



February 2011

FOUNDATION INVESTIGATION AND DESIGN REPORT

Proposed Noise Barrier Wall 6

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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Table of Contents

PART A - FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION.....	2
2.1 General.....	2
2.2 Site Geology	2
3.0 INVESTIGATION PROCEDURES.....	3
4.0 SUBSURFACE CONDITIONS	4
4.1 Site Stratigraphy	4
4.1.1 Topsoil	4
4.1.2 Fill	4
4.1.3 Silt.....	5
4.1.4 Sandy Silt.....	5
4.1.5 Clayey Silt Till.....	5
4.1.6 Silty Fine Sand	6
4.1.7 Sand	6
4.1.8 Sand and Gravel.....	6
4.2 Groundwater Conditions.....	6
5.0 MISCELLANEOUS.....	8

PART B - FOUNDATION DESIGN REPORT

6.0 ENGINEERING RECOMMENDATIONS.....	9
6.1 General.....	9
6.2 Noise Barrier Wall Foundation Design.....	9
6.3 Construction Considerations.....	10
7.0 MISCELLANEOUS.....	11

TABLE 1 – Foundation Design Parameters

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORD OF BOREHOLE SHEETS

FIGURE 1 - Key Plan

FIGURE 2 – Noise Barrier Wall Location Plan

DRAWING 1 – Borehole Locations



FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 6

APPENDICES

APPENDIX A

Laboratory Test Data



**FOUNDATION INVESTIGATION AND DESIGN REPORT
PROPOSED NOISE BARRIER WALL 6**

PART A

FOUNDATION INVESTIGATION REPORT

PROPOSED NOISE BARRIER WALL 6
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 the 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 6 which will be located approximately 1.5 kilometres west of the Fischer-Hallman Road Interchange between Stations 11+200 and 11+530 Lt on 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 the location and extent of the noise barrier wall 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 extends 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.

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 Rail (CNR) tracks are situated within the project limits.

Proposed noise barrier wall 6 will be located approximately 1.5 kilometres west of the Fischer-Hallman Road Interchange between Stations 11+200 and 11+530 Lt on Highway 7/8 within a predominantly residential area. The location of the noise barrier wall is shown on Figure 2. The topography along the alignment of the proposed barrier wall generally slopes eastwards with elevations ranging from about 380 metres at about Station 11+200 Lt Highway 7/8 to about 350 metres around the Fischer-Hallman Road Interchange.

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

The Geologic Survey of Canada Map 1263A entitled "Geology, Toronto-Windsor Area, Ontario" indicates that the subcropping bedrock in the area of the site is dolomite and mudstone of the Salina formation of Upper Silurian age. Based on the Ministry of Natural Resources Map P.168 entitled "Bedrock Topography Series, Stratford, Southern Ontario", the bedrock surface in the vicinity of the proposed noise wall 6 to the Fischer-Hallman Interchange subcrops at about elevations 259 to 265 metres or some 80 to 85 metres below ground surface at Highway 7/8.

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



3.0 INVESTIGATION PROCEDURES

The foundation investigation for the design of the proposed noise barrier wall 6 was carried out on November 11, 2010 at which time five boreholes were drilled along the wall alignment. The borehole locations are shown on Drawing 1.

The boreholes, numbered 77 to 81, inclusive, were advanced to a depth of 5.2 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)
77	4 808 622	221 197	366.64	5.18
78	4 808 591	221 128	375.40	5.18
79	4 808 557	221 056	372.74	5.18
80	4 808 529	220 990	380.08	5.18
81	4 808 500	220 919	379.73	5.18

The drilling was carried out using a track mounted CME 45 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. Larger particle sizes, including cobbles and boulders, are known to be present in the glacial till deposits as discussed in the text of this report.

The groundwater conditions were observed throughout the drilling operations and, upon completion of drilling, a 12.5 millimetre diameter standpipe was installed in borehole 77 to monitor the groundwater conditions. The boreholes were backfilled in accordance with current Ontario Ministry of Transportation (MTO) procedures and Ontario Regulations 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 along the noise barrier wall alignment generally encountered highly complex and variable conditions consisting of topsoil and granular fill underlain by silt, sandy silt, clayey silt till, silty sand, 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 Topsoil

Topsoil was encountered at the ground surface in boreholes 77 through 81. The thickness of the topsoil ranged from 200 to 460 millimetres. It should be noted that traces of topsoil were also encountered within the granular fill layer in borehole 79. Materials designated as topsoil in this report were classified 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 landscape vegetation.

4.1.2 Fill

A 0.8 metre thick layer of granular fill was encountered underlying the topsoil in borehole 79 at elevation 372.3 metres. The fill is comprised of sandy silt with traces of topsoil. The loose granular fill had an N value of 4 blows per 0.3 metres.



4.1.3 Silt

Silt layers were encountered underlying the topsoil in boreholes 78 and 80 from elevations 374.9 to 379.8 metres. Silt was also found underlying silty fine sand in borehole 80 at elevation 375.7 metres. The thickness of the silt layers ranged from 0.4 to 1.3 metres.

The silt is loose to dense with N values varying from 5 to 37 blows per 0.3 metres.

4.1.4 Sandy Silt

Sandy silt layers were found underlying the topsoil in boreholes 77 and 81 from elevations 366.4 and 379.5 metres, respectively, and beneath the fill in borehole 79 from elevation 371.5 metres. The thickness of the sandy silt layers ranged from 0.6 to 2.8 metres.

The very loose to compact sandy silt had N values of 4 to 17 blows per 0.3 metres penetration with a water content of 13 per cent. The sandy silt exhibits low plasticity and is a borderline silt to clay with a plastic limit of 15 per cent a liquid limit of 20 per cent and a plasticity index of 5 per cent based on the results of a single Atterberg limits determination. The Atterberg limits data are shown on Figure A-4.

The results of the grain size testing conducted on a sample of the sandy silt obtained during standard penetration testing are presented on Figure A-1.

4.1.5 Clayey Silt Till

Clayey silt till was encountered underlying sandy silt and silt in boreholes 77 through 81 from elevations 365.6 to 378.9 metres. The clayey silt till was interlayered with sandy silt in borehole 77. The thickness of the clayey silt till ranged from 0.9 to 2.7 metres. Borehole 79 was terminated in the clayey silt till after exploring the layer for 1.2 metres. Sand layers were noted in the clayey silt till. Although not specifically encountered in the boreholes, cobbles and boulders should be anticipated in the clayey silt till due to the depositional history of this material.

The soft to hard clayey silt till had N values of 3 to 41 blows per 0.3 metres with water contents ranging from 10 to 19 per cent. The results of the Atterberg limits determinations indicate that the clayey silt till is of low plasticity. The ranges of plastic limit, liquid limit and plasticity index for the clayey silt till were 12 to 17, 18 to 33 and 6 to 16 per cent, respectively. The Atterberg limits results for tests performed on samples of the clayey silt till are shown on Figure A-4.

The results of the grain size testing conducted on samples of the clayey silt till recovered from the standard penetration testing are presented on Figure A-2.



4.1.6 Silty Fine Sand

Layers of silty fine sand were found between sand layers in borehole 77 from elevation 362.6 metres and in boreholes 78 and 80 from elevations 372.2 and 376.2 metres, respectively, beneath clayey silt till. The thickness of the silty fine sand layers ranged from 0.3 to 0.5 metres.

The silty fine sand is dense with N values of 36 and 39 blows per 0.3 metres.

4.1.7 Sand

Sand layers were encountered beneath the clayey silt till in borehole 77 from elevation 362.6 metres and below the silt in borehole 80 from elevation 375.2 metres. In borehole 77, a layer of silty fine sand was found between sand layers. Where fully penetrated, the sand was 0.4 to 0.5 metres thick. Boreholes 77 and 80 were terminated in sand after exploring these layers for 0.5 and 0.3 metres, respectively. The N values in the dense sand ranged from 32 to 37 blows per 0.3 metres.

4.1.8 Sand and Gravel

Dense to very dense sand and gravel layers were found in boreholes 78 and 81 at elevations 371.7 and 376.1 metres, respectively. The sand and gravel to silty sand and gravel layers were found underlying silty fine sand and clayey silt till. Boreholes 78 and 81 were terminated in the sand and gravel after exploring the layer for 1.5 metres.

The N values in the sand and gravel ranged from 38 to 50 blows per 0.3 metres with a water content of 7 per cent.

The results of the grain size testing conducted on a sample of the sand and gravel obtained during standard penetration testing are presented on Figure A-3.

4.2 Groundwater Conditions

The groundwater conditions in 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 tables.



FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 6

Borehole	Ground Surface Elevation	Encountered Groundwater Level	
		Depth	Elevation
	(m)	(m)	(m)
77	366.64	2.1	364.5
78	375.40	Dry	Below 370.2
79	372.74	Dry	Below 367.6
80	380.08	Dry	Below 374.9
81	379.73	Dry	Below 374.6

During the field work, groundwater was encountered at elevation 364.5 metres in borehole 77. The remaining boreholes were dry and were advanced to a depth of approximately 5 metres and terminated in clayey silt till, sand and sand and gravel. With the exception of borehole 79, grey soils were not encountered in any of the boreholes which were dry upon completion. As a result, the groundwater level is inferred to be below the bottom of any borehole that was dry and did not intercept grey soils.

A 12.5 millimetre diameter standpipe was installed in borehole 77. The standpipe installed in borehole 77 on November 11, 2010 was found to be dry on that date and groundwater was measured at a depth of 1.0 metre or elevation 365.6 metres on November 25, 2010.

Borehole	Ground Surface Elevation (m)	Installation	Measured Groundwater Elevation (m)	
			Nov. 11, 2010 (Date of installation)	Nov. 25, 2010
77	366.64	Slotted Standpipe	Dry to below 361.5	365.62

The above noted encountered groundwater levels are not considered to be representative of the long-term, stabilized groundwater conditions as the readings were taken for a short duration only. From Station 11+200 to 11+320 Lt, the groundwater level has been inferred to be below the depth of exploration (5 metres) or below elevation 375 metres. From Station 11+320 to 11+460 the groundwater level is inferred to be below elevation 370 metres. East of Station 11+460 Lt, the groundwater level is inferred to be at elevation 366 metres. The groundwater levels are expected to fluctuate due to climatic and seasonal variations.



FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 6

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 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 6**

PART B

FOUNDATION DESIGN REPORT

PROPOSED NOISE BARRIER WALL 6

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 proposed noise barrier wall 6 along Highway 7/8 between Stations 11+200 and 11+530 Lt. The proposed noise barrier wall is to be located along the northerly limit of the of the right-of-way.

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 foundation 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. 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 and drained 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 undrained condition, and the larger of the two calculated caisson depths shall govern.

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 ground behind the proposed noise barrier wall will slope downward at about 2 horizontal to 1 vertical between Stations 11+200 and 11+320 and between 11+390 and 11+460 Lt Highway 7/8. Adjusted K_p values are provided 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 slope; below this elevation, the K_p for a horizontal surface value is to be applied.



6.3 Construction Considerations

Excavation for the construction of the noise barrier wall foundations will penetrate the surficial fill and will extend through deposits of silt, sandy silt, clayey silt till, silty fine sand, sand and sand and gravel. The sands and sand and gravels are predominantly fine to coarse grained and uniform in composition. The sands, silts and clayey silt tills at the site are susceptible to disturbance during caisson excavation and construction.

Excavation of granular materials below the groundwater table may be required in the vicinity of Station 11+340 and between Stations 11+475 to 11+530 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 caissons 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 augered excavations 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 Provisional Standard Specification 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.



FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED NOISE BARRIER WALL 6

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 6**

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/ 2H:1V	Coefficient of Active Pressure, K_a Level Ground	Unit Weight ³ (kNm ⁻³)	
								Bulk γ	Effective γ'
11+200 to 11+230 Borehole 81	Firm to very stiff clayey silt till	378.0 to 376.0	Below 375.0	50	30	3.0/1.1	0.33	21.0	11.0
	Dense silty sand and gravel	Below 376.0		-	34	3.5/1.3	0.28	20.5	10.5
11+230 to 11+320 Borehole 80	Very stiff to hard clayey silt till	378.5 to 376.0	Below 375.0	150	30	3.0/1.1	0.33	21.0	11.0
	Dense silty sand to sand	Below 376.0		-	32	3.3/1.2	0.31	19.0	9.0
11+320 to 11+390 Borehole 79	Very loose to compact sandy silt	371.0 to 368.5	Below 370.0	-	29	2.9/N/A	0.35	18.5	8.5
	Soft to stiff clayey silt till	Below 368.5		75	30	3.0/N/A	0.33	19.5	9.5
11+390 to 11+460 Borehole 78	Very stiff clayey silt till	374.0 to 372.0	Below 370.0	150	30	3.0/1.1	0.33	21.0	11.0
	Dense sand and gravel	Below 372.0		-	34	3.5/1.3	0.28	20.5	10.5
11+460 to 11+530 Borehole 77	Stiff to very stiff clayey silt till	365.0 to 362.5	Below 366.0	100	30	3.0/N/A	0.33	21.0	11.0
	Dense sand to silty sand	Below 362.5		-	32	3.3/N/A	0.31	19.0	9.0

**FOUNDATION DESIGN PARAMETERS
PROPOSED NOISE BARRIER WALL 6**

NOTES:

1. Where both c_u and ϕ 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 ground behind the proposed noise barrier wall will slope downwards at about 2 horizontal to 1 vertical within the following approximate station ranges:
 - Station 11+200 Lt to 11+320 Lt Highway 7/8;
 - Station 11+390 Lt to 11+460 Lt Highway 7/8.
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: MSWL

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.)

Consistency

	<u>kPa</u>	<u>psf</u>
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

(b) Cohesive Soils

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 77

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4808622.1 ; E 221196.7 ORIGINATED BY MA
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY LMK/AMG
DATUM GEODETIC DATE November 11, 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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
366.64	GROUND SURFACE																
0.00	TOPSOIL, silty Brown																
0.27	SANDY SILT, some clay, trace gravel Compact Brown																
365.57			1	SS	16												
1.07	CLAYEY SILT TILL, some sand, trace gravel, with sand layers Very stiff Brown																
364.66			2	SS	17												
1.98	SANDY SILT, some clay, trace gravel Compact Brown																
364.05			3	SS	14												
2.59	CLAYEY SILT TILL, trace sand, trace gravel Stiff Brown																
			4	SS	14												
362.64																	
4.00	SAND, fine to medium, trace silt Dense Brown		5	SS	33												
362.22																	
4.42	SILTY FINE SAND, Dense Brown																
4.72			6	SS	32												
361.46	SAND, fine to medium, trace gravel Dense Brown																
5.18	END OF BOREHOLE																
	Groundwater encountered at about elev. 364.5m during drilling on November 11, 2010.																
	Standpipe dry to elev. 363.49m on November 11, 2010.																
	Water level measured at elev. 365.62m on November 25, 2010.																

RECORD OF BOREHOLE No 78

1 OF 1

METRIC

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4808591.3 :E 221128.3

ORIGINATED BY MA

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY LMK/AMG

DATUM GEODETIC

DATE November 11, 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								
375.40	GROUND SURFACE						20	40	60	80	100							
0.00	TOPSOIL, sandy Brown																	
374.94																		
0.46	SILT, trace sand, some clay Compact Brown		1	SS	19													
373.64			2	SS	20													
1.76	CLAYEY SILT TILL, some sand, trace gravel Very stiff Brown		3	SS	24							○	11			0 12 66 22		
372.24			4	SS	36													
3.16	SILTY FINE SAND, trace gravel Dense Brown																	
371.71																		
3.69	SAND AND GRAVEL, some silt, trace clay Dense Brown		5	SS	47							○				33 50 13 4		
			6	SS	47													
370.22																		
5.18	END OF BOREHOLE																	
	Borehole dry during drilling on November 11, 2010.																	

RECORD OF BOREHOLE No 79

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4808556.5 ; E 221056.1 ORIGINATED BY MA
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY LMK/AMG
DATUM GEODETIC DATE November 11, 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											
372.74	GROUND SURFACE						20	40	60	80	100										
0.00	TOPSOIL, silty Brown																				
372.34																					
0.40	FILL, sandy silt, trace clay, trace topsoil Loose Brown		1	SS	4																
371.52																					
1.22	SANDY SILT, some clay, trace gravel Very loose to compact Brown to grey at about elev. 369.1m		2	SS	10																
			3	SS	17																
			4	SS	4																
368.72																					
4.02	CLAYEY SILT TILL, trace sand, trace gravel Soft to stiff Grey		5	SS	3																
			6	SS	9																
367.56																					
5.18	END OF BOREHOLE Borehole dry during drilling on November 11, 2010.																				

RECORD OF BOREHOLE No 80

1 OF 1

METRIC

PROJECT 08-1132-084-1

W.P. 131-98-00

LOCATION N 4808528.9 ; E 220989.8

ORIGINATED BY MA

DIST HWY 7/8

BOREHOLE TYPE POWER AUGER / HOLLOW STEM

COMPILED BY LMK/AMG

DATUM GEODETIC

DATE November 11, 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		
380.08	GROUND SURFACE																	
0.00	TOPSOIL, silty Brown																	
0.30	SILT, trace sand, trace clay Loose Brown																	
378.86			1	SS	5													
1.22	CLAYEY SILT TILL, some sand, trace gravel Very stiff to hard Brown		2	SS	16													
			3	SS	15													
			4	SS	41													
376.15																		
3.93	SILTY FINE SAND Dense Brown		5	SS	39													
375.66																		
4.42	SILT, trace clay with clayey silt layers Dense Brown		6	SS	37													
375.23																		
4.85																		
374.90																		
5.18	SAND, fine, some silt Dense Brown END OF BOREHOLE Borehole dry during drilling on November 11, 2010.																	

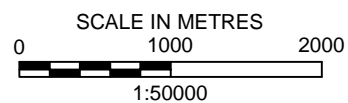
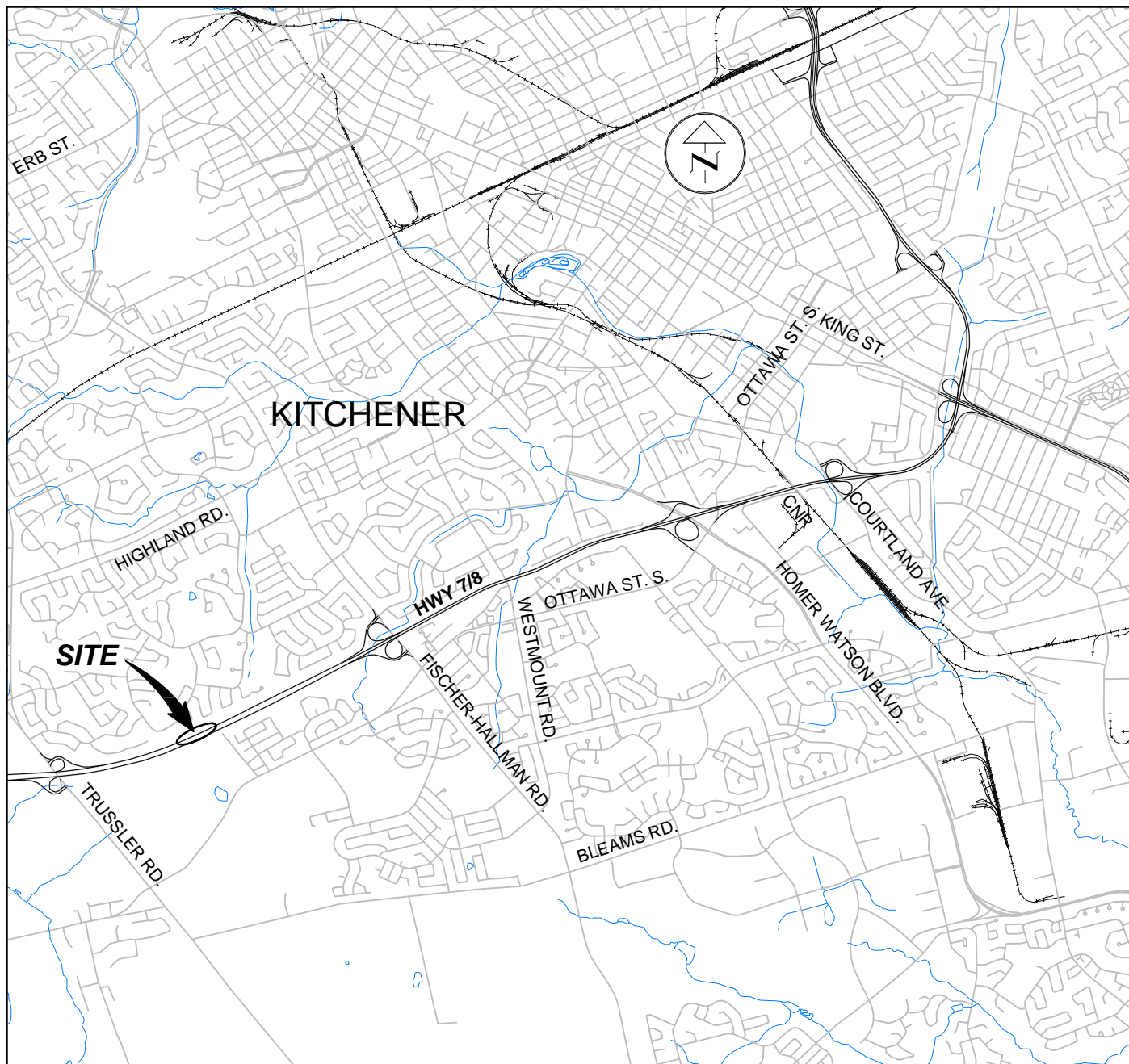
RECORD OF BOREHOLE No 81

1 OF 1

METRIC

PROJECT 08-1132-084-1
W.P. 131-98-00 LOCATION N 4808499.5 ; E 220919.2 ORIGINATED BY MA
DIST HWY 7/8 BOREHOLE TYPE POWER AUGER / HOLLOW STEM COMPILED BY LMK/AMG
DATUM GEODETIC DATE November 11, 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									
379.73	GROUND SURFACE						20	40	60	80	100						
0.00	TOPSOIL, silty Brown																
0.20	SANDY SILT, some clay, trace gravel, Compact Brown		1	SS	10												
378.36																	
1.37	CLAYEY SILT TILL, some sand, trace gravel Firm to very stiff Brown		2	SS	6											1 27 45 27	
			3	SS	7												
			4	SS	24												
376.07																	
3.66	SILTY SAND AND GRAVEL, trace clay Dense to very dense Brown		5	SS	38											5 22 49 24	
			6	SS	50												
374.55																	
5.18	END OF BOREHOLE Borehole dry during drilling on November 11, 2010.																



REFERENCE

DRAWING BASED ON CANMAP STREETFILES V2005.4.

NOTE

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

PROJECT

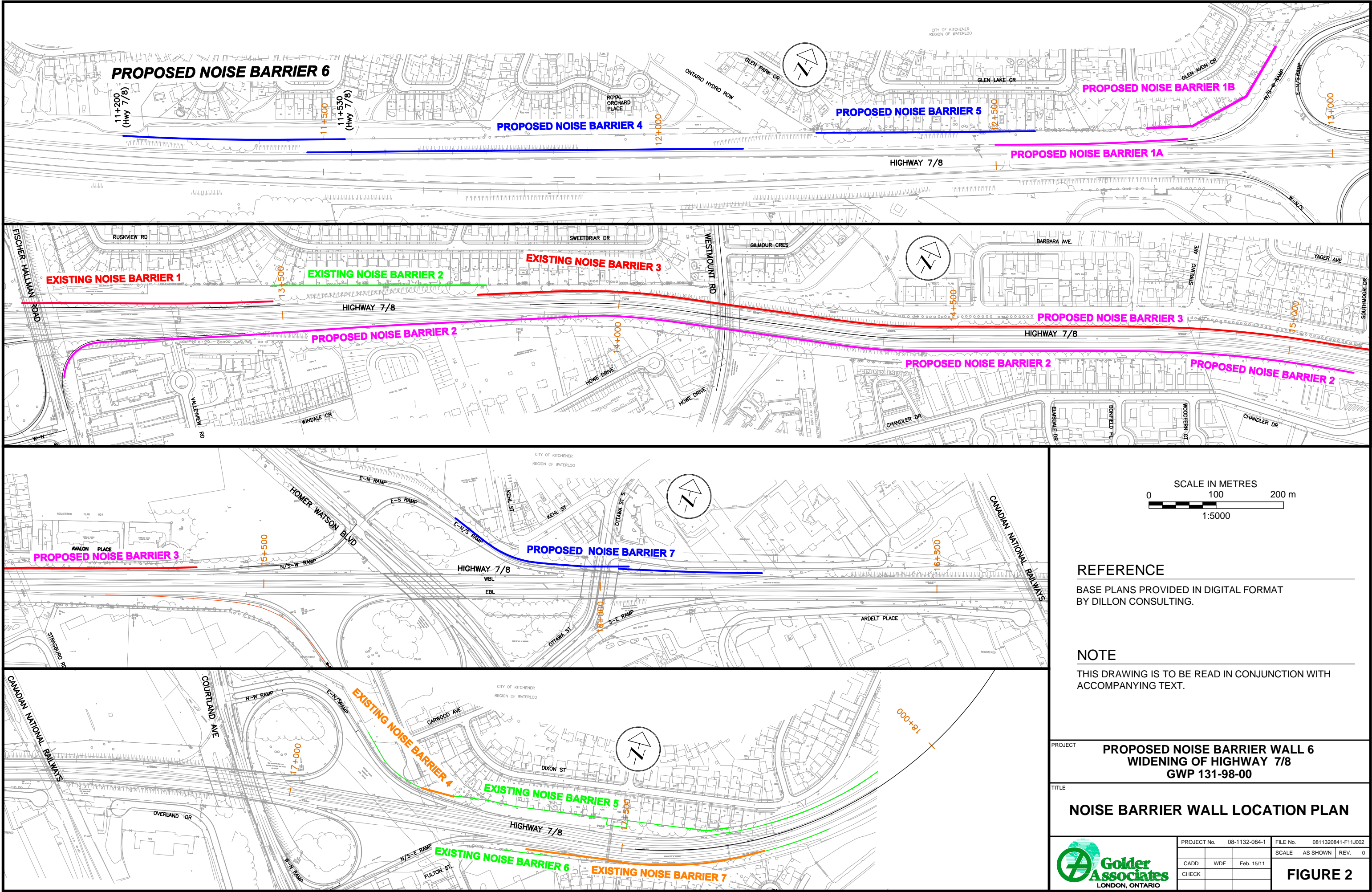
**PROPOSED NOISE BARRIER WALL 6
WIDENING OF HIGHWAY 7/8
GWP 131-98-00**

TITLE

KEY PLAN



PROJECT No. 08-1132-084-1		FILE No. 0811320841-F11J001	
CADD	LMK/WDF	Feb. 15/11	SCALE AS SHOWN
CHECK			REV.
			FIGURE 1



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

CONT No.
 WP No. 131-98-00



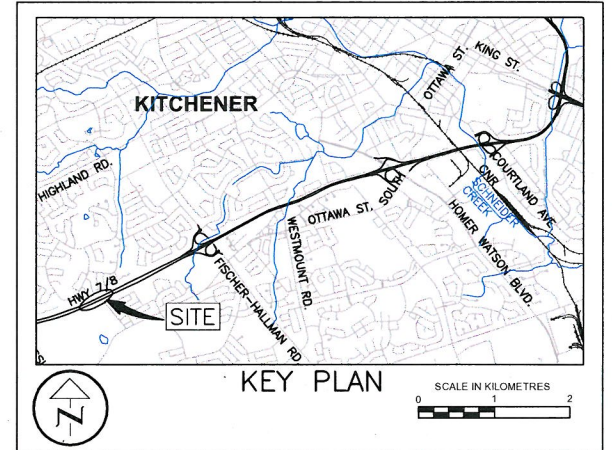
PROPOSED NOISE BARRIER WALL 6

SHEET

WIDENING OF HIGHWAY 7/8
 BOREHOLE LOCATIONS



Golder Associates Ltd.
 LONDON, ONTARIO, CANADA



LEGEND

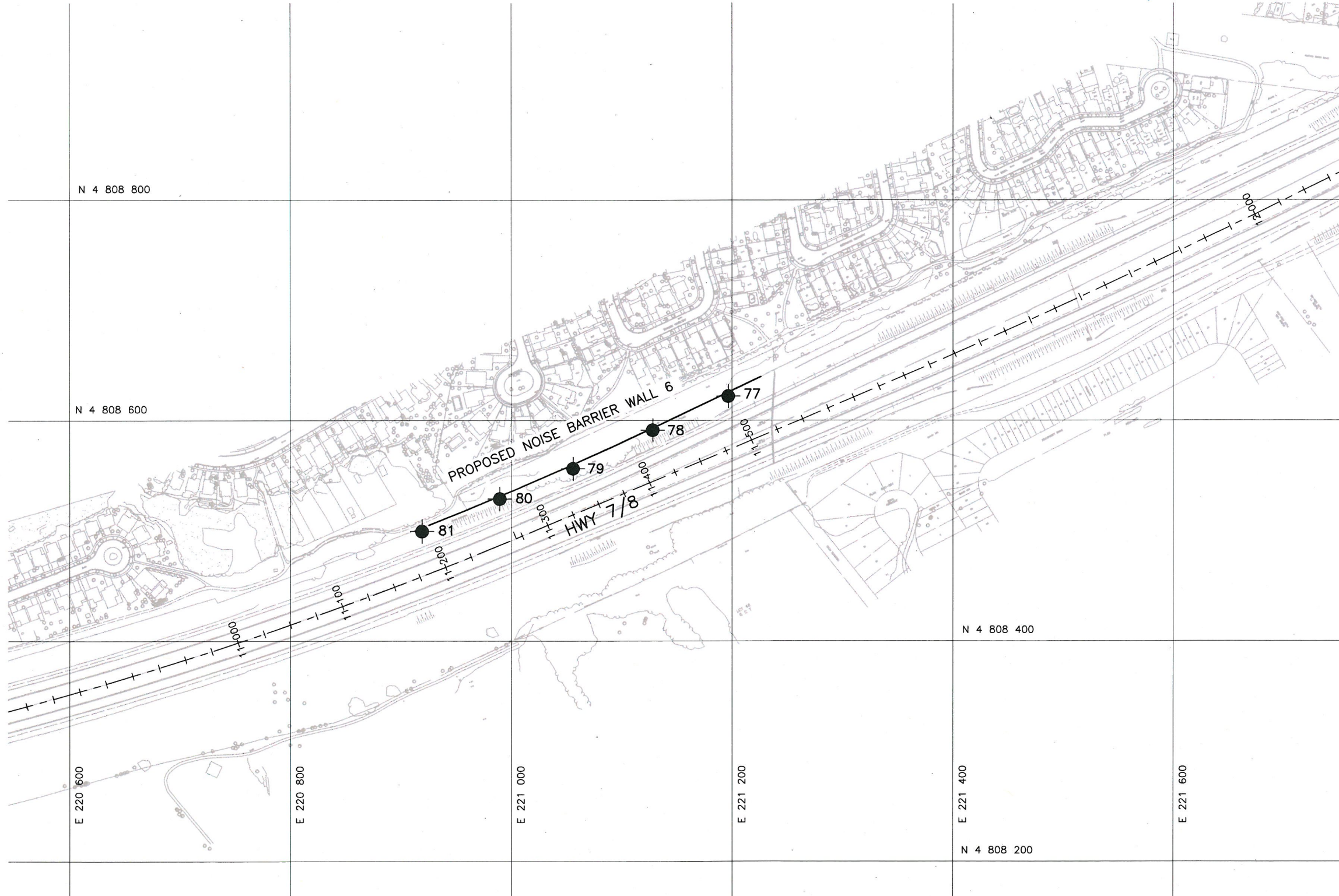
No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
77	366.64	4 808 622.1	221 196.7
78	375.40	4 808 591.3	221 128.3
79	372.74	4 808 556.5	221 056.1
80	380.08	4 808 528.9	220 989.8
81	379.73	4 808 499.5	220 919.2

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.



PLAN

SCALE
 0 40 m



NO.	DATE	BY	REVISION

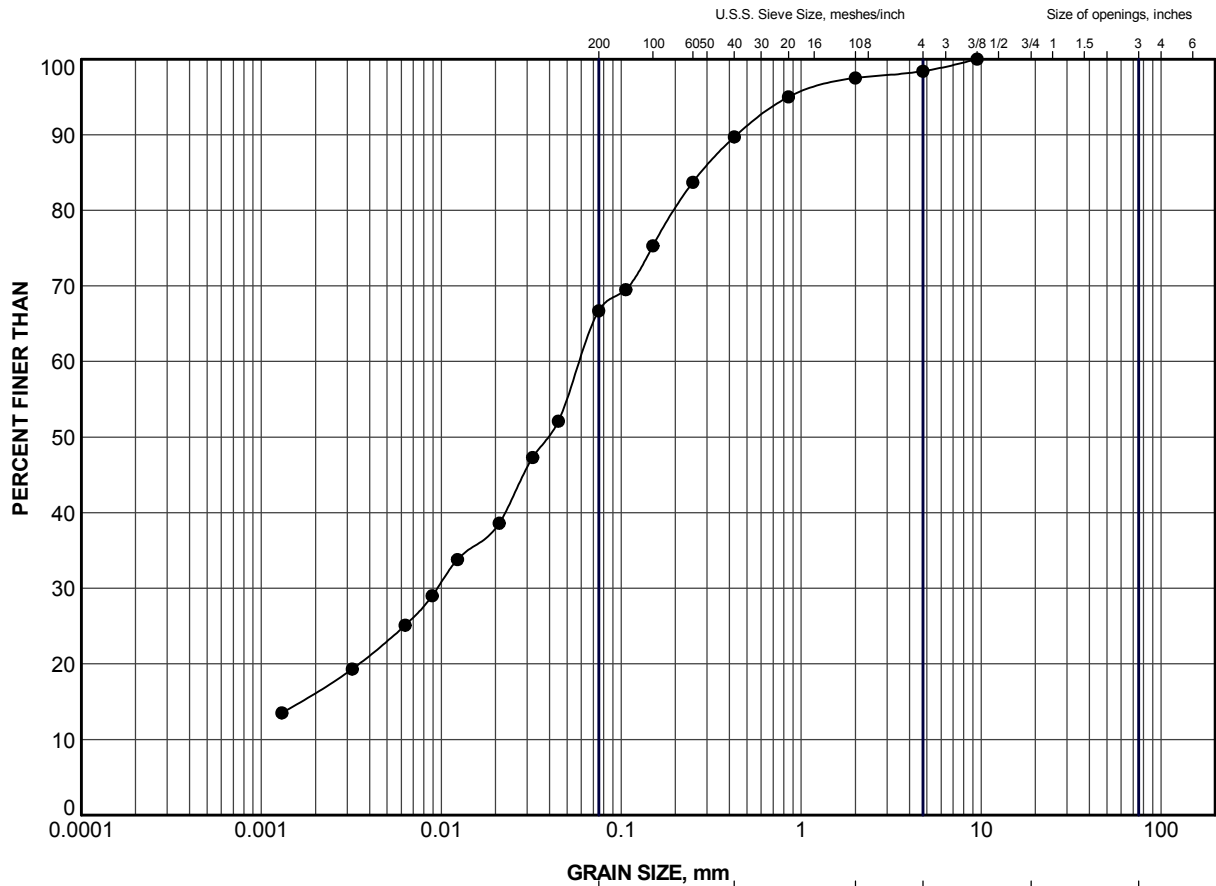
Geocres No. 40P7-64

HWY. 7/8	PROJECT NO. 08-1132-084-1	DIST.
SUBM'D. ML	CHKD.	DATE: Feb. 15/11
DRAWN: WF/AG	CHKD.	APPD.
		DWG. 1



APPENDIX A


Laboratory Test Data



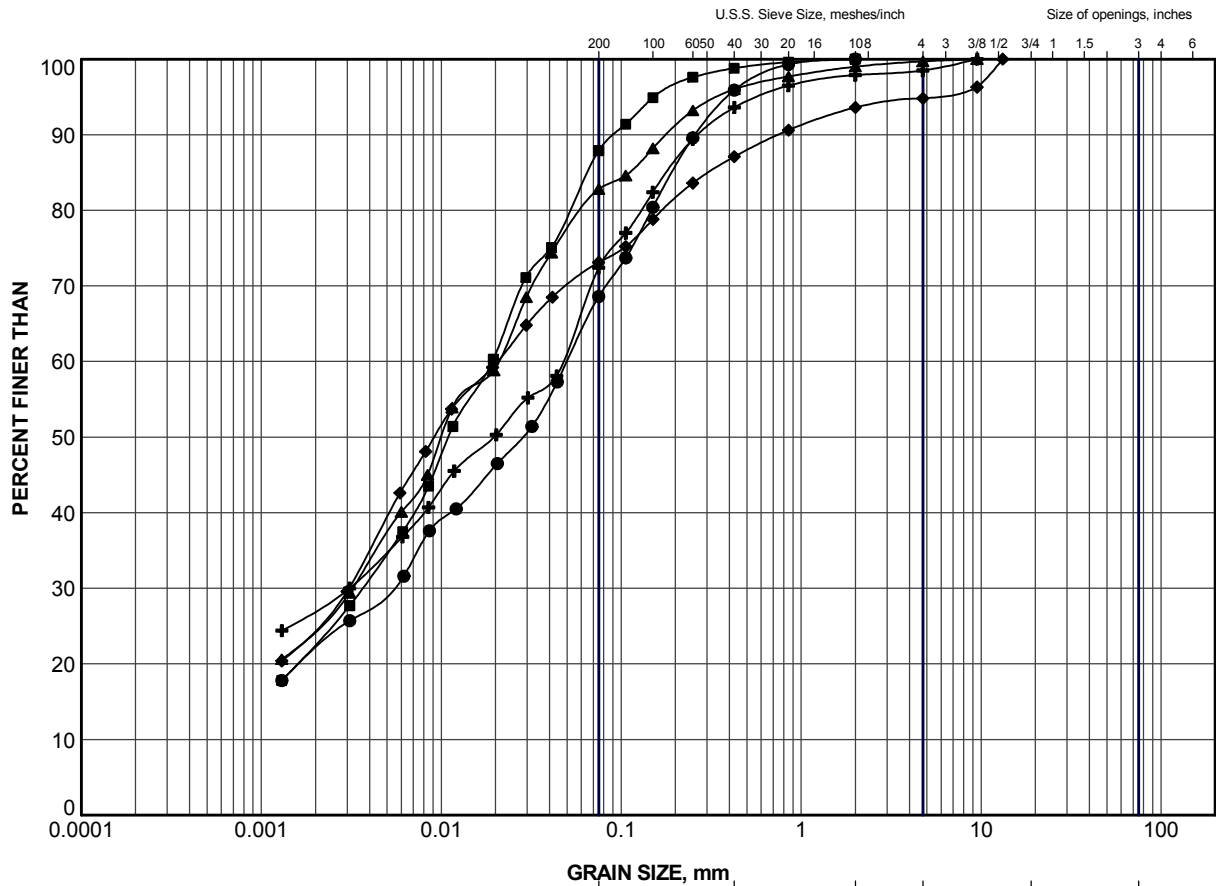
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	79	4	369.5

PROJECT	PROPOSED NOISE BARRIER WALL 6 WIDENING OF HIGHWAY 7/8 GWP 131-98-00				
TITLE	GRAIN SIZE DISTRIBUTION SANDY SILT				
 <div> <div>Golder Associates</div> <div>LONDON, ONTARIO</div> </div>	PROJECT No.	08-1132-084-1	FILE No.	0811320841-F11J0A1	
	DRAWN	WDF	Feb. 15/11	SCALE	N/A
	CHECK			REV.	
			FIGURE A-1		

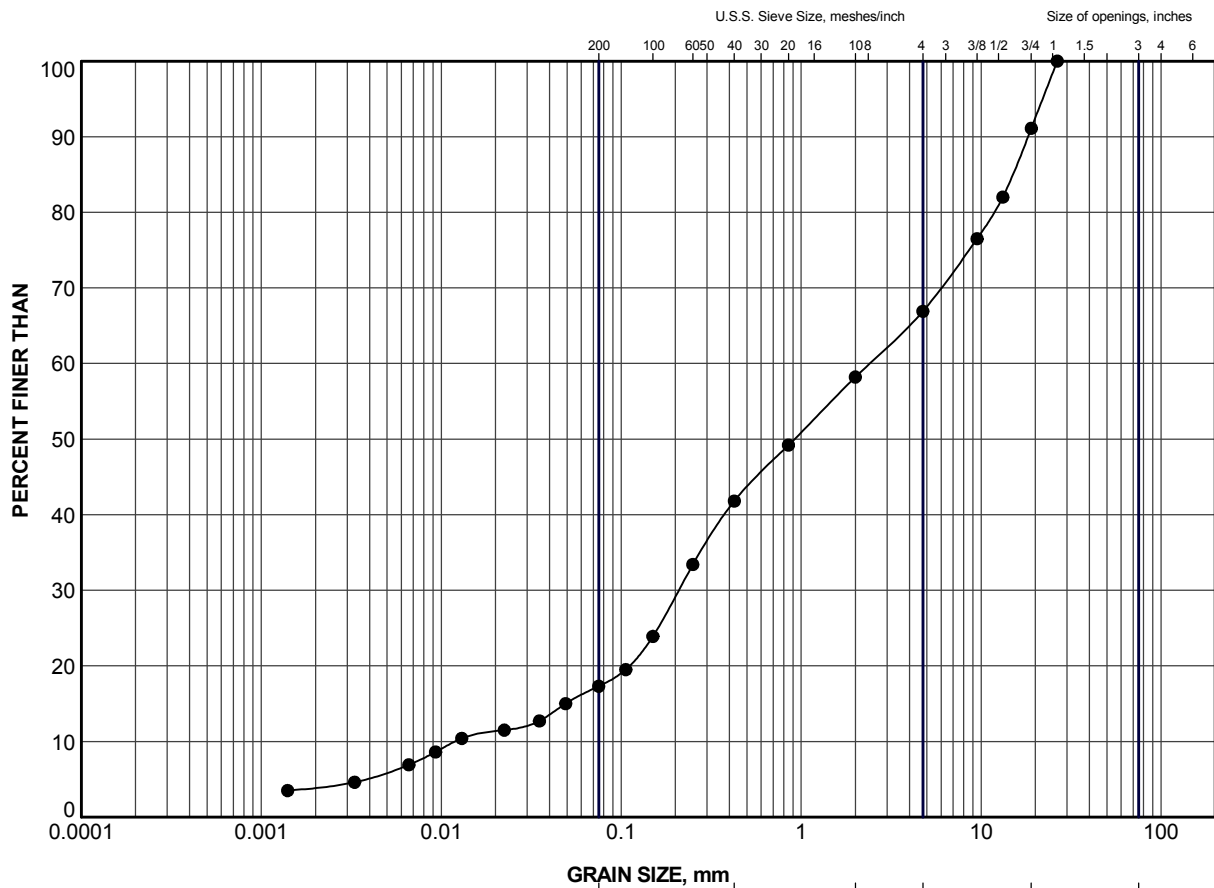
LDN_MTO_NEW_GLDR_LDN.GDT



LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	77	2	364.9
■	78	3	372.9
▲	80	3	377.6
+	81	2	378.0
◆	81	4	376.5

PROJECT				PROPOSED NOISE BARRIER WALL 6 WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F11J0A2	
DRAWN		WDF		Feb. 15/11		SCALE N/A REV.	
CHECK						FIGURE A-2	





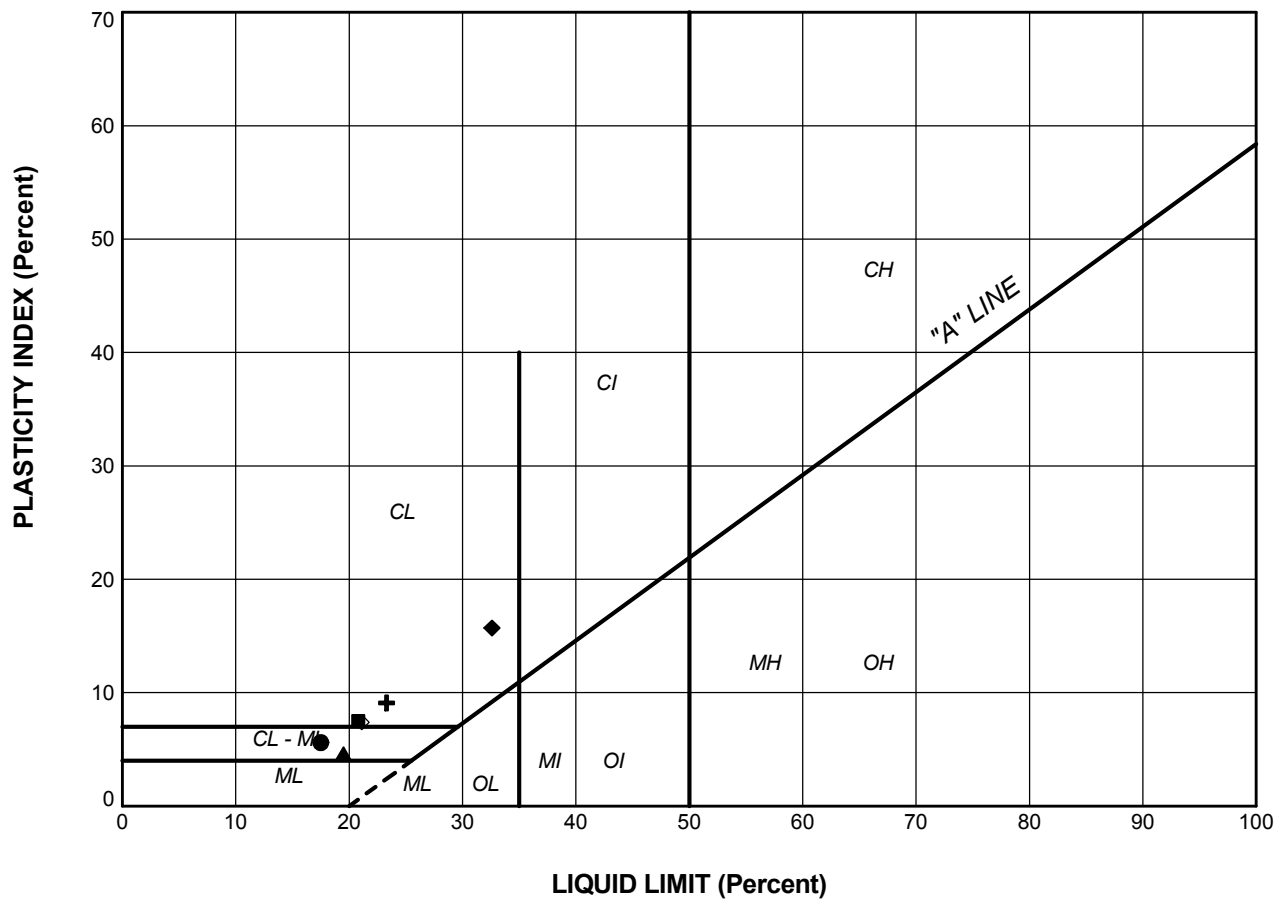
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	78	5	371.4

PROJECT				PROPOSED NOISE BARRIER WALL 6 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-F11J0A3	
DRAWN		WDF		Feb. 15/11		SCALE N/A REV.	
CHECK						FIGURE A-3	





LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
CLAYEY SILT TILL					
●	77	2	17.5	11.9	5.6
■	78	3	20.8	13.3	7.5
+	80	3	23.3	14.2	9.1
◆	81	2	32.6	16.9	15.7
◇	81	4	21.1	13.7	7.4
SANDY SILT					
▲	79	4	19.5	14.9	4.6

PROJECT				PROPOSED NOISE BARRIER WALL 6 WIDENING OF HIGHWAY 7/8 GWP 131-98-00			
TITLE				PLASTICITY CHART			
PROJECT No.		08-1132-084-1		FILE No.		0811320841-F11J0A4	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			



FIGURE A-4

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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