



**April 2013**

# **FOUNDATION INVESTIGATION AND DESIGN REPORT**

## **Retaining Walls**

## **Highway 89 Structure Replacements and Rehabilitation**

**From 6.0 Km West of Mount Forest to Shelburne**

**GWP 3049-08-00**

**Ministry of Transportation, Ontario - West Region**

### **Submitted to:**

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**REPORT**



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LIST OF ABBREVIATIONS

LIST OF SYMBOLS

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#### APPENDIX A

Laboratory Test Data

#### APPENDIX B

Site Photographs



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# **FOUNDATION INVESTIGATION AND DESIGN REPORT RETAINING WALLS**

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## **PART A**

### **FOUNDATION INVESTIGATION REPORT**

#### **RETAINING WALLS**

#### **HIGHWAY 89 STRUCTURE REPLACEMENTS AND REHABILITATIONS**

#### **FROM 6.0 KM WEST OF MOUNT FOREST TO SHELBURNE**

#### **GWP 3049-08-00**

#### **MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 3049-08-00. The project involves the replacement and rehabilitation of several structures along Highway 89 from 6.0 kilometres west of Mount Forest to Shelburne, Ontario.

This Foundation Investigation and Design Report was prepared for the design of retaining walls at four structural culverts located along Highway 89 in the Township of Proton. The locations of the sites are shown on the Key Plan, Figure 1, and site photographs are provided in Appendix B.

The purpose of the foundation investigation was to explore the subsurface conditions at the location of the proposed works by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P1-1132-109-P01 dated November 3, 2011. The work was carried out in accordance with Golder's Quality Control Plan for Foundation Engineering dated March 8, 2012.

Golder Associates was provided with digital copies of preliminary drawings prepared by MH for this project.



## 2.0 SITE DESCRIPTION

### 2.1 General

The existing four structural culverts under Highway 89 are located between Wellington Road 14 and Highway 25 at Stations 10+280, 17+254, 22+907 and 24+500, respectively and are on the boundary of Wellington County and Grey County, Ontario. For the purpose of this report, Highway 89 is assumed to be oriented in an east-west direction.

The embankment side slopes adjacent to the culverts were observed to be stable and no evidence of settlement of the pavement was observed at any of the four culvert sites. Currently, there are no retaining wall structures at any of the culvert locations; however, sand bags have been used to retain the fills at all four corners of the culvert at Station 24+500 (Site 35-516/C).

Land use in the region of the site is primarily rural agricultural and residential. The surrounding topography is irregular and hilly with ground surface elevations ranging from about 475 to 490 metres in the vicinity of the culvert sites. The drainage channel banks near the culverts are grass covered and the channels flow through fields adjacent to Highway 89. Site photographs are provided in Appendix B.

### 2.2 Site Geology

The project sites lie within the physiographic region of southern Ontario known as the Dundalk Till Plain<sup>1</sup>. This region is a drumlinized till plain characterized by swamps or bogs and poorly drained depressions.

Based on the Ministry of Natural Resources Map P.727 entitled "Quaternary Geology, Dundalk Area, Southern Ontario", the four culverts are located along a section of Highway 89 where the surficial geology is mapped primarily of Tavistock Till consisting of silt to clayey silt glacial till with areas of bog deposits.

The Geologic Survey of Canada Map 1263A entitled "Geology, Toronto-Windsor Area, Ontario" indicates that the bedrock underlying the glacial deposits in the area of the site is dolomite of the Guelph Formation of Middle Silurian age. Based on the Ministry of Natural Resources Preliminary Map P.306 entitled "Bedrock Topography, Dundalk Area, Southern Ontario", the bedrock surface at the sites varies in elevation from about 460 to 470 metres or some 20 to 30 metres below ground surface at Stations 17+254, 22+907 and 24+500 and some 15 metres below ground surface at Station 10+280.

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



### 3.0 INVESTIGATION PROCEDURES

The foundation investigation field work was carried out between August 20 and 31, 2012, at which time sixteen boreholes, numbered 401 through 416, were drilled in the area of the proposed rehabilitation of the four culverts. The boreholes were generally drilled on the shoulder or roundings of Highway 89. The borehole locations are shown on Drawings 1 to 4.

The boreholes were drilled using track-mounted CME45 drilling equipment, supplied and operated by a specialist drilling contractor. The soil stratigraphy encountered in the boreholes is shown on the attached Record of Boreholes sheets.

During drilling, samples of the overburden were obtained at intervals of 0.75 metres using 50 millimetres outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The recorded SPT N values are noted on the Record of Borehole sheets. According to ASTM D1586, the SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split spoon sampler a distance of 300 millimetres. The samplers used in the investigations limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes, including cobbles and boulders are known to be present in the native till materials as discussed in the text of this report.

The groundwater conditions in the boreholes were observed throughout the drilling operations and upon completion of the field work. Standpipes were installed in boreholes 403, 407, and 412 to monitor the groundwater conditions. The groundwater observations are noted on the Record of Borehole sheets. The boreholes were backfilled in accordance with current regulations, MTO recommended procedures and Ontario Regulation 903, as amended.

The field work was supervised on a full-time basis by an experienced member of our engineering staff who arranged for underground utility locates, directed the drilling, sampling and in situ testing operations, logged the boreholes and surveyed the borehole locations and elevations. The soil samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, grain size distribution analyses and Atterberg Limits determination, were carried out on selected samples. The results of the field and laboratory testing are given on the Record of Borehole sheets and in Appendix A.

The as-drilled borehole locations and ground surface elevations are shown on the Record of Borehole sheets and on Drawings 1 to 4. The table below summarizes the coordinates, ground surface elevations at the location of the boreholes and the depths of the boreholes.





## FOUNDATION INVESTIGATION AND DESIGN REPORT RETAINING WALLS

Borehole	Location (m)		Ground Surface Elevation (m)	Depth (m)
	Northing	Easting		
Station 10+280 (Site 35-487/C)				
401	4 873 783	219 416	475.38	7.32
402	4 873 779	219 407	475.41	7.32
403	4 873 764	219 419	475.36	7.32
404	4 873 766	219 425	475.44	7.32
Station 17+254 (Site 35-513/C)				
413	4 875 674	226 136	491.23	7.32
414	4 875 673	226 131	491.22	7.32
415	4 875 688	226 127	491.39	7.32
416	4 875 689	226 133	491.40	7.32
Station 22+907 (Site 35-515/C)				
405	4 877 207	231 560	486.83	7.47
406	4 877 220	231 572	485.19	7.32
407	4 877 190	231 580	485.14	7.25
408	4 877 200	231 589	486.78	7.47
Station 24+500 (Site 35-516/C)				
409	4 877 626	233 121	483.26	7.47
410	4 877 622	233 109	483.22	7.32
411	4 877 630	233 094	483.29	7.47
412	4 877 634	233 106	483.17	7.47



## 4.0 SUBSURFACE CONDITIONS

### 4.1 Site Stratigraphy

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

Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

The locations of the boreholes are shown on the attached Drawings 1 to 4. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized below for each culvert location.

### 4.2 Station 10+280 (Site 35-487/C)

Boreholes 401 to 404 were drilled through the embankment fill at the north and south roundings of the Highway 89 embankment to explore the subsurface conditions for the design of the retaining wall structures at this location. The subsurface conditions encountered in the vicinity of the proposed culvert and retaining walls generally consist of surficial fill, topsoil and peat to approximate elevations of 472.5 to 473.0 metres with layers of sand less than 1 metre thick also encountered in boreholes 401 and 403. The surficial materials are underlain in sequence by clayey silt to elevation 472.5 and 471.7 metres on the north and south sides of Highway 89 respectively, then clayey silt till. The simplified stratigraphic profile for this culvert is shown on Drawing 1.

#### 4.2.1 Fill

Fill layers were found at the ground surface in boreholes 401 to 404. The thickness of the fill layers ranged from 0.5 to 2.3 metres.

The fill layers typically comprised topsoil, peat, sand and gravel and clayey silt. The fill was very soft with measured N values of 1 to 2 blows per 0.3 metres and water contents varying from 32 to 40 per cent.



### 4.2.2 Topsoil

In borehole 402, a 0.8 metre thick layer of buried topsoil was found beneath the fill layers at elevation 473.3 metres. An N value of 2 blows per 0.3 metres was recorded in the buried topsoil and a water content of 29 per cent was measured.

### 4.2.3 Peat

An approximately 1.2 metre thick layer of peat was found beneath the fill layer at borehole 401 at elevation 474.9 metres. The fill below elevation 474.2 metres in borehole 402 and in borehole 403 contained varying amounts of peat. The peat had a measured N value of 2 blows per 0.3 metres and a water content of 70 per cent.

### 4.2.4 Sand

Sand layers were found beneath the peat in borehole 401 and beneath the fill layers in borehole 403 at elevations 473.7 and 473.1 metres, respectively. The sand was 0.5 metres thick in borehole 401 and 0.6 thick in borehole 403. The sand was very loose to loose with recorded N values of 1 and 5 blows per 0.3 metres.

### 4.2.5 Clayey Silt

Soft to firm layers of clayey silt were found underlying sand in boreholes 401 and 403 from elevations 473.3 and 472.5 metres, respectively, and beneath the fill layer in borehole 404 from elevation 473.3 metres. The thickness of the clayey silt layers ranged from 0.8 to 1.5 metres.

Standard penetration test N values recorded in the clayey silt layers ranged from 3 to 6 blows per 0.3 metres. Water contents of 12 to 17 per cent were measured for these materials. Based on the Atterberg limits determination carried out on samples obtained during standard penetration testing, the clayey silt is of low plasticity. The plastic limits were 12 to 14 per cent, the liquid limits were 19 to 24 per cent, and the plasticity indices ranged from 5 to 8 per cent. The Atterberg limits data for the clayey silt are presented on Figure A-10. The results of the grain size testing conducted on samples of the clayey silt obtained during standard penetration testing are presented on Figure A-7.



### 4.2.6 Clayey Silt Till

Firm to hard layers of clayey silt glacial till were found underlying clayey silt in boreholes 401, 403 and 404, from elevations 471.7 to 472.5 metres and below the buried topsoil in borehole 402 from elevation 472.5 metres. Boreholes 401 to 404 were terminated in the clayey silt till after exploring the layer for 3.7 to 4.4 metres. Cobbles and possible boulders were found within the clayey silt till layers during drilling.

Standard penetration testing N values of 6 to 75 blows per 0.3 metres were recorded in the clayey silt till. Typically, however, the N values were below 28 blows per 0.3 metres. The value of 75 blows per 0.3 metres was obtained near elevation 470 metres in borehole 404 and is likely attributable to encountering cobbles. Water contents of 8 to 15 per cent were measured on samples of the till. Based on the Atterberg limits determination carried out on samples obtained during standard penetration testing, the clayey silt till is of low plasticity. The plastic limits were 12 to 14 per cent, the liquid limits were 21 to 23 per cent, and the plasticity indices ranged from 7 to 10 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-10. The results of the grain size testing conducted on samples of the clayey silt till obtained during standard penetration testing are presented on Figure A-8.

### 4.2.7 Groundwater Conditions

The groundwater conditions in the boreholes were monitored during drilling. The observed groundwater conditions as noted on the Record of Borehole sheets, are summarized in the following tables and text.

**Summary of Encountered Groundwater Levels**

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level	
		Depth (m)	Elevation (m)
401	475.38	1.7	473.7
402	475.41	2.7	472.7
403	475.36	2.3	473.1
404	475.44	Dry	Below 468.1

**Summary of Measured Groundwater Levels**

Borehole	Ground Surface Elevation (m)	Installation	Measured Groundwater Elevation (m)	
			August 20/12	September 10/12
403	475.36	Standpipe	Dry below 471.7	473.73



Groundwater was first encountered in boreholes 401 to 403 between elevations 473.7 and 472.7 metres. Free-water was not observed in borehole 404 during drilling. The encountered groundwater levels are not considered representative of long-term stabilized conditions as the readings were taken for a short duration.

A 12.5 millimetre diameter standpipe was installed in borehole 403. The most recent groundwater level was measured on September 10, 2012 at elevation 473.7 metres, shortly before the standpipe was decommissioned. The water level in the culvert at the outlet was at elevation 473.4 metres on August 20, 2012. This culvert conveys flows from south to north beneath Highway 89.

The groundwater level at this site has been inferred to range between elevation 473 and 474 metres. The inferred groundwater levels are based on encountered and measured groundwater levels, nearby water levels and change in soil colour from brown to grey. The groundwater levels are expected to fluctuate due to climatic and seasonal variations.

### 4.3 Station 17+254 (Site 35-513/C)

Boreholes 413 to 416 were drilled in the north and south roundings of Highway 89 to explore the subsurface conditions for the design of the retaining wall structures at the culvert at Station 17+254. The boreholes advanced at this site encountered surficial fill to elevation 488.5 metres, then, in sequence, clayey silt till to elevation 486.5 metres, sandy silt till to elevation 485.0 metres, then silt with clayey silt layers. A simplified stratigraphic profile for this culvert is shown on Drawing 2.

#### 4.3.1 Fill

Layers of fill were found below the ground surface at boreholes 413 to 416. The thicknesses of the fill layers ranged from 2.1 and 2.7 metres. The fill layers generally comprised topsoil, sand, silty sand, silt, clayey silt and sandy silt. Within the very loose to compact non-cohesive fill layers, recorded N values ranged between 2 to 12 blows per 0.3 metres. In the soft to stiff cohesive fill layers, N values of 4 and 10 blows per 0.3 metres were measured. A water content of 19 per cent was measured in a fill sample from borehole 415. The results of the grain size testing conducted on a sample of the fill obtained during standard penetration testing are presented on Figure A-1.

#### 4.3.2 Clayey Silt Till

Layers of clayey silt glacial till were found beneath the fill layers at boreholes 413 to 416 from elevations 488.5 to 489.3 metres. The thicknesses of the clayey silt till layers ranged from 0.9 to 2.6 metres. Although cobbles and boulders were not specifically encountered within the boreholes, the presence of cobbles and boulders should be anticipated within the clayey silt till based on the depositional history of glacial tills.



The clayey silt till layers were stiff to very stiff with recorded N values of 9 to 23 blows per 0.3 metres and water contents of 12 and 13 per cent. Based on two Atterberg limits determinations carried out on samples obtained during standard penetration testing, the clayey silt till is of low plasticity. The average plastic limits were 15 per cent, the liquid limits were 25 and 27 per cent, and the plasticity indices ranged from 10 to 12 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-10. The results of the grain size testing conducted on samples of the clayey silt till obtained during standard penetration testing are presented on Figure A-9.

### 4.3.3 Sandy Silt Till

Layers of sandy silt glacial till were found beneath the clayey silt till layers in all boreholes from elevations 486.5 to 487.7 metres. The thicknesses of the sandy silt till layers ranged from 1.5 to 2.7 metres. The measured N values in the dense to very dense sandy silt till layers ranged from 31 to greater than 100 blows per 0.3 metres with water contents of 7 to 8 per cent. The results of the grain size testing for selected samples of sandy silt till recovered during standard penetration testing are presented on Figure A-4.

Cobbles and a possible boulder were found within the sandy silt till layers during drilling. The presence of both cobbles and boulders should be expected within the sandy silt till deposit.

### 4.3.4 Silt

Layers of silt with clayey silt layers were found beneath the sandy silt till layers at boreholes 413 to 415 from elevations 484.7 to 485.5 metres and beneath the clayey silt in borehole 416 from elevation 484.7 metres. Boreholes 413 to 416 were terminated in the silt after exploring the layer for 0.6 to 1.4 metres. The silt layers were dense to very dense with recorded N values of 30 to 59 blows per 0.3 metres. A single silt sample had a measured water content of 15 per cent. The results of the grain size testing for a sample of silt recovered during standard penetration testing are presented on Figure A-6.

### 4.3.5 Clayey Silt

The sandy silt till in borehole 416 was underlain by clayey silt below elevation 485.5 metres. An N value of 44 blows per 0.3 metres was measured in the hard clayey silt. The clayey silt sample had a measured water content of 10 per cent. The results of the grain size analysis on a sample of the clayey silt are shown on Figure A-7.



### 4.3.6 Groundwater Conditions

The groundwater conditions in the boreholes were monitored during drilling. The observed groundwater conditions, as noted on the Record of Borehole sheets, are summarized in the following table and text.

**Summary of Encountered Groundwater Levels**

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level	
		Depth (m)	Elevation (m)
413	491.23	2.4	488.8
		6.3	484.9
414	491.22	2.0	489.2
		6.8	484.4
415	491.39	Dry	Below 484.1
416	491.40	Dry	Below 484.1

Groundwater was first encountered in boreholes 413 and 414 on the south side of Highway 89 near the base of the fill at about elevations 489 metres and near the till/silt interface at elevation 484.5 metres. Boreholes 415 and 416 on the north side of Highway 89 did not show evidence of free-water during drilling. The groundwater levels encountered during drilling are not considered indicative of long-term, stabilized conditions. There was no water in the culvert during the period of the investigation. The flow direction in this culvert is from north to south under Highway 89.

It appears that groundwater may accumulate to an inferred level of elevation 489.5 metres in the more permeable fill overlying the clayey silt till. Based on the colour change from brown to grey and the encountered groundwater levels, the groundwater level at this site has been inferred to range from elevation 485.0 to 487.0 metres. The groundwater levels are expected to fluctuate due to climatic and seasonal variations.

## 4.4 Station 22+907 (Site 35-515/C)

Boreholes 405 to 408 were drilled on the south and north roundings of the Highway 89 embankment to explore the subsurface conditions for the design of the retaining walls for the culvert at Station 22+907. The subsurface conditions based on the boreholes typically consist of surficial topsoil and fill to elevation 484.5 metres, silts to elevation 481.5 then glacial till consisting predominantly of clayey silt till. A simplified stratigraphic profile for this culvert is presented on Drawing 3.



### 4.4.1 Topsoil

Layers of topsoil were found at ground surface in boreholes 406 and 407. The thickness of the surficial topsoil layers were 400 and 700 millimetres, respectively. Layers of buried topsoil approximately 460 and 300 millimetres thick were found beneath layers of fill in boreholes 405 and 408 at elevation 485.5 and 485.0 metres, respectively. Traces of topsoil were encountered in the fill in boreholes 405 and 408. An N value of 9 blows per 0.3 metres was measured in the buried topsoil. A single sample had a water content of 43 per cent.

### 4.4.2 Fill

Layers of fill were found at the ground surface in boreholes 405 and 408. The thickness of the fill layers were 1.4 and 1.8 metres in boreholes 405 and 408, respectively. The fill layers typically comprised sand, silty sand and silt. The loose to compact granular fill layers had recorded N values of 8 to 13 blows per 0.3 metres.

### 4.4.3 Sandy Silt

A loose layer of sandy silt was found beneath the topsoil layer in borehole 408 at elevations 484.7 metres. The thickness of the sandy silt layer was 0.8 metres. The sandy silt layer had an N value of 9 blows per 0.3 metres.

### 4.4.4 Silt

Layers of loose to compact silt were found in boreholes 405 to 407 beneath the topsoil layer at elevations ranging from 484.5 to 485.0 metres. A layer of silt was encountered below the sandy silt in borehole 408 at elevation 483.9 metres. The silt layers had thicknesses ranging from 1.0 to 3.0 metres. The layers of silt had N values of 6 to 28 blows per 0.3 metres and water contents of 11 to 26 per cent. The results of the grain size testing conducted on selected samples of silt obtained during standard penetration testing are presented on Figure A-6.

### 4.4.5 Clayey Silt Till

Layers of firm to hard clayey silt glacial till were found in boreholes 405 to 408 at elevations ranging from 481.5 to 483.0 metres. Boreholes 405, 406 and 408 were terminated in the clayey silt till after exploring the layers for 3.1 to 3.7 metres. The clayey silt till layer in borehole 407 was 3.7 metres thick. Cobbles were found during drilling through the clayey silt till layer in borehole 407. The presence of both cobbles and boulders should be anticipated within the clayey silt till deposit.





## FOUNDATION INVESTIGATION AND DESIGN REPORT RETAINING WALLS

Standard penetration test N values of 7 to greater than 100 blows per 0.3 metres were measured in clayey silt till layers. Typically, however, the N values were less than 28 blows per 0.3 metres. Water contents were 9 to 23 per cent. The clayey silt till is of low plasticity based on the plastic limits of 15 to 17 per cent, the liquid limits of 25 to 31 per cent, and the plasticity indices of 8 to 14 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-10. The results of the grain size testing conducted on selected samples of the clayey silt till obtained during standard penetration testing are presented on Figure A-9.

### 4.4.6 Sandy Silt Till

A very dense layer of sandy silt till was found beneath the clayey silt till layer in borehole 407 at elevations 479.4 metres. The thickness of the sandy silt till layer was 1.5 metres. The sandy silt till layer had N values of 61 and greater than 100 blows per 0.3 metres based on two standard penetration tests and a water content of 7 per cent measured on one sample. The results of the grain size testing conducted on a sample of the sandy silt till obtained during standard penetration testing are presented on Figure A-4. Although cobbles and boulders were not specifically encountered within the boreholes, the presence of cobbles and boulders should be anticipated within the sandy silt till based on the depositional history of glacial tills.

### 4.4.7 Groundwater Conditions

The groundwater conditions in the boreholes were monitored during drilling. The observed groundwater conditions as noted on the Record of Borehole sheets, are summarized in the following table and text.

**Summary of Encountered Groundwater Levels**

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level	
		Depth (m)	Elevation (m)
405	486.83	1.8	485.0
406	485.19	1.2	484.0
407	485.14	0.6	484.5
408	486.78	2.1	484.7

**Summary of Measured Groundwater Levels**

Borehole	Ground Surface Elevation (m)	Installation	Measured Groundwater Elevation (m)	
			September 10/12	September 11/12
407	485.14	Standpipe	484.73	484.71



Groundwater was first encountered in boreholes 405 to 408 between elevations 484.0 and 485.0 metres.

A 12.5 millimetres diameter standpipe was installed in borehole 407. The most recent groundwater level was measured on September 11, 2012 at elevation 484.7 metres, shortly before the standpipe was decommissioned. The water level in the culvert at the outlet was at elevation 484.3 metres on August 29, 2012. This culvert conveys flows from north to south beneath Highway 89.

The inferred groundwater level at this site is at about elevation 485.0 metres. The inferred groundwater level is based on encountered and measured groundwater levels and water levels in the Loughheed Drain. The groundwater levels are expected to fluctuate due to climatic and seasonal variations.

### 4.5 Station 24+500 (Site 35-516/C)

Boreholes 409 to 412 were drilled in the south and north shoulders of Highway 89 to explore the subsurface conditions for the design of the retaining walls at the culvert at Station 24+500. The stratigraphy based on the boreholes generally consists of surficial topsoil and fill to elevation 482 metres over silts interlayered with clayey silt to elevation 480 metres, sand and gravel to elevation 478 metres, then glacial till. At borehole 411, peat was encountered beneath the fill and clayey silt interlayered with silt was found between the sand and gravel and the till deposits. A simplified stratigraphic profile for this culvert is shown on Drawing 4.

#### 4.5.1 Topsoil

A 210 millimetre thick layer of buried topsoil was found beneath the fill in borehole 409 at elevation 481.3 metres.

#### 4.5.2 Granular Base and Subbase

Granular pavement base materials, approximately 180 to 400 millimetres thick, were encountered at the ground surface in boreholes 409 to 412. The granular base in borehole 410 contained trace amounts of topsoil. The granular base in borehole 409 was underlain by a 670 millimetre thick layer of granular subbase. The granular subbase in boreholes 410 to 412 could not be distinguished from the underlying fill.

#### 4.5.3 Fill

Fill layers were found in boreholes 409 to 412 beneath the granular base and subbase at elevations 482.2 to 483.0. The thicknesses of the granular fill layers were 0.9 to 2.2 metres. The fill layers typically comprised sand and gravel, sand, silt, topsoil and silty sand. The very loose to compact fill layers had N values of 3 to 13 blows



per 0.3 metres. The water content of a silty sand fill sample was 11 per cent. The results of the grain size testing conducted on a sample of the fill obtained during standard penetration testing are presented on Figure A-1.

### 4.5.4 Peat

A 910 millimetre thick layer of peat was found beneath the fill in borehole 411 at elevation 482.1 metres. The peat had an N value of 3 blows per 0.3 metres and a water content of 144 per cent.

### 4.5.5 Clayey Silt

Firm to stiff layers of clayey silt were found underlying sandy silt in boreholes 409 at elevation 480.4 metres, beneath sand and gravel in borehole 411 at elevation 479.6 metres and below the upper silt layer in borehole 412 at elevation 479.4 metres. The thickness of the clayey silt layers ranged from 0.3 to 0.8 metres.

The clayey silt had N values of 8 to 12 blows per 0.3 metres with a water content of 15 per cent. The clayey silt is of low plasticity based on a single Atterberg limit with a plastic limit of 14 per cent, liquid limit of 20 per cent, and plasticity index of 6 per cent. The Atterberg limits data for the clayey silt are presented on Figure A-10. The results of the grain size testing conducted on a sample of clayey silt obtained during standard penetration testing are presented on Figure A-7.

### 4.5.6 Silt and Sandy Silt

Silt layers were found in all boreholes below elevations ranging from 478.8 to 481.2 metres. Silt layers were encountered below the fill in boreholes 410 and 412, beneath the clayey silt in boreholes 409, 411 and 412 and beneath the peat in borehole 411. The silt layers had thicknesses ranging from 0.3 to 1.2 metres. The layers of silt had N values of 9 to 24 blows per 0.3 metres of penetration. The silt layers in borehole 410 and 412 near elevation 480.5 metres and in borehole 411 near elevation 481.2 metres were inferred to be very loose or loose. The silt samples had measured water contents of 18 and 26 per cent. The results of the grain size testing conducted on selected samples of silt obtained during standard penetration testing are presented on Figure A-6.

In borehole 409, a 0.8 metres thick layer of layered sandy silt and silt was found below the buried topsoil at elevation 481.1 metres. The loose sandy silt had a measured N value of 9 blows per 0.3 metres with a water content of 16 per cent. The results of the grain size testing conducted on a sandy silt sample obtained during the standard penetration testing are presented on Figure A-5.



### 4.5.7 Sand and Gravel

Layers of loose to compact sand and gravel were found in boreholes 409 and 411 beneath the silt layers at elevations ranging from 479.6 and 480.9 metres, respectively. In borehole 410, a 0.8 metres thick layer of silty sand and gravel was found below the silt at elevation 480.3 metres. The sand and gravel layers had thicknesses of 1.2 to 1.5 metres and N values of 5 to 20 blows per 0.3 metres with water contents of 8 to 16 per cent. The results of the grain size testing conducted on samples of sand and gravel and silty sand and gravel obtained during standard penetration testing are presented on Figures A-2 and A-3, respectively.

### 4.5.8 Clayey Silt Till

Layers of firm to hard clayey silt glacial till were found in boreholes 409 to 412 at elevations ranging from 478.1 to 479.6 metres. Borehole 409 was terminated in the clayey silt till after exploring the layer for 2.3 metres. The clayey silt layers in boreholes 410 to 412 were 1.4 to 3.2 metres thick.

Standard penetration test N values of 7 to 63 blows per 0.3 metres were measured in clayey silt till layers with water contents of 13 to 17 per cent. A single sample of the clayey silt till was of low plasticity based on a plastic limit of 16 per cent, liquid limit of 21 per cent, and plasticity index of 5 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-10. The results of the grain size testing conducted on selected samples of the clayey silt till obtained during standard penetration testing are presented on Figure A-9. Although cobbles and boulders were not specifically encountered within the boreholes, the presence of cobbles and boulders should be anticipated within the clayey silt till based on the depositional history of glacial tills.

### 4.5.9 Sandy Silt Till

Boreholes 410 to 412 encountered a layer of sandy silt till underlying the clayey silt till at elevations ranging from 476.4 to 476.7 metres. The boreholes were terminated in the sandy silt till layer after exploring for 0.5 to 0.9 metres. The very dense sandy silt till layer had N values of 75 to greater than 100 blows per 0.3 metres of penetration. Although not specifically encountered in boreholes 410 to 412, cobbles and boulders should be anticipated in the sandy silt till due to the depositional history of this material.

### 4.5.10 Groundwater Conditions

The groundwater conditions in the boreholes were monitored during drilling. The observed groundwater conditions as noted on the Record of Borehole sheets, are summarized in the following table and text.



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### Summary of Encountered Groundwater Levels

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level	
		Depth (m)	Elevation (m)
409	483.26	2.2	481.1
410	483.22	2.3	480.9
411	483.29	2.9	480.4
412	483.17	2.6	480.6

### Summary of Measured Groundwater Levels

Borehole	Ground Surface Elevation (m)	Installation	Measured Groundwater Elevation (m)		
			August 31/12	September 10/12	September 11/12
412	483.17	Standpipe	479.44	481.14	481.16

Groundwater was first encountered in boreholes 409 to 412 between elevations 480.4 and 481.1 metres.

A 12.5 millimetre diameter standpipe was installed in borehole 412. The most recent groundwater level was measured on September 11, 2012 at elevation 481.2 metres, shortly before the standpipe was decommissioned. The water level in the culvert at the outlet was at elevation 481.0 metres on August 31, 2012. This culvert conveys Municipal Drain No.1 from north to south beneath Highway 89.

The inferred groundwater level at this site is at elevation 481.5 metres. The inferred groundwater level is based on encountered and measured groundwater levels and water levels nearby. The groundwater levels are expected to fluctuate due to climatic and seasonal variations and flow levels in Municipal Drain No.1.



### 5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Aardvark Drilling Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Mike Arthur under the direction of Mr. David J. Mitchell.

The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Brett Thorner, E.I.T. under the direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng. and the Team Leader, Mr. Storer J. Boone, Ph.D., P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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**PART B**

**FOUNDATION DESIGN REPORT**

**RETAINING WALLS**

**HIGHWAY 89 STRUCTURE REPLACEMENTS AND REHABILITATIONS**

**FROM 6.0 KM WEST OF MOUNT FOREST TO SHELBURNE**

**GWP 3049-08-00**

**MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



## 6.0 ENGINEERING RECOMMENDATIONS

### 6.1 General

This section of the report provides recommendations on the foundation aspects of the design of retaining walls at the culverts at Stations 10+280, 17+254, 22+907 and 24+500 on Highway 89 along the boundary of Wellington County and Grey County.

The recommendations are based on interpretation of the factual data obtained from the sixteen boreholes advanced during the investigation at these sites. The interpretation and recommendations are intended to provide the designers with sufficient information to design the proposed retaining wall foundations. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

### 6.2 Existing Conditions

#### 6.2.1 Station 10+280

The existing culvert is a 21.88 metre long Rigid Frame Box (RFB) structure with a 3.07 metre span and a 1.8 m high opening. The invert is at elevation 473.37 metres at the inlet and 473.24 metres at the outlet. Based on information provided by MH, it is understood that new gabion retaining walls will be constructed at each corner of the existing concrete box culvert. The wingwalls will be 3.0 to 4.0 metres long with a wall height of 2.0 to 2.5 metres.

#### 6.2.2 Station 17+254

The existing culvert is a 20.70 metre long Non-rigid Frame Open Footing (NRFO) structure with a 3.05 metre span and a 1.2 m high opening with an invert elevation 489.68 metres at the inlet and 489.50 metres at the outlet. Based on information provided by MH, it is understood that new gabion retaining walls will be constructed at each corner of the existing concrete open footing culvert. Erosion protection in the form of a 3.5 metre wide, 450 millimetre thick granular apron of river-run stone will extend 4.5 and 4.0 metres beyond the culvert inlet and outlets respectively. The wingwalls will be 2.0 metres long with a maximum height of 1.5 metres.





### 6.2.3 Station 22+907

The existing culvert is a 23.60 metre long Non-rigid Frame Open Footing (NRFO) structure with a 4.88 metre span and a 1.87 m high opening. The invert is at elevation 484.43 metres at the inlet and 484.28 metres at the outlet. Based on information provided by MH, it is understood that new gabion retaining walls will be constructed at each corner of the existing concrete open footing culvert. The wingwalls will be 2.0 and 2.5 metres high with lengths of 3.0 to 4.0 metres.

### 6.2.4 Station 24+500

The existing culvert is a 24.90 metre long NRFO structure with a 4.26 metre span and a 1.88 m high opening. The invert is at elevation 480.27 metres at the inlet and 480.19 metres at the outlet. Based on information provided by MH, it is understood that new gabion retaining walls will be constructed at each corner of the existing concrete open culvert. Erosion protection in the form of a 450 millimetre thick granular aprons of river-run stone will be constructed at culvert inlet and outlets. The granular apron will be 10.0 metres wide and 8.0 metres long at the inlet. At the outlet, the apron will be 9.0 metres wide and 4.4 metres long. The wingwalls will be 3.0 and 4.0 metres long with heights of 2.0 and 2.5 metres.

## 6.3 Retaining Walls/Wing Walls

The current design drawings indicate that wingwalls for the culverts will consist of gabion walls. Alternately, the wingwalls could consist of reinforced concrete gravity or cantilever walls, concrete toe walls or reinforced soil system (RSS) walls. The concrete gravity wall could consist of precast elements or cast-in-place (CIP).

### 6.3.1 Wingwall Options

#### *Gabion Walls*

Construction of a gabion wall is geotechnically feasible at the sites. Gabion walls require the least amount of space behind the wall. Temporary shoring should not be necessary if this wall type is constructed. Gabion walls do not require an embedment depth equivalent to the frost depth provided they are founded on granular pads of 300 millimetres compacted thickness, and the foundations have adequate embedment to provide a stable structure. Advantages of gabion walls, compared to more rigid structures, include the ability to accommodate differential settlements, dissipation of the energy of flowing water, and are free-draining provided an adequate filter is placed behind and below the wall. Gabion walls can be constructed relatively quickly with minimal equipment and materials. The life expectancy of a gabion wall can be extended by utilizing PVC-coated galvanized steel baskets. Gabion walls are to be constructed in accordance with Ontario Provincial Standard



Specifications (OPSS) 512 if greater than 2 metres in height or SP 512 S03 for all other gabion walls. Non-woven geotextile should be placed between the gabions and the backfill in accordance with OPSS 512, OPSS 1860, and the manufacturer's specifications.

### ***Reinforced Concrete Gravity and Cantilever Walls***

Construction of reinforced concrete gravity or cantilever walls is geotechnically feasible. Compared to a concrete toe wall or RSS walls, footings for gravity and cantilever walls must be constructed with a frost cover of 1.6 metres. This may result in a longer foundation construction time and deeper excavations compared to a concrete toe wall or RSS wall. Groundwater control/dewatering will be required since the footing excavations will be excavated below groundwater levels.

### ***Concrete Toe Walls***

A concrete toe wall is geotechnically feasible for use as a wingwall provided the wall has a maximum height of 1.8 metres above the final ground surface. Concrete toe walls 0.8 to 1.8 metres in height require a minimum embedment depth of 450 millimetres and should be constructed to bear on undisturbed soil having a minimum factored geotechnical resistance of 300 kilopascals at Ultimate Limit States (ULS). The embedment depth is defined as the distance from the underside of the toe wall foundation to the top of finished grade in front of the wall. The concrete toe wall should be designed in accordance with the requirements for a Type II Concrete Toe Wall as shown on Ontario Provincial Standard Drawing (OPSD) 3120.100. Compared to concrete gravity and cantilever walls, construction costs and time may be reduced if a concrete toe wall is used. The use of concrete toe walls as wingwalls is only suitable where the wall height will be less than 1.8 metres and the foundation conditions are suitable to provide the required factored resistance at ULS.

### ***RSS Walls***

The height of the wingwalls will be relatively low. Therefore, a RSS wall utilizing an interlocking block system and geogrid reinforcement is a geotechnically feasible alternative. In general, RSS walls are proprietary systems which are designed by the supplier and constructed in accordance with their specifications. The internal stability of the mechanically-reinforced soil walls should be verified by the RSS supplier/designer. If an RSS wall is selected, the geotechnical aspects of the global stability of the detailed retaining wall design should be reviewed prior to construction. Depending on the design approach selected, an embedment depth equivalent to the frost depth may not be required for foundations of a RSS walls. This wall type can be constructed relatively quickly and inexpensively using small equipment.



### 6.3.2 Foundations – Wingwalls

#### 6.3.2.1 General

Reinforced concrete gravity and cantilever walls founded on concrete strip footings must be provided with a frost cover of 1.6 metres below the adjacent ground or thermal equivalent.

The RSS walls may be designed such that the facing blocks are constructed on concrete strip footings or a granular levelling pad. The levelling pad should be constructed with Granular A to a minimum thickness of 300 millimetres. Alternatively, clear stone placed to a thickness of 150 millimetres could also be used since it is understood that clear stone is preferred by the MTO for use as bedding material on this project. If clear stone is used as bedding, however, it must be fully enveloped in non-woven geotextile. The geotextile should be overlapped a minimum of 0.5 metres with upstream sections overlapping downstream sections. It is important that boundaries between the clear stone and the native materials be fully separated. Compared to Ontario Provincial Standard Specifications (OPSS) Granular A, clear stone is less well graded and has a higher permeability. It has been our experience that if clear stone bedding placed in areas of silty subgrade is not fully enveloped in a suitable non-woven geotextile, the potential for ingress of fines from the subgrade and weakening of the subgrade is increased in the long-term. As noted previously, depending on the design selected by the RSS supplier, it may not be necessary to provide 1.6 metres of earth cover or thermal equivalent for frost protection. However the foundations must have adequate embedment to provide a stable structure. Typically the embedment depth, defined as the distance between the top of the levelling pad to the top of the adjoining finished grade, is a minimum of 500 millimetres. The geotechnical resistances recommended for concrete toe walls are applicable to RSS walls founded on a granular levelling pad.

If required, a granular leveling course approximately 75 millimetres in thickness may be placed on the founding strata for gabion walls or pre-cast concrete walls. Gabion walls and pre-cast concrete walls should have sufficient embedment to provide a stable structure.

All wingwall foundations must be protected against scour as noted in the Canadian Highway Bridge Design Code (CHBDC) Section 1.9.5. The wingwalls should be structurally separate from the culvert to accommodate some differential settlement.

#### 6.3.2.2 Station 10+280 (Site 35-487/C)

Assuming the adjacent ground is at the average culvert invert elevation of 473.3 metres, reinforced concrete gravity and cantilever walls and RSS walls founded on concrete strip footings must be founded at or below elevation 471.7 metres in the stiff to very stiff clayey silt till. A factored geotechnical resistance at ULS of 300 kilopascals and a geotechnical reaction at Serviceability Limit States (SLS) of 200 kilopascals may be used for design. The SLS value corresponds to 25 millimetres of settlement.



Alternatively, gabion walls and RSS walls may be founded directly on a compacted Granular A pad placed on the firm to very stiff clayey silt till at or below about elevation 472.5 metres for the north wingwalls and 471.7 metres for the south wingwalls, provided this allows adequate embedment, using a factored geotechnical resistance of 200 kilopascals at ULS and a geotechnical reaction of 125 kilopascals at SLS.

### **6.3.2.3 Station 17+254 (Site 35-513/C)**

Reinforced concrete gravity and cantilever walls founded on concrete strip footings must be founded at or below elevation 488.0 metres in the stiff to very stiff clayey silt till based on an average culvert elevation of 489.6 metres. A factored geotechnical resistance at ULS of 300 kilopascals and a geotechnical reaction at SLS of 200 kilopascals may be used for design. The SLS value corresponds to 25 millimetres of settlement.

Gabion and RSS walls may be founded directly on a compacted Granular A pad placed on the stiff to very stiff clayey silt till at or below about elevation 489.1 metres for the wingwalls to the north of Highway 89 and the wingwall in the southwest quadrant and at or below elevation 488.5 metres for the wingwall in the southeast quadrant, provided this allows adequate embedment, a factored geotechnical resistance at ULS of 250 kilopascals and a geotechnical reaction at SLS of 175 kilopascals. The SLS value corresponds to 25 millimetres of settlement.

### **6.3.2.4 Station 22+907 (Site 35-515/C)**

Assuming the adjacent ground is at the average culvert invert elevation of 484.3 metres, reinforced concrete gravity and cantilever walls founded on concrete strip footings may be founded at or below elevation 482.7 metres in the compact silt and stiff clayey silt till. A factored geotechnical resistance at ULS of 150 kilopascals and a geotechnical reaction at SLS of 100 kilopascals may be used for design. The SLS value corresponds to 25 millimetres of settlement.

Wingwalls in the southwest and northeast quadrants of the culvert might be founded on silt based on boreholes 405 and 406, respectively. The silt subgrade will be saturated and difficult to dewater using gravity methods. It will be necessary to adhere to the recommendations for construction on silt given in Section 6.7. Alternatively, all wingwall footings could be constructed on the stiff clayey silt till at or below elevation 481.5 metres for the wingwall in the northeast quadrant and at or below elevation 482.5 metres for the remaining wingwalls, using a factored geotechnical resistance at ULS of 250 kilopascals and a geotechnical reaction at SLS of 175 kilopascals. The latter alternative is preferred since construction difficulties which may arise due to a silty subgrade are minimized.



### 6.3.2.5 Station 24+500 (Site 35-516/C)

Assuming the adjacent ground is at the average culvert invert elevation of 480.2 metres, reinforced concrete gravity and cantilever walls founded on concrete strip footings must be founded at or below elevation 479.5 metres for the wingwall in the southwest quadrant and at or below elevation 478.1 metres for the remaining wingwalls, in the firm to very stiff clayey silt till. A factored geotechnical resistance at ULS of 250 kilopascals and a geotechnical reaction at SLS of 175 kilopascals may be used for design. The SLS value corresponds to 25 millimetres of settlement.

A factored geotechnical resistance of 150 kilopascals and geotechnical reaction of 100 kilopascals may be used for RSS and gabion walls founded at or below elevation 478.2 metres in the stiff silty clay till at the northwest quadrant and at all remaining locations at or below elevation 480.3 metres in the stiff clayey silt and compact sand and gravel. The SLS value considers 25 millimetres of settlement. RSS walls are to be founded on a compacted Granular A pad of 300 millimetres thick.

## 6.4 Resistance to Lateral Forces

The lateral pressures acting on the wingwalls will depend on the backfill soils, the type and method of placement of the backfill materials behind the walls and the subsequent lateral movement of the structures. The resistance to lateral forces/sliding resistance between the compacted granular backfill (assumed to be Granular B Type II) of RSS block system walls or concrete footings for all other wall types and the subgrade soils should be calculated in accordance with Section 6.7.5 of the Canadian Highway Bridge Design Code (CHBDC). Each retaining wall shall be checked for overturning. Assuming that the founding soils are not loosened/disturbed during excavation and footing construction, the following angles of friction and corresponding unfactored coefficient of friction,  $\tan \delta$ , may be used for the interaction between the base of the wall and the founding soil:

Wall type	Interaction	Coefficient of Friction, $\delta$ (degrees)	Tan $\delta$
Reinforced Concrete Gravity or Cantilever Wall and RSS Block System Wall on concrete strip footings	Concrete footing on clayey silt till	30	0.58
	Concrete footing on silt	28	0.53
Concrete Toe Wall	Pre-cast concrete footing on clayey silt till	26	0.49
RSS Block System Wall/Gabion Walls	Granular A levelling pad on clayey silt till	30	0.58



### 6.5 Lateral Earth Pressures for Design

Lateral pressures acting on the proposed wingwalls will depend on the type and method of placement of the backfill materials, the nature of the soil behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls in accordance with the current CHBDC. It should be noted that these design recommendations and parameters assume full removal of the existing poor quality fill and 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 as described in this report.

- Select free-draining granular fill meeting the specifications of OPSS Granular A or Granular B Type II, but with less than 5 per cent passing the No. 200 sieve, should be used as backfill behind the wingwalls. This fill should be compacted in accordance with MTO's SP105S21. Longitudinal drains and weep holes should be installed within any cast-in-place concrete walls to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSD 3121.150 and 3190.100.
- The granular fill may be placed either in a zone with a width equal to at least 1.6 metres behind the back of the stem (Case (a) from Commentary on CHBDC Figure C6.20) or within the wedge-shaped zone defined by a line drawn at a maximum slope of 1 horizontal to 1 vertical extending up and back from the rear face of the foundation (Case (b) from Commentary on CHBDC Figure C6.20).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem, in accordance with CHBDC Figure C6.6. Compaction equipment should be used in accordance with SP105S21. Other surcharge loadings should be accounted for in the design, as required.
- For Case (a), the pressures are based on the existing embankment fill materials and the following parameters (unfactored) may be used:

Soil unit weight:	18 kN/m <sup>3</sup>
Coefficients of lateral earth pressure:	
Active, $K_a$	0.38
At rest, $K_o$	0.55
Passive, $K_p$	2.7



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- For walls backfilled using granular materials in accordance with Case (b), the following parameters (unfactored) may be assumed:

	GRANULAR A	GRANULAR B (Type II)
Fill unit weight:	22 kN/m <sup>3</sup>	21kN/m <sup>3</sup>
Coefficients of static lateral earth pressure:		
'active' or unrestrained, $K_a$	0.27	0.27
'at rest' or restrained, $K_o$	0.43	0.43
'passive', $k_p$	3.7	3.7

- If the wall allows lateral yielding (unrestrained structure), active earth pressures may be used in the geotechnical design of the structure. If the wall does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design.

## 6.6 Liquefaction Potential and Seismic Analysis

### 6.6.1 Seismic Parameters

The site is located near the Community of Mount Forest in southwestern Ontario. According to Table A.3.1.1 of the CHBDC, the zonal acceleration ratio,  $A$ , applicable to this site is 0.05. The corresponding acceleration related seismic zone,  $Z_a$ , is 1. Based on the site stratigraphy, the soil profile type is categorized as Type I with a seismic site response coefficient,  $S$ , of 1.0 based on the CHBDC criteria.

### 6.6.2 Seismic Hazard Assessment

A preliminary screening of the soil stratigraphy was conducted using the procedure outlined in the Federal Highway Administration recommended procedures<sup>2</sup> and Canadian Foundation Engineering Manual (CFEM). The soils at these sites are not considered to be susceptible to liquefaction or cyclic mobility. Therefore, a detailed evaluation of the liquefaction potential of the foundation soils is not considered warranted.

<sup>2</sup> Federal Highway Administration (FHWA). (1997). "Design Guidance: Geotechnical Earthquake Engineering For Highways. Volume I – Design Principles." *Geotechnical Engineering Circular No. 3: FHWA-SA-97-076*, Washington, D.C.





## 6.7 Construction Considerations

### 6.7.1 Subgrade Preparation

Care should be taken during construction to avoid disturbance of the subgrade prior to constructing foundations for the retaining walls/wingwalls. All topsoil, organics and soft or loose soils should be removed from below the proposed founding elevation and wasted or reused as landscaping fill, as required. Subgrade preparation should be performed and monitored in accordance with OPSS 902.

If the footings for the wingwalls at Station 22+907 (Site 35-515/C) are founded at elevation 482.7 metres, footings within the southwest and northeast quadrants will be founded on compact silt which is highly sensitive to disturbance and water content. The silt subgrade should be carefully prepared as described in this section. In general, the final 300 millimetres of the foundation excavation should be carried out with equipment fitted with a smooth cutting edge, rather than conventional bucket 'teeth' since these will gouge the silt and allow pooling of water. The silt subgrade within the foundation footprint should not be walked upon or otherwise disturbed.

The cleaned excavation base should be inspected by a geotechnical QVE and a working slab placed immediately after inspection to protect the founding materials. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the QVE on site with construction of the working slab commencing immediately after inspection. A Non Standard Special Provision (NSSP) should be added to the Contract Documents specifying protection of the founding soil through use of a working slab.

The retaining wall footings should be protected against erosion and scour. Consideration could be given to using suitable non-woven geotextile and rip rap, as required, to provide erosion protection based on hydraulic requirements. Where rip-rap treatment at the culvert inlet and outlet is to be provided, it should be installed in accordance with OPSD 810.010. In addition, sediment control such as silt fences and erosion control blankets may be required during construction and diversion/piping of the watercourse may be necessary to mitigate migration of fine soil particles.

MH has indicated that river-run stone will be used in place of rip-rap to address fisheries concerns. The use of river-run stone for scour protection is geotechnically feasible provided that the pad thickness is equivalent to 1.5 times the median stone diameter and the resulting velocities meet the hydraulic and fish passage requirements of the MTO Drainage Management Manual.

### 6.7.2 Excavations and Groundwater Control

Excavations will extend through the existing topsoil, peat and fill and into the underlying sand, sand and gravel, clayey silt, silt, clayey silt till and sandy silt till. Contractors should also expect and be prepared for the presence of cobbles and boulders within the till strata.





It is anticipated that the excavations will extend below the inferred groundwater level elevation for each site. It is considered that groundwater may be controlled by pumping from properly constructed and filtered sumps located at the base of the excavations provided that inflow from the adjacent watercourse is prevented from entering the excavation. Significant flows should be expected where saturated sands or sand and gravel deposits are present such as the culverts at Station 10+280 (Site 35-487/C) and Station 24+500 (Site 35-516/C). It may be necessary to blanket slopes with coarse granular materials to enhance stability. A Permit To Take Water is not considered necessary at this time. Sumps should be maintained outside of the actual foundation limits.

Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. Surface water runoff should be directed away from the excavations at all times. The existing culvert flows will need to be diverted/piped during construction. The appropriate NSSP should be included in the contract documents to alert the contractor about the need for adequate control of surface and groundwater flows.

Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fill and any cohesionless materials below the groundwater level would be classified as Type 3 soils. The cohesionless materials above the groundwater level and glacial tills would be classified as Type 2 soils.

### 6.8 Temporary Roadway Protection

If the excavations for the retaining walls will encroach the roadway during construction, temporary roadway protection will be required.

Temporary support systems could consist of soldier piles and lagging or steel sheet piles. A soldier pile and lagging system is preferred for constructability reasons and for dealing with cobbles or boulders in the till. The temporary shoring may have a maximum height of 3 metres above the excavation base.

Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The Contractor is responsible for the complete detailed design of the protection system.

Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads, such as traffic and construction equipment, as well as the effects of sloping ground behind the system (if and where applicable). Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter provided that the centre to centre pile spacing is greater than 3 times the socket diameter.

The support systems may be designed using the parameters provided in the table below. These parameters are provided to assist with design for the unfactored ultimate resistance and loading conditions and may not result in



## FOUNDATION INVESTIGATION AND DESIGN REPORT RETAINING WALLS

a temporary support design that adequately controls ground and structure displacements. Achieving adequate displacement control in accordance with the MTO performance criteria may require designs that result in a system that is stiffer than might otherwise be required based on the soil parameters provided in the table below.

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Unit Weight (kN/m <sup>3</sup> )
	Active, K <sub>a</sub>	At Rest, K <sub>o</sub>	Passive, K <sub>p</sub>		
Existing Fill	0.38	0.55	2.7	27	18.0
Sand and Gravel	0.30	0.46	3.4	33	19.5
Clayey Silt					
Station 10+280	0.39	0.56	2.6	26	19.0
Station 17+254	0.33	0.50	3.0	30	20.0
Station 24+500	0.36	0.53	2.8	28	19.5
Clayey Silt Till	0.31	0.47	3.3	32	20.0
Silt/Sandy Silt					
Station 17+254	0.31	0.47	3.3	32	19.0
Station 22+907	0.33	0.50	3.0	30	18.5
Station 24+500	0.36	0.53	2.8	28	18.5
Sandy Silt Till	0.30	0.46	3.4	33	21.0

The earth pressure coefficients identified above may be applied assuming a horizontal ground surface behind the retaining structure. Where the ground surface behind the retaining structure is sloped, the earth pressure coefficients provided in the table above must be increased. Contractors should be prepared for the presence of cobbles and boulders within the glacial tills and the appropriate NSSP should be provided.



### 7.0 MISCELLANEOUS

This report was prepared by Mr. Brett Thorner, E.I.T. under direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng. under the direction of the Team Leader, Mr. Storer J. Boone, Ph.D., P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

**GOLDER ASSOCIATES LTD.**

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## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### (b) Cohesive Soils

Consistency	$c_u, s_u$ kPa	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

#### 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, 60° 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<sup>2</sup> 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.

### 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 <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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)
$\gamma$	unit weight

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

## LIST OF SYMBOLS

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

### I. General

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

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

#### (a) Index Properties (continued)

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

#### (b) Hydraulic Properties

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

#### (c) Consolidation (one-dimensional)

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

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction $= \tan \delta$
$c'$	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
  - \* density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density x acceleration due to gravity)

# RECORD OF BOREHOLE No 401

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4873782.5 ; E 219415.7 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 20, 2012 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 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								○ UNCONFINED	+	FIELD VANE								
							● QUICK TRIAXIAL	×	LAB VANE	WATER CONTENT (%)								
							20	40	60	80	100		10	20	30			
475.38	GROUND SURFACE					▽												
0.00	FILL, topsoil, sandy Brown						475											
474.92																		
0.46	PEAT, fibrous Soft Black		1	SS	2											70		
473.70							474											
1.68	SAND, medium to coarse, some gravel, trace silt Very loose Brown		2	SS	1													
473.25																		
2.13	CLAYEY SILT, some sand, trace gravel Soft Grey		3	SS	4		473										2	31 44 23
472.48																		
2.90	CLAYEY SILT TILL, trace to some sand, trace gravel, with cobbles Stiff to very stiff Grey		4	SS	17		472											
			5	SS	9		471										1	9 69 39
			6	SS	21		470											
	Cobbles / boulders at about elev. 472.3m and 470.0m																	
			7	SS	23													
			8	SS	18	469										6	21 45 28	
			9	SS	19													
468.06																		
7.32	END OF BOREHOLE																	
	Groundwater encountered at about elev. 473.7m during drilling on August 20, 2012.																	

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

**RECORD OF BOREHOLE No 402**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4873778.5 ; E 219406.7 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 20, 2012 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub> W W <sub>L</sub>					
475.41	GROUND SURFACE					▽	20 40 60 80 100	20 40 60 80 100	10 20 30						
0.00	FILL, topsoil, sandy, trace gravel Brown						○ UNCONFINED + FIELD VANE								
475.01							● QUICK TRIAXIAL × LAB VANE								
0.40	FILL, sand and gravel, trace silt Brown														
474.65															
0.76	FILL, topsoil, sandy, with organics and wood fragments and sand and gravel layers		1	SS	2										
474.19	Very loose Brown														
1.22															
473.28	FILL, peat, fibrous, trace sand, with sand and gravel deposits		2	SS	1										
2.13	Very soft Black														
472.51	TOPSOIL, sandy, trace gravel, with organics		3	SS	2										
2.90	Very loose Brown														
	CLAYEY SILT TILL, trace to some sand, trace gravel, with silt partings and layers		4	SS	6										
	Firm to very stiff Grey														
			5	SS	10										
			6	SS	17										
			7	SS	20										
			8	SS	19										
			9	SS	17										
468.09	END OF BOREHOLE														
7.32	Groundwater encountered at about elev. 472.7m during drilling on August 20, 2012.														

**RECORD OF BOREHOLE No 403**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4873763.9 :E 219418.5 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 20, 2012 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			SHEAR STRENGTH kPa									
								20	40	60	80	100					
475.36	GROUND SURFACE																
0.00	FILL, topsoil/peat, fibrous, sandy, trace gravel, with roots Very soft Brown and black		1	SS	2		475 Bentonite										
							474										
473.53			2	SS	2												
1.83	FILL, clayey silt, with peat layers Very soft Grey and black																
473.07																	
2.29	SAND, medium to coarse, trace silt, trace gravel Loose Grey		3	SS	5		473 Backfill										
472.46																	
2.90	CLAYEY SILT, trace sand, trace gravel Firm Grey		4	SS	6		472 Standpipe										
471.70																	
3.66	CLAYEY SILT TILL, some sand, trace gravel, with silt layers and cobbles Very stiff Grey		5	SS	15		471										
			6	SS	28												
			7	SS	24		470 Bentonite										
			8	SS	23		469										
			9	SS	22												
468.04	END OF BOREHOLE																
7.32	Groundwater encountered at about elev. 473.1m during drilling on August 20, 2012.  Standpipe found to be dry after installation on August 20, 2012.  Groundwater level measured at elev. 473.73m on September 10, 2012.  Installation decommissioned following measurement on September 10, 2012.																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



**RECORD OF BOREHOLE No 404**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4873766.1 : E 219425.2 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 20, 2012 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			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20	40	60	80	100						20	40	60
475.44	GROUND SURFACE																			
0.00	FILL, topsoil, sandy, trace gravel, with roots, organics and fibres Very loose Black						475													
			1	SS	2															
			2	SS	2		474								40					
473.28	CLAYEY SILT, trace to some sand, trace gravel Soft Brown and grey mottled		3	SS	3		473										4 20 50 26			
			4	SS	3		472													
471.78	CLAYEY SILT TILL, trace sand, trace gravel, with cobbles Stiff to hard Grey		5	SS	11		471													
3.66			6	SS	25		470										16 19 39 26			
	Possible cobble near elev. 469.7m		7	SS	75		469													
			8	SS	23															
			9	SS	21															
468.12	END OF BOREHOLE																			
7.32	Borehole dry during drilling on August 20, 2012.																			

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

**RECORD OF BOREHOLE No 405**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877206.7 ; E 231559.7 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 29, 2012 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  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)					
486.83	GROUND SURFACE						20	40	60	80	100						
0.00	FILL, sand, fine to coarse, some gravel, trace silt, trace topsoil Brown																
486.34																	
0.49	FILL, silty sand, some gravel, trace topsoil Loose Brown		1	SS	8												
485.46																	
1.37	TOPSOIL, silty, with organics Loose Black		2	SS	9												
485.00																	
1.83	SILT, trace clay, trace sand, trace gravel Loose to compact Grey		3	SS	8											1 7 87 5	
			4	SS	6												
			5	SS	15												
482.41																	
4.42	CLAYEY SILT TILL, trace sand, trace gravel, with silt seams and layers Very stiff Grey		6	SS	18											0 2 59 39	
			7	SS	17												
			8	SS	16												
			9	SS	27												
479.36																	
7.47	END OF BOREHOLE																
	Groundwater encountered at about elev. 485.0m during drilling on August 29, 2012.																

**RECORD OF BOREHOLE No 406**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877219.6 ; E 231571.7 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 29, 2012 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			SHEAR STRENGTH kPa										WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE															
485.19	GROUND SURFACE							20	40	60	80	100						GR	SA	SI	CL		
0.00	TOPSOIL, silty sand, trace gravel, with cobbles Brown						485																
484.49																							
0.70	SILT, trace sand, trace clay, with clayey silt layers Loose to compact Grey		1	SS	28	▽	484								○				0	8	86	6	
			2	SS	7										○								
483.06							483																
2.13	SILT, some clay, trace sand, trace gravel Compact Grey		3	SS	14										○								
			4	SS	14		482								○								
481.53																							
3.66	CLAYEY SILT TILL, trace sand, trace gravel Stiff to very stiff Grey		5	SS	15		481								○								
			6	SS	23											○	—	—		1	3	53	43
			7	SS	28		480									○							
			8	SS	10	479										○							
477.87			9	SS	28	478									○								
7.32	END OF BOREHOLE																						
	Groundwater encountered at about elev. 484.0m during drilling on August 29, 2012.																						

**RECORD OF BOREHOLE No 407**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877189.9 ; E 231579.8 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 30, 2012 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			SHEAR STRENGTH kPa									
485.14	GROUND SURFACE							20	40	60	80	100					
0.00	TOPSOIL, silty, with organics and roots																
484.74	Brown																
0.40	SILT Loose Grey		1	SS	9												
483.77	SILT, some clay, trace sand, trace gravel, with silt layers		2	SS	8												
483.01	Loose Grey																
2.13	CLAYEY SILT TILL, trace sand, trace gravel, with silt and sand seams and layers, with cobbles		3	SS	12												0 2 60 38
	Stiff to hard Grey		4	SS	10												1 1 63 35
			5	SS	16												
			6	SS	16												
			7	SS	100/ 225mm												
479.35	SANDY SILT TILL, trace to some gravel, trace to some clay		8	SS	61												13 33 39 15
5.79	Very dense Grey		9	SS	100/ 250mm												
477.89	END OF BOREHOLE																
7.25	Groundwater encountered at about elev. 484.5m during drilling on August 30, 2012.  Standpipe found to be dry after installation on August 30, 2012.  Water level measured at elev. 484.73m on September 10, 2012.  Water level measured at elev. 484.71m on September 11, 2012.  Installation decommissioned following measurement on September 11, 2012.																

**RECORD OF BOREHOLE No 408**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877199.8 ; E 231589.2 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 29, 2012 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  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE											
486.78	GROUND SURFACE					▽														
0.00	FILL, sand, fine to coarse, some topsoil, trace gravel Brown																			
486.26																				
0.52	FILL, silt, trace to some sand, trace gravel, trace topsoil, with wood fibres Loose to compact Brown to grey		1	SS	13		486													
484.95			2	SS	6		485										43			
1.83	TOPSOIL, silty Brown																			
2.13	SANDY SILT Loose Grey		3	SS	9		484													
483.88																				
2.90	SILT, trace to some sand, trace clay Loose Grey		4	SS	9		483											0 9 86 5		
482.85																				
3.93	CLAYEY SILT TILL, trace sand, trace gravel, with silt seams and partings Firm to stiff Grey		5	SS	7	482														
			6	SS	10															
			7	SS	14	481											1 2 52 45			
			8	SS	9															
			9	SS	15	480														
479.31	END OF BOREHOLE																			
7.47	Groundwater encountered at about elev. 484.7m during drilling on August 29, 2012.																			

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

**RECORD OF BOREHOLE No 409**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877625.5 ; E 233121.3 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 30, 2012 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  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE											
483.26	GROUND SURFACE					▽		20	40	60	80	100							
0.00	FILL, crushed granular base						483												
482.86	Brown																		
0.40	FILL, sand, fine to coarse, some gravel, trace silt																		
482.19	Compact Brown		1	SS	7														
1.07	FILL, silt, trace to some sand, trace clay, trace topsoil, with topsoil layers																		
481.34	Very loose Brown		2	SS	3														
1.92	TOPSOIL, silty Black																		
2.13	SANDY SILT, trace clay, with silt layers		3	SS	9								○				1 24 66 9		
480.36	Loose Brown to grey																		
2.90	CLAYEY SILT																		
3.20	Stiff Brown and grey		4	SS	11														
479.60	SILT, trace sand, with clayey silt layers																		
3.66	Compact Grey		5	SS	10								○				35 47 14 4		
	SAND AND GRAVEL, some silt, trace clay																		
478.08	Loose to compact Grey		6	SS	5														
5.18	CLAYEY SILT TILL, trace sand, trace gravel, with silt seams and layers		7	SS	17														
	Stiff to very stiff Grey		8	SS	13														
476.55																			
6.71	CLAYEY SILT TILL, some gravel, trace sand		9	SS	48														
475.79	Hard Grey						476												
7.47	END OF BOREHOLE																		
	Groundwater encountered at about elev. 481.1m during drilling on August 29, 2012.																		

**RECORD OF BOREHOLE No 410**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877621.7 ; E 233108.8 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 30, 2012 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 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+	FIELD VANE								
							● QUICK TRIAXIAL	×	LAB VANE									
483.22	GROUND SURFACE					▽	20	40	60	80	100	10	20	30				
0.00	FILL, sand, fine to coarse, some gravel, trace topsoil																	
482.85	Brown																	
0.37	FILL, topsoil, silty sand, trace gravel																	
0.49	Brown		1	SS	4													
481.85	FILL, silt, some topsoil, trace sand, trace gravel																	
1.37	Loose Brown		2	SS	10													
481.09	FILL, sand and gravel, trace silt																	
2.13	Compact Brown																	
480.66	FILL, sand, medium to coarse, trace silt, trace gravel		3	SS	3													
2.56	Very loose Brown																	
480.32	SILT, trace topsoil																	
2.90	Very loose Grey		4	SS	15													
479.56	SILTY SAND AND GRAVEL, trace clay																	
3.66	Compact Grey		5	SS	7													
	CLAYEY SILT TILL, trace sand, trace gravel, with silt seams and layers																	
	Firm to very stiff Grey		6	SS	7													
			7	SS	23													
			8	SS	28													
476.36	SANDY SILT TILL, trace clay, trace gravel		9	SS	103													
6.86	Very dense Grey																	
475.90	END OF BOREHOLE																	
7.32	Groundwater encountered at about elev. 480.9m during drilling on August 30, 2012.																	

**RECORD OF BOREHOLE No 411**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877630.0 ; E 233093.8 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 31, 2012 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 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+	FIELD VANE								
483.29	GROUND SURFACE					▽												
0.00	FILL, crushed granular base Brown																	
0.37	FILL, sandy silt, trace gravel, trace topsoil Brown																	
482.07	FILL, sand, fine to coarse, some gravel Compact Brown		1	SS	13													
1.22	PEAT, fibrous Soft Black		2	SS	3									144				
481.16	SILT, trace clay, trace sand Loose Grey		3	SS	11													
2.13 480.85	SAND AND GRAVEL, trace silt, trace clay Compact Grey		4	SS	20													
2.44	CLAYEY SILT, trace sand, trace gravel, with sandy silt and silt layers Stiff Grey		5	SS	12													
479.63	SILT, trace to some clay, trace sand, with clayey silt seams Compact Grey		6	SS	24													
3.66	CLAYEY SILT TILL, trace sand, trace gravel, with silt seams and layers Very stiff to hard Grey		7	SS	20													
478.87	SANDY SILT TILL, some gravel Very dense Grey		8	SS	63													
4.42			9	SS	75													
478.11																		
5.18																		
476.74																		
6.55																		
475.82																		
7.47	END OF BOREHOLE																	
	Groundwater encountered at about elev. 480.4m during drilling on August 31, 2012.																	

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



**RECORD OF BOREHOLE No 412**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4877633.9 ; E 233106.1 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 31, 2012 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  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED		+ FIELD VANE							
483.17	GROUND SURFACE						20	40	60	80	100						
0.00	FILL, crushed granular base Brown																
0.18	FILL, silty sand, some gravel, trace clay, with topsoil Compact Brown		1	SS	13								○			15 46 32 7	
			2	SS	10												
481.04																	
2.13	FILL, silty sand Very loose Brown		3	SS	2												
480.52																	
2.65	SILT, trace gravel, with topsoil layers Very loose Brown		4	SS	9												
2.90	SILT, trace clay Loose Brown and grey																
479.36			5	SS	8								○			1 7 64 28	
3.81	CLAYEY SILT, trace sand, trace gravel, with silt seams and layers Firm Grey																
478.75			6	SS	9									○		0 1 94 5	
4.42	SILT, trace clay, trace gravel Loose Grey																
478.23																	
4.94	CLAYEY SILT TILL, trace sand, trace gravel, with silt seams and layers Stiff to very stiff Grey		7	SS	15									○			
			8	SS	21												
476.46																	
6.71	SANDY SILT TILL, some gravel, trace clay Very dense Grey		9	SS	83												
475.70																	
7.47	END OF BOREHOLE																
	Groundwater encountered at about elev. 480.6m during drilling on August 31, 2012.																
	Water level measured at elev. 479.44m on August 31, 2012.																
	Water level measured at elev. 481.14m on September 10, 2012																
	Water level measured at elev. 481.16m on September 11, 2012.																
	Installation decommissioned following measurement on September 11, 2012.																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

**RECORD OF BOREHOLE No 413**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4875673.6 ; E 226136.4 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 21, 2012 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  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)												
491.23	GROUND SURFACE																
0.00	FILL, silty sand, some gravel, some topsoil Brown						491										
490.77																	
0.46	FILL, topsoil, silty, trace sand, trace gravel Loose Black		1	SS	6												
489.86							490										
1.37	FILL, sandy silt, some gravel, trace clay, trace topsoil Compact Brown		2	SS	12												
489.10																	
2.13	FILL, clayey silt, with sand and gravel layers and wood fragments Stiff Grey		3	SS	10	▽	489										
488.49																	
2.74	CLAYEY SILT TILL, trace sand, trace gravel Very stiff Grey		4	SS	15		488										
487.57																	
3.66	SANDY SILT TILL, trace to some gravel, some clay, with cobbles Dense to very dense Brown		5	SS	37		487					○				6 37 42 15	
			6	SS	49												
			7	SS	81		486					○				9 33 43 15	
484.89																	
6.34	SILT, with clayey silt layers Dense Brown		8	SS	48	▽	485										
483.91			9	SS	49		484										
7.32	END OF BOREHOLE																
	Groundwater encountered at about elev. 488.8m and 484.9m during drilling on August 21, 2012.																

PROJECT 11-1132-0109		<b>RECORD OF BOREHOLE No 414</b>		1 OF 1 <b>METRIC</b>	
W.P. 3049-08-00		LOCATION N 4875672.6 ; E 226131.2		ORIGINATED BY MA	
DIST _____ HWY 89		BOREHOLE TYPE POWER AUGER, HOLLOW STEM		COMPILED BY LMK	
DATUM GEODETIC		DATE August 21, 2012		CHECKED BY _____	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL LIMIT   MOISTURE   CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × LAB VANE					w <sub>p</sub> w   w <sub>L</sub>				
491.22	GROUND SURFACE							20	40	60	80	100					
0.00	FILL, silty sand, trace gravel, some topsoil						491										
0.21	Brown																
490.55	FILL, topsoil, silty, trace sand, trace gravel																
0.67	Brown		1	SS	6												
490.24							490										
0.98	FILL, sand, fine to medium, trace silt with clayey silt layers																
489.85	Loose																
1.37	Brown		2	SS	2												
489.09	FILL, topsoil, silty, trace sand, trace gravel						489										
2.13	Loose																
	Brown																
	FILL, sandy silt, trace gravel, with roots, wood and topsoil layers		3	SS	12												
	Very loose																
	Grey and brown						488							○		0	12   46   42
	CLAYEY SILT TILL, some sand, trace gravel, with silt partings																
	Stiff to very stiff																
	Grey		5	SS	22		487										
486.53																	
4.69	SANDY SILT TILL, some gravel, some clay, with cobbles		6	SS	100/225mm		486							○		14	29   43   14
	Possible cobble or boulder near elev. 486.3m																
	Very dense																
	Grey		7	SS	50												
484.76							485										
6.46	SILT, with clayey silt layers		8	SS	90												
	Very dense																
	Grey																
483.90			9	SS	39		484										
7.32	END OF BOREHOLE																
	Groundwater encountered at about elev. 489.2m and 484.4m during drilling on August 21, 2012.																

LDN\_MTO\_06 11-1132-0109-1000.GPJ LDN\_MTO.GDT 17/04/13

**RECORD OF BOREHOLE No 415**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4875688.0 ; E 226127.1 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 21, 2012 CHECKED BY


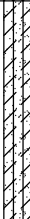

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)												
491.39	GROUND SURFACE																
0.00	FILL, topsoil, sandy Brown						491										
0.30	FILL, silt, trace sand, trace gravel, trace clay, some topsoil Loose Brown		1	SS	4												
490.02							490										
1.37	FILL, sandy silt, some clay, trace topsoil Very loose Brown		2	SS	2												
489.26																	
2.13	CLAYEY SILT TILL, trace sand, trace gravel, with silt layers Stiff to very stiff Brown		3	SS	9		489										
			4	SS	23		488										
487.73																	
3.66	SANDY SILT TILL, some clay, trace to some gravel Dense to very dense Brown		5	SS	40												
							487										
			6	SS	50												
			7	SS	31		486										
485.45																	
5.94	SILT, some gravel, trace to some clay, trace sand Dense to very dense Grey		8	SS	59		485										
			9	SS	30												
484.07																	
7.32	END OF BOREHOLE																
	Borehole dry during drilling on August 21, 2012.																

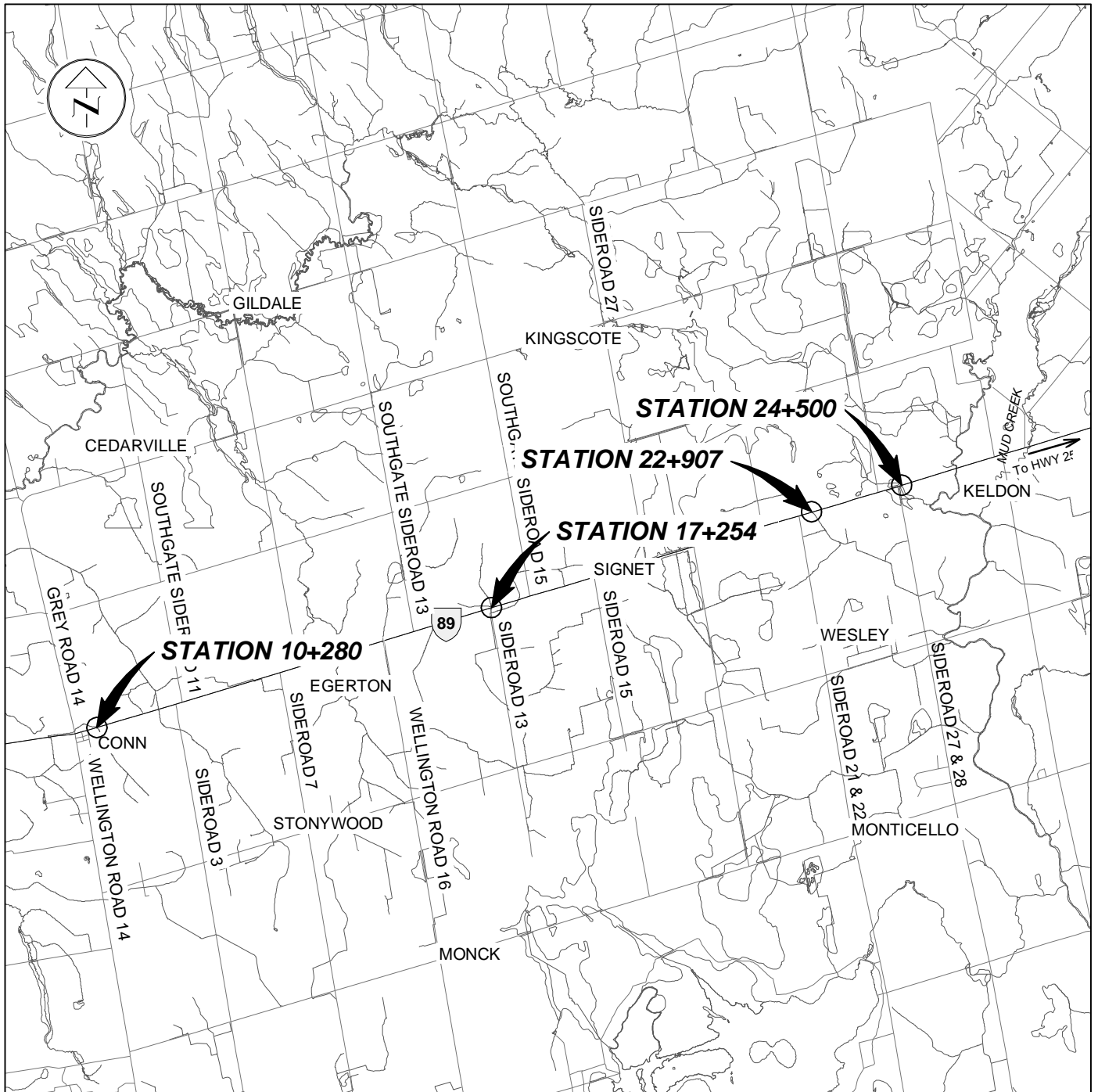
**RECORD OF BOREHOLE No 416**

1 OF 1

**METRIC**

PROJECT 11-1132-0109  
W.P. 3049-08-00 LOCATION N 4875689.4 ; E 226133.0 ORIGINATED BY MA  
DIST HWY 89 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK  
DATUM GEODETIC DATE August 21, 2012 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  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
491.40	GROUND SURFACE							20	40	60	80	100								
0.00	FILL, topsoil, sandy, trace gravel Brown						491										2 18 51 29			
0.30	FILL, sandy silt, trace gravel, trace clay, with topsoil layers Loose Brown		1	SS	6															
490.03																				
1.37	FILL, clayey silt, trace sand, trace gravel, trace topsoil Soft Brown	2	SS	4			490													
489.27																				
2.13	CLAYEY SILT TILL, trace gravel, some sand Stiff to very stiff Brown		3	SS	11			489												
			4	SS	20			488						○						
			5	SS	23															
486.98								487						○						
4.42	SANDY SILT TILL, some gravel, trace clay Dense to very dense Grey		6	SS	51		486													
		7	SS	41																
485.46																				
5.94	CLAYEY SILT, some sand, trace gravel Hard Grey		8	SS	44		485						○			3 16 60 21				
484.69																				
6.71	SILT, with clayey silt layers Dense Grey		9	SS	33															
484.08																				
7.32	END OF BOREHOLE																			
	Borehole dry during drilling on August 21, 2012.																			



## REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

## NOTE

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

### PROJECT

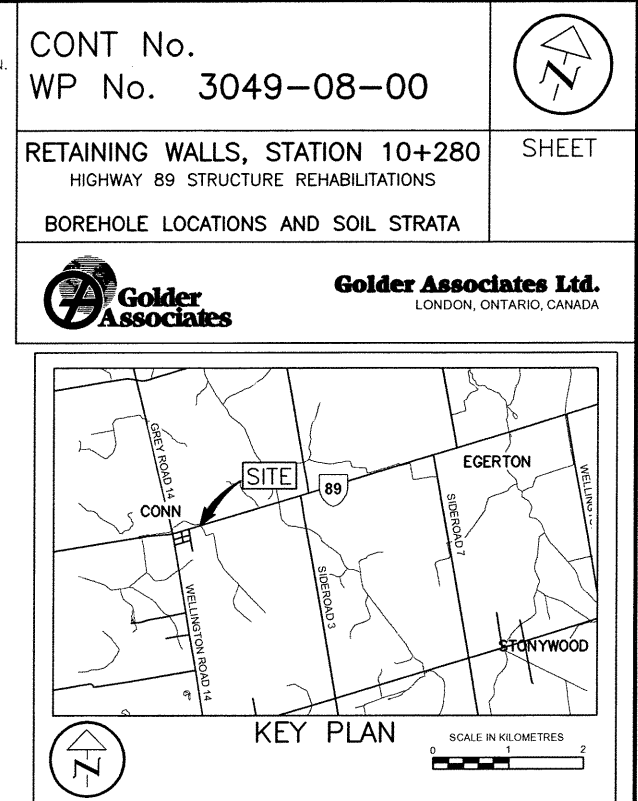
RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C  
HIGHWAY 89 STRUCTURE REHABILITATIONS  
GWP 3049-08-00

### TITLE

## KEY PLAN



PROJECT No.		11-1132-0109	FILE No.		1111320109-1000-F05001
CADD	LMK(WDF)	Jan. 18/13	SCALE	AS SHOWN	REV. 0
CHECK			<b>FIGURE 1</b>		



**NOTES**

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

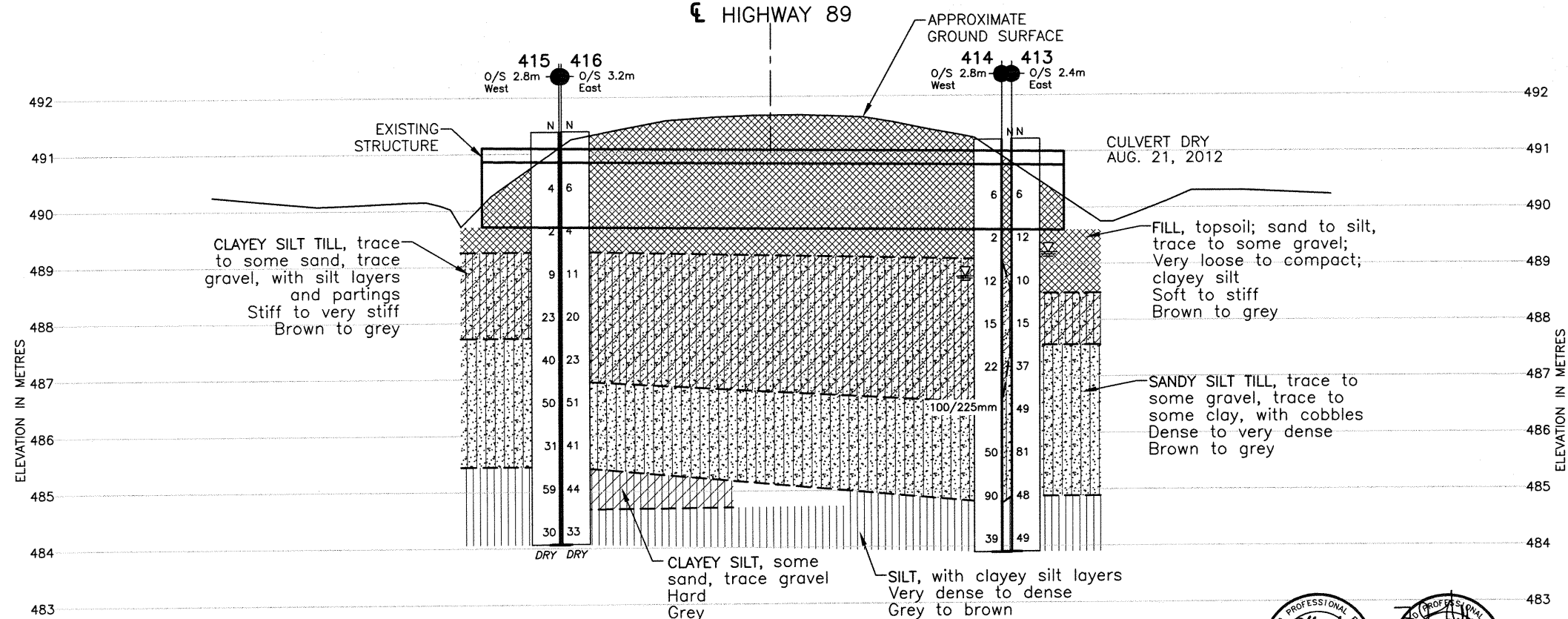
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

**REFERENCE**

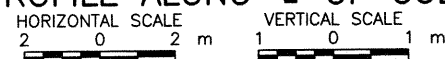
Base plans provided in digital format by Morrison Hershfield.

NO.	DATE		BY	REVISION									
Geocres No. 41A-230													
HWY. 89			PROJECT NO. 11-1132-0109							DIST.			
SUBM'D. TP			CHKD. DUP			DATE: Jan. 18/13				SITE: 35-487/C			
DRAWN: LMK			CHKD. SJB			APPD. FJH				DWG. 1			





### PROFILE ALONG C OF CULVERT



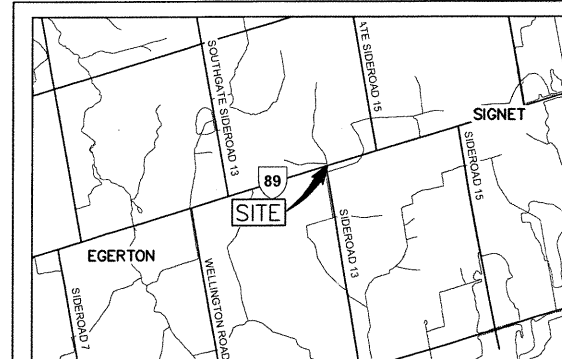
**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
WP No. 3049-08-00

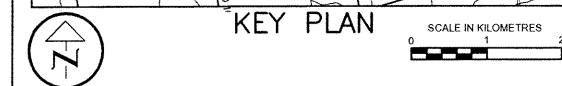
RETAINING WALLS, STATION 17+254  
HIGHWAY 89 STRUCTURE REHABILITATIONS  
BOREHOLE LOCATIONS AND SOIL STRATA





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



## KEY PLAN



### LEGEND

- |   |  |
|---|--|
|  | Borehole - Current Investigation                                   |
| N   | Standard Penetration Test Value                                    |
| 16  | Blows/0.3m unless otherwise stated<br>(Std. Pen. Test, 475 j/blow) |
|  | WL encountered during drilling                                     |
| DRY   | Borehole dry during drilling                                       |

No.	ELEVATION	CO—ORDINATES (MTM. ZONE 10)	
		NORTHING	EASTING
413	491.23	4 875 673.6	226 136.4
414	491.22	4 875 672.6	226 131.2
415	491.39	4 875 688.0	226 127.1
416	491.40	4 875 689.4	226 133.0

---

NOTES

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

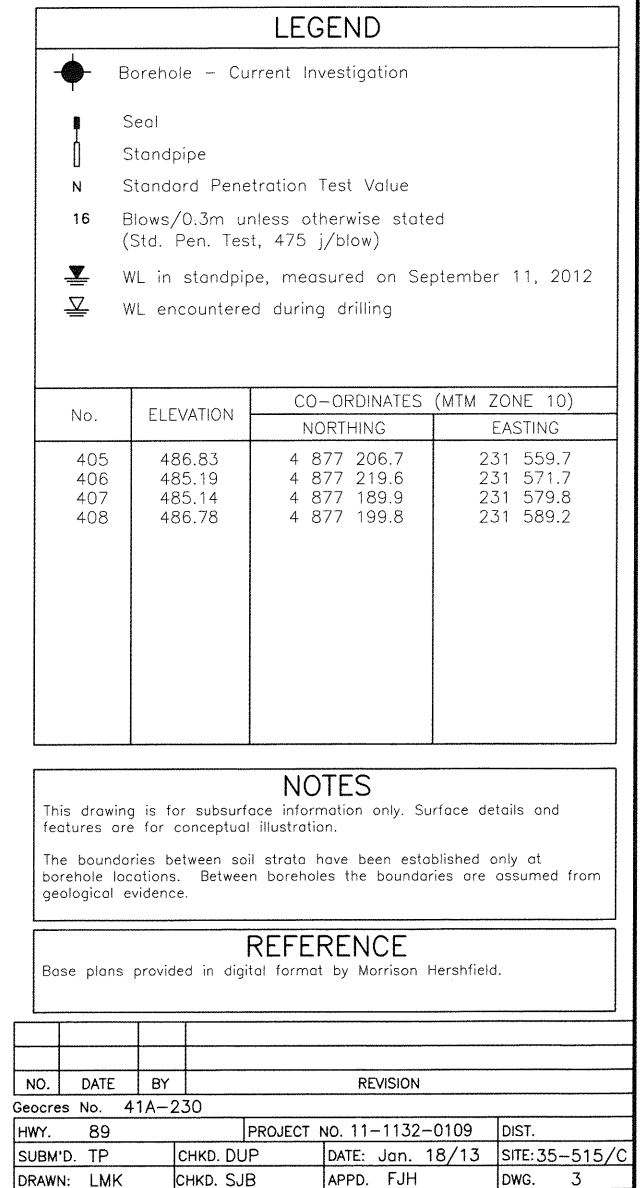
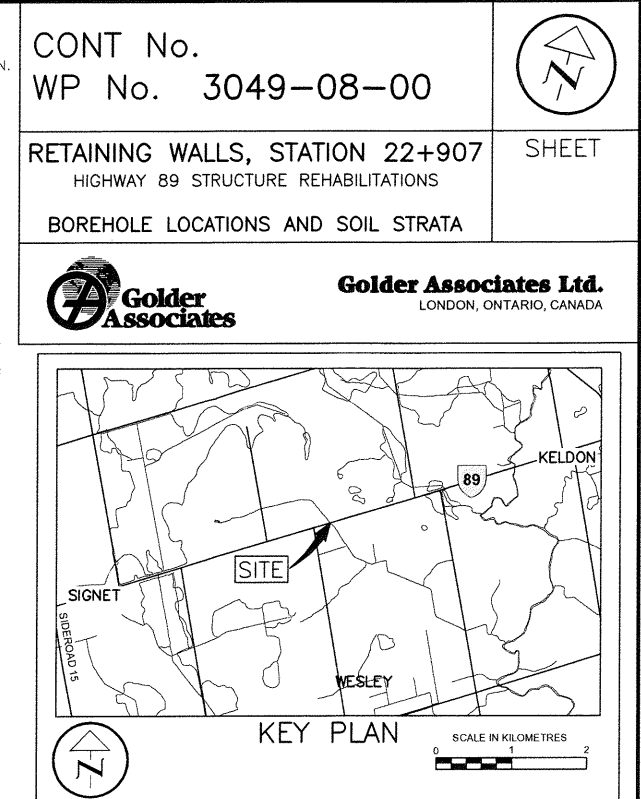
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

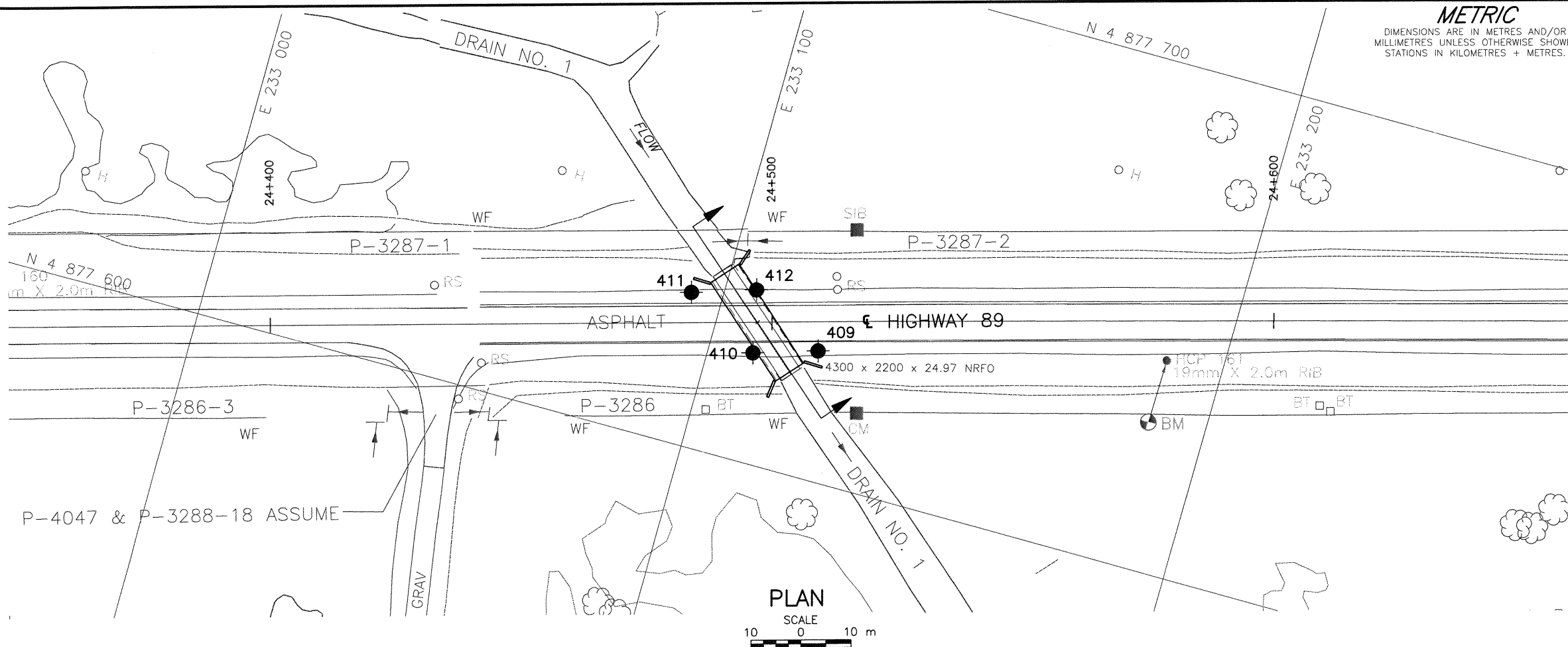
## REFERENCE

Base plans provided in digital format by Morrison Hershfield.

[illegible]







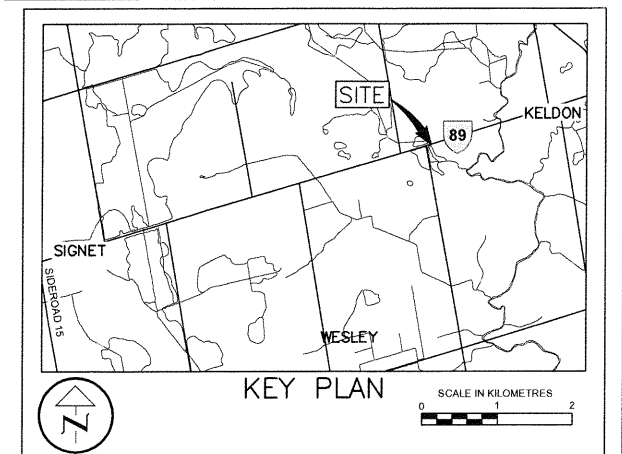
**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. WP No. 3049-08-00

RETAINING WALLS, STATION 24+500  
HIGHWAY 89 STRUCTURE REHABILITATIONS

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



- LEGEND**
- Borehole - Current Investigation
  - Seal
  - Standpipe
  - N Standard Penetration Test Value
  - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
  - WL in standpipe, measured on September 11, 2012
  - WL encountered during drilling

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
409	483.26	4 877 625.5	233 121.3
410	483.22	4 877 621.7	233 108.8
411	483.29	4 877 630.0	233 093.8
412	483.17	4 877 633.9	233 106.1

**NOTES**

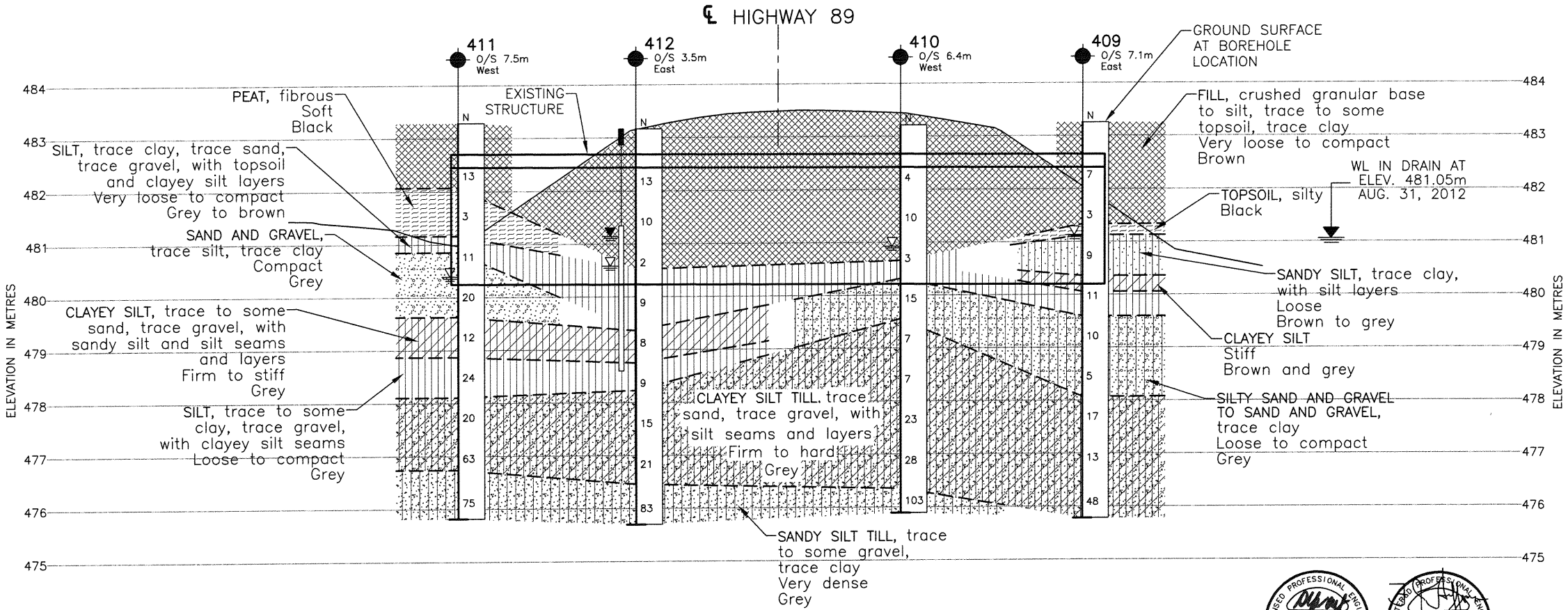
This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

**REFERENCE**

Base plans provided in digital format by Morrison Hershfield.

NO.	DATE	BY	REVISION
Geocres No. 41A-230			
HWY. 89			PROJECT NO. 11-1132-0109
SUBM'D. TP	CHKD. DUP	DATE: Jan. 18/13	SITE: 35-516/C
DRAWN: LMK	CHKD. SJB	APPD. FJH	DWG. 4



**PROFILE ALONG CL OF CULVERT**

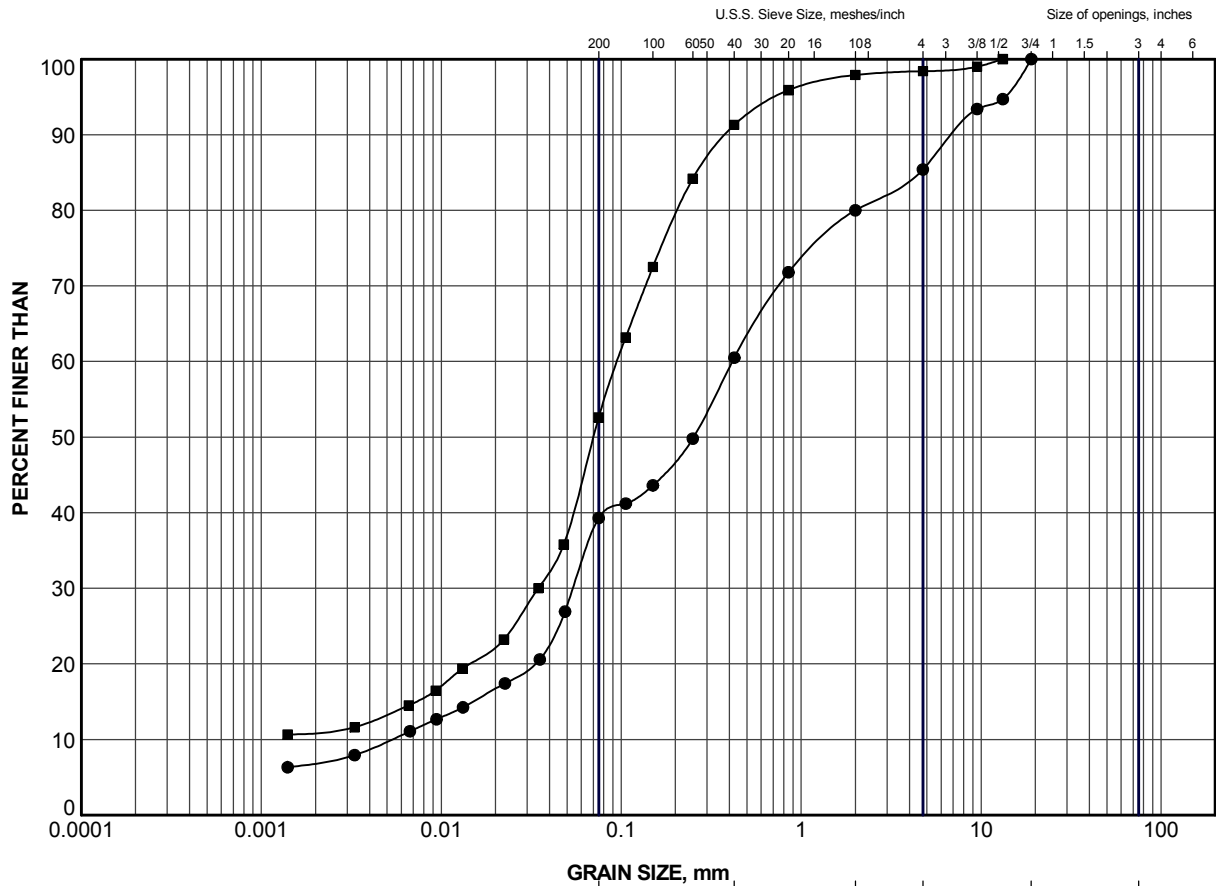
HORIZONTAL SCALE 1:200  
VERTICAL SCALE 1:10





# **APPENDIX A**

## **Laboratory Test Data**

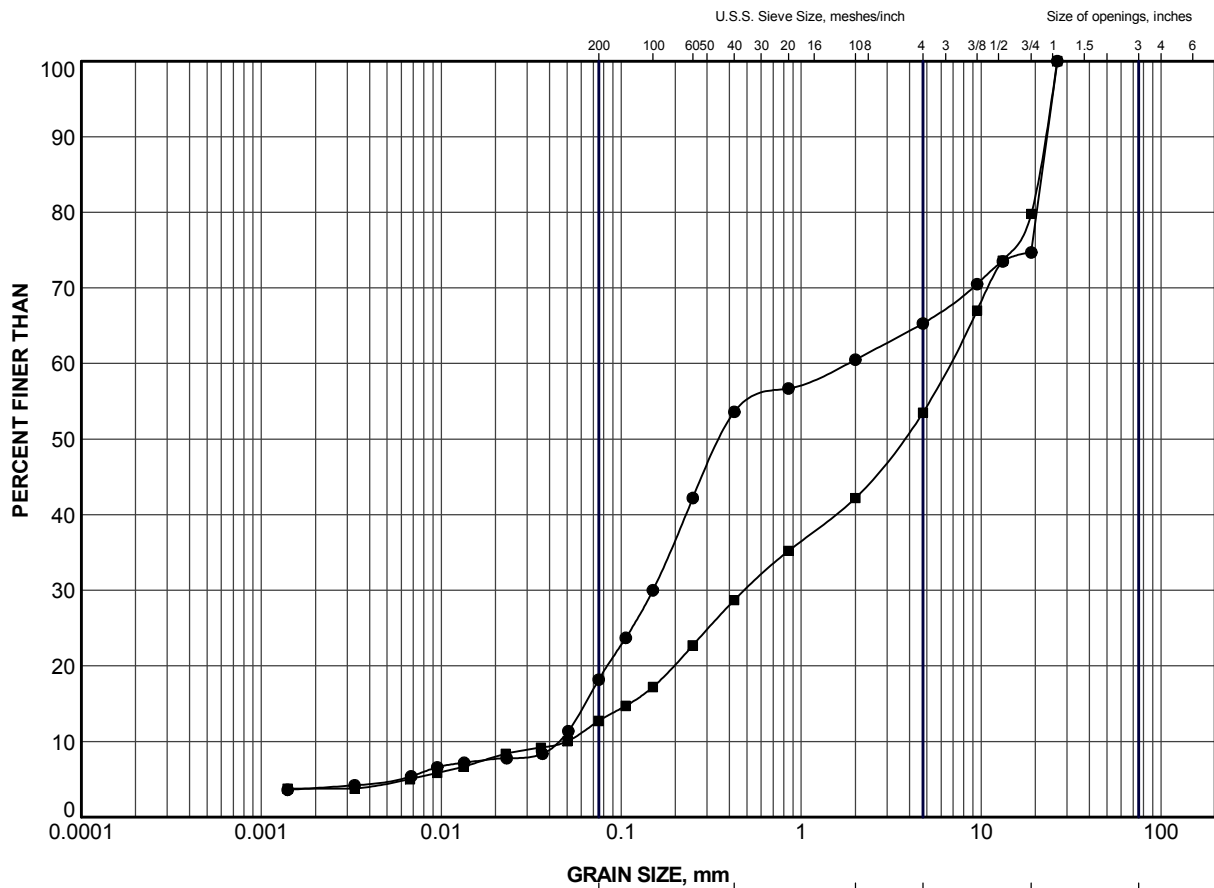


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	412	1	482.2
■	415	2	489.6

PROJECT RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C HIGHWAY 89 STRUCTURE REHABILITATIONS GWP 3049-08-00																
TITLE <h2 style="text-align: center;">GRAIN SIZE DISTRIBUTION</h2> <h3 style="text-align: center;">FILL</h3>																
 <b>Golder Associates</b> LONDON, ONTARIO		<table border="1"> <tr> <td colspan="2">PROJECT No:11-1132-0109-1000</td> <td colspan="2">FILE No. 1111320109-1000-F050A1</td> </tr> <tr> <td>DRAWN</td> <td>LMK</td> <td>Jan. 18/13</td> <td>SCALE N/A REV.</td> </tr> <tr> <td>CHECK</td> <td></td> <td></td> <td></td> </tr> </table>			PROJECT No:11-1132-0109-1000		FILE No. 1111320109-1000-F050A1		DRAWN	LMK	Jan. 18/13	SCALE N/A REV.	CHECK			
PROJECT No:11-1132-0109-1000		FILE No. 1111320109-1000-F050A1														
DRAWN	LMK	Jan. 18/13	SCALE N/A REV.													
CHECK																
		<h2>FIGURE A-1</h2>														

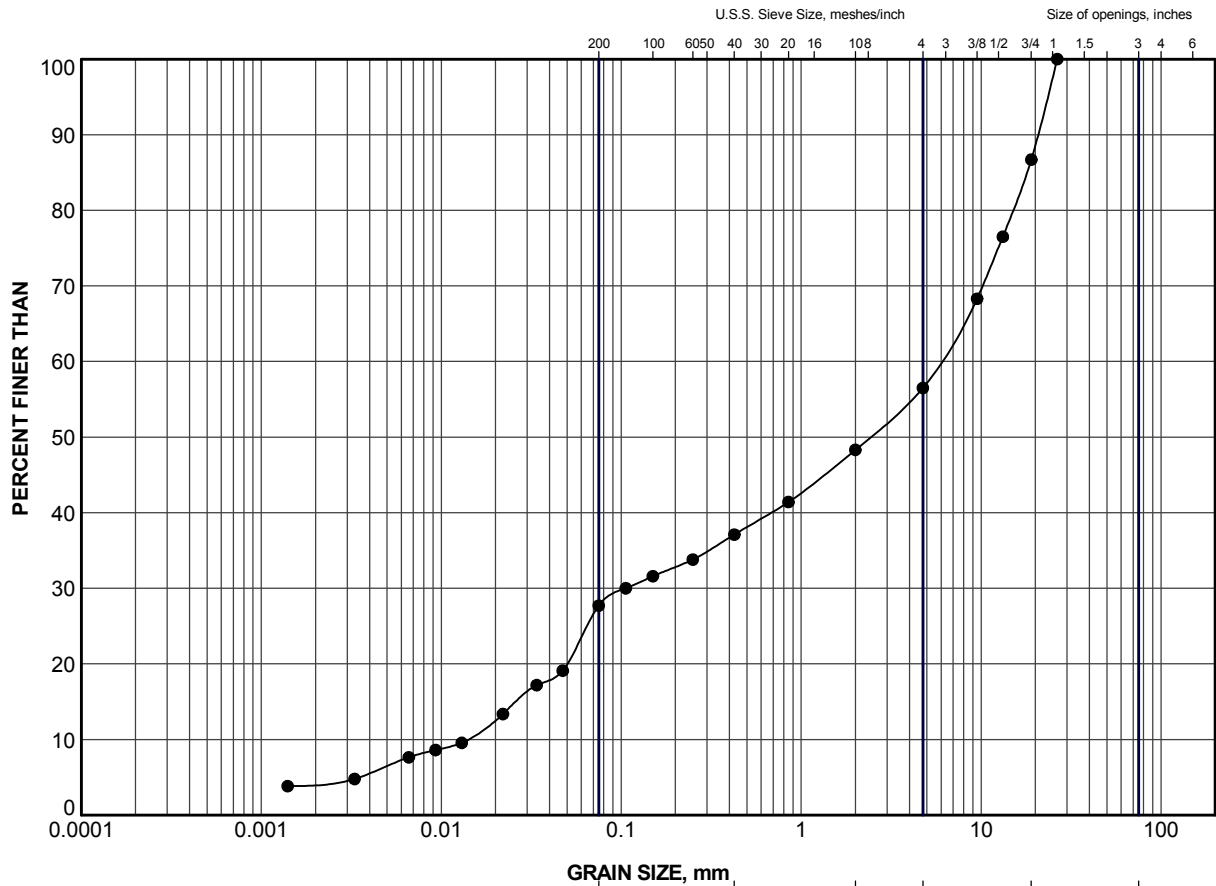
LDN\_MTO\_GSD\_GLDR\_LDN.GDT



### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	409	5	479.2
■	411	4	480.0

PROJECT RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C HIGHWAY 89 STRUCTURE REHABILITATIONS GWP 3049-08-00			
TITLE <b>GRAIN SIZE DISTRIBUTION SAND AND GRAVEL</b>			
PROJECT No: 11-1132-0109-1000		FILE No. 1111320109-1000-F050A2	
DRAWN	LMK	Jan. 18/13	SCALE N/A REV.
CHECK			
 <b>Golder Associates</b> LONDON, ONTARIO			<b>FIGURE A-2</b>

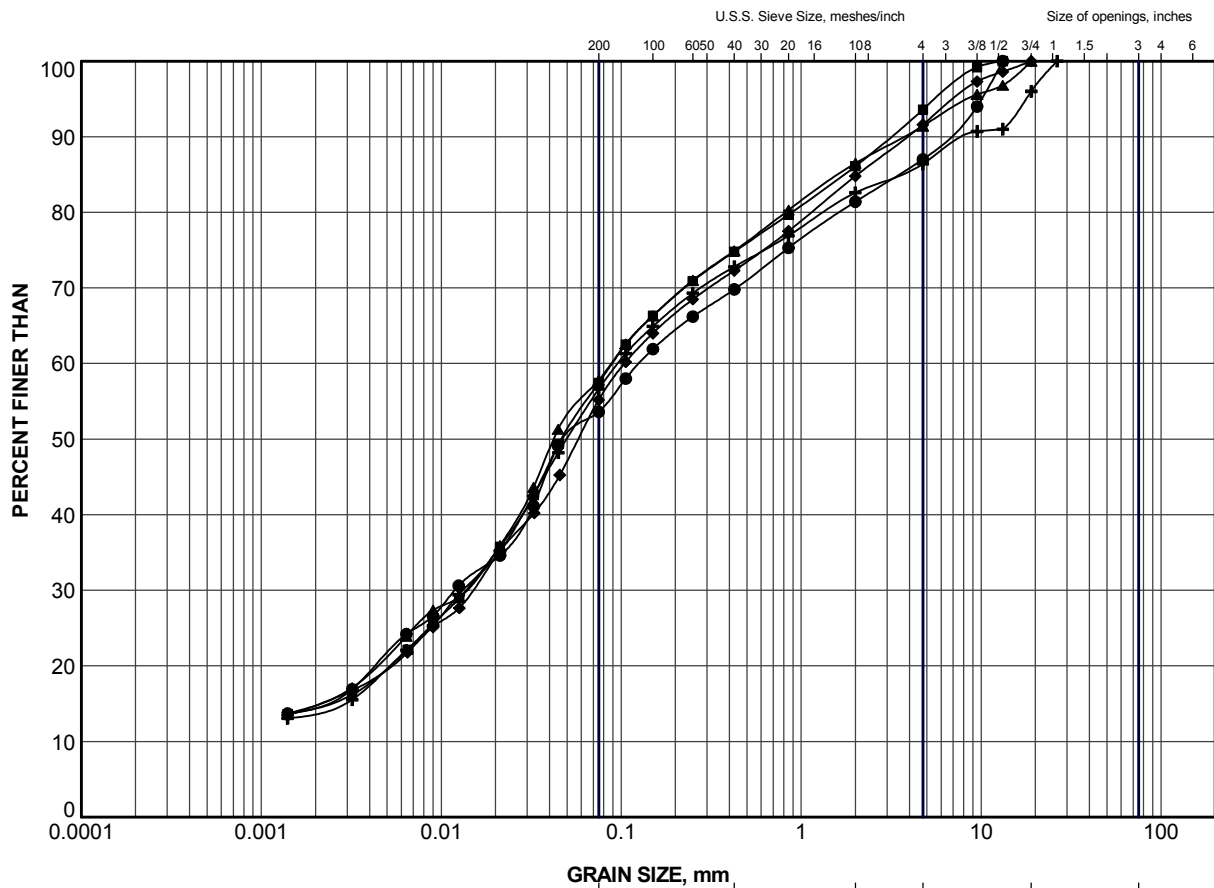


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	410	4	479.9

PROJECT RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C HIGHWAY 89 STRUCTURE REHABILITATIONS GWP 3049-08-00			
TITLE <h2 style="text-align: center;">GRAIN SIZE DISTRIBUTION</h2> <h3 style="text-align: center;">SILTY SAND AND GRAVEL</h3>			
 <b>Golder Associates</b> LONDON, ONTARIO		PROJECT No: 11-1132-0109-1000 FILE No. 1111320109-1000-F050A3 SCALE N/A REV.	<b>FIGURE A-3</b>


LDN\_MTO\_GSD\_GLDR\_LDN.GDT

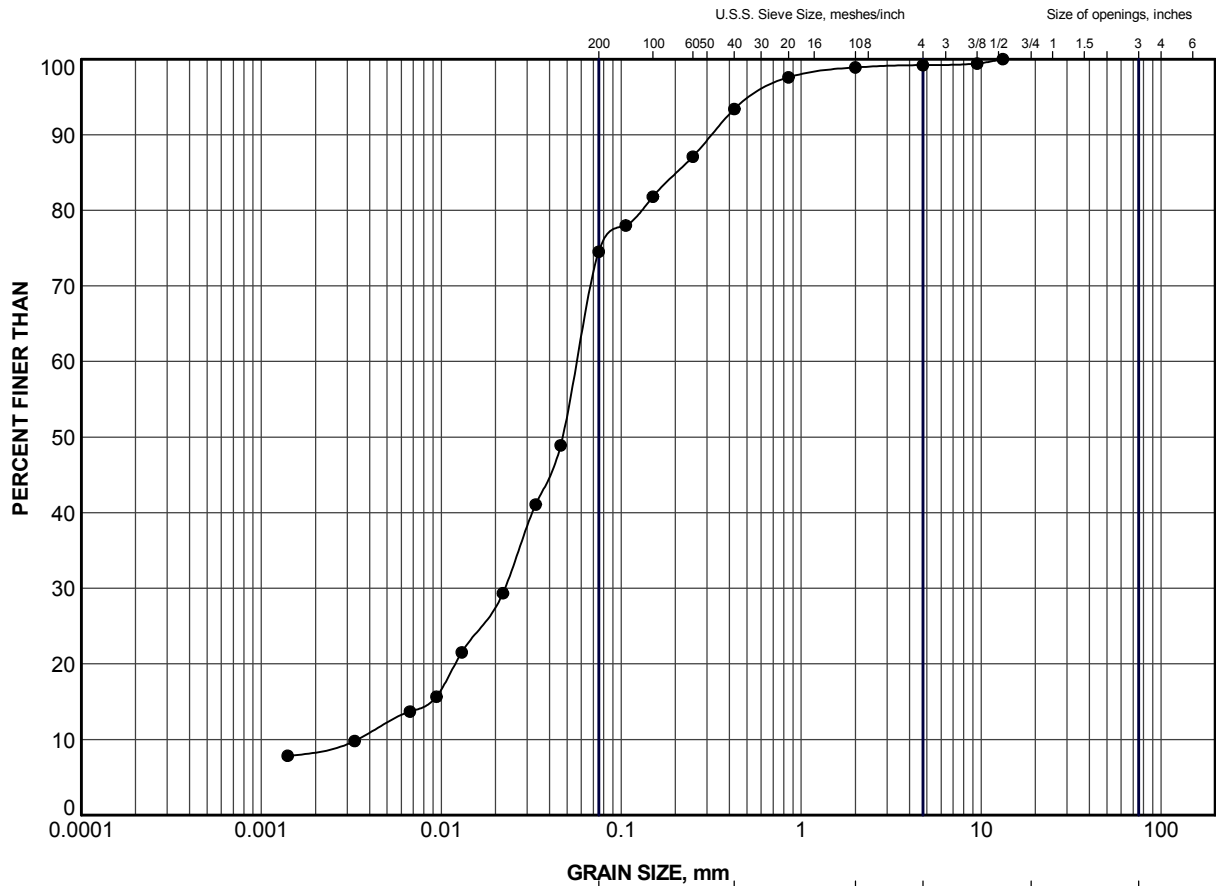


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	407	8	478.8
■	413	5	487.2
▲	413	7	485.7
+	414	7	485.7
◆	415	5	487.3

PROJECT RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C HIGHWAY 89 STRUCTURE REHABILITATIONS GWP 3049-08-00			
TITLE <b>GRAIN SIZE DISTRIBUTION</b> <b>SANDY SILT TILL</b>			
 <b>Golder Associates</b> LONDON, ONTARIO	PROJECT No.	11-1132-0109	FILE No. 111320109-1000-F050A4
	DRAWN	LMK	Jan. 18/13
	CHECK		
			SCALE N/A REV.
			<b>FIGURE A-4</b>

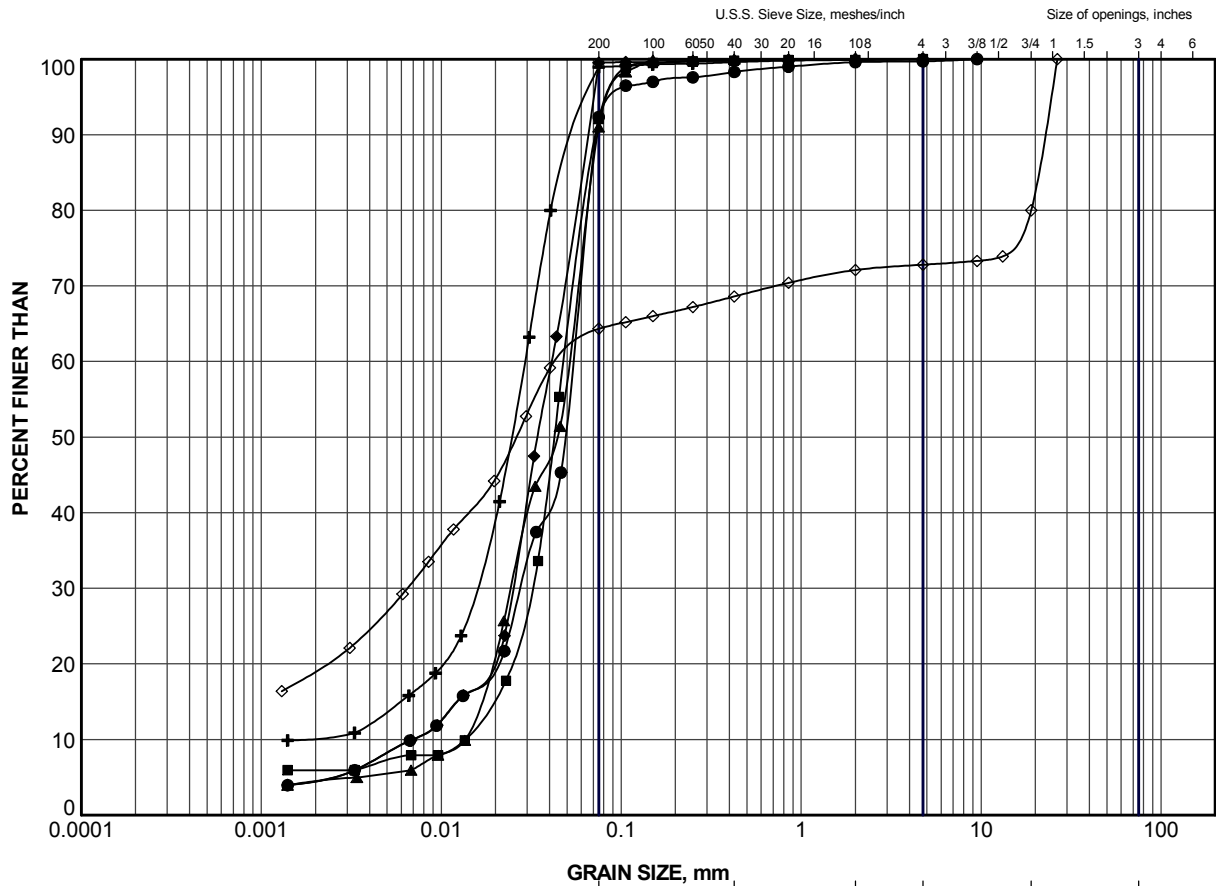


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	409	3	480.7

PROJECT RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C HIGHWAY 89 STRUCTURE REHABILITATIONS GWP 3049-08-00															
TITLE <h2 style="text-align: center;">GRAIN SIZE DISTRIBUTION</h2> <h3 style="text-align: center;">SANDY SILT</h3>															
 <b>Golder Associates</b> LONDON, ONTARIO		<table border="1"> <tr> <td colspan="2">PROJECT No: 11-1132-0109-1000</td> <td colspan="2">FILE No. 1111320109-1000-F050A5</td> </tr> <tr> <td>DRAWN</td> <td>LMK</td> <td>Jan. 18/13</td> <td>SCALE N/A</td> </tr> <tr> <td>CHECK</td> <td></td> <td></td> <td>REV.</td> </tr> </table>		PROJECT No: 11-1132-0109-1000		FILE No. 1111320109-1000-F050A5		DRAWN	LMK	Jan. 18/13	SCALE N/A	CHECK			REV.
PROJECT No: 11-1132-0109-1000		FILE No. 1111320109-1000-F050A5													
DRAWN	LMK	Jan. 18/13	SCALE N/A												
CHECK			REV.												
		<b>FIGURE A-5</b>													





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

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	405	3	484.3
■	406	1	484.1
▲	408	4	483.5
+	411	6	478.5
◆	412	6	478.4
◇	415	8	485.1

PROJECT  
RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C  
HIGHWAY 89 STRUCTURE REHABILITATIONS  
GWP 3049-08-00

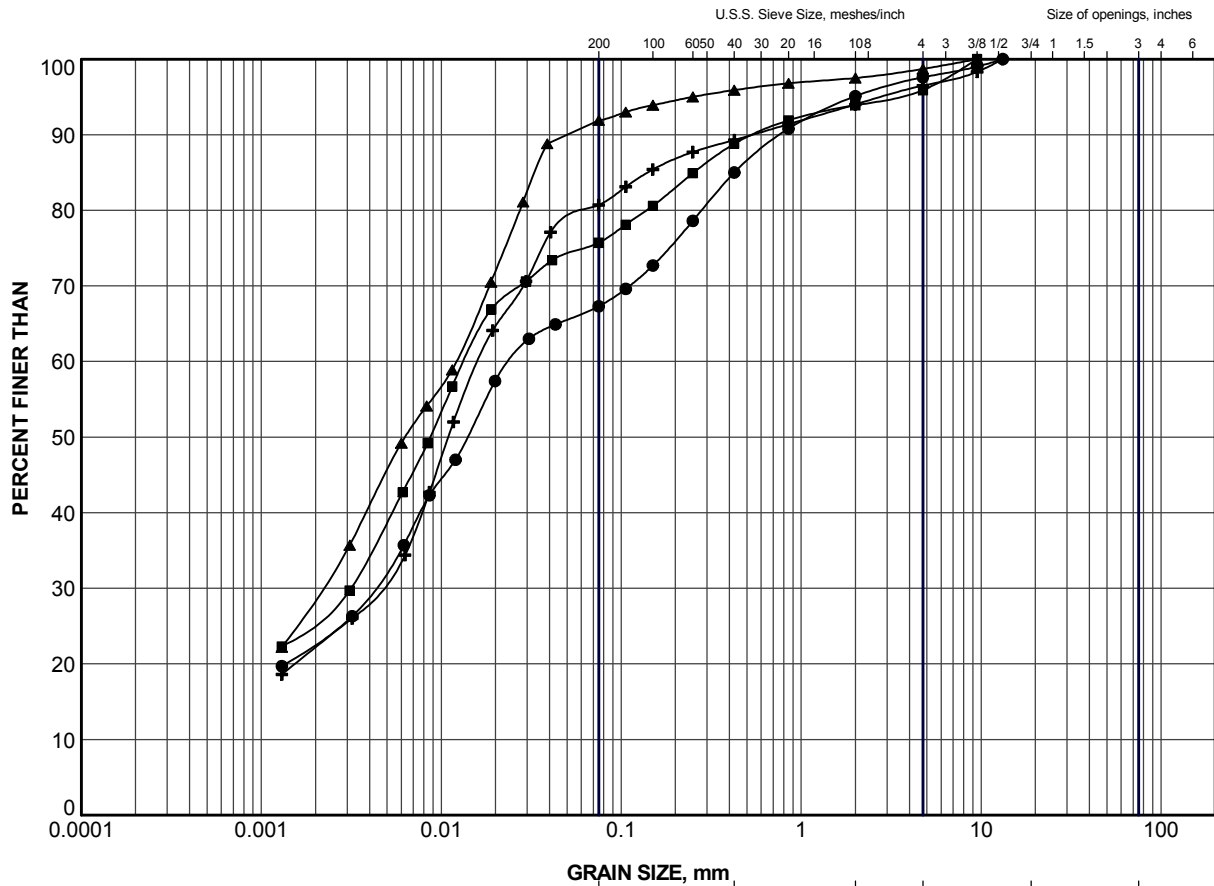
TITLE

## GRAIN SIZE DISTRIBUTION SILT



**Golder Associates**  
LONDON, ONTARIO


PROJECT No:11-1132-0109-1000			FILE No. 1111320109-1000-F050A6		
DRAWN	LMK	Jan. 18/13	SCALE	N/A	REV.
CHECK			<b>FIGURE A-6</b>		

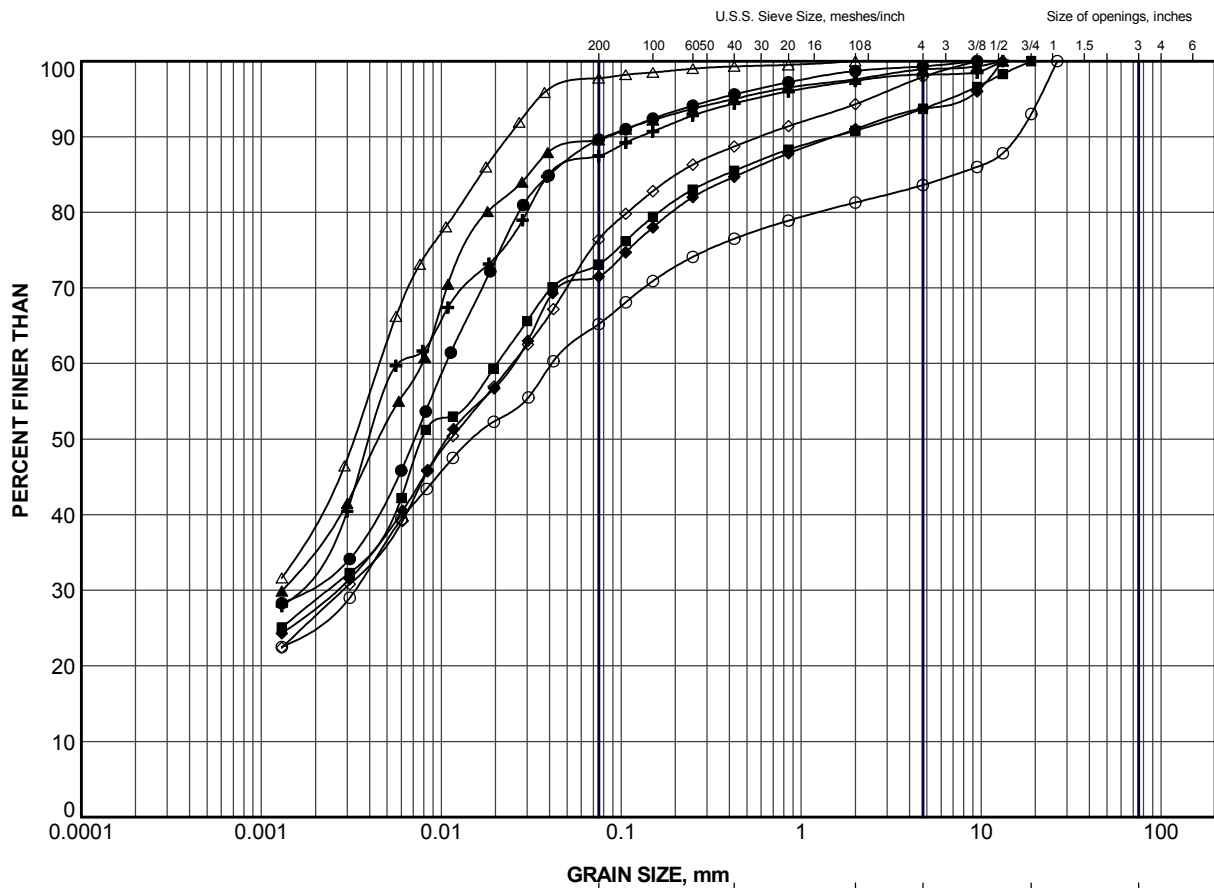


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	401	3	472.9
■	404	3	472.9
▲	412	5	479.1
+	416	8	485.1

PROJECT RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C HIGHWAY 89 STRUCTURE REHABILITATIONS GWP 3049-08-00			
TITLE <b>GRAIN SIZE DISTRIBUTION</b> <b>CLAYEY SILT</b>			
 <b>Golder Associates</b> LONDON, ONTARIO	PROJECT No.	11-1132-0109	FILE No. 1111320109-1000-F050A7
	DRAWN	LMK	Jan. 18/13
	CHECK		
			SCALE N/A REV.
			<b>FIGURE A-7</b>



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	401	5	471.3
■	401	8	469.1
▲	402	4	472.1
+	402	6	470.6
◆	402	8	469.1
◇	403	7	469.8
○	404	6	470.6
△	405	6	482.0

PROJECT  
RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C  
HIGHWAY 89 STRUCTURE REHABILITATIONS  
GWP 3049-08-00

TITLE

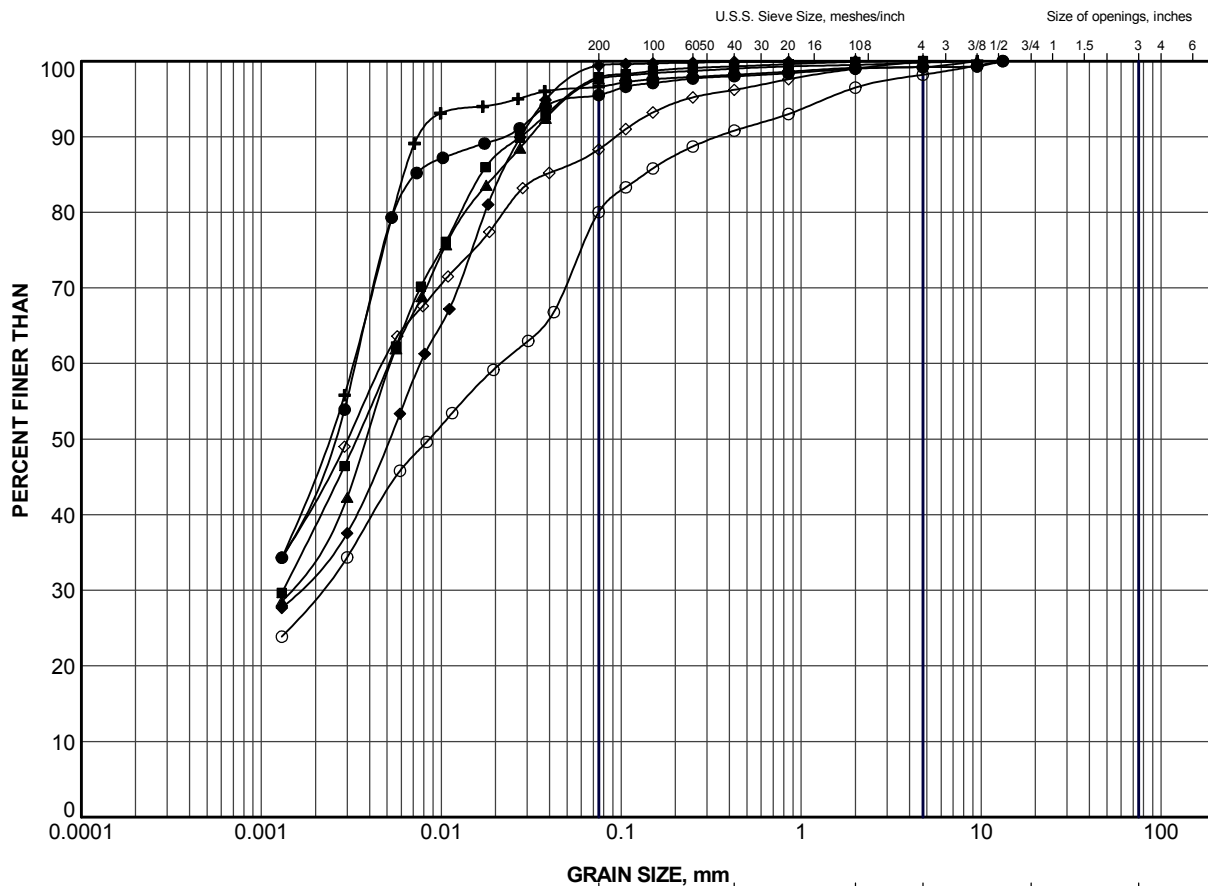
## GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL



**Golder  
Associates**  
LONDON, ONTARIO

PROJECT No.	11-1132-0109	FILE No.	1111320109-1000-F050A8
DRAWN	LMK	Jan. 18/13	SCALE N/A REV.
CHECK			

**FIGURE A-8**



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	406	6	480.4
■	407	3	482.6
▲	407	4	481.9
+	408	7	481.2
◆	410	8	476.9
◇	414	4	487.9
○	416	4	488.1

PROJECT  
RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C  
HIGHWAY 89 STRUCTURE REHABILITATIONS  
GWP 3049-08-00

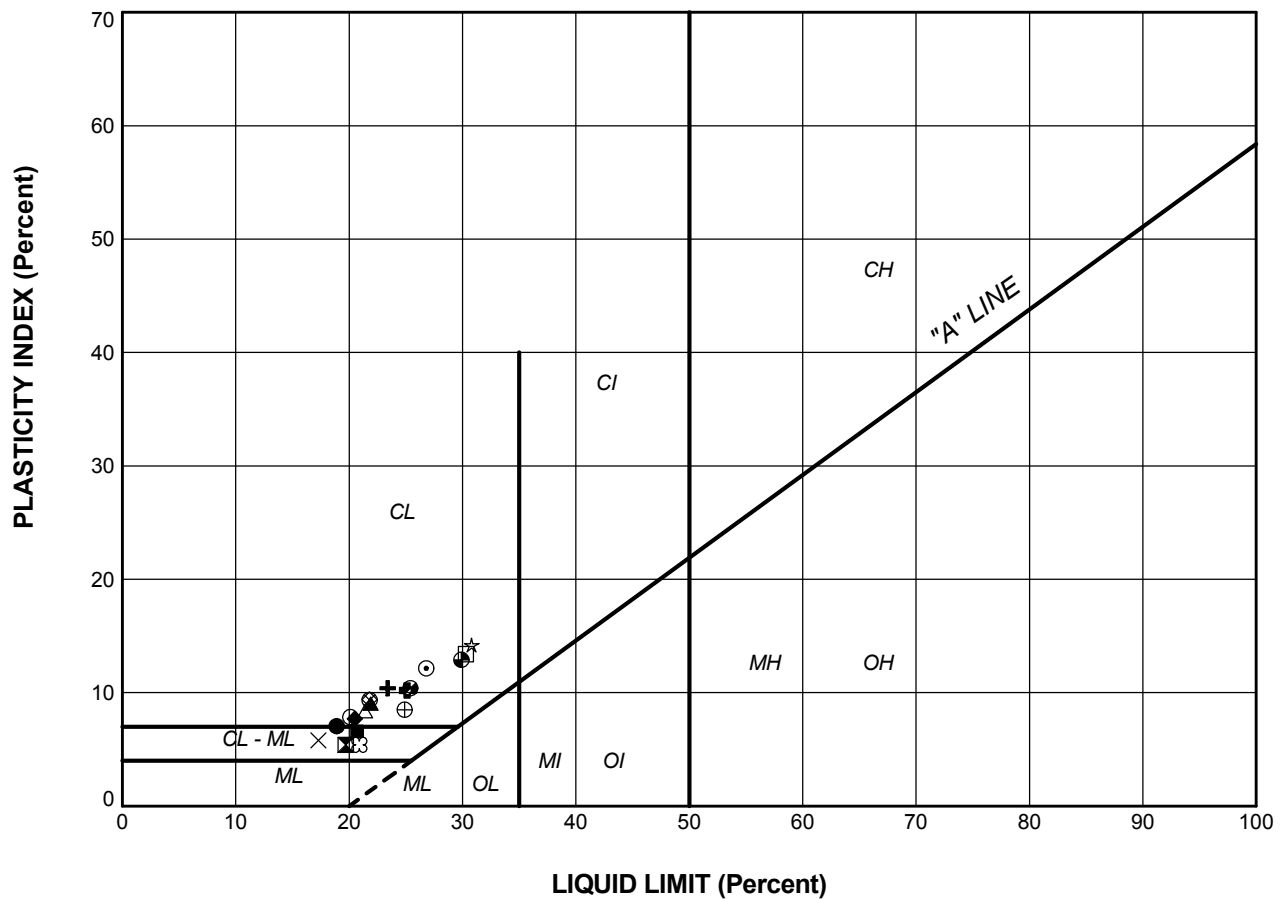
TITLE

## GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL



PROJECT No.	11-1132-0109	FILE No.	1111320109-1000-F050A9
DRAWN	LMK	Jan. 18/13	SCALE N/A REV.
CHECK			

**FIGURE A-9**



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
<b>CLAYEY SILT</b>					
●	401	3	18.9	11.9	7.1
⊠	412	5	19.7	14.3	5.4
×	416	8	17.3	11.5	5.8
△	404	3	21.4	13.1	8.4
<b>CLAYEY SILT TILL</b>					
■	401	5	20.7	14.1	6.6
▲	401	8	21.9	12.9	9.1
+	402	4	23.4	13.0	10.4
◆	402	6	20.5	12.8	7.7
◇	402	8	21.8	12.4	9.4
○	403	7	20.1	12.3	7.9
⊗	404	6	21.8	12.5	9.4
⊕	405	6	24.9	16.4	8.5
□	406	6	30.3	16.9	13.4
⊙	407	3	25.4	15.0	10.4
⊛	407	4	29.9	17.0	12.9
☆	408	7	30.8	16.6	14.2
⊞	410	8	20.9	15.5	5.4
⊚	414	4	26.8	14.7	12.2
⊛	416	4	25.1	14.9	10.2

PROJECT  
 RETAINING WALLS, CULVERT SITES 35-487/C, 35-513/C, 35-515/C, 35-516/C  
 HIGHWAY 89 STRUCTURE REHABILITATIONS  
 GWP 3049-08-00

TITLE

### PLASTICITY CHART



PROJECT No.	11-1132-0109	FILE No.	1111320109-1000-F050A10
DRAWN	LMK	Jan. 18/13	SCALE N/A REV.
CHECK			

**FIGURE A-10**



# **APPENDIX B**

## **Site Photographs**



## APPENDIX B SITE PHOTOGRAPHS



Photograph 1: Station 10+280 (Site 35-487/C) south face of culvert, looking northwest.



Photograph 2: Station 17+254 (Site 35-513/C) north face of culvert, looking south.





## APPENDIX B SITE PHOTOGRAPHS



Photograph 3: Station 22+907 (Site 35-515/C) south face of culvert, looking northwest.



Photograph 4: Station 24+500 (Site 35-516/C) south face of culvert, looking northwest.

n:\active\2011\1132-geo\1132-0100\11-1132-0109 mh-po 3011-e-0001-hwy 89\ph 1000-prelim& detail fdns gwp 3049-08-00\rpts\r05\1111320109-1000-r05 apr 19 13 (final)-app b - site photos.docx



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[www.golder.com](http://www.golder.com)

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