THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT C4 REPLACEMENT
HIGHWAY 404
SOUTH OF 19TH AVENUE
MARKHAM, ONTARIO
G.W.P. 2930-02-00

GEOCRES NO. 30M14-467

Report

to

WSP Canada Inc.

Date: February 23, 2018
File: 15786

103, 2010 Winston Park Drive, Oakville, ON L6H 5R7 T: 905 829 8666 F: 905 829 1166
thurber.ca

THURBER

TABLE OF CONTENTS

PART 1: FACTUAL INFORMATION

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

APPENDICES

THURBER

FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT C4 REPLACEMENT
HIGHWAY 404
SOUTH OF 19TH AVENUE
MARKHAM, ONTARIO
G.W.P. 2930-02-00

GEOCRES NO. 30M14-467

PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the replacement of an existing culvert (designated as C4) that crosses under Highway 404 at Station 22+043, south of 19th Avenue in the City of Markham, Ontario.

The purpose of this investigation was to explore the subsurface conditions at selected locations near the alignment, and based on the data obtained, to provide a borehole location plan, 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 the MTO Assignment Number 2016-E-0014.

For preparation of this report, reference has been made to culvert design information provided by WSP.

2. PROJECT AND SITE DESCRIPTION

The culvert is located on Highway 404, near Station 22+043, approximately 290 m south of 19th Avenue in Markham, Ontario. The general location of the proposed culvert replacement is shown on the key plan on the Borehole Locations and Soil Strata Drawing in Appendix D.

The existing culvert is a 1200 mm diameter corrugated steel pipe (CSP). The Highway 404 grade at the existing culvert is at approximate Elevation 241.0 m. The culvert invert is at approximate Elevation 238.2 m at the inlet and 237.7 m at the outlet. The existing culvert is reportedly in a good condition at the inlet but fair condition at the outlet. Holes were noted at the top of the culvert near the outlet, and corrosion of the culvert was observed.

The land use adjacent to this section of Highway 404 is largely rural and agricultural, although there is increasing residential and commercial development in recent years. The vegetation cover beyond the paved areas of the highway comprises grasses, bushes and stands of trees. Photographs of the culvert and surrounding area are presented in Appendix C.

The culvert site is located within the physiographic region known as Peel Plain. The topography is flat to gently undulating. The soil cover in the region typically comprises silty clay glacial tills with sand and silt layers. Shale bedrock of the Georgian Bay Formation is anticipated at an approximate depth of 50 m.

3. SITE INVESTIGATION AND FIELD TESTING

The borehole investigation and field testing program for this project was carried out from September 6 to 8, 2017, and consisted of drilling and sampling three (3) boreholes, designated as Boreholes C4-01 to C4-03, near the existing culvert alignment. The boreholes were terminated at 11.1 m depth (Elevations 229.5 to 230.5).

Lane closures and traffic control were carefully planned for drilling each borehole. Prior to commencement of drilling, utility clearances were obtained for all borehole locations.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D. Northing and easting coordinates at the borehole locations were obtained by Thurber using a Trimble GPS Pathfinder ProXRT, and the corresponding ground surface elevations were provided by WSP based on the project DTM survey. The coordinates and elevations of the boreholes are given on these drawings and on the individual Record of Borehole Sheets in Appendix A.

The boreholes were advanced using a truck-mounted D-90 drill rig. Hollow stem augers were used to advance the boreholes, and soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with the Standard Penetration Test (SPT).

A member of Thurber's engineering staff supervised the drilling and sampling operations on a full-time basis. The supervisor logged the boreholes, visually examined the recovered soil samples, and transported them to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Standpipe piezometers were installed in boreholes near the inlet and outlet to permit monitoring of groundwater levels. The piezometers consisted of 25 mm and 50 mm PVC pipes with slotted screens. Upon completion, the boreholes were abandoned in general accordance with Ontario Regulation 903 amended by Ontario Reg. 372 (O.Reg. 903). Once the field investigation is completed, the piezometers will be decommissioned in general accordance with O.Reg. 903. The details of borehole completion are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole No.	Borehole Depth / Base Elevation (m)	Piezometer Tip Elevation (m)	Completion Details
C4-01	11.1/229.5	10.7/229.9	Borehole backfilled with a sand filter from 11.1 m to 7.0 m, bentonite holeplug from 7.0 m to 0.3 m, then cement to surface.
C4-02	11.1/229.8	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.3 m, cement to 0.1 m, then asphalt to surface.
C4-03	11.1/230.5	10.4/231.2	Borehole caved to 10.4 m, backfilled with sand filter from 11.1 m to 6.7 m, bentonite holeplug and auger cuttings from 6.7 m to 0.3, then cement to surface.

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out in accordance with MTO and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets and on the accompanying figures in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A for details of the encountered soil stratigraphy. A soil profile along the culvert alignment is presented on the "Borehole Locations and Soil Strata" drawing in Appendix D. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations.

In general, the subsurface conditions encountered in the boreholes consist of a pavement structure and silty clay embankment fill overlying native silty clay till deposits, which is underlain by sand at some locations. The groundwater level in the boreholes varied from 3.7m to 4.2 m depths.

More detailed descriptions of the individual stratum are presented below.

5.1 Pavement Structure

A pavement structure consisting of asphalt overlying granular fill materials was encountered in Boreholes C4-01 to C4-03. The asphalt thickness ranged from 125 mm to 150 mm.

The granular fill consisted of brown sand and gravelly sand ranging between 0.6 m and 1.0 m in thickness, with base elevations varying between 239.5 and 240.8.

An SPT 'N' value measured in the gravelly sand fill was 24 blows per 0.3 m of penetration indicating a compact state. Measured moisture contents of the cohesionless fill ranged from 2 percent to 12 percent.

The results of a grain size distribution analysis carried out on a sample of this cohesionless fill is presented on the Record of Borehole Sheets included in Appendix A and on Figure B1 of Appendix B. Results of the gradation testing are summarized below:

Soil Particles	Percentage (%)
Gravel	21
Sand	54
Silt	16
Clay	9

5.2 Silty Clay Embankment Fill

The surficial sand fill was underlain by cohesive embankment fill at all three borehole locations. This cohesive fill was encountered at depths ranging from 0.8 m to 1.1 m. This fill consisted of brown to grey silty clay with sand and trace gravel. The silty clay fill ranged from 2.2 m to 3.0 m in thickness and extended to depths ranging from 3.0 m to 4.1 m (Elevations 238.6 to 236.5).

SPT 'N' values recorded in the silty clay fill ranged from 6 to 24 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. Measured moisture contents of samples of the silty clay fill varied between 10 percent and 23 percent.

The results of grain size distribution analyses carried out on two samples of this cohesive fill are presented on the Record of Borehole Sheets included in Appendix A and on Figure B2 of Appendix B. The results of the gradation testing are summarized below:

Soil Particles	Percentage (%)
Gravel	0 to 1
Sand	35 to 39
Silt	36 to 38
Clay	23 to 28

The results of Atterberg Limits tests conducted on samples of the silty clay fill are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B5 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Plastic Limit	12 to 20
Liquid Limit	26 to 36
Plasticity Index	14 to 16

The results of the Atterberg Limits testing indicate that this deposit has low to medium plasticity with group symbols of CL and CI.

5.3 Silty Clay Till

Underlying the silty clay fill at all three borehole locations was a deposit of brown to grey native silty clay till with sand, containing trace gravel and occasional cobbles. This till was encountered at depths ranging from 3.0 m to 4.1 m. Sandy silt to sand interlayers were found embedded within the silty clay till (see Sections 5.4 and 5.5). The silty clay till was 3.5 m to 7.4 m in overall thickness, and extended to depths of 8.7 m and 10.4 m (Elevations 231.9 to 231.2) in Boreholes C4-01 and C4-03, respectively. Borehole C4-02 was terminated within the silty clay till at a depth of 11.1 m (Elevation 229.8).

SPT 'N' values recorded in the silty clay till ranged from 10 to 75 blows per 0.3 m of penetration indicating a stiff to hard consistency. An SPT 'N' value of 50 blows per 0.1 m of penetration was measured in Borehole C4-03, which inferred the presence of cobbles near Elevation 237.0. Measured moisture contents of samples of the silty clay till varied between 8 percent and 25 percent.

The results of grain size distribution analyses carried out on samples of the silty clay till are presented on the Record of Borehole Sheets included in Appendix A and on Figure B3 of Appendix B. The results of the gradation testing are summarized below:

Soil Particles	Percentage (%)
Gravel	0 to 3
Sand	5 to 36
Silt	37 to 48
Clay	23 to 48

The results of Atterberg Limits tests conducted on four samples of the silty clay till are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B6 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Plastic Limit	11 to 17
Liquid Limit	20 to 33
Plasticity Index	9 to 18

The results of the Atterberg Limits testing indicate that this deposit has low plasticity with a group symbol of CL.

Glacially derived soils inherently contain cobbles and boulders.

5.4 Sandy Silt Till

A 1.1-m thick layer of grey sandy silt till containing trace clay and trace gravel was encountered within the silty clay till layer in Borehole C4-01 and extended from 6.0 m to 7.1 m depth. Glacially derived soils inherently contain cobbles and boulders.

The SPT 'N" value recorded in the sandy silt till was 100 blows for less than 0.3 m of penetration indicating a very dense state. The measured moisture content of the sandy silt till was 9 percent.

5.5 Sand

A layer of grey sand containing trace to some silt and trace clay was encountered beneath the silty clay till at 8.7 m and 10.4 m depth in Boreholes C4-01 and C4-03, respectively. A layer of grey sand of approximately 1 m in thickness was found embedded within the silty clay till at 7.0 m depth in Borehole C4-02. Boreholes C4-01 and C4-03 were terminated within the sand layer at a depth of 11.1 m (Elevations 230.5 to 229.5).

SPT 'N' values recorded in the sand ranged from 15 blows to 39 blows per 0.3 m of penetration, indicating a compact to dense state. Measured moisture contents of samples of the sand varied between 13 percent and 19 percent.

The results of a grain size distribution analysis carried out on a sample of the sand is presented on the Record of Borehole Sheets included in Appendix A and on Figure B4 of Appendix B. The results of the gradation testing are summarized below:

Soil Particles	Percentage (%)
Gravel	0
Sand	86
Silt	13
Clay	1

5.6 Groundwater Conditions

Groundwater levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. Standpipe piezometers were installed in Boreholes C4-01 and C4-03 to permit longer term monitoring. Water levels measured in the standpipes and open boreholes are presented below.

Table 5-1. Groundwater Level Measurements

Borehole Number	Date	Groundwater Level		Comments
		Depth (m)	Elevation (m)	
C4-01	September 7, 2017	4.3	236.3	Open borehole
	September 24, 2017 October 23, 2017 February 15, 2018	3.9 3.7 3.3	236.7 236.9 237.3	Piezometer
C4-02	September 6, 2017	4.7	236.2	Open borehole
C4-03	September 8, 2017	6.2	235.4	Open borehole
	September 24, 2017 October 23, 2017 February 15, 2018	5.6 4.2 frozen	236.0 237.4 -	Piezometer

The values shown in Table 5-1 are short-term readings, and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation.

6. CORROSIVITY TEST RESULTS

A sample of the silty clay fill from each of Boreholes C4-01 and C4-03 were submitted for analytical testing of corrosivity parameters. The results of the analytical tests are shown in Table 6.1 below. The laboratory certificates of analysis are presented in Appendix B.

Table 6.1- Analytical Test Results

Parameter	Units (Soil)	Test Results	
		C4-01 SS 3 Depth 1.7 m	C4-03 SS 3 Depth 2.5 m
		(Soil Sample)	(Soil Sample)
Sulphide	%	<0.02	<0.02
Chloride	µg/g	930	360
Sulphate	µg/g	72	7.1
pH	-	9.09	8.22
Electrical Conductivity	µS/cm	884	397
Resistivity	Ohm.cm	1130	2520
Redox Potential	mV	231	285

7. MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. WSP provided the northing and easting coordinates and ground surface elevations.

Walker Drilling of Utopia, Ontario, supplied and operated a track-mounted D-90 drill rig to carry out the drilling, sampling and in-situ testing operations for the boreholes.

The drilling and sampling operations in the field were supervised on a full-time basis by Ms. Eckie Siu of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

Overall project management was provided by Ms. Rocio Palomeque Reyna, P.Eng. Interpretation of the field data and preparation of this report was completed by Dr. Nancy Berg, EIT. The report was reviewed by Dr. Sydney Pang, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER

THURBER ENGINEERING LTD.

Nancy Berg, Ph.D.
Geotechnical Engineer-in-Training

Sydney Pang, P.Eng.
Associate, Senior Foundations Engineer

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

THURBER

FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT C4 REPLACEMENT
HIGHWAY 404
SOUTH OF 19TH AVENUE
MARKHAM, ONTARIO
G.W.P. 2930-02-00

GEOCRES No. 30M14-467

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This section of the report presents interpretation of the geotechnical data presented in the factual information section and provides foundation recommendations for the replacement of the existing culvert (designated as C4) that crosses under Highway 404 at Station 22+043, south of 19th Avenue in Markham, Ontario. The design and installation of replacement culvert pipes by trenchless methods are discussed. It is understood that open cutting is currently not being considered.

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 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.

The subsurface stratigraphy revealed in the boreholes drilled near the existing culvert alignment generally consists of a pavement structure (asphalt, granular base/subbase) overlying embankment fill (firm to very stiff silty clay), which is underlain by native stiff to hard silty clay till. The existing ground surface at the borehole locations on the highway ranges from Elevations 240.6 to 241.6 m. Groundwater levels measured in two piezometers installed in the boreholes were 3.7 m and 4.2 m below ground surface.

The discussion and recommendations presented in this report are based on information provided by WSP to Thurber, and on the factual data obtained during the course of this investigation.

9. CULVERT REPLACEMENT

Available information indicates that the existing culvert consist of a 1,050 mm diameter corrugated steel pipe (CSP). The inlet (east) and outlet (west) invert levels are at approximate Elevations 238.2 and 237.7, respectively.

The existing culvert will be replaced due to corrosion. It is understood that the replacement culvert will consist of twin 900 mm diameter circular pipes. As part of the highway reconstruction, the median will be converted from an open ditch to a closed drainage system with tall wall and median sewer. This will likely occur after the new culvert installation. Based on the Thurber pavement design report, the northbound lanes will have a 50 mm grade raise. It is anticipated that the proposed pipe invert elevations would be similar to those of the existing culvert quoted above.

Current design information provided by WSP indicates that the new twin pipes will be located several metres to the south of, and parallel to, the existing pipe. It is understood that the existing culvert will be abandoned and grouted once the new twin culvert becomes operational.

9.1 Culvert Installation in Open Cut

Staged open excavation is technically feasible and generally carries lesser risk than the trenchless methods in terms of potential ground settlement. However, open cut construction would result in disruption to Highway 404 traffic flow amongst other logistics issues. Protection Systems (temporary shoring) and groundwater control will be required. This approach will require MTO approval and it is understood that the current design approach does not consider open excavation. Trenchless techniques are currently being considered for the culvert replacement.

Since open cutting is not considered at this time, foundation recommendations for culvert options such as concrete open footings or box sections were not developed in this report.

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can also be satisfied.

The new culvert pipes should be designed to resist external loadings including lateral earth pressures, weight of embankment fill, hydrostatic pressure, frost forces, traffic loadings and surcharges due to construction equipment.

9.2 Trenchless Methods

Consideration may be given to installing the replacement pipes by trenchless techniques provided that there is sufficient crown cover. Based on past MTO projects, a crown cover of 3.0 m between the top of pavement and the top of pipe, and 2.0 m between the underside of the pavement subbase and the top of pipe, are generally required to minimize the potential for pavement surface settlement and formation of sinkholes. In any case, a minimum crown cover of two (2) times the pipe diameter must be satisfied. The following table summarizes the crown cover for the proposed pipes under the various criteria.

Pipe Diameter (m)	Invert Elevation (m)	Crown Cover Below Top of Pavement (m)	Crown Cover Below Underside of Pavement (m)	Comments on Crown Cover
900	238.2 (inlet)	2.5	1.7	< 3 m below pavement top < 2 m below pavement u/s > 2 times pipe diameter
	237.7 (outlet)	2.0	0.9	< 3 m below pavement top < 1 m below pavement u/s > 2 times pipe diameter

A 900 mm diameter pipe placed at the existing invert elevations will not meet some of the above criteria. Based on the borehole information, there are risks of adverse impact on the pavement granulars at locations where the top of pipe would be less than 1 m below the base of the granulars. In order to reduce such risks, the following alternatives may be considered:

1) Lower the pipe invert elevations to meet the criterion.
2) Replace larger diameter pipes with multiple smaller diameter pipes that would sufficiently increase the crown cover.

3) Where the pipe alignment crosses under the travelled lanes of the highway, employ a trenchless technique in conjunction with a series of one-lane closures; this methodology would allow remedial measures to be implemented immediately should surficial distress including sinkhole formation be observed and/or settlements be detected from instrumentation monitoring results.

4) Construct the pipe crossings using staged open cutting.

All work must 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 F.

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

- Tunnelling - hand-mining
- Micro-tunnelling (MTBM)
- Horizontal directional drilling
- Pipe ramming
- Jack and bore

Selection of an appropriate trenchless method should be the responsibility of the Contractor and will depend upon the relative costs and risks associated with each method. The experience of the Contractor is of primary importance for trenchless installation. The Contractor must submit a detailed work plan, including the proposed methodology, maintenance of alignment, and disposal of cuttings, all in accordance with the NSSP in Appendix F.

Based on the available subsurface information, the replacement culvert pipes under Highway 404 will generally be installed through cohesive firm to stiff silty clay fill and the upper, stiff to very stiff portion of the silty clay till. Cobbles and boulders should be anticipated within the glacial till deposit.

Tunnelling (hand-mining) is not considered practical for this project due to the relatively small tunnel diameter and shallow crown cover.

Micro-tunnelling using a MTBM (with face pressure balance if required) may be used to advance the bore after which the pipe can be installed. Micro-tunnelling is technically feasible for the soil and groundwater conditions at this site.

Horizontal directional drilling procedures are not suitable for this culvert replacement since the method may encounter difficulties maintaining the required invert elevations of the pipe.

Pipe ramming involves advancing a liner (typically steel casing or sleeve) along the proposed alignment. Once the liner is in place, the new pipes may then be threaded through the liner and grouted in place. Should obstructions be encountered during installation, however, the potential of pipe mis-alignment would be increased.

Conventional jack and bore involves augering and jacking a steel liner in place, although direct jacking of concrete pipes is possible in some situations. The jack and bore technique is considered feasible for installing the culvert, but the equipment must be capable of excavating and advancing through cobbles and boulders and any other obstructions that may be present in the fill and glacial till materials. It is recommended that preference be given to using equipment with alignment adjustment capabilities.

From a foundations technical, constructability and risk management perspective, it is considered that micro-tunnelling carries relatively lower risks. Both jack and bore and pipe ramming carry a certain degree of risk associated with potential surface settlement due to the relatively shallow soil crown cover below the pavement. The suitability of these trenchless techniques depends on factors including soil types, groundwater conditions, equipment availability, contractor's expertise and experience. Relative advantages and disadvantages of these methods are summarized in in Appendix E.

In addition to the NSSP referenced above, it is recommended that the Contractor be alerted to the following points, either by a further NSSP or otherwise by inclusion in the Contract Documents in an appropriate manner:

- The fill materials and glacial till deposits may contain cobbles and boulders. The Contractor must be equipped to dislodge, remove and otherwise handle such obstructions at the tunnel face should it be required.
- The majority of the pipe installation will be carried out through silty clay fill and silty clay glacial till. The Contractor's equipment must be capable of advancing the pipes through these cohesive deposits.
- At locations where the pavement granulars or water-bearing sands and silts may daylight at the tunnel face, loss of ground due to sloughing or caving can occur in the borings. The Contractor's methodology must include means of handling potential sloughing of these soils and water seepage at the tunnel face.

A NSSP for the above is included in Appendix F.

Based on groundwater observations and measurements in the boreholes, groundwater seepage from the cohesive soils during installation of the pipe culvert crossing is anticipated to be minimal. It is anticipated that sumps and pumps should be adequate to handle groundwater and surface runoff entering the launching and receiving pit excavations. The Contractor is responsible for maintaining dry excavations during construction.

10. INSTRUMENTATION AND MONITORING PROGRAM

Instrumentation and monitoring for potential settlements on the highway will be required for trenchless construction methods.

The impact of the proposed installation on existing nearby structures and underground utilities should be assessed. A pre-construction condition survey should be carried out to document the existing condition of the highway pavement and assess the potential for damage to all facilities and underground services along the alignments of the trenchless crossings. Monitoring of the roadway surface and underground utilities should be carried out during construction.

A monitoring program and condition survey of the Highway 404 pavement in the proximity of the culvert replacement has been prepared in general accordance with MTO's Guidelines for Foundation Engineering - Tunnelling Specialty for Corridor Encroachment Permit Application.

Detailed specifications and drawing for the implementation of the monitoring program are presented in Appendix G.

11. TEMPORARY PITS AND ROADWAY PROTECTION

Temporary launching and receiving pit excavations at either end of the pipe crossing will extend through the pavement granulars, firm to very stiff silty clay fill into the native stiff to hard silty clay glacial till with sand and silt interlayers.

All temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario and local regulations. The fill and native soils at this site are classified as Type 3 soils under OHSA.

Where excavation for the pipe installation is located in close proximity to live traffic lanes or existing buried utilities, roadway protection (temporary shoring) will be required. Given the subsurface conditions, a braced soldier pile and wood lagging system may be considered as an option at this site. It is envisaged that a soldier pile should be embedded within the stiff to very stiff silty clay till below the fill. Such system will need to be implemented in conjunction with adequate groundwater control. It is anticipated that sump pumping will be required to maintain reasonably dry excavations throughout construction.

Design of the roadway protection system is the responsibility of the Contractor. The temporary shoring should be designed by a licensed Professional Engineer experienced in such designs, with consideration of adjacent traffic loads and any sloping retained surfaces. Protection systems should be provided as per OPSS.PROV 539, which should be included in the contract documents. Performance Level 2 corresponding to not more than 25 mm ground movement should be specified.

The parameters given below should be used for roadway protection design:

Soil Bulk Unit Weight	γ	=	20 kN/m^3
Soil Submerged Unit Weight (below gwl)	γ'	=	10 kN/m^3
Coefficient of Active Earth Pressure	K_a	=	0.33 (silty clay fill)
		=	0.31 (silty clay till)
Coefficient of Passive Earth Pressure	K_p	=	3.2 (silty clay till)

12. CORROSION POTENTIAL

The results of corrosivity testing conducted on two silty clay fill samples are included in Appendix B. Based on the test results, the following statements can be made.

- There is moderate to severe potential for corrosion on metals due to the relatively low resistivity values and high chloride contents. The effects of road de-icing salts should be considered when selecting the corrosion mitigation measures.
- There is low potential for sulphate attack on concrete from the surrounding silty clay fill due to low sulphate contents and slightly alkaline pH values. The effects of road de-icing salts should be considered when selecting the class of concrete.

13. CONSTRUCTION CONCERNS

Potential construction concerns that have been identified for this project include the following:

13.1 Loss of ground

Trenchless installations with relatively shallow soil crown cover below the highway top of pavement inherently include some risk of loss of ground into the bore. If it is significant, this loss of ground can create settlement of the pavement surface and safety hazards. Pipe horizontal alignment control is also important to confirm that the design culvert alignment remains intact. The Contractor's methodology selection must recognize this fact and take into consideration this inherent risk. Contingency plans should be in place to manage any adverse impacts on the highway.

Each of the feasible trenchless methods discussed in Section 9 above carries varying degree of risks of loss of ground. The Contractor is required to select a suitable method for culvert installation such that the ground settlement review and alert levels of 10 mm and 15 mm, respectively, stipulated in the instrumentation and monitoring program in Appendix G can be satisfied.

13.2 Obstructions

Glacial tills typically contain cobbles and boulders, and existing highway embankment fill may contain similar and other obstructions. The Contractor's equipment and methodology must be selected to handle such obstructions and successfully remove them without jeopardizing the highway. The selected trenchless installation methodology should be capable of mitigating potential pipe mis-alignments (horizontal and vertical) due to such obstructions.

13.3 Buried Utilities

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

14. CLOSURE

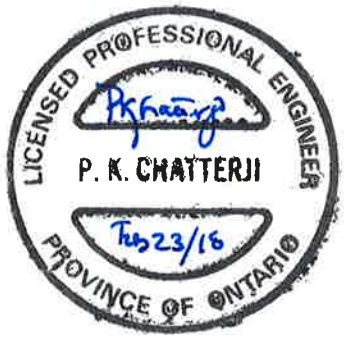
Engineering analysis and preparation of the foundation design report was conducted by Ms. Rocío Palomeque Reyna, P.Eng and Dr. Sydney Pang, P.Eng. Dr. P. K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.

THURBER

THURBER ENGINEERING LTD.

Rocío Palomeque Reyna, P.Eng.
Geotechnical Engineer

Sydney Pang, P.Eng.
Associate, Senior Geotechnical Engineer



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

THURBER

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

UNIFIED SOILS CLASSIFICATION

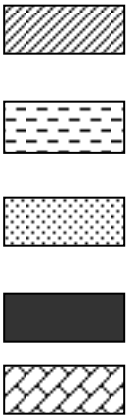
MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS



CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

DISCONTINUITY SPACING

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

TERMS

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

STRENGTH CLASSIFICATION

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

THURBER

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No C4-01 1 OF 2 METRIC

W.P. 2930-02-00 LOCATION SB N 4 864 076.9 E 313 769.6 ORIGINATED BY ES

HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP

DATUM Geodetic DATE 2017.09.07 - 2017.09.07 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
240.6	GROUND SURFACE						240				
0.0	**ASPHALT:** (125mm)										
0.1	Gravelly **SAND**, some silt, trace clay Compact Brown Moist (FILL)		1	GS					○		
239.5			1	SS	24		239		○		21 54 16 9
1.1	Silty **CLAY**, with sand, trace gravel Firm to Stiff Brown to Grey (FILL)		2	SS	12				○		Corrosivity testing
	occasional rootlets Wet		3	SS	6		238		○		0 39 38 23
236.5			4	SS	13	▼	237		○		
4.1	Silty **CLAY** with sand, trace gravel Hard Grey Moist (TILL)		5	SS	63		236		○		
234.6							235				
6.0	Sandy **SILT**, trace clay, trace gravel Very Dense Grey Moist (TILL)		6	SS	100/ .0.200		234		○		
233.5							233				
7.1			7	SS	41				○		
231.9							232				
8.7	**SAND**, some silt, trace clay Compact Grey Wet		8	SS	15		231		○		0 86 13 1

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

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

ONTMT4S MTO-15786.GPJ 2017TEMPLATE(MTO).GDT 2/22/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No C4-01 2 OF 2 METRIC

W.P. 2930-02-00 LOCATION SB N 4 864 076.9 E 313 769.6 ORIGINATED BY ES

HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP

DATUM Geodetic DATE 2017.09.07 - 2017.09.07 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	SAND, some silt, trace clay Dense Grey Wet						230				
229.5			9	SS	39				○		
11.1	END OF BOREHOLE AT 11.1m. BOREHOLE OPEN TO 10.7m AND WATER LEVEL AT 4.3m DEPTH UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.09.24	3.9	236.7
2017.10.23	3.7	236.9
2018.02.15	3.3	237.3

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE

$+^3$, $\times^3$: Numbers refer to Sensitivity

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

ONTMT4S MTO-15786.GPJ 2017TEMPLATE(MTO).GDT 2/22/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No C4-02 1 OF 2 METRIC

W.P. 2930-02-00 LOCATION SB N 4 864 090.7 E 313 783.8 ORIGINATED BY ES

HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP

DATUM Geodetic DATE 2017.09.06 - 2017.09.06 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
240.9	GROUND SURFACE										
0.0	**ASPHALT:** (150mm)										
0.2	**SAND**, trace gravel Brown Moist		1	GS							
240.1	(FILL)						240				
0.8	Silty **CLAY** with sand, trace gravel Very Stiff to Stiff Brown Moist (FILL)		1	SS	19						
			2	SS	16		239				1 35 36 28
			3	SS	12						
237.7							238				
3.2	Silty **CLAY**, with sand, trace gravel Stiff to Hard Grey Wet (TILL)		4	SS	13						
			5	SS	68	▽	236				3 35 39 23
			6	SS	37		235				
233.9							234				
7.0	**SAND**, trace silt Compact Grey Wet		7	SS	17						
232.9							233				
8.0			8	SS	34		232				
							231				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

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

ONTMT4S MTO-15786.GPJ 2017TEMPLATE(MTO).GDT 2/22/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No C4-02 2 OF 2 METRIC

W.P. 2930-02-00 LOCATION SB N 4 864 090.7 E 313 783.8 ORIGINATED BY ES

HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP

DATUM Geodetic DATE 2017.09.06 - 2017.09.06 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
229.8	Silty **CLAY** with sand Hard Grey Moist (TILL)		9	SS	37		230				0 5 47 48
11.1	END OF BOREHOLE AT 11.1m. BOREHOLE OPEN AND WATER LEVEL AT 4.7m DEPTH UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTIINGS TO 0.3m, CEMENT TO 0.1m THEN ASPHALT TO SURFACE.										

○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE

$+^3$, $\times^3$: Numbers refer to Sensitivity

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

ONTMT4S MTO-15786.GPJ 2017TEMPLATE(MTO).GDT 2/22/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No C4-03 1 OF 2 METRIC

W.P. 2930-02-00 LOCATION NB N 4 864 108.1 E 313 815.1 ORIGINATED BY ES

HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP

DATUM Geodetic DATE 2017.09.08 - 2017.09.08 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
241.6	GROUND SURFACE										
0.0	**ASPHALT:** (150mm)										
0.2	**SAND**, trace gravel Brown Moist (FILL)		1	GS			241		○		
240.8											
0.8	Silty **CLAY**, with sand, trace gravel Very Stiff Brown Moist (FILL)		1	SS	18				○		
			2	SS	24		240		○		
			3	SS	20		239		○		Corrosivity testing
238.6											
3.0	Silty **CLAY** with sand, trace gravel Stiff to Hard Brown to Grey Moist (TILL) Occasional cobbles		4	SS	10		238		⊖		0 36 37 27
			5	SS	50/.100		237		○		
			6	SS	75		236		○		
			7	SS	65		235		⊖		0 25 48 27
			8	SS	34		234		○		
							233				
							232				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15}\oplus\frac{5}{10}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No C4-03 2 OF 2 METRIC

W.P. 2930-02-00 LOCATION NB N 4 864 108.1 E 313 815.1 ORIGINATED BY ES

HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP

DATUM Geodetic DATE 2017.09.08 - 2017.09.08 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
231.2	Silty **CLAY** with sand, trace gravel Hard Grey Moist (TILL)						231				
10.4			9	SS	17				○		
230.5	**SAND**, trace silt Compact Grey Wet										
11.1	END OF BOREHOLE AT 11.1m. BOREHOLE OPEN TO 10.4m AND WATER LEVEL AT 6.2m DEPTH UPON COMPLETION Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.09.24	5.6	236.0
2017.10.23	4.2	237.4
2018.02.15	Frozen	-

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

THURBER

Appendix B

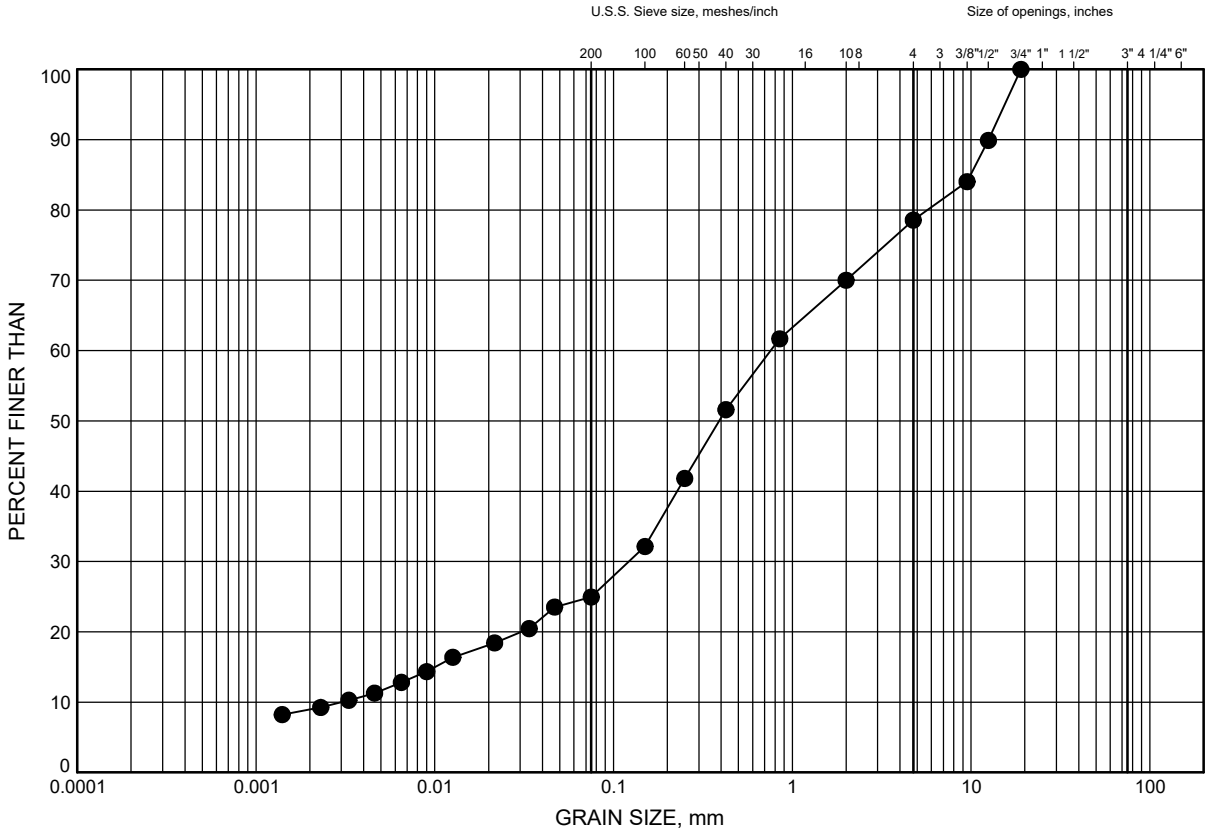
Geotechnical and Analytical Laboratory Test Results

HWY 404 Widening

GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C4-01	1.0	239.6

Date February 2018

W.P. 2930-02-00

THURBER

Prep'd AN

Chkd. RPR

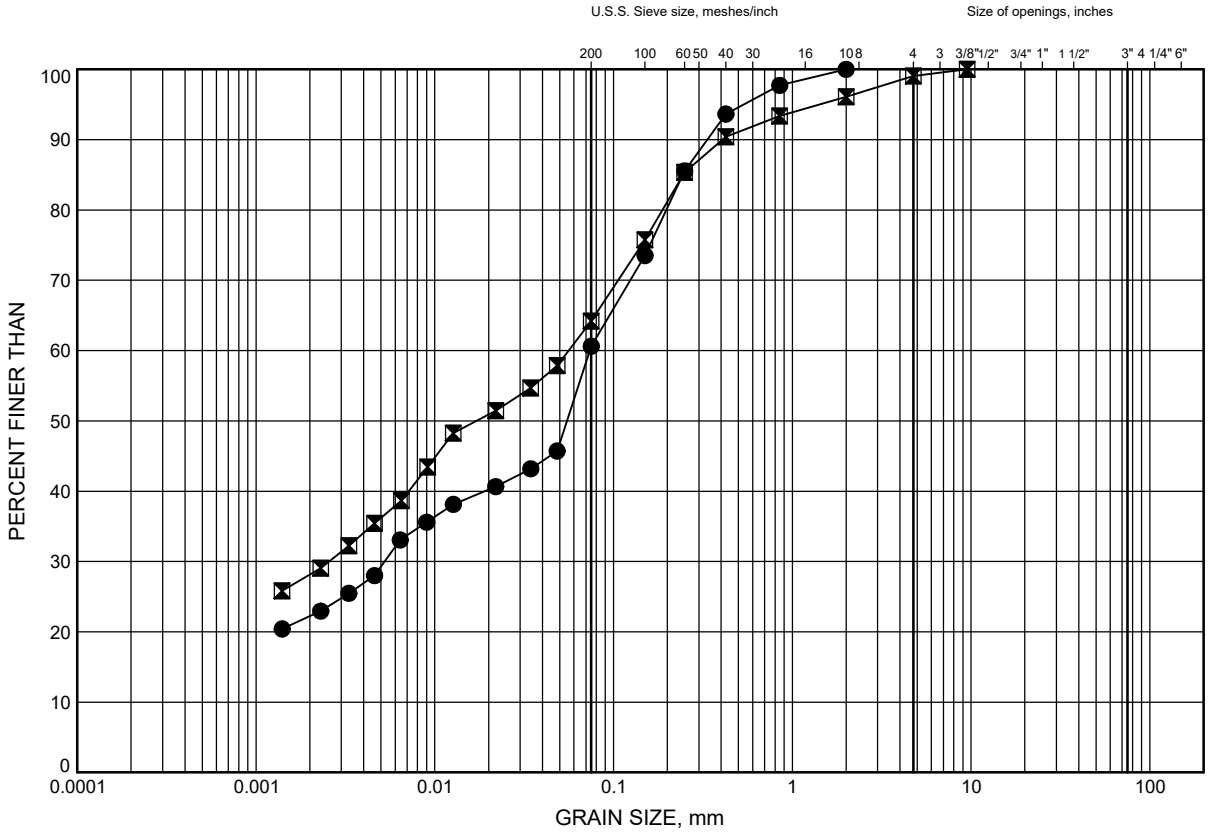
GRAIN SIZE DISTRIBUTION - THURBER MTO-15786.GPJ 2/20/18

HWY 404 Widening

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY with SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C4-01	2.5	238.1
⊠	C4-02	1.8	239.1

Date February 2018

W.P. 2930-02-00

THURBER

Prep'd AN

Chkd. RPR

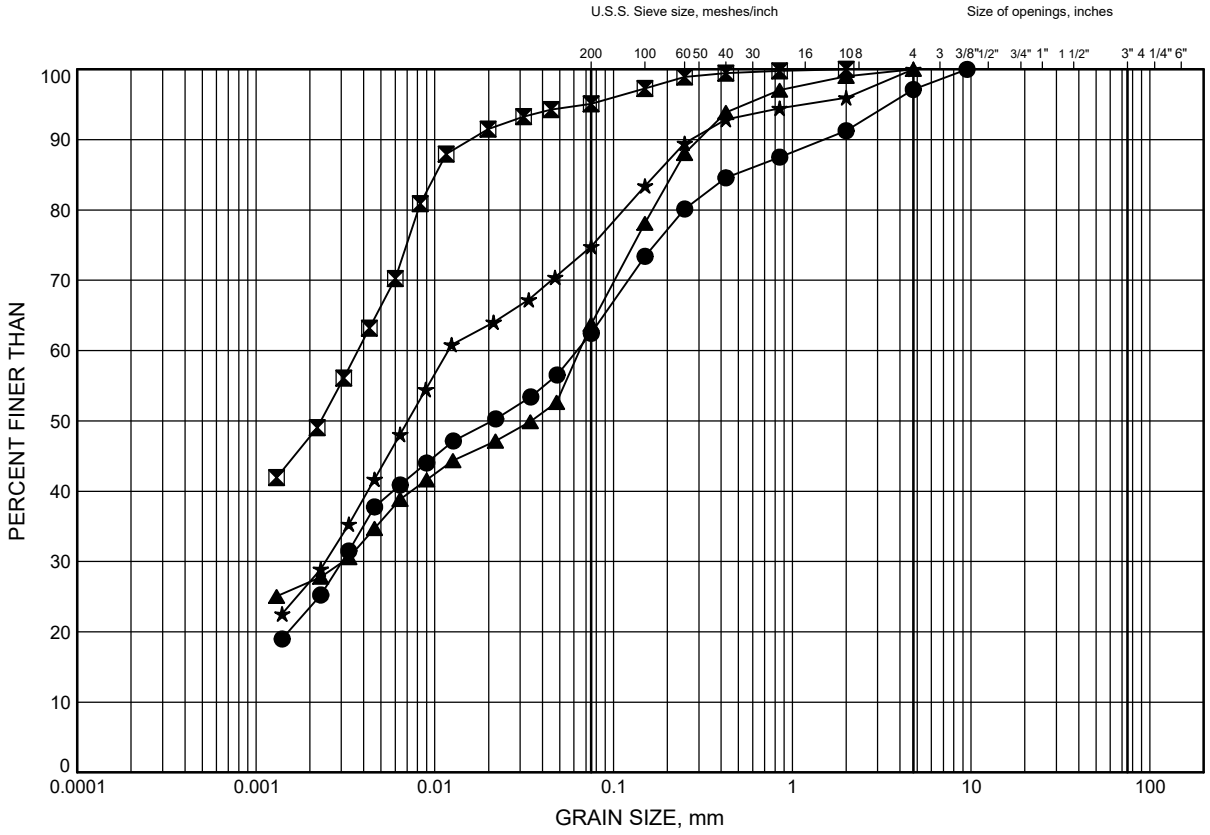
GRAIN SIZE DISTRIBUTION - THURBER MTO-15786.GPJ 2/20/18

HWY 404 Widening

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY with SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C4-02	4.8	236.1
⊠	C4-02	10.9	230.0
▲	C4-03	3.3	238.3
★	C4-03	7.8	233.8

Date February 2018

W.P. 2930-02-00

THURBER

Prep'd AN

Chkd. RPR

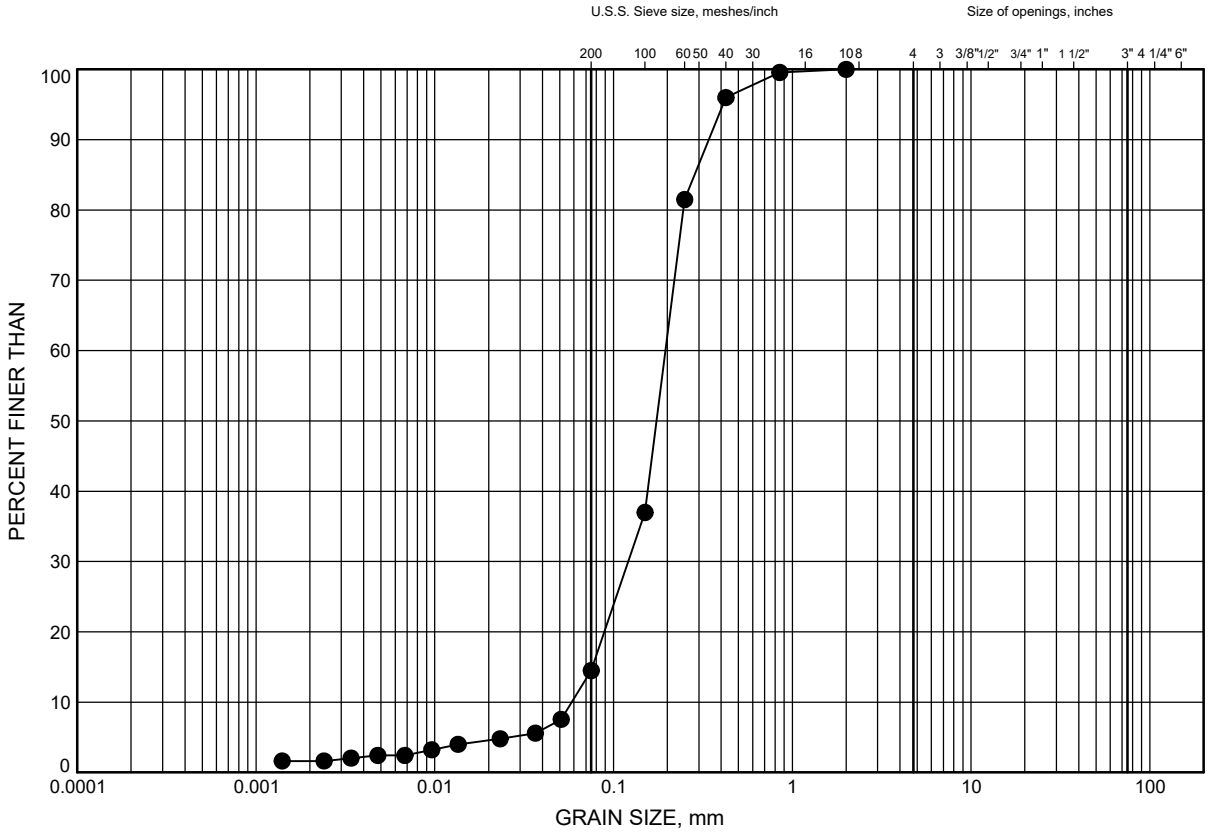
GRAIN SIZE DISTRIBUTION - THURBER MTO-15786.GPJ 2/20/18

HWY 404 Widening

GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C4-01	9.4	231.2

Date February 2018

W.P. 2930-02-00

THURBER

Prep'd AN

Chkd. RPR

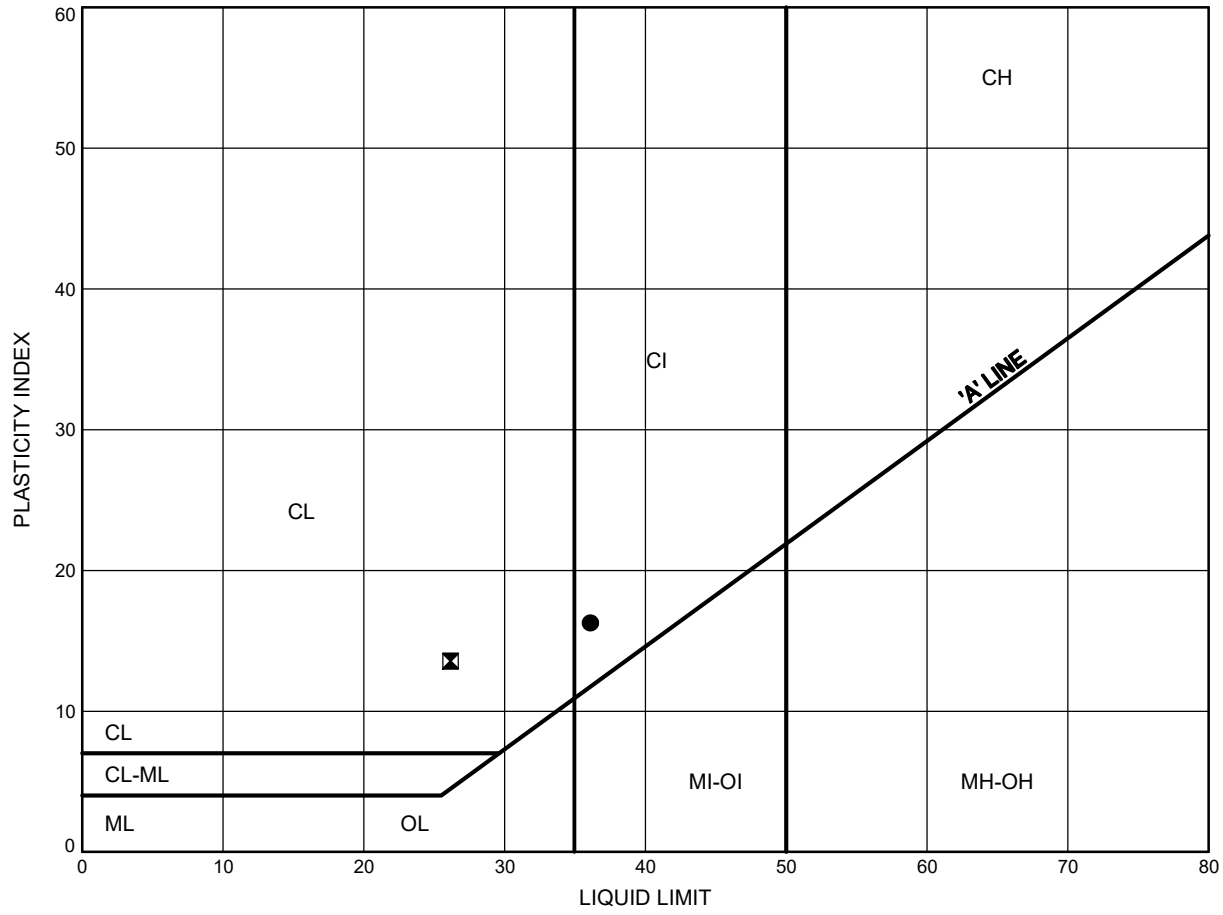
GRAIN SIZE DISTRIBUTION - THURBER MTO-15786.GPJ 2/20/18

HWY 404 Widening

ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty CLAY with SAND FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C4-01	2.5	238.1
⊠	C4-02	1.8	239.1

Date February 2018

W.P. 2930-02-00

THURBER

Prep'd AN

Chkd. RPR

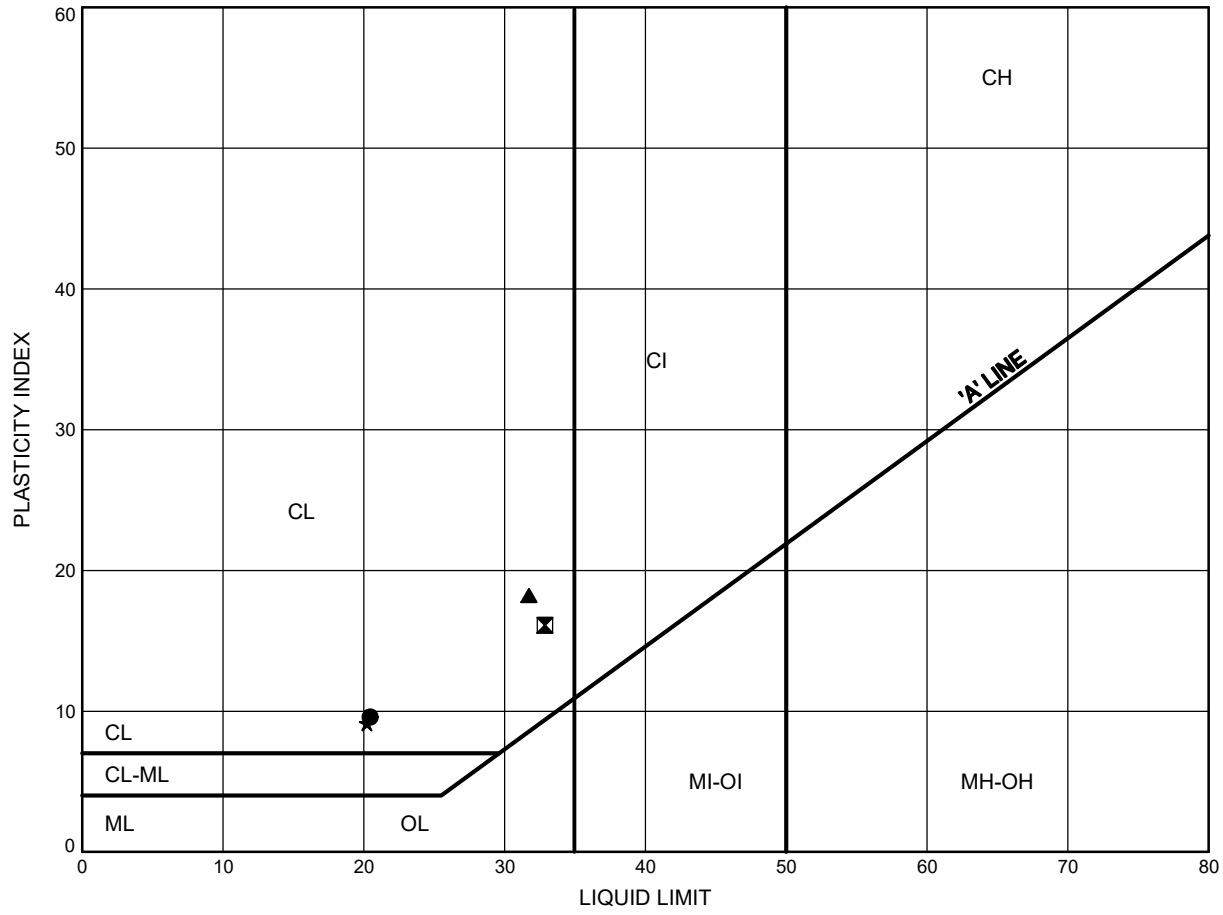
THURBALT MTO-15786.GPJ 2/20/18

HWY 404 Widening

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Silty CLAY with SAND TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	C4-02	4.8	236.1
⊠	C4-02	10.9	230.0
▲	C4-03	3.3	238.3
★	C4-03	7.8	233.8

Date February 2018

W.P. 2930-02-00

THURBER

Prep'd AN

Chkd. RPR

THURBALT MTO-15786.GPJ 2/20/18

FINAL REPORT

CA15233-OCT17 R1

15786

Prepared for

Thurber Engineering Ltd.

FINAL REPORT

CA15233-OCT17 R1

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	Thurber Engineering Ltd.	Project Specialist	Deanna Edwards, B.Sc, C.Chem
		Laboratory	SGS Canada Inc.
Address	103, 2010 Winston Park Drive Oakville, ON L6H 5R7.	Address	185 Concession St., Lakefield ON, K0L 2H0
Contact	Rocío Palomeque	Telephone	705-652-2000
Telephone	905-829-8666 x 263	Facsimile	705-652-6365
Facsimile		Email	deanna.edwards@sgs.com
Email	rreyna@thurber.ca	SGS Reference	CA15233-OCT17
Project	15786	Received	10/12/2017
Order Number		Approved	10/18/2017
Samples	Soil (4)	Report Number	CA15233-OCT17 R1
		Date Reported	10/18/2017

COMMENTS

Temperature of Sample upon Receipt: 17 degrees C
Cooling Agent Present: No
Custody Seal Present: No

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

SIGNATORIES

Deanna Edwards, B.Sc, C.Chem

TABLE OF CONTENTS

Client: Thurber Engineering Ltd.

Project: 15786

Project Manager: Rocío Palomeque

Samplers: ,

PACKAGE: **REG153 - 1.3 Other (ORP)** (SOIL)

L1 = REG153 / SOIL / COARSE - TABLE 2 - Agricultural/Other - UNDEFINED

L2 = REG153 / SOIL / COARSE - TABLE 2 - Industrial/Commercial - UNDEFINED

				Sample Number	5	6	7	8
				Sample Name	C7-02-SS2	C7-04-SS4	C4-01-SS2	C4-03-SS3
				Sample Matrix	Soil	Soil	Soil	Soil
				Sample Date	06/09/2017	05/09/2017	09/09/2017	08/09/2017
Parameter	**Units**	**RL**	**L1**	**L2**	**Result**	**Result**	**Result**	**Result**
1.3 Other (ORP)								
Chloride	µg/g	0.4			320	890	930	360

Client: Thurber Engineering Ltd.

Project: 15786

Project Manager: Rocío Palomeque

Samplers: ,

PACKAGE: **REG153 - Corrosivity Index** (SOIL)

L1 = REG153 / SOIL / COARSE - TABLE 2 - Agricultural/Other - UNDEFINED

L2 = REG153 / SOIL / COARSE - TABLE 2 - Industrial/Commercial - UNDEFINED

				Sample Number	5	6	7	8
				Sample Name	C7-02-SS2	C7-04-SS4	C4-01-SS2	C4-03-SS3
				Sample Matrix	Soil	Soil	Soil	Soil
				Sample Date	06/09/2017	05/09/2017	09/09/2017	08/09/2017
Parameter	**Units**	**RL**	**L1**	**L2**	**Result**	**Result**	**Result**	**Result**
Corrosivity Index								
Corrosivity Index	none	1			15.5	17.5	14.0	3.0
Soil Redox Potential	mV	-			292	271	231	285
Sulphide	%	0.02			0.02	0.02	< 0.02	< 0.02
pH	no unit	0.05			9.38	9.30	9.09	8.22
Resistivity (calculated)	ohms.cm	-9999			1560	872	1130	2520

QC SUMMARY

Anions by IC

Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-[ENV]IC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0265-OCT17	µg/g	0.4	<0.4	0	20	99	80	120	109	75	125
Sulphate	DIO0265-OCT17	µg/g	0.4	<0.4	2	20	98	80	120	99	75	125

Carbon/Sulphur

Method: ASTM E1915-07A | Internal ref.: ME-CA-[ENV]ARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	ECS0027-OCT17	%	0.02	<0.02	ND	20	109	80	120			

Conductivity

Method: SM 2510 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0213-OCT17	uS/cm	2	< 0.002	0	10	103	90	110	NA		

QC SUMMARY

pH

Method: SM 4500 I Internal ref.: ME-CA-[ENV]EWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0213-OCT17	no unit	0.05	NA	0		100			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

Multielement Scan Qualifier: as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

Duplicate Qualifier: for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Matrix Spike Qualifier: for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

LEGEND

FOOTNOTES

NSS Insufficient sample for analysis.
RL Reporting Limit.
↑ Reporting limit raised.
↓ Reporting limit lowered.
NA The sample was not analysed for this analyte
ND Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

-- End of Analytical Report --

SGS

Request for Laboratory Services and CHAIN OF CUSTODY

SGS Environmental Services - Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Toll Free: 877-747-7658 Fax: 705-652-6365
- London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361 Web: www.ca.sgs.com

No:

Page ___ of ___

Laboratory Information Section - Lab use only

Received By: Tammy Martensen
Received Date (mm/dd/yyyy): 10.12.17 (mm\dd\yy)
Received Time: 20 S
Received By (signature): [signature]
Custody Seal Present: ☐
Custody Seal Intact: ☐
Cooling Agent Present: ☐ No cooler
Temperature Upon Receipt (°C): 20,17,17,18
LAB LIMS #: Oct 15233

REPORT INFORMATION	INVOICE INFORMATION	PROJECT INFORMATION
Company: Thurber Eng.	☑ (same as Report Information)	Quotation #:
Contact: Rocio Palomeque	Company:	Project #: 15786 P.O. #:
Address: 103-2010 Winston Park Dr.	Contact:	Site Location/ID:
Phone: 905-829-8666	Address:	
Fax:	Phone:	
Email: rreyna@thurber.ca	Email:	

TURNAROUND TIME (TAT) REQUIRED

☑ Regular TAT (5-7days) — TAT's are quoted in business days (exclude statutory holidays & weekends). Samples received after 3pm or on weekends : TAT begins the next business day

RUSH TAT (Additional Charges May Apply) ☐ 1 Day ☐ 2 Days ☐ 3-4 Days

PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

Specify Due Date: Rush Confirmation ID:

DRINKING WATER SAMPLES (POTABLE WATER FOR HUMAN CONSUMPTION) MUST BE SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY

REGULATIONS

Regulation 153 (2011): ☐ Table 1 ☐ Table 2 ☐ Table 3 ☐ Table ___ ; ☐ Res/Park ☐ Ind/Com ☐ Agri/Other ; Soil Texture: ☐ Coarse ☐ Medium ☐ Fine

Other Regulations: ☐ Reg 347/558 (3 Day min TAT) ☐ PWQO ☐ MMER ☐ CCME ☐ Other: ☐ MISA

Sewer By-Law: ☐ Sanitary ☐ Storm ; Municipality:

RECORD OF SITE CONDITION (RSC) ☐ YES ☐ NO

ANALYSIS REQUESTED: Corrosivity Package (Anx. 4SS)

	SAMPLE IDENTIFICATION	DATE SAMPLED	TIME SAMPLED	# OF BOTTLES	MATRIX	Corrosivity Package	COMMENTS: Field Filtered (F) Preserved (P)
1	C7-02 - SS2	Sep/6/17				✓	
2	C7-04 - SS4	Sep/5/17				✓	
3							
4	C4-01 - SS2	Sep/9/17				✓	
5	C4-03 - SS3	Sep/8/17				✓	
6							
7							
8							
9							
10							

Observations/Comments/Special Instructions

Sampled By (NAME): Signature: [signature] Date: Oct 13 2017 (mm/dd/yy) Pink Copy - Client

Relinquished by (NAME): Rocio Palomeque Signature: Date: __/__/__ (mm/dd/yy) Yellow & White Copy - SGS

Revision #: 1.0
Date of Issue: 01 June, 2014

THURBER

Appendix C

Selected Site Photographs

Photo 1: East end of culvert looking east

Photo 2: East end of culvert looking west

Photo 3: East embankment looking north

Photo 4: East embankment looking south

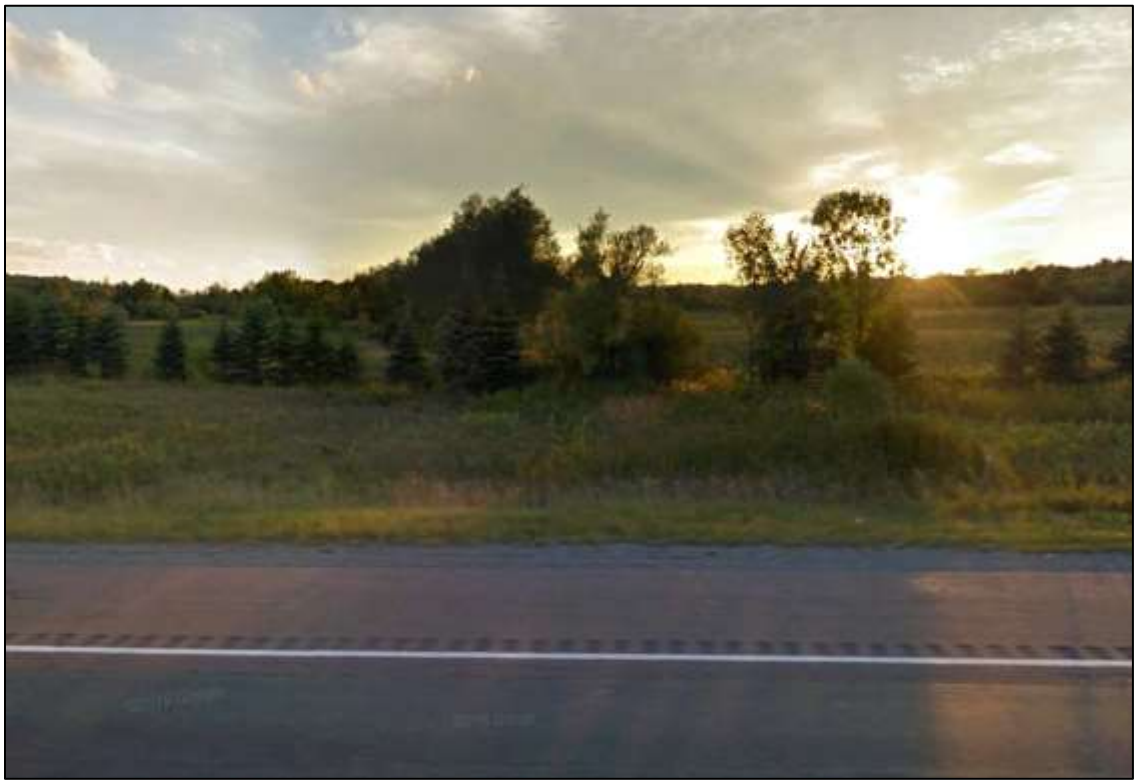


Photo 5: West end of culvert looking west

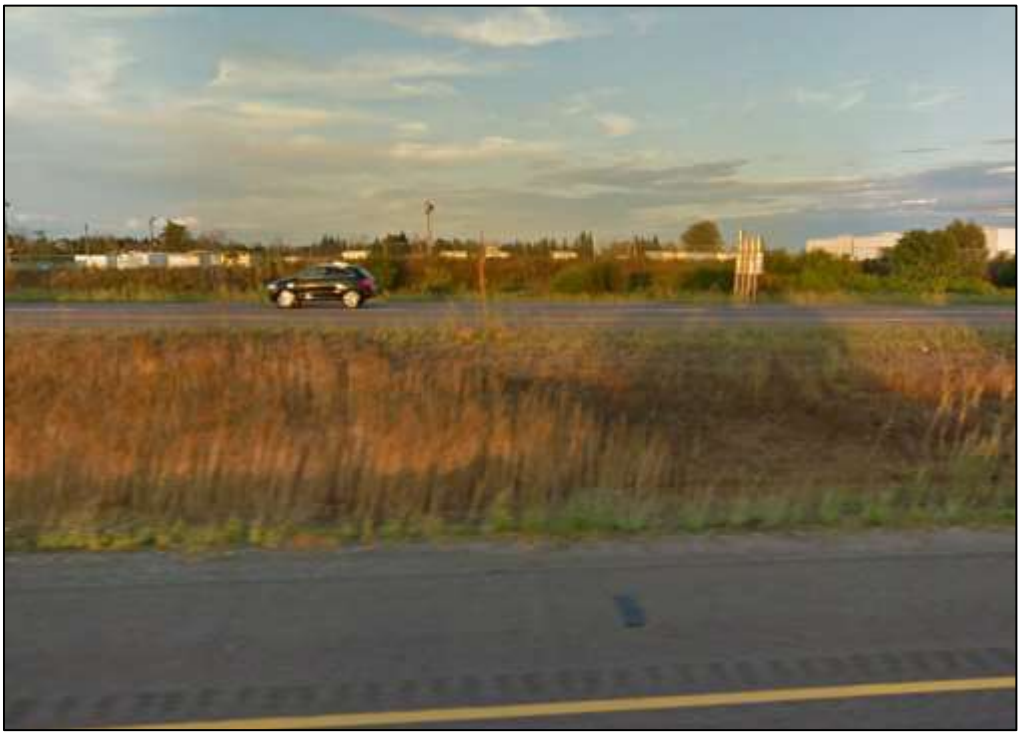


Photo 6: West end of culvert looking east

Photo 7: West embankment looking south

Photo 8: West embankment looking north

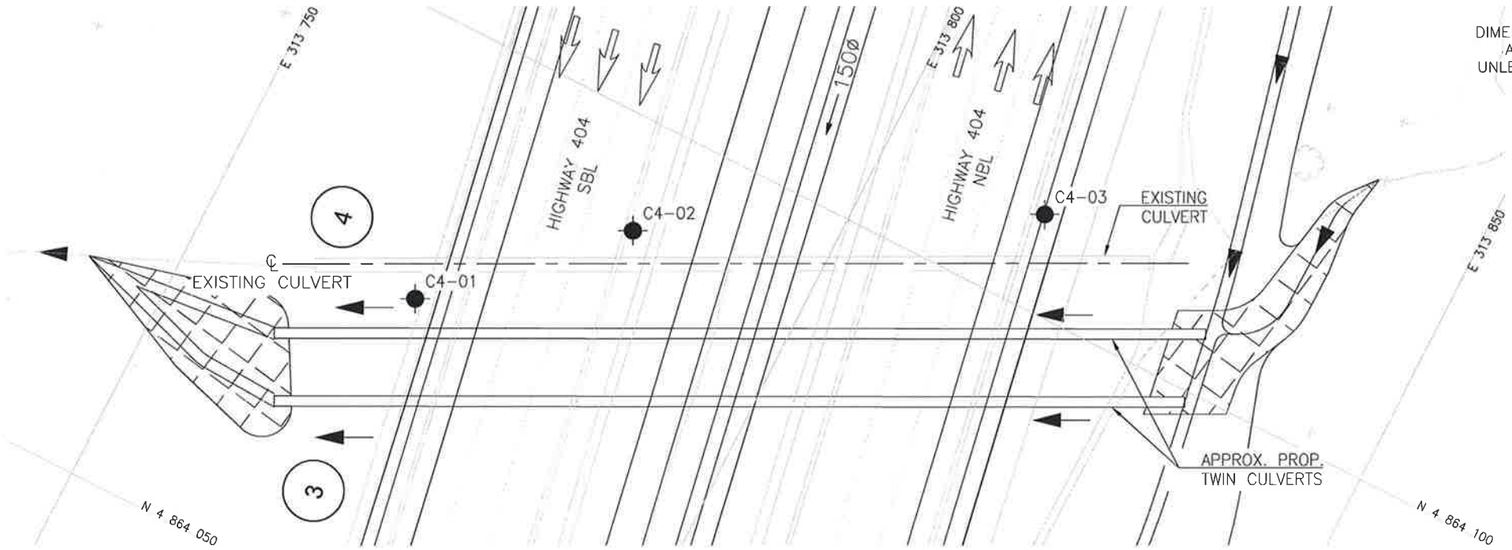
THURBER

Appendix D

Borehole Locations and Soil Strata Drawing

METRIC

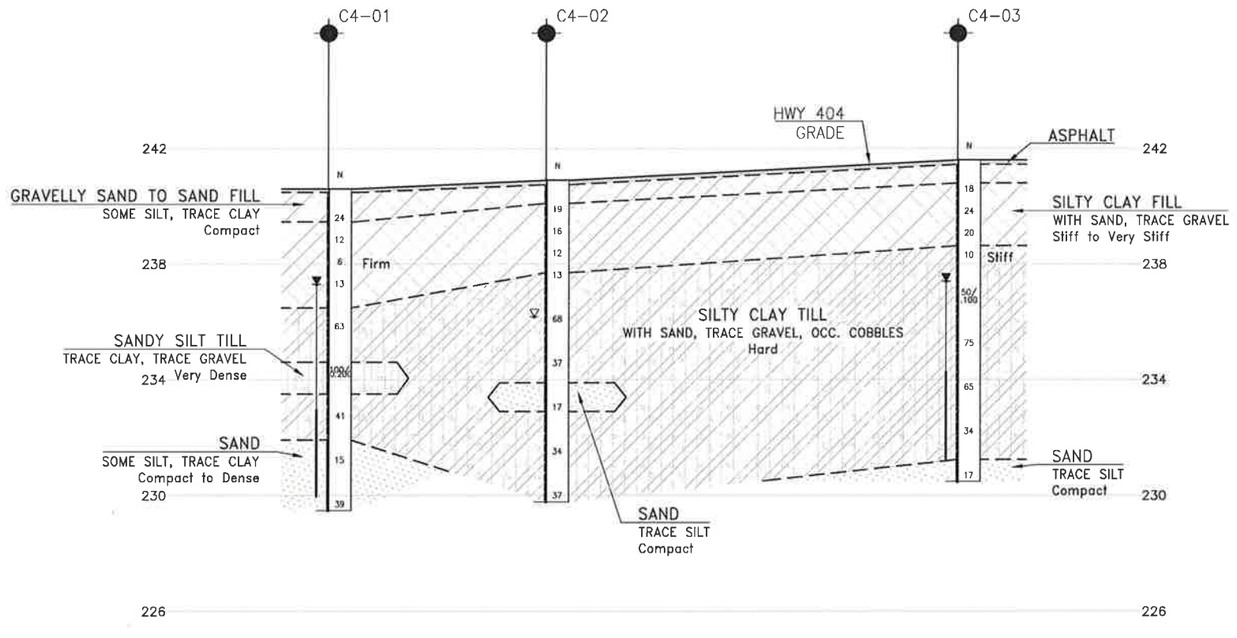
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



PLAN

10 0 10 20m

SCALE 1:500



PROFILE ALONG EXISTING CULVERT C4

10 0 10 20m H 1:500

4 0 4 8m V 1:200

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Feb 23/18
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
S. PANG
35314509
Feb. 23/18
PROVINCE OF ONTARIO

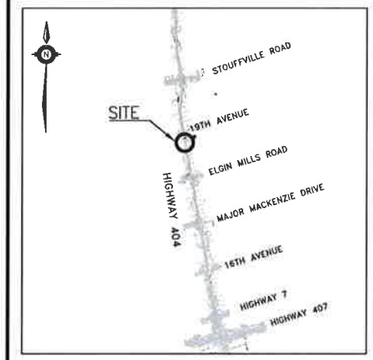
CONT No 2017-2045
WP No 2930-02-00

HIGHWAY 404 WIDENING
CULVERT C4
STATION 22+043
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

wsp

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
C4-01	240.6	4 864 076.9	313 769.6
C4-02	240.9	4 864 090.7	313 783.8
C4-03	241.6	4 864 108.1	313 815.1

-NOTES-

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

GEOCRES No. 30M14-467

REVISIONS			
DATE	BY	DESCRIPTION	
DESIGN RPR	CHK SKP	CODE	LOAD
DRAWN AN	CHK RPR	SITE	STRUCT

DATE FEB 2018

DWG 1

FILENAME: H:\Drafting\15000\15786\TED-15786-PLPR (Culvert-C4).dwg
PLOTDATE: 2/27/2018 2:22 PM

THURBER

Appendix E

Trenchless Methods Comparison

THURBER

Table E1 Trenchless Methods Comparison

Trenchless Method	Advantages	Disadvantages	Relative Risks and Cost Effectiveness *
Jack and Bore	• No uncased bore at any time • Equipment and crew readily available locally • Generally more suitable for clayey silt to silty clay soils with minimal water seepage	• Subject to misalignment due to oversized obstructions, although specialized equipment allows for alignment adjustments • Generally less suitable for sands and gravel with water seepage problems, and locations of high groundwater table where dewatering would be required.	• Medium to high risk • Cost effective if no oversized obstructions are encountered
Pipe Ramming	• Versatility in accommodating various subsurface conditions • Generally suitable for soils with water seepage problems • Dewatering is usually not required	• Minimal alignment control especially if oversized obstructions are encountered • May only advance steel casing/sleeve within which pipe is threaded through and grouted	• Medium to high risk • Cost effective if no oversized obstructions are encountered
Micro-tunnelling	• High precision alignment control is possible • Versatility in accommodating various subsurface conditions • Dewatering is usually not required • Concrete pipe (with appropriate reinforcement) may be installed as part of the tunnelling operation.	• If oversized obstructions are anticipated, cutter heads on the MTBM must be designed to accommodate the situation • Wet spoil management requires adequate space and access	• Medium risk • Cost effective if multiple trenchless installations are completed for the same contract

THURBER

Appendix F

List of Special Provisions

and

Suggested Wording for NSSP

THURBER

1. List of Special Provisions Referenced in this Report

- OPSS.PROV 539

2. Suggested Text for NSSP on Trenchless Installation.

The Contractor's attention is drawn to the following:

- The fill materials and glacial till deposits may contain cobbles and boulders. The Contractor must be equipped to dislodge, remove and otherwise handle such obstructions at the tunnel face should it be required.

- The majority of the pipe installation will be carried out through silty clay fill and silty clay glacial till. The Contractor's equipment must be capable of advancing the pipes through these cohesive deposits.

- At locations where the pavement granulars or water-bearing sands and silts may daylight at the tunnel face, loss of ground due to sloughing or caving can occur in the borings. The Contractor's methodology must include means of handling potential sloughing of these soils and water seepage at the tunnel face.

THURBER

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

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

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

2. REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials

Ontario Provincial Standard Specifications, Construction

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

Ontario Provincial Standard Specifications, Material

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

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin 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.

THURBER

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 OHSA 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.

THURBER

Appendix G

Instrumentation and Monitoring Program

THURBER

INSTRUMENTATION AND MONITORING PROGRAM **- Item No.**
PROPOSED CULVERT C4 REPLACEMENT
HIGHWAY 404
SOUTH OF 19th AVENUE, STATION 22+043

Special Provision

1 GENERAL

1.1 Scope

This special provision contains the requirements for the supply, installation and monitoring of the following instruments:

- Surface Monitoring Point (SMP)
- Settlement Rod (SR)

The instruments shall be installed along the centreline of the culvert alignment and in array. Each array consists of a group of instruments installed approximately perpendicular to the culvert alignment.

1.2 Purpose

The purpose of these instruments is to monitor settlements during installation of the replacement twin culverts.

The methodologies and rate of installation may need to be adjusted as a result of the instrumentation readings.

1.3 Contractor's Scope of Work

The Contractor shall be fully responsible to procure, install, protect, monitor, reduce and transmit data for all monitoring instruments and to decommission the instruments as described herein.

The required survey of all the instruments shall be carried out by the Contractor's qualified surveyors.

THURBER

1.4 Or equal

The term ‘or equal’ shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration.

1.5 Notification

The Owner, the Ontario Ministry of Transportation (MTO), the Contract Administrator (CA), and CA’s Geotechnical Consultant, shall be notified five days in advance of commencing the installation of instruments. All instruments shall be installed and their baseline readings (see Section 6.3) established to the satisfaction of all parties listed above not less than five days in advance of the installation operations.

1.6 Instrument Installation and Monitoring Requirements

The Contractor shall be prepared to install and monitor all instruments.

1.7 Drawings

Reference shall be made to Drawing 15786-C4-1 for instrument locations.

1.8 Subsurface Conditions

- The subsurface conditions at the site are described in Thurber’s Report titled: “Foundation Investigation Report, Culvert C4 Replacement, Highway 404, South of 19th Avenue, Ontario, G.W.P. 2930-02-00, by Thurber Engineering Ltd., Reference No. 15786”.

2 INSTALLATION

2.1 General

There are eighteen (18) surface monitoring points (SMP) and six (6) settlement rods (SR) to be installed at this site as shown on Drawing 15786-C4-1.

SMPs will be installed along the centreline of traffic lanes and / or paved shoulders in arrays of either three (3) instruments or one (1) single instrument. SRs will be installed on

the side slopes or at the toes of highway embankments along the proposed culvert centreline.

The number of monitoring points that will be installed at the culvert replacement are shown in the table below:

Approx. Station No.	Twin Pipes Diameter (mm)	Trenchless Length (m)	Depth of Pipe Crown Below Top of Pavement (m)	Number of Monitoring Points	
				SMP	SR
22+043	900	73	2.0 to 2.5	18	6

The array with three instruments will consist of the following:

- One (1) instrument installed at the proposed twin culvert centreline
- One (1) instrument installed at 1.5 m north of the proposed twin culvert
- One (1) instrument installed at 1.5 m south of the proposed twin culvert.

2.2 Instrument Location

The Contractor's surveyors shall accurately survey the location of each instrument to obtain coordinates and elevations.

2.3 Survey Benchmarks

The Contractor's surveyors shall identify or establish non-yielding survey benchmarks (BM) at the site in order to carry out elevation surveying and achieve the accuracy specified below.

2.4 Accuracy of Surveying for Elevations

Elevations shall be surveyed to an accuracy of $\pm$ 2 millimetres or better.

2.5 Materials and Equipment

The Contractor shall supply all materials and equipment required for installation of the instrumentation.

2.6 Protection of Instruments

All instruments shall be adequately protected by the Contractor such that they are not damaged during construction. Any instrument damaged directly or indirectly by the Contractor's work shall be immediately replaced by the Contractor at the Contractor's expense.

Instruments installed in the travelled portion of the roadway (lanes and shoulders) shall be protected to avoid puncturing of vehicle tires.

2.7 Installation Program

Instrument installation and baseline readings shall be completed before any trenchless installation operations.

3 SURFACE MONITORING POINT (SMP) - SUPPLY & INSTALLATION

3.1 General

3.1.1 Scope

This Section contains the requirements for the supply and installation of SMPs.

The purpose of SMP is to monitor settlement of asphalt paved surface. The ground movement readings shall assist in assessing the culvert performance and any need to modify the installation methodology as required. Settlement is measured by level surveying the SMPs with reference to stable, non-settling benchmarks.

3.1.2 General Procedure

SMPs shall be rigidly affixed so as not to move relative to the asphalt pavement surface to which they are attached.

3.1.3 Location

The locations of SMPs are shown on Drawing 15786-C4-1.

3.2 Materials

3.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the SMPs.

3.2.2 Steel Markers

The Contractor shall supply hardened steel markers with an exposed convex head, similar to surveyor's PK nails, treated or coated to resist corrosion. The steel markers shall have a minimum diameter of 12 mm and have sufficient length for anchoring in the pavement and to withstand the weather conditions and effects of traffic.

The exposed nail head shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment.

3.3 Installation

3.3.1 General

Traffic shall be managed by the Contractor using short term lane closures in accordance with the Ontario Traffic Manual (OTM), Book 7.

3.4 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

- SMP easting, northing and elevation;
- Dates of installation;
- Installation notes / sketches.

4 SETTLEMENT ROD (SR) - SUPPLY & INSTALLATION

4.1 General

4.1.1 Scope

This Section contains the requirements for the supply and installation of SRs.

The purpose of SR is to monitor the settlement of the ground and highway embankments along the proposed culvert alignment. The settlement readings shall assist in assessing the culvert performance and any need to modify the installation methodology as required. Settlement is measured by surveying the top of the rod with reference to stable, non-settling benchmarks.

THURBER

4.1.2 General Procedure

The SR shall consist of a 12 to 18 mm diameter rebar encased in a PVC pipe used as a friction reducing sleeve.

The assembly shall be placed in a drilled hole and backfilled with anchor grout and clean washed sand as shown on Insert A of the attached Drawing 15786-C4-1.

4.1.3 Location

The locations of SRs are shown on Drawing 15786-C4-1.

4.2 Materials

4.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the SRs.

4.2.2 Rod

The Contractor shall supply 12 to 18 mm diameter steel rebars in the required lengths in order to complete this installation.

The top end of each rod shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment.

4.2.3 Anchor

The Contractor shall supply concrete for anchoring the lower end of the steel rebar. The concrete shall be prepared in accordance with OPSS 1350 with a minimum compressive strength of 10 MPa.

4.2.4 Sand

The Contractor shall supply clean washed sand. The sand will be Sakcrete washed general purpose sand, or equal.

4.2.5 Friction Reducing Sleeve

The Contractor shall supply a friction reducing sleeve consisting of Schedule 40, 50 mm O.D. PVC pipe cut perpendicular to the axis of the pipe.

4.2.6 Protective Casing

The Contractor shall supply protective steel casings installed flush with the ground surface where the SRs are installed in shoulders that can be travelled by vehicles.

4.3 Installation

4.3.1 General

The Contractor shall install SRs as per Insert A on Figure 15786-C4-1 in addition to what is stated or emphasized below. Traffic control for instrument installation shall be managed by the Contractor, as required, using short term lane closures in accordance with the Ontario Traffic Manual (OTM), Book 7.

4.3.2 Rod

The rod shall be centred in the borehole.

4.3.3 Friction Reducing Sleeve

The friction reducing sleeve shall extend for the length of the rod above the anchor grout.

4.4 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

- SR location, easting and northing;
- Elevation of top of rod;
- Dates of installation;
- Installation notes / sketches.

5 DECOMMISSIONING OF INSTRUMENTS

5.1 General

The Contractor shall decommission all SMPs and SRs after the completion of the monitoring program as directed by CA and CA's Geotechnical Consultant.

6 MONITORING PROGRAM

6.1 General

The instrumentation monitoring services specified herein apply to all the SMPs and SPs

for this site. The requirements include data collection, reporting, data reduction and data transmission.

The Contractor shall carry out the monitoring program for this project. The required tasks include the following:

- Supply materials and equipment required for monitoring;
- Survey the instruments with no interference with the traffic on Hwy 404 and its ramps;
- Compile and reduce the survey data as described in Section 6.4.2;
- Transmit the settlement data and associated pipe installation / construction activities to CA, CA's Geotechnical Consultant and MTO;
- Notify CA, CA's Geotechnical Consultant and MTO of any required modifications to the construction procedures;
- Notify CA, CA's Geotechnical Consultant and MTO of any modifications of the original site conditions related to pipe installation or otherwise, including appearance of cracks on the pavement and shoulder, concrete barriers etc;
- Notify immediately CA, CA's Geotechnical Consultant and MTO if Review or Alert Levels have been reached or exceeded and follow the procedures outlined in Section 6.5.

6.2 Purpose

The purpose of this program is to monitor settlement of the paved surfaces and embankments at selected locations during the trenchless installation of the replacement twin culverts.

The rate and / or methodology of trenchless installation may need to be adjusted based on the instrumentation readings.

6.3 Reading Schedule and Frequency

The Contractor shall keep a complete record in electronic and hard copy formats of all instrumentation survey and associated data, including the location of the advancing face at the time of each survey.

Monitoring shall commence after the installation of an instrument. Monitoring is to continue as specified in this document and as required by CA and CA's Geotechnical Consultant.

The minimum monitoring frequencies along with the anticipated number of readings are given in Table 6.1 below. The monitoring frequency is the same for each individual instrument. Instruments shall be read more frequently as required by CA and CA's Geotechnical Consultant.

THURBER

Table 6.1 - Minimum Monitoring Frequency

STAGE	FREQUENCY	ANTICIPATED NO. OF READINGS PER INSTRUMENT (**)
Baseline Readings (*)	3 readings on 2 consecutive days	3
Just prior to start of culvert installation	Once	1
During culvert installation	A minimum of three (3) sets of readings be taken daily for all instruments located above a culvert being installed, provided that movements are within anticipated limits. Monitoring of movements is also required during work stoppages, such as during non-operation periods (off-shifts) or weekends.	Variable
After completion of culvert installation	After the end of installation of each culvert, all instruments located above the culvert shall be read weekly for the first month.	4

(*) Baseline Readings: Instrument elevation readings taken prior to culvert installation to provide a baseline against which all subsequent readings are compared to assess settlements of the ground.

(**) Number of readings may vary.

6.4 Specific Requirements

6.4.1 Surveying

The elevations of the instruments shall be surveyed to an accuracy of plus/minus two (±2) millimetres or better, and shall be reported to the nearest millimetre. Shoulder and lane closures for instrument readings are not permitted.

6.4.2 Data Recording and Data Reduction

For every instrument elevation reading the following information shall be recorded electronically in an Excel spreadsheet containing the following information:

- Date and time of the day
- Location of the advancing face (i.e. distance from launching point) at the time of data

recording
- Construction activities (e.g. culvert installation underway; weekend – no construction; boulder encountered at the advancing face of installation, etc)
- Pavement visual survey (e.g.: No visual pavement distress; 1 mm wide, 3 m long pavement crack parallel to west shoulder and close to instruments No. A, B and C, sketches and photos, etc.)
- Instrument Number
- Settlement Array Number
- Horizontal distance measured along the culvert alignment between the advancing face of installation and the instrument or array of instruments that contains the instrument being monitored
- Instrument elevation
- Instrument settlement

The settlement data shall be presented in X-Y charts as follows:

- Settlement versus Time for each instrument
- Settlement versus Distance from the advancing face of installation for each instrument
- Settlement profile for different dates along each of the culvert alignment
- Settlement profile for different dates along each of the settlement arrays

Reported information should be supplemented by sketches, diagrams and plots as necessary.

6.4.3 Data Transmission

All settlement data obtained on a particular day shall be reported in electronic format to CA, CA's Geotechnical Consultant and MTO not later than mid-day on the next calendar day. Any unusual movements deduced from the field data must be reported immediately before leaving the site.

6.5 Criteria for Assessment

The following settlement levels are to be observed:

Review Level – A maximum value of 10 mm relative to the baseline or zero readings. If the Review Level is exceeded, the Contractor shall immediately notify CA, CA's Geotechnical Consultant and MTO, and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Level from being reached. All construction work shall be continued such that Alert Level is not reached.

Alert Level – A maximum value of 15 mm relative to the baseline or zero readings. If the Alert Level is reached or exceeded, or lesser ground settlements cause or threaten to cause damage to utilities or the highway pavement, as indicated by monitoring instruments

or direct observation, the Contractor shall cease installation operation immediately and inform CA, CA's Geotechnical Consultant and MTO. No construction shall take place until all 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;
- CA, CA's Geotechnical Consultant and MTO deem it is safe to proceed.

7 CONTRACTOR'S RESPONSIBILITY FOR RESTORATION

Notwithstanding the monitoring program to assess the adequacy of the culvert installation method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving and fill placement) should movements or other surface distress occurs.

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

℄ PROPOSED TWIN CULVERT C3 & C4

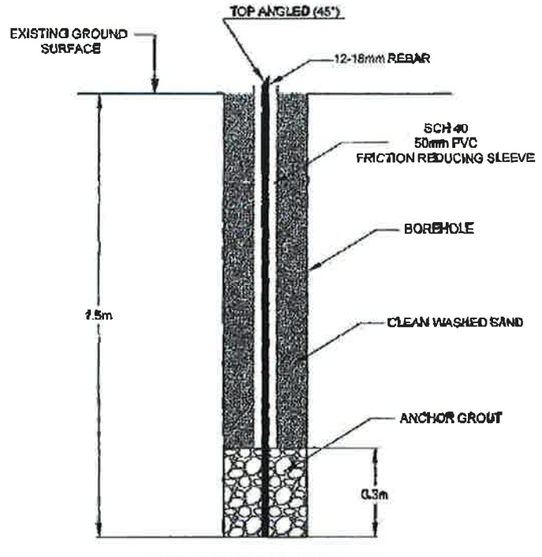
℄ EXISTING CULVERT C4

HIGHWAY 404 SBL

HIGHWAY 404 NBL

22+000

22+100



SETTLEMENT ROD (SR) DETAILS

PLAN

10 0 10 20m

SCALE 1:500

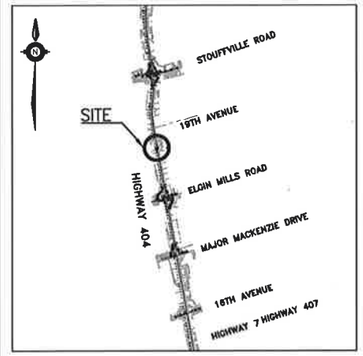
CONT No 2017-2045
WP No 2930-02-00

HWY 404 WIDENING S. OF 19TH AVE
PROP. CULVERT REPLACEMENT
STATION 22+043
INSTRUMENTATION & MONITORING PROGRAM

SHEET

wsp

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

× Surface Monitoring Point (SMP)

● Settlement Rod (SR)

NO	ELEVATION	NORTHING	EASTING

-NOTES-

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

GEOCRES No. 30M14-467

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
PROVINCE OF ONTARIO
Aug 23/18

LICENSED PROFESSIONAL ENGINEER
S. PANG
35314509
PROVINCE OF ONTARIO
Feb 23/18

REVISIONS			
DATE	BY	DESCRIPTION	
DESIGN SKP	CHK PKC	CODE	LOAD DATE FEB 2018
DRAWN AN	CHK SKP	SITE	STRUCT DWG 15786-C4-1

FILENAME: n:\Drafting\15000\15786\TD-15786-PLAN (Monitoring-C4).dwg
PLOTDATE: 2/27/2018 2:25 PM