



THURBER ENGINEERING LTD.

**FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 11 CULVERT
0.6 KM NORTH OF HIGHWAY 572, PLAYFAIR TOWNSHIP
NEAR STATION 11+975**

G.W.P. 5054-01-00

Geocres No.: 42A00-121

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 at the Highway 11 culvert crossing near Station 11+975. The culvert is located approximately 0.6 km north of Highway 572 within Playfair 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-0041.

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 information was available for the subject culvert site within the Geocres library.

2 SITE DESCRIPTION

The existing culvert is a 900 mm diameter non-structural corrugated steel pipe (CSP) culvert and is approximately 45.6 m long with a generally northeast to southwest alignment. The flow through the culvert is to the southwest.

At the location of the culvert at Station 11+977 (Linear Highway Referencing System Base Point: 17450, Offset: 0.6), Highway 11 is a two-lane highway with a rural cross-section and gravel shoulders. The Highway 11 embankment fill height is approximately 6.1 m with the road surface at approximate elevation 283.2 m. The existing slopes are inclined at approximately 2H:1V to 2.7H:1V. No guiderails are present at the site. The land adjacent to the highway is generally undeveloped and consist of densely vegetated areas with shrubs and trees, and open farm fields. Fibre optic cables are in close proximity to the west end of the culvert and cross the road just south of the culvert. A buried gas pipeline also crosses the road just south of the culvert. Wildgoose Creek crosses Highway 11 approximately 600 m north of the culvert. Traffic volumes on Highway 11 are understood to be 3,250 AADT (2016).

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

3 SITE INVESTIGATION AND FIELD TESTING

The initial site investigation and field testing program was carried out between October 14th and October 16th, 2016. A supplemental site investigation was carried out on April 30th, 2018. The field investigations consisted of advancing five boreholes identified as 16-01 through 16-04 and 18-05. The drilling was carried out using portable equipment for off-road Boreholes 16-03 and 16-04, a rubber tired CME 550 drill rig and a track mounted CME 850 drill rig for the on-road Boreholes 16-01 and 16-02 and a truck mounted CME 55 drill rig for on-road Borehole 18-05. 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 16-03 and 16-04, which were drilled with portable equipment, also utilized a full-weight hammer for SPT testing. In-situ vane shear testing was completed in the cohesive soils. A Thin Walled (Shelby) Tube sample of clay was retrieved from Borehole 16-01 to obtain a relatively undisturbed soil sample for further laboratory testing. The boreholes were sampled to depths ranging from 12.8 to 17.4 m (elev. 270.3 to 265.0 m) below the existing ground surface. Borehole 16-03 was extended below the base of the sampled borehole with a Dynamic Cone Penetration Test (DCPT) to a base elevation of 264.1 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.

A 19 mm diameter standpipe piezometer was installed in Borehole 16-04 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the Record of Borehole sheet for Borehole 16-04, provided in Appendix B. Following completion of the field investigation the remaining boreholes were backfilled in accordance with MOE requirements (O.Reg. 903 as amended). Boreholes 16-01, 16-02 and 18-05 were capped with 150 mm of cold patch asphalt to reinstate the traveling surface. The piezometer was decommissioned on June 12, 2017 in accordance with MOE requirements.

The 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. A single sample, obtained with a Thin Walled (Shelby) Tube, underwent one-dimensional consolidation testing. Three samples of soil recovered from within the boreholes were selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

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

In general terms, the site was found to be underlain by asphalt and granular fill over clay fill overlying a deposit of native clay underlain by silty sand. Bedrock was not encountered within the depth of investigation.

5.1 Embankment

5.1.1 Asphalt

Boreholes 16-01, 16-02 and 18-05 were drilled through the existing Highway 11 embankment and encountered a layer of asphalt with a thickness of 130 mm. A 75 mm thick buried asphalt layer was encountered in Borehole 18-05 within the sand fill at a depth of 0.7 m.

5.1.2 Fill: Sand

Below the asphalt pavement in Boreholes 16-01, 16-02 and 18-05 was a layer of fill consisting of sand with gravel over sand with silt and gravel. The underside depth of the fill was 1.5 to 2.3 m below the existing roadway surface (elev. 281.7 to 280.9 m).

The SPT tests conducted in the unfrozen sand fill gave N-values typically ranging from 15 to 29 blows indicating a compact relative density. It is noted that the sand fill encountered in Borehole 18-05 was frozen at the time of drilling and those N-values have not been included in the range given above. A single SPT test with results as high as 100 blows for 175 mm of penetration was recorded near the surface of Borehole 16-02. Recorded moisture contents ranged from 1 to 24%. The results of grain size analyses conducted on two samples of the sand fill material are summarized below and are illustrated on Figure C1 in Appendix C.

Soil Particle	Percentage (%)
Gravel	22 - 26
Sand	70 - 71
Silt & Clay	3 - 8

5.1.3 Fill: Clay

A layer of clay fill was encountered directly below the sand fill in Boreholes 16-01, 16-02 and 18-05 with a recorded thickness 4.6 to 5.5 m and an underside depth of 6.1 to 7.6 m below the existing roadway surface (elev. 277.1 to 275.6 m).

The SPT tests conducted in the clay fill gave N-values ranging from 4 to 16 blows. Shear vane testing was attempted at four locations in Borehole 18-05 and resulted in an undrained shear strength of greater than 106 kPa indicating a very stiff consistency. The recorded moisture contents varied from 18 to 46%. The results of grain size analyses conducted on four samples of the clay fill material are summarized below and are illustrated on Figure C2 of Appendix C.

Soil Particle	Percentage (%)
Gravel	0 - 1
Sand	1 - 7
Silt	29 - 72
Clay	26 - 70

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

Parameter	Value
Liquid Limit	39 - 52
Plastic Limit	17 - 23
Plasticity Index	16 - 32

5.2 Clay (CI to CH)

A native deposit of clay was encountered below the fill layers in Boreholes 16-01, 16-02 and 18-05 and from the surface in Boreholes 16-03 and 16-04. Silt layers were observed in the clay deposit. Where fully penetrated this layer has a thickness ranging from 7.6 m to 11.9 m with an underside elevation of 268.0 to 265.9 m. Borehole 18-05 and 16-03 were terminated within this layer at sampled depths of 12.8 m below the ground surface (elev. 270.3 and 265.7 m respectively).

The SPT N-values ranged from weight of hammer to 4 blows. Field vane tests were performed within the deposit and recorded undrained shear strengths ranging from 18 to 75 kPa indicating a soft to stiff consistency. Remolded field vane testing indicates that the clay shows some sensitivity. The moisture content of the samples tested ranged from 32% to 70%. The results of grain size analyses conducted on eleven samples of the native clay are summarized below and are illustrated on Figures C3 and C4 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0
Sand	0 - 7
Silt	17 - 52
Clay	44 - 83

Atterberg Limit testing was completed on eleven samples of the native clay deposit. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figures C8 and C9 of Appendix C. The laboratory results are summarized below and indicate that the clay varies from intermediate to high plasticity (CI to CH).

Parameter	Value
Liquid Limit	35 - 63
Plastic Limit	18 - 28
Plasticity Index	16 - 40

An Oedometer (one-dimensional consolidation) Test was carried out on a relatively undisturbed sample obtained from a Thin Walled (Shelby) tube sample taken in Borehole 16-01 at a depth of 7.9 m. The results are presented in Appendix C and summarized in the following table. The compressibility characteristics will vary with depth in accordance with the soil index parameters and stress history.

Table 5-1. Summary of Oedometer Test Results and Interpretations

Parameter		Units	Value
Borehole		-	BH16-01
Sample Depth (Elevation)		m	7.9 (275.3)
Natural Moisture Content, w_n		%	56.9
Initial Void Ratio, e_o		-	1.526
Unit Weight, γ		kN/m ³	16.5
Existing Vertical Effective Stress, σ'_{vo}		kPa	140
Preconsolidation Pressure, σ'_c		kPa	140
Over Consolidation Ratio, OCR		-	~1
Recompression Zone	Recompression Index, C_r	-	0.088
	Coefficient of Consolidation, c_{vr}	cm ² /s	3.3 to 0.06 x 10 ⁻²
	Average Permeability, k_{vr}	m/s	2 x 10 ⁻⁹
Virgin Compression Zone	Compression Index, C_c	-	0.64
	Coefficient of Consolidation, c_v	cm ² /s	4.9 to 0.3 x 10 ⁻⁴
	Average Permeability, k_v	m/s	5 x 10 ⁻¹¹
Modulus of Elasticity (Constrained), E_c		kPa	1,650

5.3 Silty Clay (CL-ML)

Below the clay within Boreholes 16-01 and 16-02 was a deposit of silty clay. The silty clay was 1.6 m thick in Borehole 16-02 with an underside depth of 16.8 m (elev. of 266.4 m). Borehole 16-01 was terminated 2.2 m into the silty clay at a depth of 17.4 m (elev. 265.8 m).

The SPT N-value ranged from 3 to 16 blows. The moisture content of the samples tested ranged from 23 to 48%. A single gradation analysis was completed on the silty clay material with results of 0% gravel, 1% sand 75% silt and 24% clay. The results of the grain size analysis are illustrated on Figure C5 in Appendix C. An Atterberg Limit test provided a liquid limit of 24 and a plastic limit of 19 resulting in a plasticity index of 5 and a CL-ML classification. The result of the Atterberg limit test is presented in Figure C10 in Appendix C.

5.4 Silty Sand

A layer consisting of silty sand with gravel was encountered below the silty clay in Borehole 16-02 and below the clay in Borehole 16-04. Both boreholes were terminated within this stratum at a depth of 12.8 to 17.4 m (elev. of 265.8 to 265.0 m).

The SPT N-values of 20 to 55 blows were recorded indicating a compact to very dense relative density. The moisture content for the samples tested ranged from 12% to 15%. A single grain size analysis was conducted on the silty sand material with results of 26% gravel, 51% sand and 23% fines. The results of the grain size analysis are illustrated on Figure C6 in Appendix C.

5.5 Groundwater

At the completion of drilling, the groundwater level was measured at 9.1 m below the ground surface (elev. 268.7 m) within the standpipe piezometer installed in Borehole 16-04. The culvert was dry at the time of the field investigation. During site visits on April 17, 2017 and June 12, 2017 the water level within the standpipe piezometer was observed at 9.3 m (elev. 268.5 m) and 8.8 m (elev. 269.0) below the ground surface respectively. A low level of water was present in the culvert on April 17, 2017. The standpipe piezometer was decommissioned on June 12, 2017.

During the 2018 field investigation, Borehole 18-05 was dry upon completion.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different 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.

5.6 Analytical Testing

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

Borehole	Sample	Depth (m)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)
16-03 (C28-3*)	SS2	0.7 – 1.4	15	7.5	1310	765	343
16-04 (C28-4*)	SS1	0 – 0.6	21	7.6	1000	999	493
18-05	SS9	7.6 – 8.2	14	7.6	2450	408	118

Note: (*) sample label as submitted to Paracel

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the culvert location. The as-drilled locations and ground surface elevation of the 2016 borehole investigation were surveyed by McIntosh Perry following completion of the initial field program. Thurber surveyed the location of the borehole from the 2018 field investigation based on benchmarks provided by MPCE.

Landcore Drilling of Chelmsford, Ontario supplied and operated the equipment to conduct the drilling, soil sampling, in-situ testing and borehole decommissioning. The field investigation was supervised on a full-time basis by Mr. Jeff Morrison, E.I.T. and Mr. Sean O'Bryan of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. One-dimensional consolidation testing was completed by Stantec's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario.

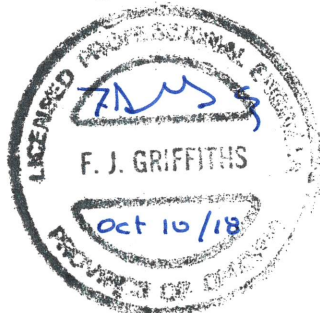
Interpretation of the factual data and preparation of this report were carried out by Mr. Christopher Murray, P.Eng. and Mr. Stephen Peters P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.



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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 project team in designing a suitable replacement of the existing culvert crossing Highway 11 at Station 11+977. 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.

The existing culvert is located at Station 11+977 and is a 900 mm diameter non-structural corrugated steel pipe (CSP) culvert approximately 45.6 m long with a generally northeast to southwest alignment. The invert of the existing culvert is reported to be at elevation 278.18 m and 276.85 m at the inlet and outlet respectively. The embankment fill height is in the order of 6.1 m with the road surface at elevation 283.2 m. The existing embankment slopes are approximately inclined between 2H:1V and 2.7H:1V. It is noted that limited water was present in the culvert at the time of the site visits.

No previous foundation investigation information for the subject culvert was available on the Geocres Library.

7.1 Proposed Structure

It is proposed to replace the existing culvert on an alignment 4.0 m north of the existing culvert at Station 11+973 with a 1.4 m diameter culvert installed parallel to the existing culvert alignment. The new culvert is indicated to be the same length. It is assumed the invert elevations will be similar to the existing culvert.

7.2 Applicable Codes and Design Considerations

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

It is understood that 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 for this non-structural culvert. If the consequence classification changes, the geotechnical recommendations will need to be reviewed and revised.

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). 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 calculated data sheet for this site is included in Appendix F

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA) at this site for a reference Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.098g. This value is to be scaled by the $F(PGA)$ based on 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. This site has been classified as a Site Class E in accordance with Section 4.4.3.2 of the CHBDC (S6-14).

8.3 Seismic Liquefaction

Based on the low reference PGA, the subsurface conditions encountered at the drilled locations at this site and using the Seed & Idriss Simplified Method for liquefaction assessment, the non-cohesive foundation soils are considered not susceptible to liquefaction during a seismic event.

The native silty clay deposit encountered at this site is classified as susceptible to cyclic mobility based on the criteria presented by Bray et al (2004) and the measured moisture content and Atterberg limits of one sample. This layer was subsequently assessed based on correlated shear strength measurements and the reference PGA using the simplified procedure outlined in Boulanger and Idriss (2007). Based on the results of this analysis, the silty clay material is considered not susceptible to cyclic mobility or cyclic softening.

The native clay deposits have been classified as not susceptible to cyclic mobility by utilizing the Bray et al (2004) criteria.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

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

- Circular Pipes (Concrete, HDPE, Steel)
From a foundation engineering perspective, a pipe culvert is a technically feasible alternative. It is understood that an internal pipe diameter of 1.4 m is proposed. The use of a circular pipe culvert would also facilitate a trenchless installation.
- Open Bottom Culvert (Box, Arch)
An open bottom culvert is not recommended for this site from a foundation engineering perspective due to the relatively low available bearing capacity in the foundation clay, the requirement for greater excavation depths and dewatering during construction and potential for differential settlement following construction. Additionally, the size of culvert anticipated for this site would typically be too small for an open bottom culvert installation.
- 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.

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 roadway protection and water flow diversion. However, it is understood that an acceptable detour is not available and therefore this option is not feasible.
- Open Cut with Staged Temporary Widening and/or Lowering
Widening of the existing highway and/or construction of a temporary detour embankment to accommodate traffic passage during construction is not considered feasible from a geotechnical perspective due to the proximity of a buried gas pipeline

to this site. Settlement of the firm clay soils under the existing and temporary detour embankments is to be expected. Additionally, a review of the requirement for property acquisition and highway geometry is needed to assess this option.

Temporary grade lowering can be incorporated into the design to reduce the overall height of embankment above the base of the proposed excavation while maintaining traffic within the existing embankment footprint. However, the vertical road alignment and traffic speed constraints will need to be reviewed from highway design perspective. It is also noted that clay fill was observed in the boreholes at depths of 1.5 to 2.3 m below the road surface. Its presence may limit the depth of a temporary grade lowering to approximately 1 m unless over excavation is carried out to allow construction of a temporary pavement structure. The project pavement engineer should be consulted if this approach is to be carried forward.

- Open Cut and Temporary Protection System (TPS)

The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. This option includes roadway protection, as discussed further in Section 12.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. Although not encountered in the boreholes, the contractor will need to consider the potential for cobbles/obstructions in the embankment fill during the design and installation of the roadway protection. To reduce lateral deflections of the protection system, the roadway protection may need to include a bracing system. The TPS would need to protect a temporary cut height of more than 6 m. The height of the TPS could be reduced if a temporary grade lowering was also included.

- Temporary Modular Bridge

A temporary modular bridge (TMB) could provide traffic passage while allowing for full excavation and replacement of the culvert without staged excavations. A reduced quantity of roadway protection is also anticipated. Additional boreholes will be required at the temporary abutment locations for the TMB for foundation design.

- Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. Additional discussion on various trenchless installation methods are provided in the comparison table provided in Appendix E.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, the preferred approach is to install a pipe culvert on a new alignment using trenchless techniques. Based on observations during the field investigation the culvert is dry periodically, thus, it is anticipated that this waterway is not fish habitat and watercourse realignment could be an available option. The existing culvert would need to be decommissioned in accordance with OPSS 510.

An alternative approach is to replace the existing culvert with either a circular or a closed box culvert using open cut techniques. TPS would be needed to facilitate construction.

Design of the TPS will need to account for the relatively low lateral capacity available in the native soils at this site and the need to brace the TPS. Grade lowering could be considered to reduce the height of the TPS.

If a pipe culvert is selected with an open cut installation technique it should be designed and constructed in accordance with OPSS 421, OPSD 802.010 (with Granular A used as bedding and embedment material) and OPSD 803.031 (with a frost depth as noted in Section 11.3). The recommendations of Sections 11.2, 11.4, 11.5, 11.6 and 12 should be applied.

10 TRENCHLESS DESIGN RECOMMENDATIONS

The road surface elevation is approximately 283.1 m. The invert of the replacement pipe will be similar to the existing at approximate elevation 278.18 m and 276.85 m at the inlet and outlet respectively. The internal diameter of the pipe will be approximately 1.4 m and the length approximately 47 m. Groundwater was observed in the monitoring well installed in Borehole 16-4 at elevation 269.0 m on June 12, 2017. It is anticipated that the soils which will be encountered during trenchless installation will consist of clay fill and native clay. Within the pipe installation depth, the clay fill was noted to be very stiff and the native clay was noted to be firm. Based on the Tunnelman's Ground Classification System (modified by Heuer 1974 from Terzaghi 1950) the soils are described as 'squeezing' to 'slow raveling'.

Typically, trenchless installations are provided with cover over the pipe equivalent to at least two pipe diameters along the centreline of the roadway. The edge to edge horizontal clearance between existing culverts and new pipes is typically one to two pipe diameters. If the horizontal clearance is less than 2 pipe diameters however, care must be exercised so as to not adversely affect the performance of the existing culvert.

Trenchless installation should be completed in accordance with the requirements of the Special Provision (SP) "Pipe Installation by Trenchless Methods provided in Appendix G. Amongst the important issues discussed in the SP are maintenance of alignment, handling of obstructions and disposal of cuttings. Monitoring of the roadway surface will be required during trenchless installation. The settlement monitoring program and condition survey should follow Section 7.06 of the SP in Appendix G. It is noted that the SP for Pipe Installation by Trenchless Methods should be modified to remove references to a Quality Verification Engineer; suggested wording for an NSSP is also provided in Appendix G.

Trenchless methods that are typically considered to install pipes under highways include: jack and bore, pipe ramming, pipe jacking, microtunneling (MTBM), hand mining and horizontal directional drilling. Hand mining is not considered feasible due to the limited diameter. Horizontal directional drilling (HDD) is not considered feasible as the proposed pipe diameter is nearing the maximum for the technique and the risk of loss of drilling mud is significant. It is recommended that an NSSP be included in the contract package excluding Hand Mining and HDD from consideration. A table with comparisons of the feasible trenchless installation methods has been provided in Appendix E. Selection of the appropriate trenchless method is the responsibility of the Contractor. The experience of the Contractor is of primary importance for trenchless installation. Based on the results of the investigation and the size and invert elevation of the culvert, pipe ramming or jack and bore

with a soil plug techniques are likely the preferred approaches while microtunneling (MTBM) with pipe jacking are considered feasible but more expensive.

Abandonment of the existing culvert should be in accordance with OPSS 510.

The design of safe and stable entry and exit pits for the trenchless installation is the responsibility of the Contractor. Available geotechnical bearing resistances at the base of entry and exit pits should follow recommendations and values provided in Section 11.1. Entry and exit pits shall be cut with side slopes that follow the recommendations provided in Section 12.1 or temporary protection systems may be required to support temporary excavations. The temporary excavation support system should be designed and constructed as outlined in Section 12.2. Dewatering and surface water control must be employed as necessary to keep the entry and exit pits dry as discussed further in Section 12.3.

11 OPEN CUT FOUNDATION DESIGN RECOMMENDATIONS

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

11.1 Culvert Foundation Bearing Resistances

The replacement culvert will be constructed 4 m north of the existing culvert. The embankment will be reconstructed with no grade raise or widening (temporary or permanent). Therefore, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

11.1.1 Box Culvert

The recommended geotechnical resistances for a pre-cast box culvert less than 2.0 m wide and installed with invert elevations similar to the current culvert (approximate elev. 276.85 m at the outlet) on an undisturbed native clay subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 125 kPa
- Factored Geotechnical Resistance at SLS of 55 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 above SLS resistance, is expected to be less than 25 mm.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 11.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A geotechnical resistance factor against sliding (ϕ_{gu}) of 0.80 may be used.

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

11.1.2 Pipe Culvert

Geotechnical resistance values are not required for pipe culverts. A modulus of subgrade reaction of 10 MN/m³ can be used for a pipe culvert installed at this site.

11.2 Subgrade Preparation, Bedding and Backfilling

After excavation and removal of the existing culvert and existing fill, any organics, soft or loose deposits, disturbed soils, loose alluvial deposits and deleterious materials must be stripped from the footprint of the culvert to expose competent native undisturbed subgrade material at or below the desired founding elevations. Given the firm conditions of the clay subgrade anticipated at the founding level of the replacement culvert, construction equipment should not be permitted to travel on the exposed final subgrade.

The exposed final 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 with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction. The granular fill should be compacted as per OPSS.PROV 501. In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010 (box culvert) and OPSD 802.010 (pipe culvert).

The compaction of granular bedding directly above the clay subgrade is likely to result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include installation of a Class II non-woven geotextile with a maximum FOS of 150 μ m (OPSS 1860) installed beneath the Granular A material. The geotextile should be placed as soon as possible after reaching the subgrade level and receipt of written notice to proceed in accordance with SP109S12.

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

It is recommended that culvert cover be in accordance with OPSS 902 and consist of free-draining, non-frost susceptible granular materials such as Granular A 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 Granular

B Type I and should be compacted in regular lifts as per OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert. Heavy compaction equipment, used adjacent to the culvert, must be restricted in accordance with OPSS.PROV 501.

11.3 Frost Depth

The depth of frost penetration at this site is 2.4 m (OPSD 3090.100). It is not necessary to found a closed box or pipe culvert at a depth below frost penetration. However, frost taper treatment should be as per OPSD 803.010 (box culvert) or OPSD 803.031 (pipe culvert) and as directed within the Pavement Design Report.

11.4 Lateral Earth Pressures

Lateral earth pressures parameters provided in Table 11-1 and Table 11-2 in the sections below are based on the assumptions that the wall is vertical and 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. Where ground surfaces are horizontal or sloped at 2H:1V behind vertical walls, the corresponding coefficients provided in Tables 11-1 and 11-2 should be used. For other backfill and wall geometries, the appropriate earth pressure coefficients must be calculated.

11.4.1 Static Lateral Earth Pressure Coefficients

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

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

where:

p_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below) (K_a for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

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

Table 11-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)							
	OPSS Granular A or 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 Silty Sand Fill $\phi = 30^\circ$ $\gamma = 21.0 \text{ kN/m}^3$		Existing Clay Fill $\phi = 27^\circ$ $\gamma = 17.5 \text{ kN/m}^3$	
	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)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.40	0.31	0.48	0.33	0.54	0.38	0.71
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-	0.55	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-	2.7	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose 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 earth pressure coefficient (Granular A or Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 11-1. Active pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest horizontal earth pressures be used for design.

11.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

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

- $k_h = \frac{1}{2} * F(PGA) * PGA$, 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 11-2 may be used. The provided earth pressure coefficients are based on a Seismic Site Class E, PGA with a 2% probability of exceedance in 50 years of 0.098g (Geological Survey of Canada – Fifth Generation) and a F(PGA) of 1.81 as per Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016).

Table 11-2. 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	0.32	0.51	0.36	0.61
Active, K_{AE} Non-Yielding Wall	0.38	0.67	0.43	0.78

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 (see Table 11-1)
(K_A for yielding walls, K_o for non-yielding walls)
- γ = unit weight of retained soil, use submerged unit weight below groundwater level
- K_{AE} = combined static and seismic earth pressure coefficient
- H = total height of the wall (m)

11.5 Embankment Design and Reinstatement

11.5.1 Embankment Reconstruction

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

11.5.2 Embankment Settlement and Stability

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

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

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

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

11.6 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 5.6 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

12 CONSTRUCTION CONSIDERATIONS

12.1 Excavation

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fills as well as the native clays both above and below the water table may be classified as Type 3 soil. Cohesionless soils below the groundwater level are classified as Type 4 soils.

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 may extend into the underlying native clay deposits. The sides of temporary excavations must be sloped in accordance with the requirement of OHSA. Protection of adjacent utilities from any damage

or displacement will need to be taken into consideration when evaluating the excavation limits.

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

12.2 Temporary Protection Systems

Temporary Protection Systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. The protection system near the culvert could be left in place and cut off in accordance with OPSS.PROV 539 to limit the disturbance of subgrade under the new culvert during removal of the TPS.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through granular embankment fill and culvert backfill are provided in Table 11-1.

Roadway protection is the responsibility of the Contractor and should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. Both sheet piles and soldier piles with lagging are considered feasible at this site from a geotechnical perspective. A suitable bracing system may need to be incorporated into the roadway protection design to resist the lateral loadings including traffic loading and surcharge loading due to construction equipment and operations.

12.3 Surface and Groundwater Control

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

The culvert was dry at the time of the borehole investigations. Some water was observed in the culvert on April 17, 2017. The piezometer showed a maximum water level of 269.0 m which is well below the culvert base. However, these are short term readings and the water level may rise. Accordingly, provisions must be made for diversion of flow and measures must be included to dewater the temporary excavation so that the culvert bedding and culvert construction may be carried out in the dry. Dewatering measures will likely include pumping from sumps and should 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 not required, thus Designer Fill-In ***** in this SP should be "N/A".

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of construction should be taken as the water level from the design storm period defined by the contract documents.

12.4 Scour Protection and Erosion Control

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

Particle size analyses in conjunction with the Wischmeier Nomograph indicate that the sand fill and native silty sand with gravel have a low potential for soil erodibility and the clay fill, native clay and silty clay have a moderate potential for soil erodibility.

Typically, rock protection should be provided over all earth surfaces in contact with flowing water. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

It is recommended that a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert.

13 CONSTRUCTION CONCERNS

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

- Disturbance of the soil subgrade. For open cut culvert replacement, where fine-grained soils are exposed at the culvert subgrade following excavation, these areas will be firm and moisture sensitive. Construction traffic must not be allowed on the final clay subgrade. The final subgrade should be protected with geotextile and bedding granular materials.
- Although not encountered during drilling, buried obstructions may be encountered during excavation in the embankment fill or interfere with driving of protection systems. Obstructions within the fill could also interfere during excavation and tunnelling activities.
- Consideration will have to be given to the proximity of the nearby utilities including the TransCanada pipeline and fibre optic cables located in the area of the culvert alignment and special attention will need to be taken into account during construction to avoid any damage to the utilities.
- Groundwater levels will fluctuate. Excavation may require lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert installation will depend largely upon good workmanship and quality control during construction. Subgrade examination in accordance with SP109S12 should be carried out by qualified geotechnical personal during construction to confirm that foundation recommendations are correctly implemented, and material specifications are met.

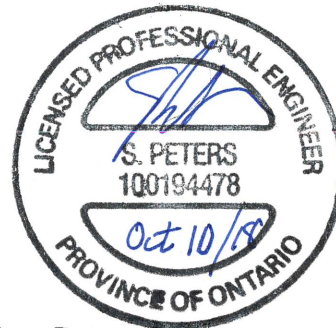
14 CLOSURE

Engineering analysis and preparation of this report were carried out by Mr. Christopher Murray, 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.

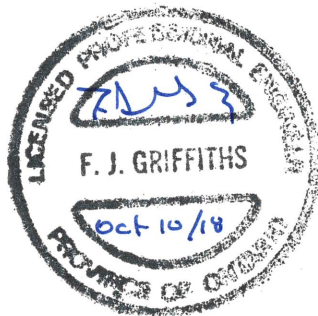
Thurber Engineering Ltd.
Report Prepared By:



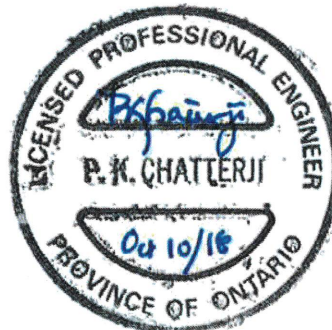
Christopher Murray, M.A.Sc., P.Eng.
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Geotechnical Engineer



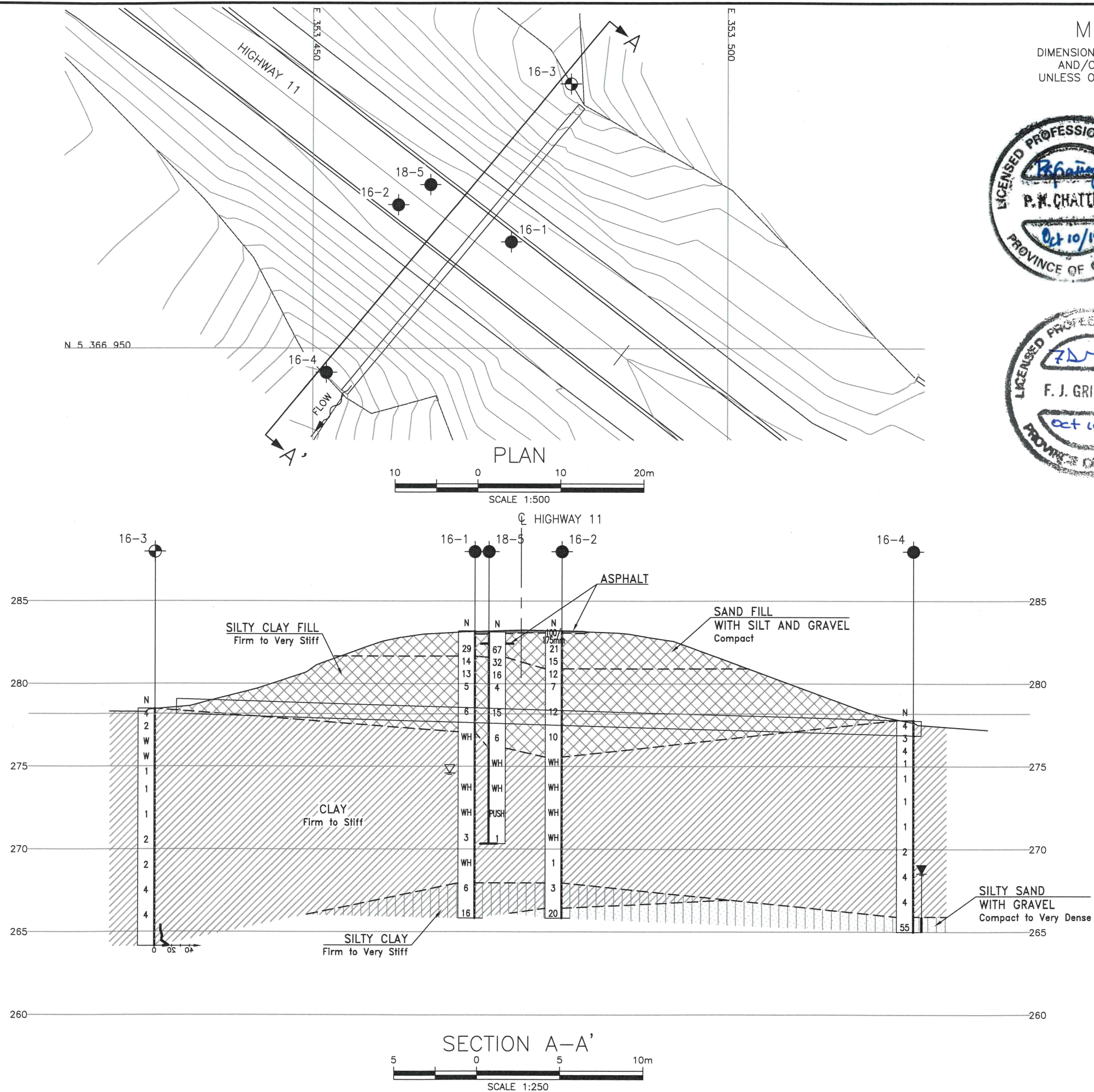
Dr. Fred Griffiths, P.Eng.
Senior Associate
Senior Geotechnical Engineer



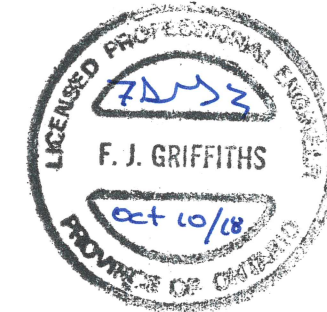
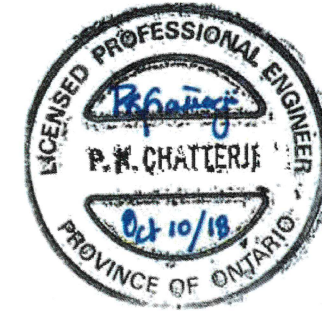
Dr. P.K. Chatterji, P.Eng.
Review Principal,
Senior Geotechnical Engineer

Appendix A.

Drawings

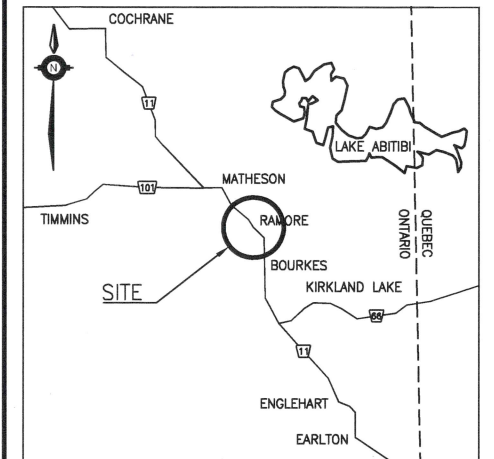


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN








CONT No	(
GWP No 5054-01-00)

HIGHWAY 11
CULVERT AT 11+975
PLAYFAIR TOWNSHIP
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

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

[illegible]

-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. 42A00-121

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NOTES:
1. LOCATIONS OF UNDERGROUND UTILITIES APPROXIMATE

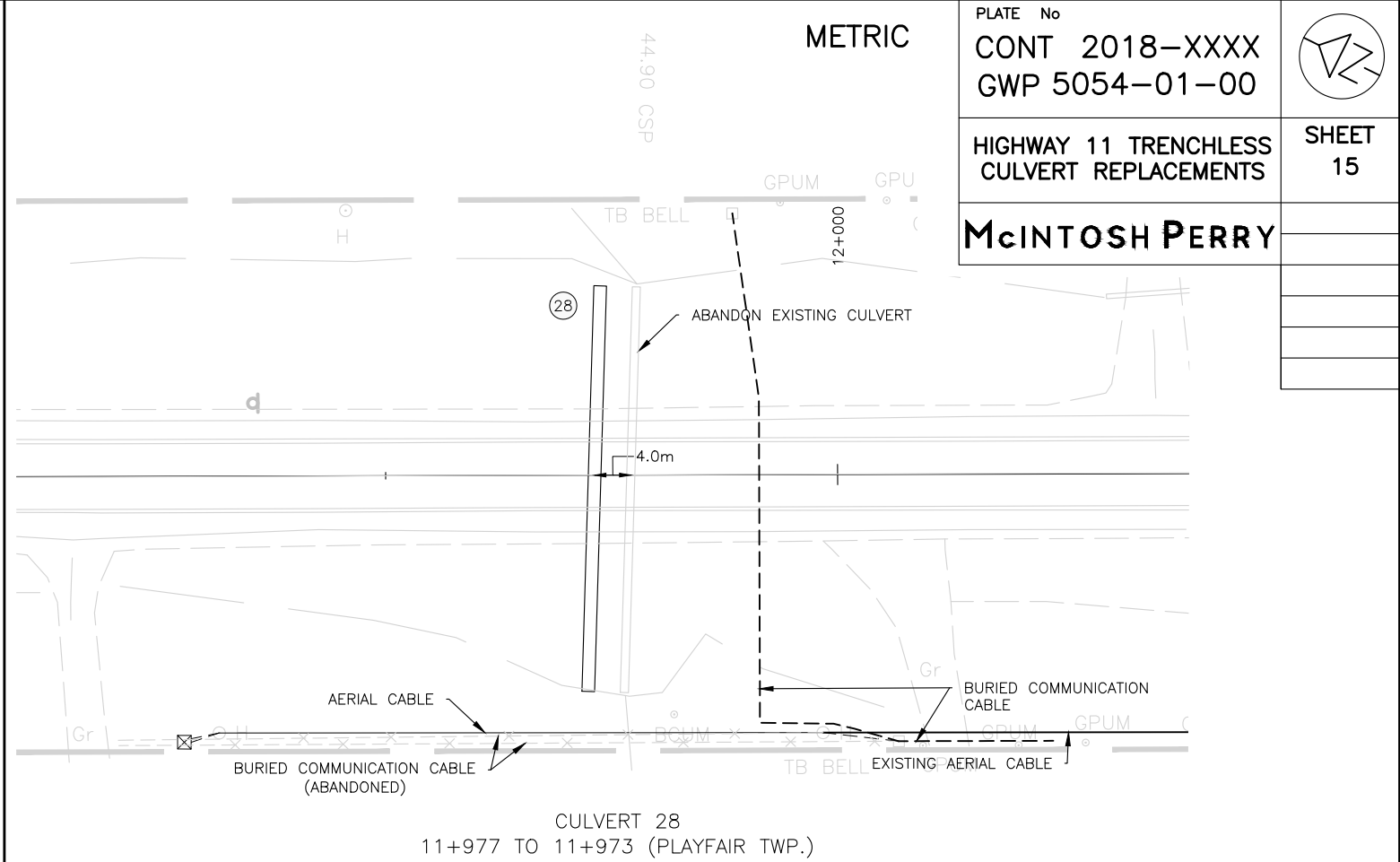
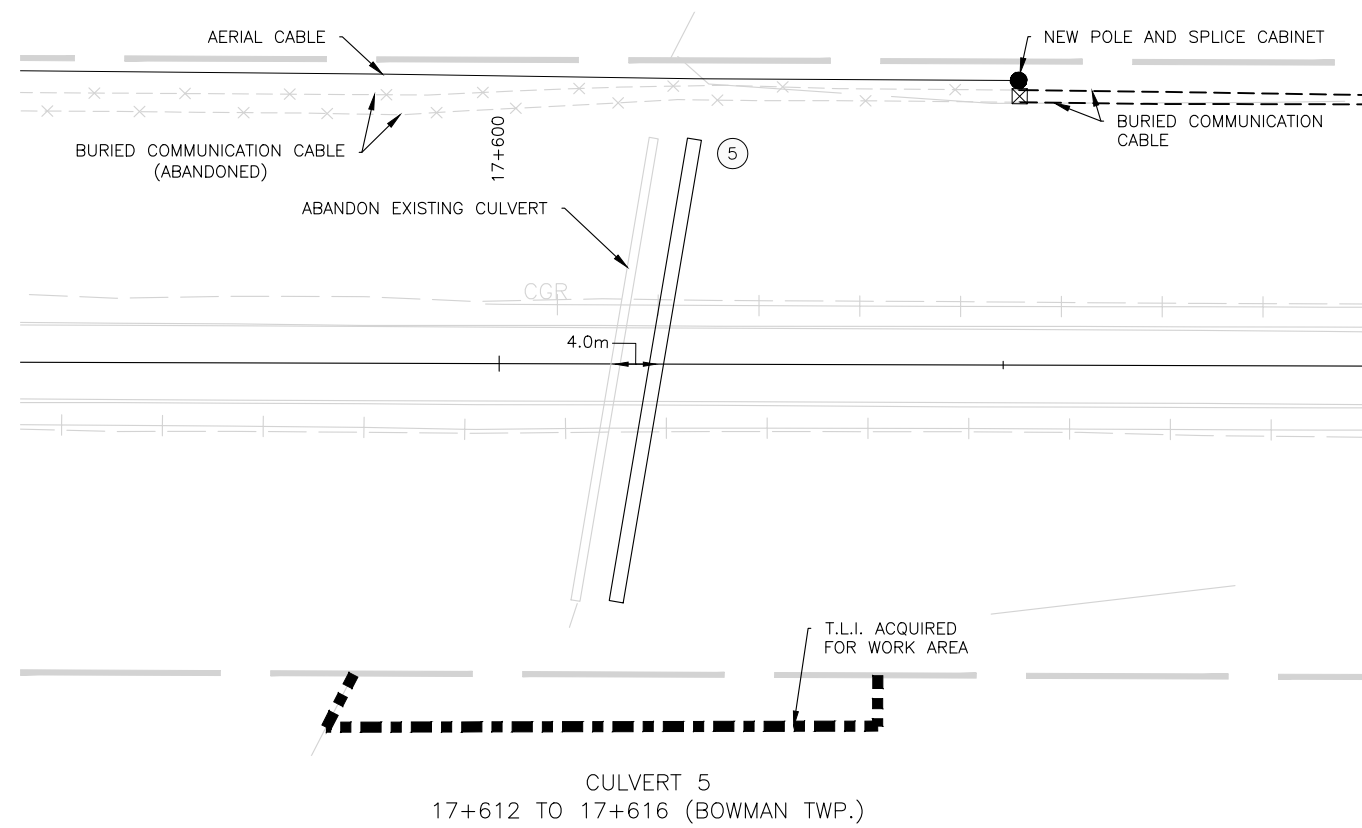

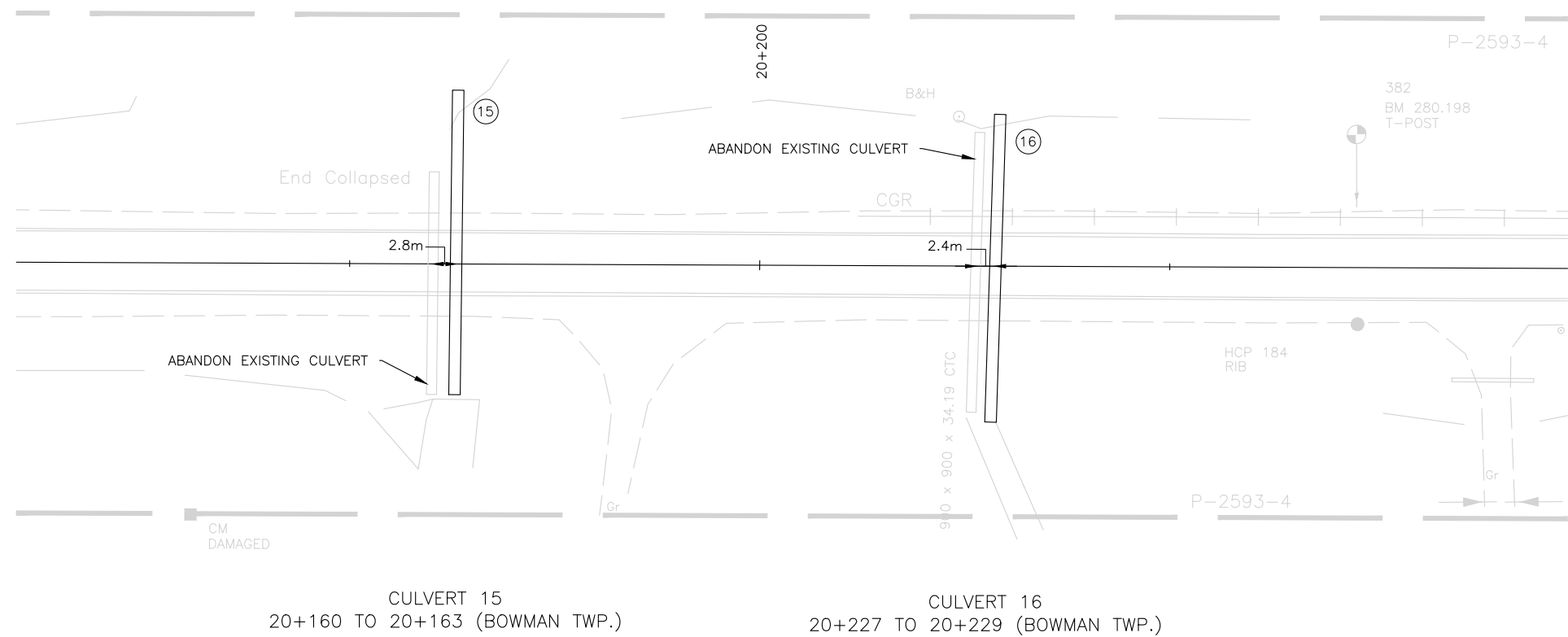


PLATE No CONT 2018-XXXX GWP 5054-01-00	 SHEET 15
HIGHWAY 11 TRENCHLESS CULVERT REPLACEMENTS	
McINTOSH PERRY	



SCALE
3.75m 0 7.5m
Horizontal

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).

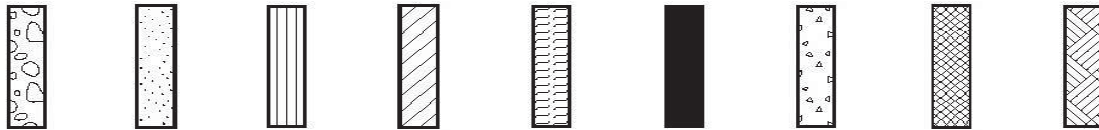
DYNAMIC CONE PENETRATION TEST (DCPT):

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 16-01

1 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4394362°, Long: -80.3420829°
Hwy 11 BOREHOLE TYPE HSA / CME 550 Buggy Mount ORIGINATED BY SOB
DATUM Geodetic DATE 2016.10.14 - 2016.10.14 COMPILED BY JM
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				
								20 40 60 80 100				
								20 40 60 80 100				
283.2												
0.0	ASPHALT (130mm)						283					
0.1	SAND with gravel Compact Brown		1	AS								
282.4	FILL											
0.8	SAND with silt and gravel Brown Compact		1	SS	29		282					
281.7	FILL											
1.5	CLAY Stiff to firm Brownish grey		2	SS	14		281					
			3	SS	13							
			4	SS	5		280					
			5	SS	6		279					
							278					
277.1												
6.1	CLAY (CH) Grey Firm to stiff		6	SS	WH		277					
							276					
			1	ST								
							275					
274.1							274					
9.1	CLAY (Cl) Grey Stiff		7	SS	WH							

Continued Next Page

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

DOUBLE LINE 13058 CULVERT 28.GPJ 2012TEMPLATE(MTO).GDT 10/10/18

RECORD OF BOREHOLE No 16-01

2 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4394362°, Long: -80.3420829°
Hwy 11 BOREHOLE TYPE HSA / CME 550 Buggy Mount ORIGINATED BY SOB
DATUM Geodetic DATE 2016.10.14 - 2016.10.14 COMPILED BY JM
CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL 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 (%)					
								20 40 60 80 100				W P W W L					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page						273			4.8 +							
			8	SS	WH		272						o				
										6.0 + 3.3 +							
			9	SS	3		271						o				
							270										
			10	SS	WH		269						o				
										5.1 + 3.5 +							
268.0							268						o				
15.2	Silty CLAY (CL-ML) Grey Stiff		11	SS	6		267								0 1 75 24		
			12	SS	16		266						o				
265.8																	
17.4	End of borehole Water level measured at 8.6 m B.G.S. on completion																

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

RECORD OF BOREHOLE No 16-02

1 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4394777° Long: -80.3422662°
Hwy 11 BOREHOLE TYPE SSA / NW Casing / CME 850 Trackmount ORIGINATED BY SOB
DATUM Geodetic DATE 2016.10.16 - 2016.10.16 COMPILED BY JM
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						
283.2													
0.0	ASPHALT (130mm)						283						26 71 3 (SI+CL)
0.1	SAND with gravel Brown Very dense FILL		1	SS	100/ 175mm								
282.4													
0.8	SAND with silt and gravel Brown Compact FILL		2	SS	21		282						
			3	SS	15								
							281						
280.9													
2.3	CLAY Greyish brown Stiff FILL		4	SS	12								1 7 50 42
							280						
			5	SS	7								
							279						
			6	SS	12								
							278						
			7	SS	10		277						
							276						
275.6													
7.6	CLAY (CH) Grey Firm to stiff		8	SS	WH								0 0 23 77
							275	2.7 +					
								4.0 +					
			9	SS	WH		274						
								3.3 +					

Continued Next Page

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

DOUBLE LINE 13058 CULVERT 28.GPJ 2012TEMPLATE(MTO).GDT 10/10/18

RECORD OF BOREHOLE No 16-02

2 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4394777° Long: -80.3422662°
Hwy 11 BOREHOLE TYPE SSA / NW Casing / CME 850 Trackmount ORIGINATED BY SOB
DATUM Geodetic DATE 2016.10.16 - 2016.10.16 COMPILED BY JM
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			20	40	60	80	100		
	Continued From Previous Page													
272.5	CLAY (CH) Grey Firm to stiff						273			5.5				
10.7	CLAY (CI) Grey Firm to stiff		10	SS	WH		272			4.4				
							271			6.0				
			11	SS	WH		270							
							269							
268.0	Silty CLAY (CL-ML) Grey Stiff		13	SS	3		268							
266.4	Silty SAND (SM) with gravel Grey Compact		14	SS	20		267							
265.8							266							
17.4	End of borehole													

DOUBLE LINE 13058 CULVERT 28.GPJ 2012TEMPLATE(MTO).GDT 10/10/18

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

RECORD OF BOREHOLE No 16-03

1 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4396074° Long: -80.3419834°
Hwy 11 BOREHOLE TYPE NW Casing / Tripod ORIGINED BY JM
DATUM Geodetic DATE 2016.10.14 - 2016.10.14 COMPILED BY JM
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 (%)		
								○ UNCONFINED + FIELD VANE									W _p W W _L		
								● QUICK TRIAXIAL × LAB VANE											
278.5							20	40	60	80	100								
0.0	CLAY Greyish brown Firm - crust		1	SS	4											0 7 41 52			
277.9																			
0.6	CLAY (CH) Grey Firm		2	SS	2														
			3	SS	WH											0 0 24 76			
			4	SS	WH														
			5	SS	1														
			6	SS	1														
273.0																			
5.5	CLAY (Cl) Grey Firm to stiff																		
			7	SS	1														
			8	SS	2														
			9	SS	2											0 0 29 71			

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-03

2 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4396074° Long: -80.3419834°
Hwy 11 BOREHOLE TYPE NW Casing / Tripod ORIGINATED BY JM
DATUM Geodetic DATE 2016.10.14 - 2016.10.14 COMPILED BY JM
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															
	CLAY (Cl) Grey Firm to stiff		10	SS	4		268									
							267									
			11	SS	4		266									
							265									
264.1	End of borehole															



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

RECORD OF BOREHOLE No 16-04

1 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4392958°, Long: -80.3423861°
Hwy 11 BOREHOLE TYPE NW Casing / Tripod ORIGINATED BY JM
DATUM Geodetic DATE 2016.10.14 - 2016.10.15 COMPILED BY JM
CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
							WATER CONTENT (%)									
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L									
277.8	CLAY (CH) Brownish grey Firm - crust		1	SS	4											
			2	SS	3											
			3	SS	4											
275.7	CLAY (CH), silt layers Grey Firm															
			4	SS	1											
			5	SS	1											

Continued Next Page

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

DOUBLE LINE 13058 CULVERT 28.GPJ 2012TEMPLATE(MTO).GDT 10/10/18

METRIC

SOIL PROFILE						SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES	20	40	60			80	100	w _p	w	w _L			kN/m ³	GR
	Continued From Previous Page																		
265.9	CLAY (Cl) , silt layers Grey Firm		10	SS	4											0	0	51	49
11.9																			
265.0	Silty SAND Grey Very Dense		11	SS	55														
12.8	End of borehole Piezometer readings: DATE DEPTH (m) ELEV. (m) 2016.10.20 9.1 268.7 2017.04.17 9.3 268.5 2017.06.12 8.8 269.0																		

+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]


+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-05

2 OF 2

METRIC

GWP# 5015-E-0041 LOCATION Lat: 48.4394994° Long: -80.3422134°
Hwy 11 BOREHOLE TYPE HSA / CME 55 Truck Mount ORIGINATED BY NW
DATUM Geodetic DATE 2018.04.30 - 2018.04.30 COMPILED BY CM
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							20 40 60 80 100									
	CLAY (CH) Grey Firm to stiff						273										
			10	ST	PUSH		272										
	</																

DOUBLE LINE 13058 CULVERT 28.GPJ 2012TEMPLATE(MTO).GDT 10/10/18

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

Appendix C.
Laboratory Testing

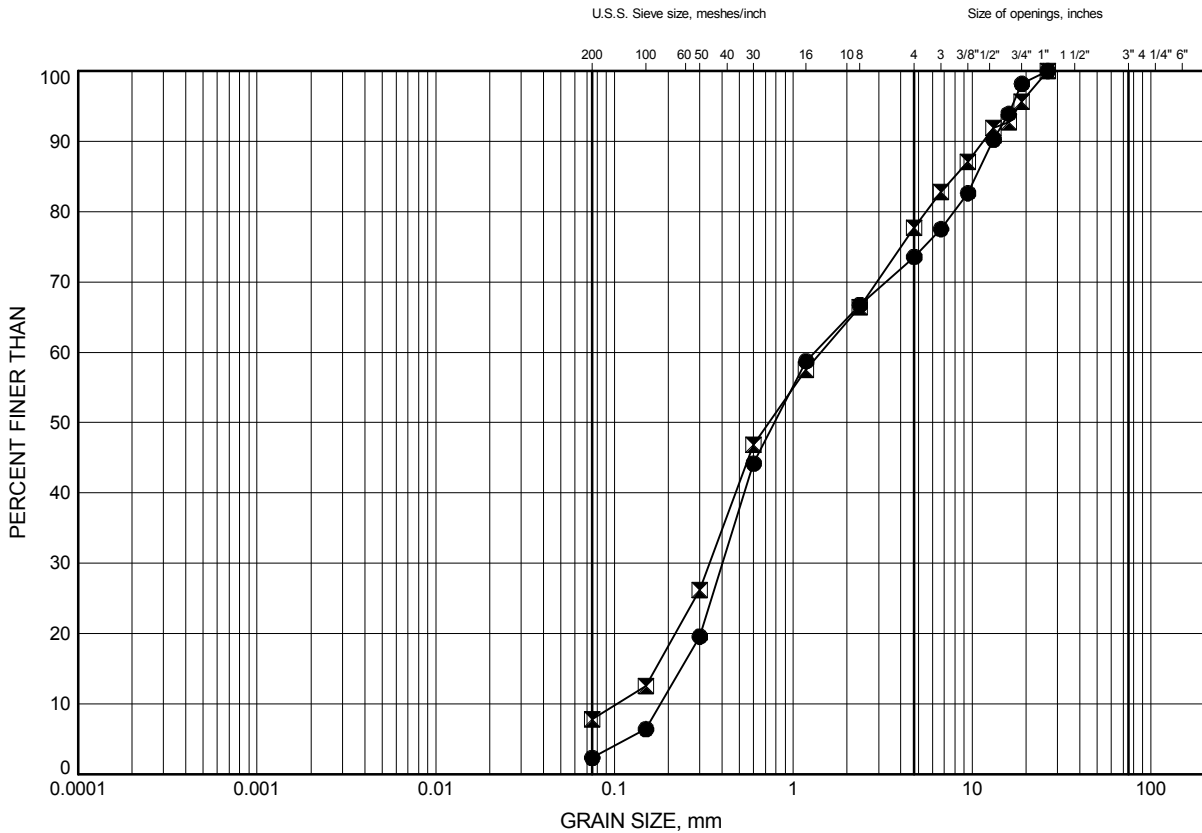
Appendix C.1
Particle Size Analysis Figures

Hwy 11 - Culvert at 11+975

GRAIN SIZE DISTRIBUTION

FIGURE C1

Sand Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	0.30	282.90
⊠	18-05	1.07	282.06

Date June 2018

GWP# 5015-E-0041



Prep'd CM

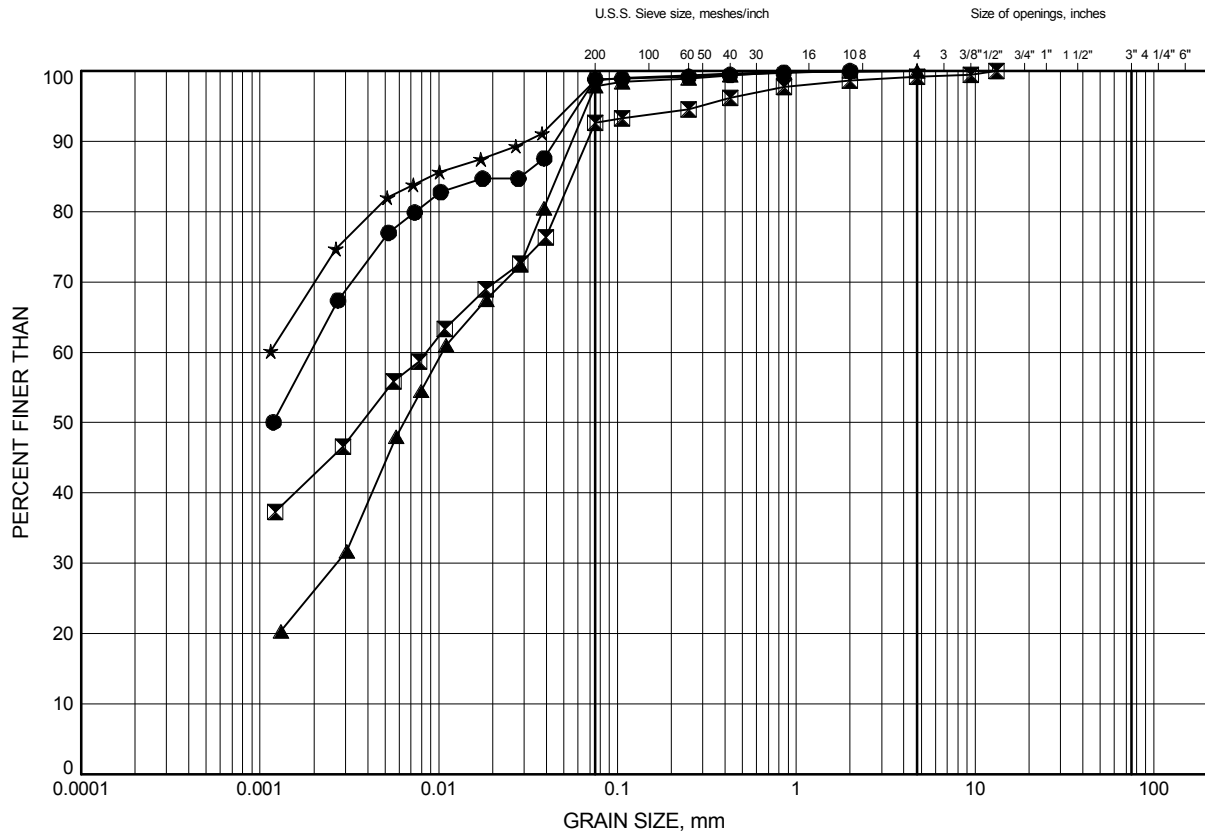
Chkd. SP

Hwy 11 - Culvert at 11+975

GRAIN SIZE DISTRIBUTION

FIGURE C2

Clay Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	3.35	279.85
⊠	16-02	2.59	280.61
▲	18-05	4.88	278.25
★	18-05	6.40	276.73

Date June 2018

GWP# 5015-E-0041



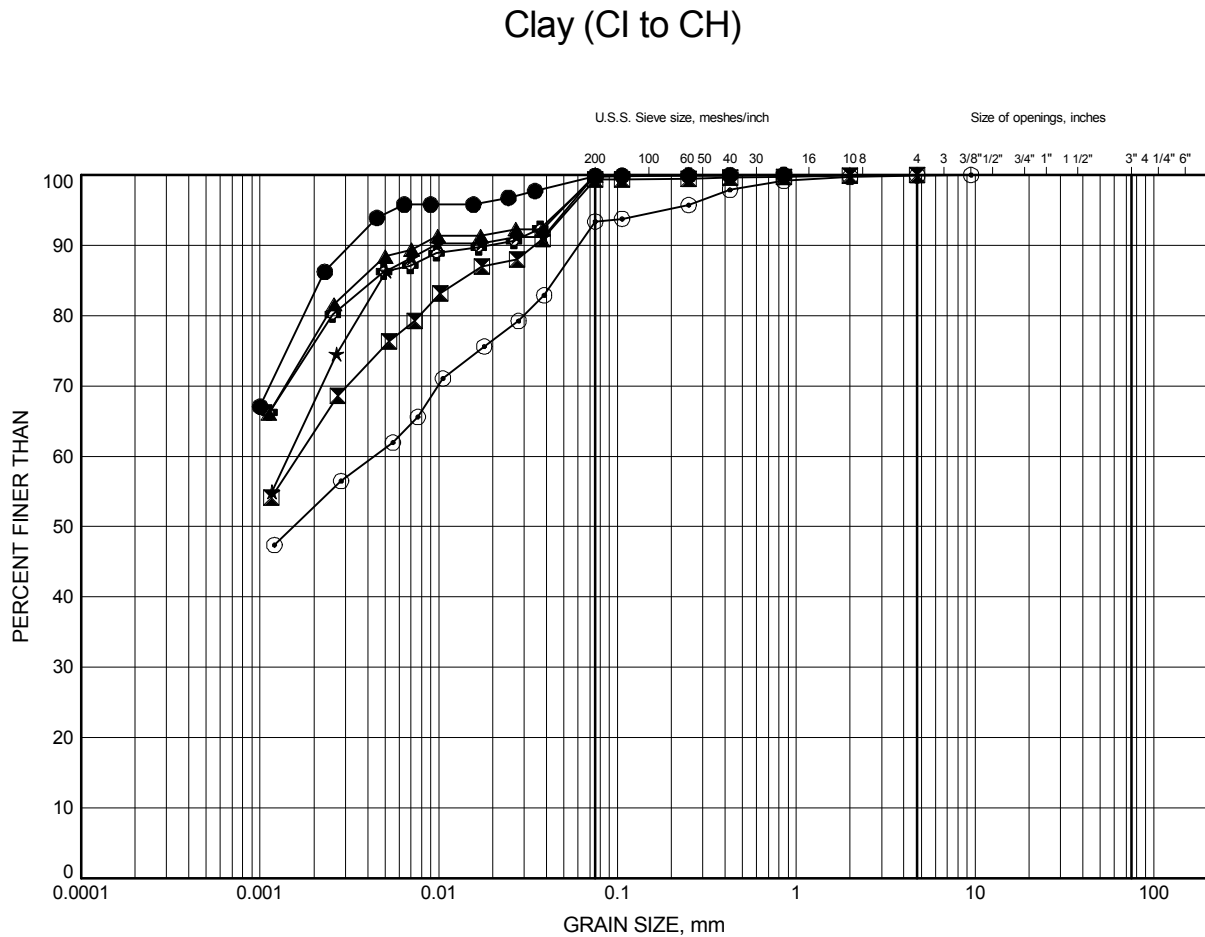
Prep'd CM

Chkd. SP

Hwy 11 - Culvert at 11+975

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)
●	16-01	7.92	275.28
⊠	16-01	9.45	273.75
▲	16-02	7.92	275.28
★	16-02	12.50	270.70
⊙	16-03	0.30	278.20
⊕	16-03	1.98	276.52

Date June 2018

GWP# 5015-E-0041



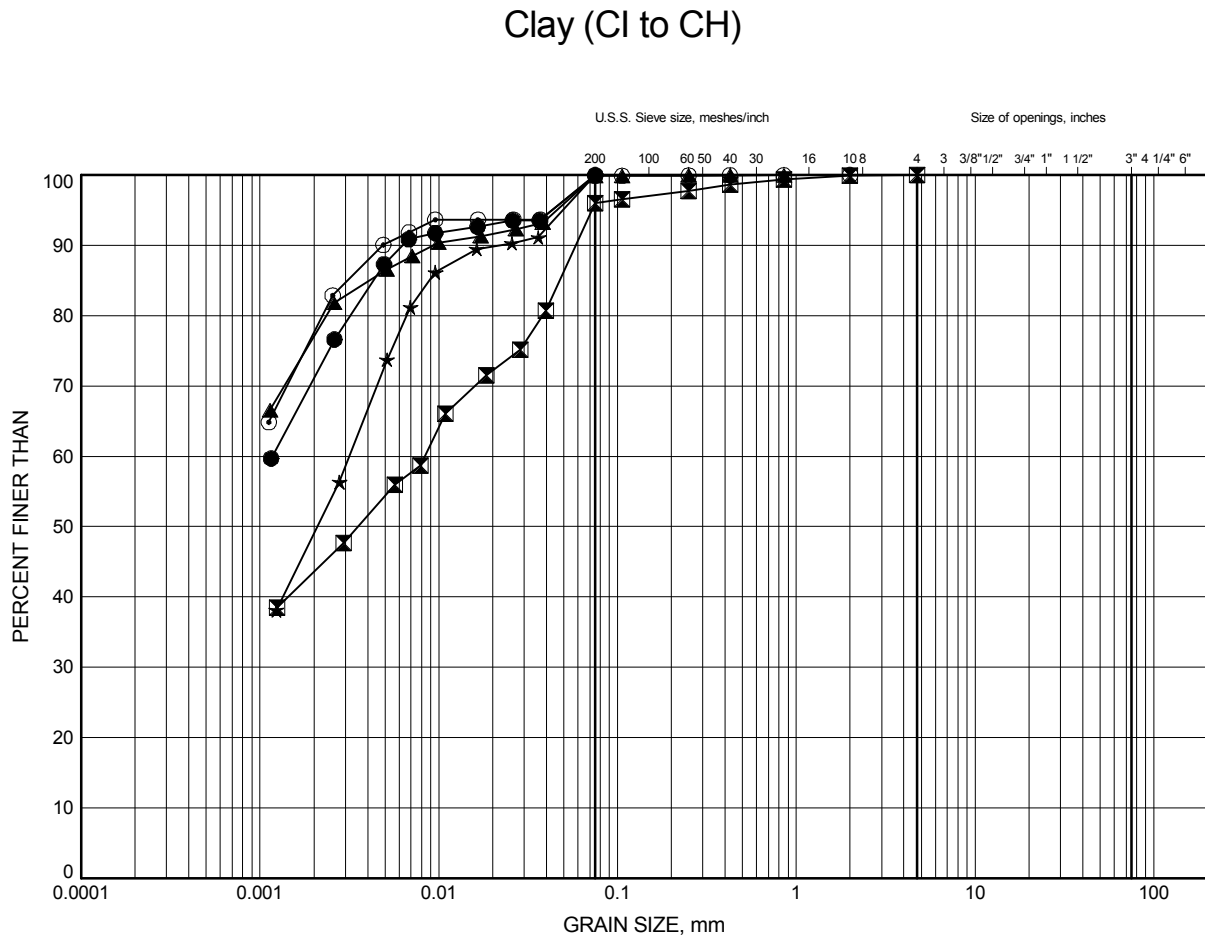
Prep'd CM

Chkd. SP

Hwy 11 - Culvert at 11+975

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)
●	16-03	9.45	269.05
⊠	16-04	1.07	276.73
▲	16-04	4.88	272.92
★	16-04	10.97	266.83
⊙	18-05	9.45	273.68

Date June 2018

GWP# 5015-E-0041



Prep'd CM

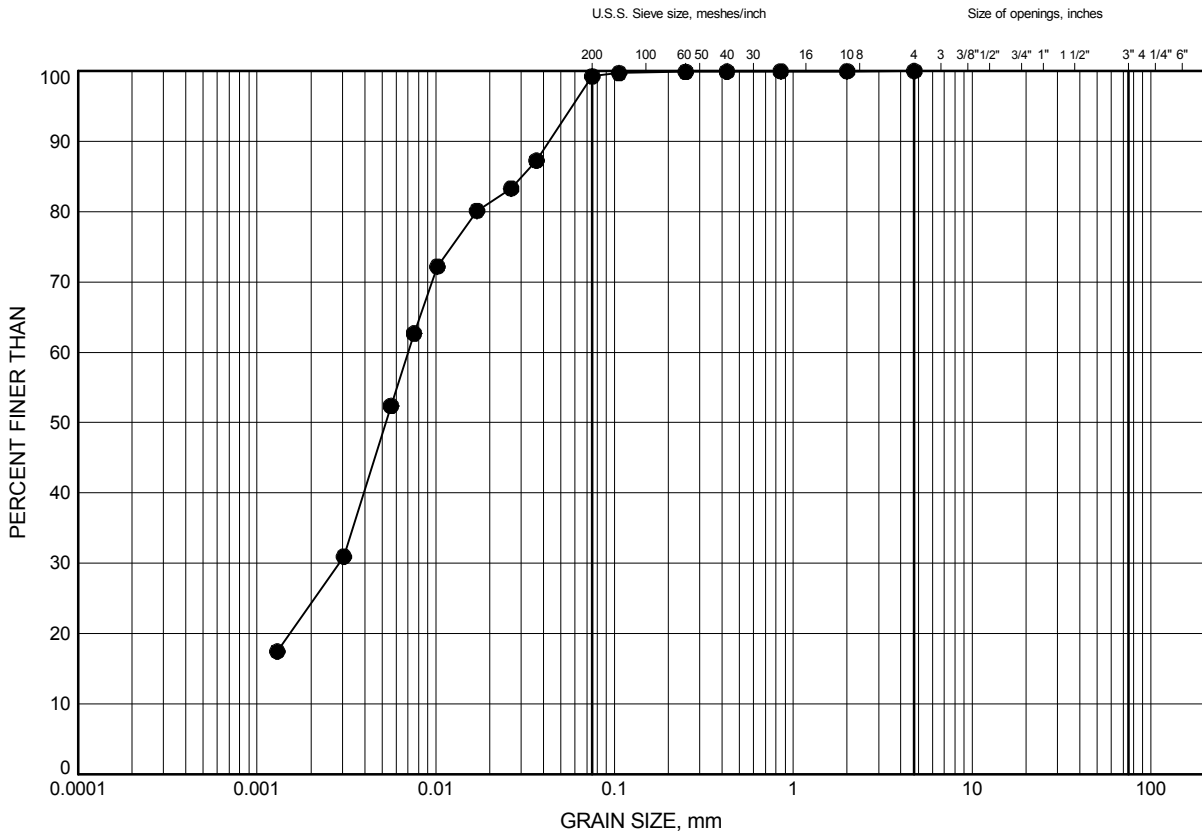
Chkd. SP

Hwy 11 - Culvert at 11+975

GRAIN SIZE DISTRIBUTION

FIGURE C5

Silty Clay (CL-ML)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	15.54	267.66

Date June 2018
GWP# 5015-E-0041



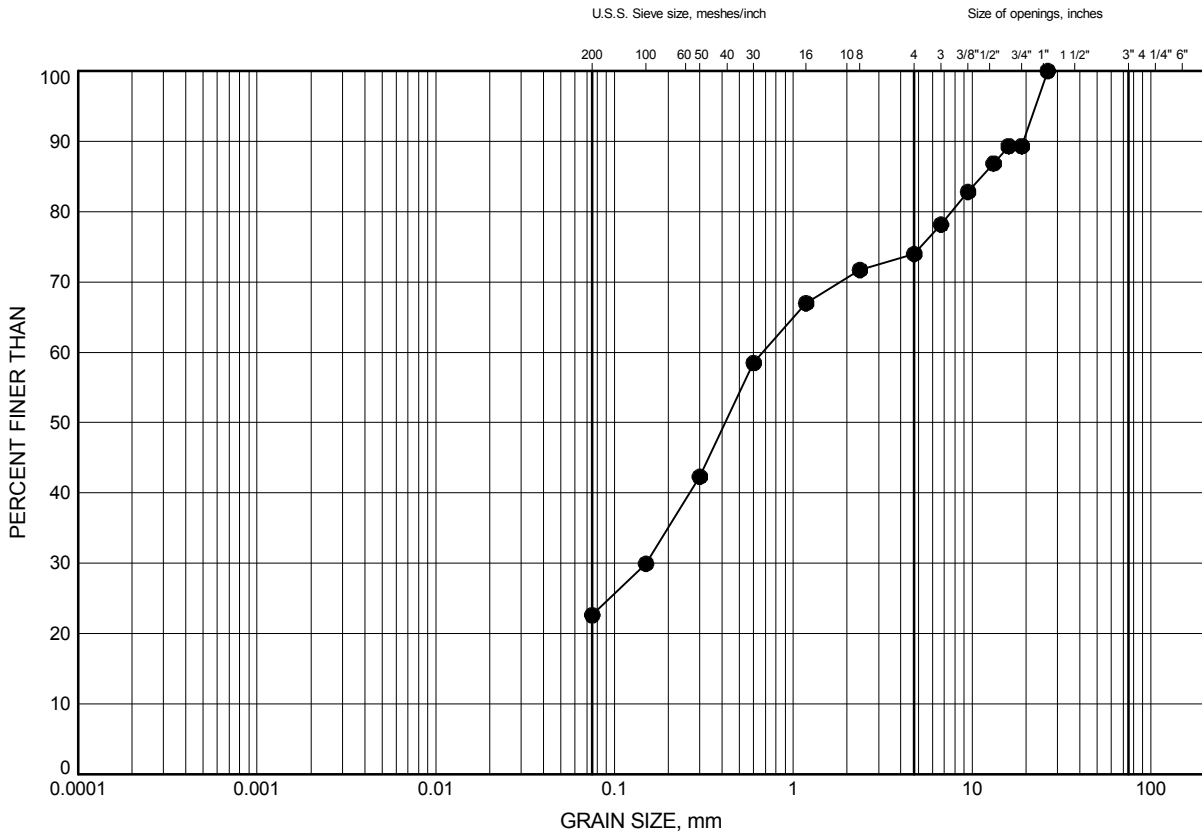
Prep'd CM
Chkd. SP

Hwy 11 - Culvert at 11+975

GRAIN SIZE DISTRIBUTION

FIGURE C6

Silty Sand (SM)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	17.07	266.13

Date June 2018
GWP# 5015-E-0041



Prep'd CM
Chkd. SP

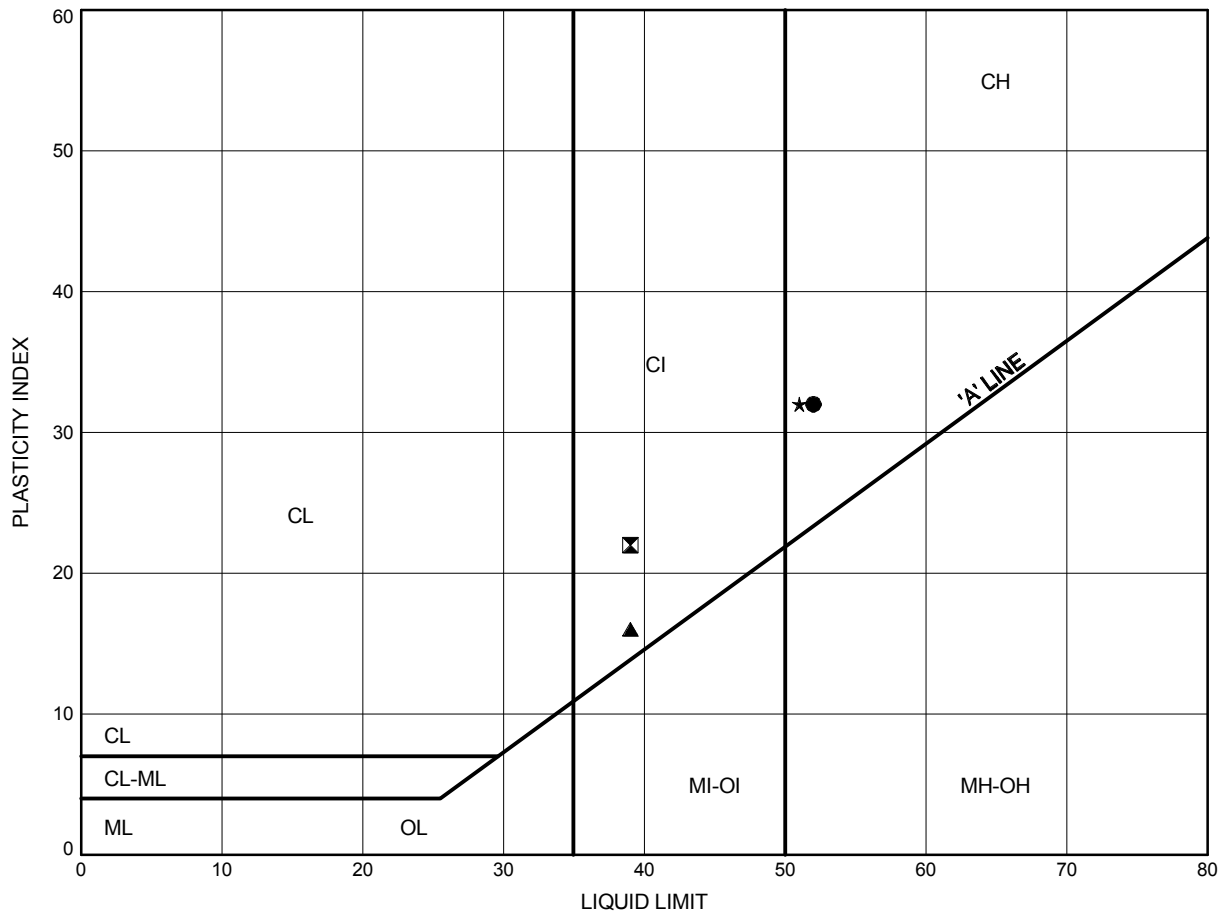
Appendix C.2
Atterberg Limit Analysis Figures

Hwy 11 - Culvert at 11+975

ATTERBERG LIMITS TEST RESULTS

FIGURE C7

Clay Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	3.35	279.85
⊠	16-02	2.59	280.61
▲	18-05	4.88	278.25
★	18-05	6.40	276.73

Date June 2018

GWP# 5015-E-0041



Prep'd CM

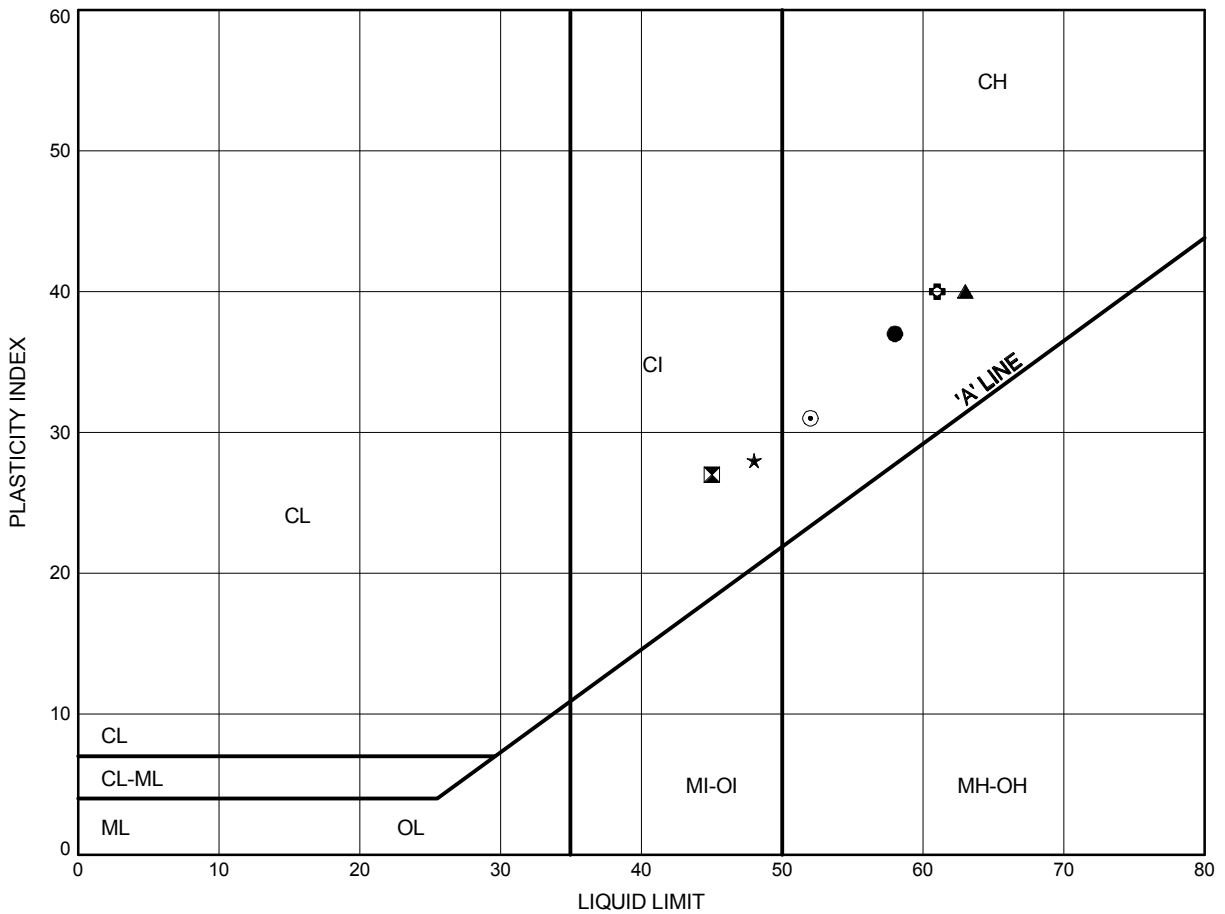
Chkd. SP

Hwy 11 - Culvert at 11+975

ATTERBERG LIMITS TEST RESULTS

FIGURE C8

Clay (CI to CH)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	7.92	275.28
⊠	16-01	9.45	273.75
▲	16-02	7.92	275.28
★	16-02	12.50	270.70
⊙	16-03	0.30	278.20
⊕	16-03	1.98	276.52

Date June 2018
GWP# 5015-E-0041



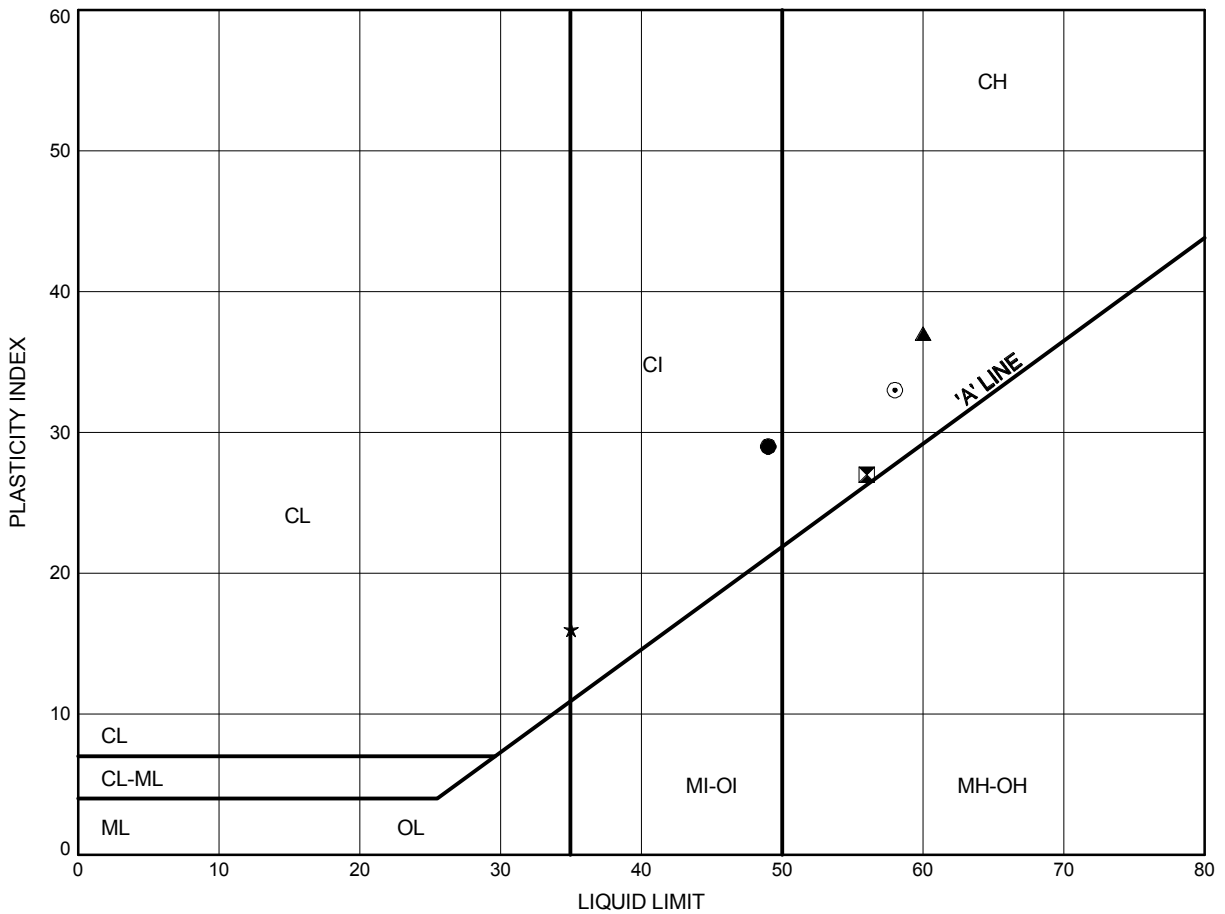
Prep'd CM
Chkd. SP

Hwy 11 - Culvert at 11+975

ATTERBERG LIMITS TEST RESULTS

FIGURE C9

Clay (CI to CH)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	9.45	269.05
⊠	16-04	1.07	276.73
▲	16-04	4.88	272.92
★	16-04	10.97	266.83
⊙	18-05	9.45	273.68

Date June 2018
GWP# 5015-E-0041



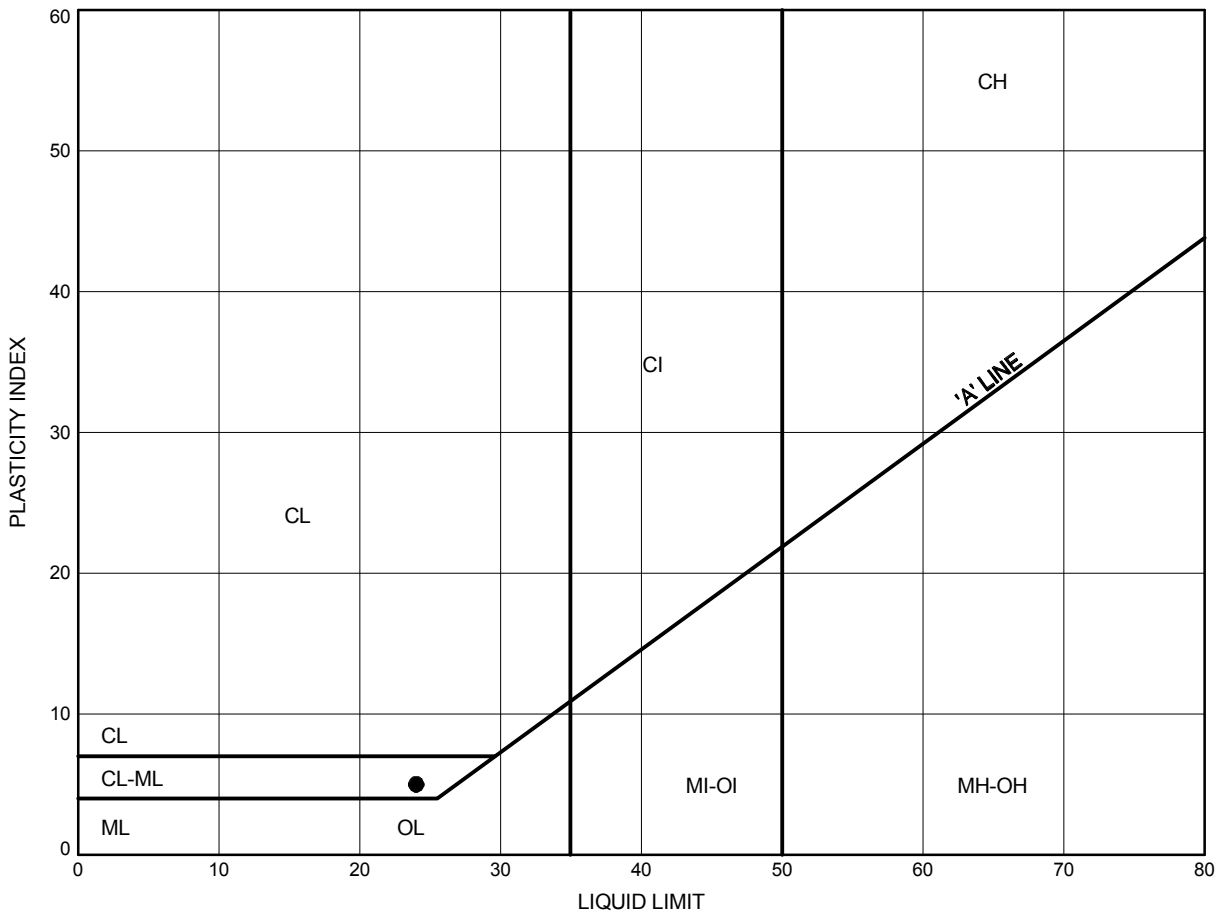
Prep'd CM
Chkd. SP

Hwy 11 - Culvert at 11+975

ATTERBERG LIMITS TEST RESULTS

FIGURE C10

Silty Clay (CL-ML)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	15.54	267.66

Date June 2018
GWP# 5015-E-0041

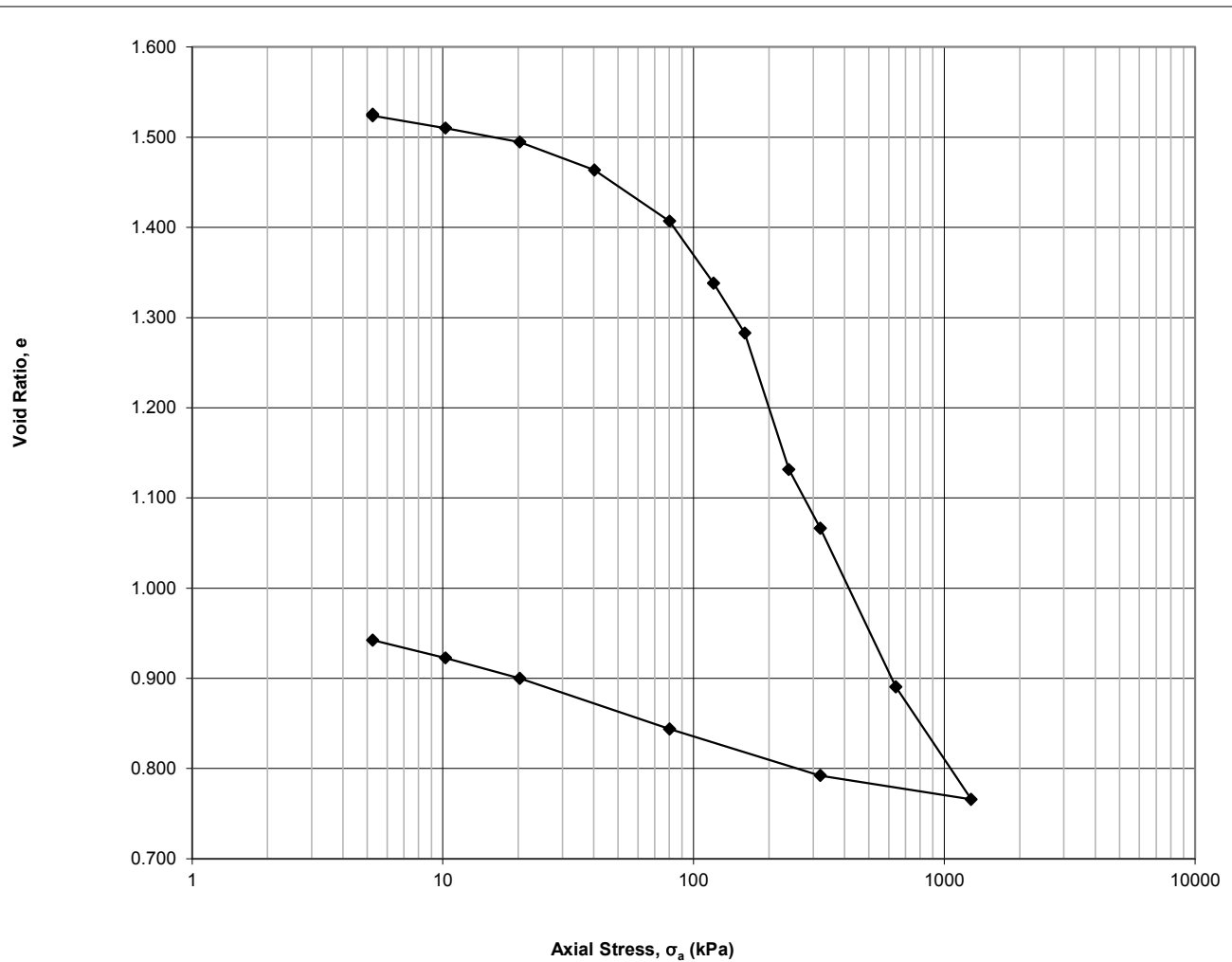


Prep'd CM
Chkd. SP

Appendix C.3
Consolidation Test Results

Project
Project No.
Borehole No.
Sample No.
Sample Depth

Thurber Engineering, File# 13058
122410864
C28
1
25-27 ft



One-Dimensional Consolidation Test using Incremental Loading
ASTM D2435/D2435M - 11

Specimen Details

Project Name	Thurber Engineering, File# 13058
Project Location	-
Borehole	C28
Sample No.	1
Depth	25-27 ft
Sample Date	October 14, 2016
Test Number	Two
Technician Name	Daniel Boateng

Soil Description & Classification

CH	
Specific Gravity of Solids	2.723
Liquid Limit %	58
Plastic Limit %	21
Plasticity Index %	37
Average water content of trimmings %	57
Additional Notes (information source, occurrence and size of large isolated particles etc.)	

Initial Specimen Conditions

Height	mm	20.00
Diameter	mm	50.00
Area	mm ²	1963
Volume	mm ³	39270
Mass	g	66.43
Dry Mass	g	42.34
Density	Mg/m ³	1.692
Dry Density	Mg/m ³	1.078
Water Content	%	56.90
Degree of Saturation	%	100.0
Height of Solids	mm	7.92
Initial Void Ratio		1.526

Final Specimen Conditions

Water Content	%	37.69
Final Void Ratio		0.942

One-Dimensional Consolidation Test using Incremental Loading

ASTM D2435/D2435M - 11

Specimen Details

Project Name	Thurber Engineering, File# 13058
Project Location	-
Borehole	C28
Sample No.	1
Depth	25-27 ft
Sample Date	October 14, 2016
Test Number	Two
Technician Name	Daniel Boateng

Test Procedure

Date Started	November 4, 2016
Date Finished	November 21, 2016
Machine Number	Frame D
Cell Number	D
Ring Number	D
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	5
Water Used	Distilled
Test Method	A
Interpretation Procedure for c_v	2

All Departures from Outlined ASTM D2435/D2435M-11 Procedure

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Calculations

Load Increment	Increment Duration	Axial Stress σ_a kPa	Corrected Deformation ΔH mm	Specimen Height H mm	Axial Strain ϵ_a %	Void Ratio e
Seating	0.0	5	0.0000	20.0000	0.00	1.526
1	1440.0	5	0.0140	19.9860	0.07	1.524
2	1440.0	10	0.1224	19.8776	0.61	1.510
3	1440.0	20	0.2449	19.7551	1.22	1.495
4	1440.0	40	0.4907	19.5093	2.45	1.464
5	1440.0	80	0.9403	19.0597	4.70	1.407
6	1440.0	120	1.4845	18.5155	7.42	1.338
7	1440.0	160	1.9231	18.0769	9.62	1.283
8	1440.0	240	3.1216	16.8784	15.61	1.131
9	1440.0	320	3.6364	16.3636	18.18	1.066
10	1440.0	640	5.0294	14.9706	25.15	0.890
11	1440.0	1280	6.0168	13.9832	30.08	0.766
12	1440.0	320	5.8082	14.1918	29.04	0.792
13	1440.0	80	5.3996	14.6004	27.00	0.844
14	1440.0	20	4.9529	15.0471	24.76	0.900
15	1440.0	10	4.7747	15.2253	23.87	0.923
16	1440.0	5	4.6180	15.3820	23.09	0.942

One-Dimensional Consolidation Test using Incremental Loading

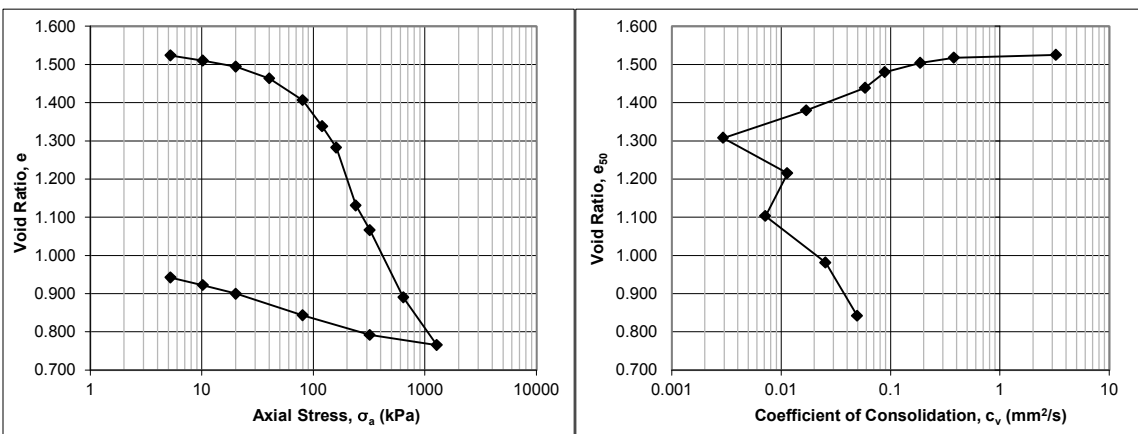
ASTM D2435/D2435M - 11

Specimen Details

Project Name	Thurber Engineering, File# 13058
Project Location	-
Borehole	C28
Sample No.	1
Depth	25-27 ft
Sample Date	October 14, 2016
Test Number	Two
Technician Name	Daniel Boateng

Calculations

Load Increment	Axial Stress σ_a , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation ΔH_{50} mm	Specimen Height H_{50} mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio e_{50}	Time t_{50} sec	Coeff. Consol. c_v mm ² /s	Time t_{90} sec	Coeff. Consol. c_v mm ² /s
Seating	3								
1	5	0.0018	19.9982	0.01	1.525			26	3.26E+00
2	8	0.0584	19.9416	0.29	1.518			222	3.80E-01
3	15	0.1699	19.8301	0.85	1.504			445	1.87E-01
4	30	0.3625	19.6375	1.81	1.480			922	8.87E-02
5	60	0.6880	19.3120	3.44	1.439			1352	5.85E-02
6	100	1.1510	18.8490	5.75	1.380			4439	1.70E-02
7	140	1.7231	18.2769	8.62	1.308			24053	2.94E-03
8	200	2.4545	17.5455	12.27	1.216			5728	1.14E-02
9	280	3.3423	16.6577	16.71	1.104			8200	7.17E-03
10	480	4.3082	15.6918	21.54	0.982			2052	2.54E-02
11	960	5.4117	14.5883	27.06	0.842			911	4.95E-02
12	800	5.9099	14.0901	29.55	0.779				
13	200	5.5996	14.4004	28.00	0.818				
14	50	5.1929	14.8071	25.96	0.870				
15	15	4.9071	15.0929	24.54	0.906				
16	8	4.7195	15.2805	23.60	0.930				



Appendix C.4
Analytical Testing Results

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

Report Date: 02-Nov-2016

Order Date: 28-Oct-2016

Project Description: 13058

Client ID: Sample Date: Sample ID: MDL/Units		C2-3 SS1 0'-2' 18-Oct-16 1644497-01 Soil	C2-4 SS3 5'-7' 18-Oct-16 1644497-02 Soil	C6-3 SS2 2'-6'-4'-6' 18-Oct-16 1644497-03 Soil	C6-4 SS3A 5'-6' 18-Oct-16 1644497-04 Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	74.7	79.6	76.7	74.5
General Inorganics					
Conductivity	5 uS/cm	357	494	795	344
pH	0.05 pH Units	7.59	7.52	7.54	7.60
Resistivity	0.10 Ohm.m	28.0	20.2	12.6	29.1
Anions					
Chloride	5 ug/g dry	49	236	314	67
Sulphate	5 ug/g dry	11	8	21	14
Client ID: Sample Date: Sample ID: MDL/Units		C7-3 SS2 2'-6'-4'-6' 18-Oct-16 1644497-05 Soil	C7-4 SS3 5'-7' 18-Oct-16 1644497-06 Soil	MC16-4 SS1 0'-2' 18-Oct-16 1644497-07 Soil	MC16-6 SS3 5'-7' 18-Oct-16 1644497-08 Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	64.7	72.9	65.0	88.2
General Inorganics					
Conductivity	5 uS/cm	226	616	729	56
pH	0.05 pH Units	7.52	7.62	6.21	6.35
Resistivity	0.10 Ohm.m	44.3	16.2	13.7	179
Anions					
Chloride	5 ug/g dry	11	187	328	9
Sulphate	5 ug/g dry	19	21	30	7
Client ID: Sample Date: Sample ID: MDL/Units		C28-3 SS2 2'-6'-4'-6' 18-Oct-16 1644497-09 Soil	C28-4 SS1 0'-2' 18-Oct-16 1644497-10 Soil	C34-3 SS3 5'-7' 18-Oct-16 1644497-11 Soil	C34-4 SS1 0'-2' 18-Oct-16 1644497-12 Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	71.3	70.8	79.9	91.9
General Inorganics					
Conductivity	5 uS/cm	765	999	233	208
pH	0.05 pH Units	7.47	7.60	7.65	6.95
Resistivity	0.10 Ohm.m	13.1	10.0	42.8	48.2
Anions					
Chloride	5 ug/g dry	343	493	13	18
Sulphate	5 ug/g dry	15	21	36	24

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

Report Date: 10-May-2018

Order Date: 4-May-2018

Project Description: 13058

Client ID:		20+172 Bowman,18-5,SS11 (25'-27')	11+967 PlayFair,18-5, SS9(25'-27')	20+237 Bowman,18-5,SS8(1 7'6"-19'6")	17+619 Bowman,18-5,SS13 (30'-32')
Sample Date:		05/02/2018 12:00	04/30/2018 14:30	05/02/2018 16:00	05/03/2018 11:30
Sample ID:		1818665-01	1818665-02	1818665-03	1818665-04
MDL/Units		Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	71.9	61.4	72.8	92.1
General Inorganics					
Conductivity	5 uS/cm	308	408	564	654
pH	0.05 pH Units	7.79	7.56	6.82	7.11
Resistivity	0.10 Ohm.m	32.5	24.5	17.7	15.3
Anions					
Chloride	5 ug/g dry	56	118	284	17
Sulphate	5 ug/g dry	23	14	11	7

Appendix D.
Site Photographs



Photo 1. Looking south along Highway 11.



Photo 2. Looking north along Highway 11.



Photo 3. Looking west of Highway 11.



Photo 4. Looking east of Highway 11.

Appendix E.
Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

	<i>Circular Pipe or Closed Box Culvert</i>	<i>Circular Pipe Culvert (Trenchless Installation)</i>	<i>Open Bottom Culvert</i>
<i>Advantages</i>	Typically least costly culvert type. Relatively expedient installation if precast units are used. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.	Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts). Avoids open cut Allows two lanes of traffic to be maintained throughout construction	Relatively expedient installation if precast units are used. Possibility to maintain work zone to span the existing waterway.
<i>Disadvantages</i>	Requires large excavation and roadway protection. Requires water flow realignment or installation of a temporary by-pass culvert to maintain existing water flow alignment	Requires construction of entry and exit pits and access to toes of slope. Requires specialised construction equipment. Feasibility also depends on flow capacity and other hydraulic properties.	Requires deeper excavation increasing excavation volume and dewatering concern. Requires roadway protection. Founding subgrade will provide lower geotechnical resistances. Potential for post construction settlement.
<i>Risks/ Consequences</i>	Disruption to traffic	Possibility of encountering obstructions and mixed soils Proximity of buried utilities may limit installation type and location of entry/exit pits	Disruption to traffic
<i>Relative Cost</i>	Low to Medium	Medium to High	Medium
<i>Recommendation</i>	Feasible	Recommended	Not Recommended

COMPARISON OF ALTERNATIVE TRENCHLESS INSTALLATION METHODS

1.4 m diameter pipe, 47 m in length through very stiff clay fill and firm native clay

<i>Method</i>	<i>Jack and Bore</i>	<i>Pipe Ramming</i>	<i>Pipe Jacking</i>	<i>Microtunnelling (MTBM)</i>
<i>Advantages</i>	Suitable for firm to very stiff clays Equipment and crew readily available Typically, a less costly technique	Suitable for soft to very stiff clay soils Suitable for pipe diameters between 0.5 and 3.6 m and length < 100 m Typically, a less costly technique	Suitable for firm to very stiff clay soils	High precision in alignment Worker safety is enhanced Suitable for soft to very stiff clay soils
<i>Disadvantages</i>	Incapable of handling unforeseen obstructions Prone to misalignment Nearing the maximum diameter	Minimal precision in alignment control Unable to access tunnel face due to pipe diameter; incapable of handling unforeseen obstructions	Risk increased by presence of soft clay. Typically, a moderately costly technique	Unforeseen oversized obstructions would slow progress High operator skill required Typically, an expensive technique.
<i>Risks/Consequences</i>	Obstructions	Obstructions	Obstructions	Obstructions
<i>Recommendation</i>	Recommended	Recommended	Feasible	Feasible

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

March 24, 2017

Site: 48.4394 N, 80.3422 W User File Reference: Highway 11

Requested by: , Thurber Engineering Ltd.

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

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
0.142	0.179	0.155	0.122	0.091	0.050	0.025	0.0062	0.0026	0.098	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)	0.010	0.040	0.072
Sa(0.1)	0.016	0.057	0.097
Sa(0.2)	0.018	0.055	0.089
Sa(0.3)	0.016	0.046	0.072
Sa(0.5)	0.013	0.036	0.055
Sa(1.0)	0.0062	0.021	0.031
Sa(2.0)	0.0027	0.0098	0.015
Sa(5.0)	0.0006	0.0021	0.0036
Sa(10.0)	0.0004	0.0010	0.0015
PGA	0.0091	0.031	0.053
PGV	0.0074	0.026	0.042

References

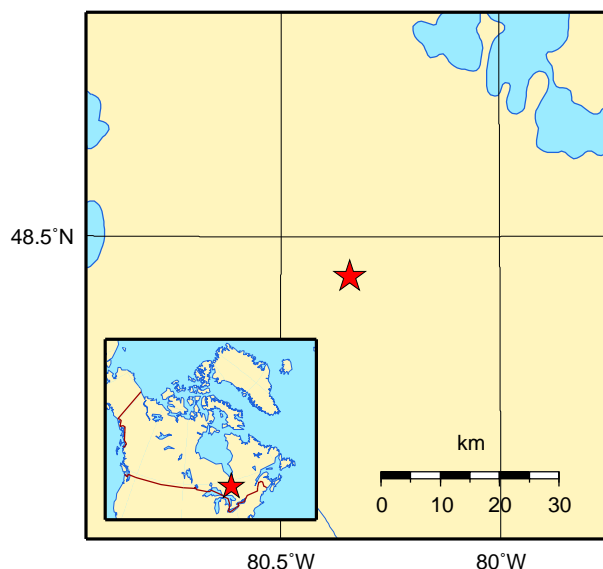
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

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

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

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
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 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cuts
OPSS.PROV 501	Construction Specification for Compacting
OPSS 510	Construction Specification for Removal
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextile
OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Span Less than or Equal to 3.0 m
OPSD 803.031	Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Depths for Northern Ontario
SP109S12	Amendment to OPSS 902 - QVE, Backfilling Compaction, and Certificate of Conformance
SP517F01	Amendment to OPSS 517 - Dewatering System
SPFOUN0003	Amendment to OPSS 902 – Dewatering Structure Excavations

2. Suggested text for an NSSP to apply to the Special Provision for “Pipe Installation by Trenchless Method”

The SP for Pipe Installation by Trenchless Method shall be amended by the following:

- Hand Mining and Directional Drilling shall not be utilized for the culvert installation at Station 11+973 Playfair.
- Quality Verification Engineers (QVE) are no longer utilized in MTO Contracts. All occurrences of the words “Quality Verification Engineers (QVE)” in the SP shall be replaced with the words: “Contractor’s Engineer”

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials
----------	---

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS.PROV 1004	Aggregates - Miscellaneous
OPSS.PROV 1350	Concrete - Materials and Production
OPSS.PROV 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS.PROV 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand-mining (man-entry operation or “Jack and Mine) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid’s pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;

- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:

- The methods to be employed to monitor and maintain the alignment of the installation.

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to

commencement of each subsequent operation for each pipe installation:

- Site Surveying (as noted in Section 4.02)
- Excavation for pits including dewatering of excavations
- Jacking/Ramming/Directional Drilling of Casing/Liner
- Installation of the Product
- Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.

Use of explosives is prohibited.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS.PROV 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA’s may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or

could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS.PROV 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as

indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7.05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OSHA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

- **Review Level:** If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- **Alert Level:** If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
 - The cause of the settlement has been identified.
 - The Contractor submits a corrective/preventive plan.
 - Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless

installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.