



April 2011

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**Fischer-Hallman Road S-E Ramp Retaining Walls  
Widening of Highway 7/8  
From 1.9 km West of Fischer-Hallman Road Interchange  
Easterly to 0.8 km East of Courtland Avenue Interchange  
Kitchener  
GWP 131-98-00  
Ministry of Transportation, Ontario - West Region**

**Submitted to:**

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REPORT



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LIST OF SYMBOLS

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**PART A**

**FOUNDATION INVESTIGATION REPORT**

**FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS**  
**WIDENING OF HIGHWAY 7/8**  
**FROM 1.9 KM WEST OF FISCHER-HALLMAN ROAD INTERCHANGE**  
**EASTERLY TO 0.8 KM EAST OF COURTLAND AVENUE INTERCHANGE**  
**KITCHENER**  
**GWP 131-98-00**  
**MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 131-98-00, the reconstruction and widening of Highway 7/8. This report presents the results of the foundation investigation carried out for the proposed Fischer-Hallman Road S-E ramp retaining walls located in the southeast quadrant of the Fischer-Hallman Road Interchange.

The purpose of the foundation investigation is to determine the subsurface conditions at the locations of the proposed work 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, Golder Associates' proposal P81-3002 dated April 8, 2008, our letters dated July 21 and 22, 2008 and our revised scope of work letter dated April 13, 2010. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated July 4, 2008.

Dillon provided Golder Associates with draft design information for the retaining walls, presented in plan and cross-section, in digital format.



## 2.0 SITE DESCRIPTION

### 2.1 General

The Highway 7/8 project area is located in the south-central portion of Kitchener, Ontario. The overall project limits extend from 1.9 kilometres (km) west of Fischer-Hallman Road easterly to 0.8 km east of Courtland Avenue. The location of the project is shown on the Key Plan, Figure 1.

This section of Highway 7/8 is currently a four lane divided highway oriented generally east-west. Overpass structures at Westmount Road, Homer Watson Boulevard, Ottawa Street South and Courtland Avenue East, one underpass structure at Fischer-Hallman Road and an overhead structure at the Canadian National Rail (CNR) tracks are situated within the project limits.

Land use adjacent to this site is typically urban residential north of Highway 7/8 with predominantly industrial, commercial, institutional and residential areas to the south.

The proposed retaining walls will extend from the following approximate limits along the Fischer-Hallman S-E Ramp: 10+076 Lt to 10+271 Lt and 10+070 Rt to 10+120 Rt. The topography in the vicinity of the retaining wall generally slopes downwards along the alignment of the ramp from Fischer-Hallman Road to Highway 7/8. The ground surface elevation along the S-E ramp ranges from about 350 metres at Fischer-Hallman Road to about 343 metres at the east end of the ramp adjacent to Highway 7/8.

### 2.2 Site Geology

This project lies within the physiographic region of southwestern Ontario known as the Waterloo Hills<sup>1</sup>. The soils generally consist of sandy hills; some consist of sandy till while others are kames or kame moraines, with outwash sands deposited in the valleys. Adjoining the sandy hills is the Grand River spillway system comprised of alluvial terraces of sand and gravel.

Based on the Ministry of Natural Resources Map P.2559 entitled "Quaternary Geology, Stratford Area, Southern Ontario", the site lies in an area of primarily Maryhill clayey till.

The Geologic Survey of Canada Map 1263A entitled "Geology, Toronto-Windsor Area, Ontario" indicates that the subcropping bedrock in the area of site is dolomite and mudstone of the Salina formation of Upper Silurian age. Based on the Ministry of Natural Resources Map P.168 entitled "Bedrock Topography Series, Stratford, Southern Ontario", the bedrock surface along the proposed alignment of the Fischer-Hallman S-E ramp subcrops at about elevation 259 to 265 metres or some 80 to 85 metres below ground surface.

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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 for this component of the project was carried out between May 12 and June 8, 2010 during which time eight (8) boreholes, numbered 805 to 812, were drilled along the Fischer-Hallman Road S-E ramp between approximately Stations 10+020 and 10+290. The borehole locations are shown on Drawing 1.

The boreholes were advanced to depths of 9.6 to 12.7 metres at or within the immediate vicinity of the proposed retaining walls.

The subsurface conditions along the ramp are presented in profile on Drawing 1.

The table below summarizes the borehole locations, ground surface elevations at the borehole locations and the borehole depths:

Borehole	Location (m)		Ground Surface Elevation	Borehole Depth
	Northing	Easting	(m)	(m)
805	4 809 296	222 748	344.73	9.60
806	4 809 312	222 776	345.35	9.60
807	4 809 343	222 813	342.58	9.60
808	4 809 362	222 850	342.89	9.60
809	4 809 376	222 877	343.20	9.60
810	4 809 396	222 914	343.56	9.60
811	4 809 224	222 763	350.34	10.36
812	4 809 255	222 737	350.05	12.65

The drilling was carried out using track mounted CME 45 and truck mounted CME 55 power augers supplied and operated by specialist drilling contractors. In the boreholes, samples of the overburden were obtained at 0.75 and 1.5 metre intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. 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 glacial till deposits as discussed in the text of this report.



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## FOUNDATION INVESTIGATION AND DESIGN REPORT FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS

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Groundwater conditions were observed throughout the drilling operations and a summary of the groundwater level measurements in the boreholes is provided in Section 4.2. Following completion of drilling and sampling, the boreholes were backfilled in accordance with current Ontario Ministry of Transportation (MTO) procedures and Ontario Regulation 372/07.

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





## **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 in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets and stratigraphic profiles 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.

The boreholes drilled at the site generally encountered highly variable ground conditions, ranging from surficial topsoil and / or variable layers of fill underlain by layers of clayey silt till, clayey silt, silty sand, sandy silt, sand and gravel and sand.

The borehole locations are shown on Drawing 1. The detailed subsurface conditions encountered in the boreholes are provided on the Record of Borehole sheets and are summarized below.

#### **4.1.1 Pavements**

Asphaltic concrete was encountered from the ground surface in boreholes 811 and 812. The asphalt layers were 230 and 180 millimetres thick in boreholes 811 and 812, respectively.

Granular base and subbase materials were encountered underlying the asphaltic concrete in boreholes 811 and 812. The granular roadbase layers were 0.5 and 1.2 metres in boreholes 811 and 812, respectively. It should be noted that cobbles were noted when drilling through the granular subbase in borehole 812.

#### **4.1.2 Topsoil**

Topsoil layers were encountered at the ground surface in boreholes 805 through 810. Topsoil was also encountered within and beneath the fill in borehole 811 at elevations 347.9 and 345.9 metres, respectively. The surficial topsoil layers ranged from 130 to 200 millimetres. The buried topsoil layers in borehole 811 were about 0.5 to 0.9 metres thick.

The buried topsoil layers had N values, as determined in the standard penetration testing, of 7 and 28 blows per 0.3 metres indicating a loose to compact condition. The water contents were 13 to 20 per cent. 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.



### 4.1.3 Fill

Fill was encountered underlying pavement structure or topsoil in boreholes 806, 810, 811 and 812 from elevations 343.4 to 349.6 metres. In boreholes 806 and 810, the fill typically consisted of clayey silt. The fill in boreholes 811 and 812 generally consisted of granular fill with layers of cohesive fill. The granular fill generally consisted of sand and gravel, silt and sandy silt. The thickness of the fill ranged from 1.2 to 3.8 metres.

The granular fill was very loose to dense with N values of 2 to 48 blows per 0.3 metres and water contents ranging from 2 to 25 per cent.

The N values in the soft to hard cohesive fill were 2 to 35 blows per 0.3 metres. The water contents ranged from 11 to 13 per cent. The cohesive fill is of low plasticity based on an Atterberg limits determination carried out on a sample of clayey silt fill with a plastic limit, a liquid limit and a plasticity index of 12, 22 and 10 per cent, respectively. These data are shown on Figure A-8 in Appendix A.

The results of the grain size testing carried out on samples of the fill are presented on Figure A-1.

### 4.1.4 Silt

Layers of silt were encountered in borehole 811 beneath the fill and topsoil layers at elevation 345.5 metres and below a clayey silt layer at elevation 344.4 metres. The upper and lower silt layers were 0.6 and 0.8 metres thick respectively.

The upper silt layer was inferred to be loose based on the N value of 9 blows per 0.3 metres. The lower silt layer was compact with an N value of 13 blows per 0.3 metres.

### 4.1.5 Sandy Silt

Layers of sandy silt were encountered in boreholes 806, 808, 809, 810 and 812 between elevations 336.9 and 344.9 metres. The sandy silt layers were found underlying the fill, clayey silt and silty sand and within the clayey silt and were about 0.8 to 4.6 metres thick.

The N values for the sandy silt ranged from 10 to 50 blows per 0.3 metres. The water contents were about 7 to 16 per cent. An Atterberg limits determination carried out on a sample of the sandy silt indicated plastic and liquid limits of 13 and 17 per cent, respectively, and a plasticity index of 4 per cent indicating a silt of low plasticity. These data are provided on Figure A-8.

The results of grain size analyses conducted on samples of the sandy silt obtained during standard penetration testing are presented on Figure A-2.



#### **4.1.6 Clayey Silt**

Layers of clayey silt were encountered in boreholes 805 through 810 from elevations 334.7 to 344.9 metres. The clayey silt layers were found underlying the surficial topsoil in boreholes 805, 808 and 809, underlying the fill in boreholes 806 and 810 and underlying the lower sand in borehole 807. In boreholes 805, 808, 809 and 810, the clayey silt was interlayered with silty fine sand and sandy silt. Silty sand and sand seams were also observed in the clayey silt layers in all of the boreholes with the exception of borehole 810. The thickness of the clayey silt layers ranged from 0.5 to 5.3 metres. Boreholes 807 and 808 were terminated in the clayey silt after exploring it for 1.4 to 2.1 metres.

The firm to very stiff clayey silt had N values of 6 to 27 blows per 0.3 metres. Water contents in the clayey silt ranged from 13 to 17 per cent. The clayey silt is of low plasticity based on plastic limits, liquid limits and plasticity indices ranging from 11 to 15, 18 to 25 and 7 to 12 per cent, respectively. These data are provided on Figure A-8.

The results of the grain size testing conducted on selected clayey silt samples obtained during the standard penetration testing are presented on Figure A-3.

#### **4.1.7 Clayey Silt Till**

Clayey silt till was encountered in borehole 811 beneath layers of silt and clayey silt at elevation 343.6 metres.

The very stiff clayey silt till had N values of 15 to 17 blows per 0.3 metres. A water content of 14 per cent was measured for a sample of the clayey silt till. The Atterberg limits testing indicated that the clayey silt till is of low plasticity. The plastic limit, liquid limit and plasticity index for a clayey silt till sample were 13, 21 and 9 per cent, respectively. These data are shown on Figure A-8.

The results of the grain size testing conducted on a sample of the clayey silt till obtained during standard penetration testing is presented on Figure A-4. Although not specifically encountered in the boreholes, cobbles and boulders should be anticipated in the clayey silt till.

#### **4.1.8 Sand and Gravel**

A 2.0 metre thick layer of dense sand and gravel was encountered beneath the sandy silt in borehole 812 at elevation 343.0 metres. Cobbles were noted during drilling in the sand and gravel.

The sand and gravel had an N value 43 blows per 0.3 metres and water content of 3 per cent. A grain size distribution curve for a sand and gravel sample recovered from the standard penetration testing is presented on Figure A-5.



#### **4.1.9 Silty Sand**

Layers of loose to very dense silty sand and silty fine sand were encountered in boreholes 805, 806, 807, 808, 809 and 812 from elevations 337.1 to 342.5 metres. The silty sand was encountered underlying topsoil, clayey silt, sandy silt and sand and gravel. In boreholes 805, 807 and 808, the silty sand was interlayered with clayey silt and sand layers. Where fully penetrated, the silty sand layers were 0.4 to 2.8 metres thick. Boreholes 805, 806, 809 and 812 were terminated in the silty sand after exploring it for 1.4 to 5.2 metres.

The silty sand had N values of 5 to 59 blows per 0.3 metres with water contents of 5 to 17 per cent.

The results of grain size testing conducted on samples of the silty sand obtained during standard penetration testing are presented on Figure A-6.

#### **4.1.10 Sandy Silt Till**

Sandy silt till was encountered beneath clayey silt till at elevation 340.6 metres in borehole 811. This borehole was terminated in sandy silt till after exploring it for some 0.6 metres.

The sandy silt till was compact with an N value of 12 blows per 0.3 metres.

#### **4.1.11 Sand**

Layers of compact to dense sand were found within or underlying sandy silt and silty sand layers in boreholes 807 and 810 at elevations 339.7 and 334.6 metres, respectively. The sand layers in borehole 807 were 1.7 and 0.8 metres thick. Borehole 810 was terminated in sand after exploring it for 0.6 metres.

N values in the sand layers ranged from 26 to 37 blows per 0.3 metres with a water content of 18 per cent. A grain size distribution curve for a sample of the sand obtained during standard penetration testing is presented on Figure A-7.



### 4.2 Groundwater Conditions

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

Borehole	Ground Surface Elevation	Encountered Groundwater Level	
		Depth	Elevation
	(m)	(m)	(m)
805	344.73	Dry	Below 335.5
806	345.35	Dry	Below 336.0
807	342.58	2.9	339.7
808	342.89	3.3	339.6
809	343.20	Dry	Below 334.0
810	343.56	Dry	-
811	350.34	5.1	345.2
812	350.05	Dry	Below 337.5

During the field work, groundwater was encountered between elevation 339.6 and 345.2 metres in boreholes 807, 808 and 811. The remaining boreholes were dry. Of the dry boreholes, grey soils were intercepted only in borehole 810.

Groundwater levels along the Fischer-Hallman Road S-E Ramp alignment are variable. The inferred groundwater levels at the site are as follows:

- Station 10+000 to 10+040 Fischer-Hallman Road S-E Ramp – below elevation 345 metres
- Station 10+040 to 10+150 Fischer-Hallman Road S-E Ramp – below elevation 336 metres
- Station 10+150 to 10+225 Fischer-Hallman Road S-E Ramp – elevation 340 metres
- Station 10+225 to 10+300 Fischer-Hallman Road S-E Ramp – below elevation 334 metres

The inferred groundwater levels are based on the encountered groundwater levels and the colour change from brown to grey.

The above noted groundwater levels are not necessarily considered to be representative of the long-term, stabilized groundwater conditions as the readings were taken for a short duration only. The groundwater levels are expected to fluctuate due to climatic and seasonal variations.



## **5.0 MISCELLANEOUS**

This investigation was carried out using equipment supplied and operated by Aardvark Drilling Ltd., who is an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Mathew Riopelle and Mr. Matthew Rhody under the direction of Mr. David J. Mitchell.

The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by the Project Engineer, Ms. Dirka U. Prout, P.Eng., under the direction of the Team Leader, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS**

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**PART B**

**FOUNDATION DESIGN REPORT**

**FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS**  
**WIDENING OF HIGHWAY 7/8**  
**FROM 1.9 KM WEST OF FISCHER-HALLMAN ROAD INTERCHANGE**  
**EASTERLY TO 0.8 KM EAST OF COURTLAND AVENUE INTERCHANGE**  
**KITCHENER**  
**GWP 131-98-00**  
**MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



## **6.0 ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides our recommendations on the foundation aspects of the design of the two Retained Soil System (RSS) walls that will be constructed along the proposed Fischer-Hallman Road S-E Ramp. The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

A new ramp, approximately 350 metres long, joining the northbound lanes of Fischer-Hallman Road to the eastbound lanes of Highway 7/8 will be constructed in the southeast quadrant of the Fischer-Hallman Road Interchange. Where possible the ramp will be constructed at grade and on embankments with 3 horizontal to 1 vertical side slopes. Elsewhere, RSS walls are proposed.

Alternatively, concrete cantilever retaining walls could be used. A comparative summary of the advantages/disadvantages, relative costs, risks/consequences associated with use of each retaining wall type is presented in Table I. RSS retaining walls are the preferred retaining wall solution from a foundations engineering perspective.

The following discussion pertains to the RSS walls that will be constructed within the following approximate limits along the Fischer-Hallman S-E Ramp:

- 10+076 to 10+270 Lt and
- 10+070 to 10+120 Rt.

### **6.2 Foundations**

#### **6.2.1 Subsurface Conditions**

The subsurface conditions in the areas where the retaining wall will be constructed consist of topsoil and surficial fill underlain by discontinuous layers of clayey silt interlayered with silty fine sand to sandy silt.

The groundwater level was inferred to vary between elevation 336 metres near Station 10+070 and elevation 334 metres near Station 10+285.





### 6.2.2 Geotechnical Resistance – Shallow Foundations

The wall along the left side of the Fischer-Hallman S-E ramp will vary in height about 3.5 metres near Station 10+070 Lt, to the maximum wall height of 6.6 metres near Station 10+115 Lt, then to less than 1 metre east of Station 10+250 Lt. On the right side of the ramp, the wall height will be about 3.5 metres near Station 10+070 Rt, then increase to 6.6 metres near Station 10+115 Rt, then reduce to 6.2 metres at Station 10+120 Rt.

RSS wall footings designed with the geotechnical resistances given below may be founded on a 0.3 metre thick compacted Granular A levelling pad. Alternatively, if concrete cantilever walls are constructed, they can be founded on strip footings constructed in/on the native materials. It is anticipated that the walls can be founded in the native soils beneath all surficial fill and topsoil using the following geotechnical resistances:

Location	Maximum Founding Elevation (m)	Anticipated Founding Conditions	Geotechnical Resistance (kPa)	
			Factored ULS	SLS
10+075 to 10+145	344.6 to 343.2	Firm to very stiff clayey silt	175	125
10+145 to 10+190	342.5	Dense silty fine sand	450	300
10+190 to 10+285	342.5	Stiff to very stiff clayey silt	250	175

The Serviceability Limit States (SLS) value allows for 25 millimetres of settlement. Some minor additional settlement will occur as a result of the placement of the embankment fill for the S-E Ramp.

To improve resistance to general bearing failure and to provide access for future maintenance and repairs, a minimum 1.0 wide bench should be provided in front of the wall if the ground in front of the wall is sloped.

### 6.2.3 Frost Protection and Embedment

All footings should be provided with adequate frost protection consisting of 1.4 metres of soil cover or thermal equivalent. All RSS walls founded on granular levelling pads should have sufficient embedment to provide frost protection and overall stability. The embedment depth, defined as the distance from the top of the levelling pad to the top of the adjoining finished grade at the toe of the wall should be the maximum of:

- 0.5 metres;
- The minimum depth required for overall stability;
- $H/20$  – if the area in front of the wall is horizontal; or
- $H/10$  – if the area in front of the wall slopes at 3 horizontal to 1 vertical.



where H is the total wall height<sup>2</sup>.

### 6.3 Resistance to Lateral Forces

The lateral pressures acting on the retaining walls 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 fill (assumed to be Granular A) 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 angle of friction and corresponding unfactored coefficient of friction,  $\tan \delta$ , may be used for the interaction between the concrete and the founding soil:

Footing Type	Subgrade	Angle of Friction (°)	Tan $\delta$
RSS wall levelling pad	Granular A	35	0.70
Strip	Clayey silt	28	0.53
Strip	Silty fine sand	30	0.58

In accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

### 6.4 RSS Wall Stability

The internal stability of the mechanically-reinforced soil walls should be verified by the RSS supplier/designer. An examination of the global and external stability of the RSS retaining wall at 10+115 LT was conducted. At this location, the RSS wall has a maximum height of approximately 6.6 metres. A reinforcement length of 0.7 times the wall height was assumed. The wall was found to be stable and satisfied the required Factors of Safety of 1.5 for sliding and 2.0 for eccentricity/overturning and bearing.

The Factor of Safety related to the global stability under static loading for properly designed and constructed RSS walls at this site is greater than 1.3. Upon completion of the detail design, the RSS wall designer/supplier should provide the results of analyses of the internal, external, global and compound stability confirming that the RSS retaining walls that will be constructed at this site will be stable.

<sup>2</sup> FHWA (2001). Mechanically Stabilized Earth Walls and Reinforced Soil Slopes: Design and Construction Guidelines. FHWA-NHI-00-043. Federal Highway Administration, Washington, D.C., USA.



## 6.5 Lateral Earth Pressures

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

Select, free-draining granular fill meeting the specifications of MTO Special Provision (SP) 110S13 Granular A or Granular B, Type III but with less than 5 per cent passing the No. 200 sieve should be used as backfill behind the wall. The granular fill should be placed in accordance with Ontario Provincial Standard Drawing (OPSD) 3121.150 and compacted in loose lifts not greater than 200 millimetres in thickness in accordance with OPSS 501. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to subdrains should be in accordance with OPSD 3190.100.

A compaction surcharge equal to 12 kilopascals should be included in the lateral earth pressures for the structural design of the abutment wall in accordance with the CHBDC, Figure 6.6. Compaction equipment should be used in accordance with SP 105S10.

The granular fill may be placed either in a zone with a width equal to at least 1.4 metres behind the back of the reinforced mass/wall stem (Case (a) from Commentary on CHBDC Figure C6.20) or within the wedge-shaped zone defined by a line drawn at a maximum 1 horizontal to 1 vertical slope extending up and back from the rear face of the reinforced mass/wall stem (Case (b) from Commentary on CHBDC Figure C6.20).

For Case (a), the pressures are based on the embankment fill consisting of Select Subgrade Material (SSM) and the following parameters (unfactored) may be assumed:

Soil unit weight: 18.5 kN/m<sup>3</sup>

Coefficients of lateral earth pressure:

Active,  $K_a$       0.33

At rest,  $K_o$       0.50

Passive,  $K_p$       3.0

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

	<u>GRANULAR A</u>	<u>GRANULAR B</u> (Type III)
Soil unit weight:	22 kN/m <sup>3</sup>	21 kN/m <sup>3</sup>
Coefficients of lateral earth pressure:		
Active, $K_a$	0.27	0.31



## FOUNDATION INVESTIGATION AND DESIGN REPORT FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS

	<u>GRANULAR A</u>	<u>GRANULAR B</u> (Type III)
At rest, $K_o$	0.43	0.47
Passive, $K_p$	3.7	3.3

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

It should be noted that the above design parameters assume that the ground in front of and behind the wall are level.

### 6.5.1 BBRSS Walls and Wall Interaction

The approximate separation distance,  $D$ , defined as the distance between the faces of the two BBRSS walls, will be 9.4 metres. Assuming the reinforcing length for each wall will be in the range of 0.7 to 0.8 times the wall height, overlapping of the reinforcement of the reinforcement will not occur. According to the design information provided, the heights of the BBRSS walls are such that the full active thrust will be mobilized for both walls. However, should the separation distance or reinforcement length be altered such that either overlapping of the reinforcement occurs, or  $D$  is less than or equal to half the height of the taller wall then the lateral pressure must be modified for the assessment of the external stability.

## 6.6 Settlement

Total settlement is expected to be greatest between approximately Station 10+075 and 10+150 where the average height of the RSS walls will be approximately 5 metres and the surficial foundation soil will typically consist of firm to stiff clayey silt layers 4.4 to 5.3 metres thick. Beyond Station 10+150 LT, the Fischer-Hallman Road S-E Ramp will be less than 4 metres in height and constructed on dense silty fine sand or stiff to very stiff clayey silt interlayered with sand seams or layers.

The total settlement along the S-E Ramp, in areas where the RSS walls will be erected, is summarized as follows:

Location	Estimated Total Settlement (mm)
10+075 to 10+115	35
10+115 to 10+150	25
10+150 to 10+275	<10



### **6.6.1 Differential Settlement**

Some differential settlement should be expected due to the variability in subsurface conditions and wall height. The differential settlement along the wall is expected to be less than 1 per cent. Therefore, pre-cast concrete panels or block facings can be used for the RSS walls.

## **6.7 Additional Design Considerations**

The RSS retaining walls are to be designed for high performance in accordance with MTO Special Provision (SP) 599S22 and the Non-Standard Special Provision for the design and construction of RSS walls dated September 2005.

Stepped footings, if required, should not exceed a height of 0.5 metres and should be provided with a minimum 1 metre length of horizontal footing on each side.

### **6.7.1 Drainage**

The design must incorporate subsurface and surface drainage elements. Much of the ramp in the area where the RSS or cantilever walls will be located will be built along an existing drainage ditch between the Highway 7/8 road platform and the southern cut-slope. Surface flows that would have otherwise been conveyed by the subject ditch section should be adequately redirected.

If metallic reinforcement will be utilized for the RSS walls, it is recommended that an impervious barrier be placed between the pavement structure and reinforcement fill to protect it from damage by de-icing salts.

### **6.7.2 Utilities and Highway Infrastructure**

It is preferred that utilities with alignments parallel to the wall face not be placed within the reinforcement zone of RSS walls. Proposed Noise Barrier Wall 2 will be erected along the right side of the right-of-way along the Fischer-Hallman S-E ramp from Station 10+050 Rt continuing past the end of the ramp. The design of the retaining walls must consider the proposed highway infrastructure such as culverts and noise barrier walls. This may require construction of a structural frame around the obstruction, splaying or full or partial omission of reinforcement in the area of the obstruction. The adjacent reinforcement must be designed to accommodate the additional loading resulting from removal of reinforcing elements in the area of the obstruction.



## **6.8 Construction Considerations**

The RSS retaining walls are to be inspected and the component materials tested in accordance with SP599S23. Excavation and backfilling operations for concrete cantilever retaining walls are to be conducted in accordance with OPSS 902. Care should be taken during construction to minimize disturbance of the fine-grained subgrade. If soft/loose materials, wet or other deleterious materials are found at the foundation level, these materials should be removed and replaced with engineered fill consisting of compacted Granular A. The cleaned excavation base should be inspected by a Quality Verification Engineer (QVE) qualified in geotechnical engineering prior to construction of any levelling pad or footing and prior to placement of the first lift of backfill in the reinforced zone. It is recommended that footing excavations be carried out such that the final 0.5 metres of excavation is completed with the geotechnical personnel on site.

## **6.9 Excavations and Temporary Cut Slopes**

Excavations for the wall footings and RSS wall levelling pad will extend through the surficial topsoil and fill and terminate in the firm to very stiff clayey silt or dense silty fine sand. The footing excavations are not expected to intercept the groundwater level. Sumps used to remove excess water in the excavation following periods of high precipitation should be maintained outside of the actual footing limits. Surface water runoff should be directed away from the excavations at all times. The appropriate Non Standard Special Provision (NSSP) for the control of surface and water flows should be included in the contract documents.

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

Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical.

Where space is restricted and will not permit open cuts, a temporary roadway protection support system should be installed to support the sides of the excavation and permit the use of vertical cuts. The temporary support system could consist of soldier piles and lagging where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds or could consist of driven steel sheet piling. Support to the system could be in the form of struts and walers in the case of footing excavations or rakers and anchors in the case of roadway protection.

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.



## FOUNDATION INVESTIGATION AND DESIGN REPORT FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS

The unfactored triangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; increasing with depth), can be calculated as follows:

$$p = K_a (\gamma H + q)$$

where  $H$  = the height of the excavation at any point in metres

$K_a$  = active coefficient of earth pressure

$\gamma$  = soil unit weight

$q$  = surcharge for traffic and other loading

For the granular fill and native materials, the unfactored rectangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; constant with depth), can be calculated as follows:

$$p = 0.65 K_a (\gamma H + q)$$

where  $H$  = the total height of the excavation

$K_a$  = active coefficient of earth pressure

$\gamma$  = soil unit weight

$q$  = surcharge for traffic and other loading

For the cohesive native materials, the unfactored trapezoidal earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; varying with depth); can be calculated as follows:

$$p = 0.2\gamma H_T \text{ to } 0.4\gamma H_T$$

where  $H_T$  = the total height of the excavation

$\gamma$  = soil unit weight

$q$  = surcharge for traffic and other loading



## FOUNDATION INVESTIGATION AND DESIGN REPORT FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS

The support systems may be designed using the following parameters:

Soil Type	Coefficient of Earth Pressure			Angle Of Internal 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>		
Granular Fill	0.33	0.50	3.0	30	19.0
Clayey Silt	0.38	0.55	2.7	27	19.0
Sand and Silty Sand	0.35	0.52	2.9	29	20.0

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficients should be adjusted accordingly.

The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system.

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





## **7.0 MISCELLANEOUS**

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

**GOLDER ASSOCIATES LTD.**

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DUP/PRB/FJH/cr/ly

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ret walls se ramp parts a&b.docx

TABLE I

**COMPARISON OF RETAINING WALL ALTERNATIVES**

Fischer-Hallman Road S-E Ramp Retaining Walls  
 Highway 7/8 Widening  
 GWP 131-98-00

<b>RETAINING WALL OPTION</b>	<b>FEASIBILITY</b>	<b>ADVANTAGES</b>	<b>DISADVANTAGES</b>	<b>ESTIMATED COSTS</b>	<b>RISKS/ CONSEQUENCES</b>
RSS Wall	<ul style="list-style-type: none"> <li>• Feasible</li> <li>• Preferred Technical Alternative</li> </ul>	<ul style="list-style-type: none"> <li>• Lower cost option</li> <li>• Easier to construct; formwork not required</li> <li>• More rapid construction</li> <li>• Reduced site preparation and excavation effort particularly if levelling pad used</li> <li>• More tolerant of differential settlement</li> <li>• Lower space requirements in front of the wall</li> </ul>	<ul style="list-style-type: none"> <li>• Select granular backfill required within reinforced zone</li> <li>• Reinforcing elements subject to degradation from UV exposure or de-icing salts</li> <li>• Placement of highway infrastructure limited within reinforced zone</li> <li>• Design of construction of curved alignments can be difficult</li> </ul>	<ul style="list-style-type: none"> <li>• \$810 to \$1,160 per m<sup>2</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Low to Moderate risk</li> <li>• Risk highly dependent on adequacy of compaction control and care with which reinforcing elements are installed</li> </ul>
Concrete Cantilever Wall	<ul style="list-style-type: none"> <li>• Feasible</li> </ul>	<ul style="list-style-type: none"> <li>• Less stringent backfill requirements compared to an RSS wall</li> <li>• No restrictions on placement of highway infrastructure behind wall</li> <li>• Curved walls easily constructed</li> </ul>	<ul style="list-style-type: none"> <li>• More expensive option</li> <li>• Longer construction time</li> <li>• Less accommodating of differential settlement</li> <li>• Greater effort required for site preparation time and excavation</li> </ul>	<ul style="list-style-type: none"> <li>• \$975 to \$1,350 per m<sup>2</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Low risk</li> </ul>

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

Prepared By: DUP

Checked By: PRB

## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### 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 805**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4809296.0 ; E 222748.0

ORIGINATED BY MR

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY WDF/LMK

DATUM GEODETIC

DATE May 12, 2010

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  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
344.73	GROUND SURFACE							20	40	60	80	100						
0.00	TOPSOIL, silty Black																	
0.18	CLAYEY SILT, trace sand, trace gravel, with silty sand seams Firm to very stiff Brown		1	SS	6		344											
			2	SS	14		343											
			3	SS	16		342										0	15 60 25
			4	SS	15		341											
			5	SS	8		340											
340.16	SILTY FINE SAND, trace gravel Loose Brown		6	SS	5		339										0	48 38 14
339.70	CLAYEY SILT, trace gravel, with sand seams Stiff Brown		7	SS	11		338											
338.79	SILTY FINE SAND, trace clay Loose to compact Brown		8	SS	8		337										0	54 40 6
			9	SS	15		336											
337.64	CLAYEY SILT Very stiff Brown to grey		10	SS	34													
7.09	SILTY SAND, trace clay Dense to very dense Brown		11	SS	38													
7.32			12	SS	59													
335.13	END OF BOREHOLE																	
9.60	Borehole dry during drilling on May 12, 2010.																	

**RECORD OF BOREHOLE No 806**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4809312.0 ; E 222776.0

ORIGINATED BY MR

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY WDF/LMK

DATUM GEODETIC

DATE May 12, 2010

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									
345.35	GROUND SURFACE							20	40	60	80	100								
0.00	TOPSOIL, silty Black						345													
0.15	FILL, silt, some sand, trace clay, with topsoil Very Loose Brown		1	SS	2										○					
343.98							344													
1.37	FILL, clayey silt, some sand, with topsoil Firm Brown		2	SS	6									○			0 32 48 20			
343.22							343													
2.13	CLAYEY SILT, some sand, trace gravel, with sand seams Stiff to very stiff Brown		3	SS	14															
			4	SS	24		342													
			5	SS	11									○			0 22 56 22			
			6	SS	11		341													
			7	SS	18		340													
			8	SS	16		339								○		1 29 51 19			
			9	SS	14		338													
337.88																				
7.47	SANDY SILT Dense Brown		10	SS	50									○			0 41 52 7			
337.12							337													
8.23	SILTY FINE SAND Dense to very dense Brown		11	SS	49															
335.75			12	SS	53		336													
9.60	END OF BOREHOLE																			
	Borehole dry during drilling on May 12, 2010.																			

**RECORD OF BOREHOLE No 807**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4809343.0 ; E 222813.0

ORIGINATED BY MR

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY WDF/LMK

DATUM GEODETIC

DATE May 12, 2010

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT   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					W <sub>p</sub> W   W <sub>L</sub>				
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × LAB VANE					WATER CONTENT (%)				
342.58	GROUND SURFACE					▽		20	40	60	80	100					
0.00	TOPSOIL, silty						342										
0.13	Black						341								○		0   59   31   10
	SILTY FINE SAND, trace to some clay, trace gravel						340										
	Dense		1	SS	32												
	Brown		2	SS	32												
			3	SS	36												
339.68																	
2.90	SAND, some silt, trace clay						339										
	Compact														○		0   86   11   3
	Brown			4	SS		26										
			5	SS	26												
338.01																	
4.57	SILTY FINE SAND, trace to some clay					338											
	Compact																
	Brown			6	SS	25											
			7	SS	22												
			8	SS	25										○	0   61   29   10	
335.87																	
6.71	SAND, fine to medium, trace silt					336											
	Compact																
	Brown			9	SS	28											
335.11																	
7.47	CLAYEY SILT, with silty sand seams					335											
	Very stiff																
	Grey			10	SS	21											
			11	SS	21												
			12	SS	24												
332.98	END OF BOREHOLE						333										
9.60	Groundwater encountered at about elev. 339.7m during drilling on May 12, 2010.																

**RECORD OF BOREHOLE No 808**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4809361.5 ; E 222849.5

ORIGINATED BY MR

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY WDF/LMK

DATUM GEODETIC

DATE May 17, 2010

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  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	w <sub>p</sub> w      w <sub>L</sub>								
						● QUICK TRIAXIAL      × LAB VANE											
342.89	GROUND SURFACE					▽		20	40	60	80	100					
0.00	TOPSOIL, silty Black																
0.20	CLAYEY SILT, some sand, trace gravel, with silty sand layers Very stiff Brown turning grey at about elev. 339.8m		1	SS	17		342										
			2	SS	15		341										
			3	SS	18		340						10	20	30	0	27 53 20
339.63			4	SS	26		339										
3.26	SILTY SAND Compact Brown						338									1	27 58 14
339.23	SANDY SILT, some clay, trace gravel Compact Grey		5	SS	10		337						10	20	30		
3.66			6	SS	22		336										
			7	SS	28		335										
			8	SS	21		334										
			9	SS	26												
			10	SS	19												
334.66																	
8.23	CLAYEY SILT, trace silty sand seams, trace gravel Stiff to very stiff Grey		11	SS	11												
			12	SS	17												
333.29	END OF BOREHOLE																
9.60	Groundwater encountered at about elev. 339.6m during drilling on May 17, 2010.																

LDN\_MTO\_06 08-1132-084-1.GPJ LDN\_MTO.GDT 26/01/11



**RECORD OF BOREHOLE No 809**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1  
W.P. 131-98-00 LOCATION N 4809375.5 ; E 222877.0 ORIGINATED BY MR  
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF/LMK  
DATUM GEODETIC DATE May 17, 2010 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					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W <sub>P</sub>	W	W <sub>L</sub>		
343.20	GROUND SURFACE						20	40	60	80	100						
0.00	TOPSOIL, silty																
0.15	Black																
	CLAYEY SILT, with sand seams, trace gravel Stiff to very stiff Brown		1	SS	13												
			2	SS	23												
341.07																	
2.13	SANDY SILT, trace clay, trace gravel Compact Brown		3	SS	17												
			4	SS	11												
339.54																	
3.66	CLAYEY SILT, with sand seams, trace gravel Very stiff Brown		5	SS	27												
338.78																	
4.42	SILTY FINE SAND, trace gravel, trace clay Compact to dense Brown		6	SS	34												
			7	SS	29												
			8	SS	30												
			9	SS	32												
			10	SS	38												
			11	SS	35												
			12	SS	32												
333.60																	
9.60	END OF BOREHOLE																
	Borehole dry during drilling on May 17, 2010.																

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

**RECORD OF BOREHOLE No 810**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1  
W.P. 131-98-00 LOCATION N 4809396.0 ; E 222913.5 ORIGINATED BY MR  
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF/LMK  
DATUM GEODETIC DATE May 17, 2010 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 (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×					LAB VANE							
343.56	GROUND SURFACE																							
0.00	TOPSOIL, silty Black																							
0.18	FILL, clayey silt, with topsoil, trace gravel Stiff Brown and black		1	SS	8																			
342.19																								
1.37	CLAYEY SILT, some sand, trace gravel Stiff to very stiff Brown		2	SS	12													1	11	63	25			
			3	SS	16																			
340.66																								
2.90	SANDY SILT, some clay, trace gravel Compact Brown		4	SS	14																			
			5	SS	19																			
			6	SS	16																			
338.38																								
5.18	CLAYEY SILT, trace sand, trace gravel Very stiff Grey		7	SS	19																			
			8	SS	17																			
336.85																								
6.71	SANDY SILT, trace to some clay, trace gravel Compact Brown		9	SS	19																			
			10	SS	13																			
			11	SS	10																			
334.57																								
8.99	SAND, fine to medium, trace silt Dense Brown		12	SS	37																			
333.96																								
9.60	END OF BOREHOLE																							
	Borehole dry during drilling on May 17, 2010.																							

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



**RECORD OF BOREHOLE No 812**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4809254.8 ; E 222736.6

ORIGINATED BY MR

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY WDF/LMK

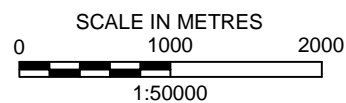
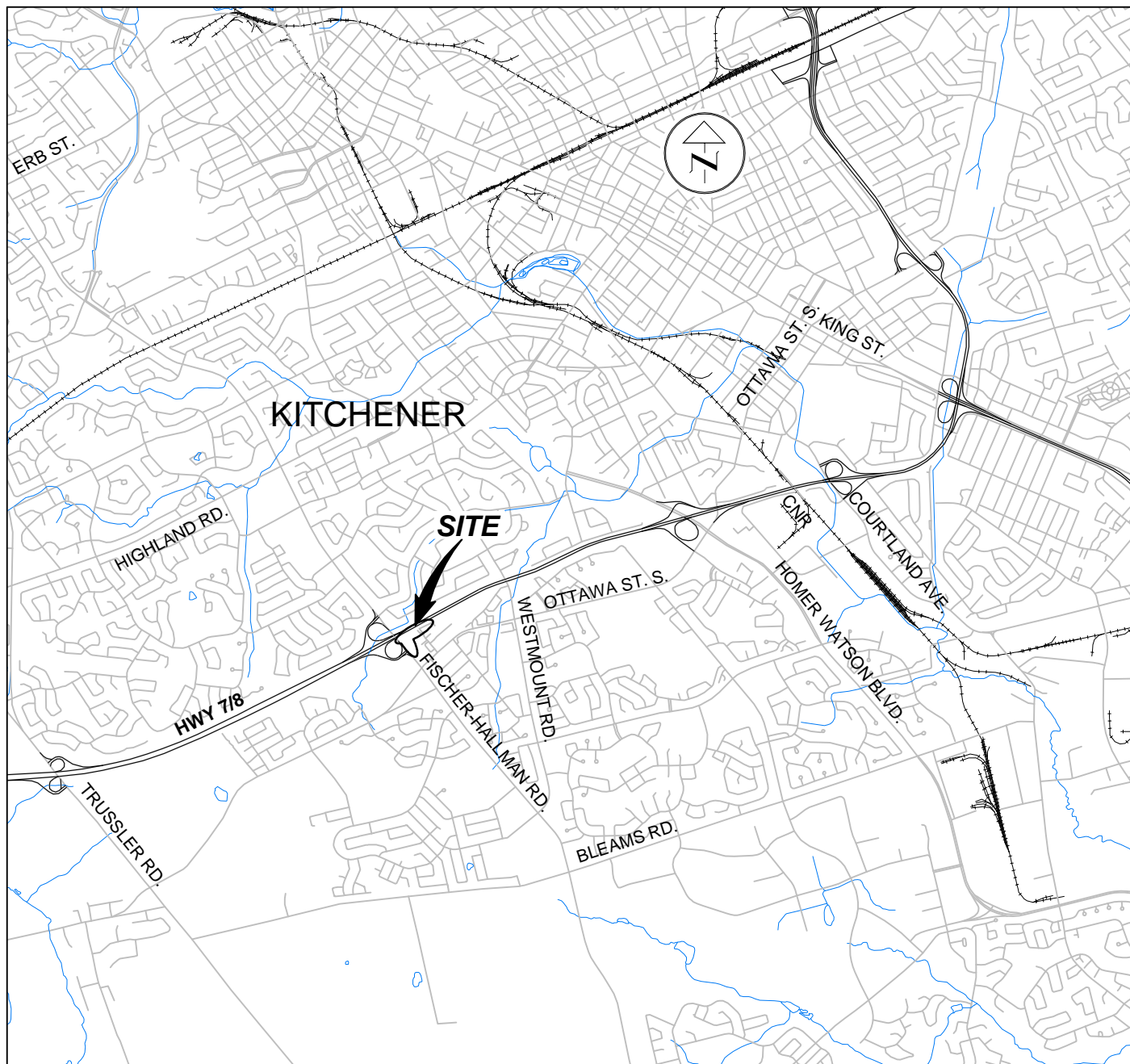
DATUM GEODETIC

DATE June 8, 2010

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										
350.05	ROAD SURFACE						20	40	60	80	100									
0.00	ASPHALT																			
0.18	FILL, sand and gravel, crushed Brown																			
0.38	FILL, sand and gravel, some silt with cobbles Dense Brown		1	SS	31								○							
348.68																				
1.37	FILL, sandy silt, trace to some clay, trace gravel, with topsoil layers at about elev. 346.1m Loose to compact Brown		2	SS	19								○							
			3	SS	8								○							
			4	SS	11								○				4 28 51 17			
			5	SS	14								○							
													○							
			6	SS	9								○							
344.87																				
5.18	SANDY SILT, trace clay Compact Brown		7	SS	15								○							
			8	SS	18								○							
343.04																				
7.01	SAND AND GRAVEL, with cobbles, trace silt, trace clay Dense Brown		9	SS	43								○				42 48 7 3			
341.06																				
8.99	SILTY FINE SAND, trace clay, trace gravel Compact to dense Brown		10	SS	19															
			11	SS	32								○				1 58 36 5			
			12	SS	42															
337.40																				
12.65	END OF BOREHOLE																			
	Borehole dry during drilling on June 8, 2010.																			

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



## REFERENCE

DRAWING BASED ON CANMAP STREETFILES V2005.4.

## NOTE

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

### PROJECT

FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS  
WIDENING OF HIGHWAY 7/8  
GWP 131-98-00

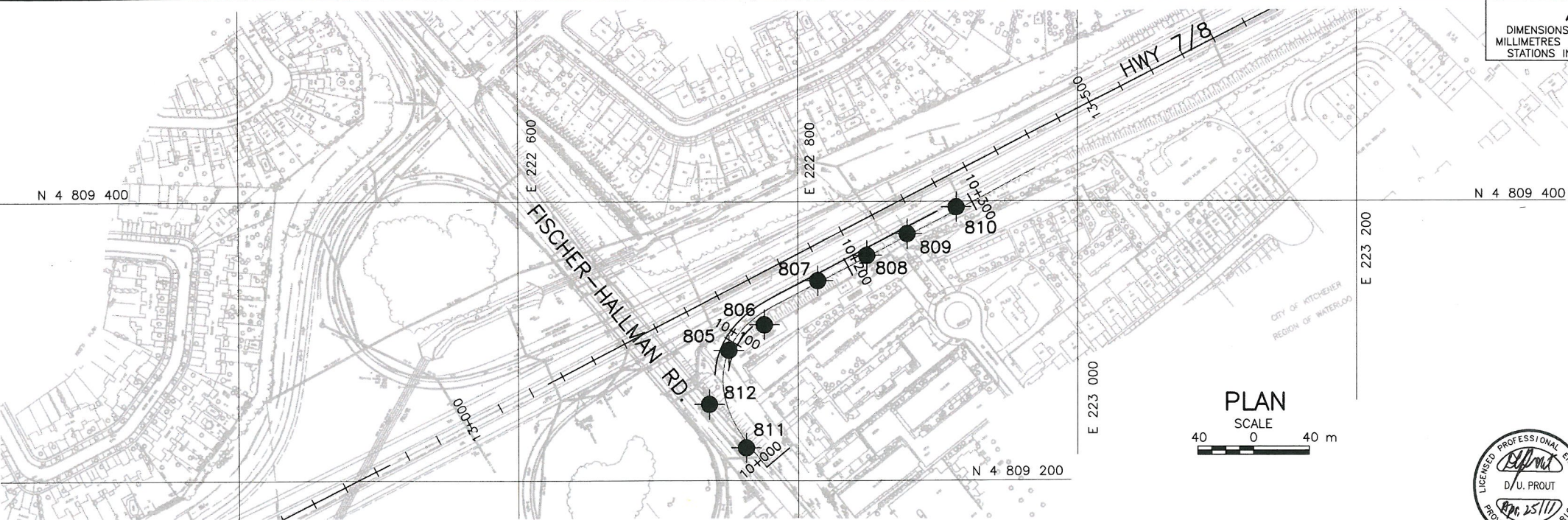
### TITLE

## KEY PLAN



PROJECT No.			FILE No.		
08-1132-084-1			0811320841-F16001		
CADD	WF/AG/LK	Feb. 18/11	SCALE	AS SHOWN	REV.
CHECK			<b>FIGURE 1</b>		





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

CONT No.  
 WP No. 131-98-00

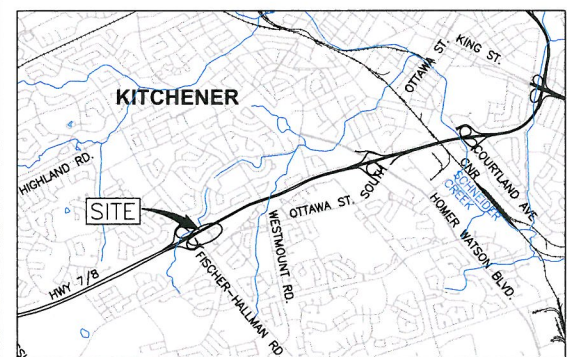


SHEET

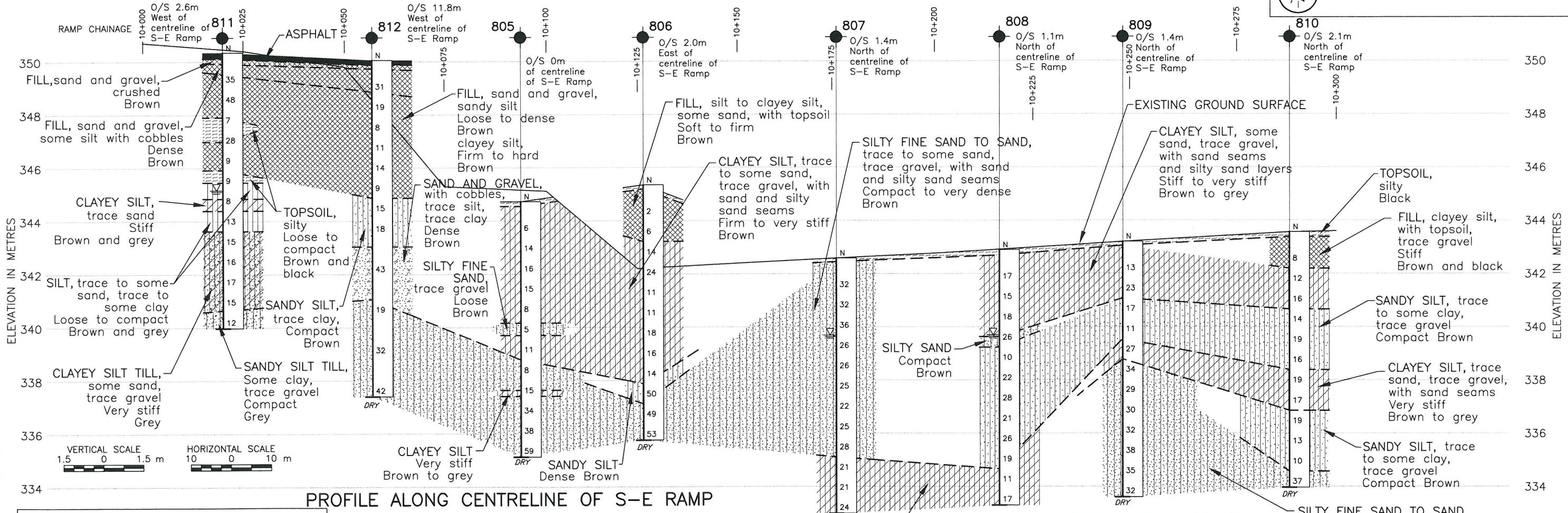
FISCHER-HALLMAN ROAD, S-E RAMP/RETAINING WALLS  
 WIDENING OF HIGHWAY 7/8  
 BOREHOLE LOCATIONS AND SOIL STRATA



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



KEY PLAN  
 SCALE IN KILOMETRES



PROFILE ALONG CENTRELINE OF S-E RAMP

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

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
805	344.73	4 809 296.0	222 748.0
806	345.35	4 809 312.0	222 776.0
807	342.58	4 809 343.0	222 813.0
808	342.89	4 809 361.5	222 849.5
809	343.20	4 809 375.5	222 877.0
810	343.56	4 809 396.0	222 913.5
811	350.34	4 809 223.6	222 763.0
812	350.05	4 809 254.8	222 736.6

CLAYEY SILT, with silty sand seams, trace gravel Stiff to very stiff Grey

**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.  
 Stratigraphy has been simplified for clarity. Please refer to Record of Boreholes for further details.

**REFERENCE**

Base plans provided in digital format by Dillon Consulting Limited.

NO.	DATE	BY	REVISION

Geocres No. 40P7-62

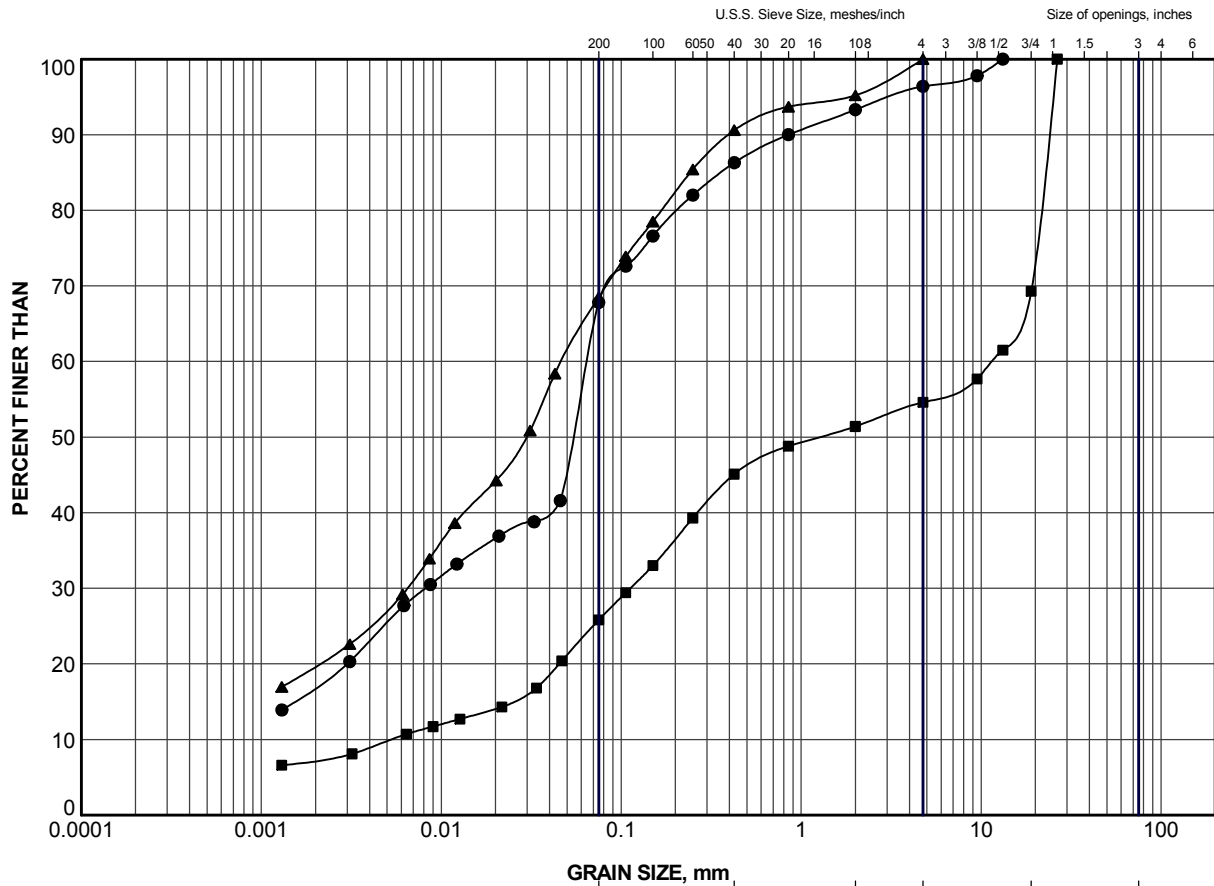
HWY. 7/8	PROJECT NO. 08-1132-084-1	DIST.
SUBM'D. ML	CHKD.	DATE: Feb. 18/11
DRAWN: WF/LK/AG	CHKD.	APPD.
		DWG. 1





# **APPENDIX A**

## **Laboratory Test Data**



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

### LEGEND

SYMBOL BOREHOLE SAMPLE ELEV (m)

#### NON-COHESIVE

■ 811 5 346.3  
● 812 4 346.8

#### COHESIVE

▲ 806 2 343.6

PROJECT  
FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS  
WIDENING OF HIGHWAY 7/8  
GWP 131-98-00

TITLE

## GRAIN SIZE DISTRIBUTION FILL

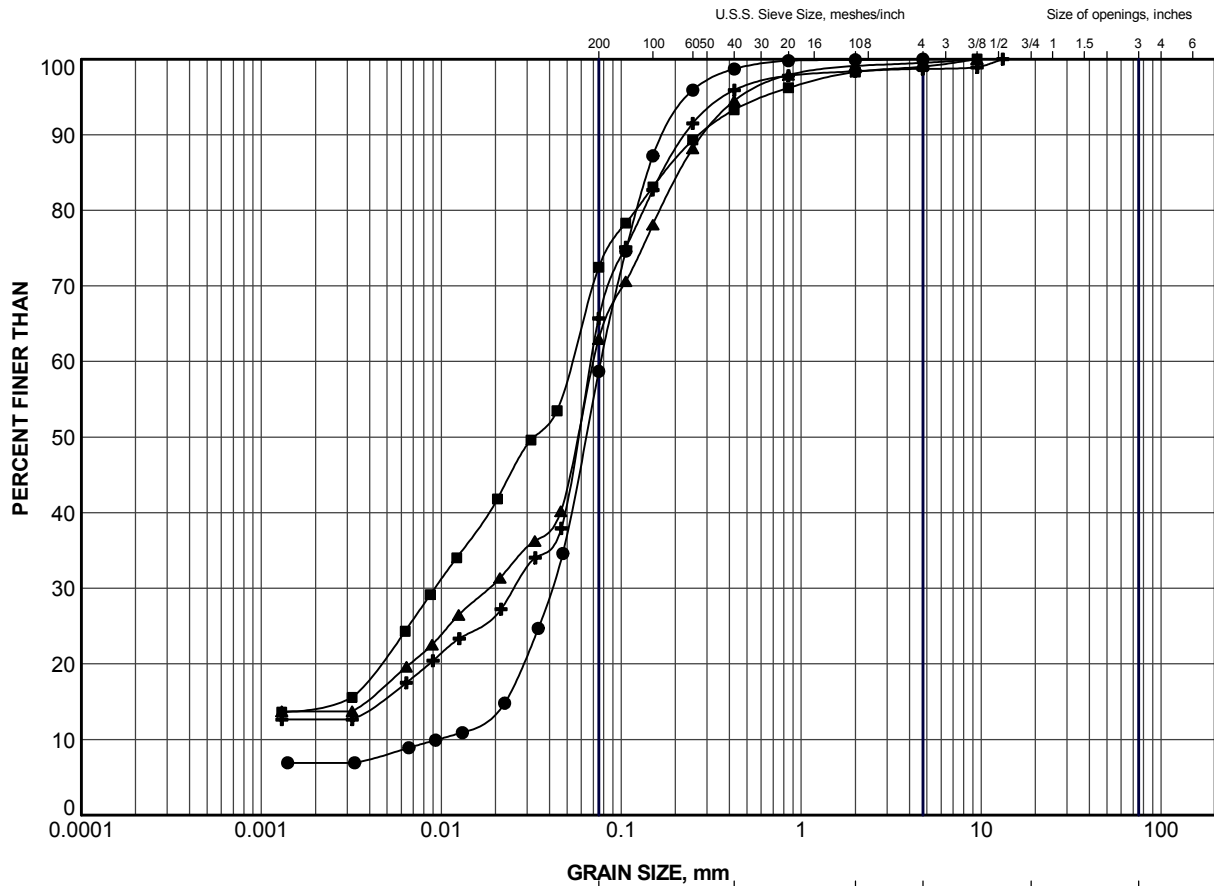


**Golder  
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LONDON, ONTARIO

PROJECT No.	08-1132-084-1	FILE No.	0811320841-F160A1
DRAWN	LMK	Feb. 18/11	SCALE N/A REV.
CHECK			

**FIGURE A-1**





### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	806	10	337.5
■	808	6	338.1
▲	810	6	338.8
+	810	9	336.5

PROJECT  
FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS  
WIDENING OF HIGHWAY 7/8  
GWP 131-98-00

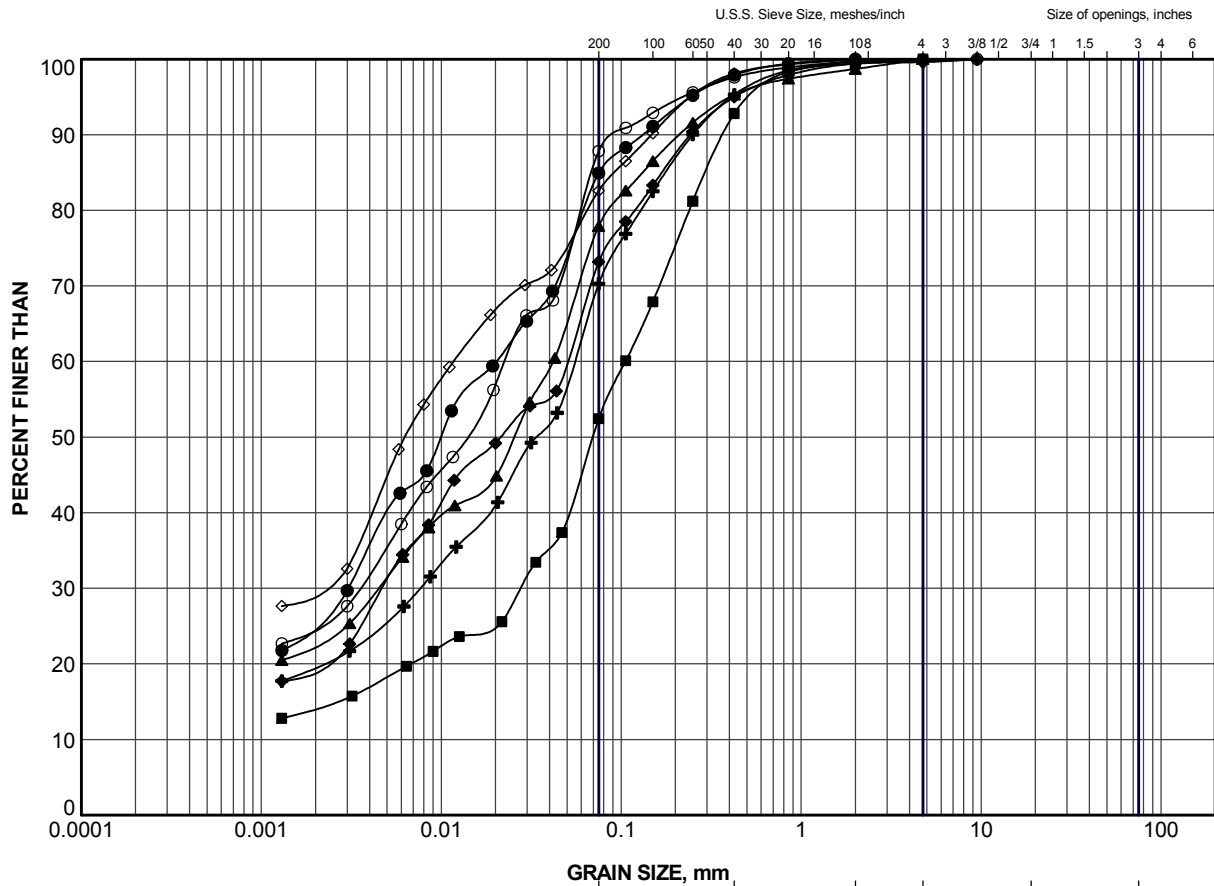
TITLE

## GRAIN SIZE DISTRIBUTION SANDY SILT



PROJECT No.	08-1132-084-1	FILE No.	0811320841-F160A2
DRAWN	AG/LMK	Feb. 18/11	SCALE N/A REV.
CHECK			


**FIGURE A-2**

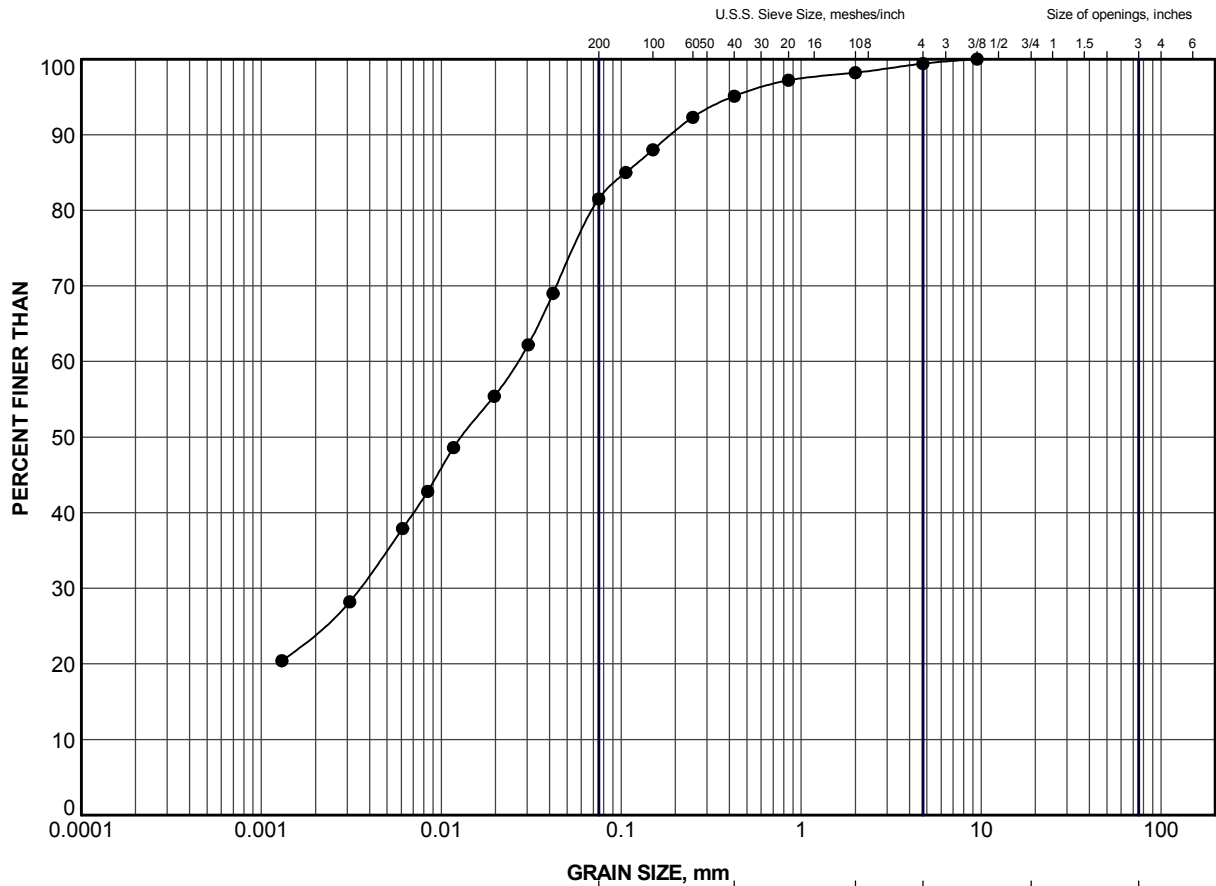


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	805	3	342.2
■	805	7	339.2
▲	806	5	341.3
+	806	8	339.0
◆	808	3	340.4
◇	809	2	341.5
○	810	2	341.8

PROJECT			
FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE			
GRAIN SIZE DISTRIBUTION CLAYEY SILT			
PROJECT No. 08-1132-084-1		FILE No. 0811320841-F160A3	
DRAWN	AG/LMK	Feb. 18/11	SCALE N/A REV.
CHECK			
 <b>Golder Associates</b> LONDON, ONTARIO			<b>FIGURE A-3</b>



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


LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	811	9	343.3

PROJECT

FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS  
WIDENING OF HIGHWAY 7/8  
GWP 131-98-00

TITLE

GRAIN SIZE DISTRIBUTION  
CLAYEY SILT TILL



Golder

Associates

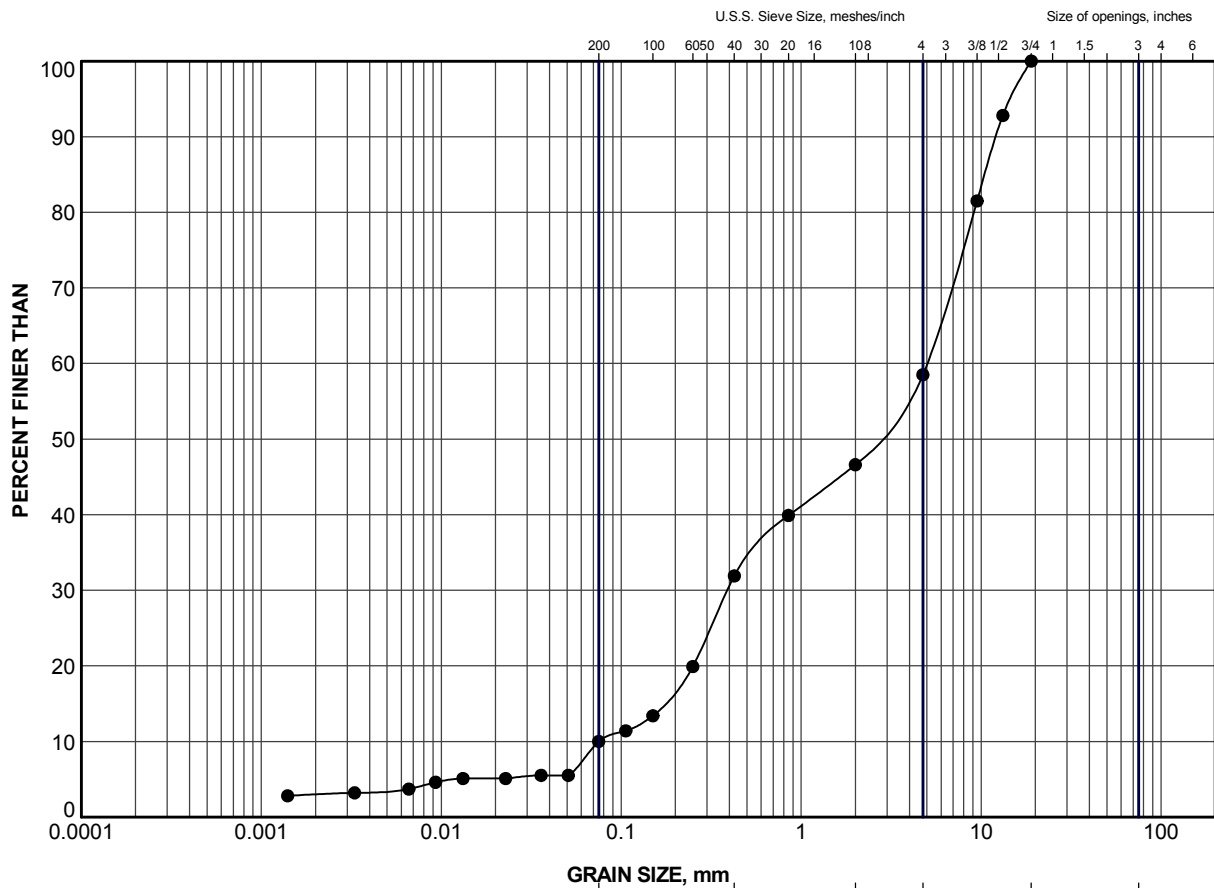
LONDON, ONTARIO

PROJECT No.	08-1132-084-1	FILE No.	0811320841-F160A4
DRAWN	LK/AG	Feb. 18/11	SCALE N/A
CHECK			REV.

FIGURE

A-4

LDN\_MTO\_NEW\_GILDR\_LDN.GDT



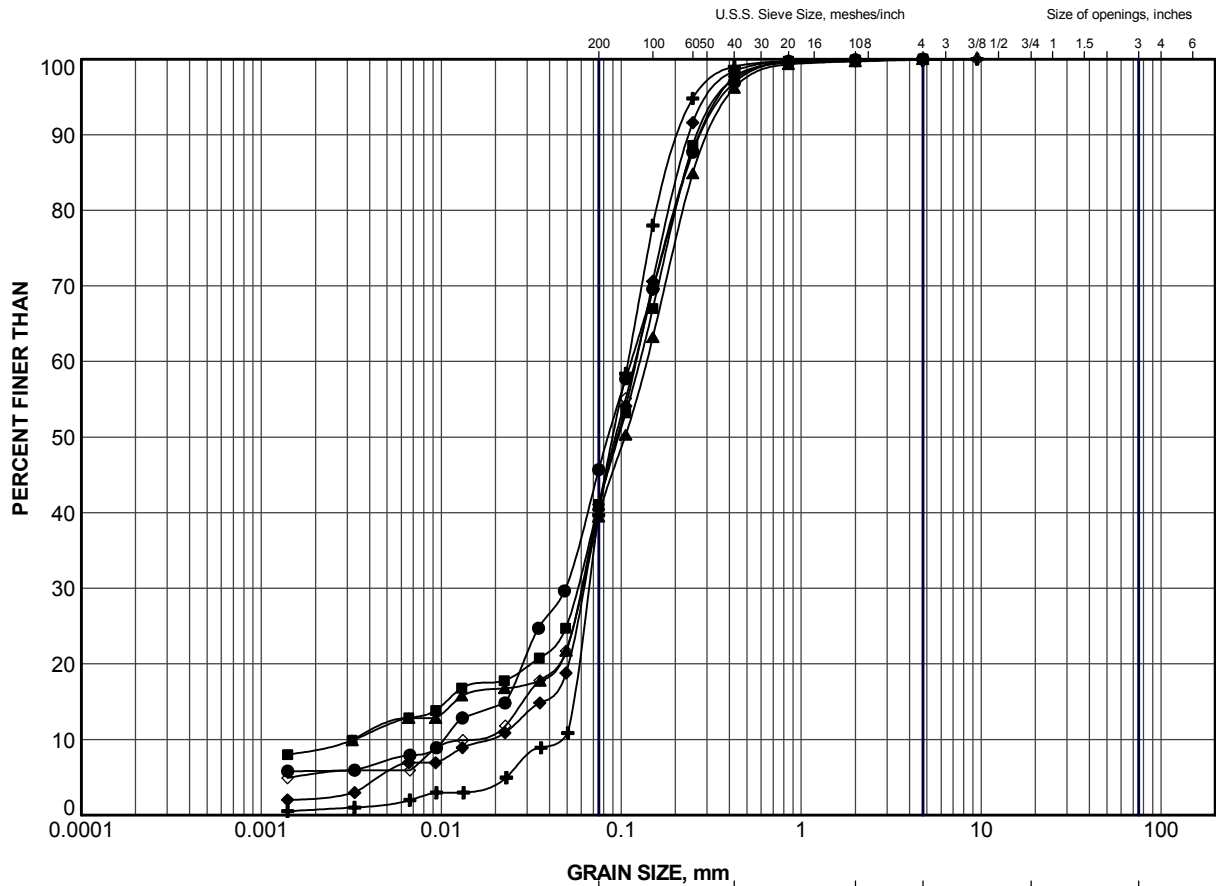
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	812	9	342.2

PROJECT FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE <b>GRAIN SIZE DISTRIBUTION SAND AND GRAVEL</b>			
PROJECT No. 08-1132-084-1		FILE No. 0811320841-F160A5	
DRAWN	LK/AG	Feb. 18/11	SCALE N/A REV.
CHECK			<b>FIGURE A-5</b>





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

#### LEGEND

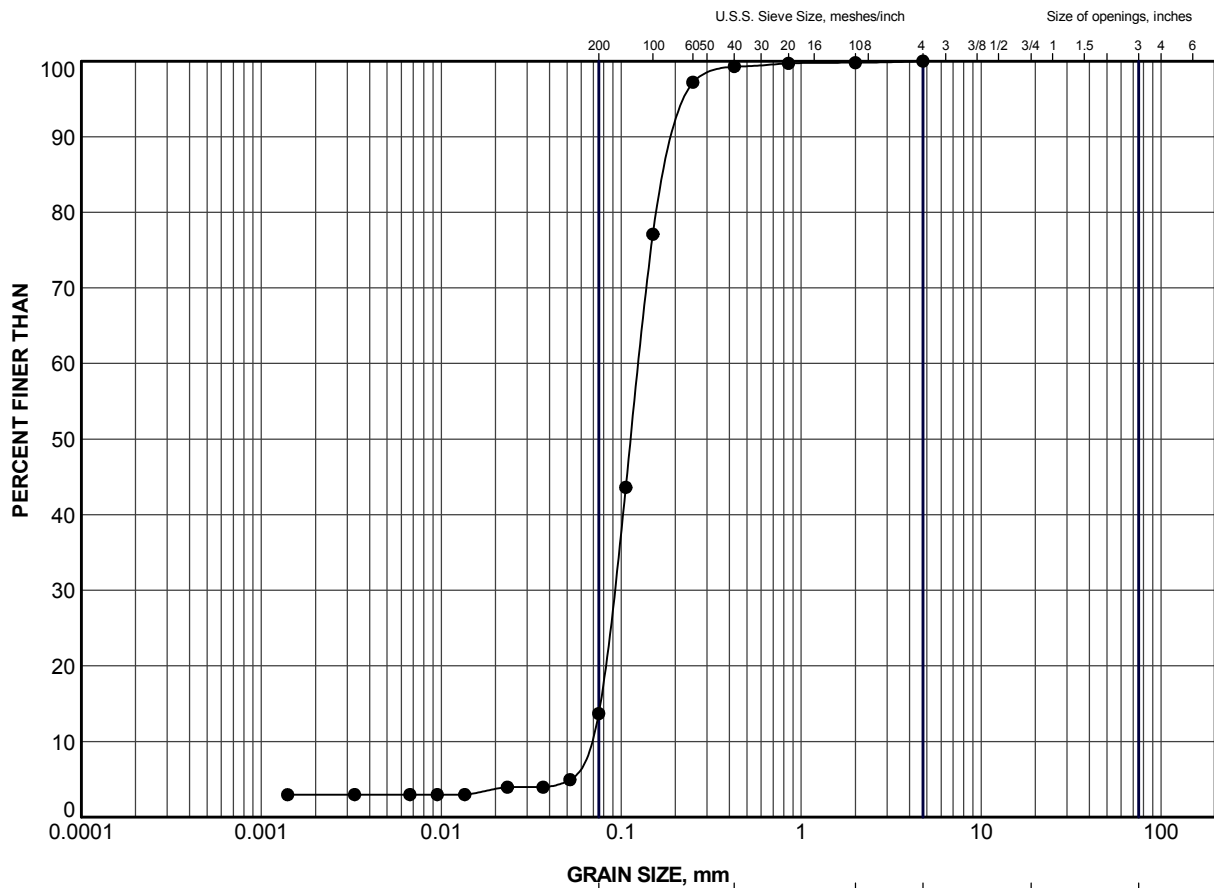
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	805	10	336.9
■	807	2	340.8
▲	807	8	336.3
+	809	6	338.4
◆	809	9	336.1
◇	812	11	339.2

PROJECT  
FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS  
WIDENING OF HIGHWAY 7/8  
GWP 131-98-00

TITLE  
**GRAIN SIZE DISTRIBUTION**  
**SILTY SAND**




PROJECT No.	08-1132-084-1	FILE No.	0811320841-F160A6
DRAWN	AG/LMK	Feb. 18/11	SCALE N/A REV.
CHECK			<b>FIGURE A-6</b>

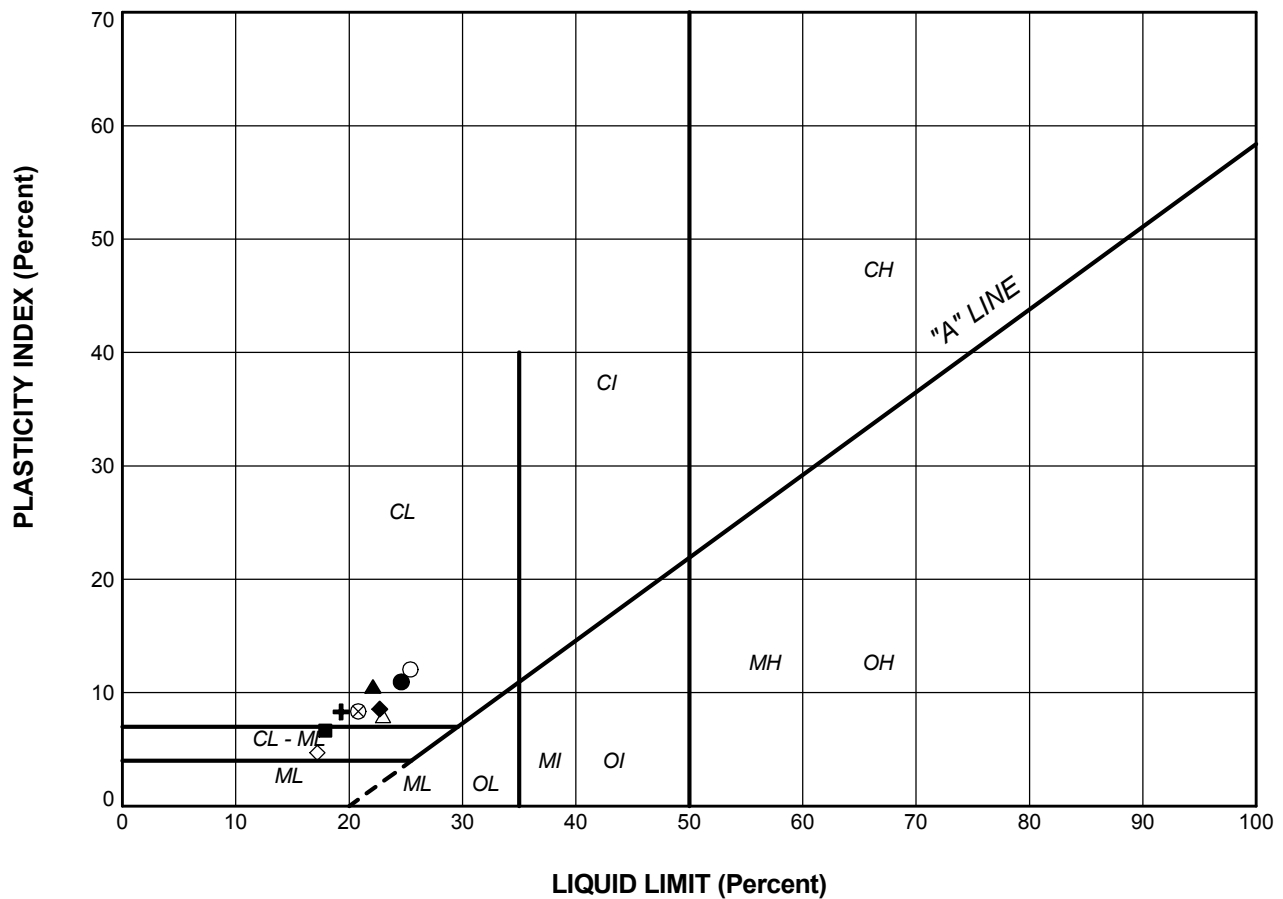


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	807	5	338.5

PROJECT FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE <b>GRAIN SIZE DISTRIBUTION</b> <b>SAND</b>			
PROJECT No. 08-1132-084-1		FILE No. 0811320841-F160A7	
DRAWN	AG/LMK	Feb. 18/11	SCALE N/A REV.
CHECK			
 <b>Golder Associates</b> LONDON, ONTARIO			<b>FIGURE A-7</b>



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
FILL-COHESIVE					
▲	806	2	22.1	11.6	10.6
CLAYEY SILT TILL					
⊗	811	9	20.8	12.5	8.4
CLAYEY SILT					
●	805	3	24.6	13.7	11.0
■	805	7	17.9	11.3	6.7
+	806	5	19.3	11.0	8.3
◆	808	3	22.7	14.2	8.6
○	809	2	25.4	13.4	12.1
△	810	2	23.0	15.1	8.0
SANDY SILT					
◇	808	7	17.2	12.5	4.7

PROJECT  
 FISCHER-HALLMAN ROAD S-E RAMP RETAINING WALLS  
 WIDENING OF HIGHWAY 7/8  
 GWP 131-98-00

TITLE

### PLASTICITY CHART



PROJECT No.	08-1132-084-1	FILE No.	0811320841-F160A8
DRAWN	LMK	Feb. 18/11	SCALE N/A REV.
CHECK			

**FIGURE A-8**

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

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North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

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

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