



**FOUNDATION INVESTIGATION AND
DESIGN REPORT
PROPOSED WATERMAIN AND
SANITARY SEWER CROSSING
HWY 427 – BETWEEN HWY 407 & HWY 7
VAUGHAN, ONTARIO**

Report Submitted

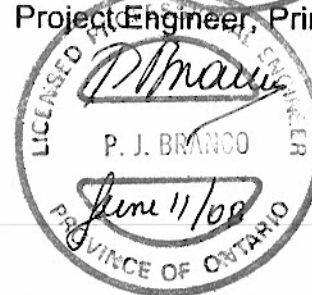
To

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1.0 INTRODUCTION

This report presents the results of a geotechnical investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed installation of a 94m long, 400 mm diameter watermain and a 95m long, 675 mm diameter sanitary sewer under the Hwy 427 corridor in Vaughan, Ontario. This section of Hwy 427 is located between Hwy 407 and Hwy 7.

The purpose of the geotechnical investigation was to determine the subsurface conditions along the watermain and sanitary sewer alignments and provide recommendations for installation of these utilities using trenchless technology. The investigation was carried out in general accordance with MTO's Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application and as per Thurber's proposal letter dated April 7, 2008. The open cut sections of the utility installations east and west of the Hwy 427 corridor are not part of this scope of work.

The contents of this report are subject to the Statement of General Conditions attached at the end of the text. The reader's attention is specifically drawn to these conditions as it is essential that they be followed for the proper use and interpretation of this report.

2.0 SITE DESCRIPTION

The site is located in Vaughan at Hwy 427 between Hwy 407 and Hwy 7. Hwy 427 at the proposed pipe crossing is located in a shallow cut, with the top of pavement at EL.177.5, approximately 1m below the original ground surface. The adjacent lands are presently commercial/industrial developments on the east side and agricultural land on the west side. Surface drainage is locally controlled by the Hwy 427 side ditches.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

The field investigation was carried out on May 8 and 9, 2008 and consisted of three boreholes advanced to depths of 9.5m to 11.1m (EL. 167.3 to 168.0). The locations of the boreholes are shown on Drawing 1, Appendix A.

The boreholes were initially located with reference to the pipe alignment as staked in the field by others. The borehole locations and elevations were subsequently surveyed by Schaeffer and Dzaldov Limited.

All borehole locations were cleared of utilities prior to commencement of drilling. Road occupancy permits were also obtained. Traffic control was provided during drilling.

The boreholes were advanced using a truck-mounted CME-55 drill rig supplied and operated by DBW Drilling Limited of Ajax, Ontario. Solid stem augers were employed in the overburden and samples of the soil were obtained in conjunction with the Standard Penetration Test (SPT).

The groundwater conditions in the open boreholes were observed throughout the drilling operations. Piezometers were installed in BH08-1 & BH08-3 to measure stabilized groundwater levels. BH08-2 was backfilled with bentonite grout upon completion in accordance with MOE Regulation 903.

The field investigation was carried out under the full-time supervision of Thurber technical staff. All boreholes were logged in the field. Soil samples were identified, placed in labelled containers and transported to Thurber's laboratory in Oakville for visual identification and testing.

Results of the field drilling, sampling and testing are presented on the Record of Borehole sheets in Appendix B.

3.2 Laboratory Tests

Geotechnical laboratory testing consisted of natural moisture content determinations, visual classification and description of all soil samples. Grain size



distribution analyses and Atterberg Limits tests were conducted on selected samples obtained from the boreholes.

Results of the geotechnical laboratory testing are presented on the Record of Borehole sheets, Appendix B, and in Appendix C.

Three soil samples were submitted to a qualified laboratory for analytical testing to assess disposal requirements for excess excavated soils. The samples were tested for selected metals and inorganic parameters established in O. Reg. 153. The laboratory Certificates of Analysis are provided in Appendix D.

4.0 SUBSURFACE CONDITIONS

A generalized description of the subsurface conditions encountered in the boreholes is given below. The Record of Borehole sheets in Appendix B provide detailed descriptions of the soil conditions at specific locations drilled, and must be used in preference to these generalized descriptions. It should be recognized that soil conditions may vary between and beyond borehole locations.

The subsurface conditions interpreted from the boreholes and from a visual inspection of the site consist of surficial topsoil and fills of the Hwy 427 pavement structure and shoulders underlain by a sequence of overconsolidated cohesive and cohesionless glacial (till) deposits to approximate EL. 173.9m. The till is underlain by a deposit of hard layered silty clay to elevations ranging from 170.3m to 169.6m. The tunnel alignments are proposed at the interface of the layered silty clay and the overlying till. The layered silty clay is locally underlain by dense sandy silt with sand seams and till with variable contents of silt and clay. The groundwater table measured in piezometers sealed in the till below Elevation 170.3m was at or above the proposed tunnels, at Elevations 176.5m and 174.2m at the west and east ends of the tunnels, respectively.

4.1 Sand Fill

Sand fill was encountered below the topsoil in Boreholes 08-1 and 08-2, in the shoulders of Hwy 427 southbound lanes. The fill extended to depth of 0.2m to 0.7m (Elevations 177.1m to 176.9m), deeper towards the east. SPT N-values in

the fill ranged from 5 to 11 blows, indicating a loose to compact consistency. Moisture contents of 7 to 14% were measured in the fill.

4.2 Silty Clay Till

Native silty clayey till was encountered below the topsoil and granular fill in all boreholes to depths of 2.6m to 4.5m (Elevations 174.7m to 173.9m).

SPT N-values of 26 blows to more than 100 blows were measured in this deposit, indicating very stiff to hard consistency. Moisture contents ranged from 8 to 18%. Glacial tills are known to contain cobble and boulders and some of the high SPT N-values may reflect such obstructions.

The results of grain size distribution analyses conducted on samples of the sandy silty clay till are presented on Figures C1 and C2 of Appendix C. The results were as follows:

Gravel %	1 to 3
Sand %	17 to 34
Silt %	45 to 57
Clay %	19 to 27

The results of Atterberg Limits testing, presented on Figures C3 and C4 indicate that this material is classified as CL, clay of low plasticity, according to the Unified Soil Classification System.

4.3 Sand and Silt Till

Below depths of 2.6m and 2.8m in boreholes 08-1 and 08-2, respectively, the till was described as sand and silt with trace clay and trace gravel. The material was moist with moisture content of 3% to 7%. The bottom of this deposit was encountered at 3.5m and 3.6m depth, (Elevation 173.8m to 173.9m), respectively. SPT N-values in excess of 100 blows were measured in the sand and silt till, indicating a very dense condition.

The result of grain size distribution analyses conducted on one sample of the sand and silt till is presented on Figures C1 of Appendix C. The results were as follows:

Gravel %	1
Sand %	51
Silt %	41
Clay %	7

Auger grinding followed by auger refusal was noted from 2.8m to 3.1m in Borehole BH08-1 indicating the presence of obstructions such as cobbles and boulders, commonly encountered in till. The borehole was moved 0.9m to the north of the original location and the drilling progressed through the sand and silt till without refusal.

4.4 Silty Clay (Layered)

Silty clay (layered) was encountered below the silty clay till in Borehole 08-3 and below the sand and silt till in boreholes BH08-1 and BH08-2 to depths of 7.2m to 8.7m (Elevations 170.3m to 169.6 m).

SPT N-values of 72 blows to more than 100 blows were measured in the silty clay indicating hard consistency. Moisture contents ranged from 12 to 21%.

The results of grain size distribution analyses conducted on samples of the silty clay are presented on Figures C1 and C2 of Appendix C. The results were as follows:

Gravel %	0
Sand %	0
Silt %	53 to 65
Clay %	35 to 47

The results of Atterberg Limits testing, presented on Figures C3 and C4, indicate the till would classify as clay of low plasticity (CL).

4.5 Sandy Silt

A 1.1m thick layer of very dense sandy silt with thin sand seams was encountered underlying the layered silty clay in BH08-1. The water content obtained from one sample collected from this deposit was 10%.

4.6 Lower Silty Clay Till

Silty clay till and clayey silt till were encountered below 8.8 and 8.7m depth in BH08-1 and BH08-3, respectively. The material was grey in colour, it contained trace of sand and gravel and it was described as hard, with SPT N-values more than 100. Both boreholes were terminated in this material.

4.7 Groundwater

Groundwater was observed in Borehole BH08-1 at 2.1m depth upon completion of drilling. Borehole BH08-3 was dry upon completion of drilling. The groundwater levels were monitored in both boreholes 18 days and 28 days after drilling and the results are shown in Table 4.1.

Table 4.1 – Water Levels in Piezometers

Borehole	Date	Water Level	
		Depth (m)	Elevation
08-1	26-May-2008	0.82	176.48
	05-June-2008	0.91	176.39
08-3	26-May-2008	4.24	174.16
	05-June-2008	3.57	174.83

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected.

5.0 GEOTECHNICAL EVALUATION AND RECOMMENDATIONS

This section provides geotechnical recommendations for design and installation of the proposed sanitary sewer and watermain. The recommendations are based on the subsurface soil and groundwater conditions encountered during the investigation carried out by Thurber. The soil conditions may vary between and beyond the borehole locations, and accordingly geotechnical inspection during construction is important to assess any variation of subsurface conditions and to provide additional recommendations if necessitated by such variations.

The proposed utility pipes will be 94m long and will be installed inside steel casings advanced from shafts located just outside the limits of the Hwy 427 corridor.

The 675mm sanitary sewer is proposed to be installed within a 1.5m diameter steel liner with crown elevation ranging from approximate EL. 174.8 at the west shaft location to approximate EL. 174.4 at the east shaft. The crown cover below the top of pavement under Hwy 427 ranges from 2.7m to 3.2m with minimum crown cover of 1.3m under the Hwy427 west ditch.

The 400mm watermain is proposed to be installed within a 1.2m diameter steel liner with crown elevation ranging from approximate EL. 174.0 at the west shaft location to approximate EL. 174.4 at the east shaft. The crown cover below the top of pavement under Hwy 427 is in the order of 3.5m with minimum crown cover of 2m under the Hwy427 east ditch.

The proposed horizontal distance between the two steel casing centrelines is 4.0m, leaving a minimum pillar width of 2.65m between both steel liners.

It is understood that tunnelling is contemplated for installation of the sanitary sewer liner and jack-and-bore techniques for the installation of the watermain liner.

The following sections of this report provide recommendations for the shaft design and for the steel casing installations. The open cut sections east and west of the Hwy 427 are not part of the scope of work and accordingly are not addressed herein.

5.1 Shaft Excavation

5.1.1 General

The access shafts for tunnelling or pipe jacking are expected to be approximately 6.0m deep and should be designed for the earth pressures provided in the following sections.

All temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario and local regulations. The native materials are typically very stiff to hard within the excavation depths and are classified as a Type 2 soil.

5.1.2 West Shaft

Based on Borehole BH08-1 information, the west shaft will be excavated primarily in stiff to hard cohesive till and clay material, except between EL. 174.7 and EL.173.8, where there is potential for the presence of a very dense sand and silt till.

The borehole was dry during drilling but the groundwater rose to 2.1m depth after the installation of a standpipe. The groundwater level was subsequently measured very close to surface, at 0.9m depth, at EL.176.39. Considering the consistency and relatively low permeability of the soils on site, dewatering using sumps and pumps is considered feasible. The possibility exists that additional pumps may be required if concentrated seepage is experienced from the sand and silt till and seams of sand or gravel in the silty clay till.

The west shaft walls should be supported by a braced shoring system designed to resist the lateral earth pressure distribution illustrated in Figure 1, attached at the end of the report. The following parameters are presented for use in the figure:

$$\begin{aligned}\gamma &= 21 \text{ kN/m}^3 \\ \gamma_w &= 9.8 \text{ kN/m}^3 \\ h_w &= \text{Compatible with the GWT at EL.177} \\ K &= 0.30\end{aligned}$$

The design of all structural members of the shoring system should include the effects of surcharge loads such as those imposed by adjacent utilities, construction equipment and road traffic. Soil should not be stockpiled within a horizontal distance from the shaft wall equal to the depth of the shaft. If this cannot be avoided, the soil surcharge must be incorporated into the shoring design.

The design of the shoring system and selection of excavating equipment are the responsibility of the Contractor.

Provision should be made for handling possible obstructions in the fill, and potential cobbles and boulders in the silty clay till and in the sand and silt till during excavation.

5.1.3 East Shaft

Based on Borehole BH08-3 information, the west shaft will be excavated primarily in stiff to hard cohesive till and clay materials.

The borehole was dry during drilling but the groundwater rose to 3.6m depth (EL.174.8m) 28 days after completion of drilling. Considering the consistency and relatively low permeability of the soils on site, dewatering using sumps and pumps is considered feasible. The possibility exists that additional pumps may be required if concentrated seepage is experienced from seams of sand or gravel in the till.

The east shaft walls should be supported by a braced shoring system designed to resist the lateral earth pressure distribution illustrated in Figure 1 and design recommendations provided in Section 5.1.2 above.

5.2 Trenchless Installation

5.2.1 Sanitary Sewer – 1.5m Diameter Steel Casing

It is understood that the 1.5m diameter steel casing is proposed to be installed using tunnelling methods. These methods are usually preferred to pipe-jacking in order to better control and to correct, if necessary, the tunnel alignment during construction, a critical issue in sanitary sewer installations. Pipe-jacking techniques, particularly jack-and-bore methods that use power augers are not considered suitable for the installation of the 1.5m steel casing due to the potential presence of obstructions at the proposed horizon as described below. It is

considered critical that the face of excavation be accessible for monitoring of conditions, which is not practical with power augers.

As shown on the attached longitudinal profile, the proposed tunnel is anticipated to be advanced in mixed face conditions, at the interface of the till deposits (sand and silt till and silty clay till) and the underlying layered silty clay deposit. The layered silty clay deposit is expected to be encountered at the bottom part of the tunnel throughout the alignment. In the western portion of the alignment, and possibly through most of the alignment, the upper part of the tunnel is expected to consist of the very dense sand and silt till. In the eastern end of the alignment, the sand and silt till is not anticipated to be present and the upper part of the tunnel is expected to consist of silty clay till.

The presence of sand and silt till in the upper part of the tunnel face and high groundwater conditions are not favourable for tunnelling in view of the potential for excessive loss of ground during tunnelling and associated settlements at ground surface. In this case, however, the top of the sand and silt till layer is overlain by mostly hard silty clay and the interface of both deposits is at or immediately above the tunnel crown. Ideally the tunnel vertical alignment should be lowered to avoid mixed face condition but it is understood that this is not a feasible alternative for the sanitary sewer discussed herein. Therefore face stability and loss of ground control is considered critical for the success of the tunnel construction.

The tunnel walls should be supported immediately after excavation to reduce the potential for instability associated with pore pressure build up in the sand and silt till. The recommended temporary support for this tunnel is steel liner plates erected as close as possible to the face of excavation. The maximum distance, measured parallel to the tunnel axis, between the face of excavation and the completely assembled circular liner plates should not be greater than 0.6m at any point in time. The annular space between the steel liner plates and surrounding soil should be grouted every 12 hours or at the end of each working day, whichever occurs first, using a fast-set unshrinkable grout. The face of excavation should be bulk-headed tight against the liner plates when tunnelling activities are stopped and the face of excavation may be exposed for more than two hours.

Based on the obstruction encountered in the sand and silt till during the drilling of BH08-1, the contractor should be prepared to encounter cobbles and boulders in the upper part of the face of excavation during tunnelling. The obstructions should be broken down and removed causing minimum over excavation beyond the limits of the tunnel perimeter. Upon the formation of voids beyond the perimeter of excavation, the liner plates should be promptly erected against the face of excavation and the voids around the lining grouted immediately using a fast-set unshrinkable grout.

Based on borehole observations and piezometer readings, it is anticipated that groundwater flow into the tunnel will be moderate and should not impact tunnelling.

Under normal tunnelling conditions, the settlement of the Hwy427 pavement associated with the construction of the sanitary sewer is anticipated to be in the order of 10mm, as shown on Figure 2.

The combined pipe walls and surrounding grout should be designed to withstand a uniform radial pressure equivalent to the weight of soil above the tunnel level, plus groundwater pressure.

5.2.2 Watermain – 1.2m Diameter Steel Casing

It is understood that the proposed 1.2m diameter steel casing is proposed to be installed using pipe-jacking methods. The 1.2m diameter steel casing is proposed to be installed at approximately the same horizon proposed for the 1.5m diameter sanitary sewer lining. At the East Shaft the 1.2m diameter liner is approximately 0.8m lower than the sanitary sewer liner. At the West Shaft both liners are proposed essentially with the same crown elevation.

In order to avoid the mixed face conditions described in Section 5.2.1 and to reduce potential for encountering obstructions in the till deposits, the it is recommended that the 1.2m steel liner alignment be lowered by a minimum of 1.5m. Pipe-jacking at a deeper elevation in the layered silty clay is expected to be significantly easier than in the overlying till materials.

The pipe-jacking operation should be carried out maintaining the steel liner within 0.3m of the face of excavation. Although not encountered during the drilling program, there is potential for the presence of obstructions in the form of cobbles and boulders in silty clay deposit. Therefore, the use of power augers is not considered suitable for this operation. It is considered critical that the face of excavation be accessible for monitoring of conditions, which is not practical with power augers.

If encountered during pipe-jacking, boulders should be broken down and removed causing minimum over excavation beyond the limits of the liner perimeter.

Immediately upon completion of pipe-jacking, the annulus between the liner and the surrounding soil should be grouted with a fast-set unshrinkable grout.

Based on borehole observations and piezometer readings, it is anticipated that groundwater flow into the tunnel will be low and should not impact trenchless installation.

Under normal construction conditions, the settlement of the Hwy427 pavement associated with the construction of the watermain alone is anticipated to be in the order of 4mm, as shown on Figure 2.

The combined pipe walls and surrounding grout should be designed to withstand a uniform radial pressure equivalent to the weight of soil above the tunnel level, plus groundwater pressure.

5.5.3 Combined Tunnel Performance and Horizontal Distance between Liners

Both tunnel liner centrelines are proposed to be spaced at 4m, resulting in a pillar with minimum width of 2.65m. This geometry is considered feasible provided that the watermain vertical alignment be lowered by 1.5m, as discussed above.

In order to avoid disturbing the sand and silt till before the installation of the 1.5m diameter liner it is also recommended that the 1.5m liner be installed before the installation of the Watermain 1.2m diameter liner.

The anticipated surface settlement trough associated with the construction of both tunnels with the Watermain installed at a lower elevation is shown on Figure 2. This figure shows that there is only a minor increase in surface settlement above the Sanitary Sewer liner due to the installation of the Watermain liner. It can therefore be concluded that the interaction between both tunnels is minimum.

5.3 Monitoring Program and Condition Survey

A monitoring program and condition survey of the Hwy 427 pavement in the proximity of the tunnels should be prepared following MTO's Guidelines for Foundation Engineering - Tunnelling Specialty for Corridor Encroachment Permit Application. Section of this guideline has been included in Appendix E for reference. It is recommended that two lines of surface settlement instruments, one above each of the pipe alignments, be installed.

Preparation of detailed specifications, drawings and the implementation of the monitoring program are beyond the scope of this work.

6.0 MANAGEMENT OF EXCESS MATERIALS

The strategies developed herein for excess soil management and disposal are based on field observations and analytical testing carried out at specific borehole locations to date. Due to the inherent variability of subsurface conditions, inspection will be required during construction in order to confirm that the quality of the excess excavated soils are consistent with the assumptions made in establishing these soil management procedures.

Additional analytical testing of excavated soils may be required during construction to meet the requirements of re-use on site and/or the receivers of excess fill off site.

Visual and olfactory examination of the soil samples recovered from the field investigation program revealed no unusual staining or odours indicative of hydrocarbon impact or other contamination.

One sample of the silty clay till and two samples of the layered silty clay recovered from the proposed excavation depths were submitted to AGAT Laboratories Limited for analysis of Metals and Inorganics in Soil outlined in Ontario Regulation 153/04 (O.Reg. 153). The results are presented in Appendix D.

The analytical results were compared to the Full Depth Background Site Condition Standards (Table 1) and Industrial/Commercial Community Property Use (Table 2) of O.Reg. 153. The concentrations of all parameters meet the background standards established in the Regulation. The excess soils may therefore be reused on site or disposed of as non-subject waste at facilities licensed to receive such soils. Soils with asphalt, topsoil or organics are rejected by fill receivers.

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STATEMENT OF GENERAL CONDITIONS

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering or environmental consulting practices in this area. No other warranty, expressed or implied, is made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document, subject to the limitations provided herein, are only valid to the extent that this Report expressly addresses proposed development, design objectives and purposes, and then only to the extent there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation or to consider such representations, information and instructions.

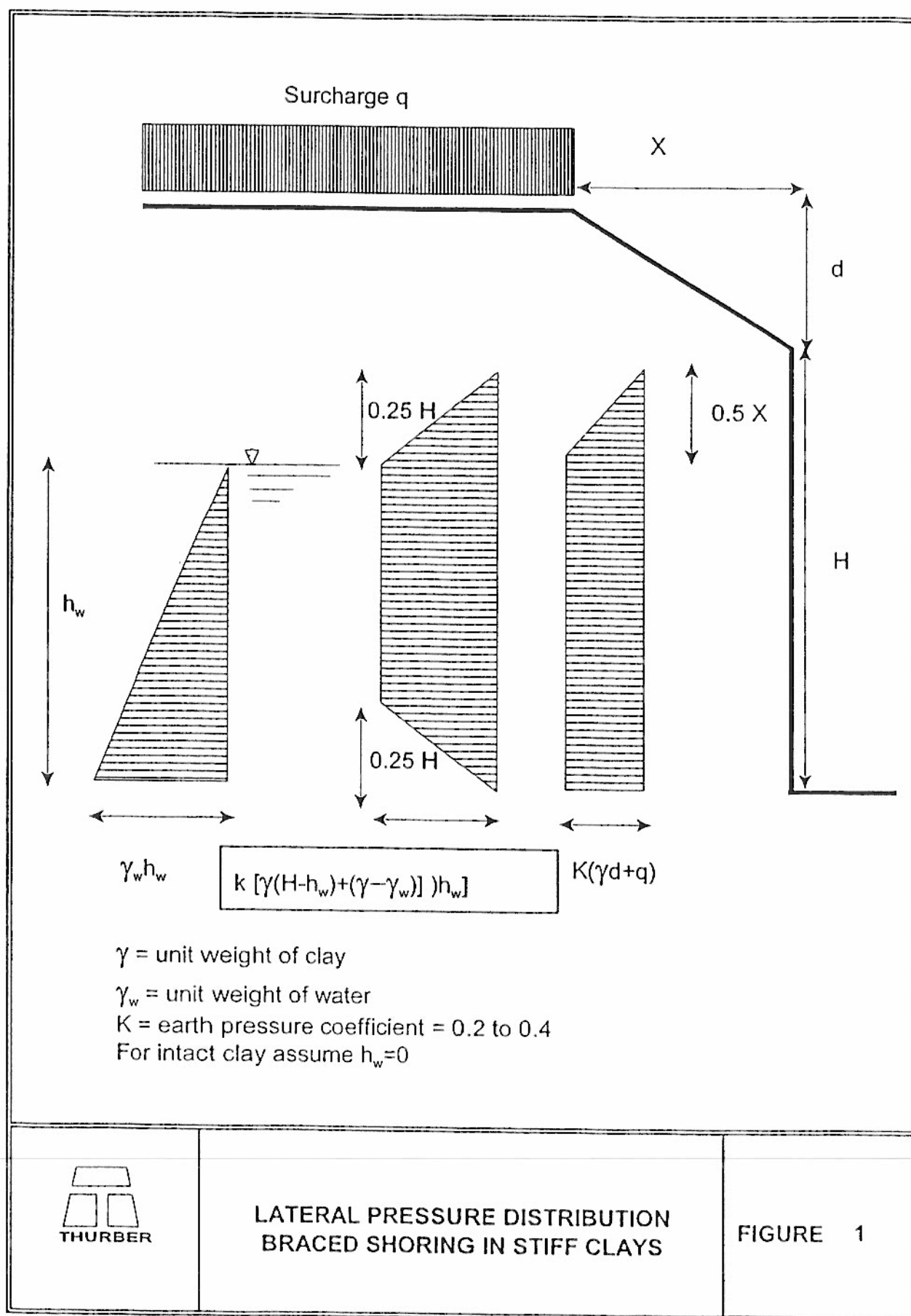
4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS WE MAY EXPRESSLY APPROVE. The contents of the Report remain our copyright property. The Client may not give, lend or, sell the Report, or otherwise make the Report, or any portion thereof, available to any person without our prior written permission. Any use which a third party makes of the Report, are the sole responsibility of such third parties. Unless expressly permitted by us, no person other than the Client is entitled to rely on this Report. We accept no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without our express written permission.

5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and this report is delivered on the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by us. We are entitled to rely on such representations, information and instructions and are not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.





SETTLEMENT DUE TO TUNNELLING

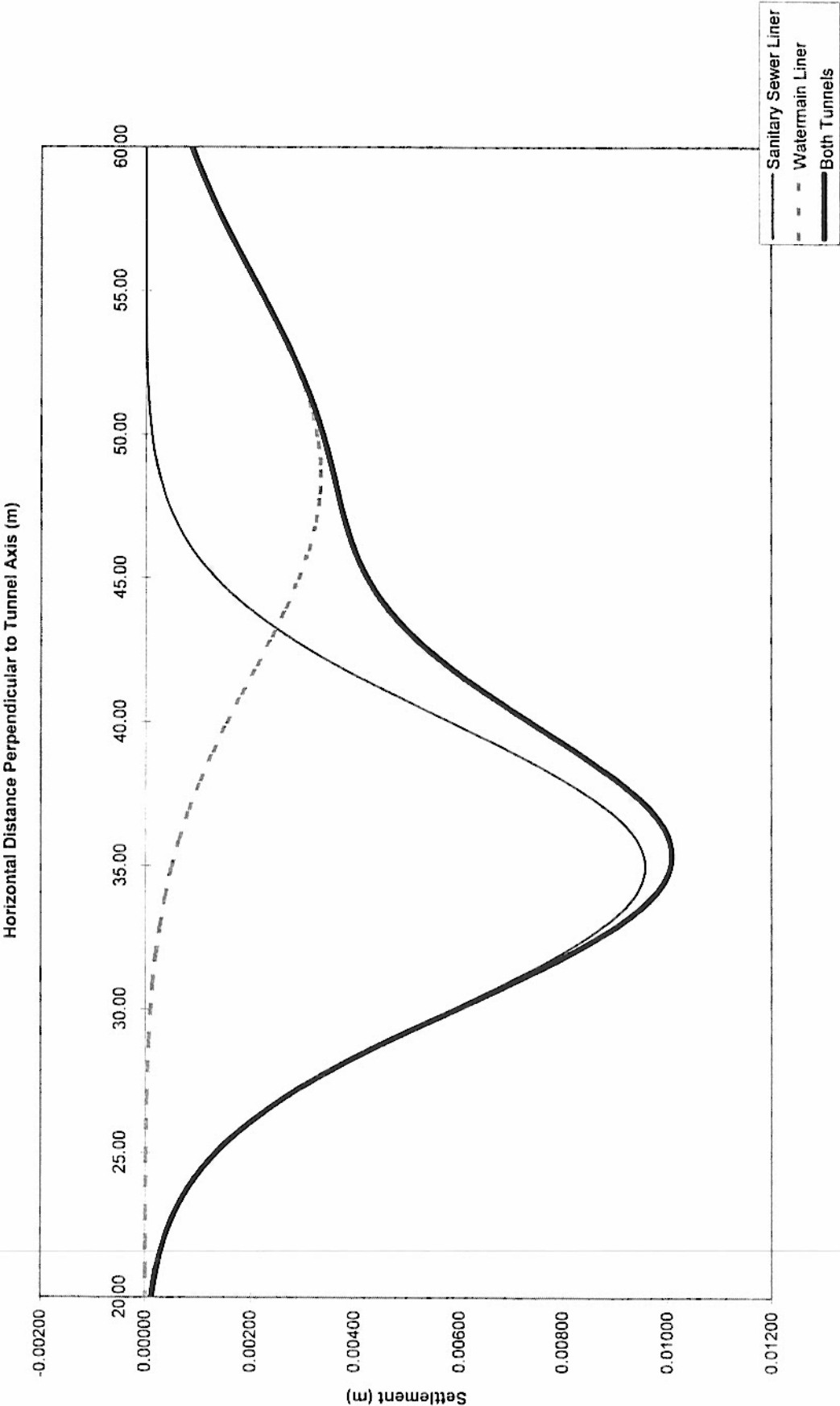
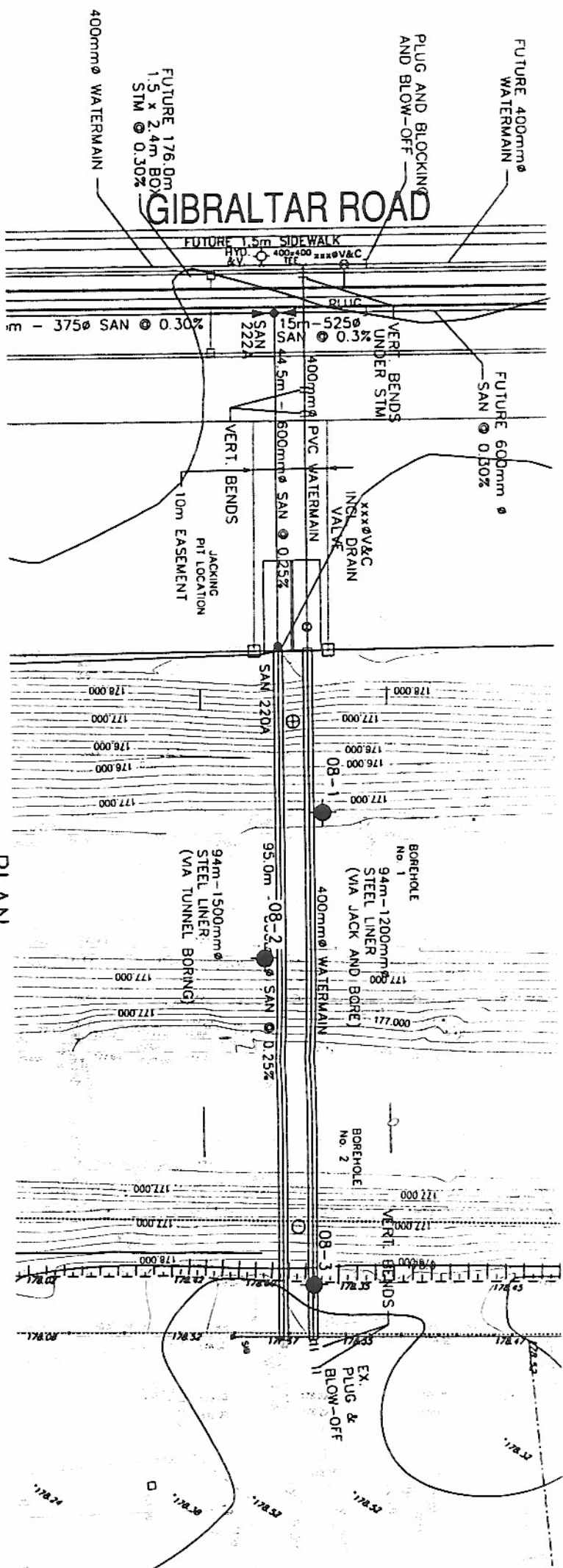


FIGURE 2

APPENDIX A

**BOREHOLE LOCATION PLAN
AND
STRATIGRAPHIC PROFILE**



METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

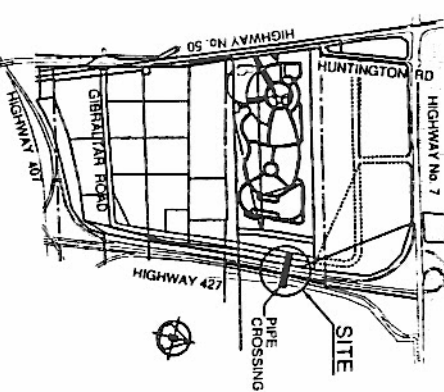
CONT NO
CWP No



HIGHWAY 427
WATERMAIN AND SANITARY
SEWER CROSSING
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

THURBER ENGINEERING LTD.
BOTHEMICAL • ENVIRONMENTAL • WATERMAINS



LEGEND

◆	Borehole
◆	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
↑	Head Artesian Water
90%	Piezometer
A/R	Rock Quality Designation (RQD)
	Auger Refusal
NO	ELEVATION
08-1	177.32 4 847 197.97 294 046.73
08-2	177.53 4 847 191.40 294 066.69
08-3	178.43 4 847 201.12 294 110.38

NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Pipe and tunnel alignments have been obtained from UEL's drawing, P-100 dated August 2007.

REVISIONS	DATE	BY	DESCRIPTION	DATE
DESIGN PJB	CHK WJL	CODE	LOAD	MAY 2008
DRAWN WJA	CHK PJC	SITE	STRUCT	DEC 1

APPENDIX B

RECORD OF BOREHOLE SHEETS

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

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			

METRIC

G.W.P.	LOCATION	N 4 847 197.97 E 294 046.73	ORIGINATED BY	SLL
HWY 427	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	WM
DATUM Geodetic	DATE	2008.05.08 - 2008.05.08	CHECKED BY	PJB

[illegible]

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-1

2 OF 2

METRIC

G.W.P. _____ LOCATION N 4 847 197.97 E 294 046.73 ORIGINATED BY SLL
 HWY 427 BOREHOLE TYPE Solid Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.08 - 2008.05.08 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
	Continued From Previous Page																
	with a 1.52 m slotted screen.																
	WATER LEVEL READINGS: DATE DEPTH(m) ELEV(m) 08/05/08 2.09 175.21 26/05/08 0.82 176.48 05/06/08 0.91 176.39																

RECORD OF BOREHOLE No 08-2

1 OF 2

METRIC

G.W.P. _____ LOCATION N 4 847 191.40 E 294 066.69 ORIGINATED BY SLL
 HWY 427 BOREHOLE TYPE Solid Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.08 - 2008.05.08 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
							20 40 60 80 100	20 40 60 80 100	20 40 60					
177.5	TOPSOIL: (25 mm)													
176.9	SAND, some gravel, trace silt Compact Brown Moist (FILL)		1	SS	11									
0.7	Silty, Sandy CLAY, trace gravel Hard Brown Moist (TILL)		2	SS	100									
			3	SS	50/ .100									3 33 45 19
			4	SS	100/ .150									
174.7	SAND and SILT, trace clay, trace gravel Very Dense Grey Moist (TILL)		5	SS	100/ .150									1 51 41 7
173.9	Silty CLAY, layered, with silt pockets Hard Grey		6	SS	100/ 250									0 0 64 36
3.6			7	SS	72									
			8	SS	80									
170.3	Silty CLAY, trace sand, trace gravel Hard Grey (TILL)		9	SS	100									
7.2			10	SS	100/ 250									
168.0	END OF BOREHOLE AT 9.55 m. BOREHOLE DRY ON COMPLETION. BOREHOLE GROUTED TO													
9.5														

Continued Next Page

+ 3 x 3 Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

METRIC

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

RECORD OF BOREHOLE No 08-3

1 OF 2

METRIC

G.W.P. _____ LOCATION N 4 847 201.12 E 294 110.38 ORIGINATED BY SLL
 HWY 427 BOREHOLE TYPE Solid Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.08 - 2008.05.09 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL × LAB VANE			
178.4							20	40	60	80	100		
0.0	TOPSOIL: (125 mm)												
0.1	Silty CLAY, some sand to sandy, trace gravel Very Stiff to Hard Brown to Grey (TILL)		1	SS	6								
			2	SS	26								
			3	SS	100/ 250								
			4	SS	100								
			5	SS	100/ 225								
			6	SS	71								
173.9													
4.5	Silty CLAY, layered Hard Grey		7	SS	56/ 125								
			8	SS	100								
			9	SS	100/ 225								
			10	SS	74								
169.7													
8.7	Silty CLAY, trace sand, trace gravel Hard Grey (TILL)		11	SS	100/ 250								

Continued Next Page

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

RECORD OF BOREHOLE No 08-3

2 OF 2

METRIC

G.W.P. _____ LOCATION N 4 847 201.12 E 294 110.38 ORIGINATED BY SLL
 HWY 427 BOREHOLE TYPE Solid Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.08 - 2008.05.09 CHECKED BY PJB

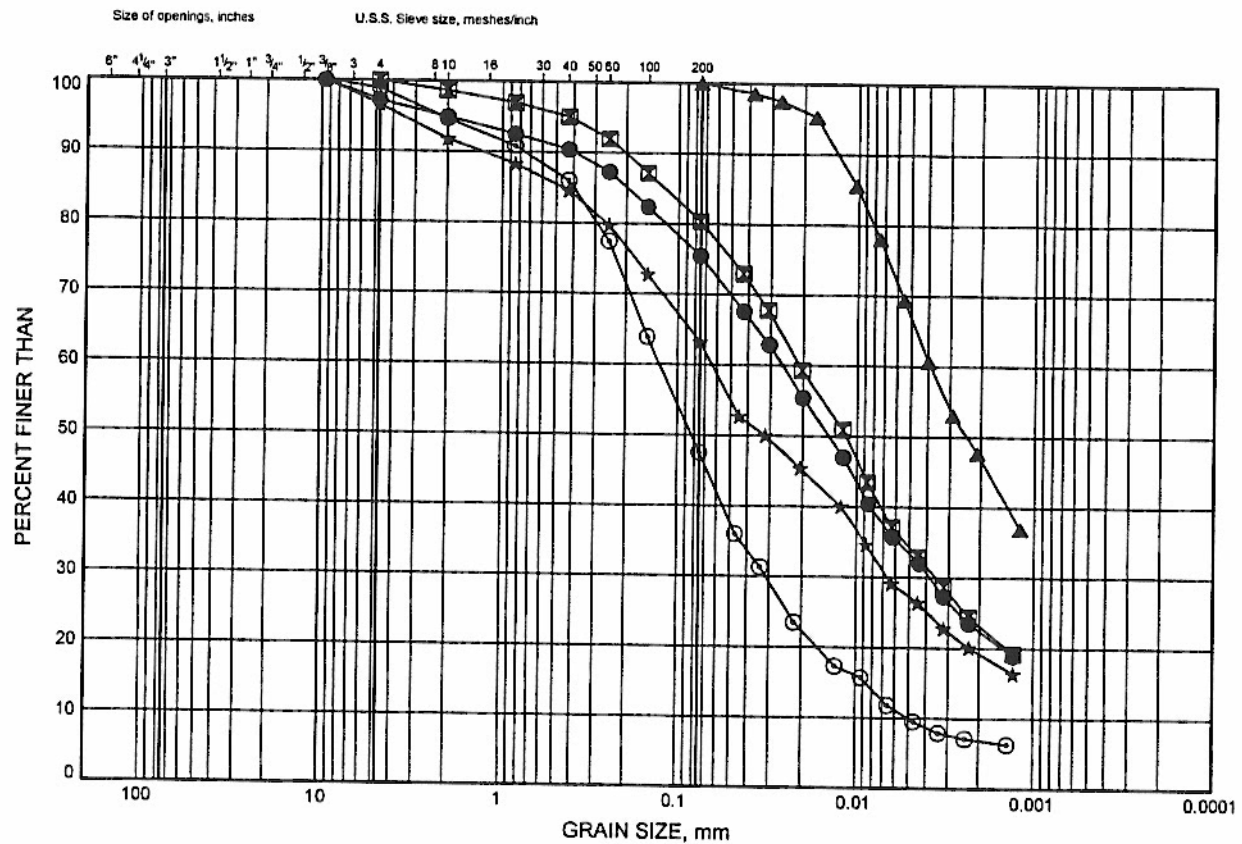
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	w _p	w	w _L		
	Continued From Previous Page																
168.2																	
10.2	Clayey SILT, trace sand, trace gravel Hard Grey (TILL)																
167.3			12	SS	100/ 275												
11.1	END OF BOREHOLE AT 11.10 m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH(m) ELEV(m) 26/05/08 4.24 174.16 05/06/08 3.57 174.83																

APPENDIX C

GEOTECHNICAL LABORATORY TEST RESULTS

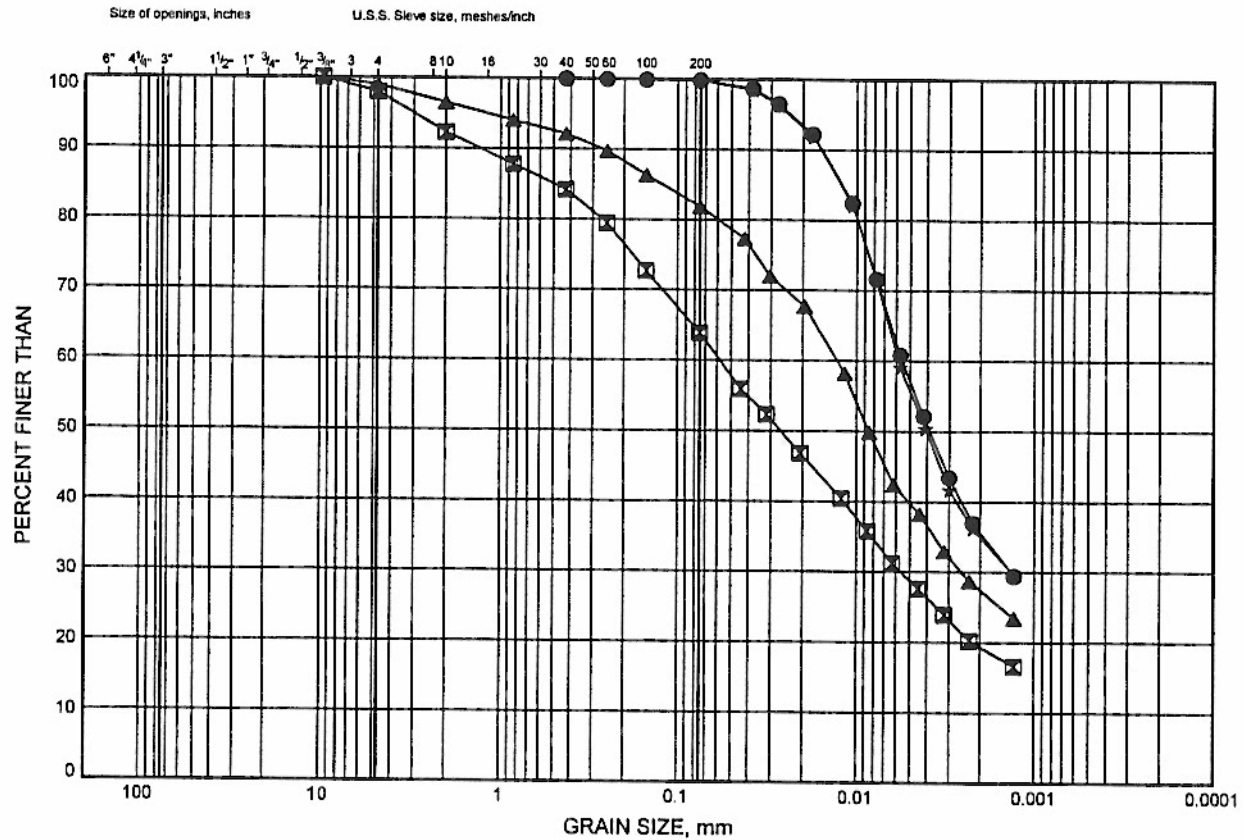
Watermain and Sanitary Sewer Crossing GRAIN SIZE DISTRIBUTION

FIGURE C1



Watermain and Sanitary Sewer Crossing GRAIN SIZE DISTRIBUTION

FIGURE C2



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-2	3.96	173.57
⊠	08-3	3.20	175.23
▲	08-3	4.04	174.39
★	08-3	4.80	173.63



Date May 2008

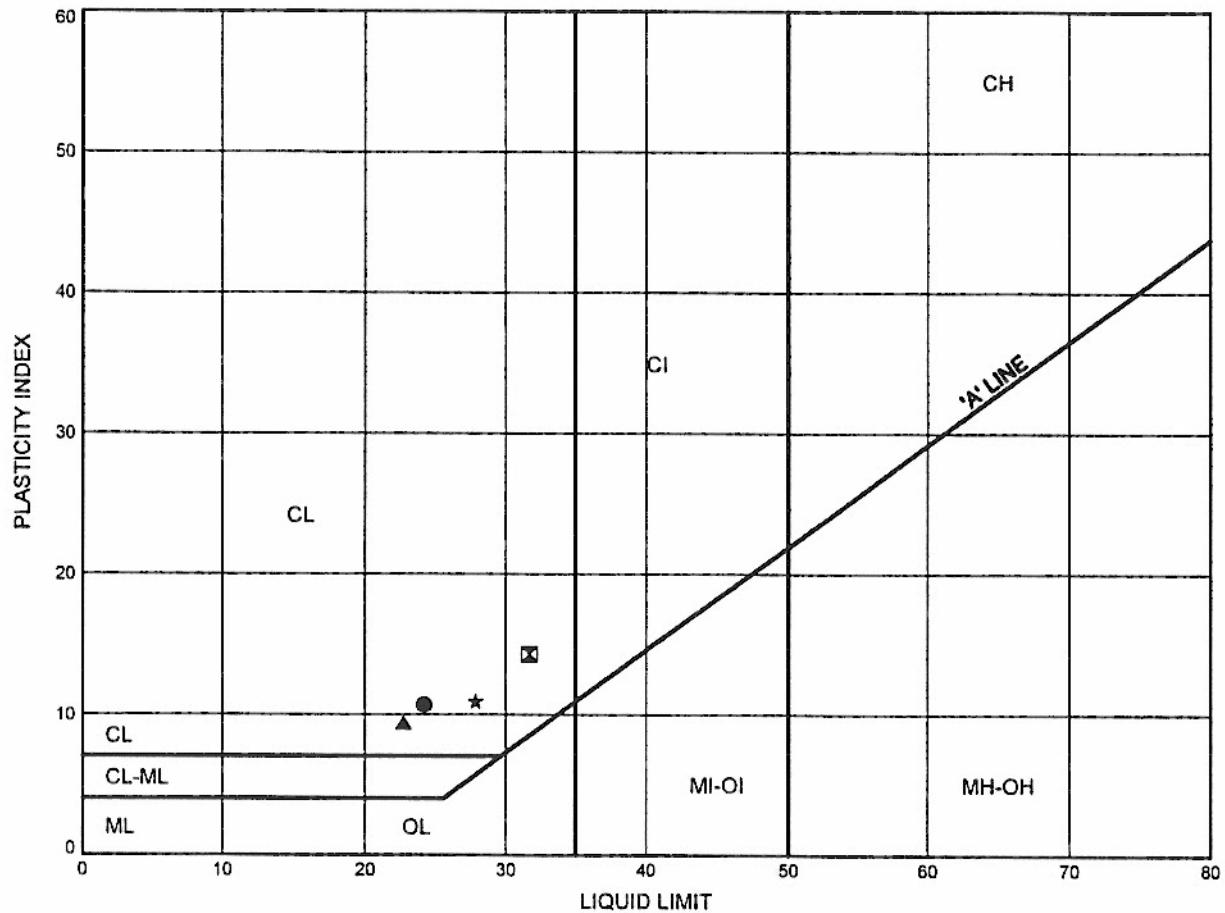
Project

Prep'd WM

Chkd. PJB

Watermain and Sanitary Sewer Crossing ATTERBERG LIMITS TEST RESULTS

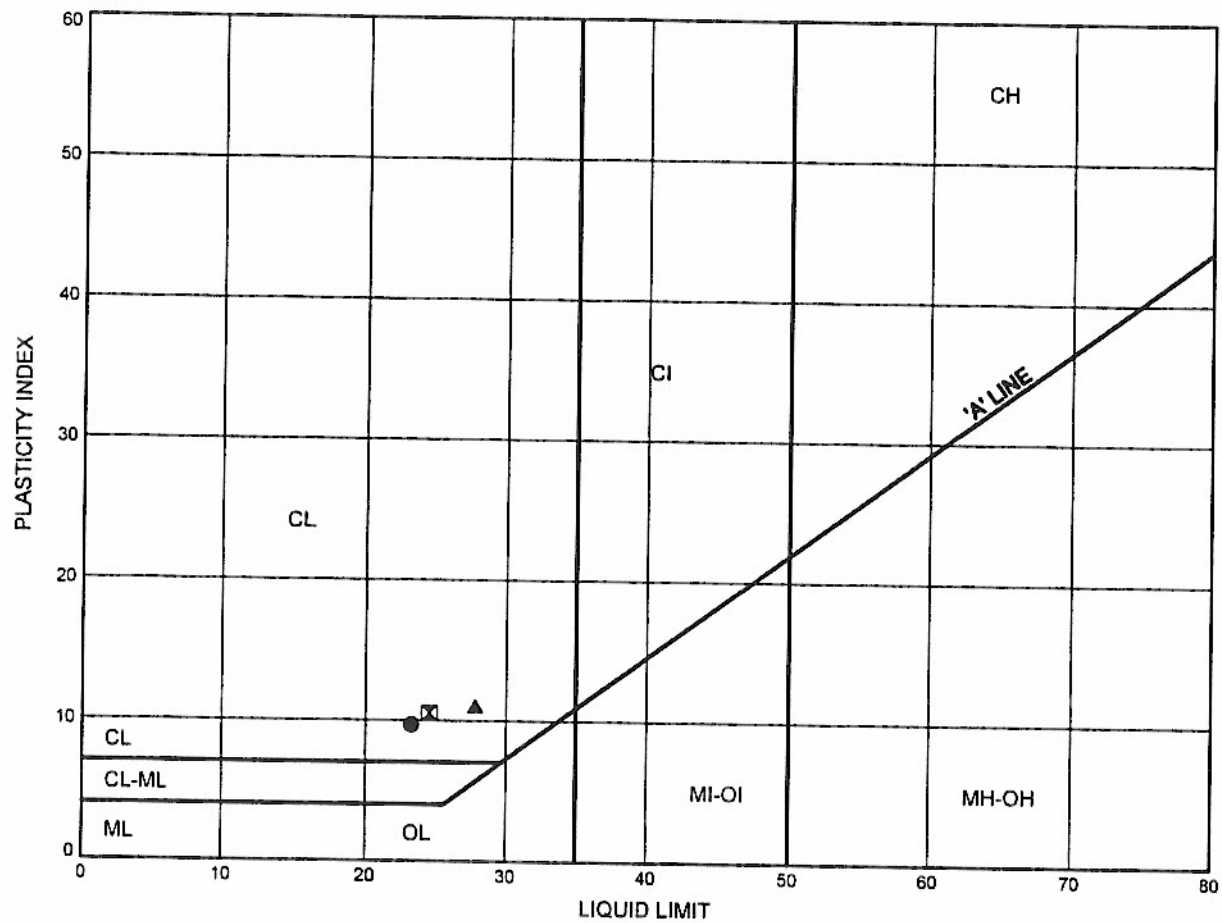
FIGURE C3



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-1	2.36	174.96
⊠	08-1	4.04	173.28
▲	08-2	1.75	175.78
★	08-2	3.96	173.57

Watermain and Sanitary Sewer Crossing ATTERBERG LIMITS TEST RESULTS

FIGURE C4



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-3	3.20	175.23
⊠	08-3	4.04	174.39
▲	08-3	4.80	173.63



Date May 2008
Project

Prep'd WM
Chkd. PJB

APPENDIX D

ANALYTICAL LABORATORY CERTIFICATE OF ANALYSIS



Certificate of Analysis

AGAT WORK ORDER: 08T274548
PROJECT NO: 19-5336-0

5623 MCADAM ROAD
MISSISSAUGA, ONTARIO
CANADA L4Z 1N9

TEL: (905) 501-9998
FAX: (905) 501-0589
www.agatlabs.com

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: WEISS MEHDAWI

O. Reg. 153 Metals & Inorganics in Soil			
DATE SAMPLED: May 08, 2008	DATE RECEIVED: May 27, 2008	DATE REPORTED: May 29, 2008	SAMPLE TYPE: Soil
Unit	G / S	RDL	
Antimony	40	1.6	<1.6
Arsenic	40	0.6	2.4
Barium	1500	0.3	104
Beryllium	1.2	0.4	0.5
Boron (Hot Water Extractable)	2.0	0.10	0.43
Cadmium	12	0.4	<0.4
Chromium	750	0.6	24.6
Cobalt	80	0.3	8.1
Copper	225	0.3	20.9
Lead	1000	0.5	6.6
Molybdenum	40	0.5	<0.5
Nickel	150	0.6	17.6
Selenium	10	0.8	<0.8
Silver	40	0.4	<0.4
Thallium	32	0.4	<0.4
Vanadium	200	0.4	32.2
Zinc	600	0.4	38.7
Chromium, Hexavalent	8	0.40	<0.40
Cyanide, Free	100	1.0	<1.0
Mercury	10	0.011	0.014
Electrical Conductivity (2:1)	1.4	0.002	0.397
Sodium Adsorption Ratio (2:1)	12	N/A	0.508
pH (2:1)		N/A	7.98

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard; Refers to T2(ICC)

Certified By:

Joby Takewell



Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 08T274548

PROJECT NO: 19-5336-0

ATTENTION TO: WEISS MEHDAWI

Soil Analysis

RPT Date: May 29, 2008			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE			MATRIX SPIKE			
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

O. Reg. 153 Metals & Inorganics in Soil

Antimony (µg/g)	0		< 1.6	< 1.6	0.0%	< 1.6	99%	90%	110%	95%	90%	110%	93%	70%	130%
Arsenic (µg/g)	0		2.8	2.4	15.4%	< 0.6	99%	90%	110%	95%	90%	110%	90%	70%	130%
Barium (µg/g)	0		37.2	37.3	0.3%	< 0.3	107%	90%	110%	98%	90%	110%	101%	70%	130%
Beryllium (µg/g)	0		< 0.4	< 0.4	0.0%	< 0.4	99%	90%	110%	93%	90%	110%	101%	70%	130%
Boron (Hot Water Extractable) (µg/g)	1	975261	0.431	0.426	1.2%	< 0.10	97%	90%	110%	110%	90%	110%	100%	80%	120%
Cadmium (µg/g)	0		< 0.4	< 0.4	0.0%	< 0.4	93%	80%	120%	98%	90%	110%	94%	70%	130%
Chromium (µg/g)	0		5.5	5.7	3.6%	< 0.6	104%	90%	110%	97%	90%	110%	98%	70%	130%
Cobalt (µg/g)	0		2.2	2.1	4.7%	< 0.3	104%	80%	120%	91%	90%	110%	91%	70%	130%
Copper (µg/g)	0		15.7	16.6	5.6%	< 0.3	101%	90%	110%	100%	90%	110%	96%	70%	130%
Lead (µg/g)	0		115	127	9.9%	< 0.5	106%	90%	110%	105%	90%	110%	96%	70%	130%
Molybdenum (µg/g)	0		< 0.5	< 0.5	0.0%	< 0.5	93%	90%	110%	91%	90%	110%	101%	70%	130%
Nickel (µg/g)	0		4.5	4.4	2.2%	< 0.6	110%	90%	110%	100%	90%	110%	98%	70%	130%
Selenium (µg/g)	0		< 0.8	< 0.8	0.0%	< 0.8	98%	80%	120%	94%	90%	110%	86%	70%	130%
Silver (µg/g)	0		< 0.4	< 0.4	0.0%	< 0.4	94%	80%	120%	105%	90%	110%	91%	70%	130%
Thallium (µg/g)	0		< 0.4	< 0.4	0.0%	< 0.4	117%	80%	120%	90%	90%	110%	95%	70%	130%
Vanadium (µg/g)	0		9.8	9.8	0.0%	< 0.4	96%	80%	120%	93%	90%	110%	93%	70%	130%
Zinc (µg/g)	0		56.5	56.8	0.5%	< 0.4	101%	90%	110%	98%	90%	110%	99%	70%	130%
Chromium, Hexavalent (µg/g)	1		< 0.40	< 0.40	0.0%	< 0.40	101%	90%	110%	101%	90%	110%	100%	90%	110%
Cyanide, Free (µg/g)	1		< 1.0	< 1.0	0.0%	< 1.0	97%	90%	110%	105%	90%	110%	102%	80%	120%
Mercury (µg/g)	1	975262	0.012	0.012	0.0%	< 0.011	103%	90%	110%	109%	90%	110%	106%	70%	130%
Electrical Conductivity (2:1) (mS/cm)	1		0.364	0.359	1.4%	< 0.002	100%	90%	110%						
pH (2:1) (N/A)	1		7.78	7.77	0.1%	N/A	100%	90%	110%						

Certified By:

Joey Takewski

AGAT QUALITY ASSURANCE REPORT (V1)

Page 3 of 4

AGAT Laboratories is accredited to ISO/IEC 17025 by the Canadian Association for Environmental Analytical Laboratories (CAEAL), for specific tests listed on the scope of accreditation. AGAT Laboratories (Mississauga) is also accredited by the Standards Council of Canada (SCC) for specific drinking water tests. Accreditations are location and parameter specific. A complete listing of parameters for each location is available from www.caeal.ca and/or www.scc.ca. The tests in this report may not necessarily be included in the scope of accreditation.

Results relate only to the items tested



Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 08T274548

PROJECT NO: 19-5336-0

ATTENTION TO: WEISS MEHDAWI

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Antimony	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Arsenic	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Barium	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Beryllium	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Boron (Hot Water Extractable)	MET 1004	EPA SW 846 6010, MSA Part 3, Ch.21	ICP/OES
Cadmium	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Chromium	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Cobalt	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Copper	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Lead	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Molybdenum	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Nickel	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Selenium	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Silver	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Thallium	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Vanadium	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Zinc	MET 1003	EPA SW-846 3050 & 6020	ICP-MS
Chromium, Hexavalent	INOR 1029	SM 3500 B; MSA Part 3, Ch.25	SPECTROPHOTOMETER
Cyanide, Free	INOR 1052	MOE CN-3015 & E 3009 A & SM 4500 CN	TECHNICON AUTO ANALYZER
Mercury	MET 1001	EPA SW 846 7471A, 245.5	CVAAS
Electrical Conductivity (2:1)	INOR 1036	McKeague 4.12 & SM 2510 B	EC METER
Sodium Adsorption Ratio (2:1)	INOR 1007	McKeague 4.12 & 3.26 & EPA SW-846 6010B	ICP/OES
pH (2:1)	INOR 1031	McKeague 4.12 & SM 4500-H+ B	pH METER

APPENDIX E

**SELECTED SECTION FROM
MTO'S GUIDELINES FOR FOUNDATION ENGINEERING
TUNNELLING SPECIALTY FOR CORRIDOR
ENCROACHMENT PERMIT APPLICATION**

APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING

The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.

Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

Surface Monitoring Points

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.

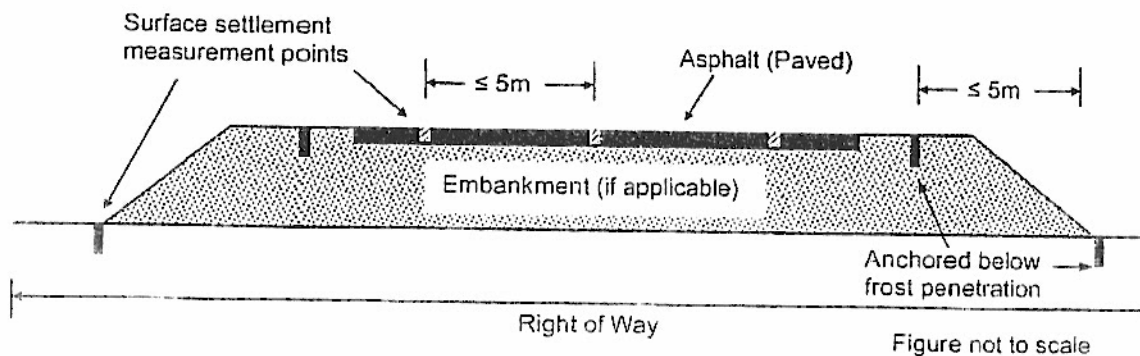


Figure 1: Typical configuration of surface settlement monitoring points along the tunnel alignment.

Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

Review of Contractor's Proposed Method

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

Contractor's Responsibility For Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.