PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AT SITE #21-498C,
HIGHWAY 7A, MUNICIPALITY OF PETERBOROUGH
TOWNSHIP OF CAVAN-MONAGHAN

W.P. 4013-13-01

Geocres Number: 31D-614

Report to

AECOM

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation, completed at the location of a proposed culvert replacement at Site # 21-498C on Highway 7A in the Township of Cavan-Monaghan, Ontario.

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, record of borehole sheets, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to AECOM under the Ministry of Transportation (MTO) Agreement Number 4013-E-0015.

2 SITE DESCRIPTION

The culvert at Site 21-498C is located on Highway 7A, approximately 370 m west of the intersection of Highway 7A and Highway 115 in the Township of Cavan-Monaghan, Ontario. The existing culvert is a corrugated steel pipe arch (CSP) 3.1 m x 1.9 m x 30.5 m in size.

The surrounding land is treed and relatively flat with areas of swamp present at low points. The highway is elevated approximately 2 m to 3 m above the swamp level. The unnamed creek collects water from the surrounding swamps that flows south-north through the culvert. The creek continues to flow north and eventually drains into a small stream which meanders eastward until it drains into the Trent Canal. The photographs of the site are enclosed in Appendix C.

The site is located within the physiographic region known as the Peterborough Drumlin Field, which is characterized by drumlinized till deposit. The culvert lies in an area of textured glaciolacustrine deposit of silt and clay, minor sand and gravel.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project was carried out between December 2 and 3, 2014 and consisted of drilling and sampling a total of four boreholes identified as Boreholes

14-02 to 05. An additional borehole (Borehole 14-08) was augered by hand on December 18, 2014. The boreholes were extended to depths ranging from 2.0 to 9.7 m below the existing ground surface. The approximate borehole locations are shown on the attached Borehole Locations Drawing included in Appendix D.

Prior to commencement of drilling, utility clearances were obtained for all borehole locations. Drilling was carried out using a truck mounted D90 drill rig with solid and hollow stem augers. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

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

Groundwater conditions were observed in the open boreholes during and upon completion of the drilling operations. A standpipe piezometer, consisting of 19 mm Schedule 40 PVC pipe with a 3.0 m long slotted screen, was installed in borehole 14-05. The piezometer screen was enclosed in filter sand to permit groundwater level monitoring. All boreholes were backfilled upon completion, and the piezometer was decommissioned following the final water level reading in general accordance with Ontario Regulation 903. Details of borehole completion are shown in Table 3-1.

Table 3-1. Borehole Completion Details

Borehole	Borehole Depth/ Base Elevation (m)	Borehole Backfilling Details
14-02	9.2 / 189.4	Bentonite holeplug and cuttings from 9.2 m to ground surface
14 -03	9.7 / 189.1	Bentonite holeplug and cuttings from 9.7 m to ground surface
14 -04	9.7 / 188.6	Bentonite holeplug and cuttings from 9.7 m to ground surface
14 -05	7.8 /190.3	Piezometer with 3.0 m slotted screen installed. Bentonite holeplug and cuttings from 7.9 to 6.2 m, piezometer tip at 6.1 m (Elev. 192.2), sand filter from 6.1 to 3.0 m, bentonite holeplug and cuttings from 3.0 m to ground surface
14 -08	2.0 / 195.1	Bentonite holeplug and cuttings from 2.0 m to ground surface

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limits testing where appropriate. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets 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 and interpretation of the site conditions.

It should be recognised that soil conditions may vary between and beyond borehole locations. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and represent transition between soil types rather than exact geological change.

In general, the subsurface conditions consist of embankment fill underlain by glaciolacustrine clayey silt to silty clay, which in turn was underlain by till deposit comprising silty sand to clayey silt and sand.

More detailed descriptions of the individual strata are presented below.

5.1 Gravelly Sand to Silty Sand Fill

Boreholes 14-02 to 14-05 were advanced from the existing Highway 7A embankment grade in proximity to the existing culvert and encountered fill materials ranging in composition from gravelly sand to silty sand. The fill layer was between 2.2 m and 4.1 m thick, with the base encountered between Elev. 194.5 and Elev. 196.1, raising from south to north.

Gravelly sand fill with some silt and trace organics was encountered in Borehole 14-02. The fill extended to depth of 4.1 m below the ground surface (Elev. 194.5 m). SPT tests performed in the granular fill gave N-values between 10 and 27 blows per 0.3 m of penetration, indicating a compact relative density. Moisture contents within the granular fill varied from 6 to 10%.

Silty sand fill with trace to some gravel and trace clay was encountered in Boreholes 14-03 and 14-04. The silty sand fill was extending to depth from 2.2 to 4.1 m (Elev. 194.7 to 196.1 m). SPT tests performed in this fill resulted in N-values between 6 and 32 blows per 0.3 m of penetration, indicating a loose to dense relative density. Moisture contents within the granular fill varied from 7 to 10%.

In borehole 14-05, sand fill with some silt and some gravel was encountered. The sand fill extended to depth of 2.3 m (195.8 m). SPT tests N-values ranging from 5 to 30 blows per 0.3 m of penetration were obtained, indicating a loose to dense relative density. Moisture contents within the sand fill ranged from 5 to 21%.

Grain size analyses were completed on five samples of the fill. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves in Figure B1 of Appendix B.

The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	9 to 22
Sand	51 to 64
Silt	24
Clay	8
Silt and Clay	22 to 40

5.2 Clayey Silt to Silty Clay

A layer of clayey silt to silty clay with trace to some sand and trace gravel was encountered below the embankment fill in Boreholes 14-02 to 14-05. Where fully penetrated in Boreholes 14-02 to 14-04, the thickness of this layer varied from 3.1 to 5.4 m with an underside depth of 7.2 to 7.6 m (Elev. 190.7 to 191.6 m). Borehole 14-05 was terminated upon auger refusal on probable bedrock at a depth of 7.8 m (Elev. 190.3 m). The silty clay was encountered in Borehole 14-08 extending from the ground surface to 2 m depth, where borehole was terminated.

SPT tests performed in the clayey silt/silty clay resulted in N-values between 3 and 34 blows per 0.3 m of penetration, indicating a soft to hard consistency. Moisture contents within the clayey silt/silty clay varied from 13 to 38%.

Grain size distribution analyses were completed on five samples of this cohesive deposit. The results are summarized on the Record of Borehole sheets in Appendix A, and the grain size distribution curves are included in Figure B2 of Appendix B. The results of the laboratory test are summarized as follows:

Soil Particles	Percentage (%)
Gravel	0 to 5
Sand	0 to 21
Silt	50 to 75
Clay	16 to 27

Atterberg Limits analyses were completed on two samples of this layer. The results are summarized on the Record of Borehole sheets in Appendix A and the Atterberg Limits graphs are included in Figure B4 of Appendix B. The results of the laboratory test indicate on inorganic clay of low plasticity and clayey silt of medium compressibility. The results of Atterberg Limits tests are summarized below:

Parameter	Value
Plastic Limit	19 to 28
Liquid Limit	32 to 40
Plasticity Index	12 to 13

5.3 Clayey Silt and Sand Till

A layer of clayey silt and sand till with trace to some gravel was encountered in Boreholes 14-02 to 14-04. All three boreholes were terminated within this layer at depths of 9.2 to 9.7 m (Elev. 188.6 to 189.4 m).

SPT tests resulted in N-values ranging from 81 to in excess of 100 blows per 0.3 m of penetration, indicating a hard consistency. Moisture contents within this layer varied from 7 to 12%.

Grain size distribution analyses were completed on three samples of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves are presented in Figure B3 of Appendix B. The results of the laboratory tests are summarized as follows:

Soil Particles	Percentage (%)
Gravel	3 to 12
Sand	43 to 45
Silt	31 to 32
Clay	13 to 20

Atterberg Limits test was also completed on a sample of this deposit. The results are summarized on the Record of Borehole sheets in Appendix A and presented in Figure B5 of Appendix B. The results of the laboratory test indicate intermediate plasticity of the deposit.

Parameter	Value
Plastic Limit	26
Liquid Limit	38
Plasticity Index	12

5.4 Groundwater Levels

Where present, water levels were observed in the open boreholes upon completion of the drilling. As outlined in Table 3-1, one standpipe piezometer was installed in Borehole 14- 05 to monitor groundwater levels after drilling. The measured groundwater levels are summarized in Table 5-1.

Table 5-1. Measured Groundwater Levels

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
14-02	Dec. 2, 2014	2.9	195.7	Open Borehole
14-03	Dec. 2, 2014	2.9	195.9	Open Borehole
14-04	Dec. 3, 2014	2.3	196.0	Open Borehole
14-05	Dec. 4, 2014 Dec. 14, 2014	2.3 2.0	195.8 196.1	Piezometer

The values shown are short-term readings and seasonal fluctuations of the groundwater level are to be expected. The water levels in open boreholes are believed to represent the water level in the creek. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation events.

6 MISCELLANEOUS

Borehole locations were selected and marked in the field by an experienced Thurber staff member and were established with a Trimble Pathfinder ProXRT differential GPS unit.

Walker Drilling Ltd. from Utopia, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field program. The field investigation was supervised on a full time basis by Mr. Sean Petrus, EIT of Thurber. Overall supervision of the investigation program was conducted by Mr. Weiss Mehdawi, P.Eng.

Routine laboratory testing was carried out by Thurber's geotechnical laboratory in Oakville, Ontario. Interpretation of the data and preparation of this report were carried out by Mr Michael Eastman, EIT and Ms. Anna Piascik, P.Eng.

The report was reviewed by Mr. Alastair Gorman, P.Eng and Dr. P.K. Chatterji, P.Eng. who is a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

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PART 2: ENGINEERING DISCUSSION

7 INTRODUCTION

This section of the report provides an interpretation of the factual data and presents engineering discussion for planning of the proposed culvert replacement on Highway 7A in the Township of Cavan-Monaghan, Ontario.

The existing culvert consists of a corrugated steel pipe arch (CSP) 3.1 m width x 1.9 m rise x 30.5 m span. An unnamed creek flows in the northerly direction at the site and eventually drains into the Trent Canal. The existing highway embankment at the culvert site is approximately 2.0 m to 3.0 m in height. The fill thickness above the culvert crown was estimated to be between 0.5 m and 0.8 m.

The discussions and recommendations presented in this report are for planning purposes only. The Design Builder shall satisfy themselves as to the sufficiency of the information required to meet the requirements for detailed design. The Design Builder is solely responsible for selecting the appropriate foundation alternatives for replacement of the structure and detailed design of the structure.

8 CULVERT FOUNDATION

8.1 General

In general terms, the subsurface conditions encountered at the site consisted of embankment fill underlain by clayey silt to silty clay, which was further underlain by clayey silt and sand till.

Groundwater levels measured in a standpipe piezometer installed at the site ranged from 2.0 to 2.3 m below the ground surface.

8.2 Foundation Alternatives

This section presents discussions on foundation alternatives for culvert replacement, and on a feasible and/or preferred foundation options. Some common culvert alternatives and foundation types are listed below and a comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E.

The following culverts are discussed in the report:

- Circular Pipes (Concrete, CSP, HDPE)
- Box Culvert
- Open Footing Culvert

All three culvert types are considered to be possible candidates for this site. However, pipe or pre-cast box culvert options would offer relatively easy construction.

Considering the presence of cohesive native deposits underlying the site, the pre-cast box culvert seems to be the preferred option for the replacement structure based on the following considerations:

- pre-cast box elements would form a flexible structure allowing for some mitigation of the differential settlements along the culvert,
- depth of excavation and groundwater control requirements will be less than that required for an open-footing concrete culvert,
- pre-cast box culvert can be installed relatively quickly, allowing for shorter duration of the culvert construction.

Details of the proposed culvert replacement were unavailable during writing of this report. The comments on the culvert replacement design are provided for planning purposes. The Design Builder is solely responsible for selecting the appropriate foundation alternatives for replacement of the structure and detailed design of the structure.

8.3 Pipe Culvert

Installation of a pipe culvert, including concrete pipe, CSP (circular or arch), or HDPE pipes could be considered for this site.

The native stiff to very stiff clayey silt to silty clay at or below Elev. 194.0 is considered to be an adequate founding stratum to support a pipe culvert. If the founding surface is not disturbed and groundwater/surface water is controlled during construction, sufficient bearing capacities can be obtained to install the culvert.

Base on the characteristics of the founding soils, the following bearing capacities can be used in design of a pipe culvert:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Reaction at SLS (less than 25 mm settlement) of 130 kPa.

The geotechnical reaction at SLS assumes the diameter of the culvert of 3 m.

A minimum thickness of 300 mm of granular bedding material conforming to OPSS 1010 Granular A or B Type II should be placed under the base of the pipe culvert. Following inspection and subgrade approval, the bedding material should be placed as soon as practical on the approved subgrade for protecting the subgrade from disturbance during construction.

Preparation of the subgrade has been addressed in Sec. 8.7 of this report.

8.4 Box Culvert

Installation of a precast concrete box culvert is considered feasible at this site. Based on the factual data, the concrete box culvert could be founded at or below Elevation 194.0. The current preliminary investigation shows the presence of soft clayey silt/silty clay below the embankment fill on the north (downstream) end of the existing culvert. Any soft soils encountered at the base of excavation should be removed and replaced by granular material conforming to OPSS 1010 Granular A or B type II.

A minimum thickness of 300 mm of granular bedding material conforming to OPSS 1010 Granular A or B Type II material should be provided under the base of the box culvert as per OPSD 803.010. The bedding material should be placed on the approved subgrade as soon as practicable for protecting the subgrade from disturbance during construction following subgrade inspection and approval. Construction equipment should not be allowed to travel on the bedding material or the prepared subgrade.

Groundwater and creek/surface water control/diversion will be required for excavation and construction of the culvert replacement.

The geotechnical resistance at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS) for the above founding elevation, assuming 3 m wide culvert, could be used as follows:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Reaction at SLS (less than 25 mm settlement) of 130 kPa

The geotechnical resistance and reaction provided above are based on loading applied perpendicular to the footings. Appropriate inclination should be taken into account conforming to the Canadian Highway Bridge Design Code (CHBDC) where the load is not applied perpendicular to the surface of the footing.

Resistance to lateral forces/sliding between precast concrete and the underlying bedding material should be evaluated in accordance with Section 6.7.2 of the CHBDC assuming an ultimate/unfactored coefficient of friction of 0.4.

The box culvert should be designed to resist external loadings including lateral earth pressure, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment and activities.

8.5 Open Footing Culvert

Strip footings for an open footing culvert replacement could be founded at a minimum depth of 1.6 m below the lowest surrounding ground surface to ensure adequate protection against frost penetration, as per OPSD 3090.101. Furthermore, the footings should extend below any existing embankment fill and surficial organic materials, where encountered.

Based on the factual data, the current preliminary investigation indicate on the presence of soft clayey silt/silty clay below the embankment fill on the north (downstream) end of the existing culvert. The strip footing should be founded at or below Elevation 194.0 m on the undisturbed, very stiff clayey silt/silty clay deposit.

To protect the subgrade from degradation and loosening from exposure to water and construction traffic, a 100 mm thick concrete working slab should be placed on the inspected and approved footing subgrade.

Groundwater control and creek/surface water diversion will be required for excavation and construction of the open footing culvert replacement.

The geotechnical resistance at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS) for the above noted founding elevation and 1 m in width footing could be used as follows:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Reaction at SLS (less than 25 mm settlement) of 130 kPa

The geotechnical resistance and reaction provided above are based on loading applied perpendicular to the footings. Appropriate inclination should be taken into account conforming to the CHBDC where the load is not applied perpendicular to the surface of the footing.

Resistance to lateral forces/sliding between precast concrete and the underlying Granular A bedding material should be evaluated in accordance with the CHBDC assuming an ultimate/unfactored coefficient of friction of 0.5.

8.6 Settlement

It is understood that there is no grade raise at this site and that the culvert will be replaced along the same alignment as the existing culvert. As no substantial additional loads are anticipated at the proposed culvert replacement, the settlement of the foundation soils is estimated to be less than 25 mm based on the preliminary investigation.

8.7 Subgrade Preparation

After completion of excavation for the new culvert, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, organics, soft creek bed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint should be further sub-excavated to undisturbed, competent native soils. The sub-excavated area should be replaced with well compacted granular fill consisting of OPSS 1010 Granular A or B Type II material, as soon as practical.

The contract should contain an Operational Constraint advising the Contractor to protect the subgrade from disturbance and degradation at all times. This includes, though is not limited to disturbance from traffic, equipment operation and exposure to the weather. The

Contractor is not permitted to operate equipment on the exposed subgrade. If protection of the subgrade is required prior to placing the bedding, consideration could be given to methods such as a concrete mud slab. All works should be carried out in accordance with OPSS 902.

9 BACKFILL AND LATERAL EARTH PRESSURES

For a box culvert replacement, reference should be made to the backfill arrangements stipulated in OPSS 422 for pre-cast rigid frame culverts. Backfill for a concrete rigid frame culvert should be completed in accordance with OPSD 803.010, and for the pipe culvert in accordance with OPSD 803.06.

All fills should be placed in regular lifts and be compacted in accordance with OPSS 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of the backfill elevation should be similar on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roofs of the culvert.

Earth pressures acting on the culvert walls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC but are generally given by the expression:

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

Where

p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see table below)

γ = bulk unit weight of retained soil (see table below)

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

q = value of any surcharge (kPa)

If full drainage is not achievable, the culvert walls should be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design creek water level/high water level.

Earth pressure coefficients for backfill are dependent on the material used as backfill. Unfactored values shown below in Table 9-1 could be used for design. The factors are “ultimate” values and require certain movements for the respective conditions to mobilize. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC.

Table 9-1. Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II ϕ = 35°; γ = 22.8 kN/m^3		OPSS Granular B Type I Or Granular B Type III ϕ = 32°; γ = 21.2 kN/m^3		Embankment Fill ϕ = 30°; γ = 20.0 kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.70	-	3.30	-	3.00	-

Note: Submerged unit weight should be used below the groundwater level.

For rigid structures, such as a concrete box culvert, at-rest horizontal earth pressures could be used for design.

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I, or at a depth of 1.7 m for Granular A or B Type II.

10 EMBANKMENT RESTORATION

Embankment restoration after culvert replacement, should be carried out in accordance with OPSS 206. The embankment fill should consist of imported Granular A or B Type II material. Excavated granular fill may also be reused as backfill provided the following conditions are satisfied:

- There is sufficient space to stockpile on site and control moisture content within acceptable limits for compaction
- No peat or organic materials are included in the fill
- Gradation and compaction characteristics meet the requirements prior to reuse as backfill.

Where applicable, benching the existing slope surface should be carried out to allow for better interaction between the existing and new fill/backfill. Provided that the subgrade is prepared as outlined in Section 8.6 and granular fill is placed as indicated in Section 9, it is anticipated that an embankment slope inclination of 2H : 1V, or flatter, should remain stable.

11 EROSION CONTROL

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

Typically, rip-rap should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the outlets should be in accordance with 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 804.

A clay seal or a concrete cut-off wall could be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205. A geosynthetic clay liner may be used as a clay seal.

12 EXCAVATION AND GROUNDWATER CONTROL

12.1 General

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native clayey silt at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level.

12.2 Excavations

The excavation for the culvert replacement will be carried out through the existing embankment fill and extend into the underlying native clayey silt/silty clay. At locations where there is space restriction or where a slope has to be retained, the excavation will need to be carried out in conjunction with a protection system. Any protection system should be designed by a licensed Professional Engineer experienced in such designs. OPSS 539 “Construction Specifications for Protection Systems” will have to be included in the contract documents.

12.3 Groundwater Control

It is expected that groundwater and surface water will accumulate in the excavation during culvert construction. The groundwater level is expected to be largely governed by the water level in the creek and seasonal weather patterns. The Contractor should make provisions to control any creek water, groundwater seepage, surface runoff and ponding by measures including creek diversion and protection systems such as sheetpiled enclosures, cofferdams, the use of sump pumps, etc., to maintain dry excavations during the course of construction. All dewatering operations should be conducted in accordance with OPSS 518.

13 ROADWAY PROTECTION DESIGN

Roadway protection will be required during various stages of construction. The design of roadway protection should be the responsibility of the Contractor and all protection systems should be designed by a Professional Engineer experienced in such designs.

The roadway protection should be designed for Performance Level 2 (maximum 25 mm horizontal deflection).

14 CLOSURE

Engineering analysis and preparation of the report was carried out by Anna Piascik, P.Eng.

The report was reviewed by Mr. Alastair Gorman, P.Eng and Dr. P.K. Chatterji, P.Eng. who is a Designated Principal Contact for MTO Foundations Projects.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT[(1)] 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

- SS Split Spoon Sample
- WS Wash Sample
- AS Auger (Grab) Sample
- TW Thin Wall Shelby Tube Sample
- TP Thin Wall Piston Sample
- PH Sampler Advanced by Hydraulic Pressure
- PM Sampler Advanced by Manual Pressure
- WH Sampler Advanced by Self Static Weight
- RC Rock Core
- SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value — Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT — Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
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 structure are preserved.

DISCONTINUITY SPACING

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

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	(psi)	Field Estimation of Hardness*
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

<u>UNIFIED SOILS CLASSIFICATION</u>

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	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	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and 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. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No 14-02

METRIC

W.P.	4013-13-01	LOCATION	Site 21-498/C, Hwy 7A N 4 896 436.0 E 388 425.7	ORIGINATED BY	SDP
HWY	7A	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.12.02 - 2014.12.02	CHECKED BY	MW

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
198.6	GROUND SURFACE								
0.0	Gravelly **SAND**, some silt, trace organics (topsoil) in top layer Compact Brown Moist (FILL)	1	SS	25					
		2	SS	14					
		3	SS	10		22	56	22 (SI+CL)	
		4	SS	10	▽				
		5	SS	27					
194.5 / 4.1	Clayey **SILT** to Silty **CLAY**, trace sand, trace gravel Very Stiff Grey Moist	6	SS	16		0	0	73	27
		7	SS	22					
191.4 / 7.2	Clayey **SILT** and **SAND**, some gravel Very Dense Grey Moist (TILL)	8	SS	81		12	44	31	13
189.4 / 9.2	END OF BOREHOLE AT 9.2m UPON REFUSAL. WATER LEVEL IN OPEN BOREHOLE AT 2.9m DEPTH ON COMPLETION OF DRILLING.	9	SS	50/ 0.025					

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; ELEVATION SCALE (198, 197, 196, 195, 194, 193, 192, 191, 190); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m3

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 14-02

METRIC

W.P. 4013-13-01 | LOCATION Site 21-498/C, Hwy 7A N 4 896 436.0 E 388 425.7 | ORIGINATED BY SDP

HWY 7A | BOREHOLE TYPE Solid Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2014.12.02 - 2014.12.02 | CHECKED BY MW

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.2m, THEN SAND FILL TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 14-03

METRIC

W.P.	4013-13-01	LOCATION	Site 21-498/C, Hwy 7A N 4 896 438.4 E 388 433.7	ORIGINATED BY	SDP
HWY	7A	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.12.02 - 2014.12.02	CHECKED BY	MW

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
198.8	GROUND SURFACE									
0.0	Silty **SAND**, some gravel, trace clay Compact to Dense Brown Moist (FILL)		1	SS	32					
			2	SS	18		11	64	25 (SI+CL)	
			3	SS	12					
			4	SS	10	∇				
			5	SS	17		13	55	24	8
	Trace organics (topsoil)									
194.7 4.1	Clayey **SILT**, trace gravel, trace sand Very Stiff Grey Moist									
			6	SS	18					
			7	SS	19		5	7	72	16
191.6 7.2	Clayey **SILT** and **SAND**, trace gravel Hard Grey Wet (TILL)									
			8	SS	100/ 0.250		3	45	32	20
			9	SS	100					
189.1 9.7	END OF BOREHOLE AT 9.7m UPON AUGER REFUSAL.									

ELEVATION SCALE: 198, 197, 196, 195, 194, 193, 192, 191, 190

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m3

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-03

METRIC

W.P.	4013-13-01	LOCATION	Site 21-498/C, Hwy 7A N 4 896 438.4 E 388 433.7	ORIGINATED BY	SDP
HWY	7A	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.12.02 - 2014.12.02	CHECKED BY	MW

SOIL PROFILE: ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	WATER LEVEL IN OPEN BOREHOLE AT 2.9m DEPTH ON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.2m, THEN SAND FILL TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-04

METRIC

W.P. 4013-13-01
LOCATION Site 21-498/C, Hwy 7A N 4 896 454.7 E 388 443.6
ORIGINATED BY SDP
HWY 7A
BOREHOLE TYPE Solid Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2014.12.03 - 2014.12.03
CHECKED BY MW

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
198.3	GROUND SURFACE						
0.0	Silty **SAND**, trace gravel, Loose to Compact, Brown, Moist (FILL)	1	SS	23			
		2	SS	9			9 51 40 (SI+CL)
		3	SS	6			
196.1 / 2.2	Clayey **SILT**, some sand, Soft to Very Stiff, Brown to Grey, Wet	4	SS	3	∇ (approx. El. 196.0)		
		5	SS	16			
		6	SS	11			0 11 72 17
		7	SS	34			
190.7 / 7.6	Clayey **SILT** and **SAND**, trace gravel, Hard, Grey, Moist (TILL)	8	SS	84			
		9	SS	77/0.275		Wp–WL range shown	5 43 32 20
188.6 / 9.7	END OF BOREHOLE AT 9.7m UPON						

Elevation scale: 198, 197, 196, 195, 194, 193, 192, 191, 190, 189

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 14-04

METRIC

W.P.	4013-13-01	LOCATION	Site 21-498/C, Hwy 7A N 4 896 454.7 E 388 443.6	ORIGINATED BY	SDP
HWY	7A	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.12.03 - 2014.12.03	CHECKED BY	MW

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	AUGER REFUSAL. WATER LEVEL IN OPEN BOREHOLE AT 2.3m DEPTH ON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.2m, THEN SAND FILL TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-05

METRIC

W.P. 4013-13-01 | LOCATION Site 21-498/C, Hwy 7A N 4 896 450.7 E 388 443.6 | ORIGINATED BY SDP

HWY 7A | BOREHOLE TYPE Solid Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2014.12.03 - 2014.12.03 | CHECKED BY MW

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
198.1	GROUND SURFACE						
0.0	**SAND**, some silt, some gravel Loose to Dense Brown Moist (FILL)	1	SS	30	198	~5	
		2	SS	24	197	~10	17 59 24 (SI+CL)
		3	SS	5	196	~20	
195.8 2.3	Clayey **SILT** to Silty **CLAY**, some sand, trace gravel Soft to Very Stiff Black to Grey Wet	4	SS	3	195	~37	2 21 50 27
		5	SS	3	194	~21	
	Trace sand	6	SS	16	193	~16	
	Trace gravel	7	SS	24	192, 191	~16 (wP ~28, wL ~40)	0 6 75 19
190.3	Trace cobbles	8	SS	50/0.050		~17	
7.8	END OF BOREHOLE AT 7.8m UPON AUGER REFUSAL ON PROBABLE BEDROCK. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.						

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Dec 04/14	2.3	195.8
Dec 14/14	2.0	196.1

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT wP, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wL; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m3

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-08

METRIC

W.P. 4013-13-01 LOCATION Site 21-498/C, Hwy 7A N 4 896 465.7 E 388 446.5 ORIGINATED BY SDP

HWY 7A BOREHOLE TYPE Hand Auger COMPILED BY AN

DATUM Geodetic DATE 2014.12.12 - 2014.12.18 CHECKED BY MW

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
197.1	GROUND SURFACE										
0.0	Silty **CLAY**, trace sand, trace gravel, trace organics (amorphous) Brown to Black Moist						197				
			1	AS							
							196				
			2	AS							
195.1 / 2.0	END OF BOREHOLE AT 2.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

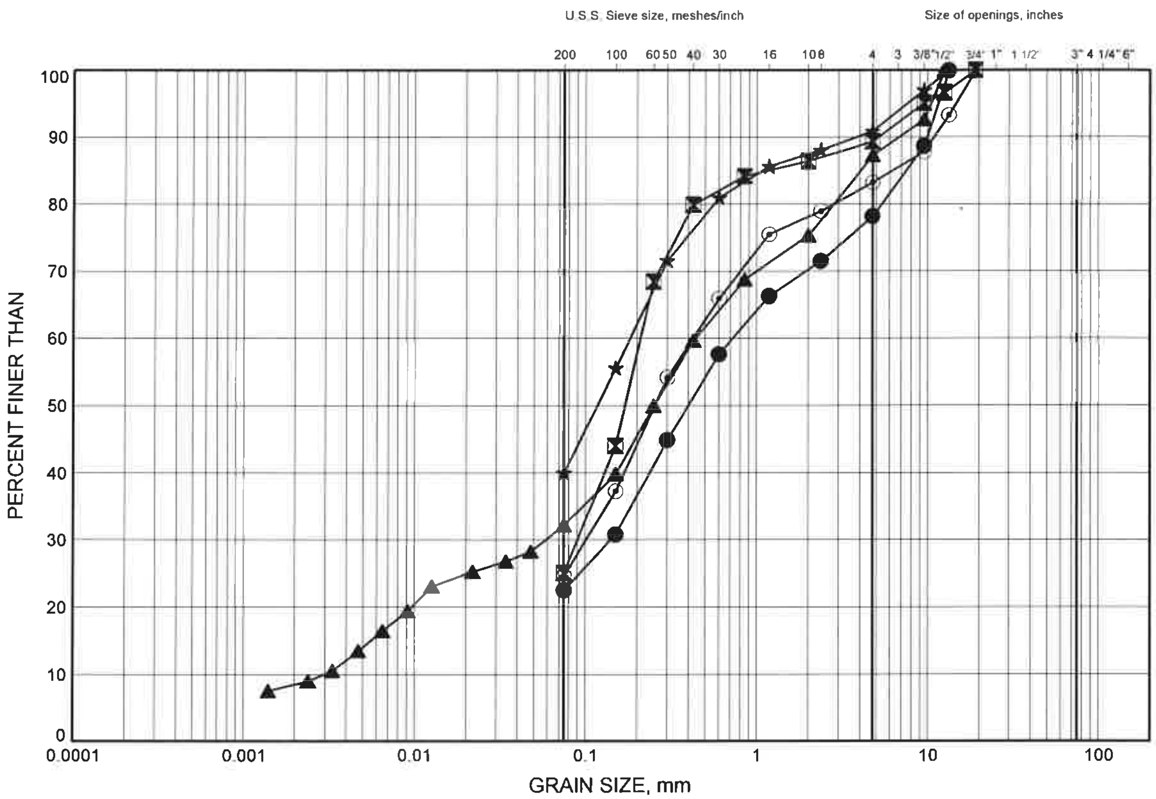
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION	FIGURE B1

SILTY SAND to GRAVELLY SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-02	1.83	196.77
⊠	14-03	1.07	197.73
▲	14-03	3.35	195.45
★	14-04	1.07	197.23
⊙	14-05	1.07	197.03

Date April 2015

W.P. 4013-13-01

THURBER

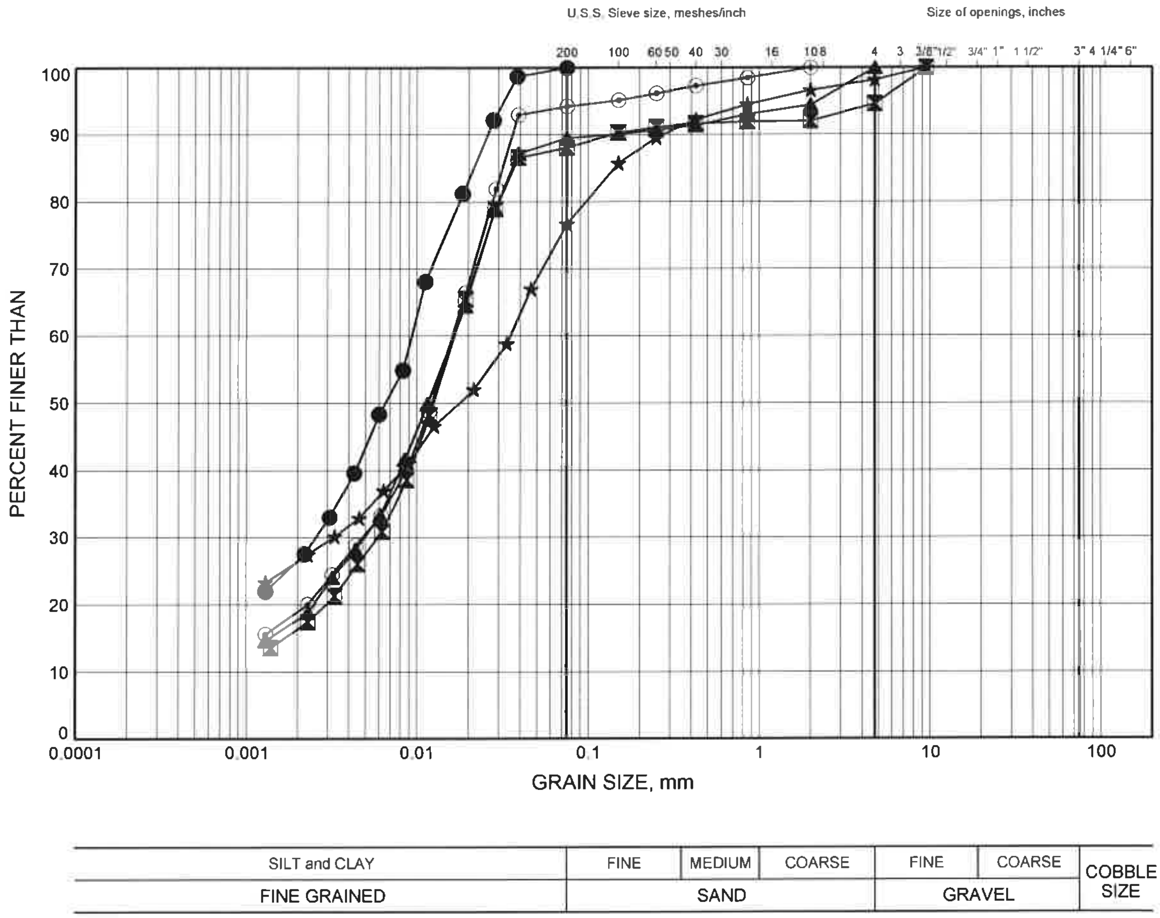
Prep'd AN

Chkd. AMP

GRAIN SIZE DISTRIBUTION

FIGURE B2

CLAYEY SILT to SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-02	4.88	193.72
⊠	14-03	6.40	192.40
▲	14-04	4.88	193.42
★	14-05	2.59	195.51
⊙	14-05	6.40	191.70

Date April 2015

W.P. 4013-13-01

THURBER

Prep'd AN

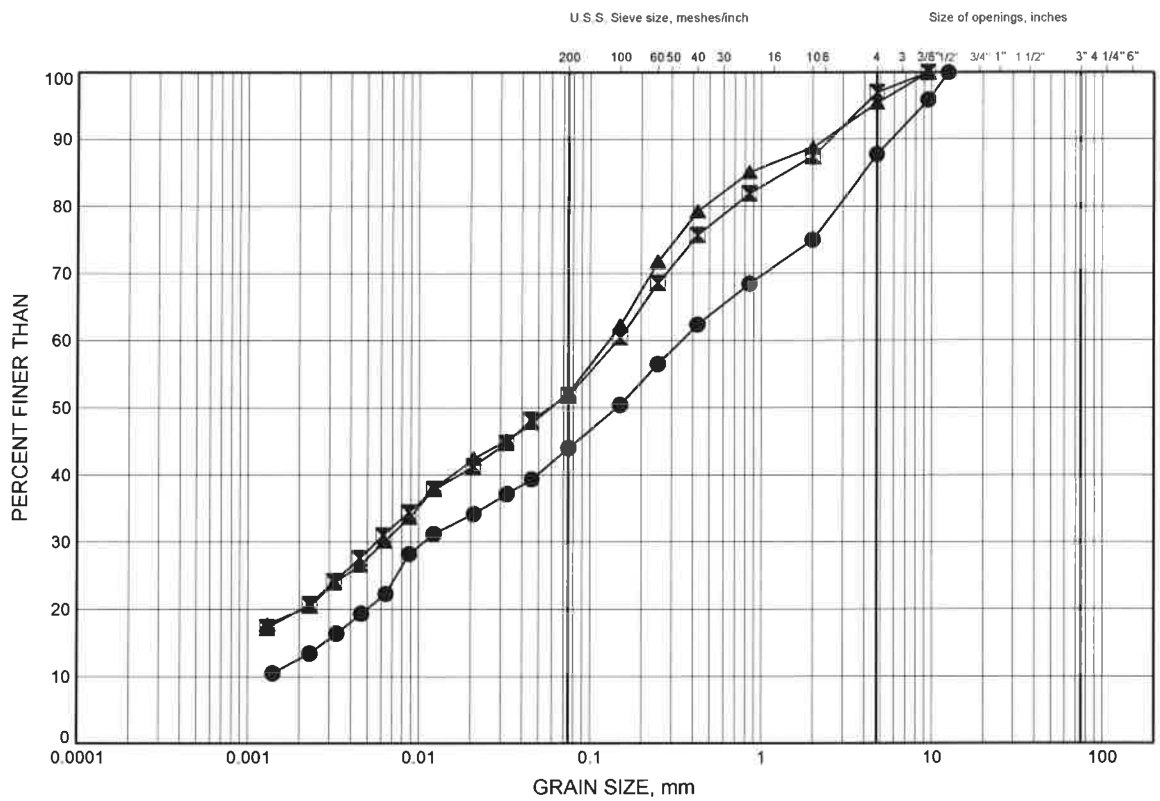
Chkd. AMP

GRAIN SIZE DISTRIBUTION - THURBER 0620.GPJ 4/13/15

GRAIN SIZE DISTRIBUTION

FIGURE B3

CLAYEY SILT & SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-02	7.92	190.68
⧗	14-03	7.92	190.88
▲	14-04	9.44	188.86

GRAIN SIZE DISTRIBUTION - THURBER 0620 GPJ 4/13/15

Date April 2015

W.P. 4013-13-01

THURBER

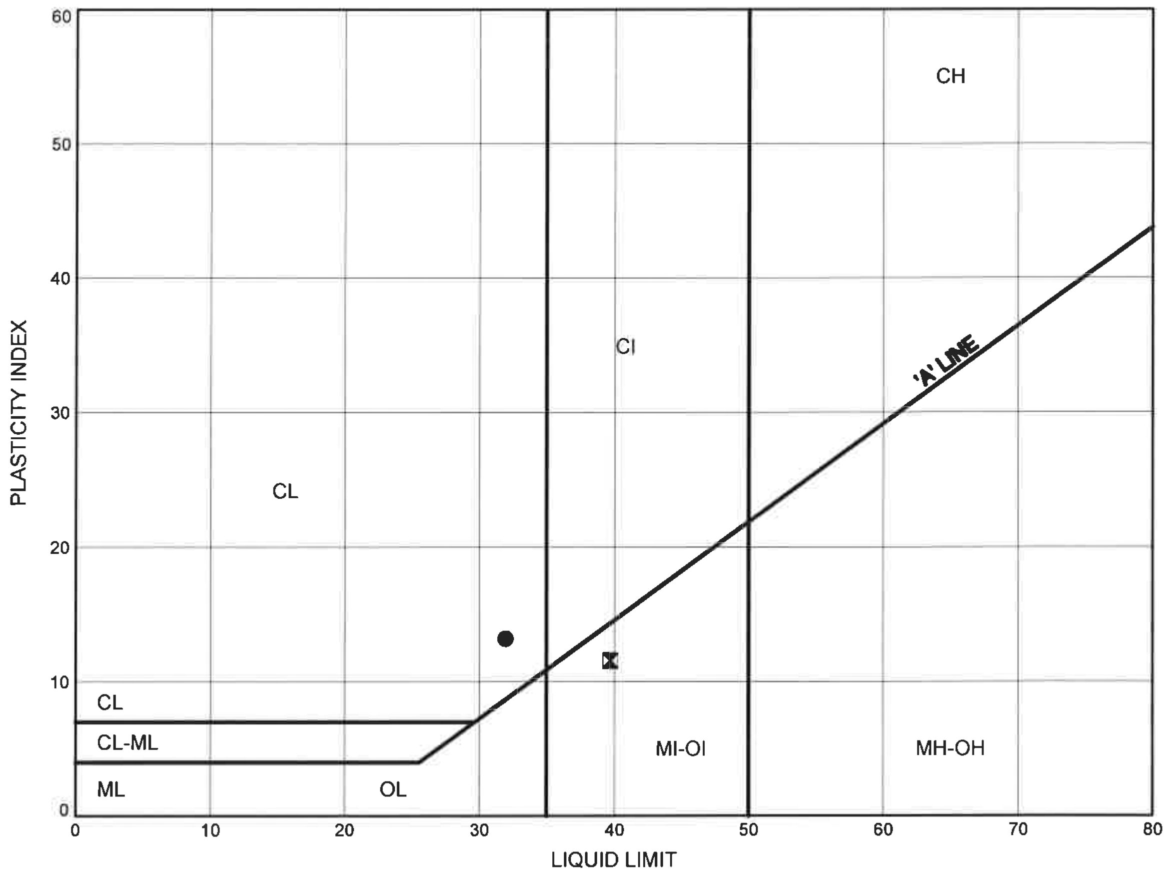
Prep'd AN

Chkd. AMP

ATTERBERG LIMITS TEST RESULTS

FIGURE B4

CLAYEY SILT to SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-02	4.88	193.72
⧗	14-05	6.40	191.70

THURBALT 0620.GPJ 4/13/15

Date April 2015
W.P. 4013-13-01

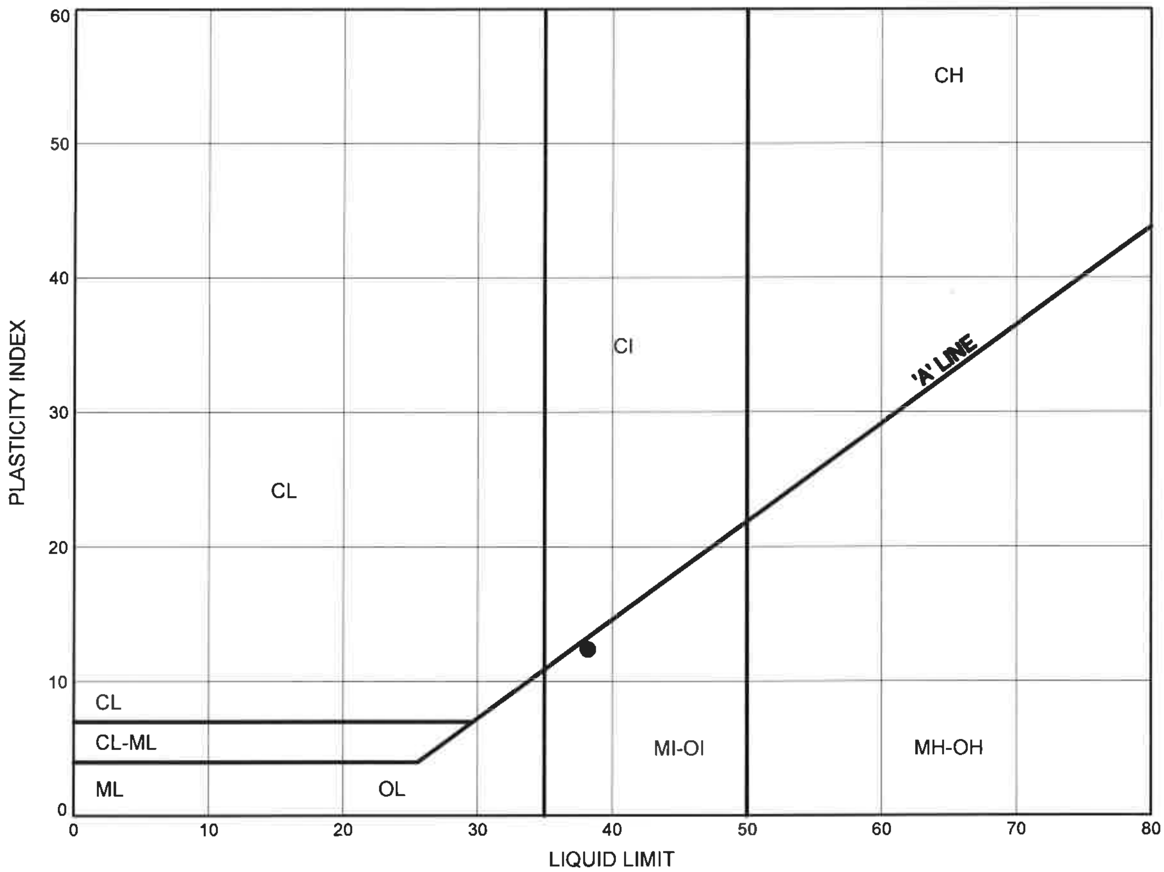
THURBER

Prep'd AN
Chkd. AMP

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

CLAYEY SILT & SAND TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-04	9.44	188.86

THURBALT 0620.GPJ 4/13/15

Date April 2015

W.P. 4013-13-01

THURBER

Prep'd AN

Chkd. AMP

Appendix C

Site Photographs

Photograph 1- North side of the culvert

Photograph 2 – South side of the culvert

Appendix D

Borehole Locations Drawing

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

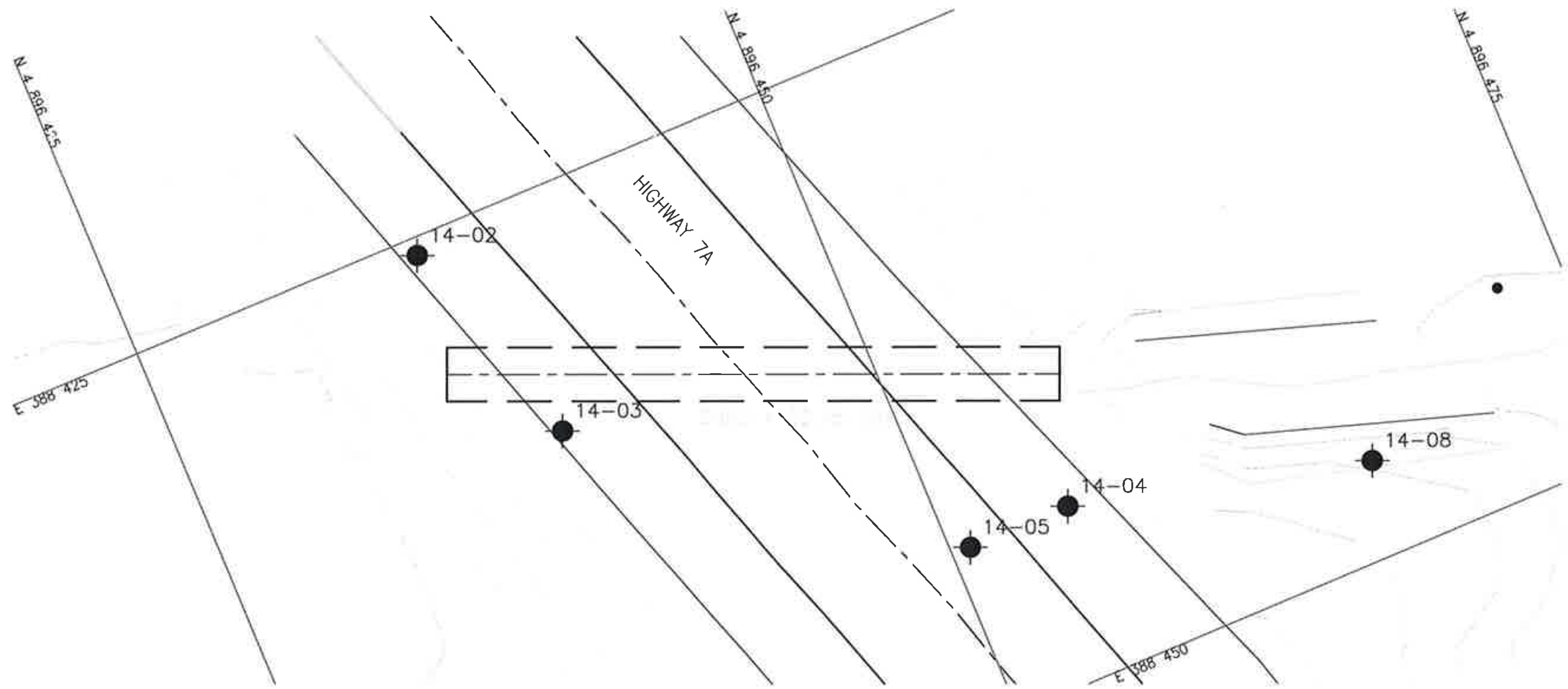
CONT No
WP No 4013-13-01

SHEET

HIGHWAY 7A
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

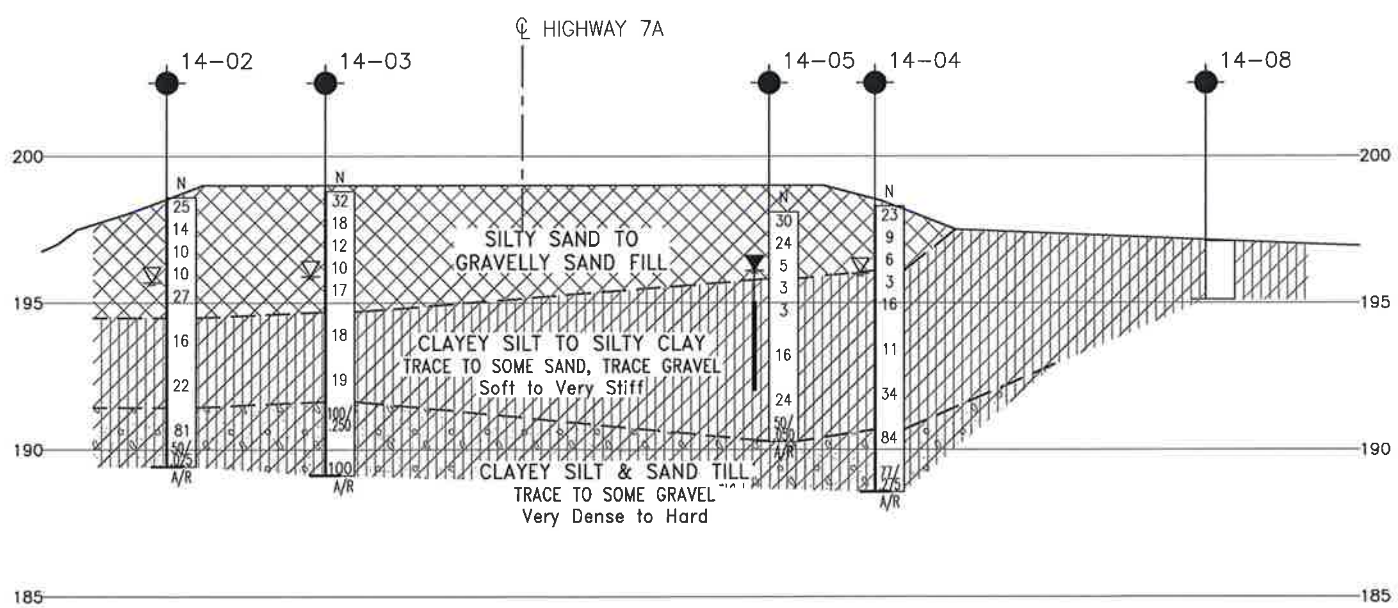
AECOM

THURBER ENGINEERING LTD.



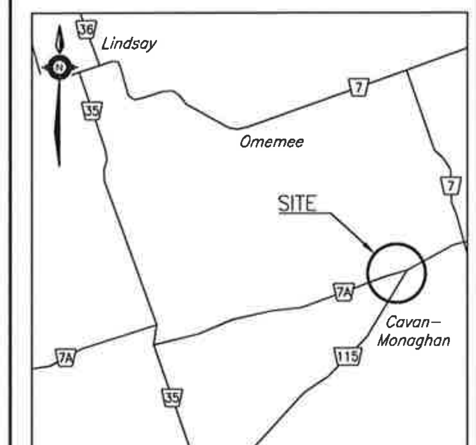
PLAN

SCALE 1:250



PROFILE ALONG ℄ OF CULVERT

SCALE 1:250



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
14-02	198.6	4 896 436.0	388 425.7
14-03	198.8	4 896 438.4	388 433.7
14-04	198.3	4 896 454.7	388 443.6
14-05	198.1	4 896 450.7	388 443.6
14-08	197.1	4 896 465.7	388 446.5

LICENSED PROFESSIONAL ENGINEER
A. PIASCIK
Sep. 23/15
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Sep 23/15
PROVINCE OF ONTARIO

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 31D-614

REVISIONS	DATE	BY	DESCRIPTION

DESIGN AEG	CHK ULVE	CODE	LOAD	DATE SEP 2015
DRAWN MFA	CHK AEG	SITE 21-498/C	STRUCT	DWG 1

FILENAME: H:\Drafting\19\4406\20\ted0620-Plan&Profile(Highway7A).dwg
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Appendix E

Comparison of Culvert Foundation Alternatives

COMPARISON OF CULVERT FOUNDATION ALTERNATIVES

Circular Pipe Culvert - Concrete	**Circular Pipe Culvert - CSP or HDPE**	**Concrete Rigid Box Culvert**	**Concrete Open Footing Culvert**
Advantages: i. Relatively simple installation/construction ii. Lower cost than a concrete rigid frame culvert	***Advantages:*** i. Relatively simple installation/construction ii. Can tolerate larger magnitude of settlement than a concrete pipe or rigid frame culvert iii. Lower cost than a concrete pipe or rigid frame culvert	***Advantages:*** i. Relatively expedient installation if precast units are used ii. Minimizes depth of excavation and duration of construction/dewatering iii. Can tolerate larger magnitude of differential settlements than open footing culvert, if precast units are used iv. Smaller magnitude of settlement than an open footing culvert due to lower bearing stress on subgrade	***Advantages:*** i. Relatively expedient installation if precast units used ii. Would satisfy fisheries requirements
Disadvantages: i. Feasibility depends on flow capacity and other hydraulic properties ii. May require deeper excavation than for box culvert	***Disadvantages:*** i. Feasibility depends on flow capacity and other hydraulic properties ii. CSP and HDPE pipes not as durable as a concrete culvert iii. May require deeper excavation than for box culvert	***Disadvantages:*** i. Requires dewatering and compacted granular bedding on subgrade ii. Some risk of disturbance of the founding stratum during construction.	***Disadvantages:*** i. Greater risk of disturbance of the founding stratum during construction than for box culvert. ii. May require longer construction duration. iii. Potential for more elaborate dewatering system than for the box culvert.
FEASIBLE	**FEASIBLE**	**PREFERRED**	**FEASIBLE**