

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
SEWER PIPE INSTALLATION BY TRENCHLESS METHODS  
HWY 401 WIDENING, HWY 410 TO WEST OF HURONTARIO STREET  
MISSISSAUGA, ONTARIO  
G.W.P. 2107-05-00**

**Geocres Number: 30M12-280**

**Report to**

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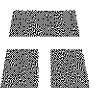
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**PART 1: FACTUAL INFORMATION**

## **1 INTRODUCTION**

This report presents the factual findings obtained from a geotechnical investigation conducted at the location of two proposed sewer pipes to be installed by trenchless method at Highway 401 and Highway 410 interchange and Highway 401 and Hurontario Street interchange in Mississauga, Ontario. Installation of the sewer pipes is part of the Highway 401 widening from Highway 410 to west of Hurontario Street in Mississauga, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the proposed trenchless installation locations and, based on the data obtained, to provide a borehole location plan, records of boreholes, laboratory test results, stratigraphic profiles and a written description of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to MMM Group Limited (MMM) under the Ministry of Transportation Ontario (MTO) Agreement Number 2005-A-000347.

## **2 SITE DESCRIPTION**

Installation of two pipes by trenchless methods is proposed under Highway 401 mainline and 401E to 410N Ramp at the following locations:

- Approximately 245 m west of Hurontario Street and Highway 401 interchange
- Approximately 415 m west of Highway 410 and Highway 401 interchange

The lands west of the Highway 401 and Highway 410 interchange are generally vacant and undeveloped. Vegetation is moderate consisting mainly of tall grass and shrubs. In general the lands

to the west of Highway 401 and Hurontario Street interchange have been developed for commercial and industrial uses. The topography is typically flat, sloping gently towards Lake Ontario to the south.

Two photographs of the site are included in Appendix D and show the general nature of the surrounding land.

The general site area is located within the physiographic region known as the Peel Plain, characterized by a level to undulating cohesive glacial till typically less than 1 m to 7 m thick which is underlain by grey and reddish brown shale bedrock with hard limestone and siltstone interbeds.

### 3 SITE INVESTIGATION AND FIELD TESTING

Site investigation and field testing for the proposed trenchless installations consisted of drilling and sampling five boreholes at and near the proposed trenchless locations. Boreholes were drilled from March 25 to 30, 2009. A summary of the borehole designations is provided in Table 3.1.

**Table 3.1 – Borehole Designations**

<b>Trenchless</b>	<b>Location</b>	<b>Borehole</b>	<b>Borehole Termination Depth (m)</b>	<b>Stratum at Termination Depth</b>
1	Across Hwy 401 W- Hwy 410 N Ramp, 415 m west of Hwy 410	T-01	6.7	Shale bedrock
		T-02	5.3	Shale bedrock
2	Across Hwy 401 and across Hwy 401 W- Hurontario St. Ramp, 245 m west of Hurontario Street	T-03	7.0	Shale bedrock
		T-04	9.1	Shale bedrock
		T-05	7.3	Shale bedrock

No boreholes were drilled through the Highway 401 mainline or the ramps.

The approximate borehole locations are shown on the Borehole Location Drawing in Appendix E. The coordinates and elevations of the boreholes are given on this drawing and on the individual Record of Borehole Sheets in Appendix A.

Prior to commencement of drilling, utility clearances were obtained for all borehole locations.

Solid stem augers were used to advance the boreholes in the overburden and into the shale. Samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). NQ rock coring equipment was used to recover core samples of the bedrock in the boreholes.

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

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

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Two standpipe piezometers consisting of 19 mm PVC pipes with screens were installed in the boreholes to permit monitoring of groundwater levels. Details of the piezometer installations and other borehole completion details are as shown in Table 3.2.

**Table 3.2 – Borehole Completion Details**

<b>Trenchless</b>	<b>Location</b>	<b>Borehole</b>	<b>Piezometer Tip Depth/ Elevation (m)</b>	<b>Completion Details</b>
1	Across Hwy 401 W- Hwy 410 N Ramp, 415 m west of Hwy 410	T-01	6.7/178.2	Piezometer with 1.5 m slotted screen installed with sand filter to 4.9 m, holeplug from 4.9 m to surface.
		T-02	No Installation	Holeplug to surface.
2	Across Hwy 401 and across Hwy 401 W- Hurontario St. Ramp, 245 m west of Hurontario Street	T-03	7.0/181.8	Piezometer with 1.5 m slotted screen installed with sand filter to 5.2 m, holeplug from 5.2 m to surface.
		T-04	No Installation	Holeplug to surface.
		T-05	No Installation	Holeplug to surface.

#### 4 LABORATORY TESTING

All recovered soil and rock samples were subjected to Visual Identification (VI) and geological logging. Moisture content determinations were carried out on all soil samples. At total of 37% of the recovered soil samples were also subjected to grain size distribution analyses (sieve and hydrometer) and Atterberg Limits testing where appropriate. The results of this testing program are presented on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

Core samples of the shale bedrock were carefully protected to prevent drying during transport to the laboratory. Point load tests were carried out on selected samples of intact shale, limestone and siltstone upon arrival at the laboratory to assist evaluation of the compressive strength of the bedrock. The results of point load tests on the selected rock core samples are shown on the Record of Borehole sheets and in Table 1, immediately following the text.

#### 5 DESCRIPTION OF SUBSURFACE CONDITIONS

This section presents a generalized summary of the subsurface conditions encountered at the borehole locations drilled for the proposed trenchless alignments. Reference is made to the Records of Borehole sheets in Appendix A. Details of the encountered soil and rock stratigraphy are presented in the appendix. An overall description of the stratigraphy encountered in Boreholes T-01 to T-05 is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general terms, the soil stratigraphy encountered at this site consists of topsoil and fill underlain by native silty clay till deposit. Shale bedrock was contacted below the silty clay till deposit. More detailed descriptions of the individual stratum are presented below. It should be noted that since no boreholes were drilled through the Highway 401 mainline or ramps, information on any highway embankment fill (estimated to be 4.5 m high at Trenchless 1 and 2.0 m high at Trenchless 2) or the pavement structure along the pipe alignment are not available.

### **5.1 Topsoil**

Topsoil was identified at ground surface in all the boreholes. The topsoil thickness ranged from 50 mm to 150 mm. The topsoil thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities.

### **5.2 Fill**

Fill was encountered below the topsoil in Boreholes T-01 and T-04.

The fill consists of brown to reddish brown silty clay containing trace to some sand and trace of gravel. Thickness of the fill was 750 mm.

The depth to the base of the fill was 0.8 m in both boreholes (Elevations 184.1 and 187.6).

Based on recorded SPT N-values of 7 blows for 0.3 m of penetration, the silty clay fill is described as firm.

The natural moisture contents of the fill samples obtained ranged approximately from 10% to 21%.

### **5.3 Silty Clay Till**

Native brown to reddish brown and grey silty clay till containing trace sand to sandy and trace gravel was contacted below the fill in Boreholes T-01 and T-04 and below the topsoil in Boreholes T-02, T-03 and T-05. Thickness of the till deposits ranged from 0.75 m to 2.6 m.

The depth to the base of the silty clay till deposits ranged from 0.9 m to 3.4 m (Elevations 181.5 to 187.8).

Based on SPT N-values ranging from 5 to 77 blows for 0.3 m of penetration, the silty clay till is described as firm to hard, although typically the till is stiff to hard. An SPT N-value of 50 blows per 0.15 m of penetration was measured in Borehole T-01 near Elevation 181.7.

The natural moisture contents of the samples recovered from the silty clay till layer ranged from 10% to 25%.

Grain size distribution curves for silty clay till samples tested are presented on the Record of Borehole sheets and on Figure B1 of Appendix B. Atterberg Limit test results are presented on Figure B3 of Appendix B.

The results of laboratory gradation and Atterberg Limits tests are summarized as follows:

Soil Particles	(%)
Gravel	0 to 8
Sand	15 to 34
Silt	41 to 53
Clay	17 to 34

Index Property	(%)
Liquid Limit	29 to 35
Plastic Limit	17 to 18

The above results show that the silty clay till is of low plasticity with a group symbols of CL.

Although not encountered in the boreholes, glacial tills inherently contain cobbles and boulders and the lower part of the till may contain pieces and slabs of bedrock, particularly slabs of hard limestone or siltstone.

#### 5.4 Bedrock

The soils described above were found to be underlain by grey to reddish brown shale bedrock. The shale encountered in the boreholes is described as thinly bedded and contains numerous hard interbedded siltstone and limestone layers. The shale bedrock is typically highly weathered within the upper 1.0 m to 2.0 m with the degree of weathering decreasing with depth. SPT N-values obtained in the upper part of the shale bedrock ranged from 20 blows per 0.3 m of penetration to higher than 50 blows per less than 0.15 m penetration. Moisture contents of disturbed shale samples ranged from 8% to 16%. Elevations of the top of bedrock are shown in Table 5.1.

**Table 5.1 – Elevation of Top of Weathered Bedrock**

Trenchless	Location	Borehole	Depth to Weathered Bedrock (m)	Top of Weathered Bedrock Elevation (m)
1	Across Hwy 401 W- Hwy 410 N Ramp, 415 m west of Hwy 410	T-01*	3.4	181.5
		T-02*	2.1	182.1
2	Across Hwy 401 and Hwy 401 W- Hurontario St. Ramp, 245 m west of Hurontario Street	T-03*	1.1	187.8
		T-04*	2.6	185.8
		T-05*	0.9	185.2

\* Proved by coring below augered depth

Bedrock cores were collected using NQ sized coring equipment. Total Core Recovery (TCR) in the bedrock ranged from 70% to 100% in all the core runs.



The RQD values recorded for most of the core runs ranged from 48% to 100% indicating poor to excellent rock quality. RQD values of 21% and 30% were measured in Borehole T-04 Run 1 and Borehole T-05 Run 1, respectively. Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to greater than 5.

The results of Point Load tests conducted on shale samples and hard interbeds of siltstone and limestone core samples were as follows:

<b>Rock Type</b>	<b>Inferred Unconfined Compressive Strength (UCS) (MPa)</b>
Shale	3 to 9
Siltstone	3 to 32
Limestone	3 to 169

Typically the inferred UCS of siltstone interbeds is approximately 30 MPa and the inferred UCS of limestone interbeds ranges from 16 to 169 MPa.

It must be noted, however, that point load tests were possible only on less weathered shale or higher strength limestone and siltstone interbed samples as the more typically weathered shale cores tended to be too weak for point load testing. Broken zones were observed within the cores at various depths as indicated in the logs.

The strength of the shale bedrock increases with depth. Furthermore, the shale bedrock typically contains frequent layers of siltstone and limestone that can be significantly harder than the shale itself. The distribution, thickness and strength of these layers vary from location to location, and these layers typically exhibit less pronounced weathering than the shale. The borehole logs indicated that these hard interbeds range approximately from 10 to 400 mm in thickness. Sampling and interpretation from small diameter boreholes may underestimate the frequency, thickness and strength of the strong layers and therefore geological expertise and past experience must be applied in any decision making process regarding the bedrock.

## **5.5 Water Levels**

Water level was observed in the boreholes during and upon completion of drilling. Two standpipe piezometers were installed to monitor water levels after completion of drilling. The water levels measured in the piezometers are summarized in Table 5.2.

**Table 5.2 – Measured Groundwater Levels**

Trenchless	Location	Borehole	Date (2009)	Water Level (m)		Comment
				Depth	Elevation	
1	Across Hwy 401 W- Hwy 410 N Ramp, 415 m west of Hwy 410	T-01	April 7	1.9	183.0	In piezometer
		T-02	March 30	0.3	184.0	In open borehole*
2	Across Hwy 401 and Hwy 401 W- Huronario St. Ramp, 245 m west of Huronario Street	T-03	April 7	4.5	184.3	In piezometer
		T-04	March 25	2.1	186.3	In open borehole*
		T-05	March 30	0.0	186.1	In open borehole*

\*Affected by coring water

The above table indicates that the groundwater levels range from Elevations 183.0 to 184.3 m.

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

## 6 MISCELLANEOUS

Borehole locations and ground surface elevations were supplied to Thurber by MMM Group Limited. The drilling and sampling equipment was supplied and operated by DBW Drilling of Ajax, Ontario and Walker Drilling Ltd. of Utopia, Ontario.

The field work was supervised on a full time basis by Mr. George Azzopardi of Thurber Engineering Ltd.

Laboratory testing was carried out at Thurber's Laboratory in Oakville, Ontario.

Supervision of the field program was conducted by Mr. David E. Elwood, P.Eng. and Ms. R. Palomeque Reyna, P.Eng. Interpretation of the field data and preparation of the investigation report was conducted by Ms. Rocío Palomeque Reyna, P.Eng. and Mr. A. Gorman, P. Eng.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This section of the report presents geotechnical recommendations for the design of the proposed installation of two sewer pipes by trenchless methods. The proposed sewer pipe diameters vary from 750 mm to 875 mm.

Pipe installations using trenchless technology are proposed under the existing Highway 401 W-Highway 410 N Ramp approximately 415 m west of Highway 410 (Trenchless 1) and across/under existing Highway 401 and Highway 401 W- Hurontario St. Ramp, approximately 245 m west of Hurontario Street (Trenchless 2).

Information on the general layout of the proposed trenchless installation locations was provided to Thurber by MMM Group Limited during preparation of this report. Available details of pipe installation by trenchless method are included in Table 7.1.

The subsurface stratigraphy revealed in the boreholes drilled at the proposed trenchless installation areas consists of topsoil or fill overlying stiff to hard silty clay till underlain by shale bedrock encountered at 0.9 m to 3.4 m depth (Elevations 181.5 to 187.8). Existing ground surface at the borehole locations drilled west of Hurontario Street ranges from elevations 186.1 to 188.8 and ground surface at borehole locations drilled on the west side of Highway 410 ranges from elevations 184.3 to 184.9.

No boreholes were drilled through the Highway 401 mainline or ramps, information on any highway embankment fill or the pavement structure along the pipe alignment are not available. However, based on a profile provided by MMM Group, the Highway 401 W-Highway 410 N Ramp embankment (Trenchless 1) is approximately 4.5 m high and the Highway 401 embankment on the west side of Hurontario Street (Trenchless 2) is approximately 2.0 m high.

Groundwater levels measured in the piezometers installed at the proposed Trenchless 1 and 2 locations were at 1.9 m and 4.5 m (Elevations 183.0 and 184.3) below ground surface, respectively.

Based on the planned invert levels, both crossings will be installed either in the silty clay till or in the shale bedrock, with the invert level typically some 0.2 m to 1.6 m below the bedrock surface. In some cases the pipe will be installed in a mixed face condition of clay till and shale bedrock. The sewer pipe will be installed under the Highway 401 pavement structure. Within the proposed pipe installation horizon, the bedrock is poor to excellent quality and consists of weak to medium strength, horizontally bedded shale with frequent hard limestone interbeds.

**Table 7.1 – Trenchless Design Details**

Trenchless	Borehole	Location	Station	Invert Elevation (m)	Depth (m)	Length (m)	Pipe diameter (mm)
1	T-01 T-02	Across Hwy 401 W- Hwy 410 N Ramp, 415 m west of Hwy 410	20+884	181.3 to (north)	3.8	35.0	825
			20+885	181.0 (south)	7.3		
2	T-03 T-04 T-05	Across Hwy 401	18+855	187.22 (north)	2.0	55	875
			18+855	186.59 (middle)	3.2		875
		Across Hwy 401 W- Hurontario St. Ramp, 245 m west of Hurontario Street	18+840	183.56 (south)	2.6	66	750

The discussion and recommendations presented in this report are based on Thurber's understanding of the project and on the factual data obtained in the course of this investigation.

## 8 TRENCHLESS METHODS RECOMMENDATIONS

All work must be carried out in accordance with the requirements of the NSSP "Pipe Installation by Trenchless Methods". A copy of this NSSP is attached in Appendix C.

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 addition to the NSSP referenced above, it is strongly 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:

- Mixed face conditions will be encountered along the proposed pipe alignments. Mixed face conditions may be problematic during trenchless installation, and selection of equipment that is capable of excavating the different material types with minimum loss of ground is critical for successful construction.
- The silty clay till deposit may contain cobbles, boulders and slabs of bedrock, particularly strong to very strong limestone.
- The shale bedrock contains strong to very strong limestone or siltstone layers. Trenchless technology that can penetrate both hard rock and highly weathered shale must be supplied.
- The shale bedrock is bedded horizontally and contains frequent hard limestone and siltstone layers that may tend to deflect boring equipment when contacted. The Contractor's equipment must be prepared to maintain the alignment in these conditions.
- The pipe installation will be done through cohesive till and shale bedrock. Contractor's equipment must be able to drill through these cohesive deposits without choking up the augers.

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

- Tunnelling - hand-mining or tunnel boring machine (TBM)
- Horizontal directional drilling
- Jack and bore
- Pipe ramming

Tunnelling (hand mining or TBM) is not recommended at this site due to the low crown cover below the native ground.

Horizontal directional drilling procedures may not be suitable at this site due to the difficulty to maintain both, the stability of the cavity and the proposed grade of the pipe.

The jack and bore technique is considered feasible but must be carefully planned as discussed below.

Pipe ramming is not considered to be suitable for penetrating the shale.

### **8.1 Jack and Bore**

Pipe installation through the silty clay till and shale bedrock is considered feasible using jack and bore methods.

The NSSP "Pipe Installation by Trenchless Methods" lays out the requirements governing this construction technique.

The following points should also be taken into consideration both in design and when evaluating Contractor's submissions for this site:

1. The difficulties associated with mixed face boring could be avoided by either lowering the alignment to lie entirely in the shale bedrock. Raising the alignment would also simplify boring but there is marginal cover in some places and the connections to catch basins might not work.
2. The impact of the pipe installation on existing underground utilities that cross or closely parallel the bore path must be considered when finalizing the vertical and horizontal alignment of the bore path.
3. A minimum vertical distance of 2.0 m between the liner crown and the bottom of cohesionless fill is recommended to reduce the potential for disturbance of the highway pavement structure.
4. The Contractor's submission must identify that he understands the ground conditions reported for this site and that the bore may be in a mixed earth/shale bedrock face or may be glancing along the bedrock surface. The submission must clearly identify how alignment will be maintained under these conditions.

## **9 INSTRUMENTATION AND MONITORING PROGRAM**

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

An instrumentation and monitoring program and condition survey of the Hwy 401 pavement and access ramps in the proximity of the tunnels should be prepared as per Guidelines for Foundation Engineering - Tunnelling Specialty for Corridor Encroachment Permit Application. The guideline has been attached in Appendix C.

## **10 TEMPORARY PITS AND ROADWAY PROTECTION**

Temporary pit excavations at the site will extend through the fill, native silty clay till and into the underlying bedrock.

All temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario and local regulations. The fill is classified as a Type 3 soil under OHSA; the underlying silty clay till is classified as a Type 2 soil. Where space restrictions preclude excavation of inclined slopes, service installation may be carried out using a trench box and temporary shoring. Design of the temporary shoring is responsibility of the contractor.

Temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring, with consideration of adjacent traffic loads and any sloping retained surfaces. If roadway protection is required, it should be provided as per SP539SO1 should be included in the contract documents. Performance Level 2 is recommended as per Clause 539.04.02.01.

Use of a hydraulic excavator should be suitable for temporary pit excavation. Provision should be made for handling and removal of possible obstructions in the fill, and cobbles, boulders or chunks of shale and limestone in the till soils during excavation.

The upper 0.6 to 2.0 m of the shale is highly weathered and excavation should be possible using heavy excavation equipment and rippers, supplemented by pneumatic rock breakers where thick layers of hard material are encountered. The shale below this depth is harder and less weathered, and intensive use of pneumatic/hydraulic breakers or other methods of loosening the bedrock will likely be required.

## **11 CONSTRUCTION CONCERNS**

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

### **11.1 Loss of ground**

Trenchless installations at shallow depth below a highway inherently include some risk of loss of ground into the bore. If it is significant, this loss of ground can create settlement in the pavement surface. The Contractor's methodology must recognize this inherent risk and contain contingency plans to manage any adverse impacts on the highway.

### **11.2 Obstructions**

Glacial till soils typically contain cobbles and boulders and in the Mississauga area the lower levels of till, close to the bedrock contact, frequently contain hard slabs of limestone of siltstone detached from the bedrock. Fill placed for the highway construction may contain similar obstruction. The Contractor's equipment and methodology must be selected to handle such obstructions and successfully remove them without jeopardizing the highway.

### **11.3 Control of Alignment**

There is a potential for mixed-face boring at this site with the face partially in bedrock and partially in glacial till. The Contractor's methodology for maintaining the alignment of the bore must take account of these conditions. Although not identified in the boreholes drilled for the trenchless crossings, the shale bedrock in the Mississauga area may be capped by a hard limestone layer, typically in the order of 300 to 400 mm thick. The existence of such a cap cannot be ruled out at this site.

Similarly, a bore entirely within the bedrock will have to contend with the presence of hard limestone or siltstone seams interbedded in the shale.



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

### 12 CLOSURE

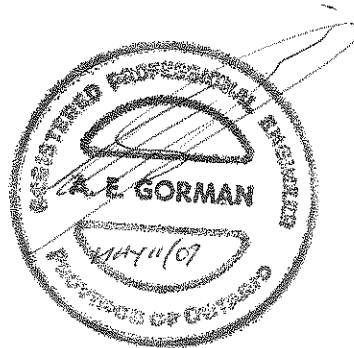
Engineering analysis and preparation of the foundation design report was conducted by Ms. Rocío Palomeque Reyna, P.Eng. The report was reviewed by Mr. Alastair E. Gorman, P.Eng. and Dr. P. K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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**TABLE 1 -Point Load a Test Results  
Highway 401 Widening – TRENCHLESS**

[illegible][illegible][illegible]

**TABLE 1 -Point Load a Test Results  
Highway 401 Widening – TRENCHLESS**

[illegible][illegible]

**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 <sup>(1)</sup> '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	PM Sampler Advanced by Manual Pressure
	PH Sampler Advanced by Hydraulic Pressure	RC Rock Core	SC Soil Core
	WH Sampler Advanced by Self Static Weight		

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

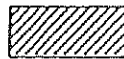
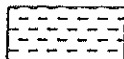
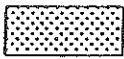


 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (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.

# 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
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

## EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION		SYMBOLS	
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)

DISCONTINUITY SPACING		STRENGTH CLASSIFICATION			
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				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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



# RECORD OF BOREHOLE No T-01

1 OF 1

METRIC

G.W.P. 2107-05-00 LOCATION N 4 833 013.9 E 291 488.9 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers/NQ2 Coring Equipment COMPILED BY AN  
 DATUM Geodetic DATE 2009.03.25 - 2009.03.26 CHECKED BY RPR

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								WATER CONTENT (%)
184.9	Geodetic						20	40	60	80	100					
0.0	TOPSOIL: (50mm)						40	80	120	160	200					
184.1	Silty CLAY, trace to some sand, trace gravel Firm Brown (FILL)		1	SS	7											
0.8	Silty CLAY, trace to some sand, trace gravel, occasional oxidized staining Very Stiff to Hard Brown (TILL)		2	SS	16											
			3	SS	26											
			4	SS	77											
181.5			5	SS	50/ 0.150											
3.4	SHALE, highly weathered Grey Coring started at 3.6m. Slightly weathered to fresh, strong Horizontal joints at 3.9m and 4.5m.		1	RUN												
	Shale interbeds from 4.9m to 5.0m.															
	Slightly weathered to fresh, strong to weak															
	Horizontal joints from 5.7m to 5.9m. Limestone interbeds at 5.3m to 5.7m, 5.8m, 5.9m, 6.0m, 6.1m, 6.2m, 6.3m and 6.4m and 6.6m. Highly broken zone at 5.7m and 5.8m.		2	RUN												
178.2	END OF BOREHOLE AT 6.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2009.04.07 1.9 183.0 2009.04.15 1.8 183.1															
6.7																

+<sup>3</sup>, x<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No T-02

1 OF 1

METRIC

G.W.P. 2107-05-00 LOCATION N 4 832 983.0 E 291 518.8 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers/NQ2 Coring Equipment COMPILED BY AN  
 DATUM Geodetic DATE 2009.03.30 - 2009.03.30 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
184.3	Geodetic							20	40	60	80	100					
0.0	TOPSOIL (100mm)							40	80	120	160	200					
0.1	Silty CLAY, some sand to sandy, trace gravel Stiff to Very Stiff Brown Dry (TILL)		1	SS	8		184										5 31 46 18
			2	SS	29		183										
			3	SS	26												
182.1							182										
2.1	SHALE, slightly weathered to fresh Grey Coring started at 2.3m.  Horizontal joints at 2.8m, 3.4m, 3.5m and 3.7m.  Horizontal joints at 3.8m, 3.9m, 4.4m, 4.5m, 4.6m and 5.2m. Shale interbeds at 3.9m, 4.0m, 4.4m, 4.6m, 4.9m, 5.1m and 5.2m.		1	RUN			181										RUN 1# TCR=100%, SCR=100%, RQD=100%, Average UCS=77MPa (Limestone)
			2	RUN			180										
178.9							179										
5.3	END OF BOREHOLE AT 5.3m. BOREHOLE OPEN AND WATER LEVEL AT 0.3m. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.																

+ 3, X 3: Numbers refer to  
Sensitivity

20  
15 5  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No T-03

1 OF 1

METRIC

G.W.P. 2107-05-00 LOCATION N 4 832 124.3 E 289673.4 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers/NQ2 Coring Equipment COMPILED BY AN  
 DATUM Geodetic DATE 2009.03.25 - 2009.03.25 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE					
188.8	Geodetic						20	40	60	80	100					
0.0	TOPSOIL (50mm)		1	SS	16											8 34 41 17
	Silty CLAY, some sand to sandy, trace gravel Very Stiff Grey to Reddish Brown (TILL.)		2	SS	20											
187.8																
1.1	SHALE, highly weathered, thinly bedded Reddish Brown		3	SS	74											8 26 54 12
			4	SS	89											
			5	SS	50/ 0.150											
	Coring started at 3.9m. Slightly weathered Highly broken zone from 3.9 to 4.0m and 5.4 to 5.5m. Horizontal joints at 4.1, 4.2, 4.3, 4.8 and 5.1m. Limestone interbeds at 4.2, 4.3 and 5.3m. Siltstone interbeds at 4.1, 4.5, 5.1, 5.3 and 5.5m.		1	SS												RUN 1# TCR=100%, SCR=83%, RQD=48%, UCS=3MPa
	Slightly weathered Limestone interbeds at 5.7 and 6.1m. Siltstone interbeds at 5.5, 5.6, 5.7, 5.9, 6.2, 6.3, 6.4, 6.6 and 6.7m. Highly broken zone at 5.6, 5.7 and 5.8m. Horizontal joints at 5.5, 5.6 and 5.8m.		2	SS												(Shale) UCS= 8MPa (Silt Stone)
181.8																
7.0	END OF BOREHOLE AT 7.0m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.															
	WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2009.04.07 4.5 184.3 2009.04.15 3.2 185.6															

+<sup>3</sup>. X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No T-04

1 OF 1

METRIC

G.W.P. 2107-05-00 LOCATION N 4 832 075.6 E 289 699.9 ORIGINATED BY GA  
 HWY 401 BOREHOLE TYPE Solid Stem Augers/NQ2 Coring Equipment COMPILED BY AN  
 DATUM Geodetic DATE 2009.03.25 - 2009.03.25 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
188.4	Geodetic							20	40	60	80	100		
0.8	TOPSOIL (50mm)		1	SS	7		188							
187.6	Silty CLAY, some sand to sandy, trace gravel Firm Reddish Brown (FILL)		2	SS	12		187							0 27 53 20
0.8	Silty CLAY, trace to some sand, trace gravel Stiff to Hard Reddish Brown (TILL)		3	SS	12		186							2 26 52 20
185.8	SHALE, highly to moderately weathered, thinly bedded Very Stiff Grey to Reddish Brown		4	SS	66		185							
2.6			5	SS	66/ 0.300		184							
	Coring started at 3.9m.  Highly broken zone at 3.9m, 4.2m, 4.4m to 4.5m, 5.1m to 5.2m and 5.2m to 5.3m. Core washed away from 4.5 to 5.0m.		1	RUN			183							RUN 1# TCR=71%, SCR=90%, RQD=21%, Average UCS=3MPa (Shale) UCS=147MPa (Limestone)
	Limestone interbeds at 5.3m.  Silt stone interbeds at 5.5m, 5.7m, 5.8m, 6.3m, 6.4m, 6.5m, 6.6m, 6.7m and 7.0m. Horizontal joints at 5.6m, 6.0m and 6.4m.		2	RUN			182							RUN 2# TCR=100%, SCR=96%, RQD=85%, Average UCS=3MPa (Shale) UCS=30MPa (Silt Stone) UCS=52MPa (Limestone)
	Limestone interbeds at 6.7m, 7.1m, 7.2m and 8.3m.		3	RUN			181							RUN 3# TCR=70%, SCR=70%, RQD=70%, Average UCS=3MPa (Shale) UCS=3MPa (Silt Stone) UCS=36MPa (Limestone)
	Silt stone interbeds at 7.3m, 7.4m, 7.5m and 7.7m.		4	RUN			180							RUN 4# TCR=100%, SCR=91%, RQD=91%, Average UCS=67MPa (Limestone)
179.2	END OF BOREHOLE AT 9.1m. BOREHOLE OPEN AND WATER LEVEL AT 2.1m. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.													
9.1														

+<sup>3</sup> . X<sup>3</sup> : Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No T-05

1 OF 1

METRIC

G.W.P. 2107-05-00 LOCATION N 4 832 038.7 E 289 701.6 ORIGINATED BY GA  
HWY 401 BOREHOLE TYPE Solid Stem Augers/NQ2 Coring Equipment COMPILED BY AN  
DATUM Geodetic DATE 2009.03.30 - 2009.03.30 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								20 40 60 80 100							
186.1	Geodetic														
0.0	TOPSOIL (150mm)														
0.2	Silty CLAY, trace to some sand, trace gravel Firm to Hard Brown to Reddish Brown (TILL)		1	SS	5		186							0 22 53 25	
185.2	SHALE, highly weathered, thinly bedded Hard Reddish Brown to Grey		2	SS	67/ 0.300		185								
0.9	Occasional limestone layers		3	SS	50/ 0.0		184								
	Coring started at 2.7m. Highly broken zone from 2.9m to 3.0m, 3.1m, 3.5m to 3.6m, 3.7m and 4.0m. Silt stone interbeds at 2.9m, 3.3m, 3.6m and 3.7m. Horizontal joints at 2.9m, 3.0m, 3.2m, 3.4m, 3.7m, 3.8m and 4.0m. Limestone interbeds at 3.0m and 3.2m.		1	RUN			183							RUN 1# TCR=88%, SCR=63%, RQD=30%, Average UCS=20MPa (Limestone)	
	Silt stone interbeds at 4.3m, 4.4m, 4.6m, 4.7m, 4.8m, 5.0m, 5.1m, 5.5m and 5.6m.		2	RUN			182							RUN 2# TCR=100%, SCR=96%, RQD=75%, Average UCS=22MPa (Silt Stone) UCS=36MPa (Limestone)	
	Limestone interbeds at 5.0m and 5.1m to 5.3m. Highly broken zone at 4.8m and 4.9m. Horizontal joints at 4.4m, 4.6m, 4.7m, 4.8m, 5.1m and 5.5m.		3	RUN			181							RUN 3# TCR=100%, SCR=100%, RQD=100%, Average UCS=3MPa (Shale) UCS=54MPa (Limestone)	
	Silt stone interbeds at 5.7m, 5.8m, 5.9m, 6.0m, 6.2m, 6.4m, 6.6m and 6.8m.						180								
	Limestone interbeds at 6.5m, 6.6m, 6.7m, 6.9m and 7.1m.						179								
178.8															
7.3	END OF BOREHOLE AT 7.3m. BOREHOLE OPEN AND WATER LEVEL AT SURFACE. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.														

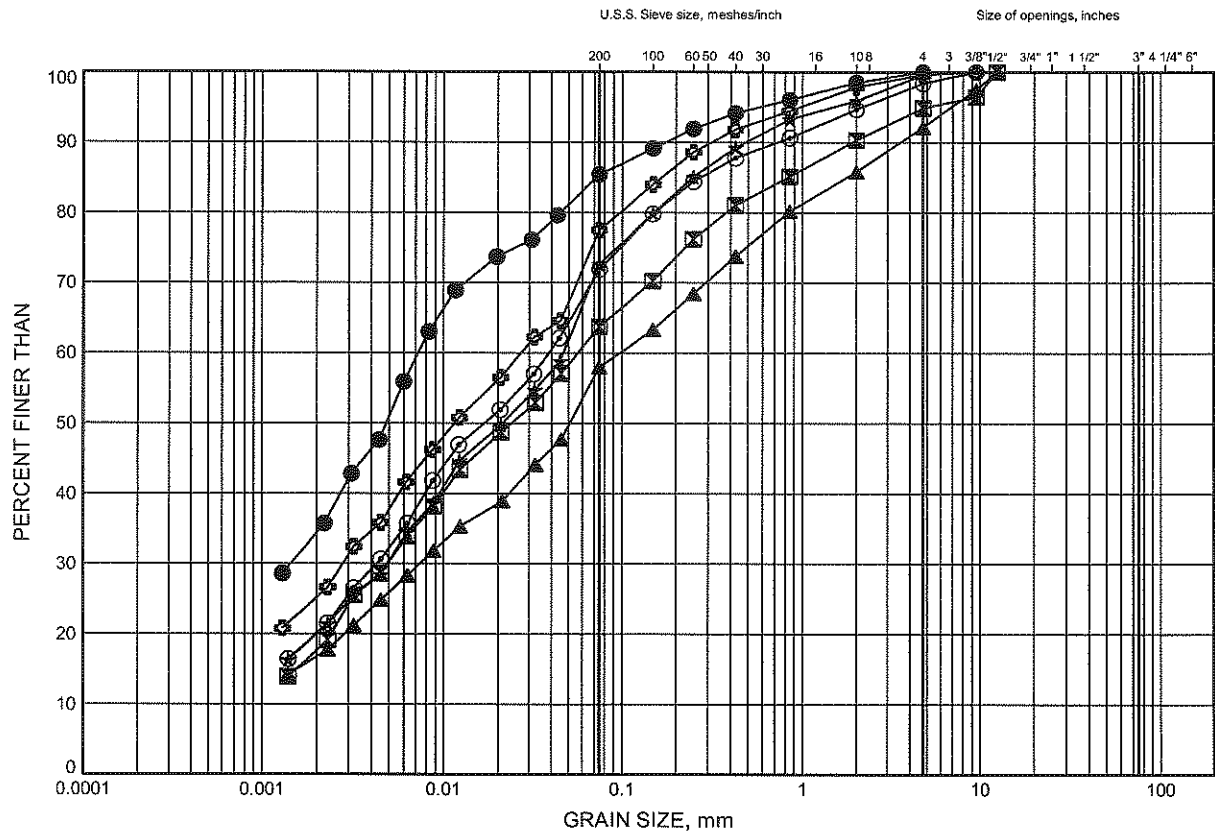
## **Appendix B**

### **Laboratory Test Results**

# Hwy 401 Widening GRAIN SIZE DISTRIBUTION

FIGURE B1

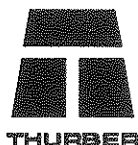
## Silty Clay TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	T-01	1.83	183.07
⊠	T-02	1.07	183.19
▲	T-03	0.30	188.52
★	T-04	1.07	187.29
⊙	T-04	2.59	185.77
⊕	T-05	0.30	185.79

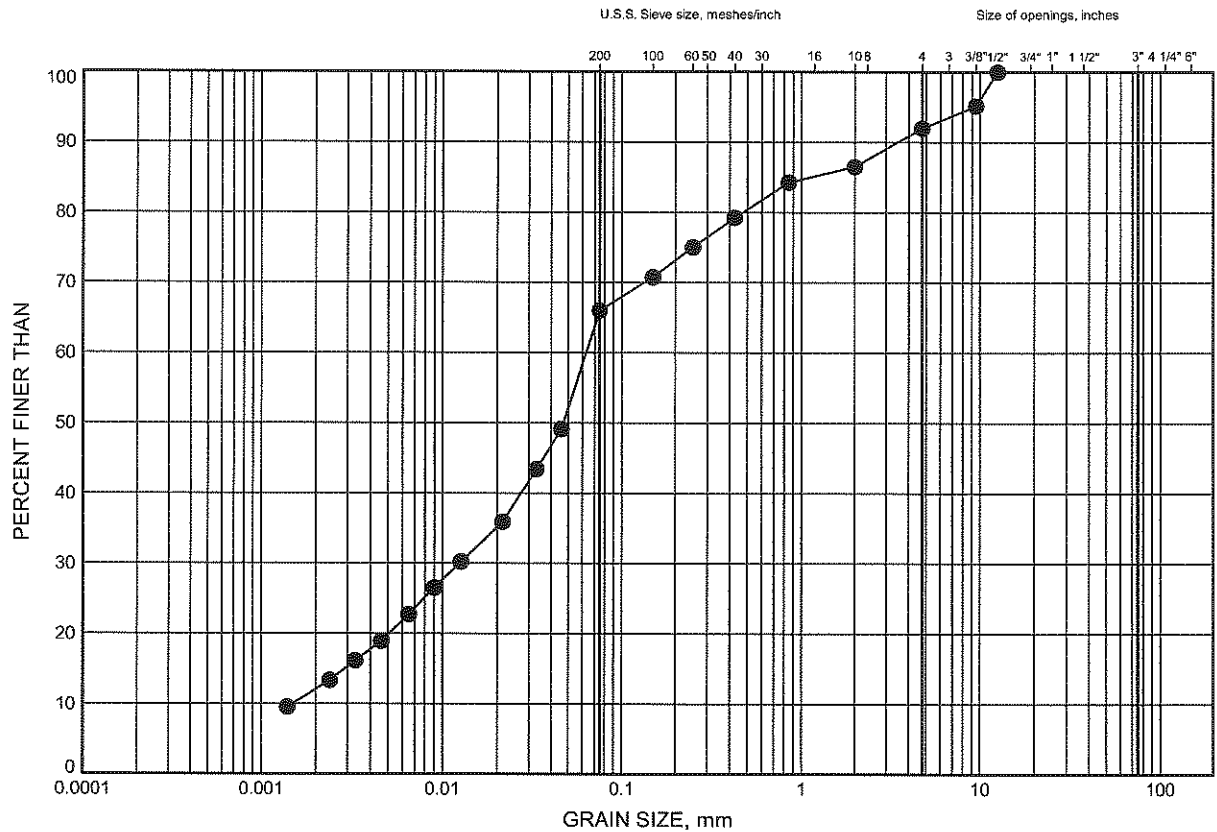


W.P.# 2107-05-00.....  
Prepared By AN.....  
Checked By RPR.....

Hwy 401 Widening  
GRAIN SIZE DISTRIBUTION

FIGURE B2

Shale



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	T-03	1.83	187.00



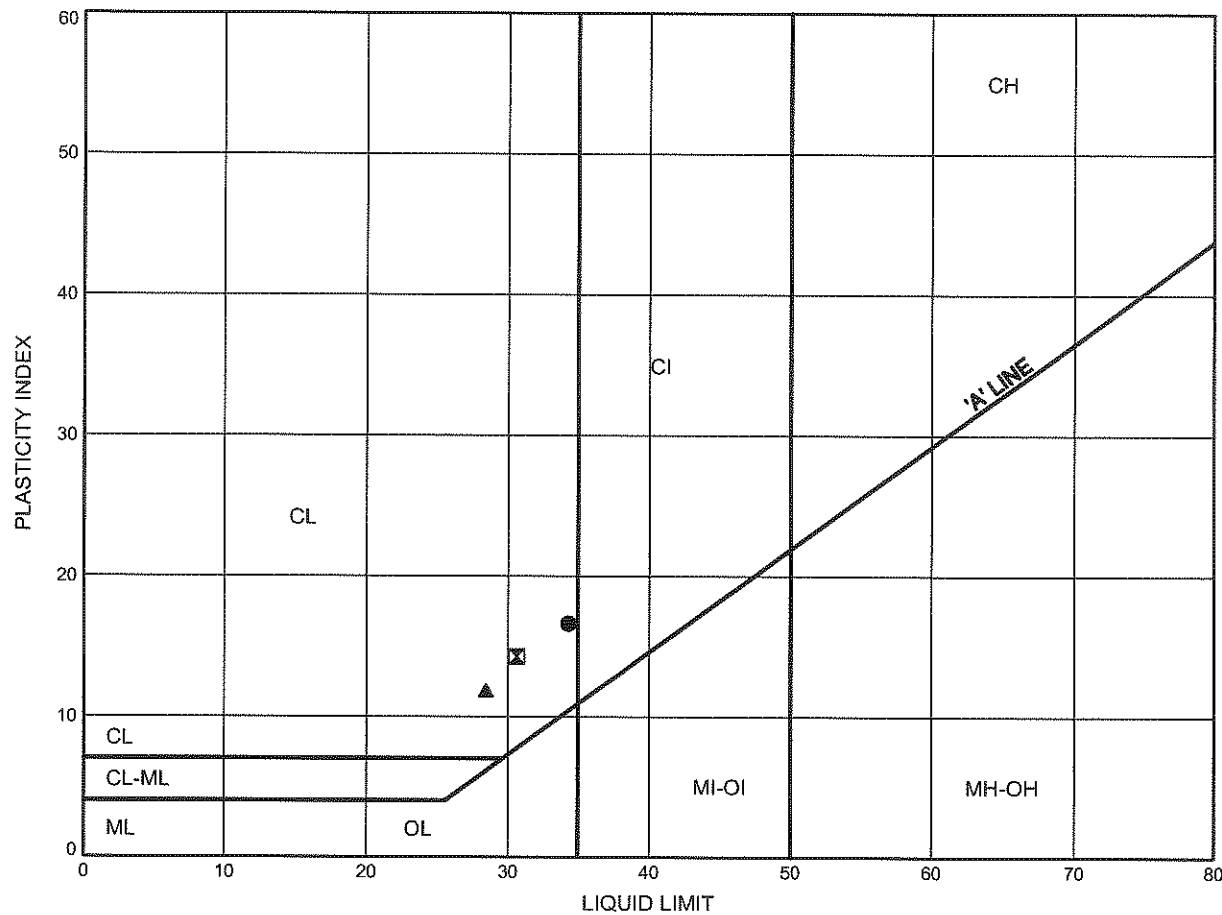
W.P.# .2107-05-00.....  
Prepared By .AN.....  
Checked By .RPR.....

Hwy 401 Widening

# ATTERBERG LIMITS TEST RESULTS

FIGURE B3

Silty Clay TILL



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	T-01	1.83	183.07
⊠	T-02	1.07	183.19
▲	T-04	1.07	187.29

Date April 2009  
Project 2107-05-00



Prep'd AN  
Chkd. RPR



**Appendix C**  
**List of Special Provisions**  
**and**  
**Suggested Text for NSSP**

**1. List of Special Provisions Referenced in this Report**

- SP539SO1

**2. Suggested Text for NSSP on Trenchless Installation.**

The Contractor's attention is drawn to the following:

- Mixed face conditions will be encountered along the proposed pipe alignments. The Contractor shall select equipment that is capable of excavating the different material types with minimum loss of ground.
- The silty clay till deposit may contain cobbles, boulders and slabs of bedrock, particularly strong to very strong limestone.
- The shale bedrock contains strong to very strong limestone or siltstone layers. Trenchless technology that can penetrate both hard rock and highly weathered shale shall be supplied.
- The shale bedrock is bedded horizontally and contains frequent hard limestone and siltstone layers that may tend to deflect boring equipment when contacted. The Contractor shall select equipment capable of maintaining the alignment in these conditions.
- The pipe installation will be done partially through cohesive till and shale bedrock. The Contractor shall select equipment capable of drilling through these cohesive deposits.
- The Contractor's submission shall identify that he understands the ground conditions reported for this site and that the bore may be in a mixed earth/shale bedrock face or may be glancing along the bedrock surface. The submission shall clearly identify how alignment will be maintained under these conditions.

## **PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.**

---

### **Non Standard Special Provision**

---

#### **1. SCOPE**

This specification covers the general requirements for the installation of pipes by trenchless methods.

The Contractor shall determine the most appropriate method of installation. Specifications for Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling are provided herein, and shall be applied to the installation method considered feasible by the Contractor.

OPSS 415 (Construction Specification for Pipeline and Utility Installation by Tunnelling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling) shall not be used to do the work for the above tender item.

#### **2. REFERENCES**

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

Foundation Investigation and Design Report, Pipe Installation Trenchless by Trenchless Method, Hwy 401 widening, Hwy 410 to Credit River, Mississauga, Ontario, G.W.P. 2107-05-00, by Thurber Engineering Ltd. Reference No. 19-1423-11.

##### **Ontario Provincial Standard Specifications, General**

OPSS 180 Management and Disposal of Excess Material

##### **Ontario Provincial Standard Specifications, Construction**

OPSS 504 Preservation, Protection, and Reconstruction of Existing Facilities

OPSS 507 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures in Open Cut

OPSS 514 Trenching, Backfilling, and Compaction

OPSS 517 Dewatering of Pipeline, Utility, and Associated Structure Excavation

OPSS 538 Support Systems

OPSS 539 Protection Schemes

**Ontario Provincial Standard Specifications, Material**

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe

**MTO Specifications**

OPSS 1820	Material Specification for Circular Concrete Pipe
OPSS 1840	Material Specification for Non-Pressure Polyethylene Plastic Pipe
Products	
SP 105S19	Construction Specification for Protection Systems

**American Society for Testing and Materials (ASTM) International Standards**

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

**Canadian Standards Association Standards:**

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

**3. DEFINITIONS**

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

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

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

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

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

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

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

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

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

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

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

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

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

**Grouting:** injection of grout into voids.

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

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

**HDPE:** high density polyethylene.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

#### **4. DESIGN AND SUBMISSION REQUIREMENTS**

##### **4.01 General**

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

##### **4.02 Working Drawings**

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one (1) week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

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

a) Plans, Elevations and Details:

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

b) Design Criteria:

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

c) Materials:

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

d) Upstream/Downstream Portal Installation Procedure:

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

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

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

f) Excavation and Dewatering:

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

g) Monitoring Method

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

#### **4.03 Site Survey**

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

#### **4.04 Certificate of Conformance**

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

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

- Site Surveying (as noted in Section 4.02)
- Excavation for pits including dewatering of excavation
- Jacking/Ramming/Directional Drilling of Casing/Liner
- Excavation and Dewatering



## Installation of the Product Grouting Operations

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

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

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

### **5. MATERIALS**

#### **5.01 Product**

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

#### **5.02 Concrete**

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

#### **5.03 Concrete Reinforcement**

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

#### **5.04 Timber**

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

#### **5.05 Grout**

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

#### **5.06 Auger Jack & Bore Materials**

##### **5.06.01 Pipe Materials**

Steel pipe shall conform with ASTM A252-95 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS 1820.

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

## **5.07 Pipe Ramming Materials**

### **5.07.01 Pipe Materials**

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

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

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

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. A minimum wall thickness of 50 mm and minimum yield strength of 240 MPa is required.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

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

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

### **5.07.02 Mill Certificates**

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

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

## **5.08 Directional Drilling Materials**

### **5.08.01 Drilling Fluids**

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

### **5.08.02 Pipe Materials**

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

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

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

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

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

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

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

## **5.09 Tunnelling Materials**

### **5.09.01 Primary Liner**

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

### **5.09.02 Secondary Liner**

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

#### **5.09.02.01 Concrete Pipe**

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

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

#### **5.09.02.02 High Density Polyethylene (HDPE)**

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

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

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

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

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

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

### **6. EQUIPMENT**

#### **6.01 Auger Jack & Bore Equipment**

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

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

#### **6.02 Pipe Ramming Equipment**

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

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

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

## **6.03 Directional Drilling Equipment**

### **6.03.01 General**

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

### **6.03.02 Drilling Rig**

The directional drilling rig shall:

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

### **6.03.03 Drill Head**

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

### **6.03.04 Guidance System**

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

### **6.03.05 Drilling Fluid Mixing System**

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

### **6.03.06 Drilling Fluid Delivery System**

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

## **6.04 Tunnelling Equipment**

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

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

## **7. CONSTRUCTION**

### **7.01 General**

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

#### **7.01.01 Layout, Alignment and Depth Control**

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

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

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

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

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

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

#### **7.01.02 Construction Shafts**

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

Shafts shall be maintained in a drained condition.

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

#### **7.01.03 Protection Schemes**

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

#### **7.01.04 Settlement or Heave**

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the 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, 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 504.

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

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

#### **7.01.07 Transporting, Unloading, Storing and Handling Materials**

Manufacturer's handling and storage recommendations shall be followed.

#### **7.01.08 Trenching, Backfilling and Compacting**

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 514.

#### **7.01.09 Support Systems**

Support systems shall be according to OPSS 538.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in SP105S19.

#### **7.01.10 Dewatering**

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

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

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

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

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

Dewatering shall be according to OPSS 517.

#### **7.01.11 Removal of Boulders**

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

#### **7.01.12 Record Keeping**

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

#### **7.01.13 Testing**

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

#### **7.01.14 Management and Disposal of Excess Material**



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

#### **7.01.15 Site Restoration**

Site restoration shall be according to OPSS 507.

#### **7.01.16 Supervision**

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

### **7.02 Auger Jack & Bore Installation**

#### **7.02.01 Method of Installation Procedure**

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

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

#### **7.02.02 Pipe Installation**

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

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

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

### **7.03 Pipe Ramming Installation**

For pipe ramming installation the following requirements apply:

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

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

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

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

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

## **7.04 Directional Drilling Installation**

### **7.04.01 General**

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

### **7.04.02 Site Preparation**

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

### **7.04.03 Pilot Bore**

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

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

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

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

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

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

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

#### **7.04.04 Drilling Fluid Fracture (Frac-Out)**

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

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

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

#### **7.04.05 Reaming**

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

#### **7.04.06 Product Installation**

##### **7.04.06.01 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 exceeded.

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

#### **7.04.06.02 Pullback and Grouting**

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

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

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

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

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

### **7.05 Tunnelling Installation**

#### **7.05.01 General**

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

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

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

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

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

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

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

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

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

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

#### **7.05.01 Tunnelling Method**

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

#### **7.05.02 Primary Liner (Support System)**

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

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

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

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

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

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

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

#### **7.05.03 Secondary Liner**

##### **14 7.05.03.01 PLACING OF GROUT**

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

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

#### **7.06 Instrumentation Monitoring**

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

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

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

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

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

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

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

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

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

#### **7.07 Criteria for Assessment of Roadway Subsidence/Heave**

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

- **Review Level:** If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate of sequence of construction or ground stabilization measures to mitigate further ground displacement.

If the Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- **Alert Level:** If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

No construction shall take place until all the following conditions are satisfied:

- The cause of the settlement has been identified.
- The Contractor submits a corrective/preventive plan.
- Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
- The CA deems it is safe to proceed.

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

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

## **9. MEASUREMENT FOR PAYMENT**

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

## **10. BASIS OF PAYMENT**

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

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

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

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

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

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



**INSTRUMENTATION AND MONITORING PROGRAM**  
**PROPOSED SEWER CROSSING**  
**HIGHWAY 401**

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- Item No.

Special Provision

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**1.0 GENERAL**

1.0.1 Scope

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

- In-Ground Monitoring Points (IGMP)
- Surface Settlement Markers (SSM)

The instruments shall be installed along the centreline of the tunnel alignment and in arrays. Each array consists of a group of one or five instruments installed along a line approximately perpendicular to the tunnel alignment.

1.0.2 Purpose

The purpose of these instruments is to monitor settlements during construction of a proposed 750 mm to 875 mm diameter tunnel for the installation of a watermain sewer.

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

1.0.3 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 instrumentation shall be carried out by the Contractor's qualified surveyors.

1.0.4 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.

#### 1.0.5 Notification

The Owner, the Owner's Engineer, and the Owner'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 sub-section below) established to the satisfaction of all parties listed above not less than five days in advance of the tunnelling operations.

#### 1.0.6 Instrument Installation and Monitoring Requirements

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

#### 1.0.7 Drawings

Drawings should be prepared for instrument locations.

#### 1.0.8 Subsurface Conditions

The subsurface conditions at the site are described in Section 5 of this report.

### **2.0 INSTALLATION**

#### 2.0.1 General

Installation should be as per indicated in the monitoring/instrument drawings.

#### 2.0.2 Instrument Location

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

#### 2.0.3 Survey Benchmarks

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

#### 2.0.4 Accuracy of Surveying for Elevations

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

#### 2.0.5 Materials and Equipment

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

#### 2.0.6 Underground Utilities

The ground in the immediate vicinity of any proposed IGMP must be cleared of utilities prior to instrument installation.

#### 2.0.7 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.

#### 2.0.8 Installation Program

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

### **3.0 IN-GROUND MONITORING POINTS (IGMP) - SUPPLY & INSTALLATION**

#### **3.1 General**

##### **3.1.1 Scope**

This Section contains the requirements for the supply and installation of In-Ground Monitoring Points (IGMP).

The purpose of the IGMP is to monitor subsurface ground movements below the frost line. The ground movement readings shall assist in assessing the tunnel performance and any need to modify the tunnelling methodology as required. Settlement is measured by level surveying with total-station equipment of the top of the rebar with reference to stable, non-settling benchmarks.

##### **3.1.2 General Procedure**

IGMP shall consist of a 12 to 18mm diameter rebar encased in a 50mm, Schedule 40 PVC pipe. The assembly shall be placed in a drilled hole and backfilled with anchor grout and clean washed sand as shown on the attached Figure 4.

##### **3.1.3 Location**

The IGMP locations are shown on the monitoring/instrument drawing.

#### **3.2 Materials**

##### **3.2.1 General**

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

##### **3.2.2 Rod**

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

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

##### **3.2.3 Anchor Grout**

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 10MPa.

#### 3.2.4 Sand

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

#### 3.2.5 Friction Reducing Sleeve

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

#### 3.2.6 Protective Casing

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

### 3.3 **Installation**

#### 3.3.1 General

The Contractor shall install IGMPs as per Figure 4 in addition to what is stated or emphasized below. Traffic 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.

#### 3.3.2 Rod

The rod shall be centred in the borehole.

#### 3.3.3 Friction Reducing Sleeve

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

### 3.4 **Documentation**

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

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

## **4.0 SURFACE SETTLEMENT MARKERS (SSM) - SUPPLY & INSTALLATION**

### **4.1 General**

#### **4.1.1 Scope**

This Section contains the requirements for the supply and installation of Surface Settlement Markers (SSM).

The purpose of the SSM is to monitor settlement of asphalt paved surfaces. The ground movement readings shall assist in assessing the tunnel performance and any need to modify the tunnelling methodology as required. Settlement is measured by level surveying the SSM using total-station equipment with reference to stable, non-settling benchmarks.

#### **4.1.2 General Procedure**

SSMs shall be rigidly affixed so as not to move relative to the asphalt pavement surface to which it is attached.

#### **4.1.3 Location**

The SSM locations are shown on monitoring/instrument drawing.

### **4.2 Materials**

#### **4.2.1 General**

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

#### **4.2.2 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 12mm 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.

### **4.3 Installation**

#### **4.3.1 General**

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

#### **4.4 Documentation**

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

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

#### **5.0 DECOMMISSIONING OF INSTRUMENTS**

##### **5.0.1 General**

The Contractor shall decommission all IGMPs and SSMs after the completion of the monitoring program as directed by the Owner's Consultant.

#### **6 MONITORING PROGRAM**

##### **6.0 General**

The instrumentation monitoring services specified herein apply to all the IGMPs and SSMs 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 that are required for monitoring;
- Level survey the instruments using total-station equipment with no interference with the traffic on Hwy 401;
- Transmit the settlement data and associated tunnelling/construction activities to the Owner's Consultant, the Owner's Geotechnical Consultant and MTO;
- Notify Owner, the Owner's Engineer, and the Owner's Geotechnical Consultant of any required modifications to the construction procedures;
- Notify Owner, the Owner's Engineer, and the Owner's Geotechnical Consultant of any modifications of the original site conditions related to the tunnelling or otherwise, including appearance of cracks on the pavement and shoulder, concrete barriers etc;
- Notify immediately Owner, the Owner's Engineer, and the Owner's Geotechnical Consultant if Review or Alert Levels have been reached or exceeded and follow the procedures outlined in Section 6.6.

## **6.1 Purpose**

The purpose of this program is to monitor settlement of the paved surfaces and ground at selected locations during the tunnelling operations for the sewer installation.

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

## **6.2 Reading Schedule And Frequency**

The Contractor shall keep a complete record in electronic and hard copy format of all instrumentation survey and associated data, including the location of the tunnel 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.

The minimum monitoring frequencies prior, during and after pipe installation along with the anticipated number of readings are given should be determined

## **6.3 SPECIFIC REQUIREMENTS**

### **6.3.1 Surveying**

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

### **6.3.2 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
- Tunnel face of excavation station at the time of reading
- Tunnelling activities (e.g. excavation underway, weekend – no excavation and face supported with bulkhead; boulder encountered at the face of excavation, etc)
- Pavement visual survey (e.g.: No visual pavement distress; 1mm wide, 3m long pavement crack parallel to west shoulder and close to instruments no. A, B and C, etc)
- Instrument Number
- Settlement Array Number
- Horizontal distance measured along the tunnel alignment between the tunnel face of excavation 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 date for each instrument
- Settlement versus distance from face of tunnel for each instrument
- Settlement profile for different dates along each of the tunnel alignments
- Settlement profile for different dates along each of the two settlement arrays

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

#### 6.3.3 Data Transmission

All settlement data obtained on a particular day shall be reported in electronic to Owner, the Owner's Engineer, and the Owner's Geotechnical Consultant 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.

#### 6.4 **Criteria for Assessment**

The following settlement levels are to be observed:

Review Level – A maximum value of 15 mm relative to the baseline or zero readings. If the Review Level is exceeded, the Contractor shall immediately notify Owner, the Owner's Engineer, and the Owner's Geotechnical Consultant 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 Alert Levels are not reached.

Alert Level – A maximum value of 20mm 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 tunnel operation immediately and inform Owner, the Owner's Engineer, and the Owner's Geotechnical Consultant. 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
- The Owner, the Owner's Engineer, and the Owner's Geotechnical Consultant deem it is safe to proceed.

#### 7 **CONTRACTOR'S RESPONSIBILITY FOR RESTORATION**

Notwithstanding the monitoring program to assess the adequacy of the tunnelling construction method to control potential ground movements and groundwater, the Contractor

is responsible for reinstatement (such as surface paving) should movements or other surface distress occurs.

## **Appendix D**

### **Site Photographs**



Photo 2 - Looking north of Borehole T-5

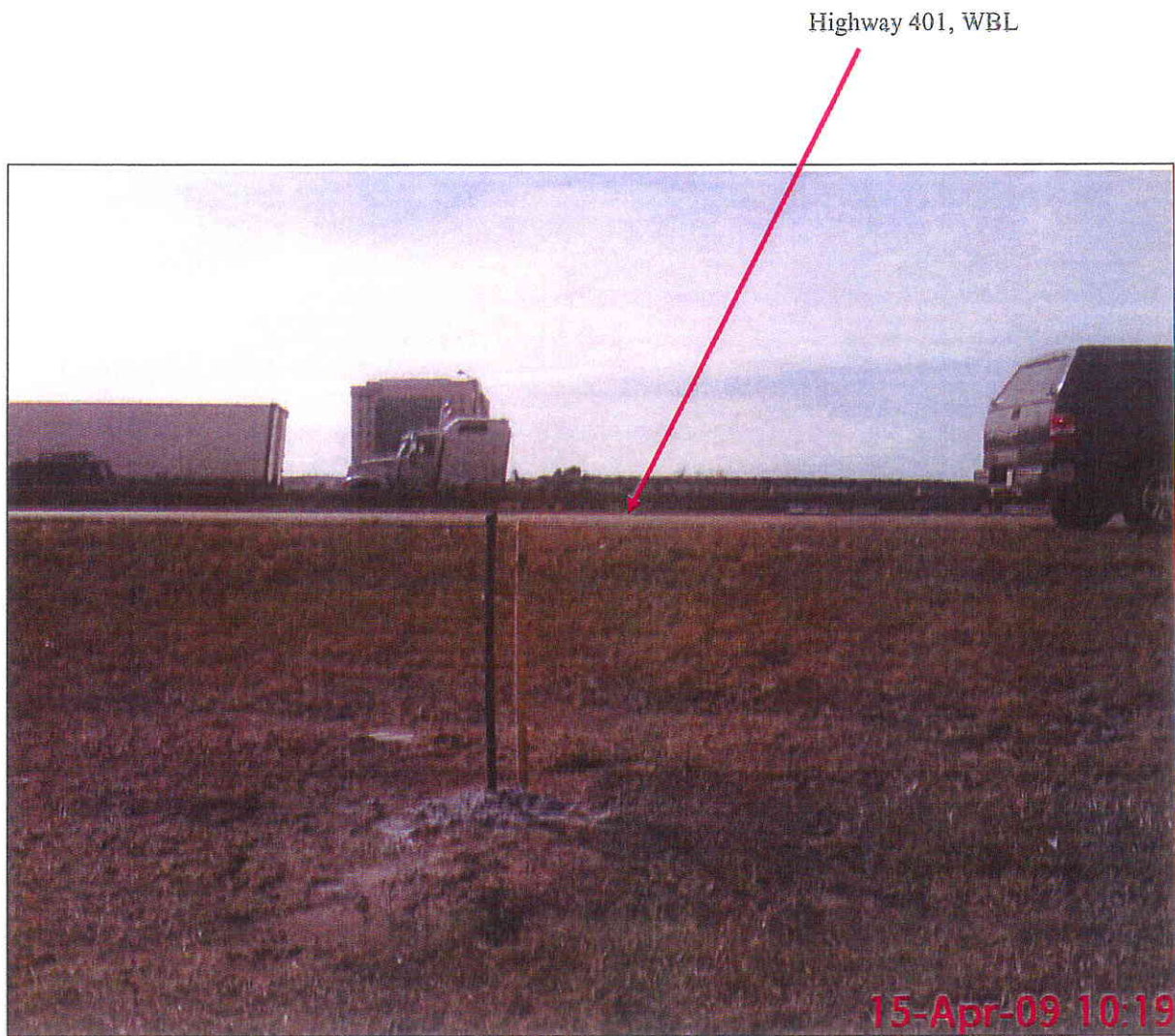
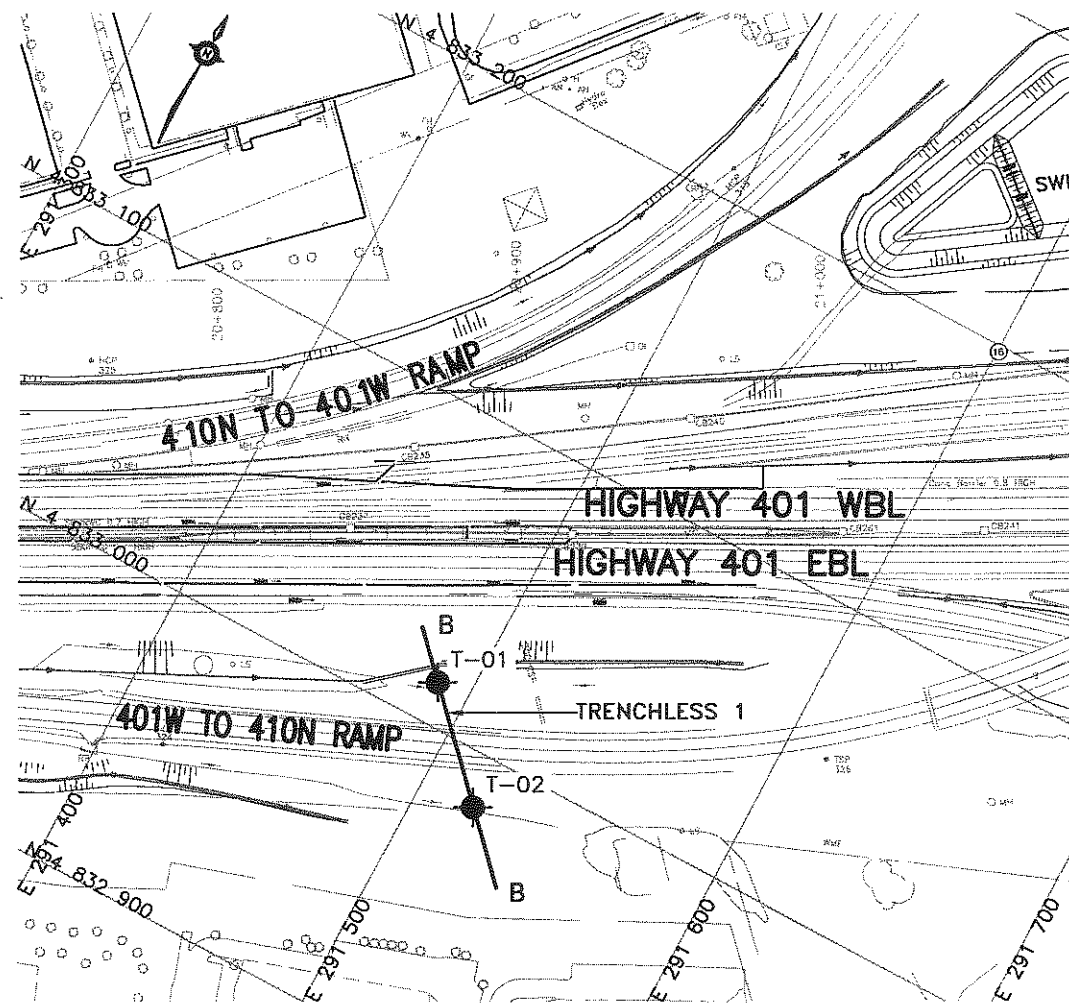
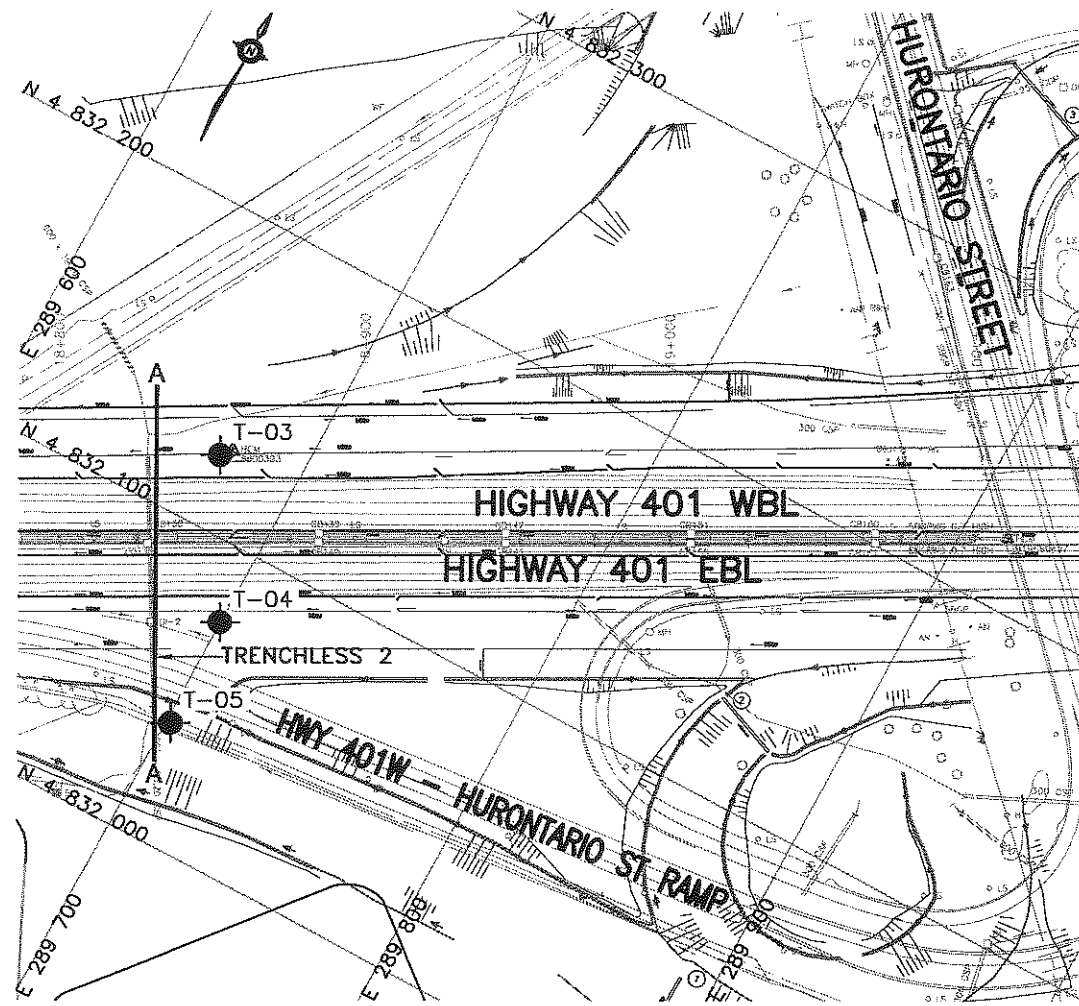


Photo 1 - Looking south of Borehole T-3

## **Appendix E**

### **Borehole Location Drawings**





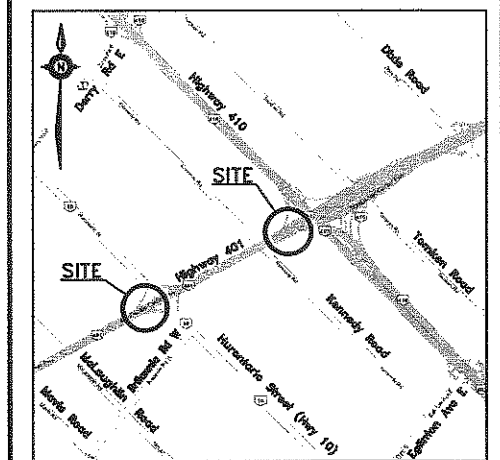
**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
GWP No

HIGHWAY 401  
AT HIGHWAY 410 & HURONTARIO ST  
TRENCHLESS  
BOREHOLE LOCATIONS AND SOIL STRATA

**MMM GROUP**

**THURBER ENGINEERING LTD.**  
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



**LEGEND**

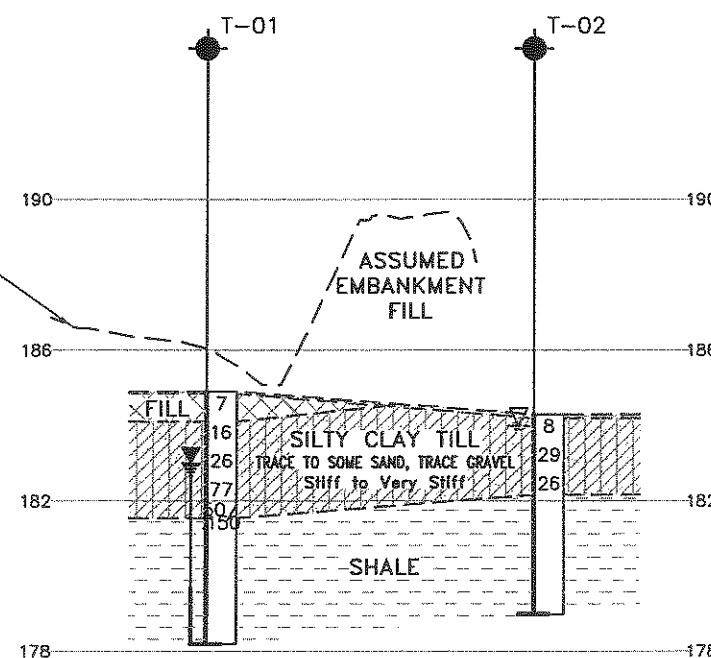
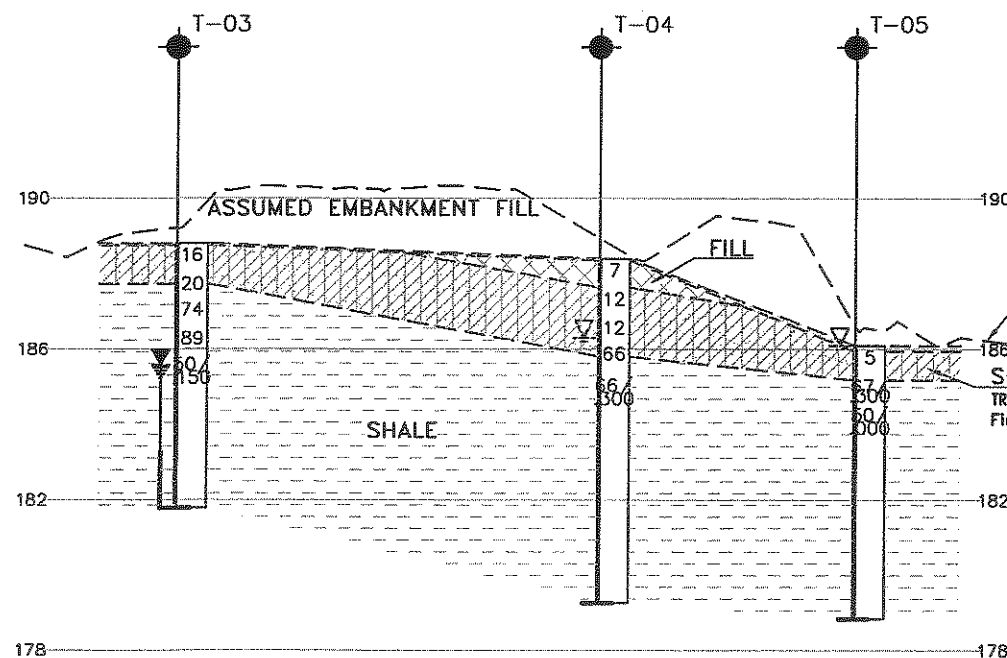
- ◆ Borehole
- ◆ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- HA Head Artesian Water
- PZ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
T-01	184.9	4 833 013.9	291 488.9
T-02	184.3	4 832 983.0	291 518.8
T-03	188.8	4 832 124.3	289 673.4
T-04	188.4	4 832 075.6	289 699.9
T-05	186.1	4 832 038.7	289 701.6

**NOTES**

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

**GEOCREs No. 30M12-280**



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK	PKC
DRAWN	MFA	CHK	AEQ
DATE	MAY 2009	DATE	MAY 2009
STRUCT	DWG	1	