

FINAL REPORT

Foundation Investigation and
Design Report
Christina Street Underpass,
Site 14-37 Highway 402
City of Sarnia, Ontario
District - London
G.W.P. 3038-03-00

STANTEC CONSULTING LTD.

PROJECT NO. 1012607
GEOCRES NO. 40J16-78

PROJECT NO. 1012607

REPORT TO

**Stantec Consulting Inc.
1400 Rymal Road East
Hamilton, ON
L8W 3N9**

FOR

**Final
Foundation Investigation and Design
Report**

ON

**Christina Street Underpass,
Site 14-37 Highway 402
City of Sarnia, Ontario
G.W.P. 3038-03-00
District – London
GEOCRES NO. 40J16-78**

September 26, 2008

Jacques Whitford Limited
7271 Warden Avenue
Markham, Ontario
L3R 5X5

Phone: 905-474-7700
Fax: 905-479-9326

www.jacqueswhitford.com

Table of Contents

FOUNDATION INVESTIGATION REPORT	1
1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 PHYSIOGRAPHY	2
4.0 BACKGROUND.....	2
5.0 INVESTIGATION PROCEDURES.....	3
5.1 Field Program.....	3
5.2 Survey	4
5.3 Laboratory Testing	4
6.0 RESULTS OF THE INVESTIGATION	5
6.1 Subsurface Conditions	5
6.2 Soil	5
6.2.1 Asphalt	5
6.2.2 Topsoil.....	5
6.2.3 Sand Fill	6
6.2.4 Native Sand.....	6
6.2.5 Peat.....	7
6.2.6 Clayey Silt / Silty Clay	7
6.2.7 Silt	8
6.2.8 Sandy Silt Till	8
6.3 Groundwater	9
7.0 CLOSURE.....	10
FOUNDATION DESIGN REPORT	11
8.0 DISCUSSION.....	11
8.1 General	11
8.2 Proposed Development.....	11
8.3 Soil Summary.....	12
8.4 Preliminary Foundation Design Report	12
8.5 Foundation Assessment.....	13
9.0 RECOMMENDATIONS.....	15
9.1 Pile Foundations	15
9.1.1 End Bearing Piles.....	15
9.1.2 Down Drag Forces	15
9.1.3 Friction Piles.....	16
9.1.4 Lateral Resistance	16
9.1.5 Lateral Deflections	16
9.1.6 Group Effects on Lateral Deflections	17
9.1.7 Tensile Resistance.....	18



9.1.8 Piling Notes	18
9.2 Earth Pressure Design	19
9.3 Soil Profile Type	19
9.4 Seismic Forces on Abutments and Retaining Walls	19
9.5 Embankment Design and Construction	20
9.6 Retaining Structures	22
9.6.1 Retained Soil System (RSS)	22
9.6.1.1 Geotechnical Resistance	22
9.6.1.2 Resistance to Lateral Loads	23
9.6.1.3 Stability	23
9.6.2 Concrete Retaining Walls	23
10.0 CONSTRUCTION RECOMMENDATIONS	23
10.1 Open Cut Excavations	23
10.2 Staging	24
10.3 Shoring	24
10.4 Groundwater Control	24
10.5 Erosion control	25
10.6 Frost Protection	25
11.0 CLOSURE	25

List of Appendices

- APPENDIX A Drawings
- APPENDIX B Terms and Symbols used On the Record of Borehole Sheets
Record of Borehole Sheets
- APPENDIX C Geotechnical Laboratory Test Results
- APPENDIX D Laboratory Test Results – Preliminary Foundation Investigation Report
- APPENDIX E Representative Site Photographs

FOUNDATION INVESTIGATION REPORT

**Christina Street Underpass,
Site 14-37 Highway 402
City of Sarnia, Ontario
G.W.P. 3038-03-00
District – London**

1.0 INTRODUCTION

Jacques Whitford Limited (Jacques Whitford) was retained by Stantec Consulting Ltd., to complete a Foundation Investigation and Design Report for the proposed Highway 402 Underpass at Christina Street, in the City of Sarnia, Ontario, (GWP No. 3038-03-00).

The work was carried out under Agreement No. 3005-E-0029 and in general accordance with the Subconsultant Agreement dated May 24, 2006. Authorization to proceed with the investigation was provided by Mr. David Emery, P.Eng., of Stantec Consulting Ltd., the prime consultant on this detailed design assignment.

The scope of work for the foundation investigation is incorporated within Stantec's project, which forms part of the above noted subconsultant agreement.

This foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of foundation investigation and laboratory testing.

2.0 SITE DESCRIPTION

The site location is on Highway 402 at the Christina Street Interchange (IC-2) in the City of Sarnia, Ontario.

Highway 402 at Christina Street is a semi-urban freeway with wide gravel shoulders and a wide grass covered centre median. The highway is slightly lower than the grade of the surrounding lands. Highway 402 is generally oriented in an east-west direction with two east bound and two west bound lanes passing below Christina Street.

Drainage is provided by ditches located along the sides and in the central median of the Highway. The ditches are sloped towards catch basins located along the existing highway. Regional drainage is towards the St. Clair River located approximately 1.4 km west of the project site.

The existing Christina Street underpass is a rigid frame structure, consisting of 2 - 15 m spans (approximate) with a wide central pier. The bridge is constructed of reinforced concrete. Based on the as-built drawings dated August 1950, revised October 1950, it is understood that the existing bridge structure is supported on shallow footings placed on the native sand at an elevation of approximately 179.8 m. The existing bridge deck is at an elevation of approximately 188.9 m and the profile of Highway 402 is at an elevation of approximately 181.7 m.



Christina Street is 4 lanes wide, locally widened in areas to accommodate left and right turning lanes. At the bridge approaches, the street is constructed on embankments that are approximately 6 m high at the abutment locations. Drainage is provided by concrete gutters and a series of catch basins.

A representative site photograph of the underpass structure is provided in **Appendix E**.

3.0 PHYSIOGRAPHY

Based on the physiography of Southern Ontario by Chapman and Putnam (1984), this section of Highway 402 is situated in the physiographic region known as the Huron Fringe, a narrow geological strip between Lake Huron and the adjacent St. Clair Clay Plains. The Huron Fringe is composed mainly of surficial sands, silts and gravels, underlain by lacustrine clayey silt and silty clay.

The bedrock in the area of the site consists of laminated, thinly bedded shale that is black to grey in colour and is of the Kettle Point Formation.

4.0 BACKGROUND

Previous Investigations

A previous assessment of the site was carried out by Golder Associates Ltd. The results of the assessment were provided in a written report titled:

Preliminary Foundation Investigation and Design Report, Proposed Christina Street Underpass Replacement, Highway 402, GWP 3038-03-00, Agreement Number 3005-A-000394, Dated October 14, 2005.

The reported subsurface conditions included the following strata types:

Strata	Layer Thickness (m)	Depth to underside of Strata (m)
Fill	0.8 to 1.0	0.8 to 1.0
Sand	3.7 to 4.6	4.9 to 5.9
Peat	0.15 (G-BH1 Only)	6.3
Clayey silt	11.2 to 17.7	17.4 to 22.6
Silty clay	26.2 to 31.9	48.8 to 49.4
Silt	0.9 (G-BH1 Only)	50.4
Sand and Gravel	0.9 (G-BH2 Only)	50.3
Till	3.2 and 4.8	Termination depth of the boreholes

The sand layer was generally reported to be compact with exception of the lower portion at one of the boreholes, which was very loose.

The clayey silt layer was stated to be firm to very stiff, with actual reported measurements indicating stiff to very stiff conditions. Laboratory tests were reported as follows:

- Moisture contents ranging from 12% to 26%, average of about 19%;
- Average plastic limit of approximately 15; and,
- Average liquid limit of approximately 31.
- Pre-consolidation pressure of 150 kPa from the consolidation test on a sample from Elevation 169.5 m. This indicates that the sample was slightly overconsolidated by 10 kPa.

The silty clay layers were stated to be firm to very stiff based on the SPT N-values. Laboratory tests were reported as follows:

- Moisture contents ranging from 27% to 33%, average of about 30%;
- Average plastic limit of approximately 21; and,
- Average liquid limit of approximately 43.

The till was very dense with SPT N-values exceeding 100. Laboratory tests were reported as follows:

- Moisture contents ranging from 7% to 26%, average of about 12%; and,
- Shale fragments were also reported in the till.

These boreholes have been referenced in this report as Boreholes G-BH1 and G-BH2.

5.0 INVESTIGATION PROCEDURES

5.1 Field Program

The fieldwork for the present investigation was carried out between October 31, 2006, and November 10, 2006, and December 6 to 12, 2006. A total of 13 boreholes were advanced to depths ranging from approximately 6.7 m to 57 m using a track and truck mounted drill rigs equipped with 250 mm (outside diameter), hollow-stem augers and mud-rotary drilling, supplied and operated by Aardvark Drilling Inc.

The following outlines the general purpose of the boreholes:

Location	Boreholes
South Abutment and approach fills	CS-1 and G-BH2
Central pier	CS-2
North Abutment and Approach fills	CS-3, CS-4 and G-BH1
Retaining Walls	R-1 to R-5
Embankment and approach fills	CS-1, CS-3, CS-4 and CS-6 to CS-8

Borehole CS-5 was advanced at the site for a proposed storm water management pond. The results of the storm water management pond foundation investigation and geotechnical recommendations for design are provided under separate cover.

Prior to commencing the field investigation, the borehole locations were established in the field by Jacques Whitford personnel. The borehole locations were cleared of underground utilities by the various utility companies.

Soil samples were recovered from the boreholes at regular intervals using a 50 mm Outside Diameter split-tube sampler by conducting Standard Penetration Tests (SPTs) in general accordance with the procedures outlined in the ASTM specification D1586-99. Relatively undisturbed samples were obtained by pushing thin walled sample tubes in general accordance with ASTM D1587.

Where cohesive soils were encountered, in situ shear vane testing was carried out using a vane meeting the MTO N-vane design requirements and following the procedures outlined in ASTM D2573-94.

Jacques Whitford field personnel recorded the conditions encountered in all boreholes at the time of the investigation. Soils were described in accordance with the MTO Soils Classification System for foundation reports.

The groundwater levels, where encountered, were measured in the boreholes at the completion of drilling. All boreholes were backfilled in accordance with Ontario Regulation 903, using cement/bentonite slurry.

All soil samples recovered from the boreholes were placed in moisture-proof bags and returned to our laboratory for detailed classification and testing as required.

5.2 Survey

The borehole locations were established by Jacques Whitford personnel and referenced to the stations on Christina Street, the respective ramps, or Highway 402. Offsets were referenced looking up chainage. The borehole locations are also referenced to Northing and Easting co-ordinates, which are provided on the Record of Borehole sheets and on Drawing Nos. 1 to 4.

The ground surface elevation at the borehole locations were surveyed by Jacques Whitford personnel. The boreholes were surveyed to one of the following benchmarks, as identified on a Survey Drawing by J. D. Barnes, titled "Pre-Engineering Sta. 11+000 to Sta. 11+700", with a survey date of August, 2004.

- BM 812, a bronze plate set in the concrete sidewalk on the west side of Christina Street, south of the existing south bridge abutment, with a reported Geodetic elevation of 186.87 m.
- BM 332, a monument set at Sta. 11+430, off-set 20 m left, with a reported Geodetic elevation of 183.55 m.

The benchmark locations are shown on Drawing No. 1 in **Appendix A**.

5.3 Laboratory Testing

All samples returned to the laboratory were subjected to detailed visual examination and classification. Representative samples of the native soils were tested for grain size, Atterberg Limits and unit weight testing. In addition, a series of samples were submitted for moisture content determination. Consolidation testing of one soil sample obtained by Jacques Whitford was carried out by Golder Associates on our behalf. The results of the grain size analyses, Atterberg Limits, consolidation and unit weight tests are shown on Figure Nos. 1 through 7 in **Appendix C**. The laboratory testing carried



out by Golder Associates for the preliminary foundation investigation has been incorporated into this report and is included in **Appendix D**.

Unless requested in advance, all samples will be stored in our laboratory for a period of 12 months after issuance of this report.

6.0 RESULTS OF THE INVESTIGATION

6.1 Subsurface Conditions

The subsurface conditions encountered in the boreholes are summarized on the Record of Borehole Sheets provided in **Appendix B**. An explanation of the terms used on the Record of Borehole Sheets is also provided in **Appendix B**.

The boreholes from the preliminary geotechnical investigation, completed by Golder Associates, have been incorporated herein, and are also provided in **Appendix B**. In addition, the laboratory test data from the preliminary report have been incorporated into this report and are provided in **Appendix D**.

Borehole Location plans and strata plots of the soils encountered in the boreholes are provided on Drawing Nos. 1 to 4 in **Appendix A**.

A summary of the soil and groundwater conditions encountered in the boreholes is provided below.

6.2 Soil

6.2.1 Asphalt

Asphalt was encountered at the ground surface in several boreholes. The following table outlines the borehole location, borehole number and asphalt thickness measured at each borehole, where encountered:

Location	Borehole Number	Asphalt Thickness (mm)
Christina Street	CS-1	150
Christina Street	CS-3	200
Christina Street	R-1	150
Christina Street	R-2	150
S-E Ramp	R-4	180
S-E Ramp	R-5	200

6.2.2 Topsoil

Topsoil was encountered at the ground surface in Boreholes G-BH1 and G-BH2.

6.2.3 Sand Fill

Sand fill was encountered at the ground surface in Boreholes CS-2, CS-6 to CS-8 and R-1, and below the asphalt or topsoil in all other boreholes. The granular material ranged in thickness from approximately 0.7 m to 5.1 m. Thicker sand fill, in the range of approximately 4.6 m to 5.3 m, was encountered in Boreholes CS-1 and CS-3, which were drilled through the approach embankments for the existing bridge structure.

The sand fill generally consisted of sand and gravel directly below the asphalt, grading to sand, trace gravel with increasing depth. The sand fill contained trace silt and was generally moist to damp.

Based on the N-Values obtained from the Standard Penetration Tests (SPTs), the compactness of the sand fill was variable ranging from very dense to very loose, but was typically compact.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution tests. The test results are as follows:

- Moisture Content:
 - 5% to 8%.
- Gradation:
 - 9% to 37% gravel;
 - 51% to 86% sand; and,
 - 4% to 12% fines (silt and clay).

The results of the moisture content tests and grain size distribution tests are provided on the Record of Borehole sheets in **Appendix B**.

The results of the grain size distribution tests are provided on Figure 1 in **Appendix C**.

6.2.4 Native Sand

Native sand was encountered below the fill in all boreholes. The sand was encountered at depths ranging from approximately 0.9 m to 5.3 m below existing grade, or at elevations of approximately 183.1 to 176.7 m. The thickness of the sand ranged from approximately 2.8 m to 7.6 m.

The sand was generally moist to wet. Based on the N-Values obtained from the SPTs, the compactness of the sand ranged from very dense to compact.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution tests. The test results are as follows:

- Moisture Content:
 - 10% to 30%.
- Gradation:
 - 0% to 10% gravel;
 - 83% to 96% sand; and,
 - 2% to 17% fines (silt and clay).

The results of the moisture content tests and grain size distribution tests are provided on the Record of Borehole sheets in **Appendix B**.



The results of the grain size distribution tests are provided on Figures 2 and 3 in **Appendix C** and on Figure A-1 in **Appendix D**.

A second layer of sand was encountered below the silty clay in Borehole G-BH2, at a depth of approximately 49.7 m or elevation of about 131.9 m. This layer of sand was approximately 0.6 m thick and contained gravel and trace silt.

6.2.5 Peat

A peat seam was encountered in Borehole G-BH1 below a thin seam of clay silt (noted below) at a depth of approximately 6.1 m below grade, or elevation 175.9 m. The peat was described by Golder as follows:

- 150 mm thick;
- Moisture content: 110%;
- Saturated;
- Fibrous; and,
- SPT N-value of 4.

6.2.6 Clayey Silt / Silty Clay

Clayey silt / silty clay was encountered below the sand in all boreholes. The clayey silt / silty clay was encountered at depths in the range of approximately 4.7 m to 12.2 m below existing grade, or elevations of approximately 174.7 m to 177.6 m. All boreholes, with the exception of Boreholes CS-2, G-BH1 and G BH2, were terminated in the clayey silt / silty clay at depths in the range of approximately 6.7 m to 15.8 m or elevations of approximately 170.5 m to 177.9 m. The clayey silt / silty clay was approximately 43 m, 44 m and 45 m thick in Boreholes CS-2, G-BH1, and G-BH2, respectively.

The clayey silt / silty clay was generally moist to damp.

The upper 2 m of the silty clay generally could be classified as very stiff to hard, indicating this layer is likely a desiccated layer. Below this depth, the consistency of the clayey silt / silty clay is generally stiff.

In situ shear vane testing was carried out in the clayey silt / silty clay. The results of the testing indicated that the shear strength of the clayey silt / silty clay was variable ranging from approximately 55 kPa to >140kPa, but was more typically in the range of approximately 70 kPa to 85 kPa.

Laboratory testing performed on selected samples consisted of moisture content tests, grain size distribution tests, Atterberg Limits tests, Consolidation Tests and Unit Weight tests. The test results are as follows:

- Moisture Content:
 - 13% to 34%.
- Gradation:
 - 0% to 7% gravel;
 - 5% to 32% sand;
 - 40% to 75% silt; and,
 - 17% to 42% clay.

- Atterberg Limits:
 - Liquid Limits: 24 to 47; and,
 - Plastic Limits: 10 to 24.
- Unit Weight: 20.9 to 21.5 kN/m³.

The results of the moisture content tests, grain size distribution tests, Atterberg Limits tests and unit weight tests are provided on the Record of Borehole sheets in **Appendix B**.

The results of the grain size distribution tests are provided on Figure 4 in **Appendix C** and Figure A-2 and A-5 in **Appendix D**. The results of the Atterberg Limits tests are provided on Figure 5 in **Appendix C**, and Figure A-3 and A-6 in **Appendix D**.

The results of the consolidation tests carried out by Golder on behalf of Jacques Whitford in January 2007 for the present investigation are provided on Figure 6 in **Appendix C**.

The results of the consolidation tests carried out by Golder as part of the October 2005 Preliminary Foundation Investigation are provided on Figure A-4 in **Appendix D**.

The results of the unit weight tests are provided on Figure 7 in **Appendix C**.

6.2.7 Silt

Silt was encountered below the clayey silt /silty clay in Borehole G-BH1 at a depth of approximately 49.4 m or an elevation of about 131.9 m. The silt was described by Golder as follows:

- Approximately 1 m thick;
- Contained trace clay and layers of silty clay;
- Generally wet;
- Compact; and,
- Moisture content of 26%.

6.2.8 Sandy Silt Till

Sandy silt till was encountered below the silt, sand or clayey silt / silty clay in Boreholes CS-2, G-BH1 and G-BH2 at depths in the range of approximately 47.2 m to 50.4 m below existing grade or elevations of approximately 130.9 to 133.8 m. Boreholes CS-2, G-BH1 and G-BH2 were terminated in the sandy silt till stratum at depths of approximately 53.5 to 57.0 m below existing grade, elevations of approximately 124.4 m to 128.1 m.

The sandy silt till was generally moist. Based on the N-Values obtained from the SPTs, the compactness of the sandy silt till was very dense.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution test. The test results are as follows:

- Moisture Content:
- 8% to 11%.

- Gradation:
 - 11% gravel;
 - 43% sand;
 - 33% silt; and,
 - 13% clay.

The results of the moisture content tests and grain size distribution test are provided on the Record of Borehole sheets in **Appendix B**.

The results of the grain size distribution test are provided on Figure A-7 in **Appendix D**.

6.3 Groundwater

Ground water was encountered in the boreholes during drilling. It was not practical to measure the ground water on completion of drilling in all of the boreholes, given the use of drillers mud during drilling. The following table provides a summary of the groundwater conditions encountered:

Borehole	Drill Date	Ground Water First Encountered		Ground Water measured on Completion of Drilling		Depth to Cave of Borehole (m)	
		Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
CS-1	06-11-08	-	-	7.6	179.3	6.5	180.4
CS-2	06-12-06	-	-	-	-	-	-
CS-3	06-11-08	-	-	7.6	179.2	6.7	180.1
CS-6	06-11-10	3.0	180.1	*	*	2.9	180.2
CS-7	06-11-10	3.0	180.1	*	*	2.6	180.6
CS-8	06-11-10	4.0	179.5	*	*	2.9	180.6
R-1	06-11-09	4	179.4	*	*	3.3	180.1
R-2	06-11-09	6.1	178.7	*	*	4.4	180.4
R-3	06-11-10	4.6	179.1	*	*	3.5	180.2
R-4	06-11-10	4	180.0	*	*	3.7	180.3
R-5	06-11-10	-	-	*	*	3	180.0
G-BH1	04-07-12	1.8	179.5	*	*	-	-
G-BH2	04-07-19	1.7	179.9	*	*	-	-

* - Could not be measured due to the drilling techniques used.

Fluctuation in the groundwater level due to seasonal variations or in response to a particular precipitation event should be anticipated.

7.0 CLOSURE

A soil investigation is a limited sampling of a site. The information is gathered at specific borehole locations and can only be extrapolated to an undefined limited area around the borehole locations. The extent of the limited area depends on the variability of the soil and ground water conditions as influenced by geological processes, as well as the history of the site reflecting natural conditions, construction activities and site use. Should any conditions at the site be encountered that differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

We trust the above information meets with your present requirements. Should you have any questions or require further information, please do not hesitate to contact us at your convenience.

Yours very truly,

JACQUES WHITFORD LIMITED

Original Signed By:

Geoffrey Creer, P.Eng.
Geotechnical Engineer

Original Signed By:

Raymond Haché, P.Eng.
Principal, Geotechnical Service Director, and
Designated Principal
MTO Foundations Contact

GC/RH/dd

Enclosures

\\Markppfs04\1010xxx\$\1012607\Files for CD\Geotech Report christina Street - FINAL INVEST AND DESIGN REPORT v2.doc



FOUNDATION DESIGN REPORT

**Christina Street Underpass,
Site 14-37 Highway 402
City of Sarnia, Ontario
G.W.P. 3038-03-00
District – London**

8.0 DISCUSSION

8.1 General

The existing Christina Street underpass is a reinforced concrete, rigid frame structure that consists of 2 – 15 m spans (approximate) with a wide central pier. Based on the as-built drawings dated August 1950, revised October 1950, it is understood that the existing bridge structure is supported on spread footings placed on the native sand at an elevation of approximately 590 feet (179.8 m).

The approaches to the four lane wide bridge on Christina Street are constructed on embankments that are approximately 6 m high at the abutment locations. The abutment faces are exposed adjacent to the Highway 402 shoulders. There are no fore-slopes in front of the abutments. The side slope of the embankments are generally constructed with a 2H:1V slope. Due to property limitations on the south side of Highway 402, approximately 60 m south of the south bridge abutment, concrete retaining walls are used to accommodate the grade change of the approach embankments with the neighbouring properties.

Highway 402 consists of two east bound and two west bound lanes where it passes beneath Christina Street.

8.2 Proposed Development

The Ministry of Transportation (MTO) is proposing to widen and upgrade the westbound lanes of Highway 402 to four lanes from the Blue Water International Bridge property eastward to Indian Road, a total distance of approximately 3.1 km (Sta. 10+500 to Sta. 13+600).

As part of the highway widening work, the Christina Street underpass will be demolished and reconstructed. The type of replacement bridge structure is unknown at this time. However, it is understood that the new structure will likely consist of prestressed concrete girders and a concrete bridge deck, supported on a central pier and either integral or semi-integral abutments.

To accommodate the widening of the west bound lanes, the preliminary drawings indicate that the new north abutment will be approximately 6 m to 7 m north of the existing abutment location. The location of the south abutment will be approximately 8 m to 9 m south of the existing locations.



The new bridge structure will be approximately 4 m wider than the existing structure. The widening will be to the west of the existing structure. In addition, the grade of Christina Street will be increased approximately 1.5 m.

The increased grade and subsequent widening of Christina Street will result in wider approach embankments. However, given the property limitations on the south side of the bridge structure, it is understood that the grade separation between the approach embankments and the neighbouring lands will be accommodated using both conventional embankments and retaining walls. The currently proposed wall types are either a Retained Soil System or a reinforced concrete retaining wall.

A storm water management pond has been planned for the area of the S-W Ramp. It is understood that the pond will likely be excavated below the existing grade. Geotechnical comments and recommendations for the design of the storm water management pond have been incorporated into a separate Foundation Investigation and Design report.

8.3 Soil Summary

The soil conditions below the embankments and Highway 402 are generally uniform. Characteristically, the native soils can be described as follows:

Depth	Description
0 – 6 m	Compact sand with less than 10% silt and a friction angle of about 31 degrees.
6 – 12 m	Stiff lean clayey silt with a consistent moisture content of approximately 20%, undrained shear strengths typically in the range of 70 to 85 kPa, and consolidation test results suggesting that the soil is slightly over consolidated by about 10 kPa to 50 kPa; with a compression index of 0.13 to 0.18 and a coefficient of consolidation of about 0.01 cm ² /sec.
12 – 50 m	Stiff lean silty clay with more clay size content and higher moisture content relative to the shallower clay. The moisture content is typically around 29% and the undrained shear strength is typically in the range of 60 to 70 kPa. The consolidation characteristics are likely similar to the overlying clay and possibly slightly more compressible.
50 to 57 m	Dense to very dense glacial till consisting of sandy silt with about 10% gravel content. The Standard Penetration N-value is typically more than 100 blows per 0.3 m.

The boreholes for the bridge structure drilled at this site extended to more than 3 m beyond practical refusal within the till layer. Therefore the depth to bedrock was not established.

The consolidation tests were carried out on samples obtained within boreholes drilled away from the existing embankment. The current level of stress within the soils directly beneath the embankment would exceed the natural preconsolidation pressures and therefore these underlying soils are not considered to have experienced any “over consolidation” pressures.

The above characteristic depths and descriptions represent a typical approximation of the soil conditions at the site and reflect the range of parameters carried forward in the design analyses.

8.4 Preliminary Foundation Design Report

It is noted that the preliminary foundation report by Golder was prepared with the assumption that Highway 402 was to be lowered by 1.5 m to accommodate the clearance requirements and the proposed bridge configuration. In addition, the profile height of Christina Street was to remain

unchanged. Based on these assumptions, the preliminary report stated that “only minor localized settlements are expected as a result of the minor centreline shift for Christina Street”.

The preliminary recommendations provided by Golder included the following options:

- Shallow foundation, with geotechnical bearing resistances of 150 kPa at ULS and 100 kPa at SLS, assuming a founding elevation of about 180 m geodetic;
- Perched abutment shallow foundations, with geotechnical bearing resistances of 450 kPa at ULS and 300 kPa at SLS;
- Steel end bearing piles, driven to the till. The geotechnical axial resistances for HP310X110 piles driven into the till to elevation 130.7 m geodetic, were provided as follows:
 - 1800 kN at ULS; and,
 - 1300 kN at SLS.
- Friction piles driven into the silty clay to about elevation 154 m geodetic. The geotechnical resistances for 324 mm diameter pipe pile were provided as follows:
 - 350 kN at ULS; and,
 - 225 kN at SLS.

The preliminary report indicated that the pile options are preferable for this project.

The preliminary report also provides design recommendations for retaining walls and embankments.

8.5 Foundation Assessment

The foundation assessment for the proposed development must consider the following two issues;

- 1) Presuming conventional construction materials, stress distribution and consolidation parameters provided in Section 9.5, calculations suggest that ground surface settlements at the abutments would be in the order of 75 mm near the middle of the abutments and about 125 mm at the west end of the abutment where approximately 4.3 m of embankment widening is proposed. These settlement estimates incorporate a 4.3 m embankment widening to the west, a 1.5 m profile increase for Christina Street and the shortening of the embankment lengths to accommodate the longer bridge span. The magnitude of calculated settlements reflect primarily the depth of clay that is present at the site (approximately 44 m). The time that these settlements occurs over is discussed in detail in Section 9.5; and,
- 2) The foundation loads related to the proposed bridge structure.

As part of the following discussions, it is presumed:

- That the amount of settlement, 75 mm to 125 mm, within the embankment is not acceptable;
- That consideration will be given to lowering the proposed Christina Street profile to match the existing conditions; and,
- That consideration will be given to using a light weight (polystyrene blocks) fill behind the abutments to control future settlements as a design option.

The use of integral or semi-integral abutments is being contemplated for this location. Either of these options would require the use of piles at the abutment locations. In this respect, the preferred option would be to support the abutments and piers on driven piles that would allow the use of integral or semi-integral abutments.

The following table provides a summary of the foundation options under consideration:

Foundation Option	Advantages	Disadvantages	Relative Cost	Risks/Consequences
Spread Footings supported on native sand	Lowest cost	Potential for settlement of the underlying silty clay/clayey silt. May require the use of settlement mitigation measures. May not be feasible due to low bearing capacity, even if settlement mitigation measures are taken. Geotechnical resistances at ULS and SLS are considered very low.	Low	May encounter settlement above tolerable limits, even with mitigation measures taken. The high groundwater encountered will have an impact on the construction of the footings and will likely require the use of dewatering techniques and mud slabs.
Spread footings perched on granular pads in embankments	Higher bearing resistance	Potential for settlement of the underlying silty clay/clayey silt. Most difficult construction staging, due to large footprint.	Medium	Settlements associated with the Christina Street embankments.
Steel H-Piles founded on Silty Sand Till	High capacity Minimal foundation settlement	Potential to encounter cobbles and boulders during driving.	High	Possible tip damage during driving which would require a driving shoe. Down Drag at the abutments due to the placement of the fill and the depth of the clay deposit would exceed the pile capacities unless either light weight materials are used to eliminate the potential settlements or wick drains are used to induce the settlements prior to pile installation.
Steel H-Piles friction founded in the clayey silt / silty clay	Some cost savings, reduction in number of splices	Lower bearing resistance. Some settlement under design loads.	High	Piles likely spaced closer together, which would result in reduction of capacity for pile groups. Similar to piles driven to till, measures to eliminate the settlements or to induce them prior to pile driving would be required.

9.0 RECOMMENDATIONS

9.1 Pile Foundations

9.1.1 End Bearing Piles

Given the conditions encountered during this investigation, it is likely more practical to found the bridge on driven piles. This would also allow for the use of integral abutments.

The abutments and central piers could be founded on steel H-piles, such as HP310x110, driven into the underlying very dense sandy silt till.

Piles for the abutments and central pier driven to a depth of at least 3 m into the till or elevation of 127 m, may be designed using a factored geotechnical resistance at ULS of 1800 kN, and a geotechnical reaction at SLS of 1600 kN, for 25 mm of settlement. The ULS value assumes a resistance factor of 0.4.

As part of the construction procedures, it is strongly recommended that dynamic pile load tests and dynamic analysis be carried out at each foundation unit. A minimum of four tests should be carried out at each unit. This recommendation is put forward, given that the piles are not anticipated to reach bedrock.

9.1.2 Down Drag Forces

Given that the grade of the approach embankments fills will be increased by approximately 1.5 m, and the embankments widened to the west by approximately 4.3 m, down drag forces, induced as a result of the settlement of the underlying clayey silt / silty clay under the approach fill, must be considered.

Calculations indicate that the new embankments may induce settlement as outlined in the following table:

Location	Predicted Embankment Settlement (mm)	
	Conventional Weight Fill	Light Weight Fill (Slag)
Centre line of existing embankments	75	50
Proposed embankment rounding (West Side)	125	75

Based on the settlement estimates provided above for conventional fills and light weight slag fills, the unfactored negative skin friction calculated for an HP310X110 steel H-pile supporting the abutments will exceed the geotechnical resistance at ULS of 1800 kN for both cases.

Negative skin friction was calculated using the β method using a β -value of 0.3 applied to the theoretical box around the H-pile. The calculation was only applied to depths where the relative movement between the soil and the pile exceeded 10 mm, which corresponded to an elevation of 145 m for the conventional fill and about 155 m for slag fill. In addition, the calculation did not assume a

time-lag delay; this consideration was not included due to the thickness of the clay which would render wick-drains excessively expensive and preloading excessively lengthy.

The above estimated negative skin friction load can be significantly reduced by lowering the profile of Highway 402 to eliminate the proposed grade raises. Alternatively, down drag forces can be reduced or eliminated by balancing the weight of the existing embankments and the new embankments using ultra light weight fill such as expanded polystyrene blocks. This option would require removing some of the existing fill material and replacing it with expanded polystyrene blocks.

Down Drag forces are not anticipated at the pier locations, as it is presumed that the grades at these locations will remain unchanged.

9.1.3 Friction Piles

For the central pier foundation only, friction piles may be considered as a design alternative. Friction piles, consisting of HP310 x 110 and having a minimum length of 25 m, could be designed using a factored geotechnical resistance at ULS of 600 kN, and an SLS of 400 kN. The ULS value assumes a resistance factor of 0.4.

As part of the construction procedures, it is strongly recommended that dynamic pile load tests and dynamic analysis be carried out at each foundation unit. A minimum of four tests should be carried out at each unit. This recommendation is put forward, given that the piles are not anticipated to reach bedrock.

Settlements are not expected at the central pier. Therefore no down drag forces are anticipated.

9.1.4 Lateral Resistance

Passive lateral resistance for vertical piles should be calculated as per C6.8.7.2 (Static Analysis i.e. Brom's method) of the CHBDC using the following unfactored geotechnical soil parameters:

Parameter	OPSS Granular B Type II	Native Sand	Clayey Silt / Silty Clay
Bulk Unit Weight (kN/m ³)	21	18	20
Effective friction angle	35°	30°	-
Coefficient of passive earth pressure	3.7	3.0	-
Design Undrained Shear Strength (kPa)	-	-	50

9.1.5 Lateral Deflections

The coefficient of horizontal subgrade reaction that is used for deflection calculations, may be estimated for cohesive soils as follows:



$$k_s = 67 C_u/d.$$

Where k_s = the coefficient of horizontal subgrade reaction (force per volume)
 C_u = undrained shear strength of the soil = 50 kPa for this application
 d = pile diameter or width

The coefficient of horizontal subgrade reaction that is used for deflection calculation for non cohesive soils may be estimated as follows:

$$k_s = n_h(z/d).$$

Where k_s = the coefficient of horizontal subgrade reaction (force per volume)
 n_h = Co-efficient related to soil density. This may be taken as 4 400 kN/m³ for compact to loose sandy soils (Table 20.3, p. 315, of the Canadian Foundation Engineering Manual)
 z = depth below grade
 d = pile diameter or width

9.1.6 Group Effects on Lateral Deflections

If piles are spaced at less than 8 pile diameters, center to center, parallel to the direction of lateral load, or less than 4 pile diameters, center to center, perpendicular to the lateral load, group effects will need to be considered and the lateral load at a specific deflection may need to be decreased.

The nature of pile-soil-pile interaction is complex, however is generally broken down into the following main components:

- Alteration of the soil state due to pile installation and the potential overlap of the alterations when nearby piles are driven; and,
- Superposition of strains and alterations of the soil failure zones when nearby piles are simultaneously loaded.

Studies (Reese, Isenhower and Wang, 2006) have reported the following reduction between single piles and pile groups.

- Condition No. 1: Load is parallel to pile spacing

Pile Spacing c/c	Trailing Pile Group Pile Efficiency, e_T	Lead Pile Group Pile Efficiency, e_L
7d	1.0	1.0
4d	0.8	1.0
3d	0.7	0.9
2d	0.6	0.8

- Condition No. 2: Load is perpendicular to pile spacing

Pile Spacing c/c	Group Pile Efficiency, e_p
4d	1.0
3d	0.9
2d	0.75

Where piles are on a skew to each other relative to the direction of load the Group Pile Efficiency may be calculated based on

$$e_s = (e_B^2 \cos^2 \alpha + e_p^2 \sin^2 \alpha)^{1/2}$$

where

e_B = either e_T or e_L from above

α = angle between direction of loading and the skew

Note that when piles are more than 3.3 pile diameters apart perpendicular to the direction of the load, the skew correction is not necessary. The lateral load at a specific deflection for each individual pile must consider the interaction of all piles within the group.

The reduction factor applied to a pile is the product of the efficiencies of all of the interactions of piles within that pile group.

9.1.7 Tensile Resistance

Resistance to tensile loads should be calculated based on the shaft resistance of the piles in accordance with Section 6.8.5 of the CHBDC. The following resistances at ULS are recommended for HP 310x110 H-piles in tension:

- 53 m long pile, embedded 3 m into the underlying till: tensile resistance at ULS of 1300 kN; and,
- 25 m long pile, embedded within the clayey soils: tensile resistance at ULS of 450 kN.

The above ULS tensile resistances were calculated using a geotechnical resistance factor of 0.3.

The above values do not include the weight of the piles.

9.1.8 Piling Notes

Piles should be equipped with reinforced flanges as per OPSD 3000.100 Type 1. Piles should be driven in accordance with Standard SS-103-11 using an ultimate geotechnical resistance equal to twice the factored design load at ULS.

The piles are anticipated to be approximately 50 m to 55 m in length, which will require the piles to be spliced during driving. Welded splices for steel H-piles should be in accordance with OPSD 3000.150.

For integral abutments, it is recommended that the upper 3 m of the pile (immediately below the pile cap) be placed in a pre-augered hole lined with a corrugated steel pipe. The liner should have a diameter larger than that of the piles. The space between the pile and the liner should be filled with loose sand, such as OPSS concrete sand.

The following note should be added to the foundation design drawings:

“Piles to be driven in accordance with standard SS103-11 using an ultimate geotechnical resistance of 3600 kN per pile”.

9.2 Earth Pressure Design

To prevent hydrostatic pressure build-up, backfill against the abutments should consist of free draining granular materials. OPSS Granular A or OPSS Granular B, Type II are recommended. The zone of granular backfill must be constructed in accordance with Figure C6.9.1(I) (CHBDC Commentary) and OPD 3101.150, using a frost penetration depth, f , of 1.2 m.

Earth pressure co-efficients are provided below for different backslope conditions. In order to use the coefficients of pressure for a particular granular material, the granular backfill must be provided within a wedge extending from the base of the abutment at 45° (or smaller) to the horizontal. If a smaller wedge is used, the coefficients of earth pressure of the materials outside the backfill wedge must be used for lateral pressure design calculations.

For rigidly tied structures (e.g., not integral bridge abutments), the at-rest pressure should be used for design, unless the wall can deflect enough (approximately 0.05% of the wall height) to establish the active pressure. The effect of compaction should be accounted for as per CHBDC Figure 6.9.3.

Lateral earth pressures may be calculated using the parameters in the following table:

Parameters	OPSS Granular A	OPSS Granular B, Type II	Native Sand
Unit Weight (kN/m ³)	22.0	21.0	18
Angle of Internal Friction, ϕ	35°	35°	30°
Horizontal Backslope			
Coeff. of Active Earth Pressure, K_a	0.27	0.27	0.33
Coeff. of Passive Earth Pressure, K_p	3.69	3.69	3.0
Coeff. of Earth Pressure at Rest, K_o	0.43	0.43	0.5
2H:1V Backslope			
Coeff. of Active Earth Pressure, K_a	0.39	0.39	0.54
Coeff. of Passive Earth Pressure, K_p	10.82	10.82	7.46

9.3 Soil Profile Type

It is recommended that Soil Profile III as defined in CHBDC Section 4.4.6 be used in the seismic design of this site.

9.4 Seismic Forces on Abutments and Retaining Walls

The zonal acceleration ratio for Sarnia is 0.00 as per CHBDC Table A3.1.7. Therefore, seismic design is apparently not required.

9.5 Embankment Design and Construction

It is understood that the grade of the approach embankments will be increased by approximately 1.5 m and will be widened to the west by approximately 4.3 m. The increase in grade and widening of the embankment will cause consolidation of the underlying clayey silt / silty clay.

The existing embankments are constructed with a 2H:1V slope and exhibit no visible signs of instability. It is recommended that the widened embankments could be constructed at 2H:1V.

The following parameters were used to calculate the settlements of the underlying soils. These parameters are based on the results of the consolidation testing provided on Figure 8 in Appendix C.

Parameters*	Value
Initial Void Ratio	0.55
Compression Index, C_c	0.13 - 0.18
Recompression Index, C_r	0.035
Coefficient of Consolidation, c_v	0.01 cm ² /sec

Settlement beneath the widened embankment will be variable and will depend on the type of material used for the widening. The following table outlines the predicted settlements for an 8 m high 4 m embankment widening with 2H:1V slopes:

Location	Predicted Embankment Settlement (mm)	
	Conventional Weight Fill	Light Weight Fill (Slag 13 kN/m ³)
Centre line of existing embankments	75	50
Proposed embankment rounding (West Side)	125	75

The results of the laboratory tests, combined with a total clay layer thickness of about 43 m suggest that the consolidation period would likely last several years. For example, assuming double drainage, a 43 m thick layer with no intermittent drainage path produces calculated consolidation period of about 3 years for 50% consolidation and about 12 years for 90% consolidation. If a few intermittent drainage layers are provided, such as wick drains, to reduce the effective drainage thickness to 10 m, 50% consolidation would be calculated to about 3 months and 90% consolidation at about 8 years. The ability to accurately predict the rate of consolidation based on limited field sampling and laboratory testing is limited; if time estimates are critical to the project, it is recommended that a piezocone investigation be carried out to profile the presence of drainage layers and to measure the in situ permeability by carrying out pore water dissipation tests.

It is also noted that in addition to the settlement of the underlying clayey silt / silty clay, there will be some internal settlement of the embankment material.

The settlements and rate of settlement noted above for both conventional weight fills and the light weight slag fill are excessive for the proposed development. Particularly when considering the large negative skin friction loads which would be induced on the steel H-piles. The following options may be considered to reduce or eliminate the settlement at the abutments:

- Lower the profile of Highway 402 such that the Christina Street embankments do not need to be raised;
- Construct the embankments using ultra light weight fills such as expanded polystyrene (EPS). The use of these materials would require replacing some of the existing embankment fills to achieve the correct weight balance. Where the grade raise is 1.5 m, the EPS approach would generally entail:
 - Removing 1.3 m of existing road/embankment material;
 - Placing 1.8 m of EPS blocks over the prepared existing embankment;
 - Placing the concrete protective cap and road bed/pavement material (approximately 1.0 m); and,
 - Constructing the embankment widening using EPS blocks notched into the existing side slopes and capping as required using the concrete slab and pavement material.

It is noted that the use of a surcharging program would not be considered suitable due to time constraints.

As noted above, EPS can be used to balance the weight of the existing embankments with the new embankment configuration. This would allow the constriction of the embankment widening and grade raise without imposing additional stress on the underlying clay soils, thereby reducing or eliminating potential settlements. The following table outlines the thickness of expanded polystyrene that would be required to result in no stress increase on the soils below the existing embankments as a result of the embankment widening and grade raise.

Grade Raise	Thickness of Expanded Polystyrene (m)	
	Proposed Centre Line	Proposed Rounding
0.5 m	0.7 m	3.9 m
1.0 m	1.2 m	4.6 m
1.5 m	1.8 m	5.0 m

The calculations to determine the balanced weight presume that there is 1.0 m of pavement structure (asphalt, granular and a concrete slab) placed above the EPS. As noted herein in order to achieve the weight balance it will be necessary to remove some of the existing embankment material and replace it with ultra-light weight fill.

Away from the abutments, where conventional fill is used, the following should be considered:

- Prior to placing the additional fill, all topsoil, loose, wet, organic and other deleterious material should be removed from the area of the proposed embankment. The exposed subgrade of the embankment should be proof rolled, inspected and certified by the geotechnical engineer in accordance with SP902S01, prior to the placement of any fill materials.
- The embankment should be constructed of OPSS Select Subgrade Material or earth fill in accordance with SP206S03 and SP105S10.

- The new embankment fill material should be benched into the existing embankments in accordance with OPSD 208.010.

9.6 Retaining Structures

Given the limited property available on the south side of the proposed bridge, it will be necessary to use retaining structures to achieve the grade separations between the approach embankments and the neighbouring properties. It is understood that the preferred option is to use a retained soil system or a concrete retaining wall. Retained soil systems should be constructed in accordance with SP599S22.

9.6.1 Retained Soil System (RSS)

A retained soil system is a mechanically reinforced soil retaining system that generally consists of granular fill placed and compacted in layers, and reinforced with fabric or metal strips or geogrid. The wall is faced to prevent loss of the fill material. The facing generally consists of either pre-cast concrete panels or decorative concrete blocks; both are mechanically fastened to the reinforcing strips or grids.

The base of the RSS wall at this site will generally be founded in the native sands.

The boreholes advanced along the length of the proposed retaining structures, typically encountered fill to depths of approximately 2.3 m below existing grade.

9.6.1.1 Geotechnical Resistance

The front face of an RSS wall is typically supported on a strip footing placed below the ground surface in front of the wall. The footing must be founded below any topsoil, loose fill or unsuitable native soils. For an assumed width of 0.6 m for the face footing and presuming that the footing is placed on sub-grade prepared in accordance with the recommendation herein, a factored geotechnical resistance at ULS of 150 kPa may be used for design. A resistance factor of 0.5 has been applied in the calculation.

Presuming that the reinforced soil acts as a unit, and the width of the reinforced soil mass, which is about 2/3 of the wall height, the following factored geotechnical resistances at ULS may be used for assessment of the reinforced mass bearing capacity founded on the prepared embankment fill material or native sand. A resistance factor of 0.5 has been applied in the calculation.

Wall Height	Assumed Width	Factored Geotechnical Resistance at ULS (kPa)
6.0 m	4.0 m	280
4.0 m	2.7 m	245

Settlement of the RSS wall including the reinforced mass and the concrete facing footings, will occur as a result of the loading due to the embankment, since the walls are incorporated into the embankment. The geotechnical resistance at SLS of 100 kPa may be considered. However, the settlement resulting from the combined RSS wall and the embankment widening, and presuming the use of a light weight fill such as slag, will likely be in the range of approximately 25 mm to 50 mm. Alternatively, the retaining walls could be founded on piles driven to the underlying till.

9.6.1.2 Resistance to Lateral Loads

The resistance to lateral loads between the compacted granular fill and the sub-grade should be calculated in accordance with section 6.7.5 of the CHBDC. The unfactored coefficient of friction between the compacted granular fill of the RSS wall and the existing granular fill materials or the native sand may be taken as 0.51.

9.6.1.3 Stability

Internal Stability

The internal stability of the Reinforced soil walls is the responsibility of the RSS supplier / designer, and must also include internal stability for seismic loading.

Global Stability

A global stability analysis of the proposed RSS retaining wall was carried out for the maximum proposed height of 6 m, with a base width of 4 m, using characteristic soil strength parameters and the computer software Slope/W (GeoStudio). The results of the analysis indicate that a factor of safety of greater than 1.3 can be provided by the site soils.

9.6.2 Concrete Retaining Walls

The retaining wall could be constructed using a conventional concrete retaining wall. However, a conventional wall designed in accordance with the recommendations and using the geotechnical parameters provided herein would be subject to the same settlements caused by the embankment widening and grade increase. Concrete retaining walls should only be considered if they are designed using piled foundations as per Section 9.1 of this report.

10.0 CONSTRUCTION RECOMMENDATIONS

10.1 Open Cut Excavations

Earth excavation, if required, should be carried out in accordance with OPSS-206. Side slopes for open cut excavations should conform to the requirements of the Occupational Health and Safety Act and Regulations for Construction Projects current at the time of construction.

In accordance with the present act, the existing fill and any excavations below the water level at an elevation of approximately 180.0 m, should be considered Type 3 soils. Temporary excavations should be made with side slopes no steeper than 1:1 (horizontal:vertical) from the base of the excavation.

The dense to compact sand above the water level, elevation 180.0 m, could be considered Type 2 soils. Side slopes above a 1.2 m vertical cut should be sloped a minimum of 1:1 (horizontal:vertical).

The construction should be subject to time constraints such that temporary excavations are open for no longer than 10 calendar days. Flatter side slopes will be required for open cut excavations in loose sand deposits below the water line unless appropriate dewatering methods are employed.

Excavation side slopes should be protected from erosion and should be inspected regularly for signs of instability. Slopes should be flattened as required to maintain safe working conditions.

10.2 Staging

Given that the proposed bridge will be reconstructed at the same location, it will be necessary to stage construction.

Through discussions with representatives of Stantec, the following staging is understood:

Stage 1: Divert traffic to the existing north bound lanes and have one southbound lane and one northbound lane. Demolish the existing southbound lanes and construct the new southbound bridge structure.

Stage 2: Divert traffic to the new southbound structure having one north and one southbound lane. Demolish the existing northbound lanes and construct the new northbound bridge structure.

Stage 3: Tie the southbound structure (Stage 1) and the northbound structure (Stage 2) together.

It is anticipated that there will only be short interruptions to traffic flow on Highway 402 during the construction.

It is recommended that the existing structure be monitored, given that a portion of the existing structure will be used during the construction of the new underpass. It is recommended that a visual assessment and vibration monitoring be carried out on a regular basis during the installation of the piles.

10.3 Shoring

Shoring will be required along Christina Street to build the abutment in stages and to support the traffic lanes.

Shoring should meet the requirements of Performance Level 2 as per SP105S19 and should consider backfill and traffic loading.

Shoring could consist of driven soldier piles and wood lagging or driven sheet piles.

The temporary shoring may be designed using the parameters provided in Section 9.2, titled Earth Pressure Design.

10.4 Groundwater Control

Groundwater levels measured in the open boreholes indicated variable water levels ranging between approximately 1.7 m to 7.6 m below existing grade, elevations of approximately 178.7 m to 180.6 m. Several boreholes caved at depths in the range of approximately 2.6 m to 6.7 m, elevations of about 180.0 m to 180.6 m. Therefore, excavations below an elevation of about 180.0 m will likely encounter groundwater. In addition, excavations above this elevation, may encounter perched groundwater within the fill materials. This water should be readily handled by conventional sumps and pumping techniques.

Given the soil conditions, seepage above a depth of about 180 m is anticipated to be slow and therefore should be readily handled by conventional sumps and pumping techniques. Excavations

below 180 m, may be difficult, given that cave was measured in several boreholes below this depth. Therefore, some form of dewatering, in addition to conventional sumps and pumping techniques, will likely be required.

The following table provides an estimate of the hydraulic conductivity of the various soils encountered, based on the results of the grain size distribution tests and information provided in the Supplement to the Ontario Building Code 2006 edition:

Soil type	Hydraulic Conductivity (cm/sec)
Sand fill	10^{-1} to 10^{-4}
Native Sand	10^{-1} to 10^{-3}
Native Silty Clay	10^{-6} or less

10.5 Erosion control

Slope protection and drainage measures will be required to ensure the long-term stability of the embankment slopes. Vegetation should be established as soon as possible after completion of the embankments in order to control surface erosion. Erosion control for all side slopes should be in accordance with OPSS 572.

10.6 Frost Protection

The site is located in an area with a mean freezing index of between 250 and 500 Degree days ($^{\circ}\text{Days}$), (Canadian Foundation Engineering Manual). Based on Figure 3.4 of the MTO Pavement Design and Rehabilitation Manual, the frost penetration depth for this area is 1.2 m.

11.0 CLOSURE

This report has been prepared for the sole benefit of Stantec Consulting Ltd., the Ministry of Transportation and their agents, and may not be used by any third party without the express written consent of Jacques Whitford Limited, Stantec Consulting Ltd. or the Ministry of Transportation. Any use that a third party makes of this report is the responsibility of the third party.

The information presented in this report is in accordance with our present understanding of the project.

A soils investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at specific borehole locations and can only be extrapolated to an undefined limited area around the locations. The extent of the limited area depends on the variability of the soil and ground water conditions as influenced by geological processes, as well as the history of the site reflecting natural conditions, construction activities, and site use.

Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

We trust the above information meets with your present requirements. Should you have any questions or require further information, please do not hesitate to contact us at your convenience.

Yours very truly,

JACQUES WHITFORD LIMITED

Original Signed By:

Geoffrey Creer, P.Eng.
Geotechnical Engineer

Original Signed By:

Raymond Haché, P.Eng.
Principal, Geotechnical Service Director, and
Designated Principal
MTO Foundations Contact

GC/RH/dd

Enclosures

\\Markppfs04\1010xxx\$\1012607\Files for CD\Geotech Report christina Street - FINAL INVEST AND DESIGN REPORT v2.doc



APPENDIX A

Drawings

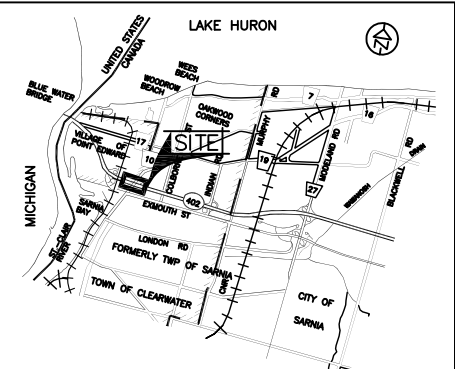
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

HWY 402
STATION —
11+200 TO 11+600



HIGHWAY 402
CHRISTINA STREET
UNDERPASS
BOREHOLE LOCATION PLAN

SHEET



N.T.S

LEGEND

- Borehole (Jacques Whitford, 2006)
- ⊕ Borehole (By Golder, 2004)
- △ Benchmark

BH No.	ELEVATION (m)	NORTHING	EASTING
CS-1	186.9	476 0877.2	313 072.4
CS-2	181.6	476 0908.3	313 107.7
CS-3	186.8	476 0940.7	313 102.6
CS-4	182.4	476 0974.3	313 133.6
CS-5	182.4	476 0953.8	313 243.0
CS-6	183.1	476 1014.9	313 255.9
CS-7	183.1	476 0961.6	313 279.1
CS-8	183.5	476 0931.3	313 327.9
R-1	183.4	476 0780.2	313 025.7
R-2	184.8	476 0821.0	313 045.6
R-3	183.7	476 0777.0	313 043.1
R-4	184.0	476 0858.0	313 093.2
R-5	183.0	476 0880.2	313 140.8
G-BH1	181.3	476 0934.8	313 086.3
G-BH2	181.6	476 0884.5	313 100.0

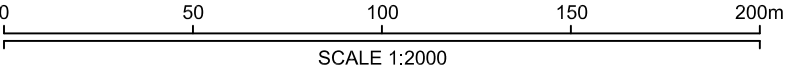
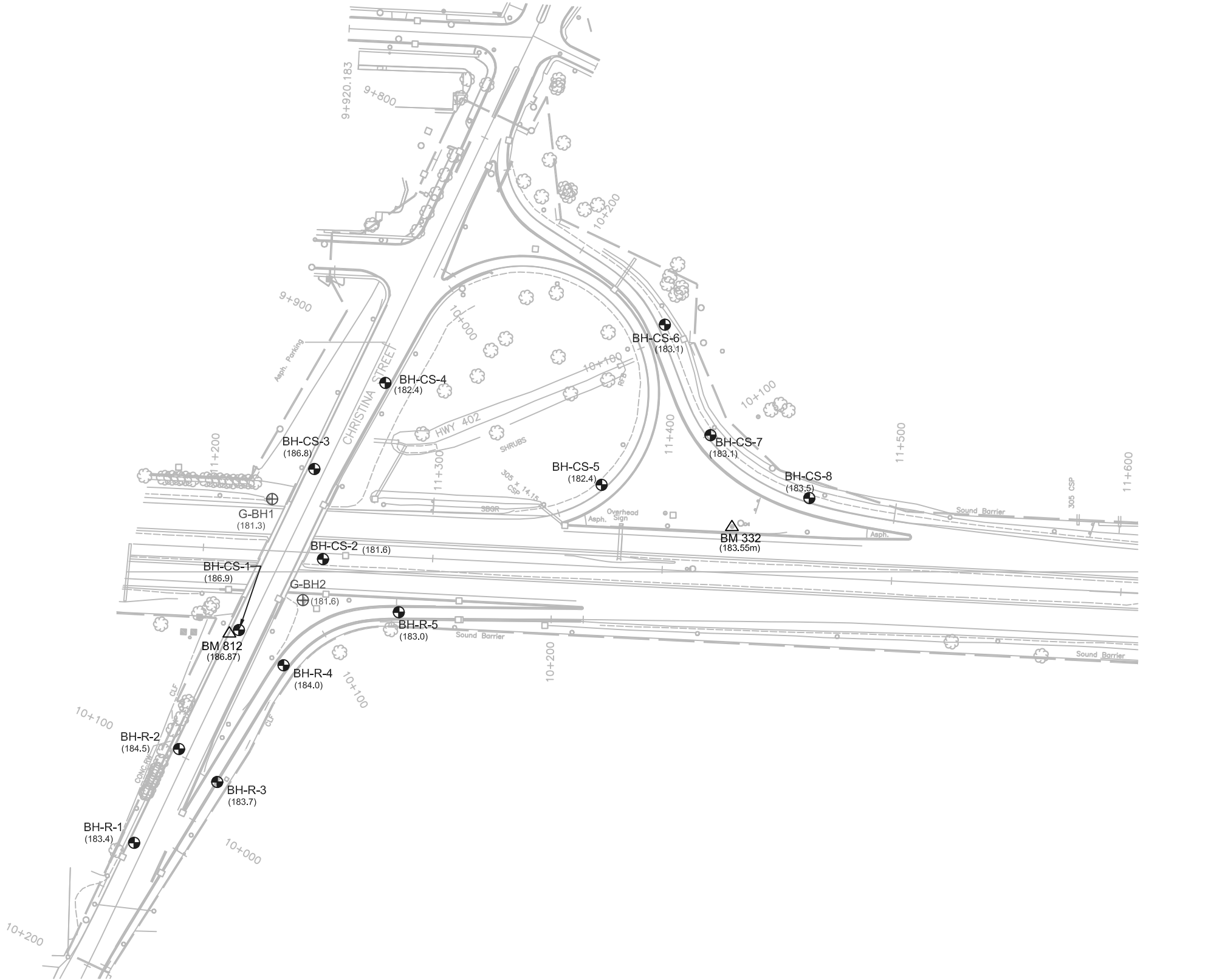
NOTE

- * Base Plan provided by Stantec Consulting.
- * Borehole locations and site features shown are approximate and may vary from that shown.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVISIONS	DATE	BY	DESCRIPTION
1	2008-09-24	GC	Initial Design

HWY No 402	SUBM'D GC	CHECKED	DATE 2008-09-24	DIST LONDON
DRAWN PC/HZ	CHECKED	APPROVED	SITE 14-37	
GEORES No 40J16-78			DWG 1012607-GE0-CS-01	

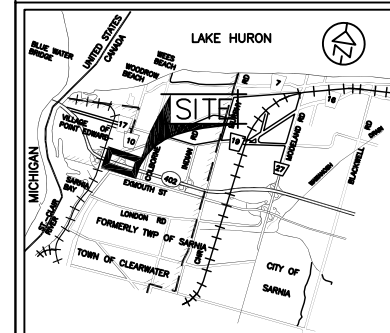


P:\1000\CHRISTINA ST\1012607-GE0-CS-01 borehole locations\20080924.dwg (Model)

HWY 402
CONT No -
WP No 3038-03-00



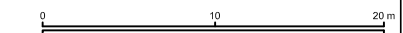
SHEET



N.T.S

- ⊕ Borehole (Jacques Whitford, 2006)
- ⊕ Borehole (By Golder, 2004)

BH No.	ELEVATION (m)	NORTHING	EASTING
CS-1	186.9	4 760 877.2	313 072.4
CS-2	181.6	4 760 908.3	313 107.7
CS-3	186.8	4 760 940.7	313 102.6
G-BH1	181.3	4 760 934.8	313 086.3
G-BH2	181.6	4 760 884.5	313 100.0



The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

3) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS					
	--	--			
DATE	BY		DESCRIPTION		
GEORES No 40J16-78					
HWY No 402			DIST LONDON		
SUBMIT'D GC			DATE 2008-09-24	SITE 14-37	
DRAWN PC/HZ			CHECKED	APPROVED	
				DWG 2	

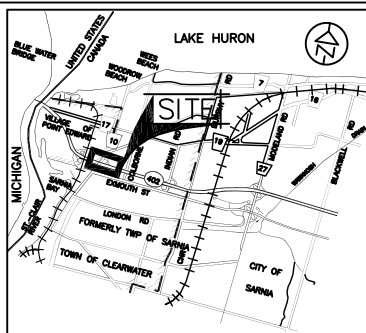
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

HWY 402
CONT No —
WP No 3038-03-00



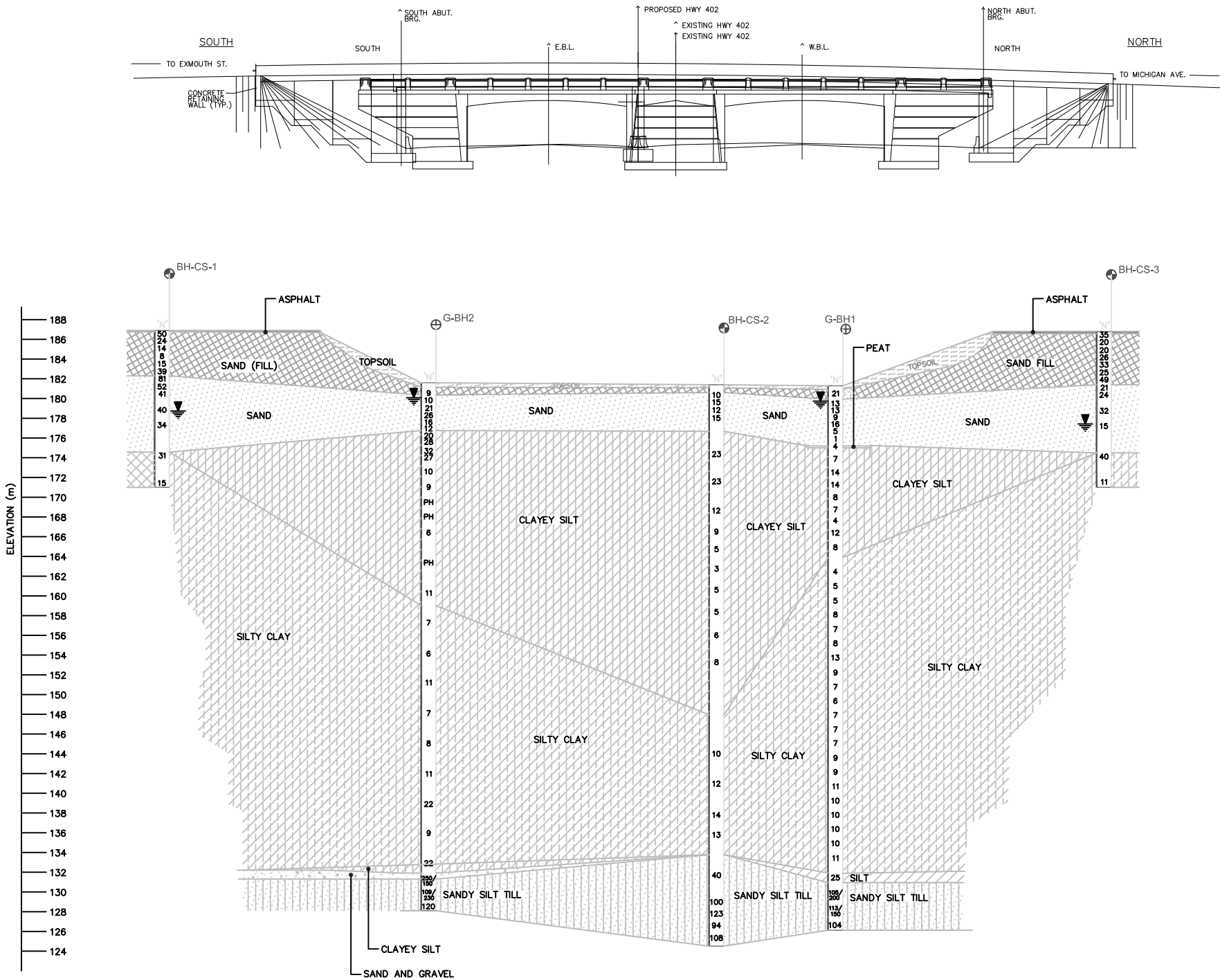
CHRISTINA STREET
UNDERPASS
SOIL STRATA SECTION A

SHEET



KEY PLAN

N.T.S

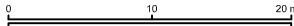


A-A SOIL PROFILE

LEGEND

- Borehole (Jacques Whitford, 2006)
- Borehole (By Golder, 2004)
- WL at time of investigation 04 03

BH No.	ELEVATION (m)	NORTHING	EASTING
CS-1	186.9	4 760 877.2	313 072.4
CS-2	181.6	4 760 908.3	313 107.7
CS-3	186.8	4 760 940.7	313 102.6
G-BH1	181.3	4 760 934.8	313 086.3
G-BH2	181.6	4 760 884.5	313 100.0



NOTES

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

- NOTES: 1) The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions.
- 2) Base plan provided by Stantec Consulting Ltd.
- 3) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS				
NO.	DATE	BY	DESCRIPTION	
1				
GEOCRES No 40J16-78				
HWY No 402				DIST LONDON
SUBM'D GC	CHECKED	DATE 2008-09-24		SITE 14-37
DRAWN PC/HZ	CHECKED	APPROVED		DWG 3

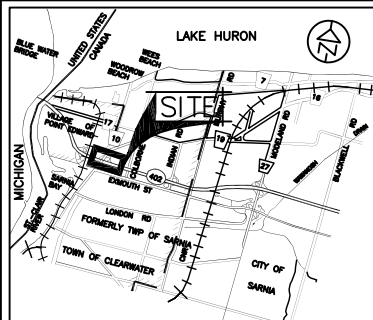
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

HWY 402
CONT No —
WP No 3038-03-00



CHRISTINA STREET
UNDERPASS
SOIL STRATA SECTION B AND C

SHEET



KEY PLAN

N.T.S.

LEGEND

- ⊕ Borehole (Jacques Whitford, 2006)
- ⊕ Borehole (By Golder, 2004)
- ↓ WL at time of investigation 04 03

BH No.	ELEVATION (m)	NORTHING	EASTING
CS-1	186.9	4 760 877.2	313 072.4
CS-3	186.8	4 760 940.7	313 102.6
G-BH1	181.3	4 760 934.8	313 086.3
G-BH2	181.6	4 760 884.5	313 100.0

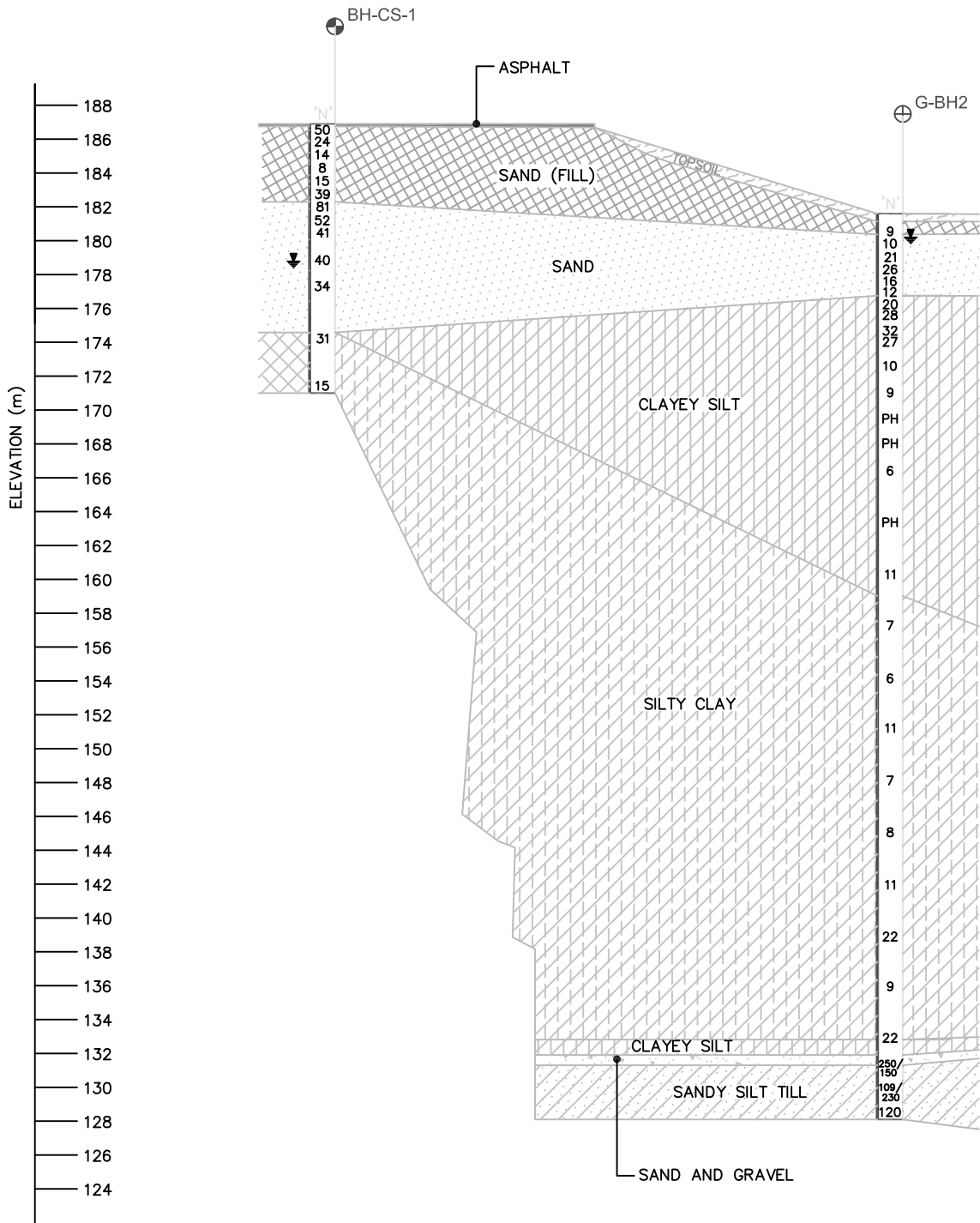
0 5 10 m

NOTES

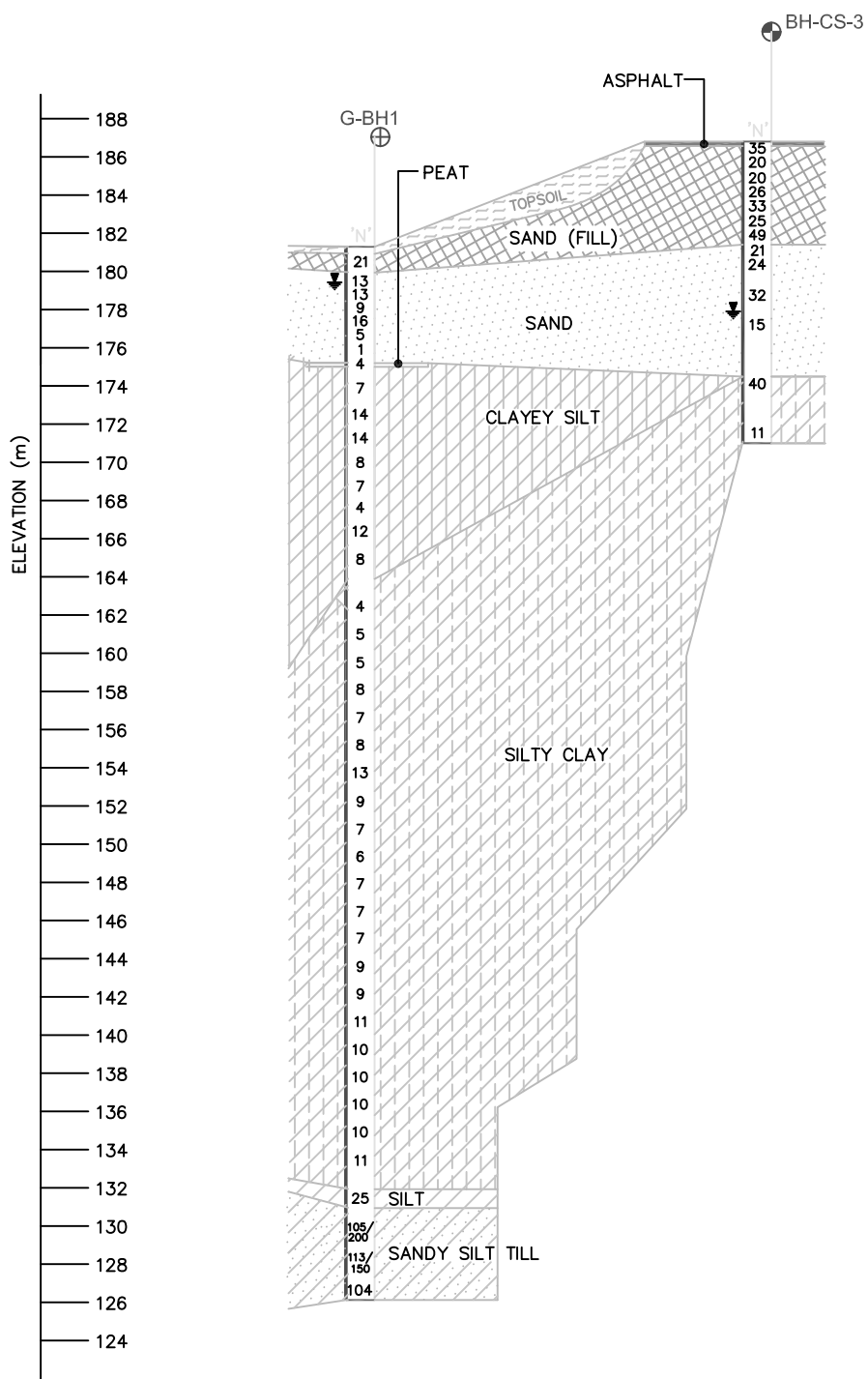
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

- NOTES: 1) The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions.
- 2) Base plan provided by Stantec Consulting Ltd.
- 3) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS	DATE	BY	DESCRIPTION
1			
GEOIDRES No 40J16-78			
HWY No 402			DIST LONDON
SUBM'D GC	CHECKED	DATE 2008-09-24	SITE 14-37
DRAWN PC/HZ	CHECKED	APPROVED	DWG 4



B-B SOIL PROFILE



C-C SOIL PROFILE

APPENDIX B

Terms and Symbols Used on the Record of Borehole Sheets
Record of Borehole Sheets

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kn/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kn/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
P	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kn/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kn/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kn/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kn/m ²	SEEPAGE FORCE
γ'	kn/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No CS-1

1 OF 2

METRIC

W.P. 3038-03-00 LOCATION Christina St. Str.: 10+035 o/s: 5.5 m Rt; N4760877.2, E313072.4 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.8.06 CHECKED BY GC

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				W _p	W	W _L			
								○ UNCONFINED	✕ FIELD VANE	● QUICK TRIAXIAL	✕ LAB VANE						WATER CONTENT (%)
186.9	Christina St S.B. D.L.						20	40	60	80	100						
186.0	150 mm ASPHALT																
0.2	SAND (FILL), trace gravel, trace silt and clay, damp, compact to dense, brown (SW) - trace gravel		1A	SS	50								○				
			1B										○				
			2	SS	24								○				
			3	SS	14								○				
	- dark brown loose		4	SS	8								○				9 86 (4)
	- brown compact		5A	SS	15								○				
			5B										○				
	- some gravel		6A	SS	39								○				
			6B										○				
182.3																	
4.6	SAND, with gravel, trace silt and clay, damp, very dense to dense, brown (SP)		7	SS	81								○				
	- trace gravel, moist		8	SS	52								○				
			9	SS	41								○				0 94 (6)
	- wet		10	SS	40									○			
	- saturated		11	SS	34									○			
174.6	- some silt		12A														
12.2	Silty CLAY, with sand, trace gravel, damp, hard to stiff, brown (CL)		12B	SS	31								●	●	○		3 32 40 25
							</										

Continued Next Page

\times^3, \times^3 : Numbers refer to Sensitivity \circ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No CS-1

2 OF 2

METRIC

W.P. 3038-03-00 LOCATION Christina St. Stn.: 10+035 o/s: 5.5 m Rt; N4760877.2, E313072.4 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.8.06 CHECKED BY GC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
								○ UNCONFINED × FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
								20	40	60	80	100		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT				
														W _p	W	W _L				
														WATER CONTENT (%)						
								20	40	60	80	100		10	20	30				

RECORD OF BOREHOLE No CS-2

1 OF 4

METRIC

W.P. 3038-03-00 LOCATION Highway 402, Stn.: 11+250 o/s: C.L.; N4760908.3, E313107.7 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Tricone, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 12.6.06 - 12.12.06 CHECKED BY GC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT 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 (%)				GR	SA	SI	CL
								<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>					
181.6	Hwy 402 Median Ditch																	
0.0	SAND (FILL), trace silt, trace gravel, trace organic matter, moist, brown (SW)						181											
180.8							180											
0.8	SAND, some silt, trace gravel, wet, compact, brown (SP)		1	SS	10													
			2	SS	15													
179.3																		
2.3	Silty SAND, trace organic matter, wet, compact, grey (SM)		3	SS	12		179											
			4	SS	15													
							178											
							177											
176.9			5a															
4.7	Clayey SILT, trace gravel, trace sand, wet, very stiff, grey (CL)		5b	SS	23													
							176											
			6	SS	23		175											
	- stiff		7	SS	12		174											
							173											
			8	SS	9		172											
	- firm		9	SS	5		171											
			10	TW			170											
	- soft		11	SS	3		169											
							168											
							167											

Continued Next Page

\times^3, \times^3 : Numbers refer to Sensitivity \bigcirc 3% STRAIN AT FAILURE

METRIC

Continued Next Page

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

 $\bigcirc^{3\%}$ STRAIN AT FAILURE

ONTARIO MOT 1012607.GPJ ONTARIO MOT.GDT 11/19/08

METRICContinued Next Page

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

 $\bigcirc^{3\%}$ STRAIN AT FAILURE

METRIC

W.P.	3038-03-00	LOCATION	Highway 402, Strn.: 11+250 o/s: C.L.; N4760908.3, E313107.7	ORIGINATED BY	KH
DIST	London	HWY	402	BOREHOLE TYPE	Hollow Stem Auger, Tricone, Split Spoon
				COMPILED BY	MW
DATUM	Geodetic	DATE	12.6.06 - 12.12.06	CHECKED BY	GC

[illegible]

RECORD OF BOREHOLE No CS-3

1 OF 2

METRIC

W.P. 3038-03-00 LOCATION Christina St. Str.: 9+965 o/s: 5.5 m Rt; N4760940.7, E313102.6 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.8.06 CHECKED BY GC

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			SHEAR STRENGTH kPa					WATER CONTENT (%)										
								○ UNCONFINED		✕ FIELD VANE			● QUICK TRIAXIAL						✕ LAB VANE				
								20	40	60	80	100	W _p						W	W _L			
186.8	Christina St S.B. D.L.																						
186.0	200 mm ASPHALT																						
0.2	SAND (FILL), trace gravel, trace silt and clay, moist, compact to dense, brown (SW)		1A	SS	35																		
	- trace gravel		1B	SS	20																		
			2	SS	20		186																
	- some gravel		3	SS	20		185									18	76	(6)					
			4	SS	26		184																
	- trace organic matter		5	SS	33		183																
	- some organic matter		6	SS	25		182																
	- 50 mm black sand seam		7	SS	49																		
181.5																							
5.3	SAND, Brown, trace gravel, trace silt and clay, moist, compact to dense, brown (SP)		8	SS	21		181																
			9	SS	24		180																
	- trace silt, wet		10	SS	32		179																
178.1																							
8.7	- grey						178																
	- some silt and clay		11	SS	15		177										0	89 (12)					
	- compact						176																
							175																
174.6																							
12.2	Silty CLAY, with sand, trace gravel, damp, hard to stiff, brown (CL)		12	SS	40		174																
							173																
172.4																							
14.5	- grey, wet						172																
	Stiff																						

Continued Next Page

\times^3, \times^3 : Numbers refer to Sensitivity \circ^3 STRAIN AT FAILURE

RECORD OF BOREHOLE No CS-3

2 OF 2

METRIC

W.P. 3038-03-00 LOCATION Christina St. Stn.: 9+965 o/s: 5.5 m Rt; N4760940.7, E313102.6 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.8.06 CHECKED BY GC

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 (%)				GR	SA	SI	CL	
								20 40 60 80 100		W _p	W	W _L						
								○ UNCONFINED × FIELD VANE										
								● QUICK TRIAXIAL × LAB VANE										
								20 40 60 80 100		10	20	30						

RECORD OF BOREHOLE No CS-4

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. Stn.: 9+925 o/s: 8.0 m Lt; N4760974.3, E313133.6 ORIGINATED BY JP
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 10.31.06 CHECKED BY GC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)			
								○ UNCONFINED × FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
182.4	Christina St N.B. D.L.							20	40	60	80	100						GR	SA	SI	CL
180.0	180 mm ASPHALT																				
0.2	SAND (FILL), with gravel, some silt and clay, damp, dense to very dense, brown (SW)		1	SS	36		182							○				37	51	(12)	
	- trace gravel, moist		2	SS	19		181														
	- trace silt and clay, trace organic matter		3	SS	17		180							○				10	83	(7)	
			4	SS	15																
	- loose		5	SS	6		179														
	- some gravel		6	SS	6		178														
	- very loose - some organic matter		7	SS	4																
177.0	SAND, some silt and clay, moist, compact to dense, brown (SP)		8	SS	22		177								○			0	86	(13)	
5.3	- wet		9	SS	26		176														
175.5	- grey		10	SS	33		175														
6.9			11	SS	18		174														
172.9	Silty CLAY, some sand, trace gravel, moist, stiff to very stiff, grey (CL)		12	SS	17		173							●	●	●		3	17	42	38
9.4							172														
			13	SS	30		171														
							170														
169.6			14	SS	11																
12.8	END OF BOREHOLE at approximately 12.8 m																				
	Groundwater measured at a depth of approximately 6.1 m (Elev. 176.3 m) on completion of drilling.																				

\times^3, \times^3 : Numbers refer to Sensitivity \circ^3 STRAIN AT FAILURE

ONTARIO MOT 1012607.GPJ ONTARIO MOT.GDT 11/19/08

RECORD OF BOREHOLE No CS-6

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. E-N Ramp Str.: 10+160 o/s: 4.0 m Rt; N4761014.9, E313255.9 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.10.06 CHECKED BY GC

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







×³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No CS-7

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. E-N Ramp Stn.: 10+100 o/s: 4.0 m Rt; N4760961.6, E313279.1 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.10.06 CHECKED BY GC



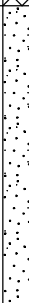

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W _p W W _L				GR	SA	SI	CL							
								20	40	60	80	100	20	40						60	80	100	10	20	30	
183.1	Christina St E-N Ramp, Rt. Shoulder		1	SS	24		182									28	67	(5)								
0.0	SAND (FILL), with gravel, trace silt and clay, trace asphalt fragment, moist, compact, brown (SW)		2	SS	12																					
181.5																										
1.5	SAND, trace gravel, trace silt and clay, moist, compact to dense, brown (SP)		3	SS	11			181													0	90	(10)			
			4	SS	30																					
	- no gravel, wet		5	SS	32																					
			6	SS	36																					
178.5	- grey		7	SS	34				179																	
4.6																										
177.4					178																					
5.6	Silty CLAY, some sand, trace gravel, moist, hard, grey (CL)		8	SS		36	177																			
	- trace gravel and sand																									
174.8			9	SS		42		176																		
8.2	END OF BOREHOLE at approximately 8.2 m																									
	Water first encountered on spoon at a depth of approximately 3.0 m (180.1 m) below grade					175																				
	Borehole caved to a depth of approximately 2.6 m (Elev. 180.5 m) on completion of drilling																									

RECORD OF BOREHOLE No CS-8

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. E-N Ramp Str.: 10+040 o/s: 3.5 m Rt; N4760931.3, E313327.9 ORIGINATED BY KH
DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
DATUM Geodetic DATE 11.10.06 CHECKED BY GC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED ✕ FIELD VANE ● QUICK TRIAXIAL ✕ LAB VANE												
183.5	Christina St E-N Ramp, Rt. Shoulder		1	SS	23		183										1 95 (4)			
0.0	SAND (FILL), with gravel, trace silt, damp, compact to dense, brown (SW)		2	SS	38		182													
	- trace silt																			
181.9			3	SS	16		181													
1.5	SAND, trace gravel, trace silt and clay, moist, compact to dense, brown (SP)		4	SS	26		180													
	- wet		5	SS	26		179													
			6	SS	36		178													
178.9	- grey, some silt and clay, no gravel		7	SS	33		177													
4.6							176													
177.8			8	SS	24															
5.6	Silty CLAY, some sand, trace gravel, wet, very stiff, grey (CL)																			
	- trace sand		9	SS	29															
175.2																				
8.2	END OF BOREHOLE at approximately 8.2 m																			
	Water first encountered on spoon at a depth of approximately 4.0 m (179.5 m) below grade																			
	Borehole caved to a depth of approximately 2.9 m (Elev. 180.6 m) on completion of drilling																			

RECORD OF BOREHOLE No R-1

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. Str.: 10+145 o/s: 5.5 m Rt; N4760780.2, E313025.7 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.9.06 - 11.9.06 CHECKED BY GC

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						
								20 40 60 80 100						
								○ UNCONFINED ✕ FIELD VANE ● QUICK TRIAXIAL ✕ LAB VANE						
							WATER CONTENT (%)							
							w _p w w _L							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT							
183.4	Christina St S.B. D.L.													
180.0	150 mm ASPHALT													
0.2	SAND (FILL), some gravel, trace silt, trace organic matter, damp, very dense to compact, brown (SW)		1	SS	88		183							
	- augers grinding on possible cobble or boulder		2	SS	19									
			3A	SS			182							
	- trace gravel		3B	SS	10									
181.1														
2.3	SAND, trace gravel, trace silt and clay, moist, dense, brown (SP)		4	SS	31		181							
	- saturated		5	SS	37		180							
			6	SS	34		179							
			7	SS	33									
177.8							178							
5.6	- grey		8	SS	39		177							
							176							
175.8	Clayey SILT, some sand, wet, very soft to firm, grey (CL)		9	SS	2		175							
	- trace sand		10	SS	5		174							
173.7														
9.8	END OF BOREHOLE at approximately 9.8 m Water first encountered on spoon at a depth of approximately 4.0 m (179.4 m) below grade Borehole caved to a depth of approximately 3.3 m (Elev. 180.1 m) on completion of drilling													

Numbers refer to
Sensitivity

STRAIN AT FAILURE

RECORD OF BOREHOLE No R-2

1 OF 2

METRIC

W.P. 3038-03-00 LOCATION Christina St. Str.: 10+100 o/s: 5.5 m Rt; N4760821.0, E313045.6 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.9.06 - 11.9.06 CHECKED BY GC

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 (%)			GR	SA	SI	CL	
								○ UNCONFINED ✕ FIELD VANE ● QUICK TRIAXIAL ✕ LAB VANE												
184.8	Christina St S.B. D.L.							20	40	60	80	100								
184.6	150 mm ASPHALT																			
0.2	SAND (FILL), some gravel, trace silt and clay, moist, dense, brown (SW)		1	SS	44															
184.0							184													
183.8	150 mm Silty CLAY (FILL), some sand, trace gravel, damp, grey (CL)		2A	SS																
0.9	SAND (FILL), trace gravel, trace silt and clay, moist, compact, brown (SW)		2B	SS	29															
183.3																				
183.2	100 mm Silty CLAY (FILL), some sand, trace gravel, damp, grey (CL)		3A	SS			183													
1.6	SAND (FILL), trace gravel, trace silt and clay, moist, compact, brown (SW)		3B	SS	17															
182.5																				
2.3	SAND, some gravel, trace silt and clay, moist, dense to compact, brown (SP)		4A	SS			182													
			4B	SS	52															
			5	SS	25		181										10 88 (2)			
			6	SS	26															
			7	SS	30		180													
179.2	- grey						179													
5.6			8	SS	31															
							178													
			9	SS	12		177													
							176													
175.6			10A	SS																
9.2	Silty CLAY, trace gravel, trace sand, damp, hard to very stiff, grey (CL)		10B	SS	40		175										21.3			
							174													
							173													
			11	SS	17		172													
							171													
	- some sand, wet Stiff						170													

Continued Next Page


Numbers refer to Sensitivity \times^3, \times^3 \circ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No R-2

2 OF 2

METRIC

W.P. 3038-03-00 LOCATION Christina St. Stn.: 10+100 o/s: 5.5 m Rt; N4760821.0, E313045.6 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.9.06 - 11.9.06 CHECKED BY GC


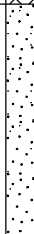

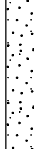

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
						20	40	60	80	100	W _p	W	W _L			
						○ UNCONFINED × FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
						20	40	60	80	100	10	20	30			
168.9	Silty CLAY, trace gravel, trace sand, damp, hard to very stiff, grey (CL) (continued)		12	SS	8										2 16 45 38	
15.8	END OF BOREHOLE at approximately 15.8 m Water first encountered on spoon at a depth of approximately 6.1 m (178.7 m) below grade Borehole caved to a depth of approximately 4.4 m (Elev. 180.4 m) on completion of drilling															

RECORD OF BOREHOLE No R-3

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. S-E Ramp Stn.: 9+985 o/s: 3.0 m Rt; N4760777.0, E313043.1 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.10.06 - 11.10.06 CHECKED BY GC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			GR	SA	SI	CL			
								○ UNCONFINED × FIELD VANE																		
								● QUICK TRIAXIAL × LAB VANE																		
183.7 0.0	Christina St S-E Ramp, Rt. Shoulder SAND (FILL), with gravel, some silt, some organic matter, moist, compact, brown (SW)		1	SS	17		183																			
			2	SS	15																					
182.0 1.7	SAND, trace gravel, trace silt and clay, moist, compact, brown (SP)		3	SS	14		182									3	95	(2)								
			4	SS	24		181																			
			5	SS	24		180																			
179.6 4.1	- grey, wet		6	SS	21		179																			
							178																			
	- some silt and clay		7	SS	14		177									1	88	(11)								
							176																			
175.8 7.9	Silty CLAY, trace gravel, trace sand, moist, hard, grey (CL)		8	SS	39		175																			
							174																			
173.9 9.8	END OF BOREHOLE at approximately 9.8 m Water first encountered on spoon at a depth of approximately 4.6 m (179.1 m) below grade Borehole caved to a depth of approximately 3.5 m (Elev. 180.2 m) on completion of drilling																									

\times^3, \times^3 : Numbers refer to Sensitivity \circ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No R-4

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. S-E Ramp Stn.: 10+077 o/s: 2.0 m Rt; N4760858.0, E313093.2 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.10.06 - 11.10.06 CHECKED BY GC

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					W _p W W _L				GR	SA	SI	CL	
								20 40 60 80 100					20 40 60 80 100								
184.0	Christina St S-E Ramp, D.L.																				
180.0	180 mm ASPHALT																				
0.2	SAND (FILL), some silt, some organic matter, trace gravel, trace clay, moist, compact, brown (SW)		1	SS	30																
183.1	SAND, trace gravel, trace silt and clay, moist, compact to dense, brown (SP)		2	SS	23																
0.9			3	SS	37																
			4	SS	14																
			5	SS	23																
179.9	- grey																				
4.1	- wet		6	SS	33																
	- some silt		7	SS	27																
176.1	Silty CLAY, trace gravel, trace sand, moist, hard, grey (CL)																				
7.9																					
			8	SS	43																
174.2	END OF BOREHOLE at approximately 9.8 m																				
9.8	Water first encountered on spoon at a depth of approximately 4.0 m (180.0 m) below grade																				
	Borehole caved to a depth of approximately 3.7 m (Elev. 180.3 m) on completion of drilling																				

Numbers refer to Sensitivity
 STRAIN AT FAILURE

RECORD OF BOREHOLE No R-5

1 OF 1

METRIC

W.P. 3038-03-00 LOCATION Christina St. S-E Ramp Stn.: 10+133 o/s: 2.0 m Rt; N4760880.2, E313140.8 ORIGINATED BY KH
 DIST London HWY 402 BOREHOLE TYPE Hollow Stem Auger, Split Spoon COMPILED BY MW
 DATUM Geodetic DATE 11.10.06 - 11.10.06 CHECKED BY GC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)					
183.0	Christina St S-E Ramp, D.L.					▽								GR SA SI CL	
182.0	200 mm ASPHALT														
0.2	SAND (FILL), some gravel, trace silt and clay, moist, very dense, brown (SW)		1	SS	60										
182.1	SAND, some gravel, trace silt and clay, moist, very dense to compact, brown (SP)		2	SS	52		182								16 80 (4)
0.9															
			3	SS	37		181								
			4	SS	29		180								
	- wet		5	SS	30	179									
178.9	- grey		6	SS	26	178									
177.4						177									
5.6	Silty CLAY, trace gravel, trace sand, wet, stiff to very stiff, grey (CL)		7	SS	14	176									
						175									
						174									
	- with sand, moist		8	SS	22						W _n = 14%		7 28 40 24		
173.3	END OF BOREHOLE at approximately 9.8 m														
9.8	Water first encountered on spoon at a depth of approximately 3.5 m (179.5 m) below grade														
	Borehole caved to a depth of approximately 3.0 m (Elev. 180.0 m) on completion of drilling														

×³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>041-130099-2</u>	RECORD OF BOREHOLE No BH1	1 OF 4	METRIC
G.W.P. <u>3038-03-00</u>	LOCATION <u>N 4760934.8 : E 313088.3</u>	ORIGINATED BY <u>MA</u>	
DIST <u>1</u> HWY <u>402</u>	BOREHOLE TYPE <u>POWER AUGER/HOLLOW STEM & MUD ROTARY</u>	COMPILED BY <u>BG</u>	
DATUM <u>GEODETIC</u>	DATE <u>July 12, 2004 - July 15, 2004</u>	CHECKED BY <u><i>[Signature]</i></u>	

[illegible]

Continued Next Page

+ 3, X 3; Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 041-130099-2

RECORD OF BOREHOLE No BH1

2 OF 4

METRIC

G.W.P. 3038-03-00

LOCATION N 4760934.8 E 313088.3

ORIGINATED BY MA

DIST 1 HWY 402

BOREHOLE TYPE POWER AUGER/HOLLOW STEM & MUD ROTARY

COMPILED BY BG

DATUM GEODETIC

DATE July 12, 2004 - July 15, 2004

CHECKED BY *RJB*

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			20	40	60	80	100		
	CLAYEY SILT, trace to some sand, trace to some gravel Firm to very stiff Grey		15	SS	12		166							
			16	SS	8		165							
163.92							164							
17.37	SILTY CLAY, trace sand, trace gravel, Firm to stiff, Grey		17	SS	4		163							
			18	SS	5		162							
			19	SS	5		161							
			20	SS	8		160							
			21	SS	7		159							
			22	SS	8		158							
			23	SS	13		157							
			24	SS	9		156							
							155							
							154							
							153							
							152							

ON MTO 041-130099-2.GPJ ON MOT.GDT 10/12/05

Continued Next Page

+3, x3: Numbers refer to Sensitivity
○ 3% STRAIN AT FAILURE

METRIC

PROJECT 041-130099-2

G.W.P. 3038-03-00

LOCATION

N 4760934.8;E 313086.3

ORIGINATED BY MA

DIST 1

HWY 402

BOREHOLE TYPE

POWER AUGER/HOLLOW STEM & MUD ROTARY

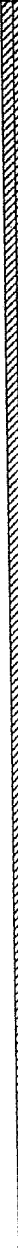

COMPILED BY BG

DATUM GEODETIC

DATE _____

July 12, 2004 - July 15, 2004

CHECKED BY AK

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			SHEAR STRENGTH kPa		WATER CONTENT (%)					
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x LAB VANE	w _p	w	w _L			
						20 40 60 80 100	20 40 60 80 100	10 20 30							
	SILTY CLAY, trace sand, trace gravel, Firm to stiff, Grey		25	SS	7										
			26	SS	8										
			27	SS	7										
			28	SS	7										
			29	SS	7										
			30	SS	9										
			31	SS	9										
			32	SS	11										
			33	SS	10										
138.01	SILTY CLAY, trace sand, Firm to stiff, Grey														
43.28															
			34	SS	10										

IN MTO 041-130099-2.GPJ ON MOT.GDT 10/2/05

5 53 42

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

O^{3%} STRAIN AT FAILURE

PROJECT <u>041-130099-2</u>		RECORD OF BOREHOLE No BH1		4 OF 4	METRIC
G.W.P. <u>3038-03-00</u>	LOCATION <u>N 4780934.8 E 313085.3</u>	ORIGINATED BY <u>MA</u>			
DIST <u>1</u> HWY <u>402</u>	BOREHOLE TYPE <u>POWER AUGER/HOLLOW STEM & MUD ROTARY</u>	COMPILED BY <u>BG</u>			
DATUM <u>GEODETIC</u>	DATE <u>July 12, 2004 - July 15, 2004</u>	CHECKED BY <u>[Signature]</u>			

[illegible]

+ 3, X 3; Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH2

1 OF 4

METRIC

PROJECT 041-130099-2

G.W.P. 3038-03-00

LOCATION N 4761884.5 E 313100.0

ORIGINATED BY MA

DIST 1 HWY 402

BOREHOLE TYPE POWER AUGER/HOLLOW STEM & MUD ROTARY/TRI-CONE

COMPILED BY BG

DATUM GEODETIC

DATE July 19, 2004 - July 20, 2004

CHECKED BY *[Signature]*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)			
								20	40	60						80	100	20	40
181.59	GROUND SURFACE																		
0.00	TOPSOIL, sandy, some gravel, Brown																		
181.16																			
0.43	FILL, fine to medium sand, some gravel, trace silt, Loose, Brown		1	SS	9														
180.37																			
1.22	SAND, fine, trace to some silt layered Compact, Brown becoming grey at about elev. 178.0m		2	SS	10														
			3	SS	21														
			4	SS	26														
			5	SS	16														
			6	SS	12														
175.71																			
4.88	CLAYEY SILT, trace to some sand, trace gravel, Firm to very stiff, Brown becoming grey at about elev. 173.4m		7	SS	20														
			8	SS	28														
			9	SS	32														
			10	SS	27														
			11	SS	10														
			12	SS	9														
			13	TO	PH														
			14	TO	PH														

Continued Next Page

+ ³/₃ × ³/₃ Numbers refer to Sensitivity

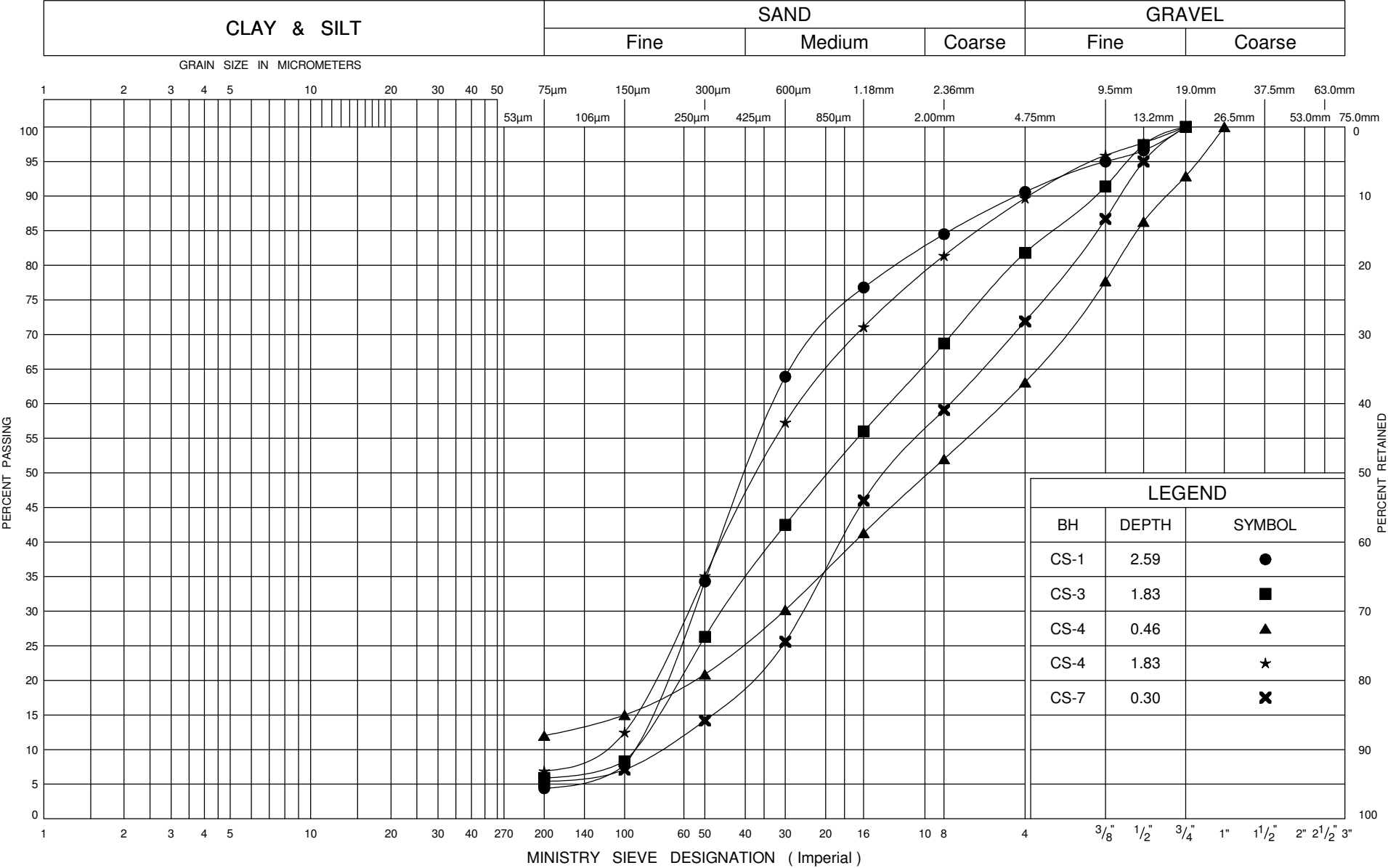
○ 3% STRAIN AT FAILURE

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

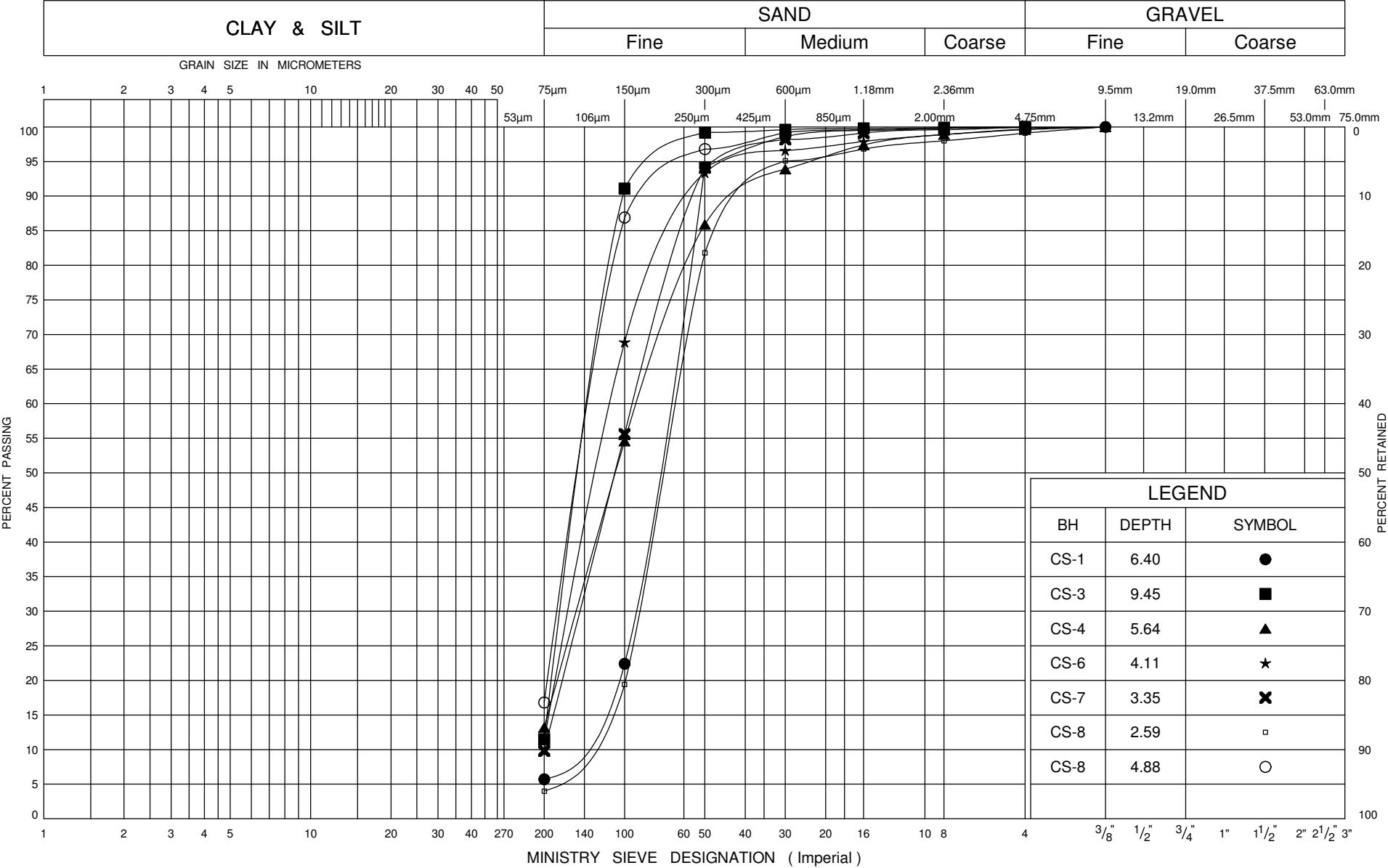
APPENDIX C

Geotechnical Laboratory Test Results

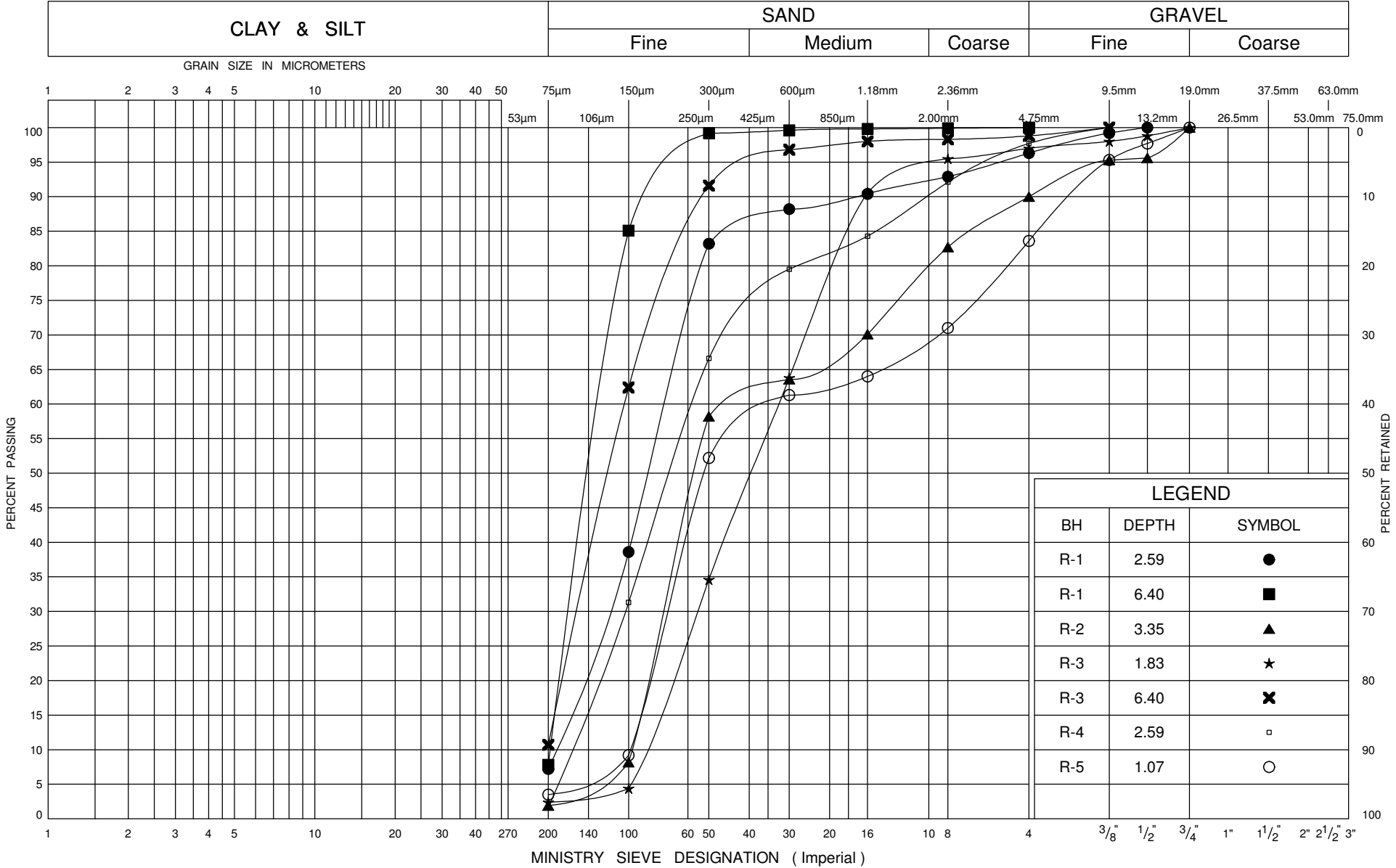
UNIFIED SOIL CLASSIFICATION SYSTEM



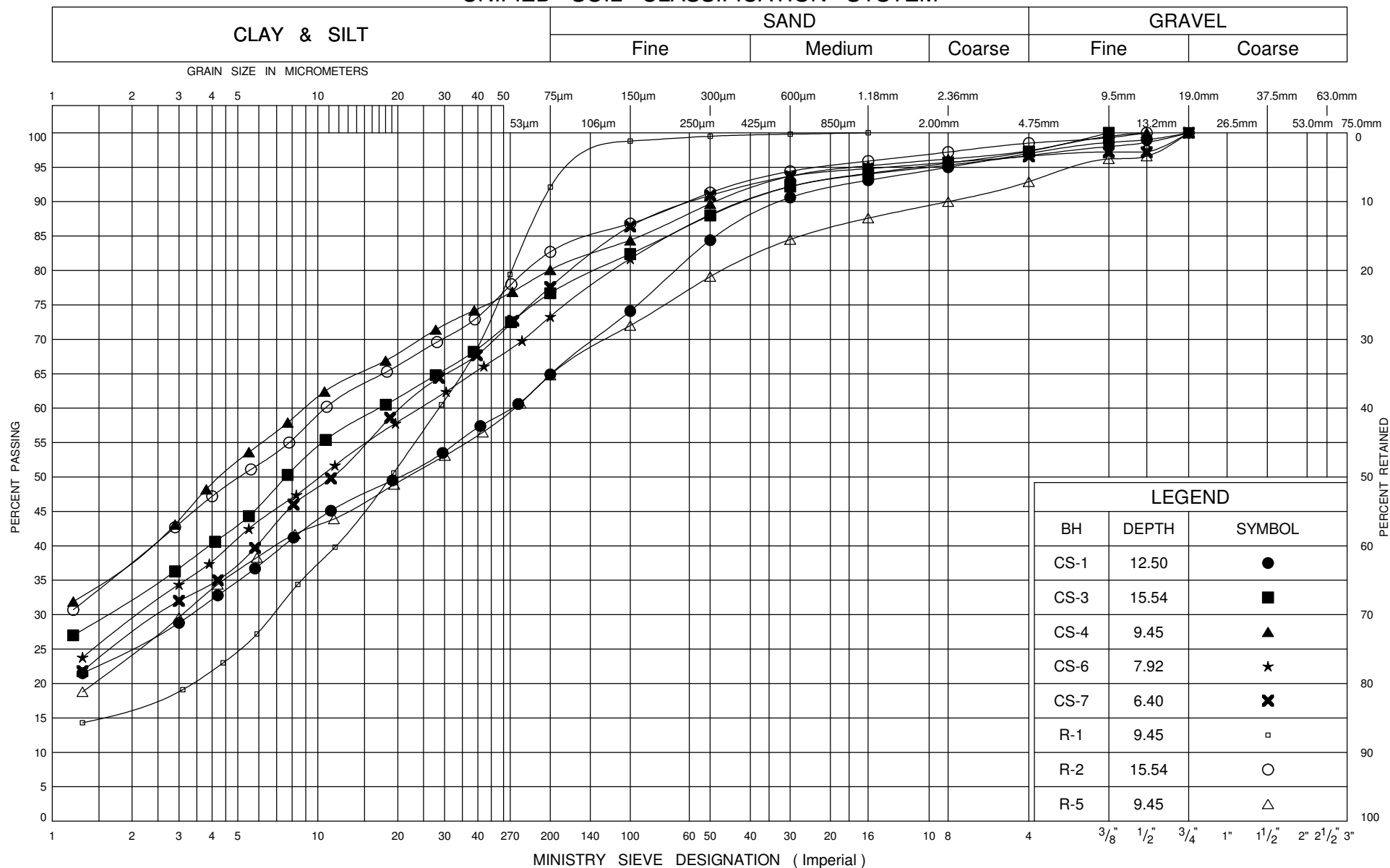
UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

Clayey SILT/ Silty CLAY

FIG No 4

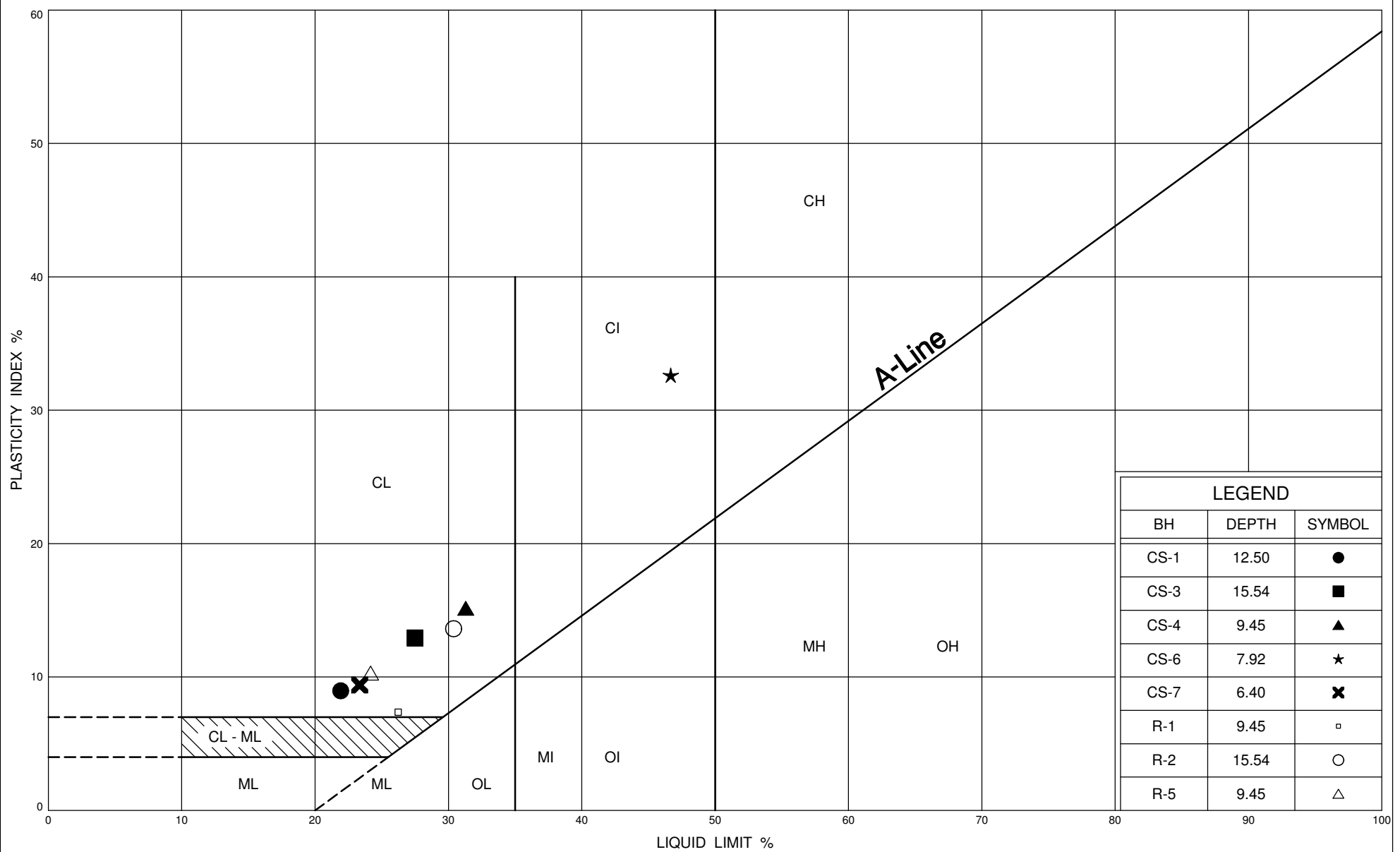
W P 3038-03-00

Hwy 402, Township of Sarnia



Ministry of
Transportation

Ontario



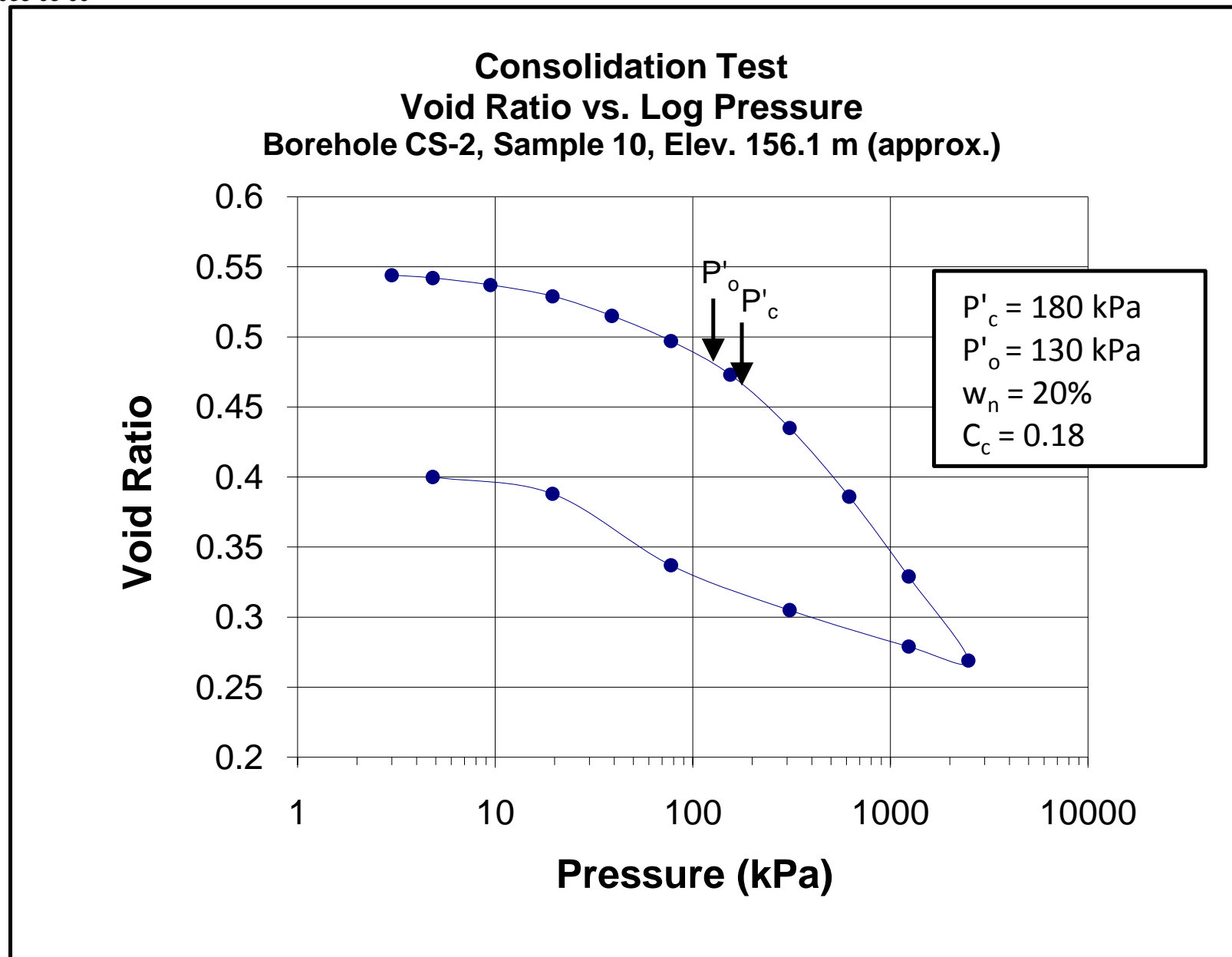


Figure 6



**Jacques Whitford
Limited**

7271 Warden Ave,
Markham, Ontario
L3R 5X5
Tel: (905) 474 -7700
Fax: (905) 479-9326

**Density/Bulk Unit Weight
Of Soil Specimen**

Figure 7

Clint: Stantec/MTO

Project No.: 1012607

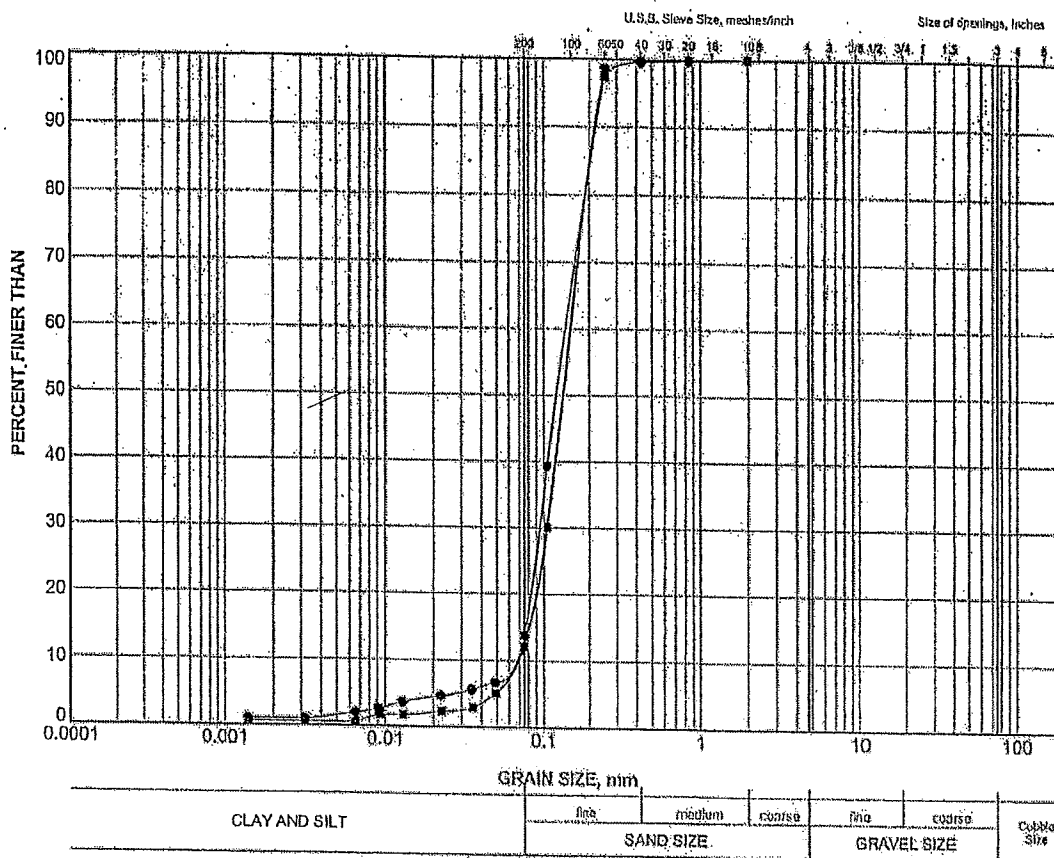
**Location: Highway 402 Underpass at Christina Street
Sarnia, Ontario**

	<i>Unit</i>		1	2	3
Borehole No.			BH R4-8	BH CS4-13	BH R2-10B
Mass of soil specimen in air	<i>gms</i>	A	138.6	96.3	97.1
Mass of soil specimen in liquid (oil)	<i>gms</i>	B	83.3	58.4	58.1
Mass of Liquid displaced	<i>cc</i>	C=(A-B)	55.3	37.9	39.0
Specific Gravity of Liquid (oil)		γ_L	0.8714	0.8714	0.8714
Density of soil sample	<i>Kg/m³</i>	$D = \frac{1000A * \gamma_L}{(A-B)}$	2184	2214	2170
Unit Weight of soil sample	<i>KN/m³</i>	$U = \frac{U}{D * 0.009807}$	21.4	21.7	21.28

APPENDIX D

Laboratory Test Results - Preliminary Foundation Investigation Report

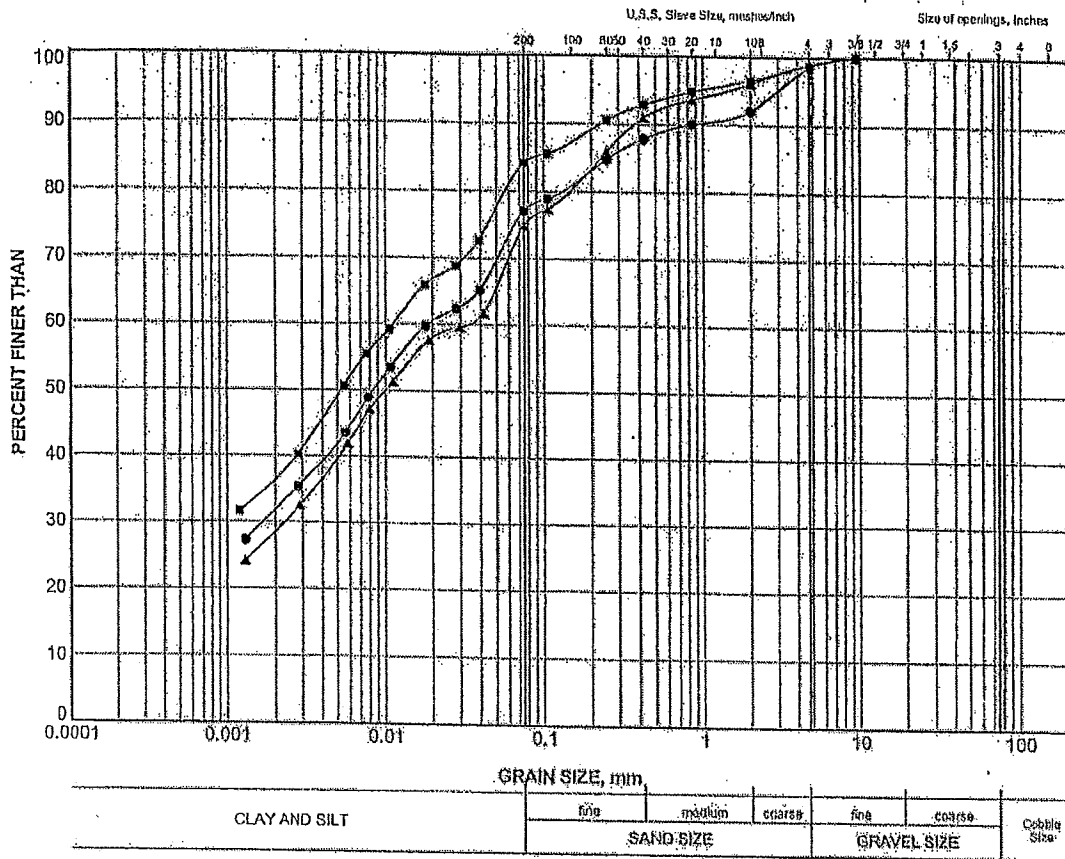




LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
•	BH1	4	178.0
■	BH2	2	179.8

PROJECT					
CHRISTINA STREET UNDERPASS REPLACEMENT					
GWP 3038-03-00					
HWY 402					
TITLE					
GRAIN SIZE DISTRIBUTION					
FINE SAND					
 Golder Associates LONDON, ONTARIO	PROJECT No.	011-120029	FILE No.	011-120029-GP1	
	DRAWN	WDF	SEP 14/04	SCALE	N/A
	CHECK	BY	Oct 1/04	REV.	
			FIGURE A-1		

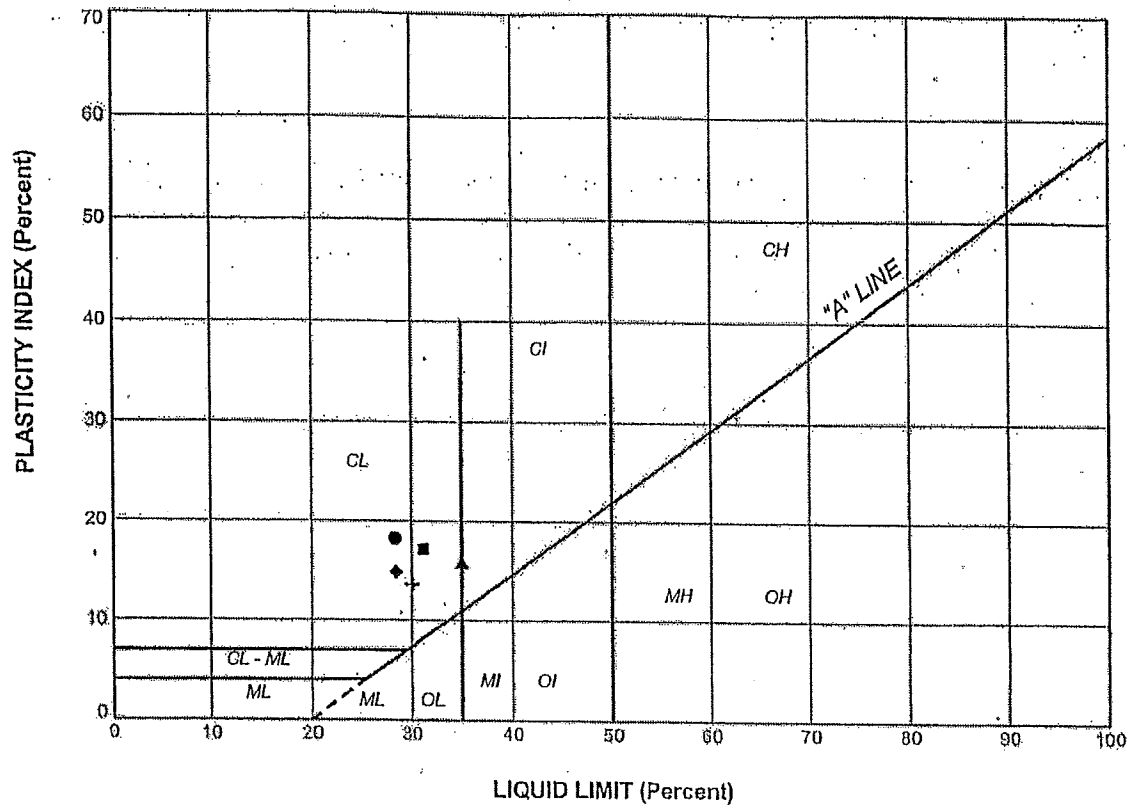
LEN 370 NEW GDR 12/4/02



LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH1	11	172.0
■	BH1	14	167.6
▲	BH2	9	174.6

PROJECT					
CHRISTINA STREET UNDERPASS REPLACEMENT					
GWP 3038-03-00					
HWY 402					
TITLE					
GRAIN SIZE DISTRIBUTION					
CLAYEY SILT					
PROJECT No.		041-100289		PLAN No.	
DRAWN		WGF		041-100289-2.GPJ	
CHECK		HJ		SCALE NA	
		Sup 11/04		REV	
		012-0165		FIGURE A-2	





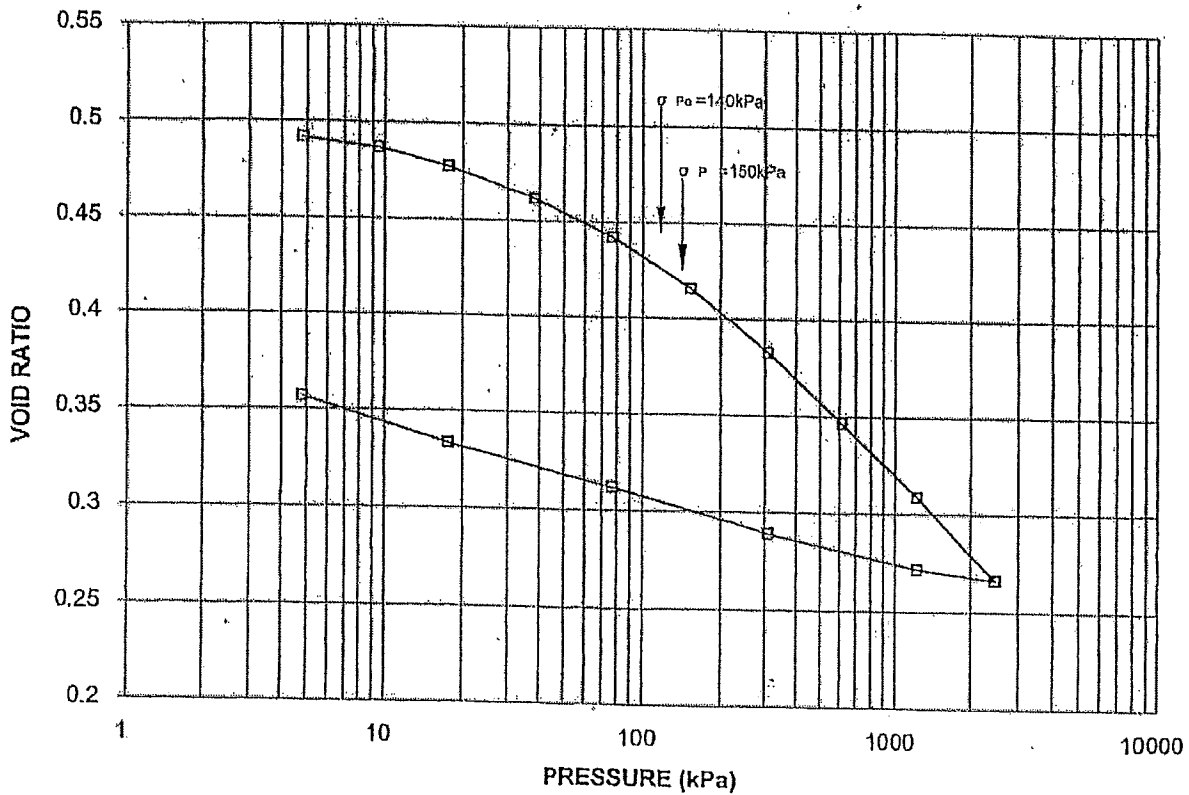
SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)	LL(%)	PL(%)	PI
●	BH1	10	173.8	28.4	10.2	18.2
■	BH1	15	166.4	31.2	14.1	17.1
▲	BH2	8	175.8	35.0	19.2	15.8
+	BH2	12	171.2	30.1	16.5	13.6
+	BH2	13	169.7	28.5	13.7	14.8


PROJECT CHRISTINA STREET UNDERPASS REPLACEMENT GWP 3038-03-00 HWY 402			
TITLE PLASTICITY CHART (Clayey Silt)			
PROJECT No. 011-100000-2		FILE No. 011-100000-2 (UP)	
DESIGNED BY	DATE	SCALE	REV.
CHECKED BY	DATE		
Golder Associates LONDON, ONTARIO		FIGURE A-3	

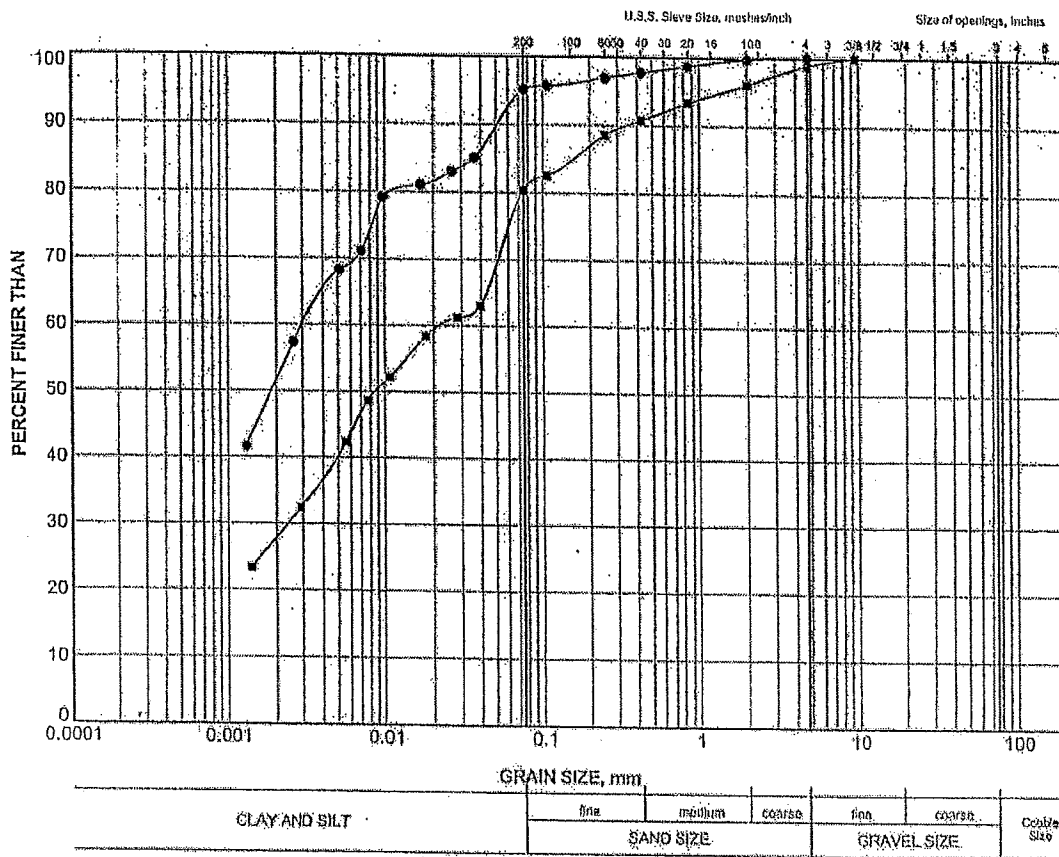


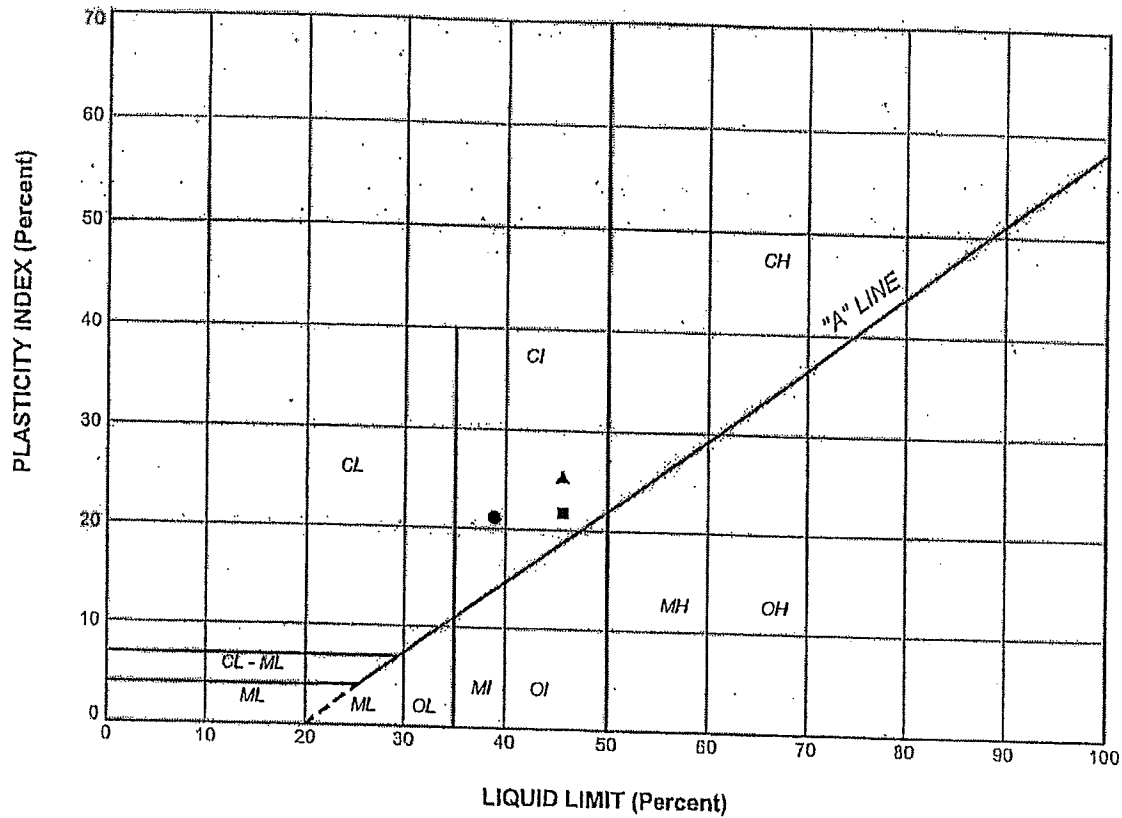
BOREHOLE 2, SAMPLE 13, ELEV. 169.5m

NOTE

- 1) THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT			
CHRISTINA STREET UNDERPASS REPLACEMENT			
GWP 3038-03-00			
HWY 402			
TITLE			
CONSOLIDATION TEST			
VOID RATIO VS. LOG PRESSURE			
PROJECT No. 041-130000-2		FILE No. 041130000-2004	
SCALE AS SHOWN		REV. 0	
 Golder Associates LONDON, ONTARIO		FIGURE A-4	

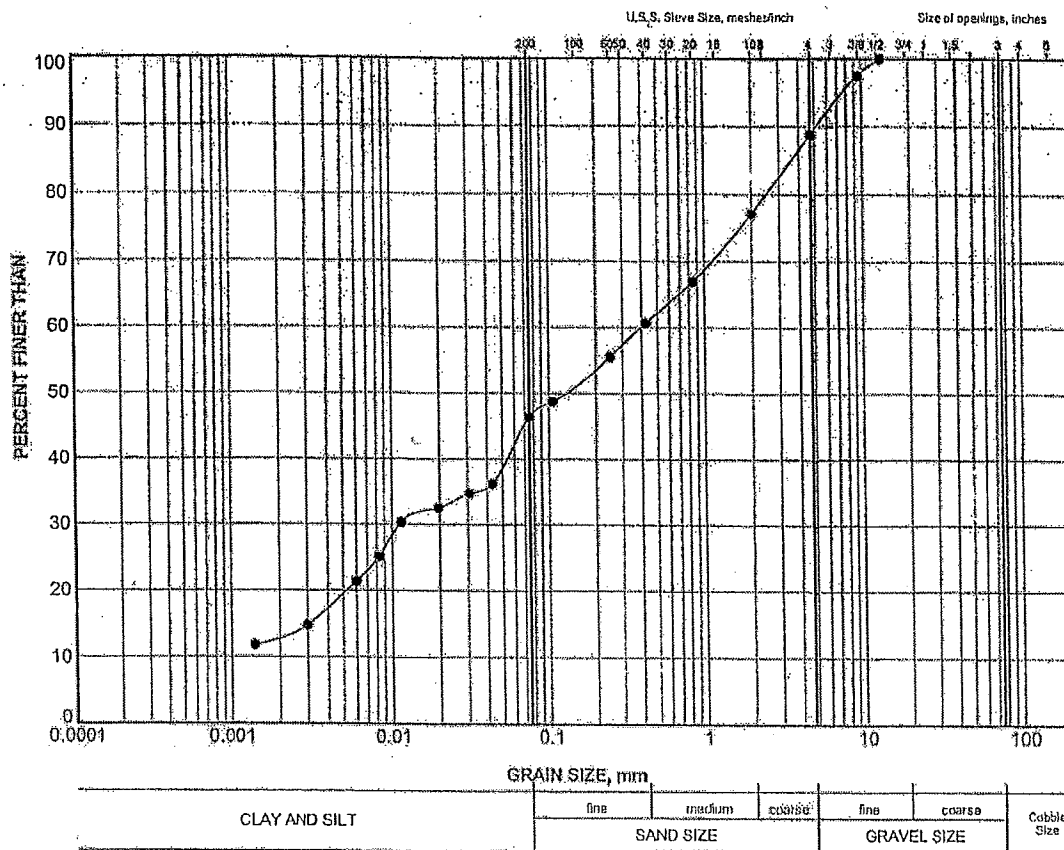




LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)	LL(%)	PL(%)	PI
●	BH1	18	161.8	38.9	17.8	21.1
■	BH1	28	146.5	45.8	23.9	21.7
▲	BH2	22	145.3	45.6	20.3	25.3

PROJECT					
CHRISTINA STREET UNDERPASS REPLACEMENT					
GWP 3038-03-00					
HWY 402					
REQ					
PLASTICITY CHART (Silty Clay)					
PROJECT No.		041-130009-2		FILE No.	
DRAWN		BO.		SEP 1994	
CHECK		JW		DEC 12/05	
SHEET		NO. 1		REV.	
Golder Associates		LONDON, ONTARIO		FIGURE A-6	



LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
•	BH1	39	129.9

PROJECT CHRISTINA STREET UNDERPASS REPLACEMENT GWP 3038-03-00 HWY 402					
TITLE GRAIN SIZE DISTRIBUTION SANDY SILT TILL					
PROJECT NO.		041-130002		FILE NO.	
DRAWN		WDR		Sep 14/04	
CHECK		HJ		07/10/05	
SCALE		N/A		REV	
Golder Associates LONDON, ONTARIO		FIGURE A-7			

LDX-M20 NEW GLDR LOGS-001

Appendix E

Representative Site Photographs



Photo 1: Christina Street Underpass looking west from Highway 402.



Photo 2: Christina Street Underpass looking south along Christina to Highway 402.