



November 2012

## PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

### Highway 427 Overpasses at 427N - 407E Ramp Highway 427 Widening, Albion Road to Highway 7, City of Toronto, The Regional Municipality of York, G.W.P 2229-09-00(b)

**Submitted to:**

McCormick Rankin, a member of MMM Group  
2655 North Sheridan Way  
Mississauga, ON  
L5K 2P8



REPORT

**GEOCRES No.** 30M13-199

**Report Number:** 10-1111-0202(b)

**Distribution:**

- 2 Copies - MTO - Central Region
- 1 Copy - MTO – Foundations Section
- 2 Copies - McCormick Rankin, a member of MMM Group
- 2 Copies - Golder Associates Ltd.





## Table of Contents

### **PART A – PRELIMINARY FOUNDATION INVESTIGATION REPORT**

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION.....</b>	<b>1</b>
<b>3.0 PREVIOUS INVESTIGATION BY OTHERS .....</b>	<b>2</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>2</b>
4.1 Regional Geology .....	2
4.2 Subsurface Conditions.....	3
4.2.1 Topsoil .....	4
4.2.2 Embankment Fill .....	4
4.2.3 Clayey Silt Till (Upper Till Deposit).....	4
4.2.4 Silty Sand to Sandy Silt.....	5
4.2.5 Silty Sand Till to Sandy Silt Till to Silt Till (Lower Till Deposit) .....	5
4.3 Groundwater Conditions .....	6
<b>5.0 CLOSURE.....</b>	<b>7</b>

### **PART B – PRELIMINARY FOUNDATION DESIGN REPORT**

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....</b>	<b>8</b>
6.1 General.....	8
6.2 Foundation Options .....	8
6.3 Shallow Foundations .....	10
6.3.1 Spread Footings on Native Soils.....	10
6.3.1.1 Geotechnical Resistance .....	11
6.3.2 Assessment of Existing Median Retaining Wall Foundations Between the Abutments.....	11
6.3.3 “Perched” Spread Footings .....	12
6.3.3.1 Founding Elevations .....	12
6.3.3.2 Geotechnical Resistances .....	12
6.4 Driven Steel H-Pile or Steel Pipe (Tube) Pile Foundations.....	13
6.4.1 Founding Elevations.....	13
6.4.2 Axial Geotechnical Resistance.....	13



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

6.5	Caissons .....	14
6.5.1	Founding Elevations.....	14
6.5.2	Axial Geotechnical Resistance.....	14
6.6	Approach Embankments .....	15
6.6.1	Subgrade Preparation and Embankment Construction .....	15
6.6.2	Settlement.....	16
6.7	Construction Considerations.....	16
6.7.1	Excavation and Temporary Protection Systems .....	16
6.7.2	Groundwater Control.....	16
6.7.3	Subgrade Protection .....	17
6.7.4	Obstructions.....	17
6.7.5	Vibration Monitoring During Pile or Caisson Installation.....	17
6.8	Recommendations for Further Work in Detail Design.....	17
7.0	<b>CLOSURE.....</b>	<b>18</b>

### REFERENCES

### TABLES

Table 1	Comparison of Foundation Alternatives
---------	---------------------------------------

### DRAWINGS

Drawing 1	Highway 427 Overpasses 427N – 407E Ramp – Borehole Locations and Soil Strata
-----------	--

### APPENDIX A Borehole Records, Drawing 1 and Laboratory Test Results (GEOCRE 30M13-052)

Records of Boreholes 1, 2 and 3	
Drawing 1	Hwy 427 Over Ramp 427N - 407E, Borehole Locations and Soil Strata
Figure 1	Grain Size Distribution – Borehole 1
Figure 2	Grain Size Distribution – Borehole 2
Figure 3	Grain Size Distribution – Borehole 3

### APPENDIX B Borehole Records and Laboratory Test Results (GEOCRE 30M13-116)

Records of Borehole 8	
Figure 1	Grain Size Distribution – Fill Material
Figure 4	Plasticity Chart – Heterogeneous Mixture of Clayey Silt, Sand and Gravel (Glacial Till) Upper



**PRELIMINARY FOUNDATION REPORT - HIGHWAY 427  
OVERPASSES AT 427N - 407E RAMP**

---

# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP  
HIGHWAY 427 WIDENING, ALBION ROAD TO HIGHWAY 7,  
CITY OF TORONTO, THE REGIONAL MUNICIPALITY OF YORK  
G.W.P. 2229-09-00(b)**



### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin, a member of MMM Group (MRC) on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the future widening of Highway 427 overpass structures at the 427N – 407E Ramp in the Regional Municipality of York, Ontario. The proposed work is part of the widening of Highway 427 from Albion Road to Highway 7 (approximately 2.3 km) in the City of Toronto and the Regional Municipality of York, Ontario, including the widening of the Highway 427 overpass structures at Steeles Avenue West and at Highway 407 and potential modifications to the underpass at Highway 7, culvert extensions, high mast light poles and overhead signs.

This report was primarily developed with information from a previous investigation at the bridge site, as follows:

- MTO GEOCREs No. 30M13-052: Report titled “Foundation Investigation Report Highway 427 over Ramp 427N – 407E, Borough of Etobicoke: W.P. 153-80-05, Site 37-1112, District 6, Toronto,” Prepared for Ministry of Transportation and Communications by Morton & Partners Limited, dated February, 1982.

In addition, since the above report was carried out prior to the construction of Highway 427 in vicinity of Highway 407 interchange the information from the following report, which was carried out after the construction of the interchange, was used to provide information on the construction of the Highway 427 embankment north of the 427N – 407E Ramp.

- MTO GEOCREs No. 30M13-116: Report titled “Foundation Investigation Report for Ramp 427S – 407W over Hwys. 427 and 407: W.P. 368-87-01, Site 37-1335, District 6, Toronto”, Prepared by Foundation Design Section, MTO, dated November 9, 1990.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO’s Request for Proposal (RFP) for Assignment No. 2009-E-0075 dated September 2010, and in Section 5.8 of the *Technical Proposal* for this assignment.

### 2.0 SITE DESCRIPTION

The existing Highway 427 structures (northbound and southbound) that are carried over the 427N - 407E Ramp are located in the City of Vaughan in the Regional Municipality of York, Ontario. Both of the existing northbound and southbound overpasses are single span structures and are each about 8.2 m long; the northbound overpass is 12.8 m wide and the southbound overpass is about 19.5 m wide due to the off-ramp. The earth between the abutments for northbound and southbound overpass structures is retained by a concrete retaining wall which is founded at about the same elevation as the abutments, both of which are founded on spread footings.

In general, the terrain in this area is relatively flat and consists of numerous on-ramps and off-ramps associated with the Highway 427 and 407 interchange. Prior to the construction of Highway 407 the original ground surface was at about Elevation 177 m and the elevation of the ramp is at about Elevation 176 m; therefore the 427N - 407E Ramp was constructed in approximately a 1 m deep cut relative the original grade. The highway embankment side slopes beyond the concrete retaining wall between the northbound and southbound and beyond the wing walls are oriented at approximately 2 horizontal to 1 vertical (2H:1V)



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

### 3.0 PREVIOUS INVESTIGATION BY OTHERS

This report was developed with information from previous investigations carried out by others at the overpass site, as referenced in Section 1.0.

The field work for the 427N – 407E Ramp subsurface investigation was drilled between January 29 and February 3, 1982 and Borehole 8 from the 427S – 407W Ramp subsurface investigation was drilled on June 19, 1990. The location of the boreholes advanced by Morton & Partners Limited (Morton) and MTO are shown on Drawing 1 and the borehole records used are presented in Appendices A and B, respectively. Piezometers were installed by Morton in Boreholes 1, 2 and 3. The results of the water content, grain size distribution and Atterberg Limit laboratory testing carried out by Morton and MTO are shown on the boreholes records and presented in Appendices A and B. Two dynamic cone penetration tests were also carried out.

The location of the four boreholes and two dynamic cone penetration tests advanced as part of the previous investigations at the site, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum, are summarized below and are shown on Drawing 1.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
GEOCREC 30M13-052				
1	4,845,667	294,187	177.6	18.5
2	4,845,713	294,232	176.8	18.4
3	4,845,689	294,212	177.1	14.1
GEOCREC 30M13-116				
8	4,845,718.5	294,231.7	181.1	12.6
Cone Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Cone Depth (m)
GEOCREC 30M13-052				
4	4,845,692	294,240	176.8	3.2
5	4,845,687	294,179	177.6	2.4

### 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

#### 4.1 Regional Geology

The Highway 427 study area lies within the Peel Plain physiographic region, as delineated in *The Physiography of Southern Ontario*<sup>1</sup>.

The Peel Plain physiographic region covers the central portions of the Regional Municipalities of York, Peel and Halton. The general topography of this region consists of level to gently rolling terrain, sloping gradually southward toward Lake Ontario. A surficial till sheet, which generally follows the surface topography, is present

<sup>1</sup> Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario*, Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.





throughout much of this area. The till is typically comprised of clayey silt to silty clay, with occasional sand to silt zones; it is mapped in this area as the Halton Till. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial meltwater ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The study area is underlain by Ordovician shales of the Georgian Bay Formation.

### 4.2 Subsurface Conditions

The subsurface conditions described in the following sections are based on a previous geotechnical investigations carried out by Morton in 1982 (GEOCRE 30M13-052) and MTO in 1990 (GEOCRE 30M13-116). Although it is not specified in the referenced report, it is assumed that the split-spoon sampling was carried out using a manual rope hammer as opposed to the automatic hammer which is typically used on current projects. The borehole locations, ground surface elevations and interpreted stratigraphic conditions are shown on Drawing 1. The detailed subsurface soil and groundwater conditions encountered in the boreholes previously advanced by Morton and MTO and the results of in situ and geotechnical laboratory testing are given on the borehole records contained in Appendices A and B. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic section on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

It should also be noted that the water levels reported in the text of the MTO report (GEOCRE 30M13-116) and on borehole records in Appendices A and B are based on information obtained during the previous investigation and may not reflect the current groundwater levels, which also may have been influenced by the construction of the Highway 407 and Highway 427 interchange and various ramps. In addition, the water levels observed in the open boreholes or measured in the piezometers by Morton are expected to fluctuate seasonally and should be expected to rise during the spring and other wet periods of the year.

In summary, the subsurface conditions encountered at the site consist a surficial deposit of clayey silt till, (having a thickness varying from 2.8 m to 3.7 m), which is underlain by a cohesionless deposit consisting of silty sand to sandy silt (having a thickness of between 1.8 m and 6.5 m, where penetrated). The cohesionless deposit is underlain by a till deposit that varies in composition from silty sand to sandy silt to silt. All boreholes advanced for the Highway 427 NBL and SBL structures over the 427N – 407E Ramp terminated within the till deposit and penetrated it between about 8.5 m and 10.1 m below the surface of the deposit. At one borehole location a 1 m thick layer of varved silty clay was encountered within the till deposit.

Borehole 8, from GEOCRE 30M13-116, was advanced after construction of the embankment for Highway 427; the ground surface at this borehole is about 4 m above the boreholes advanced for the 427N – 407E Ramp overpass structure; and encountered approximately 5.3 m of fill overlying native soils as described above. This borehole provides some indication as to the composition of the fill material used to construct the Highway 427 embankment.

A more detailed description of the soil deposits encountered in the boreholes is provided in the following sections.



### 4.2.1 Topsoil

Approximately 200 mm of topsoil was encountered immediately below the existing ground surface in Boreholes 1, 2 and 3 advanced during the previous investigation.

### 4.2.2 Embankment Fill

Based on a previous investigation carried out for 427S – 407W Ramp over Highway 427 and Highway 407 (GEOCRE 30M13-116) the embankment for Highway 427, north of the 427N – 407E Ramp, consists of sandy silt fill material underlain by clayey silt fill material. Based on Borehole 8 the fill material extends to a depth of about 5.3 m below the ground surface (about Elevation 175.8 m). The sandy silt portion of the fill extended from ground surface to a depth of about 4.1 m below ground surface (Elevation 177 m). Fill consisting of clayey silt was encountered underlying the sandy silt portion of the fill and extended to a depth of 5.3 m (Elevation 175.8 m); therefore having a thickness of about 1.2 m. The sandy silt portion of the fill material contains trace gravel.

The results of a grain size distribution test previously completed by others on one sample of the sandy silt portion of the fill is shown on Figure 1 in Appendix B. The water content measured on a sample of the sandy silt fill material was 12 per cent. The borehole log for Borehole 8 indicates that the underlying clayey silt fill material contains sand and gravel; however no laboratory testing was carried out on this sample.

The measured SPT “N” values within the sandy silt portion of the fill material was 3 and 5 blows per 0.3 m of penetration, indicating a very loose to loose relative density. The measured SPT “N” values within the clayey silt portion of the fill material was 15 blows per 0.3 m of penetration, suggesting a stiff consistency.

### 4.2.3 Clayey Silt Till (Upper Till Deposit)

A deposit of clayey silt till was encountered below the topsoil or fill material in all boreholes advanced for the 427N – 407E Ramp (GEOCRE 30M13-052) and 427S – 407W Ramp (GEOCRE 30M13-116). The surface of the clayey silt till deposit was encountered at between Elevation 177.4 m and 175.8 m. The thickness of the till deposit varies from about 1.9 m to 3.5 m. The till deposit extends to approximately between Elevation 174.8 m to 173.1 m; to depths of between 2.8 m and 3.7 m below ground surface in Boreholes 1, 2 and 3 and to a depth of 7.2 m below ground surface in Borehole 8.

The till deposit consists of clayey silt containing some to with sand and trace gravel. The results of grain size distribution tests previously completed by others on seven samples of the clayey silt till is shown on Figures 1, 2 and 3 in Appendix A and on Figure 4 in Appendix B. Atterberg limits testing was conducted on one selected sample of the clayey silt till, and measured a plastic limit of 17 per cent, a liquid limit of 34 per cent, and a plasticity index of 17 per cent. These test results, which are plotted on a plasticity chart on Figure 4 of Appendix B, confirm that the till deposit consists of clayey silt of low to medium plasticity. It is noted that the logs for the boreholes completed by Morton indicate that the till consists of silty clay; however no Atterberg limits were conducted on samples of this material by Morton, but the Atterberg limit completed by the MTO on a sample of the till indicated that the material is a clayey silt and also considering that the clay content measured from the grain size distribution test carried out on samples from boreholes completed by Morton, which ranged from about 14 per cent to 37 per cent was generally less than the clay content of 35 per cent of the sample measured by MTO, it is considered that the till deposit in Boreholes 1, 2 and 3 should be classified as a clayey silt till and not silty clay till. The natural water content measured on samples of the clayey silt till range from 10 per cent to 22 per cent. The unit weight measured on samples of the clayey silt till range from 20.7 kN/m<sup>3</sup> to 22.3 kN/m<sup>3</sup>.





The measured SPT “N” values within the clayey silt till generally range from 23 blows to 61 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

### 4.2.4 Silty Sand to Sandy Silt

A deposit of silty sand to sandy silt was encountered underlying the upper clayey silt till deposit in all boreholes advanced for the 427N – 407E Ramp (GEOCRE 30M13-052) and in Borehole 8 advanced for the 427S – 407W Ramp (GEOCRE 30M13-116). The surface of the silty sand to sandy silt deposit was encountered at between Elevation 174.8 m to 173.1 m; at depths of between 2.8 m and 3.7 m below ground surface in Boreholes 1, 2 and 3 in at a depth of 7.2 m below ground surface (Elevation 173.9 m) in Borehole 8. The deposit extends to depths of between 5.5 m and 9.3 m below ground surface (between Elevations 171.6 m and 168.3 m) in Boreholes 1, 2 and 3 in the Morton report. Borehole 8 terminated within the silty sand to sandy silt deposit at a depth of 12.6 m below ground surface (Elevation 168.5 m) and had a thickness of at least 5.3 m. Boreholes 1, 2 and 3 fully penetrated the deposit, which was found to have a thickness of 6.5 m, 1.8 m and 2.5 m, respectively.

It is noted that, although Borehole 2 (GEOCRE 30M13-052) and Borehole 8 (GEOCRE 30M13-116) are within about 4 m of each other; Borehole 8 indicates that it terminated within the sandy silt at Elevation 168.5 m; however Borehole 2 indicates that the base of the silty sand was encountered at Elevation 171.3 m, a difference of 2.8 m.

The deposit of silty sand to sandy silt contains trace to some gravel and trace clay. The results of grain size distribution tests completed on four samples of the cohesionless deposit are shown on Figures 1, 2 and 3 in Appendix A. It is noted that the results of grain size distribution tests completed by the MTO are not presented on a figure in their report but the percentages of the gravel, sand and fines are presented on the borehole log in Appendix B. The natural water content measured on samples of the silty sand to sandy silt range from 5 per cent to 22 per cent. The unit weight measured on samples of the silty sand to sandy silt range from 19.8 kN/m<sup>3</sup> to 22.3 kN/m<sup>3</sup>.

The measured SPT “N” values within the deposit of silty sand to sandy silt range from 56 blows to greater than 100 blows per 0.3 m of penetration, indicating a very dense relative density.

### 4.2.5 Silty Sand Till to Sandy Silt Till to Silt Till (Lower Till Deposit)

A till deposit consisting of silty sand to silt was encountered below the silty sand deposit in Boreholes 1, 2 and 3. The text of the report and the soil strata on Drawing 1 for 427N – 407E Ramp (GEOCRE 30M13-052) both indicate that the silty sand encountered in Boreholes 1, 2 and 3 are underlain by silty sand till to silt till; however the borehole logs for Boreholes 2 and 3 state that the material is silt with some sand and silty sand and do not indicate that the material is a till deposit. This deposit has been interpreted as a till in this report based on the previous report, the relative density of the deposit and the glacial history in this area.

The surface of the till deposit was encountered at between Elevation 171.6 m to 168.3 m (at depths of between 5.5 m and 9.3 m below ground surface). All of the boreholes advanced for the 427N – 407E Ramp overpass structure terminated within the till deposit at depths of between 14.1 m and 18.5 m below ground surface (between Elevations 163.0 m and 158.4 m). Within the till deposit in Borehole 2 a layer of varved silty clay was encountered at a depth of about 10.0 m below ground surface (Elevation 166.8 m). The layer is about 1 m thick, with its base at approximately Elevation 165.8 m.



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

Grain size distribution testing was not carried out on any of the samples of till; however based on field observations during the previous investigation the silty sand till to silt till deposit contains trace to some gravel, trace clay, and rock fragments. Although cobbles and boulders were not noted within the till deposit on the borehole records, the rock fragments may be indicative of cobbles that the spoon sampler has broken up. The natural water content measured on samples of the silty sand till to silt till range from 6 per cent to 20 per cent. The unit weight measured on samples of the silty sand till to silt till range from 21.8 kN/m<sup>3</sup> to 23.9 kN/m<sup>3</sup>.

The measured SPT “N” values within the silty sand till to silt till deposit range from 50 blows to greater than 100 blows per 0.3 m of penetration, indicating a very dense relative density.

### 4.3 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the borehole records from the 1982 investigation, contained in Appendix A. There were not comments regarding the moisture of the samples during drilling on the borehole records and the groundwater conditions encountered in Borehole 8 were not recorded on the borehole log. The report prepared by MTO (GEOCRE 30M13-116) does however indicate that at two boreholes (Boreholes 9 and 10), located at about 50 and 100 m south and east of Borehole 8, that wash boring techniques were required to advance the boreholes through the silty sand to sandy silt deposit. The report indicates that this deposit was under “sub-artesian head”.

Three standpipe piezometers were installed during the 1982 investigation in Boreholes 1, 2 and 3 (GEOCRE 30M13-052) to monitor the groundwater levels at the site. The water levels shown on the borehole records in Appendix A reflect those taken in the piezometer; the water level in the borehole upon completion of drilling is not recorded on the borehole record; however it is provided in the text of the report. The water levels measured within the open boreholes upon completion of drilling and in the piezometers are summarized in the table below:

Borehole Number	Ground Surface Elevation (m)	Stratum Sealed Into	Piezometer Tip Elevation (m)	Depth to Water Level (m)	Depth to Water Elevation (m)	Date
1	177.6	Sand and Silt Till	166.6	7.5 7.5	170.1 170.1	Upon Completion of drilling February 10, 1982
2	176.8	Silt Till	166.7	Dry Dry	-- --	Upon Completion of drilling February 10, 1982
3	177.1	Silty Sand Till	165.7	6.1 7.0	171.0 170.1	Upon Completion of drilling February 10, 1982

It is noted that the water levels in the piezometers were obtained about one week following piezometer installation, which may not have allowed sufficient time for the water levels to stabilize. At this preliminary stage, based on these measurements and the observations of “sub-artesian head” in the boreholes drilled within 100 m south of this site and the measured water levels in the piezometers installed for the Highway 427 overpass at



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

Highway 407 (located just to the north), it is estimated that the stabilized groundwater level could be as high as approximately Elevation 174 m.

It should also be noted that the water levels reported on the borehole records are based on information obtained during the previous investigation and may not reflect the current groundwater levels, which may have been influenced by the construction of the Highway 407 and Highway 427 interchange and various ramps.

The groundwater levels are expected to fluctuate seasonally and are expected to rise during wet periods of the year.

### 5.0 CLOSURE

This Preliminary Foundation Investigation Report was prepared by Ms. Sandra McGaghran, P.Eng. a senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

**GOLDER ASSOCIATES LTD.**

Sandra McGaghran, P.Eng.  
Senior Geotechnical Engineer



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



SMM/LCC/MSD/FJH/jl

n:\active\2010\1111\10-1111-0202 mrc hwy 427 toronto\6 - reports\b - ramp 427n - 407e\final\10-1111-0202 final rpt(b) 12nov6 ramp 427n - 407e.docx



**PRELIMINARY FOUNDATION REPORT - HIGHWAY 427  
OVERPASSES AT 427N - 407E RAMP**

---

## **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP  
HIGHWAY 427 WIDENING, ALBION ROAD TO HIGHWAY 7,  
CITY OF TORONTO, THE REGIONAL MUNICIPALITY OF YORK  
G.W.P. 2229-09-00(b)**



## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides preliminary foundation design recommendations for the proposed widening of the existing Highway 427 overpass structures (northbound (NBL) and southbound (SBL)) at 427N – 407E Ramp. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during previous subsurface investigations which were completed by others. These boreholes were advanced prior to the construction of the Highway 427 overpass structures at 427N – 407E Ramp and activity associated with the construction of the overpass may have altered the ground conditions from what is presented in the borehole logs. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the structure foundations; the previous investigation data and the preliminary foundations assessments and recommendations are not sufficient for detail design. Further investigation and analysis will be required during detail design, once the configuration of the proposed overpass is finalized, to confirm and expand on the preliminary foundation recommendations provided in this report.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project, and for which special provisions may be required in the Contract Documents. 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.

### **6.2 Foundation Options**

Based on the planning study completed to date for the widening of Highway 427 from Albion Road to Highway 7, it is understood that the future widening could consist of two additional lanes in both the northbound and southbound directions on Highway 427 and that this will be achieved by filling in the median and widening the east side of the NBL and the west side of the SBL of Highway 427.

The existing Highway 427 overpasses (NBL and SBL) that are carried over the 427N - 407E Ramp are single span structures. A concrete retaining wall was constructed between the NBL and SBL abutment on the north side and south side of the ramp to retain the soil between the NBL and SBL structures. The concrete retaining walls and abutments are founded on spread footings and based on the *General Arrangement* (GA) drawing for the existing structures, the underside of the footings varies from between about Elevation 174.2 m at the west side of the SBL abutment to Elevation 173.6 m at the east side of the NBL abutment. Based on the subsurface conditions from the previous investigation the footings for both the north and south abutments and the concrete retaining wall are likely founded on very dense silty sand over the majority of the foundation units and may possibly be founded on the overlying hard clayey silt till (upper till deposit) along a portion of the foundation unit. The current grade of Highway 427 in vicinity of the overpass structure is at about Elevation 182 m and the 427N – 407E Ramp pavement is at about Elevation 176 m. Prior to construction of the existing NBL and SBL overpass structures in about 1983, the original ground surface was at about Elevation 177 m; therefore the 427N – 407E Ramp is constructed within a 1 m cut and Highway 427 is constructed on an approximately 5 m high fill embankment. The top of the existing retaining wall is at about Elevation 179.5 m and the soil behind the concrete retaining wall is sloped at a gradient of 2 horizontal to 1 vertical.



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

Based on the subsurface conditions from the previous investigation, both shallow and deep foundation options have been considered for the widening of the existing Highway 427 overpass structures at the 427N - 407E Ramp. A summary of the advantages and disadvantages associated with each option is provided below, and a comparison of the alternative foundation options based on advantages, disadvantages and risks and is provided in Table 1 following the text of this report.

- **Strip or spread footings founded on the very dense silty sand:** Shallow footings are feasible for support of the new widened abutments at this site due to the generally very dense nature of the overburden subsoils. It is recommended that the new strip/spread footings be founded at about the same elevation as the existing footings for the abutment in order to minimize disturbance to the existing abutment footings. Therefore, excavations will be required to extend to Elevation 174 m, which corresponds to a depth of about 2 m below the grade of the ramp, and about 6 m to 8 m below the fill behind the existing retaining walls. The excavations would extend through clayey silt till to found on the very dense silty sand. There is a potential for up to approximately 10 mm to 15 mm of differential settlement between the existing structure and the new widened portions; if the widened portion of the abutment is to be structurally connected to the existing NBL and SBL structure, the connection would have to accommodate the anticipated differential settlement. As discussed in Section 4.3, the water level for this site is interpreted to be at about Elevation 174 m; therefore, the groundwater level may be coincident with the elevation of the proposed footings. Temporary roadway protection would likely be required along the east side of the southbound lanes of Highway 427, along the west side of the northbound lanes of Highway 427 and adjacent to the ramp. Further foundation investigation and assessment should be conducted at the detail design along the alignment of the temporary shoring. This founding option is preferred at this site for the outside widening of Highway 427 NBL and SBL overpasses where the existing wall footings would not be suitable to be removed for the widened abutments.
- **Utilize existing retaining wall footings between the existing abutments:** The existing median retaining wall footings between the NBL and SBL abutments, could be reused to support the widened overpasses. In fact, it is understood that the existing median retaining walls were designed to be converted to abutment walls for a future median widening, and therefore the existing footings and stem of the retaining walls between the abutments can be utilized. This option would require excavation sufficient to structurally connect the top of the existing retaining wall to the proposed structure. Based on the GA drawing for the existing structure the retaining wall footings between the NBL and SBL abutments are at a depth of 2 m below the 427N – 407E Ramp (at about Elevation 174 m) and the footings are 5 m wide. The original GA drawing for the existing structure also indicates that there is a construction joint between the abutment and the concrete retaining wall; therefore, the settlement impacts from additional loading on the existing footing will be minimized.
- **Footings “perched” on a compacted granular pad in the widened Highway 427 approach embankments:** To minimize the height of the abutment walls, spread footings for the overpass abutments may be placed on a compacted Granular ‘A’ pad constructed within the approach embankment fill. The existing fill overlying the existing retaining wall footing was found to be very loose to loose in Borehole 8 and would have to be subexcavated and replaced with compacted Granular ‘A’; this would require excavations to about 7 m depth below the grade of Highway 427 to the original ground surface. This option would require a longer span structure to accommodate the “open” configuration with abutment foreslopes, which may not be compatible with the existing structure. Longer protection systems would be required





## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

than for “closed” structure configurations. As well the perched footings would not match the existing footings and also there may be difficulties in matching the bridge decks. As such this option is not considered to be viable.

- **Steel H-piles driven to found in the very dense silty sand to silt/sand and silt till:** Driven steel H-piles are feasible and suitable for support of the abutment widening. Differential settlement between the existing structures (which are founded on spread footings) and the widenings would be negligible. The elevation of the surface of “100-blow” soil is variable across the site; therefore pre-augering is recommended in order for the piles to reach their target elevations (i.e. minimum embedment of 3.5 m below Elevation 174 m). The piles should be placed within a centering template and then driven to achieve the required geotechnical resistances. The annular space left by pre-augering can be filled with lean concrete similar to a soldier pile installation.
- **Driven steel pipe (tube) piles driven to found in the very dense silty sand to silt/ sand and silt till:** Steel tube (pipe) piles could also be considered as a deep foundation option for support of the abutments as well as associated wing walls/retaining walls at this site. However, pipe piles are considered to have a slightly higher risk than H-piles for “hanging up” or being deflected away from their vertical or battered orientation due to the potential presence of cobbles and/or boulders within the glacially-derived soils at this site. Since the elevation of the surface of “100-blow” soil is variable across the site, similarly to installation of steel H-piles, pre-augering is recommended for the installation of pipe piles.
- **Caissons:** Caissons founded within the “100-blow” silty sand to silt/sand and silt till are feasible for support of the abutment widening. However, this option is considered to have potential difficulties associated with the groundwater pressure and ground loss in the silty sand to silt: there is a risk of base disturbance for caissons founded in the silty sand to silt. Provisions are required to prevent disturbance of the sides and bases of the caissons and this would be up to the contractor, but consideration could be given to using liners or drilling mud and tremie concreting techniques. These details would have to be considered in the scope at detail design, if caissons are considered as an option.

Based on the above considerations, the preferred option from a geotechnical/foundations perspective is to support the abutments for the widening of the Highway 427 overpass structures at 427N – 407E Ramp on spread footings founded at the same elevation as the existing footings on the very dense silty sand. Steel H-pile and pipe pile foundations are also feasible and are considered to be an acceptable alternative; however pre-augering would be required to reach the minimum required length of pile.

## 6.3 Shallow Foundations

### 6.3.1 Spread Footings on Native Soils

For support of widened abutments and new retaining walls east of the existing NBL structure and west of the existing SBL structure, strip or spread footings should be founded below the fill and any loose or soft to stiff surficial soils, on the very dense silty sand to sandy silt deposit. For preliminary design it is recommended that the strip/spread footings be founded on the very dense silty sand to sandy silt deposit at Elevation 174.0 m to match the existing foundation elevation at the abutments. This would involve an excavation of 2 m below the ramp grade and up to 6 m to 8 m of fill behind the backslope which would require shoring along the west side of



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

the NBL and along the east side of the SBL of Highway 427. As discussed in Section 4.3, the water level for this site is interpreted to be at about Elevation 174 m, therefore, the groundwater level may be coincident with the elevation of the proposed footings. It is not recommended to found the footings below this elevation as excavations adjacent to the existing abutment footings may disturb the integrity of the bearing stratum. Strip or spread footings should be founded at a minimum depth of 1.4 m below the lowest surrounding grade to provide adequate protection against frost penetration (per OPSD 3090.101 – *Foundation Frost Depths for South Ontario*).

The founding soils will be susceptible to disturbance due to construction traffic and surface run-off and should be protected with a concrete working slab (100 mm thick concrete slab with a compressive strength of 20 MPa) if the concrete for the footing is not placed within four hours of the inspection and approval of the subgrade.

### 6.3.1.1 Geotechnical Resistance

New strip or spread footings for the widened north and south abutments and the retaining walls placed on the properly prepared, very dense silty sand to sandy silt at the design elevations given in the preceding section should be designed based on a factored geotechnical resistance at Ultimate Limit States (ULS) of the order of 600 kPa and a geotechnical reaction at Serviceability Limit States (SLS) of the order of 400 kPa (for 10 mm to 15 mm of settlement). These preliminary geotechnical resistances may be used for footings widths of between 2 m and 5 m. There is a potential for up to approximately 10 mm to 15 mm of differential settlement between the existing structure and the new widened portions; if the widened portion of the abutment is to be structurally connected to the existing NBL and SBL structure, the connection would have to accommodate the anticipated differential settlement.

These preliminary geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC 2006)* and its *Commentary*.

The preliminary geotechnical resistance values provided above will have to be re-evaluated and modified as necessary during detail design, based on future additional subsurface investigation at the proposed abutment widening and retaining wall locations.

### 6.3.2 Assessment of Existing Median Retaining Wall Foundations Between the Abutments

The following design drawings are available for the existing Highway 427 overpass structures at 427N – 407E Ramp:

- WP No. 153-80-05, Drawing No. 1 and 3 “427N – 407E Ramp Overpass at Hwy 427” General Arrangement and Footing Layout, prepared by SWR Engineering Limited, dated January, 1983.

Based on the above referenced drawings, there is a construction joint between the foundation element of the abutment and the median retaining wall; therefore they are not structurally connected. The existing north and south median retaining wall footings are supported on shallow foundations, with the retaining wall between the abutments on the north and south side of the ramp founded at Elevation 174 m, with a footing width and length of 5 m and 13.7 m, respectively.



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

It is noted that although the retaining wall footing is 5 m wide, the GA drawing also indicates that the abutment strip footing for the Highway 427 overpass structures (NBL and SBL) that are carried over the 427N - 407E Ramp rigid frame bridge is 1.8 m wide. Based on visual observations, the existing abutments and retaining walls are considered to have performed satisfactorily.

We have assessed the factored geotechnical resistance at ULS and the geotechnical reaction at SLS for the existing retaining wall foundations, using the design founding elevations, foundation geometry, and subsurface conditions to complete bearing capacity and settlement analyses. Considering that the top of the existing retaining walls are at about Elevation 179.5 m and Highway 427 is at about Elevation 182 m the additional soil loading from the 2.5 m height of soil will induce a settlement of about 10 mm to 15 mm at the abutment. The SLS value given below is based on a total estimated settlement of 10 mm to 15 mm from the additional soil loading and the proposed widened structure. A factored geotechnical resistance at ULS of the order of 600 kPa and a geotechnical reaction at SLS of the order of 350 kPa (for 10 mm to 15 mm of settlement) may be used for preliminary design purposes for the existing retaining wall footings between the abutments for the Highway 427 overpass structures (NBL and SBL).

### 6.3.3 “Perched” Spread Footings

In order to minimize the height of the abutments walls, spread footings for the overpass abutments may be placed on a compacted Granular ‘A’ pad constructed within the approach embankment fill. However, this would require a longer bridge span to accommodate the abutment foreslopes, as well as extensive subexcavation of existing loose fill and longer temporary protections systems. The following sections provide geotechnical resistances for spread footings at the abutments that are “perched” within the approach embankment fill on a compacted granular pad.

#### 6.3.3.1 Founding Elevations

“Perched” abutment spread footings founded on Granular A pads (in accordance with provincial standards), should be provided with a minimum of 1.4 m of soil cover to provide adequate protection against frost penetration (per OPSD 3090.101 – *Foundation Frost Depths for South Ontario*).

For this option, extensive subexcavation of the fill material behind the existing retaining wall will be required to the top of the existing footings; i.e. to a depth of about 7 m below the grade of Highway 427, with associated temporary protection systems. It is recommended that the Granular A pad extend down to the top of the footing of the existing retaining wall or to the original ground surface. The area to be subexcavated should be defined by a line extending from the toe of the Granular A pad, outward and downward at 1 horizontal to 1 vertical (1H:1V) and should extend at least 1 m beyond the plan limits of the footing, where possible – for example this will not be possible adjacent to the existing wingwall for the north and south abutment of the Highway 427 overpass structures (NBL and SBL) at 427N – 407E Ramp. The subexcavation should be replaced with compacted Granular A. The Granular A pad should be constructed in accordance with provincial standards.

#### 6.3.3.2 Geotechnical Resistances

Assuming the above subexcavation depths and filling procedures, a factored geotechnical resistance at ULS of the order of 850 kPa may be used for preliminary design purposes, assuming 3 m wide footings. The geotechnical reaction at SLS of the order of 350 kPa may be used for preliminary design. These geotechnical resistances will have to be reviewed during detail design, if this option is adopted, after further drilling has been



carried out at the foundation elements to confirm the extent of subexcavation that is required, and once the final geometry of the foundations has been established.

The geotechnical resistances provided above are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.4 of the *CHBDC 2006* and its *Commentary*.

## 6.4 Driven Steel H-Pile or Steel Pipe (Tube) Pile Foundations

### 6.4.1 Founding Elevations

Driven steel H-pile or pipe pile foundations are feasible for support of the widened abutments at this site. However, the use of deep foundations does present constructability challenges since the depth to “100-blow” soil is relatively shallow (though variable) across the site. At Borehole 3 (GEOCRESS 30M13-052) drilled near the centreline of Highway 427 and along the centreline of the 427N – 407E Ramp, “100-blow” soil was encountered at about Elevation 165 m, whereas at Borehole 1 (GEOCRESS 30M13-052 located west of the south abutment for the SBL structure) and Boreholes 2 and 8 (located north of the north abutment for the NBL structure), “100-blow” soil was encountered between about Elevation 173.3 m and 172 m (some 8 m higher). The highest SPT “N” value of “100-blow” soil is located within about 9.5 m of Highway 427 grade, or about 3.5 m below the 427N – 407E Ramp grade. Depending on the pile cap elevation, pre-augering may be required to allow the steel H-piles or pipe piles to reach their target depths (minimum embedment of 3.5 m below Elevation 174 m) and then driven or placed with a centering template to achieve the required geotechnical resistances. Therefore, based on this procedure the design pile tip is estimated to be at Elevation 168.5 m and length is estimated to be about 5.5 m below the pile cap. Pre-augered holes to Elevation 170.5 m will extend through the silty sand to sandy silt material and will be about 3.5 m below the interpreted groundwater level; therefore, it is recommended that a temporary liner be used to support the soils during pre-augering and pile installation. The annular space left by pre-augering can be filled with lean concrete similar to a soldier pile installation.

The pile caps should be constructed at a minimum depth of 1.4 m for frost protection purposes, per OPSD 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*).

For the installation of steel pipe piles consideration must be given to the potential presence of cobbles and boulders within the soil deposits. In this regard, steel H-piles are preferred over steel pipe piles as pipe piles are considered to pose a higher risk of “hanging up” or being deflected away from their vertical or battered orientation during installation, due to their larger end area.

### 6.4.2 Axial Geotechnical Resistance

For preliminary design, steel HP 310x110 piles drive to found within the very dense silty sand to sandy silt should be designed based on a factored axial resistance at ULS of the order of 1,600 kN and an axial geotechnical reaction at SLS of the order of 1,250 kN (for 10 mm to 15 mm of settlement). Similar axial resistances may be used in the design of closed-end, concrete-filled, 324 mm (12 ¾ in.) diameter steel pipe piles having a minimum wall thickness of 9.5 mm (3/8 in.).



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

Pile installation should be in accordance with provincial standards. The pile termination or set criteria will be dependent on the pile driving hammer type, helmet, selected pile and length of pile; the criteria must therefore be established at the time of construction after the piling equipment is known. The pile capacity should then be verified in the field by the use of the Hiley formula (MTO Standard Structural Drawing SS-103-11) during the final stages of driving below the pre-augered hole to achieve the appropriate ultimate capacity.

The preliminary geotechnical resistances provided above will have to be re-evaluated and modified as necessary during detail design in consideration of the additional subsurface investigation that will be carried out at the widened foundation elements.

### 6.5 Caissons

Caisson foundations are feasible for support of abutments for the widening of the Highway 427 overpass structures (NBL and SBL) that are carried over the 427N - 407E Ramp.

Running or flowing of water-bearing cohesionless soil strata could occur during or after drilling of the caissons due to the unbalanced hydrostatic heads, and basal heave could occur where water-bearing cohesionless soils are present at/near the caisson base; therefore mud drilling techniques may have to be incorporated. In addition, if caisson foundations are adopted, a liner would be required to support the soils during construction.

Construction experience in similar soil conditions has demonstrated that temporary liners can be difficult to withdraw, owing to the length of the liners and the very dense nature of the “100-blow” material. Such difficulties can result in “necking” of the caisson, although this can be controlled by tremie-pumping the concrete into the caisson and ensuring that the base of the liner always remains below the surface of the pumped concrete during withdrawal. Alternatively, permanent liners could be considered for the construction of the caissons in these soil conditions.

#### 6.5.1 Founding Elevations

The widened abutments could be supported on caissons founded within the very dense soils (with SPT “N” values of greater than 100 blows per 0.3 m of penetration) that were encountered below approximately Elevation 167 m. For preliminary design, the following caisson base elevations may be assumed based on the borehole results:

Foundation Element	Founding Stratum	Estimated Design Caisson Elevation
North and South Widened Abutment	Very Dense Silty Sand to Sandy Silt	167 m

#### 6.5.2 Axial Geotechnical Resistance

The caissons will derive the majority of their capacity from base resistance, although some shaft friction has also been taken into account based on “socketing” approximately 1.5 m into the “100-blow” soil. Using the preliminary design elevations given above the factored axial geotechnical resistance at ULS and the axial reaction at SLS (for 10 mm to 15 mm of settlement) or the order of the values given below may be used for preliminary design purposes:



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

Caisson Diameter	Factored Axial Geotechnical Resistance at ULS	Geotechnical Reaction at SLS *
1.2 m	4,500 kN	3,500 kN
1.5 m	6,500 kN	5,500 kN

\* For 10 mm to 15 mm of settlement

The preliminary geotechnical resistances provided above will have to be re-evaluated and modified as necessary during detail design in consideration of the additional subsurface investigation that will be carried out at the widened foundation elements.

### 6.6 Approach Embankments

Based on the planning study completed to date for the widening of Highway 427 from Albion Road to Highway 7, it is understood that the future widening could consist of two additional lanes in both the northbound and southbound directions on Highway 427 and that this will be achieved by filling in the median and widening of the east side of the NBL and the west side of the SBL.

In the median, the top of the existing retaining wall is at about Elevation 179.5 m and the existing grade of Highway 427 is at about Elevation 182 m. The slope is at a gradient of about 2 horizontal to 1 vertical and meets the current grade of Highway 427 at a distance of about 6 m from the abutment (i.e. the length of the wing wall for the existing abutment). Therefore, depending on the foundation option adopted, the grade behind the existing retaining wall will be raised by up to about 2.5 m.

East of the existing NBL structure and west of SBL structures for the proposed widened Highway 427 overpasses at the 427N – 407E Ramp a 3.6 m and 2.8 m wide abutment, respectively, is also required to accommodate the widening. It is understood that new wing walls will also be constructed outside of the widened abutments. North and south of the wings walls the widened roadway will result in about a 2 m fill thickness over the existing embankment slope face. Based on the previous boreholes advanced at the site, the existing embankment is likely founded on the very stiff to hard till and as such no instability problems are anticipated.

#### 6.6.1 Subgrade Preparation and Embankment Construction

It is recommended that all organic material and any softened/loosened native soils be stripped from the footprint of the proposed widened Highway 427 approach embankments. The depth and extent of stripping should be assessed during detail design when additional subsurface information will be available for the widened approach embankment areas.

The embankment fill for the Highway 427 widening should be placed and compacted in accordance with MTO's special provision. Benching of the existing Highway 427 embankment side slopes should be carried out to "key in" the new fill materials for the widening, in accordance with provincial standards.

Additional fill for construction of the embankment widening could consist of clean earth fill or granular fill. From a geotechnical/foundations perspective, both earth and granular fill will provide good compatibility with the existing Highway 427 embankment fill materials – both those fill materials remaining in-place in the existing embankment side slope, and any existing embankment fill that is re-used for the widening after being cut from the benches.





### **6.6.2 Settlement**

The median widening will require placement of approximately 2.5 m of fill/pavement structure on top of the existing swale in the median area and a fill thickness of about 2 m along the existing embankment slope face north and south of the proposed wing walls. None of the boreholes used to prepare this report were advanced through the existing embankment north and south of the ramp; however the majority of the settlement will be elastic in nature and should occur in a short period after placement of the fill. At detail design stage it is recommended that boreholes be advanced behind the existing retaining walls, which are located between the Highway 427 NBL and SBL structures that are carried over the 427N - 407E Ramp, in order to estimate the elastic deformation modulus and the estimated settlement.

## **6.7 Construction Considerations**

The following subsections identify future construction issues that should be considered at this stage as they may impact the planning and preliminary design. Where applicable, Non-Standard Special Provisions (NSSP) should be developed during detail design for incorporation in the Contract Documents.

### **6.7.1 Excavation and Temporary Protection Systems**

The foundation excavations for spread footings are expected to extend to a depth of about 8 m below the Highway 427 grade and about 2 m below the current grade of 427N – 407E Ramp, through the existing very loose to loose sandy silt and stiff clayey silt fill, through the very stiff to hard clayey silt till deposit and into the very dense silty sand.

Where space permits, open-cut excavations into these materials should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) for Construction Activities. The existing fill would be classified as Type 3 soil, according to the OHSA. Temporary excavations (i.e. those that are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V.

At this preliminary stage, it is anticipated that temporary roadway protection would likely be required in the median along the west side of the NBL of Highway 427, along the east side of the SBL of Highway 427 and to support the embankment outside of the NBL and SBL existing abutment structures. The excavation behind the new abutments in the Highway 427 median could be made as an open cut excavation; however it must still conform to the requirements under OHSA. In addition, temporary roadway protection would also be required along the Highway 427N-407E Ramp adjacent to the footing excavation. The temporary excavation support system should be designed and constructed in accordance with OPSS 539 (*Construction Specification for Temporary Protection Systems*). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539, provided that the existing adjacent Highway 427 structures, as well as any adjacent utilities, can tolerate this magnitude of deformation. The median area had been filled, above the competent silty sand to sandy silt, to within 2.1 m of the roadway grade. Soldier pile and lagging could be readily installed with the soldier piles driven or drilled into the cohesionless soil for toe support. Lateral resistance could be provided in the form of temporary soil anchors.

### **6.7.2 Groundwater Control**

Groundwater seepage is anticipated from the fill (“perched” conditions on top of the underlying cohesive till deposit) and from cohesionless soil lenses or layers in the clayey silt till deposit. For the potential depth of



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

excavation associated with spread footings or pile caps, the seepage volume is expected to be relatively small, such that the water inflow can be handled by pumping from filtered sumps placed at the base of the excavations. Based on these small seepage volumes, a Permit to Take Water (PTTW) may not be required for the groundwater control system at this site and should be reviewed at detail design.

As discussed in Section 6.5, running or flowing of water-bearing cohesionless soil strata could occur during or after drilling of the caissons/pre-augering for driven H-piles or pipe piles, and basal heave could occur where water-bearing cohesionless soils are present at/near the caisson base. If caisson foundations are adopted, temporary or permanent caisson liners would be required to support the soils during construction. If driven piles through pre-augered holes are adopted temporary or permanent liners would be required to support the soils prior to driving the pile.

### 6.7.3 Subgrade Protection

The silty sand/clayey silt till soils that will be exposed at the foundation subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade.

### 6.7.4 Obstructions

The soils at this site are glacially derived and as such should be expected to contain cobbles and boulders, which could affect the installation of deep foundations or protection systems. Further observation is recommended in the next stage of investigation in support of the detail design.

### 6.7.5 Vibration Monitoring During Pile or Caisson Installation

If deep foundations are adopted, pre-augering would be required to reach the minimum pile lengths and then driven in order to achieve the design geotechnical resistances. A maximum peak particle velocity (PPV) of 100 mm/s is generally considered applicable for bridge structures in good condition. Based on vibration monitoring experience, it is considered unlikely that vibrations induced by conventional construction activities (such as pile driving) will reach this threshold level. However, if the Highway 427 NBL and SBL overpass structures are determined to be sensitive to vibrations, the requirement for vibration monitoring should be assessed at detail design.

## 6.8 Recommendations for Further Work in Detail Design

Additional boreholes will be required within each of the abutment widening areas and the approach embankment widening areas during the future detail design stage of investigation, to further assess and/or confirm the subsurface conditions and the preliminary recommendations provided in this report, as follows:

#### ■ Abutments:

- Assessment of the variability and depth of any existing fill and surficial soils to confirm the founding elevation for spread footings within each widened abutment area;
- Observation of the possible presence of cobbles and/or boulders within the soil deposits, to assess the need for an NSSP to warn the contractor of the presence of such obstructions as they may affect



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

excavations and the installation of driven steel H-pile, steel pipe (tube) piles or caisson foundations, and;

- Determine the stabilized water level at the site.

### ■ Approach embankments:

- Assessment of the depth and extent of stripping of organic materials within the footprint of the widened approach embankments,
- The filling in the median was carried out subsequent to the previous 1982 foundation investigation and no boreholes are available to determine its competence. It has been assumed that proper material placement and compaction was carried out and that minimal stripping (less than 1 m) would be required. Further investigation, as recommend in the first bullet, for approach embankments would help to confirm this at detail design, and;
- Further assessment of the thickness and consolidation/elastic compression properties of the embankment fill within the footprint of the widened approach embankments, to confirm the settlement estimates.

## 7.0 CLOSURE

This Preliminary Foundation Design Report was prepared by Ms. Sandra McGaghran, P.Eng. a senior geotechnical engineer with Golder, with technical input from Ms. Lisa Coyne, P.Eng., a senior geotechnical engineer and Principal with Golder, and Mr. M.S. Devata, P.Eng., a specialist foundations consultant with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for Golder, conducted an independent review of this report.

### GOLDER ASSOCIATES LTD.

  
  
Sandra McGaghran, P.Eng.  
Senior Geotechnical Engineer

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

SMM/LCC/MSD/FJH/jl

n:\active\2010\1111\10-1111-0202 mrc hwy 427 toronto\6 - reports\6 - ramp 427n - 407e\final\10-1111-0202 final rpt(b) 12nov6 ramp 427n - 407e.docx



---

## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

---

### REFERENCES

Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4<sup>th</sup> Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Canadian Standards Association (CSA), 2006. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 06*. CSA Special Publication, S6.1 06.

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.

Ontario Geological Society, 1991. *Geology of Ontario*. Special Volume 4, Part 1. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

### Ontario Provincial Standard Specifications (OPSS)

OPSS 539      Construction Specification for Temporary Protection Systems

### Ontario Provincial Standard Drawings (OPSD)

OPSD 3090.101      Foundation Frost Penetration Depths for Southern Ontario



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

TABLE 1 – COMPARISON OF FOUNDATION ALTERNATIVES

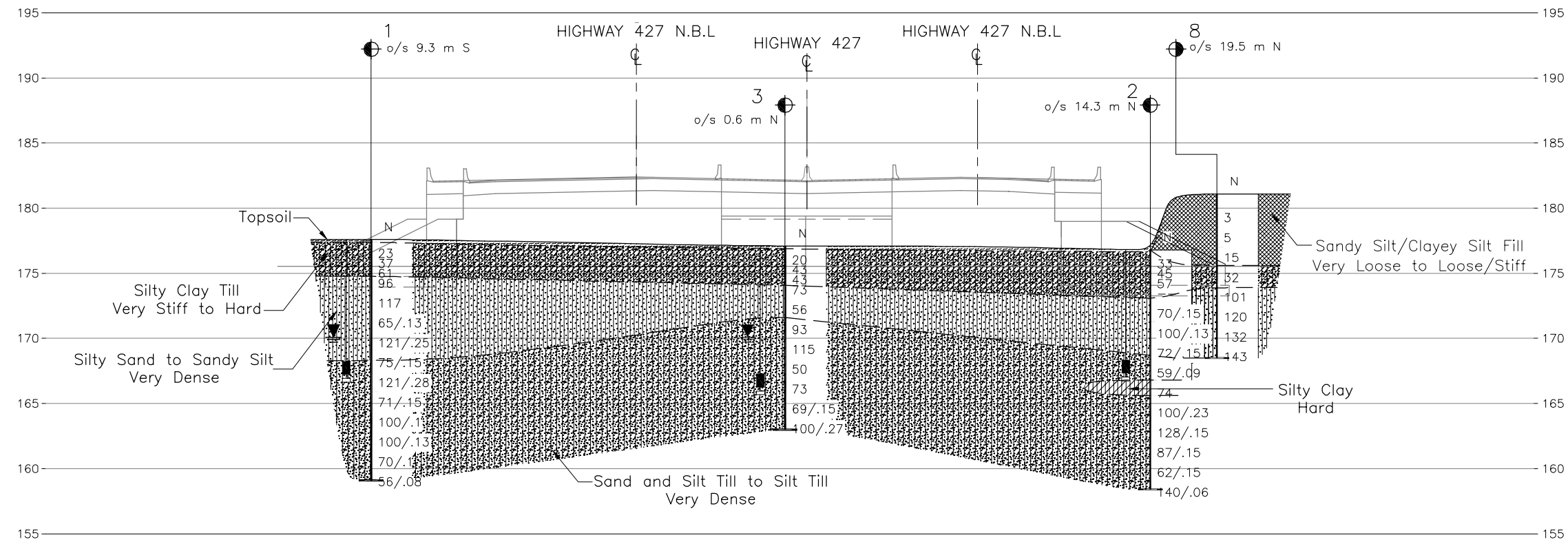
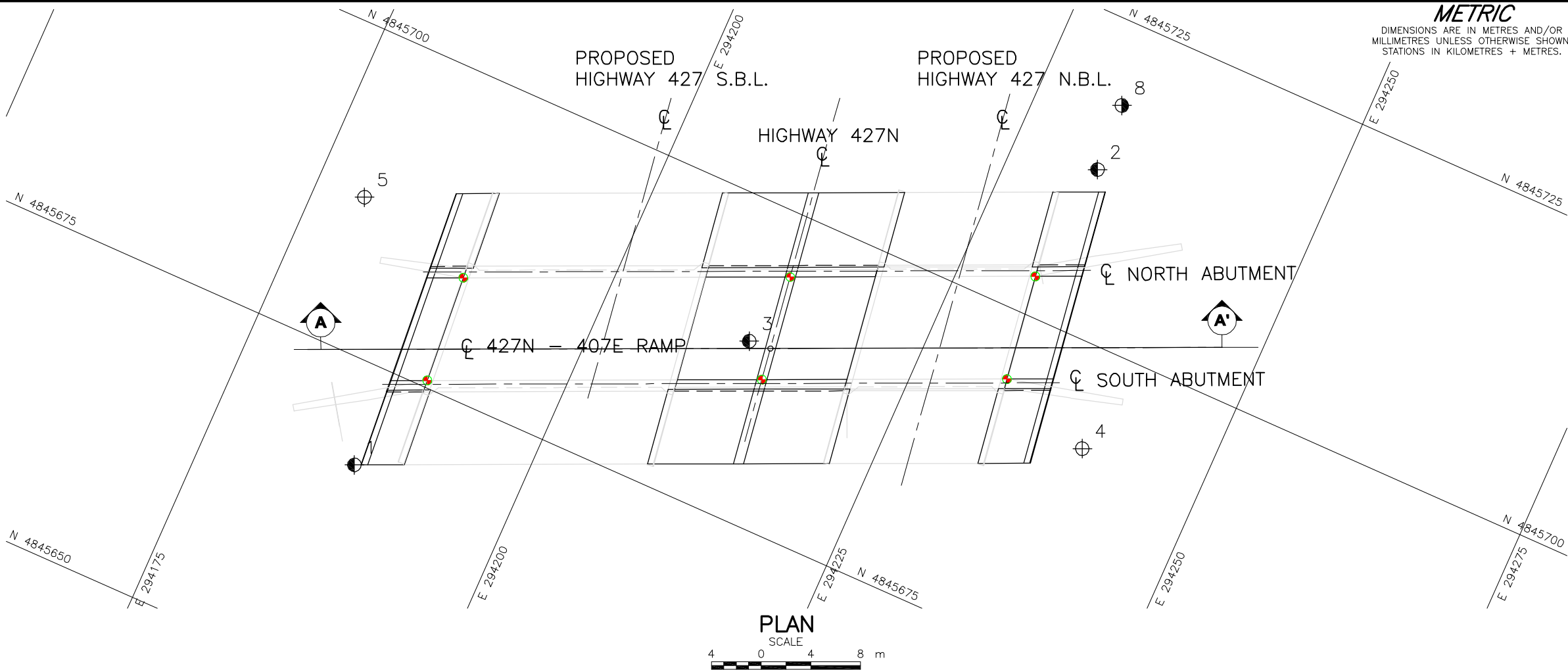
Foundation Option	Feasibility	Advantages	Disadvantages	Constructability
Spread/strip footings on very dense silty sand	<ul style="list-style-type: none"><li>• Feasible for support of widened abutments and retaining walls</li></ul>	<ul style="list-style-type: none"><li>• Existing structure supported on shallow foundations, and has performed well</li><li>• Relatively minor groundwater seepage anticipated</li><li>• Allows for semi-integral abutments</li></ul>	<ul style="list-style-type: none"><li>• Significant excavations (to a depth of up to 8 m below the Highway 427 grade) to extend below existing fill; would require temporary excavation support</li><li>• Precludes use of integral abutments</li><li>• Lower geotechnical resistances as compared with deep foundations</li></ul>	<ul style="list-style-type: none"><li>• Conventional excavation and construction techniques</li></ul>
Re-use the existing median retaining wall footing between the existing abutments	<ul style="list-style-type: none"><li>• Feasible for support of median widening of bridge structures</li><li>• Not feasible for support of outside widening of abutments</li></ul>	<ul style="list-style-type: none"><li>• Existing structure supported on shallow foundations, and has performed well</li><li>• Minimal excavation required</li><li>• Relatively minor groundwater seepage anticipated</li><li>• Allows for semi-integral abutments</li></ul>	<ul style="list-style-type: none"><li>• </li></ul>	<ul style="list-style-type: none"><li>• Conventional excavation and construction techniques</li></ul>
Spread/strip footings “perched” on compacted Granular A pad in approach embankment	<ul style="list-style-type: none"><li>• Feasible for support of widened abutments</li></ul>	<ul style="list-style-type: none"><li>• Minimizes the length of the abutment wall</li><li>• Relatively minor groundwater seepage anticipated</li><li>• Allows for semi-integral abutments</li></ul>	<ul style="list-style-type: none"><li>• Requires excavation to top of existing footing to a depth of 8 m below the Highway 427 grade to remove existing fill and replace with a Granular A pad</li><li>• Requires longer bridge structure</li><li>• Footings would be at or higher elevation and therefore no connection with existing bridge.</li></ul>	<ul style="list-style-type: none"><li>• Conventional excavation and construction techniques</li></ul>



## PRELIMINARY FOUNDATION REPORT - HIGHWAY 427 OVERPASSES AT 427N - 407E RAMP

Foundation Option	Feasibility	Advantages	Disadvantages	Constructability
Steel H-piles driven to practical refusal to found within very dense silty sand/ Lower Till Deposit	<ul style="list-style-type: none"> <li>Feasible for support of widened abutments and retaining walls</li> </ul>	<ul style="list-style-type: none"> <li>Limited groundwater control required</li> <li>Allows for integral abutment construction if existing structure can be modified to accommodate, or if replacement is adopted</li> <li>Would minimize differential settlement between existing structure and widened portions of structure</li> </ul>	<ul style="list-style-type: none"> <li>Pre-augering required to achieve the minimum embedment</li> <li>Temporary/permanent liners required to minimize disturbance to water-bearing sand and silt till deposit.</li> </ul>	<ul style="list-style-type: none"> <li>Conventional construction methods for H-pile foundations</li> </ul>
Steel pipe (tube) piles, driven to found within very dense silty sand/ Lower Till Deposit	<ul style="list-style-type: none"> <li>Feasible for support of widened abutments and retaining walls</li> </ul>	<ul style="list-style-type: none"> <li>Limited groundwater control required</li> <li>Allows for semi-integral abutment configuration</li> <li>Would minimize differential settlement between existing structure and widened portions of structure</li> </ul>	<ul style="list-style-type: none"> <li>Slightly greater risk than for steel H-pile foundations if obstructions (cobbles and/or boulders) are encountered during driving; this could result in piles "hanging up" and lower geotechnical resistances</li> </ul>	<ul style="list-style-type: none"> <li>Conventional construction methods</li> </ul>
Caissons founded within "100-blow" silty sand or Lower Till Deposit	<ul style="list-style-type: none"> <li>Feasible but not preferred for support of abutments and retaining walls</li> </ul>	<ul style="list-style-type: none"> <li>Higher capacity than for steel H-piles or pipe piles, so reduced number of deep foundation elements compared to steel H-piles or pipe piles</li> <li>Would minimize differential settlement between existing structure and widened portions of structure</li> </ul>	<ul style="list-style-type: none"> <li>Water-bearing sand and silty sand till to silt till deposits could contribute to loss of ground or base disturbance</li> <li>Temporary or permanent liners would be required</li> <li>Mud drilling may be required below the water level</li> <li>Tremie methods necessary to place concrete</li> </ul>	<ul style="list-style-type: none"> <li>Risk of loosening soils at base of caissons</li> </ul>



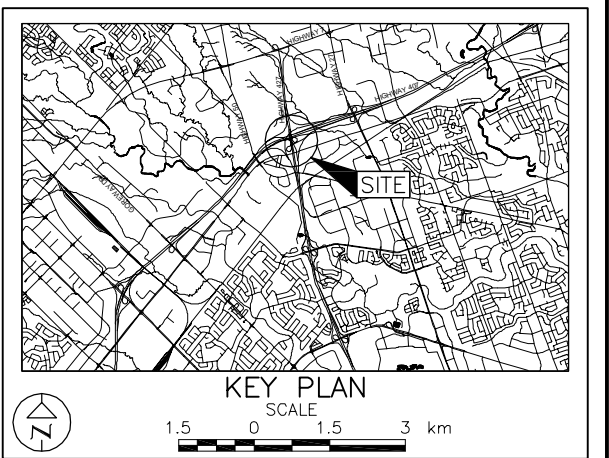


**METRIC**  
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.  
GWP No.2229-09-00(b)

HIGHWAY 427 OVERPASS  
427N - 407E RAMP  
BOREHOLE LOCATIONS AND SOIL STRATA

**Golder Associates Ltd.**  
MISSISSAUGA, ONTARIO, CANADA



LEGEND

Borehole - Previous Investigation, Morton & Partners Ltd, Geocres 30M13-052

Borehole - Previous Investigation MTO Foundation Design Section, Geocres 30M13-116

Dynamic Cone Penetration Test - Previous Investigation, Morton & Partners Ltd, Geocres 30M13-052

Seal

Piezometer

Standard Penetration Test Value

Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

WL in piezometer, measured on 02/10/1982

WL upon completion of drilling

BOREHOLE CO-ORDINATES

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 configuration as shown elsewhere in the Preliminary Design Report.

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

The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

General Arrangement provided in digital format by MRC, drawing file no. S3211001-301-0016A.dwg, received March 19, 2012.

NO.	DATE	BY	REVISION

Geocres No. 30M13-199

HWY. 427	PROJECT NO. 10-1111-0202	DIST.
SUBM'D. SMM	CHKD. LCC	DATE: 6/14/2012
DRAWN: JFC	CHKD. SMM	APPD. FJH/LCC
		DWG. 1



# **APPENDIX A**

## **Borehole Records, Drawing 1 and Laboratory Test Results GEOCRES 30M13-052**

# RECORD OF BOREHOLE No 1

METRIC

W P 153-80-05 LOCATION Co-ords. 4 845 667 N; 294 187 E. ORIGINATED BY \_\_\_\_\_  
 DIST 6 HWY 427 BOREHOLE TYPE Solid Stem Auger COMPILED BY \_\_\_\_\_  
 DATUM Geodetic DATE 82-02-03 CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80						100
								SHEAR STRENGTH									WATER CONTENT (%)
							○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    x LAB VANE										
177.6	Ground Level																
0.2	Silty clay, sandy, trace of gravel (Till)  Very stiff to hard, brown		1	SS	23										20.9		
			2	SS	37										21.8	2 24 49 25	
174.8			3	SS	61										20.9	1 35 50 14	
2.8	Sand, fine, silty to very silty, occasional coarser layers with some gravel  Very dense, brown		4	SS	96										19.8	14 83 3	
			5	SS	117												
			6	SS	65/130mm										22.2		
			7	SS	21/250mm										20.6		
168.3			8	SS	75/150mm												
9.3	Sand, fine, with silt and some gravel. (Till) Very dense, grey		9	SS	121/230mm										22.6		
165.9			10	SS	77/150mm										22.9		
11.7	Silt, some sand, trace of clay, occasional rock fragments (Till) Very dense, grey		11	SS	100/200mm										23.9		
			12	SS	100/230mm										23.1		
			13	SS	200/200mm										21.8		
159.1			14	SS	56/200mm										23.7		
18.5	End of Borehole																

OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to  
Sensitivity

20  
15 + 5 (%) STRAIN AT FAILURE  
10

# RECORD OF BOREHOLE No 2

METRIC

W P 153-80-05 LOCATION Co-ords. 4 845 713 N, 294 232 E. ORIGINATED BY \_\_\_\_\_  
 DIST 6 HWY 427 BOREHOLE TYPE Solid Stem Auger COMPILED BY \_\_\_\_\_  
 DATUM Geodetic DATE 82-01-29 CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT $\gamma$					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ KN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100					
176.8	Ground Level															
0.2	Silty clay, sandy, trace of gravel (Till) Hard, brown		1	SS	33										21.4	
			2	SS	45										21.4	
			3	SS	57										22.3	27 52 21
			4	AS	-	*										3 24 45 28
173.1																
3.7	Sand, fine, silty, some gravel, (possibly Till lenses in part) Very dense, brown		5	SS	70/150mm											4 53 38 5
171.3																
5.5	Silt, some sand, trace of clay, occasional rock fragments and gravel Very dense, grey		6	SS	100/130mm											
			7	SS	72/150mm										23.7	
			8	SS	59/90mm										23.6	
			9	SS	74										20.7	
	Hard grey varved silty clay layer at elev. 166		10	SS	100/230mm										22.6	
			11	SS	128/150mm										23.6	
			12	SS	87/150mm										23.6	
			13	SS	62/150mm										23.7	
158.4			14	SS	140/150mm										23.4	
18.4	End of Borehole															
	Note: sampler refusal at elev. 173.9. Augered through and took auger sample															

+3, x5: Numbers refer to  
Sensitivity

20  
15  $\phi$  5 (%) STRAIN AT FAILURE  
10

OFFICE REPORT ON SOIL EXPLORATION

# RECORD OF BOREHOLE No 3

METRIC

W P 153-80-05 LOCATION Co-ords. 4 845 689 N; 294 212 E. ORIGINATED BY  
DIST 6 HWY 427 BOREHOLE TYPE Solid Stem Auger COMPILED BY  
DATUM Geodetic DATE 82-02-02 CHECKED BY

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ KN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100		
177.1	Ground Level												
0.2	Silty clay, sandy, trace to some gravel (Till) Stiff to hard, brown		1	SS	20							20.7	
			2	SS	43							21.2	16 47 37
174.1			3	SS	43							21.7	6 36 38 20
3.0	Sand, fine to coarse, silty to very silty, trace to some gravel, Very dense, brown		4	SS	71								28 60 12
			5	SS	56							21.2	
171.6	Sand, fine, silty to very silty, occasional coarser layers with some gravel and rock fragments Very dense, brown to grey-brown		6	SS	93							22.3	
			7	SS	115								
			8	SS	50								
			9	SS	73								
165.0			10	SS	69/150mm							23.3	
12.1	Silt, sandy, trace of clay, trace of gravel (Till) Very dense, grey		11	SS	100/270mm							23.4	
163.0													
14.1	End of Borehole												

+3, x5: Numbers refer to  
Sensitivity

20  
15  
10  
5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION



RECORD OF CONE No 4

METRIC

W P 153-80-05 LOCATION Co-ords. 4 045 692 N; 294 240 E. ORIGINATED BY \_\_\_\_\_  
DIST 6 HWY 427 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY \_\_\_\_\_  
DATUM Geodetic DATE (Cone 4 82-01-29) (Cone 5 82-02-02) CHECKED BY \_\_\_\_\_

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20					
176.8	Ground Level												
173.6	3.2 End of Dynamic Cone 4 Penetration Test												
177.6	Ground Level												
175.2	2.4 End of Dynamic Cone 5 Penetration Test												

RECORD OF CONE No 5

Co-ords. 4 045 687 N; 294 179 E.

OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to  
Sensitivity

20  
15  $\phi$  5 (%) STRAIN AT FAILURE  
10



# METRIC

DIMENSIONS ARE IN METRES  
AND / OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 153-80-05

HWY 427 OVER RAMP 427N-407

BORE HOLE LOCATIONS & SOIL STRATA

MORTON AND PARTNER



KEY PLAN  
SCALE

## LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test
- ⊕ Bore Hole & Cone
- N Blows/0.3m (5rd Pen Test, 4
- CONE Blows/0.3m (60° Cone, 47
- ⬇ WL at time of investigation

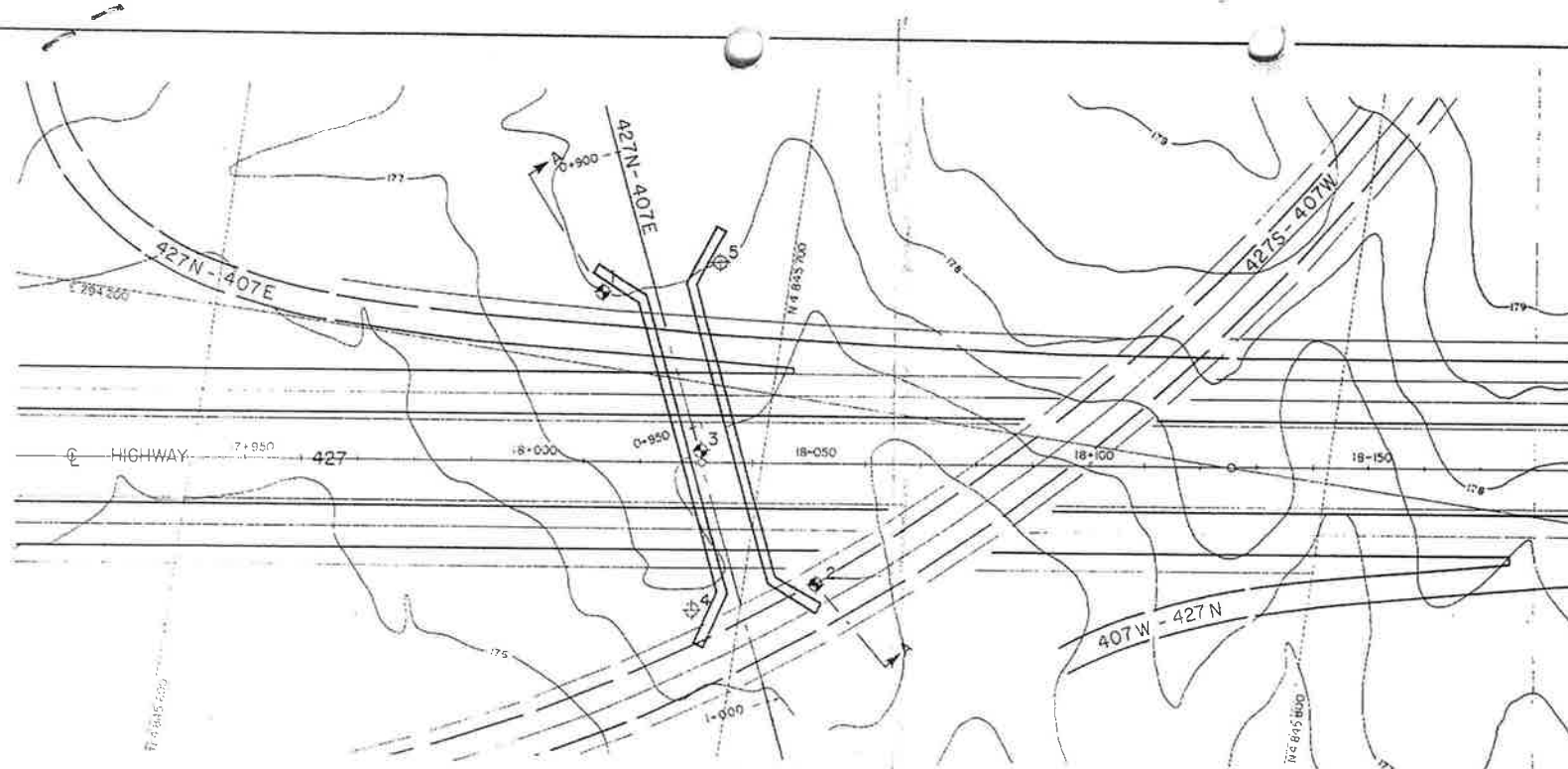
No	ELEVATION	CD-CRDN NORTH
1	177.6	N4 845 667
2	176.8	N4 845 713
3	177.1	N4 845 689
4	176.8	N4 845 692
5	177.6	N4 845 687

**NOTE**  
The boundaries between soil strata have  
only at Bore Hole locations. Between  
boundaries are assumed from geology.

REVISIONS	DATE	BY	DESCRIPTION

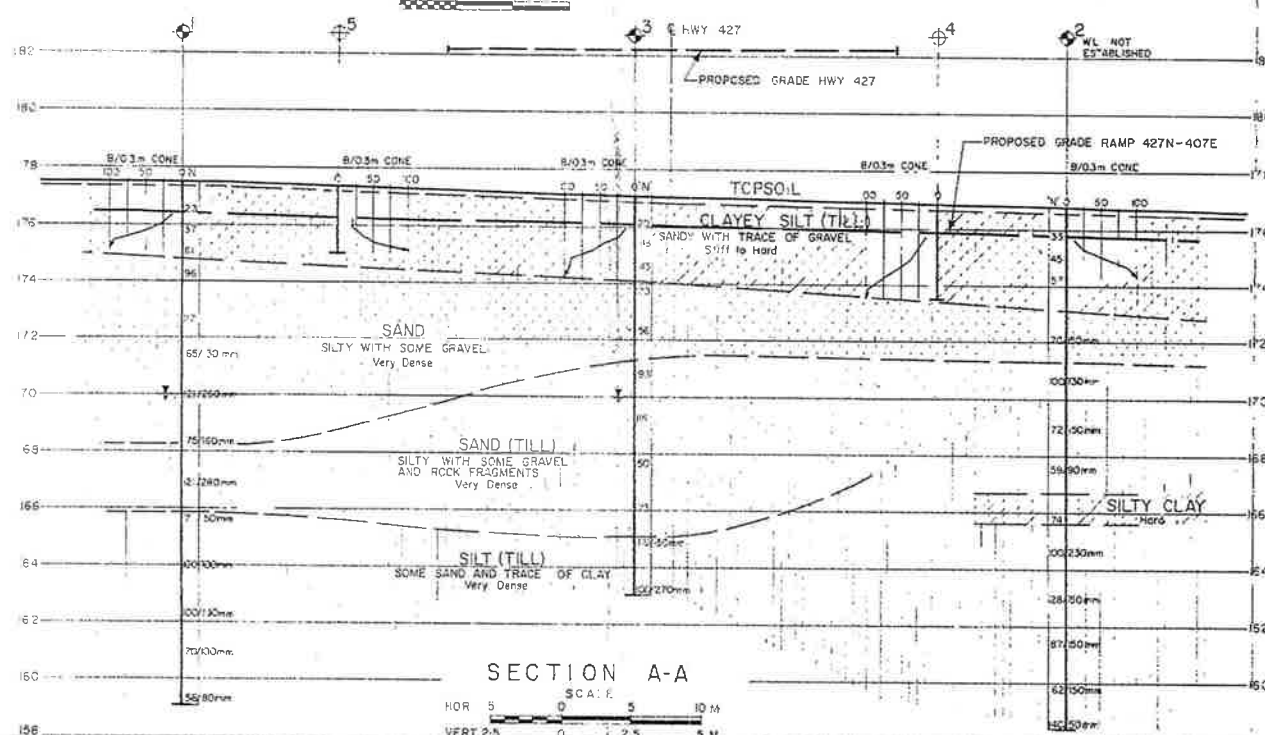
Geocres No 30413-52

HWY No 427	SUBM'D	CHECKED	DATE 82-02-09
DRAWN	CHECKED	ATTACHED	



## PLAN

SCALE 10 20M

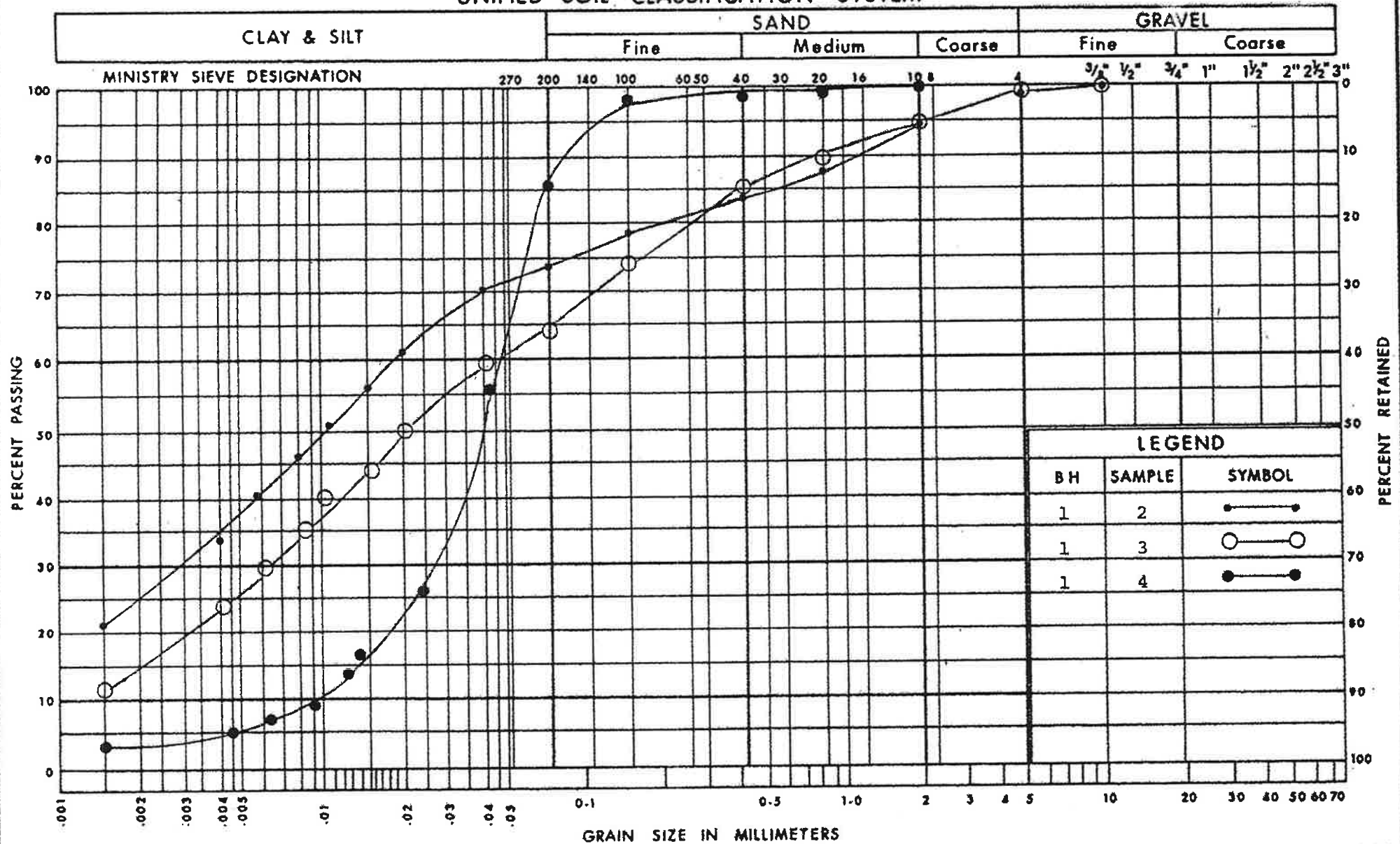


## SECTION A-A

HOR SCALE 0 5 10 M

VERT SCALE 0 2.5 5 M

## UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of  
Transportation and  
Communications

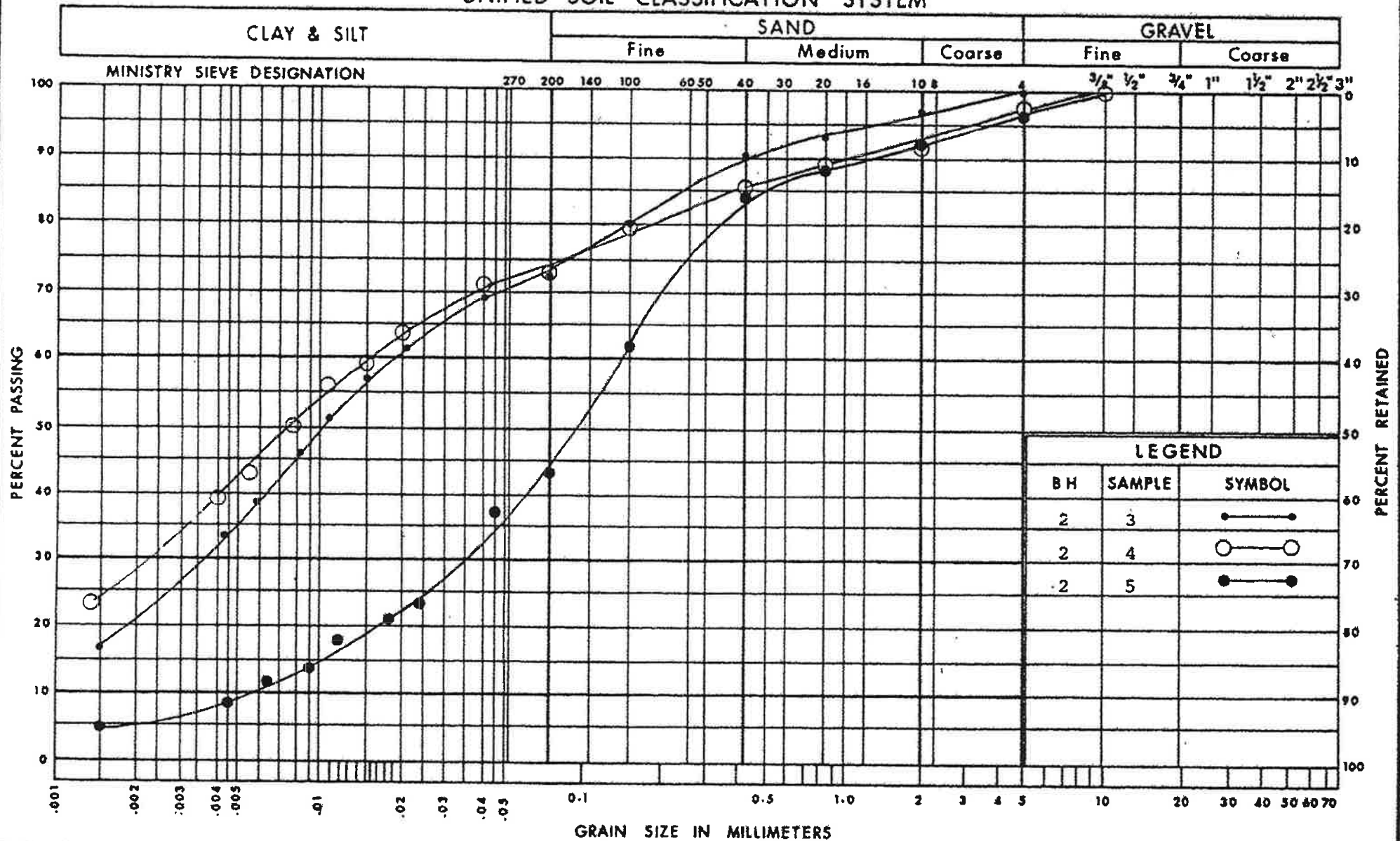
## GRAIN SIZE DISTRIBUTION

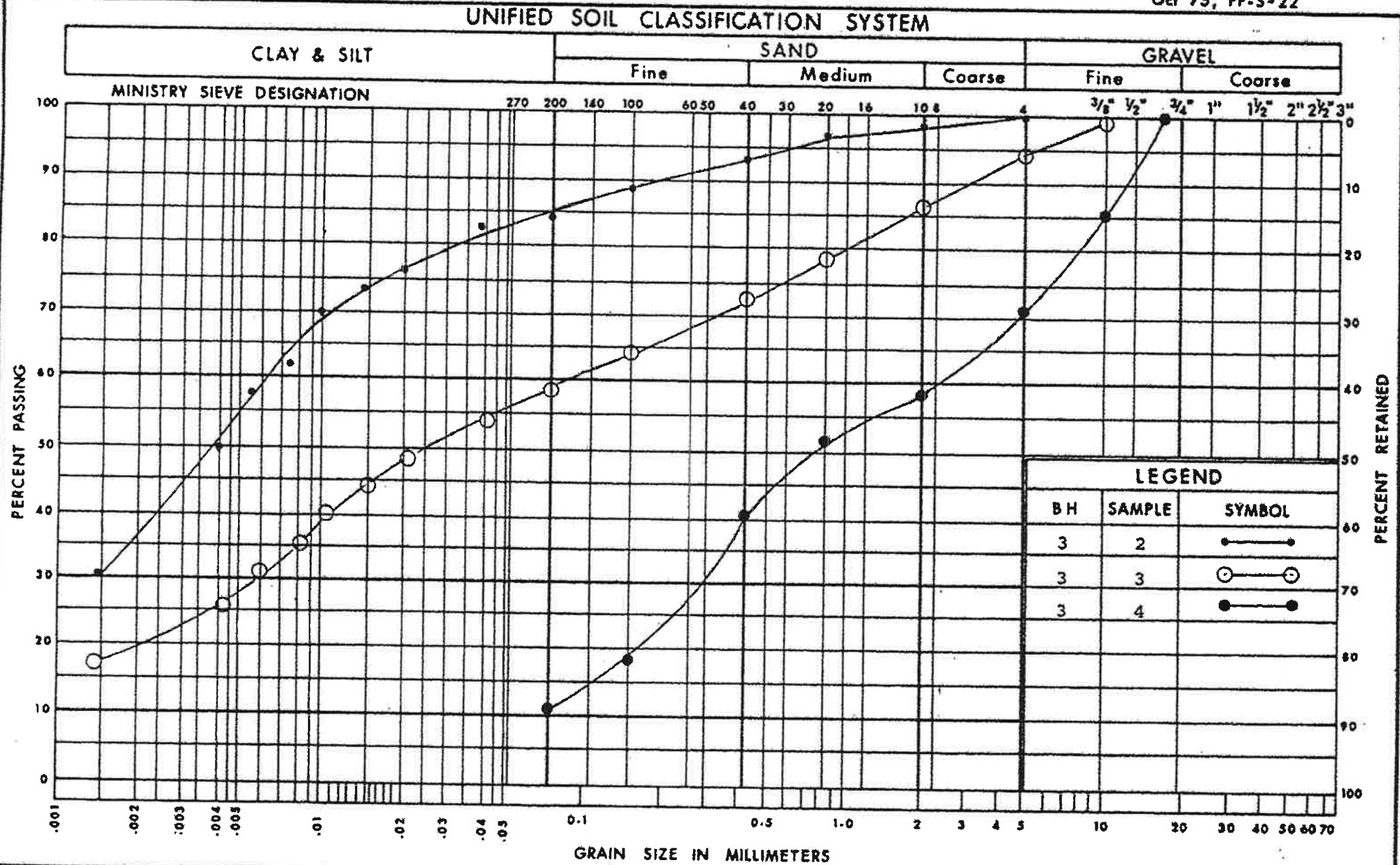
Silty clay (Till) (Sa. 2 & 3)  
Silty sand (Sa. 4)

FIG No 1

W P 153-80-05

## UNIFIED SOIL CLASSIFICATION SYSTEM





Ministry of  
Transportation and  
Communications

## GRAIN SIZE DISTRIBUTION

Silty clay (Till) (Sa. 2 & 3)  
Sand with gravel (Sa. 4)

FIG No 3

W P 153-80-05



# **APPENDIX B**

## **Borehole Records and Laboratory Test Results GEOCRES 30M13-116**



# RECORD OF BOREHOLE No 8

1 OF 1

METRIC

W.P. 388-87-01 LOCATION Co-ords: N 4 845 718.5 : E 294 231.7 ORIGINATED BY MN  
 DIST 6 HWY 407 BOREHOLE TYPE H5 Auger, Washboring COMPILED BY MI  
 DATUM Geodetic DATE 90 05 19 CHECKED BY IS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N° VALUES			20	40	60	80	100					
181.1	Ground Surface																
0.0						DRY											
	Sandy Silt Brown, V. Loose to Loose (Fill Material)		1	SS	3		180										
			2	SS	5		178										2 35 (63)
177.0																	
4.1	Irregular mixture of Clayey Silt, sand and gravel (Fill Material)		3	SS	15		178										
175.8	Brown, Stiff																
5.3	Heterogeneous mixture of Clayey Silt, sand and gravel (Glacial Till) Brown, Hard		4	SS	32		174										2 13 50 35
173.9																	
7.2			5	SS	101		172										
	Brown																
	Grey																
	Sandy Silt V. Dense		6	SS	120		170										
			7	SS	132												6 34 (60)
			8	SS	143												
168.5																	
12.6	End of Borehole																



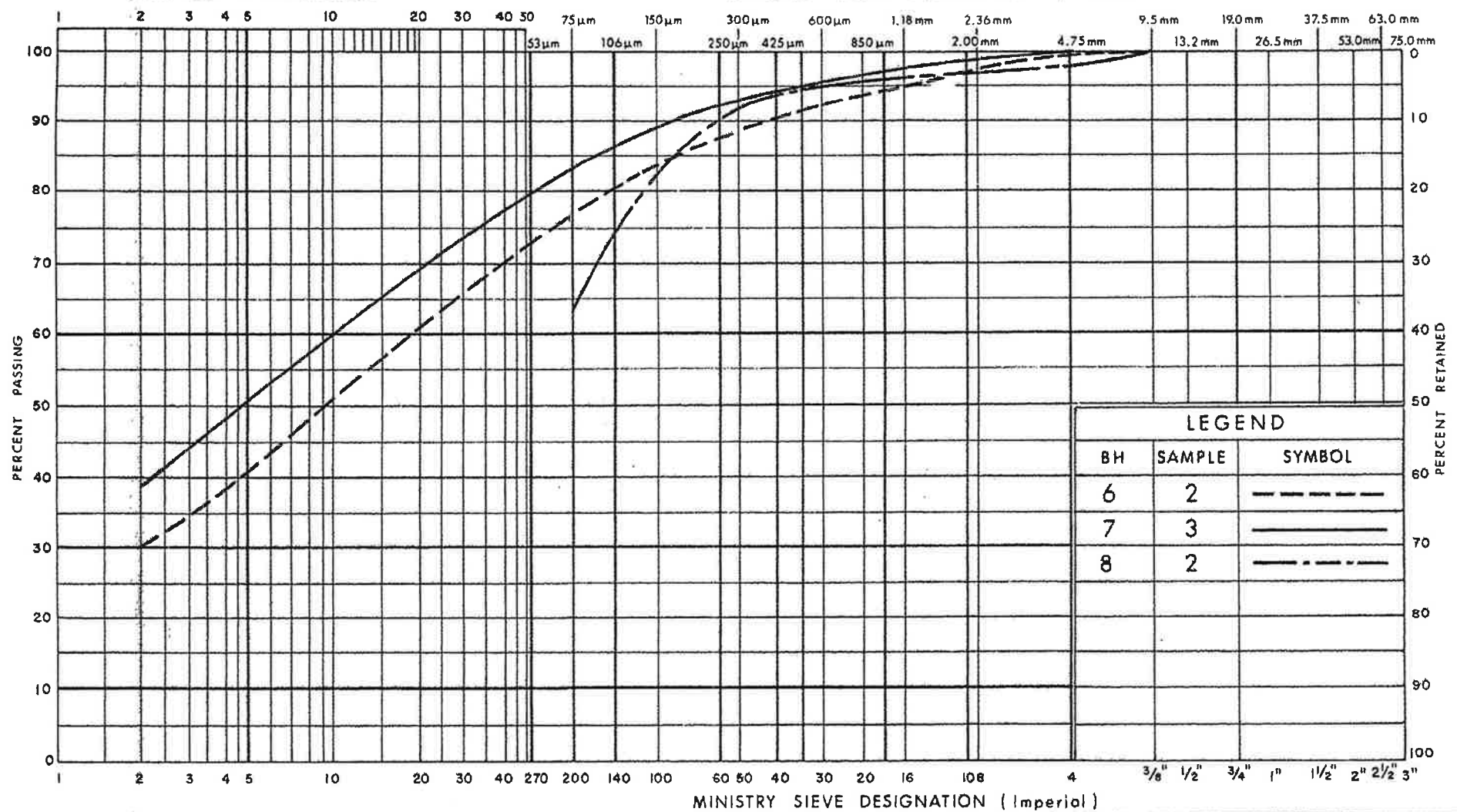


UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT					SAND			GRAVEL	
					Fine	Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

MINISTRY SIEVE DESIGNATION (Metric)

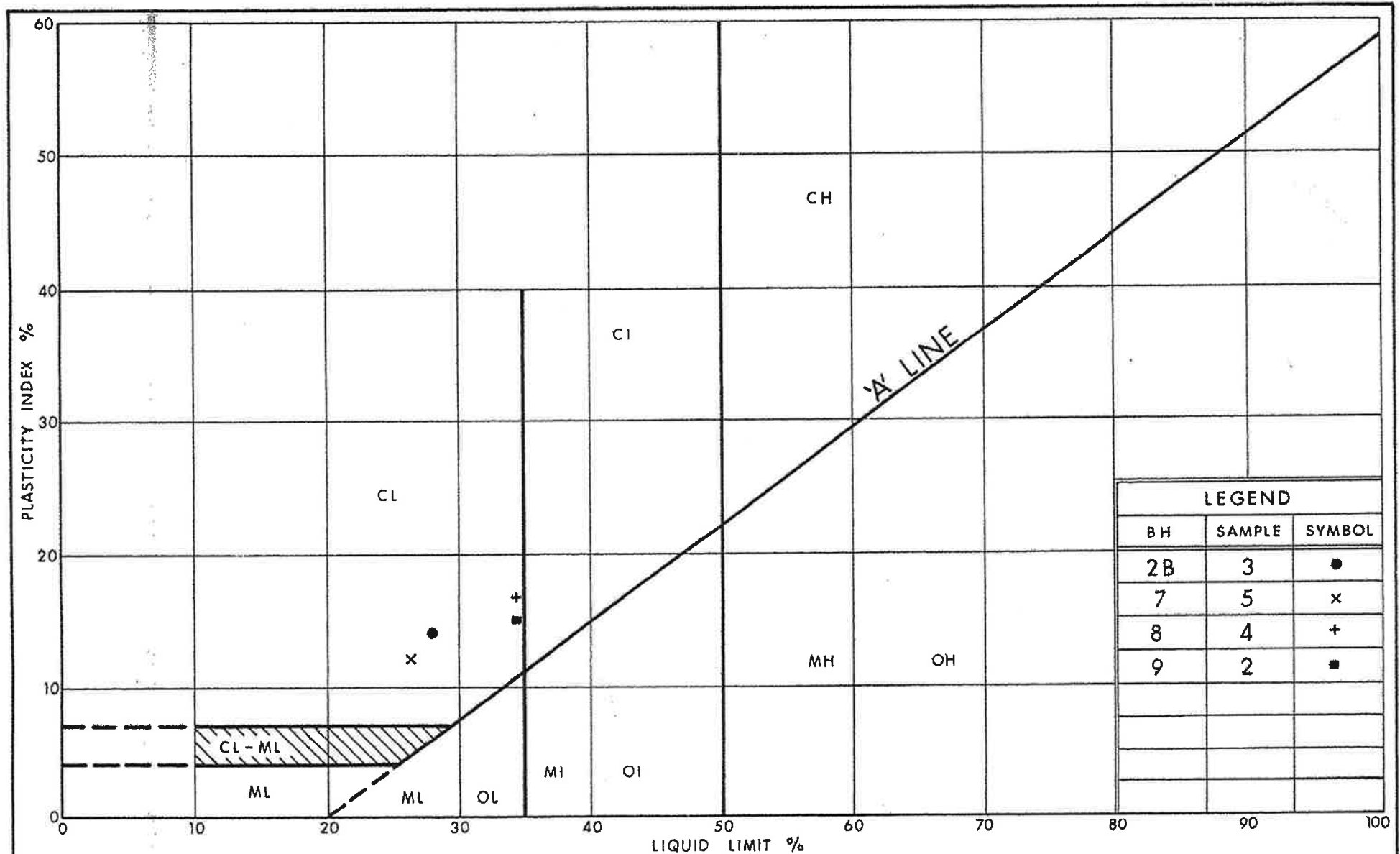


Ministry of  
Transportation

GRAIN SIZE DISTRIBUTION  
(FILL MATERIAL)

FIG No 1

W P 368-87-01



Ministry of  
Transportation

PLASTICITY CHART  
HET MIXTURE OF CLAYEY SILT, SAND & GRAVEL  
(GLACIAL TILL) UPPER

FIG No 4

W P 368-87-01

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

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

[solutions@golder.com](mailto:solutions@golder.com)  
[www.golder.com](http://www.golder.com)

**Golder Associates Ltd.**  
**2390 Argentia Road**  
**Mississauga, Ontario, L5N 5Z7**  
**Canada**  
**T: +1 (905) 567 4444**

