June 9, 2017

FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 401 Structural Culvert - Site No. 22-438/C Rehabilitation/Replacement - Highway 35/115 and Highway 401
Ministry of Transportation, Ontario
W.P. 2242-14-00

Submitted to:
D.M. Wills Associates Ltd.
150 Jameson Drive
Peterborough, ON
K0J 0B9

GEOCRES NO: 30M15-317

Report Number: 1540419-8

Distribution:

1 Copy - Ministry of Transportation, Ontario, Downsview, Ontario (Foundations Section)
1 Copy - Ministry of Transportation, Ontario, Downsview, Ontario
1 Copy - D.M. Wills Associates Ltd.
1 E-Copy - Golder Associates Ltd., Mississauga, Ontario

REPORT

TABLE OF CONTENTS

TABLES

DRAWINGS

APPENDICES

PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 401 STRUCTURAL CULVERT, SITE NO. 22-438/C
STRUCTURAL CULVERT REHABILITATION/REPLACEMENT
HIGHWAY 35/115 AND HIGHWAY 401
MINISTRY OF TRANSPORTATION, ONTARIO
W.P. 2242-14-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by D.M. Wills Associates Ltd. (D.M. Wills) on behalf of Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the rehabilitation and extension of a structural culvert at STA 14+714 on Highway 401 in the Town of Whitby, Regional Municipality of Durham, Ontario (MTO Structure Site No. 22-438/C) as shown on the Key Plan on Drawing 1.

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Quotation, dated August 2015. Golder's proposal for the Foundation Engineering services associated with the rehabilitation/replacement of various culverts on Highway 35/115 and Highway 401 is contained in Section 3.5 of D.M. Wills' Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated December 1, 2016.

This report addresses the investigation carried out for the structural culvert at about STA 14+714 on Highway 401 (MTO Structure Site No. 22-438/C) which has been identified for potential rehabilitation and extension 8.9 m to the north and 5.1 m to the south. The foundation investigation and design associated with the other culverts, which forms part of the Foundation assignment are presented in separate reports. The current investigation was supplemented with information from a previous investigation for the Highway 401 and Pringle Creek area, as follows:

- **Golder Associates Report No. 13-1186-0419**: Geotechnical Investigation Report: Proposed Watermain Replacement Crossing Highway 401 Right-of-Way at Pringle Creek, Town of Whitby, Ontario" Dated 2015.

2.0 SITE DESCRIPTION

The structural culvert at Site No. 22-438/C (Culvert C8) requiring rehabilitation and extension or replacement, is located at approximately STA 14+714 on Highway 401 in the Town of Whitby, Regional Municipality of Durham, Ontario. The existing structural culvert is an open footing concrete structure and is 56.65 m long, 6.09 m wide by 3.5 m high. The structure is located within the highway embankment and has less than approximately 1 m of cover. Details of the culvert are summarized in Table 1 following the text of this report.

The overall surface topography in the vicinity of the site is generally flat-lying to gently sloping, with the natural ground surface at approximately Elevation 79 m. The Highway 401 grade over the culvert is at about Elevation 81.1 m. The existing Highway 401 embankment consist of earth fill, up to about 3.5 m high with side slopes inclined at approximately 2 horizontal to 1 vertical (2H:1V).

3.0 INVESTIGATION PROCEDURES

3.1 Current Investigation

The fieldwork for the current investigation associated with structural culvert Site No. 22-438/C was carried out on July 28 and December 19, 2016, and January 16, 24 and 25, 2017 during which time a total of three boreholes, designated as Boreholes C8-1, C8-2 and C8-4, were advanced at, or in the immediate vicinity of the culvert alignment as shown in plan on Drawing 1.

The field investigation was carried out using a variety of drilling equipment as a result of accessibility and restrictions associated with the terrain at the culvert site. The details of the drilling equipment and suppliers are listed below.

Drilling Equipment	Supplied and Operated By
Truck-Mounted CME 75	AtCost Drilling Inc. of Gormley, Ontario
Track-Mounted Mini-Mole	Kodiak Drilling Inc. of Oakville, Ontario
Portable Equipment	Walker Drilling Ltd. of Utopia, Ontario

The boreholes drilled by the truck-mounted CME75 drill rig were advanced through the overburden using 208 mm outer diameter (O.D.) 108 mm inner diameter (I.D.) hollow stem augers. The boreholes drilled by the track-mounted Mini-Mole rig were advanced through the overburden using 102 mm diameter solid stem augers. The boreholes completed with the portable equipment were advanced through the overburden using BW size casing with wash boring techniques. Soil samples were obtained continuously at some borehole locations but generally at intervals of depth of about 0.75 m and 1.5 m using a 50 mm O.D. split-spoon sampler operated by an automatic hammer on the drill rigs, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586[1]). Borehole C8-1 advanced by portable equipment employed a 40.8 kilogram hammer lifted manually and dropped from the SPT height; the SPT 'N'-values shown on the Record of Borehole for C8-1 have been corrected to the 'N'-values expected to have been achieved when using a full weight hammer. Bedrock in Boreholes C8-1 and C8-2 was cored using wet diamond drilling techniques and BQ and NQ core sizes, respectively. At the location of Borehole C8-1, approximately 1 m of the bedrock was cored from Elevations 73.2 m to 72.2 m. At the location of Borehole C-8-2, approximately 4.2 m of the bedrock was cored from Elevations 73.2 m to 69.0 m.

A piezometer was installed in Borehole C8-4 to allow monitoring of the groundwater level at this site. The piezometer consists of a 25 mm diameter PVC pipe, with a slotted screen sealed within the sand and gravel to clayey silt deposits. The borehole and annulus surrounding the piezometer pipe above the screen and sand pack were backfilled with bentonite pellets to ground surface. The piezometer installation details and water level readings are noted on the Record of Borehole C8-4 in Appendix A. All other boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Regulation 903 (Wells) (as amended). The groundwater soil sample conditions were noted as the samples were retrieved but the water levels in the open boreholes were not recorded immediately prior to start of coring operations nor following the drilling operations, after introduction of drilling water, as noted on the Record of Borehole sheets in Appendix A. The groundwater level in the piezometer in Borehole C8-4 was monitored immediately after installation and about eight months later (March 2017) and as noted on the Record of Borehole sheet and summarized in Section 4.2.11.

The fieldwork was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil and bedrock samples. The soil and bedrock samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were

[1] ASTM D1586-11 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils, ASTM International, West Conshohocken, PA, 2011

carried out to MTO Laboratory and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples and strength testing (Unconfined Compression and Point Load) was carried out on selected samples of the cored bedrock. The results of the laboratory testing are summarized on the Record of Borehole and Record of Drillhole sheets in Appendix A and provided in Appendix B.

A soil sample obtained during the field investigation at about the culvert invert elevation, using appropriate sampling protocols, was submitted to a specialist analytical laboratory under chain of custody procedures for chemical analysis of conductivity / resistivity, pH, sulphate and chloride content and redox potential to assess the potential for the soil to cause corrosion to buried concrete and steel. The results of the analytical testing are presented in Appendix C and summarized in Section 4.3.

The as-drilled borehole locations were measured relative to existing site features and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. The Geodetic elevation of the boreholes was obtained by plotting the borehole locations on the topographic mapping provided by D.M. Wills on January 20, 2016. The borehole locations given on the Record of Borehole and Record of Drillhole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are as follows:

Borehole	Location (m)		Location (degrees)		Ground Surface Elevation (m)	Depth of Borehole (m)
	Northing	Easting	Lat.	Long.		
C8-1	4858601.8	350978.9	43.865944	-78.925481	78.8	6.6*
C8-2	4858584.5	350977.3	43.865800	-78.926000	81.0	12.0*
C8-4	4858535.8	350986.1	43.865349	-78.925399	79.1	5.5

*Includes 1.0 m and 4.2 m of bedrock coring, respectively.

3.2 Previous Investigation

The field work for the previous investigation was carried out between June 17 and July 3, 2015, during which time three boreholes (Boreholes 15-1 to 15-3) were drilled at the approximate locations shown on Drawing 1. The boreholes were advanced with track-mounted and truck-mounted drill rigs, supplied and operated by AtCost Drilling Inc. of Gormley, Ontario.

The boreholes were advanced through the overburden using 210 mm O.D. hollow stem augers. Soil samples were obtained continuously at some borehole locations but generally at intervals of depth of about 0.75 m using a 50 mm O.D. split-spoon sampler operated by an automatic hammer on the drill rigs, performed in accordance with SPT procedures. HQ coring was advanced within the bedrock in Borehole 15-1, between the depths of 6.3 m and 7.2 m, followed by hollow stem augering to carry out an SPT in the shale bedrock at this location as groundwater pressures affected the ability to continue rock coring operations.

Piezometers were installed in Boreholes 15-1 and 15-3 to allow monitoring of the groundwater level at this site. The piezometers consist of 50 mm diameter PVC pipe, with a slotted screen sealed within the shale bedrock. The borehole and annulus surrounding the piezometer pipe above the screen and sand pack were backfilled with bentonite pellets to ground surface. The piezometer installation details and water level readings are noted on the Record of Boreholes 15-1 and 15-3 in Appendix D. Boreholes 15-2 was backfilled with bentonite upon completion of drilling in accordance with Ontario Regulation 903 (Wells) (as amended). The groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations and are described on the Record of Borehole sheets in Appendix D.

The fieldwork at that time was observed by members of Golder's engineering and technical staff. Soil and bedrock samples were identified in the field, placed in appropriate containers, labelled and transported to our Whitby geotechnical laboratory where the samples underwent further visual examination and classification testing (water content, Atterberg limits and grain size distribution) of selected soil samples. The results of the laboratory testing are summarized on the Record of Borehole and Record of Drillhole sheets and laboratory test sheets in Appendix D.

The borehole locations given on the Record of Borehole and Record of Drillhole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are as follows:

Borehole	**Location (m)**		**Ground Surface Elevation (m)**	**Depth of Borehole (m)**
	Northing	**Easting**		
15-1	4858611.3	3510003.9	79.0	7.7*
15-2	4858562.5	351014.0	81.5	9.2
15-3	4858525.5	351015.5	79.2	7.7

*Includes 0.9 m of bedrock coring

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 401 is located within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)[2] and *Urban Geology of Canadian Cities* (Karrow and White, 1998)[3]. The Iroquois Plain extends around the western shores of Lake Ontario. The Plain is comprised of the flat to undulating lakebed and beaches of the former glacial Lake Iroquois, which occupied this area during the last glacial recession. The surficial soils in this area of the Iroquois Plain are typically comprised of glaciolacustrine clays, silts and sands to gravelly sands and underlain by the black bituminous shale of the Whitby Formation.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation as well as the previous investigation, together with the results of the laboratory tests carried out on

[2] Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

[3] Karrow, P. F., and White, O. L., 1998. *Urban Geology of Canadian Cities.* Geological Association of Canada Special Paper No. 42. St. John's, Nfld.

selected soil samples, are presented on the Record of Borehole and Drillhole sheets and the laboratory test sheets in Appendices A, B, and D. The stratigraphic boundaries shown on the Record of Boreholes and Record of Drillhole sheets and stratigraphic profile are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The stratigraphy at the locations of the current investigation and previous borehole locations at the culvert site consists of embankment fill materials which extend to between approximately Elevations 77.3 m and 79.6 m, except at Borehole C8-4 where no fill was encountered. From the ground surface at Borehole C8-4 and underlying the fill materials there are variable native deposits consisting of loose to dense gravelly sand, very soft to very stiff clayey silt and till-like materials, and glacial tills ranging in gradation from clayey silt, silty sand, gravelly sand to sand and gravel. Shale bedrock, which was found to be weathered and highly fractured, water-bearing and pressurized, was encountered at depths ranging from Elevation 73.9 m at the location of Borehole C8-2 to Elevation 74.7 at the location of Borehole 15-1. Sampler and auger refusal in Borehole C8-4 occurred at elevation 73.6 m.

A detailed description of the subsurface conditions at the culvert crossing is provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

4.2.1 Asphalt and Road Base

Boreholes C8-2 and 15-2 were advanced through the paved shoulder of the westbound Highway 401 and through the left (median) shoulder of eastbound Highway 401, respectively. These boreholes penetrated an asphalt layer between approximately 150 mm and 125 mm thick, respectively. The underlying layer of road base material consists of sand and gravel fill and is 600 mm and 715 mm thick at the respective boreholes.

The SPT 'N'-values measured in this layer are 14 blows and 76 blows per 0.3 m of penetration, indicating a compact to very dense relative density.

4.2.2 Topsoil

A 25 mm thick layer of topsoil was encountered at ground surface in Borehole C8-1. In Borehole 15-3, a topsoil sandy silt fill mixture extended from ground surface to a depth of 1.9 m below ground surface. In Borehole 15-2, an approximately 0.8 m thick layer of mixed topsoil and silty sand fill was encountered at the bottom of the embankment fill (described below).

The SPT 'N'-values measured within the topsoil/topsoil-sandy silt fill mixture range from 4 blows to 11 blows per 0.3 m of penetration, indication a loose to compact relative density.

4.2.3 Embankment Fill

An embankment fill layer, approximately 0.7 m to 2.9 m thick was encountered in all boreholes, with the exception of Borehole C8-4, immediately below existing ground surface and underlying the topsoil or road base layer (where present). The embankment fill consists of various layers, thicknesses and composition, especially in Borehole 15-1. In Borehole C8-1, an approximately 0.7 m thick layer of silty sand, some gravel and containing trace topsoil inclusions was encountered below the surface topsoil layer. In Borehole C8-2, an approximately 0.6 m thick layer of sandy clayey silt with some gravel was encountered below the asphalt and road base material.

In Borehole 15-1, a 0.7 m thick layer of silt and sand with some gravel and organic inclusions was encountered below ground surface, underlain by an approximately 1 m thick layer of silty sand containing rootlets , organic inclusions and wood fragments.

In Borehole 15-2 underlying the asphalt and road base materials, the borehole penetrated an approximately 3.9 m tick deposit of fill comprised of a 0.9 m thick layer of silty sand with some clay and gravel, underlain by a 0.4 m thick layer of silty clay and some sand, and a 0.8 m thick layer of sandy clayey silt, underlain by the layer of topsoil and silty sand mixture (as described in previous section).

The SPT ‘N’-values measured within the non-cohesive embankment fill layers range between 2 blows and 11 blows per 0.3 m of penetration, indicating a very loose to compact relative density. The SPT ‘N’-values measured in the cohesive embankment fill layers are 11 blows and 21 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

The natural water content measured on three samples of the cohesive embankment fill from the current and previous investigations range from 10 per cent to 14 per cent.

The natural water content measured on eight samples of the non-cohesive embankment fill from the current and previous investigations range from 8 per cent to 32 per cent.

The result of a grain size distribution test completed on one sample of the silty sand fill encountered in Borehole 15-2 is shown on Figure D1 in Appendix D.

An Atterberg limits test carried out one sample of the sandy cohesive embankment fill measured a liquid limit of about 20 per cent, a plastic limit of about 13 per cent and a plasticity index of about 7 per cent. The test result, which is plotted on a plasticity chart on Figure B1 in Appendix B, indicates that the material is a clayey silt of low plasticity.

4.2.4 Silty Sand to Sand

A 1.6 m thick deposit of silty sand and a 2.3 m thick deposit of sand was encountered below the fill materials in Borehole C8-2 and from ground surface in Borehole C8-4 at Elevation 79.6 m and 79.1 m respectively.

SPT “N”-values ranging from 5 blows to 21 blows per 0.3m of penetration were measured within this layer, indicating a loose to compact relative density.

The natural water contents of two samples of the silty sand to sand are 9 per cent and 13 per cent. A grain size distribution curve for one sample the sand portion of the deposit is shown on Figure B2 in Appendix B

4.2.5 Gravelly Sand

A deposit of gravelly sand was encountered below the fill materials in Borehole 15-2 at Elevation 77.8 m and extended to a depth of about 5.5 m below existing ground surface. In Borehole C8-2 a 4.1 m thick deposit of gravelly sand was encountered below the silty sand deposit at Elevation 78.0 m.

SPT “N”-values ranging from 8 blows to 15 blows per 0.3 m of penetration were measured within this deposit, indicating a loose to compact relative density.

The natural water content of the samples of the gravelly sand ranged from about 5 per cent to 28 per cent. The results of four grain size distribution curves for the samples of gravelly sand are shown on Figure B3 in Appendix

B and Figure D2 in Appendix D. An Atterberg Limits test carried out on a sample of the gravelly sand deposit indicates a plastic limit of about 15 per cent, a liquid limit of about 22 per cent and a plasticity index of about 7 per cent, indicating that the fines material of the deposit is a silty clay of low plasticity as shown on Figure B4 in Appendix B.

4.2.6 Clayey Silt to Sandy Clayey Silt

A 1.2 m and 0.5 m thick deposit of clayey silt to sandy clayey silt was encountered below the fill deposits in Boreholes 15-1 and 15-3 at Elevation 77.3 m; and a 1.8 m thick deposit of clayey silt was encountered below the sand and gravel (till-like) deposit (described below) in Borehole C8-4 at Elevation 75.0 m. SPT "N"-values of 1 blow to 2 blows per 0.3 m of penetration, and 70 blows for 0.15 m of penetration, were measured in this deposit, suggesting a very soft to hard consistency. The harder 'N'-values are likely due to the presence of shell fragments in this portion of the deposits.

The natural water contents of the samples of the clayey silt to sandy clayey silt range from about 9 per cent to 26 per cent. The grain size distribution curve for a sample of the sandy clayey silt is shown on Figure D3 in Appendix D. Atterberg limits testing carried out on two samples of sandy clayey silt to clayey silt yielded liquid limits of about 24 per cent, plastic limits of about 12 per cent and 17 per cent, and plasticity indices of about 12 per cent and 7 per cent, indicating a clayey silt of low plasticity, as shown on the plasticity chart on Figure D4 in Appendix D and Figure B in Appendix B.

4.2.7 Silty Sand and Gravel to Sand and Gravel (Till-Like)

A 1.4 m thick till-like deposit of silty sand and gravel to sand and gravel was encountered below the sandy clayey silt deposit in Borehole 15-1 at Elevation 76.1 m. In Boreholes C8-1 and C8-4, a silty sand deposit grading to a till-like sand and gravel deposit was encountered below the silty sand till layer and below the sand deposit, respectively. The deposit was encountered at Elevations 78.0 m and 76.8 m in the respective boreholes and the layers are 1.5 m and 2.1 m thick in Borehole C8-1 and C8-4.

SPT "N"-values measured within the till-like layers range from 7 blows to 76 blows per 0.3 m of penetration, and 90 blows for 0.08 m of penetration, indicating a loose to very dense relative density.

Grain size distribution test results of four samples of the till-like silty sand and gravel are shown on Figure B6 and D5 in Appendices B and D, respectively.

An Atterberg limits test carried out on a sample of the silty sand (till-like) deposit and measured a plastic limit of about 23 per cent, a liquid limit of about 15 per cent corresponding to a plasticity index of about 8 per cent, indicating that the fines portion of the till-like deposit is a silt of slight plasticity as shown on Figure B7 in Appendix B.

4.2.8 Clayey Silt Till to Clayey Silty Sand Till

A till deposit comprised of clayey silt to clayey silty sand was encountered below the clayey silt deposit in Borehole 15-3 at Elevation 76.8 m and is 2.0 m thick.

SPT "N"-values of 57 blows per 0.3 m of penetration and 50 blows per 0.13 m of penetration were measured within the till, indicating a hard consistency. The till deposits of the Greater Toronto Area known to contain cobbles and boulders, and these materials are anticipated to be present within the till deposits at this site as inferred from auger grinding in this borehole.

The measured water contents of the samples of the clayey tills ranged between about 6 per cent and 7 per cent. A grain size distribution test on a sample of clayey silty sand till is shown on Figure D6 in Appendix D. An Atterberg limits test carried out on a samples of the cohesive till measured a liquid limit of about 21 per cent, a plastic limit of 12 per cent, and a plasticity index of about 9 per cent, indicating a clayey silt of low plasticity, as shown on the plasticity chart on Figure D7 in Appendix D.

4.2.9 Silty Sand Till to Gravelly Silty Sand Till

A 2.0 m thick and 0.8 m thick deposit of silty sand to gravelly silty sand till was encountered in Boreholes 15-2 and 15-3 at Elevations 76.0 m and 74.8 m, respectively.

Standard Penetration Tests carried out within the silty sand till to gravelly silty sand till measured SPT “N”-values ranging from 34 blows to 42 blows per 0.3 m of penetration and 95 blows for 0.28 m of penetration, indicating a dense to very dense relative density.

The measured water contents of the samples of the silty sand to gravelly silty sand till range from about 6 per cent to 10 per cent. The grain size distribution test results for one sample of the silty sand till and one sample of gravelly silty sand till portions of the deposit are shown on Figure D8 in Appendix D.

4.2.10 Shale Bedrock

Shale bedrock was encountered in Boreholes C8-1, C8-2, 15-1, 15-2, and 15-3 at depths ranging from approximately 4.3 m and 7.5 m below ground surface (between Elevations 74.7 m and 73.9 m). The upper 0.7 m to 2.0 m of the bedrock is inferred to be highly weathered to moderately weathered, fractured and water-bearing based on various SPT samples and examination and the groundwater conditions observed during drilling of the boreholes. The SPT “n”-values in the weathered shale portion of the bedrock are 55 blows and 63 blows per 0.3 m of penetration and range from 32 blows for 0.1 m of penetration to 50 blows for no penetration (spoon bouncing) suggesting the variability in the weathered nature of the upper portion of the bedrock. The shale is also bituminous in nature as inferred from the hydrocarbon-like odour observed in the shale bedrock in Borehole 15-1.

At the location of Borehole 15-1, approximately 0.9 m of the bedrock was cored using wet diamond drilling techniques (HQ core size) from Elevation 72.7.

The bedrock in Boreholes C8-1 and C8-2 was cored using wet diamond drilling technical and BQ and NQ core sizes, respectively. At the location of Borehole C8-1, approximately 1 m of the bedrock was cored from Elevation 73.2 m and in Borehole C8-2, approximately 4.2 m of the bedrock was cored from Elevation 73.2 m.

The Total Core Recovery (TCR) of the cored bedrock ranges between about 77 per cent and 100 per cent, the Solid Core Recovery (SCR) ranges between about 60 per cent and 100 per cent. The Rock Quality Designation (RQD) ranges between about 0 per cent and 32 per cent with core runs of up to 100 per cent, indicating rock of very poor to excellent quality as per Table 3.10 of CFEM (2006).

Based on a review of the recovered bedrock core samples, the bedrock consists of black, moderately weathered shale. Detailed descriptions of the bedrock are presented on the Record of Drillhole sheets in Appendix A.

An Unconfined Compressive Strength (UCS) test carried out on one sample of the shale bedrock from Borehole C8-2 measured a uniaxial compressive strength of about 45 MPa. The test result which is shown on the Record of Drillhole sheet in Appendix A and summarised in Table B1 in Appendix B, indicates that the bedrock is medium strong (R3) as per Table 3.5 of CFEM (2006).

Axial point load index tests were performed on eight selected samples of the rock core recovered from Boreholes C8-1 and C8-2 at this site and the strength index values are presented on the Record of Drillhole Sheets in Appendix A and detailed in Table B2 in Appendix B. The point load index (Is_{50}) results of core samples of the shale bedrock range from approximately 1.8 MPa to 3.9 MPa. These index values correspond to UCS values ranging between about 28 MPa and 62 MPa, based on a relationship between Is_{50} and UCS which is given by a correlation factor (C), estimated to be equal to 15.9 for this site, and calculated as the ratio of the laboratory UCS and average corresponding point load test index value from all of the drillholes at this site. These values have been given for comparison only and should be interpreted together with the results of the UCS tests.

Based on the laboratory UCS tests and point load testing results, the estimated intact strength of the shale bedrock generally ranges from medium strong (R3, 25 MPa < UCS < 50 MPa) to strong (R4, 50 MPa < UCS < 100 MPa); (Table 3.5 of CFEM, 2006).

4.2.11 Groundwater Conditions

The water level was not recorded in Boreholes C8-1 and C8-2 prior to bedrock coring.

A standpipe piezometer had been installed in Borehole C8-4 west of the existing culvert outlet. Standpipe piezometers previously installed in Boreholes 15-1 and 15-3 were monitored at the time of the previous investigation. The observed groundwater levels are shown on the Record of Borehole sheets and summarized below.

Borehole	Depth to Water Level (m)	Groundwater Elevation	Date of Measurement
C8-4	4.6	74.5	July 28, 2016
	1.1	78.0	March 28, 2017
15-1	0.3	78.7	July 8, 2015
	0.5	78.5	July 13, 2015
	0.6	78.4	July 15, 2015
15-3	0.9	78.3	July 8, 2015
	1.1	78.1	July 13, 2015
	1.1	78.1	July 15, 2015

The water level observed in the boreholes during and/or upon completion of drilling may not represent the longer-term, stabilized groundwater level at the site. The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation.

4.3 Analytical Testing of Soil Sample

Analytical testing was carried out on a composite soil sample constituted from the SPT samples recovered from near the culvert invert elevation at Borehole C8-1. The analytical parameters include conductivity / resistivity, pH sulphate and chloride to allow for the assessment of the potential for the soil to cause deterioration of concrete and corrosion of steel. The laboratory test results are included in Appendix D and are summarized below.

Parameter	Test Result
Soil Resistivity	1800 ohm-cm
Soil Conductivity	550 umho/cm
Sulphate Concentration	160 ug/g
Chloride Concentration	180 ug/g
PH	7.9

5.0 CLOSURE

Messrs. Pat Speirs and Michael Bentley, and Ms. Amelia Jewison supervised the borehole investigation program. This report was prepared by Mr. Peter Giuliani, P.Eng., a geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.

Report Signature Page

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
P. GIULIANI
100128521
June 9, 2017
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
J. M. A. COSTA
June 9, 2017
PROVINCE OF ONTARIO

Peter Giuliani, P.Eng.
Geotechnical Engineer

Jorge M. A. Costa, P.Eng.
Designated MTO Foundations Contact, Senior Consultant

PG/MWK/JMAC/mck

n:\active\2015\3 proj\1540419 dm wills_culverts hwy35_on\culvert c8\reporting\final\1540419-8 fidr 17jun09 wp 2186-15-00 - culvert 8 pg.docx

PART B

FOUNDATION DESIGN REPORT
HIGHWAY 401
STRUCTURAL CULVERT - SITE NO. 22-438/C
HIGHWAY 35/115 AND HIGHWAY 401
STRUCTURAL CULVERT REHABILITATION/REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 2242-14-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of a structural Culvert (C8) (structure Site No. 22-438/C) at Station 14+714 on Highway 401 at Pringle Creek, in the Town of Whitby, Regional Municipality of Durham, Ontario. The existing culvert is 56.7 m long (including previously constructed extensions of 3.05 m and 6.1 m to the south and north, respectively) and consists of a 6.09 m wide by 3.5 m high open footing concrete structure. The current design based on direction provided at the 90% executive review meeting requires rehabilitation of the existing culvert and construction of culvert extensions. The recommendations contained in this report are intended to provide an overview of the feasible trenchless installation methods for this site should the need to install a new culvert arise in the future, and provides foundation design recommendations for the culvert extensions.

These recommendations are based on interpretation of the factual data obtained from a previous (2015) foundation investigation, supplemented with the boreholes advanced during a current investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives. The Foundation Investigation Report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build Contractor. Additional detailed recommendations will be required to carry out the design of a replacement culvert, if required, once invert elevations, alignment and the culvert size are known. Where comments are made on construction, they are provided in order to highlight those aspects that could affect the design of the project. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

This report addresses potential construction concerns and geotechnical problems associated with installation of a new/replacement culvert installed by means of a trenchless method. Since no design details are available at this time it has been assumed that any new/replacement culvert will be installed at approximately the same elevations as the existing culvert and will be approximately the same size. If space and hydraulic requirements permit it is recommended that the new culvert be installed at least two diameters away from the existing structures. The existing culvert has less than approximately 1 m of cover along most of its alignment. Installation of a trenchless crossing with a thickness of cover less than 2 times the diameter of the crossing is considered to be very high risk and it is recommended that if a new/replacement culvert is required at this location alternative methods of installation (i.e. open cut) be considered.

The contractor should be fully responsible for the selection of the trenchless technology which best fits the contract requirements and subsurface conditions. The work plan should include a provision for grouting around the outside of any temporary or permanent ground support systems should the need arise. It is recommended that the geotechnical aspects of the contractor’s work plan for the trenchless undercrossing be reviewed by a qualified geotechnical engineer prior to construction.

In general, when crossing beneath highways, trenchless operations should be carried out continuously (i.e., 24 hours per day) from the start until the installation is complete. Continuous operations assist with minimizing risks of equipment becoming bound in the excavation by time-dependent increases in friction and/or adhesion, uncontrolled ground losses, and other critical problems that may occur while the work area is unattended.

Recommendations specific to the methodologies appropriate for this site are provided in the following sections of this report.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC 2014) and its Commentary, a classification of 'typical' consequence level has been assumed for a replacement culvert section and foundation system. This consequence classification should be confirmed by the MTO.

The degree of site understanding based on the scope of the foundation investigation and proximity of the boreholes to the culvert alignment is considered to be a 'typical' degree of site and prediction model understanding as described in Clause 6.5.3.2 of the 2014 CHBDC. Accordingly the appropriate corresponding Ultimate Limit States (ULS) and Serviceability Limits (SLS) consequence factor Ψ, geotechnical resistance factors at ULS, $\phi_{gu,}$ and SLS, ϕ_{gs}, respectively from Tables 6.1 and 6.2 of the CHBDC have been used for design.

6.3 Design Assumptions – Trenchless Replacement

It is anticipated that a replacement culvert at Site No. 22-438/C would likely be installed adjacent to and at a vertical profile at the existing culvert at approximate invert Elevations of 76.4 m at the inlet and outlet ends. Assuming that the existing open footing culvert is representative of the minimum size required to convey the design flows and satisfy hydraulic requirements, a replacement culvert would be expected to have an equivalent diameter of about of about 5.2 m. Based on these assumptions, there would not be adequate depth/thickness of cover relative to the existing Highway 401 pavement surface to provide an equivalent diameter pipe maintaining the same approximate invert elevation. Therefore, either a smaller diameter replacement culvert would need to be used to maintain the current invert elevations, or multiple smaller diameter culverts would be required to transmit the present hydraulic flow capacity, or a box section replacement culvert would have to be constructed similar to the dimensions of the existing culvert requiring open cut methods of installation.

As noted in Section 6.1, installation of a trenchless crossing with less cover than 2 times the diameter of the crossing is considered to be very high risk and therefore trenchless construction of a new/replacement culvert is considered to be not feasible for all available trenchless technologies.

6.4 Anticipated Ground Conditions

The stratigraphy along the culvert alignment, based on the current investigation and previous borehole locations near the culvert consists of embankment fill materials which extend to between approximately Elevations 79.6 m to 77.3 m, except at Borehole C8-4, immediately beyond the culvert inlet end, where no fill was encountered. From the ground surface at Borehole C8-4 and underlying the fill materials there are variable native deposits consisting of loose to dense silty sand to sad to gravelly sand, a dense to very dense granular till-like material deposit, a hard clayey silt deposit and a glacial till deposit comprised of dense silty sand. Shale bedrock, which is weathered and highly fractured, water-bearing and pressurized, was encountered at levels ranging from Elevation 74.7 at the location of Borehole 15-1 to Elevation 73.9 m at the location of Borehole C8-2. Sampler and auger refusal in Borehole C8-4 occurred at elevation 73.6 m and bedrock was cored or confirmed by split-spoon sampling at the other borehole locations from about Elevation 74.0 m to 73.8 m.

The presence of cobbles and boulders in the fill has been inferred from auger resistance/grinding encountered in the boreholes. Cobbles and/or boulders should also be expected in the native sand and gravel till-like deposits and the glacial till deposit. In addition to cobbles and boulders in the fill, there is the potential for encountering debris in the fill from the original culvert construction. The groundwater level along the tunnel profile within the overburden soils is expected to be near or below the culvert invert. The water level in the shale bedrock is expected to be pressurized and has been measured as high Elevations 78.1 m to 78.4 m in the piezometers installed in Borehole C8-4.

6.5 Construction of Culvert Extension Sections by Open-Cut Methods

It is understood that new culvert sections will be constructed at each end of the existing culvert extensions, further extending the overall length of the culvert by 8.9 m to the north and 5.1 m to the south. The new north and south extension sections to the existing open footing culvert are proposed to be constructed by open-cut methods as they are located beyond the north and south toes of the Highway 401 embankment. It is understood that the new extension culvert sections will match the size of the existing culvert and will be supported on footings measuring 1520 mm wide and 1200 mm thick.

The footings for the new culvert extensions may be founded on the silty sand to sand and gravel deposit, or gravelly silty sand to silty sand and gravel till-like deposit expected to be encountered at the south and north extension at Elevation 75.2 m. At the south extension, the footing may be founded on the hard clayey silt deposit and the very dense zone of the silty sand to gravelly sand deposit at Elevation 75.2 m. A factored ultimate geotechnical resistance of 550 kPa and factored serviceability geotechnical resistance of 375 kPa may be used for design. The SLS value assumes a settlement of less than 25 millimetres. If the strip footings are founded within the shale bedrock, a factored ultimate geotechnical resistance of 2.5 MPa may be used for design of footings on the good quality (RQD > 75%) shale bedrock at/below Elevation 72 m. The good quality shale bedrock is considered to be relatively unyielding and therefore the SLS resistance does not apply. It should be noted that in the previously conducted investigation (i.e. Borehole 15-2), measured groundwater levels in the shale bedrock were significantly higher than the water level observed during the current investigation as measured at about Elevation 78.0 m in the piezometer positioned on the bedrock and straddling the clayey silt/silty sand to sand and gravel deposit. Therefore it is recommended that the footing not be founded on the underlying shale bedrock due to the potential of encountering hydrostatic conditions above the design footing elevation, unless the overburden/shale bedrock is depressurized to a groundwater level lower than 0.3 m below the footing founding level.

6.5.1 Frost and Scour Protection

All footings for the culvert extensions should be provided with 1.2 m of earth cover or thermal equivalent for frost protection as interpreted from OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario). All culvert footings should also be adequately protected against scour as noted in Section 1.9.5 of the CHBDC (2014).

6.5.2 Resistance to Lateral Forces/Sliding Resistance

The resistance to lateral forces/sliding resistance between the base of the culvert footings and the foundations soils should be calculated in accordance with Section 6.10.5 of the CHBDC (2014).

The factored horizontal geotechnical resistance, H_{ri}, is calculated as follows:

$$H_{ri} = \psi \phi_{gu} (A'c'_i + V_f \tan\delta_{эi}) > H_f$$

Where:

Ψ = consequence factor, given in Section 6.5.2, Table 6.1 of the CHBDC

ϕ_{gu} = ultimate geotechnical resistance factor for siding, given in Section 6.9.1, Table 6.2 of the CHBDC

A' = effective contact area, (m^2)

c'_i = effective cohesion intercept, nil

tan δ' = friction factor, given below

V_f = factored vertical force, (kN)

H_f = factored horizontal load, (kN)

The factored horizontal resistance may be calculated using the parameters in the following table:

Structure	Interaction	Angle of Friction, δ (degrees)	Coefficient of Friction, tan δ
Concrete Culvert	Cast-in-place footing on Silty Sand to Sand and Gravel, Silty Sand Till and Gravelly Silty Sand to Sand and Gravel Till-Like	31	0.60
	Cast-in-place footing on Clayey Silt (if encountered)	26	0.49
	Cast-in-place footing on Shale Bedrock	35	0.70

6.5.3 Lateral Earth Pressures for Design

The lateral pressures acting on the proposed walls of the culvert extensions will depend on the type and method of placement of the backfill materials, on the nature of the soil behind the backfill, on the magnitude of surcharge including construction loadings, 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 walls in accordance with the CHBDC (2014). It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design in accordance with Figure 6.6 of CHBDC (2014).
- If the wall support does not allow lateral yielding (such is typically the case for a rigid concrete box culvert), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.2 m behind the culvert walls (Case (a) from the Commentary to CHBDC (2014) Figure C6.20).

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

Soil unit weight:	19 kN/m^3
Coefficients of lateral earth pressure:	
'At rest' or restrained, K_o	0.53

6.6 Construction Considerations

It is recommended that geotechnical review and consultation continue throughout the detail design and construction stages. A program of inspection and monitoring will be required during construction to ascertain whether the intent of the detail design recommendations provided in this report for the new extensions are being met and that the various project criteria are being achieved.

6.6.1 Excavations for Culvert Extension Foundations

When excavating near the portions of the existing culvert footings which are to remain in place, care should be taken to ensure that the footings and its founding soils are not disturbed or undermined. Care should also be taken during construction to avoid disturbance of the subgrade prior to pouring the new foundations. All existing fill and any topsoil, organics, and soft or loose soils should be stripped from the proposed founding areas prior to placement of the concrete for the footings. Subgrade preparation should be performed and monitored in accordance with OPSS 902 (Excavating and Backfilling Structures).

Temporary erosion protection and sedimentation control measures should be implemented in accordance with OPSS 805 (Temporary Erosion and Sediment Control Measures), together with diversion of any flows to mitigate migration of fine soil particles.

6.6.2 Culvert Backfill, Cover and Erosion Protection

Frost treatment (i.e. backfill and cover) for the concrete culvert should be in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). Cover to the culvert walls and top should consist of granular fill meeting the specifications of OPSS.PROV 1010 (Aggregates) Granular A or Granular B Type II. Backfill above the cover soil could consist of the excavated soils (i.e. re-use the excavated soils) provided they are free of organics and/or other deleterious materials. Alternatively, imported soil meeting OPSS.PROV 1010 Select Subgrade Material (SSM) could be used for backfill. The backfill and cover should be placed and compacted in accordance with OPSS.PROV 501 *(Compacting)*. The culvert should be designed for the full overburden pressure and live loads, assuming an embankment fill unit weight of 22 kN/m^3 for Granular A, and 21 kN/m^3 for Granular B Type II or SSM above and/or surrounding the culvert.

6.6.3 Groundwater and Surface Water Control for Culvert Extension Excavations

Control of surface water and groundwater will be necessary for the construction of the culvert extension sections to allow excavation, construction of the new culvert extension footings and culvert, and backfilling to be carried out in dry conditions.

Depending on the volume of water flow through the existing culvert at the time of construction, the surface water flow could be passed through the culvert by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam/cut-off wall, however, this option could prove to be difficult to construct due to the presence of shale bedrock below the underside of footing elevation. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the soils immediately surrounding the existing footings.

The groundwater table in the vicinity of the culvert is anticipated to be at or above the culvert invert based on the most recent measurements in the piezometer installed in one of the boreholes, but will fluctuate seasonally in response to changes in precipitation and snow melt. Perched groundwater may be encountered where the granular materials overly the lower permeability native clayey silt deposit. Excavations for the culvert replacement will likely extend to below the measured groundwater level at this site. Groundwater control may be required to control seepage from granular zones within the existing embankment fill; and, significant groundwater flow could occur in excavations extending through the granular soils below the groundwater level. It is anticipated that the groundwater inflow can be controlled by pumping from properly installed sumps within the excavations, provided that dewatering is carried out ahead of the excavating operation to the extent that the groundwater level is be maintained at least 0.3 m below the maximum excavation depth (to the bottom of the new culvert footings), until such time as construction has proceeded to above the static groundwater level.

6.6.4 Excavation and Temporary Roadway Protection

Temporary excavations for the culvert replacement sections will be made through the existing loose to compact silty sand to sand and gravel fill and the silty clay to sandy clayey silt embankment fill, as well as the native gravelly silty sand till-like deposit, loose to very dense silty sand to sand and gravel and very dense silty sand till layers. Excavation works must be carried out in accordance with the guidelines outlined in the latest version of the Occupational Health and Safety Act and Regulations for Construction Projects. The existing fills and loose to very dense sand, silty sand to sand and gravel, and gravelly silty sand to sand and gravel till-like deposits are classified as Type 3 soil, according to the OHSA. Where space permits, temporary open-cut excavations through these materials should be made with side slopes formed no steeper than 1H:1V, assuming proper groundwater and surface water control is in place. Granular soils and fill located below the groundwater table should be classified as Type 4 soil and will slough to flatter (3H:1V) excavation side slopes.

If adequate space for open cut excavations is not available a temporary excavation support system will be required and should be designed and constructed in accordance with OPSS.PROV 539 *(Construction Specification for Temporary Protection Systems).* The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any adjacent utilities can tolerate this magnitude of deformation.

6.7 Corrosion Assessment and Protection

Soil corrosivity may affect concrete pipes and headwalls, steel pipes and reinforced steel and other concrete elements buried in the soil. The long-term performance and durability of the structures are directly related to their respective corrosion resistance. Generally, the corrosivity of a structure depends on the soil resistivity, hydrogen ion concentration, salts (chloride and sulphate) concentrations and redox potential. The analytical results for a single composite soil sample from about the invert elevation of the existing culvert are presented in Section 4.3 and are included in Appendix C.

The analytical test results were compared to CSA Standard, CAN/CSA-A23.1-14 Table 3 *("Additional requirements for concrete subjected to sulphate attack")* for potential sulphate attack on concrete. The sulphate concentration measured in the soil sample tested is less than 0.1 per cent, which is below the exposure class of S-3 (Moderate). Therefore, based on the test results of the single composite sample of existing fill and native soils, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the existing fill and native deposits around the culvert may not need to be considered.

The soil has a pH of 7.9 and a resistivity of 1,800 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability. However, the resistivity is less than 4,500 ohm-cm, which indicates that the soil corrosiveness is Severe (2,000 ohm-cm > R), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). Based on these results some level of pipe protection (concrete and reinforcing elements) will likely be required. Further, given that the culvert extensions will be located north and south of the roadway shoulders and will be exposed to de-icing salt, consideration should be given by the designer to designing for a “C” type exposure class as defined by CSA A23.1 Table 1.

It is ultimately up to the designer to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 “Durability Requirements” are followed.

6.8 Further Investigation for Detail Design of Future Replacement/Relief Culverts

The foundation investigation carried out for this report is considered adequate for detailed design of a replacement culvert using conventional cut-and-cover excavation techniques in conjunction with temporary protection systems and construction staging. However it may be necessary to advance test pits or boreholes at the outlet locations for design of any temporary shoring/dewatering requirements and wingwalls / headwalls, or if multiple (relief) culverts are proposed or the new alignments will be offset some distance from the existing boreholes.

7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Peter Giuliani, P.Eng., and reviewed by Mr. Matthew Kelly, P.Eng, a geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.

Report Signature Page

GOLDER ASSOCIATES LTD.

Peter Giuliani, P.Eng.
Geotechnical Engineer

Matthew Kelly, P.Eng.
Geotechnical Engineer

Jorge M. A. Costa, P.Eng.
Designated MTO Foundations Contact, Senior Consultant

PG/MWK/JMAC/mck

n:\active\2015\3 proj\1540419 dm wills_culverts hwy35_on\culvert c8\reporting\final\1540419-8 fidr 17jun09 wp 2186-15-00 - culvert 8 pg.docx

REFERENCES

Chapman, L. J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual, 4th Edition.

Canadian Standards Association (CSA), 2014. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-14. CSA Special Publication, S6.1-14.

Karrow, P. F., and White, O. L., 1998. Urban Geology of Canadian Cities. Geological Association of Canada Special Paper No. 42. St. John's, Nfld.

Ontario Ministry of Transportation, 2014. MTO Gravity Pipe Design Guidelines: circular culverts and storm sewers, St. Catharines, Ontario

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects as amended by O. Reg. 443/09

Ontario Water Resources Act:

Ontario Regulation 372/9 Amendment to Ontario Regulation 903

ASTM

ASTM D1586-11 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils, ASTM International, West Conshohocken, PA, 2011

TABLES

Table 1: Summary of Existing Culvert Details

Culvert Location (Township)	Culvert ID	Approximate Height of Embankment [1]	Existing Culvert			Approximate Invert Elevation [2]		Boreholes	Previous Investigation Boreholes
			Type	Approximate Dimension	Approximate Length	North End of Culvert	South End of Culvert		
STA 14+417 (Whitby)	C8	Up to about 3.7 m	Open Footing	6.1 m x 3.5 m	56.65 m	76.37 m	76.40 m	3 Boreholes (C8-1, C8-2 and C8-4)	3 Boreholes (15-1, 15-2 and 15-3)

Notes: 1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.

2. Culvert invert elevations are estimated based on the top of culvert surveys and culvert dimensions provided by MTO.

DRAWINGS

MINISTRY OF TRANSPORTATION, ONTARIO

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

CONT No. 2017-2016
WP No. 2242-14-00

HIGHWAY 401
STRUCTURAL CULVERT STA. 14+714
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 18

Golder Associates

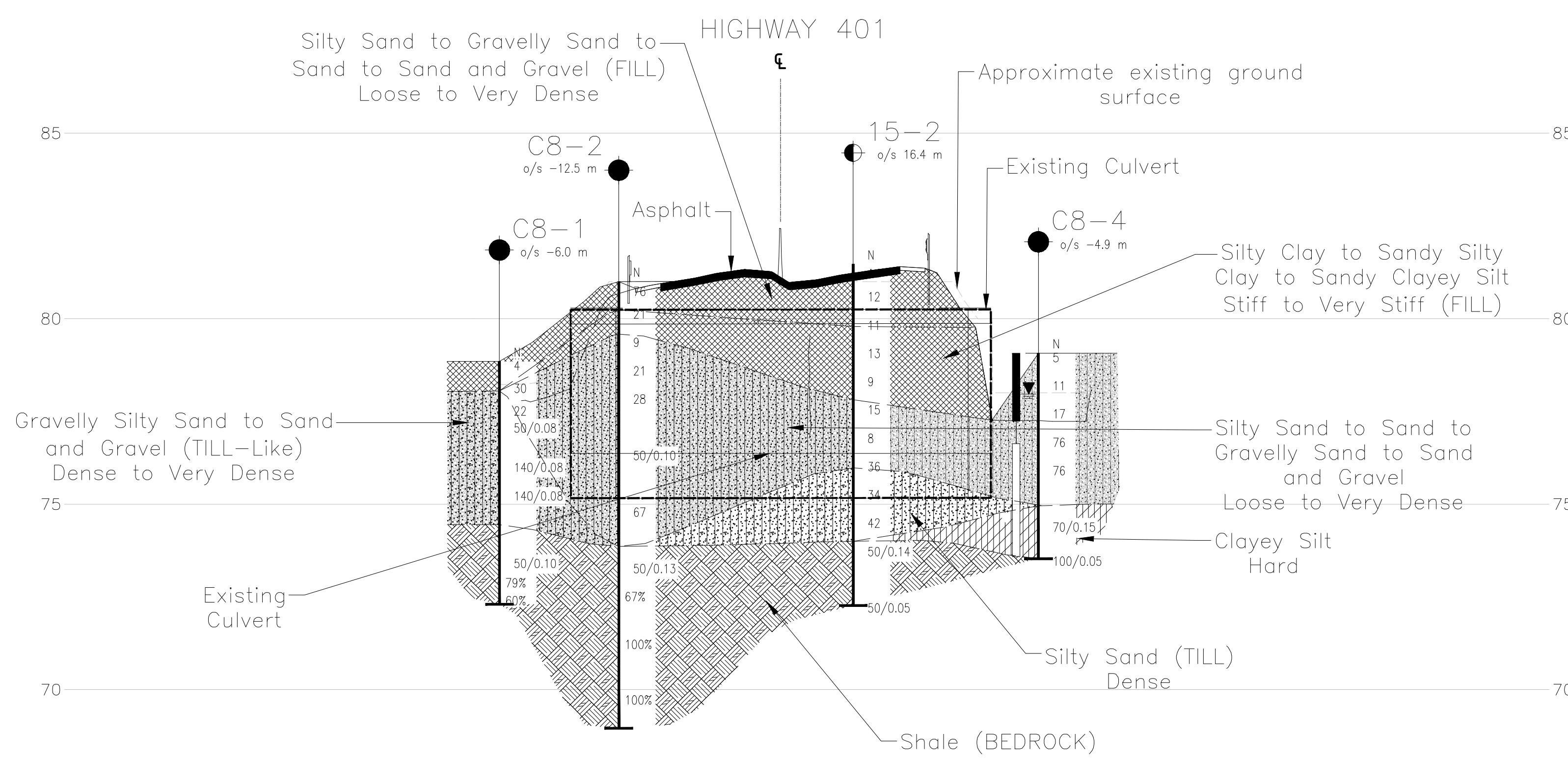
PLAN

SCALE 10 0 10 20 m

KEY PLAN
SCALE 6 0 6 12 km

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)*
- WL in piezometer, measured on SEP 13, 2016



A-A' CULVERT C8
STA. 14+714

HORIZONTAL SCALE 10 0 10 20 m

VERTICAL SCALE 2 0 2 4 m

BOREHOLE NOTE

* Borehole C8-1 SPT N-Values corrected for ⅔ Weight Hammer.

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
15-1	79.0	4858611.3	351003.9
15-2	81.5	4858562.5	351014.0
15-3	79.2	4858525.5	351015.5
C8-1	78.8	4858601.8	350978.9
C8-2	81.0	4858584.5	350977.3
C8-4	79.1	4858535.8	350986.1

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

Geographic Coordinates of Culvert: Latitude 43.865380; Longitude −78.925308

REFERENCE

Base Plan and Contours provided in digital format by DM Wills, drawing file nos. 123019.dwg, received Jan. 20, 2016. Design Plan and Section provided in digital format by DM Wills, drawing file no. 4561-C8 GA.dwg, received Jan. 3, 2017.

LICENSED PROFESSIONAL ENGINEER P. GIULIANI 100128521 June 9, 2017 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J. M. A. COSTA June 9, 2017 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 30M15-317

HWY. 401		PROJECT NO. 1540419	DIST.
SUBM'D. MCK	CHKD. MCK	DATE: 5/30/2017	SITE: 22-438/C
DRAWN: SMD/MR	CHKD. MWK	APPD. JMAC	DWG. 1

PLOT DATE: June 9, 2017

APPENDIX A

Record of Boreholes – Current Investigation

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
FoS	factor of safety

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
υ	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

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

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	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_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(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 ($\phi = 0$ 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

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
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
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.) drive open 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) Non-Cohesive 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.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

Golder Associates

RECORD OF BOREHOLE No C8-1

SHEET 1 OF 1

METRIC

PROJECT 1540419

W.P. 2242-14-00

LOCATION N 4858601.8; E 350979.0 MTM ZONE 10 (LAT. 43.865944; LONG. -78.925481)

ORIGINATED BY MB

DIST ____ HWY 401

BOREHOLE TYPE Portable Equipment, BW Casing, Washboring (Manual Hammer)

COMPILED BY SMD

DATUM Geodetic

DATE January 16 to 25, 2017

CHECKED BY MCK

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
78.8	GROUND SURFACE
0.0	TOPSOIL
0.1	Silty sand, some gravel, trace organic inclusions (FILL) Very loose Dark brown Wet
78.0 0.8	SAND and GRAVEL, some silt, trace clay (TILL-LIKE) Compact to dense Grey Moist
76.5 2.3	Gravelly SILTY SAND, trace clay (TILL-LIKE) Very dense Grey Moist to wet
74.4 4.4	Weathered SHALE (BEDROCK)
73.2 5.6	Shale (BEDROCK) Bedrock cored from depths of 5.6 m to 6.6 m For bedrock coring details, refer to Record of Drillhole C8-1.
72.2 6.6	END OF BOREHOLE

NOTE:

1. Water level in borehole not recorded prior to rock coring.

2. Borehole advanced with 2/3 weight hammer; SPT N-Values have been corrected to the values expected if using full weight hammer.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	3	
2	SS	19	
3	SS	14	31 53 14 2
4	SS	32	
5	SS	90	19 47 30 4
6	SS	90	
7	SS	32	
8	SS	32	
1	RC	REC 100%	RQD = 32%
2	RC	REC 100%	RQD = 0%

ELEVATION SCALE: 78, 77, 76, 75, 74, 73

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 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

PROJECT: 1540419

RECORD OF DRILLHOLE: C8-1

SHEET 1 OF 1

LOCATION: N 4858601.77 ;E 350978.95

DRILLING DATE: January 24 and 25, 2017

DATUM: Geodetic

DRILL RIG: Portable Equipment

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Walker Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY: TOTAL CORE % (80 60 40 20)	RECOVERY: SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER (5 10 15 20)	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	Axial Point Load Index (MPa) (2 4 6)	FEATURES	PIEZOMETER
		GROUND SURFACE		73.26															
6	35mm Dia. BQ Core, Jan. 25, 2017	Moderately weathered, thinly bedded, black, fine grained, non-porous, weak SHALE (Whitby formation)		5.59	1							BD,PL,SM BD,PL,SM	1 1	1 1	16 16			BC	Axial Axial Axial Axial
				72.25	2							BD,PL,SM	1	1	16			BC	Axial
		END OF DRILLHOLE		6.60															
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MB

CHECKED: MWK

Golder Associates

RECORD OF BOREHOLE No C8-2

SHEET 1 OF 1 — METRIC

PROJECT	1540419
W.P.	2242-14-00
DIST	
HWY	401
DATUM	Geodetic
LOCATION	N 4858584.5; E 350977.3 MTM ZONE 10 (LAT. 43.8658; LONG. -78.926)
BOREHOLE TYPE	CME 75, 208 mm O.D., 108 mm I.D. Hollow Stem Augers
DATE	December 19, 2016
ORIGINATED BY	AJ
COMPILED BY	SMD
CHECKED BY	MCK

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
81.0	GROUND SURFACE
0.0	ASPHALT
0.2	Sand and gravel (FILL) Very dense Brown Moist
80.2 0.8	Sandy clayey silt, some gravel (FILL) Very stiff Brown Moist
79.6 1.4	SILTY SAND, some gravel, trace clay Loose to compact Brown Moist
78.0 3.0	Gravelly SAND, some silt, trace clay, trace shale fragments Compact to hard Brown to grey Moist to wet - Augers grinding between depths of 3.6 m and 4.6 m
75.5 5.5	Gravelly CLAYEY SILT with SAND Hard Grey Moist
73.9 7.1	Weathered SHALE (BEDROCK)
73.2 7.8	Shale (BEDROCK) Bedrock cored from depths of 8.0 m to 12.0 m For bedrock coring details, refer to Record of Drillhole C8-2.
69.0 12.0	END OF BOREHOLE NOTE: 1. Water level in borehole not recorded prior to rock coring.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	76	
2	SS	21	
3	SS	9	
4	SS	21	
5	SS	28	25 53 18 4
6	SS	50/0.10	
7	SS	67	29 53 16 2
8	SS	50/0.13	
1	RC	REC 77%	RQD = 0%
2	RC	REC 100%	RQD = 100%
3	RC	REC 100%	RQD = 100%

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (80, 79, 78, 77, 76, 75, 74, 73, 72, 71, 70, 69); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_401_&_HWY35-115\02_DATA\GINT\HWY_401_AJAX_TO_NEWTONVILLE.GPJ GAL-GTA.GDT 06/09/17

PROJECT: 1540419

RECORD OF DRILLHOLE: C8-2

SHEET 1 OF 1

LOCATION: N 4858584.51 ;E 350977.29

DRILLING DATE: December 19, 2016

DATUM: Geodetic

DRILL RIG: CME 75

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: At Cost Drilling Inc.

NOTE: For abbreviations, symbols and descriptions refer to **LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY**

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	PIEZOMETER
		GROUND SURFACE	73.05			
8	NQ Rock Core, December 19, 2016	Slightly weathered to fresh bedded, dark grey, fine grained, weak SHALE	7.95	1	BD,PL,SM; BD,IR,SM; BD,UN,SM; BD,PL,SM; BD,CU,SM; BD,PL,SM; BD,UN,SM; BD,UN,SM; BD,UN,SM; BD,UN,SM; BD,UN,SM	
9				2	BD,UN,SM; BD,PL,SM; BD,IR,SM; BD,CU,RO; BD,IR,SM; BD,UN,SM; BD,UN,SM; BD,UN,SM; BD,PL,SM; BD,IR,SM; BD,CU,SM; BD,UN,SM	UCS = 45 MPa
10–11				3		
12		END OF DRILLHOLE	68.96 / 12.04			

Column headings: SYMBOLIC LOG; FLUSH RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER; DIP w.r.t. CORE AXIS; Jr Ja Jn; WEATHERING INDEX (W1–W6); Axial Point Load Index (MPa); FEATURES.

Depth scale: 8, 9, 10, 11, 12, 13, 14, 15, 16, 17

GTA-RCK 049 S:\CLIENTS\MTO\HWY_401_&_HWY35-115\02_DATA\GINT\HWY_401_AJAX_TO_NEWTONVILLE.GPJ GAL-MISS.GDT 06/09/17

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AJ
CHECKED: MWK

RECORD OF BOREHOLE No C8-4

SHEET 1 OF 1 **METRIC**

PROJECT 1540419
W.P. 2242-14-00
LOCATION N 4858535.8; E 350986.1 MTM ZONE 10 (LAT. 43.865349; LONG. -78.925399)
ORIGINATED BY PKS
DIST HWY 401
BOREHOLE TYPE Mini-Mole 102 mm O.D. Continuous Flight Solid Stem Augers
COMPILED BY ZMR/MR
DATUM Geodetic
DATE July 28, 2016
CHECKED BY MCK

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
79.1	GROUND SURFACE									
0.0	SAND, some silt, some gravel, trace clay Loose to compact Brown Moist	1	SS	5						
		2	SS	11	78	○	19	57	16	8
	- Becoming wet below a depth of 2.1 m	3	SS	17	77					
76.8 2.3	SAND and GRAVEL, trace to some silt, trace clay, trace black shale fragments (TILL-LIKE) Very dense Grey to brown Wet - Augers grinding at a depth of 2.3 m (Elev. 76.8 m)	4	SS	76		○	50	36	11	3
		5	SS	76	76					
75.0 4.1	CLAYEY SILT, some black shale fragments Hard Grey Wet				75					
		6	SS	70/0.15	74	○ (with plastic/liquid limit range)				
73.6 5.5	END OF BOREHOLE SAMPLER REFUSAL AUGER REFUSAL	7	SS	100/0.05						

NOTE:

1. Water level measured in piezometer:

Date	Depth (m)	Elev. (m)
07/28/16	4.6	74.5
03/28/17	1.1	78.0

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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 (%)

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

APPENDIX B

Laboratory Test Results

UNCONFINED COMPRESSION TEST (UC)

TABLE B1

ASTM D 7012-04

SAMPLE IDENTIFICATION

PROJECT NUMBER	1540419	SAMPLE NUMBER	Run2
BOREHOLE NUMBER	C8-2	SAMPLE DEPTH, m	1.025-1.192

TEST CONDITIONS

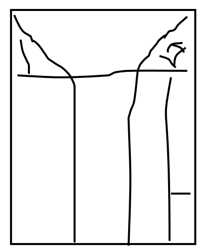
MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.37

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	11.23	WATER CONTENT, (specimen) %	0.53
SAMPLE DIAMETER, cm	4.73	UNIT WEIGHT, kN/m^3	24.46
SAMPLE AREA, cm^2	17.58	DRY UNIT WT., kN/m^3	24.33
SAMPLE VOLUME, cm^3	197.45	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	492.63	VOID RATIO	0.09
DRY WEIGHT, g	490.03		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	45.0

REMARKS:		DATE:	1/16/2017

Golder Associates

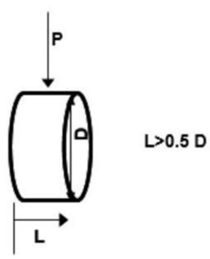
POINT LOAD TESTS ON ROCK SAMPLES **TABLE B2**

PROJECT NO. 1540419
TITLE DM Wills/Culverts Hwy35/ON
DATE September, 2016

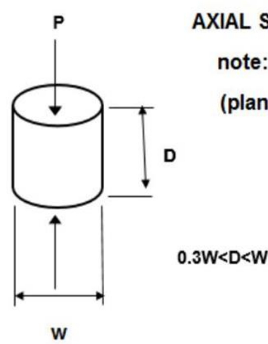
Borehole Number	Sample Number	Sample Depth (m)	Test Type	Core Length (mm)	Core Diameter (mm)	Equivalent Diameter (mm)	Is Axial (MPa)	Is Diametral (MPa)	**Is (50mm)** (MPa)	**Approx. UCS** [1] (MPa)
C8-2	Run 2	9.14 - 9.21	A	25.02	47.32	38.83	4.038	-	3.603	57
C8-2	Run 1	8.56 - 8.59	A	29.21	47.14	41.87	1.936	-	1.787	28
C8-2	Run 3	8.04 - 8.08	A	23.87	47.20	37.87	4.401	-	3.884	62
C8-1	PLT1	5.96-5.99	A	21.47	36.00	31.37	3.361	-	2.725	43
C8-1	PLT2	6.045-6.075	A	18.34	35.99	28.99	3.383	-	2.647	42
C8-1	PLT3	6.125-6.155	A	21.41	36.03	31.34	2.403	-	1.947	31
C8-1	PLT4	6.21-6.24	A	19.19	35.98	29.65	4.665	-	3.687	59
C8-1	PLT5	6.26-6.29	A	23.94	35.97	33.11	2.787	-	2.316	37

[1] Is_{50} x C, from ISRM "Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Comm
Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60.
C=15.9, calculated from Is50 average (3 tests) equal to 2.825 MPa on axial orientation and UCS equal to 45 MPa (1 test)

DIAMETRAL SPECIMEN SHAPE REQUIREMENTS
note: Diametral tests are perpendicular to core axis
(planes of weakness)

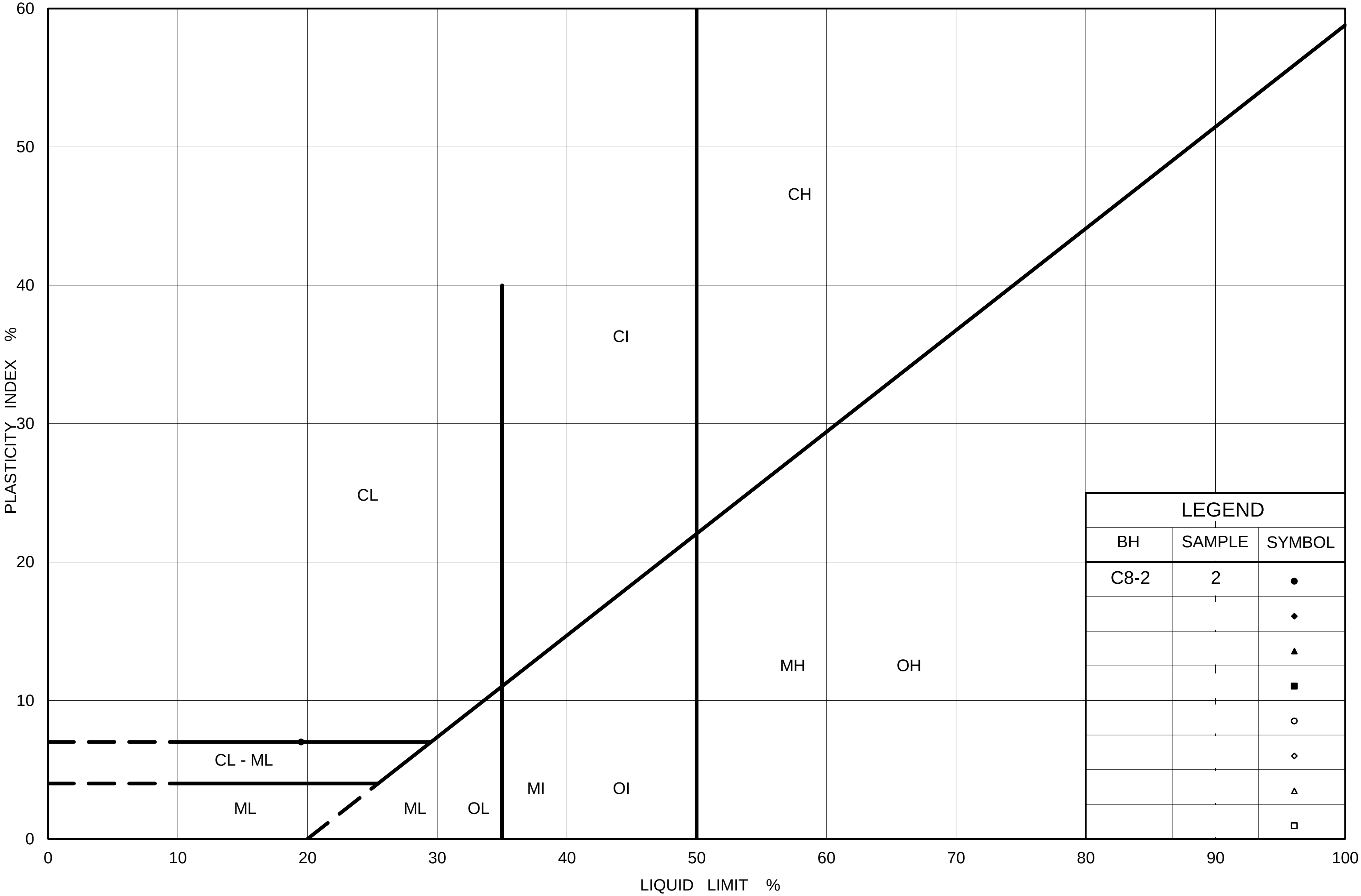


AXIAL SPECIMEN SHAPE REQUIREMENTS
note: Axial tests are parallel to core axis
(planes of weakness)



Checked By: **Golder Associates**

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt

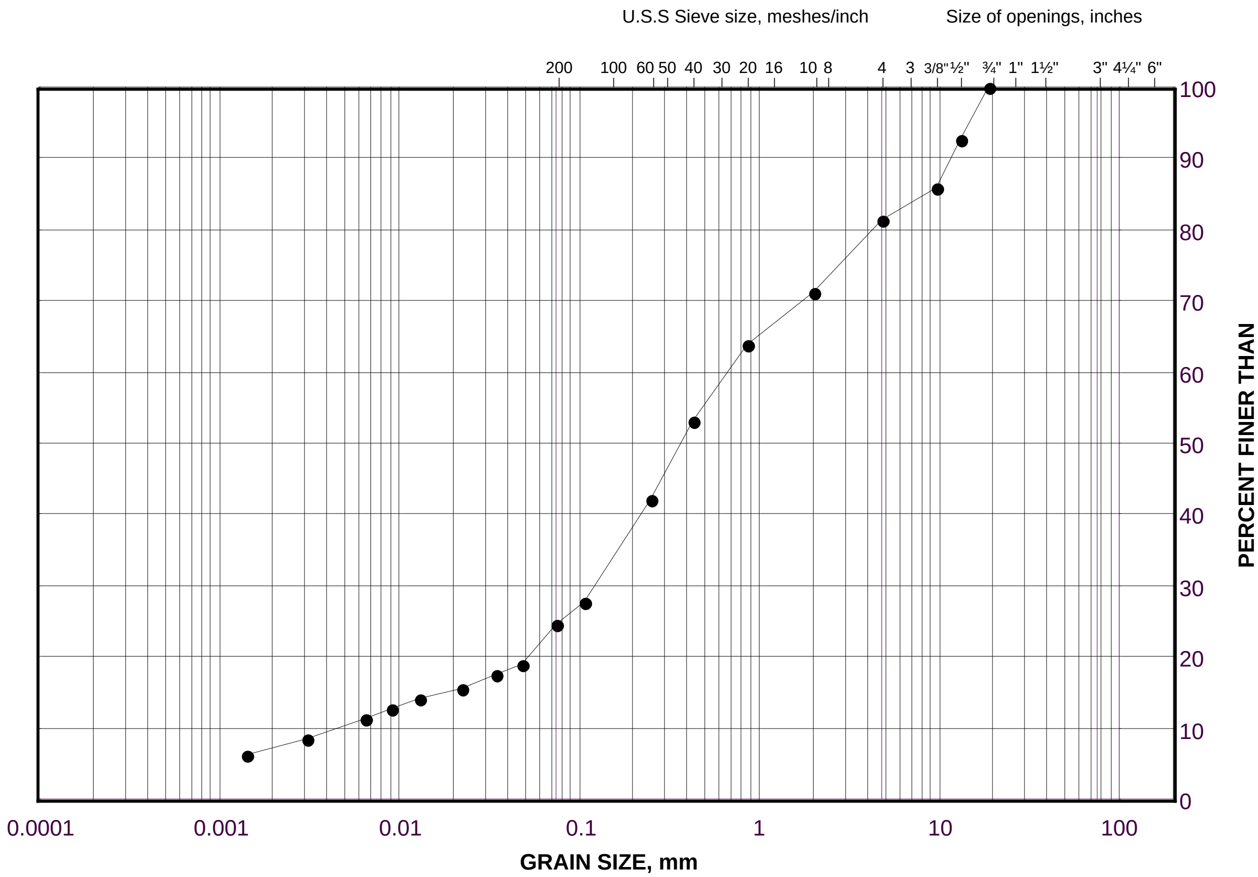
Figure No. B1

Project No. 1540419

Checked By: MWK

GRAIN SIZE DISTRIBUTION
Sand

FIGURE B2



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C8-4	2	78.0

Project Number: 1540419

Checked By: MWK

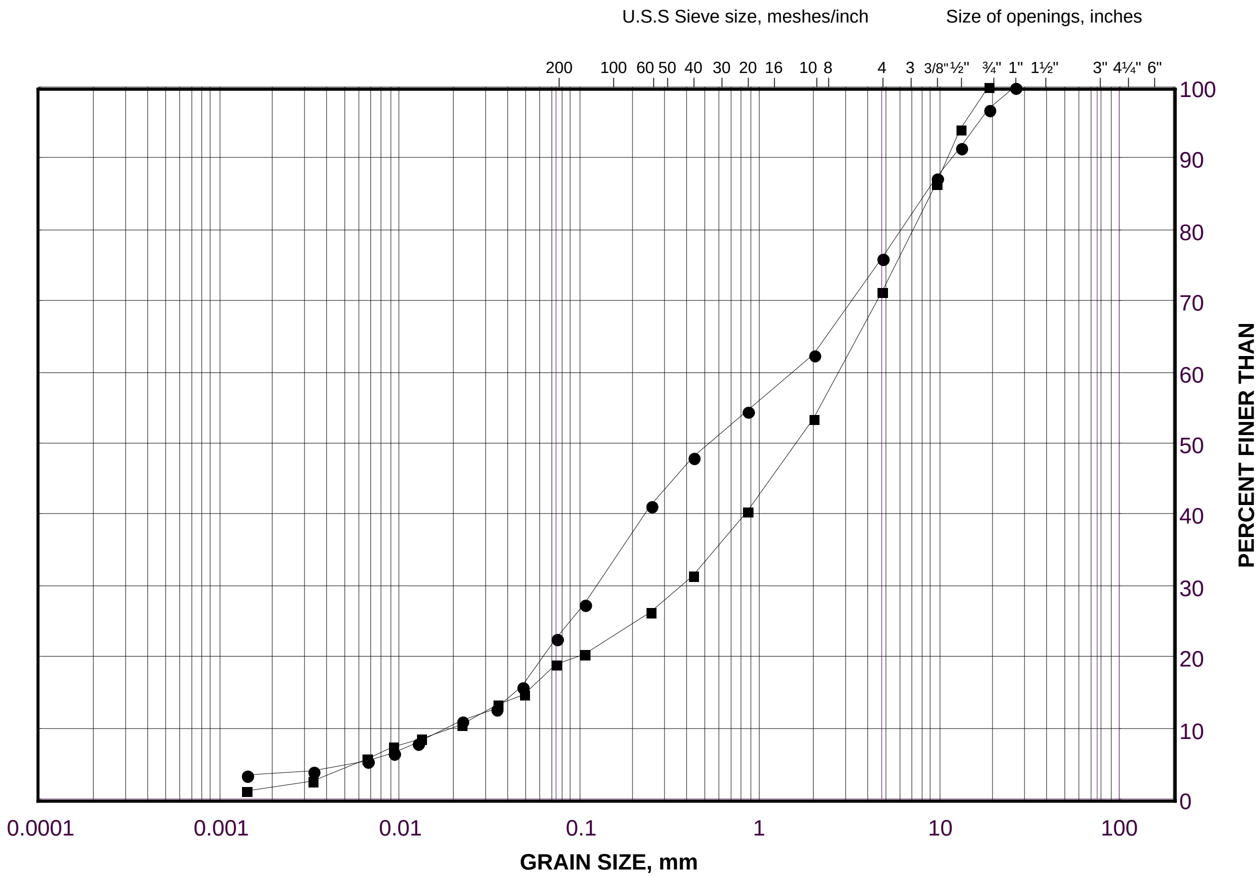
Golder Associates

Date: 26-Apr-17

GRAIN SIZE DISTRIBUTION

Gravelly Sand

FIGURE B3



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C8-2	5	77.6
■	C8-2	7	74.6

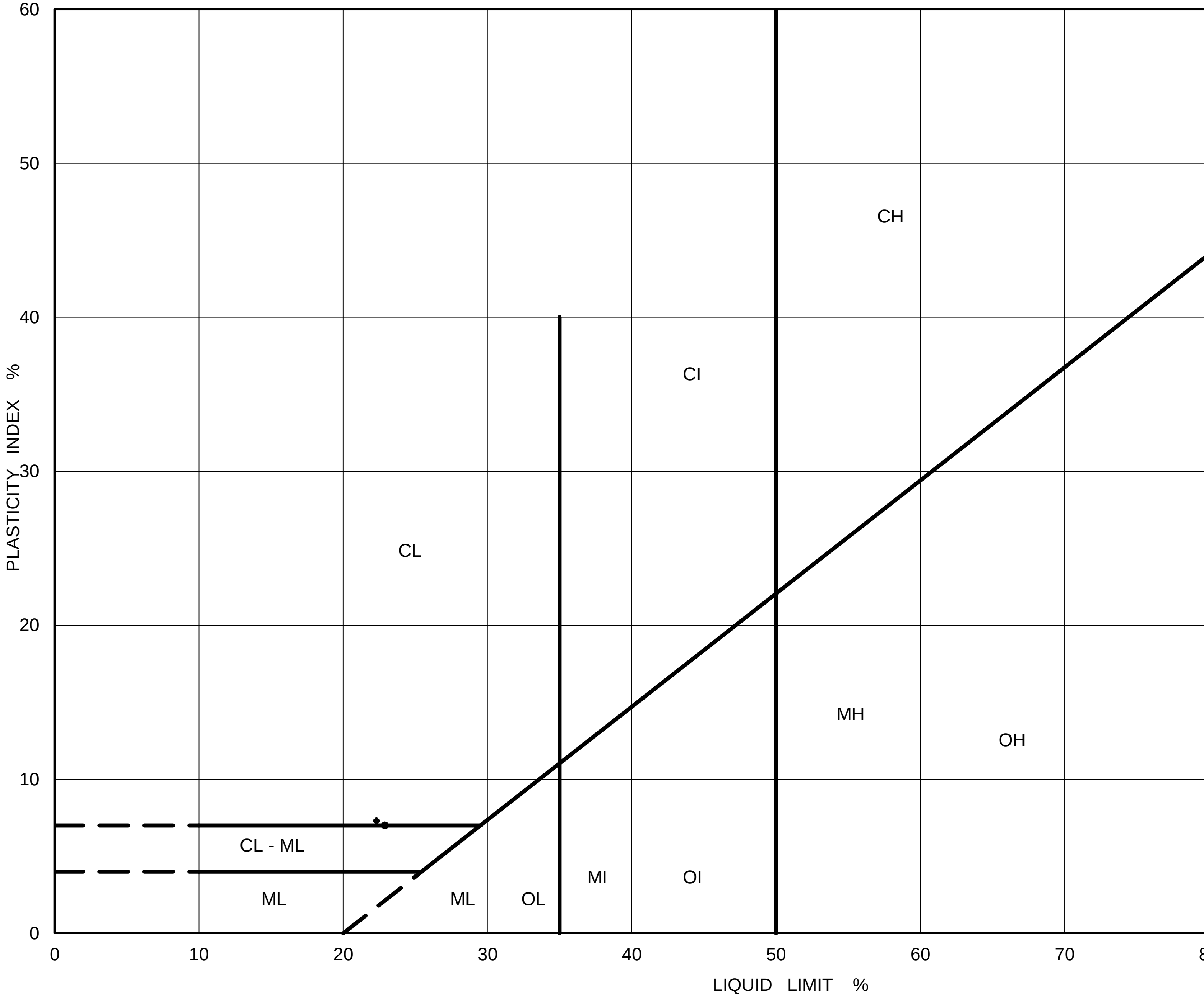
Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 26-Apr-17

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
C8-4	6	●
C8-2	7	◆
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt

Figure No. B4

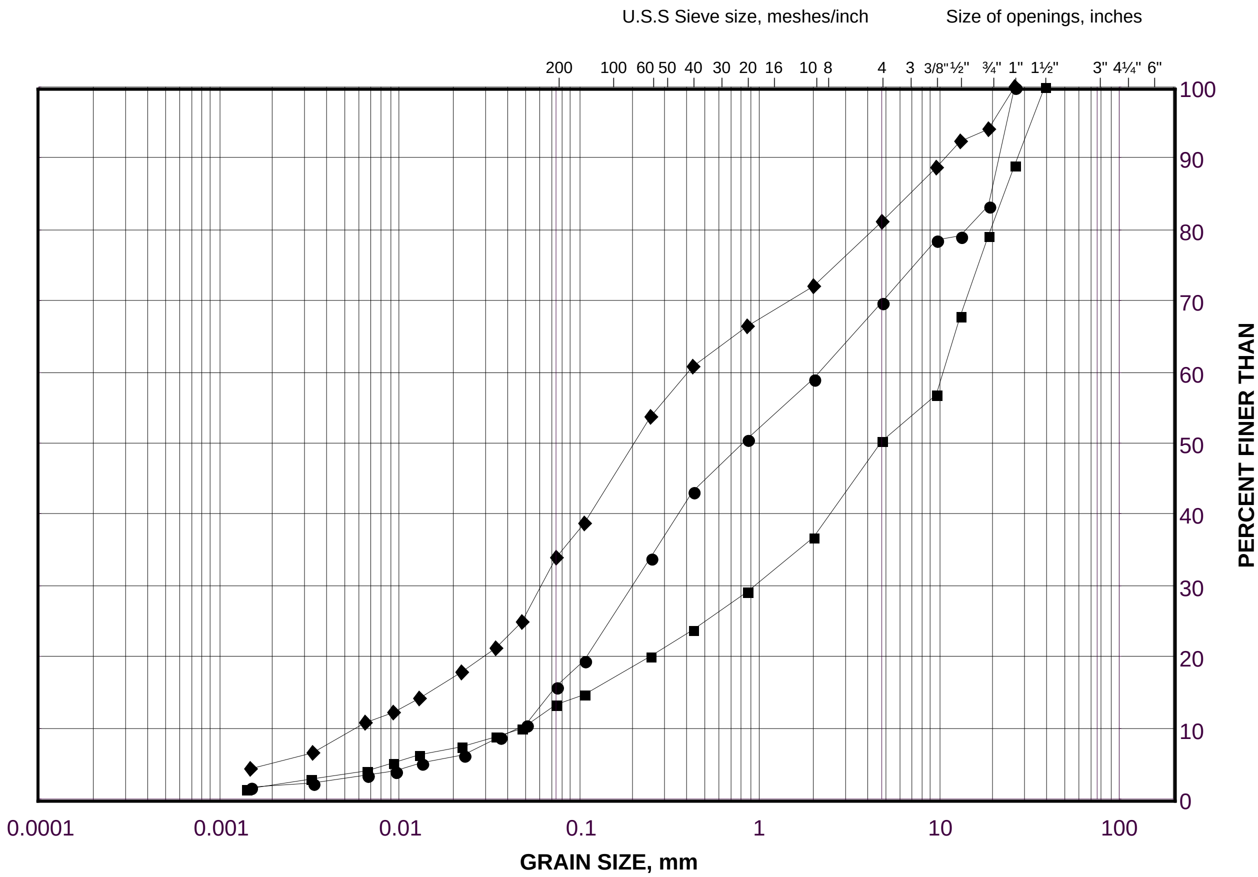
Project No. 1540419

Checked By: MWK

GRAIN SIZE DISTRIBUTION

Silty Sand to Sand and Gravel (Till-Like)

FIGURE B5



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	C8-1	3	77.5
■	C8-4	4	76.5
◆	C8-1	5	76

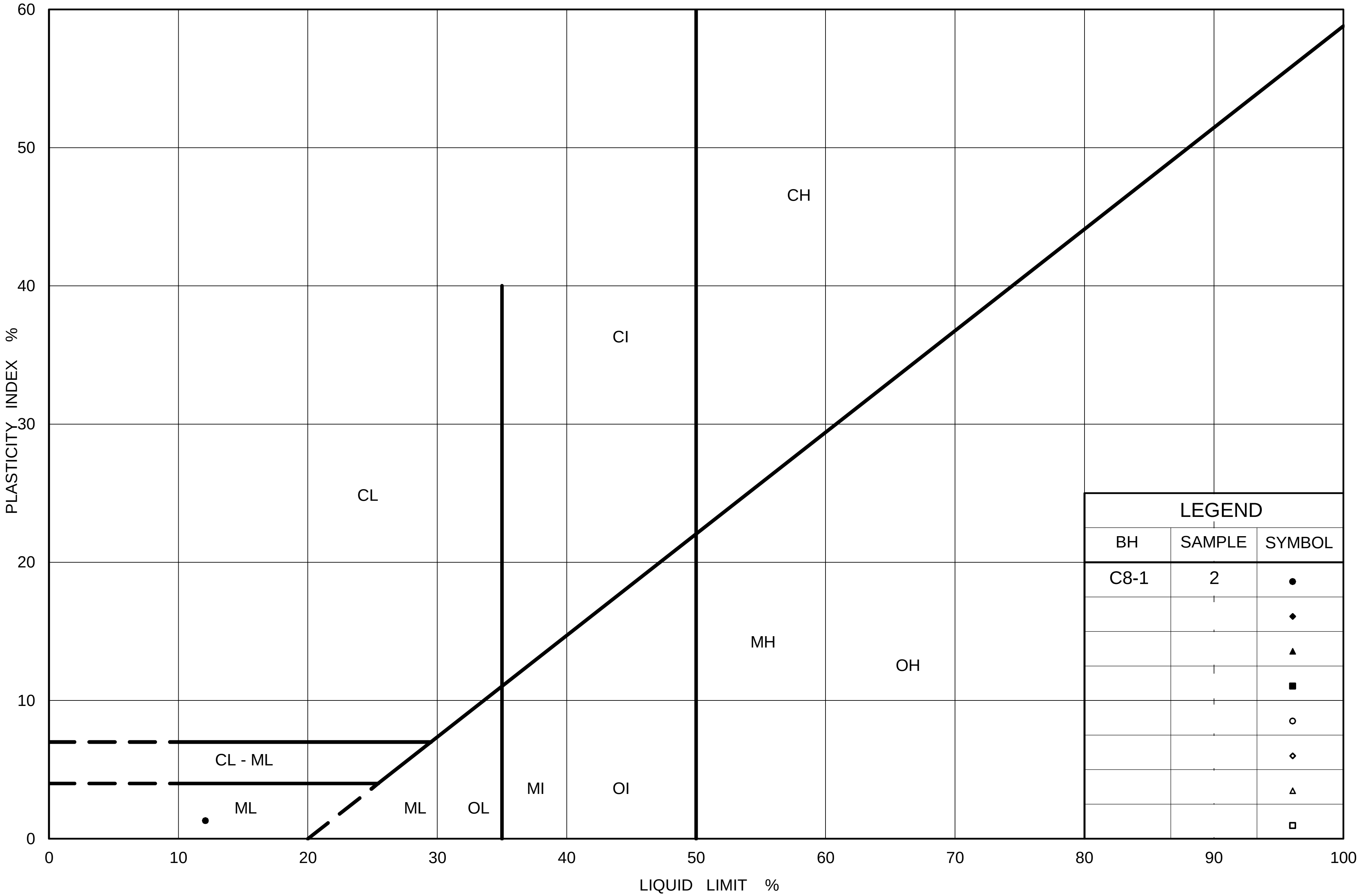
Project Number: 1540419

Checked By: MWK

Golder Associates

Date: 17-May-17

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silt and Sand (Till)

Figure No. B6

Project No. 1540419

Checked By: MWK

APPENDIX C

Analytical Test Results

Your Project #: 1540419
Your C.O.C. #: 573330-01-01

Attention:Matt Kelly

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2017/01/19
Report #: R4329708
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B708468
Received: 2017/01/13, 16:11

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	1	N/A	2017/01/18	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2017/01/17	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	1	2017/01/16	2017/01/16	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2017/01/13	2017/01/17	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	1	N/A	2017/01/18	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods. Results relate to samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Your Project #: 1540419
Your C.O.C. #: 573330-01-01

Attention:Matt Kelly

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2017/01/19
Report #: R4329708
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B708468
Received: 2017/01/13, 16:11

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Ema Gitej, Senior Project Manager
Email: EGitej@maxxam.ca
Phone# (905)817-5829
==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B708468
Report Date: 2017/01/19

Golder Associates Ltd
Client Project #: 1540419
Sampler Initials: MK

RESULTS OF ANALYSES OF SOIL

Maxxam ID		DTH264	DTH264		
Sampling Date		2016/12/19 14:30	2016/12/19 14:30		
COC Number		573330-01-01	573330-01-01		
	UNITS	**C8**	**C8 Lab-Dup**	**RDL**	**QC Batch**
Calculated Parameters					
Resistivity	ohm-cm	1800			4825290
Inorganics					
Soluble (20:1) Chloride (Cl)	ug/g	180	180	20	4828244
Conductivity	umho/cm	550		2	4826709
Available (CaCl2) pH	pH	7.90			4826275
Soluble (20:1) Sulphate (SO4)	ug/g	160	150	20	4828235

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B708468
Report Date: 2017/01/19

Golder Associates Ltd
Client Project #: 1540419
Sampler Initials: MK

TEST SUMMARY

Maxxam ID: DTH264
Sample ID: C8
Matrix: Soil

Collected: 2016/12/19
Shipped:
Received: 2017/01/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4828244	N/A	2017/01/18	Alina Dobreanu
Conductivity	AT	4826709	N/A	2017/01/17	Tahir Anwar
pH CaCl2 EXTRACT	AT	4826275	2017/01/16	2017/01/16	Neil Dassanayake
Resistivity of Soil		4825290	2017/01/17	2017/01/17	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	4828235	N/A	2017/01/18	Alina Dobreanu

Maxxam ID: DTH264 Dup
Sample ID: C8
Matrix: Soil

Collected: 2016/12/19
Shipped:
Received: 2017/01/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	4828244	N/A	2017/01/18	Alina Dobreanu
Sulphate (20:1 Extract)	KONE/EC	4828235	N/A	2017/01/18	Alina Dobreanu

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam Job #: B708468
Report Date: 2017/01/19

Golder Associates Ltd
Client Project #: 1540419
Sampler Initials: MK

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	6.0°C

Results relate only to the items tested.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam Job #: B708468
Report Date: 2017/01/19

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1540419
Sampler Initials: MK

			Matrix Spike		SPIKED BLANK		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
4826275	Available (CaCl2) pH	2017/01/16			99	97 - 103			2.2	N/A
4826709	Conductivity	2017/01/17			100	90 - 110	<2	umho/cm	1.6	10
4828235	Soluble (20:1) Sulphate (SO4)	2017/01/18	NC	70 - 130	109	70 - 130	<20	ug/g	4.9	35
4828244	Soluble (20:1) Chloride (Cl)	2017/01/18	NC	70 - 130	104	70 - 130	<20	ug/g	0.081	35

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Ewa Pranjic, M.Sc., C.Chem, Scientific Specialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam — Maxxam Analytics International Corporation o/a Maxxam Analytics
6740 Campobello Road, Mississauga, Ontario Canada L5N 2L8 Tel:(905) 817-5700 Toll-free:800-563-6266 Fax:(905) 817-5777 www.maxxam.ca

IMMEDIATE TEST

CHAIN OF CUSTODY RECORD

Page 1 of 1

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name:	#1326 Golder Associates Ltd	Company Name:	Golder Associates Ltd.	Quotation #:	B63104	Maxxam Job #:	Bottle Order #: 573330
Attention:	Central Acct:1112, 1113, 1118	Attention:	Matt Kelly	P.O. #:			
Address:	6925 Century Ave Suite 100	Address:		Project:	1540419	COC #: C#573330-03-01	Project Manager: Ema Gitej
	Mississauga ON L5N 7K2			Project Name:			
Tel:	(905) 567-4444 Fax: (905) 567-6561	Tel:	Fax:	Site #:			
Email:	Catherine_Guiao@golder.com, Rachel_Benjamin@gol	Email:	Matthew_Kelly@golder.com, MadKennedy@golder.com	Sampled By:			

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011): ☐ Table 1 ☐ Res/Park ☐ Medium/Fine ☐ Table 2 ☐ Ind/Comm ☐ Coarse ☐ Table 3 ☐ Agri/Other ☐ For RSC ☐ Table ___

Other Regulations: ☐ CCME ☐ Sanitary Sewer Bylaw ☐ Reg 558 ☐ Storm Sewer Bylaw ☐ MISA Municipality ___ ☐ PWQO ☐ Other ___

Special Instructions:

Include Criteria on Certificate of Analysis (Y/N)? ___

ANALYSIS REQUESTED (PLEASE BE SPECIFIC): Field Filtered (please circle): Metals / Hg / Cr VI; Corrosivity pkg (Cl, SO4, EC, Resistivity, pH)

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects

Regular (Standard) TAT: ☐
(will be applied if Rush TAT is not specified)
Standard TAT = 5-7 Working days for most tests
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
Date Required: ___ Time Required: ___ ☐
Rush Confirmation Number: ___ *(call lab for #)*

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered	Corrosivity pkg	# of Bottles	Comments
1		C8	Dec 19, 2016	2:30pm	Soil		X	1	
2									
3									
4									
5									
6									
7									
8									
9									
10									

13-Jan-17 16:11
Ema Gitej
B708468
GK1 ENV-676

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
MADISON KENNEDY	17/01/13	4:10pm	[signature]	2017/01/13	16:11	

Laboratory Use Only				
Time Sensitive	Temperature (°C) on Receipt	Custody Seal	Yes	No
	6/6/6	Present		✓
		Intact		

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxam Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

APPENDIX D

Record of Boreholes and Laboratory Test Results from Previous Investigation

Golder Associates

Foundation Design

RECORD OF BOREHOLE No 15-1

SHEET 1 OF 1

METRIC

PROJECT 13-1186-0419

LOCATION N 4858611.3 ;E 351003.9

ORIGINATED BY EW

DIST Central HWY 401

BOREHOLE TYPE 210 mm Diameter Hollow Stem Augers

COMPILED BY EW

DATUM Geodetic

DATE June 22, 2015

CHECKED BY AM/DUP

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
79.0	GROUND SURFACE				
0.0	Silt and sand, some gravel, organic inclusions (FILL) Very soft, loose Brown	1	SS	2	
78.3 / 0.7	Silty sand, rootlets, oxidation staining, organic inclusions, wood fragments (FILL) Loose to very loose Grey Moist to wet	2	SS	6	
		3	SS	2	
77.3 / 1.7	Sandy CLAYEY SILT, trace gravel Very soft Grey	4	SS	1	2 20 39 39
76.1 / 2.9	SILTY SAND and GRAVEL, trace to some clay (TILL-LIKE) Loose Grey	5	SS	7	40 30 22 8
74.7 / 4.3	Weathered shale (BEDROCK) with sandy silt, sulphur odour; black (~70%), grey (~30%)	6	SS	55	
		7	SS	63	
		8	SS	50/0.03	
72.7 / 6.3	See Drillhole Log 15-1	1	RC	REC 85.4%	RQD = 19.6%
71.8 / 7.2	Shale (BEDROCK), hydrocarbon-like odour	9	SS	50/0.03	
71.3 / 7.7	END OF BOREHOLE				

Elevation scale: 78, 77, 76, 75, 74, 73, 72

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED — 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

NOTES:

1. Water encountered during drilling at a depth of 2.3 m (Elev. 76.7 m) on June 22, 2015
2. Water level in monitoring well at a depth of 0.34 m (Elev. 78.70 m) on July 8, 2015
3. Water level in monitoring well at a depth of 0.5 m (Elev. 78.5 m) on July 13, 2015
4. Water level in monitoring well at a depth of 0.6 m (Elev. 78.4 m) on July 15, 2015

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

GTA-MTO 001 S:\CLIENTS\DURHAM_REGION\401_WATERMAIN_CROSSING\02_DATA\GINT\1311860419MTO.GPJ GAL-GTA.GDT 11/9/15 MK July 2015

PROJECT: 13-1186-0419

RECORD OF DRILLHOLE: 15-1

SHEET 1 OF 1

LOCATION: N 4858611.3 ;E 351003.9

DRILLING DATE: June 22, 2015

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Track Mount CME-55

DRILLING CONTRACTOR:

NOTE: For abbreviations, symbols and descriptions refer to **LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY**

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	ROCK STRENGTH INDEX	WEATHERING INDEX	FEATURES	PIEZOMETER
		Continued from Borehole 15-1		72.76														
7	Track-Mounted Power Augers 200 mm O.D. Hollow Stem Augers (Automatic Hammer)	Weathered shale (BEDROCK)		6.28	1							FR						Screen
				71.36														
8		END OF DRILLHOLE		7.68														

Depth scale: 7 – 16 m

GTA-RCK 043 S:\CLIENTS\DURHAM_REGION\401_WATERMAIN_CROSSING\02_DATA\GINT\13118604190MTO.GPJ GAL-MISS.GDT 11/9/15 MK July 2015

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EW

CHECKED: AM

Golder Associates

Foundation Design

RECORD OF BOREHOLE No 15-2

SHEET 1 OF 1 **METRIC**

PROJECT 13-1186-0419

LOCATION N 4858562.5 ;E 351014.0

ORIGINATED BY EW

DIST Central HWY 401

BOREHOLE TYPE 210 mm Diameter Hollow Stem Augers

COMPILED BY EW

DATUM Geodetic

DATE July 3, 2015

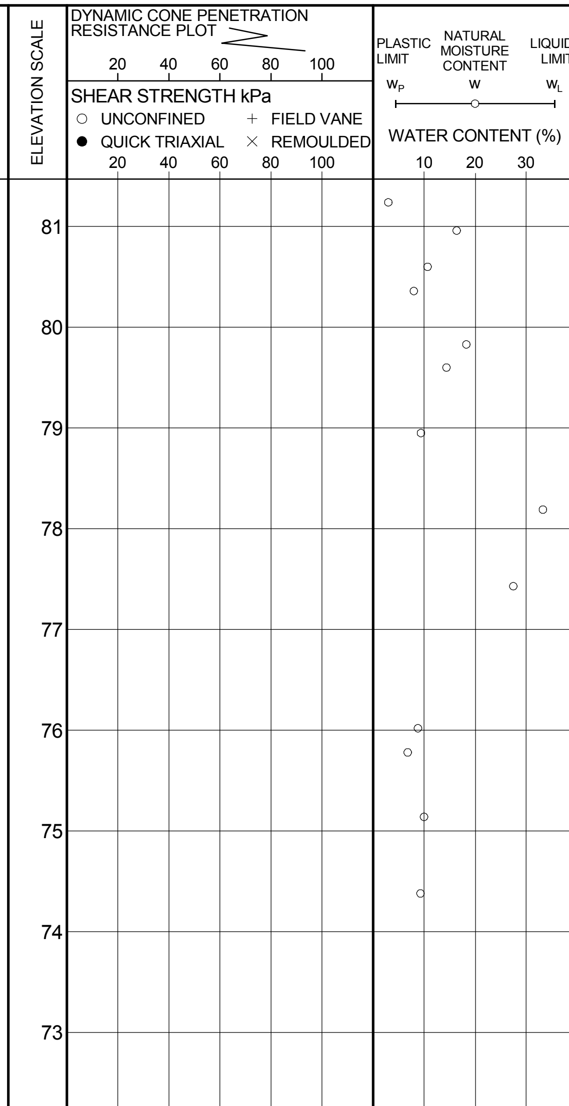
CHECKED BY AM/DUP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
81.5	GROUND SURFACE
0.0	ASPHALT
0.3	Gravelly sand, Granular Base (FILL) Compact Brown
80.7 / 0.8	Sand, some gravel, Granular Subbase (FILL) Compact Brown
79.8 / 1.7	Silty sand, some clay, some gravel, zones of clayey silt, organic inclusions (FILL) Stiff Dark brown
79.4 / 2.1	Silty clay, some sand, zones of silt, in varved 60 mm layers (FILL) Stiff Grey
78.6 / 2.9	Sandy clayey silt, some gravel (FILL) Stiff Grey
77.8 / 3.7	Topsoil and silty sand mix (FILL) Black
	Gravelly SAND, coarse, some silt, rootlets Loose to dense Grey
76.0 / 5.5	SILTY SAND, some gravel, some clay (TILL) Dense Grey
	-Shale fragments at Elev. 74.5 m
74.0 / 7.5	Weathered shale (BEDROCK), containing silt in fractures/discontinuities Black Wet
	-Becoming less weathered at Elev. 72.6 m
72.3 / 9.2	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	14				
2	SS	12				
3	SS	11				
4	SS	13	13	45	28	14
5	SS	9				
6	SS	15	29	57	11	3
7	SS	8				
8	SS	36	21	65	12	2
9	SS	34	11	52	28	9
10	SS	42				
11	SS	50/0.14				
12	SS	50/0.05				



GROUND WATER CONDITIONS | UNIT WEIGHT γ kN/m³

NOTES:

1. Water level encountered during drilling at a depth of 3.8 m (Elev. 77.7 m), July 3, 2015

2. Borehole caved to a depth of 5.5 m (Elev. 76.0 m), upon completion of drilling, July 3, 2015

3. Water level in open portion of borehole at a depth of 3.8 m (Elev. 77.7 m), upon completion of drilling, July 3, 2015

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

GTA-MTO 001 S:\CLIENTS\DURHAM_REGION\401_WATERMAIN_CROSSING\02_DATA\GINT\1311860419MTO.GPJ GAL-GTA.GDT 11/9/15 MK July 2015

Golder Associates

RECORD OF BOREHOLE No 15-3

SHEET 1 OF 1

METRIC

PROJECT 13-1186-0419

LOCATION N 4858525.5 ;E 351015.5

ORIGINATED BY EW

DIST Central HWY 401

BOREHOLE TYPE 210 mm Diameter Hollow Stem Augers

COMPILED BY EW

DATUM Geodetic

DATE June 17, 2015

CHECKED BY AM/DUP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
79.2	GROUND SURFACE
0.0	Topsoil and sandy silt, some clay (FILL) Compact to loose Dark brown to black
77.3 / 1.9	CLAYEY SILT, trace to some sand, varved Soft to firm Grey and brown
76.8 / 2.4	CLAYEY SILT to CLAYEY SILTY SAND, some gravel, cobbles and boulders, shale fragments (TILL) Hard Grey -Auger grinding on inferred cobble or boulder 2.44 m to 2.52 m
74.8 / 4.4	Gravelly SILTY SAND, trace to some clay, cobbles and boulders, shale fragments (TILL) Very dense Grey
74.0 / 5.2	Weathered shale (BEDROCK), some silt, sulphur odour Black
71.5 / 7.7	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	Water content (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	9		
2	SS	11		
3	SS	4	52.5	
4	SS	50/.013		
5	SS	57		18 42 26 14
6	SS	95/0.28		31 48 16 5
7	SS	50/0.10		
8	SS	50/0.13		
~~9~~	~~SS~~	~~50/0.13~~		
~~10~~	~~SS~~	~~50/0.13~~		

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (79, 78, 77, 76, 75, 74, 73, 72); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (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.

NOTES:

1. Water encountered during drilling at depths of 2.4 m and 5.3 m (Elev. 76.8 m and 73.9 m), June 17, 2015

2. Water level at ground surface, upon completion of drilling (Elev. 79.2 m), June 17, 2015

3. Water level in monitoring well at a depth of 0.9 m (Elev. 78.3 m), July 8, 2015

4. Water level in monitoring well at a depth of 1.1 m (Elev. 78.1 m), July 13, 2015

5. Water level in monitoring well at a depth of 1.1 m (Elev. 78.1 m), July 15, 2015

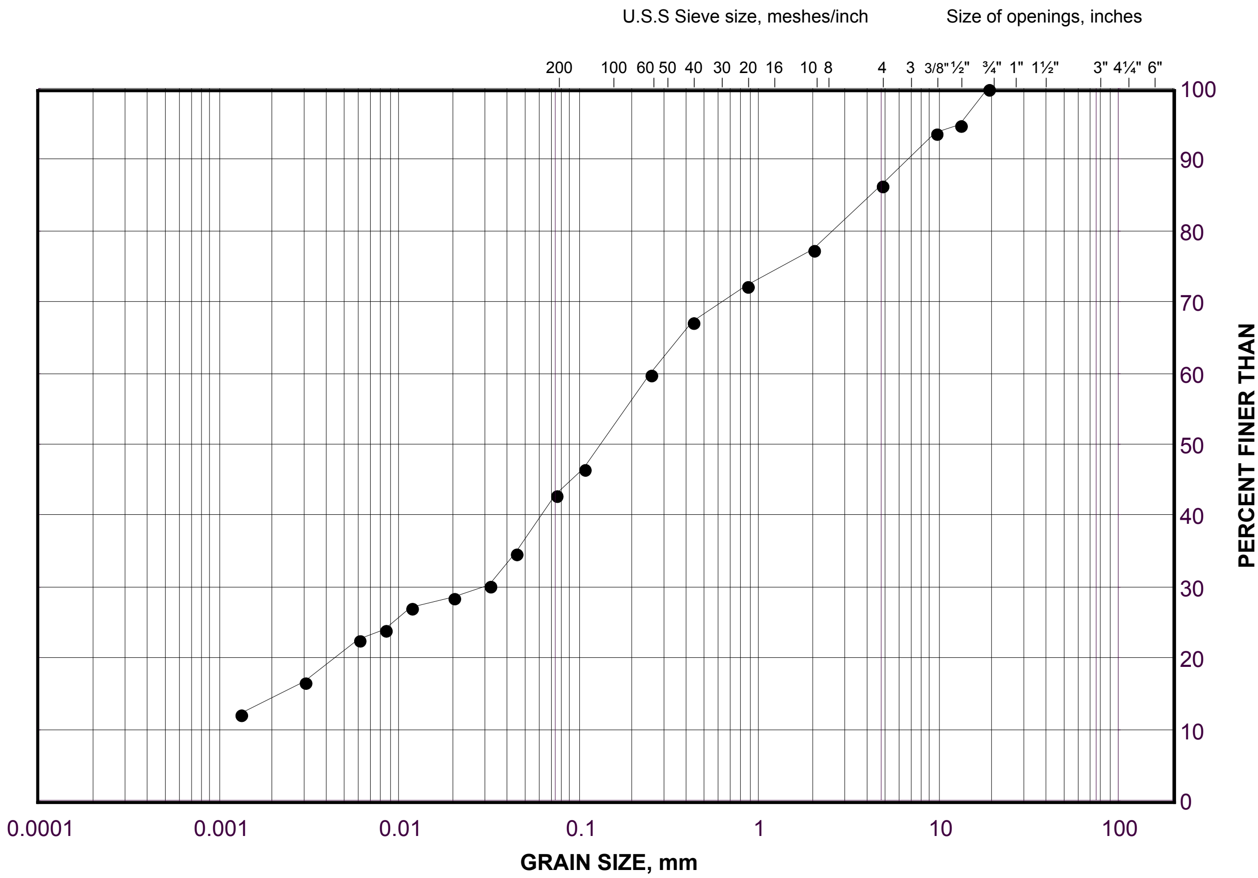
+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION

Silty Sand FILL

FIGURE D1



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	15-2	4	79.0

Project Number: 13-1186-0419

Checked By: AM

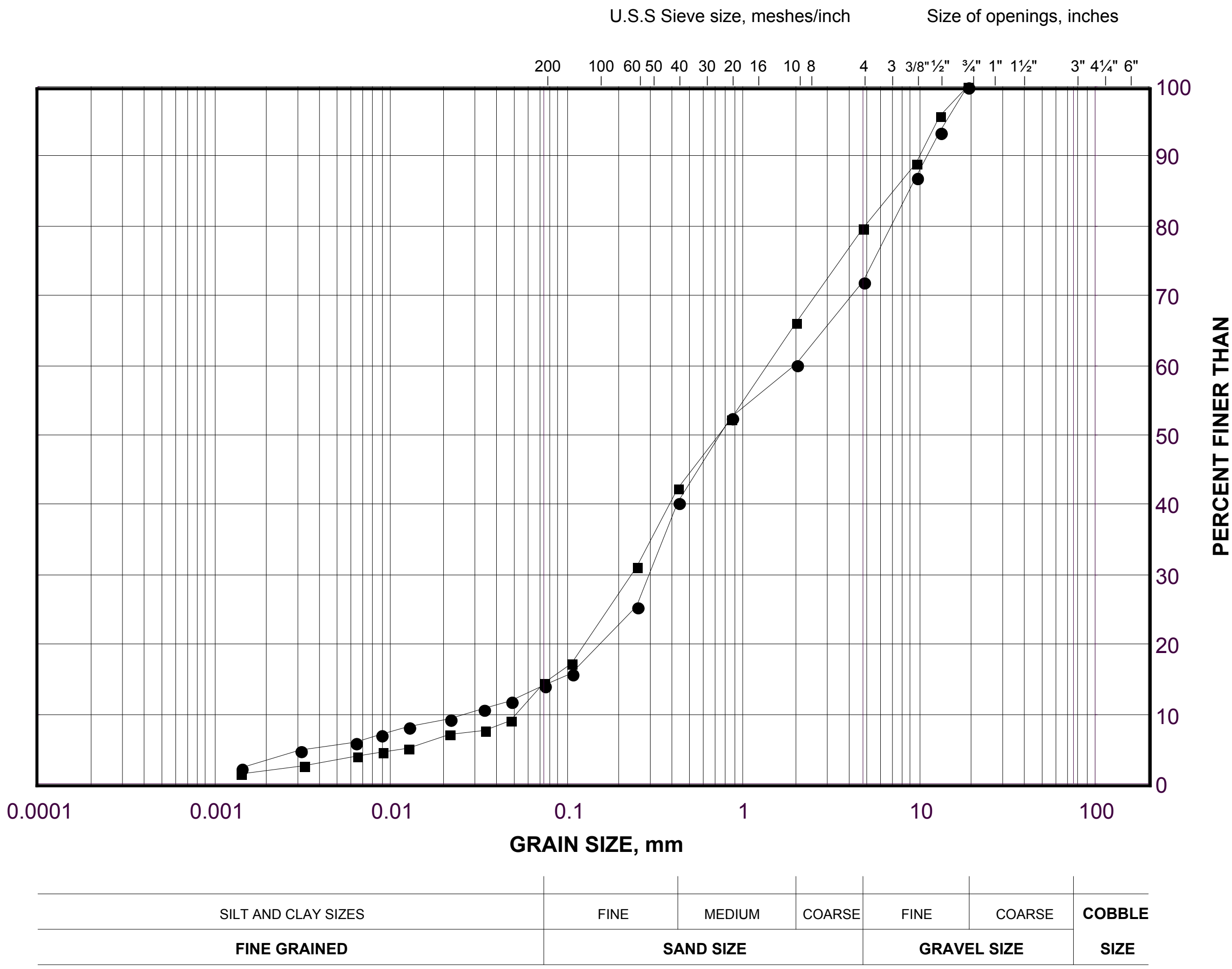
Golder Associates

Date: 04-Aug-15

GRAIN SIZE DISTRIBUTION

Gravelly SAND

FIGURE D2



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	15-2	6	77.5
■	15-2	8A	75.9

Project Number: 13-1186-0419

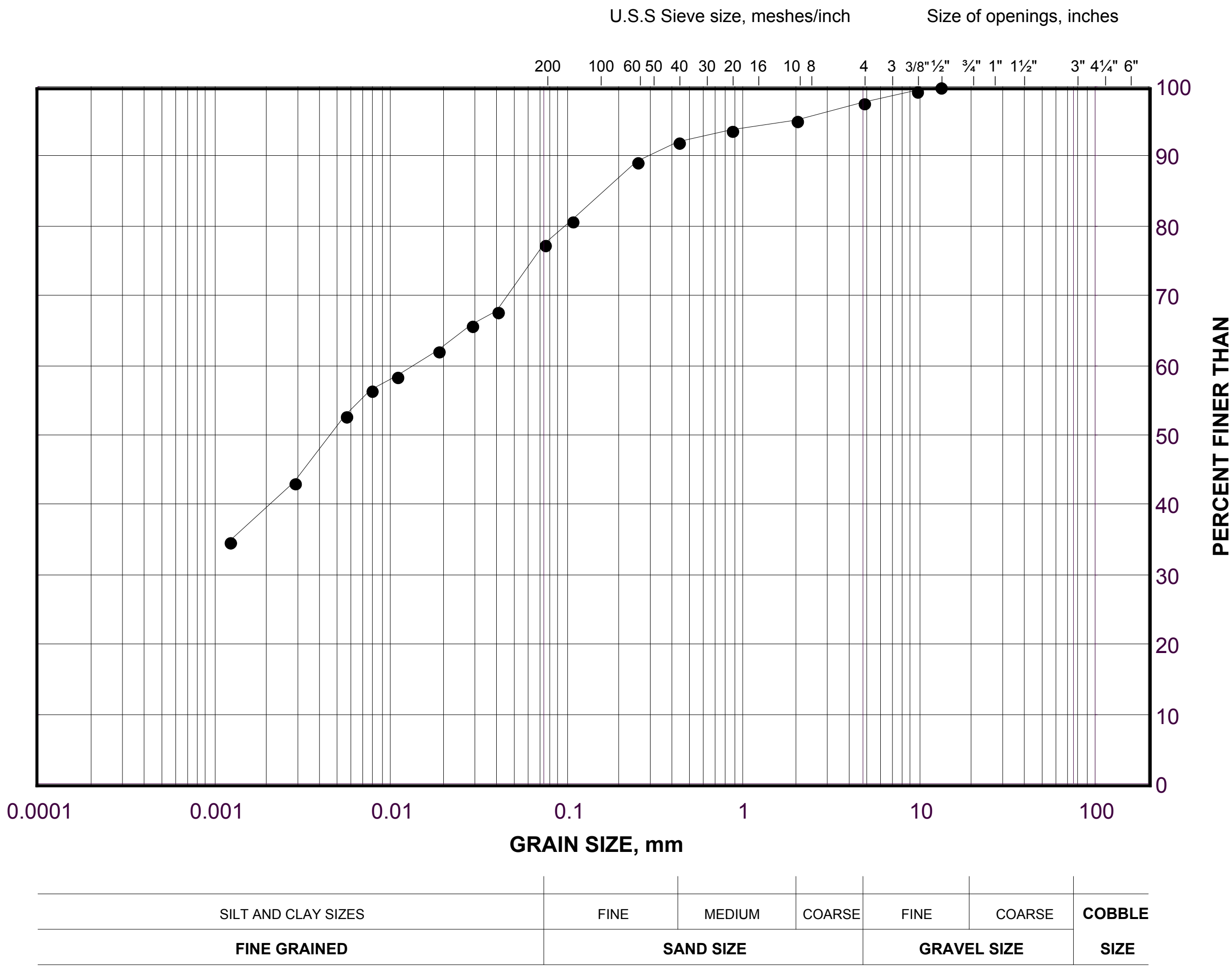
Checked By: AM

Golder Associates

Date: 04-Aug-15

GRAIN SIZE DISTRIBUTION
Sandy CLAYEY SILT

FIGURE D3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	15-1	4	76.6

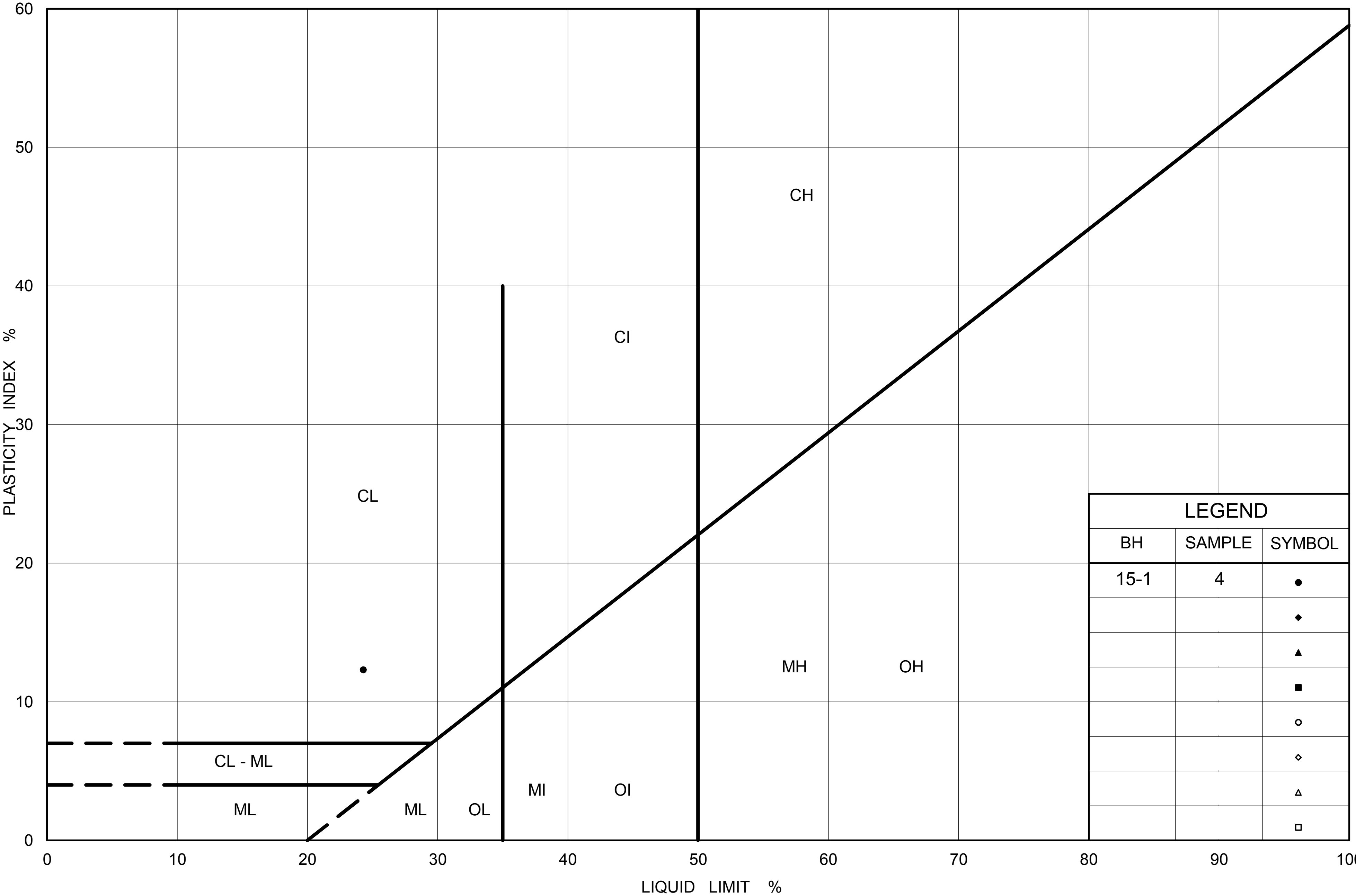
Project Number: 13-1186-0419

Checked By: AM

Golder Associates

Date: 04-Aug-15

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
15-1	4	●
		◆
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation

Ontario

PLASTICITY CHART
CLAYEY SILT

Figure No. D4

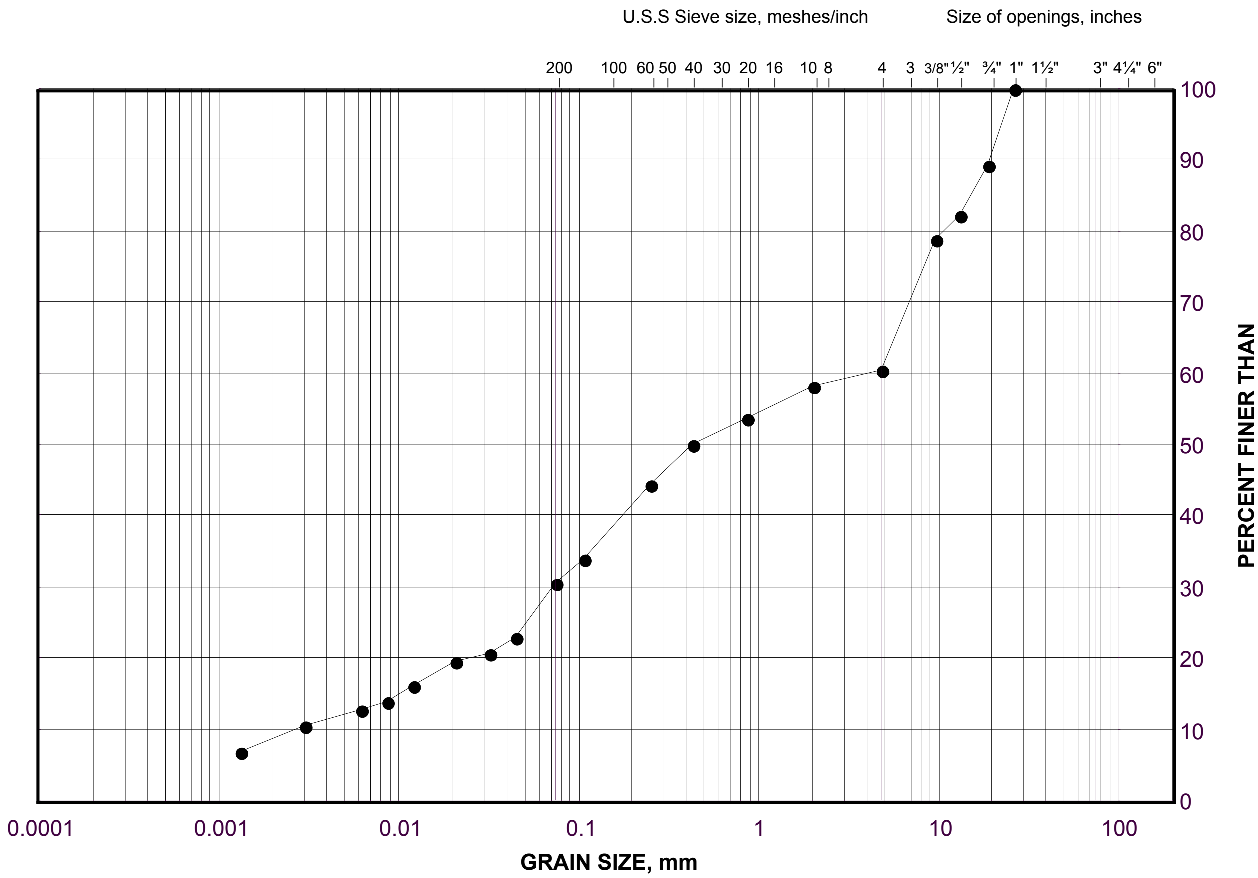
Project No. 13-1186-0419

Checked By: AM

GRAIN SIZE DISTRIBUTION

SILTY SAND and GRAVEL (TILL-LIKE)

FIGURE D5



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	15-1	5	75.6

Project Number: 13-1186-0419

Checked By: AM

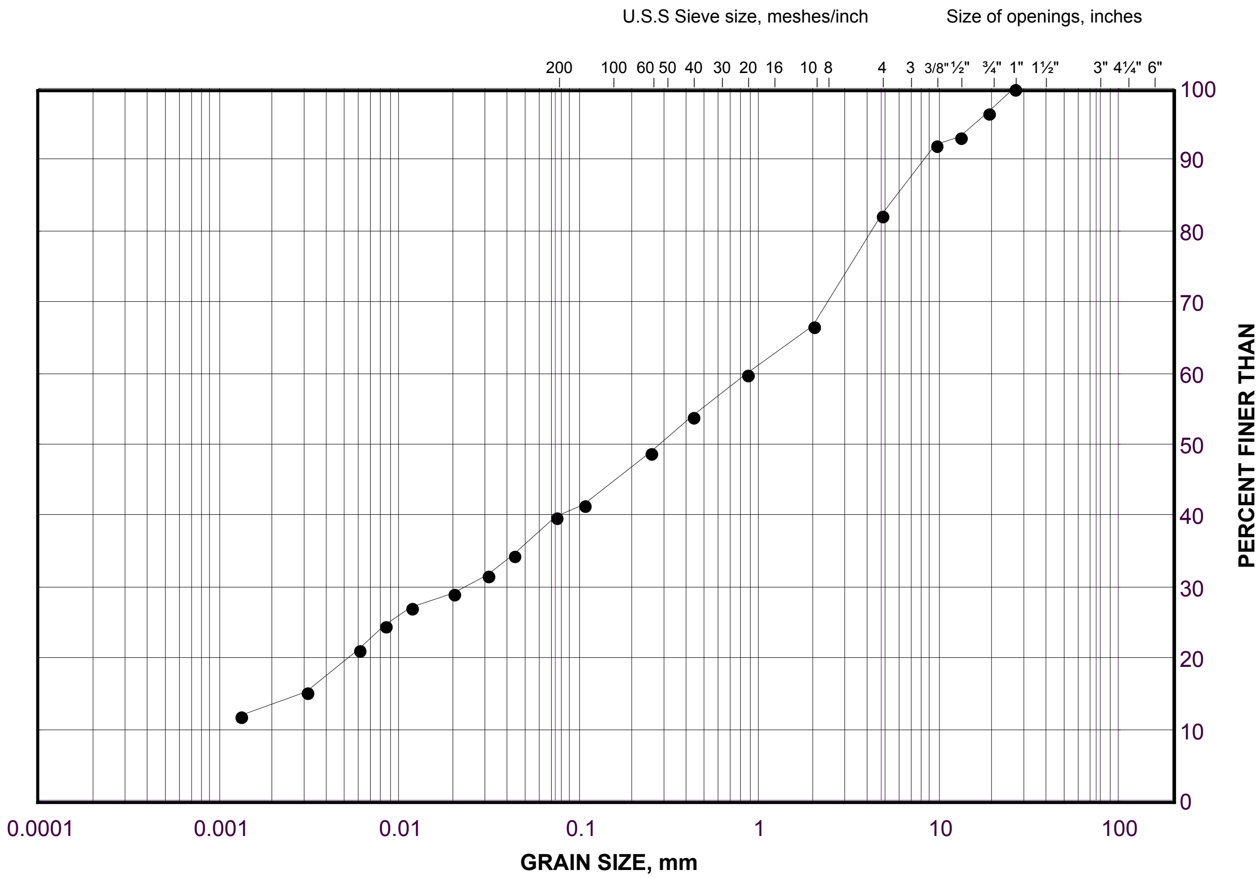
Golder Associates

Date: 04-Aug-15

GRAIN SIZE DISTRIBUTION

CLAYEY SILTY SAND TILL

FIGURE D6



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

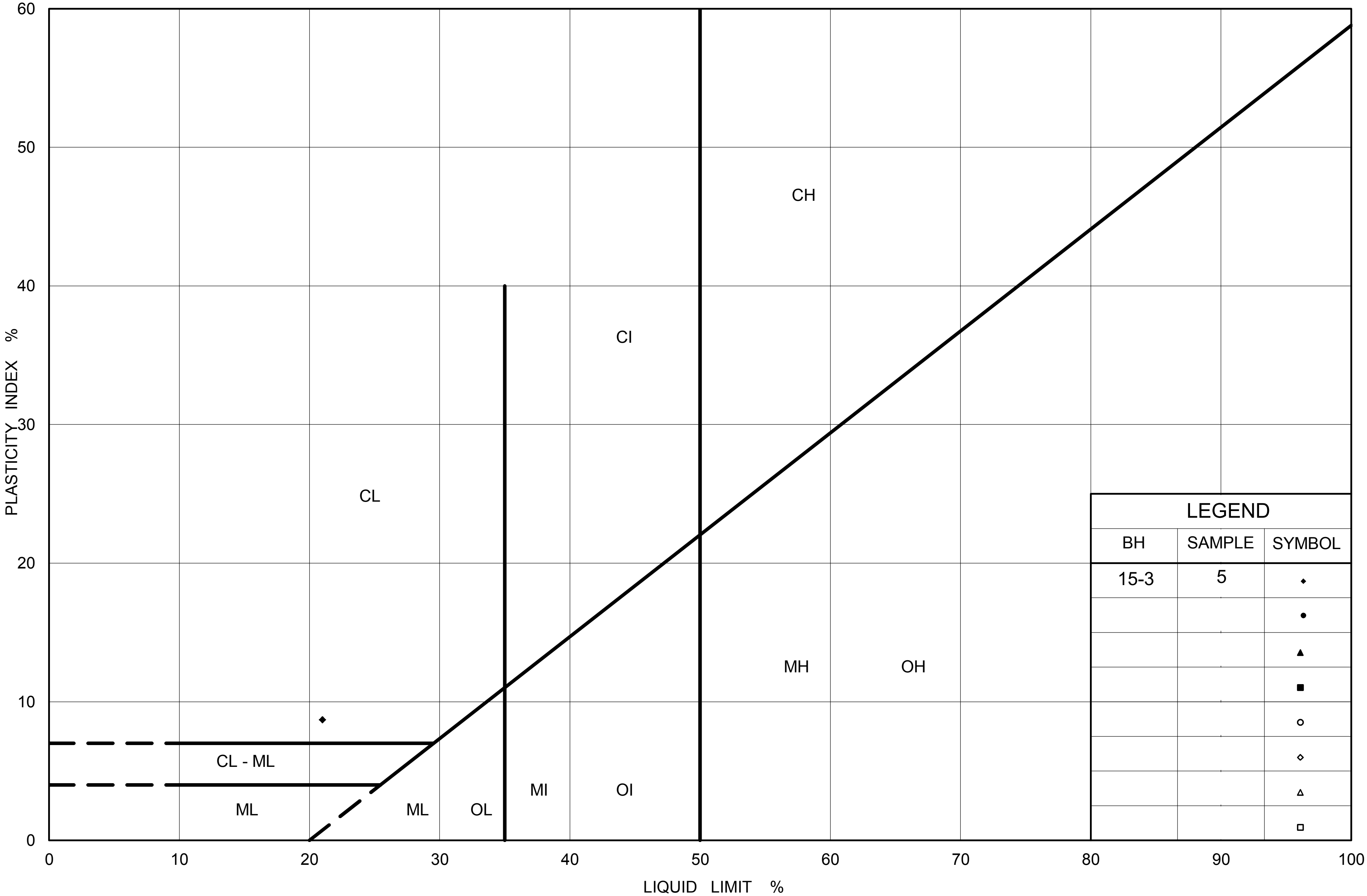
SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	15-3	5	75.2

Project Number: 13-1186-0419

Checked By: AM

Golder Associates

Date: 04-Aug-15



LEGEND		
BH	SAMPLE	SYMBOL
15-3	5	◆
		●
		▲
		■
		○
		◇
		△
		□

Ministry of Transportation

Ontario

PLASTICITY CHART
CLAYEY SILT TILL

Figure No. D7

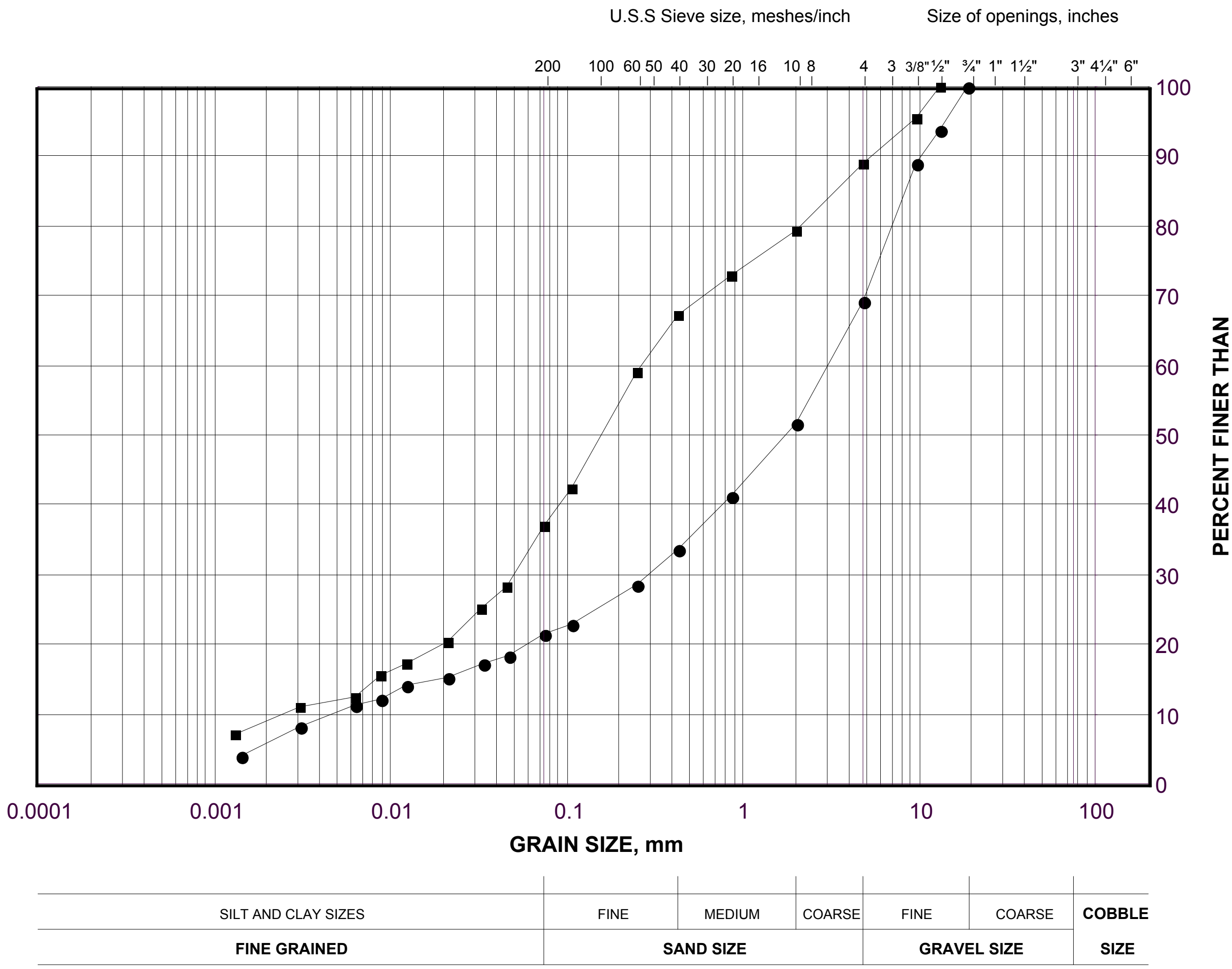
Project No. 13-1186-0419

Checked By: AM

GRAIN SIZE DISTRIBUTION

SILTY SAND TILL to Gravelly SILTY SAND TILL

FIGURE D8



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	15-3	6	74.3
■	15-2	9	75.2

Project Number: 13-1186-0419

Checked By: AM

Golder Associates

Date: 04-Aug-15

Africa + 27 11 254 4800
Asia + 86 21 6258 5522
Australasia + 61 3 8862 3500
Europe + 44 1628 851851
North America + 1 800 275 3281
South America + 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444

Golder Associates