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**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**HIGHWAY 17 DINORWIC LAKE CULVERT REPLACEMENT**
**1.85 KM WEST OF HIGHWAY 72/HIGHWAY 17 JUNCTION**
**SITE NO.: 41S-247/C**

**4015-E-0015, ASSIGNMENT NO. 2**
GWP 6370-14-00

Geocres No.: 52F-55

Report to:

**Mcintosh Perry Consulting Engineers Ltd. / LEA Consulting Ltd.**

October 2017
Thurber File: 13161

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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 replacement at the Highway 17 crossing of Dinorwic Lake, GWP 6370-14-00. The structure is located approximately 1.85 km west of the Junction of Highway 72 and Highway 17. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry–LEA Engineering Joint Venture under Agreement No. 4015-E-0015, Assignment No. 2.

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 of the anticipated geotechnical conditions influencing design and construction was developed in the course of the current investigation. No previous foundation investigation information was available for the subject culvert site.

## 2 SITE DESCRIPTION

The existing culvert is a cast-in-place concrete box culvert located near Sta. 15+426 on Highway 17 (Linear Highway Referencing System Base Point: 22030, Offset: 1.855). The culvert is reported to be 3.7 m wide by 1.8 m high and approximately 64 m long with a generally north to south alignment. The flow through the culvert ultimately drains into Dinorwic Lake to the south.

At the location of the culvert, Highway 17 is a two-lane highway with a westbound passing lane, a rural cross-section and paved shoulders. The road surface of the Highway 17 embankment is approximately 11.0 m above the top of the culvert at an elevation of 381.7 m. The existing slopes are inclined at approximately 2.0H:1V and 1.5H:1V for the south and north embankment slopes, respectively. Steel guiderails are present on both sides of the highway in the area of the culvert. The land adjacent to the highway is undeveloped with vegetation consisting of grasses on the embankment slope and waters edge with shrubs and trees located at higher elevations. Traffic volumes are understood to be 3,400 AADT (2012).

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 current site investigation and field testing program was carried out between July 14th and 20th, 2016 and on August 21, 2016. Drilling consisted of advancing four boreholes identified as DL16-1 through DL16-4. The drilling was carried out using portable tripod equipment and a CME 45 for off road boreholes DL16-1 and DL16-4, respectively. Truck-mounted CME 850 and CME 750 drills were used for the on road boreholes DL16-2 and DL16-3, respectively. 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). Borehole DL16-1 which was drilled with a portable tripod equipment utilized a half-weight hammer for SPT testing. The boreholes were sampled to depths ranging from 4.4 to 21.3 m (elev. 365.5 to 358.5 m) below the existing ground surface. Borehole DL16-1 was extended to a depth of 8.2 m (elev. 361.7 m) with a dynamic cone penetration test.

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. Following completion of the field investigation the boreholes were backfilled in general accordance with MOEE requirements (O.Reg. 903).

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 Atterberg Limit testing and gradation analysis (hydrometer and/or sieve). The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Two samples of soil recovered from within the boreholes were selected and submitted for analytical testing of corrosivity parameters and sulphate content. 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 stratigraphy encountered consisted of a pavement structure and embankment fill overlying a deposit of clay over a deposit varying from sandy silt to silty sand. Bedrock was not encountered within the depth of investigation.

## 5.1 Topsoil

Boreholes DL16-1 and DL16-4 were drilled adjacent to the culvert inlet and outlet and encountered a 25 to 50 mm thick layer of topsoil at the surface of the borehole.

## 5.2 Embankment

### 5.2.1 Asphalt

Borehole DL16-2 and DL16-3 were drilled through the existing Highway 17 embankment and encountered a layer of asphalt varying in thickness from 45 to 145 mm.

### 5.2.2 Fill: Sand

Below the asphalt within the road borehole DL16-03 was a layer of granular fill consisting of sand to silty sand with gravel. The granular fill had an underside depth of 7.3 (elev. 374.5) below the existing roadway surface.

SPT tests recorded N-values in the granular fill typically ranging from 20 to 50 blows indicating a relative density of compact to dense. A single SPT N-Value corresponding to a loose relative density was noted near the base of the granular fill and an elevated SPT N-value corresponding to a very dense relative density was encountered locally at a depth near 0.8 m below the surface of the roadway. Recorded moisture contents ranged from 2 to 17%.

Gradation analysis was completed on one sample of the granular fill. The grain size distribution curve for this sample is included in Figure C1 of Appendix C. The results of the test is summarized below and is presented on the corresponding Record of Borehole sheet in Appendix B and indicate an SM material.

| Soil Particle | Percentage (%) |
|---|---|
| Gravel | 12 |
| Sand | 45 |
| Silt | 26 |
| Clay | 17 |

### 5.2.3 Fill: Silty Sand with Cobbles and Boulders

Below the asphalt within the road borehole DL16-2 was a layer of fill consisting of silty sand with gravel and frequent cobbles and boulders throughout with noted diameters up to 600 mm (possible rock fill). The granular fill had an underside depth of 8.4 m (elev. 373.3 m) below the existing roadway surface.

Rock coring techniques were required to advance through the cobbles and boulders. Where SPT testing was possible, the recorded N-values ranged from 21 to 54 blows indicating a relative density of compact to dense. Recorded moisture contents ranged from 2 to 10%.

Gradation analysis was completed on one sample of the granular fill (excluding the cobbles and boulders). The grain size distribution curve for this sample is included in Figure C1 of Appendix C. The results of the test is summarized below and is presented on the corresponding Record of Borehole sheet in Appendix B and indicate an SM material (excluding the cobbles and boulders).

| Soil Particle | Percentage (%) |
|---|---|
| Gravel | 34 |
| Sand | 53 |
| Silt | 13 |
| Clay | |

### 5.2.4 Fill: Clay

A layer of fill consisting of clay with sand was encountered under the granular fill in boreholes DL16-2 and DL16-3. The clay fill layer was 3.2 to 4.3 m in thickness with an underside elevation at 370.1 to 370.2 m.

SPT tests recorded N-values in the clay fill typically ranging from 6 to 47 blows indicating a firm to very stiff consistency. The recorded moisture contents varied from 5 to 28%.

Gradation analyses were completed on two samples of the clay fill. The grain size distribution curves for these samples are included in Figure C2 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---|---|
| Gravel | 0 - 6 |
| Sand | 24 - 30 |
| Silt | 37 - 38 |
| Clay | 32 - 33 |

Atterberg Limit testing was completed on two samples of the clay fill layer. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C6 of Appendix C. The laboratory results are summarized below and indicate that the clay fill exhibits low plasticity (CL).

| Parameter | Value |
|---|---|
| Liquid Limit | 31 - 32 |
| Plastic Limit | 15 - 18 |
| Plasticity Index | 14 -16 |

### 5.3 Silt

A native deposit of silt was encountered directly below the topsoil in both off-road boreholes. The silt varied from clayey silt with cobbles in Borehole DL16-1 to sandy silt with organics in Borehole DL16-4 and ranged in thickness from 100 to 900 mm. The recorded moisture contents varied from 18 to 40%.

### 5.4 Sand

A deposit of sand was encountered below the silt in both off-road boreholes. The deposit varied from sand to sand with silt and was 3.9 m thick in Borehole DL16-4 with an underside elevation at 367.2 m. Borehole DL16-1 was investigated 3.5 m (elev. 365.5 m) into the sand layer before sampling was discontinued due to difficulty in advancing casing through cobbles noted below 3.0 m depth. Borehole DL16-1 was subsequently extended with the use of DCPT testing below this elevation.

SPT tests in Borehole DL16-1 gave N-values ranging from 21 to 59 blows. SPT tests in Borehole DL16-4 gave N-values ranging from 3 to 11 blows indicating a very loose to compact relative density. The recorded moisture contents ranged from 5 to 22%.

Gradation analyses were completed on three samples of the sand deposit. The grain size distribution curves for these samples are included in Figure C3 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---|---|
| Gravel | 0 - 24 |
| Sand | 65 - 95 |
| Silt | 1 - 11 |
| Clay | |

### 5.5 Clay

A deposit of clay was encountered beneath the clay fill in Boreholes DL16-2 and DL16-3 and below the sand deposit in Borehole DL16-4. Silt seams were observed within the clay in Borehole DL16-4. The thickness of the deposit ranged from 6.1 to 7.3 m (base elev. 364.0 to 361.1 m).

SPT tests performed within the clay deposit gave N-values typically ranging from weight of hammer to 13 blows with a single test in Borehole DL16-3 exhibiting an N-Value of 21. Field vane tests were performed within the deposit and recorded undrained shear strengths typically ranging from 55 to greater than 100 kPa. The clay is firm to very stiff in consistency. Remolded field vane testing indicates that the clay shows some sensitivity. The recorded moisture contents varied from 31 to 68%

Gradation analyses were completed on four samples of the clay deposit. The grain size distribution curves for these samples are included in Figure C4 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---|---|
| Gravel | 0 |
| Sand | 0 - 6 |
| Silt | 28 - 62 |
| Clay | 32 - 72 |

Atterberg Limit testing was completed on four samples of the clay deposit. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C7 of Appendix C. The laboratory results are summarized below and indicate that the clay varies from low to high plasticity (CL to CH).

| Parameter | Value |
|---|---|
| Liquid Limit | 27 - 73 |
| Plastic Limit | 16 - 24 |
| Plasticity Index | 12 - 50 |

### 5.6 Silty Sand

A silty sand deposit was encountered directly below the clay in Boreholes DL16-2 and DL16-3. Below the clay in Borehole DL16-4 was a sandy silt deposit transitioning to the silty sand deposit. All borehole sampling was terminated in the sand layer at a depth ranging from 12.8 to 21.3 m (elev. 361.3 to 358.5 m) below the existing ground surface. Borehole DL16-3 and DL16-4 encountered sand which flowed into the casing.

SPT tests gave N-values ranging from 6 to 25 blows per 300 mm of penetration indicating a loose to compact relative density. The moisture content within the sand deposit ranged between 11 to 19%

Gradation analysis were completed on two samples of the sand deposit. The grain size distribution curves for these samples are included in Figure C5 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---|---|
| Gravel | 0 - 12 |
| Sand | 56 - 84 |
| Silt & Clay | 16 - 32 |

### 5.7 Groundwater

No artesian conditions were encountered during drilling and it is expected that the groundwater level will largely be controlled by the water level in Dinorwic Lake, which is identified on the base plans as being at elevation 369.338 m at the culvert outlet on May 22, 2013. It should be noted that the groundwater level at the time of construction and 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.

## 6 MISCELLANEOUS

Borehole locations were selected relative to existing site features and the proposed foundation locations and the drilled locations were measured by Thurber after completion of drilling. Ground surface elevation were interpreted from topographic drawings provided by McIntosh Perry.

RPM Drilling Limited from Thunder Bay, Ontario supplied the portable tripod, CME45, and CME750 drilling equipment. The CME850 drill rig was supplied by Cartwright Drilling Inc. from Thunder Bay, Ontario. The drilling subcontractors conducted the drilling, soil sampling, in-situ testing and borehole decommissioning.

The field investigation was supervised on a full time basis by Mr. Chris Murray, E.I.T. and Troy Mckinnon, C.E.T. of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Oakville, Ontario and at Stantec's laboratory in Ottawa, Ontario. Analytical testing was completed by AGAT Laboratories in Mississauga, Ontario. Interpretation of the factual data and preparation of this report were carried out by Mr. Paul Carnaffan, P.Eng. 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 and presents geotechnical recommendations to assist the design team in designing a suitable foundation for the proposed replacement of the existing Dinorwic Lake culvert crossing Highway 17. The discussion and recommendations presented in this report are based on the information provided by McIntosh Perry-LEA Engineering Joint Venture (MPLEJV)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, conveying Dinorwic Lake under Highway 17, is a cast-in-place concrete box culvert approximately 64 m long with an opening of 3.7 by 1.8 m. The top of the existing culvert is reported to be at elevation 370.61 m and 370.55 m at the inlet and outlet respectively. The embankment fill height above the culvert is in the order of 11.0 m. No previous foundation investigation information for the subject culvert was available in the Geocres Library. Possible rock fill was identified in Borehole DL16-2, located within the passing lane. Similar material was not encountered in the adjacent main lanes, suggesting that the passing lane may have been added at a later date as an embankment widening with rock fill.

Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to MPLEJV under Contract No. 4015-E-0015, Assignment No. 2.

## 7.1 Proposed Structure

The General Arrangement (GA) drawing, dated September 2017, indicates replacement of the existing culvert with twin 3.55 x 3.55 x 66.0 m concrete box culverts with invert elevations of 368.43 and 368.41 m for the inlet and outlet of the culvert, respectively. The new culverts are proposed to be constructed east of the existing culvert alignment with a separation of 2 m from the current culvert. The new culverts are shown to be constructed with a 60 mm separation, resulting in an overall width of 9360 mm.

Flow will be maintained through the existing culvert during installation of the new twin box culverts. The existing culvert is to be abandoned and filled with cellular concrete after installation of the new culverts.

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

## 8 SEISMIC CONSIDERATIONS

### 8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth generation seismic model developed by the Geological Survey of Canada. 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).

### 8.2 CHBDC Seismic Site Classification

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

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

### 8.3 Seismic Liquefaction

Based on the subsurface condition encountered at the drilled locations at this site the foundation soils are considered to be not susceptible to moderately susceptible to liquefaction. However, due to the low PGA values for this site liquefaction is not considered to be a concern.

# 9 DESIGN OPTIONS

## 9.1 Culvert Type and Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirement, geotechnical resistance available in the foundation soils, the 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, pipe culverts are a technically feasible alternative, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied.
- Open Bottom Culvert (Box, Arch)
  Open bottom culverts are not recommended for this site from a foundation engineering perspective since the post construction settlement in the foundation clay from this type of culvert would be greater than alternative options and would also require greater excavation and dewatering efforts during construction to place the foundation in the dry.
- Closed Culvert (Box)
  Precast segmental box culvert in an open cut construction 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. However, the open cut construction would require a very deep excavation through the embankment and a robust roadway protection design.
- Precast Cap Panel on Sheet Piles
  Another culvert alternative from a geotechnical perspective is precast concrete cap panels supported on steel sheet piles. However, sheet piles would have difficulty penetrating the boulders in the fill so this option will not be developed further within this report.

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.

## 9.2 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 a detour is not available and therefore this option is not feasible.

- Open Cut with Staged Temporary Widening

  Widening of the existing highway and/or construction of a detour embankment to accommodate a temporary traffic passage is considered feasible from a geotechnical perspective. However, placement of additional fill will require additional field investigation to assess the impacts of an increase in loading on the subgrade soils and the potential for time-dependant settlement for both the temporary detour and existing embankment. Additionally, a review of embankment slope instability and the requirement for property acquisition will be required to complete this option.

- Open Cut with Staged Temporary Lowering and Temporary Protection System

  The use of open cut techniques in conjunction with lowering and staged culvert replacement is a potentially feasible construction staging option from a geotechnical perspective. This option will require roadway protection, as discussed further in Section 11.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. However, the extent of boulders/obstructions within the embankment fill is not known and may therefore become an interference during installation of roadway protection. Due to the required height, the roadway protection would need bracing such as struts, deadman and anchors to reduce lateral deflections as well as an adequate embedment depth of the protection system.

- Trenchless Techniques

  Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, the size and type of replacement culvert, potential to encounter obstruction within the existing embankment fill, characteristics of the subgrade soils, and the topography of the surrounding terrain will need to be taken into consideration. Trenchless techniques are not recommended for this site.

### 9.3 Recommended Approach for the Culvert Replacement

Foundation design aspects for a replacement culvert includes subgrade conditions, geotechnical resistances, settlements of founding soils, imposed loading pressures, erosion control, protection system design, groundwater control, staged excavation and stability of detour embankment. 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.

From a foundation engineering perspective, the alternative of replacing the existing culvert with closed box culverts using open cut techniques with staged construction, temporary lowering and temporary protections systems is the recommended culvert replacement option. This report will focus on providing foundation recommendations on the design and construction for closed box culverts.

# 10 FOUNDATION DESIGN RECOMMENDATIONS

## 10.1 Culvert Foundation Bearing Resistances

Provided 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.

The recommended geotechnical resistances for two 4.65 m wide pre-cast concrete box culvert installed directly adjacent to each other and at an invert elevation of 368.43 and 368.41 m for the inlet and outlet of the culvert, respectively, on an undisturbed native subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 395 kPa
- Factored Geotechnical Resistance at SLS of 200 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor ($\Psi$) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
  - $\phi_{gu}$ = 0.5 (static analysis; typical degree of understanding)
  - $\phi_{gs}$ = 0.8 (static analysis; typical degree of understanding)

The factored geotechnical resistance at ULS takes into account the full embedment of the culvert beneath the highway. The geotechnical resistance will decrease with decreasing embedment, however the load on the culvert will also decrease.

The factored geotechnical resistance at SLS corresponds to the uniform stress increase beneath the footprint of the culvert that would result in 25 mm of settlement.

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.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular ‘A’ bedding (Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45.

It is noted that construction will extend below the measured water level. Water diversion and dewatering (Section 11.3) will be required to place the bedding material and install the culvert in dry.

## 10.2 Subgrade Preparation, Bedding and Backfilling

All organics, existing fill, soft or loose deposits, disturbed soils, 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. The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials 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 500 mm thick layer of 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.

Given the conditions anticipated at the founding level of the replacement culvert, construction equipment should not be permitted to travel on the exposed subgrade. In addition, the compaction of granular bedding directly above the subgrade is likely to 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 over excavation to allow placement of a mud slab 100 mm thick beneath the 500 mm thick Granular A bedding layer. The mud slab should be placed as soon as possible after reaching the subgrade level and following confirmation of QVE acceptance. An NSSP is provided in Appendix G to include in the contract document to alert the Contractor of the sensitive nature of the foundation soils.

Dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

It is recommended that culvert cover consist of free-draining, non-frost susceptible granular materials such as Granular A material meeting the requirements of OPSS.PROV 1010. The cover must be in accordance with OPSS 902 and placed to the extent shown on OPSD 3101.150.

Culvert backfill should be in accordance with OPSS 902 and consist of material meeting the requirements of OPSS Select Subgrade Material and should be compacted in regular lifts as per OPSS.PROV 501. Heavy compaction equipment, used adjacent to structure, 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.

## 10.3 Frost Depth

The depth of frost penetration at this site is 2.5 m. It is not necessary to found a closed box culvert at a depth below frost penetration. Backfill, cover and frost tapers should be as per OPSD 803.010. It is noted that the top of the culverts is below the depth of frost penetration and therefore a frost taper need not be incorporated into the cover material. Pavement reinstatement and transitions are addressed in the pavement design memorandum.

## 10.4 Embankment Design and Reinstatement

### 10.4.1 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. To match the existing north side slope of 1.5H:1V, Granular B Type II or rock fill should be used. The existing clay fill material is not considered acceptable material for reuse during reconstruction of the embankment core. However, the existing sand fill that is free of organics 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 content within acceptable limits for 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.

Provided construction of embankment and cut slopes are carried out in accordance with recommendations provided within this report, the minimum required factor of safety will be maintained for seismic loading conditions.

#### 10.4.2 Embankment Settlement and Stability

The condition of the embankment slopes was examined in the field during the field investigation; no evidence of instability (tension cracks etc.) was noted, at that time. Surficial instability along the existing river banks was noted near the northwest corner of the culvert. It is anticipated that this area will be outside of the construction zone.

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. In addition, the Contractor’s selection and placement of construction equipment (such as heavy cranes) are also the Contractor’s responsibility.

It is understood that no grade raise is anticipated along the alignment of Highway 17 and therefore negligible foundation settlement is expected to occur. Further assessment should be carried out where construction staging dictates the requirement for additional loading and the proximity of the temporary alignments.

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

### 10.5 Lateral Earth Pressure

Lateral earth pressure parameters provided in Table 10-1 and Table 10-2 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.

#### 10.5.1 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)
$\gamma$ = unit weight of retained soil (see table below), adjusted for water 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 10-1.

**Table 10-1. 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 and Clay 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 | 0.40 | 0.31 | 0.48 | 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 10-1. 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 10-1 should be used.

### 10.5.2 Combined Static and Seismic Lateral Earth Pressure Parameters

In accordance with Clause 4.6.5 of the CHBDC (S6-14), retaining structures 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 the 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 10-2 may be used. The provided earth pressure coefficients are based on a Seismic Site Class E, PGA with a 2% probability of exceedance in 50 years of 0.044g (Geological Survey of Canada – Fifth Generation) and a F(PGA) of 1.81 as per Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016).

**Table 10-2. 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 | Sloping Surface Behind Wall (2H:1V) | Horizontal Surface Behind Wall | Sloping Surface Behind Wall (2H:1V) |
| Active, $K_{AE}$ Yielding Wall | 0.29 | 0.45 | 0.33 | 0.54 |
| Active, $K_{AE}$ Non-Yielding Wall | 0.32 | 0.51 | 0.35 | 0.65 |

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 included consideration of material properties and the soil profile.

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

where:

$\sigma_h$ = 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)
$\gamma$ = unit weight of retained soil, adjusted for water level
$K_{AE}$ = combined static and seismic earth pressure coefficient
H = total height of the wall (m)

# 11 CONSTRUCTION CONSIDERATIONS

## 11.1 Excavations

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fill and native soils above as well as the native soils below the water table may be classified as Type 3 soil. The organic soils, any cohesionless soils and alluvial deposits below the water table are classified as Type 4 soils.

All excavations must not encroach within 1H:1V from the base of the excavation to the existing culvert foundation.

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 native clay and sand deposits. The Contractor must consider the potential for unbalanced lateral earth pressure on the existing and proposed culvert while installing the new culvert. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA. The Contractor should carry out a detailed embankment stability assessment prior to construction when the preferred culvert replacement strategy and methodology has been determined. Stockpiling or surface surcharge should not be allowed within a horizontal distance encompassed within a 1H:1V inclination from the perimeter of the base of the excavation

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. Any protection system must be designed by a licensed Professional Engineer experienced in such design. Further discussion is presented in Section 11.2.

### 11.2 Roadway Protection

Roadway protection will be required during various stages of construction. Roadway protection 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. It is recommended that an NSSP be included in the tender documents to alert the Contractor to the height of the protection system required, potential for boulders and obstructions within the fill and the potential need for soil anchors, deadman tie-backs, struts and/or raker supports to achieve the specified performance level. The protection system should be installed at a sufficient distance away from the new culvert to limit the disturbance to the subgrade associated with removal of the protections system. Alternatively, the sheet pile could be left in place and cut off at or below 2.5 m beneath the finished pavement grade. Due to possible disturbance to the subgrade soils, vibration must not be used for installation or extraction of the sheet piling.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design for the embankment fill and culvert backfill are provided in Table 10-1. The lateral earth pressure coefficients for the underlying native clay soils at the existing embankment centerline are given below:

| | | | |
|---|---|---|---|
| $\gamma_w$ | = | 10 | (kN/m$^3$, unit weight of water) |
| $\gamma$ | = | 18 | (kN/m$^3$, bulk unit weight of soil) |
| $K_A$ | = | 0.39 | |
| $K_P$ | = | 2.6 | |

The design of roadway protection is the responsibility of the Contractor. The designer of the roadway protection system should ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations. A suitable bracing system may need to be incorporated into the roadway protection design. All shoring should be designed by a licensed Professional Engineer experienced in such designs.

### 11.3 Surface and Groundwater Control

Culvert construction, subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. Provided the existing culvert is maintained operational during construction, a temporary flow passage is not expected to be required to convey creek flow around the construction site. Construction of cofferdams will be required to divert the creek flow away from the culvert subgrade area.

Excavation below the groundwater level to construct the culvert foundation will be required. 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 soil below the water level, making it difficult to maintain a dry, sound base on which to work. 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. Dewatering systems should be designed, operated and removed in accordance with OPSS.PROV 517.

Based on the groundwater and soil conditions, special attention must be paid to construction dewatering. It is recommended that excavations be enclosed within a water tight sheet pile enclosure. The groundwater level within the enclosure should be lowered by pumping from sumps prior to excavation to a minimum of 500 mm below the underside of the final subgrade. As indicated in Section 10.2, a mud slab should be poured with lean mix concrete to protect the exposed subgrade surface within the excavation from disturbance.

Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field.

### 11.4 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.

## 12 CONSTRUCTION CONCERNS

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

- Disturbance of the soil subgrade. Where fine-grained soils are exposed following clearing, grubbing and stripping activities, these areas will be soft and moisture sensitive and may become heavily disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade condition. The contractor must be aware of the issue so that he may adjust his operations to suit the subgrade conditions
- Cobbles, boulders, rock fill or other buried obstructions will be encountered in the existing embankment fill. Obstructions within the fill could interfere with roadway protection installation. An NSSP should be included in the contract alerting the Contractor to these conditions.
- 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 dewatering scheme will be critical for culvert construction at this site. An NSSP should be included in the contract alerting the Contractor to these conditions.
- 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).

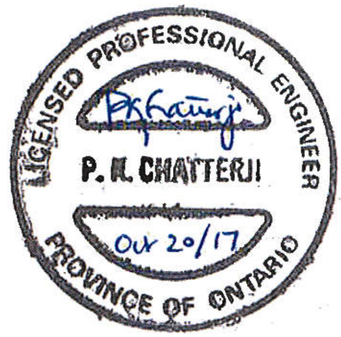
The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personal during construction to confirm that foundation recommendations are correctly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

## 13 CLOSURE

Engineering analysis and preparation of this report were carried out by Mr. Paul Carnaffan, P.Eng 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.


Stephen Peters, P.Eng.
Geotechnical Engineer


Paul Carnaffan, P.Eng.
Principal, Branch Manager Senior
Geotechnical Engineer




P.K. Chatterji, P.Eng., Ph.D.
Review Principal,
Senior Geotechnical Engineer

# Appendix A.

## Borehole Location Plan and Stratigraphic Drawings

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

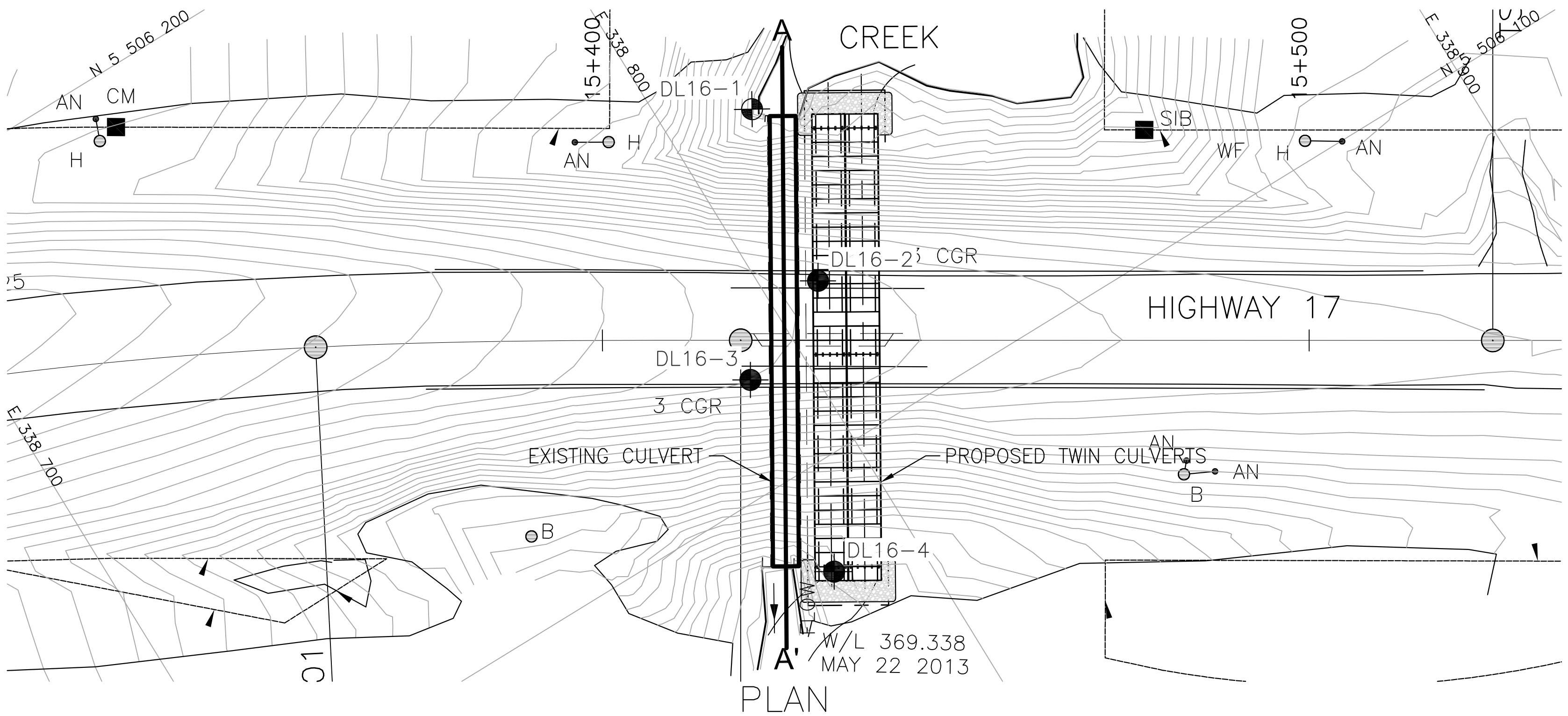
CONT No
GWP No 6370-14-00

HIGHWAY 17
DINORWIC LAKE
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

LEA McINTOSH PERRY Joint Venture

THURBER ENGINEERING LTD.

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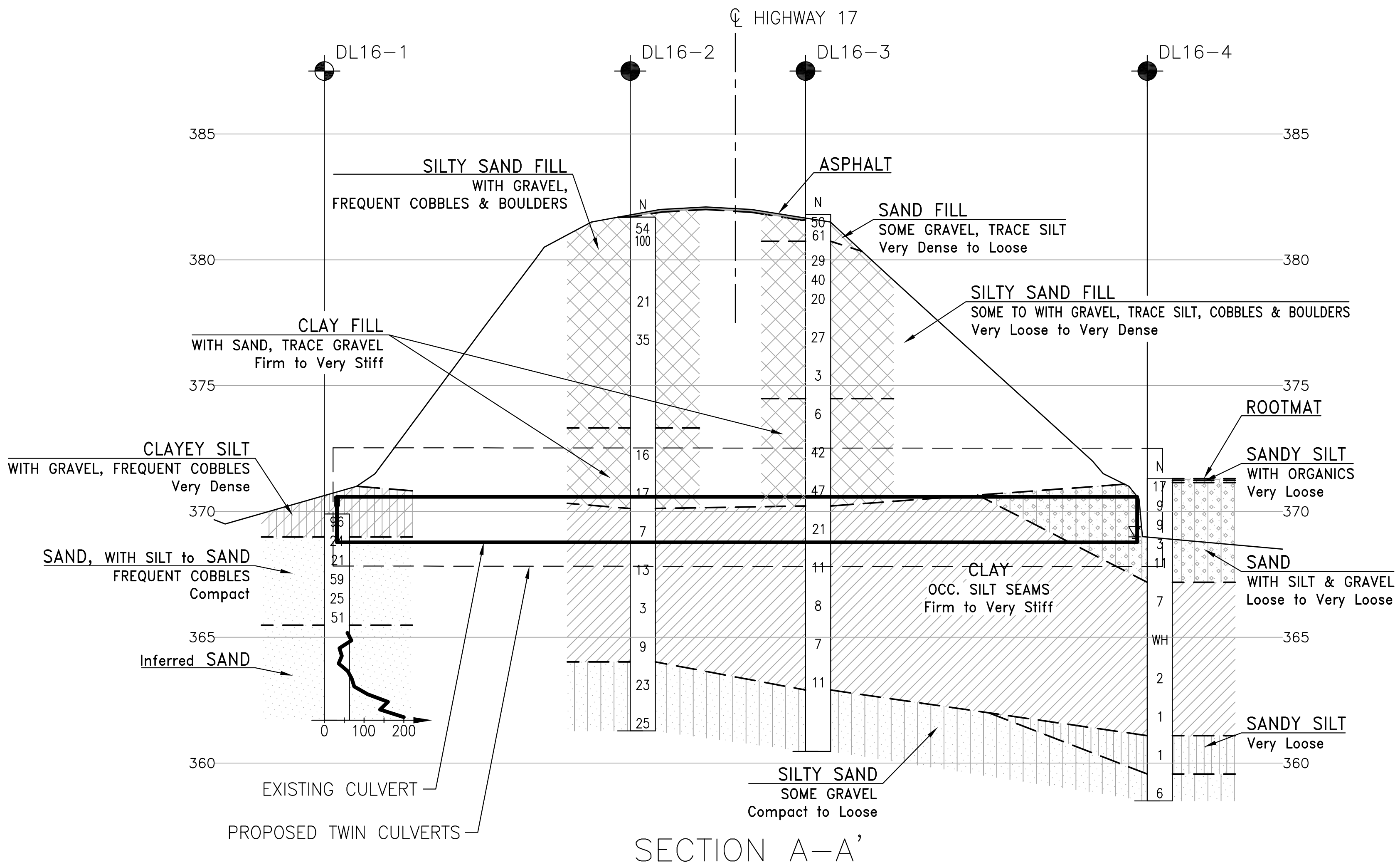


SECTION A–A'

H 1:500
V 1:250

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
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PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
S. PETERS
100194478
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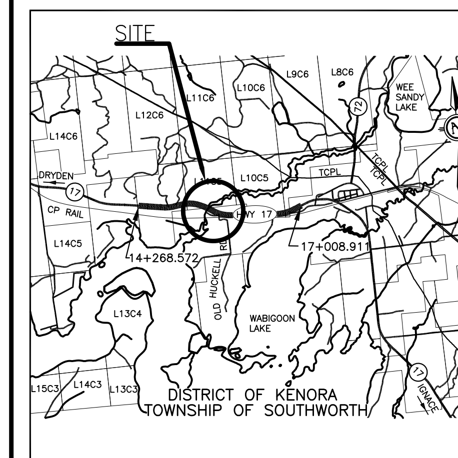
PROVINCE OF ONTARIO




KEYPLAN

## LEGEND

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

| NO | ELEVATION | NORTHING | EASTING |
|---|---|---|---|
| DL16-1 | 369.9000 | 5506147.4624 | 338812.1063 |
| DL16-2 | 381.7000 | 5506121.9001 | 338807.3617 |
| DL16-3 | 381.8000 | 5506114.9475 | 338791.8920 |
| DL16-4 | 371.3000 | 5506085.6527 | 338787.8143 |

## -NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3) MTM Zone 16 co-ordinate system used to obtain borehole Northings and Eastings.

**GEOCRES No. 52F-55**

REVISIONS — DATE | BY | DESCRIPTION

| | | | | | |
|---|---|---|---|---|---|
| DESIGN SBP | CHK – | CODE | LOAD | DATE OCT 2017 | |
| DRAWN MFA | CHK SBP | SITE | STRUCT | DWG 1 | |

FILENAME: H:\Drafting\13000\13161\TED-13161-BHPP-DL.dwg
PLOTDATE: 10/20/2017 10:00 AM

MINISTRY OF TRANSPORTATION, ONTARIO

# Appendix B.

## Record of Borehole Sheets

# SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

**TERMINOLOGY DESCRIBING COMMON SOIL GENESIS**

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

**TERMINOLOGY DESCRIBING SOIL STRUCTURE:**

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

**RECOVERY:**

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

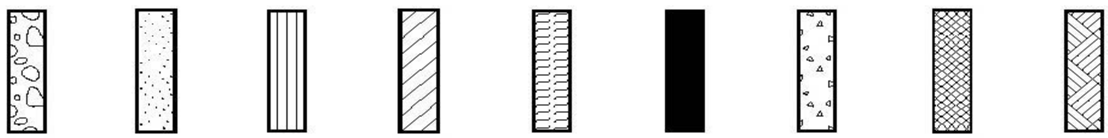
**N-VALUE:**

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

**DYNAMIC CONE PENETRATION TEST (DCPT):**

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

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



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

**TEXTURING CLASSIFICATION OF SOILS**

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

**SAMPLE TYPES**

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

**TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)**

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

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

**TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)**

| Descriptive Term | SPT “N” Value |
|---|---|
| Very Loose | Less than 4 |
| Loose | 4 – 10 |
| Compact | 10 – 30 |
| Dense | 30 – 50 |
| Very Dense | Greater than 50 |

THURBER

60 YEARS

## MODIFIED UNIFIED SOIL CLASSIFICATION

| Major Divisions | | Group Symbol | Typical Description |
|---|---|---|---|
| COARSE GRAINED SOIL | GRAVEL AND GRAVELLY SOILS | GW | Well-graded gravels or gravel-sand mixtures, little or no fines. |
| | | GP | Poorly-graded gravels or gravel-sand mixtures, little or no fines. |
| | | GM | Silty gravels, gravel-sand-silt mixtures. |
| | | GC | Clayey gravels, gravel-sand-clay mixtures. |
| | SAND AND SANDY SOILS | SW | Well-graded sands or gravelly sands, little or no fines. |
| | | SP | Poorly-graded sands or gravelly sands, little or no fines. |
| | | SM | Silty sands, sand-silt mixtures. |
| | | SC | Clayey sands, sand-clay mixtures. |
| FINE GRAINED SOILS | SILT AND CLAY SOILS $W_L < 35\%$ | ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity. |
| | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. |
| | | OL | Organic silts and organic silty-clays of low plasticity. |
| | SILT AND CLAY SOILS $35\% < W_L < 50\%$ | MI | Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts. |
| | | CI | Inorganic clays of medium plasticity, silty clays. |
| | | OI | Organic silty clays of medium plasticity. |
| | SILT AND CLAY SOILS $W_L > 50\%$ | MH | Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts. |
| | | CH | Inorganic clays of high plasticity, fat clays. |
| | | OH | Organic clays of high plasticity, organic silts. |
| HIGHLY ORGANIC SOILS | | Pt | Peat and other organic soils. |

Note - $W_L$= Liquid Limit

THURBER

# EXPLANATION OF ROCK LOGGING TERMS

## ROCK WEATHERING CLASSIFICATION

| | |
|---|---|
| Fresh (FR) | No visible signs of weathering. |
| Fresh Jointed (FJ) | Weathering limited to surface of major discontinuities. |
| Slightly Weathered (SW) | Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials. |
| Moderately Weathered (MW) | Weathering extends throughout the rock mass, but the rock material is not friable. |
| Highly Weathered (HW) | Weathering extends throughout the rock mass and the rock is partly friable. |
| Completely Weathered (CW) | Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved. |

## TERMS

| | |
|---|---|
| Total Core Recovery: (TCR) | Core recovered as a percentage of total core run length. |
| Solid Core Recovery: (SCR) | Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run. |
| Rock Quality Designation: (RQD) | Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length |
| Unconfined Compressive Strength: (UCS) | Axial stress required to break the specimen. |
| Fracture Index: (FI) | Frequency of natural fractures per 0.3 m of core run. |

## DISCONTINUITY SPACING

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

## STRENGTH CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No DL16-1



**METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 6370-14-00 | LOCATION | Hwy 17 - Dinorwic Lake Culvert | ORIGINATED BY | CM |
| HWY | 17 | BOREHOLE TYPE | Portable / NW Casing | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.07.15 - 2016.07.15 | CHECKED BY | SP |

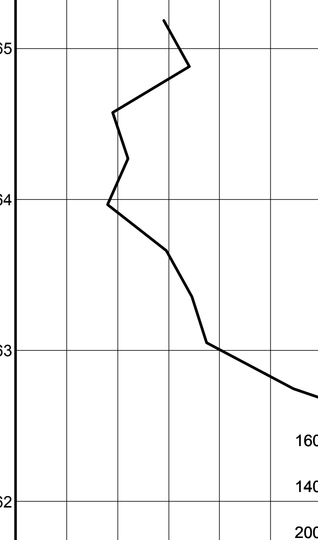
## SOIL PROFILE

| ELEV / DEPTH | DESCRIPTION |
|---|---|
| 369.9 | |
| 0.0 / 0.1 | **TOPSOIL** |
| | **CLAYEY SILT** with gravel, frequent cobbles<br>Very Dense<br>Brown |
| 369.0 / 0.9 | **SAND** with Silt to **SAND**<br>Compact<br>Brown<br>-Frequent Cobbles |
| 365.5 / 4.4 | Inferred **SAND**<br>- unable to advance casing, switch to DCPT below 4.4 m |
| 361.7 / 8.2 | - End of DCPT at 8.2 m<br>End of Borehole<br>SPT Testing was completed with half weight hammer. Reported "N" values are blow per 300 mm penetration using the half weight hammer |

## SAMPLES

| NUMBER | TYPE | "N" VALUES | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|
| 1 | SS | 96 | |
| 2 | SS | 24 | |
| 3 | SS | 21 | 0 95 5 (SI+CL) |
| 4 | SS | 59 | |
| 5 | SS | 25 | |
| 6 | SS | 51 | 7 92 1 (SI+CL) |

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (369, 368, 367, 366, 365, 364, 363, 362); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT $w_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $w_L$; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.




+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No DL16-2



**METRIC**

GWP# 6370-14-00 | LOCATION Hwy 17 - Dinorwic Lake Culvert | ORIGINATED BY CM

HWY 17 | BOREHOLE TYPE HSA / H casing with Truckmount CME 850 | COMPILED BY JM

DATUM Geodetic | DATE 2016.07.18 - 2016.08.20 | CHECKED BY SP

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 381.7 | | | | | | | |
| 0.0 / 0.1 | **ASPHALT** | | | | | | |
| | SILTY SAND with gravel, frequent cobbles and boulders, Compact to Very Dense, Brown, **FILL** | 1 | SS | 54 | | ○ (~2) | 34 53 13 (SI+CL) |
| | | | | | 381 | | |
| | | 2 | SS | 100 | | ○ (~2) | |
| | - boulder from 0.9m to 1.5m | | | | | | |
| | | | | | 380 | | |
| | - boulder from 1.8m to 2.1m | | | | | | |
| | - boulder from 2.3m to 2.6m | | | | | | |
| | | | | | 379 | | |
| | | 3 | SS | 21 | | ○ (~6) | |
| | | | | | 378 | | |
| | | | | | 377 | | |
| | | 4 | SS | 35 | | | |
| | - boulder from 5.2m to 5.5m | | | | | | |
| | | | | | 376 | | |
| | - boulder from 5.8m to 5.9m | | | | | | |
| | - boulder from 6.1m to 6.4m | | | | | | |
| | - boulder from 6.5m to 6.9m | | | | | | |
| | - boulder from 7.0m to 7.3m | | | | | | |
| | | | | | 375 | | |
| | - boulder from 7.5m to 7.8m | | | | | | |
| | - boulder from 7.9m to 8.4m | | | | | | |
| | | | | | 374 | | |
| 373.3 / 8.4 | CLAY with sand, trace gravel, Stiff to Very Stiff, Grey, **FILL** | | | | | | |
| | | | | | 373 | | |
| | | 5 | SS | 16 | | ○ (~12) | |
| | | | | | 372 | | |

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; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 9/12/16

Ministry of Transportation
Ontario

THURBER

# RECORD OF BOREHOLE No DL16-2



**METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 6370-14-00 | LOCATION | Hwy 17 - Dinorwic Lake Culvert | ORIGINATED BY | CM |
| HWY | 17 | BOREHOLE TYPE | HSA / H casing with Truckmount CME 850 | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.07.18 - 2016.08.20 | CHECKED BY | SP |

Continued From Previous Page

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | SHEAR STRENGTH kPa | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY with sand, trace gravel<br>Stiff to Very Stiff<br>Grey<br>**FILL** | | | | 371 | | | | | | |
| | | 6 | SS | 17 | | | wP ~29, w ~31, wL ~31 | 6 | 24 | 38 | 32 |
| 370.1<br>11.6 | **CLAY (CH)**<br>Firm to Stiff<br>Grey<br>Wet | | | | 370 | | | | | | |
| | | 7 | SS | 7 | 369 | | w ~42 | | | | |
| | | 8 | SS | 13 | 368 | | wP ~20, w ~30, wL ~62 | 0 | 0 | 33 | 67 |
| | | | | | 367 | | | | | | |
| | | 9 | SS | 3 | 366 | Field vane ~106 | w ~45 | | | | |
| | | 10 | SS | 9 | 365 | | w ~42 | | | | |
| 364.0<br>17.7 | **SILTY SAND** some gravel<br>Compact<br>Grey<br>Wet | | | | 364 | | | | | | |
| | | 11 | SS | 23 | 363 | | w ~19 | | | | |
| | | | | | 362 | | | | | | |

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 9/12/16

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No DL16-2



**METRIC**

GWP# 6370-14-00 LOCATION Hwy 17 - Dinorwic Lake Culvert ORIGINATED BY CM

HWY 17 BOREHOLE TYPE HSA / H casing with Truckmount CME 850 COMPILED BY JM

DATUM Geodetic DATE 2016.07.18 - 2016.08.20 CHECKED BY SP

| ELEV DEPTH | SOIL PROFILE DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) 20 40 60 80 100 | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT w / LIQUID LIMIT $w_L$ — WATER CONTENT (%) 20 40 60 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Continued From Previous Page | | | | | | | | | | |
| 361.3 | | | 12 | SS | 25 | | | | ○ (approx. 19) | | 12 56 32 (SI+CL) |
| 20.4 | - End of borehole at 20.4 m | | | | | | | | | | |

+ ³, × ³: Numbers refer to Sensitivity

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

ONTMT4S 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 9/12/16

# RECORD OF BOREHOLE No DL16-3



**METRIC**

| | | | |
|---|---|---|---|
| GWP# 6370-14-00 | LOCATION Hwy 17 - Dinorwic Lake Culvert | | ORIGINATED BY TM |
| HWY 17 | BOREHOLE TYPE CME-750 HSA | | COMPILED BY JM |
| DATUM Geodetic | DATE 2016.08.21 - 2016.08.21 | | CHECKED BY SP |

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 381.8 / 0.0 | **ASPHALT** | | | | | | |
| 0.1 | SAND some gravel, trace silt, Very Dense to Loose, Brown, **FILL** | 1 | SS | 50 | | | |
| | | 2 | SS | 61 | 381 | | |
| 380.7 / 1.1 | SILTY SAND some gravel, Very Loose to Dense, Brown to Grey, **FILL** | 3 | SS | 29 | 380 | | |
| | | 4 | SS | 40 | 379 | | |
| | | 5 | SS | 20 | 378 | | |
| | | 6 | SS | 27 | 377 | | 12 45 26 17 |
| | | | | | 376 | | |
| | | 7 | SS | 3 | 375 | | |
| 374.5 / 7.3 | CLAY with sand, Firm to Very Stiff, Grey, **FILL** | 8 | SS | 6 | 374 | | 0 30 37 33 |
| | | | | | 373 | | |
| | | 9 | SS | 42 | 372 | | |

Column headings: SOIL PROFILE; STRAT PLOT; 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

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 DL16-3



**METRIC**

GWP# 6370-14-00 | LOCATION Hwy 17 - Dinorwic Lake Culvert | ORIGINATED BY TM

HWY 17 | BOREHOLE TYPE CME-750 HSA | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.21 - 2016.08.21 | CHECKED BY SP

Continued From Previous Page

| ELEV / DEPTH | DESCRIPTION |
|---|---|
| 370.2 / 11.6 | **CLAY (CH to CL)** Stiff to Very Stiff, Grey, Wet |
| 362.9 / 18.9 | **SILTY SAND** some gravel, Compact, Grey, Wet |

| NUMBER | TYPE | "N" VALUES | GR | SA | SI | CL |
|---|---|---|---|---|---|---|
| 10 | SS | 47 | | | | |
| 11 | SS | 21 | | | | |
| 12 | SS | 11 | 0 | 0 | 28 | 72 |
| 13 | SS | 8 | | | | |
| 14 | SS | 7 | | | | |
| 15 | SS | 11 | 0 | 6 | 62 | 32 |

Elevation scale: 371, 370, 369, 368, 367, 366, 365, 364, 363, 362

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No DL16-3



**METRIC**

GWP# 6370-14-00 | LOCATION Hwy 17 - Dinorwic Lake Culvert | ORIGINATED BY TM

HWY 17 | BOREHOLE TYPE CME-750 HSA | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.21 - 2016.08.21 | CHECKED BY SP

| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) 20 40 60 80 100 | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) 20 40 60 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Continued From Previous Page | | | | | | | | | | |
| | - Flowing Sand, unable to continue sampling | | | | | | 361 | | | | |
| 360.5<br>21.3 | - End of borehole at 21.3 m due to flowing sand<br>- Sand rose 3.7 m inside augers | | | | | | | | ○ | | |

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

# RECORD OF BOREHOLE No DL16-4



**METRIC**

GWP# 6370-14-00 | LOCATION Hwy 17 - Dinorwic Lake Culvert | ORIGINATED BY CM

HWY 17 | BOREHOLE TYPE HSA / CME Trackmount | COMPILED BY JM

DATUM Geodetic | DATE 2016.07.14 - 2016.07.14 | CHECKED BY SP

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 371.3 | | | | | | |
| 0.0 / 0.1 | **TOPSOIL** | | | | | |
| 0.2 | **SANDY SILT** with organics, very loose, brown | 1 | SS | 17 | 371 | |
| | **SAND** with silt and gravel, loose to very loose, brown | 2 | SS | 9 | 370 | |
| | | 3 | SS | 9 | 369 | |
| | | 4 | SS | 3 | | |
| | | 5 | SS | 11 | 368 | 24 65 11 (SI+CL) |
| 367.2 / 4.1 | **CLAY (CI)** with occasional silt seams, Very Stiff to Stiff, moist to wet, grey | | | | 367 | |
| | | 6 | SS | 7 | 366 | |
| | | 7 | SS | WH | 365 | 0 0 48 52 |
| | | | | | 364 | |
| | | 8 | SS | 2 | 363 | |
| | | 9 | SS | 1 | 362 | |

Dynamic cone penetration resistance plot / Shear strength kPa (20, 40, 60, 80, 100): field vane values with sensitivity 4.3, 2.3, 3.8, 4.2.

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. Water content (%) 20, 40, 60; Plastic limit $w_P$, Natural moisture content $w$, Liquid limit $w_L$. Unit weight γ kN/m³.

Continued Next Page

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

ONTMT4S 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 9/12/16

# RECORD OF BOREHOLE No DL16-4



**METRIC**

| | | | | | |
|---|---|---|---|---|---|
| GWP# | 6370-14-00 | LOCATION | Hwy 17 - Dinorwic Lake Culvert | ORIGINATED BY | CM |
| HWY | 17 | BOREHOLE TYPE | HSA / CME Trackmount | COMPILED BY | JM |
| DATUM | Geodetic | DATE | 2016.07.14 - 2016.07.14 | CHECKED BY | SP |

| ELEV / DEPTH | DESCRIPTION (SOIL PROFILE) | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|
| | Continued From Previous Page | | | | | | | | |
| 361.1 | | | | | | | | | |
| 10.2 | **SANDY SILT** Very Loose Grey | | | | | 361 | | | |
| | | 10 | SS | 1 | | | ~19 | | |
| | | | | | | 360 | | | |
| 359.6 / 11.7 | **SILTY SAND** loose grey | | | | | 359 | | | |
| | | 11 | SS | 6 | | | ~17 | | 0 84 16 (SI+CL) |
| 358.5 / 12.8 | End of borehole at 12.8 m due to flowing sand. Water at 2.31 m below ground surface on July 15, 2016 | | | | | | | | |

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

# Appendix C.

# Laboratory Testing

# Appendix C.1

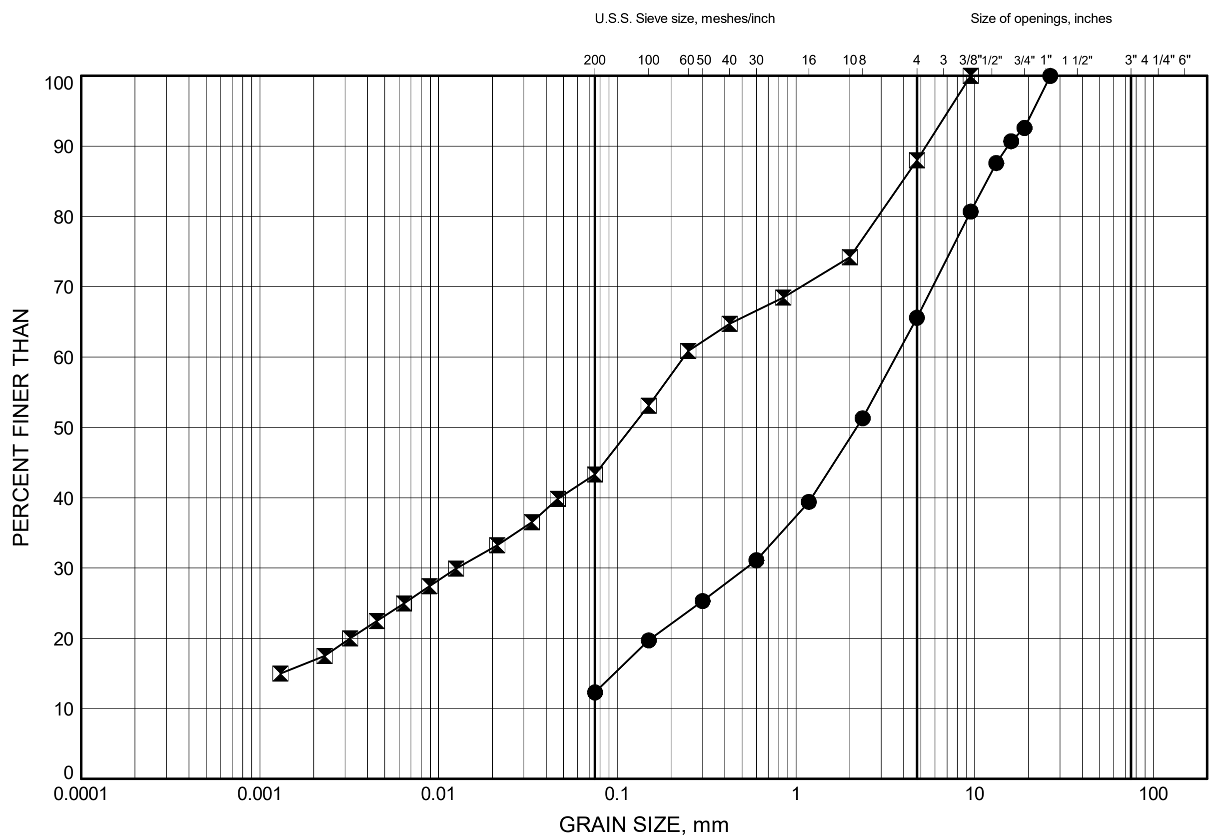
## Particle Size Analysis Figures

Hwy 17 - Dinorwic Lake Culvert

# GRAIN SIZE DISTRIBUTION

FIGURE C1

## Sand FILL




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | DL16-2 | 0.51 | 381.19 |
| ⧗ | DL16-3 | 4.88 | 376.92 |

GRAIN SIZE DISTRIBUTION - THURBER 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 7/12/16

Date December 2016

GWP# 6370-14-00

THURBER

Prep'd JM

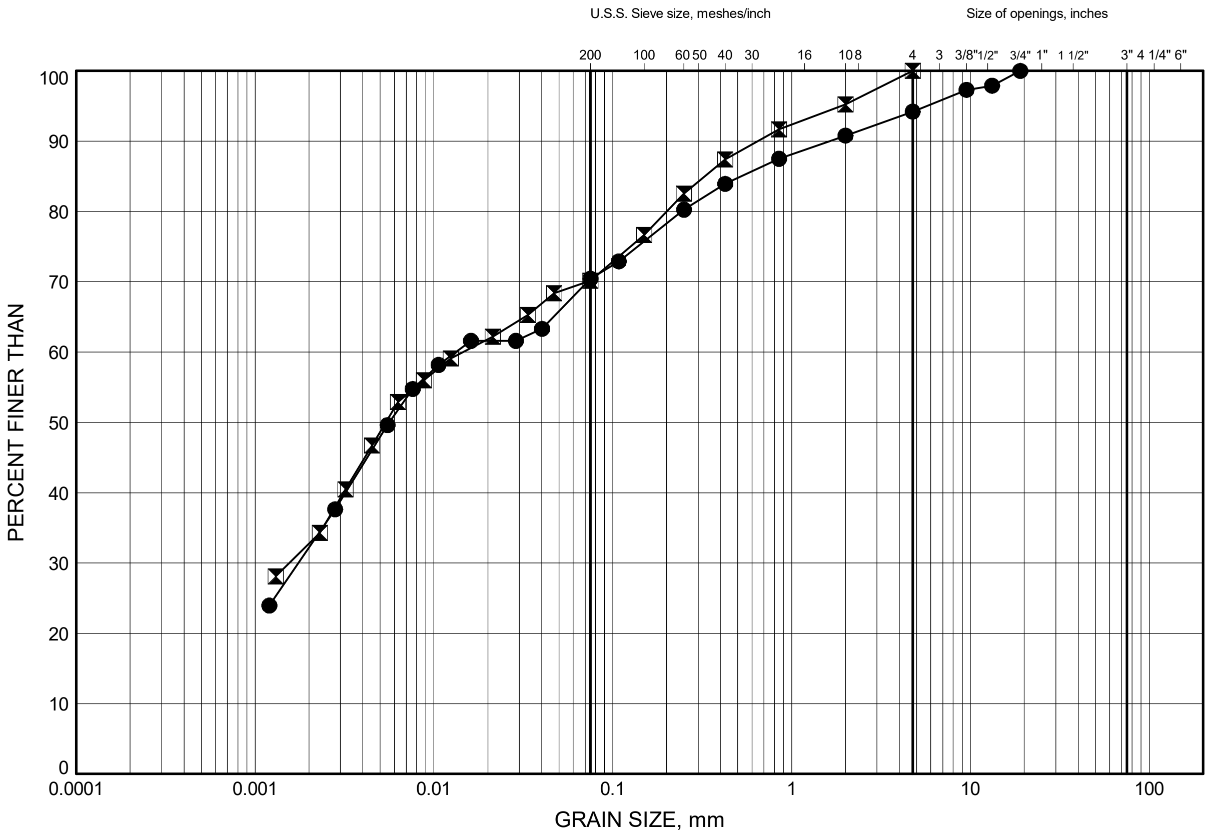
Chkd. SP

Hwy 17 - Dinorwic Lake Culvert

# GRAIN SIZE DISTRIBUTION

FIGURE C2

## Clay FILL




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | DL16-2 | 10.97 | 370.73 |
| ⧗ | DL16-3 | 7.92 | 373.88 |



Date October 2016

GWP# 6370-14-00

THURBER

Prep'd ..................

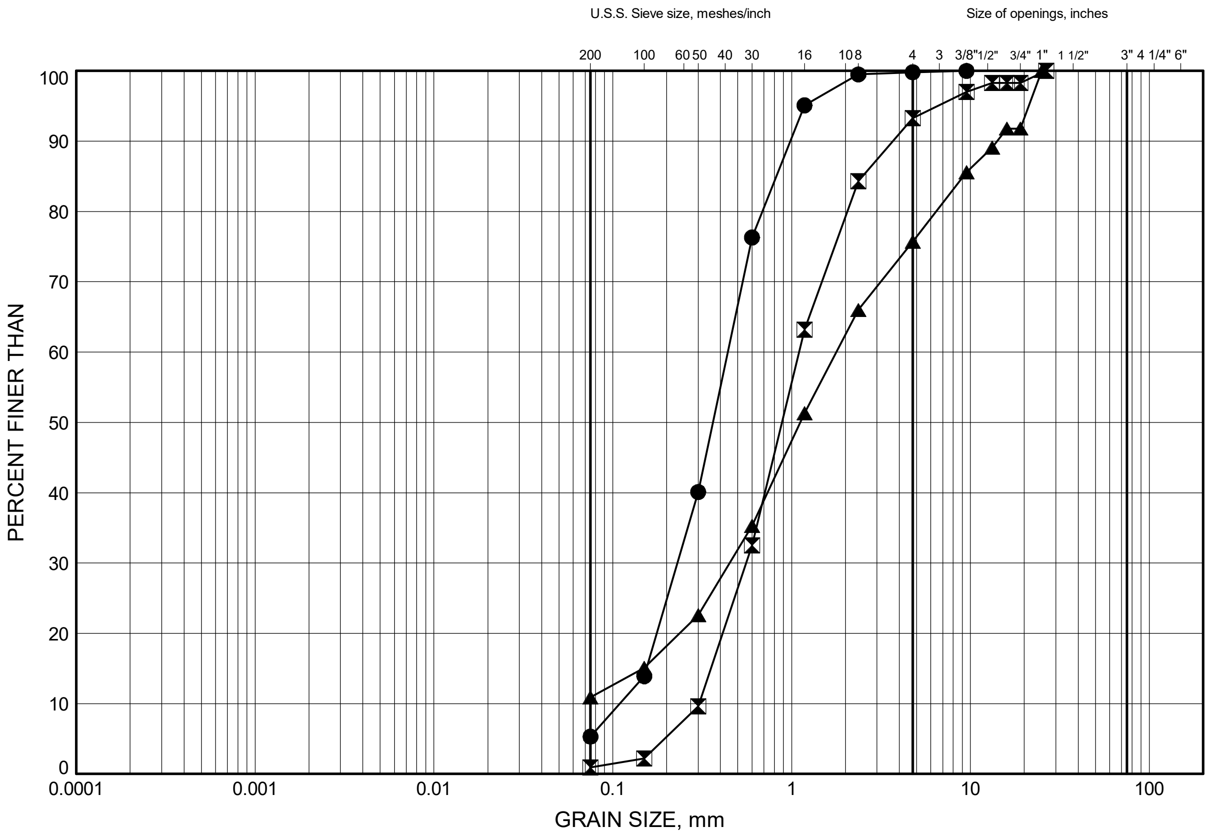
Chkd. ..................

Hwy 17 - Dinorwic Lake Culvert

# GRAIN SIZE DISTRIBUTION

FIGURE C3

## SAND to SAND with SILT




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | DL16-1 | 1.83 | 368.08 |
| ⧗ | DL16-1 | 4.11 | 365.80 |
| ▲ | DL16-4 | 3.35 | 367.97 |

Date December 2016

GWP# 6370-14-00

THURBER

Prep'd JM

Chkd. SP

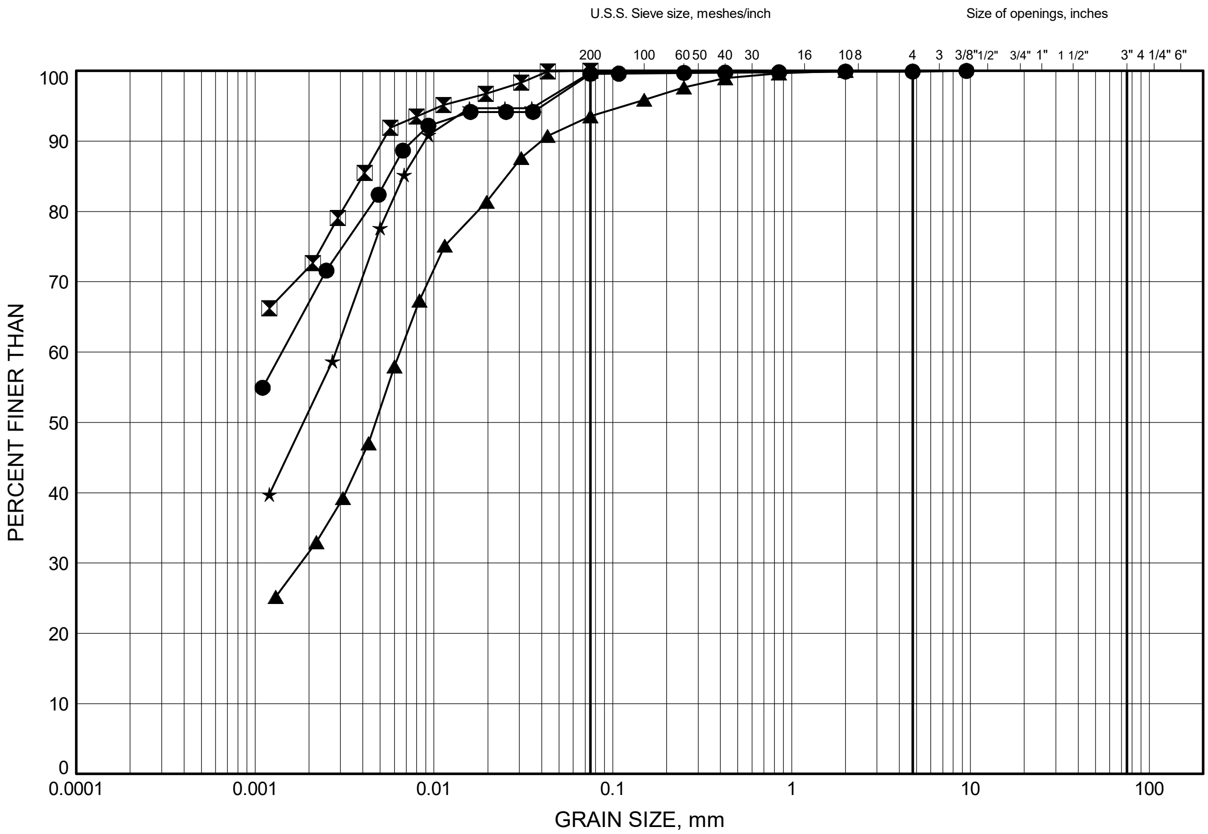
GRAIN SIZE DISTRIBUTION - THURBER 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 7/12/16

Hwy 17 - Dinorwic Lake Culvert

# 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) |
|---|---|---|---|
| ● | DL16-2 | 14.02 | 367.68 |
| ⧗ | DL16-3 | 14.02 | 367.78 |
| ▲ | DL16-3 | 18.59 | 363.21 |
| ★ | DL16-4 | 6.40 | 364.92 |

Date December 2016

GWP# 6370-14-00

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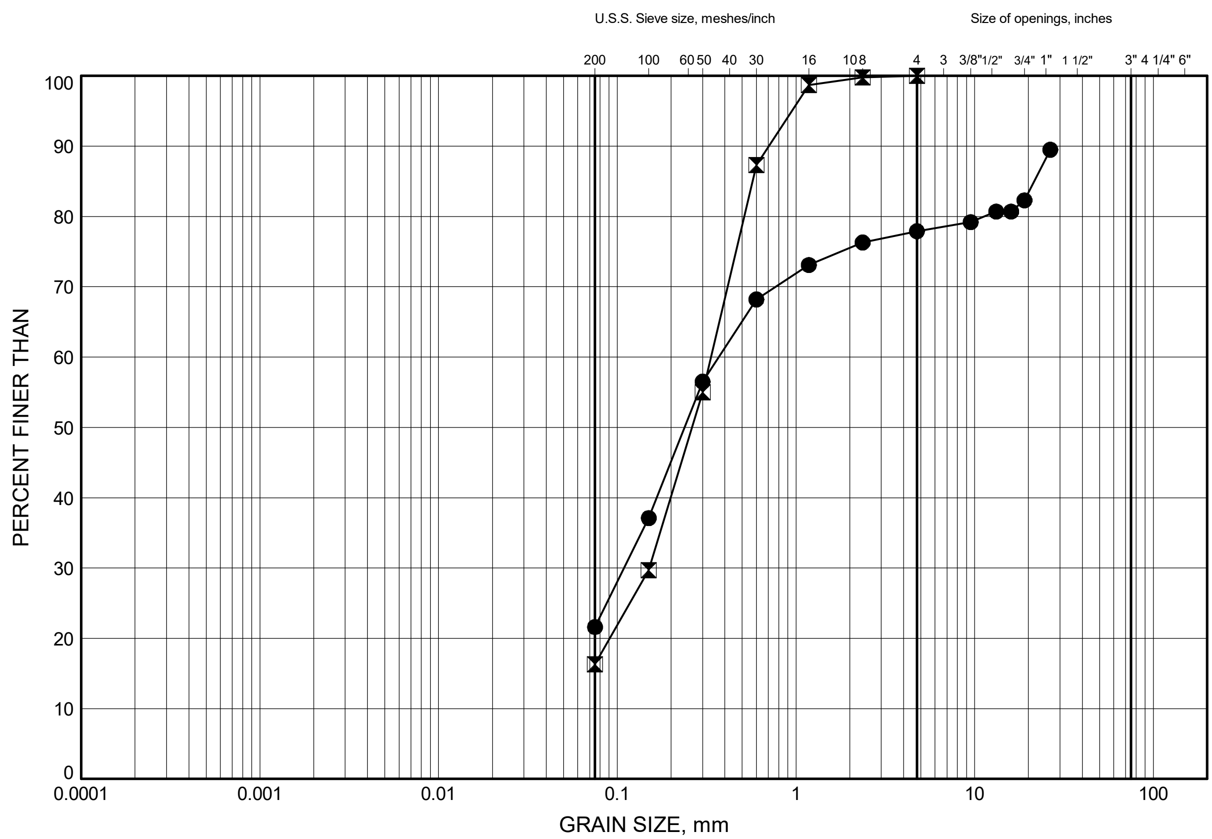
Hwy 17 - Dinorwic Lake Culvert

# GRAIN SIZE DISTRIBUTION

FIGURE C5

## Silty SAND




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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | DL16-2 | 20.12 | 361.58 |
| ⧗ | DL16-4 | 12.50 | 358.82 |

Date December 2016

GWP# 6370-14-00

THURBER

Prep'd JM

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## Appendix C.2

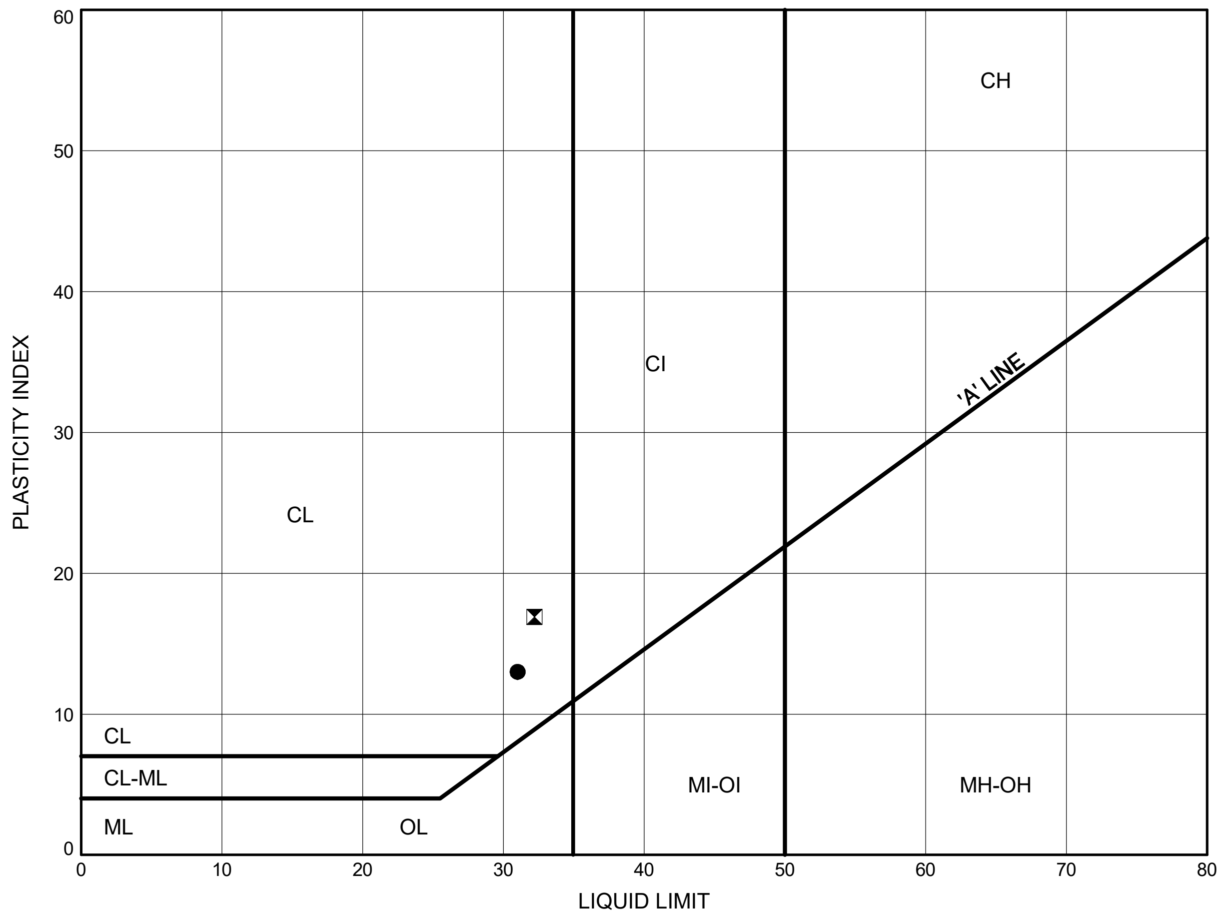
## Atterberg Limit Analysis Figures

Hwy 17 - Dinorwic Lake Culvert

# ATTERBERG LIMITS TEST RESULTS

FIGURE C6

## Clay FILL




LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | DL16-2 | 10.97 | 370.73 |
| ⧗ | DL16-3 | 7.92 | 373.88 |

Date December 2016

GWP# 6370-14-00

THURBER

Prep'd JM

Chkd. SP

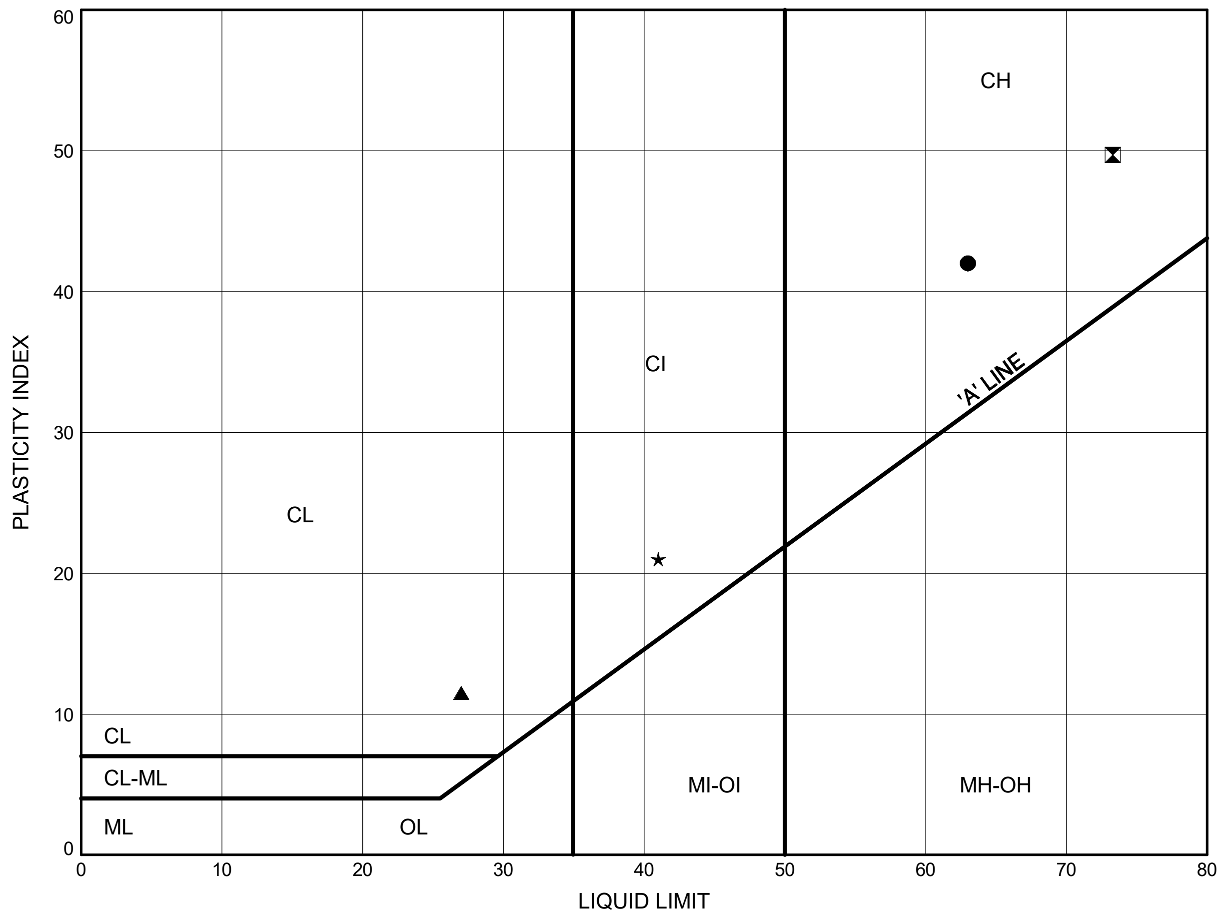
THURBALT 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 7/12/16

Hwy 17 - Dinorwic Lake Culvert

# ATTERBERG LIMITS TEST RESULTS

FIGURE C7

## CLAY




## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|---|---|---|---|
| ● | DL16-2 | 14.02 | 367.68 |
| ⧗ | DL16-3 | 14.02 | 367.78 |
| ▲ | DL16-3 | 18.59 | 363.21 |
| ★ | DL16-4 | 6.40 | 364.92 |

Date December 2016

GWP# 6370-14-00

THURBER

Prep'd JM

Chkd. SP

THURBALT 13161 HWY 17 DINORWIC LAKE CULVERT.GPJ 7/12/16

# Appendix C.3

# Analytical Testing Results

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

| | |
|---|---|
| **CLIENT NAME:** | **THURBER ENGINEERING LTD**<br>**SUITE 103, 2010 WINSTON PARK DRIVE**<br>**OAKVILLE, ON L6H5R7**<br>**(905) 829-8666** |
| **ATTENTION TO:** | **WEISS MEHDAWI** |
| **PROJECT:** | **13161** |
| **AGAT WORK ORDER:** | **16T139309** |
| **SOIL ANALYSIS REVIEWED BY:** | **Amanjot Bhela, Inorganic Coordinator** |
| **DATE REPORTED:** | **Sep 27, 2016** |
| **PAGES (INCLUDING COVER):** | **5** |
| **VERSION*:** | **1** |

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

**All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.**

# Certificate of Analysis

**AGAT WORK ORDER: 16T139309**
**PROJECT: 13161**

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

**CLIENT NAME: THURBER ENGINEERING LTD**

**ATTENTION TO: WEISS MEHDAWI**

**SAMPLING SITE:**

**SAMPLED BY:**

## Corrosivity Package

**DATE RECEIVED: 2016-09-20**

**DATE REPORTED: 2016-09-27**

| Parameter | Unit | G / S | RDL | DL-3/SS7 (20-22') | DL-3/SS9 (30-32') | MK-2/SS7 (20-22') | MK-3/SS8 (25-27') |
|---|---|---|---|---|---|---|---|
| SAMPLE DESCRIPTION: | | | | DL-3/SS7 (20-22') | DL-3/SS9 (30-32') | MK-2/SS7 (20-22') | MK-3/SS8 (25-27') |
| SAMPLE TYPE: | | | | Soil | Soil | Soil | Soil |
| DATE SAMPLED: | | | | 8/16/2016 | 8/16/2016 | 8/16/2016 | 8/16/2016 |
| | | | | 7859856 | 7860180 | 7860181 | 7860182 |
| Sulphide | % | | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Chloride (2:1) | µg/g | | 2 | 313 | 320 | 446 | 45 |
| Sulphate (2:1) | µg/g | | 2 | 92 | 19 | 8 | 7 |
| pH (2:1) | pH Units | | NA | 8.67 | 7.90 | 7.57 | 8.17 |
| Electrical Conductivity (2:1) | mS/cm | | 0.005 | 0.767 | 0.645 | 0.803 | 0.231 |
| Resistivity (2:1) | ohm.cm | | 1 | 1300 | 1550 | 1250 | 4330 |
| Redox Potential (2:1) | mV | | 5 | 212 | 243 | 254 | 242 |

**Comments:** RDL - Reported Detection Limit; G / S - Guideline / Standard

**7859856-7860182** EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
Please note that samples were analyzed past hold time.

Certified By: Amanjot Bhela

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

# Quality Assurance

**CLIENT NAME: THURBER ENGINEERING LTD** | **AGAT WORK ORDER: 16T139309**

**PROJECT: 13161** | **ATTENTION TO: WEISS MEHDAWI**

**SAMPLING SITE:** | **SAMPLED BY:**

## Soil Analysis

| RPT Date: Sep 27, 2016 | | | DUPLICATE | | | | REFERENCE MATERIAL | | | METHOD BLANK SPIKE | | | MATRIX SPIKE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | Batch | Sample Id | Dup #1 | Dup #2 | RPD | Method Blank | Measured Value | Acceptable Limits Lower | Acceptable Limits Upper | Recovery | Acceptable Limits Lower | Acceptable Limits Upper | Recovery | Acceptable Limits Lower | Acceptable Limits Upper |
| **Corrosivity Package** | | | | | | | | | | | | | | | |
| Sulphide | 7859856 | 7859856 | < 0.05 | < 0.05 | NA | < 0.05 | 100% | 80% | 120% | NA | | | NA | | |
| Chloride (2:1) | 7862971 | | <2 | <2 | NA | < 2 | 93% | 80% | 120% | 98% | 80% | 120% | 99% | 70% | 130% |
| Sulphate (2:1) | 7862971 | | 23 | 24 | 4.3% | < 2 | 92% | 80% | 120% | 96% | 80% | 120% | 98% | 70% | 130% |
| pH (2:1) | 7862971 | | 7.49 | 7.46 | 0.4% | NA | 101% | 90% | 110% | NA | | | NA | | |
| Electrical Conductivity (2:1) | 7861508 | | 1.32 | 1.32 | 0.0% | < 0.005 | 99% | 90% | 110% | NA | | | NA | | |
| Redox Potential (2:1) | 7861508 | | 88 | 88 | 0.0% | < 5 | 102% | 70% | 130% | NA | | | NA | | |

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By: Amanjot Bhela

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# Method Summary

**CLIENT NAME: THURBER ENGINEERING LTD** | **AGAT WORK ORDER: 16T139309**

**PROJECT: 13161** | **ATTENTION TO: WEISS MEHDAWI**

**SAMPLING SITE:** | **SAMPLED BY:**

| PARAMETER | AGAT S.O.P | LITERATURE REFERENCE | ANALYTICAL TECHNIQUE |
|---|---|---|---|
| **Soil Analysis** | | | |
| Sulphide | MIN-200-12025 | ASTM E1915-09 | GRAVIMETRIC |
| Chloride (2:1) | INOR-93-6004 | McKeague 4.12 & SM 4110 B | ION CHROMATOGRAPH |
| Sulphate (2:1) | INOR-93-6004 | McKeague 4.12 & SM 4110 B | ION CHROMATOGRAPH |
| pH (2:1) | INOR 93-6031 | MSA part 3 & SM 4500-H+ B | PH METER |
| Electrical Conductivity (2:1) | INOR-93-6036 | McKeague 4.12, SM 2510 B | EC METER |
| Resistivity (2:1) | INOR-93-6036 | McKeague 4.12, SM 2510 B,SSA #5 Part 3 | CALCULATION |
| Redox Potential (2:1) | | McKeague 4.12 & SM 2510 B | REDOX POTENTIAL ELECTRODE |

# Appendix D.

## Site Photographs

**Photo 1. Looking toward culvert inlet.**

**Photo 2. Looking toward culvert outlet.**

**Photo 3. Looking downslope toward culvert inlet.**

**Photo 4. Looking downslope toward culvert outlet.**

**Photo 5. Looking east along Highway 17.**

**Photo 6. Looking west along Highway 17.**

# Appendix E.

# Foundation Comparison

## COMPARISON OF ALTERNATIVE FOUNDATION TYPES

| | ***Closed Box Culvert*** | ***Circular Pipe Culvert (with Trenchless Installation)*** | ***Open Bottom Culvert*** |
|---|---|---|---|
| *Advantages* | i. Relatively expedient installation if precast units are used.<br>ii. Smaller magnitude of settlement than open footing culvert due to lower bearing stresses on subgrade. | i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts.<br>ii. Avoids open cut<br>iii. Possibly allows two directions of traffic to be maintained throughout construction | i. Relatively expedient installation if precast units are used. |
| *Disadvantages* | i. Requires large excavation and roadway protection<br>ii. Requires compacted granular pad on subgrade.<br>iii. Requires installation of a temporary by-pass culvert to maintain existing creek alignment | i. Requires construction of entry and exit pits and access to toes of slope.<br>ii. Requires specialized construction equipment<br>iii. Feasibility also depends on flow capacity and other hydraulic properties.<br>iv. Obstructions in fill mean many techniques not feasible<br>v. Mixed soil face conditions | i. Requires deeper excavation increasing excavation volume and dewatering concern<br>ii. Founding subgrade will provide lower geotechnical resistances.<br>iii. Potential for post construction settlement. |
| *Risks/ Consequences* | i. Groundwater control may require sheet pile enclosed excavation | i. Groundwater control may require sheet pile enclosed excavation<br>ii. Possibility of encountering obstructions | i. Groundwater control may require sheet pile enclosed excavation<br>ii. Increased risk of basal instability of footing excavation due to depth of excavation below water table |
| | **Recommended** | **High Risk / Not Recommended** | **Not Feasible** |

# 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

October 21, 2016

Site: 49.6917 N, 92.5286 W      User File Reference: Dinorwic Lake Culvert

Requested by: ,

**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)** |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.060 | 0.081 | **0.072** | 0.057 | **0.040** | **0.019** | **0.0078** | **0.0015** | **0.0007** | **0.044** | **0.028** |

**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) | 0.0022 | 0.015 | 0.029 |
| Sa(0.1) | 0.0037 | 0.022 | 0.042 |
| Sa(0.2) | 0.0043 | 0.022 | 0.039 |
| Sa(0.3) | 0.0038 | 0.018 | 0.031 |
| Sa(0.5) | 0.0027 | 0.013 | 0.022 |
| Sa(1.0) | 0.0011 | 0.0057 | 0.011 |
| Sa(2.0) | 0.0005 | 0.0022 | 0.0041 |
| Sa(5.0) | 0.0002 | 0.0005 | 0.0008 |
| Sa(10.0) | 0.0001 | 0.0003 | 0.0005 |
| PGA | 0.0020 | 0.012 | 0.022 |
| PGV | 0.0013 | 0.0076 | 0.014 |


**References**

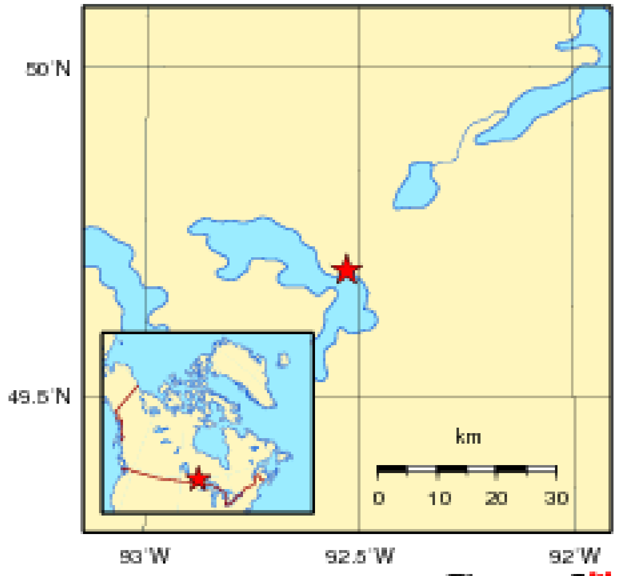
**National Building Code of Canada 2015 NRCC no. 56190;**
**Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

**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, Draft NSSPs**

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

   - OPSS.PROV 206
   - OPSS 422
   - OPSS.PROV 501
   - OPSS.PROV 517
   - OPSS.PROV 539
   - OPSS.PROV 804
   - OPSS 902
   - OPSS.PROV 1010
   - OPSS.PROV 1205

   - OPSD 208.010
   - OPSD 803.010
   - OPSD 810.010
   - OPSD 3101.150

2. Suggested text for NSSP on "Protection of Sensitive Foundation Soils"

   The Contractor is advised that the soil 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 mud slab placed between the native subgrade and granular bedding.

3. Suggested text for NSSP on "Obstructions"

   Excavation or installation of sheet piled protection system could encounter obstructions such as cobbles or boulders. Such obstructions may impede excavation and sheet pile installation and prohibit reaching the designed installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the sheet piles to the design depths.

4. Suggested text for NSSP on "Dewatering"

   The excavation will extend below the groundwater level and could lead to instability and sloughing of the sides of the excavation and heaving of the base, accompanied by loss of geotechnical resistance of the soils. Appropriate means of dewatering must be implemented to depress the groundwater level sufficiently below the base of the excavation to prevent any instability, sloughing, or heaving and so as to preserve the stability of the excavation and to allow the culvert subgrade preparation work to proceed in the dry. Temporary dewatering measures will be required to remain operation during construction until the culvert is installed and backfilled.