TUNNELLING INVESTIGATION AND DESIGN REPORT
STORM SEWER OUTLETS TO BRONTE CREEK
QEW BRONTE CREEK TWIN BRIDGE

W.P. 2264-03-01

Geocres Number: 30M5-236 A

Report to

McCormick Rankin Corporation

Thurber Engineering Ltd.
2010 Winston Park Drive, Suite 103
Oakville, Ontario
L6H 5R7
Phone: (905) 829 8666
Fax: (905) 829 1166

November 21, 2005
File: 19-1351-92
C:\Thurber\Projects\19\1351 MRC\92 Bronte Outfall\FIDR FINAL.doc

November 23, 2005 File: 19-1351-92

McCormick Rankin Corporation
2655 North Sheridan Way
Mississauga, Ontario
L5K 2P8

Attn: Mr. K. Rodger, P.Eng.

Response to MTO Comments
Tunnelling Investigation and Design Report
Storm Sewer Outlets to Bronte Creek
QEW Bronte Creek Twin Bridge
W.P. 2264-03-01

Dear Mr. Rodger:

We have reviewed the comments received from MTO regarding our Draft Tunnelling Investigation and Design Report. Our responses are documented below.

I MTO Memorandum dated November 9, 2005

7.1 and 7.2 Actual Size of Boring

A comment has been added to indicate that the actual size of the boring will be dictated by the method of trenchless installation selected by the Contractor.

7.1 Non-Standard Special Provision (NSSP) for Trenchless Installation

A NSSP has been developed by MRC with input from Thurber. A draft copy of the NSSP has been included in an Appendix to the Final Report.

11.0 Construction Concerns

Draft NSSPs for trenchless methods, prepared by MRC with Thurber input, have been included in an Appendix to the Final Report.

Foundation Investigation Report

A separate Foundation Investigation Report, consisting of factual information only, has been submitted in addition to the combined Foundation Investigation and Design Report.

Geotechnical Review of Contract Package

Thurber will review the geotechnical design details and provide a separate letter to MRC confirming that the geotechnical recommendations have been appropriately incorporated in the contract package.

II MTO email of November 14, 2005 (Has Shah)

7.1 Pipe Jacking

The report text has been revised to clarify that pipe jacking may not be viable due to access constraints.

We trust that these revisions fully address the Ministry's comments. If you have any questions, do not hesitate to call our office.

Yours truly
Thurber Engineering Ltd.
Paulo J. Branco, P.Eng.
Designated Review Principal

LICENSED PROFESSIONAL ENGINEER
P. J. BRANCO
Nov. 23.05
PROVINCE OF ONTARIO

Murray R. Anderson, P.Eng.
Senior Foundations Engineer.

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Nov 23/05
PROVINCE OF ONTARIO

TABLE OF CONTENTS

TUNNELLING INVESTIGATION AND DESIGN REPORT
STORM SEWER OUTLETS TO BRONTE CREEK
QEW BRONTE CREEK TWIN BRIDGE
W.P. 2264-03-01

Geocres Number: 30M5-236

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual information obtained from a tunnelling investigation conducted at the proposed locations of new storm sewer outlets to Bronte Creek adjacent to the proposed QEW twin bridge in Oakville, Ontario.

The proposed storm sewers will be installed down the slopes of the Bronte Creek valley with drops of about 24 and 25 m on the west and east sides of the valley, respectively.

The purpose of the investigation was to explore the subsurface conditions at the outlet locations and, based on the data obtained, to provide borehole logs, borehole location plans, stratigraphic profiles, and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed through interpretation of the data obtained in the course of the present investigation.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to McCormick Rankin Corporation (MRC), under the Ministry of Transportation Ontario (MTO) Agreement Number 2005-A-000346.

2 SITE DESCRIPTION

The proposed sewer outlet sites are located approximately 35 and 50 m south of the existing structure carrying the QEW over Bronte Creek. Bronte Road runs along the east valley slope of Bronte Creek and passes under the QEW through the second from east span of the existing bridge.

The creek valley is incised approximately 25 m below the surrounding tableland. The valley slopes are steep and, at a bend in the creek a short distance to the south, a near-vertical bluff is eroded in the shale bedrock. The width of the valley at the site is approximately 200 m crest-to-crest. The creek is about 20 m wide with a normal water level near elevation 90.0m and a 100-year high level at elevation 91.3m.

Drainage at the site flows down the valley slopes and directly into Bronte Creek, which flows southward to Lake Ontario. A storm sewer outfall exists at the toe of the east valley slope approximately 50 m south of the QEW bridge. Present on the opposite bank is a concrete structure that appears to be a former bridge abutment with a storm outfall in the face.

The lands north of the QEW are occupied by Bronte Creek Provincial Park west of Bronte Road, and by Deerfield Golf Course east of Bronte Road. To the south of the QEW, the lands are developed for commercial and industrial uses.

3 INVESTIGATION PROCEDURES

3.1 Field Investigation

The site investigation and field testing for this project were carried out between September 4 and 22, 2005 and consisted of drilling seven boreholes at selected locations along the alignment of the proposed storm sewers. The boreholes were extended to depths ranging from 4.2 to 24.1 m using both soil drilling and rock coring procedures. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing in Appendix C.

The proposed borehole locations were staked in the field and ground elevations were provided by J.D. Barnes Limited surveyors. Where site access conditions required repositioning of boreholes, the revised borehole location and elevation were estimated by Thurber field personnel relative to the staked location.

DBW Drilling Limited supplied and operated the drilling and sampling equipment used for the investigation. Solid stem augers were used to advance the boreholes and samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Rock coring operations were carried out using a diamond bit NQ core barrel.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor recorded the borehole stratigraphy, logged the recovered samples, and transported the labelled samples to Thurber's office. The groundwater conditions in the boreholes were observed during drilling.

Standpipe piezometers consisting of 19 mm PVC pipe were installed in all boreholes to monitor groundwater levels. The piezometer installation details are shown on the borehole logs, Appendix A. The boreholes were backfilled with bentonite grout to the ground surface.

Packer testing was carried out at three intervals to evaluate the bulk permeability of the rock mass. The packer testing involved flushing the borehole with clean water to clear the borehole sidewalls, lowering the double-packer test assembly to the selected depth interval, inflating the packers, and recording the rate of water flow into the bedrock between the packers over sequential time periods for a series of different chamber pressures. The results of the packer tests are presented in Appendix A.

3.2 Laboratory Testing

All recovered soil samples were subjected to visual identification and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A.

Selected samples were subjected to gradation analysis (sieve and hydrometer) and Atterberg Limits testing where appropriate. The test results are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

All recovered cores of the shale bedrock were visually examined in the laboratory to confirm and supplement the field descriptions. Selected core samples were also subjected to unconfined compressive strength (UCS) and swell testing. The test results are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B. Point Load tests conducted on the cores were not representative since the cores would easily split along the bedding planes at very low loads.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets in Appendix A and the Borehole Locations and Soil Strata Drawing in Appendix C. A generalized description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the borehole logs takes precedence over this general description and interpretation of the site conditions. Subsurface conditions may vary between borehole locations.

In general terms, the soil stratigraphy encountered along the sewer alignments consists of fill and silty clay deposits overlying shale bedrock.

More detailed descriptions of the individual strata are presented below.

4.2 Topsoil

A 50 to 150 mm thick layer of topsoil was identified surficially in all boreholes except borehole 05-6 drilled on Bronte Road. The topsoil consists of a layer of roots and decayed organic matter that has developed over old fill material.

4.3 Fill

Fill was encountered in all boreholes. The composition of the fill varied as follows:

- Above the slope on the west side of the valley, the fill comprised gravelly silty sand over crushed shale/silty clay in borehole 05-1, silty clay in borehole 05-2, and silt and sand in borehole 05-3. The fill is compact to dense/hard with SPT N-values of 26 blows/0.3 m penetration to 50 blows/0.1 m. The fill extends to depths of 2.3 to 4.9 m (elevation 110.4 to 107.2 m).
- In borehole 05-4 on the west side of the valley base, a soft, dark brown silty clay layer was encountered to 0.8 m depth (elevation 88.3). This material may represent a creek alluvium.

- On the east side of the creek, the fill consists of silty clay. SPT N-values in the clay fill typically ranged from 7 to 27 blows/0.3 m, indicating a generally stiff to very stiff consistency. The lower boundary of the fill varied from elevation 87.0 m (5.8 m depth) at the toe of the valley slope, elevation 91.0 m (14.9 m depth) in borehole 05-6 drilled through the Bronte Road embankment, and elevation 99.6 m (3.5 m depth) in borehole 05-7 drilled east of Bronte Road.

In borehole 05-6 drilled on Bronte Road, the fill is overlain by a roadway pavement structure consisting of 165 mm of asphalt over approximately 900 mm of compact sand and gravel.

The results of grain size distribution analyses conducted on the various types of fill are presented on Figures B1 and B2, Appendix B. The percentage of clay size particles in the silty clay fill ranged from about 17 to 30%. The results of Atterberg Limits tests conducted on the clay, presented on Figure B3, indicate low plasticity (CL), with Plastic Limits of about 16 to 17 and Liquid Limits from 25 to 31. Moisture contents ranged from about 4 to 10% in the cohesionless fill and 7 to 21% in the silty clay fill.

Shale and limestone fragments were encountered throughout the fill material. The potential exists that larger rock fragments and/or other obstructions will be encountered.

4.4 Silty Clay

In boreholes 05-3 and 05-7, a native silty clay layer was encountered below the fill. N-values obtained in the clay exceeded 50 blows/0.15 m penetration, indicating a hard consistency, but may also reflect the presence of shale fragments at the sampler tip. The silty clay layer was 1.6 and 1.4 m thick in boreholes 05-3 and 05-7, respectively.

Dark brown silty clay was encountered below the fill in borehole 05-6 at 14.9 m depth (elevation 91.0 m). The clay is very stiff with one N-value of 24 blows/0.3 m obtained. This borehole was terminated in the clay at 15.8 m depth (elevation 90.1 m).

4.5 Bedrock

Shale bedrock was encountered below the fill and clay till deposits in all boreholes except borehole 05-6. The depth to bedrock ranged from 0.8 to 5.8 m as follows:

Table 4.1 – Depth to Bedrock

Borehole Number	Shale Bedrock	
	Depth (m)	Elevation (m)
05-1	4.9	109.3
05-2	2.3	110.4
05-3	4.3	105.6
05-4	0.8	88.3
05-5	5.8	87.0
05-6	-	-
05-7	4.9	98.2

The bedrock comprises reddish-brown shale of the Queenston Formation. The shale contains frequent interbeds of grey siltstone of up to 200 mm in thickness, typically less than 50 mm, at the borehole locations. Seams of very weathered material (essentially a silty clay), about 20 to 80 mm thick, were also present in the shale at the valley base level and in the upper 1.0 m of shale on the tableland. Occasional near-vertical fracturing was also encountered within the cores.

Total core recovery (TCR) of the bedrock cores ranged from 78 to 100%. The Rock Quality Designation (RQD) of the rock cores obtained from above the valley slopes indicates that this formation is of fair to good quality (RQD of 48 to 88%) in the upper 5 to 8 m and becomes good to excellent quality (RQD of 83 to 100%) below this depth. In borehole 05-4 drilled within the valley, and in borehole 05-3 below a corresponding elevation of 88.5m (21.4 m depth), the shale is of very poor quality with RQD values of 13 to 25%.

The unconfined compressive strength (UCS), unit weight and Young's Modulus of selected rock cores determined by laboratory compression testing (Appendix B) were as follows:

Table 4.2 – Laboratory Unconfined Compressive Strength Tests

Borehole No.	Run No.	Depth (m)	Unit Weight (kN/m^3)	Young's Modulus E_{50} (MPa)	Unconfined Compressive Strength (MPa)
05-2	2	5.23 – 5.43	28.7	-	5.7
	7	13.94 – 14.23	25.1	-	46.5
05-7	2	4.97 – 5.24	24.6	1,700	8.5

The results of swell tests carried out on samples of the shale are presented in Table 4.3. The suppression pressure is defined as the confining pressure above which the bedrock swelling potential is essentially zero.

Table 4.3 – Laboratory Swell Tests

Borehole No.	Run No.	Depth (m)	Suppression Pressure (kPa)
05-2	1	3.94 – 4.02	7.5
05-3	7	13.94 – 14.23	32.5

Packer tests were carried out in the shale bedrock at two depths in borehole 05-2 and at one depth in borehole 05-3. The results are presented in Appendix B. Bulk permeabilities of 4.11×10^{-10} and 1.24×10^{-10} m/sec were determined at two test locations and no appreciable flow into the rock was measured in the third test.

4.6 Water Levels

Upon completion of drilling, water was measured at 4.7 m depth in borehole 05-5, and was not observed in borehole 05-6. Water was introduced into the remaining boreholes during coring and therefore water levels were not obtained. The groundwater levels subsequently measured in the piezometers installed in the boreholes are summarized in Table 4.4.

Table 4.4 – Piezometer Water level Readings

Borehole	Date	Water Level Measured in Piezometer	
		Depth (m)	Elevation
05-1	22-Sept-2005 27-Oct-05	5.40 4.50	108.8 109.7
05-2	22-Sept-2005 27-Oct-05	4.20 4.40	108.5 108.3
05-3	22-Sept-2005 27-Oct-05	20.17 19.90	89.7 90.0
05-4	22-Sept-2005 27-Oct-05	1.75 0.35	87.3 88.8
05-5	22-Sept-2005 27-Oct-05	4.40 4.16	88.4 88.6
05-6	-	-	
05-7	22-Sept-2005 27-Oct-05	6.40 6.00	96.7 97.1

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.

5 MISCELLANEOUS

Full time supervision of the field activities, including obtaining utility clearances, was carried out by Mr. Stephane Loranger of Thurber.

Interpretation of the field data and preparation of the investigation report was conducted by Mr. Murray Anderson, P.Eng. Development of the field program was performed by Mr. Alastair E. Gorman, P.Eng. The investigation report was reviewed by Mr. Paulo Branco, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.
Murray R. Anderson, P.Eng.
Senior Geotechnical Engineer

Paulo J. Branco, P.Eng.
Review Principal

TUNNELLING INVESTIGATION AND DESIGN REPORT
STORM SEWER OUTLETS TO BRONTE CREEK
QEW BRONTE CREEK TWIN BRIDGE
W.P. 2264-03-01

Geocres Number: 30M5-236

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 INTRODUCTION

Part 2 of this report presents interpretation of the geotechnical data in the factual report and presents geotechnical comments and recommendations regarding installation of the proposed storm sewer outlets.

Twinning of the bridge carrying the QEW over Bronte Creek in Oakville is planned. As part of the project, installation of storm sewers outletting to the Bronte Creek is proposed. The storm sewers will be installed down the slopes of the Bronte Creek valley with drops of about 25 m on the west side and 24 m on east side of the valley. Installation using trenchless methods is contemplated.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigation. The plans and profiles used for preparation of the report were provided by MRC (October 2005).

7 TRENCHLESS INSTALLATION

7.1 West Side of Bronte Creek Valley

Preliminary profiles call for the section of the storm sewer between the top and bottom of the slope (borehole 05-2 to 05-4) to be installed using trenchless methods. This section will descend from near elevation 110 m to elevation 89 m over a lateral distance of about 100 m, for an overall inclination of about 5H:1V. The sewer diameter will be 600 mm; the actual diameter of the tunnel/bore will depend upon the installation methodology adopted.

The borehole information indicates that this section of the sewer will be installed within reddish brown shale bedrock of the Queenston Formation. The shale is horizontally bedded and contains frequent interbeds of strong, grey siltstone of up to 200 mm in thickness, typically less than 50 mm. Seams of very weathered material (essentially a silty clay), about 20 to 80 mm thick, were also present in the shale at the valley base level and in the upper 1.0 m of shale on the tableland.

Sewer installation through the shale bedrock is considered technically feasible using tunnelling methods or directional drilling. Pipe jacking may not be viable due to the constrained access conditions at the valley base. Jack and bore procedures are not suitable for the bedrock conditions at this site. Selection of an appropriate method should be the responsibility of the Contractor and will depend upon the relative costs and risks associated with each method.

Directional drilling is expected to be the most economical method, however the potential exists that the pilot bore may veer off alignment on the hard siltstone interbeds in the shale. Equipment that can penetrate the hard siltstone layers at a relatively flat angle will be required.

Tunnelling is likely to involve the least risk, as maintaining alignment and variations in rock strength at the tunnel face can easily be dealt with. However, costs are likely to be higher as this method is labour intensive, and a larger diameter tunnel will be needed to enable worker access into the tunnel.

The experience of the Contractor is of primary importance for trenchless installation. The Contractor must submit a detailed work plan, including the proposed methodology for boring, maintenance of alignment, and disposal of cuttings. A draft Non-Standard Special Provision (NSSP) for the trenchless installation work, prepared by MRC with input by Thurber, is provided in Appendix D. The NSSP alerts the Contractor to the following:

- The shale bedrock is bedded horizontally and contains hard siltstone layers that may tend to deflect boring equipment laterally when contacted on an inclination. The Contractor must be prepared to maintain the inclined alignment in these conditions.
- The shale bedrock contains strong to very strong siltstone layers. Tunnelling equipment or trenchless technology that can penetrate hard rock must be supplied.
- Spoils, drilling mud, sediment and drilling fluids must be collected and disposed of appropriately, and must not be permitted to enter the Bronte Creek.

The bedrock tunnel should be supported immediately after excavation to reduce the potential for deterioration and instability. Temporary support for tunnelling may consist of steel liner plates or steel ribs and lagging. The annular space between the liner and bedrock should be grouted soon after installation. The combined pipe walls and surrounding grout should be designed to withstand a uniform radial pressure equivalent to the weight of soil and rock above the tunnel level, plus groundwater pressure.

Directional drilling procedures must address the potential for ravelling of the bedrock on the excavation walls, as well as hydraulic fracturing (frac-out) of the rock around the hole due to drilling fluid pressure. Maintaining drilling fluid in the hole during drilling may be considered to control ravelling. To reduce the potential for frac-out, a minimum cover depth of 5 m is recommended between the pipe and the ground surface at the bottom of the valley slope. Casing should be supplied for support in any areas of overburden or highly weathered bedrock where ravelling or instability is experienced, and for sections of the pipe near the exit pit with less than 5 m of cover.

Based on groundwater observations during drilling, piezometer measurements, and the results of the in situ packer tests conducted in the rock, groundwater seepage from the bedrock is expected to be minimal. A system of sumps and pumps should be adequate for the tunnel and launching shaft. The shale is fractured however and water-bearing fissures producing relatively higher inflow of groundwater are likely to be encountered, particularly near the valley base where excavation may extend below the water level in Bronte Creek.

7.2 East Side of Bronte Creek Valley

The original concept for storm sewer installation down the slope on the west side of the creek valley called for a 900 mm pipe descending from near elevation 101 m (at borehole 05-7) to elevation 90 m (at borehole 05-5), over a lateral distance of about 50 m (5H:1V). The borehole information indicates that sewer installation along this alignment would be carried out within stiff to very stiff clay fill, some 1 to 5 m above the native clay surface and at least 2.4 m above the shale bedrock

Sewer installation by tunneling or pipe jacking (including jack-and-bore) methods is considered feasible in the cohesive silty clay fill. However, the potential exists that variable conditions and obstructions such as wood, rock fragments or other unidentified materials may be encountered in the fill, with resultant work interruption and procedure modification required during tunnel advance or pipe jacking. Work procedures must avoid loss of ground at the tunnel face and associated settlement at the road surface of Bronte Road if soft zones or large obstructions are encountered during tunnelling or pipe jacking.

Further, mixed face conditions may be encountered if the native surface or bedrock is encountered at higher elevations than indicated at the borehole locations. Mixed face conditions are typically problematic during pipe jacking, and selection of equipment that is capable of excavating the different material types with minimum loss of ground is critical for successful construction.

To reduce the potential difficulties and risks associated with inclined sewer installation through clay fill, the proposed vertical alignment has been revised to decrease the length of tunnel within the fill. The sewer will be installed by pipe jacking through the fill below Bronte Road, and by open cut with two drop chambers down the slope on the west side of the roadway.

Pipe jacking operations in the clay fill are considered feasible. A minimum vertical distance of 3 m is recommended between any underground utilities and the proposed pipe. A preconstruction survey of utilities should be carried out, and visual monitoring of the roadway surface, underground utilities, and any nearby structures should be carried out during pipe jacking to minimize the impacts of any settlement caused by the underground operations. The pipe installation should not be interrupted if the face of the casing is within 5 m of any utility in plan view.

The potential for roadway settlement could be reduced further by dropping the tunnel level to greater depth under the roadway using a deeper drop shaft on the east side of the road. However, construction costs would increase accordingly with the additional shaft depth and groundwater control requirements.

Based on the soil description, it is anticipated that groundwater flow in the fill will be moderate and should be controlled with a system of sumps and pumps in the tunnel and launching shaft. Seepage should be anticipated at the fill/native boundary and above the bedrock surface.

8 OPEN CUT INSTALLATION

Open cut excavation will be used to install the storm sewer west of borehole 05-2 and east of borehole 05-7. The depth to the proposed invert level will be less than 3 m. Stepped installation down the slope on the east side of the valley will require excavations of some 5 to 6 m in height on the upslope face.

Excavation will primarily extend through stiff to hard silty clay fill, locally compact to dense, gravelly, silty sand fill near borehole 05-1. In the vicinity of boreholes 05-2 and 05-4, the excavation may extend about 1 to 2 m into the underlying shale bedrock.

Temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario. For the purposes of assessing excavation slope requirements in compliance with the OHSA, the existing fill is classified as Type 3 soil. Where space restrictions preclude excavation of trench sidewalls using inclined slopes, service installation may be carried out using a trench box.

Use of a hydraulic excavator should be suitable for trench excavation in the fill. Provision should be made for handling of possible obstructions in the fill, and fragments of shale and limestone.

The upper 1.0 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 becomes less weathered with depth, and intensive use of pneumatic/hydraulic breakers or other methods of loosening the bedrock will likely be required if excavation extends deeper. Near vertical sidewalls may be employed for shallow excavation in shale bedrock.

In general, water was measured at depths below the anticipated excavation depth, and dewatering using sumps and pumps is considered feasible. The possibility exists that additional pumps may be required if localized zones of perched water are encountered in the fill, or if concentrated seepage is experienced from seams or fractures in the shale bedrock. Concentrated seepage should be anticipated from the highly weathered bedrock below the creek water level in the valley base.

The base of the sewer trench should be maintained in a dry condition, free of loose or disturbed material. The pipe must be placed on a uniformly competent subgrade. Pipe bedding, cover and backfill should follow OPSD 802.031 and OPSS 514.

9 SHORING DESIGN

Temporary shoring will be required to retain the embankment fill during sewer installation down the east valley slope. Shoring may also be required at the tunnel entrance and exit points on the west side of the valley. Based on available subsurface information, a shoring system consisting of steel H-piles with timber lagging may be considered. 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. Roadway protection should be supplied in accordance with SP 539S01 and designed for Performance Level 2.

The earth pressure coefficients to be used for shoring design are dependent on the type of material supported. Recommended unfactored values for materials at the site are shown in Table 9.1. Active pressures are suitable for typical shoring design requirements. The at-rest coefficients should be employed for excavation near existing utilities and structures where settlement of the soil behind the shoring is cannot be tolerated, or if the wall is restrained from lateral yielding.

Table 9.1 – Earth Pressure Coefficients (K)

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		Silty Clay Fill or Native Silty Clay $\phi = 27°, \gamma = 19.5$ kN/m^3		Highly Weathered Shale $\phi = 27°, \gamma = 25$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.38	0.70	0.38	0.70
At rest (Restrained Wall)	0.43	-	0.55	-	0.55	-
Passive (Movement Towards Soil Mass)	3.7	-	2.7	-	2.7	-

The earth pressure coefficients for shale provided in Table 9.1 are for the highly weathered material in the upper 1 to 2 m below the shale surface. Temporary support of the excavation face in sound shale below this level may be provided by shotcrete protection. The excavation face excavated in sound bedrock may be cut at inclinations of up to 1H:5V, and should be cleaned of all loosened bedrock and debris. A welded wire mesh should be pinned to the rock face prior to shotcreting, or steel fibre reinforced shotcrete should be applied. A minimum shotcrete thickness of 50 mm is recommended. Drain holes should be provided to minimize build up of water pressure behind the shotcrete.

Decisions regarding dewatering, shoring methods and sequencing are the responsibility of the Contractor. The Contract Documents should alert him to the requirement to maintain a stable excavation and that any shoring system should be designed by a shoring specialist, taking account of the need to control groundwater. The proposed shoring design and installation procedures should be submitted to the Contract Administrator for information purposes.

10 EROSION CONTROL

Erosion protection should be provided at the outlet areas as applicable. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rip-rap should be provided over all surfaces with which storm water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in accordance with OPSS 572.

11 CONSTRUCTION CONCERNS

- Inclined tunneling and directional drilling operations in shale bedrock on the west side of the valley may tend to veer horizontally from the desired alignment due to hard interbeds in the rock. The Contractor must be prepared to deal with this possibility and maintain or, if necessary, correct the alignment.
- Obstructions may be encountered in the fill soils existing on-site. This is of particular concern on the east valley slope where pipe jacking operations are planned below Bronte Road. Productivity loss, misalignment, or loss of ground with consequent settlement of the roadway surface are possible.
- Seepage zones may be encountered in the fill materials or from fractures or bedding planes in the shale bedrock. Greater seepage volumes should be anticipated from the highly weathered shale bedrock at the valley base if excavation extends below the water level in Bronte Creek.
- Spoils, drilling mud, sediment and drilling fluids must be collected and disposed of appropriately, and must not be permitted to enter the Bronte Creek

12 CLOSURE

Engineering analysis and preparation of the foundation report was conducted by Mr. Murray R. Anderson, P.Eng. The report was reviewed by Dr. Paulo J. Branco, Ph.D., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.
Murray R. Anderson, P.Eng.
Senior Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
NOV 21/05
PROVINCE OF ONTARIO

Paulo J. Branco, P.Eng.
Review Principal

LICENSED PROFESSIONAL ENGINEER
P. J. BRANCO
NOV. 21.05
PROVINCE OF ONTARIO

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▽ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS

- CLAYSTONE
- SILTSTONE
- SANDSTONE
- COAL
- Bedrock (general)

DISCONTINUITY SPACING

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

TERMS

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

STRENGTH CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 05-1

METRIC

W.P. 2264-03-01	LOCATION N: 4 807 539.3 E: 285 134.0	ORIGINATED BY SLL
HWY QEW	BOREHOLE TYPE Solid Stem Augers	COMPILED BY WM/HS
DATUM Geodetic	DATE 21.09.05 - 21.09.05	CHECKED BY MRA

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
114.2					
0.0	TOPSOIL (150 mm)				
0.2	Gravelly, Silty **SAND**, trace clay, with shale and limestone fragments, Compact to Dense, Reddish Brown, Moist to Dry (FILL)	1	SS	28	
		2	SS	37	25 40 28 7
		3	SS	50/.100	
111.2 / 3.0	**CRUSHED SHALE** Dense, Reddish Brown, Moist (FILL)	4	SS	31	
		5	SS	88	
109.3 / 4.9	Highly weathered, very weak to weak, reddish brown to grey, **SHALE**, occasional limy interbeds				
108.0 / 6.2	END OF BOREHOLE AT 6.20m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen.	6	SS	50/.100	

WATER LEVEL READINGS:

DATE	DEPTH (m)
22/09/05	5.40
27/10/05	4.50

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (114, 113, 112, 111, 110, 109); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m3

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

RECORD OF BOREHOLE No 05-2

METRIC

W.P. 2264-03-01	LOCATION N: 4 807 540.5 E: 285 160.3	ORIGINATED BY SLL
HWY QEW	BOREHOLE TYPE Solid Stem Augers / NQ Coring	COMPILED BY WM/HS
DATUM Geodetic	DATE 20.09.05 - 21.09.05	CHECKED BY MRA

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
112.7							
0.0	**TOPSOIL** (100mm)						
0.1	Silty **CLAY**, some sand, with shale and limestone fragments Hard Reddish Brown Moist (FILL)				112		
		1	SS	32			
		2	SS	38	111		
110.4 2.3	Highly weathered, very weak to weak, reddish brown, **SHALE**, very thinly bedded	3	SS	38	110	PL–LL plotted ≈ 20	0 4 81 14
		4	SS	50/ .075			
	3.41m - 3.49m clay seams				109		RUN #1 TCR=100% SCR=100% RQD=78%
	4.11m - 4.24m siltstone layers 4.13m - 4.21m vertical joint	1	RUN		▼		
	slightly weathered, weak				108		RUN #2 TCR=98% SCR=98% RQD=63% UCS=5.7 MPa
		2	RUN		107		
	5.79m - 5.87m siltstone layer						
	6.15m - 6.25m, 6.25m - 6.28m and 6.31m - 6.40m siltstone layers				106		RUN#3 TCR=100% SCR=100% RQD=88%
		3	RUN				
	7.49m - 7.60m siltstone layer				105		
	8.08m - 8.13m and 8.15m - 8.17m siltstone layers						RUN#4 TCR=93% SCR=93% RQD=84%
	8.51m - 8.61m and 9.02m - 9.05m siltstone layers	4	RUN		104		
	9.19m - 9.24m and 9.89m - 9.91m siltstone layers				103		

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 05-2

METRIC

W.P. 2264-03-01 | LOCATION N: 4 807 540.5 E: 285 160.3 | ORIGINATED BY SLL

HWY QEW | BOREHOLE TYPE Solid Stem Augers / NQ Coring | COMPILED BY WM/HS

DATUM Geodetic | DATE 20.09.05 - 21.09.05 | CHECKED BY MRA

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	10.21m - 10.29m siltsone layer		5	RUN							RUN#5 TCR=100% SCR=100% RQD=95%
102.0 / 10.7	END OF BOREHOLE AT 10.72m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.						102				

Shear strength legend: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. Plastic limit w_P, natural moisture content w, liquid limit w_L.

WATER LEVEL READINGS:

DATE	DEPTH (m)
22/09/05	4.20
27/10/05	4.40

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 05-3

METRIC

W.P. 2264-03-01 | LOCATION N: 4 807 595.2 E: 285 209.2 | ORIGINATED BY SLL

HWY QEW | BOREHOLE TYPE Solid Stem Augers / NQ Coring | COMPILED BY WM/HS

DATUM Geodetic | DATE 16.09.05 - 19.09.05 | CHECKED BY MRA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
109.9						
0.0	TOPSOIL (50mm)					
	SILT and SAND, some clay, trace gravel, some shale and limestone fragments Compact to Dense Reddish Brown Moist (FILL)	1	SS	26	109	3 45 38 14
		2	SS	42	108	
107.2 2.7		3	SS	85/ 275		
	Silty **CLAY**, with shale fragments Hard Reddish Brown	4	SS	95/ 225	107	
					106	
105.6 4.3	Highly to moderately weathered, very weak to weak, reddish brown, **SHALE,** thinly bedded 4.59m - 4.72m rubble zone				105	RUN#1 TCR=100% SCR=80% RQD=48%
	5.54m - 5.59m, 5.89m - 5.97m and 5.99m to 6.02m siltstone layers	1	RUN		104	
	6.71m - 6.76m siltstone layer	2	RUN		103	RUN#2 TCR=98% SCR=92% RQD=87%
	7.01m - 7.06m rubble zone slightly weathered, weak to medium strong 7.52m - 7.55m siltstone layer 7.64m - 7.82m vertical joint 7.94m - 7.97m siltstone layer				102	RUN#3 TCR=100% SCR=98% RQD=57%
	8.21m - 8.33m and 8.43m - 8.48m siltstone layers 8.51m - 8.61m and 9.04m - 9.12m vertical joints 8.82m - 8.84m and 8.92m - 8.99m siltstone layers	3	RUN		101	RUN#4 TCR=100% SCR=100% RQD=100%
	9.80m - 9.85m siltstone layer	4	RUN		100	

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

Continued Next Page

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

ONTMT4S 5192.GPJ 21/11/05

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 05-3

METRIC

W.P. 2264-03-01 | LOCATION N: 4 807 595.2 E: 285 209.2 | ORIGINATED BY SLL

HWY QEW | BOREHOLE TYPE Solid Stem Augers / NQ Coring | COMPILED BY WM/HS

DATUM Geodetic | DATE 16.09.05 - 19.09.05 | CHECKED BY MRA

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P – NATURAL MOISTURE CONTENT w – LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	10.26m - 10.28m, 10.46m - 10.48m and 10.97m - 10.99m siltstone layers										
							99				RUN#5 TCR=100% SCR=92% RQD=61%
	11.33m - 11.35m, 11.41m - 11.43m and 11.51m - 11.63m siltstone layers		5	RUN							
							98				
	11.94m - 12.09m, 12.24m - 12.26m and 12.26m - 12.39m siltstone layers										
											RUN#6 TCR=100% SCR=100% RQD=97%
			6	RUN			97				
	13.61m - 13.67m and 13.87m - 13.89m siltstone layer										
							96				RUN#7 TCR=100% SCR=100% RQD=97% UCS=46.5 MPa
	14.41m - 14.49m and 14.94m - 14.99m siltstone layer		7	RUN							
							95				
	15.02m - 15.09m siltstone layer										
											RUN#8 TCR=100% SCR=98% RQD=93%
			8	RUN			94				
	16.59m - 16.66m siltstone layer										
							93				
	16.97m - 17.09m, 17.51m - 17.55m, 17.68m - 17.70m and 17.73m - 17.75m siltstone layers										RUN#9 TCR=100% SCR=97% RQD=84%
			9	RUN							
							92				
	18.19m - 18.24m, 18.61m - 18.80m and 18.95m - 19.00m siltstone layers										RUN#10 TCR=90% SCR=87% RQD=83%
							91				
			10	RUN							
	19.49m - 19.51m, 19.53m - 19.55m and 19.66m - 19.71m siltstone layers 19.76m - 19.78m and 19.89m - 19.96m						90				

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 05-3

METRIC

W.P. 2264-03-01 LOCATION N: 4 807 595.2 E: 285 209.2 ORIGINATED BY SLL

HWY QEW BOREHOLE TYPE Solid Stem Augers / NQ Coring COMPILED BY WM/HS

DATUM Geodetic DATE 16.09.05 - 19.09.05 CHECKED BY MRA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	siltstone layers 20.27m - 20.37m, 20.41m - 20.42m and 20.76m - 20.88m siltstone layers 21.01m - 21.07m and 21.24m - 21.29m siltstone layers Highly weathered, weak to very weak	11	RUN		89	RUN#11 TCR=100% SCR=100% RQD=100%
	21.89m - 21.91m and 22.30m - 22.35m clay seams 22.00m - 22.10m and 22.20m - 22.33m rubble zones	12	RUN		88	RUN#12 TCR=88% SCR=67% RQD=25%
	23.04m - 23.24m and 23.57m - 23.70m siltstone layers 23.58m - 23.64m vertical joint	13	RUN		87, 86	RUN#13 TCR=78% SCR=75% RQD=20%
85.8 24.1	END OF BOREHOLE AT 24.13m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

WATER LEVEL READINGS:

DATE	DEPTH (m)
22/09/05	20.17
27/10/05	19.90

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; GR SA SI CL

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 05-4

METRIC

W.P. 2264-03-01 | LOCATION N: 4 807 626.7 E: 285 228.3 | ORIGINATED BY SLL

HWY QEW | BOREHOLE TYPE Solid Stem Augers / NQ Coring | COMPILED BY WM/HS

DATUM Geodetic | DATE 15.09.05 - 15.09.05 | CHECKED BY MRA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
89.1							
0.0	TOPSOIL (150mm)					89	
0.2	Silty **CLAY**, trace roots and wood fragments, occasional sand seams Soft Dark Brown Wet (FILL)	1	SS	2			
88.3 / 0.8	Highly weathered, very weak, reddish brown, **SHALE**, very thinly bedded, 1.15m - 1.17m siltstone layer 1.35m - 1.39m and 1.45m - 1.47m clay seams 1.50m - 1.81m and 2.29m - 2.31m clay seams 1.93m - 2.03m and 2.34m - 2.39m vertical joints 2.18m - 2.20m and 2.59m to 2.61m siltstone layers	2	SS	50/ .075		88	
		1	RUN		▼	87	RUN#1 TCR=97% SCR=65% RQD=22%
	2.84m - 2.94m and 3.49m - 3.51m siltstone layers 3.18m to 3.23m clay seam 3.64m - 3.74m and 3.86m - 3.89m siltstone layers	2	RUN			86	RUN#2 TCR=82% SCR=77% RQD=13%
84.9						85	
4.2	END OF BOREHOLE AT 4.19m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.						

Water content plot (%): approx. 43 at sample 1; approx. 20 at sample 2.

WATER LEVEL READINGS:

DATE	DEPTH (m)
22/09/05	1.75
27/10/05	0.35

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; GR SA SI CL

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 5192.GPJ 28/10/05

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 05-5

METRIC

W.P. 2264-03-01 LOCATION N: 4 807 677.3 E: 285 289.9 ORIGINATED BY SLL

HWY QEW BOREHOLE TYPE Solid Stem Augers COMPILED BY WM/HS

DATUM Geodetic DATE 15.09.05 - 15.09.05 CHECKED BY MRA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
92.8					
0.0	TOPSOIL: (100mm)				
0.1	Silty **CLAY**, trace to some sand, occasional topsoil pockets, roots and rootlets, occasional shale and limestone fragments Hard to Stiff Reddish Brown Moist (FILL)	1	SS	42	
		2	SS	23	
		3	SS	10	0 11 64 26
		4	SS	13	
	Very Stiff Wet	5	SS	22	
87.0 5.8	Highly weathered, very weak, reddish brown, **SHALE**, occasional clay seams	6	SS	50/.100	
85.7 7.1	END OF BOREHOLE AT 7.14m. BOREHOLE OPEN AND WATER LEVEL AT 4.72 m UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.	7	SS	50/.125	

WATER LEVEL READINGS:

DATE	DEPTH (m)
22/09/05	4.40
27/10/05	4.16

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (92, 91, 90, 89, 88, 87, 86); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 05-6

METRIC

W.P. 2264-03-01
LOCATION N: 4 807 711.2 E: 285 316.4
ORIGINATED BY SLL

HWY QEW
BOREHOLE TYPE Solid Stem Augers
COMPILED BY WM/HS

DATUM Geodetic
DATE 22.09.05 - 22.09.05
CHECKED BY MRA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
105.9						
0.0	**ASPHALT**(165 mm)					
0.2	**SAND and GRAVEL** Compact Brown Moist (FILL)				105	
104.8 / 1.1	Silty **CLAY**, some sand, trace gravel, trace rootlets, occasional shale fragments Stiff to Very Stiff Brown Moist (FILL)	1	SS	16		
		2	SS	8	104	1 18 61 20
	occasional wood fibers	3	SS	18	103	
		4	SS	7	102	
		5	SS	27	101	0 15 55 30
					100	
		6	SS	17	99	
		7	SS	18	98	
					97	
		8	SS	8	96	0 14 66 20

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

15 ⊕ 5 (20, 10) (%) STRAIN AT FAILURE

ONTMT4S 5192.GPJ 28/10/05

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 05-6

METRIC

W.P. 2264-03-01
LOCATION N: 4 807 711.2 E: 285 316.4
ORIGINATED BY SLL
HWY QEW
BOREHOLE TYPE Solid Stem Augers
COMPILED BY WM/HS
DATUM Geodetic
DATE 22.09.05 - 22.09.05
CHECKED BY MRA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)
		9	SS	23	95	~18
		10	SS	16	94 / 93	~19
		11	SS	22	92	~18
91.0 / 14.9	Silty **CLAY**, trace sand, trace topsoil Very Stiff Dark Brown Moist	12	SS	24	91	~25
90.1 / 15.8	END OF BOREHOLE AT 15.85m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m)					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 05-7

METRIC

W.P. 2264-03-01	LOCATION N: 4 807 725.3 E: 285 324.3	ORIGINATED BY SLL
HWY QEW	BOREHOLE TYPE Solid Stem Augers / NQ Coring	COMPILED BY WM/HS
DATUM Geodetic	DATE 14.09.05 - 15.09.05	CHECKED BY MRA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
103.1						
0.0	TOPSOIL: (100 mm)					
0.1	Silty **CLAY**, trace sand, occasional wood fragments, Stiff, Reddish Brown, Moist (FILL)	1	SS	14	o	
		2	SS	10	o	0 6 77 17
		3	SS	7	o	
	trace shale fragments	4	SS	8	o	
99.6 / 3.5	Silty **CLAY**, trace sand, trace rootlets, occasional shale and limestone fragments, Firm to Hard, Brown, Moist	5	SS	50/ .100	o	
98.2 / 4.9	Highly weathered, very weak, reddish brown, **SHALE**. 4.88m - 4.90m, 5.31m - 5.33m and 5.62m - 5.66m clays seams	1	RUN		o	RUN#1 TCR=85% SCR=62% RQD=53%
96.7 / 6.4	END OF BOREHOLE AT 6.40m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (103, 102, 101, 100, 99, 98, 97); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

WATER LEVEL READINGS:

DATE	DEPTH (m)
22/09/05	6.4
27/10/05	6.00

+ ³, × ³: Numbers refer to Sensitivity

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

PACKER TEST RESULTS SUMMARY

BOREHOLE 05-2 TEST 1

Borehole diameter =	47.00 mm	1.85 inches		
Borehole radius =	23.50 mm			
Length of test zone =	1525 mm	Depth below ground surface =		4.0 to 5.5 m
Height of Gauge above GWT =	1900 mm	Depth below bedrock surface =		0.6 to 2.1 m

STAGE NUMBER	FLOW RATE (USgal/min)	FLOW RATE (ft^3/min)	GAUGE PRESSURE (psi)	DIFF. HEAD (ft)	k (ft/min)	k (m/sec)	$k_{average}$ (m/sec)
1	0	0.00000	4.0	15.5	0.00E+00	0.00E+00	0.00E+00
2	0	0.00000	8.0	24.7	0.00E+00	0.00E+00	
3	0	0.00000	13.0	36.2	0.00E+00	0.00E+00	
4	0	0.00000	40.0	98.5	0.00E+00	0.00E+00	

BOREHOLE 05-2 TEST 2

Borehole diameter =	47.00 mm	1.85 inches		
Borehole radius =	23.50 mm			
Length of test zone =	1525 mm	Depth below ground surface =		7.6 to 9.1 m
Height of Gauge above GWT =	4400 mm	Depth below bedrock surface =		4.3 to 5.8 m

STAGE NUMBER	FLOW RATE (USgal/min)	FLOW RATE (ft^3/min)	GAUGE PRESSURE (psi)	DIFF. HEAD (ft)	k (ft/min)	k (m/sec)	$k_{average}$ (m/sec)
1	0.0005	0.00007	8.0	32.9	2.70E-07	1.37E-09	4.11E-10
2	0.0005	0.00007	16.0	51.4	1.73E-07	8.77E-10	
3	0	0.00000	25.0	72.1	0.00E+00	0.00E+00	
4	0.00025	0.00003	38.0	102.1	4.34E-08	2.21E-10	
5	0	0.00000	16.0	51.4	0.00E+00	0.00E+00	
6	0	0.00000	8.0	32.9	0.00E+00	0.00E+00	

BOREHOLE 05-3 TEST 1

Borehole diameter =	47.00 mm	1.85 inches		
Borehole radius =	23.50 mm			
Length of test zone =	1525 mm	Depth below ground surface =		12.2 to 13.7 m
Height of Gauge above GWT =	20300 mm	Depth below bedrock surface =		7.6 to 9.1 m

STAGE NUMBER	FLOW RATE (USgal/min)	FLOW RATE (ft^3/min)	GAUGE PRESSURE (psi)	DIFF. HEAD (ft)	k (ft/min)	k (m/sec)	$k_{average}$ (m/sec)
1	0	0.00000	13.0	96.6	0.00E+00	0.00E+00	1.24E-10
2	0.0005	0.00007	26.0	126.6	7.01E-08	3.56E-10	
3	0.00025	0.00003	40.0	158.9	2.79E-08	1.42E-10	
4	0	0.00000	55.0	193.5	0.00E+00	0.00E+00	

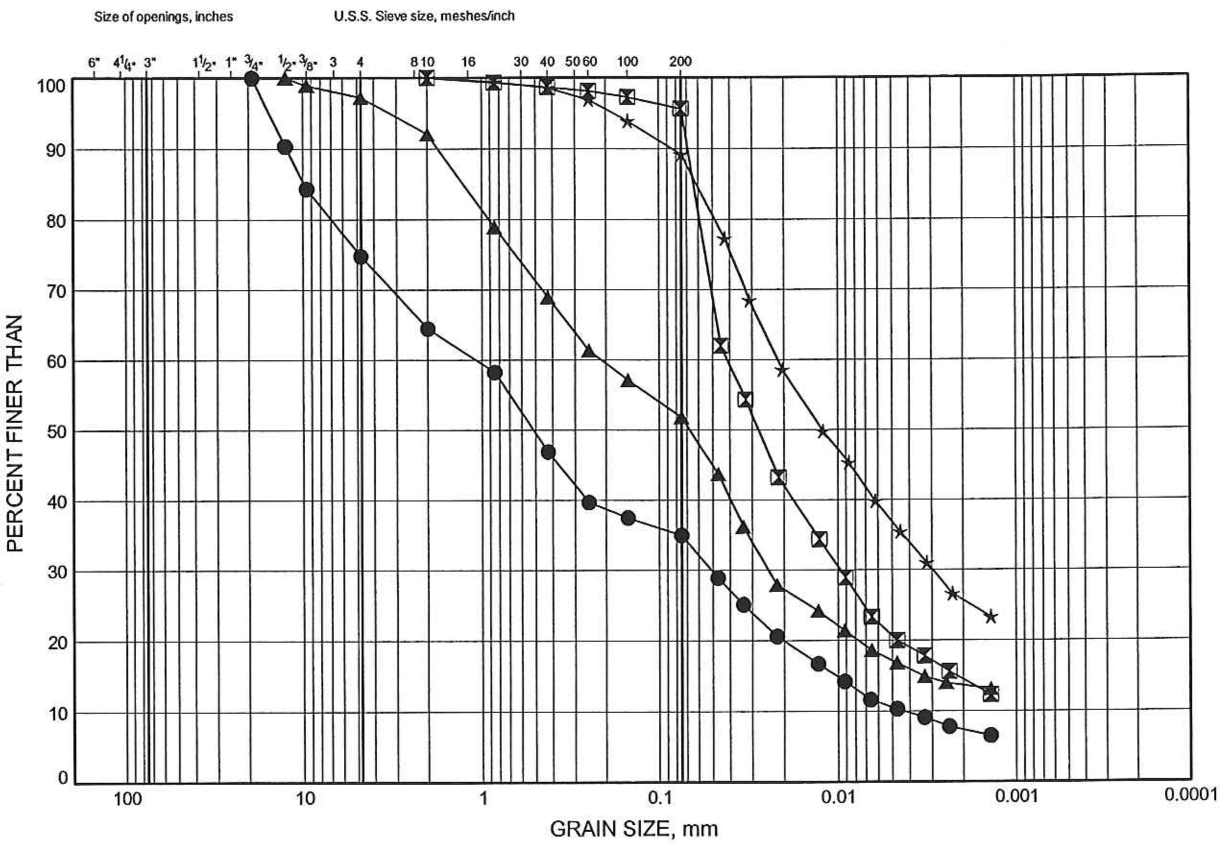
Appendix B

Laboratory Test Results

Bronte Creek Sewer Outfalls

GRAIN SIZE DISTRIBUTION

FIGURE B1



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	05-1	1.83	112.37
⊠	05-2	2.59	110.11
▲	05-3	1.07	108.83
★	05-5	2.59	90.21

THURBGSD 5192.GPJ 21/11/05

Date November 2005

Project 2264-03-01

THURBER

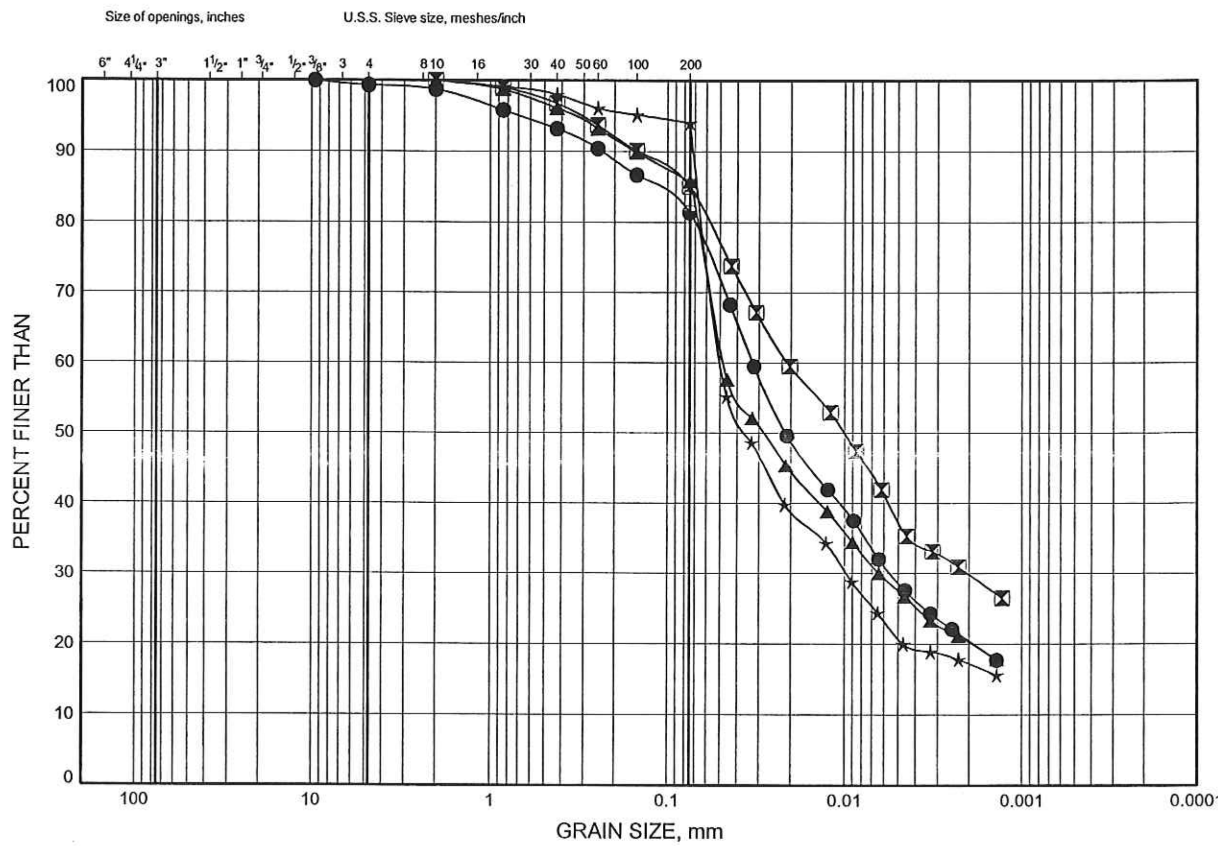
Prep'd HS

Chkd. MRA

Bronte Creek Sewer Outfalls

GRAIN SIZE DISTRIBUTION

FIGURE B2



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	05-6	1.83	104.07
⊠	05-6	4.88	101.02
▲	05-6	9.45	96.45
★	05-7	1.83	101.27

Date October 2005

Project 2264-03-01

THURBER

Prep'd WM

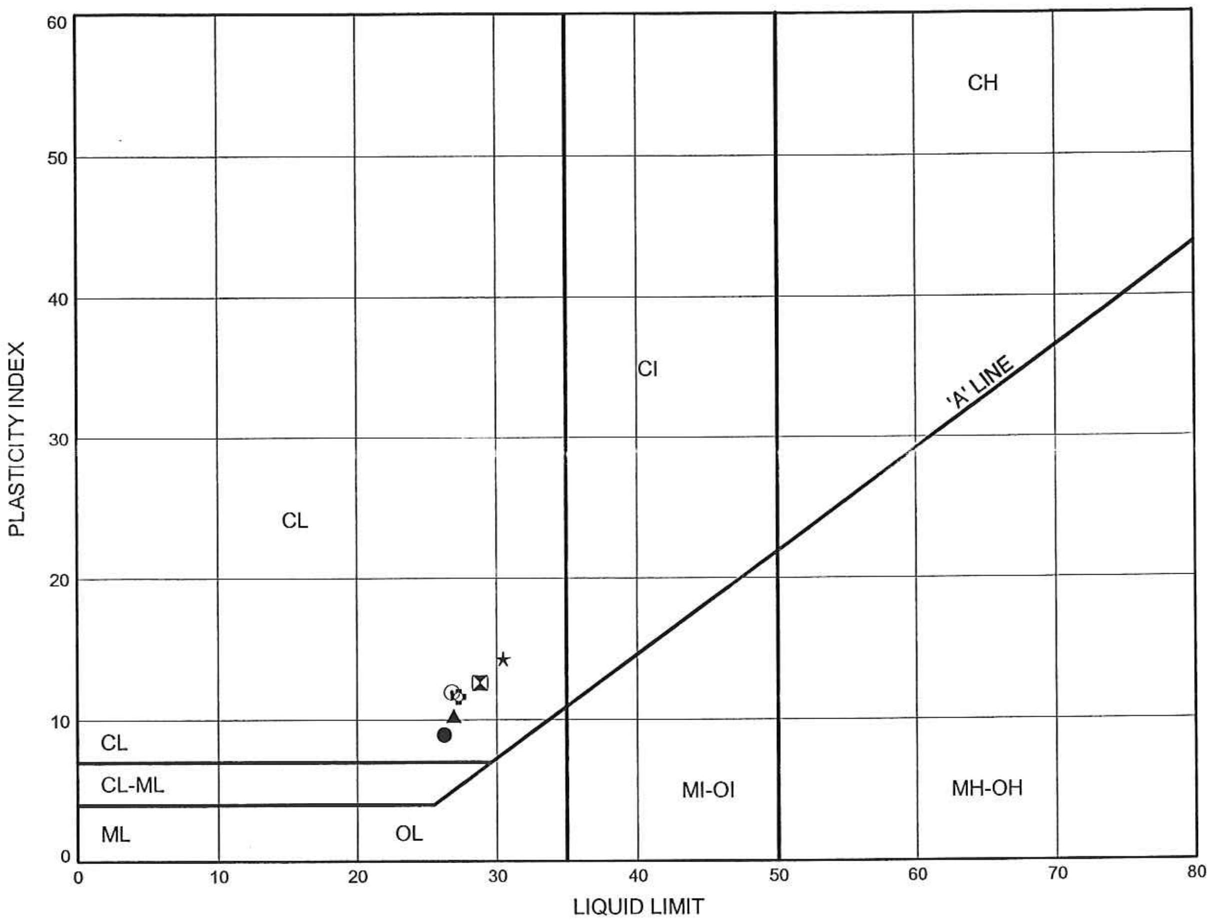
Chkd. MRA

THURBGSD 5192.GPJ 31/10/05

Bronte Creek Sewer Outfalls

ATTERBERG LIMITS TEST RESULTS

FIGURE B3



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	05-2	2.59	110.11
⊠	05-5	2.59	90.21
▲	05-6	1.83	104.07
★	05-6	4.88	101.02
⊙	05-6	9.45	96.45
✪	05-7	1.83	101.27

Date October 2005

Project 2264-03-01

THURBER

Prep'd WM

Chkd. MRA

THURBALT 5192.GPJ 31/10/05

ONE-DIMENSIONAL SWELL POTENTIAL OF COHESIVE SOILS
ASTM D4546-03

SAMPLE IDENTIFICATION

Project Number	05-1116-041	Sample Number	Run 1
Borehole Number	05-2-NQ	Sample Depth, m	3.94-4.02

TEST CONDITIONS

Test Method	B	Load Duration, hr	46.8
Oedometer Number	8		
Date Started	09/26/2005		
Date Completed	09/28/2005		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	24.45
Sample Diameter, cm	4.83	Dry Unit Weight, kN/m^3	23.26
Area, cm^2	18.32	Specific Gravity, assumed	2.70
Volume, cm^3	35.00	Solids Height, cm	1.678
Water Content, %	5.13	Volume of Solids, cm^3	30.74
Wet Mass, g	87.25	Volume of Voids, cm^3	4.26
Dry Mass, g	82.99	Degree of Saturation, %	100.0

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm
0.00	1.910	0.139	1.910
7.54	1.909	0.138	1.910

Notes:

Swell pressure σ_{sp}=7.54 kPa

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	24.68
Sample Diameter, cm	4.83	Dry Unit Weight, kN/m^3	23.26
Area, cm^2	18.32	Specific Gravity, assumed	2.70
Volume, cm^3	34.98	Solids Height, cm	1.678
Water Content, %	6.07	Volume of Solids, cm^3	30.74
Wet Mass, g	88.03	Volume of Voids, cm^3	4.25
Dry Mass, g	82.99		

Prepared By: LFG

Golder Associates

Checked By: MM

ONE-DIMENSIONAL SWELL POTENTIAL OF COHESIVE SOILS
ASTM D4546-03

SAMPLE IDENTIFICATION

Project Number	05-1116-041	Sample Number	Run 7
Borehole Number	05-3-NQ	Sample Depth, m	13.94-14.23

TEST CONDITIONS

Test Method	B	Load Duration, hr	18.2
Oedometer Number	8		
Date Started	09/28/2005		
Date Completed	09/29/2005		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	23.45
Sample Diameter, cm	4.83	Dry Unit Weight, kN/m^3	22.83
Area, cm^2	18.32	Specific Gravity, assumed	2.70
Volume, cm^3	35.00	Solids Height, cm	1.647
Water Content, %	2.74	Volume of Solids, cm^3	30.17
Wet Mass, g	83.70	Volume of Voids, cm^3	4.82
Dry Mass, g	81.47	Degree of Saturation, %	46.2

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm
0.00	1.910	0.160	1.910
32.51	1.910	0.160	1.910

Notes:

Swell pressure σ_{sp}=32.51 kPa

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	23.86
Sample Diameter, cm	4.83	Dry Unit Weight, kN/m^3	22.83
Area, cm^2	18.32	Specific Gravity, assumed	2.70
Volume, cm^3	34.99	Solids Height, cm	1.647
Water Content, %	4.49	Volume of Solids, cm^3	30.17
Wet Mass, g	85.13	Volume of Voids, cm^3	4.82
Dry Mass, g	81.47		

Prepared By: LFG

Golder Associates

Checked By: MM

UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166-00e1

SAMPLE IDENTIFICATION

PROJECT NUMBER	05-1116-041	SAMPLE NUMBER	Run 2
BOREHOLE NUMBER	05-2-NQ	SAMPLE DEPTH, m	5.23-5.43

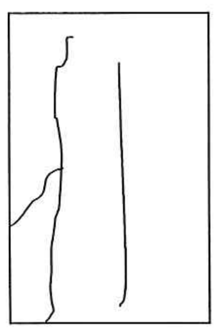
TEST CONDITIONS

MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST, min	>2 <15	L/D	2.97

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.03	WATER CONTENT, (specimen) %	4.60
SAMPLE DIAMETER, cm	4.72	UNIT WEIGHT, kN/m^3	28.69
SAMPLE AREA, cm^2	17.50	DRY UNIT WT., kN/m^3	27.66
SAMPLE VOLUME, cm^3	245.49	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	625.72	VOID RATIO	0.11
DRY WEIGHT, g	598.20		

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, kPa	5,715

REMARKS:

DATE: 09/28/2005

UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166-00e1

SAMPLE IDENTIFICATION

PROJECT NUMBER	05-1116-041	SAMPLE NUMBER	Run 7
BOREHOLE NUMBER	05-3-NQ	SAMPLE DEPTH, m	13.94-14.23

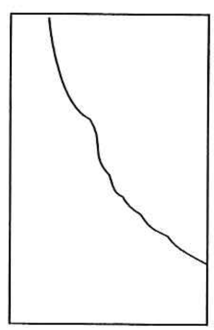
TEST CONDITIONS

MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST, min	>2 <15	L/D	2.89

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	13.59	WATER CONTENT, (specimen) %	2.40
SAMPLE DIAMETER, cm	4.71	UNIT WEIGHT, kN/m^3	25.13
SAMPLE AREA, cm^2	17.42	DRY UNIT WT., kN/m^3	27.90
SAMPLE VOLUME, cm^3	236.78	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	617.66	VOID RATIO	0.06
DRY WEIGHT, g	603.18		

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, kPa	46,489

REMARKS:

DATE: 09/28/2005

UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166-00e1

SAMPLE IDENTIFICATION

PROJECT NUMBER	05-1116-041	SAMPLE NUMBER	Run 2
BOREHOLE NUMBER	05-7	SAMPLE DEPTH, m	4.97-5.24

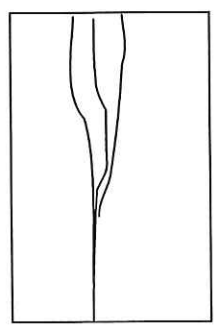
TEST CONDITIONS

MACHINE SPEED, mm/min	0.35	TYPE OF SPECIMEN	Rock Core
RATE OF AXIAL STRAIN, %/min	0.44	L/D	1.67

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	7.87	WATER CONTENT, (specimen) %	5.50
SAMPLE DIAMETER, cm	4.71	UNIT WEIGHT, kN/m^3	24.58
SAMPLE AREA, cm^2	17.42	DRY UNIT WT., kN/m^3	23.30
SAMPLE VOLUME, cm^3	137.12	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	343.83	VOID RATIO	0.14
DRY WEIGHT, g	325.91		

FAILURE SKETCH

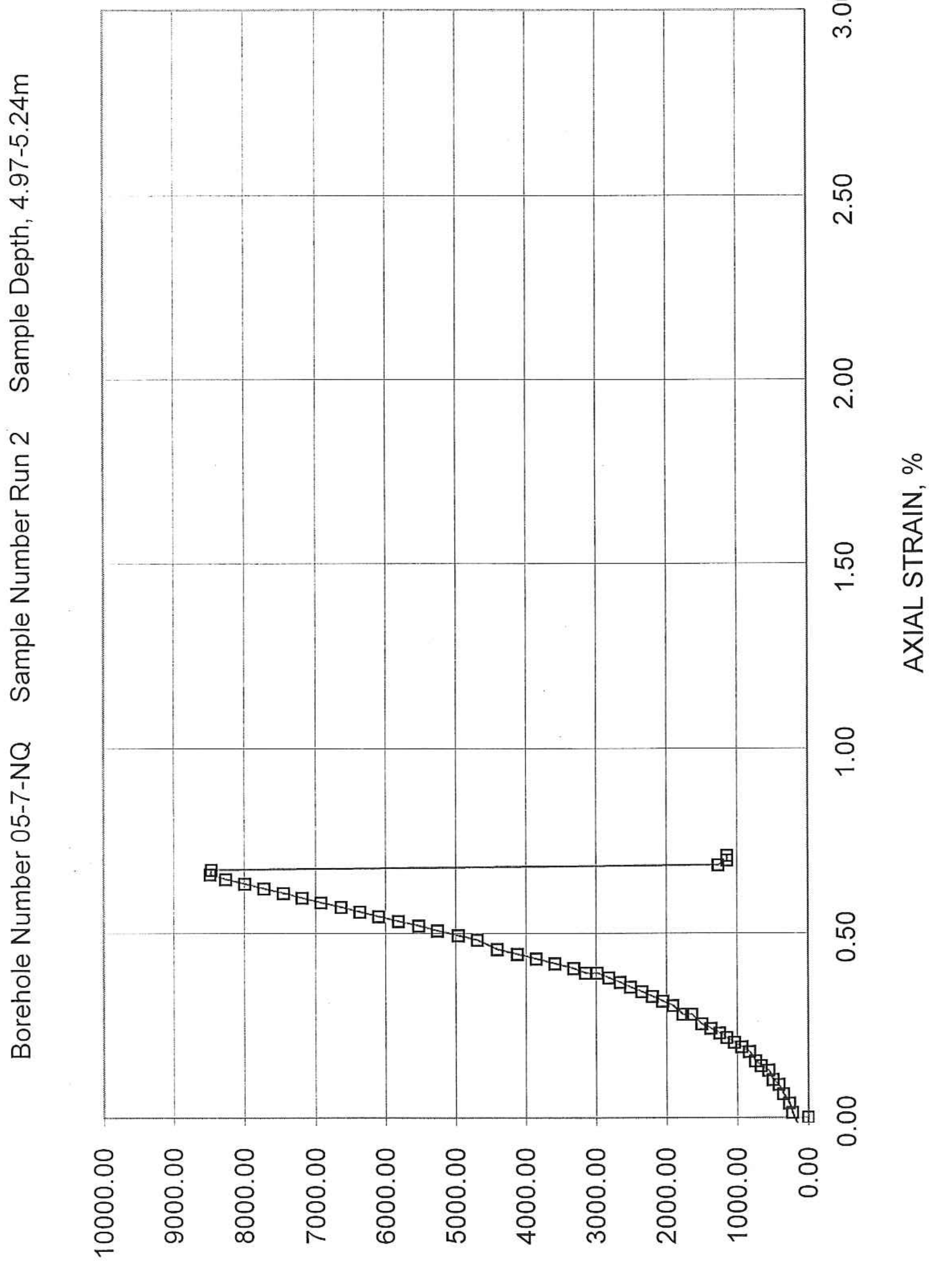


TEST RESULTS

STRAIN AT FAILURE, %	0.7	COMPRESSIVE STRESS, kPa	8,485

REMARKS: L/D ratio not in accordance with specifications. DATE: 09/27/2005

UNCONFINED COMPRESSION TEST (UC)	FIGURE



Project No. 05-1116-041

Appendix C

Borehole Locations and Soil Strata Drawing

Appendix D

Draft

Non-Standard Specification (NSSP) for Trenchless Installation

TUNNEL – Item No.

Non-standard Special Provision

Sewer Installation by Trenchless Methods

OPSS 415 is deleted and replaced with the following:

1. Scope

This specification addresses the installation of sewers by trenchless methods as identified in the contract.

The Contractor shall review the provided geotechnical information and shall determine the most appropriate method of installation from the various available trenchless construction methods available. Specifications for directional drilling, pipe jacking and tunnelling are provided herein, and shall be applied to the installation method considered feasible by the Contractor.

The Contractor shall be responsible for the complete design of the installation, including all temporary requirements, as specified herein.

The Contractor's design, documentation, submission requirements and installation methods shall specifically consider and address the presence of hard layers of rock (limestone, limey shale, etc.) as identified in the geotechnical information. These hard layers of rock will be intersected by the sewer alignment on a relatively flat angle. The Contractor shall also note the large elevation difference between the entry and exit points of the sewer alignment.

2. References

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

Foundations Investigation Report

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 409	Closed Circuit Television Inspection of Pipelines
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 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete

MTO Material Specifications

Form 1820	Concrete Pipe
Form 1840	Polyethylene Pipe

American Society for Testing and Materials (ASTM) International Standards

ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F667-85	Large Diameter Corrugated Polyethylene Tubing and Fittings
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.

3. Definitions

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

Backreamer: means a cutting head designed for the subsurface conditions and that is attached to the leading end of a drill string to enlarge the pilot bore during a pullback operation to enable installation of the product.

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

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

Drilling Fluid Fracture or Frac Out: means 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: means a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

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

Entry Point: means the location or excavation from which the trenchless method is initiated for the installation of product.

Exit Point: means the location or excavation to which the trenchless method is directed for the installation of product.

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

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

HDPE: means high density polyethylene.

Inadvertent Returns: means the flow of unexpected fluids towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

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

Multi Product Installation: means two or more products installed in the same bore path. The products may or may not have the same diameters.

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

Product: means pipelines, conduits, cable, or ducts.

Pullback: means that part of the DD method in which the drill string is pulled back through the bore path to the entry point, usually installing the product at the same time.

Quality Verification Engineer (QVE): means 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: means 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 could include multiple passes.

Rock: means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, of sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m3 or greater.

Single Product installation: means a single product installed into a bore path. The product may or may not have a tracer wire attached to it.

Strike Alert: means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm is set off when the sensor contacts 42.5 volts or 0.5 amperes. The alarm may be audio or visual or both.

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

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

4. Submission and Design Requirements

When any of the following information is not specified in the Contract Documents, six copies of the document containing the required information shall be submitted to the Contract Administrator for review at least three weeks prior to commencing trenchless sewer installation operations:

- 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;
- The access shaft or pit details, if applicable;
- The methods to be employed to monitor and maintain the alignment of the installation;
- 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 any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;
- Face support and other temporary support details, if applicable;
- Excavation and pipe jacking procedures, including methodology to handle obstructions as described in this specification;
- Primary liner design details, if applicable;
- 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;
- Material mixture for filling voids and installation procedures;
- Tunnel boring machine information, if applicable; and
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.

The above submissions shall bear the seals and signatures of the Design and Checking Engineers experienced in this field. These Engineers will not be permitted to carry out the work of the Quality Verification Engineer.

The Contractor shall provide a Certificate of Conformance to the Contract Administrator, sealed and signed by a Quality Verification Engineer (QVE), that the installation of the tender item is in general conformance with the Contract Documents and the Contractor's Submission and Design Requirements.

5. Materials

5.01 Concrete

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

5.02 Concrete Reinforcement

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

5.03 Timber

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

5.04 Cement Grout

Grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA-A5-M and two parts mortar sand conforming to OPSS 1004 wetted with only sufficient water to make the mixture plastic.

5.05 Tunnelling Materials

Should the contractor elect to carry out the work by tunnelling, the following requirements apply:

5.05.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor. The design shall be submitted to the Contract Administrator as specified herein.

5.05.02 Secondary Liner

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

5.05.02.01 Concrete Pipe

Concrete pipe as per MTO Form 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 their submission requirements.

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

5.05.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per MTO Form 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 their submission requirements.

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

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

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

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

5.06 Pipe Jacking Materials

Should the contractor elect to carry out the work by pipe jacking, the following requirements apply:

5.06.01 Pipe Materials

Concrete pipe as per MTO Form 1820 shall be used. The Contractor shall select pipe class for pipe jacking and identify this in their submission requirements.

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

5.07 Materials for Directional Drilling Methods

Should the contractor elect to carry out the work by directional drilling, the following requirements apply:

5.07.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions. No hazardous additives may be used.

5.07.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per MTO Form 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 support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in their submission requirements.

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

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

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

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

6. Equipment

6.01 Tunnelling Equipment

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

6.02 Pipe Jacking Equipment

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

6.03 Directional Drilling Equipment

Should the contractor elect to carry out the work by directional drilling, the following requirements apply:

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 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.

7. Construction

7.01 General

7.01.01 Layout

The location of the installation shall be established from the lines, elevations, and tolerances specified in the Contract Documents.

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 10 m in normal conditions and every 5 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).

The sewer installation shall be constructed to the pipe horizontal and vertical alignments specified in the drawings.

For directional drilling, the contractor shall ensure during pilot hole drilling the maximum degree of deviation or "dog-leg" shall be 2.5 degrees per 9m drill pipe. 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.

Excavation of the valley slope above the elevation of the finished grade of the adjacent energy dissipation manhole (manhole #4) shall not be permitted.

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, railway, 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 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.

7.01.05 Supervision

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

7. 02 Tunnelling Requirements

Should the contractor elect to carry out the work by tunnelling, the following requirements apply:

7.02.02 Tunnelling Method

The tunnelling method shall be suitable to deal with changing ground conditions that may be encountered during the progress of the work. Tunnelling in the bedrock will encounter hard layers of rock (limestone, limey shale, etc) at a relatively flat angle with the tunnel alignment. The selection of the tunnelling method in the bedrock should consider the presence and inclination of these hard rock layers with respect to the tunnel alignment.

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

7.02.03 Primary Liner

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. The primary lining shall be installed within 1.8m of the face of 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.

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.

Tunnels excavated in rock shall be supported in a manner that prevents scaling and ravelling of the rock and also protects the rock from weathering or deterioration.

7.02.04 Secondary Lining

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

7.03 Pipe Jacking Requirements

Should the contractor elect to carry out the work by pipe jacking, the following requirements apply:

7.03.01 Method of Installation Procedure

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

- Only concrete pipe shall be used.
- 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 presence and inclination of hard layers of rock (limestone, limey shale, etc.) at a relatively flat angle within the pipe alignment.

7.03.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820.04.02 and must withstand high jacking forces, determined by the Contractor.

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

7.04 Directional Drilling Requirements

Should the contractor elect to carry out the work by directional drilling, the following requirements apply:

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 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 backreamer 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 bore 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.

7.04.04 Transporting, Unloading, Storing, and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.04.05 Trenching, Backfilling, and Compacting

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

7.04.06 Support Systems

Support systems shall be according to OPSS 538.

7.04.07 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances specified elsewhere in this document. The contractor's methods shall take into consideration the presence and inclination of hard layers of rock (limestone, limey shale, etc.) at a relatively flat angle within the pipe alignment and shall be suitable to address the potential for deflection off of these layers.

In the event the pilot bore does deviate, 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 of the action taken.

At the entry and exit points, there is potential for ravelling of the existing soil and 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. This is over and above the casing requirements for prevention of drilling fluid fracture specified elsewhere.

If a drill hole beneath a road 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 and back pull 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.

7.04.08 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 shall be maintained between the pipe and the ground surface at the valley bottom. Sections of the pipe close to the exit pit with less than 5m cover with shall be cased.

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. 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

7.04.09 Reaming

When necessary, the bore shall be reamed using the appropriate tools to a diameter 50% greater than the outside diameter of the product to a maximum of 300 mm beyond the product diameter.

7.04.10 Product Installation

7.04.10.01 General

The product shall be jointed according to manufacturer's recommendations. Where space permits, the length of the product to be pulled shall be jointed as one length before commencement of the 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.

7.04.10.02 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 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 cement grout.

7.05 Dewatering

Dewatering shall be according to OPSS 517.

7.06 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.

7.07 Testing

Testing of the product installation shall be as specified in the Contract Documents.

7.08 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180.

7.09 Site Restoration

Site restoration shall be according to OPSS 507.

8. Quality Assurance

Not used.

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 invert line of the sewer, of the actual length of sewer 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 the sewers, supply and installation of primary liners, restoration and for all other work necessary to complete the sewer as specified.

Payment for connecting intercepted drains and service connections into the sewer system 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 installation of sewers.

(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.