



January 2011



## FOUNDATION INVESTIGATION AND DESIGN REPORT

**Proposed Noise Barrier Wall 1A**

**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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## FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 1A

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#### APPENDIX A

Laboratory Test Data



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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
PROPOSED NOISE BARRIER WALL 1A**

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**PART A**

**FOUNDATION INVESTIGATION REPORT**

**PROPOSED NOISE BARRIER WALL 1A**  
**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**



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## FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 1A

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### 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 conducted for proposed noise barrier wall 1A that will be located to the west of the Fischer-Hallman Road Interchange from Station 12+500 to 12+785 Lt along the north side of Highway 7/8.

The purpose of the foundation investigation is to determine the subsurface conditions at the locations 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, Golder Associates' proposal P81-3002 dated April 8, 2010, 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 the locations and extents of the noise wall barriers in plan for this project in digital format.



## 2.0 SITE DESCRIPTION

### 2.1 General

The project area of Highway 7/8 is located in the south-central area of Kitchener, Ontario. The project limits extend from 1.9 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. The location of proposed noise barrier wall 1A is shown on the Noise Barrier Wall Location Plan, Figure 2.

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

Proposed noise barrier wall 1A is to be constructed west of the Fischer-Hallman Road Interchange from Station 12+500 to 12+785 Lt along Highway 7/8. Land use adjacent to this site is typically urban residential. The Voisin Greenway Mall shopping complex is located southwest of the Fischer-Hallman Road Interchange.

The topography is hummocky and generally slopes northeast towards Borden Creek. The ground surface elevations along the wall alignment vary from approximately elevation 351 to 345 metres immediately west of the Fischer-Hallman Road Interchange.

### 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 are ridges 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 Northern Development and Mines Map 2559 entitled "Quaternary Geology, Stratford Area", the site lies on the edge of an area of ice-contact gravel surrounded by Maryhill Till (clay till) deposits. The ice-contact gravel deposits are described as "poorly to well sorted, fine gravel and/or sand to coarse gravel and/or sand textured". Areas of ice-contact sand are present to the east of the site.

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 Area,

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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.



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## FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 1A

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Southern Ontario”, the bedrock surface at the site is at about elevation 270 metres with the bedrock sloping downwards towards the east end of the site.



### 3.0 INVESTIGATION PROCEDURES

The foundation investigation for the design of proposed noise barrier wall 1A was carried out on May 3 and 4, 2010 during which time five boreholes were drilled on Highway 7/8 along the alignment of the proposed noise barrier wall. The borehole locations are shown on the Borehole Location Plan, Drawing 1.

The boreholes (17 to 21) were advanced to a depth of 4.7 to 6.6 metres. 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)
17	4 809 031	222 085	350.38	4.67
18	4 809 063	222 153	348.42	5.03
19	4 809 096	222 220	346.75	5.79
20	4 809 130	222 287	345.41	6.55
21	4 809 165	222 354	344.70	5.18

The drilling was carried out using a track mounted CME 55 power auger supplied and operated by a specialist drilling contractor. In the boreholes, samples of the overburden were obtained at 0.75 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.

The groundwater conditions were observed throughout the drilling operations and upon completion of drilling. A summary of the groundwater level observations for all of the boreholes is presented in Table 1. 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.

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





## **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 are inferred from non-continuous sampling and observations of drilling resistance and 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 variable ground conditions, consisting of surficial topsoil and / or variable layers of fill underlain by sand and gravel, silty sand, sandy silt, silt, sand and silty clay.

A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized below.

#### **4.1.1 Fill**

All of the boreholes were advanced in the existing shoulder area of Highway 7/8. Granular roadbase materials were encountered from ground surface in boreholes 17 to 21, inclusive. The thickness of the granular roadbase varied from 200 to 580 millimetres.

Granular fill was encountered underlying the granular roadbase in boreholes 19, 20 and 21 at elevations 346.4, 344.8 and 344.2 metres, respectively. In borehole 18, granular fill was found underlying layers of cohesive fill at elevation 347.1 metres. The granular fill comprised sand, silty sand, silt and sandy silt and was found to be approximately 1.0 to 2.3 metres thick.

The granular fill had standard penetration test N values ranging from 8 to 40 blows per 0.3 metres with water contents which ranged from 11 to 23 per cent.

Cohesive fill layers consisting of clayey silt were encountered underlying granular fill or granular roadbase in boreholes 18, 19 and 20 at elevations 347.9, 345.4 and 343.3 metres, respectively. The thickness of the cohesive fill varied from 0.8 to 1.5 metres. It should be noted that cobbles and boulders were encountered during drilling in borehole 17 and borehole 19 at elevations 347.6 and 343.7 metres, respectively. Boulders were encountered at elevation 347.6 metres in borehole 17. Further, traces of topsoil were observed within the cohesive fill layers in boreholes 19 and 20 from elevations 345.4 and 343.3 metres, respectively.

The cohesive fill had N values ranging from 9 blows to over 100 blows per 0.3 metres penetration. Four water contents of 11 to 16 per cent were measured from samples obtained during standard penetration testing. Due to insufficient recovery of the samples in borehole 19 at elevations 345.4 and 342.9 metres, Atterberg limits testing



was carried on only one sample. The plastic limit, liquid limit and plasticity index were measured to be 14, 25 and 11 per cent, respectively. The Atterberg limits results for the cohesive fill are presented on Figure A-7.

The results of the grain size testing conducted on granular and cohesive fill materials are presented on Figure A-1 in Appendix A.

### 4.1.2 Topsoil

Topsoil was encountered underlying the fill in borehole 19 at elevation 342.2 metres. The approximate thickness of the topsoil was 460 millimetres. A water content of 17 per cent was measured from a sample obtained during standard penetration testing. 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 Sand and Gravel

A layer of very dense sand and gravel was encountered in borehole 17 from elevation 350.2 metres. Borehole 17 was terminated after investigating the sand and gravel for 4.5 metres.

The N values in the sand and gravel ranged from 68 blows to over 100 blows per 0.3 metres. The general trend of the N values indicated the sand and gravel increases in density with increases in depth. The sand and gravel had a water content of 3 per cent.

The results of the grain size testing conducted on a sand and gravel sample obtained during the standard penetration testing are presented on Figure A-2.

Cobbles and boulders were encountered in the sand and gravel.

### 4.1.4 Silty Sand

Layers of loose to compact silty sand to silty fine sand were encountered underlying layers of fill in boreholes 18 and 21 at elevations 344.8 and 342.9 metres, respectively. The silty sand was found overlying sandy silt in both boreholes. The thicknesses of the silty sand layers were 0.8 and 1.1 metres in boreholes 18 and 21, respectively.

The silty sand had N values of 8 to 17 blows per 0.3 metres and water contents of 16 to 17 per cent.

The results of grain size testing conducted on silty sand samples obtained during standard penetration testing are presented on Figure A-3.



#### **4.1.5 Sandy Silt**

Sandy silt layers were found underlying silty sand in boreholes 18 and 21 at elevations 344.0 and 341.8 metres, respectively. The thickness of the sandy silt layer in borehole 21 was approximately 0.8 metres. Borehole 18 was terminated in the sandy silt after exploring it for 0.6 metres.

The sandy silt had N values of 11 and 37 blows per 0.3 metres indicating a compact to dense condition. Water contents of 8 and 13 per cent were measured on samples obtained during standard penetration testing. An Atterberg limits determination was carried out for a sandy silt sample that contained some clay which confirmed the material to be non-plastic.

The results of a grain size analysis conducted on a single sandy silt sample obtained during standard penetration testing are presented on Figure A-4.

#### **4.1.6 Silt**

A compact layer of silt was encountered in borehole 19 underlying topsoil at elevation 341.7 metres. Borehole 19 was terminated in the silt after exploring the stratum for 0.8 metres. The silt had an N value of 22 blows per 0.3 metres.

#### **4.1.7 Sand**

A layer of sand was encountered in borehole 20 at elevation 341.8 metres. The sand was found underlying layers of fill. Borehole 20 was terminated in the sand after exploring the stratum for 2.9 metres.

N values in the sand layer ranged from 1 to 32 blows per 0.3 metres. The sand above the groundwater level was dense. Below the groundwater table, the N values generally indicated the sand to be in a loose to compact condition. A water content of 6 per cent was measured for a sand sample.

The grain size distribution curve for a sample of sand obtained during standard penetration testing is presented on Figure A-5.

#### **4.1.8 Silty Clay**

A layer of silty clay with silt seams was encountered in borehole 21 underlying sandy silt at elevation 341.0 metres. Borehole 21 was terminated in the silty clay after exploring it for 1.5 metres.



## FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 1A

The N values in the silty clay were 14 and 16 blows per 0.3 metres indicating a stiff to very stiff consistency. A water content of 23 per cent was measured. The Atterberg limits testing determined the plastic limit, liquid limit and plasticity index to be 18, 38 and 20 per cent, respectively, indicating an inorganic clay of intermediate plasticity. The results of the Atterberg limit test are presented on Figure A-7.

The grain size distribution curve for the silty clay is shown on Figure A-6.

### 4.2 Groundwater Conditions

The groundwater conditions in the current boreholes were monitored during and upon completion of drilling. The observed groundwater conditions are noted on the Record of Borehole sheets and are summarized in the following text and Table 1.

**Table 1: Summary of Encountered Groundwater Levels**

Borehole	Ground Surface Elevation	Encountered Groundwater Level	
		Depth	Elevation
	(m)	(m)	(m)
17	350.38	Dry	Below 345.7
18	348.42	Dry	Below 343.4
19	346.75	5.2	341.6
20	345.41	4.4	341.0
21	344.70	1.8	342.9

During the fieldwork, groundwater was encountered between elevations 341.0 and 342.9 metres in boreholes 19 to 21. Boreholes 17 and 18 were dry during and upon completion of drilling. It should be noted that the above encountered groundwater level observations are not considered to be representative of the long-term, stabilized groundwater conditions as the readings were taken for a short duration only. The long-term inferred groundwater level is expected to vary from below elevation 346 metres near Station 12+500 Lt to elevation 341 metres at Station 12+700 and elevation 343 metres near Station 12+775 Lt. 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. 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  
PROPOSED NOISE BARRIER WALL 1A**

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**PART B**

**FOUNDATION DESIGN REPORT**

**PROPOSED NOISE BARRIER WALL 1A**

**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 geotechnical parameters and recommendations for the geotechnical aspects of the design for proposed noise barrier wall 1A along the north side of Highway 7/8 between Stations 12+500 and 12+785 Lt. This new segment of noise barrier wall is to be shoulder mounted.

The design parameters and recommendations have been developed based on interpretation of the factual data obtained from the boreholes advanced at the site. The interpretation and recommendations provided are intended to provide the designers with sufficient information to design the proposed noise barrier wall foundations. Where comments are made on construction, they are provided in order to highlight those aspects that could affect the design or for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect the equipment selection, proposed construction methods, scheduling and the like.

### **6.2 Noise Barrier Wall Foundation Design**

The noise barrier wall foundations should be designed and constructed in accordance with MTO's SP599F01. It is recommended that the noise barrier wall be supported using conventional augered caissons with a diameter of 0.6 to 0.9 metres. Geotechnical design parameters for design of the caisson foundations are provided in Table I following the text of this report based on the soil conditions encountered along the proposed noise barrier wall alignment. The stratigraphy presented in Table I has been simplified for the purposes of the noise barrier wall foundation design.

Where both an undrained shear strength,  $c_u$ , and an effective friction angle,  $\phi'$ , have been given for a specific stratum, the caisson design should be checked for both the drained and undrained condition and the larger of the two calculated caisson depths shall govern.

Portions of the caisson that will be embedded in organic materials, such as the topsoil in borehole 19, should be neglected in the design. The passive resistance in the upper 1.4 metres below the ground should be neglected to account for frost action. In addition, for foundation design, full passive resistance will be mobilized only where the ground surface in front and behind the caisson is level. Where sloping ground is present adjacent to the noise barrier wall, the  $K_p$  values used in the calculation should be adjusted to account for the presence of the sloping ground. The entire noise barrier wall will be constructed along the crest of the highway embankment which will have side slopes of 2 horizontal to 1 vertical. Adjusted  $K_p$  values are provided in Table I for these areas. The adjusted  $K_p$  value is to be applied to that portion of the caisson that is above the elevation of the ground surface at the toe of the embankment or slope; below this elevation, the full  $K_p$  is to be applied.



## FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 1A

A 2100 by 1640 millimetre oval corrugated steel pipe (CSP) culvert is located near approximately Station 12+710 Lt. The approximate top of obvert elevation of this culvert is 342 metres. The presence of this culvert must be considered in the design of the foundations for the proposed noise barrier wall.

### 6.3 Construction Considerations

Excavations for the construction of the caisson noise barrier wall foundations will penetrate the surficial fill and will extend through or into deposits of sand and gravel, silty sand, sandy silt, silt, sand and silty clay. The sands are predominantly fine to medium coarse grained and uniform in composition. The sands, silts and silty clays at this site are susceptible to disturbance during caisson excavation and construction. In addition, excavation of granular materials below the groundwater level will be required along the eastern portion of proposed noise barrier wall 1A beyond approximately Station 12+700 Lt.

With proactive dewatering, a temporary liner will be required to support the sides of the excavation and permit cleaning and inspection of the base. Careful cleaning of the base of the caisson should be carried out prior to placement of concrete to remove all loosened or disturbed materials. Alternatively, the foundations could be installed using mud drilling techniques (augered with the hole filled with bentonite slurry) and placement of the concrete by tremie. Surface water run off should be directed away from the excavation. It is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to alert the Contractor about the requirements for support of augered excavations and measures to deal with excavation of saturated granular soils below the groundwater level. The contractor should be prepared for the presence of cobbles and boulders within the fill, particularly near Stations 12+500 Lt and 12+625 Lt and in the sand and gravel near Station 12+500 Lt.

The caissons should be constructed and inspected in accordance with Ontario Provisional Standard Specifications 903 and SP599F01. Following construction, the Quality Verification Engineer shall submit a Certificate of Conformance confirming that the noise barrier wall foundations have been constructed in general conformance with the Contract Documents.





## **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.

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TABLE I

**FOUNDATION DESIGN PARAMETERS  
PROPOSED NOISE BARRIER WALL 1A**

Widening of Highway 7/8  
GWP 131-98-00

Station and Borehole	Soil Type	Elevation Interval (m)	Design Groundwater Elevation (m)	Undrained Shear Strength, $c_u^1$ (kPa)	Effective Angle of Friction, $\phi^1$ (°)	Coefficient of Passive Pressure, $K_p^2$ Level Ground / 2H:1V Slope	Coefficient of Active Pressure, $K_a$ Level Ground	Unit Weight <sup>3</sup> (kNm <sup>-3</sup> )	
								Bulk $\gamma$	Effective, $\gamma'$
12+500 to 12+525 Borehole 17	Very dense sand and gravel	Below 349	Below 346	-	35	3.7 / 1.4	0.27	21.0	11.0
12+525 to 12+600 Borehole 18	Compact to dense granular fill	Above 345	Below 343	-	30	3.0 / 1.1	0.33	19.0	9.0
	Compact silty sand to dense sandy silt	Below 345		-	30	3.0 / 1.1	0.33	19.0	9.0
12+600 to 12+665 Borehole 19	Stiff to hard cohesive fill	345 to 342	342	125	28	2.8 / 1.0	0.36	18.5	8.5
	Compact silt	Below 342		-	30	3.0 / 1.1	0.33	18.5	8.5
12+665 to 12+750 Borehole 20	Compact granular fill	344 to 343	341	-	30	3.0 / 1.1	0.33	19.0	9.0
	Stiff to very stiff cohesive fill	343 to 342		100	28	2.8 / 1.0	0.36	18.5	8.5
	Very loose to compact sand	Below 342		-	30	3.0 / 1.1	0.33	19.0	9.0
12+750 to 12+785 Borehole 21	Compact silty sand to sandy silt	343 to 341	343	-	30	3.0 / 1.1	0.33	19.0	9.0
	Stiff to very stiff silty clay	Below 341		100	28	2.8 / 1.0	0.36	19.0	9.0

**FOUNDATION DESIGN PARAMETERS  
PROPOSED NOISE BARRIER WALL 1A**

**NOTES:**

1. Where both  $c_u$  and  $\gamma'$  have been given for a specific stratum, the foundation design should be checked for both the drained and undrained conditions and the larger of the two calculated foundation depths shall govern.
2. Passive earth pressure coefficient ( $K_p$ ) values are provided for level ground. Where sloping ground is present adjacent to the noise barrier wall, adjusted  $K_p$  values must be used in the foundation design. The embankment slope behind the entire proposed noise barrier wall will slope downwards at 2 horizontal to 1 vertical.
3. Below the groundwater level, the effective unit weight of the soil ( $\gamma'$ ) should be used.
4. This table is to be read in conjunction with the accompanying report.

Prepared By: ML

Checked By: DUP

## 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	$c_u, s_u$	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 17**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1  
W.P. 131-98-00 LOCATION N 4809030.7 :E 222085.4 ORIGINATED BY MR  
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF/LMK  
DATUM GEODETIC DATE May 4, 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									
								○ UNCONFINED	+ FIELD VANE								
								● QUICK TRIAXIAL	× LAB VANE								
350.38	GROUND SURFACE						20	40	60	80	100						
0.00	FILL, sand and gravel Brown																
0.20	SAND AND GRAVEL, trace silt, trace clay, with cobbles and boulders (boulder at about elev. 347.6m to about elev. 347.4m) Dense to very dense Brown		1	SS	68												
			2	SS	68												
			3	SS	78												
			4	SS	42												
			5	SS	76												
345.71	END OF BOREHOLE		6	SS	50/ 100mm												
4.67	Borehole dry during drilling on May 4, 2010.																

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

**RECORD OF BOREHOLE No 18**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4809062.8 ; E 222153.2

ORIGINATED BY MR

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY WDF/LMK

DATUM GEODETIC

DATE May 4, 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 (%)					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    x LAB VANE					w <sub>p</sub> w      w <sub>L</sub>					
348.42	GROUND SURFACE							20	40	60	80	100						
0.00	FILL, sand and gravel, trace silt Brown						348											
347.87	FILL, clayey silt, trace sand, trace gravel Very stiff Brown		1	SS	17													
347.05	FILL, sand, fine, some silt Compact Brown						347											
1.37	FILL, sand, fine, some silt Compact Brown		2	SS	23													
346.59	FILL, silty sand, some clay, trace to some gravel Compact to dense Brown						346											
1.83	FILL, silty sand, some clay, trace to some gravel Compact to dense Brown		3	SS	27													
344.76			4	SS	40		345											
3.66	SILTY SAND, some clay, trace gravel Compact Brown																	
344.00			5	SS	14													
4.42	SANDY SILT, some clay, trace gravel Dense Brown						344											
343.39			6	SS	37													
5.03	END OF BOREHOLE																	
	Borehole dry during drilling on May 4, 2010.																	

**RECORD OF BOREHOLE No 19**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1  
W.P. 131-98-00 LOCATION N 4809096.1 ; E 222220.3 ORIGINATED BY MR  
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF/LMK  
DATUM GEODETIC DATE May 4, 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	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													
346.75	GROUND SURFACE						20	40	60	80	100						GR	SA	SI	CL	
0.00	FILL, sand and gravel																				
346.41	Brown																				
0.34	FILL, silt, some sand, some clay, trace gravel																				
345.84	Compact		1	SS	33																
0.91	Brown																				
345.38	FILL, silty fine sand																				
1.37	Dense																				
	Brown																				
	FILL, clayey silt, trace sand, trace gravel, trace topsoil, with cobbles and boulders from about elev. 343.7m to about elev. 343.4m	2	SS	24														1	29	51	19
	Stiff to hard																				
	Brown	3	SS	13														1	20	54	25
		4	SS	50/ 50mm																	
																		</			



**RECORD OF BOREHOLE No 20**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1  
W.P. 131-98-00 LOCATION N 4809130.0 ; E 222287.2 ORIGINATED BY MR  
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF/LMK  
DATUM GEODETIC DATE May 3, 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									
								<div><div></div><div></div><div></div><div></div><div></div></div> <div>20406080100</div>									
								<div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>									
345.41	GROUND SURFACE																
0.00	FILL, sand and gravel Brown					▽	345									0 66 29 5	
344.83																	
0.58	FILL, sandy silt, some clay, trace gravel Compact Brown		1	SS	17												
344.04							344										
1.37	FILL, silty fine sand, trace clay Compact Brown		2	SS	24									○			
343.28																	
2.13	FILL, clayey silt, trace sand, trace gravel, trace topsoil Stiff to very stiff Brown		3	SS	9		343										
			4	SS	25												
341.75							342										
3.66	SAND, fine to medium, some gravel, trace to some silt, trace clay Very loose to dense Brown		5	SS	32								○				
						341											
			6	SS	12												
						340											
			7	SS	1												
			8	SS	9	339											
338.86	END OF BOREHOLE																
6.55	Groundwater encountered at about elev. 341.0m during drilling on May 3, 2010.																

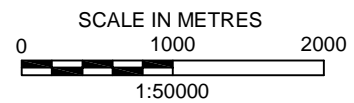
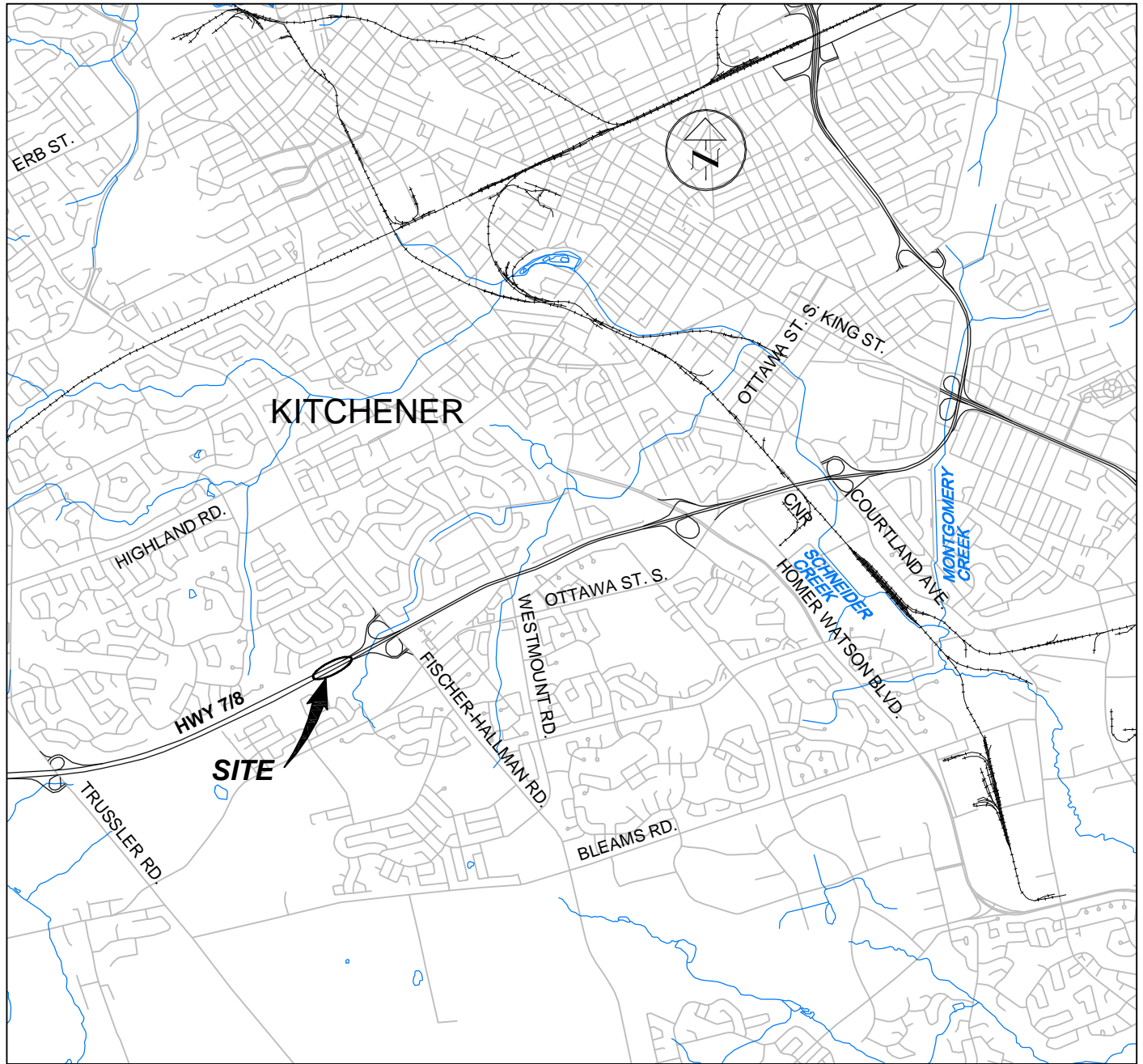
**RECORD OF BOREHOLE No 21**

1 OF 1

**METRIC**

PROJECT 08-1132-084-1  
W.P. 131-98-00 LOCATION N 4809164.6 ; E 222353.8 ORIGINATED BY MR  
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF/LMK  
DATUM GEODETIC DATE May 3, 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	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														
344.70	GROUND SURFACE					▽	344	20	40	60	80	100						GR SA SI CL				
0.00	FILL, sand and gravel, trace silt, crushed Brown																					
344.15																						
0.55	FILL, sandy silt, with clayey silt layers Loose to compact Brown		1	SS	15											○						
342.87			2	SS	8											○						
1.83	SILTY FINE SAND, some clay Loose to compact Brown															○						
341.80			3	SS	17											○			0 50 40 10			
341.80																						
2.90	SANDY SILT, some clay, trace gravel Compact Brown		4	SS	11											○						
341.04																						
3.66	SILTY CLAY, trace sand, with silt seams Stiff to very stiff Brown		5	SS	14										○	0 9 49 42						
			6	SS	16																	
339.52																						
5.18	END OF BOREHOLE																					
	Groundwater encountered at about elev. 342.9m during drilling on May 3, 2010.																					



## REFERENCE

DRAWING BASED ON CANMAP STREETFILES V2005.4.

## NOTE

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

PROJECT

**PROPOSED NOISE BARRIER WALL 1A  
WIDENING OF HIGHWAY 7/8  
GWP 131-98-00**

TITLE

## KEY PLAN



PROJECT No. 08-1132-084-1			FILE No. 0811320841-F11C001		
CADD	WDF	Jan 13/11	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



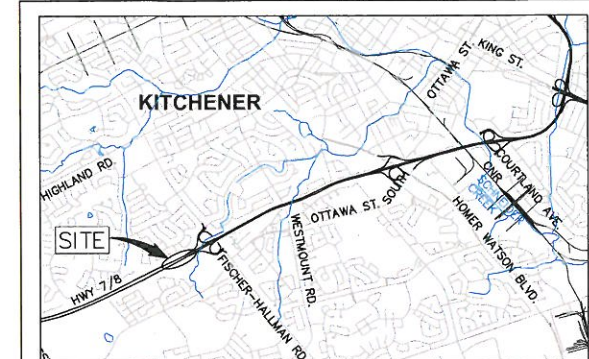
PROPOSED NOISE BARRIER WALL 1A

SHEET

WIDENING OF HIGHWAY 7/8  
 BOREHOLE LOCATIONS



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KEY PLAN  
 SCALE IN KILOMETRES

**LEGEND**

● Borehole - Current Investigation

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
17	350.38	4 809 030.7	222 085.4
18	348.42	4 809 062.8	222 153.2
19	346.75	4 809 096.1	222 220.3
20	345.41	4 809 130.0	222 287.2
21	344.70	4 809 164.6	222 353.8

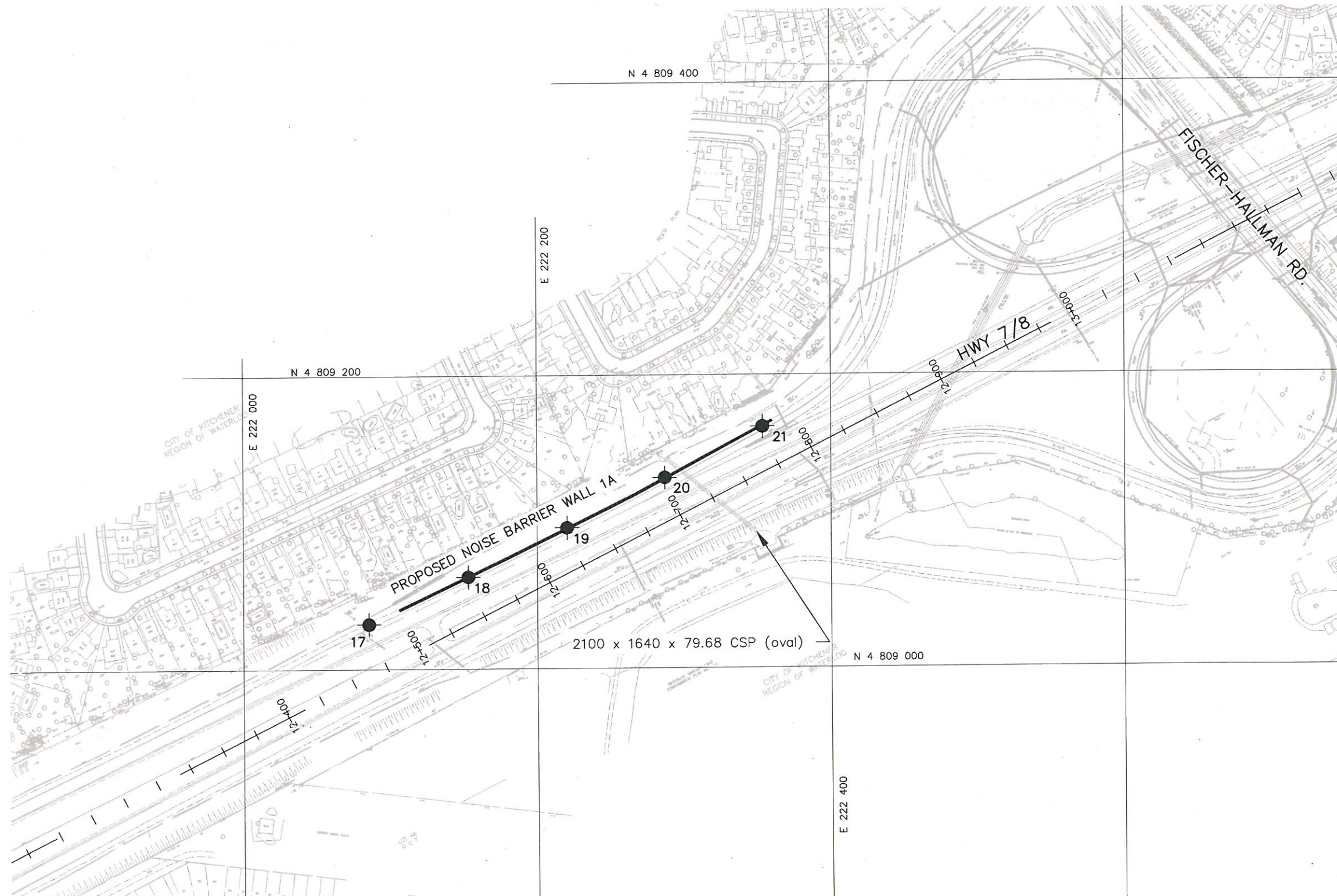
**NOTES**

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

**REFERENCE**

Base plans provided in digital format by Dillon Consulting.

NO.	DATE	BY	REVISION
Geocres No. 40P7-59			
HWY.	7/8	PROJECT NO.	08-1132-084-1
SUBW'D.	ML	CHKD.	DATE: Jan. 13/11
DRAWN:	WDF	CHKD.	APPD.
		SITE:	DWG. 1



**PLAN**

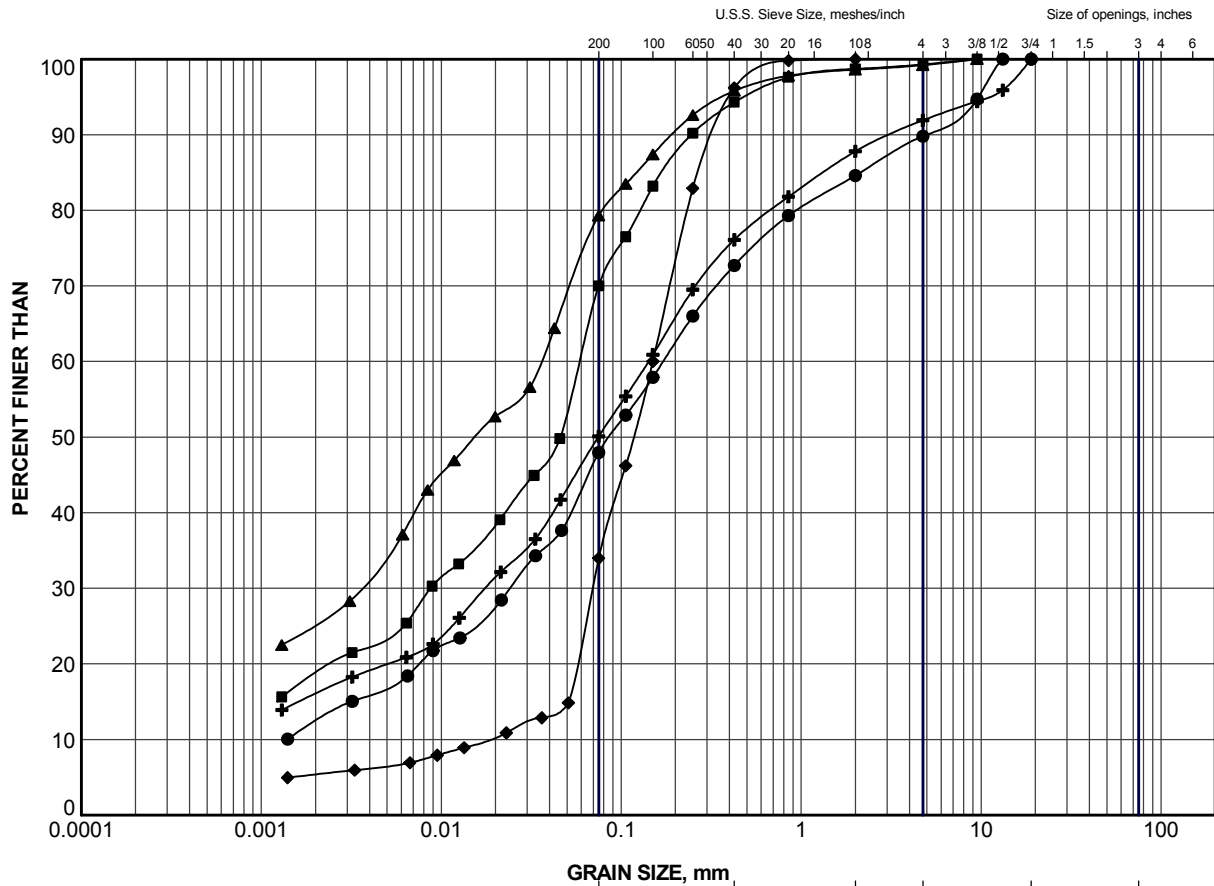
SCALE  
 0 30 m





# **APPENDIX A**

## **Laboratory Test Data**



### LEGEND

SYMBOL BOREHOLE SAMPLE ELEV (m)

#### NON COHESIVE

● 18 3 345.9  
◆ 20 2 343.7

#### COHESIVE

■ 19 2 345.0  
▲ 19 3 344.2  
+ 19 5 342.7

PROJECT

PROPOSED NOISE BARRIER WALL 1A  
WIDENING OF HIGHWAY 7/8  
GWP 131-98-00

TITLE

## GRAIN SIZE DISTRIBUTION FILL

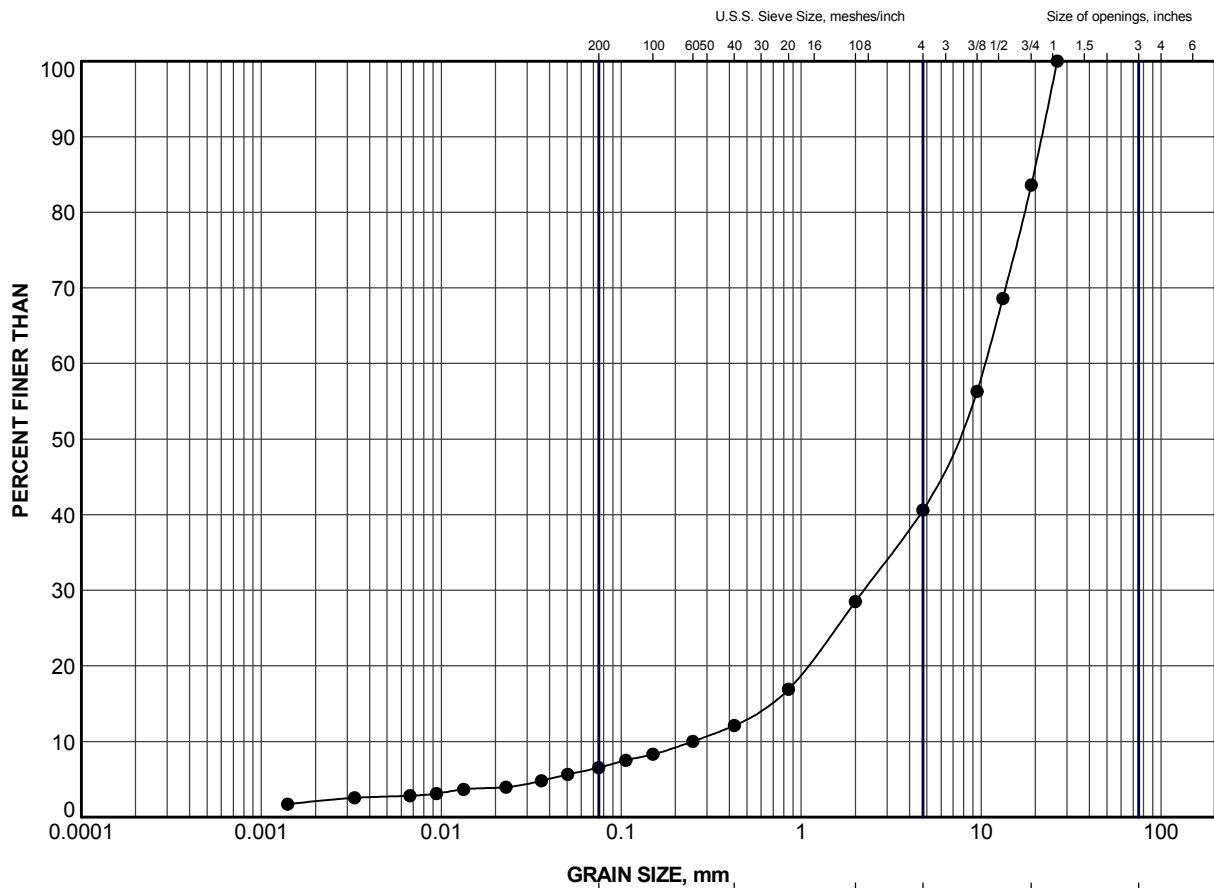


**Golder  
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LONDON, ONTARIO

PROJECT No.	08-1132-084-1	FILE No.	0811320841-F11C0A1
DRAWN	LMK	Jan. 13/11	SCALE N/A REV.
CHECK			

**FIGURE A-1**






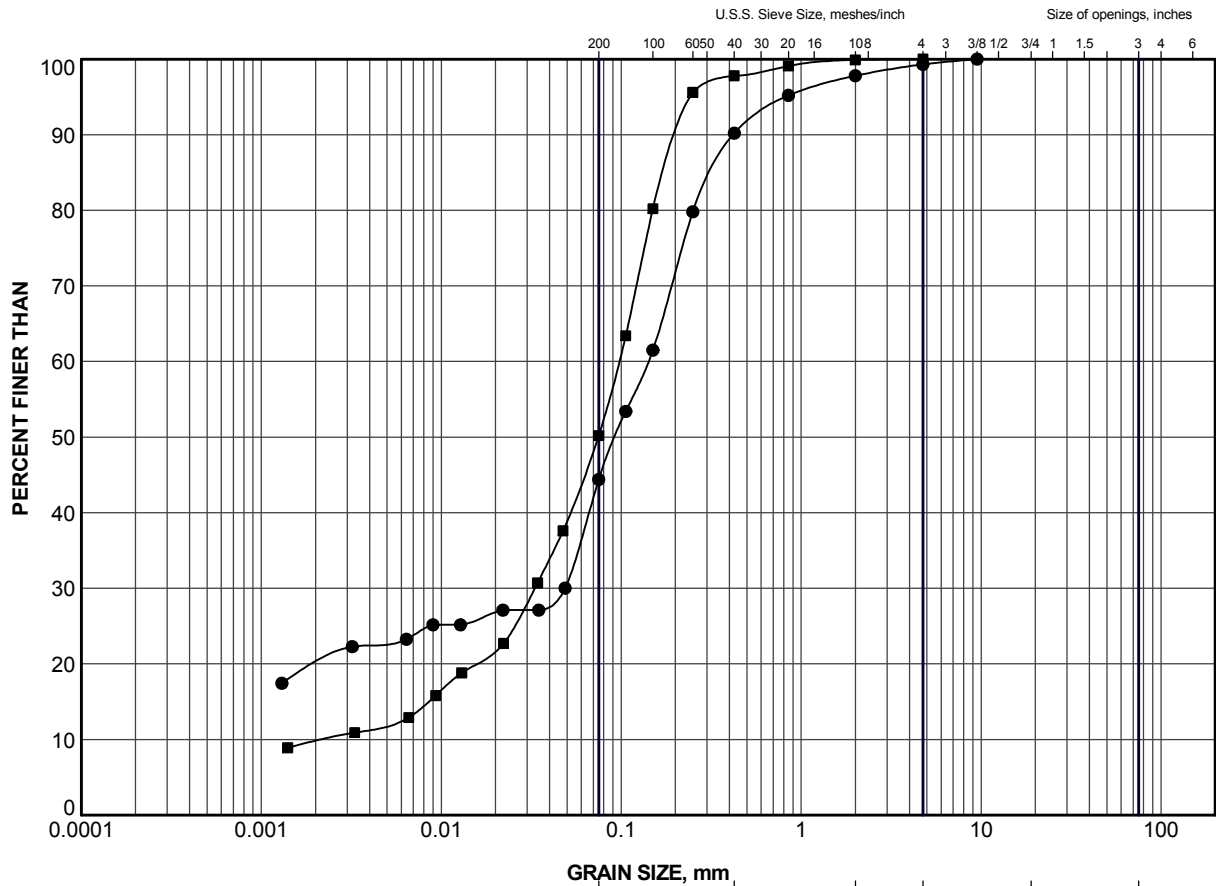
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17	2	348.6

PROJECT				PROPOSED NOISE BARRIER WALL 1A WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND AND GRAVEL			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F11C0A2	
DRAWN		LMK		SCALE		N/A	
CHECK				REV.			
 <b>Golder Associates</b> LONDON, ONTARIO				Jan. 13/11 FIGURE A-2			




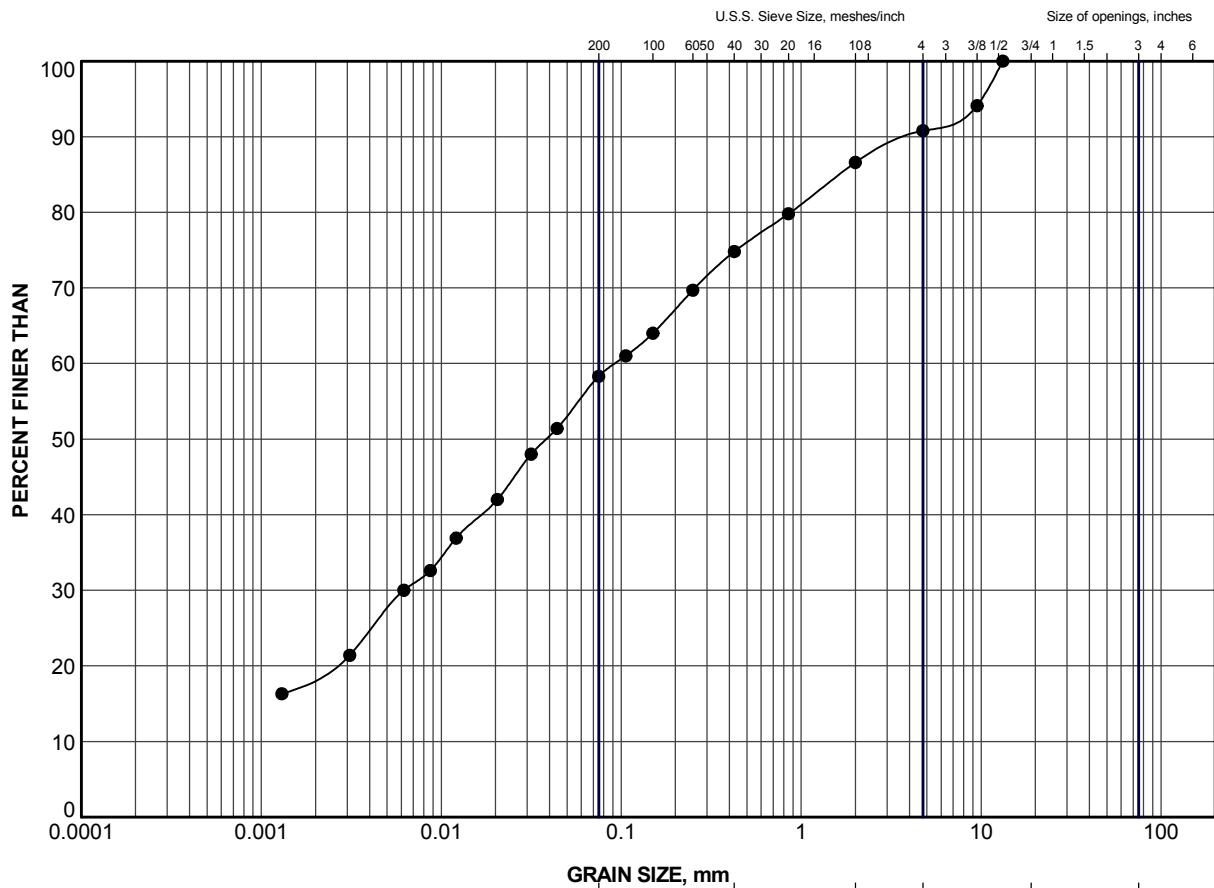


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	18	5	344.4
■	21	3	342.2

PROJECT				PROPOSED NOISE BARRIER WALL 1A WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY SAND			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F11C0A3	
DRAWN		LMK		SCALE		N/A	
CHECK				REV.			
		Jan. 13/11					
 <b>Golder Associates</b> LONDON, ONTARIO				<b>FIGURE A-3</b>			

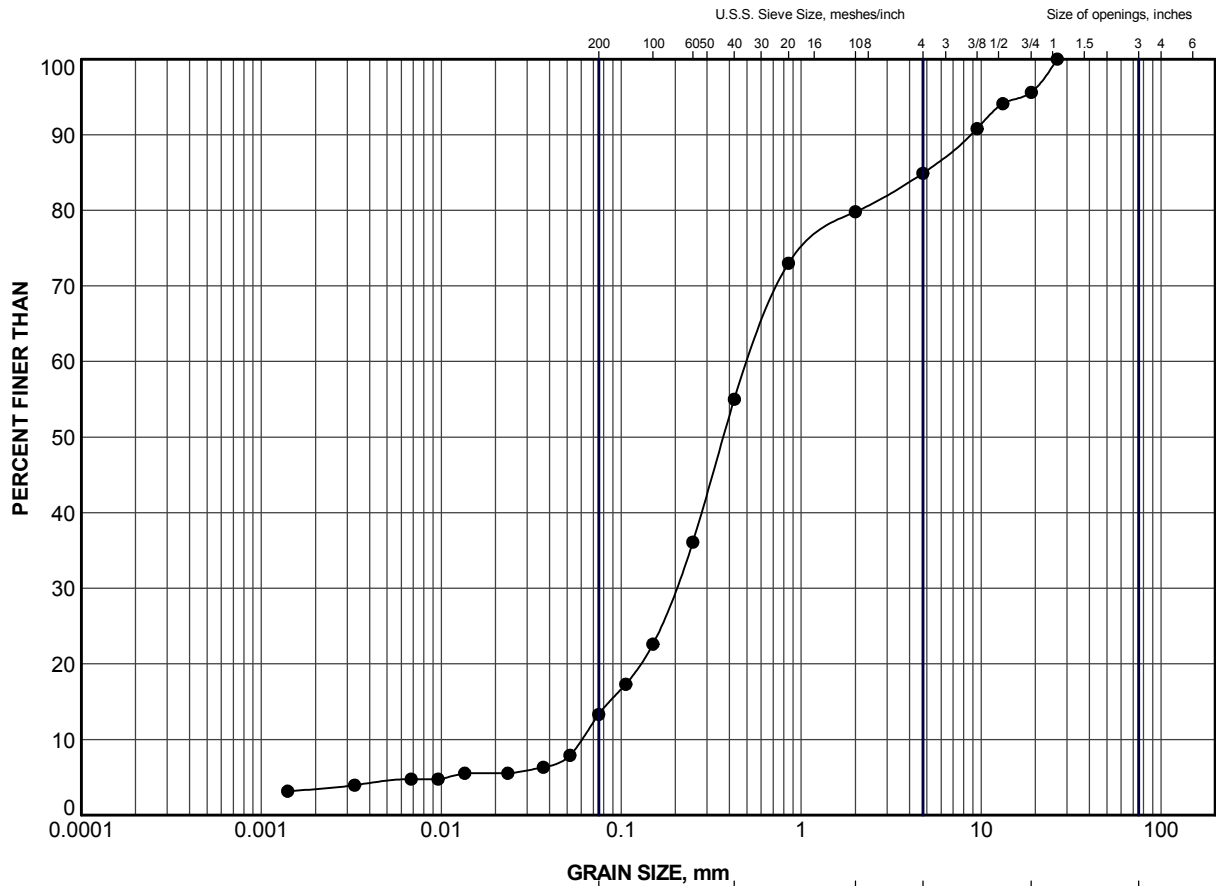


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	18	6	343.6

PROJECT				PROPOSED NOISE BARRIER WALL 1A WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F11C0A4	
DRAWN		LMK		SCALE		N/A	
CHECK				REV.			
 <b>Golder Associates</b> LONDON, ONTARIO				Jan. 13/11 FIGURE A-4			

LDN\_MTO\_NEW\_GLDR\_LDN.GDT

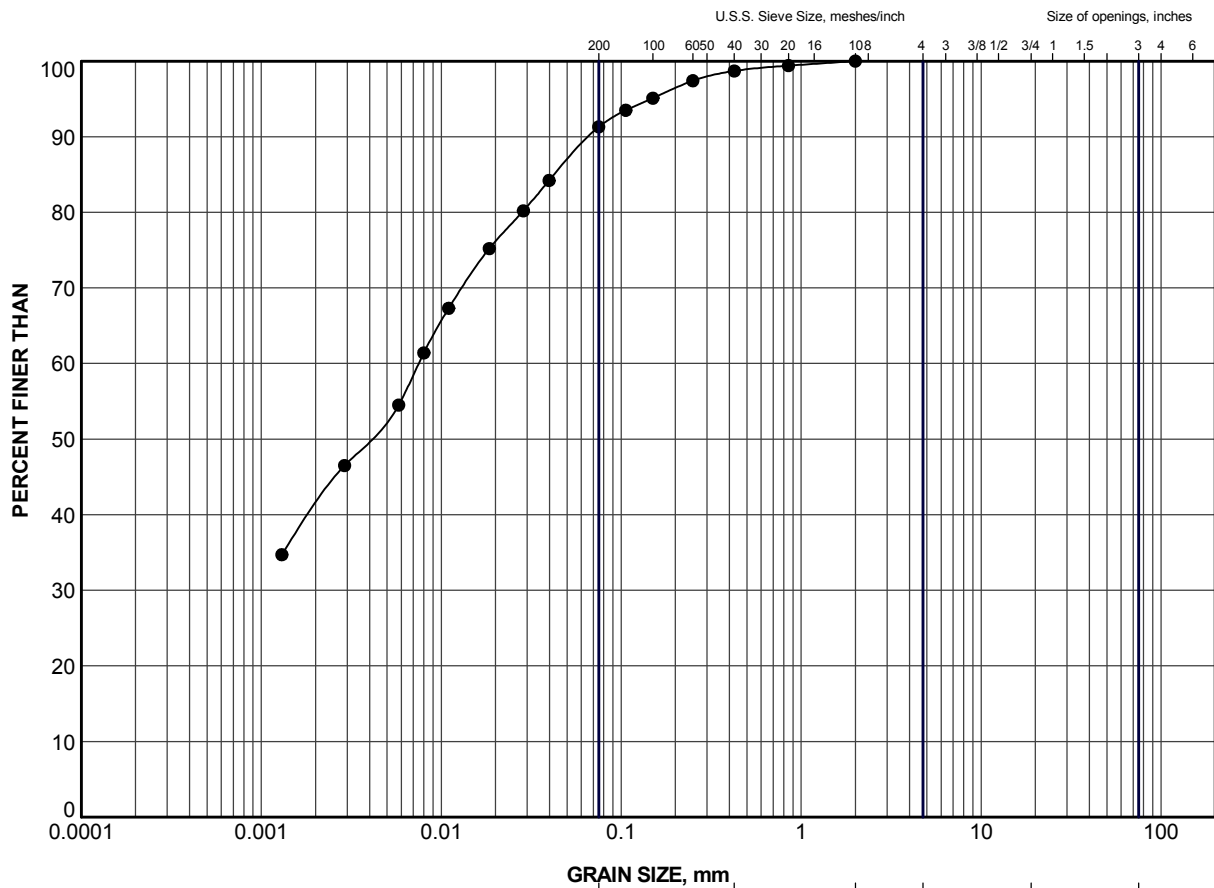


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

**LEGEND**

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	20	5	341.4


PROJECT	PROPOSED NOISE BARRIER WALL 1A WIDENING OF HIGHWAY 7/8 GWP 131-98-00		
TITLE	<b>GRAIN SIZE DISTRIBUTION</b> <b>SAND</b>		
<b>Golder Associates</b> LONDON, ONTARIO	PROJECT No.	08-1132-084-1	FILE No. 0811320841-F11C0A5
	DRAWN	LMK	Jan. 13/11
	CHECK		
	SCALE	N/A	REV.
			<b>FIGURE A-5</b>

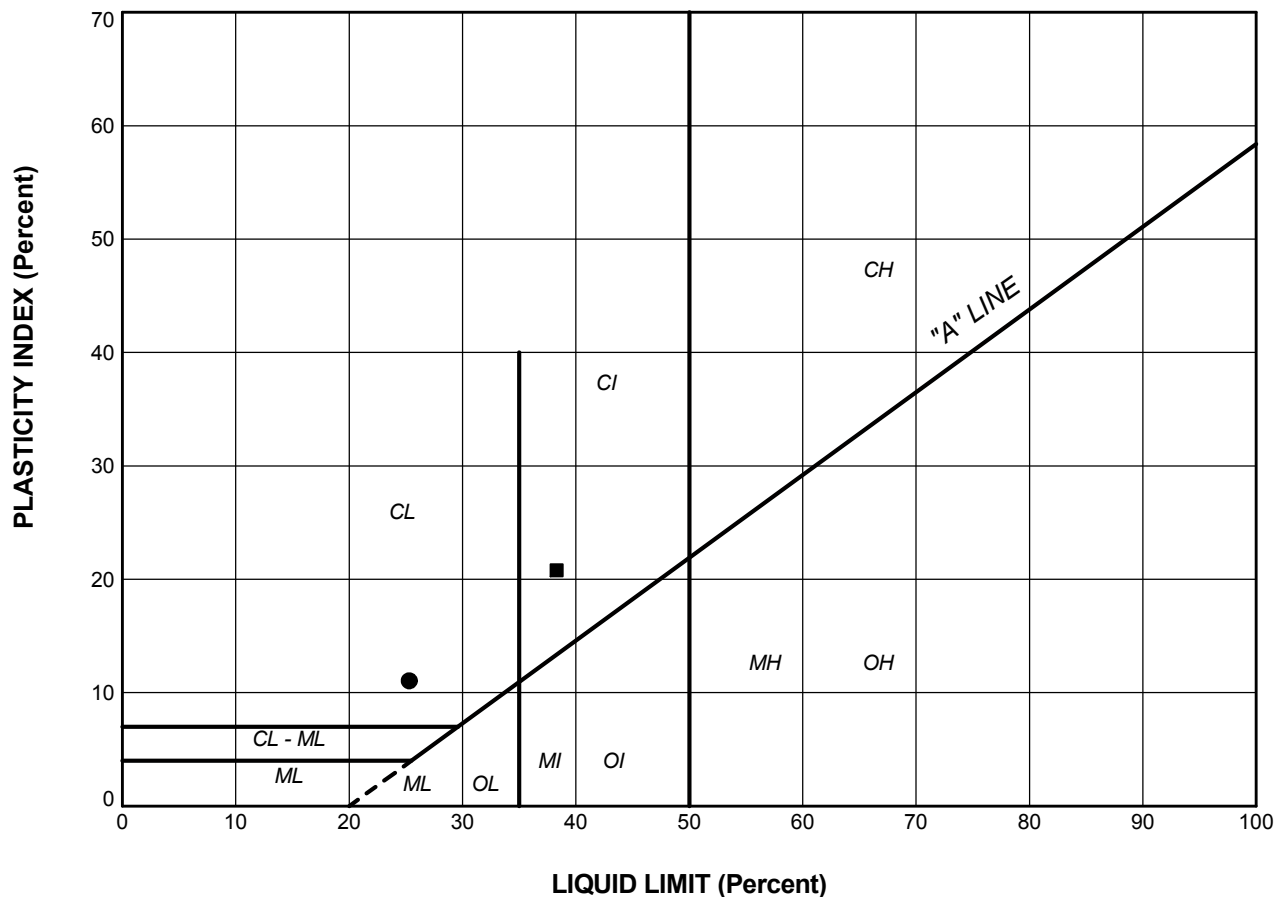


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	21	5	340.7

PROJECT				PROPOSED NOISE BARRIER WALL 1A WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY CLAY			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F11C0A6	
DRAWN		LMK		SCALE		N/A	
CHECK				REV.			
 <b>Golder Associates</b> LONDON, ONTARIO				<b>FIGURE A-6</b>			



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	19	3	25.3	14.3	11.1
■	21	5	38.3	17.5	20.8

PROJECT				PROPOSED NOISE BARRIER WALL 1A WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				PLASTICITY CHART			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F11C0A7	
DRAWN	LMK	July 23/10		SCALE	N/A	REV.	
CHECK				FIGURE A-7			



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