



THURBER ENGINEERING LTD.

FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT STRUCTURE NO. 40-116/C
HIGHWAY 35 BLACK CREEK CULVERT, LUTTERWORTH TOWNSHIP
AGREEMENT NO. 5015-E-0043

G.W.P. 5087-11-00

Geocres No.: 31D-690

Report to:

McIntosh Perry Consulting Engineers Limited

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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 Black Creek Culvert crossing of Highway 35 located approximately 1.2 km south of Haliburton Rd 2 (Deep Bay Rd) within Lutterworth Township. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (MPCE) under Agreement No. 5015-E-0043.

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

2 SITE DESCRIPTION

The existing culvert conveys creek flow from the west to the east under Highway 35. As described within the RFP, it is an open footing box culvert consisting of two types of construction. The east and west sections are reinforced concrete rigid frame open footing culverts constructed in 1968; the length is 4.9 m at the west end and 8.5 m at the east end, the span is 3.0 m and the height 3.0 m. The center section of the culvert is a reinforced concrete rigid frame open footing culvert of unknown age however the RFP indicates the culvert may have been constructed in the 1950's. The span for this section is 3.0 m, the height 2.4 m and the length approximately 20.6 m.

At the location of the culvert (Linear Highway Referencing System Base Point: 27945, Offset: 3.1), Highway 35 is a two-lane highway with a rural cross-section and gravel shoulders. A right turn taper is present in the northbound direction leading to a sideroad which is less than 20 m north of the culvert. The Highway 35 fill height above the culvert is approximately 2.4 m with the road surface at approximate elevation 273.7 m. The creek bed was at approximate elevation 268.2 and 268.1 m at the inlet and outlet respectively. The existing embankment slopes are inclined at approximately 2H:1V. Steel guiderails with steel posts are present in the vicinity of the culvert. Moore Lake is located approximately 100 m east of the culvert. The land adjacent to the highway is occupied by single family

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dwelling and cottage properties and is vegetated with shrubs and trees. Traffic volumes on this section of Highway 35 are understood to be 3150 AADT (2013).

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

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between May 8th to May 9th, 2017 for the on-road investigation and between August 14th to 17th, 2017 for the off-road investigation. The field investigation consisted of advancing six boreholes identified as 17-01 through 17-06. The drilling was carried out using portable equipment for off-road boreholes 17-03, 17-04, 17-05 and 17-06 and a truck mounted CME 75 drill rig for the on-road boreholes 17-01 and 17-02. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Boreholes 17-03, 17-04, 17-05 and 17-06, which were drilled with portable equipment, also utilized a full-weight hammer for SPT testing. The boreholes were sampled to depths ranging from 9.7 to 15.8 m (elev. 257.2 to 258.4 m) below the existing ground or creek bed surface. Boreholes 17-01, 17-02 and 17-03 were extended below the base of the sampled borehole with a Dynamic Cone Penetration Test (DCPT) to elevations ranging from 250.3 to 253.2 m.

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

Following completion of the field investigation the boreholes were backfilled in accordance with MOEE requirements (O.Reg. 903). Boreholes 17-01 and 17-02 were capped with 150 mm of cold patch asphalt to reinstate the traveling surface.

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

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. One sample of soil recovered from within each of Boreholes 17-03 and 17-05 was 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 site was found to be underlain by a pavement structure and granular fill overlying a deposit of fine grained material varying from clay to silt over a silty sand and sand deposit. A layer consisting of organic silt was present at the ground surface (underwater) at one of the off-road borehole on the west side of the culvert. Bedrock was not sampled within the depth of investigation.

5.1 Embankment Fill

5.1.1 Asphalt

Boreholes 17-01 and 17-02 were drilled through the existing Highway 35 embankment and encountered a layer of asphalt with a thickness of 180 and 165 mm, respectively.

5.1.2 Fill: Sand with Silt and Gravel

Below the asphalt in Boreholes 17-01 and 17-02 and from the creek bed surface in Borehole 17-06 was a layer of fill consisting of sand with silt and gravel. Cobbles and boulders were noted at ground surface in Borehole 17-06. The underside of the fill was at 4.4 to 5.3 m (elev. 268.3 to 269.4 m) below the existing roadway surface in Boreholes 17-01 and 17-02, respectively and at 1.6 m (elev. 266.9 m) below the existing creek bed in Borehole 17-06.

The SPT tests conducted in this fill gave N-values ranging from 3 to 72 blows indicating a relative density of very loose to very dense.

Recorded moisture contents ranged from 6 to 19%. The results of grain size analyses conducted on three samples of the fill materials are summarized below and are illustrated on Figure C1 in Appendix C.

Soil Particle	Percentage (%)
Gravel	10 - 32
Sand	63 - 84
Silt	3 - 6
Clay	

5.1.3 Fill: Silty Sand trace Gravel

A 100 mm layer of fill material consisting of silty sand with traces of gravel and organics was encountered at the creek bed surface in Borehole 17-04. The underside of the fill was at elev. 268.1 m. One moisture content of the fill was recorded at 26%.

5.2 Organic Silt (OL)

A 600 mm layer of organic silt was encountered at creek bed surface in Borehole 17-03. The underside of the organic silt was at 0.6 m (elev. 267.4 m) below the existing creek bed surface.

An SPT test conducted in this surficial layer gave an N-value of 3 blows indicating a relative density of very loose.

One moisture content of the silt was recorded at 46%. The result of a grain size analyses conducted on one sample of the organic silt is summarized below and is illustrated on Figure C2 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0
Sand	8
Silt	62
Clay	30

An Atterberg Limit test was completed on one sample of the organic silt deposit. The result is summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graph is included in Figure C9 of Appendix C. The laboratory results are summarized below and indicate that the material is a low plasticity organic (OL).

Parameter	Value
Liquid Limit	31
Plastic Limit	24
Plasticity Index	7

5.3 Silt (ML)

Boreholes 17-01, 17-03, 17-05 and 17-06 encountered a native layer of silt with clay seams and varying amounts of sand. The thickness of this layer ranged from 0.8 to 2.5 m with a base elevation ranging from 264.9 to 268.6 m.

The SPT tests conducted in this layer gave N-values ranging from 2 to 10 indicating a relative density of very loose to compact.

Recorded moisture contents ranged from 27 to 40%. The results of grain size analyses conducted on two samples of the silt are summarized below and illustrated on Figure C3 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0
Sand	0 - 1
Silt	81 - 83
Clay	16 - 19

Atterberg Limit testing was completed on one sample of the silt deposit. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graph is included in Figure C10 of Appendix C. The laboratory results are summarized below and indicate that the material ranges from a non-plastic to an inorganic silt (ML).

Parameter	Value
Liquid Limit	29
Plastic Limit	24
Plasticity Index	5

5.4 Clay (CL)

A native deposit of clay with occasional silt seams was encountered below fill material in Borehole 17-04 and below the silt in Borehole 17-01. The thickness of this clay deposit ranged from 3.6 to 3.0 m with a bottom elevation of 264.9 to 265.1 m. The SPT N-values ranged from 1 to 12 blows indicating a consistency of approximately very soft to stiff.

The moisture content of the samples tested ranged from 26 to 40%. The results of grain size analyses conducted on two samples of the clay are summarized below and are illustrated on Figure C4 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0
Sand	1 – 2
Silt	67 – 75
Clay	24 – 31

Atterberg Limit testing was completed on two samples of the clay deposit. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graph is included in Figure C11 of Appendix C. The laboratory results are summarized below and indicate that the clay is of low plasticity (CL).

Parameter	Value
Liquid Limit	32
Plastic Limit	22 – 23
Plasticity Index	9 – 10

5.5 Silty Clay (CL-ML)

A native deposit of silty clay was encountered below the embankment fill in Borehole 17-02. This thickness of this silty clay deposit was 2.0 m with a bottom elevation of 266.3 m. The SPT N-values ranged from 3 to 7 blows indicating a soft to firm consistency.

The moisture content of the samples tested ranged from 38 to 42%. The results of grain size analyses conducted on one sample of the silty clay are summarized below and illustrated on Figure C5 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0
Sand	1
Silt	80
Clay	19

Atterberg Limit testing was completed on one sample of the silty clay deposit. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graph is included in Figure C12 of Appendix C. The laboratory results are summarized below and indicate that the silty clay has low plasticity (CL-ML).

Parameter	Value
Liquid Limit	29
Plastic Limit	22
Plasticity Index	7

5.6 Silty Sand

All Boreholes encountered a layer of silty sand. The silty sand was encountered below the clay deposit in Boreholes 17-01 and 17-04, below the silty clay deposit in Borehole 17-02 and below the silt in Boreholes 17-03, 17-05 and 17-06. Boreholes 17-02, 17-03, 17-04 and 17-05 were terminated within this silty sand layer at elevations ranging from 257.7 to 258.4 m. Where fully penetrated, the thickness of this layer ranged from 3.4 to 6.7 m with a base elevation ranging from 259.0 to 261.6 m.

The SPT tests conducted in this silty sand layer gave N-values ranging from 4 to 19 blows indicating a relative density of loose to compact.

Measured moisture contents ranged from 19 to 30%. The results of grain size analyses conducted on seven samples of the silty sand material are summarized below and are illustrated on Figures C6 and C7 in Appendix C.

Soil Particle	Percentage (%)	
Gravel	0	
Sand	43 – 81	
Silt	51 – 56	19 – 53
Clay	1	

Atterberg Limit testing was completed on two samples of the silty sand deposit. The laboratory results indicated the silty sand to be non-plastic.

5.7 Sand

Boreholes 17-01 and 17-06 encountered a sand deposit below the silty sand. Both Boreholes were terminated within this layer with a base elevation ranging from 257.2 to 257.9 m.

The SPT tests conducted in this sand layer gave N-values ranging from 3 to 10 blows indicating a relative density of very loose to compact.

Recorded moisture contents ranged from 20 to 24%. The results of grain size analyses conducted on two samples of the silty sand material are summarized below and are illustrated on Figure C8 in Appendix C.

Soil Particle	Percentage (%)	
Gravel	0	
Sand	91 – 95	
Silt	5 – 9	
Clay		

5.8 Refusal

Bedrock was not encountered within the sampled depth of investigation. Boreholes 17-01, 17-02 and 17-03 were extended below sampled depth with a Dynamic Cone Penetration Test (DCPT) to refusal at elevations ranging from 250.3 to 253.2 m on inferred bedrock. It is noted that refusal could also be possible due to the presence of boulders, cobbles or very dense glacial till.

5.9 Groundwater

The water level of Black Creek was recorded during the off-road portion of the field work at elevations ranging from 269.1 to 269.3 m between August 14th to 17th, 2017. The water levels recorded in the open boreholes upon completion of drilling during the on-road portion of the field work ranged in elevations from 269.5 to 269.6 m between May 8th to 9th, 2017.

These observations are considered short term and 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.

5.10 Analytical Testing

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

Borehole	Sample	Depth (mbgs)	Sulphate ($\mu\text{g/g}$)	pH (-)	Resistivity (Ohm-cm)	Conductivity ($\mu\text{S/cm}$)	Chloride ($\mu\text{g/g}$)
17-03	SS2	0.8 - 1.4	23	8.33	10100	99	11
17-05	SS3	1.5 - 2.1	25	8.05	5680	176	51

6 MISCELLANEOUS

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

George Downing Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling and in-situ testing and borehole decommissioning of the on-road boreholes. Forage M3 Drilling Services Inc. of Hawkesbury, Ontario supplied and operated the raft supported portable drilling equipment to conduct the drilling, soil sampling, in-situ testing, and borehole decommissioning of the off-road holes. The field investigation was supervised on a full-time basis by Mr. Jeff Morrison, E.I.T. and Miss Katya Edney P.Eng. of Thurber. Overall supervision of the investigation program was provided by Mr. Stephen Peters, P.Eng.

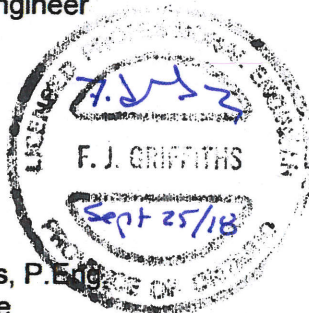
Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Dr. Fred Griffiths, P.Eng., Miss Katya Edney 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.



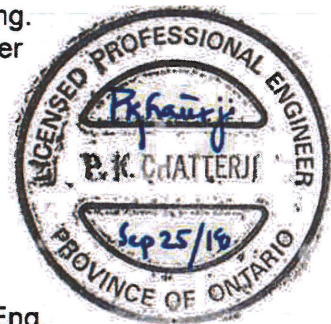
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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the design team in the proposed works for the Black Creek Culvert crossing at Highway 35, located approximately 1.2 km south of Haliburton Rd 2 (Deep Bay Rd) within Lutterworth Township. The discussion and recommendations presented in this report are based on the information provided by McIntosh Perry Consulting Engineers Ltd. (MPCE) and on the factual data obtained during the course of the investigation.

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

In general terms, the site was found to be underlain by a pavement structure and granular fill overlying a deposit of clay over a silty sand and sand deposit. A layer consisting of organic silt was present at the creek bed surface (underwater) at one of the off-road boreholes. DCPT refusal was encountered at depths of 15 to 20 m below the road surface in three boreholes. The water level of Black Creek was recorded during the off-road portion of the field work at elevations ranging from 269.1 to 269.3 m between August 14th to 17th, 2017.

7.1 Proposed Structure

No drawings for culvert rehabilitation or replacement are available. This report provides recommendations for replacement of the existing culvert on the current alignment with a similar dimensioned culvert. The existing culvert is understood to be an open-footed 3.0 x 2.4 m culvert with a length of 20.6 m. Extensions of 3.0 x 3.0 m were added to both ends in 1968. The east extension was 8.5 m long and the west extension was 4.9 m long.

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7.2 Codes and Design for Consideration

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

It is understood that a structural culvert replacement would have a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. The culvert has been assessed as a *Seismic Performance Category* of 1 as per Table 4.10 of the CHBDC.

The frost penetration depth and associated recommendations are provided in Section 10.4.

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). 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 ($S_a(T)$) for the *reference* ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is included in Appendix F

The site coefficients used to determine the design spectral acceleration and displacement values for the highway embankment are a function of the Site Class and the peak ground acceleration (PGA), which is 0.046g at this site for a 975-year seismic event (per Section 4.4.6.4 of the 2016 BC supplement to the CHBDC) and a reference Site Class C. This PGA will need to be scaled by the site-specific Site Class.

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. It should be noted that culvert boreholes terminated at Dynamic Cone Penetrometer (DCPT) refusal at less than 30 m, thus do not extend deep enough to satisfy this requirement. In the evaluation, an SPT N-value equivalent to refusal has been assumed for the interval below the DCPT refusal.

It is noted that the fundamental period of the replacement structure is likely less than 0.5 seconds, thus in accordance with Section 4.4.3.3 of the CHBDC, liquefaction need not be considered in determining Site Class. Based on the observed soil conditions, the soil profile at this site has been classified using SPT N-Values as a Site Class E in accordance with Table 4.1 of the CHBDC.

8.3 Seismic Liquefaction

Based on the subsurface condition encountered at the drilled locations at this site the soil deposits beneath the culvert foundation are considered to have a low susceptibility to

liquefaction under the design 975-year earthquake. The finding of this assessment can be attributed to the low reference PGA.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

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

- Circular Pipes (Concrete, HDPE, Steel)

From a foundation engineering perspective, a pipe culvert is a technically feasible alternative. An internal pipe area equal or greater than that of the current culvert may need to be provided to meet flow capacity, navigation and hydraulic requirements. Alternatively, multiple pipes may also be required to provide the hydraulic requirements.

- Open Bottom Culvert (Box, Arch)

The existing open bottom culvert appears to have performed satisfactorily and no documented history is available. Replacement with an open bottom culvert will have greater construction concerns due to the water elevation and requirement for greater excavation depths to construct the culvert footings to satisfy frost depth requirements. The use of an open bottom culvert would require greater dewatering efforts and has the potential for larger settlement following construction when compared to other culvert options.

- Closed Bottom Culvert (Box)

A precast segmental box culvert 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. If the culvert is to be constructed on the same alignment, the existing footings will need to be cut-off at an elevation at least 500 mm below the base of the bedding. Full depth removal of the footings could cause disturbance to the bearing soils and result in excessive excavation.

- Steel Sheet Pile Walls with Precast Concrete Slab

A sheet pile wall supporting precast concrete slabs is considered feasible from a geotechnical perspective. The presence of near surface cobbles and boulders at the culvert ends may cause difficulties with pile installation but the construction risk is considered manageable since the obstructions can be readily accessed. A deeper borehole investigation may be required to confirm bearing capacities and end bearing elevations for the sheet piles.

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 traffic staging. However, it is understood that an acceptable detour route 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 temporary detour embankment to accommodate traffic passage during construction is not likely feasible due to the presence of open water on both sides of the highway and would require further regulatory approvals. A review of the requirement for property acquisition and highway geometry would also need to be completed to assess this option.
- Open Cut with Staged Construction and Temporary Protection System
The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. This option will require roadway protection.
- Trenchless Techniques
A trenchless culvert installation is not considered feasible due to the presence of open water at both ends of the culvert and is not recommended at this site.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacing the existing open footed culvert with a closed box culvert using open cut techniques in conjunction with staged construction is the recommended culvert replacement option. Temporary protection systems (TPS) will be needed to facilitate construction, as discussed further in Section 11.2. Wingwalls are not expected to be required.

10 FOUNDATION DESIGN RECOMMENDATIONS

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

10.1 Culvert Foundation Bearing Resistances

Provided the replacement culvert is constructed on the same alignment with a similar opening size as the existing culvert and the embankment is reconstructed with no grade raise or widening (temporary or permanent), it is anticipated that the subgrade soils within

the culvert footprint will not be subjected to any significant additional loading. The subgrade should be prepared as described in Section 10.2.

The recommended geotechnical resistances for a 3.0 m wide (interior) pre-cast closed box culvert with the underside of culvert base slab at or below approximate elevation 267.7 m, installed on a bedding layer placed on an undisturbed native clay/silty clay subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Factored Geotechnical Resistance at SLS of 125 kPa

The factored geotechnical resistances include the following factors:

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

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4. Foundation settlement, based on the supplied SLS resistance, is expected to be less than 25 mm for culverts constructed on subgrades prepared with good workmanship and in accordance with Section 10.2 below.

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. A suitable reduction factor should be used in design.

Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (Section 11.3) .

10.2 Subgrade Preparation, Bedding and Backfilling

After excavation and removal of the existing culvert and existing fill, all organics, 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. Organic silt may be encountered in the area of the inlet and outlet. The bearing resistances provided above assume that organic material, where encountered at the subgrade level within the culvert footprint is removed. The subexcavation should extend down to the competent inorganic soils, or to a maximum depth of 1.0 m below the culvert invert and be replaced with well compacted Granular A.

Consideration could be given to extracting the existing culvert footings, alternatively the footings could be cut off at an elevation 500 mm below the depth of the new bedding layer to limit the excavation requirements.

The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials at the subgrade level should be sub-excavated and backfilled and compacted as per OPSS.PROV 501 with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the

subgrade from disturbance during construction. In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 300 mm thick layer of well compacted bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010.

Given the subgrade soils anticipated at the founding level of the replacement culvert, construction equipment should not be permitted to travel on the exposed subgrade. The compaction of granular bedding directly above the subgrade may result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include installation of a Class II, non-woven geotextile with a maximum FOS of 150 μm (OPSS 1860) installed beneath the Granular A material. The geotextile should be placed as soon as possible after inspection of the final subgrade level and following receipt of written notice to proceed in accordance with SP 109S12. An NSSP is provided in Appendix G to include in the contract documents to alert the Contractor of the sensitive nature of the foundation soils.

It is noted that construction will extend below the creek elevation. Creek diversion and 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 be in accordance with OPSS 902 and consist of free-draining, non-frost susceptible granular materials such as Granular A or Granular B Type II material meeting the requirements of OPSS.PROV 1010.

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

10.3 Lateral Earth Pressures

Lateral earth pressures 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 in design.

10.3.1 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:

$$\sigma_h = K * (\gamma d + q)$$

where:

σ_h	=	lateral earth pressure at depth d (kPa)
K	=	earth pressure coefficient (see table below)
γ	=	unit weight of retained soil (see table below and use submerged unit weight for soil below the groundwater level)
d	=	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 $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Sand Fill $\phi = 30^\circ, \gamma = 21.0 \text{ kN/m}^3$	
	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 (Moment towards Wall)	0.27	0.39	0.31	0.47	0.33	0.54
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

Note: (*) for use with 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 the table above. 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 should be used.

10.3.2 Combined Static and Seismic Lateral Earth Pressure Parameters

In accordance with Clause 4.6.5 of the CHBDC (S6-14), a structure should be designed using dynamic earth pressure coefficient that incorporate the effects of earthquake loading. The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using Mononobe-Okabe Method with:

- $k_h = \frac{1}{2} * F(PGA) * PGA$, 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 5% probability of exceedance in 50 years (975-year seismic event) of 0.046g (Geological Survey of Canada – Fifth Generation) and a $F(PGA)$ of 1.81 as per Table 4.8 of the CHBDC.

Table 10-2. Dynamic Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_{AE} Yielding Wall	0.29	0.44	0.33	0.51
Active, K_{AE} Non-Yielding Wall	0.32	0.49	0.37	0.57

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

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

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_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil (use submerged unit weight for soil below The groundwater level)
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.4 Frost Depth

The depth of frost penetration at this site is 1.9 m. For any new foundation element, a minimum 1.9 m of earth cover or thermal equivalent should be provided. It is not necessary to found a closed box culvert at a depth below frost. However, frost taper treatment, if required, should be as directed within the Pavement Design Report.

10.5 Embankment Design and Reinstatement

10.5.1 Embankment Reconstruction

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

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.

10.5.2 Embankment Settlement and Stability

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

It is assumed that the existing embankment geometry would not change following culvert construction and no permanent grade raise or embankment widening is proposed. Provided proper construction methods are used, no long term or global stability issues are anticipated for embankments reinstated at this site. Pseudo-static slope stability analyses have been carried out to assess stability during the design seismic event and an acceptable factor of safety has been observed.

Material stockpiling above the existing grades is a temporary construction measure and the stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as cranes) are also the Contractor's responsibility.

As no grade raise is proposed along the alignment of Highway 35 settlement of the soils beneath the embankment is expected to be negligible.

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

10.6 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.10 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavation

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

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 organic silt and/or clay deposits. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA.

Cobbles and boulders were noted at the ends of the culvert. Suggested wording concerning possible obstructions is provided in Appendix G.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion is presented in Section 11.2.

11.2 Temporary Protection Systems

Temporary Protection Systems may be required during construction and therefore must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. The protection system should be installed at a suitable distance away from the existing culvert to limit the disturbance to subgrade associated with removal of the protection system following completing of construction. Alternatively, the protection system near the culvert could be left in place and cut off in accordance with OPSS.PROV 539. Vibratory equipment

should not be permitted at this site for installation or removal of the temporary protections system. Suggested wording for an NSSP is provided in Appendix G.

Cobbles and boulders were noted at the ends of the culvert. Suggested wording concerning possible obstructions is provided in Appendix G.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through embankment fill and culvert backfill are provided in Table 10-1. The lateral earth pressure coefficients for the existing soils are given below:

Silt and Clay

$$\begin{array}{lll} \gamma & = & 19 \text{ kN/m}^3 \quad (\text{use submerged unit weight for soil below} \\ & & \text{groundwater level}) \\ K_A & = & 0.35 \\ K_P & = & 2.9 \end{array}$$

Native Silty Sand and Existing Sand Fill

$$\begin{array}{lll} \gamma & = & 19 \text{ kN/m}^3 \quad (\text{use submerged unit weight for soil below} \\ & & \text{groundwater level}) \\ K_A & = & 0.33 \\ K_P & = & 3.0 \end{array}$$

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

11.3 Surface and Groundwater Control

Creek diversion controlled by coffer dams will be required.

The depth of excavation for culvert replacement will extend below the creek level observed at the time of the investigation. The Contractor must be prepared to control the groundwater and surface water flow at the site to permit construction in a dry and stable excavation. Water from surface flow and/or groundwater must be diverted away from any excavation at all times. Groundwater perched within the embankment fill and, surface runoff will tend to seep into, and accumulate in excavations.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP No. FOUN0003 which amends OPSS 902. A preconstruction survey is recommended, thus Designer Fill-In ** in the SP should be "250m".

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01. It is recommended that the design Engineer and design-checking Engineer have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work, thus Designer Fill-In ***** in SP517F01

should be "Yes". A preconstruction survey is recommended, thus Designer Fill-In ***** in this SP should be "250m".

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed work should be taken as the water level of the design storm return period defined by SP517F01 and SP FOUN0003.

Temporary groundwater and surface water control measures will be required to remain operational during construction until the culvert is installed and backfilled. It is anticipated that the culvert replacement work will be isolated within a water tight enclosure. Sheet Pile cofferdams can be designed following the recommendations provided in Section 11.2. The comments on installation and extraction of Temporary Protection Systems are also relevant for Sheet Pile Cofferdams.

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 foundation soil below the water level, making it difficult to maintain a dry, sound base on which to work. The groundwater level within the culvert footprint should be lowered by pumping from sumps prior to excavation to at least 500 mm below the underside of the target depth of each excavation stage prior to initiating excavation.

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

Based on the subsurface conditions encountered at the drilled locations through the embankment at this site the embankment materials soils are considered to have low susceptibility to erosion as per the Wischmeier Nomograph. The native soils at the inlet and outlet are considered to have moderate susceptibility to erosion.

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.

12 CONSTRUCTION CONCERNS

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

- Disturbance of the soil subgrade. The foundation consists of fine grained soils. The moisture sensitive subgrade conditions may become heavily disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade conditions. The Contractor must be aware of the issue so that he may adjust his operations to suit the subgrade conditions.

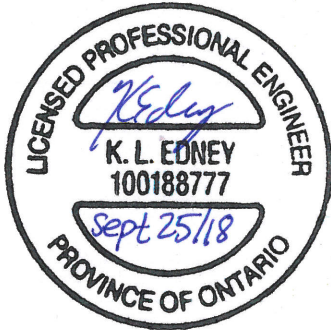
- Buried obstructions may be encountered during excavation in the embankment fill or interfere with driving of protection systems. Cobbles and boulders were observed at ground surface near Borehole 17-03.
- Creek water and groundwater levels will fluctuate. Excavation will involve lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes. An effective surface water diversion plan and dewatering system is vital to permit construction in a dry and stable excavation.
- 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.

The successful performance of the rehabilitated culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination should be carried out by qualified geotechnical personnel during construction in accordance with SP109S12 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 Miss Katya Edney, P.Eng. and Mr. Stephen Peters, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng and Dr. P.K. Chatterji, P.Eng a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:



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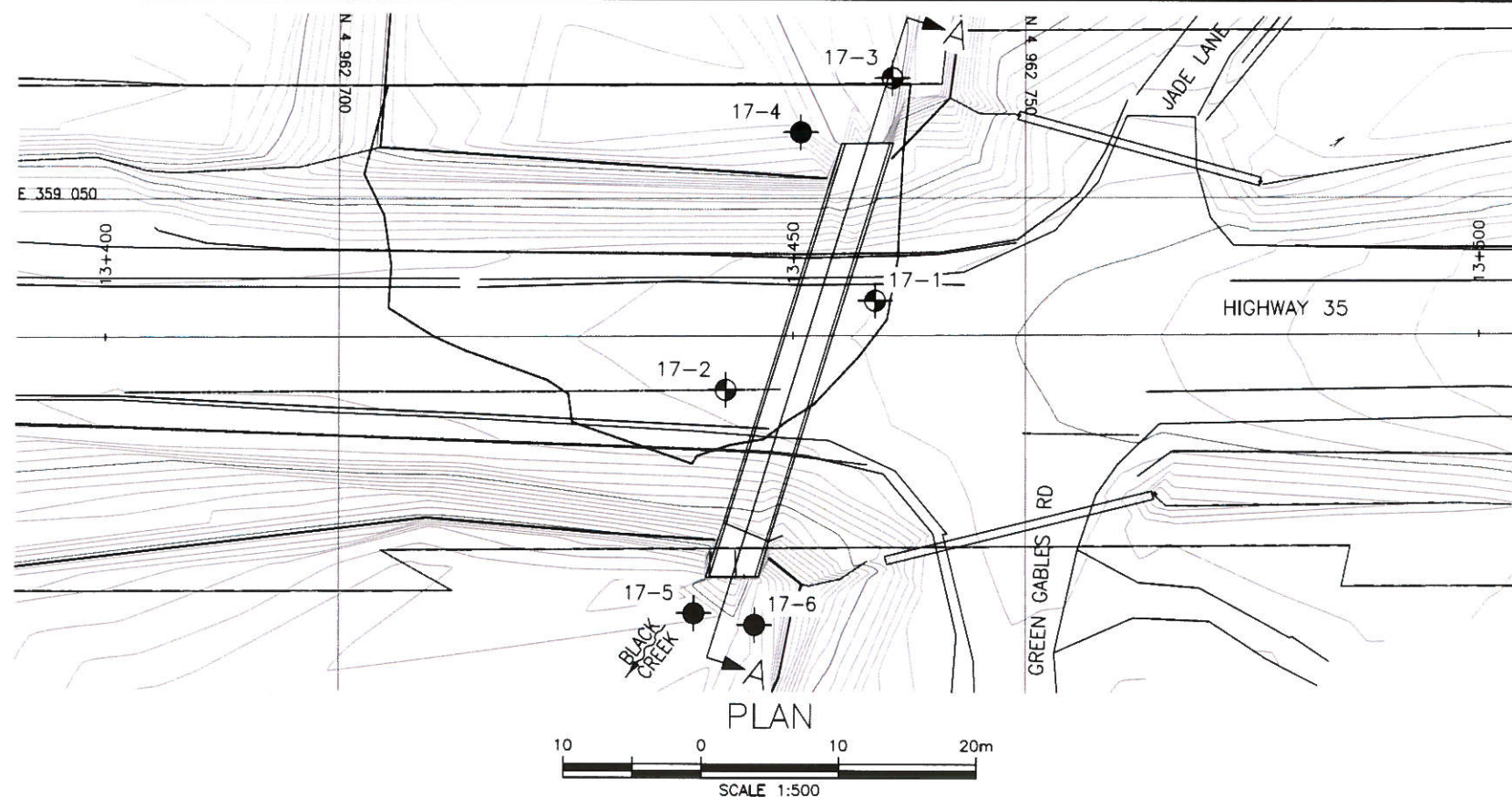


Dr. P.K. Chatterji, P.Eng.
Review Principal
Senior Geotechnical Engineer

FINAL

Appendix A.

Borehole Location Plan and Stratigraphic Drawings



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



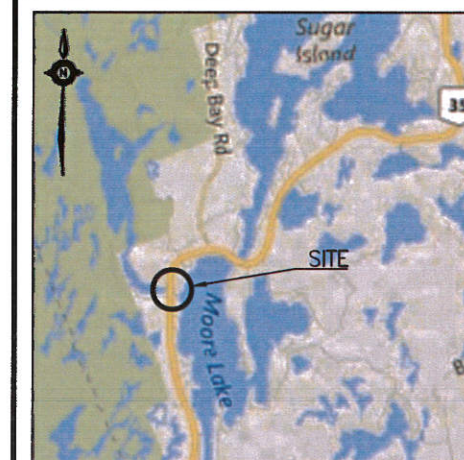
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GWP No 5087-11-00

HIGHWAY 35
BLACK CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

**McINTOSH
PERRY**








THURBER ENGINEERING LTD



KEYPLAN

LEGEND

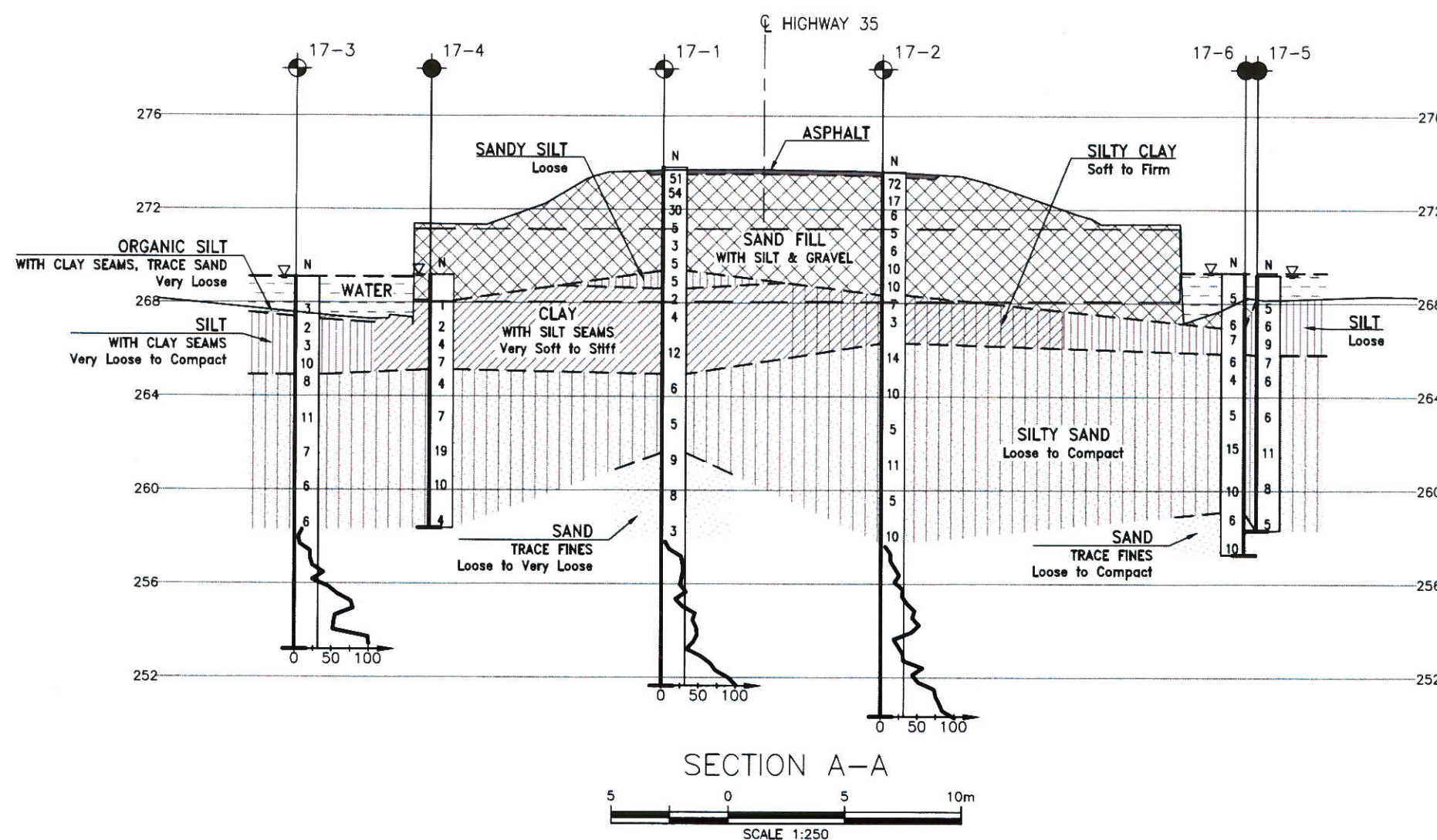
- | | |
|---|---------------------------------------|
|  | Borehole |
|  | Borehole and Cone |
| N | Blows /0.3m (Std Pen Test, 475J/blow) |
| CONE | Blows /0.3m (60° Cone, 475J/blow) |
| PH | Pressure, Hydraulic |
|  | Water Level |
|  | Head Artesian Water |
|  | Piezometer |
| 90% | Rock Quality Designation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

NO	ELEVATION	NORTHING	EASTING
17-1	273.8	4 962 739.1	359 057.7
17-2	273.6	4 962 728.2	359 063.3
17-3	269.1	4 962 740.3	359 041.1
17-4	269.2	4 962 733.6	359 045.5
17-5	269.2	4 962 725.9	359 080.5
17-6	269.3	4 962 730.3	359 080.5

-NOTES-

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

GEOCRES No. 31D-690



REVISIONS									
	DATE	BY				DESCRIPTION			
DESIGN	KE	CHK		CODE		LOAD		DATE	SEP 20
DRAWN	MFA	CHK	KE	SITE		ISTRUCT		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).

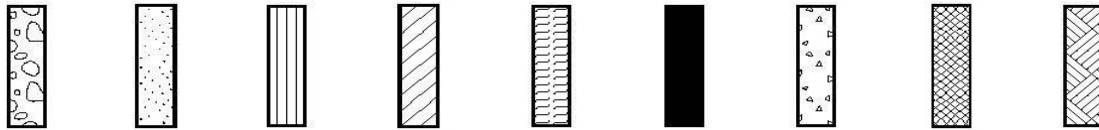
DYNAMIC CONE PENETRATION TEST (DCPT):

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

RECORD OF BOREHOLE No 17-1

1 OF 3

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962739.1 E 359057.4 ORIGINATED BY JM
 HWY 35 BOREHOLE TYPE CME75 Truck with NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.05.08 - 2017.05.08 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								
273.8								20	40	60	80	100				
0.0	180 mm ASPHALT															
0.2	SAND With Silt and Gravel Very Dense to Very Loose Brown FILL		1	SS	51		273									
			2	SS	54											
			3	SS	30		272									
			4	SS	5											
			5	SS	3		271									
			6	SS	5		270									
269.4																
4.4	SILT Sandy Loose Brown-Grey		7	SS	5		269									
268.6																
5.2	CLAY (CL) Soft to Stiff Grey		8	SS	2		268									
			9	SS	4											
							267									
			10	SS	12		266									
264.9							265									
8.8	SILTY SAND (SM) Loose Grey		11	SS	6		264									

ONTMT4S 16284 BLACK CREEK.GPJ 2012TEMPLATE(MTO).GDT 16/3/18

Continued Next Page

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

RECORD OF BOREHOLE No 17-1

2 OF 3

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962739.1 E 359057.4 ORIGINATED BY JM
 HWY 35 BOREHOLE TYPE CME75 Truck with NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.05.08 - 2017.05.08 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									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page						20 40 60 80 100										
261.6	SILTY SAND (SM) Loose Grey																
			12	SS	5												
12.2	Poorly graded SAND Trace Fines Loose to Very Loose Grey		13	SS	9												
			14	SS	8												
257.9																	
			15	SS	3												
15.8	End of sampled Borehole DCPT performed from to 15.8 to 22.1m																

Continued Next Page

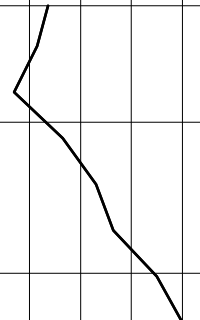
+³, ×³: Numbers refer to Sensitivity
 20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-1

3 OF 3

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962739.1 E 359057.4 ORIGINATED BY JM
 HWY 35 BOREHOLE TYPE CME75 Truck with NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.05.08 - 2017.05.08 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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W P W W L				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)						
	Continued From Previous Page							20 40 60 80 100							
	DCPT continued														
251.6															
22.1	End of DCPT upon refusal at 22.1m Water level at 4.3 m in open borehole upon completion of drilling														

RECORD OF BOREHOLE No 17-2

1 OF 3

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962728.2 E 359063.9 ORIGINATED BY JM
HWY 35 BOREHOLE TYPE CME75 Truck with NW Casing COMPILED BY DJP
DATUM Geodetic DATE 2017.05.09 - 2017.05.09 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
273.6								20 40 60 80 100						
0.0	165 mm ASPHALT							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
0.2	SAND With Silt and Gravel Very Dense to Loose Brown FILL		1	SS	72		273	20 40 60 80 100						
			2	SS	17		272	20 40 60 80 100						
			3	SS	6			20 40 60 80 100						
			4	SS	5		271	20 40 60 80 100						32 65 3 (SI+CL)
			5	SS	6		270	20 40 60 80 100						
			6	SS	10		269	20 40 60 80 100						
			7	SS	10			20 40 60 80 100						
268.3							268	20 40 60 80 100						
5.3	SILTY CLAY (CL-ML) Soft to Firm Grey		8	SS	7		267	20 40 60 80 100						0 1 80 19
			9	SS	3			20 40 60 80 100						
266.3							266	20 40 60 80 100						
7.3	SILTY SAND (SM) Compact Grey		10	SS	14		265	20 40 60 80 100						
							264	20 40 60 80 100						
			11	SS	10			20 40 60 80 100						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-2

2 OF 3

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962728.2 E 359063.9 ORIGINATED BY JM
 HWY 35 BOREHOLE TYPE CME75 Truck with NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.05.09 - 2017.05.09 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE 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			20 40 60 80 100	20 40 60 80 100	W P W W L	20 40 60			
	Continued From Previous Page													
	SILTY SAND (SM) Loose to Compact Grey													
			12	SS	5		263							0 48 51 1
							262							
			13	SS	11		261							
							260							
			14	SS	5		259							
							258							0 69 31 (SI+CL)
257.7			15	SS	10		257							
15.8	End of sampled Borehole DCPT performed from to 15.8 to 23.3m						256							
							255							
							254							

Continued Next Page

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

ONTMT4S 16284 BLACK CREEK.GPJ 2012TEMPLATE(MTO).GDT 16/3/18

METRIC

[illegible]

RECORD OF BOREHOLE No 17-3

1 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962740.3 E 359041.3 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.14 - 2017.08.15 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							
269.1								20 40 60 80 100							
								○ 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 (%)				
0.0	WATER						269								
268.0	- Boulders and Cobbles at ground surface						268								
1.1	organic SILT (OL) With Clay Seams, trace Sand Very loose Grey		1	SS	3							H	○	0 8 62 30	
267.4															
1.7	SILT (ML) With Clay Seams Very loose Grey		2	SS	2		267						○		
			3	SS	3		266					H	○	0 0 81 19	
	-Becoming Compact below 3.4 m		4	SS	10								○		
264.9							265								
4.2	SILTY SAND (SM) Loose to Compact Grey		5	SS	8								○		
							264								
			6	SS	11		263						○		
							262								
			7	SS	7								○	0 79 21 (SH+CL)	
							261								
			8	SS	6		260						○		

Continued Next Page

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

RECORD OF BOREHOLE No 17-3

2 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962740.3 E 359041.3 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.14 - 2017.08.15 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													
258.3	SILTY SAND (SM) Loose Grey		9	SS	6		259							
10.8	End of sampled Borehole DCPT performed from 10.8 to 15.9 m						258							
							257							
							256							
							255							
							254							
253.2	End of DCPT upon refusal at 15.9 m													
15.9														



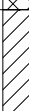

ONTMT4S 16284 BLACK CREEK.GPJ 2012TEMPLATE(MTO).GDT 16/3/18

RECORD OF BOREHOLE No 17-4

1 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962733.6 E 359045.2 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.15 - 2017.08.15 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 (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				w _p w w _L								
269.2								20	40	60	80	100		20	40	60				
0.0	WATER						269													
268.2	- Boulders and Cobbles at ground surface																			
268.0	SILTY SAND trace Gravel, with Organics		1	SS	1		268							○						
1.1	Very Loose Grey-Brown FILL														○					
	CLAY (CL) With Silt Seams Very Soft to Firm Grey		2	SS	2		267							○					0 1 75 24	
			3	SS	4										○					
			4	SS	7		266								○					
265.1															○					
4.1	SILTY SAND (SM) Loose to Compact Grey		5	SS	4		265								○					
							264													
			6	SS	7		263								○				0 76 24 (SH+CL)	
			7	SS	19		262								○					
			8	SS	10		261									○				
							260									○				

Continued Next Page

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

RECORD OF BOREHOLE No 17-4

2 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962733.6 E 359045.2 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.15 - 2017.08.15 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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
258.4	SILTY SAND (SM) Loose Grey		9	SS	4		259										
10.8	End of Borehole																

RECORD OF BOREHOLE No 17-5

1 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962725.9 E 359080.0 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.16 - 2017.08.16 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						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
							WATER CONTENT (%)							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT							
							W P W W L							
							20 40 60 80 100							
							20 40 60 80 100							
269.2														
0.0	WATER						269							
268.1	- Boulders and Cobbles at ground surface													
1.1	SILT (ML) Loose Grey		1	SS	5		268							
			2	SS	6		267							
			3	SS	9		266							
265.8														
3.4	SILTY SAND (SM) Loose Grey		4	SS	7		265							
			5	SS	6		264							
			6	SS	6		263							
	- Brown Laminations below 6.2 m													
							262							
	- Becoming Compact below 7.2 m		7	SS	11		261							
			8	SS	8		260							

Continued Next Page

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

RECORD OF BOREHOLE No 17-5

2 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962725.9 E 359080.0 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.16 - 2017.08.16 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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
	Continued From Previous Page																
258.3	SILTY SAND (SM) Loose Grey		9	SS	5		259										
10.9	End of Borehole																

RECORD OF BOREHOLE No 17-6

1 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962730.3 E 359080.9 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.16 - 2017.08.17 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 (%)
269.3								20	40	60	80	100					
0.0	WATER						269										
268.5	- Boulders and Cobbles at ground surface																
0.7	SAND with Gravel Loose Grey FILL		1	SS	5		268										
266.9			2	SS	6		267										10 84 6 (SI+CL)
2.3	SILT (ML) Loose Grey		3	SS	7												
							266										
265.8																	
3.5	SILTY SAND (SM) Loose to Compact Grey		4	SS	6		265										
			5	SS	4		264										
			6	SS	5		263										
							262										0 81 19 (SI+CL)
			7	SS	15		261										
			8	SS	10		260										

Continued Next Page

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

RECORD OF BOREHOLE No 17-6

2 OF 2

METRIC

GWP# 5087-11-00 LOCATION Black Creek, MTM Zone 12: N 4962730.3 E 359080.9 ORIGINATED BY KE
 HWY 35 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.16 - 2017.08.17 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 (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										WATER CONTENT (%)				
								20	40	60	80	100						20	40	60		
	Continued From Previous Page																					
259.0							259															
10.2	Poorly graded SAND Trace Fines Loose to Compact Grey		9	SS	6											0 91 9 (SI+CL)						
							258															
			10	SS	10																	
257.2																						
12.0	End of Borehole																					

+ ³, × ³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

Appendix C.

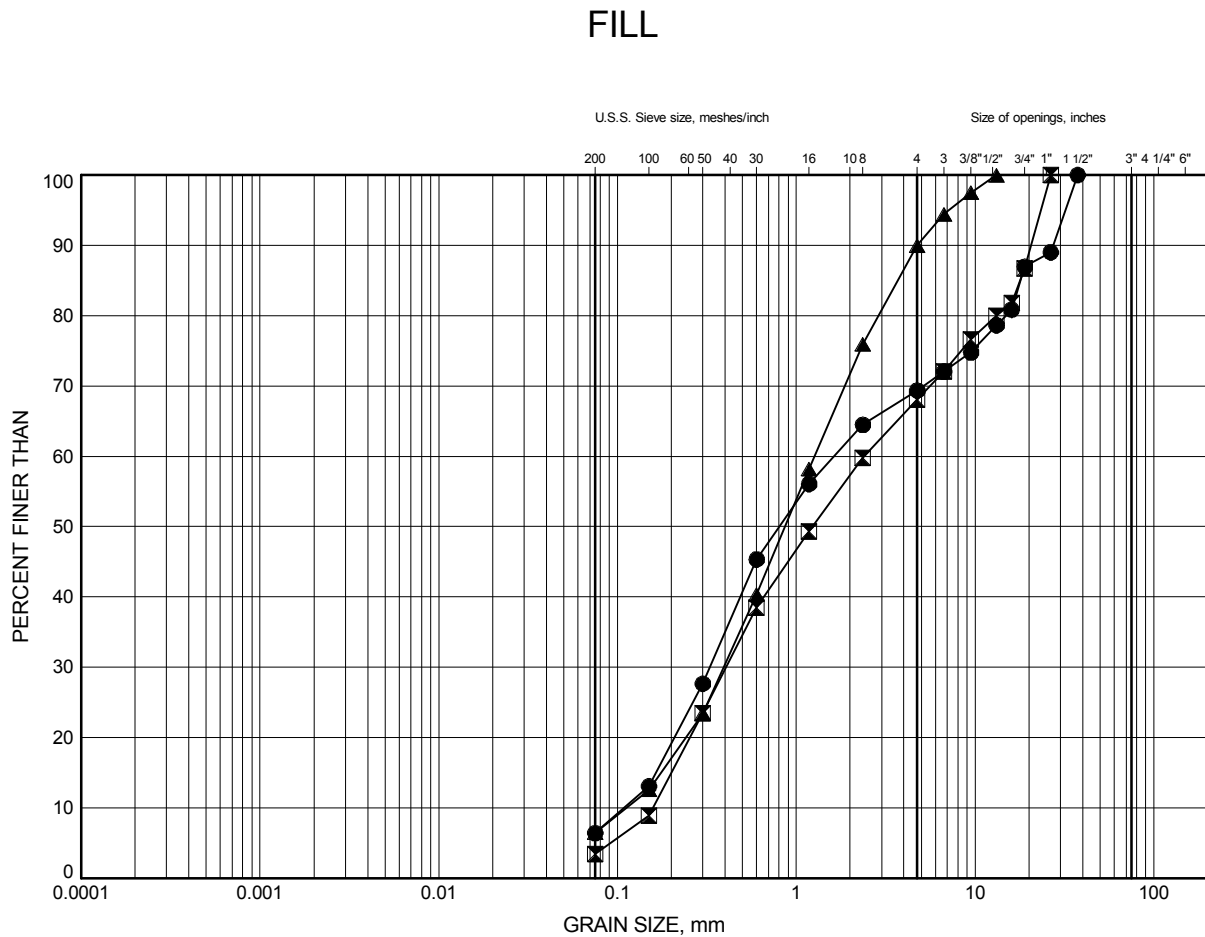
Laboratory Testing

Appendix C.1
Particle Size Analysis Figures

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	1.83	271.94
⊠	17-2	2.59	270.98
▲	17-6	2.11	267.14

Date ..September 2018.....

GWP# ..5087-11-00.....



Prep'dKE.....

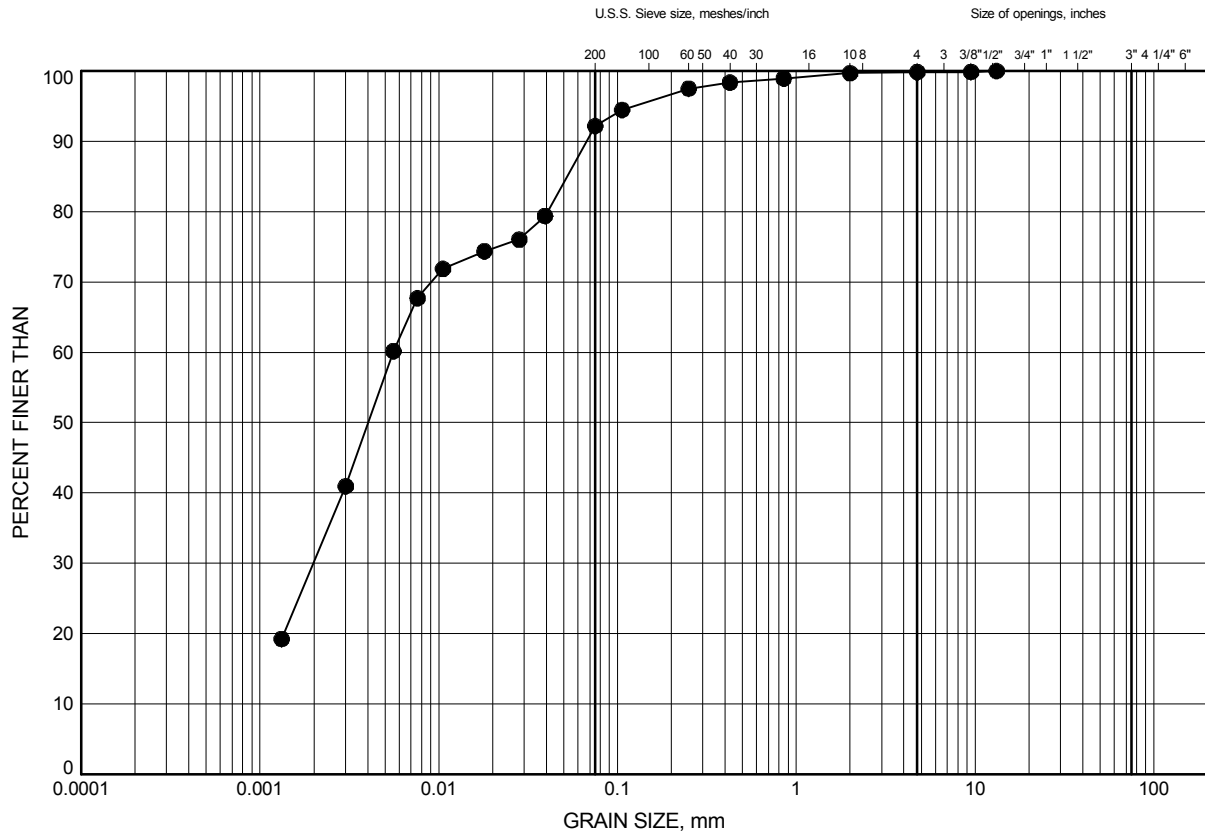
Chkd.SP.....

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C2

ORGANIC SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	1.40	267.72

Date September 2018
GWP# 5087-11-00

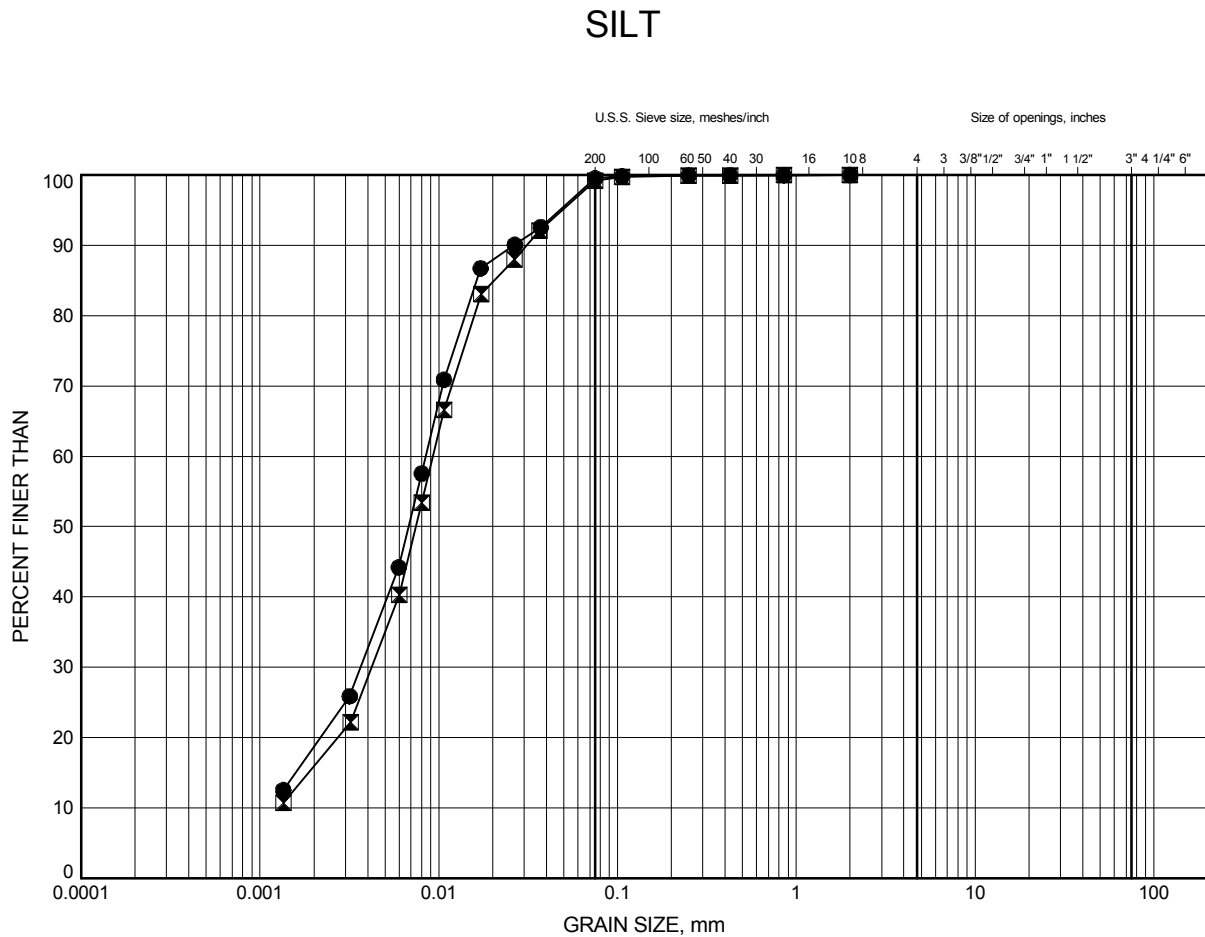


Prep'd KE
Chkd. SP

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	2.97	266.15
⊠	17-5	2.13	267.07

Date September 2018

GWP# 5087-11-00



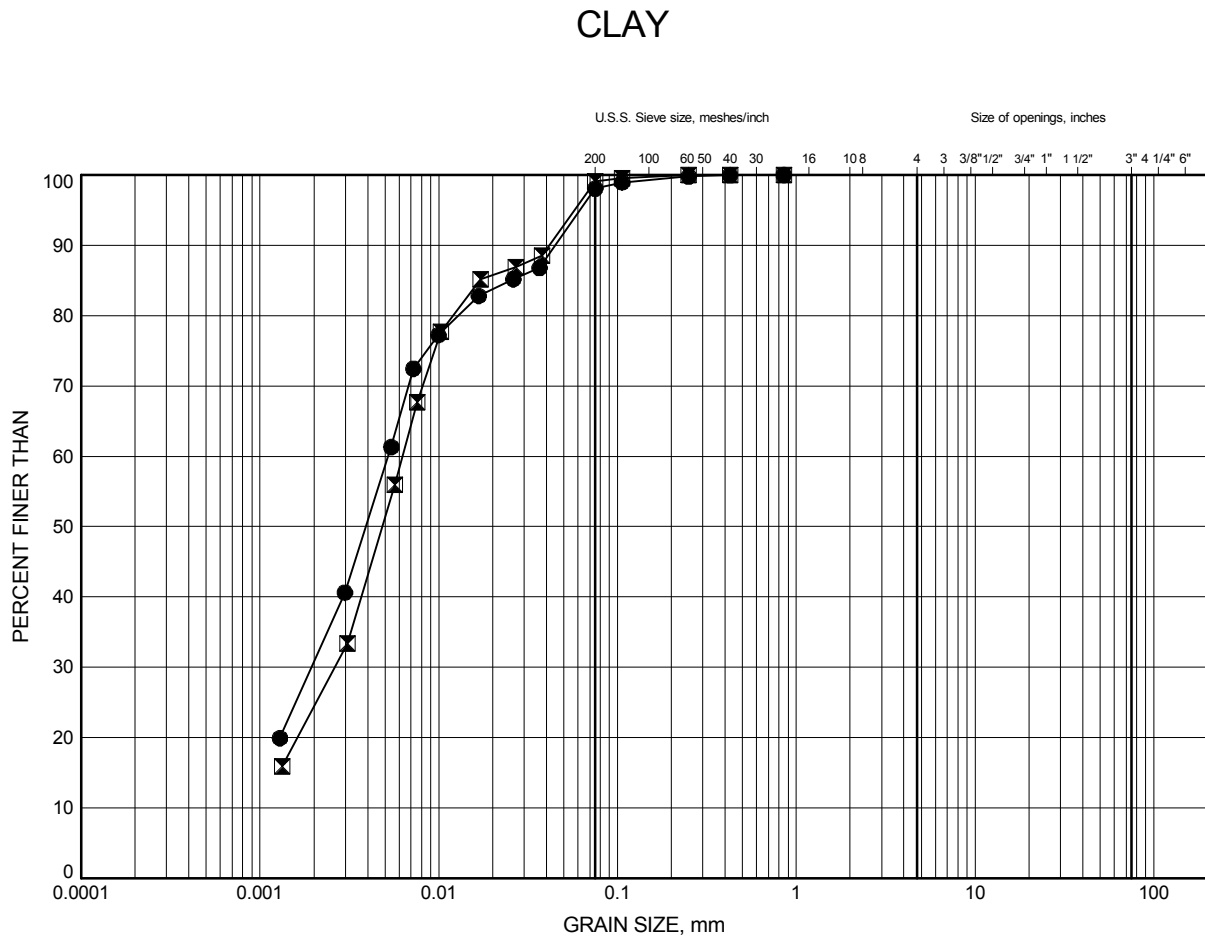
Prep'd KE

Chkd. SP

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	5.64	268.13
⊠	17-4	2.23	266.96

Date September 2018

GWP# 5087-11-00



Prep'd KE

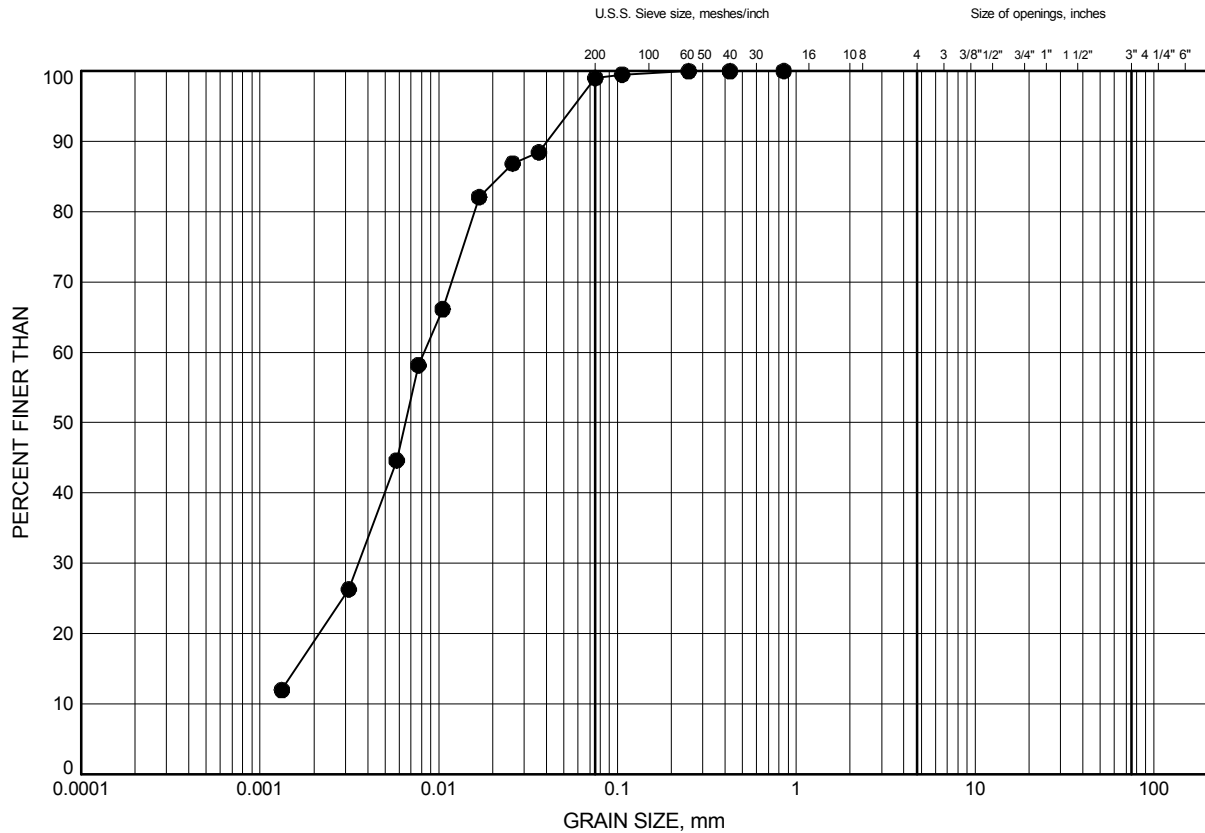
Chkd. SP

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C5

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-2	6.40	267.17

Date September 2018
GWP# 5087-11-00



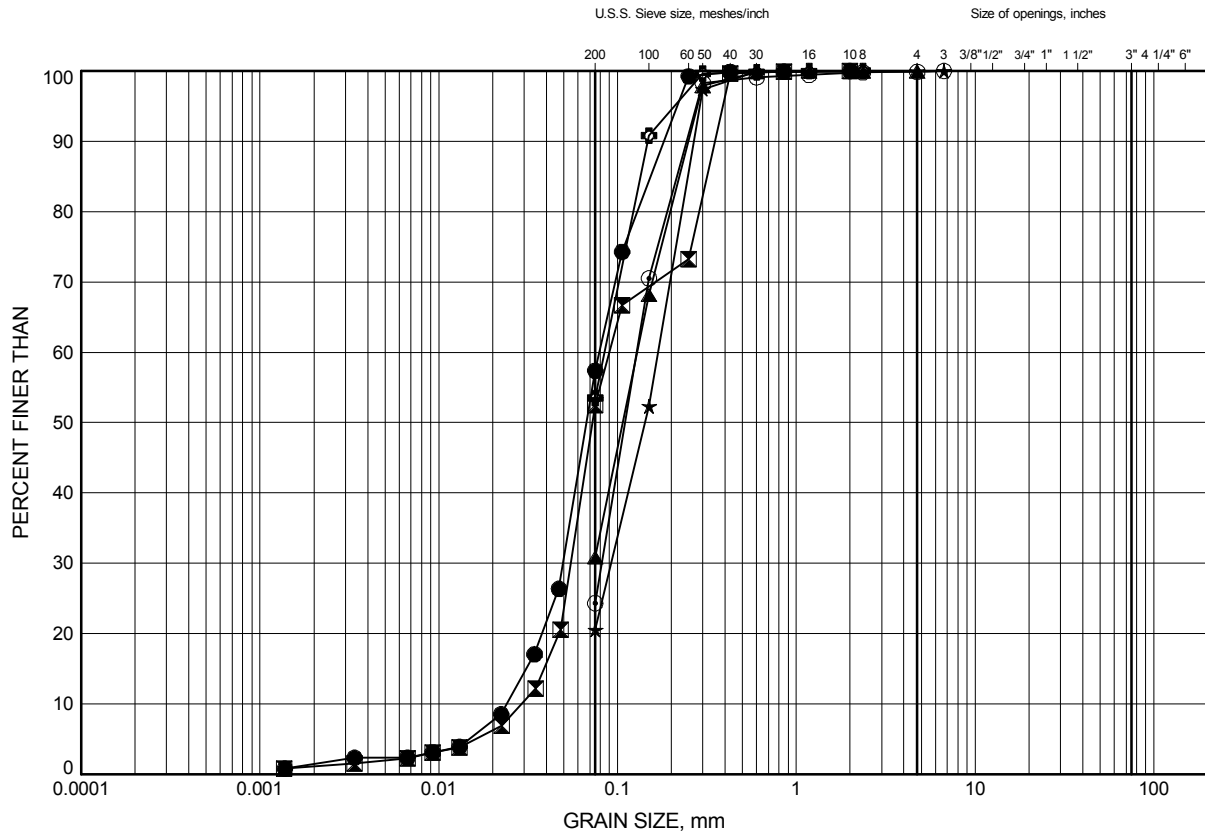
Prep'd KE
Chkd. SP

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C6

SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	9.45	264.32
⊠	17-2	10.97	262.60
▲	17-2	15.54	258.03
★	17-3	7.52	261.60
⊙	17-4	6.07	263.12
⊕	17-5	3.71	265.49

Date September 2018

GWP# 5087-11-00



Prep'd KE

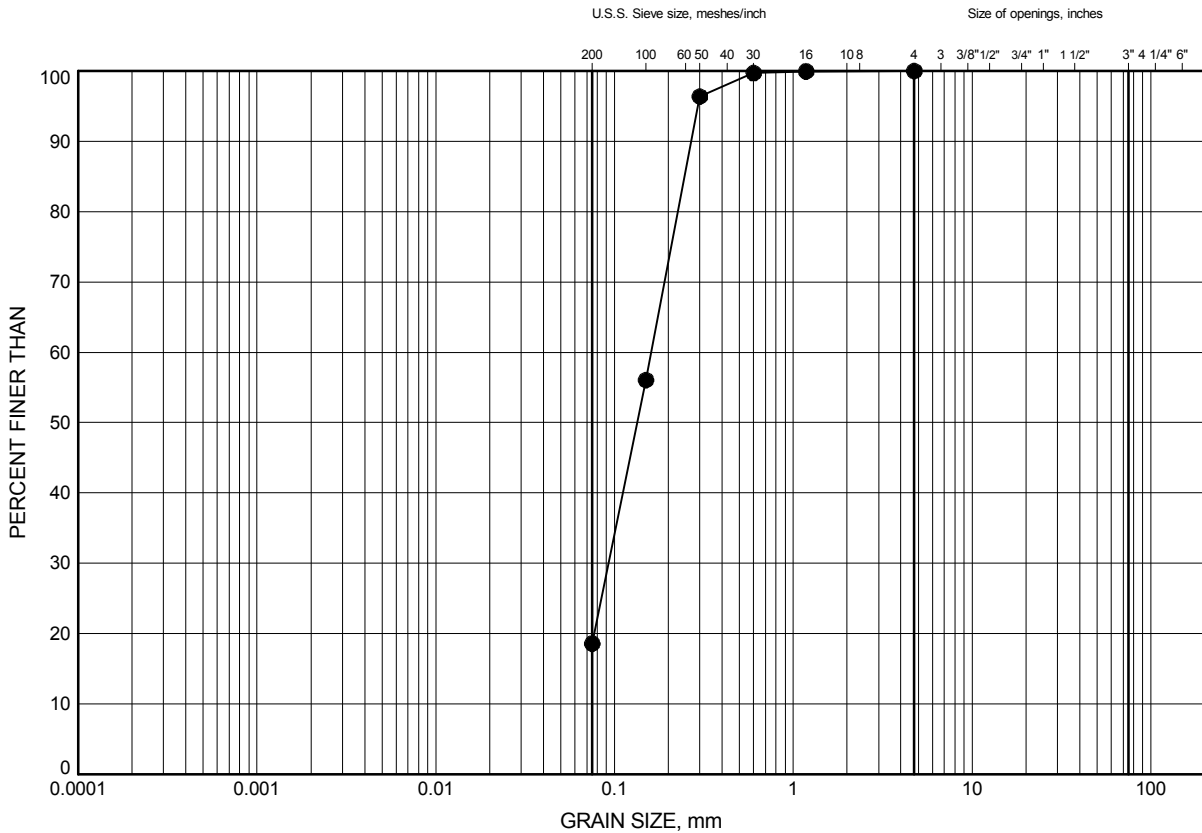
Chkd. SP

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C7

SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-6	7.47	261.78

Date September 2018

GWP# 5087-11-00



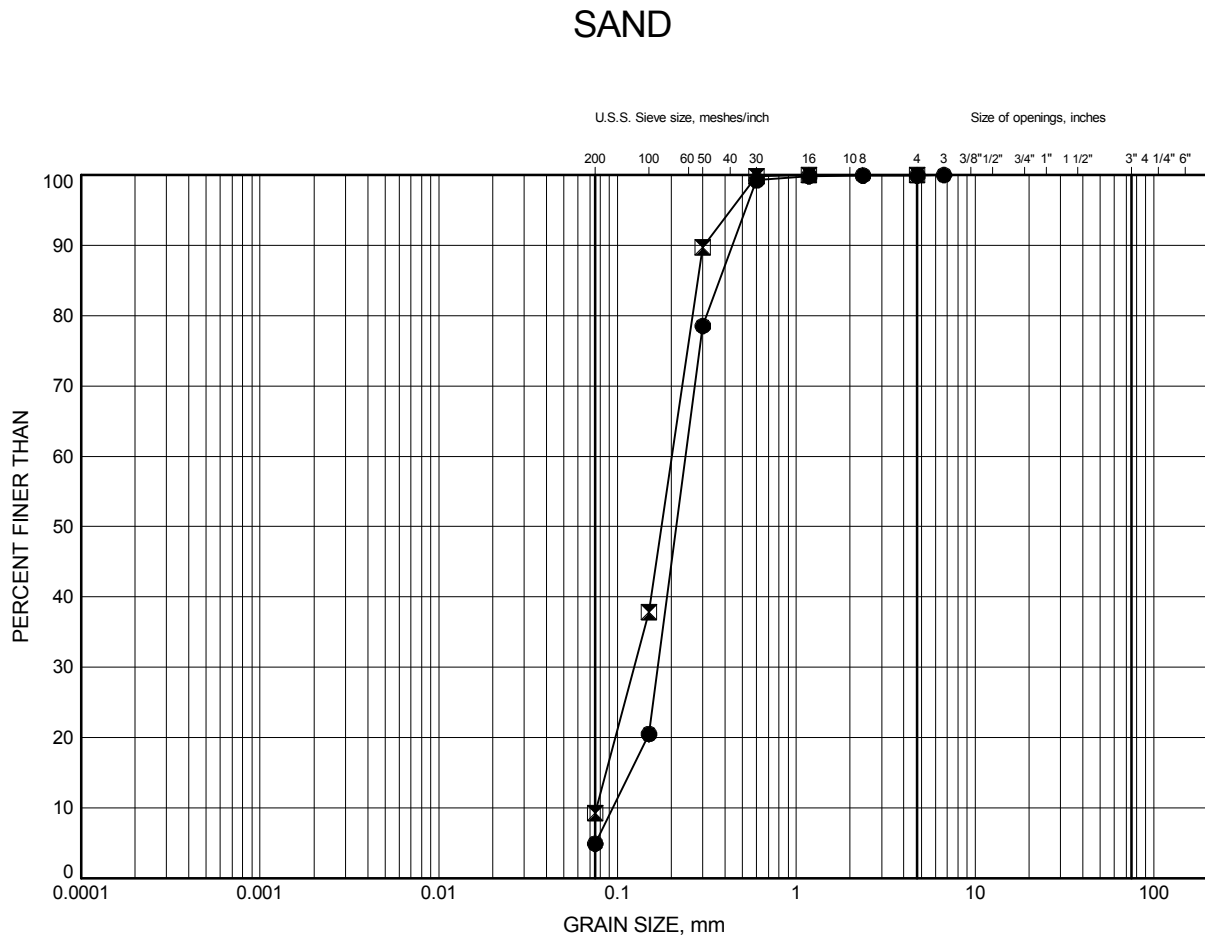
Prep'd KE

Chkd. SP

Hwy's 35 and 523, 5 Structures

GRAIN SIZE DISTRIBUTION

FIGURE C8



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	12.50	261.27
⊠	17-6	10.52	258.74

Date ..September 2018.....

GWP# ..5087-11-00.....



Prep'dKE.....

Chkd.SP.....

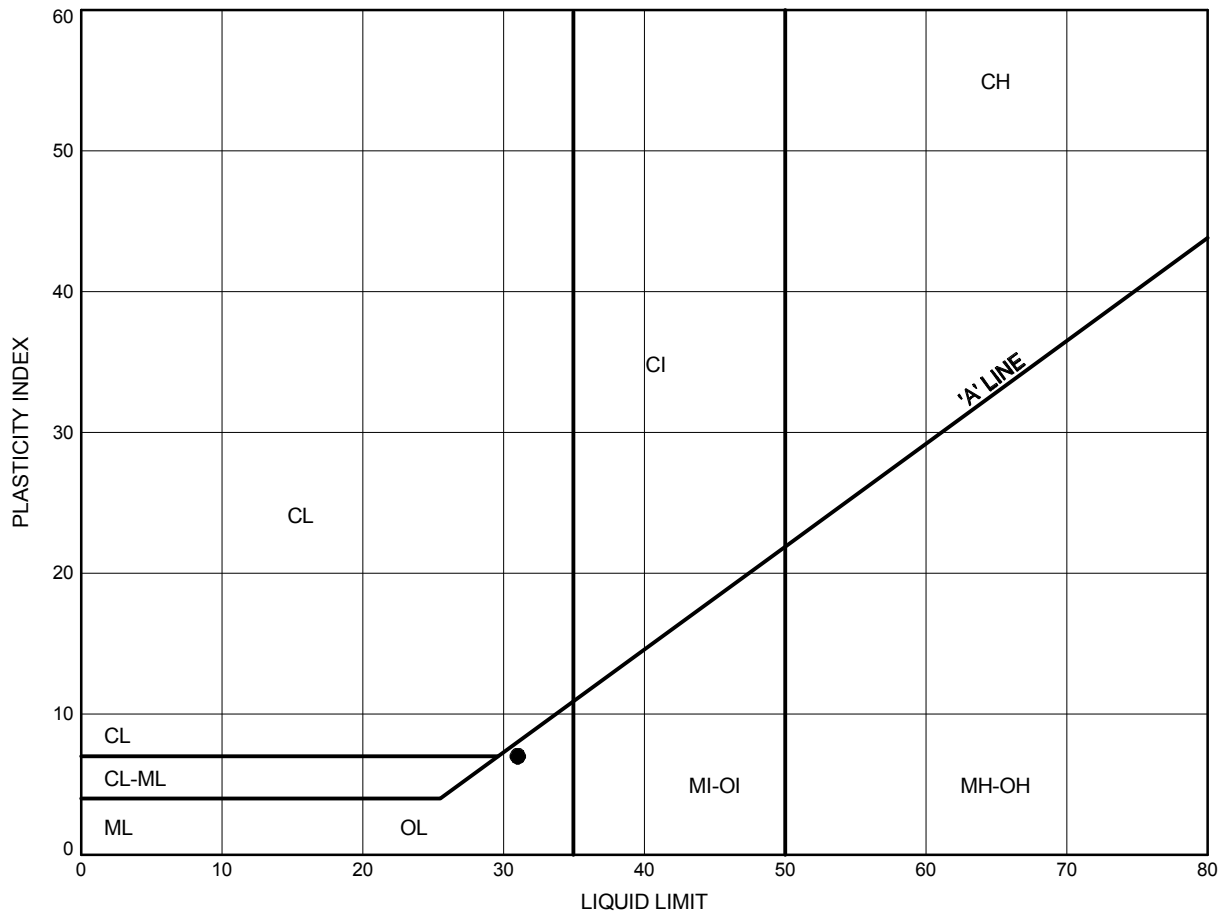
Appendix C.2
Atterberg Limit Analysis Figures

Hwy's 35 and 523, 5 Structures

ATTERBERG LIMITS TEST RESULTS

FIGURE C9

ORGANIC SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	1.40	267.72

Date ..September 2018.....
GWP# ..5087-11-00.....

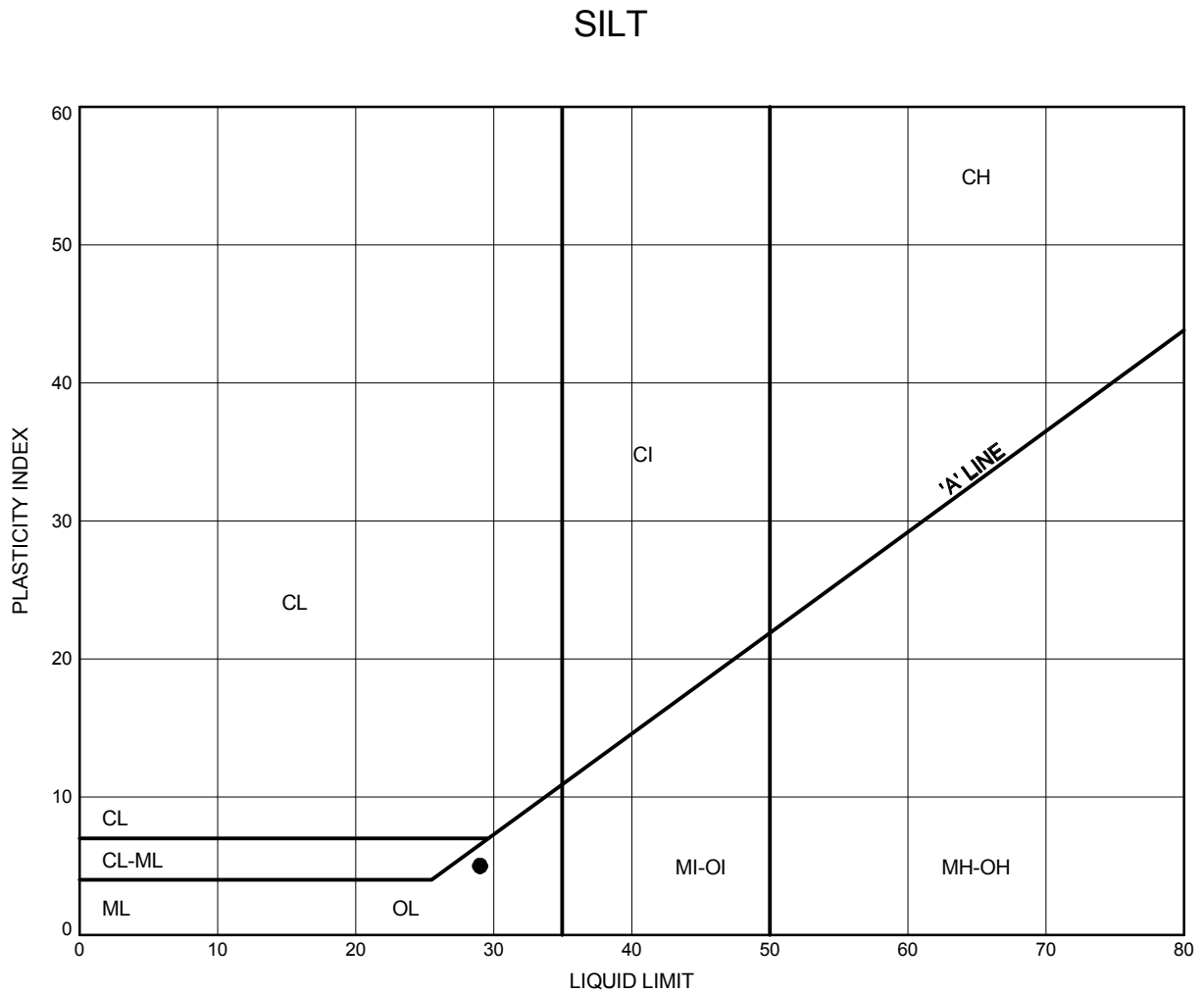


Prep'dKE.....
Chkd.SP.....

Hwy's 35 and 523, 5 Structures

ATTERBERG LIMITS TEST RESULTS

FIGURE C10



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	2.97	266.15

Date September 2018
GWP# 5087-11-00



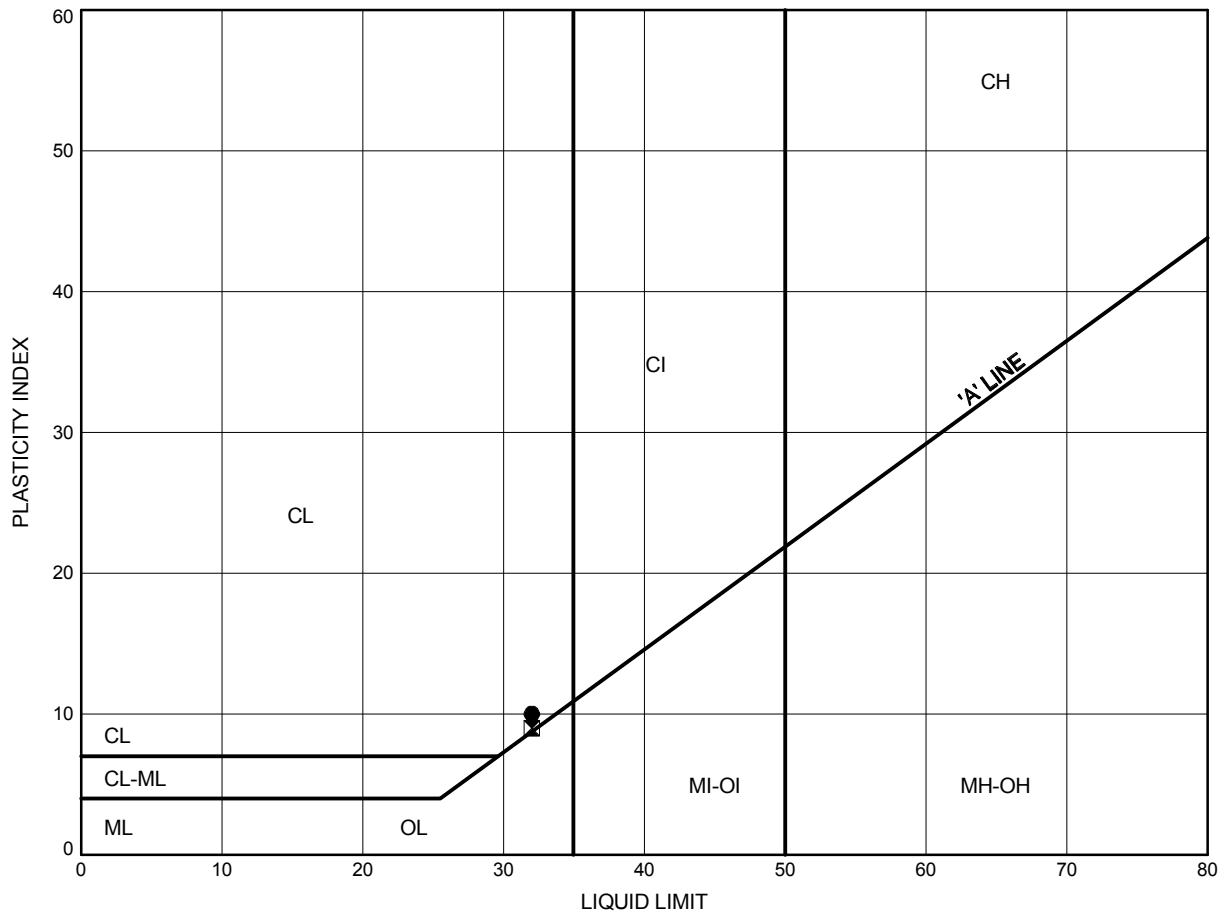
Prep'd KE
Chkd. SP

Hwy's 35 and 523, 5 Structures

ATTERBERG LIMITS TEST RESULTS

FIGURE C11

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	5.64	268.13
⊠	17-4	2.23	266.96

Date ..September 2018.....
GWP# ..5087-11-00.....



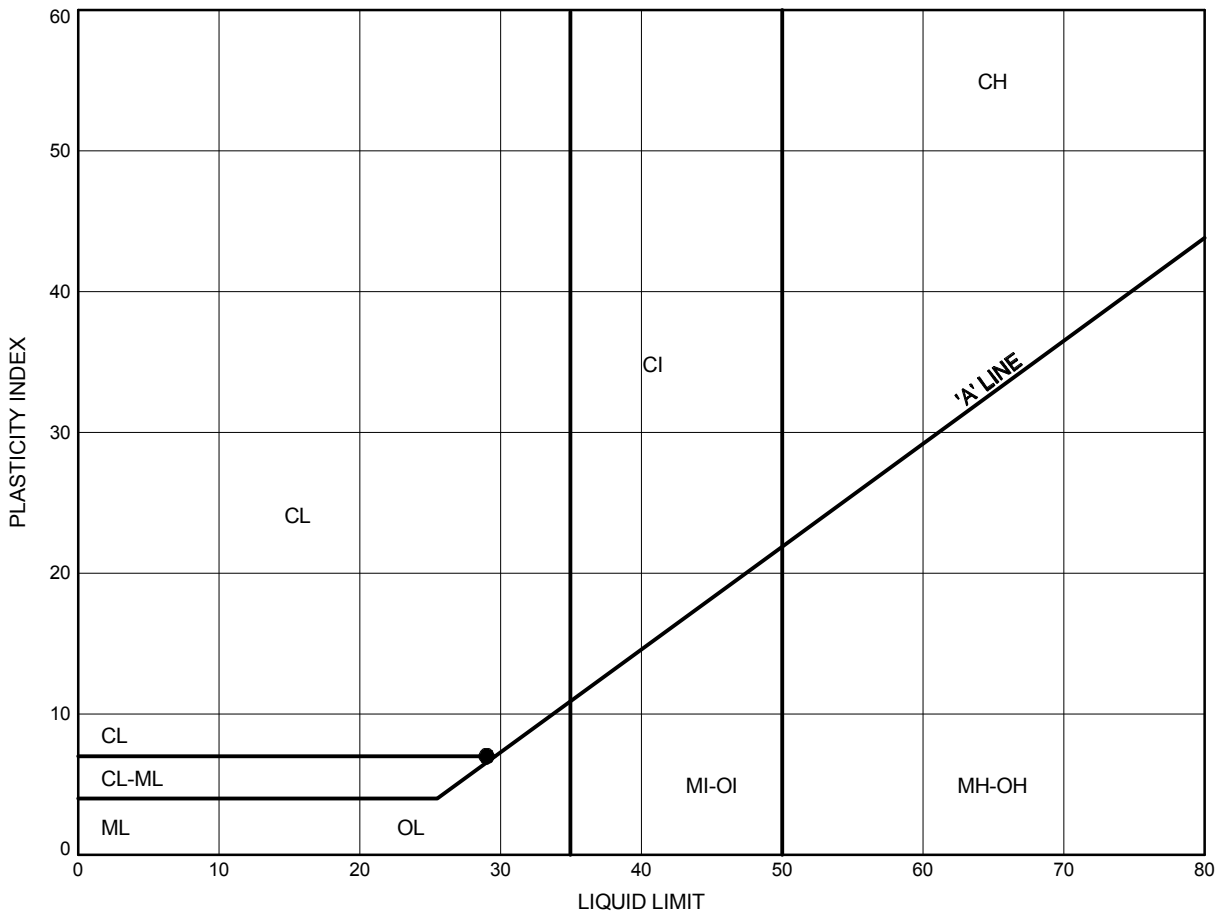
Prep'dKE.....
Chkd.SP.....

Hwy's 35 and 523, 5 Structures

ATTERBERG LIMITS TEST RESULTS

FIGURE C12

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-2	6.40	267.17

Date ..September 2018.....
GWP# ..5087-11-00.....



Prep'dKE.....
Chkd.SP.....

Appendix C.3
Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

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

Client PO: 16284
Project: Hwy 35/523
Custody: 38404

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

Order #: 1734260

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

Paracel ID	Client ID
1734260-01	Black Creek 17-3 SS#2 7.83-9.83'
1734260-02	Black Creek 17-5 SS#3 10.17-12.17'
1734260-03	Minor's Bay 17-3 SS#1 0-1.25'
1734260-04	Bark Lake 17-3 SS#3 10-12'
1734260-05	Bark Lake 17-6 SS#2 15-17'

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16284

Report Date: 29-Aug-2017
Order Date: 23-Aug-2017
Project Description: Hwy 35/523

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	25-Aug-17	25-Aug-17
Conductivity	MOE E3138 - probe @25 °C, water ext	29-Aug-17	29-Aug-17
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	28-Aug-17	28-Aug-17
Resistivity	EPA 120.1 - probe, water extraction	29-Aug-17	29-Aug-17
Solids, %	Gravimetric, calculation	26-Aug-17	26-Aug-17

Certificate of Analysis
Client: **Thurber Engineering Ltd.**
Client PO: 16284

Report Date: 29-Aug-2017
Order Date: 23-Aug-2017
Project Description: Hwy 35/523

	Client ID:	Black Creek 17-3 SS#2 7.83-9.83'	Black Creek 17-5 SS#3 10.17-12.17'	Miner's Bay 17-3 SS#1 0-1.25'	Bark Lake 17-3 SS#3 10-12'
	Sample Date:	14-Aug-17	16-Aug-17	10-Aug-17	08-Aug-17
	Sample ID:	1734260-01	1734260-02	1734260-03	1734260-04
	MDL/Units	Soil	Soil	Soil	Soil

Physical Characteristics

% Solids	0.1 % by Wt.	73.7	76.1	91.0	70.4
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General Inorganics

Conductivity	5 uS/cm	99	176	220	217
pH	0.05 pH Units	8.33	8.05	7.85	4.91
Resistivity	0.10 Ohm.m	101	56.8	45.6	46.1

Anions

Chloride	5 ug/g dry	11	51	8	6
Sulphate	5 ug/g dry	23	25	23	176

	Client ID:	Bark Lake 17-6 SS#2 15-17'	-	-	-
	Sample Date:	09-Aug-17	-	-	-
	Sample ID:	1734260-05	-	-	-
	MDL/Units	Soil	-	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	88.8	-	-	-
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General Inorganics

Conductivity	5 uS/cm	63	-	-	-
pH	0.05 pH Units	5.70	-	-	-
Resistivity	0.10 Ohm.m	158	-	-	-

Anions

Chloride	5 ug/g dry	7	-	-	-
Sulphate	5 ug/g dry	26	-	-	-

Certificate of Analysis
Client: **Thurber Engineering Ltd.**
Client PO: **16284**

Report Date: 29-Aug-2017
Order Date: 23-Aug-2017
Project Description: **Hwy 35/523**

Method Quality Control: Blank

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

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 16284

Report Date: 29-Aug-2017
Order Date: 23-Aug-2017
Project Description: Hwy 35/523

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	10.5	5	ug/g dry	10.7			1.3	20	
Sulphate	22.3	5	ug/g dry	23.3			4.4	20	
General Inorganics									
Conductivity	844	5	uS/cm	841			0.4	6.2	
pH	8.36	0.05	pH Units	8.45			1.1	10	
Resistivity	11.8	0.10	Ohm.m	11.9			0.4	20	
Physical Characteristics									
% Solids	87.3	0.1	% by Wt.	87.2			0.0	25	

Certificate of Analysis
Client: **Thurber Engineering Ltd.**
Client PO: **16284**

Report Date: 29-Aug-2017
Order Date: 23-Aug-2017
Project Description: **Hwy 35/523**

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	101	5	ug/g	10.7	90.4	78-113			
Sulphate	119	5	ug/g	23.3	96.2	78-111			

Certificate of Analysis
Client: **Thurber Engineering Ltd.**
Client PO: **16284**

Report Date: 29-Aug-2017
Order Date: 23-Aug-2017
Project Description: **Hwy 35/523**

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

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

Appendix D.

Site Photographs



Photo 1. Looking north along Highway 35 (2017/08/16)



Photo 2. Looking south along Highway 35 (2017/08/16)



Photo 3. Outlet looking east (2017/08/16)



Photo 4. Inlet looking west (2017/08/16)



Photo 5. Outlet with water level measuring instrument (2017/08/17)

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

<i>Culvert Type</i>	<i>Pipe Culvert or Closed Box Culvert</i>	<i>Circular Pipe Culvert (Trenchless Installation)</i>	<i>Open Bottom Culvert</i>	<i>Precast Concrete Slab on Steel Sheet Piles</i>
<i>Advantages</i>	<ul style="list-style-type: none"> - Relatively expedient installation if precast units are used. - Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. 	<ul style="list-style-type: none"> - Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. - Avoids open cut and large excavation quantity - Allows two lanes of traffic to be maintained throughout construction 	<ul style="list-style-type: none"> - Relatively expedient installation if precast units are used. - Possibility to maintain work zone outside of existing waterway. 	<ul style="list-style-type: none"> - Potentially minimizes volume of excavation and roadway protection - Maintains water flow throughout construction and minimizes potential for disturbance of streambed - Winter construction
<i>Disadvantages</i>	<ul style="list-style-type: none"> - Requires protection system - One lane for traffic - Requires a temporary by-pass to maintain waterflow 	<ul style="list-style-type: none"> - Requires construction of entry and exit pits and access to toes of slope. - Requires specialised construction equipment. - Feasibility also depends on flow capacity and other hydraulic properties. 	<ul style="list-style-type: none"> - Requires protection system - One lane for traffic - Deepest excavation, increases quantities and dewatering concerns. - Lower geotechnical resistances. - Potential for post construction settlement. 	<ul style="list-style-type: none"> - Requires protection system - One lane for traffic - Quantity and cost of sheet piles - Unconventional design - Differential settlement could occur between non-yielding culvert and approach fills
<i>Risks/Consequences</i>	<ul style="list-style-type: none"> - Existing footings may interfere with culvert construction 	<ul style="list-style-type: none"> - Loose cohesionless soils below the groundwater table, limit available techniques to closed faced system - Limited cover over tunnel increases risk of heave or settlement of roadway - Open water complicates construction of pits and tunnel 	<ul style="list-style-type: none"> - Increased risk of basal instability of footing excavation due to depth of excavation below water table. 	<ul style="list-style-type: none"> - Possibility of encountering obstructions - may encounter varying depth to suitable bearing stratum
<i>Relative Cost</i>	Low to Medium	High	Medium	Medium to High
<i>Recommendation</i>	Recommended	Not Feasible	Generally Feasible / Not Recommended	Generally Feasible / Not Recommended

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

March 12, 2018

Site: 44.8025 N, 78.8141 W User File Reference: Black 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)
0.087	0.121	0.120	0.104	0.087	0.053	0.028	0.0071	0.0031	0.071	0.073

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)	0.013	0.037	0.056
Sa(0.1)	0.021	0.055	0.080
Sa(0.2)	0.022	0.057	0.081
Sa(0.3)	0.020	0.050	0.071
Sa(0.5)	0.015	0.041	0.059
Sa(1.0)	0.0078	0.024	0.035
Sa(2.0)	0.0033	0.012	0.018
Sa(5.0)	0.0007	0.0027	0.0042
Sa(10.0)	0.0005	0.0012	0.0018
PGA	0.012	0.031	0.046
PGV	0.0096	0.030	0.046

References

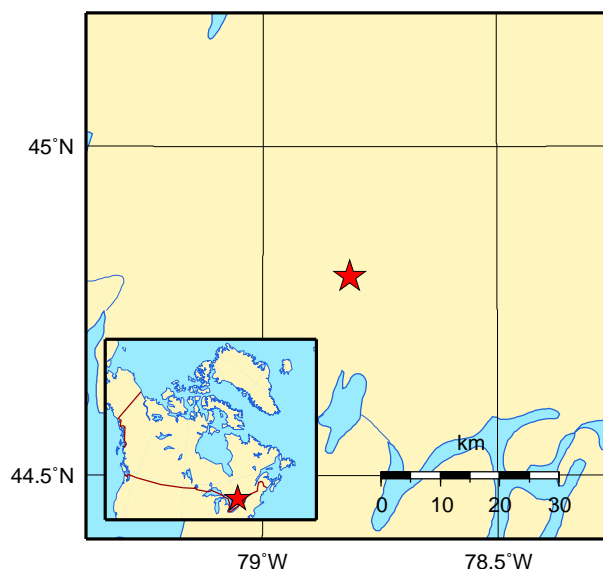
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report

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

OPSS.PROV 206	Construction Specification for Grading
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cuts
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS 1860	Material Specification for Geotextile
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Span Less than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
SP 517F01	Design Storm Return Period and Preconstruction Survey
SP 109S12	QVE, Backfilling, Compaction, and Certificate of Conformance
SP FOUN0003	Dewatering Structure Excavations

2. Suggested text for a NSSP on "Vibration"

Vibratory equipment is not permitted for installation or removal of temporary protection systems and/or coffer dams.

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

The Contractor is advised that the native clay 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.

4. Suggested text for an NSSP on "Obstructions"

"The presence of cobbles, boulders and buried obstructions within the fill may have an impact on excavations as well as the installation of protection systems and/or coffer dams at this site."