



THURBER ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF STRUCTURAL CULVERT No. 41S-138/C
McKENZIE CREEK CROSSING OF HIGHWAY 17
TOWNSHIP OF SOUTHWORTH
G.W.P. 6369-14-00
AGREEMENT NUMBER: 4015-E-0015**

GEOCRES NUMBER: 52F-56

SUBMITTED TO

**McINTOSH PERRY CONSULTING ENGINEERS LTD. / LEA CONSULTING LTD.
JOINT VENTURE**

LOCATION:

LATITUDE : 49.6860°

LONGITUDE: -92.4925

October 2017

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of the McKenzie Creek Culvert located on Highway 17, within the Township of Southworth, Ontario. Thurber carried out the investigation as a subconsultant to McIntosh Perry Consulting Engineers Ltd. – Lea Consulting Ltd. Joint Venture (MPCE-LEA) as part of Agreement No. 4015-E-0015.

General Arrangement (GA) drawings and base plan mapping were provided by MPCE-LEA for the preparation of this report.

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

2 SITE DESCRIPTION

Culvert 41S-138/C is located on Highway 17, approximately 1.1 km east of the Highway 72 / Highway 17 junction near the town of Dinorwic, Ontario. The location of the culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

The existing culvert is a cast-in-place, concrete box culvert with an internal height of 1.5 m, a span of 4.8 m and an approximate length of 55 m, that carries McKenzie Creek flow from east to west below the highway. The General Arrangement Drawing dated September 2017 indicates that the culvert invert ranges from Elevation 367.48 m at the inlet to 364.46 m at the outlet.

It is noted that for project orientation purposes, Highway 17 within the project limits, will be assumed to run north-south.

At this location, Highway 17 is undivided with one through lane in each direction with paved shoulders. A steel beam guide rail system is located along the east side of the highway while a cable wire guide rail system is present along the west side.

The culvert is located within a high fill section with a maximum height of the road embankment from shoulder to the top of the culvert of approximately 6.9 m. The embankment slopes are covered with a mixture of brush and granular material. The west side of the embankment slopes down at approximately 2.5H:1V (Horizontal:Vertical). The east side of the embankment includes a 10.2 m wide bench sloped at approximately 10H:1V; the upper and lower slopes are approximately 2H:1V. Based on the drawings provided by MPCE-LEA the elevation of the center

line of roadway was reported to be approximately 376.6 m. and the elevation of the culvert at the inlet and outlet was noted as 369.72 m and 369.70 m respectively.

An intersection with a side road is present on the east side of Highway 17, approximately 60 m north of the culvert and private entrances are present within 100 m to the north and south of the site.

The lands surrounding the project limits include forest and swampy areas. The storm water drainage in the area is to existing culverts and ditches.

Site photographs showing the general site conditions are presented in Appendix D.

3 SITE INVESTIGATION

3.1 Field Investigation

The field investigation was carried out between July 2016, and October 2016 and included advancing four boreholes. The approximate locations and elevations of the boreholes are shown on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

Table 3-1: Borehole Summary

Borehole	Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Depth (m)
16-1	Culvert outlet	5505441.3	341344.4	367.1	11.1
16-2	Highway 17	5505465.5	341400.6	376.6	20.4
16-3	Highway 17	5505445.1	341396.2	376.7	20.4
16-4	Culvert inlet	5505466.5	341428.7	370.1	14.3

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

The boreholes through the roadway embankment were advanced with a CME750 rubber tire buggy mounted drill rig. The inlet borehole was advanced with a CME45 track mount drill rig while the outlet borehole was advanced with portable drilling equipment from a raft platform using a full weight hammer and tripod.

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

The boreholes were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903. Boreholes advanced within paved areas were capped with 150 mm of cold patch asphalt.

3.2 LABORATORY TESTING

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

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

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on two soil samples. A copy of the chemical analysis results is provided in Appendix C.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Overview / General

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

For reference, the stratigraphy in the area of the boreholes is characterized by embankment fill, overlying clay overlying silt.

More detailed descriptions of the individual strata are presented below.

4.2 Fill

Fill – Gravel with silt and sand

A fill layer consisting predominantly of gravel and sand was encountered at the ground surface of Boreholes MK16-2 and MK16-3. The top of this layer ranges from Elevation 376.6 m to 376.7 m. The thickness of the layer ranged from 3.0 m to 3.8 m. The SPT 'N' values ranged from 15 to 73, indicating a compact to very dense condition. Cobbles were noted in this layer.

The moisture content of the samples tested ranged from 1% to 5%. The results of grain size analysis tests indicated a gravel content ranging from 46% to 56%, sand content from 38% to 45%, and a fines content (combined silt and clay size particles) from 6% to 9%. Grain size analysis results are illustrated on Figure 1 in Appendix C.

Fill – Clay with silt

A fill layer consisting predominantly of clay and silt was encountered below the gravel fill in Boreholes MK16-2 and MK16-3 and at the ground surface in Borehole MK16-4. The top of this layer ranges from Elevation 370.1 m to 373.6 m. The thickness of the layer ranged from 2.3 m to 4.0 m. The SPT 'N' values ranged from 2 to 33, indicating a soft to hard consistency; but typically firm.

The moisture content of the samples tested ranged from 24% to 41%. The results of grain size analysis tests indicated a gravel content of 0%, sand content of 4%, a silt content ranging from 40% to 41% and a clay content from 55% to 56%. Grain size analysis results are illustrated on Figure 2 in Appendix C.

The results of Atterberg Limits testing completed on samples of this material indicated a liquid limit ranging from 48 to 51, a plastic limit of 20, and a plasticity index from 28 to 31. Atterberg Limits analysis results are illustrated on Figure 3 in Appendix C. The test results indicate clay of medium to high plasticity (CI, CH).

4.3 Clay

A clay deposit with silt was encountered beneath the fill materials in all boreholes except Borehole MK16-1 where it was encountered at the ground surface. The clay can generally be characterized as having medium sensitivity.

The top of this layer ranges from Elevation 369.6 m to 367.1 m. The thickness of the layer ranged from 5.9 m to 10.7 m. In-situ shear vane test results indicated undrained shear strengths ranging from 25 kPa to 95 kPa; indicating a firm to stiff consistency, but typically stiff.

The moisture content of the samples tested ranged from 18% to 66%. The results of a grain size analysis tests indicated a gravel content of 0%, sand content ranging from 0% to 5%, a silt content ranging from 17% to 73% and a clay content from 25% to 82%. Grain size analysis results are illustrated on Figures 4 and 5 in Appendix C.

The results of Atterberg Limits testing completed on this material indicated a liquid limit ranging from 29 to 82, a plastic limit ranging from 19 to 26, and a plasticity index ranging from 10 to 58. Atterberg Limits analysis results are illustrated on Figures 6 and 7 in Appendix C. The test results indicate a clay of low to high plasticity (CL to CH); but typically, medium plasticity.

4.4 Silt

A stratum of silt was encountered beneath the clay materials in all boreholes. The top of this layer ranges from Elevation 358.3 m to 361.2 m. All boreholes were terminated in this stratum. The SPT 'N' values ranged from 6 to 27; indicating a loose to compact deposit.

The moisture content for the samples tested ranged from 14% to 63%. The results of a grain size analysis tests indicated a gravel content of 0%, sand content ranging from 0% to 5%, a silt content ranging from 80% to 92% and a clay content from 8% to 15%. Grain size analysis results are illustrated on Figure 6 in Appendix C. Atterberg Limits testing conducted on samples of this material indicated a non-plastic silt material.

4.5 Groundwater

The water level in McKenzie Creek was measured at the time of Thurber's field investigation at a depth of 1.2 m below the top of the culvert at the inlet; corresponding to an elevation of 368.5 m. The groundwater level in the area of the culvert is expected to reflect the creek water level.

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

5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and determined the ground surface elevations based on contract drawings provided by McIntosh Perry Consulting Engineers Ltd. / Lea Consulting Ltd. Joint Venture. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario and RPM Drilling of Thunder Bay, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full time basis by Christopher Murray, Nick Weil and Troy Mackinnon of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratories in Ottawa and Oakville.

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



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

This report presents the interpretation of the factual data obtained from a foundation investigation conducted by Thurber for the replacement of the McKenzie Creek culvert located on Highway 17, within the Township of Southworth, Ontario. Geotechnical assessment and recommendations are provided to assist the design team in designing a suitable foundation for the proposed replacement culverts.

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. Contractors must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

No previous foundation investigation information for the subject culvert was available. General Arrangement (GA) drawings and base plan mapping were provided by MPCE-LEA for the preparation of this report.

The following sections address geotechnical recommendations for the replacement of the existing McKenzie Creek Culvert. The discussions and recommendations presented in this report are based on the information provided by MPCE-LEA and on the factual data obtained during the course of this investigation.

6.1 Proposed Structure

Based on the September 2017 General Arrangement (GA) drawing, the existing 4.85 m x 1.53 m x 54.5 m box culvert is to be replaced with twin 3.55 m x 3.55 m x 60.0 m box culverts to be installed north of the existing alignment. The invert elevation of the new twin box culverts will be 367.48 m at the upstream end and 367.46 m at the downstream end.

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.

The south edge of the new twin box culverts will be offset 2 m from the north edge of the existing culvert.

6.2 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 version CSA S6-14 (CHBDC).

It is understood that the proposed culvert structures 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.

The frost penetration depth at this site is 2.5 m as per OPSD 3090.100.

6.3 Geotechnical Assessment

Based on the results of the field and laboratory investigation and the information provided by MPCE-LEA with regards to the proposed project requirements, the geotechnical foundation design considerations include:

- The culvert is located within a high embankment fill. The depth of excavation will require a high temporary protection system, grade lowering or a combination of both.
- The embankment is underlain by a native clay deposit which is capable of supporting shallow foundations with low to moderate bearing resistance, best suited to a closed bottom culvert structure.
- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert in the dry.

7 SEISMIC CONSIDERATIONS

7.1 Spectral and Peak Acceleration Hazard Values

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

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the site specific peak ground acceleration (PGA) of 0.028g.

7.2 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 below the founding elevation. Based on the soil conditions encountered below the anticipated culvert founding elevation, the site is classified as a Seismic Site Class E in accordance with Table 4.1 of the CHBDC.

7.3 Seismic Liquefaction

The soils beneath the anticipated founding elevation consist of soft to stiff clays and loose to compact silts, which are not considered susceptible to liquefaction under earthquake loading using the site-specific PGA value of 0.028g.

8 DESIGN OPTIONS

Culvert/foundation alternatives and construction approaches are presented and evaluated in the following sections and a preferred replacement alternative from a foundation engineering perspective is recommended.

8.1 Culvert Type/Foundation Alternatives

Common culvert and foundation types are listed below and a comparison of these alternatives from a foundation perspective, based on their respective advantages and disadvantages are outlined below, and are summarized in the tables provided in Appendix E.

8.1.1 Circular Pipes

From a foundation engineering perspective, circular pipes installed with appropriate granular bedding over the native clay subgrade are feasible. However, it is understood that multiple circular pipes on new alignments would be necessary to provide the required hydraulic opening.

8.1.2 Open Bottom

An open bottom culvert was considered for this project; however, the clay subgrade offers relatively low bearing resistance and is insufficient based on the proposed size of the structures and height of embankment fill.

8.1.3 Closed Box

From a geotechnical perspective, the replacement could be achieved with a closed bottom culvert. A closed box culvert offers several advantages including spreading the load over a wider area and since the base of the closed box does not need to be founded below frost depth the depth of excavation required for installation is reduced over that of an open bottom culvert.

Based on a culvert invert elevation of approximately 367.46 m, and allowing for, a 600 mm thick concrete base, 300 mm of granular bedding, and a 100 mm thick concrete mud slab, the base of excavation is expected to be around Elevation 366.46 m at which elevation the subgrade would be the native clay.

8.2 Construction Methodology Alternatives

This section presents discussions from a foundation perspective on alternative construction methods for the replacement of Culvert 41S-138/C. Further comparison of these options is summarized in the tables provided in Appendix E.

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

1. Trenchless techniques
2. Open cut with staged construction and roadway protection

3. Open cut with staged construction and platform lowering
4. Open cut with staged construction and platform widening

8.2.1 Trenchless Techniques

Although trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment, a wide body of open water is present at the outlet side of the embankment which is not well suited for entry/exit pits required for a trenchless installation. In addition, the culvert requires a large hydraulic opening which limits the possible trenchless techniques, or would likely require multiple parallel installations.

Trenchless techniques are not recommended for this site.

8.2.2 Open Cut with Staged Construction and Temporary Protection Systems

The culvert could be replaced using open cut techniques with staged construction (half and half) The use of temporary protection systems parallel to the highway would be required in order to keep at least one lane of traffic open throughout the construction period.

The height of the protection system would be close to 10 m and would be installed within relatively low strength soil. Sheet pile systems are considered feasible as the temporary protection systems at this site however, due to the embankment fill height will likely require a suitable anchoring or bracing system. Tie back anchors would likely consist of soil anchors installed within the clay. The use of deadman anchor blocks could also be considered.

8.2.3 Open Cut with Staged Construction and Platform Lowering

The culvert could be replaced using open cut techniques with staged construction and platform lowering in order to limit the depth of excavation and the height of protection systems required.

8.2.4 Open Cut with Staged Construction and Platform Widening

Temporary embankment widening and/or construction of a detour embankment could be considered, however, it is noted that existing utilities are present on both sides of the highway which may require relocation in order to facilitate the widening. In addition, the site is underlain by clay and silt and additional foundation field investigations would be required to assess settlement and stability of the proposed widening, including potential additional settlement of the existing embankment and culvert.

8.3 Recommended Approach for the Culvert Replacement

Taking into account the soil stratigraphy and the traffic requirements the recommended replacement methodology from a foundation perspective would be to replace the existing culvert in an open cut with staged construction with temporary protection systems.

9 FOUNDATION DESIGN RECOMMENDATIONS

9.1 Culvert Foundation Bearing Resistances

Based on the site conditions encountered, the recommended geotechnical resistances for two, 4.5 m wide concrete box culverts installed directly adjacent to each other, founded approximately Elevation 366.5 m in undisturbed native clay is as follows:

- Factored geotechnical resistance at ULS 260 kPa
- Factored geotechnical resistance at SLS 100 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (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 geotechnical resistances are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable, as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4.

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

9.2 Subgrade Preparation, Culvert Bedding and Backfilling

Excavation and backfilling for installation of the new culverts should be carried out in accordance with OPSS 902.

The creek water level was observed at Elevation 368.5 m on October 19, 2016, as such the base of the excavation would range from 1.0 m to 1.5 m below the measured creek level. Therefore, creek diversion and dewatering will be required for the preparation of the subgrade, placing and compacting the bedding layer and to construct the culvert in the dry.

Subgrade preparation for the culvert replacement should include excavation and removal of the existing fill and native materials to the founding elevation. Any soft, organic or alluvial materials must be removed and replaced with Granular A placed and compacted in accordance with OPSS.PROV 501. The native subgrade within the footprint of the culvert should consist of undisturbed native firm to stiff clay.

The native subgrade materials will be easily disturbed when saturated and should be protected with a concrete 100 mm thick working slab promptly after excavation and inspection. Construction

equipment should not be permitted to travel on the exposed subgrade. An NSSP is provided in Appendix F to alert the Contractor of the sensitive nature of the foundation soils.

It is understood that existing culvert will be temporary left in place to help facilitate the flow passage and/or dewatering during construction. This is acceptable provided that the new structure is founded at or below the existing culvert foundations.

Backfill for the culvert should be in accordance with OPSS 902.

The bedding layer should have a minimum thickness of 300 mm for a closed box structure.

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

9.3 Embankment Design and Reinstatement

The existing embankments have slopes ranging from approximately 2H:1V to 2.5H:1V.

The embankment slopes are covered with a mixture of brush and granular material. The west embankment slopes down at approximately 2.5H:1V. The east embankment includes a 10.2 m wide bench sloped at approximately 10H:1V; the upper and lower slopes are approximately 2H:1V.

Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206. Based on the staging drawings provided the new embankments are to be constructed to match existing with side slopes and are to be no steeper than 2H1:V. The new embankments material should consist of imported OPSS.PROV 1010 Granular A or B Type II material placed and compacted in accordance with OPSS.PROV 501. Where new embankment fill is placed against existing embankment slopes, the existing earth or fill slope must be benched in accordance with OPSD 208.010.

9.4 Lateral Earth Pressures

The lateral earth pressure parameters provided in Tables 9-1 and 9-2 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 the buildup of hydrostatic pressures should be considered in the design.

9.4.1 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 expression:

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

where:

P_h = horizontal pressure on the wall (kPa)

K = earth pressure coefficient

γ = unit weight of retained soil (kN/m³)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

The recommended lateral earth pressure parameters for use in the design for a horizontal back-slope are provided in Table 9-1.

Table 9-1: Static Lateral Earth Pressure Coefficient

Parameter	OPSS Granular A & B Type II	Existing Granular Fill	Existing Clay Fill	Native Silt	Native Clay
Soil Unit Weight, kN/m^3 , γ	21.0	20.0	18	19	18
Angle of Internal Friction, ϕ	35°	32°	27°	29°	27°
Coefficient of at Rest Earth Pressure, K_o (Restrained Wall)	0.43	0.47	0.55	0.52	0.55
Coefficient of Active Earth Pressure, K_a (Unrestrained Wall)	0.27	0.31	0.38	0.35	0.38

For rigid structures, it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls.

For static analysis, passive earth resistance should be ignored, and therefore have not been provided. A lateral pressure due to backfill compaction equal to 12 kPa at the fill surface and varying linearly to 0 kPa at a depth of 1.7 m should be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC.

9.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

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

- $k_h = \frac{1}{2} F(\text{PGA}) \cdot \text{PGA}$ for structures that allow 25 mm to 50 mm of movement, and
- $k_h = F(\text{PGA}) \cdot \text{PGA}$ for non-yielding walls

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

The recommended seismic lateral earth pressure parameters for use in the design that are provided in Table 9-2 assume the following:

- Horizontal back-slope behind the wall; and
- Seismic Site Class of E, and a PGA with a 2% probability of exceedance in 50 years of 0.028 as outlined in Section 7.0.

Table 9-2: Lateral Earth Pressure (Under Seismic Loads)

Parameter	OPSS Granular A & B Type II	Existing Fill	Existing Clay Fill	Native Silt	Native Clay
Soil Unit Weight, kN/m ³ , γ	21.0	20.0	18	19	18
Angle of Internal Friction, ϕ	35°	33°	27°	29°	27°
Non-Yielding Wall					
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.45	0.32	0.41	0.38	0.41
Yielding Wall					
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.43	0.31	0.39	0.36	0.39

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

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

where:

σ_h = lateral earth pressure at depth, d (kPa)

d = depth below the top of the wall (m)

K = static earth pressure coefficient

(K_o for non-yielding and K_a for yielding walls)

γ = unit weight of the backfill soil (kN/m³)

K_{AE} = combined static and seismic earth pressure coefficient

H = total height of the wall (m)

9.5 Cement Type and Corrosion Potential

Two samples of the native soils encountered at the site were submitted to AGAT Laboratories in Mississauga, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in Table 9-3. A copy of the test results is provided in Appendix C.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in the Table 9-3 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

Table 9-3: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
MK16-2	SS7	6.4	7.6	1250	446	8
MK16-3	SS8	7.9	8.2	4330	45	7

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is

expected for concrete in contact with soil and groundwater. Type GU Portland Cement should therefore be suitable for use in concrete at this site.

10 CONSTRUCTION CONSIDERATIONS

10.1 Excavations

The contractor must consider the potential for unbalanced lateral earth pressures on the existing box culvert while excavating for the new culvert. The contractor must protect the existing culvert from damage and movement while excavating for the new culvert. If required, a temporary sheet pile wall may be used to protect the existing culvert during construction. The support system should be installed in accordance with OPSS 404. The design of the excavation support system is the responsibility of the Contractor. The support system must be design by a Professional Engineer experienced in such design. Geotechnical parameters for the design of the support system are provided in Table 9-1.

It is anticipated that temporary excavations in the order of 9 m will be required for the removal of the existing culvert and foundations.

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills and native soils at the site should be classified as Type 3. Alluvial materials and cohesionless silts and sands should be classified as Type 4 below the groundwater table in accordance with OHSA. However, as indicated in the OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation.

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

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

10.2 Temporary Protection Systems

The proposed methodology is to construct the culvert in stages. A protection system should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2.

The design of protection systems is the responsibility of the Contractor. All shoring should be designed by a licensed professional engineer experienced in such designs. Lateral earth pressure coefficients for the use in the design are provided in Table 9.1. The designer of the protection systems must ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations and shall consider the slope of temporary embankments above the top of the protection system. A suitable bracing system may need to be incorporated into the roadway protection design. For preliminary assessment purposes, the use of sheet piles is considered feasible. Tie back anchors would likely consist of soil anchors installed within the clay. The use of deadman anchor blocks could also be considered.

10.3 Dewatering

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

Temporary water course diversion will be required to replace the culvert in the dry. It is assumed that the existing culvert will remain operational while the new culvert is being installed. Water diversion could be diverted to the existing culvert to allow the construction to take place in a dry and stable excavation. The Contractor should engage an engineer licensed to practice in Ontario, and with experience in the design of cofferdams and dewatering systems to design the cofferdam system. Dewatering systems should be design, operated, and removed in accordance with OPSS.PROV 517.

Water from either surface flow and/or groundwater must be diverted away from the excavation at all times. Groundwater perched within the embankment fill, surface runoff and/or the water from the creek will tend to seep into, and accumulate in proposed excavations.

It is recommended that the Contract Documents identify the highest water level in the creek against which the cofferdam must provide protection and prevent flooding of the work area. At a minimum, the expected spring freshet level or the level reached by a storm of an appropriate return period should be used as the design water level.

10.4 Erosion Protection

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

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

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

Consideration should be given to including cut-off walls at the culvert inlet and outlet areas.

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

10.5 Construction Concerns

The planned construction methodology includes an open cut excavation for the installation of new twin culverts adjacent to the existing culvert.

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

- A suitable anchoring or bracing system may need to be incorporated into the roadway protection design. Tie back anchors would likely consist of soil anchors installed within the clay. The use of deadman anchor blocks could also be considered.
- The staging must consider the potential for unbalanced lateral earth pressures on the existing box culvert while excavating for the new culvert. A temporary protection system may be required between the existing and new culvert to prevent such unbalanced pressures.
- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert and subgrade in the dry.
- The subgrade at the base of the excavation will be easily disturbed and should be protected promptly after excavation, inspection and approval by the QVE.
- Confirmation that the backfill is adequately placed and compacted to specifications.

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

11 CLOSURE

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



Kenton C. Power, P.Eng.
Geotechnical Engineer

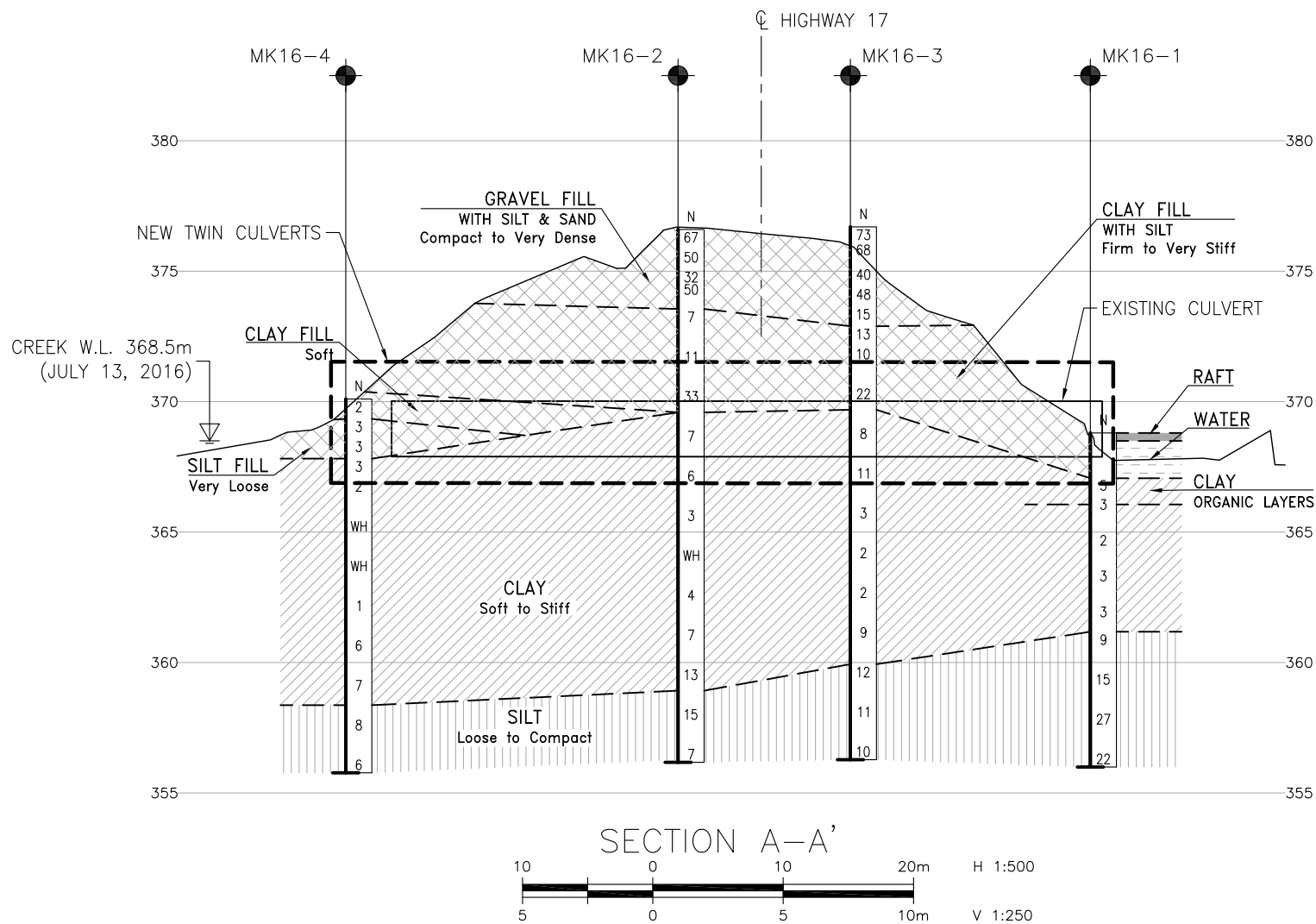
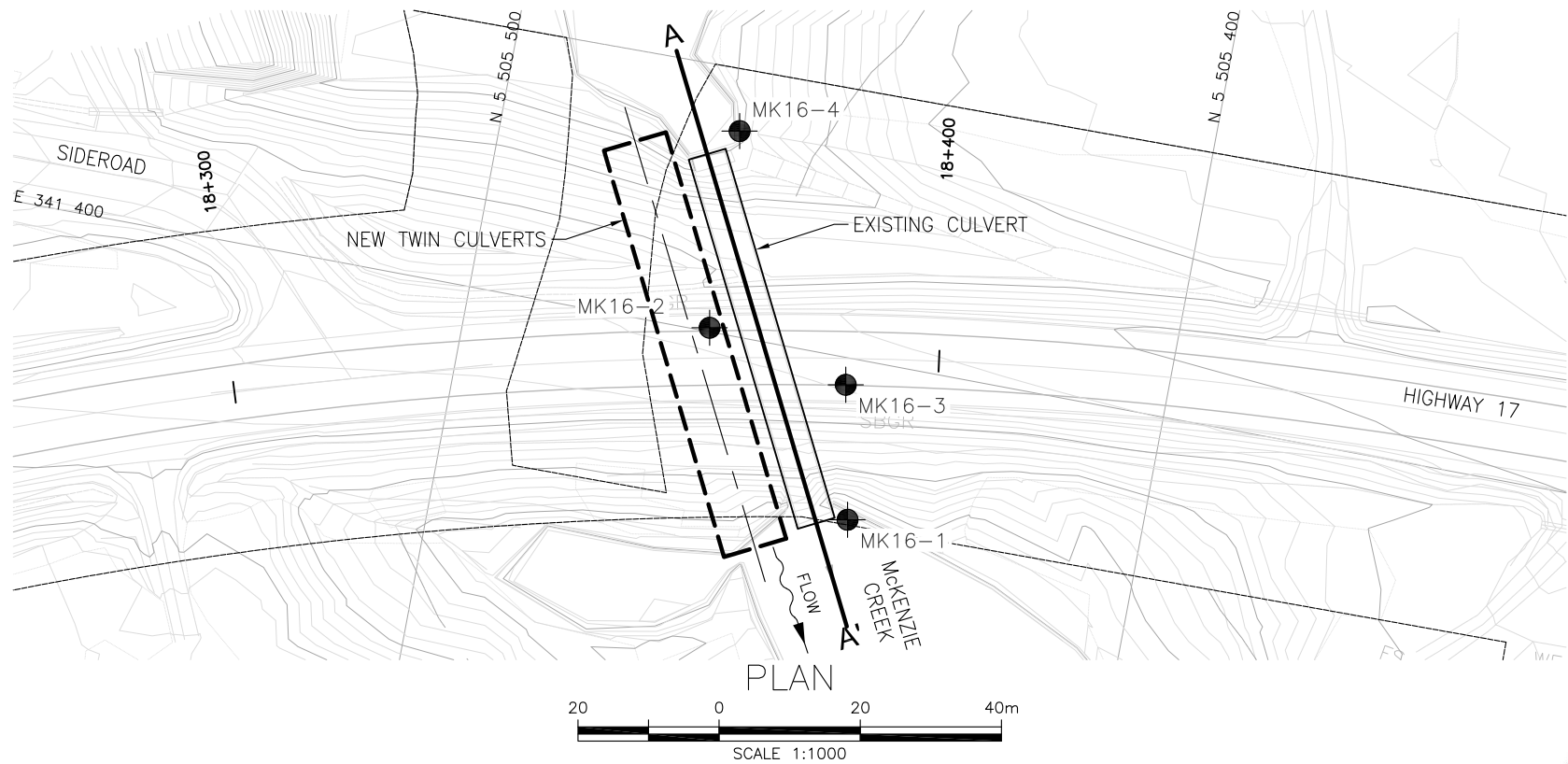


Paul Carnaffan, P.Eng.
Principal, Senior Geotechnical Engineer



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

APPENDIX A
BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS

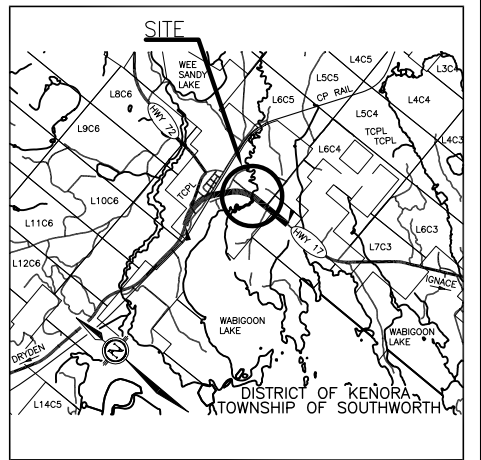


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No
GWP No 6369-14-00

HIGHWAY 17
McKENZIE CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



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
MK16-1	368.8	5 505 441.3	341 377.4
MK16-2	376.6	5 505 465.5	341 400.6
MK16-3	376.7	5 505 445.1	341 396.2
MK16-4	370.1	5 505 466.5	341 428.7

-NOTES-

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

GEOCRES No. 52F-56

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SBP	CHK -	CODE
DRAWN	MFA	CHK KCP	SITE
LOAD	DATE	OCT 2017	
STRUCT	DWG	1	

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:

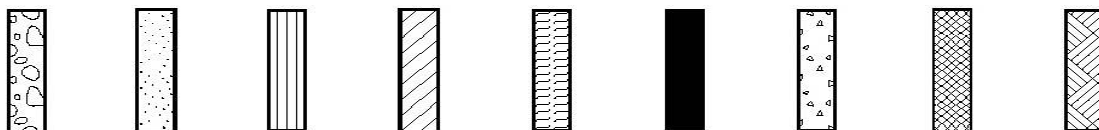
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented,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

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.

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 (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

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

METRIC

SOIL PROFILE						SAMPLES	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		
368.8 0.0	RAFT	[Solid Black]					
368.5 0.3	WATER - McKenzie Creek	[Stippled Pattern]					
367.1 1.7	CLAY (Cl) - organic layers from 1.7 m to 2.3 m	[Diagonal Hatching /]	1	SS	5		
366.1 2.7	CLAY (CL) Soft to stiff Red to grey	[Diagonal Hatching \]	2	SS	3		
	- grey below 3.7 m	[Diagonal Hatching \]	3	SS	2		
		[Diagonal Hatching \]	4	SS	3		
		[Diagonal Hatching \]	5	SS	3		
361.2 7.6	SILT (ML) Loose to compact Grey	[Vertical Lines]	6	SS	9		
		[Vertical Lines]	7	SS	15		

DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		
20	40	60	W P	W	W L
SHEAR STRENGTH kPa			WATER CONTENT (%)		
○ UNCONFINED + FIELD VANE					
● QUICK TRIAXIAL × LAB VANE					
20	40	60	20	40	60

ELEVATION SCALE	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
368		368	kN/m ³	GR SA SI CL
367		367		0 5 70 25
366		366		
365		365		
364		364		
363		363		
362		362		0 0 60 40
361		361		
360		360		
359		359		

+³, ×³: Numbers refer to Sensitivity

ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 6/10/17

RECORD OF BOREHOLE No MK16-1

2 OF 2

METRIC

GWP# 6369-14-00 LOCATION 41S-138/C McKenzie Creek Culvert N 5 505 441.3 E 341 377.4 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE Portable Raft / B Casing COMPILED BY JM
 DATUM Geodetic DATE 2016.10.19 - 2016.10.19 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W P W W L				
								20 40 60 80 100					20 40 60				
	Continued From Previous Page																
	SILT (ML) Loose to compact Grey		8	SS	27		358										
							357										
356.0			9	SS	22										0 0 91 9		
12.8	End of borehole																




ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 6/10/17

RECORD OF BOREHOLE No MK16-2

1 OF 3

METRIC

GWP# 6369-14-00 LOCATION 41S-138/C McKenzie Creek Culvert N 5 505 465.5 E 341 400.6 ORIGINATED BY TM
 HWY 17 BOREHOLE TYPE HSA / CME-750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.19 - 2016.08.19 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								20 40 60 80 100											
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
20 40 60 80 100				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W L				WATER CONTENT (%) 20 40 60											
376.6	Gravel with silt and sand, occassional cobbles Dense to very dense Brown FILL		1	SS	67														
0.0																			
			2	SS	50														
			3	SS	32														
			4	SS	50														
373.6	Clay with silt trace sand Firm to very stiff Grey FILL		5	SS	7														
3.0																			
			6	SS	11														
			7	SS	33														
369.6	CLAY (CH to CI) Firm to stiff Grey																		
7.0																			
			8	SS	7														
			9	SS	6														

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+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT GPJ 2012TEMPLATE(MTO).GDT 6/10/17

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No MK16-2

3 OF 3

METRIC

GWP# 6369-14-00 LOCATION 41S-138/C McKenzie Creek Culvert N 5 505 465.5 E 341 400.6 ORIGINATED BY TM
 HWY 17 BOREHOLE TYPE HSA / CME-750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.19 - 2016.08.19 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
356.2	SILT (ML)		16	SS	7												
20.4	End of borehole																




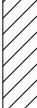
ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 6/10/17

RECORD OF BOREHOLE No MK16-3

1 OF 3

METRIC

GWP# 6369-14-00 LOCATION 41S-138/C McKenzie Creek Culvert N 5 505 445.1 E 341 396.2 ORIGINATED BY TM
 HWY 17 BOREHOLE TYPE HSA / CME-750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.17 - 2016.08.17 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				GR	SA	SI	CL		
												○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)								
376.7								20	40	60	80	100									
0.0	Gravel with silt and sand Compact to very dense Brown FILL		1	SS	73									○							
			2	SS	68										○						
			3	SS	40										○						
			4	SS	48										○						
			5	SS	15																
372.9																					
3.8	Clay with silt, trace sand Stiff to very stiff Grey FILL		5A	SS	13										○						
			6	SS	10											-----○-----					
	- some sand and gravel		7	SS	22										○						
369.7																					
7.0	CLAY (CH to CI) Soft to firm Grey		8	SS	8										○						
			9	SS	11											○					

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+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT GPJ 2012TEMPLATE(MTO) GDT 6/10/17

RECORD OF BOREHOLE No MK16-3

2 OF 3

METRIC

GWP# 6369-14-00 LOCATION 41S-138/C McKenzie Creek Culvert N 5 505 445.1 E 341 396.2 ORIGINATED BY TM
 HWY 17 BOREHOLE TYPE HSA / CME-750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.17 - 2016.08.17 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80					100	20	40	60				
	Continued From Previous Page																						
	CLAY (CH to Cl) Soft to firm Grey																						
		10	SS	3			366																
							365																
		11	SS	2			364																
							363																
		12	SS	2			362																
							361																
359.9							360																
16.8	SILT (ML) Compact Grey		14	SS	12																		
							359																
		15	SS	11			358																
							357																

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
15
10
5
0
(%) STRAIN AT FAILURE

ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 6/10/17

RECORD OF BOREHOLE No MK16-3

3 OF 3

METRIC

GWP# 6369-14-00 LOCATION 41S-138/C McKenzie Creek Culvert N 5 505 445.1 E 341 396.2 ORIGINATED BY TM
 HWY 17 BOREHOLE TYPE HSA / CME-750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.17 - 2016.08.17 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
356.3	SILT (ML)		16	SS	10											0 5 80 15	
20.4	End of borehole																

ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 6/10/17

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

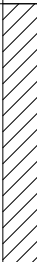

ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 6/10/17

RECORD OF BOREHOLE No MK16-4

2 OF 2

METRIC

GWP# 6369-14-00 LOCATION 41S-138/C McKenzie Creek Culvert N 5 505 466.5 E 341 428.7 ORIGINATED BY CM
 HWY 17 BOREHOLE TYPE HSA / CME Truckmount COMPILED BY JM
 DATUM Geodetic DATE 2016.07.13 - 2016.07.13 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
Continued From Previous Page								20 40 60 80 100							
	CLAY (CH to CL) Stiff Grey						360								
			10	SS	7		359								
358.3															
11.7	SILT (ML) Loose Grey						358								
			11	SS	8										
							357								
	- sandy below 13.7 m														
355.7			12	SS	6		356								
14.3	End of borehole Borehole dry on completion														

ONTMT4S 13161 HWY 17 MCKENZIE CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 6/10/17

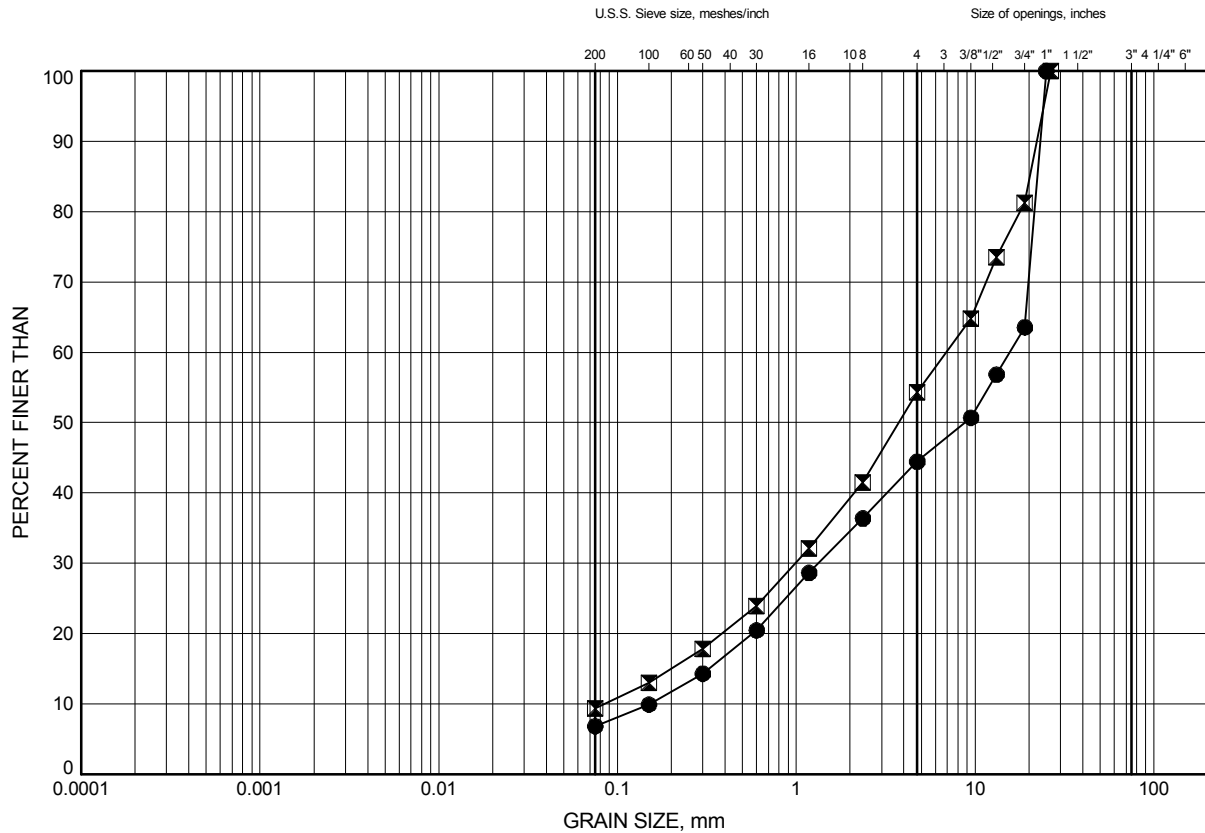
APPENDIX C
LABORATORY TEST RESULTS

Hwy 17 - McKenzie Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE 1

Fill - Gravel with silt and sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-2	1.83	374.77
⊠	MK16-3	2.59	374.11

Date December 2016

GWP# 6369-14-00



Prep'd KCP

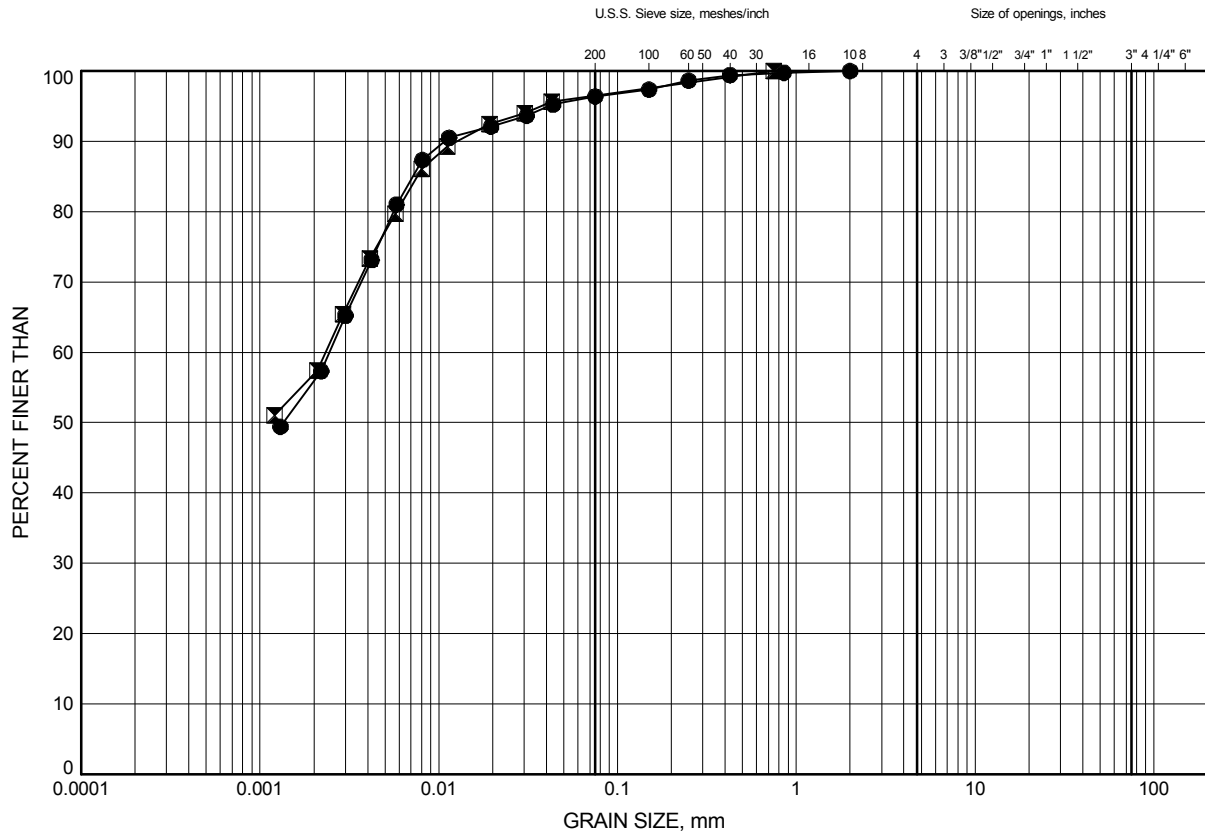
Chkd. PC

Hwy 17 - McKenzie Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE 2

Fill - Clay with silt trace sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-2	3.35	373.25
◻	MK16-3	4.88	371.82

Date December 2016
GWP# 6369-14-00

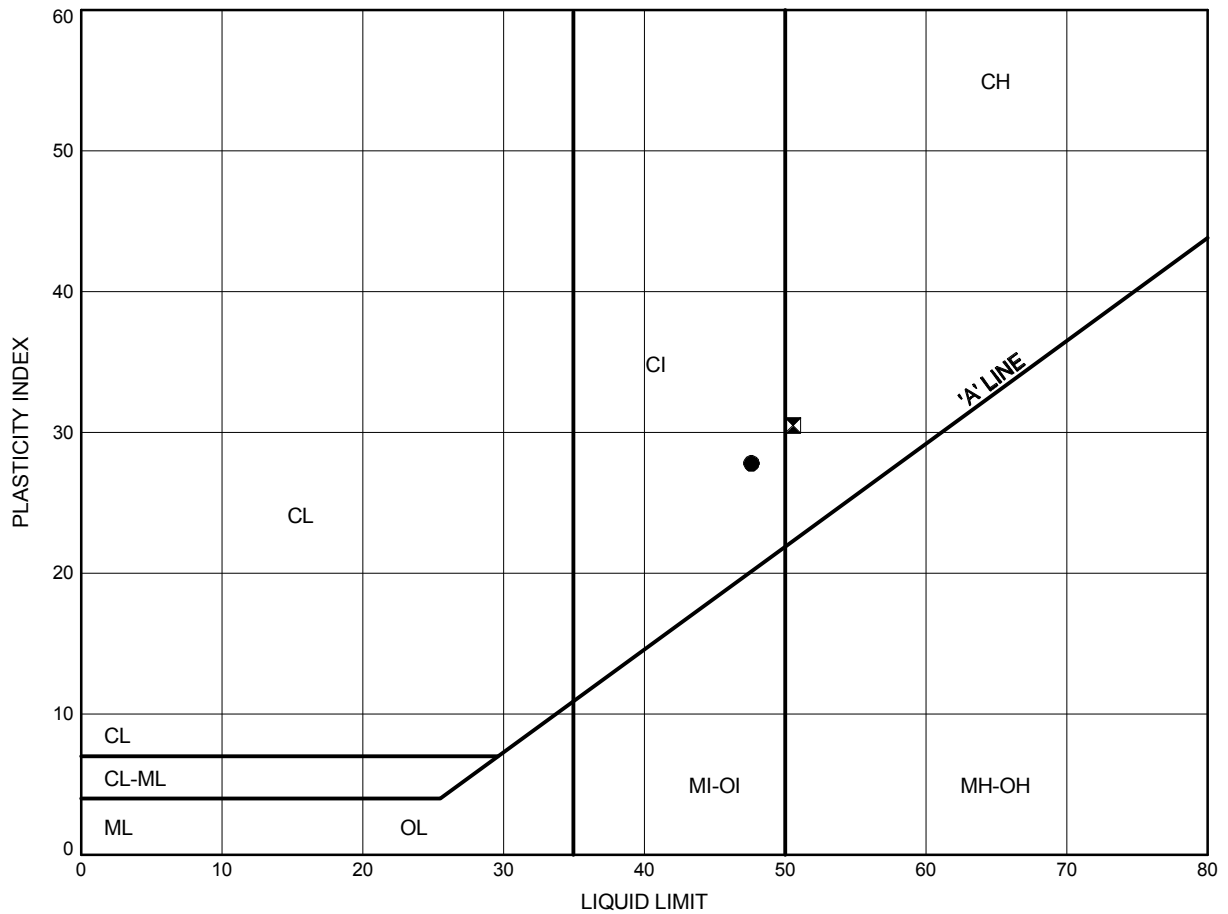


Prep'd KCP
Chkd. PC

Hwy 17 - McKenzie Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE 3



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-2	3.35	373.25
⊠	MK16-3	4.88	371.82

Date December 2016
GWP# 6369-14-00

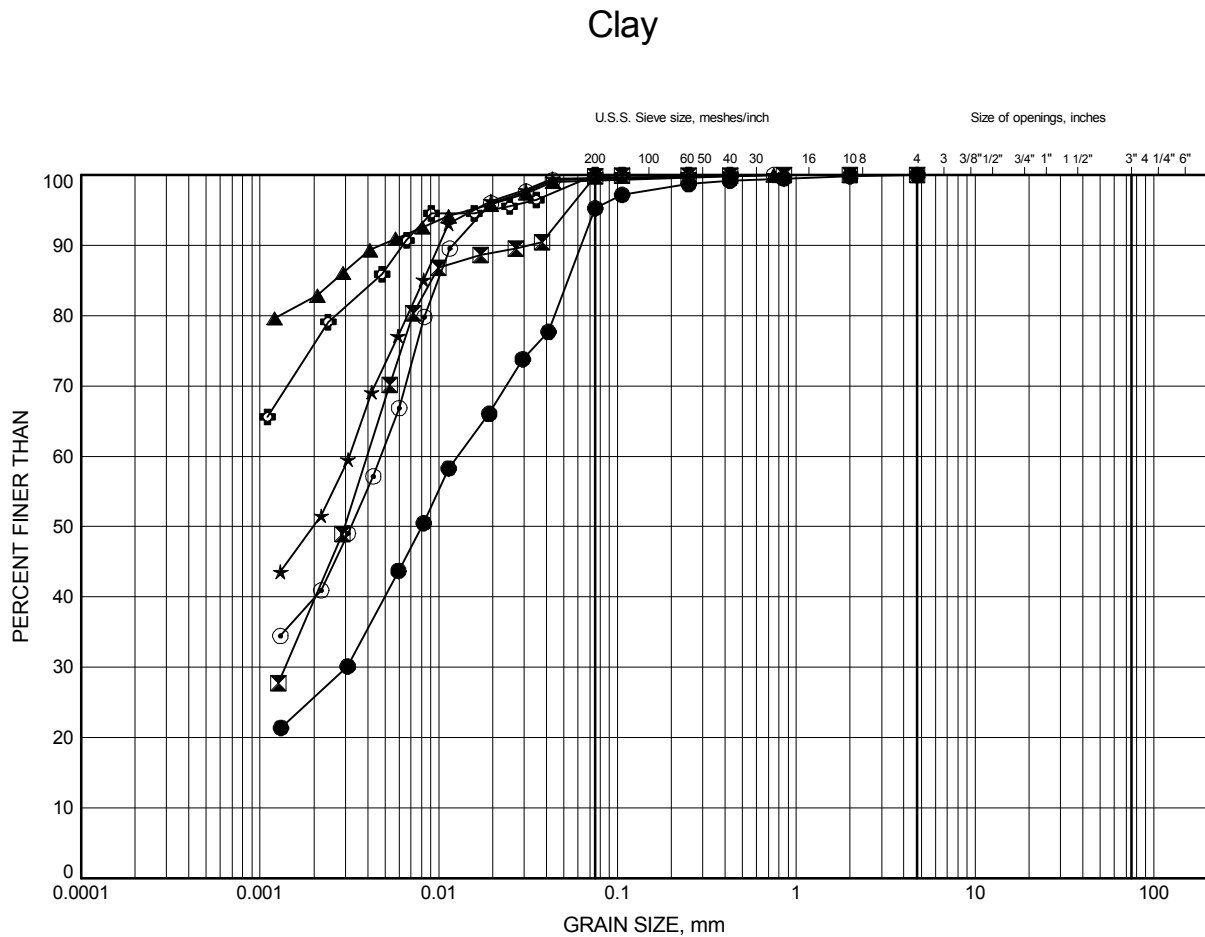


Prep'd KCP
Chkd. PC

Hwy 17 - McKenzie Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE 4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-1	1.98	366.86
⊠	MK16-1	6.86	361.98
▲	MK16-2	9.45	367.15
★	MK16-2	12.50	364.10
⊙	MK16-3	14.02	362.68
⊕	MK16-4	3.35	366.70

Date December 2016

GWP# 6369-14-00



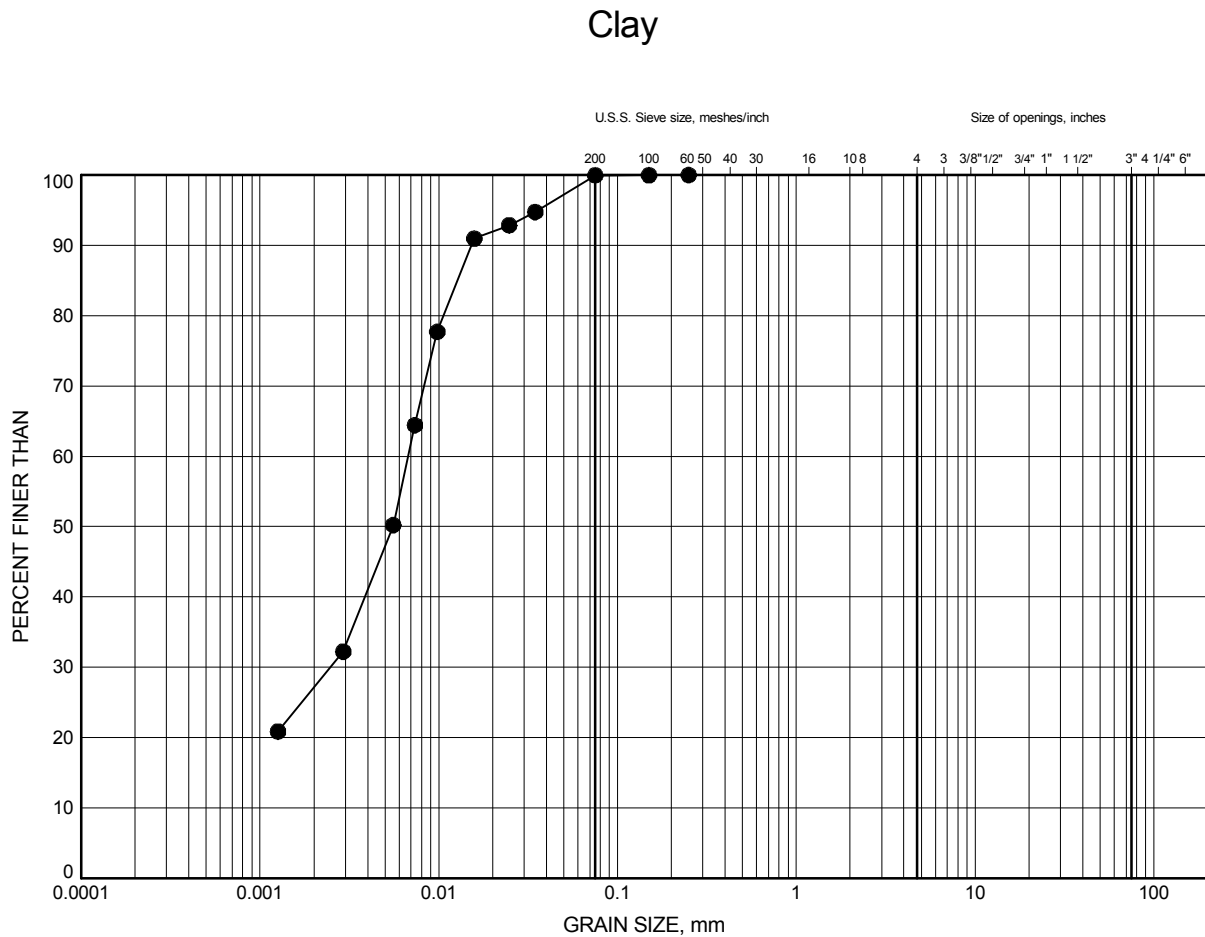
Prep'd KCP

Chkd. PC

Hwy 17 - McKenzie Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE 5



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-4	9.45	360.60

Date December 2016

GWP# 6369-14-00



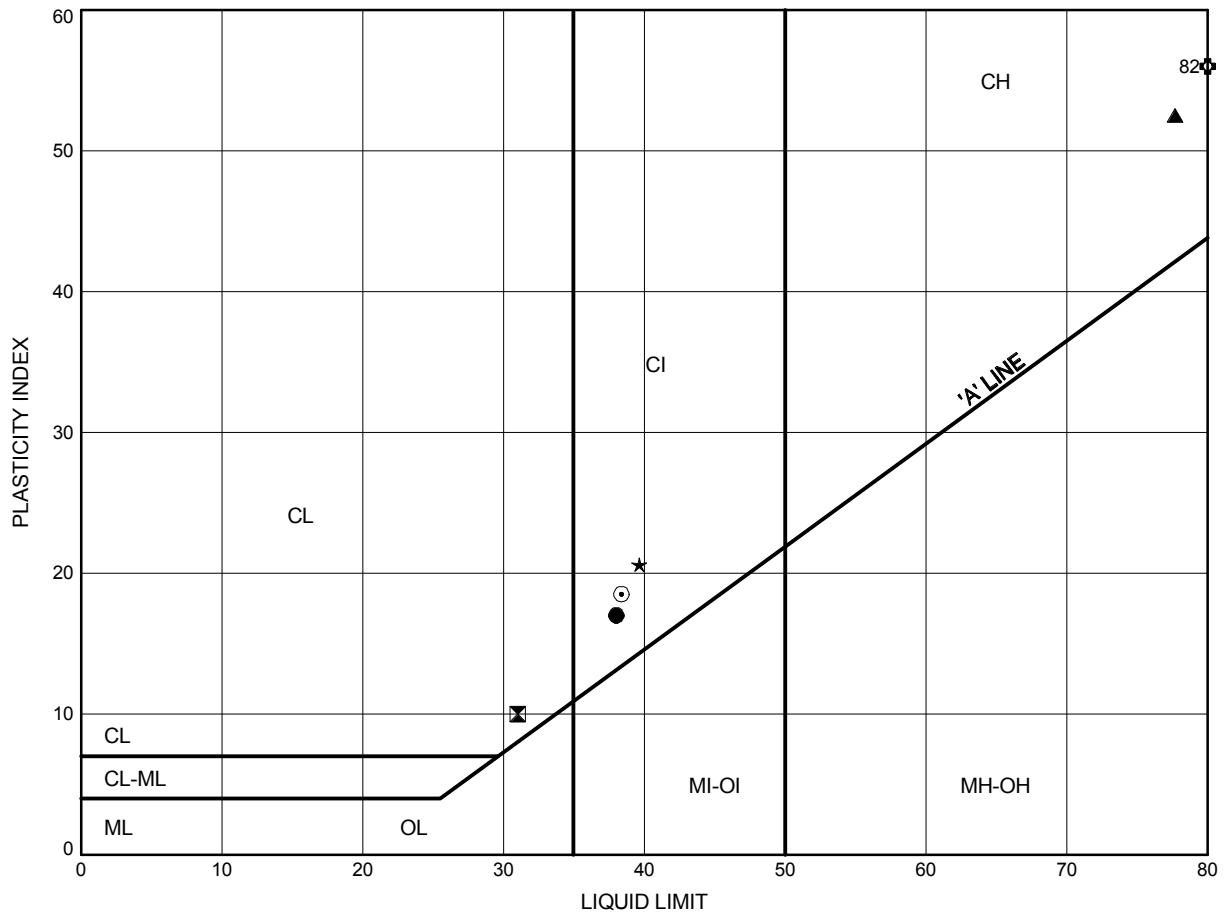
Prep'd KCP

Chkd. PC

Hwy 17 - McKenzie Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE 6



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-1	1.98	366.86
⊠	MK16-1	6.86	361.98
▲	MK16-2	9.45	367.15
★	MK16-2	12.50	364.10
⊙	MK16-3	14.02	362.68
⊕	MK16-4	3.35	366.70

Date December 2016

GWP# 6369-14-00



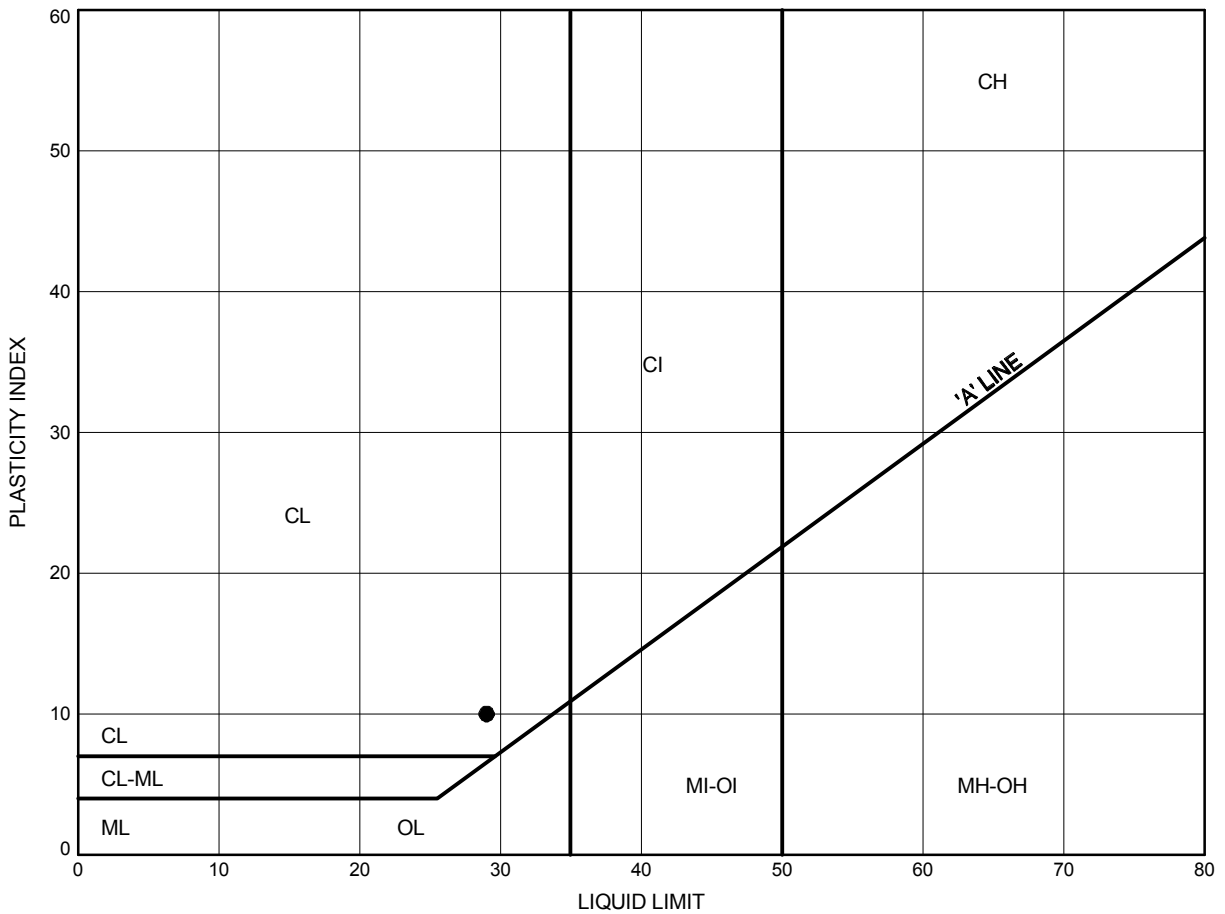
Prep'd KCP

Chkd. PC

Hwy 17 - McKenzie Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE 7



LEGEND

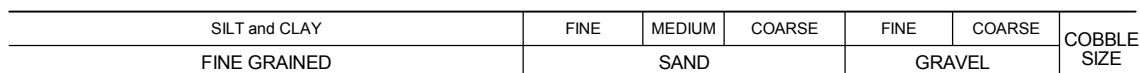
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-4	9.45	360.60

Date December 2016
GWP# 6369-14-00



Prep'd KCP
Chkd. PC

FIGURE 8



SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MK16-1	12.50	356.34
☒	MK16-2	18.59	358.01
▲	MK16-3	20.12	356.58
★	MK16-4	12.50	357.55

Chkd. PC

**CLIENT NAME: THURBER ENGINEERING LTD
SUITE 103, 2010 WINSTON PARK DRIVE
OAKVILLE, ON L6H5R7
(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.



AGAT Laboratories

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

SAMPLING SITE:

ATTENTION TO: WEISS MEHDAWI

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2016-09-20

DATE REPORTED: 2016-09-27

				DL-3/SS7 (20-22")	DL-3/SS9 (30-32")	MK-2/SS7 (20-22")	MK-3/SS8 (25-27")
SAMPLE DESCRIPTION:				Soil	Soil	Soil	Soil
SAMPLE TYPE:				Soil	Soil	Soil	Soil
DATE SAMPLED:				8/16/2016	8/16/2016	8/16/2016	8/16/2016
Parameter	Unit	G / S	RDL	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

Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 13161

SAMPLING SITE:

AGAT WORK ORDER: 16T139309

ATTENTION TO: WEISS MEHDAWI

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		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	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:



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
SELECTED PHOTOGRAPHS



Figure 1: Roadway Platform at Culvert 41S-138/C looking north



Figure 2: Culvert 41S-138/C inlet looking north



Figure 3: Looking upstream from Culvert 29-146/C



Figure 4: Looking north along the east embankment bench

APPENDIX E

COMPARISON OF CULVERT TYPE/FOUNDATION ALTERNATIVES COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS

Comparison of Culvert Type/Foundation Alternatives

Comment	Circular Pipes	Open Footing Culvert	Closed Box Culvert
<i>Advantages</i>	Readily available materials and simple installation methods		Wide base spreads out load Less prone to effects of scour and erosion
<i>Disadvantages</i>	Numerous parallel pipes required to provide hydraulic opening equivalent to existing culvert.	Founding elevation is deeper than with closed box, requiring deeper excavation	Lower geotechnical resistance if placed at higher elevation
<i>Risks / Consequences</i>	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays
<i>Relative Cost</i>	Moderate	Moderate	Moderate
	NOT RECOMMENDED	FEASIBLE	RECOMMENDED

Comparison of Construction Methodology Options

Comment	Trenchless	Staged Construction, with Roadway Protection	Staged Construction with Platform Lowering	Staged Construction with Platform Widening
Advantages	Avoids open cut.	Limits volume of earthwork compared to platform lowering/widening	Reduced depth of main excavation and height of protection systems	Avoids need for installation of protection systems through the roadway
Disadvantages	<p>Lane reductions may still be required for construction access</p> <p>Wide open water at outlet not favourable for entry/exit pit</p> <p>Large hydraulic opening likely requires multiple pipes</p>	Traffic impacts	Potentially large volumes of earthwork required	<p>Open water at or near existing toe of slope makes fill placement/compaction more difficult</p> <p>Potentially large volumes of earthwork required</p> <p>Additional foundation investigation required for assessment of settlement</p>
Risks/ Consequences	Obstructions/delays		<p>Settlement of widened portion of embankment/ increased maintenance</p> <p>Utility relocation/increase construction cost and schedule</p>	Utility relocation/increase construction cost and schedule
Relative Cost	High	Moderate	Moderate	Moderate
	NOT FEASIBLE	FEASIBLE	RECOMMENDED	NOT FEASIBLE

APPENDIX F

GSC SEISMIC HAZARD CALCULATION LIST OF REFERENCED SPECIFICATIONS NON-STANDARD SPECIAL PROVISION

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: 49.6854 N, 92.4926 W User File Reference: Mckenzie Creek 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 ($S_a(T)$, 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

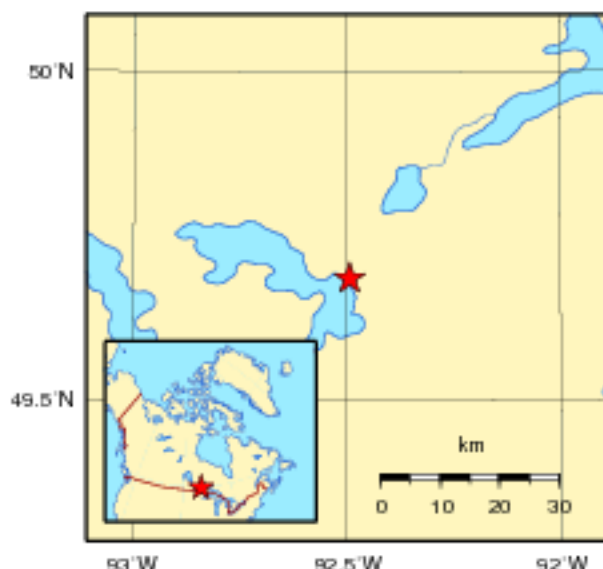
National Building Code of Canada 2015 NRCC no. 58190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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.nationalbuildingcode.ca for more information

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada

Canada

LIST OF REFERENCED SPECIFICATIONS

OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario
OPSS.PROV 206	Construction Specification for Grading
OPSS 404	Construction Specification for Support Systems
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS 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

RECOMMENDED WORDING FOR “NSSP – Protection of Sensitive Foundation Soils”

The Contractor is advised that the soil that will be exposed at the subgrade during the construction of the foundation of the culvert is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personal 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 working slab placed between the native subgrade and granular bedding.