October 2011

FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 23 - North Thames River Bridge (Site 25-128)
Highway 23 Structure Replacements
From Union Line/Perth Line 10 to Perth Line 42
GWP 3043-06-00
Ministry of Transportation - West Region

Submitted to:
Mr. Henry Huotari, P. Eng., Senior Project Manager, Principal
Delcan Corporation
214-1069 Wellington Road South
London, Ontario
N6E 2H6

REPORT

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Table of Contents

APPENDICES

PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 23 – NORTH THAMES RIVER BRIDGE (SITE 25-128)
HIGHWAY 23 STRUCTURE REPLACEMENTS
FROM UNION LINE/PERTH LINE 10 TO PERTH LINE 42
GWP 3043-06-00
MINISTRY OF TRANSPORTATION - WEST REGION

1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Delcan Corporation (Delcan) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 3043-06-00. The project involves the detail design for the replacement of Highway 23 structures from Union Line/Perth Line 10 to Perth Line 42.

This report addresses the replacement of the Highway 23 North Thames River Bridge (Site 25-128) including a temporary modular bridge to be used as part of the proposed onsite detour.

The purpose of the foundation investigation is to determine the subsurface conditions at the location of the proposed structure replacement by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P0-1132-0029 dated March 19, 2010 and our letter dated January 2011. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated June 2010.

Delcan provided Golder Associates with preliminary drawings for this project in digital format.

2.0 SITE DESCRIPTION

The Highway 23 North Thames River Bridge is located in the Community of Willow Grove, Geographic Township of Logan, Perth County, Ontario. The location of the project is shown on the Key Plan, Figure 1.

This section of Highway 23 is currently a two lane undivided rural arterial highway oriented generally north-south. The road surface elevation at the North Thames River Bridge is at approximately elevation 346.9 metres. The existing bridge was constructed in 1930 and consists of two 6.1 metre spans with a 7.3 metre wide continuous deck slab. The bridge crosses the Thames River which flows westerly. The lands adjacent to the site consist of flat-lying agricultural lands.

The temporary modular bridge will be constructed immediately east of the existing North Thames River Bridge.

Site Photographs are provided in Appendix C.

2.1 Site Geology

This project lies within the physiographic region of southwestern Ontario known as the Stratford Till Plain[1]. The soils generally consist of silty clay with variable silt and clay contents.

Based on the Ministry of Natural Resources Map P.1223 entitled “Quaternary Geology, Seaforth Area, Southern Ontario”, the site lies in an area of primarily alluvial deposits consisting of gravel, sand and silt. Adjacent to the site, the Elma stony sandy silt till is indicated.

The Geologic Survey of Canada Map 1263A entitled “Geology, Toronto-Windsor Area, Ontario” indicates that the subcropping bedrock in the area of site is dolomite of the Lucas formation of Middle Devonian age. Based on the Ministry of Natural Resources Map P.1974 entitled “Bedrock Topography Series, Goderich-Seaforth Area, Southern Ontario”, the bedrock surface at the site subcrops at about elevation 316 metres or some 30 metres below ground surface.

[1] L.J. Chapman and D.F. Putnam: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Special Volume 2, 1984.

3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out between May 17 and June 8, 2011, during which time 10 boreholes were drilled at the locations shown on the Borehole Location Plans, Drawings 1 and 2. The table below summarizes the borehole locations, ground surface elevations at the borehole locations and borehole depths:

Borehole	Location (m)		Ground Surface Elevation	Borehole Depth
	Northing	Easting	(m)	(m)
101	4 820 315	413 277	345.08	6.55
102	4 820 302	413 271	344.61	12.65
103	4 820 269	413 247	344.95	12.24
104	4 820 266	413 250	345.26	13.05
105	4 820 254	413 238	345.43	6.55
106	4 820 271	413 236	346.77	13.79
107	4 820 299	413 254	346.84	17.74
108	4 820 302	413 244	346.85	16.92
109	4 820 320	413 258	346.92	6.55
110	4 820 252	413 225	346.76	6.55

The investigation was carried out using track mounted power augers supplied and operated by a specialist drilling contractor. In the boreholes, samples of the overburden were obtained at suitable intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. The boreholes were terminated between 6.6 and 17.7 metres below the existing pavement or ground surface. Groundwater conditions in the boreholes were observed throughout the drilling operations and standpipes were installed in boreholes 101, 105 and 106 as indicated on the corresponding Record of Borehole sheets. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 372/07.

The field work was monitored on a full-time basis by experienced members of our engineering staff who located the boreholes in the field, monitored the drilling, sampling and in situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations, were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

The locations of the boreholes are shown on the Record of Borehole sheets and on Drawings 1 and 2, attached.

In addition, information from the original geotechnical investigation for the existing structure was incorporated into this report. Data from boreholes 1 and 2, from Geocres Report No. 40P11-7 entitled "Foundation Investigation Report For Prop. Bridge over North Thames River, Hwy. #23, District #3 (Stratford), W.J. 65-F-88 – W.P. 307-64" dated September 16, 1965 was used to supplement the current data.

The Record of Borehole sheets for previous boreholes are presented in Appendix B in their original format with metric elevations added at strata boundaries. The table below summarizes the locations, ground surface elevations and depths of the previous boreholes:

Borehole	Location (m)		Ground Surface Elevation	Borehole Depth
	Northing	Easting	(m)	(m)
1	4 820 278	413 229	346.25	11.13
2	4 820 306	413 263	345.03	11.28

The locations of the previous boreholes are shown in plan on Drawing 1 and are noted on the Record of Borehole sheets. The locations of the previous boreholes should be considered approximate since the locations were referenced to imperial chainages and offsets from the centreline of Highway 23 rather than metric MTM coordinates.

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

In summary, the boreholes drilled at the North Thames River Bridge site encountered the existing pavement structure overlying fill materials followed by sandy silt till and clayey silt till with occasional layers of silty fine sand, clayey silt and sandy silt. The boreholes drilled at the Temporary Bridge site encountered surficial topsoil overlying fill materials or clayey silt till followed by sandy silt till and occasional layers of silty clay till, sandy silt and silty sand.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profiles, are shown on the attached Drawings 1 to 3. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

4.2 Subsurface Conditions – North Thames River Bridge

Boreholes 106 to 110 and borehole 1 (40P11-7) were advanced in the abutment and approach areas of the existing North Thames River Bridge. The borehole locations are shown in plan on Drawing 1 and the stratigraphy is shown in profile on Drawing 1 and in section on Drawing 3.

The subsurface soil conditions typically consist of the existing pavements and embankment fill materials overlying a stratum of stiff to hard clayey silt till. The clayey silt till contains layers of silt and sandy silt till and is underlain by layers of clayey silt, sandy silt and sandy silt till.

4.2.1 Pavement Structure

Asphalt was encountered at the pavement surface in boreholes 106 to 110 at approximately elevation 346.7 metres. The asphalt was about 150 to 200 millimetres thick at the borehole locations.

Pavement granulars were encountered beneath the asphalt in boreholes 106 to 110. The granulars were about 100 to 600 millimetres thick with an average thickness of about 410 millimetres.

A layer of concrete was encountered beneath the pavement granulars in borehole 108 from elevation 342.6 metres. The concrete was about 130 millimetres thick at the borehole location.

4.2.2 Fill

Fill was encountered beneath the pavement structure in boreholes 106 to 110. The fill was variable and consisted of sand and gravel and sandy silt to silt materials. The fill materials ranged in thickness from 2.0 to 2.9 metres at the borehole locations with an average thickness of about 2.3 metres. The fill had N values, as determined in the standard penetration testing, of 2 to 20 blows per 0.3 metres. Samples of the fill had in situ water contents of 9 to 50 per cent but generally less than 25 per cent. The water content of 50 per cent was measured in a sample of fill recovered near elevation 344.5 metres in borehole 108 which contained an appreciable amount of topsoil. The sandy silt sample near elevation 345.1 metres in borehole 107 contained some clayey topsoil and had a plastic limit of 19 per cent, a liquid limit of 30 per cent and a plasticity index of 11 per cent. The results of the Atterberg limits determination carried out on this sample is presented on Figure A-7 in Appendix A.

Grain size distribution curves for two samples of the fill recovered from the standard penetration testing are provided on Figure A-1.

Soils described as fill material, some sand, some gravel, some organics were found at the ground surface in borehole 1 (40P11-7) from elevation 346.3 metres. The fill material has been interpreted to be sand and gravel fill. The sand and gravel fill had a single N value of 5 blows per 0.3 metres with a water content of 25 per cent.

4.2.3 Sandy Silt Till

Layers of compact to very dense sandy silt till were encountered beneath the fill in borehole 107, interlayerd with the clayey silt till in boreholes 106 and 108, beneath the clayey silt in borehole 108, below the sandy silt in borehole 107 and beneath the silty fine sand in borehole 109. These layers were encountered between about elevations 330.0 and 344.0 metres. The sandy silt till was about 0.3 to 2.3 metres thick where fully penetrated in boreholes 106 to 109. Boreholes 107 and 108 were terminated in the sandy silt till after exploring it for about 0.9 and 3.8 metres, respectively. The sandy silt till had N values ranging from 15 blows per 0.3 metres to 120 blows per 150 millimetres with natural water contents of about 6 to 15 per cent. The sandy silt till was of low plasticity with average plastic and liquid limits of 11 and 18 per cent, respectively, and plasticity indices of 6 to 7 per cent. The Atterberg limits data are provided on the Plasticity Chart, Figure A-7.

Grain size distribution curves for samples of the sandy silt till recovered from the standard penetration testing are provided on Figure A-4. Cobbles and boulders were encountered within the sandy silt till.

4.2.4 Clayey Silt Till

Firm to hard clayey silt till was encountered beneath the fill in boreholes 106, 108, 109 and 110, as well as beneath the sandy silt till in boreholes 106, 108 and 109 and beneath the silty fine sand in borehole 107. These layers were encountered between about elevations 336.6 and 344.4 metres. The clayey silt till was about 1.5 to 6.5 metres thick where fully penetrated in boreholes 107 to 109. Boreholes 106, 109 and 110 were terminated in the clayey silt after exploring it for about 1.4 to 9.4 metres. The clayey silt till had N values ranging from 14 blows per 0.3 metres to 120 blows per 25 millimetres with natural water contents of about 7 to 17 per cent. The clayey silt till were of low plasticity with plastic and liquid limits ranging from 11 to 16 per cent and 19 to 32 per cent, respectively, and plasticity indices of 6 to 17 per cent. The Atterberg limits data are provided on the Plasticity Chart, Figure A-7.

Grain size distribution curves for samples of the clayey silt till recovered from the standard penetration testing are provided on Figures A-2 and A-3. Cobbles and boulders were encountered within the clayey silt till.

A deposit classified as clayey silt (glacial till) was encountered beneath the fill in borehole 1 (Geocres No. 40P11-7) from elevation 342.9 metres. A 150 millimetre thick silt seam was encountered within the clayey silt till at elevation 341.2 metres. This borehole was terminated in the clayey silt till after exploring it for about 7.8 metres. The clayey silt till was hard with N values of 38 blows per 0.3 metres to 104 blows per 225 millimetres with water contents of 9 to 18 per cent. The clayey silt till was of low plasticity with plastic limits of 14 and 16 per cent, liquid limits of 29 and 31 per cent and plasticity indices of 13 and 17 per cent.

4.2.5 Silty Fine Sand

Layers of silty fine sand were encountered beneath the sandy silt till in borehole 107 and beneath the clayey silt till in borehole 109. These layers were encountered between about elevations 342.2 and 342.3 metres. The silty fine sand was about 0.2 metres thick with a water content of 12 per cent.

4.2.6 Clayey Silt

Layers of stiff to very stiff clayey silt were encountered beneath the clayey silt till in boreholes 107 and 108 from elevation 335.6 and 335.1 metres, respectively. These layers were about 1.4 and 1.5 metres thick. The clayey silt had N values ranging from 14 to 28 blows per 0.3 metres and a single water content of 30 per cent.

4.2.7 Sandy Silt

A 4.1 metre thick layer of very dense sandy silt was encountered beneath the clayey silt in borehole 107 at about elevation 334.0 metres. The sandy silt had N values ranging from 51 to 135 blows per 0.3 metres and a water content of 11 per cent.

A grain size distribution curve for a sample of the sandy silt recovered from the standard penetration testing in borehole 107 is provided on Figure A-6.

4.2.8 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling and a standpipe was installed in borehole 106. Installation details are provided on Record of Borehole 106 following the text of this report. A summary of the encountered and measured groundwater levels is provided in the following table:

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Installation	Measured Groundwater Elevation (m)	
				May 19, 2011	June 8, 2011
106	346.77	344.0	Standpipe	334.73	341.36
107	346.84	344.2	-	-	-
108	346.85	331.0	-	-	-
109	346.92	342.5	-	-	-
110	346.76	344.2	-	-	-
1 (40P11-7)	346.25	343.9	-	-	-

A standpipe was installed in borehole 106. On June 8, 2011, the water level in this standpipe was about 5.4 metres below ground surface or at about elevation 341.4 metres. This standpipe was decommissioned on June 8, 2011.

Groundwater was encountered in boreholes 106 to 110 at depths of 2.6 to 15.9 metres or between elevation 331.0 and 344.2 metres.

Groundwater was encountered in previous borehole 1 (40P11-7) at about elevation 343.9 metres or at a depth of 2.3 metres. The water level in the North Thames River at Highway 23 was measured at elevation 343.2 metres on December 9, 1962, at elevation 342.5 metres on April 21, 2010 and at elevation 342.8 metres on June 8, 2011.

Based on the measured and encountered groundwater levels and the soil colour change from brown to grey, the inferred groundwater level is at elevation 344 metres. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

4.3 Subsurface Conditions – Temporary Bridge Site

Boreholes 101 to 105 and borehole 2 (40P11-7) were drilled on the east side of the existing structure in the area of the proposed temporary bridge. The borehole locations are shown in plan on Drawing 2, and the stratigraphy is shown in profile on Drawing 2 and in section on Drawing 3.

The subsurface soil conditions typically consist of surficial layers of topsoil and fill overlying a stratum of stiff to hard clayey silt till. The clayey silt till contains layers of sand, silt and sandy silt till and is underlain by layers of sandy silt, clayey silt and sandy silt till.

4.3.1 Topsoil

Layers of topsoil were encountered at the ground surface in boreholes 101 to 105. The topsoil layers were about 200 to 760 millimetres thick with an average thickness of about 440 millimetres.

4.3.2 Fill

Fill layers approximately 1.2 metre thick were encountered beneath the topsoil in boreholes 101 and 102. The fill was variable and consisted of sandy silt to sand and gravel materials. The loose to compact fill had N values of 8 and 21 blows per 0.3 metres.

4.3.3 Sandy Silt Till

Layers of compact to very dense sandy silt till were encountered beneath the fill in borehole 102, below the clayey silt till in boreholes 101, 104 and 105 and beneath the silty clay till in borehole 103. These layers were encountered between about elevation 334.8 and 343.1 metres. The sandy silt till was about 0.6 to 2.1 metres thick where fully penetrated in boreholes 101, 102, 104 and 105. Boreholes 103 and 104 were terminated in the sandy silt till after exploring it for about 5.2 and 2.5 metres, respectively. The sandy silt till had N values ranging from 15 blows per 0.3 metres to 150 blows per 50 millimetres with natural water contents of 6 to 9 per cent. The sandy silt till was of low plasticity with plastic and liquid limits of 11 and 17 per cent, respectively, with a plasticity index of 6 per cent. The Atterberg limits data are provided on the Plasticity Chart, Figure A-7.

Grain size distribution curves for samples of the sandy silt till recovered from the standard penetration testing are provided on Figure A-4. Cobbles and boulders were encountered within the sandy silt till.

4.3.4 Clayey Silt Till

Firm to hard clayey silt till was encountered beneath the topsoil in boreholes 104 and 105, beneath the fill in borehole 101, beneath the sandy silt till in boreholes 102 and 104, beneath the clayey silt in borehole 102, beneath the sandy silt in borehole 103 and beneath the silty sand in borehole 104. These layers were encountered between about elevation 335.2 and 345.0 metres. The clayey silt till was about 0.4 to 6.1 metres thick where fully penetrated in boreholes 102 to 105. Borehole 101 was terminated in the clayey silt till after exploring it for about 2.1 metres. The clayey silt till had N values ranging from 5 blows per 0.3 metres to 150 blows per 75 millimetres with natural water contents of 10 to 17 per cent. The clayey silt till was of low plasticity with plastic and liquid limits ranging from 11 to 13 per cent and 19 to 30 per cent, respectively, and plasticity indices of 6 to 17 per cent. The Atterberg limits data are provided on the Plasticity Chart, Figure A-8. It should be noted that sample 6 from borehole 101 contained insufficient sample to conduct an Atterberg limits determination and, as a result, the Atterberg limits determination was conducted on sample 7.

Grain size distribution curves for samples of the clayey silt till recovered from the standard penetration testing are provided on Figures A-2 and A-3. Cobbles and boulders were encountered within the clayey silt till.

An approximately 10.4 metre thick stratum described as clayey silt (glacial till) was found at the ground surface in borehole 2 (40P11-7) from elevation 345.0 metres. A 150 millimetre thick silt seam was encountered within the clayey silt till at elevation 342.0 metres. The clayey silt till had N values ranging from 15 blows per 0.3 meters to 70 blows per 275 millimetres. Water contents in the clayey silt till ranged from 9 to 15 per cent. The clayey silt till was of low plasticity with plastic and liquid limits ranging from 12 to 13 per cent and 25 to 26 per cent, respectively, with plasticity indices of 12 to 13 per cent.

4.3.5 Silty Clay Till

Layers of very stiff to hard silty clay till were encountered beneath the clayey silt till in borehole 103 and beneath the sandy silt till in borehole 105. These layers were encountered from elevations 339.0 to 342.5 metres. The silty clay till was about 1.5 to 3.4 metres thick. The silty clay till had N values ranging from 21 to 66 blows per 0.3 metres with natural water contents of 9 and 15 per cent. The silty clay till was of intermediate plasticity with plastic limits of 16 to 18 per cent, liquid limits of 35 and 36 per cent and plasticity indices of 19 per cent. The Atterberg limits data are provided on the Plasticity Chart, Figure A-7.

Grain size distribution curves for samples of the silty clay till recovered from the standard penetration testing are provided on Figure A-5. Although not specifically encountered in the boreholes, the presence of cobbles and boulders in the silty clay till should be expected.

4.3.6 Sandy Silt

Layers of sandy silt were encountered beneath the topsoil in borehole 103 from elevation 344.5 metres and beneath the clayey silt till in borehole 102 from elevation 333.3 metres. The sandy silt was about 0.3 metres thick where fully penetrated in borehole 103. Borehole 102 was terminated in the sandy silt after exploring it for about 1.4 metres. The sandy silt had N values of 33 and 36 blows per 0.3 metres with a natural water content of 9 per cent.

A grain size distribution curve for a sample of the sandy silt recovered from the standard penetration testing conducted in borehole 102 is provided on Figure A-6.

4.3.7 Silty Sand

A 0.1 metre thick layer of dense silty sand was encountered beneath the clayey silt till in borehole 104 at about elevation 342.7 metres.

A 0.8 metre thick layer of dense silty fine sand was encountered beneath the sandy silt till in borehole 101 at about elevation 342.2 metres. The silty fine sand had an N value of 43 blows per 0.3 metres.

4.3.8 Sand

A 0.8 metre thick layer of very dense sand was encountered beneath the silty fine sand in borehole 101 at about elevation 341.4 metres. The sand had an N value of 80 blows per 0.3 metres.

4.3.9 Clayey Silt

A 0.6 metre thick layer of very stiff clayey silt was encountered beneath a clayey silt till layer in borehole 102 at about elevation 340.0 metres. The clayey silt had an N value of 26 blows per 0.3 metres.

4.3.10 Silty Clay

A layer described as silty clay was found beneath the clayey silt till in borehole 2 (40P11-7) from elevation 334.7 metres. Borehole 2 was terminated in the silty clay. A 150 millimetre thick silt seam was encountered within the silty clay at elevation 334.2 metres. The silty clay was hard with a single N value of 61 blows per 150 millimetres and a water content of 8 per cent. The sample with the silt seam was of low plasticity with plastic and liquid limits of 12 per cent and 20 per cent, respectively, with a plasticity index of 8 per cent.

4.3.11 Sand and Gravel

A layer of very dense sand and gravel was encountered beneath the silty clay till in borehole 105 at about elevation 339.1 metres. Borehole 105 was terminated within this layer after exploring it for about 0.2 metres. The sand and gravel had an N value of 57 blows per 0.3 metres.

4.3.12 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling and standpipes were installed in boreholes 101 and 105. Installation details are provided on Record of Boreholes 101 and 105 following the text of this report. A summary of the encountered and measured groundwater levels is provided in the following table:

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Installation	Measured Groundwater Elevation (m)	
				May 18, 2011	June 8, 2011
101	345.08	344.3	Standpipe	342.37	343.91
102	344.61	343.7	-	-	-
103	344.95	Dry	-	-	-
104	345.26	Dry	-	-	-
105	345.43	339.2	Standpipe	341.92	343.87
2 (40P11-7)	345.03	*	-	-	-

* Groundwater level not established.

Boreholes 103 and 104 remained dry during drilling. Groundwater was encountered in the other boreholes at depths of 0.8 to 3.5 metres or between elevation 341.9 and 344.3 metres.

On June 8, 2011, the water level in the standpipe installed in borehole 101 was about 1.2 metres below ground surface or at about elevation 343.9 metres. The water level in the standpipe installed in borehole 105 was about 1.6 metres below ground surface or at about elevation 343.9 metres. The standpipes in boreholes 101 and 105 were decommissioned on June 8, 2011.

The groundwater level was not established in previous borehole 2 (40P11-7).

The water level in the North Thames River at Highway 23 was measured at elevation 343.2 metres on December 9, 1962, 342.5 metres on April 21, 2010 and 342.8 metres on June 8, 2011.

Based on the measured and encountered groundwater levels, the inferred groundwater level is at elevation 344 metres. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by Aardvark Drilling Inc., which is an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Randy Axford and Mr. Matthew Rhody under the direction of Mr. David J. Mitchell. The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Tyson Pitt, P.Eng. under the direction of the Team Leader, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED	ORIGINAL SIGNED
Tyson Pitt, P.Eng. Project Engineer	Philip R. Bedell, P.Eng. Senior Consultant

ORIGINAL SIGNED

Fintan J. Heffernan, P.Eng.
MTO Designated Contact

TP/PRB/FJH/ly

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PART B

FOUNDATION DESIGN REPORT

HIGHWAY 23 – NORTH THAMES RIVER BRIDGE (SITE 25-128)
HIGHWAY 23 STRUCTURE REPLACEMENTS
FROM UNION LINE/PERTH LINE 10 TO PERTH LINE 42
GWP 3043-06-00
MINISTRY OF TRANSPORTATION - WEST REGION

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the design of the replacement of the existing Highway 23 North Thames River Bridge including a temporary modular bridge which will be part of the detour used during construction. The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Based on the preliminary design information provided by Delcan, the replacement structure will have a single span approximately 14.1 metres wide and 21.5 metres long. The roadway will be widened to 13.5 metres to accommodate a 3.75 metre wide lane and a 3.00 metre wide shoulder in each direction. A steel I-girder structure with integral abutments is currently being considered for the replacement structure. The existing profile grade will be raised approximately 1.7 metres at the north approach and 1.4 metres at the south approach. The proposed designs incorporate an optional slight realignment of the river.

A temporary crossing is required as part of the proposed onsite detour to maintain traffic during construction of the bridge replacement. The design of the temporary bridge will be carried out by the contractor. As a result, only minimal information was available for the preparation of this report. However, it is anticipated that the bridge will consist of a prefabricated modular structure designed and constructed in accordance with OPSS 918.

6.2 Existing Structure

The North Thames River Bridge was built in 1930. The structure is comprised of two 6.1 metre wide spans with a continuous deck slab. The overall structure is approximately 12 metres long. There are no as-built records for the existing structure. However, based on the original design drawing, Drawing No. E-2088-1 dated November 26, 1929, the abutments and pier of the existing structure were designed to be supported on 1.57 metre wide strip footings founded on hard clayey silt till at elevation 341.10 metres for the abutment and elevation 340.79 metres at the pier. The existing embankments are up to approximately 3.7 metres high.

Based on the 21.5 metre length for the new bridge, it is unlikely that there will be a conflict with the new foundations; however, this should be confirmed during removal of the existing bridge and related works.

6.3 Bridge Foundations – North Thames River Bridge Replacement

The subsurface soil conditions typically consist of the existing pavements and embankment fill materials overlying a stratum of stiff to hard clayey silt till. The clayey silt till contains layers of silt and sandy silt till and is underlain by layers of clayey silt, sandy silt and sandy silt till. The prevailing groundwater level was inferred to be at approximately elevation 344 metres. The water level in the North Thames River was at approximately elevation 343 metres.

Based on the results of the boreholes and the existing bridge foundations, the foundations for the replacement bridge abutments could be founded on shallow or deep foundations. The existing north and south abutments and pier are supported on strip footings. The existing structure appears to be performing adequately with shallow foundations. However, considering that integral abutments have been proposed, only H-piles are suitable. Shallow foundations and tube piles are not compatible with integral abutments.

A comparison of foundation alternatives is presented in Table I. The costs provided are estimates meant to provide an order of magnitude comparison for the alternatives for foundation engineering purposes and should not be considered to be indicative of actual construction costs.

6.3.1 Shallow Foundations

The abutments for the replacement bridge can be founded on spread/strip footings bearing on the hard clayey silt till at or below elevation 341.0 metres using a factored geotechnical resistance at Ultimate Limit States (ULS) of 600 kilopascals and a geotechnical resistance at Serviceability Limit States (SLS) of 400 kilopascals. The SLS value corresponds to a settlement of 25 millimetres. A footing width of 3 metres has been assumed.

Resistance to Lateral Forces

Resistance to lateral forces/sliding between the concrete spread/strip footings and the subsoil should be calculated in accordance with Section 6.7.5 of the CHBDC. Assuming that the founding soils are not loosened/disturbed during excavation and footing construction, the following angle of friction between the concrete and the founding soils and the corresponding unfactored coefficient of friction, tan δ, may be used:

Footings on clayey silt till	angle of friction	30°
	tan δ	0.58

Frost and Scour Protection

All footings should be provided with a minimum of 1.4 metres of earth cover or thermal equivalent for frost protection purposes. The footings are also to be adequately protected against scour as noted in Clause 1.9.5.2 of the Canadian Highway Bridge Design Code (CHBDC).

Construction Considerations

The founding soils are sensitive to disturbance and loosening due to water seepage and/or ponding. Placement of a working slab will be required at the base of the excavations for the footing areas. Exposure without protection of the working slab may result in loosening of the founding soils. The cleaned excavation base should be inspected by qualified geotechnical personnel prior to placing the working slab. It is recommended that the footing excavations be carried out such that the final 0.5 metres of excavation is completed with the geotechnical personnel on site and the working slab be placed immediately after footing inspection.

6.3.2 Deep Foundations

The abutments for the bridge replacement can be designed using driven HP 310 x 110 steel H-piles or 324 millimetre outer diameter (O.D.), concrete filled steel tube piles with a nominal 9.5 millimetre wall thickness with a cut-off elevation of 343.6 metres. The use of steel H-piles is the preferred founding option because they have the flexibility required for use with integral abutments. Piles supporting integral abutments require pre-augering and placement of a corrugated steel pipe (CSP) liner filled with loose uniform sand around the upper 3 metres of the pile to reduce resistance to lateral movement. A Non Standard Special Provision (NSSP) for CSP Integral Abutments detailing the sand gradation should be included in the Contract Documents.

Geotechnical Axial Resistance – Driven Steel H-Piles

For design, the factored axial geotechnical resistances at ULS and SLS for HP 310 x 110 piles driven to refusal at or below the elevations shown are provided in the following table. The SLS values assume 25 millimetres of settlement.

The pile depths are based on an approximate cut-off elevation of 343.6 metres.

Location	Cut-off Elevation (m)	Tip Elevation (m)	Pile Length (m)	Founding Strata	Geotechnical Resistances	
					Factored ULS (kN)	SLS (kN)
North Abutment	343.6	331.5	12.1	Very dense sandy silt/ sandy silt till	1000	800
South Abutment	343.6	336.0	7.6	Hard clayey silt till	1000	800

Due to the variations in consistency of the clayey silt till together with the presence of cobbles and boulders, considerable variations in the actual pile tip elevations should be expected. In the event that the minimum 6 metre pile length cannot be consistently installed, the contractor should be prepared to predrill to elevation 337 metres prior to pile driving.

The steel H-piles should be installed and monitored in accordance with OPSD 3000.150 and OPSS903. The piles are to be equipped with Titus bearing points or approved equivalent.

In accordance with OPSS903, provision should be made to re-tap the piles to confirm the set after adjacent piles have been driven.

A pile note is to be added to the foundation drawing that states that the piles are to be driven in accordance with Standard SS 103-11 using a maximum ultimate resistance of two times the factored ULS value shown in the above table and must be driven below the elevations shown in the above table. The wording of the pile note should match Note 2 of Section 3.3.3 of the MTO Structural Manual.

Geotechnical Axial Resistance – Driven Steel Tube Piles

If the proposed structure is designed with conventional or semi-integral abutments, concrete filled steel tube piles with a 324 millimetre outer diameter and a 9.5 millimetre wall thickness driven closed ended may be used for support of the replacement structures. A factored geotechnical resistance at ULS of 540 kN per pile and a geotechnical resistance at SLS of 450 kN per pile may be used for design. The SLS value assumes 25 millimetres of settlement. The piles are to be driven to refusal at or below the elevation shown in the following table.

The pile lengths are based on an approximate cut-off elevation of 343.6 metres.

Location	Proposed Cut-off Elevation (m)	Proposed Tip Elevation (m)	Pile Length (m)	Founding Strata
North Abutment	343.6	333.0	9.6	Very dense sandy silt till
South Abutment	343.6	338.0	5.6	Hard clayey silt till

Due to the variations in consistency of the clayey silt till together with the presence of cobbles and boulders, considerable variations in the actual pile tip elevations should be expected.

The tube foundation piles are to be equipped with Type I driving shoes as shown in OPSD 3001.100. The steel tube piles should be installed and monitored in accordance with OPSD 3001.150 and OPSS 903.

In accordance with OPSS 903, provision should be made to re-tap the piles to confirm the set after adjacent piles have been driven.

A pile note is to be added to the foundation drawing that states that the piles are to be driven in accordance with Standard SS 103-11 using a maximum ultimate resistance of two times the factored ULS value shown in the above table. The wording of the pile note should match Note 1 of Section 3.3.3 of the MTO Structural Manual.

Construction Considerations

It should be noted that cobbles and boulders are present in the till soils and may impact pile driving operations. A non-standard special provision (NSSP) should be added to the contract documents to alert the contactor to the presence of cobbles and boulders within till soils and zones where hard driving may occur.

Downdrag Load (Negative Skin Friction)

A relatively low grade raise of up to 1.7 metres will be constructed at the approach embankments in conjunction with the bridge replacement. Considering the relatively low grade raise and the predominantly very stiff to hard cohesive soils, negligible negative skin friction is expected to develop on the new piles at both abutments.

Any potential downdrag loads can be reduced or eliminated by installing the piles well after the fill has been placed.

Resistance to Lateral Loads

The lateral loading could be resisted fully or partially by the use of battered piles. In the case of integral abutments, the vertical piles must provide the resistance to the lateral loading. The stratigraphy presented in the table below has been simplified for the purposes of this report.

The horizontal reaction to the pile can be estimated using the following equation and ranges in subgrade reaction coefficient where:

k_S = coefficient of horizontal subgrade reaction (MPa/m) = $n_h\,(z/d)$ for cohesionless soils

= $\dfrac{67S_u}{d}$ for cohesive soils

d = pile width or diameter (m)

n_h, k_S = constant of horizontal subgrade reaction (MPa/m)

z = depth below ground surface grade (m)

S_u = undrained shear strength

Soil Type	Elevation (m)		n_h	S_u
	From	To	(MPa/m)	(MPa)
Very loose to loose fill (sand and gravel, silt, sandy silt)	Surface	344	-	-
Stiff to hard clayey silt till	344	335	-	0.05 – 0.38
Compact to very stiff clayey silt till (north abutment only)	343	342	4-8	-
Stiff to very stiff clayey silt till (north abutment only)	336	334	-	0.05-0.20
Very dense to sandy silt till (north abutment only)	334	329	10-12	-

Group action for lateral loading should be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R, as follows:

Pile Spacing in Direction of Loading, d = Pile Diameter	***Subgrade Reaction Reduction Factor R***
8d	1.00
6d	0.70
4d	0.40
3d	0.25

The lateral resistance for HP310 X 110 and 324 millimetre diameter, 9.5 millimetre wall thickness tube piles are summarized in the following table:

Pile Type	Lateral Resistance	
	Factored ULS (kPa)	**SLS (kPa)**
HP 310 x 110	220	125
324 mm Tube	130	45

The lateral resistances were based on assessed values given in Table C6.4 of the CHBDC. The SLS values are based on 10 millimetres of deflection at the ground surface.

Frost and Scour Protection

The pile caps should be provided with a minimum of 1.4 metres of soil cover or thermal equivalent for frost protection. The footings are also to be adequately protected against scour as noted in Clause 1.9.5.2 of the Canadian Highway Bridge Design Code (CHBDC).

6.4 Bridge Foundations – Temporary Bridge

The subsurface soil conditions typically consist of surficial layers of topsoil and fill overlying a stratum of stiff to hard clayey silt till. The clayey silt till contains layers of sand, silt and sandy silt till and is underlain by layers of sandy silt, clayey silt and sandy silt till. The groundwater level was inferred to be at approximately elevation 344 metres. The water level in the North Thames River was at approximately elevation 343 metres.

Based on the results of the boreholes and the expected type of bridge, it is anticipated that shallow crib foundations or concrete strip/spread footings will be used for the temporary bridge structure. Alternatively, deep foundations could be constructed. Shallow foundations are preferred since they are expected to be economical to construct and can be readily erected and removed from the site. Piled foundations are more expensive to install and must be left in place after construction is complete.

A comparison of foundation alternatives is presented in Table II. The costs provided are estimates meant to provide an order of magnitude comparison amongst the alternatives and are not indicative of actual construction costs.

6.4.1 Shallow Foundations

Following removal of any organic or softened surficial materials, the abutments for the temporary bridge can be supported on a minimum 500 millimetre thick Granular A pad constructed directly on the surface of the sand and gravel fill and/or clayey silt till. If the structure is to remain in place during extended periods of freezing weather, the thickness of the pad should be increased to 1 metre. A factored geotechnical resistance at ULS of 200 kilopascals and geotechnical resistance at SLS of 150 kilopascals can be used for design.

Prior to placement of timber cribs, the ground surface must be levelled. It is recommended that a levelling pad, constructed of compacted Granular A with a minimum thickness of 0.5 metres, be placed to provide a level surface. The footprint of the levelling pad must extend beyond the extents of the timber cribbing a minimum distance of 1 metre plus the thickness of the levelling pad. In areas where a continuous level area is not possible, benches may be constructed, as necessary. However, the timber cribs must be set back well away from the edges of the benches. The timber cribs should be filled with free draining coarse granular materials or rock fill.

Alternatively, cast-in-place spread/strip footings constructed in the clayey silt till or sandy silt till at or below elevation 343.0 metres can be designed using a factored geotechnical resistance at ULS of 250 Kilopascals and a geotechnical resistance at SLS of 175 kilopascals.

Frost and Scour Protection

Construction is not expected to extend into the winter months. However, should this occur, shallow strip/spread footings should be provided with frost protection in the form of a minimum of 1.4 metres of soil cover or thermal equivalent and protected against scour as noted in Clause 1.9.5.2 of the CHBDC.

6.4.2 Deep Foundations

The abutments for the proposed temporary bridge can be designed using driven 324 millimetre outer diameter steel tube piles with a nominal 9.5 millimetre wall thickness.

Geotechnical Axial Resistance – Driven Steel Tube Piles

Unfilled steel tube piles with a 324 millimetre outer diameter and a 9.5 millimetre wall thickness driven closed ended may be used for support of the temporary bridge. Tube piles used to support the temporary structure can be designed using the geotechnical resistances and tip elevations shown in the table below. The SLS values assume 25 millimetres of settlement.

Location	Ground Surface Elevation (m)	Tip Elevation (m)	Pile Length (m)	Founding Strata	Geotechnical Resistances	
					ULS	SLS
North Abutment	344.8	338.5	6.3	Hard clayey silt till	500	350
South Abutment	345.1	338.0	7.1	Very dense sandy silt till	500	350

The steel tube piles should be installed and monitored in accordance with OPSD 3001.150 and SP903S01.

In accordance with OPSS 903, provision should be made to re-tap the piles to confirm the set after adjacent piles have been driven.

A pile note is to be added to the foundation drawing that states that the piles are to be driven in accordance with Standard SS 103-11 using a maximum ultimate resistance of two times the factored ULS value shown in the above table. The wording of the pile note should match Note 1 of Section 3.3.3 of the MTO Structural Manual.

Construction Considerations

It should be noted that cobbles and boulders are present in the till soils and may impact pile driving operations. A non-standard special provision (NSSP) should be added to the contract documents to alert the contactor to the presence of cobbles and boulders within till soils and zones where hard driving may occur.

Downdrag Load (Negative Skin Friction)

The current staging concept for the North Thames River bridge replacement includes construction of a single lane detour on the east side of the bridge. The alternating single lane traffic flow will be controlled by temporary traffic signals. Based on the conceptual drawings, it has been assumed that the detour embankment will have an approximate crest width of 4.5 to 5.5 metres and a road surface elevation at the temporary bridge crossing similar to that at the existing crossing. The anticipated maximum height of the detour embankments is 2 metres. The detour embankments will be underlain by generally very stiff to hard clayey silt till and compact to very dense sandy silt till. Based on the subsurface conditions present in the detour area, the relatively low embankment height and temporary nature of the construction, it is not considered necessary to consider negative skin friction in the design of piles supporting the temporary bridge.

Resistance to Lateral Loads

The lateral loading could be resisted fully or partially by the use of battered piles. In the case of integral abutments, the vertical piles must provide the resistance to the lateral loading. The stratigraphy presented in the table below has been simplified for the purposes of this report. The horizontal reaction to the pile can be estimated using the following equation and ranges in subgrade reaction coefficient where:

k_s = coefficient of horizontal subgrade reaction (MPa/m) $= n_h\,(z/d)$ for cohesionless soils

$= \dfrac{67S_u}{d}$ for cohesive soils

d = pile width or diameter (m)

n_h, k_s = constant of horizontal subgrade reaction (MPa/m)

z = depth below ground surface grade (m)

S_u = undrained shear strength

Soil Type	**Elevation (m)**		**n_h**	**S_u**
	From	**To**	**(MPa/m)**	**(MPa)**
Compact fill (sand and gravel, silty, sand)	Surface	343	5	-
Very stiff to hard clayey silt till	343	337	-	0.10 – 0.25

Group action for lateral loading should be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R, as follows:

Pile Spacing in Direction of Loading, d = Pile Diameter	***Subgrade Reaction Reduction Factor R***
8d	1.00
6d	0.70
4d	0.40
3d	0.25

For 324 millimetre diameter tube piles with a 9.5 millimetre wall thickness, the corresponding resistances are 170 kN at factored ULS and 90 kN at SLS based on Brom’s Method. The SLS values are based on 10 millimetres of deflection.

6.5 Liquefaction Potential and Seismic Analysis

6.5.1 Seismic Parameters

The site is located near Mitchell, Ontario. According to Table A.3.1.1 of the CHBDC, the zonal acceleration ratio, A, applicable to this site is 0.00. The corresponding acceleration related seismic zone, Z_a is 0.

If the replacement bridge is a lifeline bridge, then the Seismic Performance Zone (SPZ) is 2; otherwise, the zone is SPZ 1. Based on the site stratigraphy, the soil profile type is categorized as Type I with a seismic site response coefficient, S, of 1.0 based on the CHBDC criteria. Analysis of bridges in SPZ 1 is not a requirement of the CHBDC. However, design forces for restraining elements and bridge support lengths must meet the minimum requirements as outlined in CHDBC Clause 4.4.5.1.

6.5.2 Seismic Hazard Assessment

It is considered that the soils at the site are not susceptible to liquefaction and therefore a detailed evaluation of the liquefaction potential of the foundation soils is not considered warranted.

6.6 Lateral Earth Pressures

The lateral pressures acting on the bridge abutments will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the freedom of lateral movement of the structure and on the drainage conditions behind the walls. The following recommendations are made concerning the design of the abutments, in accordance with the CHBDC:

- Select, free-draining granular fill meeting the specifications of OPSS Granular A or Granular B Type III but with less than 5 per cent passing the No. 200 sieve should be used as backfill behind the abutments and walls. This fill should be compacted in loose lifts not greater than 200 millimetres in thickness in accordance with SP 105S10. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the abutment granular backfill requirements with respect to subdrains and frost taper should be in accordance with Ontario Provincial Standard Drawing (OPSD) 3101.150 and 3190.100.
- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design of the abutment wall in accordance with CHBDC Figure 6.6. Compaction equipment should be used in accordance with SP 105S10.
- The granular fill may be placed either in a zone with a width equal to at least 1.4 metres behind the back of the stem (Case a from Commentary on CHBDC Figure C6.20) or within the wedge-shaped zone defined by

a line drawn at a maximum 1 horizontal to 1 vertical extending up and back from the rear face of the footing (Case b from Commentary on CHBDC Figure C6.20).

- For Case a, the restrained case, the pressures are based on the proposed embankment fill materials and the following parameters (unfactored) may be used assuming the use of Select Subgrade Material (SSM):

Soil unit weight:	20 kN/m³
Coefficients of lateral earth pressure:	
Active, K_a	0.33
At rest, K_o	0.50
Passive, K_p	3.0

For Case b, the unrestrained case, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	GRANULAR A	GRANULAR B Type III
Soil unit weight:	22 kN/m³	21 kN/m³
Coefficients of lateral earth pressure:		
Active, K_a	0.27	0.31
At rest, K_o	0.43	0.47

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures may be used in the geotechnical design of the structure. If the wall support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design.

- For integral abutments, passive earth pressures may be used in the geotechnical design of the structure. The movements required to fully mobilize passive pressure or resistance are much larger than those required to mobilize active pressure. In practice, movements may not be sufficient to mobilize the full passive resistance. A resistance factor equal to 0.5 should be applied to the calculated total passive resistance in accordance with Table 6.1 of the CHDBC.

It should be noted that the above design parameters assume level backfill and ground surface behind the wall. The lateral earth pressure coefficients should be adjusted if there is sloping ground at the back of the wall.

6.7 Embankments

The current design of the Highway 23 embankment at the bridge location features a grade raise of approximately 1.7 metres at the north approach, 1.4 meters at the south approach and a symmetrical widening of about 3.2 metres. The replacement bridge is to be constructed on the existing alignment. A temporary detour will be constructed on the east side of the existing bridge in order to maintain traffic flow during construction. As noted in the preceding section, the detour embankments will be 4.5 to 5.5 metres wide with a maximum height of about 2 metres at the location of the temporary bridge. The fill materials are to consist of well compacted imported materials.

6.7.1 Subgrade Preparation and Embankment Construction

All surficial topsoil, organic, loose, soft and/or otherwise deleterious materials should be stripped from areas of proposed Highway 23 embankment widening and from within the footprint of the detour embankment. The exposed subgrade should be proofrolled prior to fill placement under the direction of qualified geotechnical personnel. Grading and embankment construction should be conducted in accordance with MTO Special Provision 206S03.

Except for the top approximately 0.5 metres, where Granular A and B Type III material will be placed for the pavement, the embankment fills should consist of an approved granular borrow such as SSM or Granular B Type I or Type III. Embankment fill materials should be placed in maximum 300 millimetre thick loose lifts and properly benched into the existing embankments in accordance with Ontario Provincial Standard Drawing (OPSD) 208.010 and compacted. Upon completion of filling to the pavement subgrade level, the embankment side slopes should be trimmed to a final inclination of two horizontal to one vertical or flatter.

6.7.2 Settlement

Settlement of the proposed embankment widening was modelled using Settle^{3D}, a three-dimensional program for the analysis of consolidation and settlement. The widening was modelled using the proposed dimensions of the widening. A post-construction settlement criteria recommended by other MTO jurisdictions of an allowable settlement of 10 to 25 millimetres within 30 metres of an abutment was used to assess post-construction settlement performance of the modified approach embankments.

Total settlements in the order of 15 millimetres or less are expected for the modified Highway 23 embankment. Total settlement of the temporary detour embankment in the vicinity of the abutments is expected to be in the order of 10 millimetres. Given the modest grade raise, limited width of the widening areas and presence of dense sandy silt till and hard clayey silt till deposits, the resulting settlement is expected to occur mainly during construction and will be complete at the end of the construction period. Post-construction settlements in these areas are expected to be minimal and well within the MTO's settlement criteria.

6.7.3 Stability

Embankment side slopes formed no steeper than 2 horizontal to 1 vertical are considered suitable for this site. A Factor of Safety against deep seated failure of greater than 1.3 is available for embankments constructed with the native materials founded on the very stiff to hard cohesive soils prevalent at this site.

6.8 Excavations and Temporary Cut Slopes

Excavations for pile caps or strip/spread footing construction will extend primarily through the existing fill materials, stiff to hard clayey silt till, and compact to dense sandy silt till. Some groundwater seepage particularly from the granular fill into the excavations for the strip/spread footings or pile caps should be anticipated. It is considered that adequate groundwater control could be achieved by pumping from properly constructed and filtered sumps in the base of the excavations but outside of the actual footing limits. Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical. Groundwater control, such as pumping from properly constructed and filtered sumps, may be required based on timing of construction and prevailing weather conditions.

The requirement to protect the founding soils, as given in Section 6.3.1 under the heading Construction Considerations, must be recognized. Sumps should be maintained outside of the actual footing limits. Surface water runoff should be directed away from the excavations at all times. The appropriate Non Standard Special Provision (NSSP) should be included in the contract documents.

All excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Ontario Occupational Health and Safety Act and Regulations For Construction Projects. The fill materials at this site would be classified as Type 3 soils as would any cohesionless materials below the groundwater level. The native clayey materials, properly dewatered cohesionless materials and glacial tills would be classified as Type 2 soils.

6.8.1 Temporary Roadway Protection

Where space is restricted and will not permit open cuts, temporary roadway protection support systems should be installed to support the sides of the excavation and permit the use of vertical cuts. Temporary support systems could consist of soldier piles and lagging where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds or driven steel sheet piling. Support to the systems could be in the form of struts and walers in the case of footing excavations or rakers and anchors in the case of roadway protection. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system.

The temporary excavation support system should be designed and constructed in accordance with OPSS 539. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539.

The contractor should be prepared for the presence of cobbles and boulders when installing the temporary excavation support system. The appropriate NSSP should be included in the contract documents.

7.0 MISCELLANEOUS

This report was prepared by Mr. Tyson Pitt, P.Eng. under the direction of the Team Leader, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

ORIGINAL SIGNED

Tyson Pitt, P.Eng.
Project Engineer

Philip R. Bedell, P.Eng.
Senior Consultant

ORIGINAL SIGNED

Fintan J. Heffernan, P.Eng.
MTO Designated Contact

TP/PRB/FJH/ly

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TABLE I

COMPARISON OF FOUNDATION ALTERNATIVES REPLACEMENT STRUCTURE

Site 25-128
Highway 23 North Thames River Bridge
Highway 23 Structure Replacements
GWP 3043-06-00

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
End bearing steel H-pile foundations driven to refusal into sandy silt till or clayey silt till	• Feasible • Preferred technical alternative	• High bearing resistance • Negligible settlement • Less vibration related damage compared to steel tube piles • Only solution compatible with integral abutments	• More expensive than shallow foundations; cost competitive with tube piles • Higher capacity than steel tube piles when driven to end bearing	• Estimated cost $26,500 per abutment	• Possible pile tip damage if piles are not adequately protected while driving through very dense/hard soils • Variation in pile tip elevations
Spread footings supported on hard clayey silt till	• Feasible • Preferred technical alternative	• Least expensive option • Ease of construction • Less expensive than deep foundation options	• Not compatible with integral abutments	• Estimated cost $10,000 per abutment	• Relatively low risk

COMPARISON OF FOUNDATION ALTERNATIVES

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
End bearing concrete filled steel tube piles driven into hard clayey silt till	• Feasible	• High bearing resistance • Negligible settlement	• More costly than shallow footings • Not compatible with integral abutments	• Estimated cost $25,000	• Possible pile tip damage if piles are not adequately protected while driving through very dense/hard soils

NOTES:
1. Costs are very preliminary estimates and are intended to provide a comparison between alternatives rather than actual construction costs.
2. Table to be read in conjunction with accompanying report.

Prepared By: DUP/TP
Checked By: PRB

TABLE II

COMPARISON OF FOUNDATION ALTERNATIVES – TEMPORARY BRIDGE

Site 25-128
Highway 23 North Thames River Bridge
Highway 23 Structure Replacements
GWP 3043-06-00

FOUNDATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
Shallow Crib Foundation	• Feasible • Preferred technical alternative for pier foundations	• Lowest cost • Rapid construction • Easily removed	• Crib foundations must be constructed above the high water level in order to avoid damage during flood events (to be confirmed by designer)	• $10,000 per abutment	• Bearing materials with relatively low strengths near surface. Can be replaced with compacted Granular A pad.
Spread footings supported on very stiff to hard clayey silt till	• Feasible	• Higher geotechnical resistance compared to crib foundations • Negligible settlement	• Depending on foundation depth, not easily removed • More costly than crib foundations	• $12,000 per abutment	• Relatively low risk
End bearing open steel tube piles driven into hard clayey silt till	• Feasible	• High bearing resistance • Negligible settlement	• Most costly foundation alternative • Must be left in place • Potential for pile to be damaged due to hard driving on cobbles/boulders	• $20,000	• Possible pile tip damage if piles are not adequately protected while driving through very dense/hard soils

NOTES:
1. Costs are very preliminary estimates and are intended to provide a comparison between alternatives rather than actual construction costs.
2. Table to be read in conjunction with accompanying report.

Prepared By: DUP
Checked By: PRB

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency

	c_u, s_u kPa	c_u, s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. General

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$-u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s/\rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
l_p	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p)/I_p$
I_C	consistency index = $(w_l - w)/I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio = σ'_p/σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u,s_u	undrained shear strength (ϕ = 0 analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 + \sigma_3)$
S_t	sensitivity

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

* density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

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London, Ontario

RECORD OF BOREHOLE No 101

METRIC

PROJECT 10-1132-0029

W.P. 3043-06-00 LOCATION N 4820314.7 ;E 413276.5 ORIGINATED BY RA

DIST HWY 23 BOREHOLE TYPE POWER AUGER, SOLID STEM COMPILED BY LMK

DATUM GEODETIC DATE May 17, 2011 CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
345.08	GROUND SURFACE					345					
0.00	TOPSOIL, silty, Black										
0.20	FILL, sandy silt, some gravel, Loose, Brown	1	SS	8		344					
343.71 / 1.37	CLAYEY SILT TILL, trace sand, trace gravel, Hard, Brown	2	SS	31							
342.95 / 2.13	SANDY SILT TILL, some clay, trace gravel, Dense, Brown	3	SS	46	Holeplug	343	○	8	33	41	18
342.18 / 2.90	SILTY FINE SAND, Dense, Grey	4	SS	43		342					
341.42 / 3.66	SAND, some silt, Very dense, Grey	5	SS	80		341					
340.66 / 4.42	CLAYEY SILT TILL, some sand, some gravel, with cobbles, Hard, Grey	6	SS	45	Cuttings	340	○	14	21	32	33
		7	SS	39			○ (with plastic/liquid limit range)				
338.53 / 6.55	END OF BOREHOLE	8	SS	69	Standpipe	339					

Groundwater encountered at about elev. 344.3m during drilling on May 17, 2011.

Water level measured at elev. 342.37m on May 18, 2011.

Water level measured at elev. 343.91m on June 8, 2011.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10, 20, 30; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

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RECORD OF BOREHOLE No 102

METRIC

PROJECT	10-1132-0029		
W.P.	3043-06-00	LOCATION	N 4820301.6 ;E 413271.1
DIST		HWY	23
BOREHOLE TYPE	POWER AUGER, HOLLOW STEM		
DATUM	GEODETIC	DATE	May 17, 2011
ORIGINATED BY	RA	COMPILED BY	LMK
CHECKED BY			

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
344.61	GROUND SURFACE
0.00	TOPSOIL, silty Black
344.28 / 0.33	FILL, silty sand, trace gravel, trace topsoil Brown
0.61	FILL, sand and gravel, trace silt Compact Brown
343.09 / 1.52	SANDY SILT TILL, some clay, trace gravel, with cobbles Compact to very dense Brown
340.95 / 3.66	CLAYEY SILT TILL, some sand, some gravel, with cobbles Hard Grey
340.04 / 4.57	CLAYEY SILT, trace sand, with silt layers Very stiff Grey
339.43 / 5.18	CLAYEY SILT TILL, some sand, trace to some gravel, with cobbles and boulders Stiff to hard Grey
333.33 / 11.28	SANDY SILT, some clay, trace gravel, with cobbles Dense Grey
331.96 / 12.65	END OF BOREHOLE Groundwater encountered at about elev. 343.7m during drilling on May 17, 2011.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	21				
2	SS	15				
3	SS	37	4	29	49	18
4	SS	104				
5	SS	37				
6	SS	26				
7	SS	62	5	31	37	27
8	SS	150/75mm				
9	SS	61				
10	SS	62				
11	SS	27				
12	SS	15	1	17	35	47
13	SS	13				
14	SS	33	7	29	51	13
15	SS	36				

GROUND WATER CONDITIONS | ELEVATION SCALE: 344, 343, 342, 341, 340, 339, 338, 337, 336, 335, 334, 333, 332

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

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

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RECORD OF BOREHOLE No 103

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820268.5 ;E 413246.6
ORIGINATED BY RA
DIST ____ HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY LMK
DATUM GEODETIC
DATE May 18, 2011
CHECKED BY ____

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
344.95	GROUND SURFACE
0.00	TOPSOIL, silty Black
344.49 / 0.46	SANDY SILT, trace rootlets Brown
0.76	CLAYEY SILT TILL, trace to some sand, trace to some gravel, with cobbles Very stiff to hard Brown becoming grey at about elev. 343.6m
339.01 / 5.94	SILTY CLAY TILL, some sand, trace to some gravel, with cobbles Hard Grey
337.48 / 7.47	SANDY SILT TILL, some gravel, trace to some clay, with cobbles and boulders, possible boulder from about elev. 335.0m to 334.6m Dense to very dense Grey
332.71 / 12.24	END OF BOREHOLE Borehole dry during drilling on May 18, 2011.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	15				
2	SS	18				
3	SS	34				
4	SS	41	5	25	44	26
5	SS	38				
6	SS	21				
7	SS	38				
8	SS	66				
9	SS	41	8	27	37	28
10	SS	105				
11	SS	39				
12	SS	61				
13	SS	100/ 25mm				
14	SS	79	13	32	40	15
15	SS	150/ 50mm				
16	SS	150/ 50mm				

ELEVATION SCALE: 344, 343, 342, 341, 340, 339, 338, 337, 336, 335, 334, 333

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

GROUND WATER CONDITIONS

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

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RECORD OF BOREHOLE No 104

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820266.3 ;E 413250.2
ORIGINATED BY RA
DIST HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM / TRI-CONE
COMPILED BY LMK
DATUM GEODETIC
DATE May 20, 2011 - May 24, 2011
CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT	GR	SA	SI	CL
345.26	GROUND SURFACE								
0.00	TOPSOIL, silty, Black								
344.50 / 0.76	CLAYEY SILT TILL, some sand, trace gravel, Stiff to hard, Brown becoming grey at about elev. 343.1m	1	SS	14					
		2	SS	20					
342.73 / 2.53	SILTY SAND, trace gravel, Dense, Grey	3	SS	44					
2.65	CLAYEY SILT TILL, some sand, trace gravel, Very stiff to hard, Grey	4	SS	37					
		5	SS	43	plotted	2	19	56	23
		6	SS	29					
340.08 / 5.18	SANDY SILT TILL, some gravel, trace clay, Dense, Grey	7	SS	45					
339.32 / 5.94	CLAYEY SILT TILL, some sand, trace to some gravel, Very stiff to hard, Grey	8	SS	79	plotted	5	31	42	22
		9	SS	29					
337.79 / 7.47	SANDY SILT TILL, some gravel, trace clay, Very dense, Grey	10	SS	150/ 225mm					
336.63 / 8.63	CLAYEY SILT TILL, trace sand, trace gravel, Hard, Grey	11	SS	60					
336.27 / 8.99	SANDY SILT TILL, some gravel, some clay, Dense to very dense, Grey	12	SS	100	plotted	13	34	40	13
335.20 / 10.06	CLAYEY SILT TILL, trace sand, trace gravel, Hard, Grey	13	SS	36					
334.75 / 10.51	SANDY SILT TILL, some gravel, trace clay, with cobbles, Very dense, Grey	14	SS	101					
		15	SS	100/ 75mm					
		16	SS	120/ 75mm					
332.21 / 13.05	END OF BOREHOLE. Borehole dry during drilling on May 20-24, 2011.	17	SS	125/ 100mm					

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (345 – 333); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

LDN_MTO_06 10-1132-0029-7000.GPJ LDN_MTO.GDT 06/09/11

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RECORD OF BOREHOLE No 105

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820253.9 ;E 413237.9
ORIGINATED BY RA
DIST ______ HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY LMK
DATUM GEODETIC
DATE May 18, 2011
CHECKED BY ______

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
345.43	GROUND SURFACE										
0.00	TOPSOIL, silty Black					345					
344.98 / 0.45	CLAYEY SILT TILL, some sand, trace gravel Firm to very stiff Brown becoming grey at about elev. 344.0m	1	SS	5	Holeplug	344					
		2	SS	15				2	23	52	23
343.14 / 2.29	SANDY SILT TILL, some gravel, trace clay Dense Grey	3	SS	43	Cuttings	343					
342.53 / 2.90	SILTY CLAY TILL, some sand, trace gravel Stiff to hard Grey	4	SS	42		342					
		5	SS	21	Holeplug	341		5	22	27	46
		6	SS	27							
					Filter sand	340					
339.09 / 6.34	SAND AND GRAVEL, some silt Very dense Grey	7	SS	57	Standpipe	339					
6.55	END OF BOREHOLE										

Groundwater encountered at about elev. 339.2m during drilling on May 18, 2011.

Water level measured at elev. 341.92m upon installation on May 18, 2011.

Water level measured at elev. 343.87m on June 8, 2011.

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

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RECORD OF BOREHOLE No 106

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820271.0 ;E 413236.3
ORIGINATED BY RA
DIST HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY LMK
DATUM GEODETIC
DATE May 19, 2011
CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
346.77	ROAD SURFACE								
0.00	ASPHALT								
0.20	FILL, sand and gravel, trace silt Brown								
346.01 0.76	FILL, silt, some sand, trace to some gravel, trace to some clay, trace topsoil, with clayey silt lumps Very loose to loose Brown	1	SS	8	Cuttings				
		2	SS	2		11	12	60	17
		3	SS	3					
344.03 2.74	CLAYEY SILT TILL, trace sand, trace gravel Stiff Brown	4	SS	14	Holeplug				
343.11 3.66	SANDY SILT TILL, some gravel, some clay Dense Grey	5	SS	34		12	32	39	17
342.35 4.42	CLAYEY SILT TILL, some sand, trace to some gravel, with cobbles and boulders Hard Grey	6	SS	32					
		7	SS	35					
		8	SS	31	Cuttings				
		9	SS	107		4	24	39	33
		10	SS	36					
		11	SS	77					
		12	SS	37	Holeplug				
		13	SS	40					
		14	SS	150/ 75mm					
		15	SS	114	Filter sand	21	27	38	14
		16	SS	80					
		17	SS	100/ 75mm	Standpipe				
332.98 13.79	END OF BOREHOLE Groundwater encountered at about elev. 344.0m during drilling on May 19, 2011. Water level measured at elev. 334.73m on May 19, 2011.	18	SS	100/ 75mm					

Water level measured at elev. 341.36m on June 8, 2011.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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RECORD OF BOREHOLE No 107

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820299.1 ;E 413253.7
ORIGINATED BY RA/MR
DIST HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM / TRI-CONE
COMPILED BY LMK
DATUM GEODETIC
DATE May 24, 2011 - June 08, 2011
CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
346.84	ROAD SURFACE					
0.00	ASPHALT					
0.16	FILL, sand and gravel, trace silt; Brown					
346.08 / 0.76	FILL, sandy silt, trace to some gravel, some clayey topsoil; Very loose to loose; Brown	1	SS	6		
		2	SS	3		4 19 59 18
344.71 / 2.13	FILL, silt, some sand, trace organic matter; Loose; Black and grey	3	SS	9	▽	
344.25 / 2.59	FILL, sand and gravel, trace to some silt; Loose; Brown	4	SS	9		
343.18 / 3.66	SANDY SILT TILL, some gravel, trace clay; Compact; Brown	5	SS	22		
342.27 / 4.57	SILTY FINE SAND; Dense; Brown	6	SS	43		
4.79	CLAYEY SILT TILL, some sand, trace gravel, with cobbles; Hard; Grey	7	SS	38		
		8	SS	33		2 17 35 46
		9	SS	120/ 25mm		
		10	SS	41		
		11	SS	34		
		12	SS	57		
		13	SS	37		8 25 36 31
		14	SS	31		
335.56 / 11.28	CLAYEY SILT, trace sand; Very stiff; Grey	15	SS	16		
		16	SS	28		
334.04 / 12.80	SANDY SILT, some clay, trace gravel, with cobbles; Very dense; Grey	17	SS	51		
		18	SS	74		
		19	SS	88		

ELEVATION SCALE: 346, 345, 344, 343, 342, 341, 340, 339, 338, 337, 336, 335, 334, 333, 332

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

Continued Next Page

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

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RECORD OF BOREHOLE No 107

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820299.1 ;E 413253.7
ORIGINATED BY RA/MR
DIST
HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM / TRI-CONE
COMPILED BY LMK
DATUM GEODETIC
DATE May 24, 2011 - June 08, 2011
CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SANDY SILT, some clay, trace gravel, with cobbles Very dense Grey	20	SS	135			o (~11)	3	20	63	14
					∇	331					
329.95 16.89	SANDY SILT TILL, some gravel, trace clay, with cobbles and boulders Very dense Grey	21	SS	99/ 50mm		330					
329.10 17.74	END OF BOREHOLE Auguer refusal on probable boulder at about elev. 329.1m. Groundwater encountered at about elev. 344.2m during drilling on May 24, 2011 and about elev. 330.7m on June 8, 2011.										

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

LDN_MTO_06 10-1132-0029-7000.GPJ LDN_MTO.GDT 06/09/11

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

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RECORD OF BOREHOLE No 108

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820301.5 ;E 413244.2
ORIGINATED BY MR
DIST HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY LMK
DATUM GEODETIC
DATE June 07, 2011
CHECKED BY

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
346.85	ROAD SURFACE				
0.00	ASPHALT				
0.25	FILL, sand and gravel, trace silt Brown				
0.38	CONCRETE				
	FILL, silty sand and gravel Compact Brown	1	SS	10	
345.48 1.37	FILL, sandy silt, trace gravel, some topsoil Loose to compact Brown and black, becoming grey and black at about elev. 344.9m	2	SS	5	
344.41 2.44	CLAYEY SILT TILL, trace sand, trace gravel Stiff Grey	3	SS	14	
343.95 2.90	SANDY SILT TILL, some clay, trace to some gravel Compact to dense Grey	4	SS	15	
		5	SS	29	7 31 42 20
		6	SS	40	
341.67 5.18	CLAYEY SILT TILL, some sand, trace gravel, with silt and sand lenses Hard Grey	7	SS	39	
		8	SS	31	5 14 37 44
		9	SS	35	
		10	SS	45	
338.93 7.92	SANDY SILT TILL, some gravel, some clay, with cobbles Dense to very dense Grey	11	SS	55	16 29 36 19
336.64 10.21	CLAYEY SILT TILL, some sand, trace gravel Very stiff Grey	12	SS	29	
335.12 11.73	CLAYEY SILT, trace sand Stiff Grey	13	SS	14	
333.74 13.11	SANDY SILT TILL, trace to some gravel, some clay, with cobbles Very dense Grey	14	SS	118	7 30 50 13

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (346, 345, 344, 343, 342, 341, 340, 339, 338, 337, 336, 335, 334, 333, 332); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

50

Continued Next Page

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

LDN_MTO_06 10-1132-0029-7000.GPJ LDN_MTO.GDT 06/09/11

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RECORD OF BOREHOLE No 108

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00
LOCATION N 4820301.5 ;E 413244.2
ORIGINATED BY MR
DIST HWY 23
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY LMK
DATUM GEODETIC
DATE June 07, 2011
CHECKED BY

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SANDY SILT TILL, trace to some gravel, some clay, with cobbles Very dense Grey		15	SS	110/ 175mm				○		
						∇	331				
329.93 16.92	END OF BOREHOLE Groundwater encountered at about elev. 331.0m during drilling on June 7, 2011.		16	SS	120/ 150mm		330		○		

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

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 109

METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00 LOCATION N 4820319.8 ;E 413258.4 ORIGINATED BY MR
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE June 07, 2011 CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
346.92	ROAD SURFACE					
0.00	ASPHALT					
0.19	FILL, sand and gravel, trace silt, Brown					
346.33 / 0.59	FILL, silty sand, some gravel, trace topsoil, Compact, Brown	1	SS	20		
345.55 / 1.37	FILL, silt, some clay, trace gravel, trace to some topsoil, Loose, Brown	2	SS	5		
344.79 / 2.13	FILL, silty sand and gravel, Very loose, Brown	3	SS	3		
344.02 / 2.90	CLAYEY SILT TILL, trace to some sand, trace gravel, Very stiff to hard, Brown becoming grey at about elev. 342.5m	4	SS	20		0 7 51 42
		5	SS	32	▽	
342.20 / 4.72	SILTY FINE SAND, Compact, Grey	6	SS	28		
4.88 / 5.18	SANDY SILT TILL, some gravel, trace clay, Compact, Grey	7	SS	26		
	CLAYEY SILT TILL, some sand, trace gravel, Very stiff, Grey	8	SS	29		8 30 34 28
340.37 / 6.55	END OF BOREHOLE					

Groundwater encountered at about elev. 342.5m during drilling on June 7, 2011.

Elevation scale: 346, 345, 344, 343, 342, 341

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

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

LDN_MTO_06 10-1132-0029-7000.GPJ LDN_MTO.GDT 06/09/11

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 110

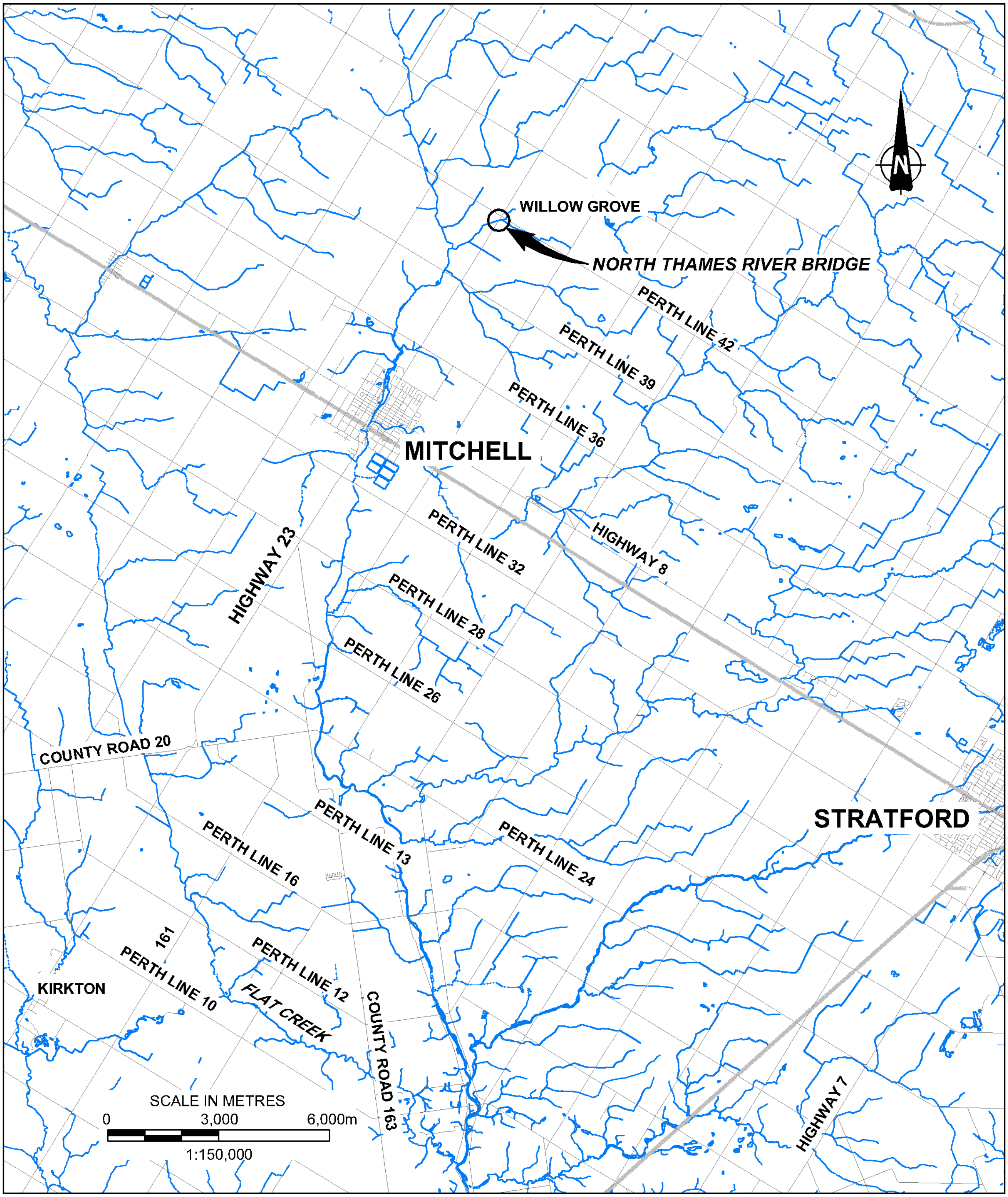
METRIC

PROJECT 10-1132-0029
W.P. 3043-06-00 LOCATION N 4820252.1 ;E 413225.1 ORIGINATED BY RA
DIST HWY 23 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE May 19, 2011 CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
346.76	ROAD SURFACE						
0.00	ASPHALT						
0.19	FILL, sand and gravel, trace silt Brown						
346.16 / 0.60	FILL, sandy silt, trace to some gravel, trace clay, topsoil, rootlets Loose to Compact Brown and grey	1	SS	15		346	
		2	SS	4		345	
344.17 / 2.59	FILL, silty sand and gravel Loose Brown	3	SS	7	∇	344	
343.86 / 2.90	CLAYEY SILT TILL, some sand, trace gravel, with cobbles Very stiff to hard Brown becoming grey at about elev. 343.1m	4	SS	20			4 22 47 27
		5	SS	36		343	
		6	SS	43		342	
		7	SS	44		341	1 17 58 24
340.21		8	SS	37			
6.55	END OF BOREHOLE Groundwater encountered at about elev. 344.2m during drilling on May 19, 2011.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

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



Drawing file: 1011320029-7000-F01001.dwg Sep 12, 2011 - 3:17pm

REFERENCE

CANMAP STREETFILES, V2008.4.

NOTES

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

ALL LOCATIONS ARE APPROXIMATE.

PROJECT

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

KEY PLAN

Golder Associates
LONDON, ONTARIO

PROJECT No. 10-1132-0029			FILE No. 1011320029-7000-F01001	
			SCALE AS SHOWN	REV. 0
CADD	LK/DH/AG	SEPT. 12/11	**FIGURE 1**	
CHECK				

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 3043-06-00

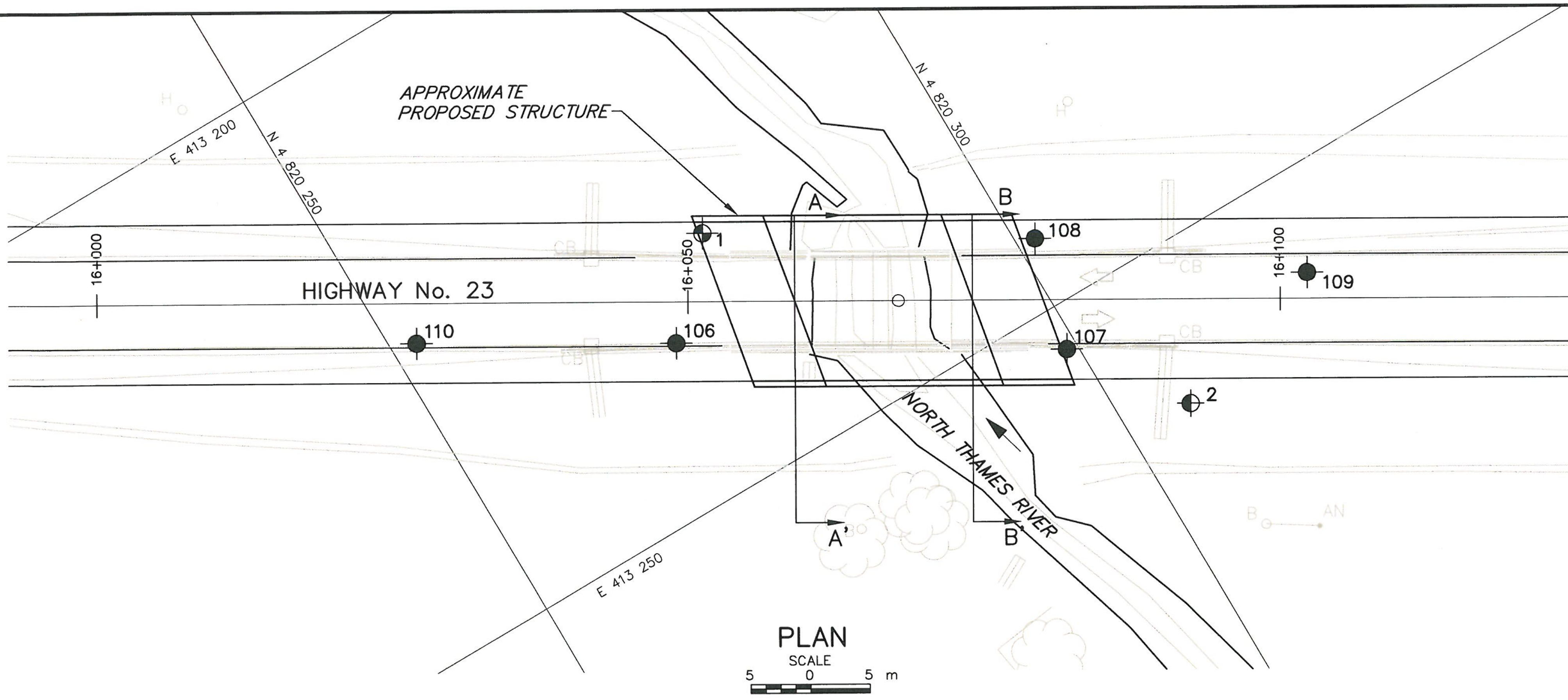
SHEET

NORTH THAMES RIVER BRIDGE

HIGHWAY 23 STRUCTURE REPLACEMENTS

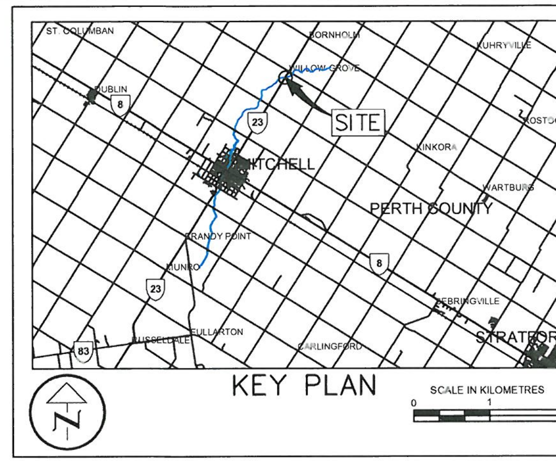
BORHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA



PLAN

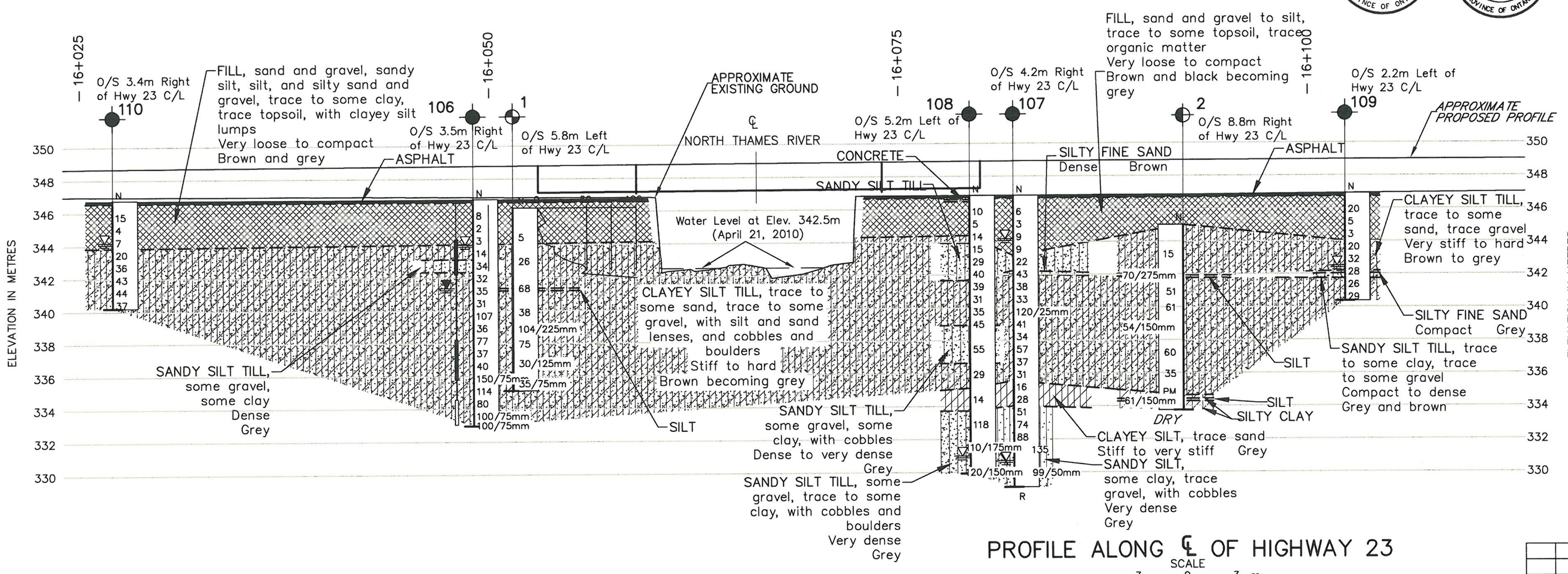
SCALE 5 0 5 m



KEY PLAN

SCALE IN KILOMETRES 0 1 2

F.J. HEFFERNAN
Oct 26/11
T.N.S.PITT
100132967
Oct 26/11



PROFILE ALONG ℄ OF HIGHWAY 23

SCALE 3 0 3 m

LEGEND

Symbol	Description
●	Borehole (Current Investigation)
⊕	Borehole and Cone (Geocres 40P11-7)
⊕	Borehole (Geocres 40P11-7)
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	Encountered WL
DRY	Borehole dry during drilling
▼	Measured WL (June 8, 2011)
R	Refusal

		CO-ORDINATES (MTM ZONE 11)	
No.	ELEVATION	NORTHING	EASTING
106	346.77	4 820 271.0	413 236.3
107	346.84	4 820 299.1	413 253.7
108	346.85	4 820 301.5	413 244.2
109	346.92	4 820 319.8	413 258.4
110	346.76	4 820 252.1	413 225.1
Geocres 40P11-7			
1	346.25	4 820 277.7	413 229.5
2	345.03	4 820 305.7	413 262.9

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration. Subsurface information has been inferred from Geocres No. 40P11-7.

REFERENCE

Base plans provided in digital format by Delcan.

NO.	DATE	BY	REVISION

Geocres No. 40P11-19			
HWY. 23		PROJECT NO. 10-1132-0029	DIST.
SUBM'D. DUP	CHKD.	DATE: Sept. 12/11	SITE: 25-128
DRAWN: DCH/LMK	CHKD.	APPD.	DWG. 1

MINISTRY OF TRANSPORTATION, ONTARIO

PLOT DATE: October 26, 2011
FILENAME: N:\active\2010\1132 - Geotechnical\1132-0000\10-1132-0029 DELCAN - GWP 3043-06-00 - HWY 23\Drafting\AutoCAD files\1011320029-7000-D01001.dwg

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 3043–06–00

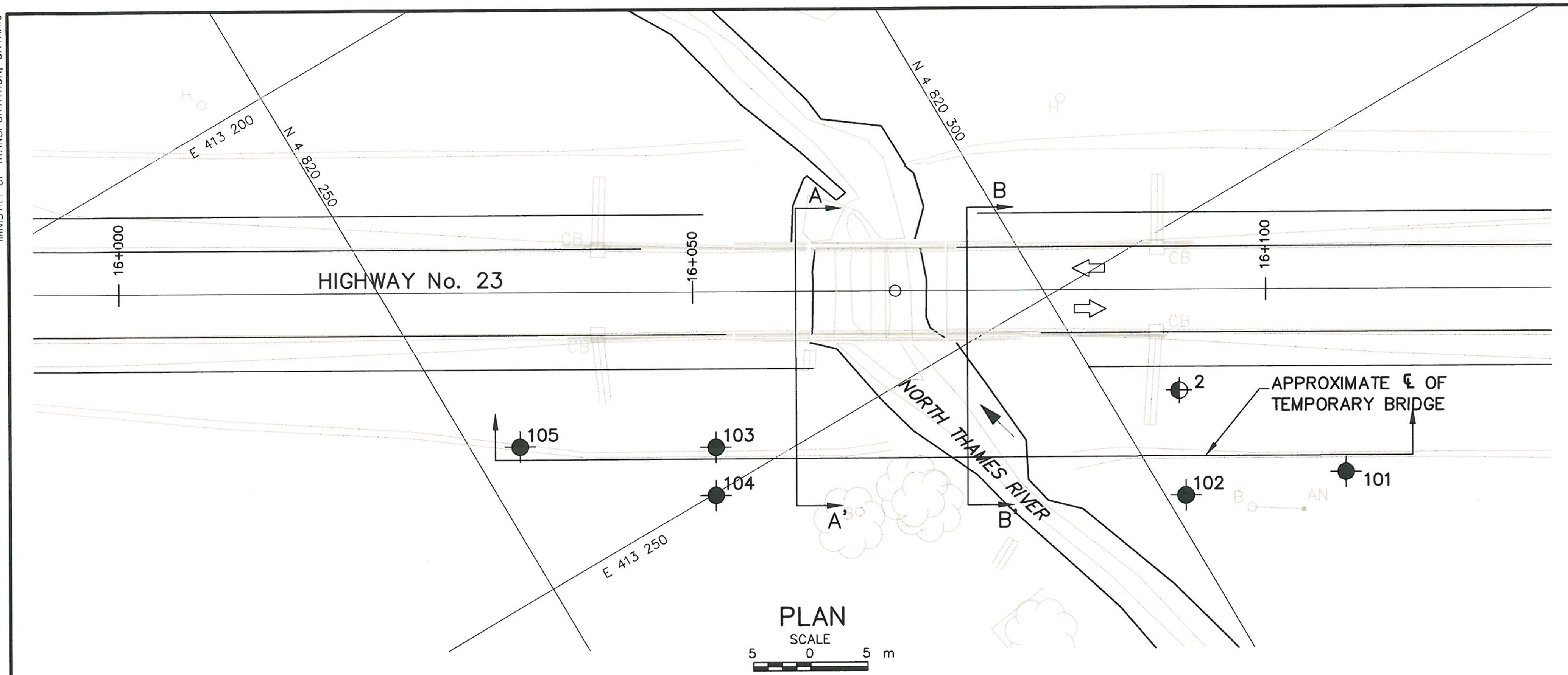
SHEET

NORTH THAMES RIVER BRIDGE

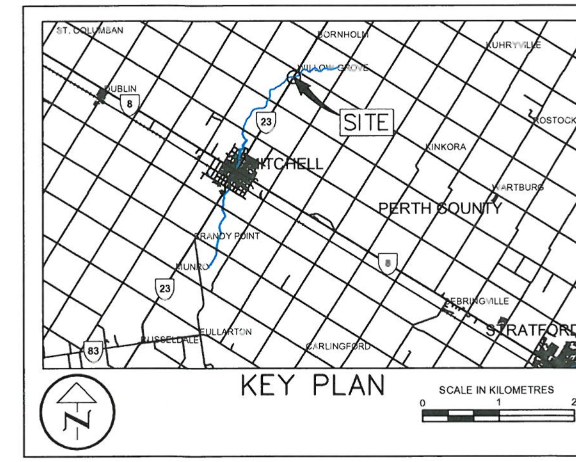
HIGHWAY 23 STRUCTURE REPLACEMENTS

BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA

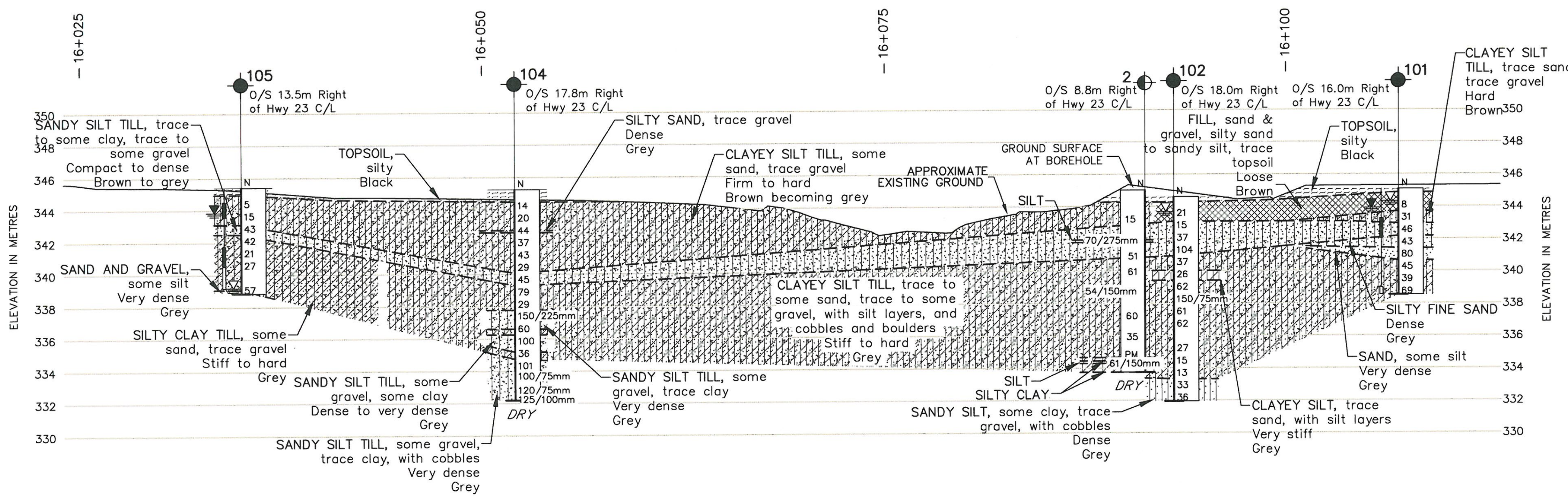


PLAN
SCALE 5 0 5 m



KEY PLAN
SCALE IN KILOMETRES 0 1 2

F.J. HEFFERNAN
OCT 26/11
T.N.S.PITT
100132967
OCT 26/11



PROFILE ALONG APPROXIMATE ALIGNMENT OF TEMPORARY BRIDGE
SCALE 3 0 3 m

LEGEND

- Borehole (Current Investigation)
- Borehole (Geocres 40P11–7)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- Encountered WL
- DRY Borehole dry during drilling
- Measured WL (June 8, 2011)

		CO–ORDINATES (MTM ZONE 11)	
No.	ELEVATION	NORTHING	EASTING
101	345.08	4 820 314.7	413 276.5
102	344.61	4 820 301.6	413 271.1
103	344.95	4 820 268.5	413 246.6
104	345.26	4 820 266.3	413 250.2
105	345.43	4 820 253.9	413 237.9
Geocres 40P11–7			
2	345.03	4 820 305.7	413 262.9

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration. Subsurface information has been inferred from Geocres No. 40P11–7.

REFERENCE

Base plans provided in digital format by Delcan.

NO.	DATE	BY	REVISION

Geocres No. 40P11–19			
HWY. 23	PROJECT NO. 10–1132–0029		DIST.
SUBM'D. DUP	CHKD.	DATE: Aug. 24/11	SITE: 25–128
DRAWN: DCH/LMK	CHKD.	APPD.	DWG. 2

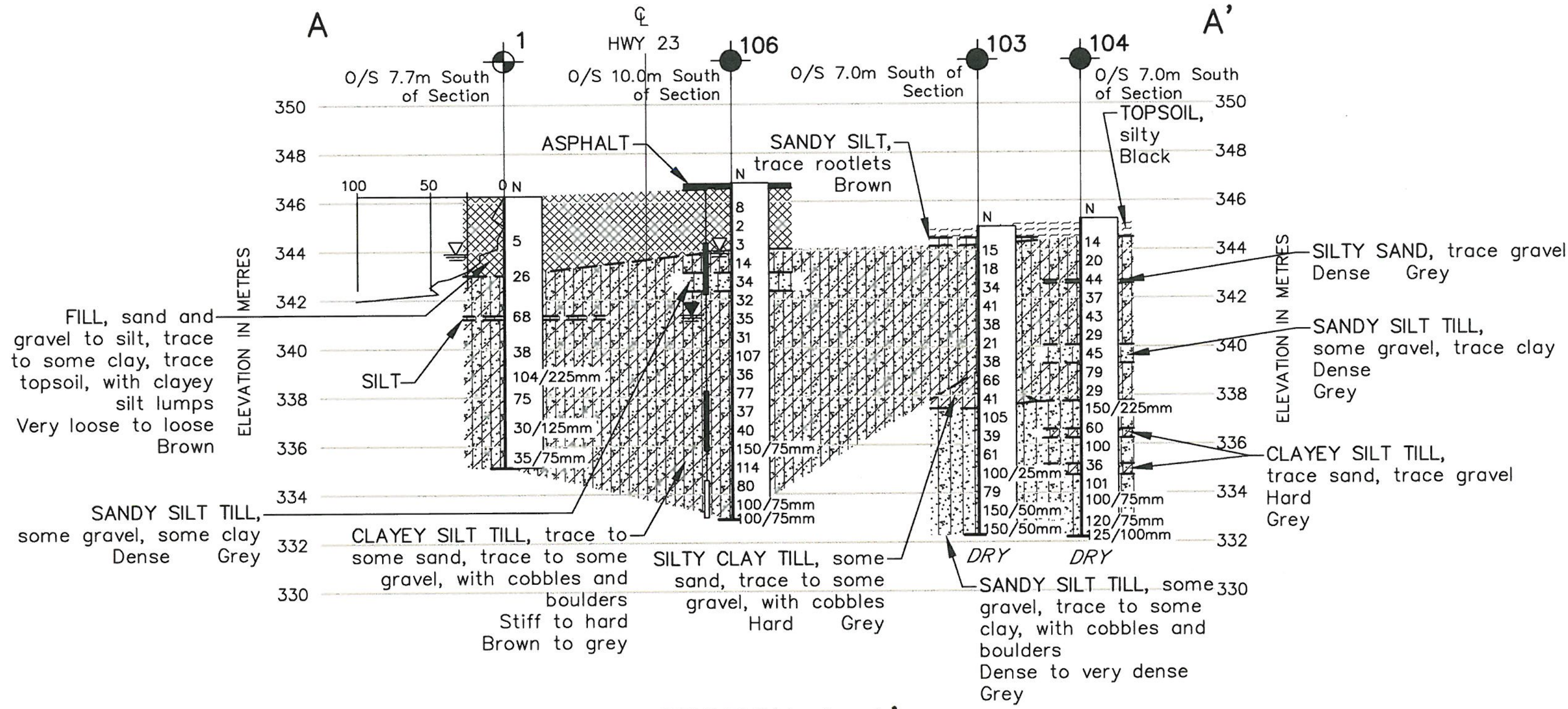
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 3043–06–00

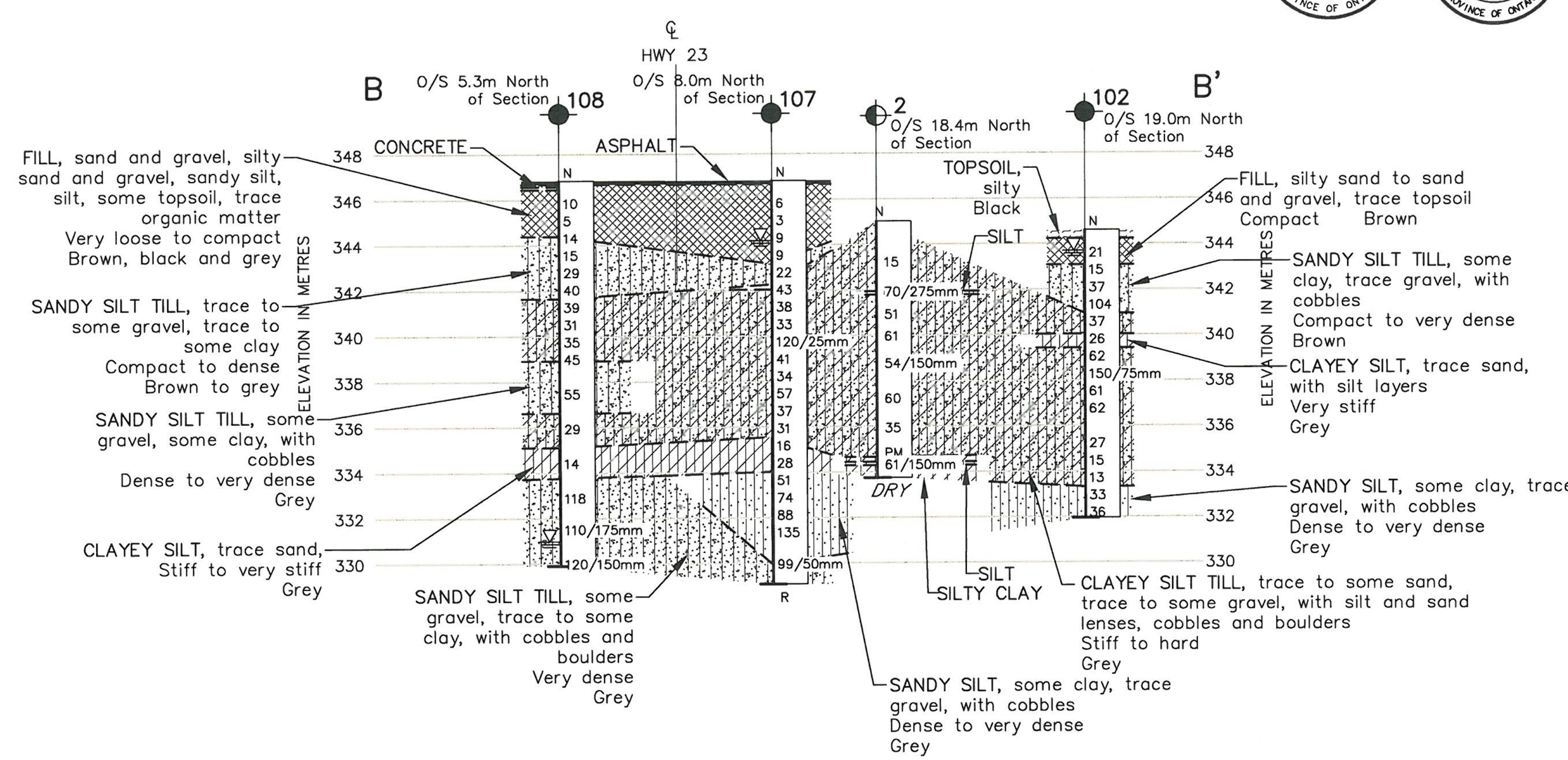
SHEET

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
SOIL STRATA

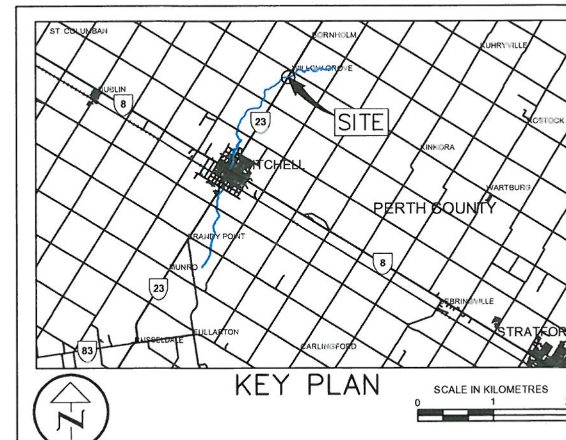
Golder Associates
Golder Associates Ltd.
LONDON, ONTARIO, CANADA



SECTION A–A'
SCALE
3 0 3 m



SECTION B–B'
SCALE
3 0 3 m



KEY PLAN
SCALE IN KILOMETRES
0 1 2

LEGEND

- Borehole (Current Investigation)
- Borehole and Cone (Geocres 40P11–7)
- Borehole (Geocres 40P11–7)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- Encountered WL
- DRY Borehole dry during drilling
- Measured WL (June 8, 2011)
- R Refusal

No.	ELEVATION	CO-ORDINATES (MTM ZONE 11) NORTHING	EASTING
102	344.61	4 820 301.6	413 271.1
103	344.95	4 820 268.5	413 246.6
104	345.26	4 820 266.3	413 250.2
106	346.77	4 820 271.0	413 236.3
107	346.84	4 820 299.1	413 253.7
108	346.85	4 820 301.5	413 244.2
Geocres	40P11–7		
1	346.25	4 820 277.7	413 229.5
2	345.03	4 820 305.7	413 262.9

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration. Subsurface information has been inferred from Geocres No. 40P11–7.

REFERENCE

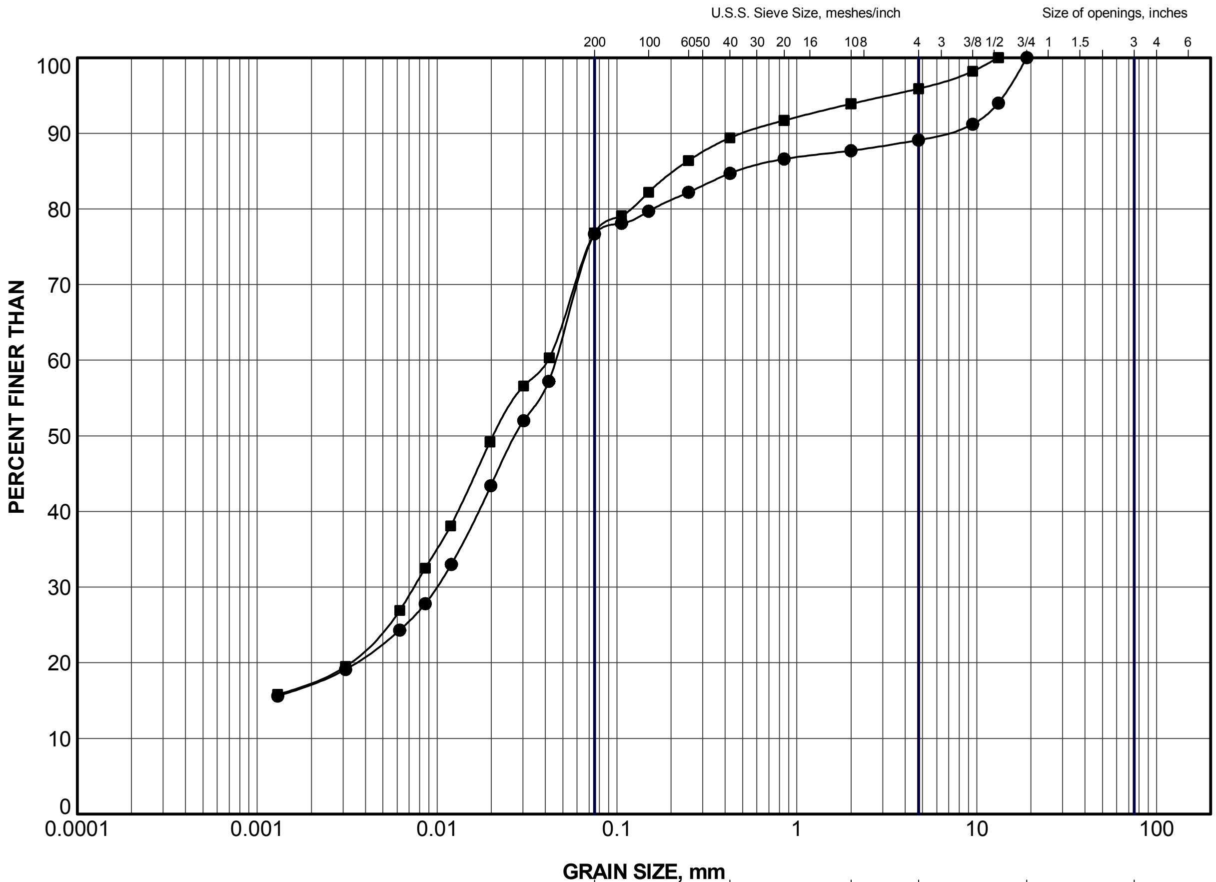
Base plans provided in digital format by Delcan.

NO.	DATE	BY	REVISION

Geocres No. 40P11–19			
HWY. 23		PROJECT NO. 10-1132-0029	DIST.
SUBM'D. DUP	CHKD.	DATE: Aug. 24/11	SITE: 25–128
DRAWN: DCH/LMK	CHKD.	APPD.	DWG. 3

APPENDIX A

Laboratory Test Data



CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	106	2	345.0
■	107	2	345.1

PROJECT

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

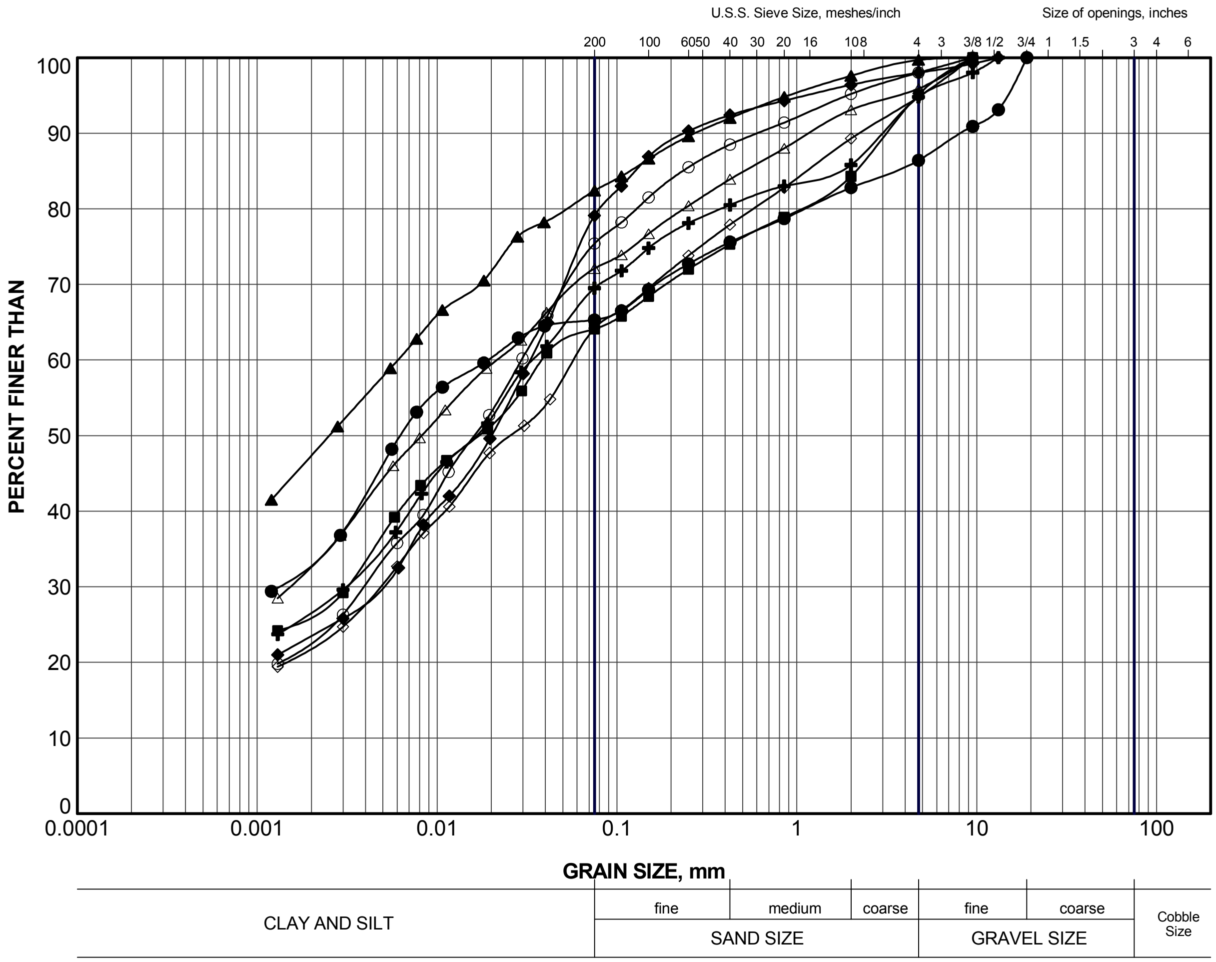
GRAIN SIZE DISTRIBUTION

FILL

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F010A1	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 12/11	FIGURE A-1
CHECK			

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	6	340.3
■	102	7	339.1
▲	102	12	334.5
✚	103	4	341.7
◆	104	5	341.2
◇	104	8	338.9
○	105	2	343.7
△	106	9	339.7

PROJECT

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

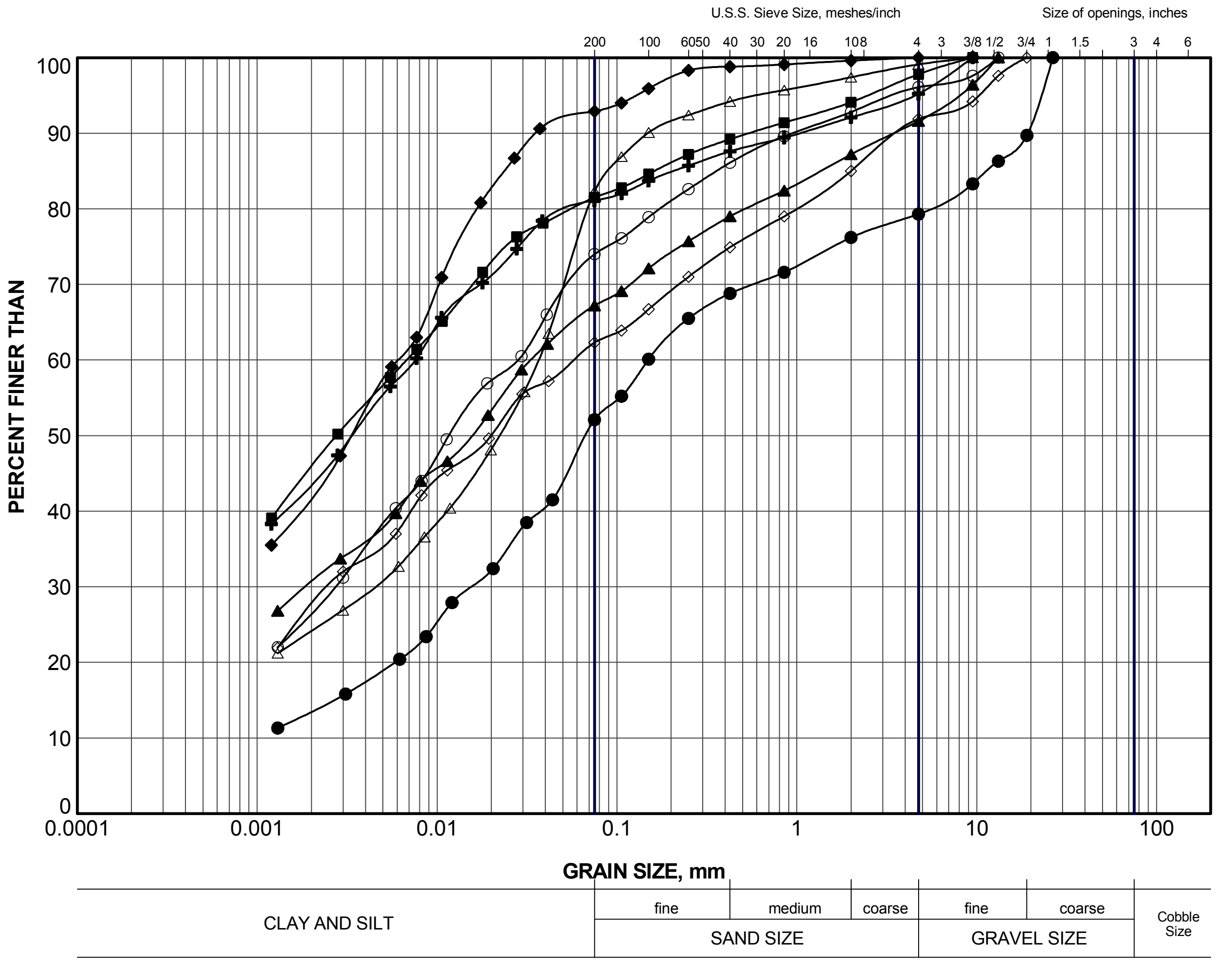
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.		10-1132-0029	FILE No. 1011320029-7000-F010A2
			SCALE N/A REV.
DRAWN	DCH/AMG	SEPT. 12/11	FIGURE A-2
CHECK			

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	106	15	335.1
■	107	8	340.5
▲	107	13	336.7
✚	108	8	340.5
◆	109	4	343.6
◇	109	8	340.6
○	110	4	343.5
△	110	7	341.2

PROJECT

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

GRAIN SIZE DISTRIBUTION

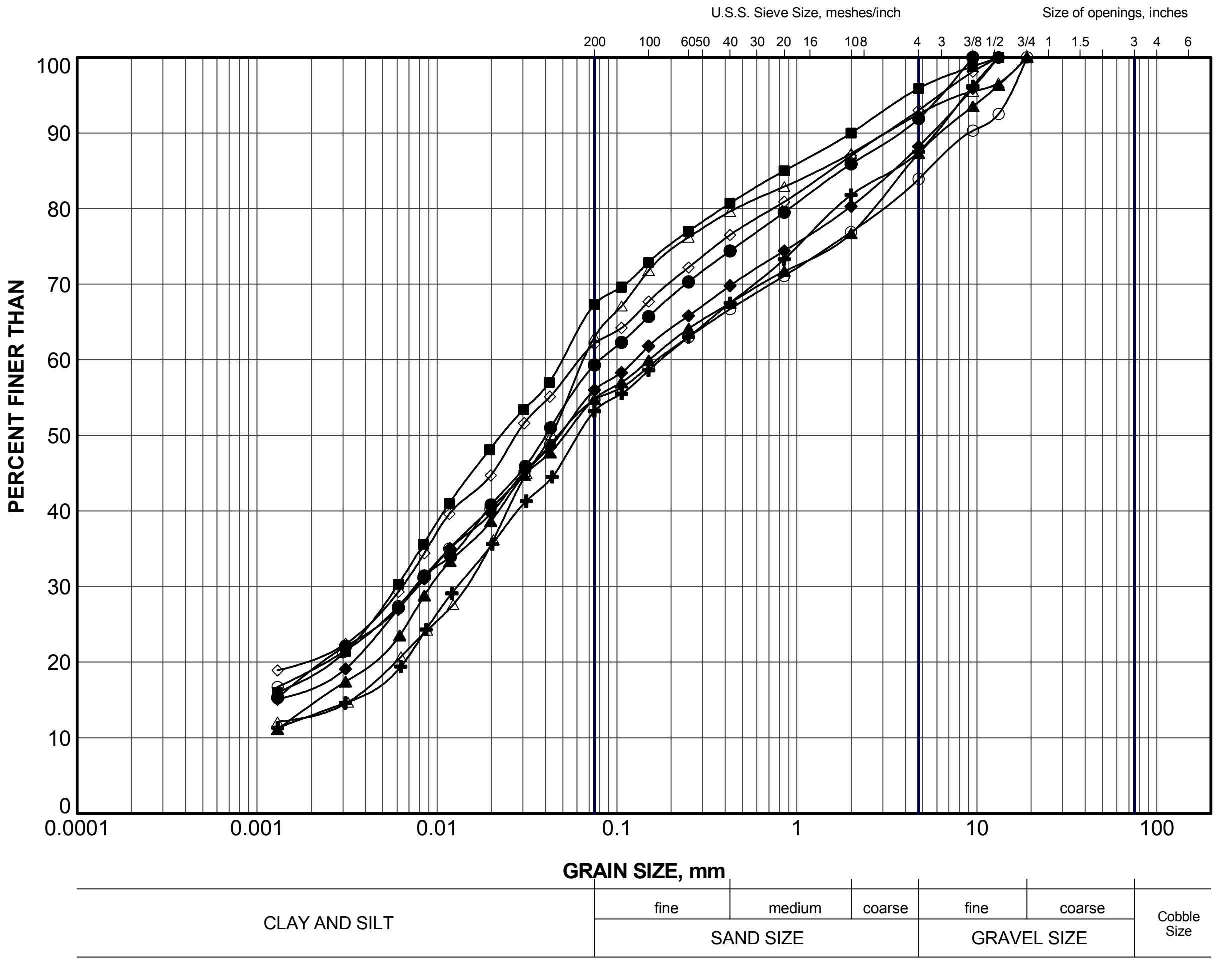
CLAYEY SILT TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F010A3	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 12/11	
CHECK			

FIGURE A-3

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	3	342.6
■	102	3	342.1
▲	103	14	334.1
✚	104	12	335.9
◆	106	5	342.7
◇	108	5	342.8
○	108	11	337.5
△	108	14	332.9

PROJECT

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

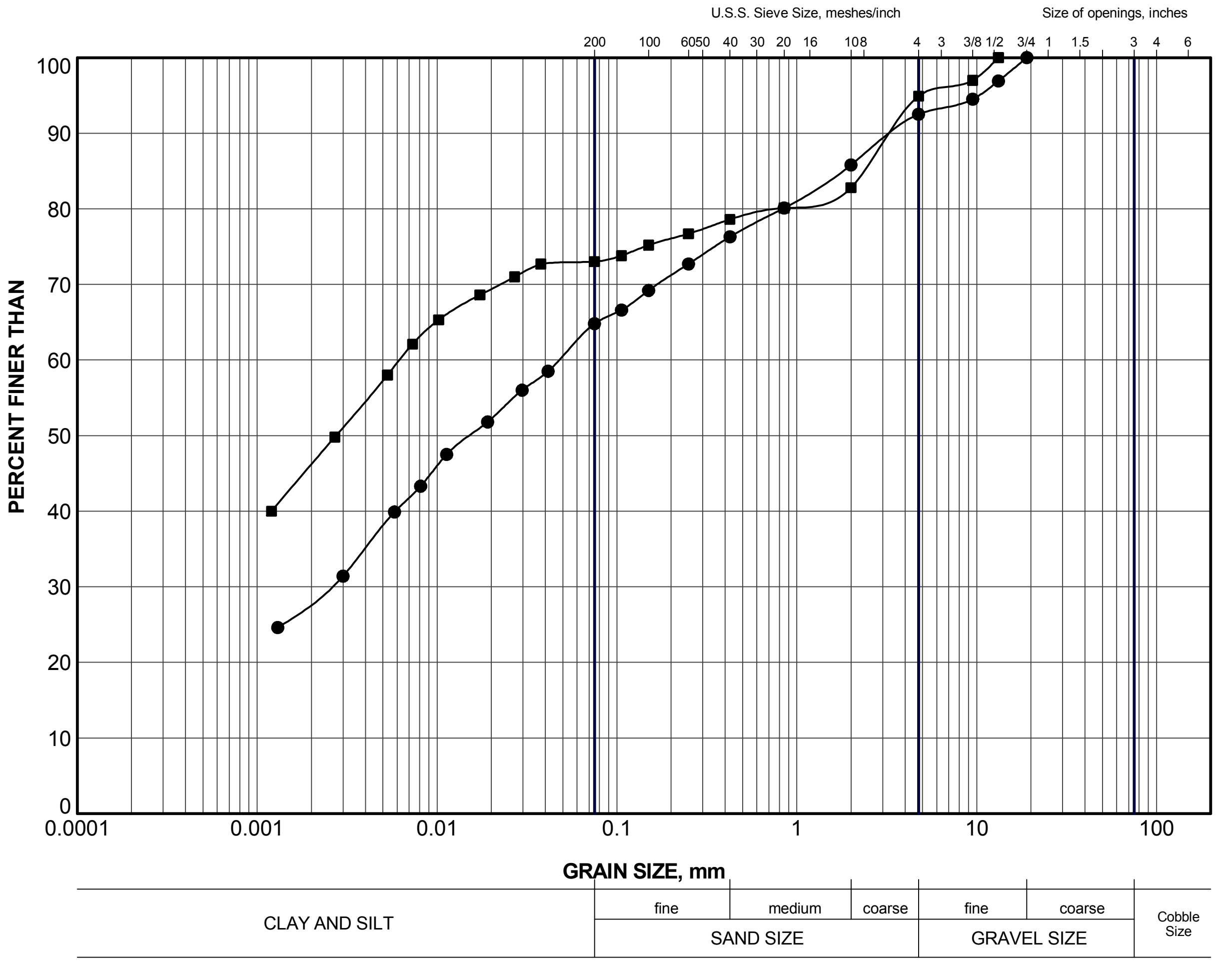
GRAIN SIZE DISTRIBUTION

SANDY SILT TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F010A4	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 12/11	FIGURE A-4
CHECK			

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	103	9	337.9
■	105	5	341.4

PROJECT

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

GRAIN SIZE DISTRIBUTION

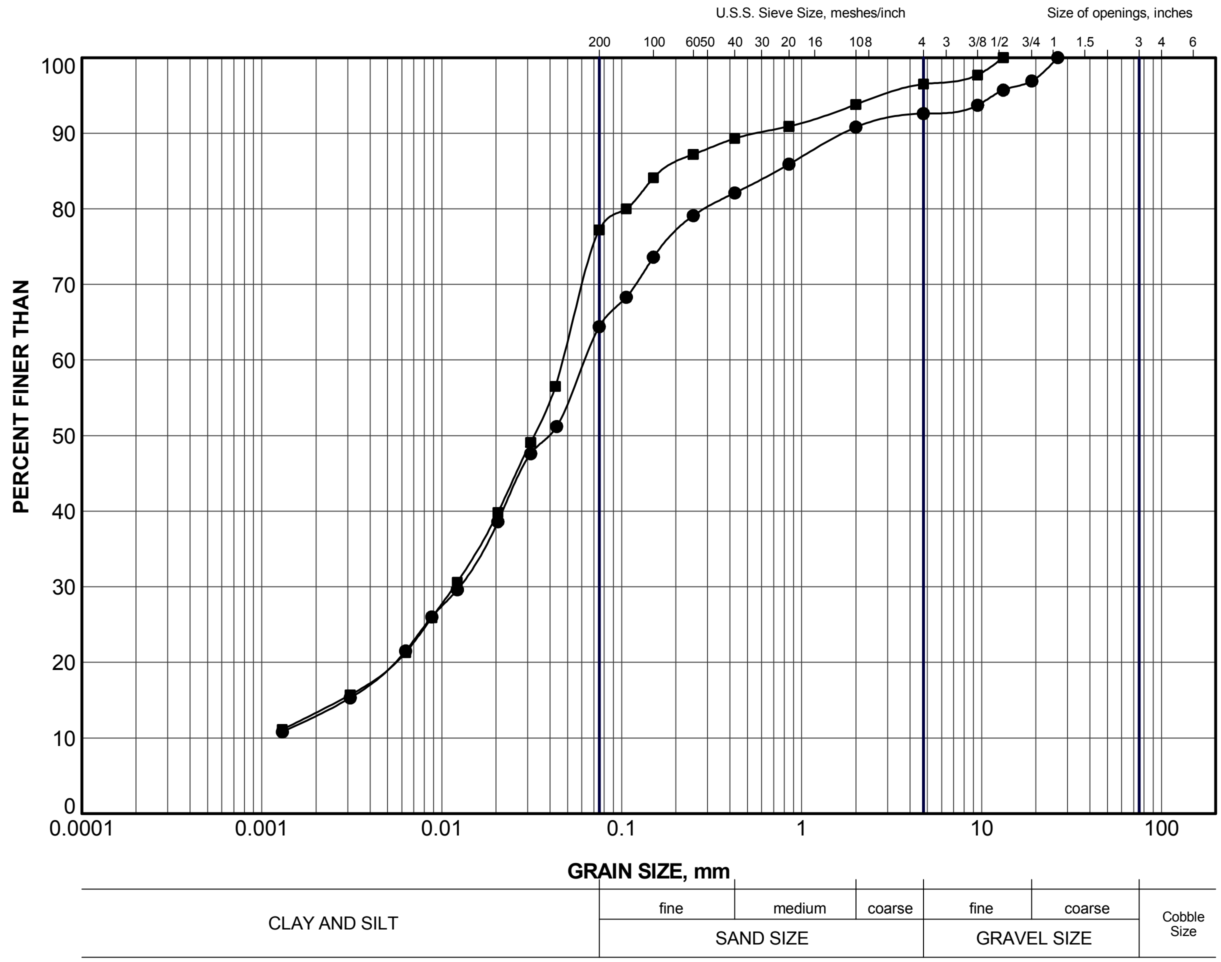
SILTY CLAY TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F010A5	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 12/11	
CHECK			

FIGURE A-5

LDN_MTO_GSD-15 GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	102	14	333.0
■	107	20	331.4

PROJECT

NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

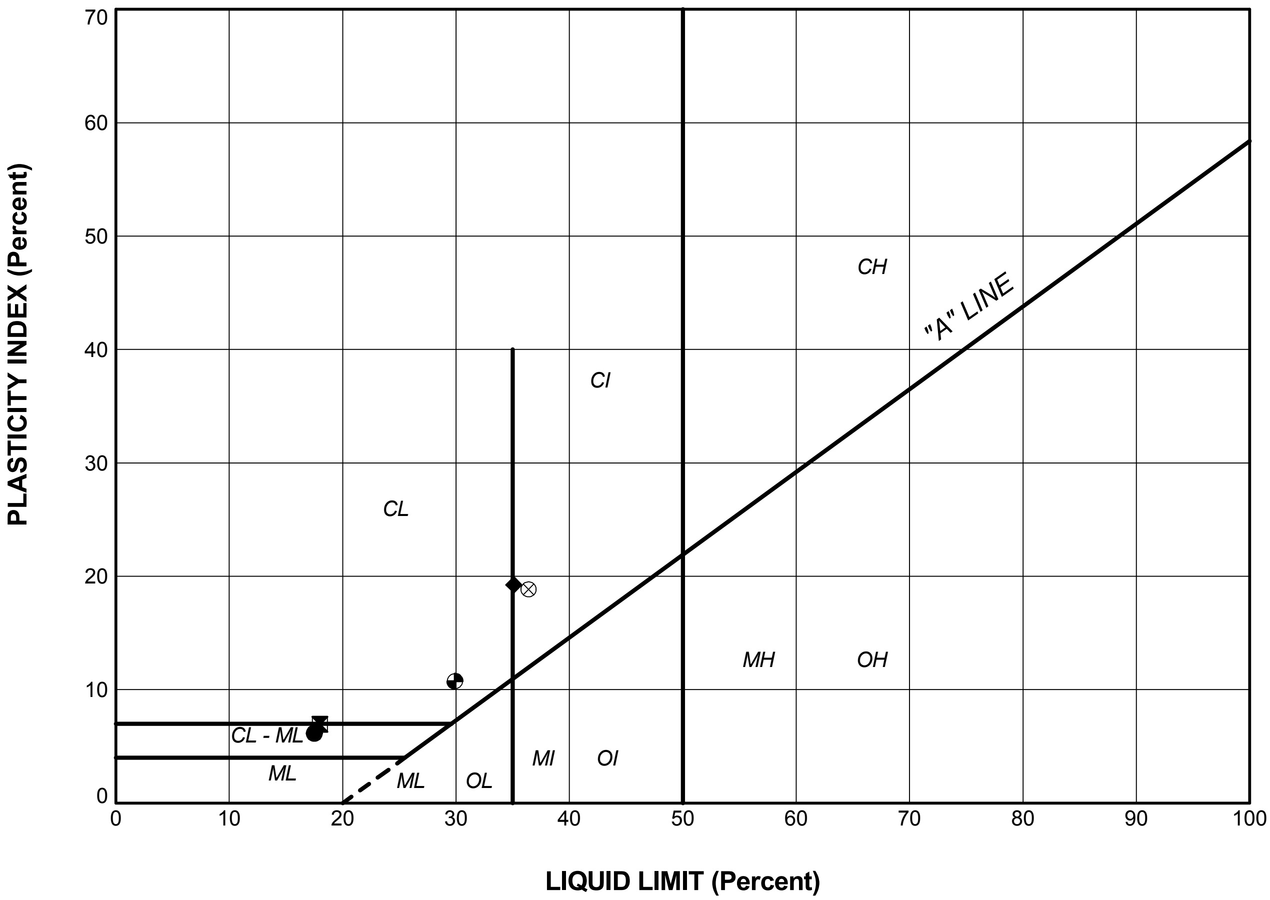
GRAIN SIZE DISTRIBUTION

SANDY SILT

PROJECT No.	10-1132-0029	FILE No. 1011320029-7000-F010A6	
		SCALE N/A	REV.
DRAWN	DCH/AMG	SEPT. 12/11	FIGURE A-6
CHECK			

Golder Associates
LONDON, ONTARIO

LDN_MTO_GSD-15 GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
FILL					
◕	107	2	29.9	19.2	10.8
SILTY CLAY TILL					
◆	103	9	35.1	15.9	19.3
⊗	105	5	36.4	17.6	18.9
SANDY SILT TILL					
●	102	3	17.5	11.4	6.2
⊕	106	5	17.5	11.3	6.2
⧗	108	5	18.0	11.1	7.0

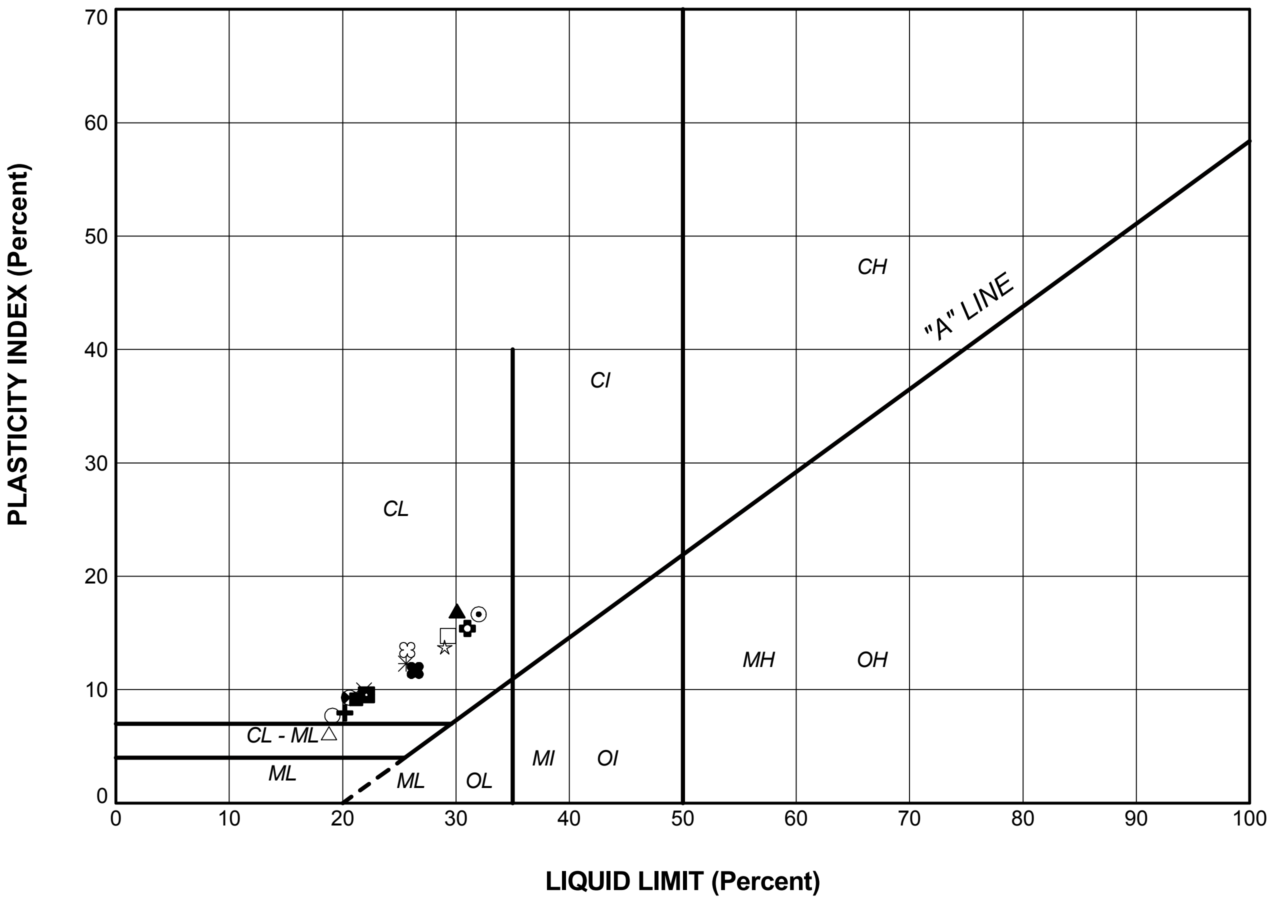
PROJECT
NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE
PLASTICITY CHART

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No.1011320029-7000-F010A7	
		SCALE N/A	REV.
DRAWN	DH/WF/AG SEPT. 12/11	**FIGURE A-7**	
CHECK			

LDN_MTO_PI_25 GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
CLAYEY SILT TILL					
✳	101	7	25.6	13.3	12.3
■	102	7	21.2	12.1	9.2
▲	102	12	30.1	13.2	17.0
✚	103	4	20.2	12.3	8.0
◇	104	5	21.7	12.2	9.6
○	104	8	19.1	11.4	7.7
△	105	2	18.8	12.7	6.2
□	106	9	29.3	14.6	14.8
●	106	15	20.6	11.3	9.3
☆	107	8	29.0	15.3	13.8
✿	107	13	25.7	12.2	13.5
⊙	108	8	32.0	15.4	16.7
✿	109	4	31.0	15.6	15.4
×	109	8	21.9	12.0	10.0
✖	110	4	26.4	14.7	11.7
■	110	7	22.1	12.6	9.6

PROJECT
NORTH THAMES RIVER BRIDGE
HIGHWAY 23 STRUCTURE REPLACEMENTS
GWP 3043-06-00, SITE 25-128

TITLE

PLASTICITY CHART

Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0029	FILE No.1011320029-7000-F010A8
		SCALE N/A REV.
DRAWN DH/WF/AG	SEPT. 12/11	FIGURE A-8
CHECK		

LDN_MTO_PI_25_GLDR_LDN.GDT

APPENDIX B

Records of Previous Boreholes (Geocres Report No. 40P11-7)

FORM DB-MT-126 (FORMERLY DB-ML-126)
65-1831

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 65-F-88
W.P. 307-64
DATUM Geodetic

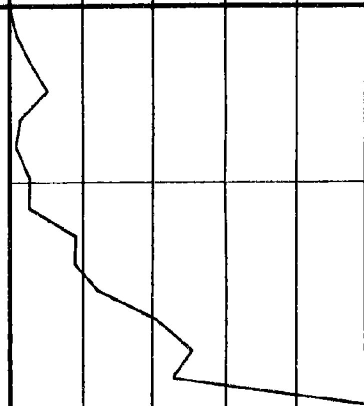
LOCATION Hwy 23, Thames River Crossing, 4Mi N of Mitchell
BORING DATE Aug 9, 1965
BOREHOLE TYPE Washboring - NX Casing.

ORIGINATED BY L.P.
COMPILED BY L.P.
CHECKED BY M.D.

ELEV. DEPTH	DESCRIPTION
346.25m 1136.0	Ground Surface
0.0	Fill Material - Some sand, some gravel, some organics.
342.90m 1125.0 11.0	Clayey silt, some sand, some gravel, (Glacial Till) Hard
341.22m 1119.5 16.5	6" Layer of Silt Very occasional thin layers of silt. Occasional Boulders
335.13m 1099.5 36.5	

SAMPLE NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	BULK DENSITY γ P.C.F.	REMARKS
					▼1128.3 7.7
1	SS	5	1130		
2	SS	26			Gr13%Sa12% Si35%Cl 40%
3	SS	68	1120		
4	SS	38		125.5	Gr&Sa16% Si34% Cl 50%
5	SS	104/9"			
6	SS	75	1110	133	Gr 11%Sa19% Si34%Cl 36%
7	SS	30/5"			
8	SS	35/3"	1090		Gr&Sa32% Si35% Cl 43%

DYNAMIC PENETRATION RESISTANCE
BLOWS / FOOT 20 40 60 80 100
SHEAR STRENGTH P.S.F.



LIQUID LIMIT — w_L
PLASTIC LIMIT — w_P
WATER CONTENT — w
WATER CONTENT % 10 20 30

FORM DB-MT-126 (FORMERLY DB-ML-126)
65-1831

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS – ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 65-F-88
W.P. 307-64
DATUM Geodetic

LOCATION Hwy 23 Thames River Crossing 4 Miles N of Mitchell
BORING DATE Aug. 10, 1965.
BOREHOLE TYPE Washboring - NX Casing.

ORIGINATED BY L.P.
COMPILED BY L.P.
CHECKED BY M.D.

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	BULK DENSITY γ P.C.F.	REMARKS
345.03m 1132.0	Ground Surface						
0.0	Clayey silt, sand, gravel, Brown (Glacial Till)				1130		
		1	SS	15			
341.80m 1121.4 10.6	6" Layer of silt	2	SS	70/11"	1120		
	Very occasional thin layers of silt.	3	SS	51			Gr6%Sa14% Si55%Cl 25%
		4	SS	61			
		5	SS	54/6"	1110		
		6	SS	60			Gr8%Sa24% Si37%Cl 31%
		7	SS	35	1100	143	
334.67m 1098.0 34.0	Silty clay						
1096.5 35.2	6" Layer of silt.	8	TW	PM6", Tap 6"			Gr33%Sa39% Si23%Cl 5%
333.76m 1095 37.0		9	SS	61/6"			
					1090		

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT
SHEAR STRENGTH P.S.F.

LIQUID LIMIT — w_L
PLASTIC LIMIT — w_P
WATER CONTENT — w

WATER CONTENT %
10 20 30

APPENDIX C

Site Photographs

Photograph 1: North Thames River Bridge, northwest quadrant.

Photograph 2: North Thames River Bridge, west elevation.

Photograph 3: North Thames River looking downstream from bridge.

Photograph 4: Highway 23 looking north. Location of temporary bridge to east of existing structure.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
309 Exeter Road, Unit #1
London, Ontario, N6L 1C1
Canada
T: +1 (519) 652 0099

Golder Associates