are summarized below and are illustrated on Figure C2 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0 – 1
Sand	13 – 23
Silt	59 – 66
Clay	16 - 23

5.2.2 Peat

A layer of peat was encountered at ground surface in Borehole 17-05 and within the organic silt layer in Borehole 17-06. The thickness of the peat ranged from 0.6 to 1.5 m. The underside of the peat ranged from 0.6 to 3.6 m (elev. 263.3 to 266.1) below the ground surface.

The SPT tests conducted in this peat gave N-values ranging from the weight of the hammer to 4 blows per 300 mm penetration indicating a relative density of very loose to loose. The organic content of the peat was measured at Borehole 17-06 to be 76%. Recorded moisture contents ranged from 97 to 441%.

5.2.3 Sand

A sand deposit with silt and gravel and varying amounts of organic material was encountered below the surficial peat at Borehole 17-05 and had a thickness of 2.8 m. The underside of the sand was at 3.4 m (elev. 263.4 m).

The SPT tests conducted in this sand deposit gave N-values ranging from 1 to 6 blows per 300 mm penetration indicating a relative density of very loose to loose. Recorded moisture contents ranged from 19 to 47%.

The result of one grain size analyses conducted on a sample of the sand material is summarized below and is illustrated on Figure C3 in Appendix C.

Soil Particle	Percentage (%)
Gravel	32
Sand	63
Silt	5
Clay	

5.3 Clay

A native deposit of clay with trace sand and occasional silt seams was encountered below the embankment fill in Boreholes 17-03 and 17-04, and underlying the organic silt and peat in all other boreholes at the site. A 0.4 m thick silt layer was observed extending to elevation 258.9 m in Borehole 17-03. Silt seams were also observed in the clay unit in Boreholes 17-01, 17-02 and 17-05. All boreholes were terminated in this deposit at depths ranging from 8.5 to 14.3 m (elev. 253.9 to 260.1 m). The SPT N-values ranged from the weight of the hammer to 14 blows per 300 mm penetration. Field vane tests were performed within the deposit and recorded undrained shear strengths ranging from 9 to 97 kPa indicating a soft to stiff consistency. Remolded field vane testing indicates that the clay shows some sensitivity.

Borehole 17-04 was extended below the base of the sampled borehole with a Dynamic Cone Penetration Test (DCPT) to refusal at elevation of 247.3 m.

The moisture content of the samples tested ranged from 15 to 62%. The results of grain size analyses conducted on eleven samples of the native clay are summarized below and are illustrated on Figures C4 and C5 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0 – 2
Sand	0 – 15
Silt	49 – 70
Clay	29 – 46

The silt layer observed in Borehole 17-03 included 5% sand, 78% silt and 17% clay sized particles.

Atterberg Limit testing was completed on eleven samples of the native clay deposit and one sample of the silt from Borehole 17-03. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figures C6 and C7 of Appendix C. The laboratory results are summarized below and indicate that the clay is typically low plasticity (CL) with occasional intermediate plasticity (CI) and inorganic silt (CL-ML) zones.

Parameter	Value
Liquid Limit	19 – 38
Plastic Limit	13 – 20
Plasticity Index	4 – 20

One Shelby Tube sample was recovered in the native clay from Borehole 17-04 at a depth of 5.2 m. The sample was submitted to Stantec’s laboratory in Ottawa, Ontario for extraction. A photograph of the sample is presented in Appendix C. No silt layering or varves were noted.

5.4 Bedrock

Bedrock was not encountered within the depth of investigation, however, Borehole 17-04 was advanced below the sampled depth with a DCPT to refusal at a depth of 21.3 m (elev. 247.3 m).

5.5 Groundwater

The water level was measured in the piezometer installed in Borehole 17-01 and is presented in the table below. The water level of the unnamed creek at Culver 39E-233/C was measured to be at elev. 266.8 m on April 30, 2017.

Date	Depth / Elevation (m)
May 14, 2017	5.0 / 262.2
May 16, 2017	2.6 / 264.6
May 30, 2017	0.9 / 266.3
June 8, 2017	0.7 / 266.5
June 12, 2017	0.6 / 266.6

These observations are considered short term seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5.6 Analytical Testing

Two samples of soil were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, resistivity and conductivity. The analysis results are summarized in the table below:

Borehole	Sample	Depth (m)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Chloride (µg/g)
17-02	SS3	1.2 – 1.8	75	7.30	1130	1770
17-06	SS2A	0.6 – 1.1	35	7.36	1120	315

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the anticipated foundation locations. The as-drilled locations and ground surface elevation were measured by Thurber following completion of the field program.

George Downing Estate Drilling Ltd. of Hawksbury, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling and in-situ testing and borehole decommissioning of the on-road boreholes. Ohlmann Geotechnical Services Inc. of Almonte, Ontario supplied and operated the portable drilling equipment to conduct the drilling, soil sampling, in-situ testing, standpipe piezometer installation and borehole decommissioning of the off-road holes. The field investigation was supervised on a full time basis by Mr. Chris Murray, E.I.T. and Mr. Jeff Morrison, E.I.T. of Thurber. Overall supervision of the investigation program was provided by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Dr. Fred Griffiths, P.Eng., Miss Deanna Pizycki, E.I.T. and Mr. Stephen Peters P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the design team in designing a suitable foundation for the proposed replacement of the existing culvert crossing Highway 11 located approximately 2.3 km west of Highway 636. The discussion and recommendations presented in this report are based on information provided by McIntosh Perry Consulting Engineers Ltd. (MPCE) and on the factual data obtained during the course of the investigation.

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 construction or 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.

The existing culvert is a twin cell timber box culvert reported to have a span of 2.1 m per cell, a length of approximately 22 m and a generally north to south alignment. The flow through the culvert is to the north. The invert of the existing culvert is reported to be at elevation 265.2 m. The Highway 11 fill height above the culvert is approximately 1.6 m with the road surface at approximate elevation 268.6 m.

The site was found to be underlain by a pavement structure and granular fill overlying a deposit of native clay. A thick organic layer consisting organic silt, peat and sand was present at the surface of the off-road boreholes. It is noted that water level in the standpipe piezometer was at 266.6 m on June 12, 2017. The water level in the culvert was recorded at elevation 266.8 m on April 30th, 2017.

8 PROPOSED STRUCTURE

At the time of preparation of the draft Foundation Investigation and Design Report, the size and type of the proposed replacement culvert had not been finalized, however it is assumed that the replacement culvert will have a similar cross-sectional area and invert elevation as the existing culvert.

8.1 Applicable Codes and Design Considerations

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 a structural culvert replacement would 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.

9 SEISMIC CONSIDERATIONS

9.1 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). The seismic hazard for this site has been obtained from the GSC calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values (Sa(T)) for the *reference* ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA), which is 0.144g at this site.

9.2 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.

The soil profile at this site has been classified as a Site Class D in accordance with Section 4.4.3.2 of the CHBDC (S6-14).

9.1 Seismic Liquefaction

Based on the subsurface condition encountered at the drilled locations through the embankment at this site the clay soils beneath the embankment fill are considered to have low susceptibility to liquefaction during a seismic event. The consequence of liquefaction would likely be limited to surficial sloughing near the toes of the embankment, which could be readily repaired.

10 DESIGN OPTIONS

10.1 Culvert Type and Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)
  From a foundation engineering perspective, a pipe culvert is a technically feasible alternative. An internal pipe area equal or greater than that of the current box culvert may need to be provided for increased flow capacity and hydraulic properties. Multiple pipes is another option.
- Open Bottom Culvert (Box, Arch)
  An open bottom culvert is not recommended for this site from a foundation engineering perspective due to the high water table and requirement for greater excavation depths to construct the culvert footings and satisfy frost depth requirements. The use of an open bottom culvert would require additional dewatering efforts and has the potential for settlement following construction.
- Closed Bottom Culvert (Box)
  A precast segmental box culvert in an open cut excavation is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.
- Steel Sheet Pile Walls with Precast Concrete Slab
  A sheet pile wall supporting precast concrete slabs is feasible but not recommended at this site on Highway 11.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report.

10.2 Construction Methodology Alternative

For the proposed culvert replacement, the following construction methods were considered.

- Open Cut with Full Road Closure and Detour
  Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with requiring roadway protection and water diversion. However, it is understood that an acceptable detour route is not available and therefore this option is not feasible.
- Open Cut with Temporary Modular Bridge
  It is considered feasible from a geotechnical perspective to complete a culvert replacement at this site within a full width open cut excavation with a single lane

temporary modular bridge spanning the excavation to allow for movement of traffic across the site. Consideration will have to be given to the clearance requirement to determine if this option is constructible. An additional borehole investigation may be required dependant on the location of the temporary abutments relative to the existing borehole locations if this option is pursued further.

- Open Cut with Staged Temporary Widening and/or Lowering

  Widening of the existing highway and/or construction of a temporary detour embankment to accommodate traffic passage during construction has been considered from a geotechnical perspective. Settlement of the foundation soils (which includes a fair thickness of organic silt and peat) under the existing embankment and temporary detour embankment should be expected. A review of the requirement for property acquisition and highway geometry will need to be completed to assess this option.

  Temporary grade lowering can be incorporated into the design to reduce the overall height of embankment above the base of the proposed excavation while maintaining traffic within the existing embankment footprint. The vertical road alignment and traffic speed constraints will need to be reviewed from a highway design perspective.

- Open Cut with Staged Temporary Protection System

  The use of open cut techniques in conjunction with staged culvert replacement is a potentially feasible construction option from a geotechnical perspective. This option will require roadway protection, as discussed further in Section 12.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. Occasional cobbles were inferred from the field investigation and therefore the potential for an obstruction within the embankment fill exists which needs to be taken into consideration during the design and installation of roadway protection.

- Trenchless Techniques

  Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment. However, there is insufficient cover above the replacement culvert and therefore a trenchless culvert installation may not be feasible at this site. Also, multiple installations may be required to provide sufficient hydraulic capacity. Furthermore, standing water was noted at both the inlet and outlet of the culvert. Cofferdams would be required for entry and exit points.

10.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacing the existing culvert with either a circular or a closed box culvert using open cut techniques is the recommended culvert replacement option. Temporary protection systems (TPS) would be needed to facilitate construction. Design of the TPS will need to account for the lateral capacity available in the foundation soils at this site. Grade lowering may be considered to reduce the height of the TPS.

11 OPEN CUT FOUNDATION DESIGN RECOMMENDATIONS

Foundation design aspects for the replacement culvert includes subgrade conditions, geotechnical resistances, settlement of the founding soils, imposed loading pressures, erosion control, protection system design, groundwater control and stability of stage construction. The culvert must be designed to resist loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities under static and seismic conditions.

11.1 Culvert Foundation Bearing Resistances

Provided the replacement culvert is constructed on the same alignment with a similar opening size as the existing culvert and the embankment is reconstructed with no grade raise or widening (temporary or permanent), it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading. It should be noted that the existing culvert is constructed in a swamp with thick organic deposits noted in the off-road boreholes.

11.1.1 Box Culvert

The recommended geotechnical resistances for a 4.2 m wide pre-cast box culvert installed at the founding elevation of the current culvert (approximate elev. 265.2 m) on the native clay material are as follows:

- Factored Geotechnical Resistance at ULS of 150 kPa
- Factored Geotechnical Resistance at SLS of 75 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per 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 bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4. Foundation settlement, based on the supplied SLS resistance, is expected to be less than 25 mm. Organic soils will be encountered in the area of the inlet and outlet. The bearing resistances provided above are based on the assumption that this organic material, where encountered at the subgrade layer, must be removed down to the competent inorganic soils and replaced with well compacted granular fill. In addition, the length of the new culvert must not be longer than the existing culvert length since additional settlement would then be expected to occur and the inlets and outlets.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular ‘A’ bedding (Section 11.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45.

Surface water diversion and dewatering (Section 12.3) will be required to place the bedding material and install the culvert in the dry.

11.1.2 Pipe culvert

If a pipe culvert is selected with an open cut installation technique it should be designed and constructed in accordance with OPSS 421, OPSD 802.010 (with Granular A used as bedding and embedment material) and OPSD 803.031 (with a frost depth as noted in Section 11.3). The recommendations of Sections 11.2, 11.5, 11.7, and 12 should be applied. Geotechnical resistance values are not required for pipe culverts. The culvert should be founded at or below elevation 265.2 m provided an adequate subgrade granular pad is built on the native firm to stiff undisturbed clay. A modulus of subgrade reaction of 12 MN/m^3 can be used for a pipe culvert installed at this site. As indicated in Section 11.1.1, organic soils will be encountered in the area of the inlet and outlet and the same recommendations with regards to subexcavation and culvert length apply for a pipe culvert.

11.2 Subgrade Preparation, Bedding and Backfilling

After excavation and removal of the existing culvert and existing fill, all organics and peat, soft or loose deposits, disturbed soils, very loose alluvial deposits and deleterious materials must be stripped from the footprint of the culvert foundation to expose competent native subgrade material at or below the desired founding elevations. It is noted that unsuitable organic soil and peat materials were observed in the boreholes to as deep as elevation 262.0 m (3.2 m below invert). As indicated earlier, this organic soil must be removed from the culvert subgrade and replaced with compacted granular fill. Given the saturated, sensitive clay materials anticipated at the founding level of the replacement culvert, construction equipment should not be permitted to travel on the exposed subgrade.

The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials at the subgrade level should be sub-excavated and backfilled and compacted as per OPSS.PROV 501 with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction. In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 1.0 m thick layer of well compacted bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010 (box culvert) and OPSD 802.010 (pipe culvert).

The compaction of granular bedding directly above the subgrade may result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include installation of Class II a non-woven geotextile with a maximum FOS of 150 μm (OPSS 1860) installed at the base of the excavation. The geotextile should be placed as soon as possible after reaching the subgrade level and following confirmation of QVE acceptance in order to protect the subgrade. An NSSP is provided in Appendix G to include in the contract documents to alert the Contractor of the sensitive nature of the foundation soils.

It is noted that construction will extend below the ditch elevation. Water diversion and dewatering will be required to prepare the subgrade in the dry. Please refer to Section 12.3 for additional comments on groundwater and surface water control.

It is recommended that culvert cover be in accordance with OPSS 902 and consist of free-draining, non-frost susceptible granular materials such as Granular A or Granular B Type II material meeting the requirements of OPSS.PROV 1010.

Culvert backfill above the granular cover should be in accordance with OPSS 902 and consist of material meeting the requirements of OPSS Select Subgrade Material or better and should be compacted in regular lifts as per OPSS.PROV 501. Heavy compaction equipment, used adjacent to the culvert, must be restricted in accordance with OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

11.3 Frost Depth

The depth of frost penetration at this site is 2.4 m. It is not necessary to found a closed box or pipe culvert at a depth below frost penetration. However, frost treatment should be as per OPSD 803.010 (box culvert) or OPSD 803.031 (pipe culvert) and as directed within the Pavement Design Report.

11.4 Lateral Earth Pressures

Lateral earth pressures parameters provided in Table 11-1 and Table 11-2 in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

11.4.1 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 following expression:

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

where:

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

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for backfill are shown in Table 11-1.

Table 11-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^o$, $\gamma = 22.8\ kN/m^3$		OPSS Granular B Type I $\phi = 32^o$, $\gamma = 21.2\ kN/m^3$		OPSS SSM and Existing Sand Fill $\phi = 30^o$, $\gamma = 21.0\ kN/m^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.39	0.31	0.47	0.33	0.54
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

Note: (*) Figure C6.16 of the Commentary to the CHBDC.

The use of a material with a high friction angle and low active pressure coefficient (Granular A or Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

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 C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 11-1. Active pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest horizontal earth pressures be used for design. Where ground surfaces are sloped behind the walls, the corresponding coefficients provided in the Table 11-1 should be used.

11.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

In accordance with Clause 4.6.5 of the CHBDC (S6-14), a structure should be designed using dynamic earth pressure coefficient that incorporate the effects of earthquake loading. 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 Mononobe-Okabe Method with:

- k_h = ½ * F(PGA) * PGA, for structures that allow 25 to 50 mm of movement, and
- k_h = F(PGA) * PGA, for non-yielding walls

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

The coefficients of horizontal earth pressure for seismic loading presented in Table 11-2 may be used. The provided earth pressure coefficients are based on a Seismic Site Class D, PGA with a 2% probability of exceedance in 50 years of 0.144g (Geological Survey of Canada – Fifth Generation) and a F(PGA) of 1.4 as per Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016).

Table 11-2. Dynamic Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^o$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32^o$, $\gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_{AE} Yielding Wall	0.33	0.48	0.37	0.59
Active, K_{AE} Non-Yielding Wall	0.37	0.69	0.41	0.90

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 soils profile.

$$\sigma_h = K * \gamma * d + (K_{AE} - K) * \gamma * (H - d)$$

where:

σ_h = lateral earth pressure at depth d (kPa)
d = depth below the top of the wall (m)
K = static earth pressure coefficient
(K_a for yielding walls, K_o for non-yielding walls)
γ = unit weight of retained soil adjusted for groundwater level
K_{AE} = combined static and seismic earth pressure coefficient
H = total height of the wall (m)

11.5 Embankment Design and Reinstatement

11.5.1 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I or II. The fill should be placed and compacted in accordance with OPSS.PROV 501.

The existing sand with gravel fill material that is unfrozen and free of organics and asphalt pieces can be reused as backfill in the areas above the culvert cover/embedment provided there is sufficient space to stockpile adjacent to the embankment footprint and control the moisture within acceptable limits for compaction. Since the fill height above the culvert is relatively small at this site, it is desirable to use imported Granular A or Granular B Type II above the culvert cover to have better compaction.

Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010.

11.5.2 Embankment Settlement and Stability

The condition of the existing embankment slopes was examined in the field during the field investigation and no evidence of instability (tension cracks etc.) was noted at that time.

Provided no grade raise or embankment widening is required and proper construction methods are used, no long term or global stability issues are anticipated for embankments built at this site. Material stockpiling above the existing grades is a temporary construction measure and the stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as cranes) are also the Contractor's responsibility.

It is understood that no grade raise is anticipated along the alignment of Highway 11 and therefore negligible foundation settlement is expected to occur.

The magnitude of the embankment compression constructed with granular materials is in the order of 0.5% of the embankment height and is expected to occur following fill placement.

11.6 Temporary Detour

A foundation investigation was not completed for a temporary detour embankment as part of the current assignment. If construction staging dictates that a temporary detour embankment is needed, additional field investigations with recommendations may be required. It should be noted that the site is a swamp with thick organic deposits noted in the off-road boreholes and temporary detour may have to be built through a swamp and may result in settlement.

11.7 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. 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. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.6 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

12 CONSTRUCTION CONSIDERATIONS

12.1 Excavation

Excavation for the culvert replacement must be carried out in accordance with OPSS 902 and will be carried out through the existing embankment fill and extend into the underlying organic soil, peat and native clay deposits.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fills and clay above the water table may be classified as Type 3 soil, however all alluvial, organic and cohesionless soils below the water table may be classified as Type 4 soil.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion is presented in Section 12.2.

12.2 Temporary Protection Systems

Temporary Protection Systems will be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. The protection system should be installed at a suitable distance away from the new culvert to limit the disturbance to subgrade associated with removal of the protection system following completing of construction. Alternatively, the protection system near the culvert could be left in place and cut off at or below 2.4 m beneath the finished pavement grade. Vibratory equipment should not be permitted at this site for installation or removal of the temporary protections system. Suggested wording for an NSSP is provided in Appendix G.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through embankment fill and culvert backfill are provided in Table 11-1. The lateral earth pressure coefficients for the existing organic silt and clay deposit are given below:

γ = 19 kN/m^3 (must be adjusted for water table)
K_A = 0.36
K_P = 2.77

Temporary protection systems are the responsibility of the Contractor and should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The Contractor must undertake an assessment of the foundation soils ability to support the weight of the crane used during installation of the protection system.

12.3 Surface and Groundwater Control

Culvert construction, subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. The Contractor must be prepared to control the groundwater and surface water flow at this site to permit construction in a dry and stable excavation. Temporary groundwater and surface water control measures will be required to remain operational during construction until the culvert is installed and backfilled. Dewatering systems must be designed by a dewatering specialist and should be designed, operated and removed in accordance with OPSS.PROV 517.

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed culvert replacement should be taken as the expected high water level in the creek at the time of construction. Excavation below the groundwater level to construct the culvert foundation will be required and excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause base heave/boiling and sloughing of the clay foundation soil below the water level, making it difficult to maintain a dry, sound base on which to work.

Construction of cofferdams will most likely be required to divert flow away from the culvert subgrade area. A sheet piled cofferdam can be designed following the recommendation provided in Sections 12.1 and 12.2. The water level within the culvert footprint should be lowered by pumping from sumps prior to excavation to at least 500 mm below the underside of the final subgrade. Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field.

12.4 Scour Protection and Erosion Control

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

Typically, rock protection should be provided over all earth surfaces subjected to flowing water. Treatment at the outlet 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 and a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert. The clay seal must extend to the order of 300 mm above the high water level and laterally for the width of the granular material, and have a minimum thickness of 500 mm. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

13 CONSTRUCTION CONCERNS

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

- This culvert is located in a swampy area with organic soils and peat layers as thick as 4.7 m noted in the off-road boreholes. Subgrade preparation will be critical for the performance of the replacement culvert.
- Disturbance of the soil subgrade due to surface water, groundwater and construction activities. The Contractor must be aware of the issue so that he may adjust his operations to suit the subgrade conditions
- Cobbles and boulders were inferred in the embankment fill which may be encountered during excavation or interfere with driving of protection systems.

- Groundwater levels may fluctuate. Excavation will involve lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personal during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

14 CLOSURE

Engineering analysis and preparation of this report were carried out by Miss Katya Edney, P.Eng. and Mr. Stephen Peters, P.Eng. The report was reviewed by Dr Fred Griffiths, P.Eng and Dr. P.K. Chatterji, P.Eng a Designated Principal Contact for MTO Foundation Projects.

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Appendix A.

Borehole Location Plan and Stratigraphic Drawings

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

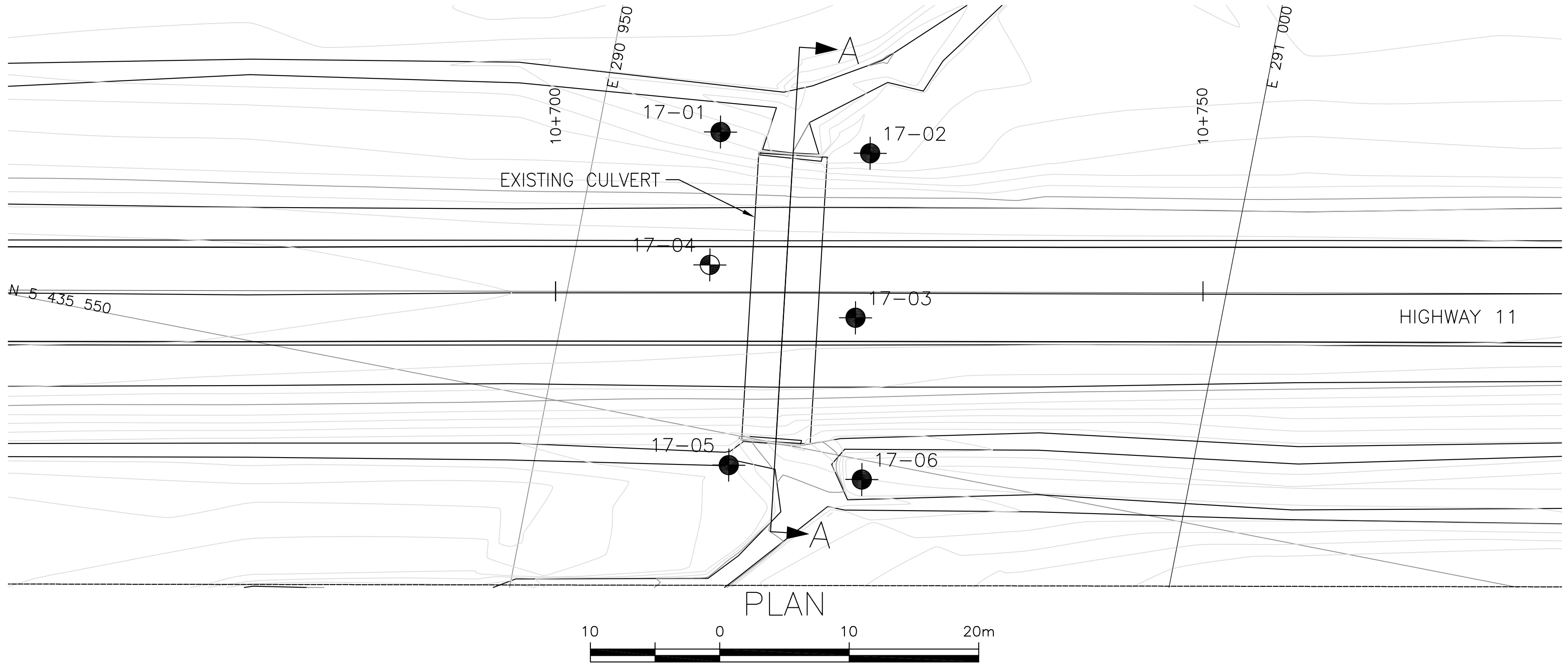
CONT No
GWP No 5129-13-00

HIGHWAY 11
CULVERT 233
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

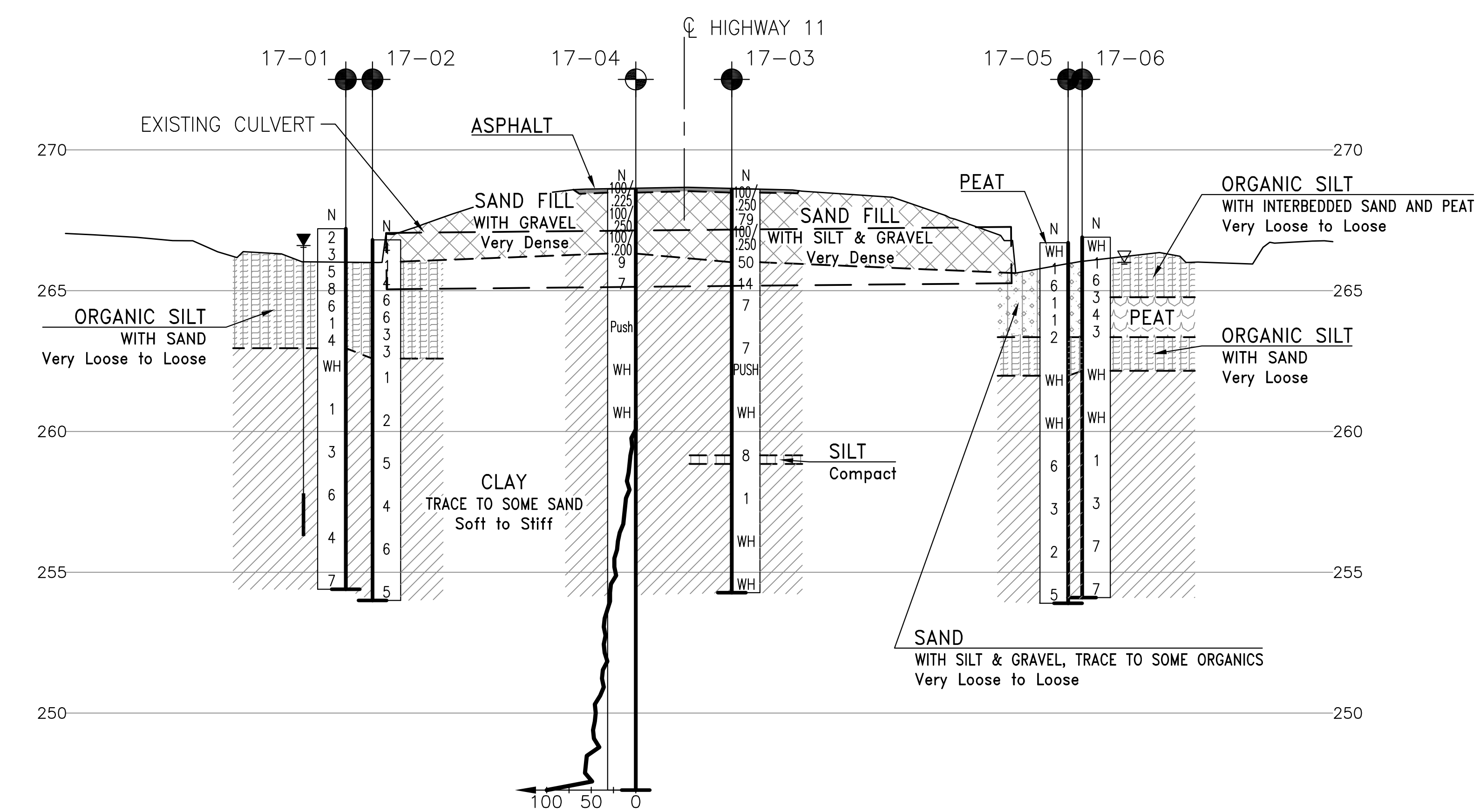
SHEET

McINTOSH PERRY

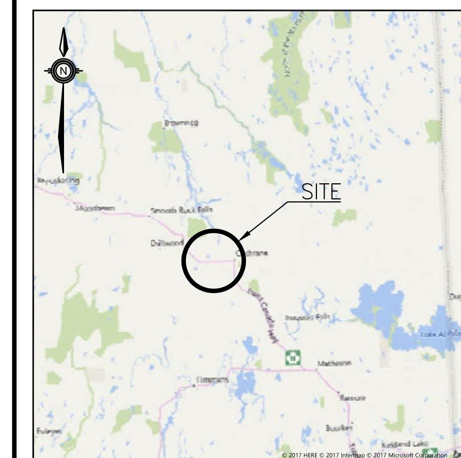
THURBER ENGINEERING LTD.



PLAN



SECTION A-A



KEYPLAN

L E G E N D

⯃	Borehole
⯐	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
∇	Water Level
▼	Head Artesian Water
│	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-01	267.2	5 435 572.8	290 959.3
17-02	266.8	5 435 573.4	290 970.9
17-03	268.6	5 435 560.7	290 972.2
17-04	268.6	5 435 562.5	290 960.4
17-05	266.7	5 435 547.6	290 964.8
17-06	266.9	5 435 548.5	290 975.1

-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.

REVISIONS	DATE	BY	DESCRIPTION

DESIGN KE	CHK PKC	CODE	LOAD	DATE AUG 2017
DRAWN MFA	CHK KE	SITE	STRUCT	DWG 1

Appendix B.

Record of Borehole Sheets

THURBER

60 YEARS

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.

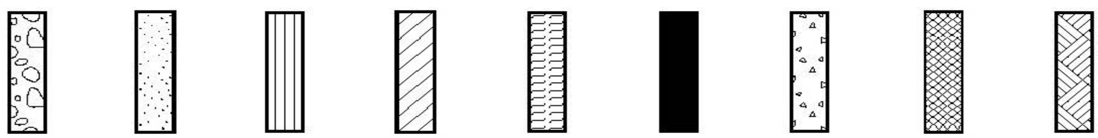
N-VALUE:

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

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

60 YEARS

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

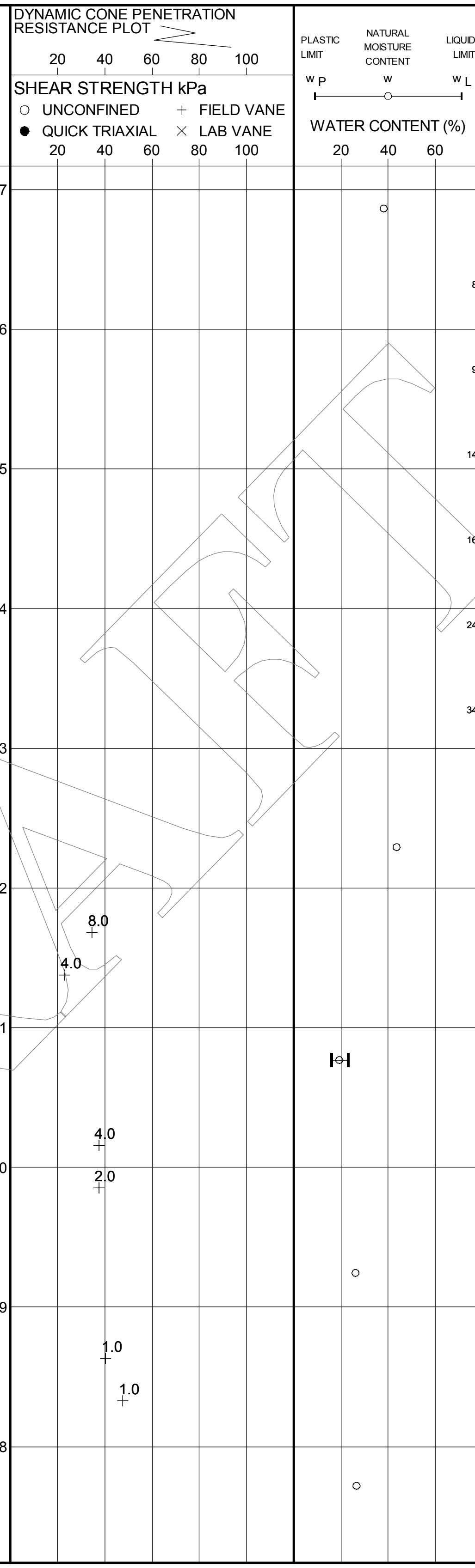
THURBER

RECORD OF BOREHOLE No 17-1

METRIC

GWP# 5129-13-01	LOCATION Site 39E-233/C, MTM z12: N 5 435 572.8 E 290 959.3		ORIGINATED BY JM
HWY 11	BOREHOLE TYPE Portable with BW Casing		COMPILED BY KE
DATUM Geodetic	DATE 14.05.2017 - 14.05.2017		CHECKED BY SP

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	NATURAL MOISTURE CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
267.2 / 0.0	**Organic SILT** with Sand, Very Loose to Loose, Brown	1	SS	2		
	- clayey from 0.61 to 1.22m	2	SS	3	87	
		3	SS	5	98	1 17 59 23
	- wood fragments from 1.83 to 2.44 m	4	SS	8	141	organic content 15%
		5	SS	6	167	0 13 66 21
		6	SS	1	241	
		7	SS	4	345	
262.9 / 4.2	**CLAY (CL)**, trace Sand, Soft to Stiff, Grey	8	SS	WH		
	- occasional silt seams (~20 - 100mm) from 6.1 to 6.7m	9	SS	1		2 3 65 30
		10	SS	3		
		11	SS	6		



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 17-1

METRIC

GWP# 5129-13-01 | LOCATION Site 39E-233/C, MTM z12: N 5 435 572.8 E 290 959.3 | ORIGINATED BY JM

HWY 11 | BOREHOLE TYPE Portable with BW Casing | COMPILED BY KE

DATUM Geodetic | DATE 14.05.2017 - 14.05.2017 | CHECKED BY SP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (Field Vane)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page								
	CLAY (CL), trace Sand Soft to Stiff Grey				257	+ (2.0), + (2.0)			
		12	SS	4	256		○		
					255	+ (4.0), + (2.0)			
254.4		13	SS	7			○		
12.8	End of Borehole Water in standpipe piezometer: Elev. 262.2 m on May 14, 2017 Elev. 264.6 m on May 16, 2017 Elev. 266.3 m on May 30, 2017 Elev. 266.5 m on June 8, 2017 Elev. 266.6 m on June 12, 2017								

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

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-2

METRIC

GWP# 5129-13-01 | LOCATION Site 39E-233/C, MTM z12: N 5 435 573.4 E 290 970.9 | ORIGINATED BY JM

HWY 11 | BOREHOLE TYPE Portable with BW Casing | COMPILED BY KE

DATUM Geodetic | DATE 14.05.2017 - 15.05.2017 | CHECKED BY SP

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)

Ground surface elevation: 266.8

ELEV / DEPTH	DESCRIPTION
266.8 / 0.0	**Organic SILT** with Sand, occasional Wood Fragments Very Loose to Loose Brown with Black Discolouration
262.6 / 4.2	**CLAY (CL)**, trace Sand Soft to Stiff Grey - occasional silt seams (~20 - 50mm) from 6.1 to 6.7m

NUMBER	TYPE	"N" VALUES	Water content label	REMARKS / GRAIN SIZE (GR SA SI CL)
1	SS	4		
2	SS	1		1 23 60 16
3	SS	4	158	organic content 34.1%
4	SS	6	241	
5	SS	6	236	
6	SS	3		
7	SS	3		
8	SS	1		
9	SS	2		0 1 70 29
10	SS	5		
11	SS	4		1 7 55 37

Field vane sensitivity labels (elevation approx.): 1.0 (~261.3), 3.0 (~261.0), 2.0 (~259.8), 2.0 (~259.5), 2.0 (~258.3), 5.0 (~258.0)

Elevation scale: 266, 265, 264, 263, 262, 261, 260, 259, 258, 257

Continued Next Page

+ ³, × ³ : Numbers refer to Sensitivity

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

ONTMT4S 16210 CULVERT 233.GPJ 2012TEMPLATE(MTO).GDT 21/8/17

RECORD OF BOREHOLE No 17-2

METRIC

GWP# 5129-13-01 | LOCATION Site 39E-233/C, MTM z12: N 5 435 573.4 E 290 970.9 | ORIGINATED BY JM

HWY 11 | BOREHOLE TYPE Portable with BW Casing | COMPILED BY KE

DATUM Geodetic | DATE 14.05.2017 - 15.05.2017 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (field vane, sensitivity)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	CLAY (CL), trace Sand Soft to Stiff Grey							+ 3.0 + 2.0			
			12	SS	6		256		○		
							255	+ 2.0 + 3.0			
254.0			13	SS	5				○		
12.8	End of Borehole										

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

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-3

METRIC

GWP#	5129-13-01	LOCATION	Site 39E-233/C, MTM z12: N 5 435 560.7 E 290 972.2	ORIGINATED BY	CAM
HWY	11	BOREHOLE TYPE	CME75 Truck with NW Casing	COMPILED BY	JSM
DATUM	Geodetic	DATE	19.04.2017 - 19.04.2017	CHECKED BY	SP

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
268.6 / 0.0	**120 mm ASPHALT**					
0.1	SAND with Silt and Gravel **FILL** Very Dense (frozen) Brown	1	SS	100/ 250mm		
		2	SS	79	268	32 57 11 (SI+CL)
		3	SS	100/ 250mm	267	
266.1 / 2.6	**CLAY (CL)**, trace Sand Firm to Stiff Grey	4	SS	50	266	
		5	SS	14		0 15 55 30
		6	SS	7	265	
					264	
		7	SS	7	263	
	- occassional to frequent silt seams from 6.7 m to 9.4 m	8	ST	PUSH	262	
		9	SS	WH	261	0 4 50 46
					260	
259.2 / 9.4	**SILT** Compact Grey	10	SS	8		0 5 78 17
258.9 / 9.8					259	

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.

Field vane shear strength plot labels (sensitivity): 30.0, 14.0 (approx. elev. 264–263.5); 10.0, 2.0 (approx. elev. 261.7–261.4); 4.0, 5.0 (approx. elev. 260.1–259.8).

Continued Next Page

+ ³, × ³ : Numbers refer to Sensitivity

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

ONTMT4S 16210 CULVERT 233.GPJ 2012TEMPLATE(MTO).GDT 21/8/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-3

METRIC

GWP#	5129-13-01	LOCATION	Site 39E-233/C, MTM z12: N 5 435 560.7 E 290 972.2	ORIGINATED BY	CAM
HWY	11	BOREHOLE TYPE	CME75 Truck with NW Casing	COMPILED BY	JSM
DATUM	Geodetic	DATE	19.04.2017 - 19.04.2017	CHECKED BY	SP

ELEV DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (field vane, sensitivity)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY (CL), trace Sand Firm to Stiff Grey	hatched									
							258				
			11	SS	1				○		
								+ 2.0			
							257	+ 2.0			
			12	SS	WH				○		
							256				
								+ 4.0			
								+ 4.0			
							255				
			13	SS	WH				○		
254.3 14.3	End of Borehole										

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

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-4

METRIC

GWP# 5129-13-01	LOCATION Site 39E-233/C, MTM z12: N 5 435 562.5 E 290 960.4		ORIGINATED BY CAM
HWY 11	BOREHOLE TYPE CME75 Truck with NW Casing		COMPILED BY JAG
DATUM Geodetic	DATE 20.04.2017 - 20.04.2017		CHECKED BY SP

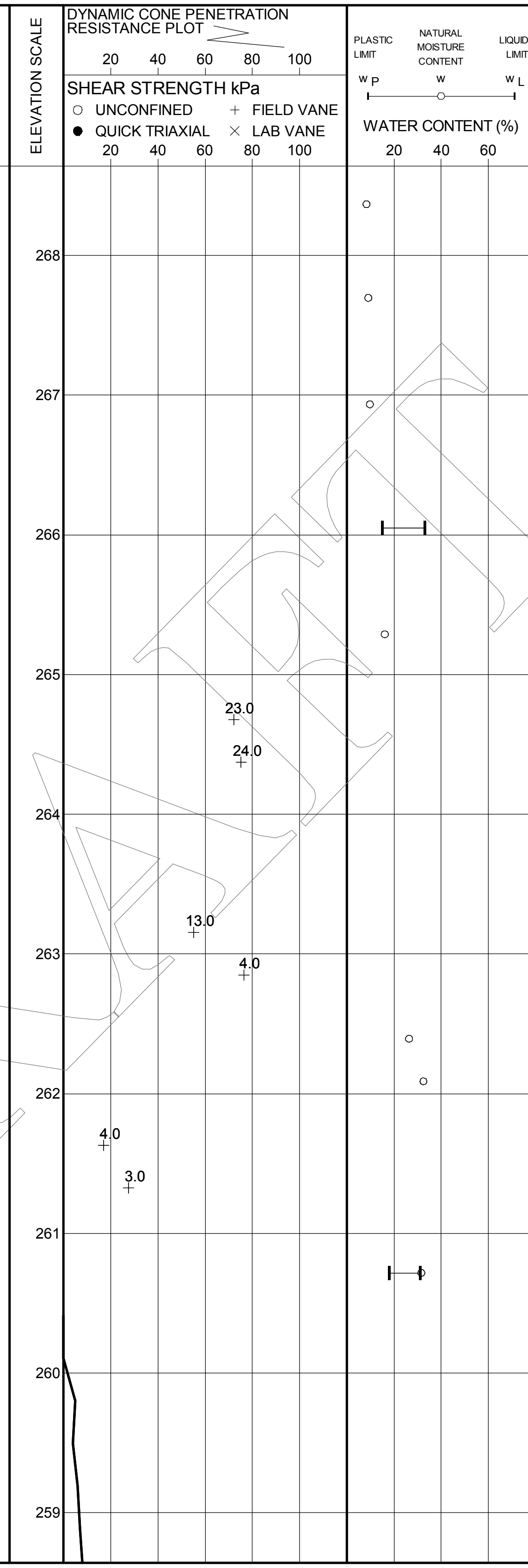
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION	STRAT PLOT
268.6		
0.0	**120 mm ASPHALT**	
0.1	SAND with Gravel **FILL** Very Dense (frozen) Brown - occasional cobbles at 1.5 m	
266.4 2.3	**CLAY (CL)**, trace to some Sand Soft to Stiff Grey	
260.1 8.5	DCPT performed from 8.2 m to 21.3 m	

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	100/ 225 mm	
2	SS	100/ 250 mm	
3	SS	100/ 200 mm	55 39 6 (SI+CL)
4	SS	9	1 15 49 35
5	SS	7	
6	ST	Push	
7	SS	WH	
8	SS	WH	0 2 53 45

GROUND WATER CONDITIONS | ELEVATION SCALE | UNIT WEIGHT γ kN/m3



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

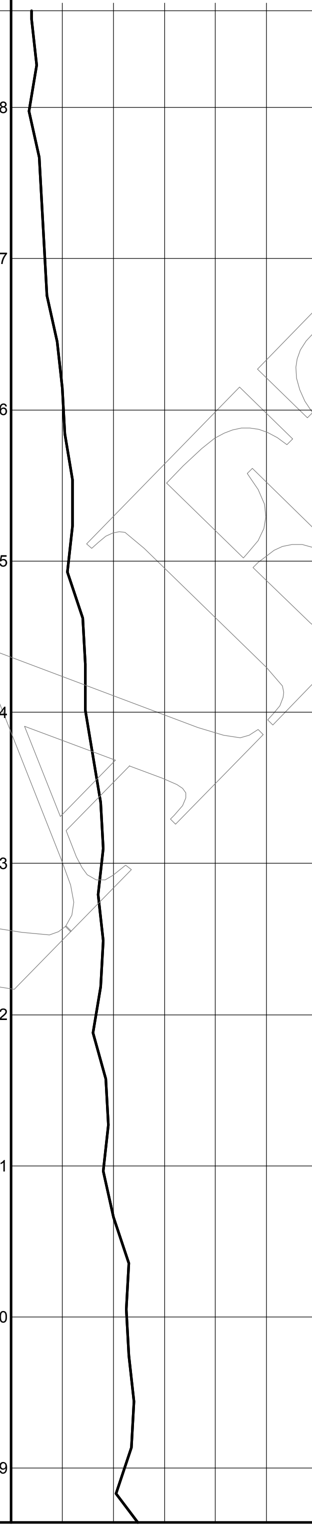
ONTMT4S 16210 CULVERT 233.GPJ 2012TEMPLATE(MTO).GDT 21/8/17

RECORD OF BOREHOLE No 17-4

METRIC

GWP# 5129-13-01	LOCATION Site 39E-233/C, MTM z12: N 5 435 562.5 E 290 960.4	ORIGINATED BY CAM
HWY 11	BOREHOLE TYPE CME75 Truck with NW Casing	COMPILED BY JAG
DATUM Geodetic	DATE 20.04.2017 - 20.04.2017	CHECKED BY SP

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	DCPT Continued						258, 257, 256, 255, 254, 253, 252, 251, 250, 249				



Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

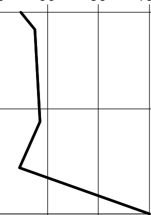
Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-4

METRIC

GWP# 5129-13-01	LOCATION Site 39E-233/C, MTM z12: N 5 435 562.5 E 290 960.4	ORIGINATED BY CAM
HWY 11	BOREHOLE TYPE CME75 Truck with NW Casing	COMPILED BY JAG
DATUM Geodetic	DATE 20.04.2017 - 20.04.2017	CHECKED BY SP

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 (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	DCPT Continued						248				
	End of DCPT at 21.3 m (Elev. 247.3 m)										

+³, ×³: Numbers refer to Sensitivity

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

ONTMT4S 16210 CULVERT 233.GPJ 2012TEMPLATE(MTO).GDT 21/8/17

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 17-5

METRIC

GWP# 5129-13-01 | LOCATION Site 39E-233/C, MTM z12: N 5 435 547.6 E 290 964.8 | ORIGINATED BY JM

HWY 11 | BOREHOLE TYPE Portable with BW Casing | COMPILED BY KE

DATUM Geodetic | DATE 08.06.2017 - 09.06.2017 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	Shear strength (field vane, kPa, sensitivity)	Water content (%)	Remarks & grain size distribution (%) GR SA SI CL
266.7							
266.7 / 0.0	**PEAT** with Silty Sand, Very Loose, Brown	1	SS	WH		97	
266.1 / 0.6	**SAND** with Silt and Gravel, trace to some Organics, Very Loose to Loose, Brown	2	SS	1			
		3	SS	6			
		4	SS	1			32 63 5 (SI+CL)
		5	SS	1			
		6	SS	2			
263.4 / 3.4	**Organic SILT**, Very Loose, Brown					114	organic content 22%
262.0 / 4.7	**CLAY (CL)**, trace Sand, Soft to Stiff, Grey	7	SS	WH			
					2.0; 3.0		
		8	SS	WH		w with PL–LL range	1 3 54 42
					3.0; 3.0		
		9	SS	6			
	- 80 mm clayey silt layer at 8.2 m				2.0; 3.0		
		10	SS	3		w with PL–LL range	1 7 56 36

Column headers: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (266, 265, 264, 263, 262, 261, 260, 259, 258, 257); 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

ONTMT4S 16210 CULVERT 233.GPJ 2012TEMPLATE(MTO).GDT 21/8/17

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-5

METRIC

GWP# 5129-13-01 | LOCATION Site 39E-233/C, MTM z12: N 5 435 547.6 E 290 964.8 | ORIGINATED BY JM

HWY 11 | BOREHOLE TYPE Portable with BW Casing | COMPILED BY KE

DATUM Geodetic | DATE 08.06.2017 - 09.06.2017 | CHECKED BY SP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (Field Vane, sensitivity)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY (CL), trace Sand Soft to Stiff Grey							+ (2.0); + (2.0)			
			11	SS	2		256		○		
							255	+ (2.0); + (2.0)			
253.9 / 12.8			12	SS	5		254		○		
	End of Borehole										

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

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 17-6

METRIC

GWP# 5129-13-01 | LOCATION Site 39E-233/C, MTM z12: N 5 435 548.5 E 290 975.1 | ORIGINATED BY JM

HWY 11 | BOREHOLE TYPE Portable with BW Casing | COMPILED BY KE

DATUM Geodetic | DATE 09.06.2017 - 09.06.2017 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
266.9 / 0.0	**Organic SILT** with interbedded Sand and Coarse Fibrous Peat, frequent Wood Fragments, Very Loose to Loose, Brown	1	SS	WH	
		2	SS	1	
		3	SS	6	organic content 20.3%
264.8 / 2.1	**PEAT** with Wood Fragments, Very Loose to Loose, Dark Brown	4	SS	3	
		5	SS	4	organic content 76.5%
		6	SS	3	
263.3 / 3.6	**Organic SILT** with Sand, Very Loose, Brown				
262.2 / 4.7	**CLAY (CI to CL)**, Soft to Stiff, Grey	7	SS	WH	0 0 55 45
		8	SS	WH	
		9	SS	1	0 5 60 35
		10	SS	3	

Natural moisture content (off-scale values, samples 1–6 zone): 82, 134, 254, 148, 173, 441, 426, 311, 206

Field vane sensitivity values plotted: 2.0 (≈261.6), 3.0 (≈261.1), 2.0 (≈259.9), 3.0 (≈259.6), 2.0 (≈258.4)

Elevation scale: 266, 265, 264, 263, 262, 261, 260, 259, 258, 257

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100
Shear Strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
Water Content (%): Plastic Limit w_P, Natural Moisture Content w, Liquid Limit w_L; 20 40 60
Unit Weight γ kN/m^3

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 17-6

METRIC

GWP#	5129-13-01	LOCATION	Site 39E-233/C, MTM z12: N 5 435 548.5 E 290 975.1	ORIGINATED BY	JM
HWY	11	BOREHOLE TYPE	Portable with BW Casing	COMPILED BY	KE
DATUM	Geodetic	DATE	09.06.2017 - 09.06.2017	CHECKED BY	SP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY (CI to CL) Soft to Stiff Grey	▨						+ 2.0; + 2.0			
		▨	11	SS	7		256		○		
		▨					255	+ 2.0; + 2.0			
254.1		▨	12	SS	7				○		
12.8	End of Borehole										

Shear strength legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. Scale: 20 40 60 80 100

Plastic limit w_P, natural moisture content w, liquid limit w_L. Water content scale: 20 40 60

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 16210 CULVERT 233.GPJ 2012TEMPLATE(MTO).GDT 21/8/17

Appendix C.

Laboratory Testing

Appendix C.1

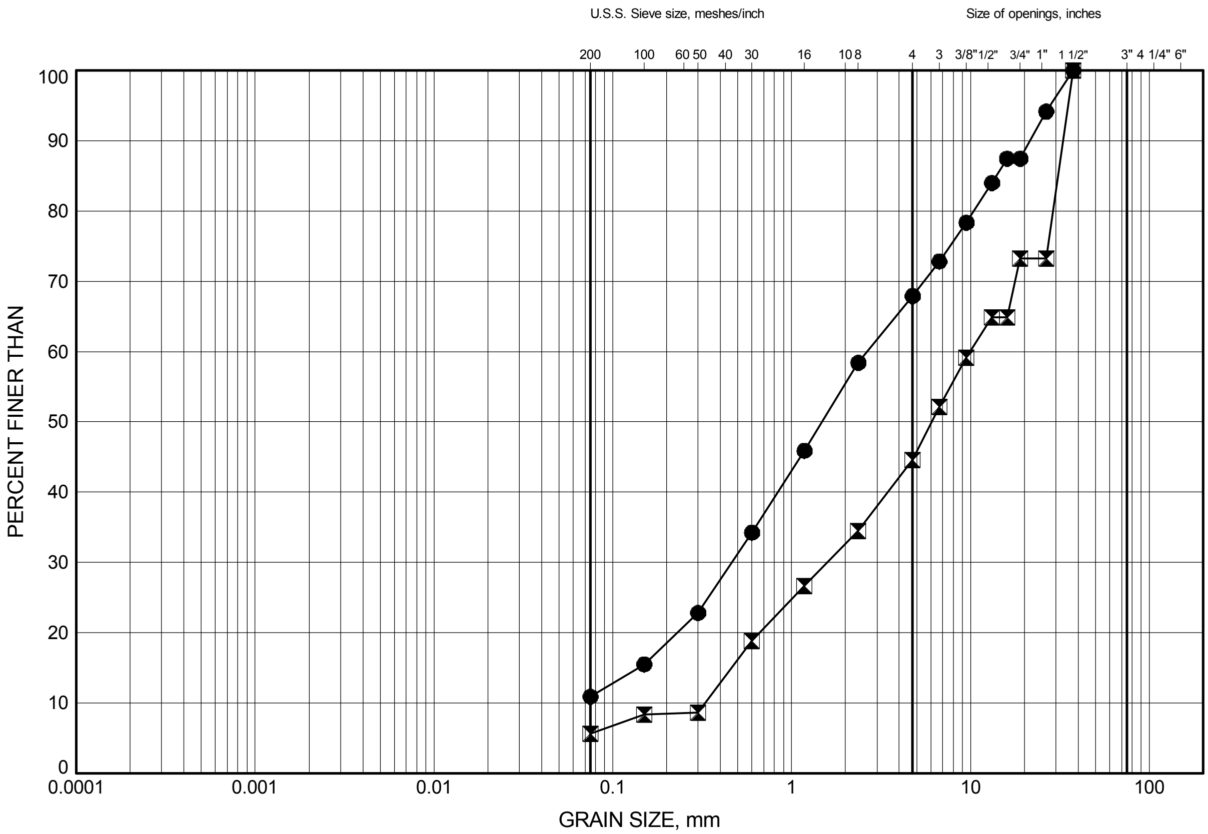
Particle Size Analysis Figures

Hwy's 11 and 652, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	1.07	267.57
⧗	17-4	1.71	266.93

Date August 2017

GWP# 5129-13-01

THURBER

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Chkd. SP

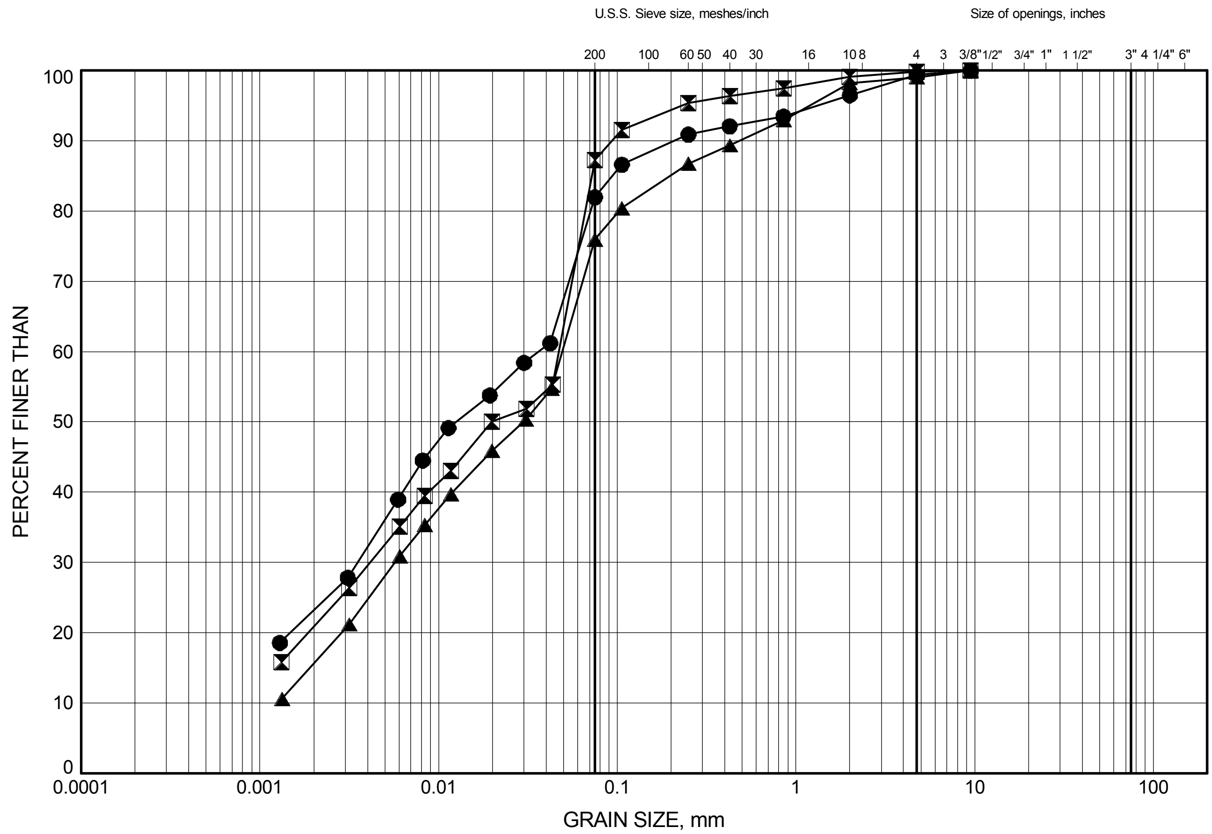
GRAIN SIZE DISTRIBUTION - THURBER 16210 CULVERT 233.GPJ 21/8/17

Hwy's 11 and 652, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C2

ORGANIC SILT WITH SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	1.52	265.65
⧗	17-1	2.74	264.43
▲	17-2	0.91	265.90

Date August 2017

GWP# 5129-13-01

THURBER

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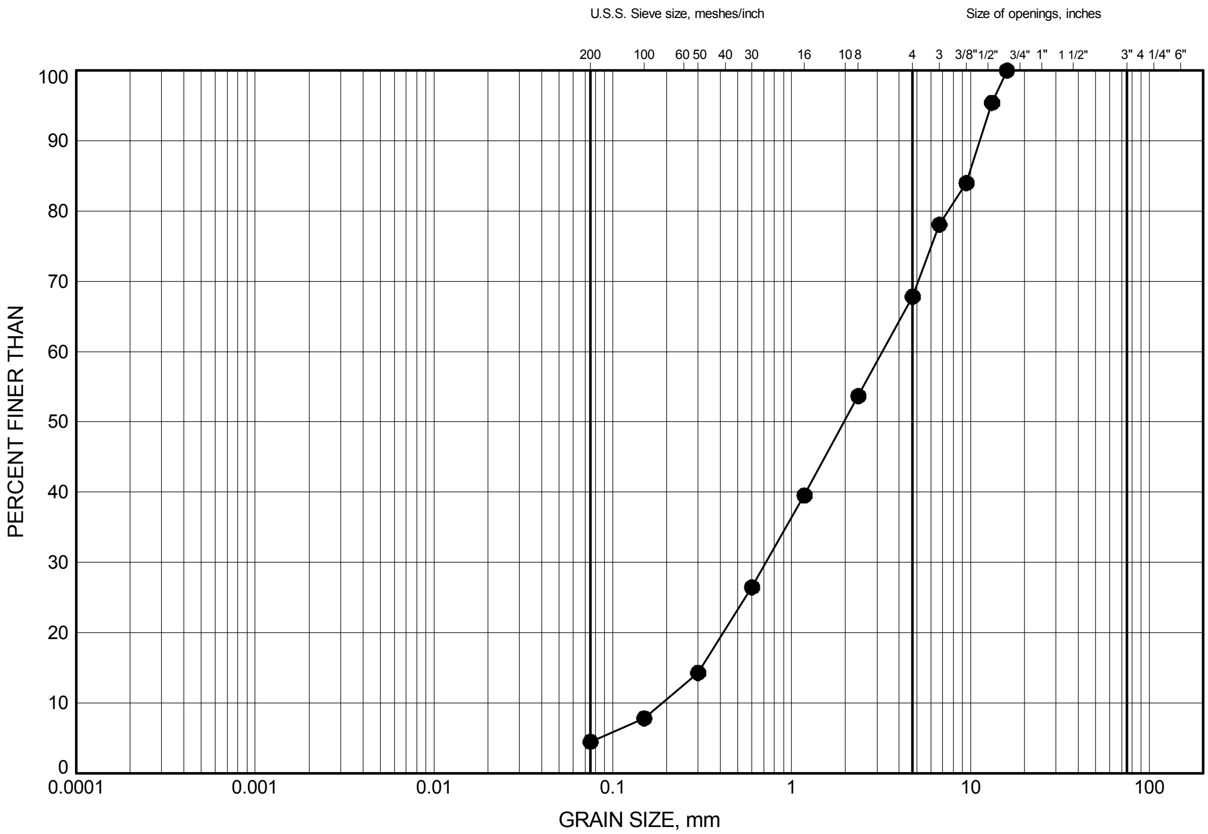
GRAIN SIZE DISTRIBUTION - THURBER 16210 CULVERT 233.GPJ 21/8/17

Hwy's 11 and 652, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C3

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-5	2.13	264.58

Date August 2017

GWP# 5129-13-01

THURBER

Prep'd KE

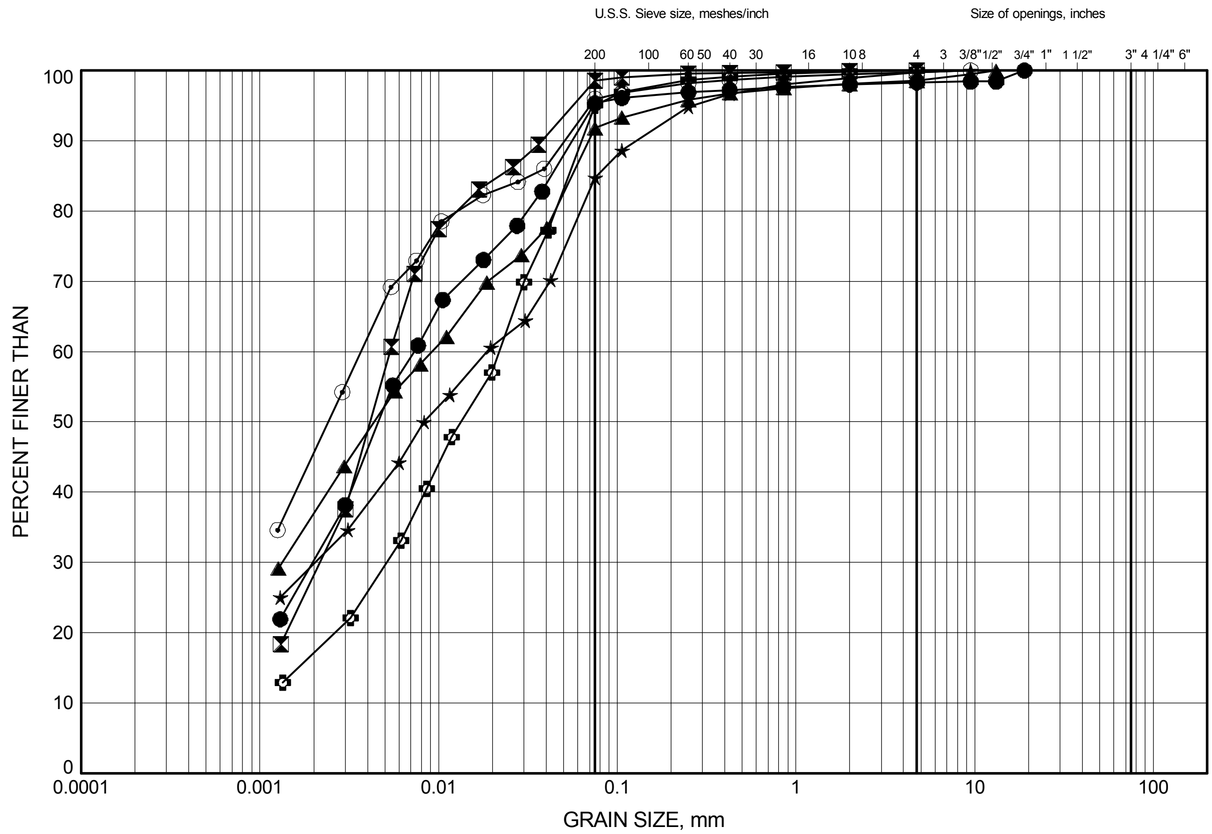
Chkd. SP

Hwy's 11 and 652, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C4

CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	6.40	260.77
⧗	17-2	6.40	260.41
▲	17-2	9.45	257.36
★	17-3	3.35	265.29
⊙	17-3	7.92	260.72
✪	17-3	9.60	259.04

Date August 2017

GWP# 5129-13-01

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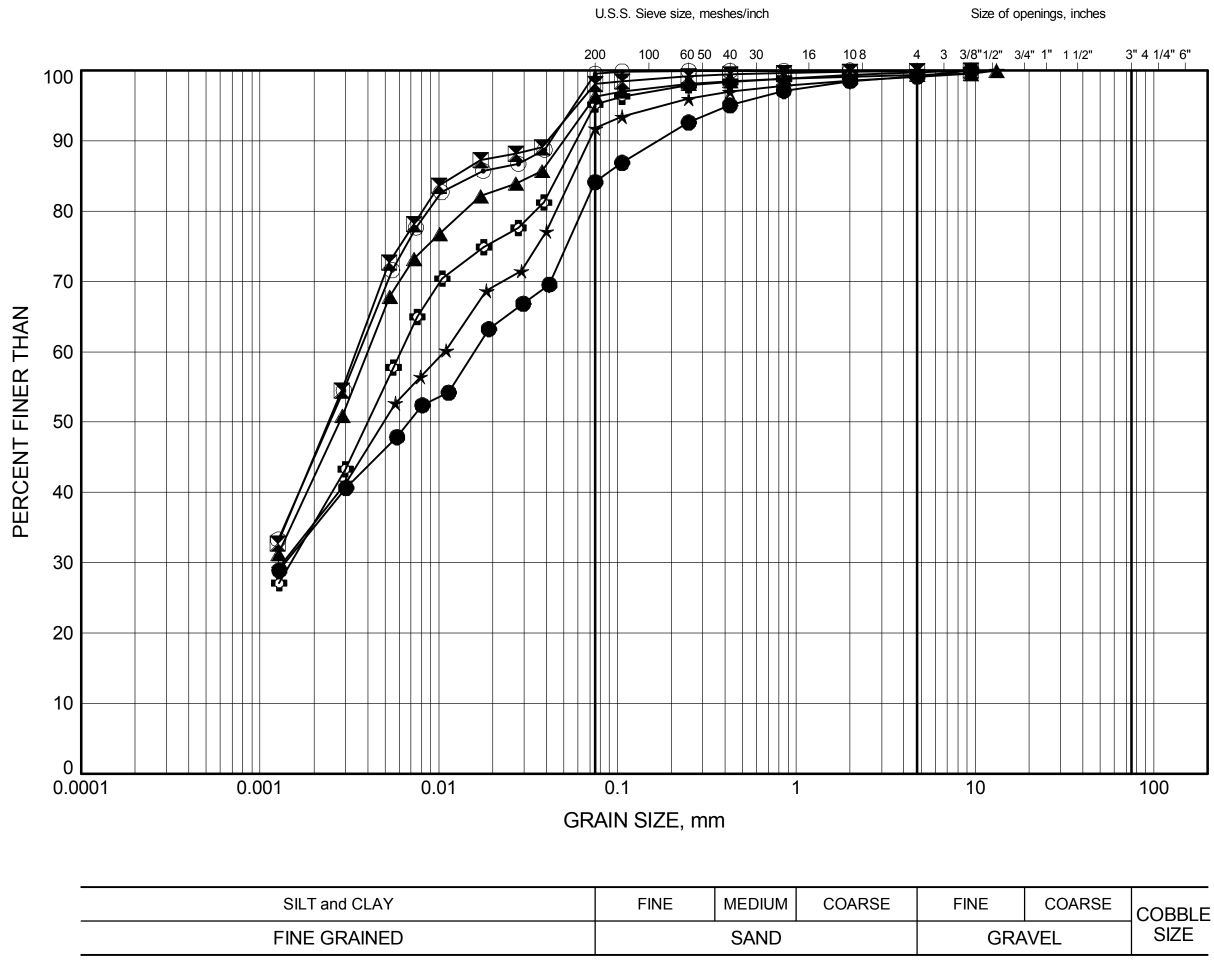
Hwy's 11 and 652, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C5

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-4	2.59	266.05
⧗	17-4	7.92	260.72
▲	17-5	6.40	260.31
★	17-5	9.45	257.26
⊙	17-6	4.88	262.02
✪	17-6	7.92	258.98

Date August 2017

GWP# 5129-13-01

THURBER

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Chkd. SP

Appendix C.2

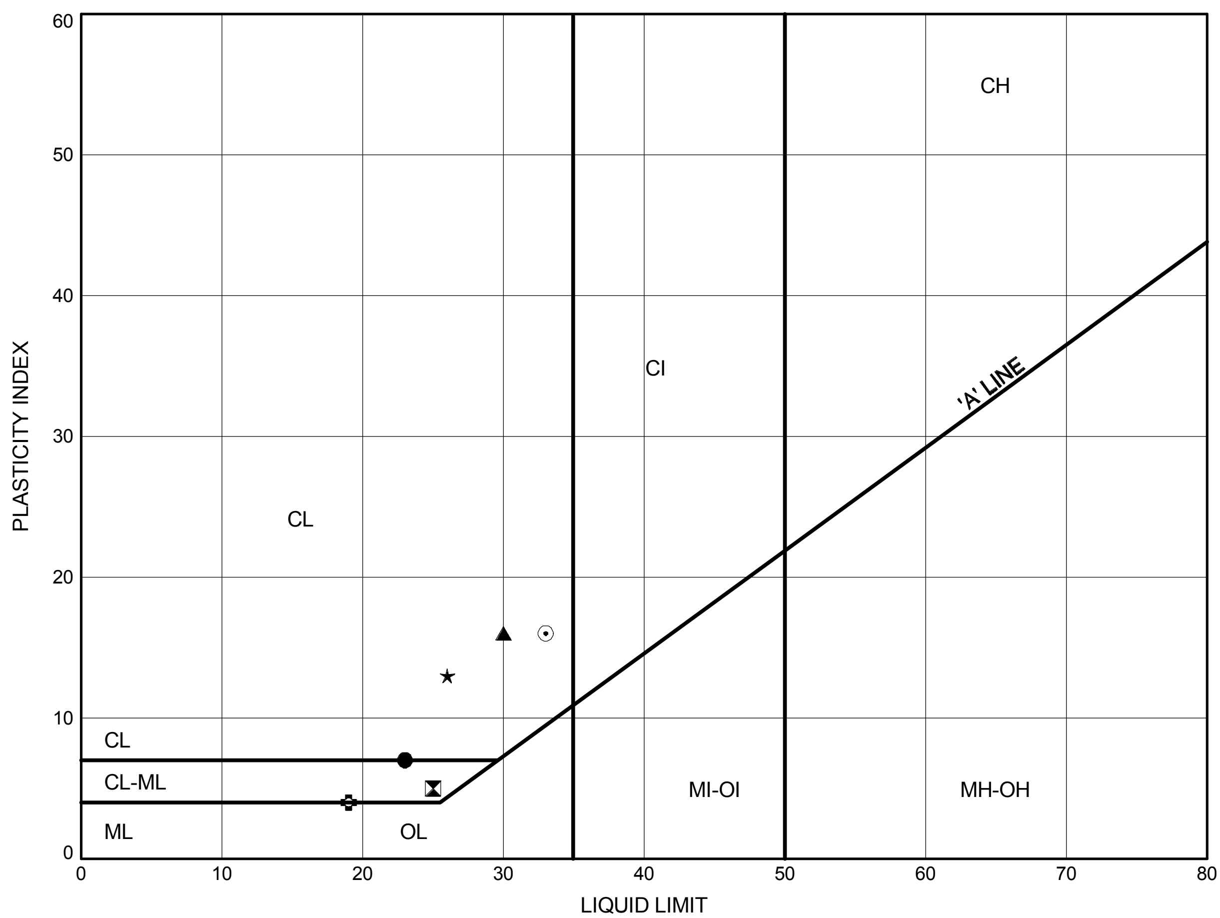
Atterberg Limit Analysis Figures

Hwy's 11 and 652, 5 Structures

ATTERBERG LIMITS TEST RESULTS

FIGURE C6

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	6.40	260.77
⧗	17-2	6.40	260.41
▲	17-2	9.45	257.36
★	17-3	3.35	265.29
⊙	17-3	7.92	260.72
✿	17-3	9.60	259.04

Date August 2017

GWP# 5129-13-01

THURBER

Prep'd KE

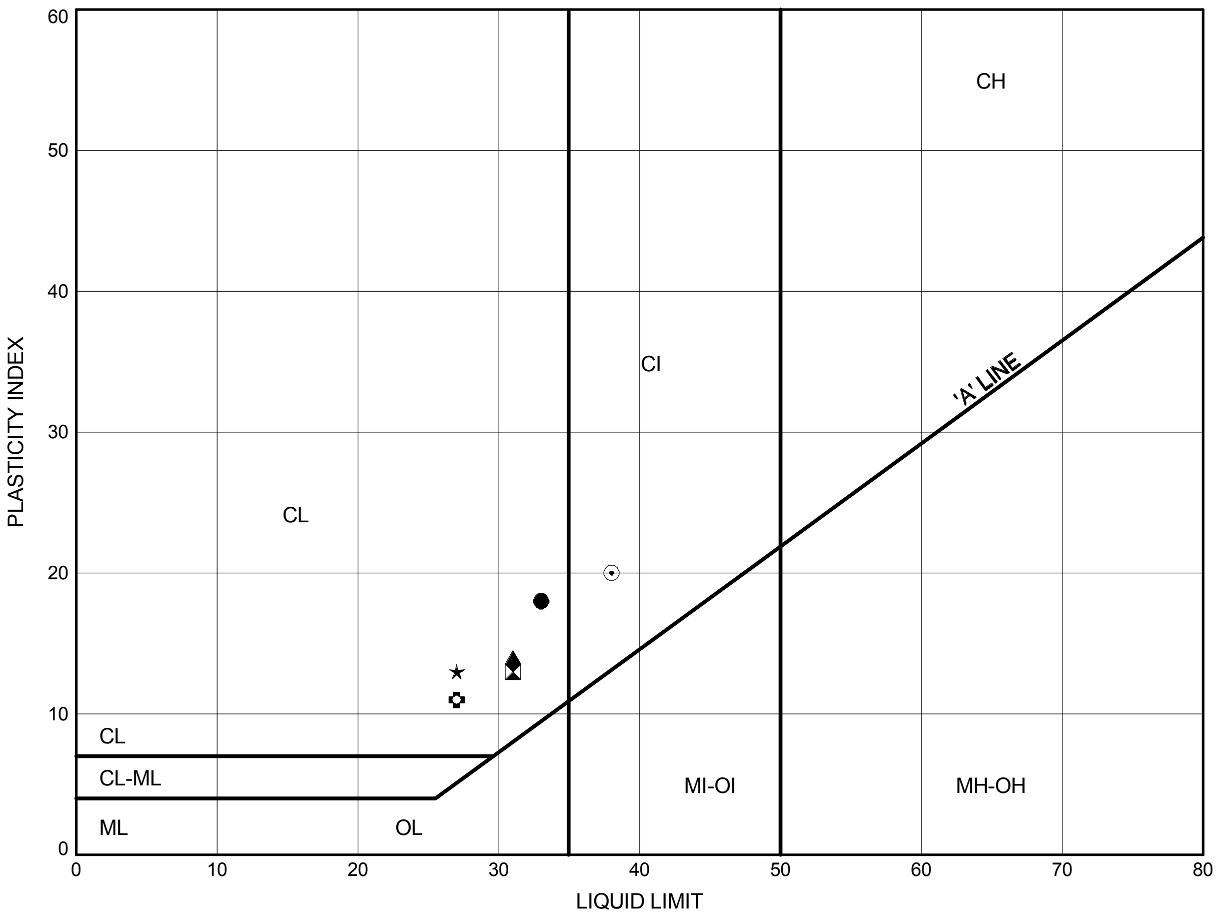
Chkd. SP

Hwy's 11 and 652, 5 Structures

ATTERBERG LIMITS TEST RESULTS

FIGURE C7

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-4	2.59	266.05
⧗	17-4	7.92	260.72
▲	17-5	6.40	260.31
★	17-5	9.45	257.26
⊙	17-6	4.88	262.02
✪	17-6	7.92	258.98

THURBALT 16210 CULVERT 233.GPJ 21/8/17

Date August 2017

GWP# 5129-13-01

THURBER

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Appendix C.3

Analytical Testing Results

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Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Sean O'Bryan

Client PO: 16210
Project: Hwy 11/652
Custody: 14055

Report Date: 29-May-2017
Order Date: 23-May-2017

Order #: 1721061

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
~~1721061-01~~	~~17-5 200/C SS3~~
~~1721061-02~~	~~17-2 199/C SS2~~
~~1721061-03~~	~~17-6 199/C SS2~~
1721061-04	17-2 233/C SS3
~~1721061-05~~	~~17-5 231/C SS2B~~

Approved By: Dale Robertson, BSc
Laboratory Director

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	25-May-17	25-May-17
Conductivity	MOE E3138 - probe @25 °C, water ext	27-May-17	27-May-17
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	25-May-17	25-May-17
Resistivity	EPA 120.1 - probe, water extraction	27-May-17	27-May-17
Solids, %	Gravimetric, calculation	26-May-17	26-May-17

PARACEL
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Order #: 1721061

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16210

Report Date: 29-May-2017
Order Date: 23-May-2017
Project Description: Hwy 11/652

	Client ID:	17-5 200/C SS3	17-2 199/C SS2	17-6 199/C SS2	17-2 233/C SS3
	Sample Date:	12-May-17	11-May-17	09-May-17	13-May-17
	Sample ID:	1721061-01	1721061-02	1721061-03	1721061-04
	MDL/Units	Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	86.9	83.7	82.9	30.2
General Inorganics					
Conductivity	5 uS/cm	121	126	145	885
pH	0.05 pH Units	7.55	7.49	7.42	7.30
Resistivity	0.10 Ohm.m	82.6	79.3	69.1	11.3
Anions					
Chloride	5 ug/g dry	11	25	14	1770
Sulphate	5 ug/g dry	19	7	9	75

	Client ID:	17-5 231/C SS2B	-	-	-
	Sample Date:	15-May-17	-	-	-
	Sample ID:	1721061-05	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	78.9	-	-	-
General Inorganics					
Conductivity	5 uS/cm	558	-	-	-
pH	0.05 pH Units	7.43	-	-	-
Resistivity	0.10 Ohm.m	17.9	-	-	-
Anions					
Chloride	5 ug/g dry	317	-	-	-
Sulphate	5 ug/g dry	<5	-	-	-

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	11.6	5	ug/g dry	11.5			1.1	20	
Sulphate	19.2	5	ug/g dry	19.1			0.2	20	
General Inorganics									
Conductivity	369	5	uS/cm	353			4.6	6.2	
pH	7.52	0.05	pH Units	7.60			1.1	10	
Resistivity	27.1	0.10	Ohm.m	28.4			4.6	20	
Physical Characteristics									
% Solids	87.7	0.1	% by Wt.	90.4			3.0	25	

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	118	5	ug/g	11.5	107	78-113			
Sulphate	119	5	ug/g	19.1	99.5	78-111			

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

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Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Stephen Peters

Client PO: 16210
Project: Hwy 11 & 652
Custody: 27363

Report Date: 23-Jun-2017
Order Date: 20-Jun-2017

Order #: 1725249

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1725249-01	Culv 200 17-2 SS3 4'-6'
1725249-02	Culv 231 17-1 SS2 2'-4'
1725249-03	Culv 232 17-1 SS3 4'-6'
1725249-04	Culv 232 17-6 SS2b 3'6"-4'
1725249-05	Culv 233 17-6 SS2a 2'-3'9"

Approved By: Dale Robertson, BSc
Laboratory Director

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	22-Jun-17	22-Jun-17
Conductivity	MOE E3138 - probe @25 °C, water ext	22-Jun-17	23-Jun-17
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	21-Jun-17	21-Jun-17
Resistivity	EPA 120.1 - probe, water extraction	22-Jun-17	23-Jun-17
Solids, %	Gravimetric, calculation	22-Jun-17	22-Jun-17

PARACEL
LABORATORIES LTD

Order #: 1725249

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16210

Report Date: 23-Jun-2017
Order Date: 20-Jun-2017
Project Description: Hwy 11 & 652

	Client ID:	Culv 200 17-2 SS3 4'-6'	Culv 231 17-1 SS2 2'-4'	Culv 232 17-1 SS3 4'-6'	Culv 232 17-6 SS2b 3'6"-4'
	Sample Date:	26-May-17	11-Jun-17	08-Jun-17	06-Jun-17
	Sample ID:	1725249-01	1725249-02	1725249-03	1725249-04
	MDL/Units	Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	86.3	72.7	79.1	81.3
General Inorganics					
Conductivity	5 uS/cm	150	761	344	389
pH	0.05 pH Units	7.68	7.56	7.71	7.77
Resistivity	0.10 Ohm.m	66.7	13.1	29.0	25.7
Anions					
Chloride	5 ug/g dry	16	320	96	133
Sulphate	5 ug/g dry	24	41	11	9

	Client ID:	Culv 233 17-6 SS2a 2'-3'9"	-	-	-
	Sample Date:	09-Jun-17	-	-	-
	Sample ID:	1725249-05	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	52.9	-	-	-
General Inorganics					
Conductivity	5 uS/cm	894	-	-	-
pH	0.05 pH Units	7.36	-	-	-
Resistivity	0.10 Ohm.m	11.2	-	-	-
Anions					
Chloride	5 ug/g dry	315	-	-	-
Sulphate	5 ug/g dry	35	-	-	-

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

PARACEL

LABORATORIES LTD.

Order #: 1725249

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16210

Report Date: 23-Jun-2017
Order Date: 20-Jun-2017
Project Description: Hwy 11 & 652

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	16.3	5	ug/g dry	16.5			0.9	20	
Sulphate	24.3	5	ug/g dry	24.3			0.1	20	
General Inorganics									
Conductivity	281	5	uS/cm	292			4.0	6.2	
pH	7.78	0.05	pH Units	7.78			0.0	10	
Resistivity	35.6	0.10	Ohm.m	34.2			4.0	20	
Physical Characteristics									
% Solids	79.4	0.1	% by Wt.	85.1			7.0	25	

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	119	5	ug/g	16.5	103	78-113			
Sulphate	124	5	ug/g	24.3	99.3	78-111			

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Appendix C.4

Shelby Tube Extraction

Photo C.1. Shelby tube sample TW6 @ 4.6 to 5.2 m from Borehole 17-4

Appendix D.

Site Photographs

Photo 1. Looking south (upstream) of Highway 11

Photo 2. Looking west along Highway 11

Photo 3. Looking north (downstream) of Highway 11

Photo 4. Looking east along Highway 11

Photo 5. Outlet looking west

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

Culvert Type	***Pipe Culvert or Closed Box Culvert***	***Circular Pipe Culvert (Trenchless Installation)***	***Open Bottom Culvert***	***Precast Concrete Slab on Steel Sheet Piles***
Advantages	- Typically the least costly culvert type - Relatively expedient installation if precast units are used. - Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.	- Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. - Avoids open cut and large excavation quantity - Allows two lanes of traffic to be maintained throughout construction	- Relatively expedient installation if precast units are used. - Possibility to maintain work zone outside of existing waterway.	- Potentially minimizes volume of excavation and roadway protection - Maintains water flow throughout construction and minimizes potential for disturbance of streambed - Allows for winter construction
Disadvantages	- Requires large excavation and roadway protection. - Requires compacted granular pad on subgrade. - Requires waterflow realignment or installation of a temporary by-pass culvert to maintain existing waterflow alignment	- Requires construction of entry and exit pits and access to toes of slope. - Requires specialised construction equipment. - Feasibility also depends on flow capacity and other hydraulic properties. - minimal cover depth	- Requires deeper excavation increasing excavation volume and dewatering concern. - Founding subgrade will provide lower geotechnical resistances. - Potential for post construction settlement.	- Quantity and cost of sheet piles - Unconventional design - Differential settlement could occur between non-yielding culvert and approach fills
Risks/ Consequences	- Disruption to traffic	- Possibility of encountering cobbles or obstructions and mixed soils	- Increased risk of basal instability of footing excavation due to depth of excavation below water table.	- Possibility of encountering obstruction and varying depth to suitable bearing stratum
Relative Cost	**Low to Medium**	**High**	**Medium**	**Medium to High**
Recommendation	**Recommended**	**Not Feasible**	**Generally Feasible / Not Recommended**	**Generally Feasible / Not Recommended**

Appendix F.

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

August 04, 2017

Site: 49.329 N, 81.1121 W User File Reference: Site 39E - 233/C

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)**
0.229	0.273	**0.221**	0.161	**0.106**	**0.050**	**0.023**	**0.0053**	**0.0022**	**0.144**	**0.082**

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)	0.0075	0.049	0.107
Sa(0.1)	0.012	0.066	0.134
Sa(0.2)	0.014	0.058	0.111
Sa(0.3)	0.013	0.046	0.082
Sa(0.5)	0.0098	0.034	0.057
Sa(1.0)	0.0045	0.018	0.029
Sa(2.0)	0.0018	0.0077	0.013
Sa(5.0)	0.0004	0.0016	0.0030
Sa(10.0)	0.0003	0.0008	0.0012
PGA	0.0068	0.035	0.071
PGV	0.0055	0.024	0.042

References

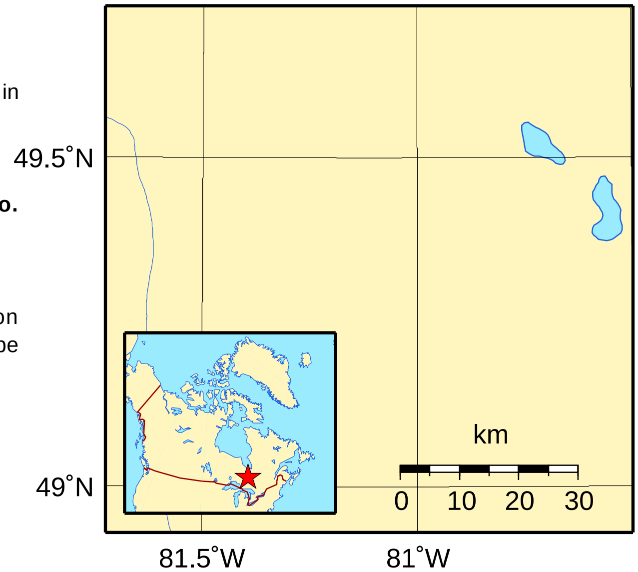
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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



Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report

1. The following Special Provisions and OPSS Documents are referenced in this report:

OPSS.PROV 206	Construction Specification for Grading
OPSS 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cuts
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextile
OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Span Less than or Equal to 3.0 m
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

2. Suggested text for a NSSP on “Installation of Temporary Protection System”

Vibratory equipment is not permitted for installation or removal of temporary protection systems

3. Suggested text for a NSSP on “Protection of Sensitive Foundation Soils”

The Contractor is advised that the native clay will that will be exposed at the subgrade following removal of existing culvert is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.

The base of the excavation should be inspected by a QVE that is experienced in geotechnical inspection to confirm that the exposed subgrade surface conforms to the design requirements. Once approved the subgrade should be protected with a non-woven geotextile placed between the native subgrade and granular bedding.