



January 2011



FOUNDATION INVESTIGATION AND DESIGN REPORT

Relocation of Existing Noise Barrier Wall 7

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 RELOCATION OF EXISTING NOISE BARRIER WALL 7

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**FOUNDATION INVESTIGATION AND DESIGN REPORT
RELOCATION OF EXISTING NOISE BARRIER WALL 7**

PART A

FOUNDATION INVESTIGATION REPORT

EXISTING NOISE BARRIER WALL 7

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 conducted for the proposed relocation of existing noise barrier wall 7 located east of the Courtland Avenue Interchange from Station 17+360 to 17+708 Rt along 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, 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 a table outlining the station limits and preliminary drawings showing the proposed locations and extent of the noise barrier walls 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 site extends from 1.9 km west of Fischer-Hallman Road easterly to 0.8 km east of Courtland Avenue. The location of the noise barrier wall is shown on the Key Plan, Figure 1, and 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 the Canadian National Railway (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, institutional, commercial and residential areas to the south. The Rockway Municipal Golf Course is northwest of the proposed site. Montgomery Creek is just east of the site.

The proposed development to be constructed for the widening scheme comprises the relocation of existing noise barrier wall 7 which will be located to the east of the Courtland Avenue Interchange from Stations 17+360 to 17+708 Rt along Highway 7/8. Residential developments and a school are located within the immediate vicinity of the site. The topography generally slopes southeast towards Montgomery Creek. The ground surface elevations along the wall vary from approximately elevation 323 metres on the east side of the Courtland Avenue Interchange to 317 metres adjacent to Montgomery Creek.

2.2 Site Geology

This project lies within the physiographic region of southwestern Ontario known as the Waterloo Hills¹. 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.2604 entitled "Quaternary Geology, Cambridge Area, Southern Ontario", the site lies in an area of primarily ice contact sands deposited in the Pleistocene era. The western part of the wall lies within a region of Port Stanley Till, a silty to sandy silt till. The eastern part lies in an area of lacustrine and outwash sands.

¹ 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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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.1985 entitled "Bedrock Topography Series, Southern Ontario", the bedrock surface at the site subcrops from elevation 267 to 274 metres along the subject section of noise barrier wall.



3.0 INVESTIGATION PROCEDURES

The foundation investigation was carried out on May 25, 27 and 28, 2010 during which time seven boreholes were drilled along Highway 7/8 in the vicinity of existing noise barrier wall 7. The borehole locations are shown on the Borehole Location Plan, Drawing 1.

The boreholes (70 to 76) were advanced to depths of 5.0 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)
70	4 810 543	226 692	321.62	6.55
71	4 810 553	226 747	321.95	5.03
72	4 810 559	226 805	321.97	5.18
73	4 810 568	226 861	321.39	5.03
74	4 810 585	226 922	320.25	5.18
75	4 810 603	226 972	319.52	5.03
76	4 810 633	227 031	319.12	5.18

The drilling was carried out using truck mounted CME 45 and CME 55 power augers 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 investigation 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. In addition, dynamic cone penetration testing was carried out adjacent to borehole 70 in order to further characterize the soils at this location.

The groundwater conditions were observed throughout the drilling operations and upon completion of drilling. No groundwater monitoring installations were installed in any of the boreholes. A summary of the groundwater level observations for all boreholes are presented in Table 1. The boreholes were backfilled in accordance with current 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.



FOUNDATION INVESTIGATION AND DESIGN REPORT RELOCATION OF EXISTING NOISE BARRIER WALL 7

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 and stratigraphic profiles 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 silt, sand and/or interlayered with clayey silt, silty sand and sand and gravel.

The borehole locations are shown on Drawing 1. 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 Pavements

Asphaltic concrete was encountered at the ground surface in all boreholes with the exception of borehole 70. The thickness of the asphalt ranged from 60 to 240 millimetres.

4.1.2 Fill

All of the boreholes were advanced in the existing shoulder area. Granular roadbase materials, consisting of crushed sand and gravel, were encountered beneath the asphalt in boreholes 71 to 76, inclusive. The surface of the granular roadbase was between elevation 318.9 and 321.9 metres. Granular roadbase materials were also found beneath the topsoil in borehole 70 from elevation 321.5 metres. The thickness of the granular roadbase varied from 220 to 400 millimetres.

Granular fill was encountered underlying the granular roadbase in boreholes 70 and 72 from elevation 316.6 to 321.9 metres. The fill comprised sand and gravel, sand and silty sand with evidence of cobbles. The thickness of the fill ranged from 0.3 to 2.5 metres.

The fill had standard penetration test N values ranging from 8 to 73 blows per 0.3 metres indicating a loose to very dense relative density. The N values indicate that the granular fill is generally compact. The presence of cobbles was noted in the fill layers at elevation 321.2, 321.5 and 319.9 metres in boreholes 70, 72 and 74, respectively. The water contents of the fill were between 5 and 11 per cent with the exception of a single water



content of 22 per cent in a sample from borehole 75 near elevation 317 metres. A higher water content was measured as this fill sample contained traces of topsoil. The result of the grain size testing conducted on a single sample of the fill is presented on Figure A-1, Appendix A.

4.1.3 Topsoil

Layers of topsoil were found at the ground surface in borehole 70 and at depth in borehole 76 at elevation 317.0 metres. The thicknesses of the topsoil layers were 90 and 160 millimetres in boreholes 70 and 76, respectively. In borehole 76, the topsoil was found underlying fill and overlying sand. Traces of topsoil was also found in the granular fill at elevation 320.7 metres in borehole 73, at elevation 318.2 to 316.6 metres in borehole 75 and at elevation 318.2 metres in borehole 76.

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.

4.1.4 Silt

Layers of silt were encountered in all boreholes except borehole 76 from elevations 316.6 to 320.8 metres. The silt was generally found underlying layers of fill in boreholes 70 and 75, beneath sand in boreholes 71, 73 and 74 and silty sand in borehole 72. The silt is interlayered with clayey silt and silty sand in borehole 70 and silt seams were found in the clayey silt layers in boreholes 72, 73 and 74. The thickness of the silt layers ranged from 1.2 to 2.9 metres. Boreholes 70, 71 and 73 were terminated in the silt after exploring the layers for 0.6, 1.7 and 2.9 metres, respectively.

The silt had N values of 3 to 18 blows per 0.3 metres indicating a loose to compact relative density. The water contents ranged from 20 to 25 per cent.

The grain size distribution curves for the silt samples recovered during standard penetration testing are shown on Figure A-2.

4.1.5 Sand

Compact to dense layers of sand were encountered in boreholes 71 and 73 through 76 from elevations 315.1 to 321.3 metres. The fine to medium grained sand layers were found to be generally underlying the fill materials, except in boreholes 75 and 76 where the sand was found beneath the silt and buried topsoil, respectively. Where fully penetrated, the sand layers ranged from about 0.8 to 2.7 metres thick. Borehole 75 was terminated in the sand after exploring the sand stratum for 0.6 metres.



The sand layers had N values of 11 to 31 blows per 0.3 metres indicating a compact to dense relative density. Water contents of 10 to 17 per cent were measured on samples of sand.

The grain size distribution curves for three sand samples obtained during standard penetration testing are presented on Figure A-3.

4.1.6 Clayey Silt

Clayey silt layers were encountered in boreholes 70, 72 and 74 at elevations 319.5, 317.7 and 315.3 metres, respectively. The clayey silt generally contained silt seams and was found between layers of silt in borehole 70 and at depth underlying layers of silt in boreholes 72 and 74. The thickness of the upper and lower clayey silt layers in borehole 70 were 0.3 and 0.8 metres, respectively. Boreholes 72 and 74 were terminated in the clayey silt after exploring it for 0.9 and 0.2 metres, respectively.

The clayey silt had N values of 3 to 12 blows per 0.3 metres indicating a soft to stiff consistency. A single water content of 20 per cent was measured for a clayey silt sample obtained during standard penetration testing. The clayey silt is of low plasticity based on a plastic limit, liquid limit and plasticity index of 15, 24 and 9 per cent, respectively. The Atterberg limits test results for the clayey silt are shown on Figure A-5.

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

4.1.7 Silty Sand

Loose to compact layers of silty sand were encountered in boreholes 70 and 72 at elevations 317.2 and 321.2 metres, respectively. The silty sand was found underlying layers of granular fill in borehole 72 and between the clayey silt and silt deposits in borehole 70. The presence of clayey silt seams was also observed in the silty sand in borehole 70. The thicknesses of the silty sand layers were 1.5 and 0.6 metres in boreholes 70 and 72, respectively.

The silty sand had N values of 5 to 21 blows per 0.3 metres.

4.1.8 Sand and Gravel

Sand and gravel was encountered in borehole 76 at elevation 315.5 metres beneath a layer of sand. The borehole was terminated in this material after exploring the stratum for about 1.5 metres.

N values in the sand and gravel were 13 and 26 blows per 0.3 metres indicating a compact condition.



4.2 Groundwater Conditions

The groundwater conditions in all of the 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)
70	321.62	1.2	320.4
71	321.95	2.3	319.7
72	321.97	1.2	320.8
73	321.39	3.1	318.3
74	320.25	2.8	317.5
75	319.52	4.6	314.9
76	319.12	4.2	314.9

During the fieldwork period, the groundwater was encountered between elevation 314.9 and 320.8 metres in the boreholes. It should be noted that the above encountered groundwater level observations are not considered to be representative of the long-term, stabilized groundwater conditions. The long term inferred groundwater level is expected to vary from elevation 320 metres near Station 17+360 Rt to elevation 315 metres near Station 17+808 Rt. 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. Michael Arthur 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
RELOCATION OF EXISTING NOISE BARRIER WALL 7**

PART B

FOUNDATION DESIGN REPORT

EXISTING NOISE BARRIER WALL 7

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 the relocation of existing noise barrier wall 7 along the southern shoulder of Highway 7/8 between Stations 17+360 and 17+808 RT.

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 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 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. Foundation 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, ϕ' , have been given for a specific stratum, the caisson design should be checked for both the drained and the undrained condition and the larger of the two calculated caisson depths shall govern.

The passive resistance in the upper 1.4 metres below 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 of 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. East of approximately Station 17+525, the ground surface behind the relocated wall will slope downwards at 3 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.



An existing pedestrian overpass is located at approximately Station 17+480. The location of the overpass footings and the type of foundation is not known. However, the design of the noise barrier should consider the presence of this overpass structure.

6.3 Construction Considerations

Excavations for construction of the caissons for the noise barrier wall foundations will penetrate the surficial fill and will extend through deposits of sand, silty sand, silt, clayey silt and sand and gravel. The sands are predominantly fine grained and uniform in composition. The sands, silts and clayey silt 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 entire segment of existing noise barrier wall 7 that will be relocated.

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 (augering with the hole filled with bentonite slurry) and placement of 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 the augered excavation and measures to deal with excavation of saturated granular soils below the groundwater level.

The caissons should be constructed and inspected in accordance with Ontario Provincial 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
RELOCATION OF EXISTING NOISE BARRIER WALL 7**

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, ϕ^1 (°)	Coefficient of Passive Pressure, K_p^2 Level Ground/ 3H:1V	Coefficient of Active Pressure, K_a Level Ground	Unit Weight ³ (kNm ⁻³)	
								Bulk γ	Effective, γ'
17+360 to 17+400 Borehole 70	Very loose to loose silt	Above 318	320	-	26	2.6/N/A	0.39	18.0	8.0
	Soft clayey silt	Above 317		20	26	2.6/N/A	0.39	18.0	8.0
	Loose to compact silty sand	317 – 316		-	30	3.0/N/A	0.33	19.0	9.0
	Compact silt	Below 316		-	30	3.0/N/A	0.33	18.5	8.5
17+400 to 17+450 Borehole 71	Compact to dense sand	Above 319	320	-	30	3.0/N/A	0.33	19.5	9.5
	Loose to compact silt	Below 319		-	29	2.9/N/A	0.35	18.5	8.5
17+450 to 17+500 Borehole 72	Compact silt	Above 318	321	-	30	3.0/N/A	0.33	18.5	8.5
	Stiff clayey silt	Below 318		80	28	2.8/N/A	0.36	18.5	8.5
17+500 to 17+575 Borehole 73	Compact sand	Above 319	319	-	32	3.3/1.8	0.31	19.5	9.5
	Loose to compact silt	Below 319		-	29	2.9/1.6	0.35	18.5	8.5
17+575 to 17+625 Borehole 74	Dense granular fill	Above 318	318	-	32	3.3/1.8	0.31	19.0	9.0
	Compact sand	318 to 317		-	30	3.0/1.6	0.33	19.5	9.5
	Compact silt	317 to 315		-	30	3.0/1.6	0.33	18.5	8.5
	Stiff clayey silt	Below 315		50	28	2.8/1.5	0.36	19.0	9.0

**GEOTECHNICAL PARAMETERS
RELOCATION OF EXISTING NOISE BARRIER WALL 7**

Station and Borehole	Soil Type	Elevation Interval (m)	Design Groundwater Elevation (m)	Undrained Shear Strength, c_u^1 (kPa)	Effective Angle of Friction, ϕ'^1 (°)	Coefficient of Passive Pressure, K_p^2 Level Ground/ 3H:1V	Coefficient of Active Pressure, K_a Level Ground	Unit Weight ³ (kNm ⁻³)	
								Bulk γ	Effective, γ'
17+625 to 17+675 Borehole 75	Loose to compact granular fill	Above 317	315	-	28	2.8/1.5	0.36	18.5	8.5
	Compact silt	317 to 315		-	30	3.0/1.6	0.33	18.5	8.5
	Compact sand	Below 315		-	32	3.3/1.8	0.31	19.5	9.5
17+675 to 17+708 Borehole 76	Compact to very dense granular fill	Above 317	315	-	32	3.3/1.8	0.31	19.0	9.0
	Compact to dense sand	317 to 315		-	32	3.3/1.8	0.31	19.0	9.0
	Compact sand and gravel	Below 315		-	34	3.5/1.9	0.28	21.0	11.0

NOTES:

1. Where both c_u and γ' 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. Between approximately Stations 17+525 and 17+808, the ground behind the relocated noise barrier wall will slope downwards at 3 horizontal to 1 vertical.
3. Below the groundwater level, the effective unit weight of the soil (γ') should be used.
4. This table is to be read in conjunction with the 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	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 cm² 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 ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

LIST OF SYMBOLS

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

I. General

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ϵ	linear strain
ϵ_v	volumetric strain
η	coefficient of viscosity
ν	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(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
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
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 ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

RECORD OF BOREHOLE No 70

1 OF 1

METRIC

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4810542.6 ; E 226691.5

ORIGINATED BY MA

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY WDF

DATUM GEODETIC

DATE May 25, 2010

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
321.62	GROUND SURFACE					▽									
0.09	TOPSOIL, sandy														
321.22	FILL, sand and gravel, crushed, trace silt														
0.40	trace silt														
320.83	FILL, sand and gravel, trace silt, with cobbles		1	SS	6										
0.79	Brown														
	SILT, some sand, with clayey silt layers		2	SS	5										
	Loose														
319.49	Brown														
2.13	CLAYEY SILT														
319.18	Soft		3	SS	3										
2.44	Brown														
	SILT, trace to some clay, trace sand		4	SS	3										
	Very loose														
	Brown														
317.96	CLAYEY SILT, trace sand, with silt seams		5	SS	3										
3.66	Soft														
317.20	Grey		6	SS	5										
4.42	SILTY SAND, fine, with clayey silt seams														
	Loose to compact		7	SS	19										
	Grey														
315.68															
5.94	SILT, trace sand		8	SS	15										
315.07	Compact														
6.55	Grey														
END OF BOREHOLE															
Groundwater encountered at about elev. 320.4m during drilling on May 25, 2010.															

RECORD OF BOREHOLE No 71

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4810553.3 ; E 226747.0 ORIGINATED BY MR
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE May 27, 2010 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
								WATER CONTENT (%)									
321.95	ROAD SURFACE					▽	321	20	40	60	80	100	10	20	30	0 96 2 2	
0.00	ASPHALT																
0.24	FILL, sand and gravel, crushed Brown																
321.31																	
0.64	SAND, fine to medium, trace silt, trace clay Compact to dense Brown		1	SS	31												
			2	SS	11												
			3	SS	11												
318.60			4	SS	18												
3.35	SILT, trace sand, trace clay Loose to compact Brown					318	318									0 5 88 7	
			5	SS	14												
316.92			6	SS	8	317	317										
5.03	END OF BOREHOLE																
	Groundwater encountered at about elev. 319.7m during drilling on May 27, 2010.																

RECORD OF BOREHOLE No 72

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4810559.4 ; E 226805.0 ORIGINATED BY MA
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE May 27, 2010 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	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		
321.97	ROAD SURFACE							20	40	60	80	100								
0.06	ASPHALT																			
321.51	FILL, sand and gravel, crushed, trace silt																			
0.46	Brown																			
321.18	FILL, sand, fine to coarse, trace gravel, trace silt, with cobbles		1	SS	21															
0.79	SILTY SAND, fine																			
320.60	Compact																			
1.37	SILT, trace sand, trace clay Compact		2	SS	10															
	Brown																			
			3	SS	11															
			4	SS	13															
318.31																				
3.66	SILT, with clayey silt layers Compact																			
317.70	Brown		5	SS	11															
4.27	CLAYEY SILT, with silt seams Stiff																			
	Brown																			
			6	SS	12															
316.79																				
5.18	END OF BOREHOLE																			
	Groundwater encountered at about elev. 320.8m during drilling on May 27, 2010.																			

RECORD OF BOREHOLE No 73

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4810568.3 ; E 226860.8 ORIGINATED BY MR
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE May 27, 2010 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
321.39	ROAD SURFACE																
0.09	ASPHALT																
0.34	FILL, sand and gravel, crushed Brown																
320.66	FILL, sand and gravel, trace silt Brown																
0.73	FILL, silty sand, fine to medium, trace topsoil		1	SS	18												
320.02	Compact Brown																
1.37	SAND, fine to medium, trace silt		2	SS	20												
319.26	Compact Brown																
2.13	SILT, trace sand, trace clay Loose to compact Brown		3	SS	12												0 3 92 5
			4	SS	10												
			5	SS	6												
316.97																	
4.42	SILT, with clayey silt seams, trace sand																
316.36	Compact Brown		6	SS	11												
5.03	END OF BOREHOLE																
	Groundwater encountered at about elev. 318.3m during drilling on May 27, 2010.																

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

RECORD OF BOREHOLE No 74

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4810585.0 ; E 226922.3 ORIGINATED BY MA
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE May 28, 2010 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	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								
320.25	ROAD SURFACE					20	40	60	80	100						
0.08	ASPHALT															
319.85	FILL, sand and gravel, crushed, trace silt															
0.40	Brown															
319.52	FILL, sand and gravel, with cobbles		1	SS	39											
0.73	FILL, silty sand Dense Brown		2	SS	49											
318.12																
2.13	SAND, fine to medium, some silt, trace clay Compact Brown		3	SS	18											
317.35																
2.90	SILT, trace sand, trace clayey silt seams Compact Brown		4	SS	15											
			5	SS	13											
315.31			6	SS	8											
4.94	CLAYEY SILT, with silt layers Stiff Brown															
5.18	END OF BOREHOLE															
	Groundwater encountered at about elev. 317.5m during drilling on May 28, 2010.															

RECORD OF BOREHOLE No 75

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4810603.2 ; E 226971.7 ORIGINATED BY MR
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE May 27, 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 × LAB VANE		w _p w w _L					
319.52	ROAD SURFACE					20	40	60	80	100	10	20	30	GR	SA	SI	CL
0.00	ASPHALT																
0.18	FILL, sand and gravel, crushed Brown																
0.40	FILL, sand and gravel, trace silt Dense Brown		1	SS	39						○						
318.15																	
1.37	FILL, silty sand, trace gravel, trace topsoil, trace clay Compact Grey		2	SS	19						○			8	55	30	7
317.39																	
2.13	FILL, sand, fine to medium, trace silt, trace topsoil Loose Brown		3	SS	8							○					
316.62																	
2.90	SILT, trace sand, trace clay Compact Brown		4	SS	15							○		0	3	93	4
			5	SS	18												
315.10																	
4.42	SAND, fine to medium, trace gravel, trace silt Compact Brown																
314.49			6	SS	20												
5.03	END OF BOREHOLE																
	Groundwater encountered at about elev. 314.9m during drilling on May 27, 2010.																

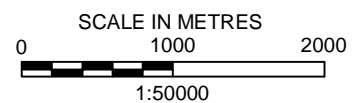
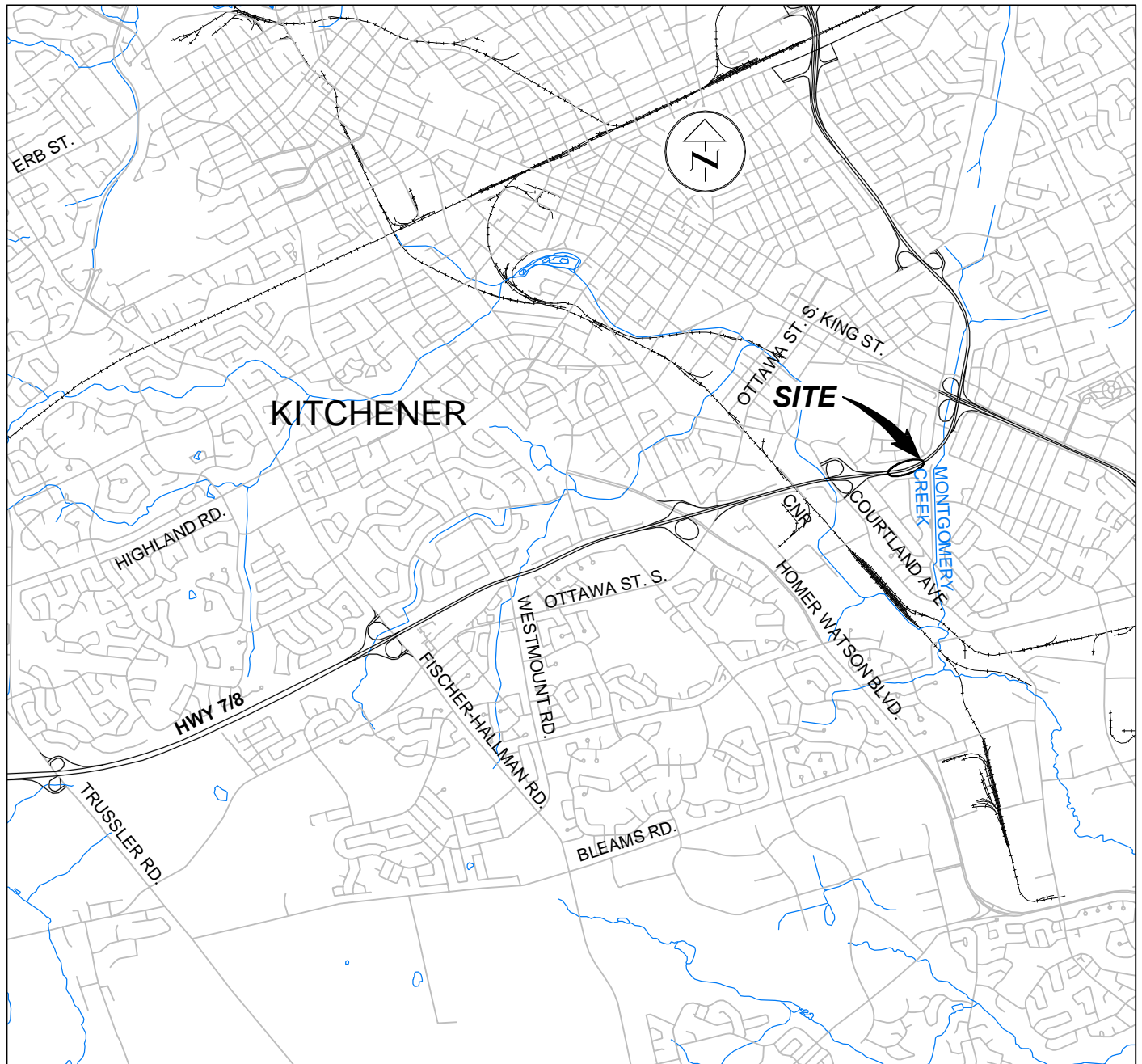
RECORD OF BOREHOLE No 76

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4810632.5 ; E 227030.5 ORIGINATED BY MA
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE May 28, 2010 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
							<div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div>				<div><div>102030</div><div>WATER CONTENT (%)</div></div>							
319.12	ROAD SURFACE					▽	319								079138			
0.00	ASPHALT																	
0.21	FILL, sand and gravel, crushed Brown																	
0.43	FILL, sand and gravel Compact Brown		1	SS	18													
318.21	FILL, fine sand, trace silt, trace topsoil Compact to very dense Brown		2	SS	73													
0.91																		
316.99	TOPSOIL, sandy Black		3	SS	30													
2.13	SAND, fine to medium, some silt, trace clay Compact to dense Brown		4	SS	29													
2.29																		
315.46	SAND AND GRAVEL, trace silt Compact Brown		5	SS	13													
3.66																		
313.94			6	SS	26													
5.18	END OF BOREHOLE						314											
Groundwater encountered at about elev. 314.9m during drilling on May 28, 2010.																		



REFERENCE

DRAWING BASED ON CANMAP STREETFILES V2005.4.

NOTE

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

PROJECT

**EXISTING NOISE BARRIER WALL 7
WIDENING OF HIGHWAY 7/8
GWP 131-98-00**

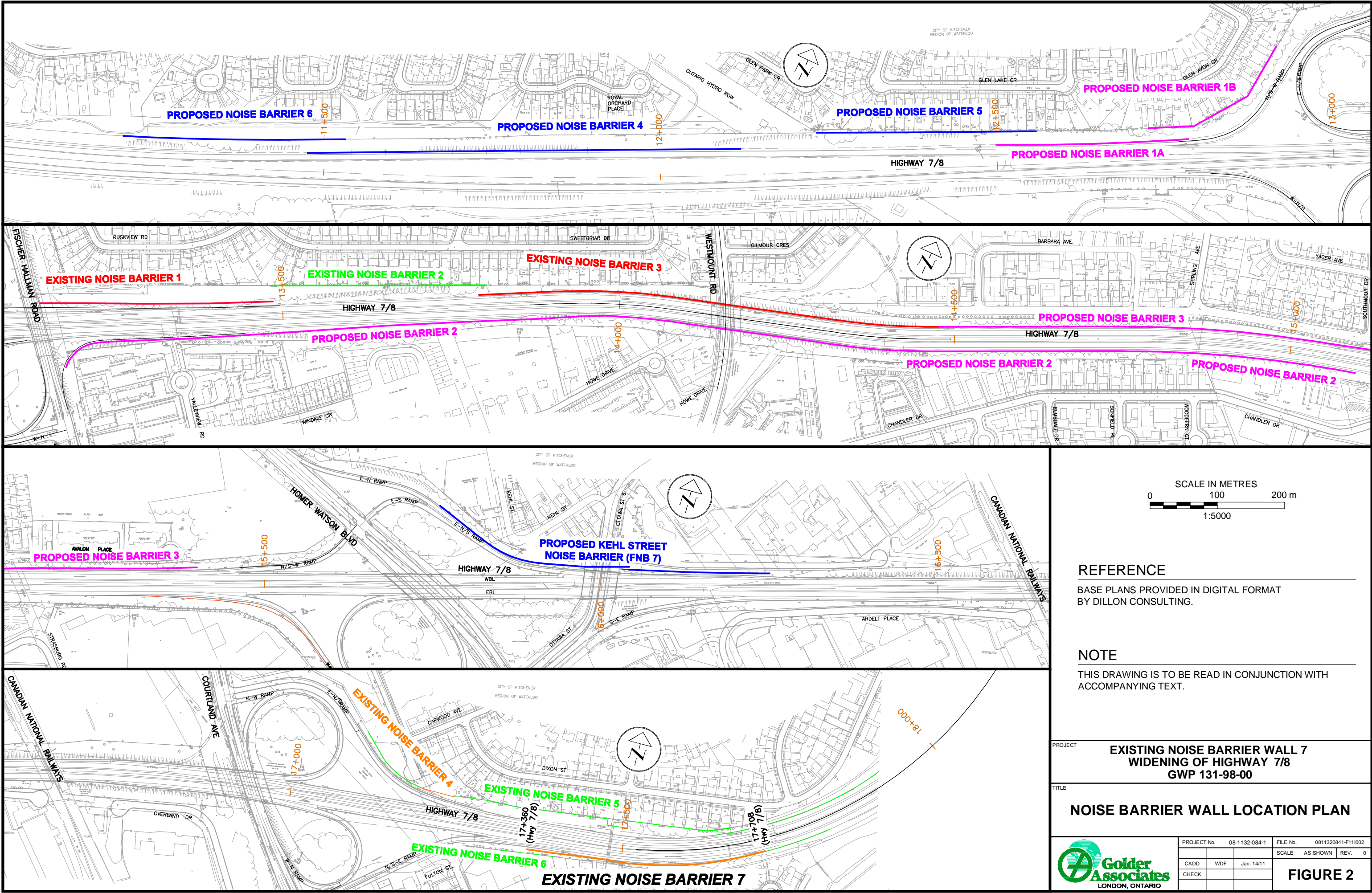
TITLE

KEY PLAN



PROJECT No.		08-1132-084-1	FILE No.		0811320841-F111001
CADD	WDF	Jan. 14/11	SCALE	AS SHOWN	REV.
CHECK			FIGURE 1		

Drawing file: 0811320841-F111002.dwg Jan 14, 2011 - 4:05pm



SHEET

SCALE IN KILOMETRES



 Borehole – Current Investigation

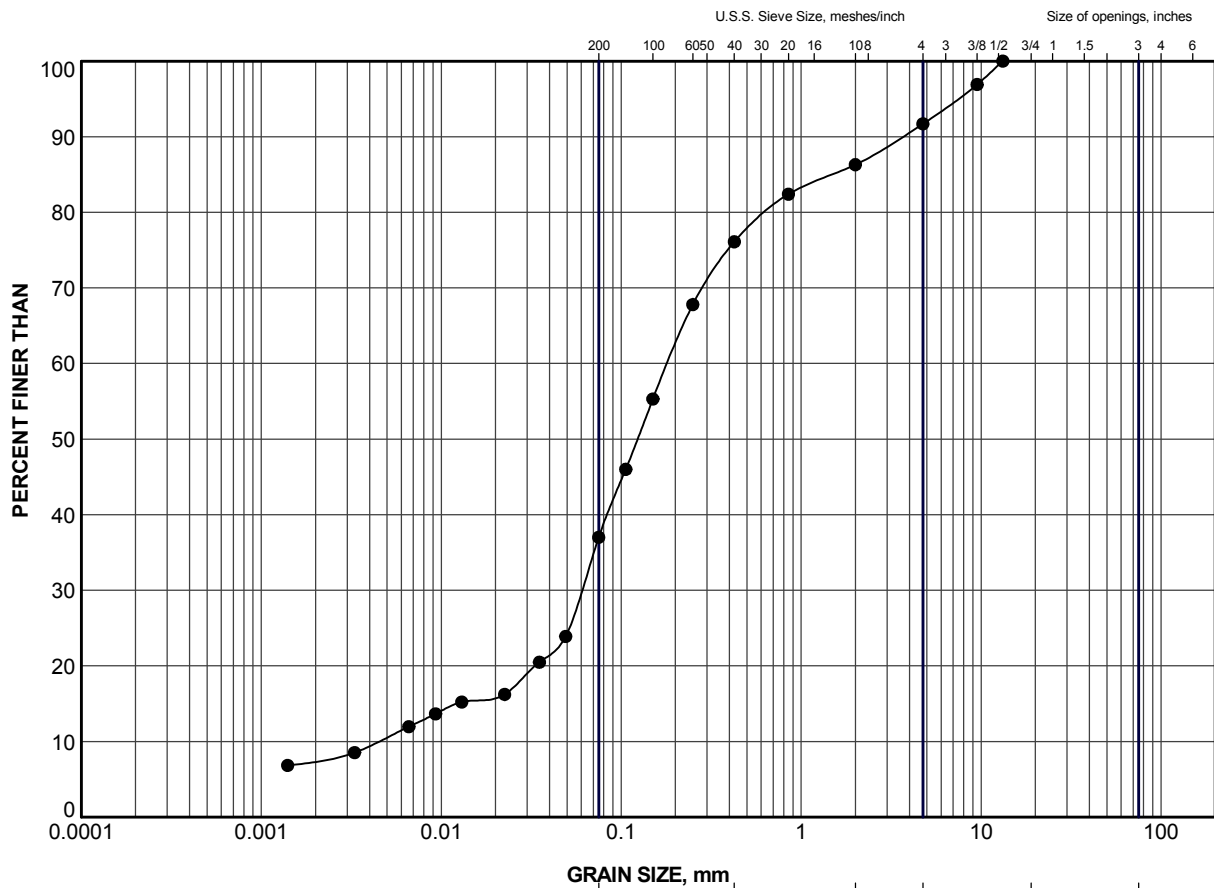
Base plans provided in digital format by Dillon Consulting.

NO.	DATE	BY	REVISION
Geocres No. 40P8-187			
Hwy. 7/B	PROJECT NO. 08-1132-084-1		DIST.
SUBM'D. ML	CHKD.	DATE: Jan. 14 /11	SITE:
DRAWN: WDF	CHKD.	APPD.	DWG. 1



APPENDIX A


Laboratory Test Data

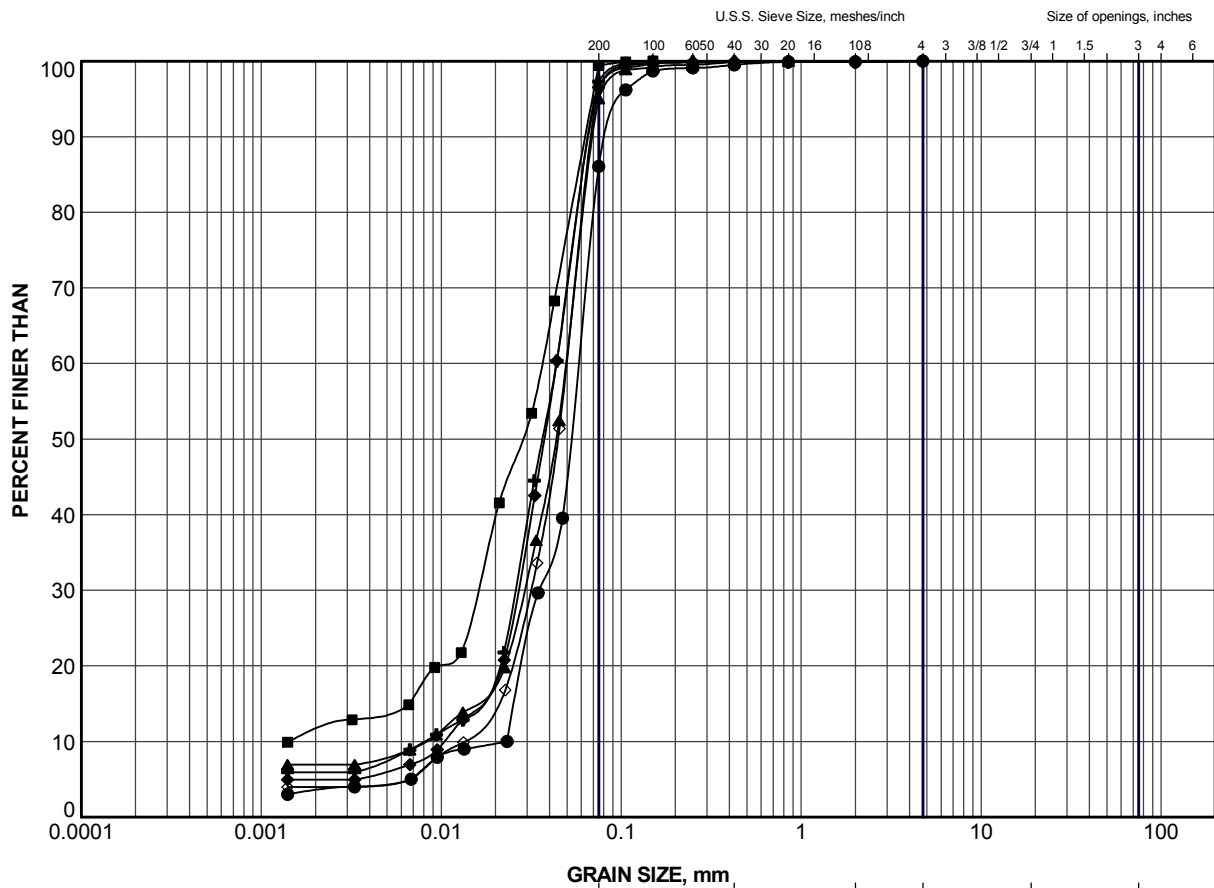


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	75	2	317.8


PROJECT				EXISTING NOISE BARRIER WALL 7 WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				GRAIN SIZE DISTRIBUTION FILL - NON COHESIVE			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F1110A1	
DRAWN		LMK		SCALE		N/A	
CHECK				REV.			
 Golder Associates LONDON, ONTARIO				FIGURE A-1			

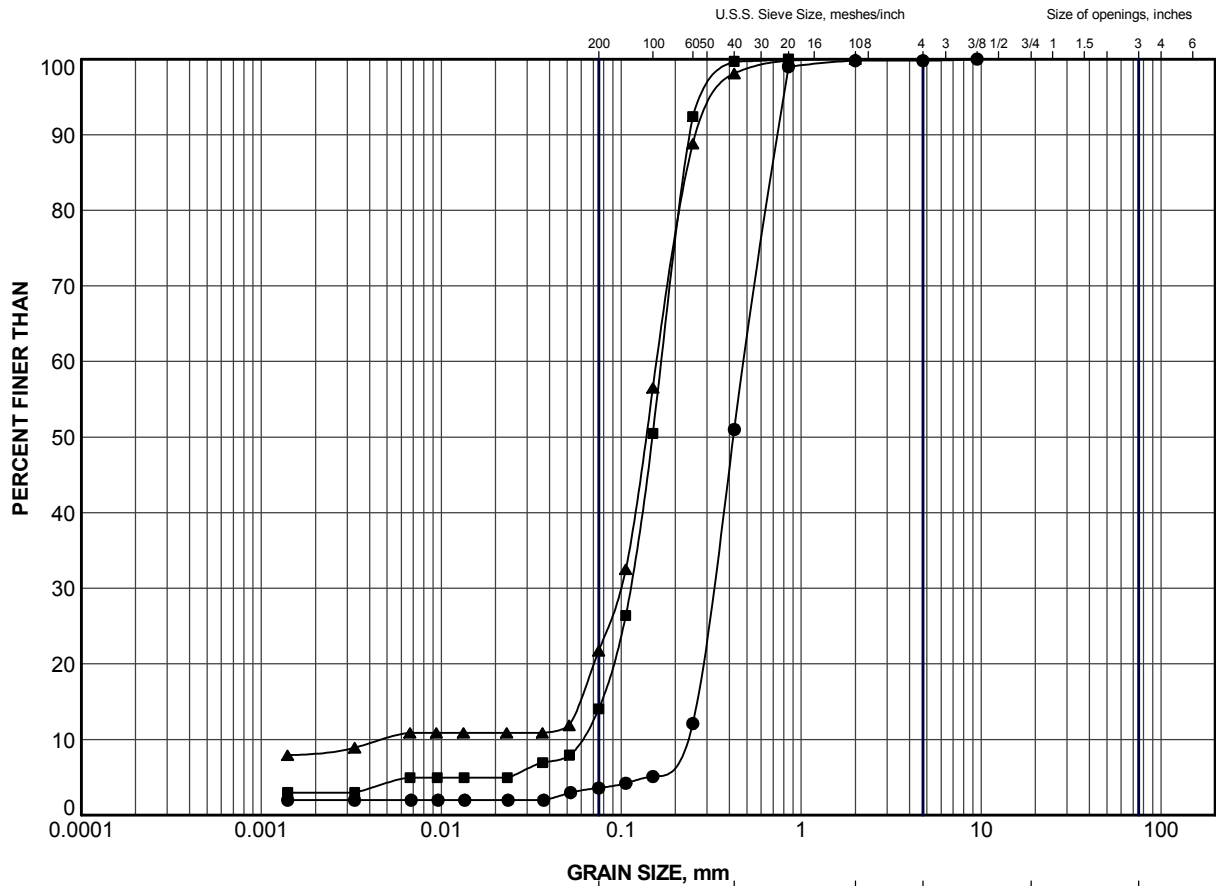


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	70	2	319.9
■	70	4	318.3
▲	71	5	317.9
+	72	3	319.5
◆	73	3	318.9
◇	75	4	316.2


PROJECT		EXISTING NOISE BARRIER WALL 7 WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE		GRAIN SIZE DISTRIBUTION SILT			
 Golder Associates LONDON, ONTARIO		PROJECT No.		08-1132-084-1	
		FILE No.		0811320841-F1110A2	
		SCALE		N/A	
		REV.			
DRAWN		LMK		Jan. 14/11	
CHECK					
		FIGURE A-2			

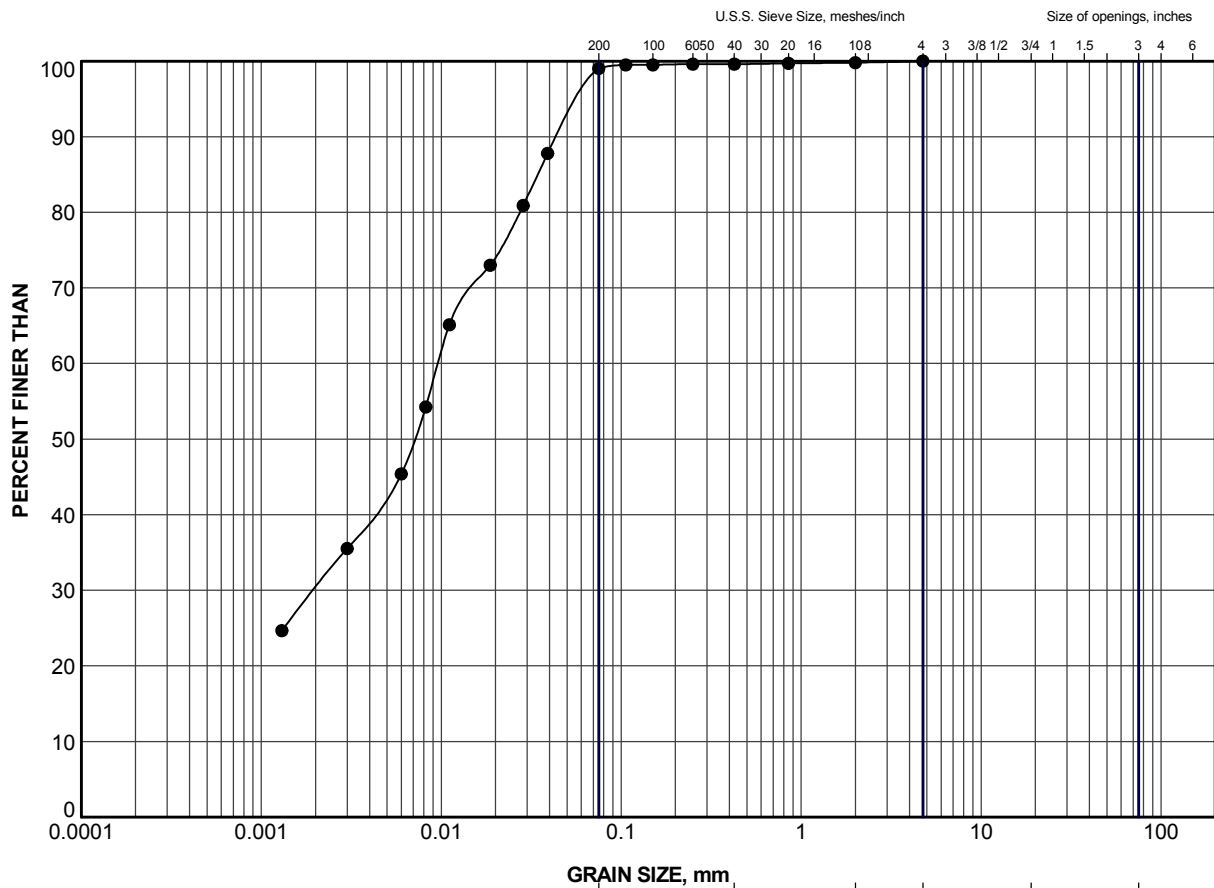


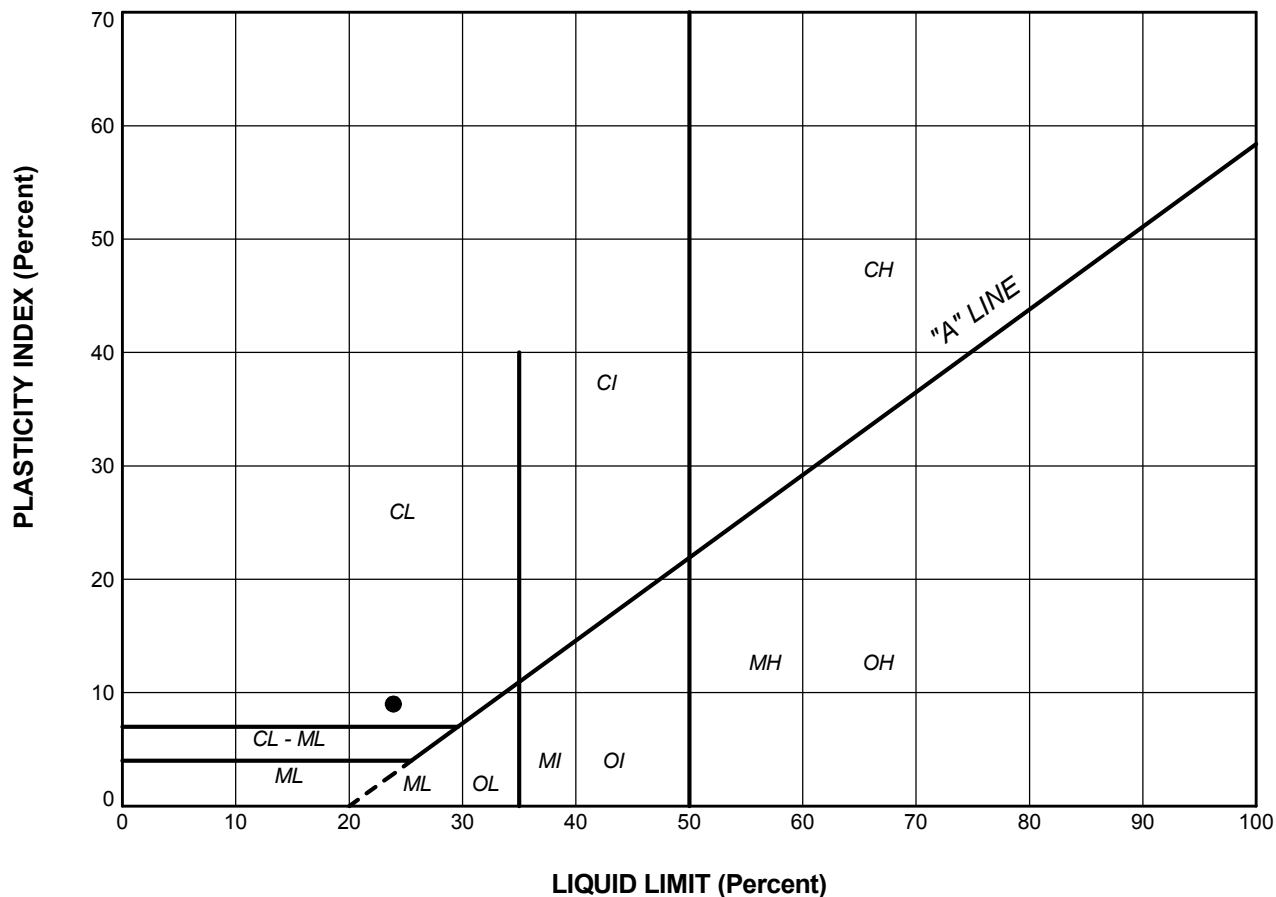
CLAY AND SILT	SAND SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	71	2	320.2
■	74	3	317.7
▲	76	3	316.6

PROJECT				EXISTING NOISE BARRIER WALL 7 WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F1110A3	
DRAWN		LMK		SCALE		N/A	
CHECK				REV.			
		Jan. 14/11					
 Golder Associates LONDON, ONTARIO				FIGURE A-3			





SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	70	5	23.9	14.9	9.0

CLAYEY SILT

PROJECT				EXISTING NOISE BARRIER WALL 7 WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				PLASTICITY CHART			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F1110A5	
DRAWN	LMK	Jan. 14/11		SCALE	N/A	REV.	
CHECK				FIGURE A-5			



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
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