



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 9 CULVERT REPLACEMENT
TOWNSHIP OF GREENOCK – STA 11+475, CULVERT C8
BROCKTON, ONTARIO
LATITUDE: 44.108167°, LONGITUDE: -81.206103°
Agreement No.: 3020-E-0004-09**

GEOCRES Number: 41A-254

Report

to

GHD Group

Date: September 9, 2022
File: 33249



TABLE OF CONTENTS

PART A: FACTUAL INFORMATION

1.	INTRODUCTION	1
2.	SITE DESCRIPTION	1
3.	INVESTIGATION PROCEDURES.....	2
4.	LABORATORY TESTING.....	3
5.	DESCRIPTION OF SUBSURFACE CONDITIONS	4
5.1	Topsoil	5
5.2	Embankment Fill.....	5
5.3	Silty Sand to Silt and Sand	5
5.4	Bedrock	6
5.5	Groundwater Conditions.....	7
6.	ANALYTICAL LABORATORY TESTING.....	7
6.1	Corrosivity and Sulphate Test Results	7
6.2	Provincial Water Quality Objectives (PWQO)	8
7.	MISCELLANEOUS	9

PART B: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8.	GENERAL.....	12
9.	CULVERT DESIGN CONSIDERATIONS.....	13
9.1	Culvert Rehabilitation	13
9.2	Culvert Replacement.....	14
9.3	Trenchless Methods.....	14
10.	SURFACE WATER AND GROUNDWATER CONTROL	17
10.1	Preliminary Dewatering Assessment for Launching and Receiving Pits.....	17
11.	INSTRUMENTATION AND MONITORING PROGRAM.....	20
12.	TEMPORARY PITS	20
13.	TEMPORARY PROTECTION SYSTEMS	21
14.	CORROSION POTENTIAL.....	21
15.	PROVINCIAL WATER QUALITY OBJECTIVES (PWQO) ANALYSIS	21
16.	CONSTRUCTION CONCERNS	22
16.1	Loss of ground	22
16.2	Obstructions.....	22
16.3	Variable Bedrock Surface Elevation	22
16.4	Buried Utilities	22
17.	CLOSURE	23



APPENDICES

Appendix A	Record of Borehole Sheets
Appendix B	Geotechnical and Analytical Laboratory Test Results
Appendix C	Site and Core Photographs
Appendix D	Tunnelman's Ground Classification System
Appendix E	Borehole Locations and Soil Strata Drawing
Appendix F	Comparison of Trenchless Methods
Appendix G	List of OPSSs and Suggested Wording for NSSP
Appendix H	Instrumentation and Monitoring Program



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PART A: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of a non-structural culvert, Culvert C8 at STA 11+475 in the Township of Greenock, on Highway 9 in Brockton, Ontario.

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

Thurber carried out the investigation as a sub-consultant to GHD, under the Ministry of Transportation, Ontario (MTO) Retainer Agreement No. 3020-E-0004 Work Order #9.

2. SITE DESCRIPTION

The existing culvert is located on Highway 9, approximately 4.4 km east of Greenock, Ontario. Details of the culverts are as follows:

Station and Township	Culvert Size and Type	Length and Depth of Culvert (m)	Invert Elevation at Inlet (m)	Invert Elevation at Outlet (m)
11+475 Greenock	600 mm dia. CSP	55.65 m long 8.3 m deep	297.300 north	294.663 south

The existing culvert allows flow of an existing ditch under the approximately 5 to 7 m high embankment fill. Based on visual observations, signs of slope instability or erosion of the



embankment was not present at the culvert site. The lands surrounding the culvert site is generally agricultural and the occasional residential dwelling. The site topography consists of rolling hills with gentle slopes that are vegetated with grass and sparsely spaced trees in places. Site photographs can be found in Appendix C.

Based on published geological information, the site area lies within the physiographic region known as the Teeswater Drumlin Field where the overburden is expected to be comprised of glaciolacustrine deposits of sands and gravels.

Based on the Ontario Geological Survey (OGS) Map MRD219 titled "Paleozoic Geology of Southern Ontario", the bedrock at the site is generally at a transition zone between the Amherstburg Formation and Bois Blanc Formation. Both the Amherstburg Formation and Bois Blanc Formation consists primarily of limestone and dolostone and is described as bituminous, cherty, and locally biohermal.

3. INVESTIGATION PROCEDURES

The field investigation and testing for this project was carried out on April 26, 27, and May 17, 2022, and consisted of drilling and sampling three boreholes, designated as Borehole C8-01 through C8-03, to depths between 4.9 m and 12.2 m (Elev. 293.2 m to 290.3 m). Boreholes C8-01 was advanced through the existing embankment on the eastbound paved shoulders, while Boreholes C8-02 and C8-03 were advanced in the ditches near the existing inlet and outlet, respectively.

The approximate locations of the boreholes from the investigation are shown on the Borehole Locations and Soil Strata Drawing included in Appendix E.

Utility clearances were obtained prior to mobilization to the site. The as-drilled borehole locations and elevations were surveyed using a Trimble Catalyst DA1 antenna with centimeter accuracy.

Details of the drilling program, including drilling depths, piezometer installation and completion details are summarized in Table 3.1 below. Groundwater levels were noted in the open borehole upon completion of drilling at Borehole C8-01 and C8-02. A 19 mm diameter piezometer were installed in Borehole C8-03 to allow for the measurement of groundwater levels. The installation details are illustrated on the Record of Borehole sheets provided in Appendix B. The monitoring well was subsequently decommissioned on May 16, 2022, in accordance with O.Reg. 903 at the completion of the field program.

Table 3.1 – Borehole Completion Details

Borehole	Borehole Depth / Base Elevation (m)	Monitoring Well Tip Depth / Elevation (m)	Completion Details
C8-01	12.2 / 290.3	None Installed	Backfilled with bentonite holeplug and auger cuttings to surface.
C8-02	4.9 / 293.2	None Installed	Backfilled with bentonite holeplug and auger cuttings to surface.
C8-03	5.4 / 290.3	2.3 / 293.4	19 mm diameter piezometer pipe with a 1.5 m slotted screen. Piezometer was decommissioned, and borehole backfilled with bentonite in general accordance with O.Reg. 903.

A truck-mounted Diedrich D120 and a track-mounted Diedrich D50 drilling rig were used to advance the boreholes through the overburden using hollow stem augers and rotary drilling techniques within HW casing. Bedrock was cored using HQ-sized coring equipment. Soil samples were obtained in the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in accordance with ASTM D1586.

All rock cores were logged and the Total Core Recovery (TCR), Solid Core Recovery (SCR), and Rock Quality Designation (RQD) were determined.

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

4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses, where appropriate. Selected rock cores were submitted to Geomechnica Inc. in Toronto, Ontario, to carry out Unconfined Compression testing. The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and on the figures included in



Appendix B.

One sample of the sand fill, and one sample of the native sand from Borehole C8-01, and one sample of groundwater from the piezometer installed in Borehole C8-03 were submitted to AGAT Laboratories, a CALA accredited analytical laboratory in Mississauga, Ontario, for analytical testing of corrosivity parameters and sulphate content to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the steel elements of the structure. The results of the analytical testing from the investigation are summarized in Section 6 and are presented in Appendix B.

In addition, Groundwater quality samples were collected from the monitoring well for the purpose of considering disposal options and potential treatment needs at a preliminary level.

The monitoring wells were developed on May 11, 2022, prior to any sampling or in-situ testing, by purging at least three well volumes. The purpose of purging was to remove excess sediment that may have entered the well during installation, to increase the representativeness of the natural groundwater in the well and to improve the transmissivity of the sand pack and well screen. Development was assessed to be completed based on the number of well volumes purged, and qualitative observations such as a decrease in turbidity of the pumped water.

Groundwater quality samples were collected from the monitoring well installed in Borehole C8-03 using low flow sampling techniques. The samples were preserved in prepared laboratory sample bottles, stored in a cooler on ice, and submitted to SGS Canada Inc., for analysis of metals and inorganics (M&I) and general chemistry (GC) parameters for comparison to Provincial Water Quality Objectives (PWQO).

A set of filtered samples was collected in addition to unfiltered samples, to provide a preliminary measurement of dissolved, and assumedly not physically filterable, parameter exceedances.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the Borehole Locations and Soil Strata Drawing included in Appendix E. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It must be recognized and expected that soil conditions may vary between and beyond the



borehole locations.

In general, the subsurface conditions encountered consisted of sand and gravel to sandy silt embankment fill, underlain by native silty sand to silt and sand overlying bedrock. Descriptions of the individual strata are presented below.

5.1 Topsoil

A 100 mm and 75 mm thick layer of topsoil was encountered at ground surface at Boreholes C8-02 and C8-03, respectively, at the toes of the embankment.

5.2 Embankment Fill

Embankment fill generally comprised of sand and gravel, trace silt to sandy silt, trace to some gravel and clay was encountered from ground surface at all boreholes. Depending on where the boreholes were advanced, the thickness of fill ranged from 0.6 m to 7.5 m, which was fully penetrated between Elev. 297.4 m and 295.0 m.

SPT 'N' values recorded in the embankment fill ranged from 6 blows to 47 blows for 0.3 m of penetration, indicating a loose to dense condition. Measured moisture content in the fill, typically ranged from 5% to 11%. Moisture content of 50% and 39% were measured at the toe of embankment in Boreholes C8-02 and C8-03, respectively.

The results of grain size analysis carried out on samples of the granular fill are presented on Figure B1 in Appendix B and summarized as follows:

Soil Particle	Embankment Fill
Gravel	10 to 21
Sand	32 to 44
Silt	38 to 39
Clay	7 to 9

5.3 Silty Sand to Silt and Sand

A deposit of silty sand, some gravel, trace clay to silt and sand, trace gravel and clay, containing occasional fractured limestone fragments was encountered underlying the embankment fill at all boreholes. The deposit is between 0.3 m and 1.9 m thick and was fully penetrated at depths that ranged from 1.0 m to 9.1 m, or between Elev. 297.1 m and 293.1 m).



SPT 'N' values recorded in the silty sand to sand and silt typically ranged from 11 blows to 38 blows per 0.3 m penetration, indicating compact to dense conditions. SPT 'N' values as high as 50 blows per less than 0.1 m of penetration were recorded prior to encountering bedrock. The measured moisture content of the sandy silt to sand ranged from 12% to 20%.

The results of grain size analyses conducted on selected samples of the cohesionless deposit are presented on Figure B2 in Appendix B and summarized as follows:

Soil Particle	Silty Sand to Silt and Sand
Gravel	2 to 20
Sand	37 to 42
Silt	31 to 47
Clay	5 to 12

5.4 Bedrock

Bedrock underlying the overburden was proven by coring at all borehole locations. The depths and elevations of the bedrock surface are summarized as below.

Borehole	Depth to Bedrock from Ground Surface (m)	Bedrock Surface Elevation (m)
C8-01	9.1	293.4
C8-02	1.0	297.1
C8-03	2.6	293.1

Based on the elevation at which the bedrock surface was encountered, the bedrock is gently sloping downwards from north to south. The bedrock encountered consisted of slightly weathered to fresh dolostone/limestone. Photographs of the bedrock core are provided in Appendix C. The rock core quality parameters are summarized below:

Rock Core Quality Parameters	Range	Average
Total Core Recover (TCR), %	92 to 100	99
Solid Core Recover (SCR), %	33 to 100	74
Rock Quality Designation (RQD), %	0 to 100	22

The Rock Quality Designation (RQD) varied from 0% to 100% but is typically between 0% to 30%, indicating a rock mass of very poor to poor quality. The results of Unconfined Compression (UC)



testing carried out on selected core samples of the bedrock are presented in Appendix B and are summarized below. Based on the test results, the bedrock is classified as strong (R4) to very strong (R5).

Sample	Depth (m)	Uniaxial Compressive Strength, UCS (MPa)
C8-01 Run #2*	11.99 to 12.19	81.9
C8-02 Run #2	2.95 to 3.10	167.1

Note: * Core sample is mislabelled as C8-07 Run #2 on Geomechanica's report titled Rock Laboratory Testing Results in Appendix B.

5.5 Groundwater Conditions

Details of the water level observed in the boreholes upon completion of drilling and in piezometer installed in a borehole are presented on the record of boreholes and summarized in Table 5-1 below.

Table 5.1 – Groundwater Measurements

Borehole	Date of Measurement	Groundwater Level (m)		Remark
		Depth	Elevation	
C8-01	May 17, 2022	7.6	294.9	In open borehole upon completion of drilling
C8-02	April 26, 2022	Dry	Dry	In open borehole upon completion of drilling
C8-03	May 11, 2022	1.0	294.7	From piezometer
	May 16, 2022	1.0	294.7	

These groundwater levels are short-term observations and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation during spring and after periods of significant or prolonged precipitation.

6. ANALYTICAL LABORATORY TESTING

6.1 Corrosivity and Sulphate Test Results

One sample of the sand fill, one sample of the native sand, and one sample of groundwater collected from the monitoring well was submitted for analytical testing of corrosivity parameters and sulphate. The analytical test results for the soil and groundwater samples are presented in Appendix B and are summarized in Table 6.1, and 6.2 below.



Table 6.1 – Analytical Test Results from Soil Samples

Borehole	C8-01	C8-01
Sample	SS9	SS11
Depth (ft, m)	20 to 22 6.1 to 6.7	25 to 27 7.6 to 8.3
Elevation (m)	296.1	294.6
Chloride (µg/g)	442	37
Sulphate (µg/g)	6	5
pH	8.18	8.32
Conductivity (mS/cm)	0.887	0.713
Resistivity (Ohm-cm)	1130	5780
Average Redox Potential (mV)	201	205

Table 6.2 – Analytical Test Results from Groundwater Sample

Monitoring Well	C8-03
Chloride (mg/L)	148
Sulphate (mg/L)	26600
pH	7.72
Conductivity (µS/cm)	1170
Resistivity (Ohm-cm)	855
Average Redox Potential (mV)	178

6.2 Provincial Water Quality Objectives (PWQO)

Testing of groundwater samples for comparison to the PWQO and Interim PWQO comprised analysis of general chemistry and selected metals and inorganic parameters. PWQO metals testing was carried out on an unfiltered ground water sample and a field-filtered sample. The results met the PWQO standards with the following exceptions:



Sample ID	Parameter	Units	Measured Concentration	PWQO	Interim PWQO
C8-03	<i>Arsenic</i>	<i>mg/L</i>	<i>0.011</i>	<i>0.1</i>	<i>0.005</i>
	<i>Dissolved Arsenic</i>	<i>mg/L</i>	<i>0.006</i>	<i>0.1</i>	<i>0.006</i>
	Cobalt	mg/L	0.0118	-	0.0009
	Copper	mg/L	0.045	-	0.005
	Iron	mg/L	24.8	0.3	-
	<i>Lead</i>	<i>mg/L</i>	<i>0.024</i>	<i>0.025</i>	<i>0.005</i>
	Phosphorous	mg/L	0.09	-	0.01 - 0.03
	Nickel	mg/L	0.039	0.025	-
	Silver	mg/L	0.0021	0.0001	-
	Thallium	mg/L	0.0004	-	0.0003
	Tungsten	mg/L	0.034	-	0.03
	Uranium	mg/L	0.007	-	0.005
	Vanadium	mg/L	0.054	-	0.006
	Zinc	mg/L	0.112	0.03	0.02

Notes:

Italics indicate the parameter has exceeded the interim PWQO but not the PWQO where both exist

“-“ indicates that the PWQO or interim PWQO standard does not exist

It should be noted that the results of the groundwater samples were representative at the time of sampling and provide a general understanding of groundwater quality under those conditions; however, the water quality may vary from the results obtained based on location, time, meteorological conditions, and on the selected construction and dewatering methods.

In addition, the extent of suspended solids in the groundwater or in water that is collected during construction dewatering (for example from a sump in an open excavation) will affect the concentrations of many parameters that may be regulated based on discharge location, particularly metals. The value of testing groundwater quality during the investigation is primarily to identify the types of contaminants that may need to be managed, the extent to which they are dissolved and therefore unlikely to be filtered by physical means alone, and the presence of anthropogenic contaminants that are listed in the given discharge criteria that may require specific treatment.

7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to mobilizing to site. The as-drilled boreholes

Client: GHD

Date: September 9, 2022

File No.: 33249

Page: 9 of 24

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locations and elevations were surveyed using a Trimble Catalyst DA1.

Walker Drilling Ltd. of Utopia, Ontario supplied and operated the drilling, sampling, and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Mr. George Azzopardi of Thurber. The overall management of the field program was conducted by Mr. Rod de Castro, P.Eng., of Thurber.

Geotechnical laboratory testing on soil samples was carried out in Thurber's geotechnical laboratory. Unconfined Compression testing on rock cores was carried out by Geomechanica Inc. Analytical laboratory testing on soil and water samples was carried out by AGAT Laboratories.

Interpretation of the field data and preparation of this report was carried out by Messrs. Rod de Castro, P.Eng., and Christopher Ng, P.Eng., respectively. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects at Thurber.



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Client: GHD
File No.: 33249

Date: September 9, 2022
Page: 11 of 24

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PART B: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the foundation investigation report and presents foundation design recommendations for the proposed culvert replacement at Station 11+475 in the Township of Greenock (Culvert C8) on Highway 9 in Brockton, Ontario. A high fill embankment exists at the location of the culvert. Accordingly, the proposed replacement culvert pipe is intended to be installed by trenchless methods. It is understood that open cut construction method is currently not being considered at this point from a traffic engineering perspective since it will require a deep excavation in the existing embankment.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, Ontario, and its designers, GHD, and shall not be used or relied upon for any other purposes or by any other parties including construction or Design-build Contractors. The Design-build Contractor must make their own interpretation based on the data provided in Part A of the report. Where comments are made on construction, they are provided to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the information provided in Part A of this report as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

A summary of assumed design information of the proposed culvert replacement are presented below in Tables 8.1 which include the soil types through which the culvert is anticipated to be installed. It is assumed that the new culvert will also be 600 mm in diameter and that the invert is anticipated to be the same as the existing culvert; however, the location of the new culvert is not yet been determined at the time of reporting. In addition to a proposed culvert replacement, it is understood pipe bursting or lining of the existing culvert are also being considered. The soil



stratigraphy along the proposed pipe is shown on the Borehole Location and Soil Strata Drawing in Appendix E.

8.1 – Culvert Design Information

Invert Elevation at Inlet (m)	Invert Elevation at Outlet (m)	Culvert Size	Soil Type Around Pipe	Tunnelman's Ground Classification System
297.300 north	294.663 south	600 mm dia.	Loose to Compact Gravelly Silt Sand to Sandy Silt Fill	Running / Flowing
			Native Compact Silt and Sand	Running / Flowing

The Tunnelman's Ground Classification System is a framework for describing soil behaviour in an unsupported tunnel heading under atmospheric conditions. It was initially developed by Terzaghi in 1950 and later modified by Heuer in 1974. A summary of the Tunnelman's Ground Classification System according to Heuer, 1974, is presented in Appendix D.

The discussion and recommendations presented in this report are based on information provided by GHD, and on the subsurface information obtained from the foundation investigation and laboratory testing.

9. CULVERT DESIGN CONSIDERATIONS

A culvert condition assessment was carried out by GHD and during which time, the existing culvert was observed to have significant rust on both the upstream and downstream end. As a result, it was identified as a candidate for rehabilitation with a liner or replacement by trenchless methods.

9.1 Culvert Rehabilitation

It is understood that a liner inside the existing 600 mm diameter CSP culvert is being considered as an alternative to installing a new culvert. This method poses the least risk. Details of the proposed liner alternative is not available at the time of reporting; however, grouting of the annular space between the existing culvert and new liner will be required.



A survey of the existing opening and alignment of the existing culvert must be completed to assess whether the proposed liner will fit into the existing CSP culvert. Grout specifications between the liner and the existing culvert must also be flowable to fill in the annular space and prevent any voids that may occur during grouting.

9.2 Culvert Replacement

Details of the proposed culvert replacement is not available at the time of reporting; however, it is understood that consideration has been given to installing the new culvert by pipe bursting method through the existing culvert or installing a new culvert adjacent to the existing culvert with invert of the inlet and outlet matching that of the existing culvert.

9.3 Trenchless Methods

Trenchless installation methods that are typically used to install culverts on a new alignment under highways include:

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

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 G.

Based on the available subsurface information, the proposed culvert under Highway 9 will be installed through loose to compact gravely silty sand to sandy silt fill, and native compact silty sand to silt and sand with groundwater table at or just above the new culvert invert. Although not encountered during the foundation investigation, cobbles, boulders, and other obstructions should be anticipated within the embankment fill.

Hand-mining is not considered practical for this project due to the small tunnel diameter.

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, but it is likely not cost-effective due to the relatively short bore length.

Horizontal directional drilling is not recommended since this method may not be able to maintain alignment.

Jack-and-bore, and pipe ramming methods are considered feasible for the culvert installation. However, these methods may experience difficulties maintaining the required alignment if obstructions such as cobbles and boulders are encountered. Once the casing is in place, the new culvert is then be threaded through the casing and the annular space between the casing and culvert is to be grouted.

From the foundation engineering perspective with regards to the technical, constructability and, risk management of the proposed work, micro-tunnelling is considered to carry relatively low risks. Jack-and-bore, and pipe ramming carry a certain degree of risk associated if obstructions are encountered; however, these methods are viable options for the proposed culvert installation. If the jack-and-bore method is adopted, a minimum soil plug of 1 m should be maintained within the leading edge of the casing during jack-and-bore operations.

The cost effectiveness of all trenchless methods should be assessed by the Contractor. The suitability of each method is subject to factors including soil types, groundwater conditions, equipment availability, and Contractor's expertise/experience. The advantages, disadvantages, and relative costs and risks of these methods are presented in Table F1 in Appendix F.

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 G.

Designer fill-ins for the NSSP "Pipe Installation by Trenchless Methods" are as follows:

Designer Fill-In	Designer Comment and Fill-In (as applicable)
* Insert the following fill-in: Any method that is not suitable shall be specified.	Add to Section 4.01.01 of the NSSP: "Hand mining and horizontal directional drilling shall not be utilized at this site."
** Insert the following fill-in: Specify minimum requirements commensurate with complexity.	Project specific minimum requirements for the project superintendent are not required. The minimum experience of the project superintendent in Section 4.02.01.01 of NSSP "Pipe Installation by Trenchless Method is applicable."



Designer Fill-In	Designer Comment and Fill-In (as applicable)
*** Insert the following fill-in: Specify minimum requirements commensurate with complexity.	Project specific minimum requirements for the trenchless contractor is not required. The minimum experience of the trenchless contractor in Section 4.02.01.02 of NSSP "Pipe Installation by Trenchless Method is applicable.
**** Insert the following fill-in: Subsurface Condition Baseline Reporting that includes Boulder Volume Ratio (BVR), Boulder Number Ratio (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.	Not applicable. The subsurface conditions are described in the FIR included in the contract.
***** Insert the following fill-in: Any known obstructions shall be specified.	Add to Section 7.01.12 of the NSSP: "Although obstructions were not encountered during the foundation investigation, the embankment fill may contain cobbles and boulder. In addition, shallow bedrock was encountered at the inlet and outlet of the existing culvert. As such, the Contractor shall be equipped to dislodge, remove, and otherwise handle such obstructions such as cobbles, boulders, bedrock knobs at the tunnel face and during excavation of the temporary pits should it be required.
***** Insert the following fill-in: The Instrumentation and Monitoring program shall be project specific. The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.	The site-specific Instrumentation and Monitoring Program for Highway 9 is included in the contract.
***** Insert the following fill-in: Project specific Review and Alert Levels shall be provided if required.	Project specific review and alert levels are not required. The review and alert levels in Section 7.08 of NSSP "Pipe Installation by Trenchless Methods" are applicable.
***** Insert the following fill-in: Payment for removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.	Add the following to Section 10 of the NSSP: "Payment of removal of boulders with diameter 250 mm or greater shall be only a time and material basis."

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:

Client: GHD

Date: September 9, 2022

File No.: 33249

Page: 16 of 24

E file: H:\30000-39999\33000-33999\33249 P - Greenock Creek Bridge\Reports & Memos\C8 Culvert Report\Final\TEL_33249_Highway 9 Culvert Replacement - Culvert C8 FIDR Final Sept9 2022.docx



- The embankment fill 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 pipe installation may be carried out through gravelly silty sand to sandy silt fill and native silty sand to silt and sand with groundwater table at or above the pipe culvert. In addition, depending on the proposed alignment of the new culvert, potential to encounter obstructions such as bedrock knobs and bedrock excavation at the exit/entry pits will need to be taken into consideration. The Contractor's equipment must be capable of advancing the pipes through these soil / rock conditions of varying strengths and maintaining these soils stable during trenchless installation.
- The Contractor's methodology must include means of handling potential sloughing of water-bearing native sands and silts and water seepage at the tunnel face.

Contingency measures should be implemented if excessive settlement occurs and/or trenchless installation is impeded by cobbles and boulders. The following contingency measures should be considered:

- 1) Where the pipe alignment crosses under the travelled lanes of the highway, employ a trenchless technique in conjunction with a lane-closure; this methodology would allow remedial measures to be implemented immediately should surficial distress including sinkhole formation is observed and/or settlements are detected from instrumentation monitoring results or obstructions are encountered during tunnelling and requires to be dislodged.
- 2) Construct the pipe crossings using staged open cutting.

10. SURFACE WATER AND GROUNDWATER CONTROL

Although groundwater observations in monitoring wells, and measurements in the open boreholes show the groundwater table is at or just above the invert of the proposed pipe, seepage from the embankment and native soils during installation of the pipe culvert crossing should be anticipated. It is expected pumping from a properly filtered sump 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.

10.1 Preliminary Dewatering Assessment for Launching and Receiving Pits

Groundwater taking for construction dewatering is governed by the Ontario Water Resources Act (OWRA), Environmental Protection Act (EPA) and the Water Taking and Transfer Regulation 387/04, a regulation under the OWRA.

Client: GHD

Date: September 9, 2022

File No.: 33249

Page: 17 of 24

E file: H:\30000-39999\33000-33999\33249 P - Greenock Creek Bridge\Reports & Memos\C8 Culvert Report\Final\TEL_33249_Highway 9 Culvert Replacement - Culvert C8 FIDR Final Sept9 2022.docx



If the water taking rate for this project will be greater than 50,000 L/day and less than 400,000 L/day, registration on the Environmental Activity and Sector Registry (EASR) is required. If the water taking rate will be greater than 400,000 L/day, a Category 3 Permit To Take Water (PTTW) is required.

Preliminary assessment of the need for a Category 3 PTTW or registration on the EASR is provided, based on dewatering estimates presented in this report. For the purpose of water taking permitting, the estimated withdrawal rates are conservatively assessed in order to reduce the likelihood that actual pumping rates might exceed the permitted allowance thereby stopping work and delaying the project.

Based on preliminary design information available to date, it is anticipated that dewatering will be required at the location of Entry/Exit Pits at C8. One Monitoring Well (C8-03) has been installed at the location of the existing outlet of the culvert. The highest groundwater elevation was 294.7 m (depth 1.0 m), measured May 16, 2022. The invert of the proposed culvert will be at approximately 294.3 m. Based on a review of borehole information, the subgrade at the underside of the culvert is expected to consist of silt and sand / sand materials. A hydraulic conductivity of $1.6 \text{ m} \times 10^{-4} \text{ m/s}$ (analyzed at C8-03) was assumed in assessing dewatering requirement for the unconfined aquifer. The estimated dimension of the proposed excavation is summarized in Table 1-1. It is assumed that the excavation would be open cut. The excavation and dewatering methods that will be used in the field will be determined by the Contractor.

Table 8-1: Proposed Structure and Assumed Excavation Dimension

Structure	Assumed Footprint (m)	Estimated Elevation (m)	Geologic Unit(s) to Dewater
Entry/Exit Pit at Culvert C8	6 x 6	293.5 (at outlet)	Silt and Sand / Sand

The following approach was used to estimate the budgeted peak water taking rate:

- A base ground water extraction flow rate was estimated, and a factor of safety of three was applied to this flow rate to provide an allowance for removal of water from soil storage, variation in hydraulic conductivity, actual excavation dimensions and geometry, and ground water levels due to seasonality or other factors;
- An allowance for removal of rainfall into the excavation was included, assuming 24 hours are used to remove 50 mm of rainfall; and,



- Lowering of groundwater to about 1 m below the base of the excavation to facilitate a dry, stable work area was assumed.

The water taking will be temporary in nature for the purpose of construction dewatering. Dewatering rates were estimated using the Dupuit analytical solution for an unconfined aquifer provided in Powers et al. (2007). The radius of influence was estimated using the Sichardt equation.

The estimated maximum construction dewatering pump rates and radii of influence for the analyzed excavations are summarized in Table 10-1. The calculations and equations for the peak flow rate and radius of influence are provided in Appendix B.

Table 8-1 – Table of Estimated Construction Dewatering Volumes

Construction Element	Base Groundwater Flow (L/day)	Groundwater Flow with Safety Factor of 3 (L/day)	Stormwater Allowance (L/day)	Estimated Peak Flow Rate (L/day)	Approx. Radius of Influence (m)
Entry/Exit Pit at Culvert C8	1,000	38,000	2,000	116,000	6

The total peak dewatering rate for the proposed excavation, including a three times safety factor on base groundwater flow and removal of 50 mm of rainfall in 24 hours, was estimated to be 116,000 L/day. Since the estimated peak water taking rate for the Entry/Exit Pits at C8 is less than 400,000 L/day but greater than 50,000 L/day, registration on the EASR would be required.

Please note that these estimates does not take into consideration excavation into the bedrock, as no slug testing was conducted within the bedrock layer.

The dewatering system is to be designed in accordance with OPSS.PROV 517 and SP 517F01. Considering the conditions on site, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing systems of similar nature and scope to the required work is not required, and thus Designer Fill-In ***** in SP 517F01 should be “No”.

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



11. 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 (including the existing culvert) 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 9 pavement in the proximity of the culvert installation 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 H.

12. TEMPORARY PITS

The temporary pits are anticipated to be shallow at the receiving and exit pits and sloped excavation should be feasible. Temporary launching and receiving pit excavations at either end of the pipe crossing will extend through the loose silty sand to sandy silt fill and native loose to very dense silty sand to silt and sand. Bedrock is anticipated underlying the sand at the inlet of the culvert.

All temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario and local regulations. The embankment fill, and native soils at this site are classified as Type 3 soils under OHSA. The bedrock may be classified as Type 1. Vertical excavation of the bedrock should stand unsupported for the construction period. However, the rock wall should be inspected at the time of excavation to remove any loose rock fragments.

Bedrock was encountered at shallow depths, especially at the inlet of the culvert. Depending on the depth of excavation of the temporary pits, some excavation of the bedrock may be necessary.

The equipment required and method of excavation within the bedrock, if required, will be dependent upon the geometry of the excavation and relative depth of excavation into the bedrock. Although the method of excavation should remain the responsibility of the contractor, and assuming that blasting will not be permitted at this site, equipment such as hoe ram, pneumatic



hammer, or equivalents should be considered. Progressively more difficult conditions should be anticipated with increasing depth of excavation. An NSSP on bedrock excavation is provided in Appendix H.

13. TEMPORARY PROTECTION SYSTEMS

Temporary protection systems may be required at the launching and receiving pits to facilitate the installation of the new pipe by trenchless methods. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539. The lateral movement of the temporary protection systems shall meet Performance Level 2 as specified in OPSS.PROV 539, provided that any existing adjacent utilities can tolerate this magnitude of deformation. The selection and design of the protection system will be the responsibility of the Contractor.

It is important to note that the top of bedrock varied within the boreholes drilled during the site investigation. Further variations in the bedrock surface elevation should be expected along the length of the temporary protection system at the inlet and outlet. Bedrock is shallow both at the inlet and outlet ends, which will dictate the type of protection system that can be used.

Suggested wording for an NSSP is provided in Appendix G.

14. CORROSION POTENTIAL

Based on results of corrosivity testing on samples of the soil and groundwater recovered, the following statements can be made.

- There is severe to very severe potential for corrosion on metals due to the relatively low resistivity values. The effects of road de-icing salts should be considered when selecting the corrosion mitigation measures. The test results may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.
- There is low potential for sulphate attack on concrete 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.

15. PROVINCIAL WATER QUALITY OBJECTIVES (PWQO) ANALYSIS

Multiple parameters exceeded the PWQO and interim limits in the unfiltered samples, including the following: Arsenic, cobalt, copper, iron, lead, phosphorus, nickel, thallium, tungsten, uranium,



vanadium, zinc, and zirconium. On review of the filtered analytical results, filtering lowered some parameters concentrations below the PWQO limits; however, the concentration of arsenic in C8-03 exceeded the interim PWQO criteria within filtered samples. Groundwater of the quality that was sampled herein could not be discharged to the natural environment without pre-treatment. Further, the results suggest that while filtration removed most metals, it may not remove enough for discharge into the natural environment.

16. CONSTRUCTION CONCERNS

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

16.1 Loss of ground

Each of the feasible trenchless methods discussed in Section 9.0 above carries varying degree of risks of loss of ground for tunnelling through mixed face conditions with groundwater table at or above the culvert invert. 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 H can be satisfied. In addition, contingency plans should be in place to manage any adverse impacts on the highway.

16.2 Obstructions

The existing highway embankment fill may contain cobbles, boulder, and other obstructions. The Contractor's equipment and methodology must be selected to handle such obstructions and successfully remove them without jeopardizing the performance of operation of the highway. The selected trenchless installation methodology should be capable of mitigating potential for both horizontal and vertical pipe misalignments due to such obstructions.

16.3 Variable Bedrock Surface Elevation

Based on the foundation investigation, shallow bedrock is anticipated to be below the trenchless installation. However, given the natural variation of the bedrock surface and that the culvert location has yet to be determined, the selected trenchless methodology should be capable of advancing through soil-bedrock mixed faced conditions while maintaining the horizontal and vertical pipe alignment throughout the installation.

16.4 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, including the existing 600 mm diameter culvert.

Client: GHD

Date: September 9, 2022

File No.: 33249

Page: 22 of 24

E file: H:\30000-39999\33000-33999\33249 P - Greenock Creek Bridge\Reports & Memos\C8 Culvert Report\Final\TEL_33249_Highway 9 Culvert Replacement - Culvert C8 FIDR Final Sept9 2022.docx



It is recommended that the existing culvert be monitored during trenchless activities. In addition, it is recommended that the proposed replacement culvert should be at least 3 m clear distance away from the existing culvert.

Any discrepancy from the Contract Drawings must be reported to the Contract Administrator.

17. CLOSURE

Engineering analysis and preparation of this report was carried out by Messrs. Rod de Castro, P.Eng., and Christopher Ng, P.Eng. Analysis and recommendations associated with dewatering was carried out Mr. Alireza Hejazi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects at Thurber.



Thurber Engineering Ltd.



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Geotechnical Engineer



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Review Principal, Designated MTO Contact

Client: GHD
File No.: 33249

Date: September 9, 2022
Page: 24 of 24

E file: H:\30000-39999\33000-33999\33249 P - Greenock Creek Bridge\Reports & Memos\C8 Culvert Report\Final\TEL_33249_Highway
9 Culvert Replacement - Culvert C8 FIDR Final Sept9 2022.docx



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


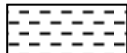



SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS

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

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
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.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

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			

RECORD OF BOREHOLE No C8-01

1 OF 2

METRIC

GWP# 3075-14-00 LOCATION C8 Culvert; MTM NAD83-10: N 4 886 774.0 E 168 216.7 ORIGINATED BY GA
 DIST HWY 9 BOREHOLE TYPE Hollow Stem Augers/ HQ Coring COMPILED BY AA
 DATUM Geodetic DATE 2022.05.17 - 2022.05.17 LATITUDE 44.108219 LONGITUDE -81.206168 CHECKED BY RdC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
302.5	GROUND SURFACE																
0.0	SAND and GRAVEL , trace silt Dense to Very Dense Brown Moist (FILL)		1	SS	47		302										
			2	SS	30												
301.1																	
1.4	Silty SAND , trace gravel and clay Compact to Dense Brown Moist (FILL)		3	SS	18		301										
			4	SS	33		300										
299.5																	
3.0	Gravelly, Silty SAND , trace clay Compact Brown Moist (FILL)		5	SS	28		299										
			6	SS	15												
			7	SS	14		298										
			8	SS	10		297										
			9	SS	21		296										
			10	SS	15												
295.0							295										
7.5	Silty SAND , some gravel, trace clay Compact to Dense Brown Wet		11	SS	27												
			12	SS	31		294										
293.4																	
9.1	DOLOSTONE/LIMESTONE fresh to moderately weathered, grey and beige Horizontal fractures from a depth of 9.1m to 9.3m and 9.6m to 9.8m		1	RUN			293										

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C8-01

2 OF 2

METRIC

GWP# 3075-14-00 LOCATION C8 Culvert; MTM NAD83-10: N 4 886 774.0 E 168 216.7 ORIGINATED BY GA
DIST HWY 9 BOREHOLE TYPE Hollow Stem Augers/ HQ Coring COMPILED BY AA
DATUM Geodetic DATE 2022.05.17 - 2022.05.17 LATITUDE 44.108219 LONGITUDE -81.206168 CHECKED BY RdC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)			
								20	40	60	80	100									
								○ UNCONFINED + FIELD VANE													
								● QUICK TRIAXIAL × LAB VANE													
								</													

RUN #2
TCR=100%
SCR=100%
RQD=100%
UCS=81.9MPa

RECORD OF BOREHOLE No C8-02

1 OF 1

METRIC

GWP# 3075-14-00 LOCATION C8 Culvert; MTM NAD83-10: N 4 886 802.6 E 168 212.2 ORIGINATED BY MA
DIST HWY 9 BOREHOLE TYPE Hollow Stem Augers/ HQ Coring COMPILED BY AA
DATUM Geodetic DATE 2022.04.26 - 2022.04.26 LATITUDE 44.108476 LONGITUDE -81.206232 CHECKED BY RdC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
298.1	GROUND SURFACE							20 40 60 80 100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
0.0	TOPSOIL: (100mm)								WATER CONTENT (%)				
0.1	Sandy SILT , trace to some gravel and clay, containing rootlets		1	SS	9		298						
297.4	Loose												
0.7	Dark Brown												
297.1	Moist		2	SS	50/								
1.0	(FILL)				0.075		297						
	Silty SAND , some gravel and clay, containing fractured limestone												
	Very Dense		1	RUN									
	Brown												
	Moist												
	DOLOSTONE/LIMESTONE slightly weathered, highly fractured, grey, very strong		2	RUN			296						
	Highly fractured zone from a depth of 1.0m to 4.0m												
							295						
			3	RUN									
							294						
293.2	END OF BOREHOLE AT A DEPTH OF 4.9m.		4	RUN									
4.9													

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C8-03

1 OF 1

METRIC

GWP# 3075-14-00 LOCATION C8 Culvert; MTM NAD83-10: N 4 886 747.3 E 168 213.9 ORIGINATED BY MA
 DIST HWY 9 BOREHOLE TYPE Hollow Stem Augers/ HQ Coring COMPILED BY AA
 DATUM Geodetic DATE 2022.04.27 - 2022.04.27 LATITUDE 44.107979 LONGITUDE -81.206197 CHECKED BY RdC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
295.7	GROUND SURFACE							20	40	60	80	100		
0.0 0.1	TOPSOIL: (75mm)		1	SS	6		295							
295.0	Silty SAND , trace gravel and clay Loose Brown													
0.7	Moist (FILL)		2	SS	11									
294.3	SILT and SAND , trace gravel and clay Compact Brown													
1.4	Wet		3	SS	38		294							
	SAND , with fracture limestone Dense to Very Dense Brown Wet													
293.1			4	SS	50/ 0.100		293							
2.6	DOLOSTONE/LIMESTONE slightly weathered, grey and beige, strong		1	RUN										RUN #1 TCR=92% SCR=42% RQD=0%
	Highly fractured zone from a depth of 2.6 to 5.4m		2	RUN			292							RUN #2 TCR=100% SCR=80% RQD=10% UCS=81.9MPa
			3	RUN			291							RUN #3 TCR=100% SCR=88% RQD=0%
290.3														
5.4	END OF BOREHOLE AT A DEPTH OF 17.83m. Monitoring Well installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen													
	WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2022.05.11 1.0 294.7 2022.05.16 1.0 294.7													

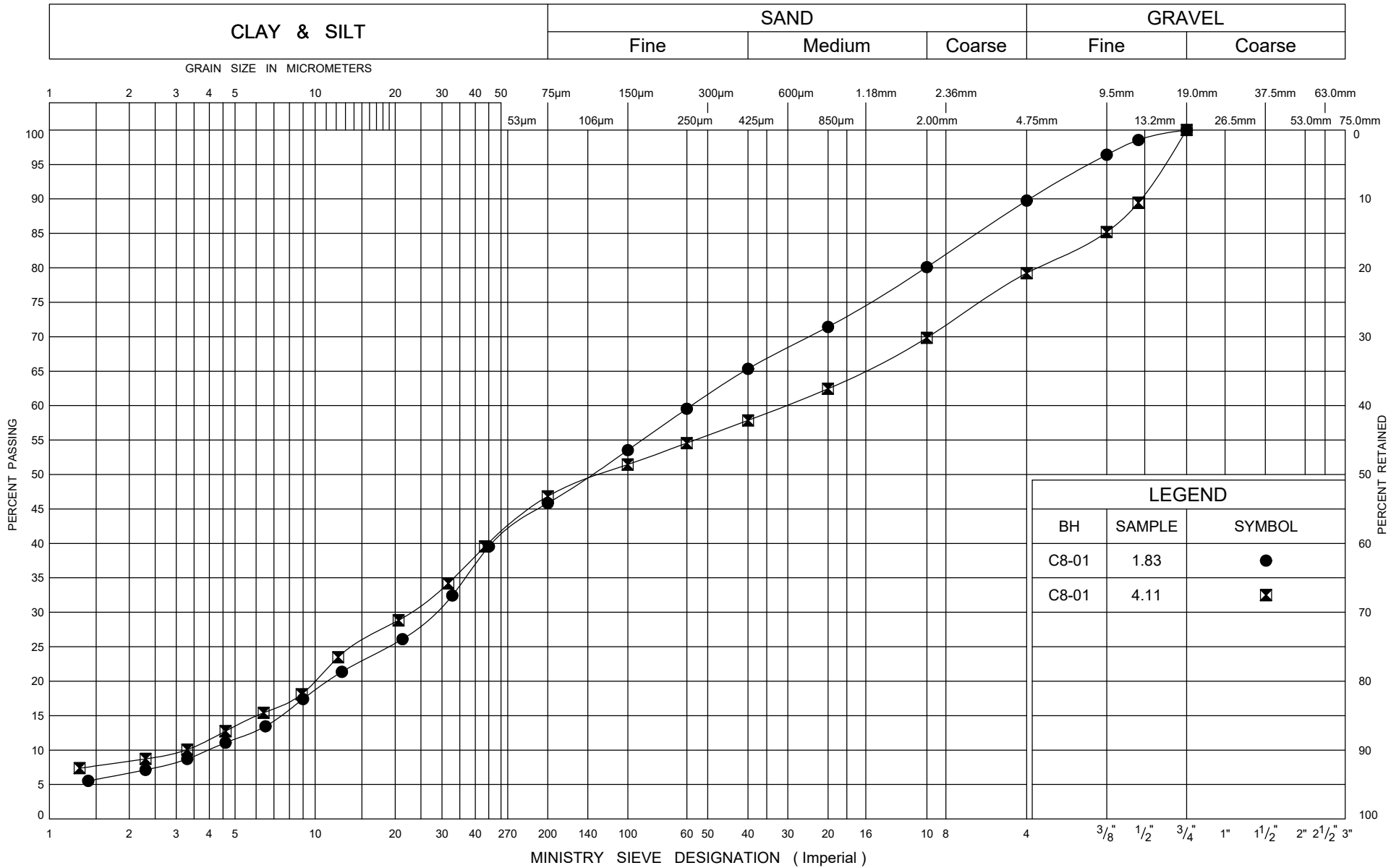
ONTMT452 2020LIBRARY(MTO) - COPY.GLB MTO-33249.GPJ 6/22/22

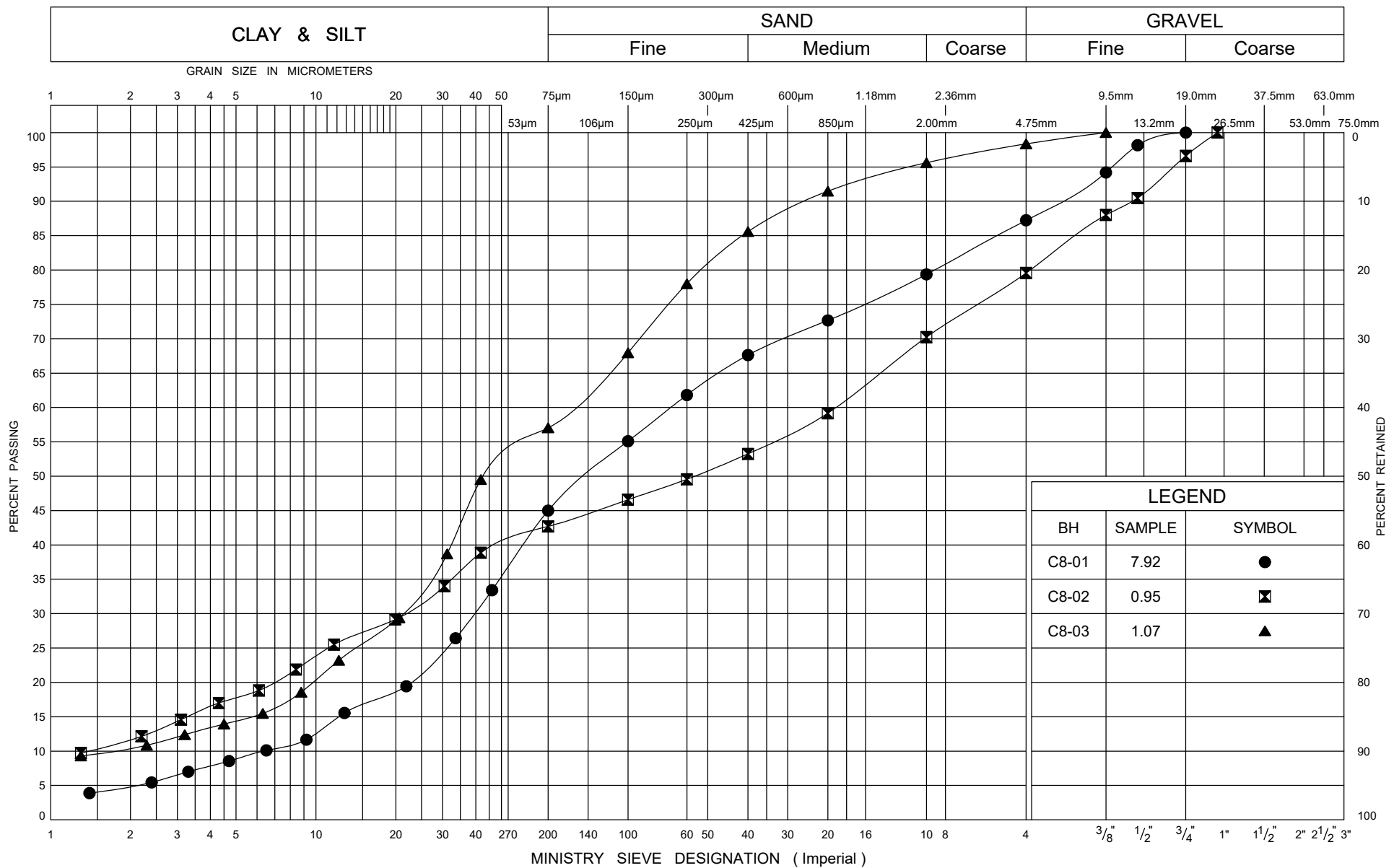
+³, ×³: Numbers refer to
Sensitivity 20
15 10
(%) STRAIN AT FAILURE





Appendix B

Geotechnical and Analytical Laboratory Test Results and Well Test Results







Uniaxial Compression Test

Client	Thurber Engineering Ltd.	Project	33249
Sample	BH C8-01, Run 2	Depth	39' 4" - 40' 0"
<div>Specimen parameters</div> <div><div>Diameter (mm) ^a</div><div>Length (mm) ^a</div><div>Bulk density ρ (g/cm³)</div><div>UCS (MPa)</div><div>Lithology</div><div>Failure description ^b</div></div>		<div>Prior to testing</div> <div></div>	<div>After testing</div> <div></div>
<div><div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet.</div><div>^b Failure description: ³ Inclined shear fracture and axial splitting failure;</div></div>			
Remarks: Loading rate of: 0.05 mm/min.			
Performed by	EM/MB	Date	2022-05-30

Uniaxial Compression Test

Client	Thurber Engineering Ltd.	Project	33249
Sample	BH C8-02, Run 2	Depth	9' 8" - 10' 2"
<div>Specimen parameters</div>		Prior to testing	After testing
Diameter (mm) ^a	63.37		
Length (mm) ^a	118.11		
Bulk density ρ (g/cm ³)	2.596		
UCS (MPa)	167.1		
Lithology	Dolostone/Limestone		
Failure description ^b	3, 2		
<div>^a Additional specimen measurement/details provided in accompanying summary spreadsheet. ^b Failure description: ³ Inclined shear fracture and axial splitting failure; ² Length:Diameter ratio less than 2;</div>			
Remarks: Loading rate of: 0.125 mm/min.			
Performed by	MB/MB	Date	2022-05-19

CLIENT NAME: THURBER ENGINEERING LTD
SUITE 103, 2010 WINSTON PARK DRIVE
OAKVILLE, ON L6H5R7
(905) 829-8666

ATTENTION TO: Rod de Castro

PROJECT: WR 3020-E-0004

AGAT WORK ORDER: 22T896882

SOIL ANALYSIS REVIEWED BY: Nivine Basily, Inorganics Report Writer

WATER ANALYSIS REVIEWED BY: Yris Verastegui, Report Reviewer

DATE REPORTED: May 27, 2022

PAGES (INCLUDING COVER): 21

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*Notes

Disclaimer:

- All work conducted herein has been done using accepted standard protocols, and generally accepted practices and methods. AGAT test methods may incorporate modifications from the specified reference methods to improve performance.
- All samples will be disposed of within 30 days after receipt unless a Long Term Storage Agreement is signed and returned. Some specialty analysis may be exempt, please contact your Client Project Manager for details.
- AGAT's liability in connection with any delay, performance or non-performance of these services is only to the Client and does not extend to any other third party. Unless expressly agreed otherwise in writing, AGAT's liability is limited to the actual cost of the specific analysis or analyses included in the services.
- This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
- The test results reported herewith relate only to the samples as received by the laboratory.
- Application of guidelines is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, warranties of merchantability, fitness for a particular purpose, or non-infringement. AGAT assumes no responsibility for any errors or omissions in the guidelines contained in this document.
- All reportable information as specified by ISO/IEC 17025:2017 is available from AGAT Laboratories upon request.



Certificate of Analysis

AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Corrosivity Package

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

				C6-01 SS7	C6-01 SS10 22.	C8-01 SS9	C8-01 SS11
SAMPLE DESCRIPTION:				15-17'	5-24.3'	20-22'	25-27'
SAMPLE TYPE:				Soil	Soil	Soil	Soil
DATE SAMPLED:				2022-05-16	2022-05-16	2022-05-17	2022-05-17
Parameter	Unit	G / S	RDL	3874389	3874395	3874396	3874397
Chloride (2:1)	µg/g	2	279		186	442	37
Sulphate (2:1)	µg/g	2	9		22	6	5
pH (2:1)	pH Units		NA	7.85	8.70	8.18	8.32
Electrical Conductivity (2:1)	mS/cm		0.005	0.605	0.531	0.887	0.173
Resistivity (2:1) (Calculated)	ohm.cm		1	1650	1880	1130	5780
Redox Potential 1	mV		NA	163	191	204	215
Redox Potential 2	mV		NA	163	190	201	201
Redox Potential 3	mV		NA	164	190	199	199

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

3874389-3874397 EC, pH, Chloride and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter.

Redox potential measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results.

Redox potential measurement in soil is quite variable and non reproducible due in part, to the general heterogeneity of a given soil. It is also related to the introduction of increased oxygen into the sample after extraction. The interpretation of soil redox potential should be considered in terms of its general range rather than as an absolute measurement.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:



Nivine Basly



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PROJECT: WR 3020-E-0004

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CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

(Water) Inorganic Chemistry

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

SAMPLE DESCRIPTION:				22-01		22-02		C6-02		C8-03
SAMPLE TYPE:				Water		Water		Water		Water
DATE SAMPLED:				2022-05-16 16:45		2022-05-16 17:00		2022-05-17 18:15		2022-05-17 14:00
Parameter	Unit	G / S	RDL	3874272	RDL	3874309	RDL	3874310	RDL	3874314
pH	pH Units		NA	7.77	NA	7.72	NA	7.77	NA	7.72
Electrical Conductivity	µS/cm		2	1670	2	719	2	1760	2	1170
Resistivity	ohms.cm			599		1390		568		855
Chloride	mg/L		0.12	354	0.10	18.6	0.24	399	0.12	148
Sulphate	µg/L		100	60700	100	144000	190	23400	100	26600
SAMPLE DESCRIPTION: Greenock Creek										
SAMPLE TYPE:				Water						
DATE SAMPLED:				2022-05-16 17:30						
Parameter	Unit	G / S	RDL	3874388						
pH	pH Units		NA	7.90						
Electrical Conductivity	µS/cm		2	542						
Resistivity	ohms.cm			1850						
Chloride	mg/L		0.10	18.9						
Sulphate	µg/L		100	10300						

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

3874272-3874388 Dilution required, RDL has been increased accordingly.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Iris Veraistegui



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AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

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CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

(Water) TSS, CrVI

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

		SAMPLE DESCRIPTION:		C6-02	C8-03
		SAMPLE TYPE:		Water	Water
		DATE SAMPLED:		2022-05-17 18:15	2022-05-17 14:00
Parameter	Unit	G / S	RDL	3874310	3874314
Total Suspended Solids	mg/L		10	75	8650
Chromium VI	mg/L	0.001	0.001	<0.001	<0.001

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to PWQO * Variable - refer to guideline reference document

Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.

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CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Dissolved Metals in Water (mg/L)

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

		SAMPLE DESCRIPTION:		C6-02	C8-03
		SAMPLE TYPE:		Water	Water
		DATE SAMPLED:		2022-05-17 18:15	2022-05-17 14:00
Parameter	Unit	G / S	RDL	3874310	3874314
Dissolved Aluminum	mg/L	*	0.004	0.014	0.013
Dissolved Antimony	mg/L	0.020	0.001	<0.001	<0.001
Dissolved Arsenic	mg/L	0.1	0.001	0.003	0.006
Dissolved Barium	mg/L		0.002	0.022	0.073
Dissolved Beryllium	mg/L	*	0.0005	<0.0005	<0.0005
Dissolved Bismuth	mg/L		0.002	<0.002	<0.002
Dissolved Boron	mg/L	0.2	0.010	0.079	0.062
Dissolved Cadmium	mg/L	0.0002	0.0001	<0.0001	<0.0001
Dissolved Chromium	mg/L		0.002	<0.002	<0.002
Dissolved Cobalt	mg/L	0.0009	0.0005	<0.0005	0.0007
Dissolved Copper	mg/L	0.005	0.001	0.006	0.003
Dissolved Iron	mg/L	0.3	0.010	<0.010	0.015
Dissolved Lead	mg/L	*	0.0005	0.0008	<0.0005
Dissolved Manganese	mg/L		0.002	0.131	0.376
Dissolved Molybdenum	mg/L	0.040	0.002	0.003	0.007
Dissolved Nickel	mg/L	0.025	0.001	0.002	0.003
Dissolved Phosphorus	mg/L		0.05	<0.05	<0.05
Dissolved Selenium	mg/L	0.1	0.001	0.002	<0.001
Dissolved Silver	mg/L	0.0001	0.0001	<0.0001	<0.0001
Dissolved Silicon	mg/L		0.05	3.75	6.29
Dissolved Strontium	mg/L		0.005	0.243	0.218
Dissolved Thallium	mg/L	0.0003	0.0003	<0.0003	<0.0003
Dissolved Tin	mg/L		0.002	<0.002	<0.002
Dissolved Titanium	mg/L		0.002	<0.002	<0.002
Dissolved Uranium	mg/L	0.005	0.0005	0.0011	0.0038
Dissolved Vanadium	mg/L	0.006	0.002	<0.002	<0.002
Dissolved Zinc	mg/L	0.030	0.005	<0.005	<0.005
Dissolved Zirconium	mg/L	0.004	0.004	<0.004	<0.004

Certified By:

Iris Veraestegui



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<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Dissolved Metals in Water (mg/L)

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to PWQO * Variable - refer to guideline reference document
Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.

3874310-3874314 Metals analysis completed on a filtered sample.

Analysis performed at AGAT Toronto (unless marked by *)

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<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

O. Reg. 153(511) - Sodium Adsorption Ratio (Water)

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

		SAMPLE DESCRIPTION:		22-01	22-02	C6-02	C8-03	Greenock Creek
		SAMPLE TYPE:		Water	Water	Water	Water	Water
		DATE SAMPLED:		2022-05-16 16:45	2022-05-16 17:00	2022-05-17 18:15	2022-05-17 14:00	2022-05-16 17:30
Parameter	Unit	G / S	RDL	3874272	3874309	3874310	3874314	3874388
Sodium Adsorption Ratio (Calculated)		NA		6.06	2.95	5.44	3.27	0.653

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

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CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Redox in water

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

		SAMPLE DESCRIPTION:		22-01	22-02	C6-02	C8-03	Greenock Creek
		SAMPLE TYPE:		Water	Water	Water	Water	Water
		DATE SAMPLED:		2022-05-16 16:45	2022-05-16 17:00	2022-05-17 18:15	2022-05-17 14:00	2022-05-16 17:30
Parameter	Unit	G / S	RDL	3874272	3874309	3874310	3874314	3874388
Redox Potential	mV		NA	133	174	170	178	186

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

3874272-3874388 Redox potential was measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Iris Veraistegui



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PROJECT: WR 3020-E-0004

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CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Water Quality Assessment - PWQO (mg/L)

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

		SAMPLE DESCRIPTION:		C6-02		C8-03
		SAMPLE TYPE:		Water		Water
		DATE SAMPLED:		2022-05-17 18:15		2022-05-17 14:00
Parameter	Unit	G / S	RDL	3874310	RDL	3874314
Electrical Conductivity	µS/cm		2	1760	2	1170
pH	pH Units	6.5-8.5	NA	7.77	NA	7.72
Saturation pH (Calculated)				6.34		6.27
Langelier Index (Calculated)				1.43		1.45
Hardness (as CaCO ₃) (Calculated)	mg/L		0.5	989	0.5	982
Total Dissolved Solids	mg/L		10	1000	10	662
Alkalinity (as CaCO ₃)	mg/L		5	365	5	423
Bicarbonate (as CaCO ₃)	mg/L		5	365	5	423
Carbonate (as CaCO ₃)	mg/L		5	<5	5	<5
Hydroxide (as CaCO ₃)	mg/L		5	<5	5	<5
Fluoride	mg/L		0.05	<0.05	0.05	<0.05
Chloride	mg/L		0.24	399	0.12	148
Nitrate as N	mg/L		0.07	0.88	0.05	0.69
Nitrite as N	mg/L		0.05	<0.05	0.05	<0.05
Bromide	mg/L		0.06	<0.06	0.05	<0.05
Sulphate	mg/L		0.19	23.4	0.10	26.6
Ortho Phosphate as P	mg/L		0.13	<0.13	0.10	<0.10
Ammonia as N	mg/L		0.02	0.04	0.02	<0.02
Ammonia-Un-ionized (Calculated)	mg/L	0.02	0.000002	0.00120	0.000002	<0.000002
Total Phosphorus	mg/L	*	0.02	0.37	0.02	0.09
Total Organic Carbon	mg/L		0.5	4.8	0.5	39.1
True Colour	TCU		5.00	<5.00	5.00	7.62
Turbidity	NTU		0.5	51.0	0.9	3730
Total Calcium	mg/L		0.32	213	0.32	270
Total Magnesium	mg/L		0.34	111	0.34	74.7
Total Potassium	mg/L		1.15	6.13	1.15	8.99
Total Sodium	mg/L		0.45	270	0.45	164
Aluminum-dissolved	mg/L	*	0.004	0.004	0.004	<0.004
Total Antimony	mg/L	0.020	0.001	<0.001	0.001	<0.001

Certified By:

Iris Veraestegui



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AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

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TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Water Quality Assessment - PWQO (mg/L)

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

		SAMPLE DESCRIPTION:		C6-02		C8-03
		SAMPLE TYPE:		Water		Water
		DATE SAMPLED:		2022-05-17 18:15		2022-05-17 14:00
Parameter	Unit	G / S	RDL	3874310	RDL	3874314
Total Arsenic	mg/L	0.1	0.003	0.006	0.003	0.011
Total Barium	mg/L		0.002	0.084	0.002	0.250
Total Beryllium	mg/L	*	0.001	<0.001	0.001	0.001
Total Boron	mg/L	0.2	0.010	0.076	0.010	0.079
Total Cadmium	mg/L	0.0002	0.0001	<0.0001	0.0001	<0.0001
Total Chromium	mg/L		0.003	0.016	0.003	0.044
Total Cobalt	mg/L	0.0009	0.0005	0.0053	0.0005	0.0118
Total Copper	mg/L	0.005	0.001	0.018	0.001	0.045
Total Iron	mg/L	0.3	0.010	14.1	0.010	24.8
Total Lead	mg/L	*	0.001	0.006	0.001	0.024
Total Manganese	mg/L		0.002	0.756	0.002	0.884
Dissolved Mercury	mg/L	0.0002	0.0001	<0.0001	0.0001	<0.0001
Total Molybdenum	mg/L	0.040	0.002	0.004	0.002	0.008
Total Nickel	mg/L	0.025	0.003	0.021	0.003	0.039
Total Selenium	mg/L	0.1	0.002	0.004	0.002	0.009
Total Silver	mg/L	0.0001	0.0001	<0.0001	0.0001	0.0021
Total Strontium	mg/L		0.005	0.335	0.005	0.331
Total Thallium	mg/L	0.0003	0.0003	<0.0003	0.0003	0.0004
Total Tin	mg/L		0.002	<0.002	0.002	0.002
Total Titanium	mg/L		0.010	0.252	0.010	0.425
Total Tungsten	mg/L	0.030	0.010	<0.010	0.010	0.034
Total Uranium	mg/L	0.005	0.002	<0.002	0.002	0.007
Total Vanadium	mg/L	0.006	0.002	0.020	0.002	0.054
Total Zinc	mg/L	0.030	0.020	0.046	0.020	0.112
Total Zirconium	mg/L	0.004	0.004	0.005	0.004	<0.004
Lab Filtration Aluminum Dissolved				2022/05/25		2022/05/25
Lab Filtration mercury				2022/05/25		2022/05/25

Certified By:

Iris Veraistegui



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

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FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE: Highway 9, Brockton ON

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Water Quality Assessment - PWQO (mg/L)

DATE RECEIVED: 2022-05-18

DATE REPORTED: 2022-05-27

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to PWQO * Variable - refer to guideline reference document
Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.
3874310-3874314 Dilution required, RDL has been increased accordingly.
Un-ionized Ammonia detection limit is a calculated RDL. The calculation of Un-ionized Ammonia is based on lab measured parameters (ammonia as N, pH and temperature). Values are reported as calculated.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Iris Veraistegui



Exceedance Summary

AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

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<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: Rod de Castro

SAMPLEID	SAMPLE TITLE	GUIDELINE	ANALYSIS PACKAGE	PARAMETER	UNIT	GUIDEVALUE	RESULT
3874310	C6-02	ON PWQO	Dissolved Metals in Water (mg/L)	Dissolved Copper	mg/L	0.005	0.006
3874310	C6-02	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Cobalt	mg/L	0.0009	0.0053
3874310	C6-02	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Copper	mg/L	0.005	0.018
3874310	C6-02	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Iron	mg/L	0.3	14.1
3874310	C6-02	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Vanadium	mg/L	0.006	0.020
3874310	C6-02	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Zinc	mg/L	0.030	0.046
3874310	C6-02	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Zirconium	mg/L	0.004	0.005
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Cobalt	mg/L	0.0009	0.0118
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Copper	mg/L	0.005	0.045
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Iron	mg/L	0.3	24.8
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Nickel	mg/L	0.025	0.039
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Silver	mg/L	0.0001	0.0021
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Thallium	mg/L	0.0003	0.0004
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Tungsten	mg/L	0.030	0.034
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Uranium	mg/L	0.005	0.007
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Vanadium	mg/L	0.006	0.054
3874314	C8-03	ON PWQO	Water Quality Assessment - PWQO (mg/L)	Total Zinc	mg/L	0.030	0.112



Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: WR 3020-E-0004

SAMPLING SITE: Highway 9, Brockton ON

AGAT WORK ORDER: 22T896882

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Soil Analysis

RPT Date: May 27, 2022

RPT Date: May 27, 2022			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE			MATRIX SPIKE			
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

Corrosivity Package

Chloride (2:1)	3875821		42	42	0.4%	< 2	94%	70%	130%	104%	80%	120%	105%	70%	130%
Sulphate (2:1)	3875821		389	394	1.4%	< 2	95%	70%	130%	101%	80%	120%	NA	70%	130%
pH (2:1)	3865809		8.19	8.18	0.1%	NA	96%	80%	120%						
Electrical Conductivity (2:1)	3865809		0.174	0.174	0.2%	< 0.005	96%	80%	120%						
Redox Potential 1	3874389						100%	90%	110%						

Comments: NA signifies Not Applicable.

pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

Matrix spike NA: Spike level < native concentration. Matrix spike acceptance limits do not apply and are not calculated.

Certified By:



Nivine Basily

Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: WR 3020-E-0004

SAMPLING SITE: Highway 9, Brockton ON

AGAT WORK ORDER: 22T896882

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Water Analysis															
RPT Date: May 27, 2022			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

(Water) Inorganic Chemistry

pH	3869835		7.35	7.36	0.1%	NA	102%	90%	110%						
Electrical Conductivity	3869835		281	282	0.4%	< 2	103%	90%	110%						
Chloride	3874310	3874310	399	391	2.0%	< 0.10	93%	70%	130%	101%	80%	120%	NA	70%	130%
Sulphate	3874310	3874310	23400	22700	3.1%	< 100	97%	70%	130%	102%	80%	120%	100%	70%	130%

Redox in water

Redox Potential	3874272	3874272	133	122	8.6%	NA	100%	90%	110%						
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Water Quality Assessment - PWQO (mg/L)

Electrical Conductivity	3869835		281	282	0.4%	< 2	103%	90%	110%						
pH	3869835		7.35	7.36	0.1%	NA	102%	90%	110%						
Total Dissolved Solids	3866735		450	454	0.9%	< 10	102%	80%	120%						
Alkalinity (as CaCO3)	3869835		88	89	1.1%	< 5	87%	80%	120%						
Bicarbonate (as CaCO3)	3869835		88	89	1.1%	< 5	NA								
Carbonate (as CaCO3)	3869835		<5	<5	NA	< 5	NA								
Hydroxide (as CaCO3)	3869835		<5	<5	NA	< 5	NA								
Fluoride	3874310	3874310	<0.05	<0.05	NA	< 0.05	109%	70%	130%	102%	80%	120%	107%	70%	130%
Chloride	3874310	3874310	399	391	2.0%	< 0.10	93%	70%	130%	101%	80%	120%	NA	70%	130%
Nitrate as N	3874310	3874310	0.88	0.88	0.0%	< 0.05	97%	70%	130%	102%	80%	120%	100%	70%	130%
Nitrite as N	3874310	3874310	<0.05	<0.05	NA	< 0.05	97%	70%	130%	102%	80%	120%	104%	70%	130%
Bromide	3874310	3874310	<0.06	<0.06	NA	< 0.05	108%	70%	130%	101%	80%	120%	100%	70%	130%
Sulphate	3874310	3874310	23.4	22.7	3.0%	< 0.10	97%	70%	130%	102%	80%	120%	100%	70%	130%
Ortho Phosphate as P	3874310	3874310	<0.13	<0.13	NA	< 0.10	95%	70%	130%	93%	80%	120%	93%	70%	130%
Ammonia as N	3867074		<0.02	<0.02	NA	< 0.02	101%	70%	130%	100%	80%	120%	110%	70%	130%
Total Phosphorus	3868914		<0.02	<0.02	NA	< 0.02	102%	70%	130%	99%	80%	120%	97%	70%	130%
Total Organic Carbon	3869835		2.1	2.2	NA	< 0.5	100%	90%	110%	93%	90%	110%	84%	80%	120%
True Colour	3866735		<5.00	<5.00	NA	< 5	98%	90%	110%						
Turbidity	3873125		3.0	3.0	0.0%	< 0.5	100%	80%	120%						
Total Calcium	3873629		88.5	85.4	3.6%	< 0.10	94%	70%	130%	95%	80%	120%	99%	70%	130%
Total Magnesium	3873629		25.6	24.9	2.8%	< 0.10	93%	70%	130%	95%	80%	120%	101%	70%	130%
Total Potassium	3873629		3.11	3.25	4.4%	< 0.50	94%	70%	130%	96%	80%	120%	99%	70%	130%
Total Sodium	3873629		13.3	12.9	3.1%	< 0.10	95%	70%	130%	95%	80%	120%	102%	70%	130%
Aluminum-dissolved	3874310	3874310	0.004	0.004	NA	< 0.004	91%	70%	130%	115%	80%	120%	117%	70%	130%
Total Antimony	3873629		<0.001	<0.001	NA	< 0.001	98%	70%	130%	100%	80%	120%	86%	70%	130%
Total Arsenic	3873629		<0.003	<0.003	NA	< 0.003	97%	70%	130%	90%	80%	120%	89%	70%	130%
Total Barium	3873629		0.027	0.027	0.0%	< 0.002	97%	70%	130%	101%	80%	120%	90%	70%	130%
Total Beryllium	3873629		<0.001	<0.001	NA	< 0.001	96%	70%	130%	91%	80%	120%	94%	70%	130%
Total Boron	3873629		0.015	0.016	NA	< 0.010	101%	70%	130%	101%	80%	120%	95%	70%	130%
Total Cadmium	3873629		<0.0001	0.0007	NA	< 0.0001	96%	70%	130%	99%	80%	120%	89%	70%	130%
Total Chromium	3873629		<0.003	<0.003	NA	< 0.003	101%	70%	130%	103%	80%	120%	91%	70%	130%

Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

ATTENTION TO: Rod de Castro

SAMPLING SITE: Highway 9, Brockton ON

SAMPLED BY: GA

Water Analysis (Continued)

RPT Date: May 27, 2022			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Total Cobalt	3873629		<0.0005	<0.0005	NA	< 0.0005	97%	70%	130%	94%	80%	120%	91%	70%	130%
Total Copper	3873629		0.003	0.002	NA	< 0.001	99%	70%	130%	104%	80%	120%	89%	70%	130%
Total Iron	3873629		0.020	0.031	NA	< 0.010	100%	70%	130%	94%	80%	120%	93%	70%	130%
Total Lead	3873629		<0.001	<0.001	NA	< 0.001	95%	70%	130%	87%	80%	120%	83%	70%	130%
Total Manganese	3873629		0.003	0.003	NA	< 0.002	96%	70%	130%	93%	80%	120%	90%	70%	130%
Dissolved Mercury	3892445		<0.0001	<0.0001	NA	< 0.0001	98%	70%	130%	97%	80%	120%	94%	70%	130%
Total Molybdenum	3873629		<0.002	<0.002	NA	< 0.002	99%	70%	130%	96%	80%	120%	95%	70%	130%
Total Nickel	3873629		<0.003	<0.003	NA	< 0.003	93%	70%	130%	95%	80%	120%	95%	70%	130%
Total Selenium	3873629		<0.002	<0.002	NA	< 0.002	102%	70%	130%	97%	80%	120%	94%	70%	130%
Total Silver	3873629		<0.0001	<0.0001	NA	< 0.0001	97%	70%	130%	96%	80%	120%	92%	70%	130%
Total Strontium	3873629		0.120	0.123	2.5%	< 0.005	92%	70%	130%	92%	80%	120%	87%	70%	130%
Total Thallium	3873629		<0.0003	<0.0003	NA	< 0.0003	90%	70%	130%	93%	80%	120%	91%	70%	130%
Total Tin	3873629		<0.002	<0.002	NA	< 0.002	92%	70%	130%	83%	80%	120%	79%	70%	130%
Total Titanium	3873629		<0.010	<0.010	NA	< 0.010	97%	70%	130%	92%	80%	120%	91%	70%	130%
Total Tungsten	3873629		<0.010	<0.010	NA	< 0.010	86%	70%	130%	86%	80%	120%	80%	70%	130%
Total Uranium	3873629		<0.002	<0.002	NA	< 0.002	90%	70%	130%	93%	80%	120%	89%	70%	130%
Total Vanadium	3873629		<0.002	<0.002	NA	< 0.002	97%	70%	130%	93%	80%	120%	93%	70%	130%
Total Zinc	3873629		0.039	0.055	NA	< 0.020	101%	70%	130%	99%	80%	120%	88%	70%	130%
Total Zirconium	3873629		<0.004	<0.004	NA	< 0.004	100%	70%	130%	103%	80%	120%	90%	70%	130%
Dissolved Metals in Water (mg/L)															
Dissolved Aluminum	3873125		0.044	0.045	2.2%	< 0.004	95%	70%	130%	101%	80%	120%	98%	70%	130%
Dissolved Antimony	3873125		<0.001	<0.001	NA	< 0.001	101%	70%	130%	97%	80%	120%	97%	70%	130%
Dissolved Arsenic	3873125		<0.001	<0.001	NA	< 0.001	96%	70%	130%	90%	80%	120%	98%	70%	130%
Dissolved Barium	3873125		0.049	0.049	0.0%	< 0.002	98%	70%	130%	100%	80%	120%	98%	70%	130%
Dissolved Beryllium	3873125		<0.0005	<0.0005	NA	< 0.0005	100%	70%	130%	94%	80%	120%	112%	70%	130%
Dissolved Bismuth	3873125		<0.002	<0.002	NA	< 0.002	94%	70%	130%	101%	80%	120%	99%	70%	130%
Dissolved Boron	3873125		0.019	0.018	NA	< 0.010	101%	70%	130%	100%	80%	120%	109%	70%	130%
Dissolved Cadmium	3873125		<0.0001	<0.0001	NA	< 0.0001	100%	70%	130%	95%	80%	120%	100%	70%	130%
Dissolved Chromium	3873125		<0.002	<0.002	NA	< 0.002	98%	70%	130%	99%	80%	120%	98%	70%	130%
Dissolved Cobalt	3873125		<0.0005	<0.0005	NA	< 0.0005	96%	70%	130%	108%	80%	120%	96%	70%	130%
Dissolved Copper	3873125		0.003	0.003	NA	< 0.001	100%	70%	130%	97%	80%	120%	95%	70%	130%
Dissolved Iron	3873125		0.054	0.052	3.8%	< 0.010	93%	70%	130%	109%	80%	120%	100%	70%	130%
Dissolved Lead	3873125		0.0006	0.0005	NA	< 0.0005	98%	70%	130%	98%	80%	120%	96%	70%	130%
Dissolved Manganese	3873125		0.005	0.004	NA	< 0.002	95%	70%	130%	110%	80%	120%	98%	70%	130%
Dissolved Molybdenum	3873125		<0.002	<0.002	NA	< 0.002	100%	70%	130%	104%	80%	120%	100%	70%	130%
Dissolved Nickel	3873125		<0.001	<0.001	NA	< 0.001	96%	70%	130%	107%	80%	120%	98%	70%	130%
Dissolved Phosphorus	3873125		<0.05	<0.05	NA	< 0.05	108%	70%	130%	91%	80%	120%	88%	70%	130%
Dissolved Selenium	3873125		<0.001	<0.001	NA	< 0.001	98%	70%	130%	85%	80%	120%	97%	70%	130%
Dissolved Silver	3873125		<0.0001	<0.0001	NA	< 0.0001	94%	70%	130%	106%	80%	120%	93%	70%	130%



Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: WR 3020-E-0004

SAMPLING SITE: Highway 9, Brockton ON

AGAT WORK ORDER: 22T896882

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

Water Analysis (Continued)

RPT Date: May 27, 2022			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Dissolved Silicon	3873125		3.47	3.33	4.1%	< 0.05	95%	70%	130%	93%	80%	120%	99%	70%	130%
Dissolved Strontium	3873125		0.159	0.171	7.3%	< 0.005	96%	70%	130%	109%	80%	120%	97%	70%	130%
Dissolved Thallium	3873125		<0.0003	<0.0003	NA	< 0.0003	99%	70%	130%	101%	80%	120%	99%	70%	130%
Dissolved Tin	3873125		<0.002	<0.002	NA	< 0.002	93%	70%	130%	94%	80%	120%	90%	70%	130%
Dissolved Titanium	3873125		<0.002	<0.002	NA	< 0.002	101%	70%	130%	102%	80%	120%	101%	70%	130%
Dissolved Uranium	3873125		<0.0005	<0.0005	NA	< 0.0005	92%	70%	130%	100%	80%	120%	98%	70%	130%
Dissolved Vanadium	3873125		<0.002	<0.002	NA	< 0.002	97%	70%	130%	110%	80%	120%	100%	70%	130%
Dissolved Zinc	3873125		0.042	0.042	0.0%	< 0.005	101%	70%	130%	95%	80%	120%	102%	70%	130%
Dissolved Zirconium	3873125		<0.004	<0.004	NA	< 0.004	98%	70%	130%	100%	80%	120%	98%	70%	130%
(Water) TSS, CrVI															
Total Suspended Solids	3866685		<10	<10	NA	< 10	98%	80%	120%						
Chromium VI	3876843		<0.001	<0.001	NA	< 0.001	100%	70%	130%	103%	80%	120%	110%	70%	130%

Comments: NA signifies Not Applicable.

Duplicate NA: results are under 5X the RDL and will not be calculated.

Matrix spike NA: Spike level < native concentration. Matrix spike acceptance limits do not apply and are not calculated.

Certified By:

Iris Veraestegui

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

ATTENTION TO: Rod de Castro

SAMPLING SITE: Highway 9, Brockton ON

SAMPLED BY: GA

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	modified from EPA 9045D and MCKEAGUE 3.11	PH METER
Electrical Conductivity (2:1)	INOR-93-6075	modified from MSA PART 3, CH 14 and SM 2510 B	PC TITRATE
Resistivity (2:1) (Calculated)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential 1	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 2	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 3	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: WR 3020-E-0004

SAMPLING SITE: Highway 9, Brockton ON

AGAT WORK ORDER: 22T896882

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Water Analysis			
pH	INOR-93-6000	modified from SM 4500-H+ B	PC TITRATE
Electrical Conductivity	INOR-93-6000	modified from SM 2510 B	PC TITRATE
Resistivity		SM 2510 B	EC METER
Chloride	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Sulphate	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Total Suspended Solids	INOR-93-6028	modified from EPA 1684, ON MOECC E3139, SM 2540C,D	BALANCE
Chromium VI	INOR-93-6073	modified from SM 3500-CR B	LACHAT FIA
Dissolved Aluminum	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Antimony	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Arsenic	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Barium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Beryllium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Bismuth	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Boron	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Cadmium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Chromium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Cobalt	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Copper	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Iron	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Lead	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Manganese	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Molybdenum	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Nickel	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Phosphorus	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Selenium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Silver	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Silicon	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Strontium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Thallium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Tin	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: WR 3020-E-0004

SAMPLING SITE: Highway 9, Brockton ON

AGAT WORK ORDER: 22T896882

ATTENTION TO: Rod de Castro

SAMPLED BY: GA

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Dissolved Titanium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Uranium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Vanadium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Zinc	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Dissolved Zirconium	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Sodium Adsorption Ratio (Calculated)		McKeague 3.26 & EPA SW-846 6010B	CALCULATION
Redox Potential		SM 2580 B	REDOX POTENTIAL ELECTRODE
Saturation pH (Calculated)		SM 2320 B	CALCULATION
Langelier Index (Calculated)		SM 2330B	CALCULATION
Hardness (as CaCO ₃) (Calculated)	MET-93-6105	modified from EPA SW-846 6010C & 200.7 & SM 2340 B	CALCULATION
Total Dissolved Solids	INOR-93-6028	modified from EPA 1684, ON MOECC E3139, SM 2540C, D	BALANCE
Alkalinity (as CaCO ₃)	INOR-93-6000	Modified from SM 2320 B	PC TITRATE
Bicarbonate (as CaCO ₃)	INOR-93-6000	modified from SM 2320 B	PC TITRATE
Carbonate (as CaCO ₃)	INOR-93-6000	modified from SM 2320 B	PC TITRATE
Hydroxide (as CaCO ₃)	INOR-93-6000	modified from SM 2320 B	PC TITRATE
Fluoride	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Nitrate as N	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Nitrite as N	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Bromide	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Ortho Phosphate as P	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Ammonia as N	INOR-93-6059	modified from SM 4500-NH ₃ H	LACHAT FIA
Ammonia-Un-ionized (Calculated)		MOE REFERENCE, PWQOs Tab 2	CALCULATION
Total Phosphorus	INOR-93-6022	modified from SM 4500-P B and SM 4500-P E	SPECTROPHOTOMETER
Total Organic Carbon	INOR-93-6049	modified from SM 5310 B	SHIMADZU CARBON ANALYZER
True Colour	INOR-93-6074	modified from SM 2120 B	LACHAT FIA
Turbidity	INOR-93-6044	modified from SM 2130 B	NEPHELOMETER
Total Calcium	MET-93-6105	modified from EPA 6010D	ICP/OES
Total Magnesium	MET-93-6105	modified from EPA 6010D	ICP/OES
Total Potassium	MET-93-6105	modified from EPA 6010D	ICP/OES
Total Sodium	MET-93-6105	modified from EPA 6010D	ICP/OES
Aluminum-dissolved	MET-93-6103	modified from EPA 200.8 and EPA 3005A	ICP-MS
Total Antimony	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Arsenic	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Barium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Beryllium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Boron	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Cadmium	MET -93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Chromium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS



Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 22T896882

PROJECT: WR 3020-E-0004

ATTENTION TO: Rod de Castro

SAMPLING SITE: Highway 9, Brockton ON

SAMPLED BY: GA

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Total Cobalt	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Copper	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Iron	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Lead	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Manganese	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Dissolved Mercury	MET-93-6100	modified from EPA 245.2 and SM 3112 B	CVAAS
Total Molybdenum	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Nickel	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Selenium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Silver	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Strontium	INOR-93-6003	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Thallium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Tin	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Titanium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Tungsten	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Uranium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Vanadium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Zinc	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Total Zirconium	MET-93-6103	modified from EPA 200.8, 3005A, 3010A & 6020B	ICP-MS
Lab Filtration Aluminum Dissolved	SR-78-9001		FILTRATION
Lab Filtration mercury	SR-78-9001		FILTRATION

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water consumed by humans)

Report Information:

Company: Thurber Engineering Ltd
Contact: Rod de Castro
Address: 2010 Winston Park Drive Unit 103
Oakville ON L6H 5R7
Phone: 647.525.3710 Fax: _____
Reports to be sent to:
1. Email: rod.decastro@thurber.ca
2. Email: _____

Regulatory Requirements:

(Please check all applicable boxes)

- ☐ Regulation 153/04 ☐ Excess Soils R406 ☐ Sewer Use
☐ Ind/Com ☐ Sanitary ☐ Storm
☐ Res/Park ☐ Agriculture ☐ Prov. Water Quality Objectives (PWQO)
☐ CCME ☐ Other
Soil Texture (Check One) ☐ Coarse ☐ Fine

Is this submission for a Record of Site Condition?

☐ Yes ☐ No

Report Guideline on Certificate of Analysis

☐ Yes ☐ No

Sample Matrix Legend

B Biota
GW Ground Water
O Oil
P Paint
S Soil
SD Sediment
SW Surface Water

Project Information:

Project: WR 3020-E-0004
Site Location: Highway 9, Buckton ON
Sampled By: GA
AGAT ID #: _____ PO: _____
Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information:

Bill To Same: Yes ☒ No ☐

Company: _____
Contact: _____
Address: _____
Email: _____

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/Special Instructions	Y/N	Field Filtered - Metals	Hg	Cu	DOC	0. Reg 153	0. Reg 558	0. Reg 406	Landfill Disposal Characterization TCLP	Excess Soils SPLP Rainwater Leach	Excess Soils Characterization Package	pH, ICPMS Metals, BTEX, F1-F4	Salt - EC/SAR	PWQO (as per email)	Consistency (as per email)	Consistency	Potentially Hazardous or High Concentration (Y/N)
22-01	16/5/22	11:45 AM	5	GW	5 bottles + 2 vials	Y																
22-02	16/5/22	12:00 PM	5	GW	5 bottles + 2 vials	Y																
C6-02	16/5/22	18:15 PM	5	GW	+ 8 bottles + 2 vials	Y																
C8-03	16/5/22	14:00 PM		GW	13 bottles + 4 vials	Y																
Garnock Creek	16/5/22	19:30 PM			5 bottles + 2 vials	Y																
C6-01 SS 715-13'	16/5/22		1	Soil																		
C6-01 SS 10 225-243	16/5/22		1	Soil																		
C8-01 SS 9 to 20	17/5/22		1	Soil																		
C8-01 SS 11 25-27'	17/5/22		1	Soil																		

Samples Relinquished By (Print Name and Sign): <u>Stephane Lorange</u>	Date: <u>May 18/22</u>	Time: <u>9:40am</u>	Samples Received By (Print Name and Sign): <u>Armando Lora</u>	Date: <u>5/18/22</u>	Time: <u>11:22AM</u>
Samples Relinquished By (Print Name and Sign):	Date:	Time:	Samples Received By (Print Name and Sign):	Date:	Time:
Samples Relinquished By (Print Name and Sign):	Date:	Time:	Samples Received By (Print Name and Sign):	Date:	Time:

Page _____ of _____
Nº: **T 123748**

Laboratory Use Only

Work Order #: 22T896882
Cooler Quantity: 1 Kg (Bureau)
Arrival Temperatures: 6.8 17.9 18.4
Custody Seal Intact: ☒ Yes ☐ No ☐ N/A
Notes: Bagged Ice

Turnaround Time (TAT) Required:

Regular TAT (Most Analysis) ☒ 5 to 7 Business Days

Rush TAT (Rush Surcharges Apply)

☐ 3 Business Days ☐ 2 Business Days ☐ Next Business Day

OR Date Required (Rush Surcharges May Apply):

Please provide prior notification for rush TAT
*TAT is exclusive of weekends and statutory holidays

For 'Same Day' analysis, please contact your AGAT CPM



THURBER ENGINEERING LTD.

Slug Test Analysis Report

Project: Grennock Creek Bridge

Number: 33249

Client: Ministry of Transportation of Ontario (MTO)

Location: Walkerton, Ontario

Slug Test: C8-03

Test Well: C8-03

Test Conducted by: GA

Test Date: 2022-05-17

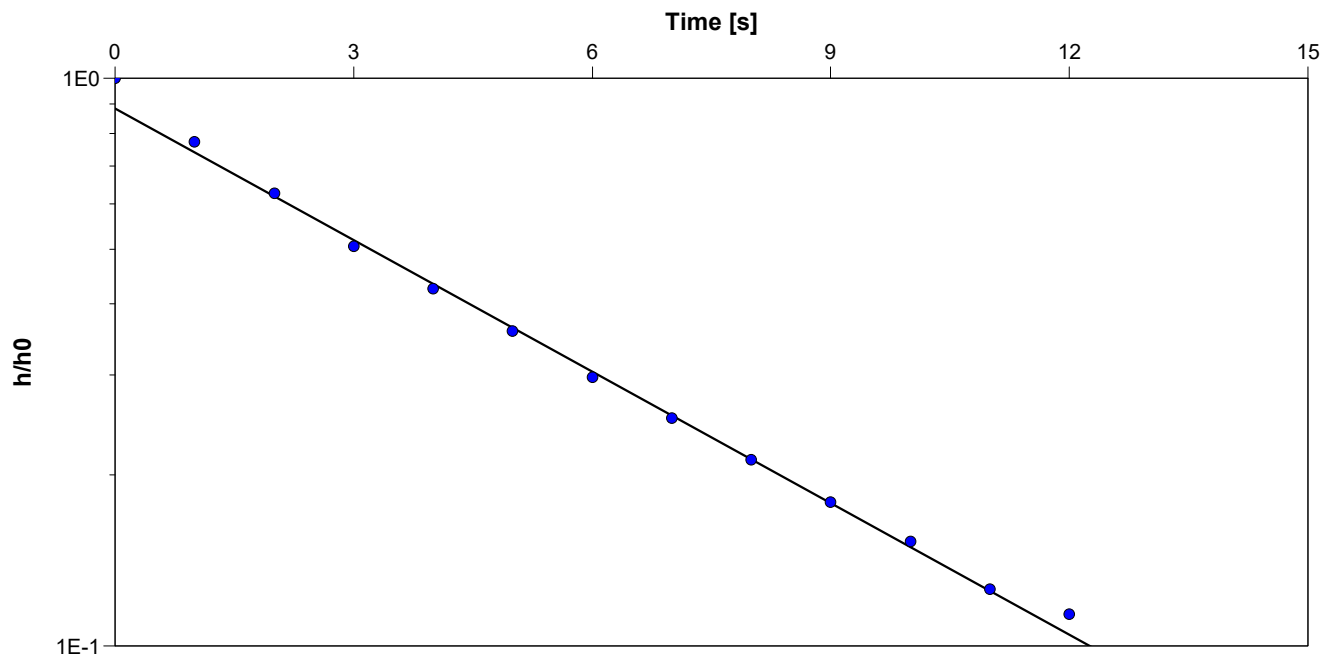
Analysis Performed by: ES

C8-03 SWRT Analysis

Analysis Date: 2022-06-09

Aquifer Thickness:

Checked By: AH



Calculation using Hvorslev

Observation Well

Hydraulic Conductivity
[m/s]

C8-03

1.6×10^{-4}



Appendix C
Site and Bedrock
Core Photographs



Photograph #1 – Looking East – C8 Culvert and North Embankment



Photograph #2 – Looking West – C8 Culvert and South Embankment



Photograph #3 – Bedrock Core Samples for Borehole C8-01

Run No. 1 – 9.1 m to 10.7 m

Run No. 2 – 10.7 m to 12.2 m



Photograph #5 – Bedrock Core Samples for Borehole C8-02

Run No. 1 – 1.4 m to 1.6 m

Run No. 2 – 1.6 m to 3.1 m

Run No. 3 – 3.1 m to 4.6 m

Run No. 4 – 4.6 m to 4.9 m



Photograph #6 – Bedrock Core Samples for Borehole C8-03

Run No. 1 – 2.6 m to 3.8 m

Run No. 2 – 3.8 m to 5.0 m

Run No. 3 – 5.0 m to 5.4 m



Appendix D

Tunnelman's Ground Classification System

Tunnelman's Ground Classification System (after Heuer, 1974)

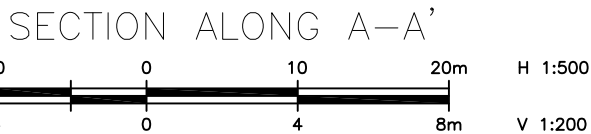
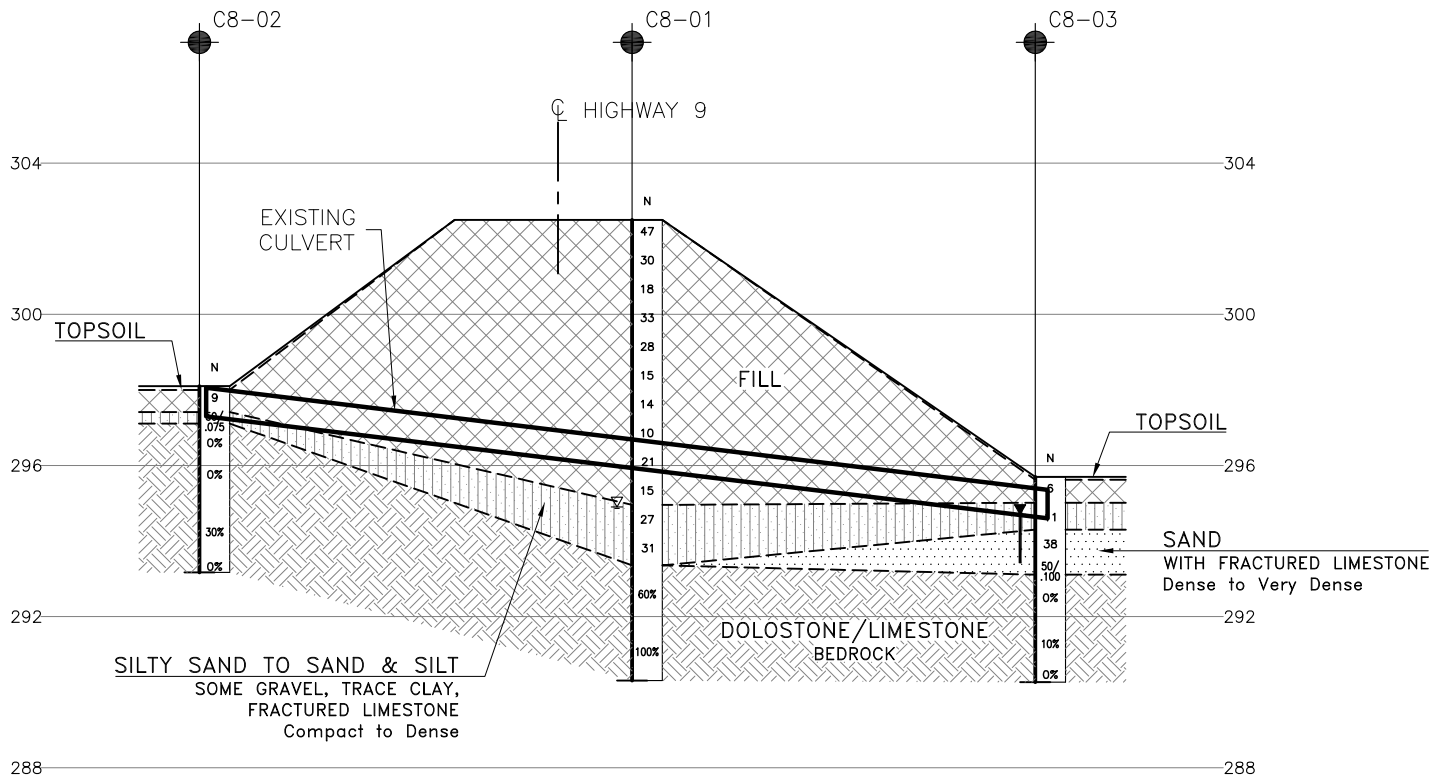
Classification		Behaviour	Typical Soil Type
Firm		Heading can be advanced without initial support, and final lining can be constructed before ground starts to move.	Loess above water table; hard clay, marl, cemented sand and gravel when not highly overstressed.
Raveling	Slow Raveling	Chunks or flakes of material begin to drop out of the arch or walls sometime after the ground has been exposed; due to loosening or to overstress and "brittle" fracture (ground separates or breaks along distinct surfaces opposed to squeezing ground). In fast raveling ground, the process starts within a few minutes; otherwise the ground is slow raveling.	Residual soils or sand with small amounts of binder may be fast raveling below the water table, slow raveling above. Stiff fissured clays may be slow or fast raveling depending upon degree of overstress.
	Fast Raveling		
Squeezing		Ground squeezes or extrudes plastically into tunnel, without visible fracturing or loss of continuity, and without perceptible increase in water content. Ductile, plastic yield and flow due to overstress.	Ground with low frictional strength. Rate of squeeze depends on degree of overstress. Occurs at shallow to medium depth in clay of very soft to medium consistency. Stiff to hard clay under high cover may move in combination with raveling at excavation surface and squeezing at depth behind surface.
Running	Cohesive Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (+/-30° to 35°). When exposed at steeper slopes they run like granulated sugar or dune sand until the slope flattens to the angle of repose.	Clean dry granular materials. Apparent cohesion in moist sand, or weak cementation in any granular soil, may allow the material to stand for a brief period of raveling before it breaks down and runs. Such behaviour is cohesive-running.
	Running		
Flowing		A mixture of soil and water flows into the tunnel like a viscous fluid. The material can enter the tunnel from the invert as well as the face, crown, and walls, and can flow for great distances, completely filling the tunnel in some cases.	Below the water table in silt, sand or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.
Swelling		Ground absorbs water, increases in volume, and expands slowly into the tunnel.	Highly pre-consolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite.

Modified from Terzaghi (1950)



Appendix E

Borehole Locations and Soil Strata Drawing



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

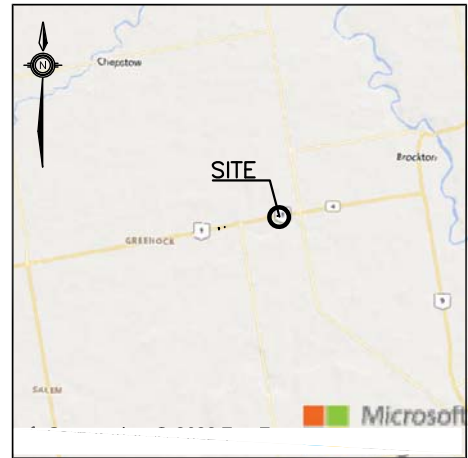


CONT No
WP No

HIGHWAY 9
CULVERT C8
REHABILITATED
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



KEYPLAN

LEGEND

	Borehole (By Thurber)
	Borehole (Previous Investigation)
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
C8-01	302.5	4 886 774.0	168 216.7
C8-02	298.1	4 886 802.6	168 212.2
C8-03	295.7	4 886 747.3	168 213.9

-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.
- 3) Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 42A-254

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
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Appendix F

Comparison of Trenchless Methods



Table F1 – Comparison of Trenchless Methods

Installation Method	Feasibility	Advantage	Disadvantage	Relative Costs and Risks
Hand Mining	Not Feasible	<ul style="list-style-type: none"> Equipment and crew readily available. 	<ul style="list-style-type: none"> Not suitable for small diameter pipes. Dewatering will be required in water-bearing granular soils. Slow process 	<ul style="list-style-type: none"> Moderately expensive method. Risk of worker injury.
Micro-tunnelling (MTBM)	Feasible	<ul style="list-style-type: none"> Provides continuous support to excavation face. Does not require groundwater lowering, only at the shaft locations. Final pipe can be installed while bore is being advanced. Can be steered continuously, providing precise control over line and grade. Hard / very dense soils, cobbles, and boulders (of limited size) can be cut and penetrated provided appropriate disc cutter face tools are utilized. 	<ul style="list-style-type: none"> Will require equipment capable of cutting cobbles and boulders or allow person-entry for removal of such obstructions. Greater cost for muck handling and disposal. Advance of MTBM may be halted by large number of cobbles or large boulders; only method of removing such obstructions may be shaft excavated from surface. Lack of readily available equipment. 	<ul style="list-style-type: none"> Most expensive method. High mobilization costs for short crossings. Low risk for culvert installation provided appropriate equipment and slurry properties are selected and controlled.
Horizontal Directional Drilling	Not recommended	<ul style="list-style-type: none"> Can be steered continuously, providing precise control over line and grade if concrete casing pipe is used. Equipment more readily available than MTBM. 	<ul style="list-style-type: none"> Diminishing accuracy for longer bores. Grouting of the annular space between the casing and culvert is required. 	<ul style="list-style-type: none"> Moderately expensive method. Obstruction can result in deflection resulting in misalignment of the culvert.



Installation Method	Feasibility	Advantage	Disadvantage	Relative Costs and Risks
Jack-and-Bore	Feasible	<ul style="list-style-type: none"> • Widely used method. • The line and grade can be maintained with moderate accuracy. • Reduce level of vibration. 	<ul style="list-style-type: none"> • Large work areas required for jacking pit. • Cobbles, boulders, and other obstructions may deflect and/or halt bore, in which case, removal of augers and person-entry would be required to remove obstructions. • Unstable water-bearing granular interlayers may go undetected until ground loss and settlement has occurred. • Grouting of the annular space between the casing and culvert is required. 	<ul style="list-style-type: none"> • Least expensive method. • Risk of encountering refusal on obstruction. • Obstructions can result in deflection of the casing resulting in misalignment of the culvert. • Potential for loss of ground into casing when saturated layers are encountered. • Potential need for excavation pits to remove obstructions. • Face instability in silts and sands under groundwater table.
Pipe Ramming	Feasible	<ul style="list-style-type: none"> • Better suited for penetrating through cobbles and boulders than Jack-and-Bore depending on the size and strength of obstructions. • Continuous casing installation. 	<ul style="list-style-type: none"> • Large work areas required for ramming pit. • Cobbles, boulders, and other obstructions may deflect and/or halt ramming. • Removal of spoil may be required after advancing the pipe partway due to the weight of and drag on pipe. • Grouting of the annular space between the casing and culvert is required. 	<ul style="list-style-type: none"> • Moderately expensive method. • Potential for heave at ground surface. • Potential for settlement of near surface fills due to vibrations.



Appendix G
List of Special Provisions
and
Suggested Wording for NSSP



1. List of Special Provisions Referenced in this Report

- OPSS PROV 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation)
- OPSS PROV 539 (Construction Specification for Temporary Protection Systems)
- Special Provision No 517F01 (Temporary Flow Passage System)

2. Suggested Text for NSSP for 'Pipe installation by Trenchless Method.

The Contractor's attention is drawn to the following:

- The embankment fill deposits may contain cobbles and boulders. the Contractor shall be equipped to dislodge, remove, and otherwise handle such obstructions such as cobbles, boulders, bedrock knobs at the tunnel face and during excavation of the temporary pits should it be required
- The pipe installation may be carried out through gravelly silty sand to sandy silt fill and native silty sand to silt and sand and/or bedrock knobs with groundwater above the pipe invert. Such obstructions may impede installation progress. The Contractor shall be prepared to remove, advance through and/or penetrate these obstructions to complete the trenchless installation
- The Contractor's methodology must include means of handling potential sloughing of water-bearing native sands and silts and water seepage at the tunnel face.
- The Contractor must accurately establish, in three dimensions, the locations of all buried utilities crossing or closely paralleling the path of the bore, including the existing 600 mm culvert to the south. It is recommended that the existing culvert be monitored during trenchless activities. Any discrepancy from the Contract Drawings must be reported to the Contract Administrator.
- Shallow bedrock is anticipated to be below the trenchless installation. The selected trenchless methodology must be capable of advancing through soil-bedrock mixed face conditions while maintain the horizontal and vertical pipe alignment through the installation. Bedrock excavation may also be required at the entry exit pits.
- The bedrock is classified as strong to very strong. If excavation of bedrock is required, equipment that can excavate hard will be required. Equipment that can penetrate hard rock will be required to excavate the bedrock at the entry/exit pits or construct temporary protection systems. Blasting of bedrock is not permitted at this site

**CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY
TRENCHLESS METHOD**

1.0 SCOPE

This Special Provision covers the requirements for the installation of pipes by a selected trenchless method.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 182 Environmental Protection for Construction in Waterbodies and On Waterbody Banks
OPSS 401 Trenching, Backfilling, and Compacting
OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets
and Valve Chambers
OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404 Construction Specification for Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 490 Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 491 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 510 Construction Specification for Removal
OPSS 517 Construction Specification for Dewatering
OPSS 539 Construction Specification for Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

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

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
B182.8 Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings

B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

A 252M-19	Standard Specification for Welded and Seamless Steel Pipe Piles
C-33	Standard Specification for Concrete Aggregates.
C-39	Standard Test method for Compressive Strength of Cylindrical Concrete
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories
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3.0 DEFINITIONS

For the purpose of this Special Provision, the following definitions apply:

Annular Space means the space between the inside edge of the opening and the outside edge of the penetrating item or inserted pipe.

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

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

Boulder Number Ratio (BNR) means the number of individual boulders per m³ of cumulative boulder volume.

Boulder Volume Ratio (BVR) means the ratio between the cumulative volume of boulders and the volume of the material excavated.

Design Engineer means the Engineer retained by the Contractor who produces the design and Working Drawings and other engineering documents required of the Contractor. 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.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades,

rams, shovels, breaker bars, etc.) or a “digger” type shield with a hydraulic excavator arm or “road-header” rock cutting machine to remove materials from inside the shield and liner pipe.

Drilling Fluids means 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 Hydraulic Fracture or “Frac Out” means a condition where the drilling fluid’s pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

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

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or 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.

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

Hand Mining means a method of forming a horizontal bore in the subsurface by 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.

Horizontal Directional Drilling (HDD) means a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final steps of the process.

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

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

Microtunnelling means an underground method of constructing a passage by using a microtunnelling boring machine (MTBM) or hand mining using a shield to support the opening.

MTBM means a microtunnelling boring machine.

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

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits, and ducts.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe Ramming means 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.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path.

Rock means 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 volume of 0.5 m³ or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a tunnel boring machine (TBM) or microtunnelling boring machine (MTBM), through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

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

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Strike Alert means 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.

TBM means a tunnel boring machine.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnelling boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of trenchless installation for each pipe crossing for each location within the terms of this specification.

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with the Contract Documents.

The detailed design of the installation method selected to carry out the Work as specified in the Contract Documents shall be completed.

* Designer Fill-in, See Notes to Designer

- Hand mining and horizontal directional drilling (HDD) shall not be utilized at this site

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names of the Project Superintendent, and Trenchless Contractor shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity.

During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change the Project Superintendent shall be submitted at least one week prior to the actual change in Project Superintendent.

** Designer Fill-in, See Notes to Designer

- Project specific minimum requirements for the project superintendent is not required. The minimum experience of the project superintendent in Section 4.02.01.01 of NSSP "Pipe Installation by Trenchless Method is applicable.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five (5) years experience on projects with similar scope and complexity.

*** Designer Fill-in, See Notes to Designer

- Project specific minimum requirements for the trenchless contractor is not required. The minimum experience of the trenchless contractor in Section 4.02.01.02 of NSSP "Pipe Installation by Trenchless Method is applicable.

4.02.02 Working Drawings

Three (3) sets of Working Drawings for the selected trenchless installation method, and a Request to Proceed shall be submitted to the Contract Administrator two weeks (2) prior to the commencement of the Work or as per the Contract Documents.

The trenchless installation operation shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

Information and details shown on the Working Drawings shall include, but not limited to the following:

a) Plans and Details:

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work.
- ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the Work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A traffic control plan.
- v. A safety plan including the company safety manual and emergency procedures.
- vi. The Working Area layout.
- vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- viii. A contingency plan with 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.
- ix. 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.
- x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- xi. Excavated materials disposal plan.
- xii. Locations of protection systems.

xiii. Contingency plans for the following potential conditions:

- Unforeseen obstructions causing stoppage.
- Deviation from required alignment and grade.
- Extended service disruption.
- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

- i. Primary Liner/Secondary Liner design (e.g. steel liner plates, steel ribs and wood lagging, and steel casing etc.).
- ii. Design assumption and material data when materials other than those specified are proposed for use.
- iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.
- iv. Minimum depth of cover for trenchless installation appropriate for the highway type and pipe diameter, maximum excavation diameter, maximum annulus, alignment and grade tolerance etc.
- v. Detailed subsurface conditions along the proposed path or within the footprint of the trenchless technology equipment or pits/shafts.

c) Materials:

- i. 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.
- ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance (EPB), Slurry Pressure Balance (SPB).
- iii. Manufacturer data sheets for drilling systems.
- iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (MTBM) operations.
- v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- vi. Compressive strength of concrete pipe products.
- vii. Pipe class for all steel pipe products.
- viii. Steel for Permanent Casings:
 - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
 - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada

to comply with the requirements of ISO/IEC 17025 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 (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

ix. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
- Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

- i. Access shaft or entry/exit pit details, as applicable.
- ii. Face support and other temporary support details, if applicable.

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

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

f) Excavation and Dewatering:

- i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
- ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
- iii. Equipment and methods for removal of cobbles and boulders;
- iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, Slurry Pressure Balance (SPB) and Earth Pressure Balance (EPB) pressures;
- v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
- vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
- vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship

- of target operating conditions to ground conditions;
- viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
- ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

- i. Maintaining the alignment of the installation;
- ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
- iii. Jacking forces on pipes, linings and cutting tools;
- iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
- v. Grout injection pressures and volumes;
- vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.); and
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction.

4.02.03 As-Built Drawings

As-built drawings shall be submitted to the Contract Administrator in a reproducible format prior to the Contract completion.

The as-built drawings shall be dated and bear the seal and signature of the Design Engineer and Design Checking Engineer.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

All joints shall be suitable for jacking operations as specified in the Working Drawings.

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 High Density Polyethylene Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

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

Jointing of HDPE piping shall be completed according to the manufacturer's recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer's instructions and ASTM D2657, the manufacturer's instructions are to be followed.

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

Selection of drilling fluid type shall be based on the soils encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer's recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel

viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

- a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;
- b) lubricate installation of primary liners as required;
- c) transport spoil through pipe systems.

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 and be wetted with only sufficient water to make the mixture plastic.

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

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 equipment with 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.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems.

6.02 Pipe Ramming

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 entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

Specific details of the equipment with 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 Horizontal Directional Drilling

6.03.01 General

The Horizontal Directional Drilling (HDD) equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

- a) 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.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) 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

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission

requirements specified herein. Specific details of the Tunnelling equipment included in the submission shall be provided for:

- a) rock or boulder breaking and removal;
- b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;
- c) jacking systems;
- d) alignment control systems;

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 without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting Microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils that will be encountered.

The Contractor shall employ Microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel.
 - ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
 - viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.

- ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control – The Contractor shall provide a MTBM that includes an active direction control system with the following features:
 - i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.
 - ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

- a) Has the main jacks mounted in a jacking frame located in the launch shaft.
- b) Has a jacking frame that successively pushes towards a receiving shaft, a string of product pipe that follows the microtunnelling excavation equipment.
- c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
- d) The main jack station may be complemented with the use of intermediate jacking stations as required.
- e) Has a capacity at least 20 % greater than the calculated maximum jacking load.
- f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
- g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
- i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7.0 CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting the work. The

proposed method of pipe installation to be used by the Contractor shall be subject to the limitations presented in the following subsections.

The Contractor's Engineer shall supervise the work at all times.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of each of the following operations and prior to commencement of each subsequent operation and no less than 2 weeks prior to the commencement of the trenchless installation.

- a) Site Surveying (see Clause 4.02)
- b) Excavation for pits including dewatering of excavations
- c) Jacking / Ramming / Directional Drilling of Casing / Liner
- d) Installation of the Product
- e) Grouting Operations

Operations a) to e) shall not proceed until the Contract Administrator has issued a Notice to Proceed for each proceeding operation.

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 Working Day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

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

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

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 539.

Where the stability, safety, or function of an existing roadway, railway, watercourse, other works, ESA's, or

proposed works 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 Contractor, 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, procedures, 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 recommendations for transporting, unloading, storing, and handling of materials 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 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 Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles and boulders shall be expected to be routine and will not be considered obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

**** Designer Fill-in, See Notes to Designer

- Not applicable. The subsurface conditions are described in the FIR included in the contract.

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal.

***** Designer Fill-in, See Notes to Designer

- Although obstructions were not encountered during the foundation investigation, the embankment fill may contain cobbles and boulder. In addition, shallow bedrock was encountered at the inlet and outlet of the existing culvert. As such, the Contractor shall be equipped to dislodge, remove, and otherwise handle such obstructions such as cobbles, boulders, bedrock knobs at the tunnel face and during excavation of the temporary pits should it be required.

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

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:

- a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- b) 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.
- c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- d) 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 watertight and according to OPSS 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 excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a watertight, 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. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits 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.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has

passed fully through and beyond the zone of influence of any overlying infrastructure.

- 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 watertight, expandable, and stable grout.

7.04 Horizontal 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.

For Horizontal Directional Drilling (HDD), the Contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9 m 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.

7.04.02 Site Preparation

Site preparation shall be according to OPSS 490 and as specified herein.

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 HDD operations are to be made. All activities shall be confined to designated Working 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, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD 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 Losses to Surface (“Frac-Out”)

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore 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.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

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

7.04.06.01 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 contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses 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 pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe 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. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe 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 ensure 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 walls of the excavated volume shall be filled with grout or slurry with gel

strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7.05 Tunnelling Installation

7.05.01 General

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 provide ventilation and lighting in accordance with OHSA requirements for the entire length of the tunnel installed as tunneling progresses.

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.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. 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.

7.05.02 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.

7.05.03 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 wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.04 Secondary Liner

7.05.04.01 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. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained 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 the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

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

7.06.02 Method of Installation

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

- 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 subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour Working Days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the casing and the wall of the excavation shall be filled with grout that is compatible with the casing.

The casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the casing.

The casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

***** Designer Fill-in, See Notes to Designer

- The site-specific Instrumentation and Monitoring Program for Highway 9 is included in the contract.

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.

The equipment and procedures used for settlement monitoring during construction must be capable of surveying

the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

7.07.02 Surface Settlement Monitoring Points

Surface settlement monitoring points shall be installed on the traffic lanes and shoulders to monitor settlement and stability. The surface settlement monitoring points shall be installed centred on the tunnel alignment as arrays of three points at intervals of 5 m or less and off-set a lateral distance of 1.5 m on either side of the tunnel centerline.

Surface settlement monitoring points 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). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.03 In-Ground Settlement Monitoring Points

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals. In-ground settlement monitoring points shall be located at intervals of 5 m or less along the tunnel alignment.

In-ground 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 or below frost penetration depth, whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field 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. Instruments damaged by the Contractor's operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.05 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

- a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and

- c) 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 Administrator 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.

7.07.06 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

***** Designer Fill-in, See Notes to Designer

- Project specific review and alert levels are not required. The review and alert levels in Section 7.08 of NSSP "Pipe Installation by Trenchless Methods" are applicable.

Based on the monitoring of the ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

- a) 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 Contract Administrator 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.
- b) 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:
 - i. The cause of the settlement has been identified.
 - ii. The Contractor submits a corrective/preventive plan complete with a Request to Proceed.
 - iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the pipe at each location. In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design Engineer and the Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, sealed Working Drawings and Contract Documents.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centreline 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.

10.0 BASIS OF PAYMENT

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

If a pipe is installed inside the pipe liner, payment for the pipe 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.

***** Designer Fill-in, See Notes to Designer

- Payment of removal of boulders with diameter 250 mm or greater shall be only a time and material basis

NOTES TO DESIGNER:

* Insert the following fill-in: Any method that is not suitable shall be specified.

** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

*** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

**** Insert the following fill-in: Subsurface Condition Baseline Reporting that includes Boulder Volume Ratio (BVR), Boulder Number Ratio (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.

***** Insert the following fill-in: Any known obstructions shall be specified.

***** Insert the following fill-in: The Instrumentation and Monitoring program shall be project specific. The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

***** Insert the following fill-in: Project specific Review and Alert Levels shall be provided if required.

***** Insert the following fill-in: Payment for removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.

WARRANT: Always with this specification.



Appendix H Instrumentation and Monitoring Program



**INSTRUMENTATION SUPPLY & INSTALLATION
AND MONITORING PROGRAM
PROPOSED CULVERT CROSSINGS AT HIGHWAY 9
CULVERT C8 AT STATION 11+475**

- Item No.

Special Provision

1 GENERAL

1.1 Scope

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

- Surface Monitoring Point (SMP)
- In-ground 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 proposed Highway 9 C8 culvert.

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.



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 of Monitoring Program) established to the satisfaction of all parties listed above not less than five days in advance of the installation operations.

1.6 Instrument Installation Requirements

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

1.7 Subsurface Conditions

- The subsurface conditions at the site are described in Thurber's Report titled: "Foundation Investigation Report, Highway 9 Culvert Replacement, Township of Greenock – Sta. 11+475, Culvert C8, Ontario, by Thurber Engineering Ltd., Reference No. 33249, dated September 9, 2022.

2 INSTALLATION

2.1 General

Based on the width of the highway at this section, it is anticipated that there will be nine (9) monitoring points (SMP) and two (2) in-ground settlement rods (SR) to be installed at this site. The Settlement Monitoring Guidelines - Tunneling of the Guidelines for Foundation Engineering - Tunnelling Specialty For Corridor Encroachment Permit Application (CMO), shall be followed.



SMPs will be installed along the centreline of traffic lanes and paved shoulders in arrays of three (3) instruments. 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.	Culvert Diameter (mm)	Trenchless Length (m)	Depth of Pipe Crown Below Top of Pavement (m)	Number of Monitoring Points	
				SMP	SR
11+475	750	54.2	7.5	9	2

The array with three instruments will consist of the following:

- One (1) instrument installed at the proposed culvert centreline
- One (1) instrument installed at 1.5 m north of the proposed culvert at centreline, east and west shoulders of Highway 9
- One (1) instrument installed at 1.5 m south of the proposed culvert at centreline, east and west shoulders of Highway 9.

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 ± 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.

3.2 **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.

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.

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 Special Provisions 'Construction Specifications for the Installation of Pipes by Trenchless Methods' dated February 2021 provided by the MTO 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 the CA.

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 9.
- 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 Highway 9 C8 culvert at Station 11+475.

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.

Table 6.1 - Minimum Monitoring Frequency

STAGE	FREQUENCY	ANTICIPATED NO. OF READINGS PER INSTRUMENT (**)
Baseline Readings (*)	3 readings on 2 consecutive days	3
During culvert installation	A minimum of two (2) set 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, or until such time at which all parties agree that further movement has stopped	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.