THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT, 22+283 HAVILLAND
HIGHWAY 17 NEAR GOULAIS RIVER
SAULT STE MARIE AREA
G.W.P. 545-00-00

GEOCRES Number: 41K-98

Report

to

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THURBER

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for replacement of a culvert under Highway 17 near Goulais River, Ontario.

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

The purpose of this investigation was to obtain subsurface information at the site and, based on the data obtained, to provide a model of the subsurface conditions including a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results and a written description of the subsurface conditions.

Thurber was retained by WSP Canada Inc. (WSP) to carry out this foundation investigation under MTO Agreement Number 5014-E-0008.

2 SITE DESCRIPTION

The culvert site is located on Highway 17, approximately 7.1 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Havilland. A 1.05 m diameter by 61.7 m long corrugated steel pipe culvert (CSP) is present at the site and covered with approximately 10 m of fill. The culvert conveys water from west to east, towards the nearby Stokely Creek. The invert elevation is 239.2 m at the east end and 245.7 m at the west end.

The grade of the existing Highway 17 in the vicinity of the culvert is at 253.8 m geodetic. The culvert is located within a fill section The embankment is constructed with side slopes approximately 1.9 horizontal to 1 vertical (1.9H:1V) and 1.8 horizontal to 1 vertical (1.8H:1V), corresponding to the east and west slopes respectively. The embankment fill height is approximately 12.6 m at the east side and approximately 9.9 m at the west side.

The existing roadway cross-section includes three 3.5 m wide lanes (two lanes in the southbound direction), a 2.2 m wide northbound paved shoulder, a 1.0 m wide southbound paved shoulder and 0.5 m rounding on both sides. Three cable guide rail is present on the northbound side of the highway. The AADT is reported to be 2650. The highway profile slopes down to the north at approximately 5.1%. Although the site is in a tangent section a curve begins less than 200 m to the south.

The site is located in a rural area with forests, swamps, creeks. The local topography is rolling with undulating hills and valleys. Selected photographs of the culvert site are attached in Appendix D.

The surficial geology of the area is typical of the Wisconsin glaciation. Soil cover consists primarily of glaciolacustrine (clay, silt, and sand) deposits underlain by glacial till.

3 SITE INVESTIGATION AND FIELD TESTING

This borehole investigation and field testing program was carried out between January 24 and 28, 2016. The program consisted of drilling and sampling four boreholes (numbered 15-17, 15-18, 15-19, and 15-20) to depths ranging from 2.6 to 21.9 m. Of these boreholes, one was located near the culvert inlet (15-20), one located near the culvert outlet (15-17), and two (15-18 and 15-19) were located through the embankment on opposite sides of the road near the culvert.

Prior to the start of drilling, the borehole locations were established in the field and utility clearances were obtained. The co-ordinates and elevations of the as-drilled boreholes were subsequently determined by Thurber based on elevation data provided by WSP.

A truck-mounted drill rig equipped with hollow stem augers was used to drill and sample the boreholes on the roadway, and a portable tripod drill rig was used to drill and sample the culvert inlet and outlet boreholes. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). In-situ shear vane testing was performed in cohesive soils with an MTO N-sized vane.

Results of the field drilling and sampling are presented on the Record of Borehole sheets in Appendix B.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the recovered soil samples in labelled containers, and transported the samples to Thurber's laboratory for further examination and testing.

The boreholes were backfilled with soil cuttings mixed with bentonite and topped to surface with the existing granular material or where required with asphalt patch.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification and to Natural Moisture Content determination. Selected soil samples were subjected to Grain Size Distribution analyses (sieve and hydrometer) and Atterberg Limit testing. The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix B and on the Figures in Appendix C.

One soil sample was submitted to Paracel Laboratories Ltd. (Ottawa) for analysis of pH, resistivity, and soluble sulphate and chloride. The results of the chemical testing can be found in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the culvert replacement alignment is presented on the Borehole Locations and Soil Strata Drawing in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the record of boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes consist of granular embankment fill overlying clay and sandy silt layers underlain by silty sand with gravel till. Bedrock was not encountered in any of the four boreholes. More detailed descriptions of the individual strata are presented below.

5.2 Sand with Gravel Fill

A layer of asphalt 80 mm in thickness was encountered at ground surface in Borehole 15-19 which was drilled through the paved shoulder of the roadway.

Sand fill with gravel extended to a depth of 0.9 m and 2.3 m below surface (elevations 251.1 m and 253.2 m) in Boreholes 15-19 and 15-18 respectively.

The moisture content of the granular fill ranged from 3% to 13%. The ground was frozen at the time of the field investigation thus the relative density of this layer could not be determined reliably.

5.3 Silty Sand Embankment Fill

Silty sand fill was encountered below the sand with gravel fill in Boreholes 15-18 and 15-19. The thickness of the silty sand fill ranged from 7.6 m to 11.7 m. The base of the silty sand fill was encountered at elevations ranging of 241.5 m and 243.5 m.

The embankment fill was observed to be silty sand to sand with silt some gravel including occasional cobbles, while the lower portion in Borehole 15-18 was a mixture of silt, sand and clay which was cohesive in nature.

Silty sand fill was also noted in the inlet and outlet boreholes with a thickness of 1.2 m and 1.8 m and a base elevation of 238.9 m and 245.5 m.

The SPT N-value for the silty sand embankment fill ranged from 7 to 33 blows per 0.3 m penetration, indicating a loose to dense state. The SPT N-value for the silty sand fill found at the inlet and outlet ranged from 2 to 7 blows per 0.3m, indicating a very loose to loose state. The water contents of the recovered silty sand embankment fill samples ranged between 10% and 22%. The colour of the silty sand fill is brown.

The SPT N-value for the silty, sandy clay fill in Borehole 15-18 ranged from 3 to 7 blows per 0.3 m penetration, indicating firm state. The water content of the silty, sandy clay fill samples ranged between 33% and 46%. The colour of the silty, sandy clay fill is reddish brown.

The results of grain size analyses conducted on five samples of the embankment fill are presented on Fig. No 1 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Silty Sand Fill	
Gravel	1 to 4
Sand	52 to 91
Silt and Clay	8 to 46
Silty, Sandy Clay Fill	
Gravel	0
Sand	42
Silt	31
Clay	27

Atterberg limit testing was carried out on one sample of the silty, sandy clay fill. The liquid limit was 33% and the plasticity index was 21%. The sample can be classified as clay of low plasticity (CL). The results are presented on Fig. No 6 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	12
Liquid Limit	33
Plasticity Index	21

5.4 Topsoil

Topsoil 25 mm in thickness, was encountered in one borehole (15-20) drilled at the inlet. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating quantities or quality.

A sandy silt fill with organics was observed over the fill in Borehole 15-17. It was 300 mm thick and had a moisture content of 21%.

5.5 Sand with Silt and Gravel

A native soil deposit likely the original creek bed ranging from sand with silt and gravel to gravel with silt and sand was encountered in three boreholes (Boreholes 15-17, 15-19, and 15-20). This soil was found just below the embankment fill. This layer, where encountered was observed to range from 1.1 m to 1.5 m in thickness with base elevation ranging from 237.5 m to 244.4 m. The upper portion of this deposit in Borehole 15-19 contained wood. This layer contained occasional to frequent cobbles.

The SPT N-value for this deposit was 6 to greater than 100 blows per 0.3 m penetration, indicating a loose to very dense state. The high N-values are likely due to the presence of cobbles within this layer. The water contents of the recovered samples typically ranged between 8% and 17%, although one sample containing wood returned a moisture content of 43%. The colour of this deposit is brown.

Grain size analyses conducted on three samples of the soil are presented on Fig. No 2 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	28 to 53
Sand	37 to 64
Silt and Clay	7 to 10

5.6 Clay (CH) to Silty Clay

A native clay deposit was encountered in two boreholes (15-18 and 15-19). In Borehole 15-18 the clay was of high plasticity, while the soil in Borehole 15-19 was a silty clay. This soil was found just below the embankment fill in Borehole 15-18 and below the silty sand and gravel in Borehole 15-19. This layer was observed to range from 4.7 m to 5.4 m in thickness with the elevation of the base of the unit ranging from 236.6 m to 236.8 m.

The SPT N-values for the clay of high plasticity ranged from 3 to 4 blows per 0.3 m penetration. In-situ shear vane test results indicated undrained shear strengths ranging from 64 kPa to 90 kPa; indicating a stiff consistency. The water content of the clay of high plasticity ranged between 34% and 66%. The colour of this material is reddish brown.

The SPT N-values measured within the silty clay ranged from 12 to 39 blows per 0.3 m penetration, indicating a stiff to very stiff consistency. The moisture content of the silty clay samples ranged from 13% to 24%. The colour of this material was brown to reddish brown.

Grain size analyses conducted on two samples of the soil are presented on Fig. No 3 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Clay (CH)	
Gravel	0
Sand	7
Silt	24
Clay	69
Silty Clay	
Gravel	0
Sand	6
Silt	81
Clay	13

Atterberg limit testing was carried out on a sample of each clay type.

The clay in Borehole 15-18 had a liquid limit was 72% and the plasticity index was 50%. The sample can be classified as clay of high plasticity (CH).

The silty clay in Borehole 15-19 had a liquid limit was 23% and the plasticity index was 6%. The sample can be classified as silty clay to clayey silt (CL-ML).

The results are presented on Fig. No 6 in Appendix C and summarized in the table below.

	Clay (CH)	Silty Clay
Test	**%**	**%**
Plastic Limit	22	17
Liquid Limit	72	23
Plasticity Index	50	6

5.7 Silt

A deposit ranging from silt with sand to sandy silt with gravel was encountered below the clay in Boreholes 15-18 and 15-19. This layer was observed to range from 1.5 m to 2.0 m in thickness with the base elevation ranging from 235.3 m to 234.6 m. A similar material was observed in Borehole 15-20 to be 2.1 m thick and extending to elevation 242.3 m

SPT N-values measured within this silt material ranged from 26 to greater than 100 blows per 0.3 m penetration, indicating a compact to very dense state. The colour of this deposit was brown to brownish grey.

The moisture content of the samples tested ranged from 10% to 27%. Two samples of this deposit were subjected to gradation analysis. The results are summarized in the table below and presented on Fig. No 4 in Appendix C.

Soil Particles	%
Gravel	0 and 22
Sand	5 and 28
Silt	40 and 90
Clay	5 and 10

The material can be classified as silt (ML).

5.8 Silty Sand with Gravel (Till)

A silty sand with gravel till was encountered below the silt in 15-18 and 15-19. Both Borehole 15-18 and Borehole 15-19 were terminated within this layer at elevations of 233.8 m and 231.5 m and 3.1 m, respectively. The top elevation of the unit ranged from 235.3 m and to 234.6 m.

SPT N-values measured within this glacial till layer material ranged from 43 to greater than 100 blows per 0.3 m penetration, indicating a dense to very dense state. The colour of this deposit was brown.

The moisture content of the samples tested ranged from 6% to 12%. Two samples of this deposit were subjected to gradation analysis. The results are summarized in the table below and presented on Fig. No 5 in Appendix C.

Soil Particles	%
Gravel	17 and 22
Sand	35 and 57
Silt and Clay	48 and 21

5.9 Groundwater Conditions

Groundwater was not observed in any of the boreholes. However, Boreholes 15-18 and 15-20 exhibited cave at depths of 9.8 m and 1.5 m (elevations 244.3 m and 245.8 m), respectively upon completion of drilling. The water level in the culvert at the inlet was observed to be at elevation 245.9 m on January 27, 2016.

Where surface water is present, the groundwater level should be assumed to coincide with the local surface or creek water level. Local high water levels and the effects of heavy rainfalls will affect water levels.

6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling.

Marathon Drilling Ltd. of Greely, Ontario, supplied and operated a truck-mounted CME 55 drill rig to carry out the drilling, sampling and in-situ testing operations on the existing highway platform. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario, supplied and operated the portable drill rig.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Justin Gray E.I.T. and Mr. Chris Murray E.I.T. of Thurber. Laboratory testing was carried out by Stantec (Ottawa) in its MTO-approved laboratory.

Overall project management and direction of the field program was provided by Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Justin Gray E.I.T. and Dr. Fred Griffiths P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents a foundation assessment and evaluation of feasible methods for replacement of a culvert under Highway 17, approximately 7.1 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Havilland.

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 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.

A 1.05 m diameter by 61.7 m long corrugated steel pipe culvert (CSP) is present at the site. The stream at the site flows from west to east. The site is on a tangent section of the highway that slopes up at 5.1% to the south, a curve begins less than 200 m to the south. The existing roadway cross-section is approximately 14.7 m wide from rounding to rounding with three cable guide rail on the northbound side of the highway.

The borehole information indicates that the base of the embankment fill ranges from 238.9 m to 245.5 m. The majority of the excavation for a new culvert would therefore be within the fill which was observed to consist of compact silty sand over firm silty sandy clay fill. Occasional cobbles were noted in the fill. The native material observed immediately beneath the fill consisted of silty sand and stiff to very stiff clay to silty clay. Indications of groundwater were observed as high as elevation 245.8 m in Borehole 15-20 located near the culvert inlet. The water level in the culvert at the inlet was at elevation 245.9 m on January 27, 2016. The frozen water level just beyond the outlet was estimated to be at elevation 238.0 on January 24, 2016.

Frost depth at this site is 2.0 m.

This report presents an evaluation of the feasible methods for the replacement of the culvert. The discussions and recommendations presented in this report are based on information provided by WSP and on the factual data obtained during the course of this investigation.

8 CULVERT FOUNDATIONS

8.1 General

It was determined by WSP that installing a culvert liner is insufficient to meet project needs and the culvert will need to be replaced. The following sections address replacement of the existing culvert. During the design process it was assumed that the replacement culvert will be installed along the existing culvert alignment, however it was understood that it may be preferable to re-align the culvert to one side or the other to allow flow to continue through the existing culvert during construction of the replacement culvert as long as the old and new culvert are spaced at least one culvert diameter apart. It is noted that the existing culvert is considered a non-structural culvert.

8.2 Culvert Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides foundation recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below along with comments on feasibility from a foundations perspective.

Circular Pipes (Concrete, Steel, HDPE)

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible.

Concrete, Open Footing Culvert

Concrete open footing culverts are considered feasible but not geotechnically preferred due to the relatively deep excavation that will be required for footing construction and the associated need for dewatering.

Concrete Box (Closed) Culvert

Concrete box (closed) culverts are considered feasible but not geotechnically preferred due to the relatively deep excavation that will be required for footing construction and possible dewatering.

Recommended Culvert

Given the fact that the existing culvert consists of a 1.05 m diameter CSP, replacement with a single pipe of similar diameter is both technically feasible and cost effective. The report herein focuses on providing foundation recommendations related to the design and construction of circular pipe culverts. Contract drawings provided by WSP indicate the planned replacement culvert is to consist of a 1200 mm diameter by 47 m long circular pipe offset approximately 4 m to the north of the existing culvert alignment. The planned invert elevations are 246.4 m and 245.4 m at the upstream and downstream ends respectively.

8.3 Construction Methodology Alternatives

This section presents discussions on alternative construction methods for replacement of the culvert. In preparation of these recommendation the following options have been considered:

1. Open cut with full road closure: not feasible
2. Open cut with single lane, traffic lights: not feasible as embankment width is insufficient
3. Open cut with a single lane, traffic lights and roadway protection.
4. Open cut with a single lane, traffic lights, and temporary grade lowering and roadway protection.
5. Open cut with a single lane, traffic lights, and temporary platform widening and roadway protection.
6. Trenchless methods.

Options 1 and 2 are not considered feasible at this site. Option 4 includes temporary modifications to the vertical alignment; given the sloping profile, it is anticipated that this temporary modification will be very difficult. Table E-1 in Appendix E provides a comparison of Options 3, 5 and 6.

Based on our understanding of the project and the existing conditions at the site Option 6 is considered the preferred method. It would eliminate an excavation in excess of 12 m depth and allow the culvert to be replaced with minimal impact to traffic.

8.4 Recommended Approach

A trenchless technique is considered the preferred alternative. The discussion and recommendations provided below are based on the culvert replacement consisting of a circular pipe installed using a trenchless method.

9 RECOMMENDATIONS

Trenchless installations should be carried out in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Methods". A copy of this NSSP is attached in Appendix E.

Trenchless methods that are typically considered to install pipes under highways include:

- Jack and bore
- Pipe ramming
- Microtunnelling (MTBM)
- Hand Mining
- Horizontal Directional Drilling

Selection of an appropriate trenchless method must be the responsibility of the Contractor and will depend on the relative costs and risks associated with each method. The experience of the Contractor is of primary importance for trenchless installation. Amongst the important issues discussed in the NSSP are maintenance of alignment, handling of oversized obstructions and disposal of cuttings.

Jack and bore is not considered feasible due to the presence of non-cohesive soils in the target depth This material could increase the risk under the presence of groundwater by creating unstable flowing conditions at the face of the installation.

During pipe ramming, the sleeve pipe is driven from the access point to the exit point using an air-powered percussion hammer. After the sleeve has been fully or partially driven, the soil is removed by augering. The pipe ramming technique can accommodate the removal of boulders. This method has versatility in accommodating a variety of subsurface conditions and is generally suitable for cohesionless soils with water seepage problems associated with low piezometric head. Under this condition dewatering is usually not required for this method. The Pipe Ramming technique does not require a backstop for reaction purposes. This technique has a further advantage in that there is only a small over-cut around the pipe, thus there is a lower potential to cause settlement of the pavement surface. The alignment control can be adversely affected if oversize obstructions are encountered

Microtunnelling is also considered feasible for this site; it is a closed face system designed to handle the flowing conditions.

Horizontal Directional Drilling is also considered feasible at this site. The method will require an initial directional drill advance and back reaming for enlargement of the hole and pipe installation. The process is carried out under fluid pressure to prevent instability of the hole during installation.

The size of the replacement pipe is too small for the hand mining approach.

Although the selection of a suitable trenchless technique is the responsibility of the contractor, in light of the materials and ground water conditions observed at this site, microtunneling and Horizontal Directional Drilling are the preferred methods at this site.

It should be noted that all trenchless methods will require a new alignment, and the clearance required between the existing and the new pipes for safe installation is typically between 1 to 2 pipe diameters.

Monitoring of the roadway surface should be carried out during the trenchless installation as specified in the NSSP.

9.1 Entry and Exit Pits

The design of safe and stable entry and exit pits for the trenchless installation is the responsibility of the contractor. Depending on the selected installation method, temporary protection systems may be required to support temporary excavations at the entry and exit pits. All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native soil at this site are classified as Type 3 soil above the water level and Type 4 soil below the water level. Sheet-piles or soldier pile & lagging walls are considered appropriate for protection systems at this site. The fill and native material below the fill was noted to include occasional cobbles. Suggested wording for an NSSP on “Obstructions” is found in Appendix E.

The temporary excavation support system should be designed and constructed in accordance with OPSS 539, November 2009. The lateral movement of the temporary shoring system should meet Performance Level 2.

Earth pressures may be calculated using the parameters provided in the following table for static conditions.

Earth Pressure Design Parameters – Static Conditions

Parameter	Soil Type									
	OPSS Granular A or OPSS Granular B Type II Φ = 35° γ = 22.8 kN/m³		OPSS Granular B Type I Φ = 32° γ = 21.2 kN/m³		OPSS SSM Fill Φ = 30° γ = 21 kN/m³		Sand or Silty Sand Φ = 29° γ = 19 kN/m³		Silty Sandy Clay Fill Φ = 27° γ = 19 kN/m³	
Surface Behind Wall	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)
Active Earth Pressure Coefficient, Ka (Unrestrained Wall)	0.27	0.39	0.31	0.47	0.33	0.54	0.35	0.58	0.38	0.70
At-rest Earth Pressure Coefficient, Ko (Restrained Wall)	0.43	-	0.47	-	0.50	-	0.52	-	0.55	-
Passive Earth Pressure Coefficient, Kp (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-	2.9	-	2.7	-

In accordance with Clause C4.6.4 of the CHBDC (2014) and related commentary, retaining structures should be designed using earth pressure coefficients that include earthquake loading, however the Zonal Acceleration Ratio for the Sault Ste Marie area is 0.0.

9.2 Dewatering

Indications of groundwater were observed in several of the boreholes at the time of drilling. It is noted however that ground water levels do fluctuate and it is expected that groundwater and surface water will accumulate in the excavations during culvert construction. The groundwater level is expected to be largely governed by the water level in the stream/ditch and seasonal weather. Construction dewatering is the responsibility of the contractor who must provide effective dewatering to install the culvert in the dry or to keep the entry and exit pits dry. However, it is anticipated that sump pumps and creek diversion will be the most applicable methods of dewatering at this site. A permit to take water is expected to be required as daily pumping rates may be over 50,000 litres per day.

9.3 Embankment Reinstatement

The existing embankment is sloped at approximately 1.8H:1V or flatter and exhibits no signs of instability. Embankment reconstruction, after culvert replacement, should be carried out in accordance with OPSS 206 and OPSD 208.010. The embankment material should consist of imported Granular B Type I or Select Subgrade material. Excavated granular fill with less than 25% fines may also be reused as backfill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction.

Provided the embankment fill is placed as recommended herein, embankment slopes matching the existing slopes, will remain stable.

9.4 Erosion Control

Erosion protection should be provided at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field. Typically, rock protection should be provided over all surfaces with which flowing surface 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.

It is recommended that a clay seal 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.

9.5 Cement Type and Corrosion Potential

A sample of the native sand with silt (Borehole 15-17, SS2) was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are included in Appendix C and summarized in the following table.

Results of Chemical Analysis

Borehole	**Sample**	**Depth (m)**	**pH**	**Resistivity (Ohm-cm)**	**Chloride (µg/g)**	**Sulphate (µg/g)**
15-17	SS2	0.9	5.4	7840	22	19

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH measured was slightly lower compared to what is considered the normal range for soil pH of 5.5 to 9.0. The test results provided may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

10 CONSTRUCTION CONCERNS

The planned construction methodology includes trenchless methods in order to replace the culvert. Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of trenchless operations on the existing pavement surface due to loss of material or heave. The Contractor`s methodology selection must recognize and take into consideration these inherent risks. Contingency plans should be in place to manage any adverse impacts on the highway.
- Implementation of an adequate and effective surface water management and dewatering plan. Surface runoff should be diverted away from excavations at all times.
- The embankment fill and portions of the underlying soils were observed to contain occasional cobbles and the fill may contain other obstructions. The Contractor`s equipment and methodology must be selected to handle such obstructions and successfully remove them without jeopardizing the highway. The impact of obstructions on the pipe alignment should be assessed.

- The Contractor must accurately establish, in three dimensions, the locations of all buried utilities crossing or closely paralleling the culvert alignment. Any discrepancies from the Contract Drawings must be reported to the Contract Administrator.

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction.

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

11 CLOSURE

Preparation of this foundation design report was carried out by Mr. Justin Gray E.I.T., and Dr. Fred Griffiths P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng.

Justin A. Gray
Geotechnical E.I.T.

LICENSED PROFESSIONAL ENGINEER
F. J. GRIFFITHS
Sept 19/16
PROVINCE OF ONTARIO

Fred J. Griffiths, P.Eng.
Senior Associate, Senior Foundations Engineer

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P. K. CHATTERJI
Sep 19/2016
PROVINCE OF ONTARIO

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

Appendix A

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No

HIGHWAY 17
22+283
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

WSP

THURBER ENGINEERING LTD.

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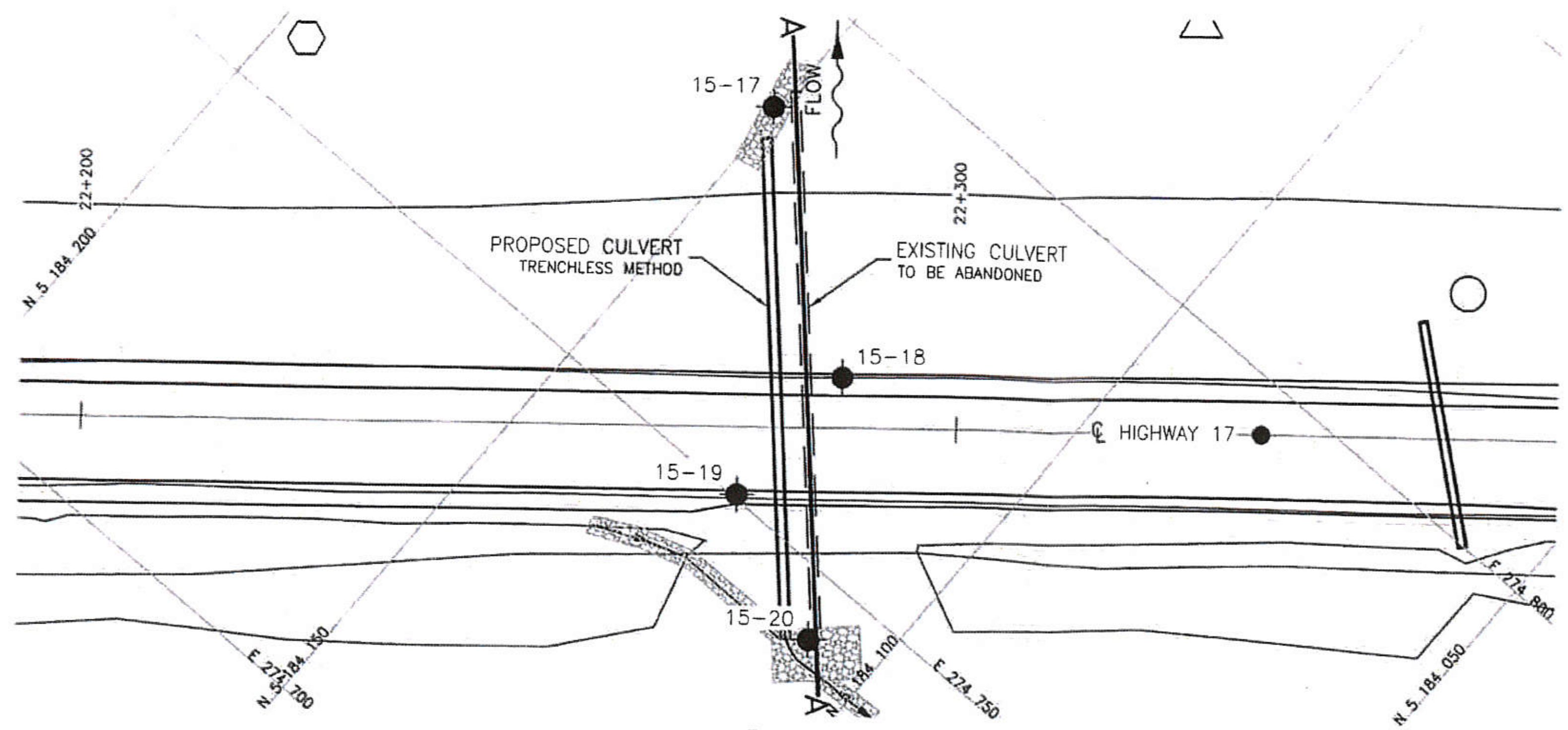
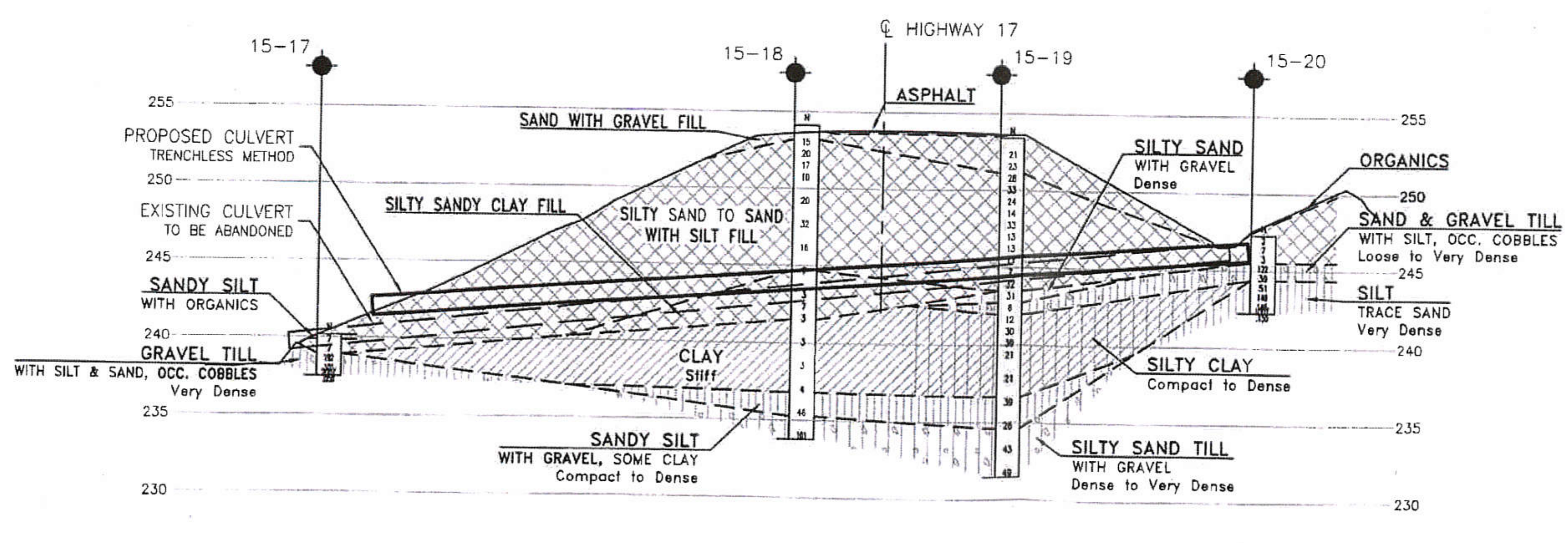


PLAN

16 0 16 32m

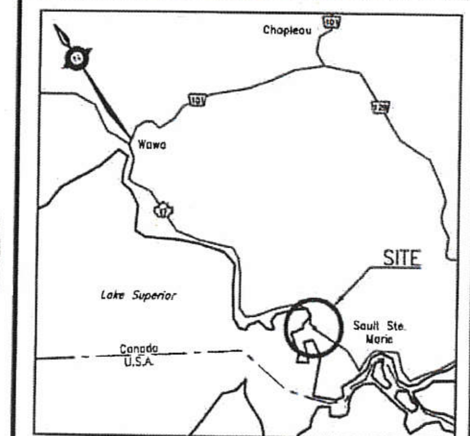
SCALE 1:800



SECTION ALONG A-A

8 0 8 16m

SCALE 1:400



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
15-17	240.1	5 184 150.6	274 786.7
15-18	254.1	5 184 124.5	274 768.3
15-19	253.4	5 184 125.0	274 750.4
15-20	247.3	5 184 108.0	274 743.1

-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. 41K-98

REVISIONS | DATE | BY | DESCRIPTION

DESIGN JG	CHK –	CODE	LOAD	DATE SEP 2016	
DRAWN MFA	CHK JG	SITE	STRUCT	DWG 1	

PLOTDATE: 9/7/2016 3:18 PM

Appendix B

Record of Borehole Sheets

THURBER

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).

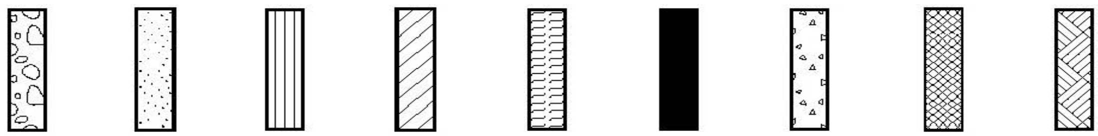
DYNAMIC CONE PENETRATION TEST (DCPT):

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.

THURBER

STRATA PLOT:

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



Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

SAMPLE TYPES

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

THURBER

MODIFIED UNIFIED SOIL CLASSIFICATION

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

Note - W_L= Liquid Limit

THURBER

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 15-17

METRIC

GWP# 545-00-00
LOCATION Culvert 22+283, Highway 17 Goulais River N 5 184 150.6 E 274 786.7
ORIGINATED BY CAM

HWY 17
BOREHOLE TYPE Portable
COMPILED BY SML

DATUM Geodetic
DATE 2016.01.24 - 2016.01.24
CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
240.1						240						
0.0	Sandy silt with organics **FILL**											
239.8 / 0.3	Silty sand, Loose, Brown, Moist to Wet, **FILL**, some clay	1	SS	7								
		2	SS	7								
238.9 / 1.2	**GRAVEL** with silt and sand, occasional cobbles, Very Dense, Brown, Wet	3	SS	192		239						
		4	SS	101		238			53	37	8	2
237.5 / 2.6	End of Borehole at 2.63 m, Borehole Open Upon Completion, Borehole Dry Upon Completion	5	SS	200/ 50 mm								

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 15-18

METRIC

GWP#	545-00-00	LOCATION	Culvert 22+283, Highway 17 Goulais River N 5 184 124.5 E 274 768.3	ORIGINATED BY	JAG
HWY	17	BOREHOLE TYPE	Hollow Stem Auger	COMPILED BY	SML
DATUM	Geodetic	DATE	2016.01.27 - 2016.01.28	CHECKED BY	FJG

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
254.1 / 0.0	Sand with gravel, Compact, Brown, Moist, **FILL**		1	AS			254	
253.2 / 0.9	Silty sand to sand with silt some gravel, occasional cobbles, Compact to Dense, Brown, Moist to wet, **FILL**		2	SS	15		253	
			3	SS	20		252	
			4	SS	17			2 52 46 (SI+CL)
			5	SS	10		251	
			6	SS	20		250, 249	
			7	SS	32		248	
	wet		8	SS	16		247, 246	
	some clay						245	
244.7 / 9.4	Silty, Sandy Clay, Reddish brown, Firm		9	SS	7			

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 15-18

METRIC

GWP# 545-00-00 | LOCATION Culvert 22+283, Highway 17 Goulais River N 5 184 124.5 E 274 768.3 | ORIGINATED BY JAG

HWY 17 | BOREHOLE TYPE Hollow Stem Auger | COMPILED BY SML

DATUM Geodetic | DATE 2016.01.27 - 2016.01.28 | CHECKED BY FJG

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%) / Shear strength	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	FILL					
		10	SS	3		0 42 31 27
		11	SS	7		
241.5		12	SS	3		
12.6	**CLAY (CH)** Stiff Reddish Brown Moist				Field vane sensitivity 4.0	
		13	SS	3		
					Field vane sensitivity 4.3; 4.0	
		14	SS	3		0 7 24 69
					Field vane sensitivity 3.5; 3.8	
236.8		15	SS	4		
17.3	Sandy **SILT** with gravel some clay Dense Brownish Grey Moist					
235.3		16	SS	46		22 28 40 10
18.8	**SILTY SAND** with gravel Very Dense Brown **TILL**					

Elevation scale: 244, 243, 242, 241, 240, 239, 238, 237, 236, 235

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-18

METRIC

GWP# 545-00-00
LOCATION Culvert 22+283, Highway 17 Goulais River N 5 184 124.5 E 274 768.3
ORIGINATED BY JAG

HWY 17
BOREHOLE TYPE Hollow Stem Auger
COMPILED BY SML

DATUM Geodetic
DATE 2016.01.27 - 2016.01.28
CHECKED BY FJG

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		17	SS	101		234		○		
233.8 20.3	End of Borehole at 20.33 m Borehole Open to 9.76 m Upon Completion										

ONTMT4S 19-5308-95.GPJ 2012TEMPLATE(MTO).GDT 9/15/16

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 15-19

METRIC

GWP# 545-00-00 | LOCATION Culvert 22+283, Highway 17 Goulais River N 5 184 125.0 E 274 750.4 | ORIGINATED BY JAG

HWY 17 | BOREHOLE TYPE Hollow Stem Auger | COMPILED BY SML

DATUM Geodetic | DATE 2016.01.25 - 2016.01.26 | CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
253.4							
0.0 / 0.1	**ASPHALT** (80 mm)						
	Sand with gravel, Compact, Brown, Moist, **FILL**				253		
		1	SS	21			
					252		
		2	SS	23			
251.1 / 2.3	Silty sand to sand with silt, Loose to Dense, Brown, Moist, **FILL**				251		
		3	SS	28			
		4	SS	33	250		4 72 24 (SI+CL)
		5	SS	24			
					249		
	occasional clay layer trace gravel	6	SS	14			
					248		
		7	SS	33			
		8	SS	13	247		
		9	SS	13			
					246		
		10	SS	11			1 91 8 (SI+CL)
					245		
		11	SS	7			
		12	SS	32	244		
243.5							

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; 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 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

ONTMT4S 19-5308-95.GPJ 2012TEMPLATE(MTO).GDT 9/15/16

RECORD OF BOREHOLE No 15-19

METRIC

GWP# 545-00-00	LOCATION Culvert 22+283, Highway 17 Goulais River N 5 184 125.0 E 274 750.4	ORIGINATED BY JAG
HWY 17	BOREHOLE TYPE Hollow Stem Auger	COMPILED BY SML
DATUM Geodetic	DATE 2016.01.25 - 2016.01.26	CHECKED BY FJG

SOIL PROFILE — Continued From Previous Page

ELEV / DEPTH	DESCRIPTION
9.9	**SILTY SAND** with gravel, occassional wood Dense Brown Wet
242.7 / 10.7	**SAND and GRAVEL** with silt occasional cobbles Loose Brown Wet
242.0 / 11.4	**SILTY CLAY** Stiff to Hard Brown to Reddish Brown
236.6 / 16.8	**SILT** with sand some clay to Sandy **SILT** Dense to Compact Brown Wet
234.6 / 18.8	**SILTY SAND** with gravel Dense Brown **TILL**

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
13	SS	31	
14	SS	6	45 48 7 (SI+CL)
15	SS	12	
16	SS	30	0 6 81 13
17	SS	39	
18	SS	21	
19	SS	21	
20	SS	39	
21	SS	26	

ELEVATION SCALE: 243, 242, 241, 240, 239, 238, 237, 236, 235, 234

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

GROUND WATER CONDITIONS; STRAT PLOT

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 15-19

METRIC

GWP# 545-00-00
LOCATION Culvert 22+283, Highway 17 Goulais River N 5 184 125.0 E 274 750.4
ORIGINATED BY JAG

HWY 17
BOREHOLE TYPE Hollow Stem Auger
COMPILED BY SML

DATUM Geodetic
DATE 2016.01.25 - 2016.01.26
CHECKED BY FJG

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Continued From Previous Page											
	SILTY SAND with gravel Dense Brown **TILL**	22	SS	43		233	○ (~10)		22	57	21 (SI+CL)	
						232						
231.5 21.9		23	SS	49			○ (~15)		17	35	44	4
	End of Borehole at 21.95 m Borehole Open to 9.8 m Upon Completion Borehole Dry Upon Completion											

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 15-20

METRIC

GWP# 545-00-00 LOCATION Culvert 22+283, Highway 17 Goulais River N 5 184 108.0 E 274 743.1 ORIGINATED BY CAM

HWY 17 BOREHOLE TYPE Portable / Casing COMPILED BY SML

DATUM Geodetic DATE 2016.01.27 - 2016.01.27 CHECKED BY FJG

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
247.3							
0.0	**TOPSOIL** (25 mm)						
	Silty sand, Very Loose to Loose, Brown, Moist to Wet, **FILL**	1	SS	2		247	
		2	SS	7			2 78 20 (SI+CL)
		3	SS	3		246	
245.5 / 1.8	**SAND** with silt and gravel, occasional cobbles, Very Dense to Dense, Brown, Wet	4	SS	122		245	
		5	SS	39			28 64 8 (SI+CL)
244.4 / 2.9	**SILT** trace sand, Very Dense, Brown, Moist	6	SS	51		244	0 5 90 5
		7	SS	149		243	
		8	SS	146			
242.3 / 5.0	End of Borehole at 2.89 m, Borehole Open to 1.5m Upon Completion	9	SS	100 /150 mm			

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

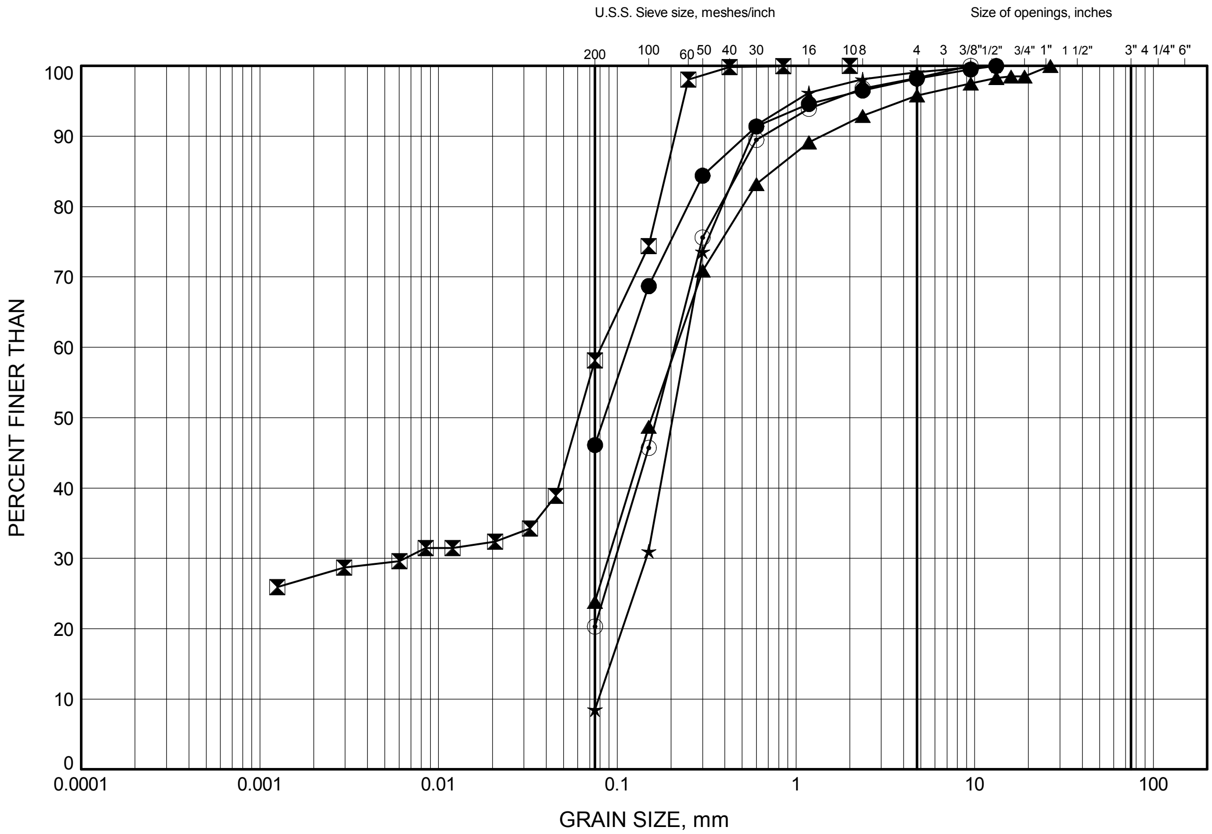
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix C

Laboratory Test Results

Culvert 22+283, Highway 17 Goulais River GRAIN SIZE DISTRIBUTION	FIGURE 1

Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-18	2.59	251.51
⧗	15-18	10.97	243.13
▲	15-19	3.35	250.05
★	15-19	7.92	245.48
⊙	15-20	0.91	246.38

Date ..March 2016...........

GWP# ..545-00-00............

THURBER

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

Chkd. ......FJG......

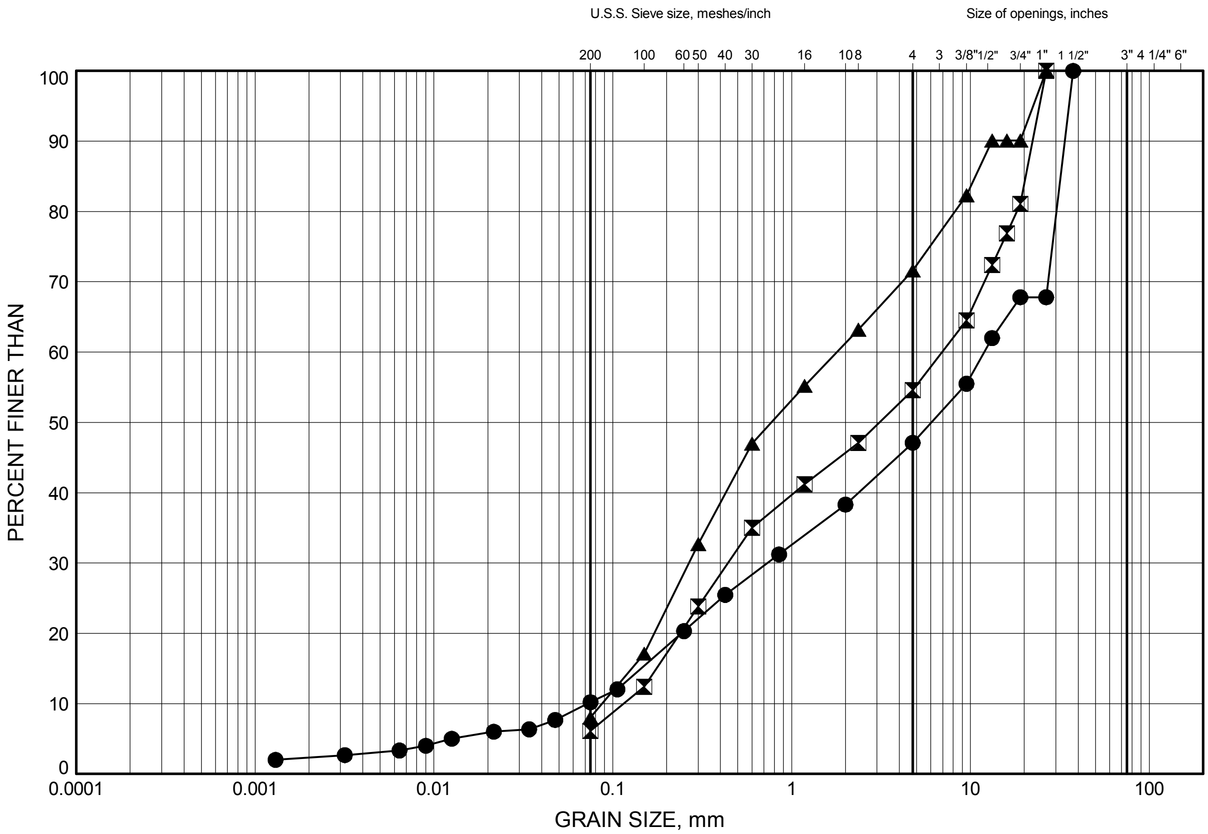
GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 23/3/16

Culvert 22+283, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 2

Gravel with Silt and Sand to Sand with Silt and Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-17	2.13	238.00
⧗	15-19	10.97	242.43
▲	15-20	2.67	244.63

GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 23/3/16

Date March 2016

GWP# 545-00-00

THURBER

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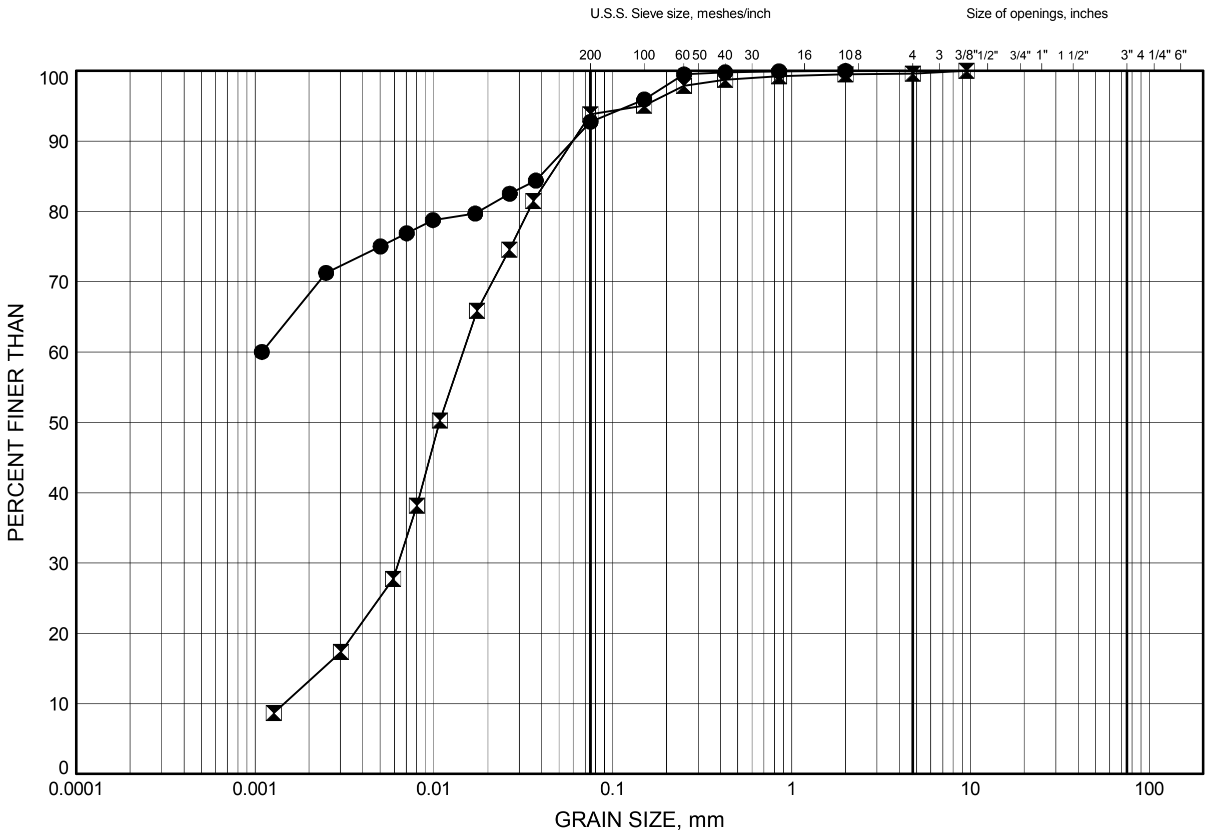
Chkd. FJG

Culvert 22+283, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 3

Clay to Silty Clay



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-18	15.54	238.56
⧗	15-19	12.50	240.90

Date March 2016

GWP# 545-00-00

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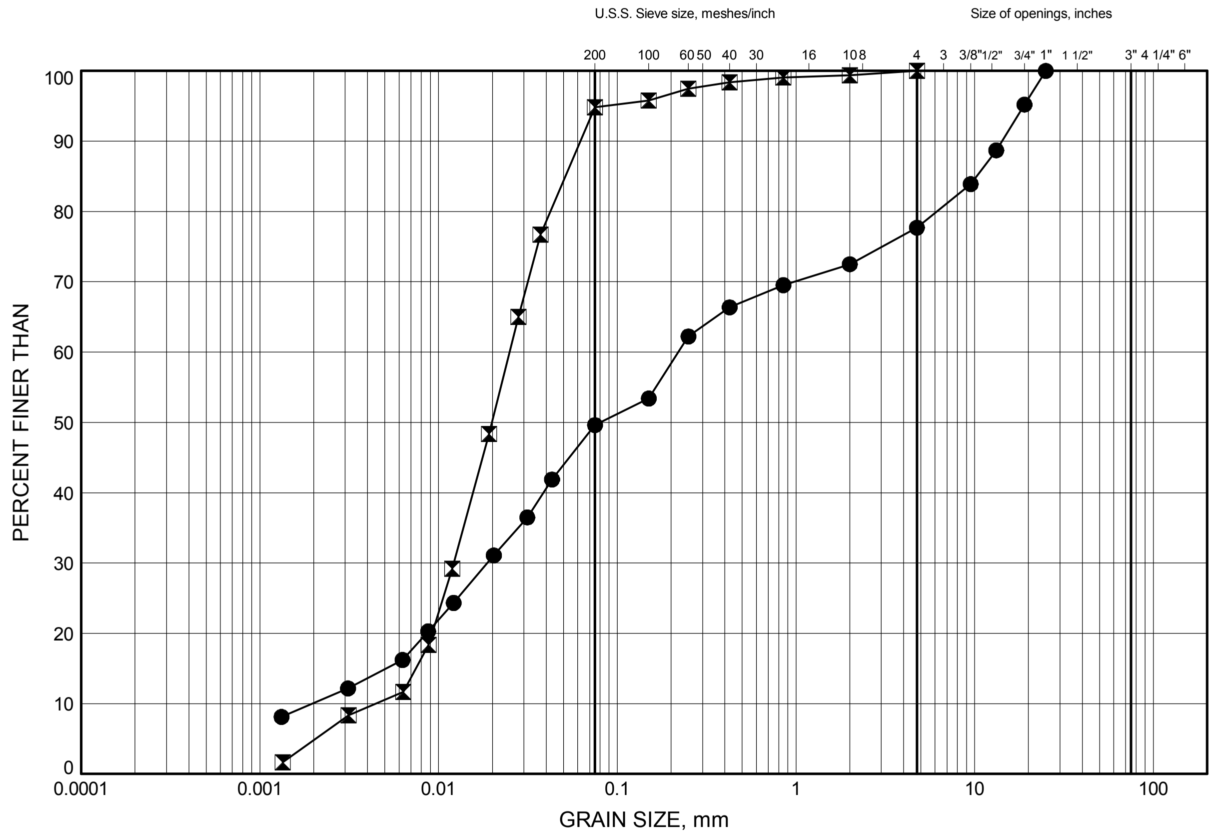
GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 23/3/16

Culvert 22+283, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 4

Sandy Silt to Silt with Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-18	18.59	235.51
⧗	15-20	3.35	243.94

GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 23/3/16

Date March 2016

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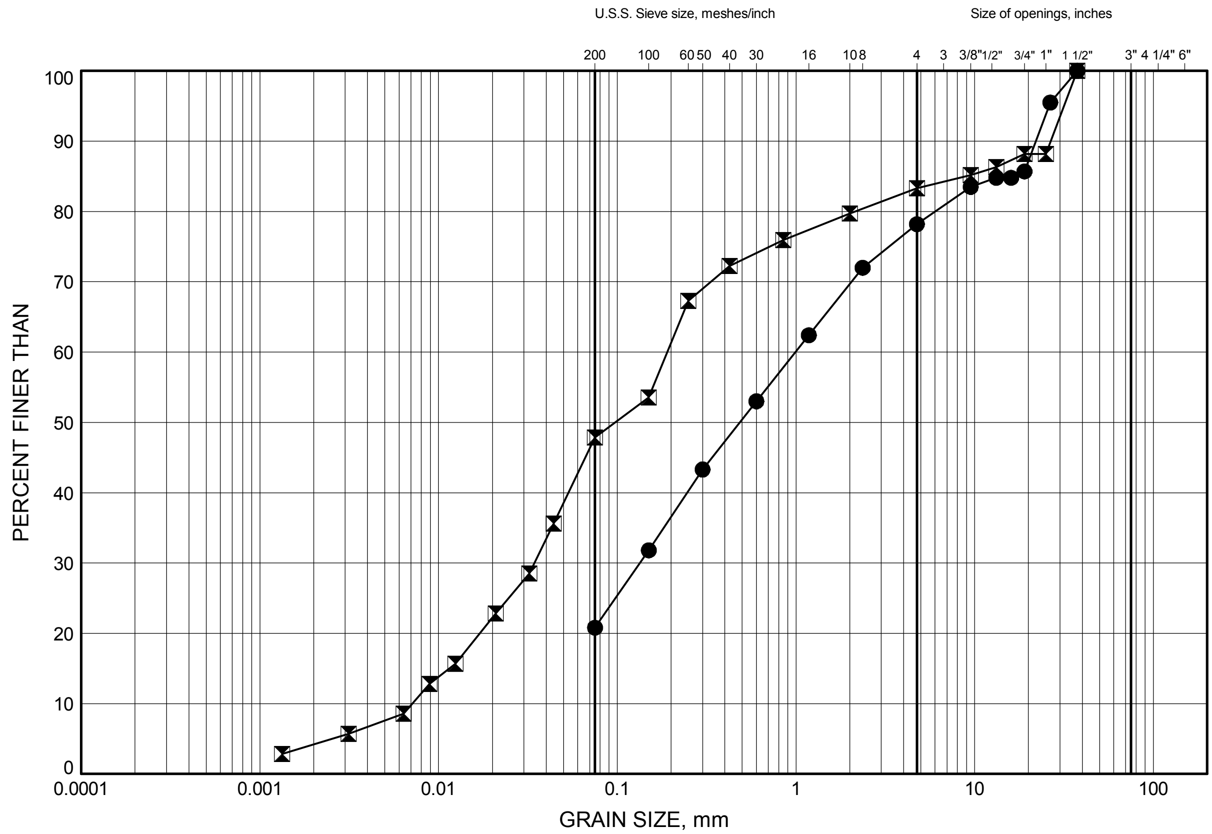
Culvert 22+283, Highway 17 Goulais River

GRAIN SIZE DISTRIBUTION

FIGURE 5

Silty Sand (Till)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-19	20.12	233.28
⧗	15-19	21.64	231.76

GRAIN SIZE DISTRIBUTION - THURBER 19-5308-95.GPJ 23/3/16

Date March 2016

GWP# 545-00-00

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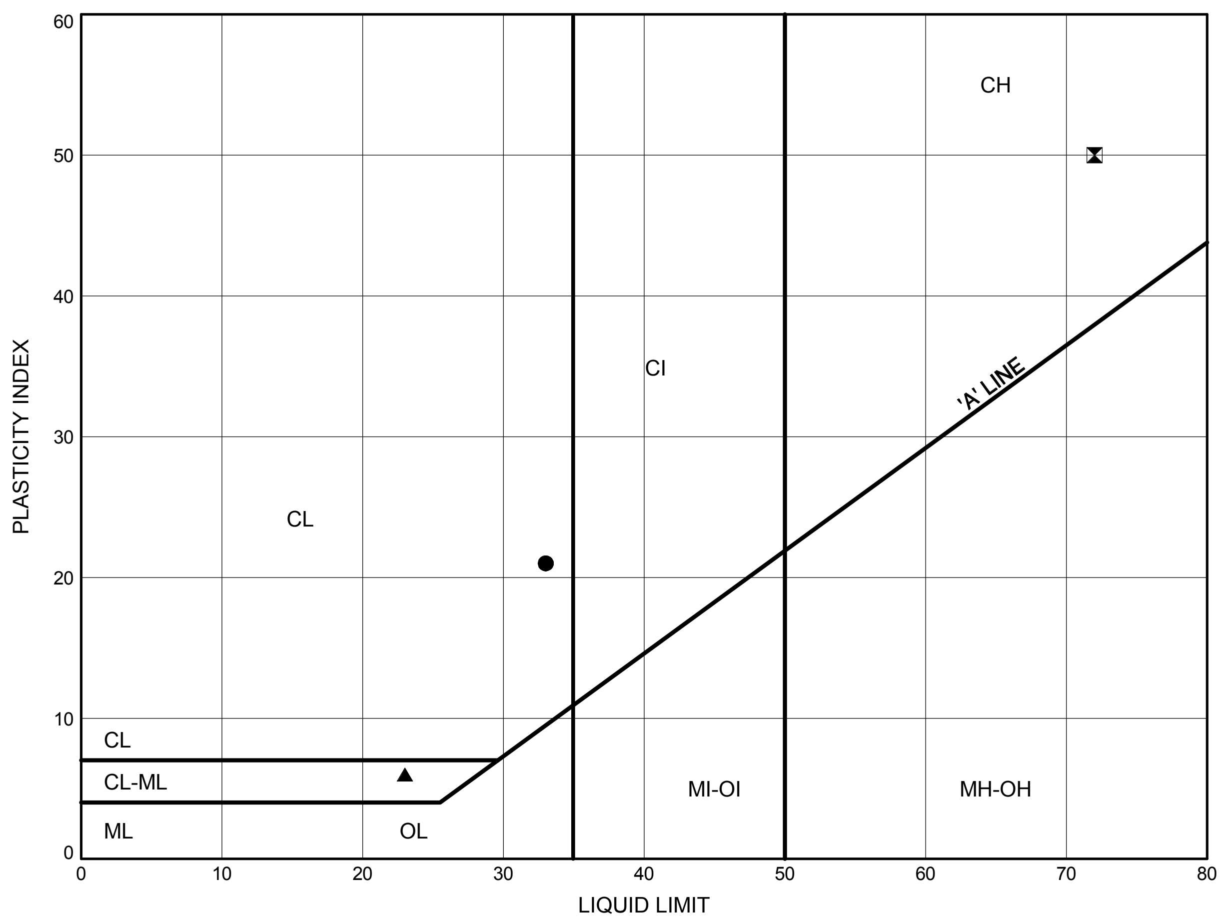
Culvert 22+283, Highway 17 Goulais River

ATTERBERG LIMITS TEST RESULTS

FIGURE 6



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-18	10.97	243.13
⧗	15-18	15.54	238.56
▲	15-19	12.50	240.90

Date May 2016

GWP# 545-00-00

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Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Shawn Lapain

Client PO:
Project: 19-5308-95
Custody: 27345

Report Date: 10-Feb-2016
Order Date: 4-Feb-2016

Order #: 1606277

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

Paracel ID	Client ID
1606277-01	BH15-17 SS2 (2'-4')

Approved By: [signature]

Tim McCooeye
Senior Advisor

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	9-Feb-16	9-Feb-16
Conductivity	MOE E3138 - probe @25 °C, water ext	9-Feb-16	9-Feb-16
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	5-Feb-16	5-Feb-16
Resistivity	EPA 120.1 - probe, water extraction	9-Feb-16	9-Feb-16
Solids, %	Gravimetric, calculation	8-Feb-16	8-Feb-16

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 10-Feb-2016

Order Date: 4-Feb-2016

Project Description: 19-5308-95

Client ID:		BH15-17 SS2 (2'-4')	-	-	-
Sample Date:		24-Jan-16	-	-	-
Sample ID:		1606277-01	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	77.9	-	-	-
General Inorganics					
Conductivity	5 uS/cm	128	-	-	-
pH	0.05 pH Units	5.39	-	-	-
Resistivity	0.10 Ohm.m	78.4	-	-	-
Anions					
Chloride	5 ug/g dry	22	-	-	-
Sulphate	5 ug/g dry	19	-	-	-

Method Quality Control: Blank

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

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 10-Feb-2016

Order Date:4-Feb-2016

Project Description: 19-5308-95

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
General Inorganics									
pH	7.94	0.05	pH Units	7.90			0.5	10	
Resistivity	41.1	0.10	Ohm.m	42.9			4.2	20	
Physical Characteristics									
% Solids	91.5	0.1	% by Wt.	91.4			0.2	25	

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	9.9		mg/L	ND	99.1	78-113			
Sulphate	9.92		mg/L	ND	99.2	78-111			

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

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

Appendix D

Selected Photographs

19-5308-95

Photo 1: West side – inlet of culvert

Photo 2: East side – outlet of culvert

Photo 3: **Looking west towards culvert inlet.**

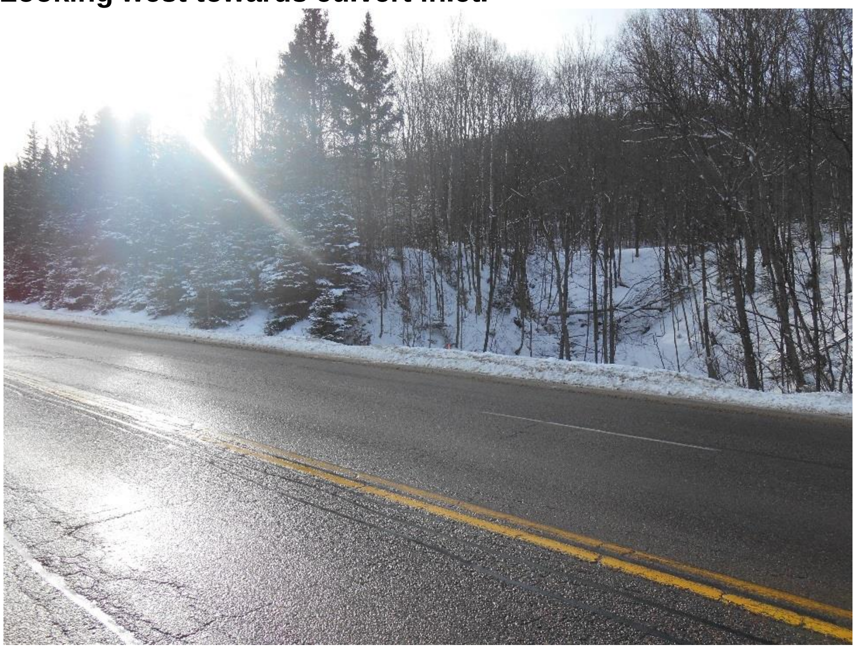

Photo 4: **Looking east towards culvert outlet.**

Photo 5: **Looking north towards culvert crossing.**

Appendix E

Table E-1: Comparison of Construction Methodology Alternatives

NSSPs

Table E-1: Comparison of Construction Methodology Alternatives

Option	3. Open Cut, staged with roadway protection	5. Open cut, staged with temporary platform widening and roadway protection	6. Trenchless installation
Advantages	Surface and groundwater controlled by sump & pump techniques	Surface and groundwater controlled by sump & pump techniques	Avoids deep excavation through highway Two lanes of traffic maintained throughout
Disadvantages	Depth of excavation greater than 12 m. Very large excavation quantities Roadway protection will require bracing or anchors due to depth of excavation	Depth of excavation greater than 12 m. Very large excavation quantities Large fill quantities to widen platform Roadway protection will require bracing or anchors due to depth of excavation Requires culvert extension	Requires construction of entry and exit pits and access to toe of slope. Must maintain surface and groundwater control
Relative Cost	Moderate	Moderate	High
Risks & Consequences	Risk if oversized obstructions encountered	Review of impact to horizontal curve and profile may preclude Risk if oversized obstructions encountered Property may be needed	Very high risk if oversized obstructions are encountered. Risk if groundwater encountered, which can be reduced using closed face techniques
Summary	Feasible	Feasible	Preferred

Suggested NSSP Wording

- Suggested Text for NSSP on “Obstructions”

“Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheetpile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.”

- Suggested Text for NSSP on “Groundwater and Dewatering”

"The Contractor is notified that the site may be prone to high groundwater levels and that these levels may be higher than the water levels shown in the Foundation Investigation Report prepared for this site. While reference should be made to that report for a description of the encountered conditions, the Contractor must satisfy himself regarding the groundwater levels likely to prevail at the time of construction and be prepared to implement dewatering procedures.

The Contractor is further notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance. "