



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT 15+818 TILLEY TOWNSHIP
HIGHWAY 17 NEAR GOULAIS RIVER
SAULT STE MARIE AREA
G.W.P. 545-00-00**

GEOCRES Number: 41K-103

Report

to

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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 for the subject culvert was available.

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 borehole location plans, stratigraphic profiles, 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 25.2 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Tilley. A 1.4 m diameter by 36 m long corrugated steel pipe culvert (CSP) is present at the site with approximately 4 m of fill above the pipe. The culvert carries stormwater under Highway 17 from east to west, towards Lake Superior. The invert elevation is 196.6 m at the east end or left and 195.1 m at the west end or right.

The grade of the existing Highway 17 in the vicinity of the culvert is at 201.3 m geodetic. The culvert is located within a fill section. The embankment is constructed with side slopes approximately 3 horizontal to 1 vertical (3H:1V) and 2H:1V corresponding to the east and west

slopes, respectively. The maximum embankment fill height measured from roadway to pipe invert is approximately 4.3 m at the east side and approximately 5.9 m at the west side.

The highway includes one southbound and two northbound lanes. The shoulders were snow covered at the time of the investigation but are gravel shoulders beyond a limited width of pavement. Guide rails are present on both sides of the highway.

The site is located in a rural area with forests, swamps, and creeks. Local topography generally consists of 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

The borehole investigation and field testing program was carried out between January 12, 2016 and January 23, 2016. The program consisted of drilling and sampling four boreholes (numbered 15-01, 15-02, 15-03, and 15-04) to depths ranging from 3.0 to 17.4 m. Of these boreholes, one was located near the culvert inlet (15-01), one located near the culvert outlet (15-04), and two (15-02 and 15-03) 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).

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.

A 25 mm diameter PVC monitoring well was installed in BH 15-04. The screen extended from a depth of 1.2 m to 3.0 m below ground surface. A bentonite seal was placed from 1.2 m depth up to ground surface.

The boreholes were backfilled with soil cuttings mixed with bentonite and topped to surface with the existing granular material.

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 the laboratory testing program are shown on the Record of Borehole sheets in Appendix B and on the Figures 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 silty sand and sand with silt deposits underlain by clay or sand layers. Bedrock was not encountered in any of the four boreholes. More detailed descriptions of the individual strata are presented below.

5.2 Pavement Structure

Boreholes 15-02 and 15-03 were drilled through the gravel shoulders of the roadway, thus asphalt thickness was not measured.

Sand with gravel likely placed as part of the pavement structure extended to a depth of 0.8 m below ground surface. The base of the pavement structure was encountered at elevations ranging from 200.3 to 200.8 m.

The moisture content of the granular fill was 6%. The ground was frozen at the time of the field investigation thus the density and gradation of this layer could not be determined reliably.

5.3 Embankment Fill

Embankment fill was encountered below the pavement granulars in Boreholes 15-02 and 15-03. The thickness of the embankment fill ranged from 3.3 to 3.8 m. A 0.6 m layer of fill was also encountered at the surface in Boreholes 15-01 and 15-04 beneath a 25 mm thick layer of topsoil. The base of the embankment fill was encountered at elevations ranging from 195.1 to 197.6 m.

The embankment fill was observed to be sand with silt trace gravel to sand with gravel.

The SPT N-value for the embankment fill ranged from 4 to 15 blows per 0.3 m penetration, indicating a loose to compact state. The water contents of the recovered embankment fill samples ranged between 7% and 16%. The colour of the embankment fill is brown.

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

Soil Particles	%
Gravel	8 to 12
Sand	82 to 85
Silt and Clay	4 to 7

5.4 Sand with Silt, trace organics

Underlying the embankment fill, a native soil deposit sand with silt was encountered in two boreholes (15-02 and 15-03). This layer was observed to range from 0.5 m to 0.6 m in thickness with the elevation of the base of the unit ranging from 195.9 m to 197.0 m. There was a 25 mm thick organic layer at the top of this layer in Borehole 15-02 and trace organic material in Borehole 15-03.

The SPT N-value for this deposit was 3 blows per 0.3 m penetration, indicating a very loose state. The water contents of the recovered samples ranged between 19% and 28%. The colour of this deposit is brown to dark brown.

5.5 Silty Sand to Sand

A native soil deposit ranging from silty sand to sand was encountered in all boreholes. This soil was found just below the sand with silt layer (15-02 and 15-03) and the embankment fill (15-01 and 15-04). Three of the four boreholes were terminated within this deposit. The thickness observed in Borehole 15-02 was 12.2 m with the base of the unit at 184.8 m. The upper portion

of this deposit contained occasional to frequent cobbles in three boreholes (15-01, 15-02, and 15-04). In Borehole 15-02, this deposit contained some wood and organics between 7 m and 14 m.

The SPT N-value for this deposit varied from 2 to greater than 100 blows per 0.3 m penetration, indicating a very loose to very dense state. The water content of the recovered samples ranged between 12% and 38%. The colour of this deposit is brown to grey.

Grain size analyses conducted on eight samples of the soil are presented on Fig. No 2 and Fig. No 3 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	0 to 39
Sand	55 to 95
Silt and Clay	4 to 37

5.6 Clay

Clay with trace sand and gravel was encountered underlying the sand deposit in Borehole 15-02. Borehole 15-02 was terminated in this clay layer.

The SPT N-value in the clay deposit was 13 blows per 0.3 m penetration, coinciding with a stiff consistency. Sampling ceased in this layer in Borehole 15-02, however a dynamic cone (DCPT) was driven 6.4 m further to assess the consistency of the soils at the base of the borehole. The DCPT revealed the material below the clay ranged from 17 to 71 blows per 0.3 m penetration, indicating the presence of a compact (or very stiff, if cohesive) to very dense (or hard) material.

The colour of the clay is reddish brown. The water content of the recovered clay sample was 41%.

The results of a grain size analyse conducted on a sample of the clay are presented on Fig. No 4 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	9
Sand	5
Silt	21
Clay	65

Atterberg limit testing was carried out on a sample of the clay. The liquid limit was 57% and the plasticity index was 37%. The sample can be classified as clay of high plasticity (CH). The results are presented on Fig. No 5 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	20
Liquid Limit	57
Plasticity Index	37

5.7 Groundwater Conditions

Groundwater was observed in Boreholes 15-02, 15-03, and 15-04 at the completion of drilling. The results are summarized in the following table.

Borehole	Depth of observed water (m)	Elevation of observed water (m)
15-02	6.6	195.0
15-03	6.5	194.6
15-04	1.8	193.9

A 25 mm inside diameter PVC monitoring well was installed in Borehole 15-04. The results are summarized in the following table. The monitoring well was decommissioned on February 19, 2016.

Date	Depth of observed water (m)	Elevation of observed water (m)
January 24, 2016	1.86	193.84
January 25, 2016	1.91	193.79
February 19, 2016	1.99	193.71

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 must also be taken into consideration.

6 MISCELLANEOUS

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

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 near Goulais River, Ontario, approximately 25.2 kilometres north of the intersection of Highway 552 and Highway 17 in the Township of Tilley.

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 1.40 m diameter by 36 m long corrugated steel pipe culvert (CSP) is present at the site. Water at the site flows from east to west, towards Lake Superior. The existing roadway cross-section includes three 3.5 m lanes (two lanes in the northbound direction), 2.0 m gravel shoulders and 0.5 m rounding. Three cable guide rail is present on both sides of the highway.

It is understood that the existing culvert is to be replaced with a similar sized culvert at similar invert elevations.

The borehole information indicates that the base of the embankment fill ranges from 195.1 m to 197.6 m. An excavation for a new culvert would therefore be within the fill which was observed to consist of loose to compact sand with silt trace to some gravel. The native material observed immediately beneath the fill consisted of sand with silt to silty sand. It was typically loose to very loose and was observed in some cases to contain organic material and cobbles. Frost depth at

this site is 2.0 m. Groundwater levels at the time of the investigation were noted at an elevation ranging from 193.7 m to 195.0 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 has been 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 recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below along with comparison based on their respective advantages and disadvantages.

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 possible 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 and possible dewatering.

Recommended Culvert

Given the fact that the existing culvert consists of a 1400 mm 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 1400 mm diameter by 36 m long circular pipe offset approximately 4 m to the south of the existing culvert alignment. The planned invert elevations are 196.63 m and 195.07 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.
2. Open cut with a single lane, traffic lights and roadway protection.
3. Open cut with a single lane, traffic lights, and temporary grade lowering.
4. Open cut with a single lane, traffic lights, and platform widening to the east.
5. Open cut with a single lane, traffic lights, and minor driving lane widening.
6. Trenchless methods.

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

Based on our understanding of the project and the existing conditions at the site Option 6 is considered the preferred method, however should situations arise which preclude the use of a trenchless replacement approach Option 5 would be appropriate. Two directions of traffic can be maintained with the use of trenchless methods.

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 feasible due to the presence of cohesionless soils in the target depth.

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 oversized 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, pipe ramming, 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 native material below the fill was noted to include occasional to frequent 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 $\Phi = 35^\circ$ $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\Phi = 32^\circ$ $\gamma = 21.2 \text{ kN/m}^3$		OPSS SSM Fill $\Phi = 30^\circ$ $\gamma = 21 \text{ kN/m}^3$		Sand or Sand with Silt $\Phi = 29^\circ$ $\gamma = 19 \text{ kN/m}^3$	
Surface Behind Wall	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)
Active Earth Pressure Coefficient, K_a (Unrestrained Wall)	0.27	0.39	0.31	0.47	0.33	0.54	0.35	0.58
At-rest Earth Pressure Coefficient, K_o (Restrained Wall)	0.43	-	0.47	-	0.50	-	0.52	-
Passive Earth Pressure Coefficient, K_p (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-	2.9	-

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

Groundwater was observed in several boreholes during the investigation at elevations as high as 195.0 m. It is noted however that groundwater 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 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 ground 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 2H: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 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 15-03, SS8) 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)
15-03	SS8	6.4	6.1	7240	73	11

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 within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. 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 recommended 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 must be monitored. 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 was observed to contain 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.

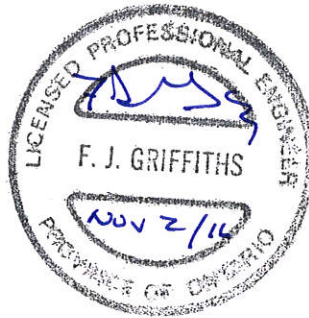
The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented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

11 CLOSURE

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



Justin A. Gray
Geotechnical E.I.T.



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



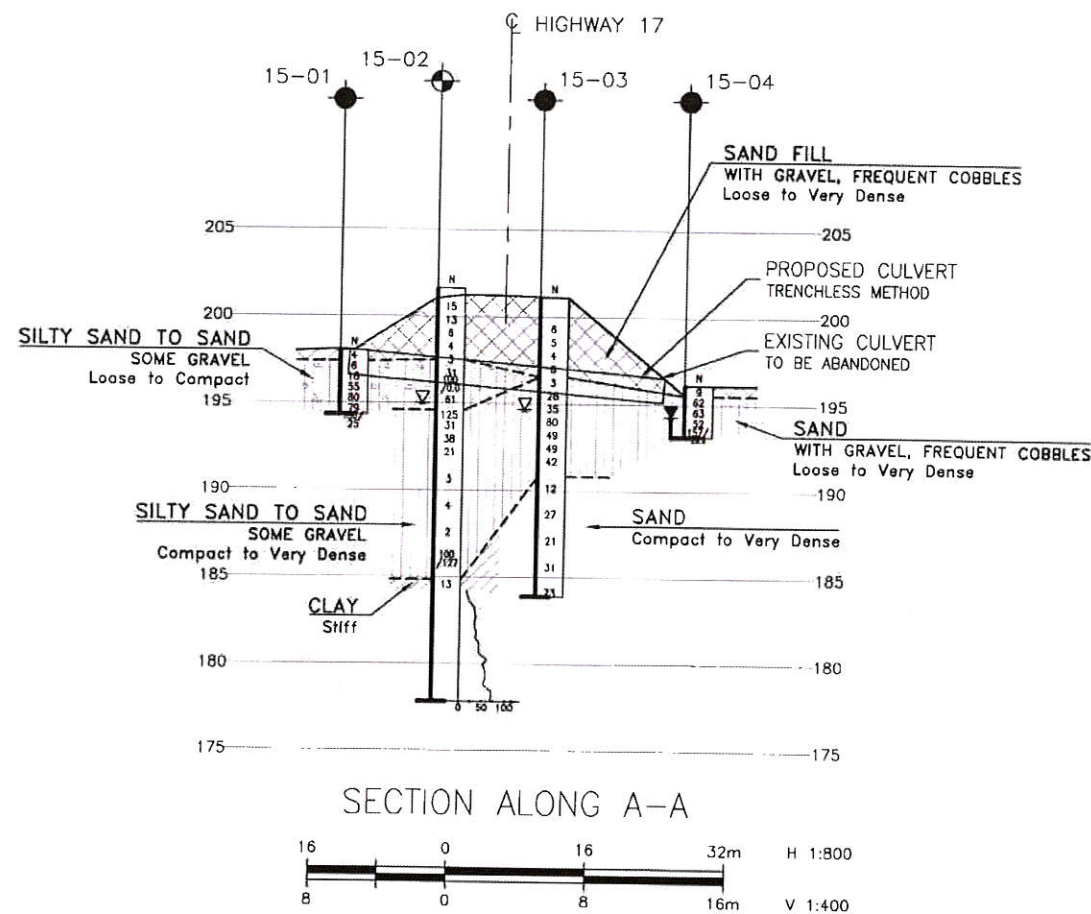
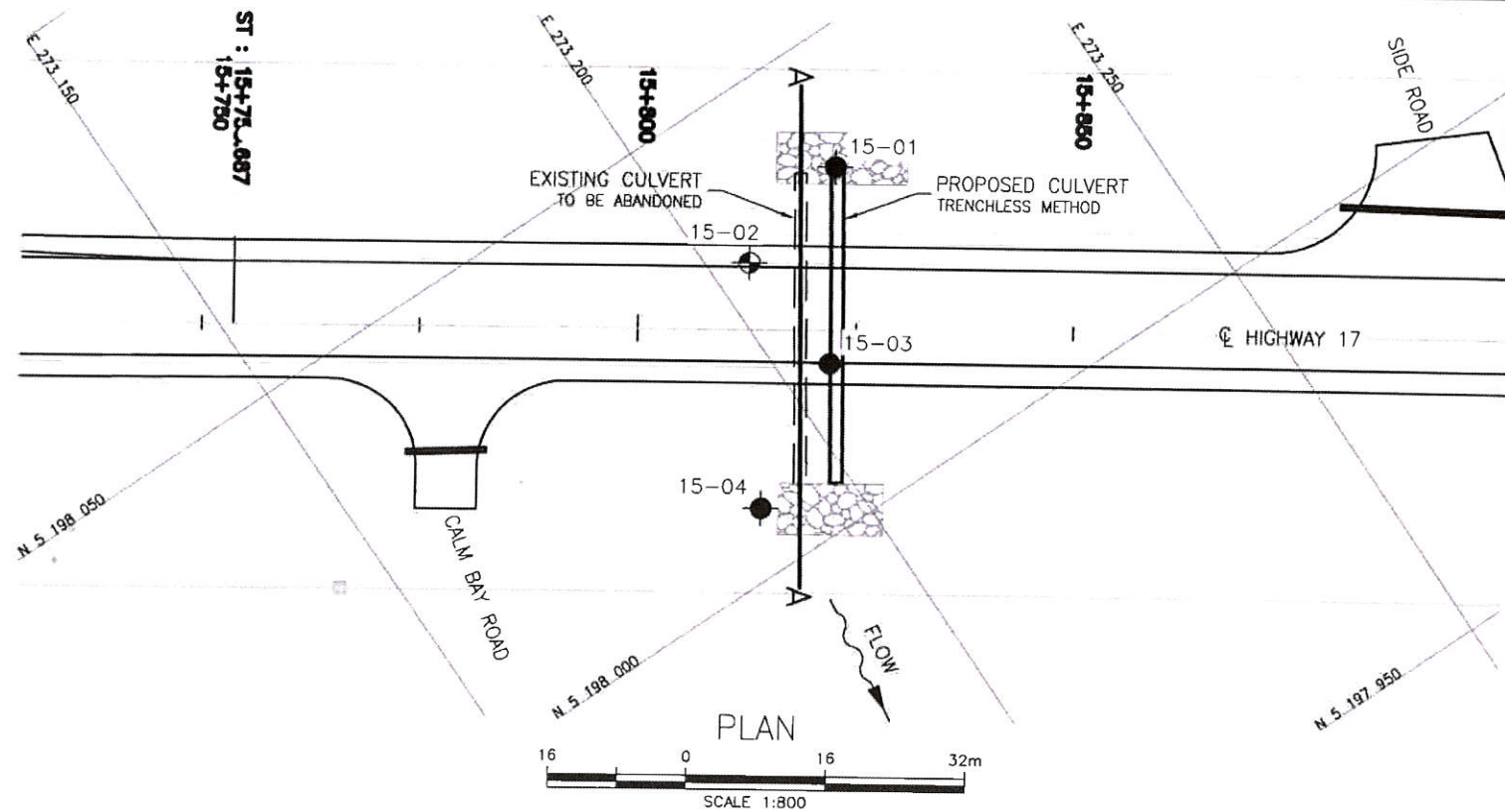
P.K. Chatterji, P.Eng.
Principal, Designated MTO Contact

Appendix A

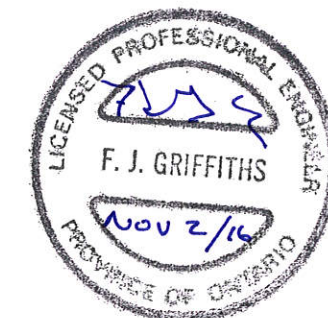
Borehole Locations and Soil Strata Drawings

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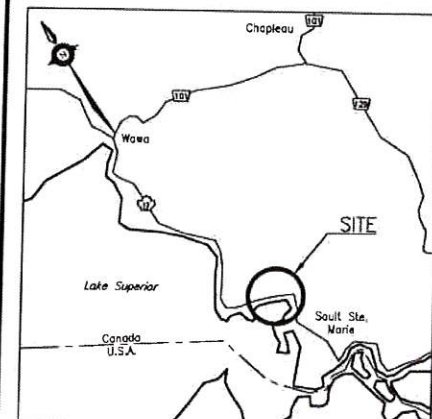


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



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HIGHWAY 17
15+818
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
15-01	198.2	5 198 035.6	273 218.6
15-02	201.6	5 198 031.8	273 204.3
15-03	201.1	5 198 016.9	273 205.4
15-04	195.7	5 198 007.3	273 189.6

NOTES-

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

GEOCREs No. 41K-103

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SEP	CHK -	CODE
DRAWN	AN	CHK SBP	SITE
STRUCT	LOAD	DATE	SEP 2016
DWG	1		

FILENAME: H:\Projects\10\3308\US Hwy 17 Gouda River\Reports & Memo\Foundations\Final\Culvert 15+818 Thru\Draw\Draw005-Plan.dwg
Culvert 15+818.dwg
PLOT DATE: 10/31/2016 9:33 AM

Appendix B

Record of Boreholes Sheets

19-5308-95



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

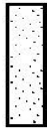


STRATA PLOT:

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



Boulders
Cobbles
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

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

MODIFIED UNIFIED SOIL CLASSIFICATION

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

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION








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

RECORD OF BOREHOLE No 15-01

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 15+818, Highway 17 Goulais River N 5 198 035.6 E 273 218.6 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML
 DATUM Geodetic DATE 2016.01.22 - 2016.01.23 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
198.2														
0.0	ROOTMAT (25 mm)		1	SS	4		198							
197.6	SAND with silt and gravel Loose Brown		2	SS	6									
0.6	FILL		3	SS	18		197							
196.4	SILTY SAND some gravel Loose to Compact Brown Moist		4	SS	55		196							
1.8	SAND with silt and gravel occasional cobbles Very Dense		5	SS	80									
			6	SS	79		195							
194.5			7	SS	100									
3.7	End of Borehole at 3.68 m Borehole Dry Upon Completion				25mm									

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

RECORD OF BOREHOLE No 15-02

1 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 15+818, Highway 17 Goulais River N 5 198 031.8 E 273 204.3 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.12.01 - 2016.12.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20	40	60	80	100	20	40	60		

201.6	SAND with gravel Brown Moist FILL		1	AS			201										11 82 7 (SI+CL)		
200.8																			
0.8	SAND with silt some gravel Compact Brown Moist FILL		2	SS	15		200												
			3	SS	13														
199.3	SAND some gravel Loose Brown Moist FILL		4	SS	6		199										12 84 4 (SI+CL)		
2.3																			
			5	SS	4		198												
197.5																			
197.5	ORGANICS (25mm)		6	SS	3														
4.1	SAND with silt Very loose						197										39 55 6 (SI+CL)		
197.0	Brown Wet																		
4.6	SAND with silt and gravel, occasional cobbles Compact to very dense Brown Moist to wet		7	SS	31		196												
			8	SS	100 /0mm														
							195												
			9	SS	61														
194.6	SILTY SAND, occasional wood, occasional organics Very Loose Grey Wet		10	SS	125		194										2 84 14 (SI+CL)		
7.0																			
					11	SS		31											
					12	SS		38		193									
			13	SS	21		192												

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 15-02

2 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 15+818, Highway 17 Goulais River N 5 198 031.8 E 273 204.3 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.12.01 - 2016.12.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)					
								20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			W _P W W _L				
Continued From Previous Page																
189.4 12.2	some wood some organics		14	SS	3		191								0 63 29 8	
								190								
			15	SS	4			189								
								188								
			16	SS	2			187								
184.8 16.8 184.2 17.4	SAND with silt some gravel Very loose to very dense Brown Wet some wood running sands occasional cobbles		17	SS	100		186									
								185								
			18	SS	13			184								9 5 21 65
DCPT driven to 23.8m							183									
							182									

Continued Next Page

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

RECORD OF BOREHOLE No 15-02

3 OF 3

METRIC

GWP# 545-00-00 LOCATION Culvert 15+818, Highway 17 Goulais River N 5 198 031.8 E 273 204.3 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.12.01 - 2016.12.01 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	W P	W	W L	WATER CONTENT (%)		
	Continued From Previous Page						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60						
177.8							181							
							180							
							179							
23.8	End of Borehole at 23.8 m Groundwater at 6.6 m						178							

RECORD OF BOREHOLE No 15-03

1 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 15+818, Highway 17 Goulais River N 5 198 016.9 E 273 205.4 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.01.13 - 2016.01.13 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
						WATER CONTENT (%)								
							20 40 60							
201.1	0.0	Sand with gravel Compact Brown Moist FILL		1	AS									
200.3	0.8	Sand with silt trace gravel Loose Brown Moist FILL												
				2	SS	6								
				3	SS	5								
				4	SS	4								
				5	SS	6								
196.5	4.6	SAND WITH SILT, trace organics Very loose Dark brown Wet		6	SS	3								
195.9	5.2	SAND WITH SILT trace gravel Compact to very dense Brown Wet		7	SS	26								
				8	SS	35								
				9	SS	80								
				10	SS	49								
				11	SS	49								
				12	SS	42								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 15-03

2 OF 2

METRIC

GWP# 545-00-00 LOCATION Culvert 15+818, Highway 17 Goulais River N 5 198 016.9 E 273 205.4 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SML
 DATUM Geodetic DATE 2016.01.13 - 2016.01.13 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _P	W	W _L		20	40	60	GR	SA	SI	CL	
SHEAR STRENGTH kPa																								
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE																								
WATER CONTENT (%)																								
Continued From Previous Page																								
190.8							191																	
10.3	SAND Compact to very dense Brown Wet		13	SS	12		190																	
				14	SS	27		189																
								188																
				15	SS	21		187																
								186																
			16	SS	31		185																	
							184																	
183.9			17	SS	73																			
17.2	End of Borehole at 17.2 m Groundwater at 6.46 m																							










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RECORD OF BOREHOLE No 15-04

1 OF 1

METRIC

GWP# 545-00-00 LOCATION Culvert 15+818, Highway 17 Goulais River N 5 198 007.3 E 273 189.6 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE Portable COMPILED BY SML
 DATUM Geodetic DATE 2016.01.23 - 2016.01.23 CHECKED BY FJG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)
195.7								20	40	60	80	100					
0.0	ROOTMAT (25 mm)		1	SS	9		195										
195.1	SAND with gravel, frequent cobbles Loose to very dense Brown Wet		2	SS	62												
0.6	SAND with silt some gravel, frequent to occasional cobbles Very Dense Brown Wet		3	SS	63		194										
			4	SS	52												12 78 10 (SI+CL)
			5	SS	157/ 229 mm		193										
192.7																	
3.0	End of Borehole at 2.97 m Groundwater at 1.83 m Well Measurements: depth (m) date 1.86 2016.01.24 1.91 2016.01.25 1.99 2016.02.19																

Appendix C

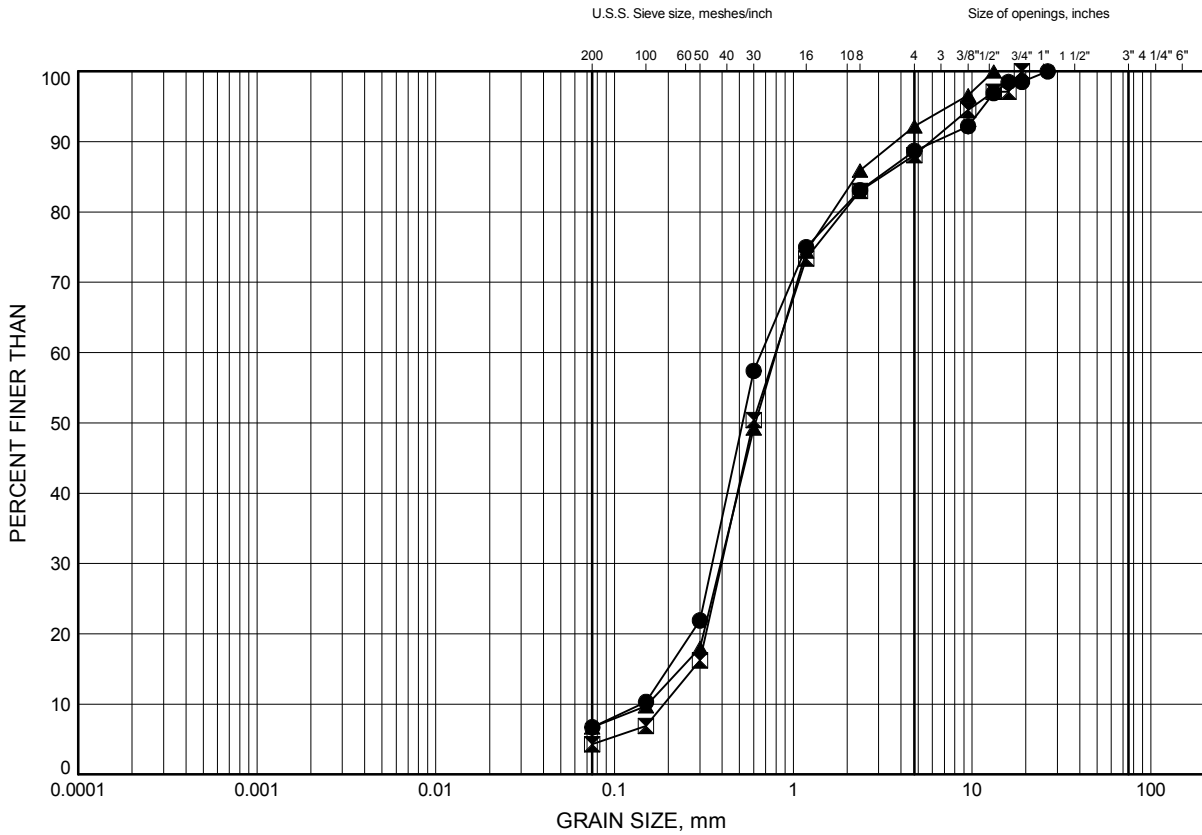
Laboratory Test Results

19-5308-95

Culvert 15+818, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 1

Embankment Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-02	1.07	200.53
⊠	15-02	2.59	199.01
▲	15-03	3.35	197.75

Date March 2016
 GWP# 545-00-00



Prep'd JAG
 Chkd. FJG

FIGURE 2

U.S.S. Sieve size, meshes/inch

Size of openings, inches

PERCENT FINER THAN

GRAIN SIZE, mm

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

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-01	2.13	196.07
☒	15-02	4.88	196.72
▲	15-02	7.92	193.68
★	15-02	10.97	190.63
⊙	15-03	5.64	195.46
⊕	15-03	7.92	193.18

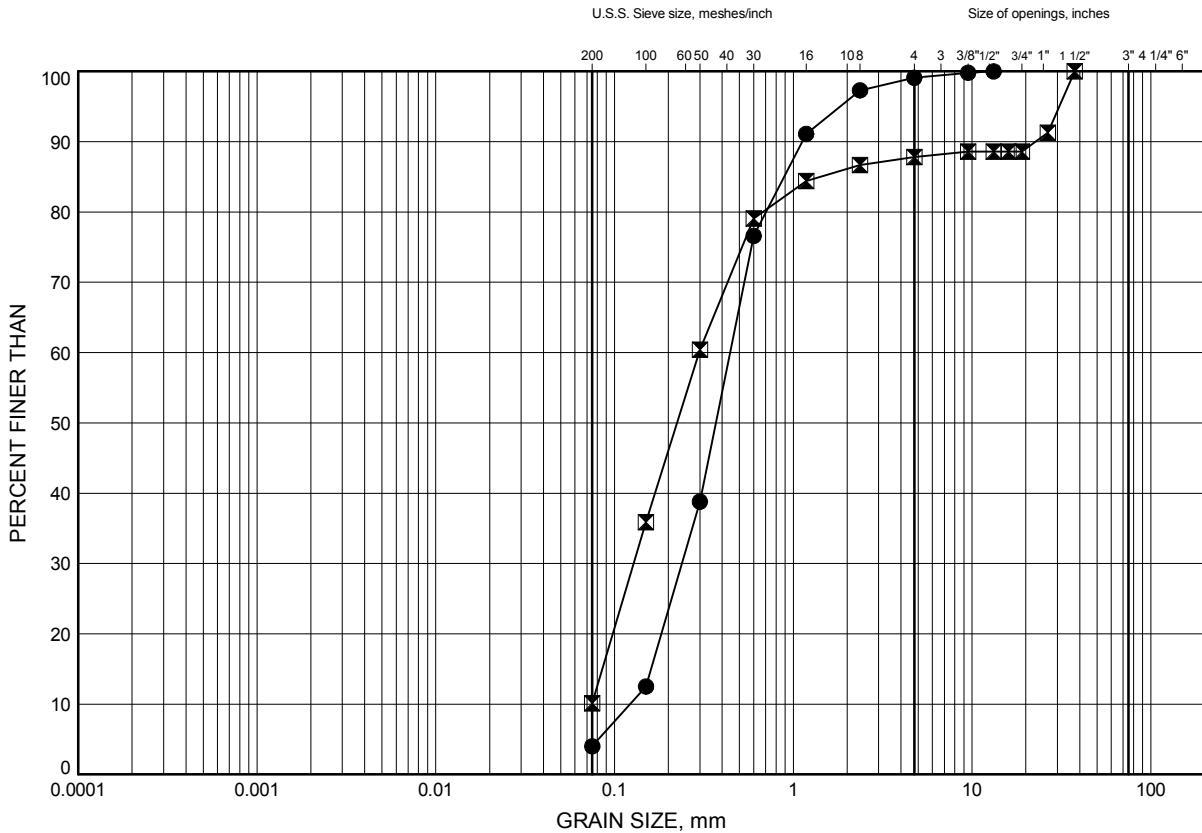


Prep'd JAG
Chkd. FJG

Culvert 15+818, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 3

Silty Sand, Sand with Silt, and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-03	15.54	185.56
⊠	15-04	2.13	193.57

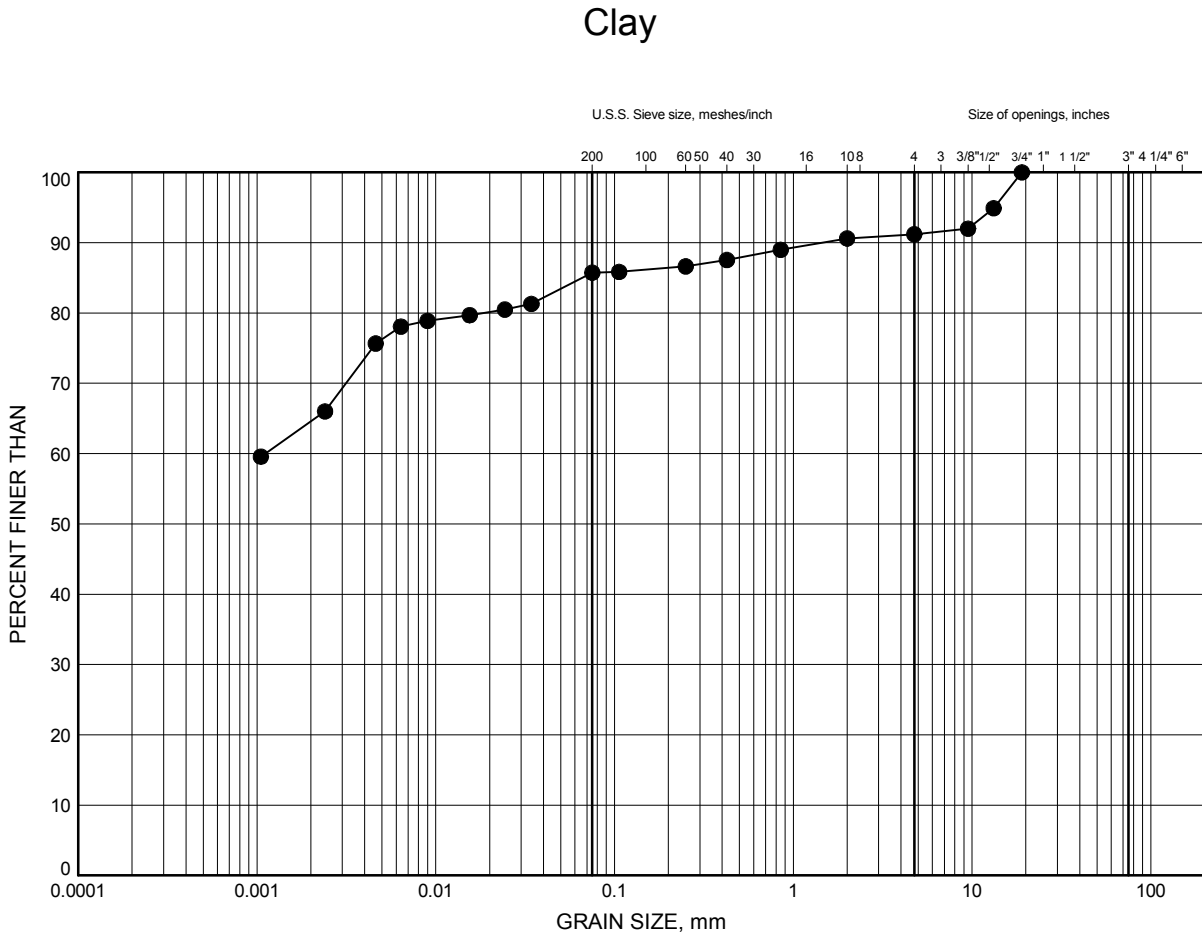
Date March 2016
 GWP# 545-00-00



Prep'd JAG
 Chkd. FJG

Culvert 15+818, Highway 17 Goulais River
GRAIN SIZE DISTRIBUTION

FIGURE 4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-02	17.07	184.53

Date March 2016
 GWP# 545-00-00

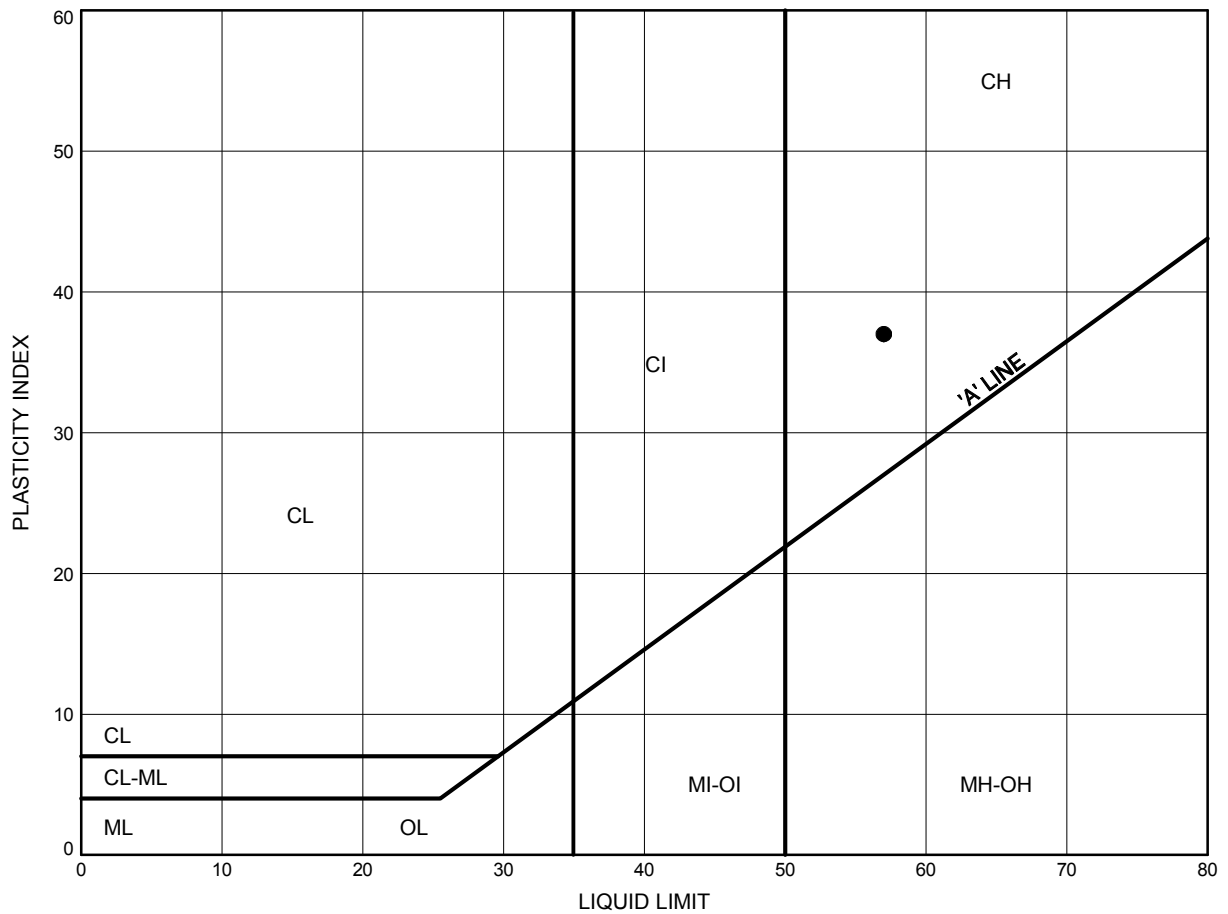


Prep'd JAG
 Chkd. FJG

Culvert 15+818, Highway 17 Goulais River

ATTERBERG LIMITS TEST RESULTS

FIGURE 5



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-02	17.07	184.53

Date March 2016
GWP# 545-00-00



Prep'd JAG
Chkd. FJG

Certificate of Analysis

Thurber Engineering Ltd.

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

Client PO:
Project: 19-5308-95
Custody: 27346

Report Date: 4-Feb-2016
Order Date: 29-Jan-2016

Order #: 1605367

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

Paracel ID	Client ID
1605367-01	BH15-23 SS11 (25'-27')
1605367-02	BH15-3 SS8 (20'-22')
1605367-03	BH15-32 SS3 (4'-6')
1605367-04	BH15-33 GS3 (2.5'-3.5')

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-2016

Project Description: **19-5308-95****Analysis Summary Table**

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	3-Feb-16	3-Feb-16
Conductivity	MOE E3138 - probe @25 °C, water ext	2-Feb-16	3-Feb-16
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	1-Feb-16	1-Feb-16
Resistivity	EPA 120.1 - probe, water extraction	2-Feb-16	2-Feb-16
Solids, %	Gravimetric, calculation	30-Jan-16	30-Jan-16

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-2016

Project Description: 19-5308-95

Client ID:	BH15-23 SS11 (25'-27')	BH15-3 SS8 (20'-22')	BH15-32 SS3 (4'-6')	BH15-33 GS3 (2.5'-3.5')
Sample Date:	07-Jan-16	18-Jan-16	18-Jan-16	21-Jan-16
Sample ID:	1605367-01	1605367-02	1605367-03	1605367-04
MDL/Units	Soil	Soil	Soil	Soil

Physical Characteristics

% Solids	0.1 % by Wt.	85.0	84.7	79.0	85.3
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General Inorganics

Conductivity	5 uS/cm	1400	138	114	108
pH	0.05 pH Units	6.14	6.11	5.34	5.70
Resistivity	0.10 Ohm.m	7.17	72.4	87.8	92.3

Anions

Chloride	5 ug/g dry	747	73	61	14
Sulphate	5 ug/g dry	22	11	11	17

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-2016

Project Description: **19-5308-95**

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: 04-Feb-2016

Order Date: 29-Jan-2016

Project Description: **19-5308-95**

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	8.7	5	ug/g dry	8.4			2.5	20	
Sulphate	298	5	ug/g dry	335			11.5	20	
General Inorganics									
Conductivity	749	5	uS/cm	758			1.3	6.2	
pH	7.76	0.05	pH Units	7.79			0.4	10	
Physical Characteristics									
% Solids	77.8	0.1	% by Wt.	78.6			1.0	25	

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-2016

Project Description: **19-5308-95****Method Quality Control: Spike**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	10.3		mg/L	0.8	94.3	78-113			
Sulphate	41.8		mg/L	33.5	83.3	78-111			

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 04-Feb-2016

Order Date: 29-Jan-2016

Project Description: **19-5308-95**

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 – end of culvert



Photo 2: East side – end of culvert



Photo 3: Looking south at culvert crossing.



Photo 4: Looking north towards culvert crossing.



Appendix E

**Table E-1: Comparison of Construction Methodology Alternatives
NSSPs**

19-5308-95

Culvert Replacement
15+818 Tilley Township, Highway 17

Table E-1: Comparison of Construction Methodology Alternatives

Option	2. Open Cut, staged with roadway protection	5. Open cut, staged with minor driving lane widening	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 6 m. Large excavation quantities	Depth of excavation greater than 6 m. Large excavation quantities	Requires construction of entry and exit pits and access to toe of slope. Must maintain surface and groundwater control
Relative Cost	Moderate	Moderate	High to Moderate if combined with other sites
Risks & Consequences	Risk if oversized obstructions encountered		Very high risk if oversized obstructions are encountered. Risk if groundwater encountered, which can be reduced using closed face techniques Some risk of damage to pavement surface
Summary	Feasible	Feasible	Recommended

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 sheet pile 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. "

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

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

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

2. REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials
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Ontario Provincial Standard Specifications, Construction

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

Ontario Provincial Standard Specifications, Material

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

American Society for Testing and Materials (ASTM) International Standards

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

Canadian Standards Association Standards:

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

3. DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

Grouting: injection of grout into voids.

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

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

HDPE: high density polyethylene.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

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

4.02 Working Drawings

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

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

a) Plans, Elevations and Details:

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

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

b) Design Criteria:

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

c) Materials:

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

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

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

g) Monitoring Method:

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

4.03 Site Survey

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

4.04 Certificate of Conformance

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

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

commencement of each subsequent operation for each pipe installation:

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

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

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

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

5. MATERIALS

5.01 Product

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

5.02 Concrete

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

5.03 Concrete Reinforcement

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

5.04 Timber

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

5.05 Grout

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

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

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

Concrete pipe as per OPSS.PROV 1820.

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

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

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

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

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

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

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

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

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

5.07.02 Mill Certificates

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

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

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

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

5.08.02 Pipe Materials

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

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

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

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

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

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

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

5.09 Tunnelling Materials

5.09.01 Primary Liner

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

5.09.02 Secondary Liner

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

5.09.02.01 Concrete Pipe

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

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

5.09.02.02 High Density Polyethylene (HDPE)

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

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

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

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

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

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

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

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

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

6.02 Pipe Ramming Equipment

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

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

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

6.03 Directional Drilling Equipment

6.03.01 General

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

6.03.02 Drilling Rig

The directional drilling rig shall:

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

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling Equipment

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

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

7. CONSTRUCTION

7.01 General

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

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

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

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

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

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

7.01.12 Record Keeping

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

7.01.13 Testing

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

7.01.14 Management and Disposal of Excess Material

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

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

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

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

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

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

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

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

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

7.04 Directional Drilling Installation

7.04.01 General

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

7.04.02 Site Preparation

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

7.04.03 Pilot Bore

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

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

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

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

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

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

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

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

7.04.04 Drilling Fluid Fracture (Frac-Out)

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

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.0 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

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

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

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

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

7.05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

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

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

7.05.01 Tunnelling Method

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

7.05.02 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

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

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

7.06 Instrumentation Monitoring

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

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

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

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

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

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

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

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

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

7.07 Criteria for Assessment of Roadway Subsidence/Heave

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

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

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

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

9. MEASUREMENT FOR PAYMENT

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

10. BASIS OF PAYMENT

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

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

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

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

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

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

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