



July 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

**Overhead and High-Occupancy Vehicle Signs
Reconstruction and Widening of Highway 401
From 0.5 KM West of Regional Road 8/King Street Easterly
to 0.5 KM East of Regional Road 24/Hespeler Road - 5.5 KM
GWP 4-00-00
Ministry of Transportation, Ontario - West Region**

Submitted to:

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REPORT



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PART A

FOUNDATION INVESTIGATION REPORT

OVERHEAD AND HOV SIGNS

RECONSTRUCTION AND WIDENING OF HIGHWAY 401

FROM 0.5 KM WEST OF REGIONAL ROAD 8/KING STREET EASTERLY TO

0.5 KM EAST OF REGIONAL ROAD 24/HESPELER ROAD – 5.5 KM

GWP 4-00-00

MINISTRY OF TRANSPORTATION - WEST REGION



1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Delcan Corporation (a Parsons Company) (Delcan) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 4-00-00. The project involves the detail design for the reconstruction and widening of Highway 401 from 0.5 kilometres west of King Street (Waterloo Regional Road 8) easterly to 0.5 kilometres east of Hespeler Road (Waterloo Regional Road 24).

This report addresses overhead signs (OHS) and high-occupancy vehicle (HOV) signs associated with the reconstruction and widening of Highway 401. Six OHSs and six median mounted HOV signs are proposed for this project. For the purposes of this report, Highway 401 is assumed to be oriented in an east-west direction.

The purpose of the foundation investigation is to explore the subsurface conditions at the proposed sign locations by drilling one borehole at or in close proximity to each sign location and carrying out in situ testing and laboratory testing on selected samples of the subsurface materials. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P0-1132-0056 dated July 23, 2010 and the revised scope of work as outlined in Golder Associates' letter 10-1132-0056-2000-L06 dated May 7, 2013. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated March 8, 2012.

Delcan provided Golder Associates with drawings for this project in digital format.



2.0 SITE DESCRIPTION

2.1 General

The reconstruction and widening of Highway 401 to be undertaken as GWP 4-00-00 extends from west of King Street (Regional Road 8) easterly to east of Hespeler Road (Regional Road 24) in the City of Cambridge, Region of Waterloo. Overhead signs are proposed at Stations 15+159 Lt, 15+703 Lt and 16+500 Lt over the westbound lanes, at Stations 17+700 Rt and 18+593 Rt over the eastbound lanes, and at Station 10+305 of the Hespeler W-N/S ramp. High-occupancy vehicle signs are proposed at Station 16+691 for the westbound lanes, and at Stations 15+350, 15+750, 17+059, 17+280, and 18+793 for the eastbound lanes. The location of the project is shown on the Key Plan, Figure 1.

This section of Highway 401 is currently a six lane divided highway oriented in a generally east-west direction. Two underpass structures for Fountain Street North and Speedville Road, two bridges for the east and west channels of the Speed River, as well as two overhead structures for the Grand River Electric Railway (GRER) tracks and the Canadian National Railway tracks are situated within the project limits.

The six OHSs, three for the westbound lanes and three for the eastbound lanes, and the six HOV signs are located between King Street and Hespeler Road. The lands adjacent to the OHSs vary in land use from industrial, commercial, residential to undeveloped lands often used for recreation purposes.

2.2 Site Geology

This project lies within the physiographic region of southwestern Ontario known as the Waterloo Hills which primarily comprises sandy glacial till ridges or glacial kame moraines with outwash sands in the lower areas. The physiographic mapping indicates that the sign locations are situated in a former glaciofluvial spillway area.¹

The quaternary geology mapping indicates that the surficial materials vary within the project extents. The surficial materials at the OHS at Station 15+159 Lt consist of outwash gravel. The OHS at Station 15+703 Lt and the HOV sign at Station 15+750 are located within the Port Stanley Till which consists of silt to sandy silt glacial till. The HOV sign at Station 15+350 is located at the transition between these two zones of surficial material. The OHS at Station 16+500 Lt is located within the Mary Hill Till which consists of clayey silt glacial till. The HOV sign at Station 16+691 is positioned near an eroded scarp which forms the transition between the Mary Hill Till and a stream deposit of gravel, sand, silt and clay associated with the Speed River flood plain. The HOV sign at Station 17+059 sits near the same eroded scarp which, at this location, forms the transition between the Mary Hill Till and the Catfish Creek Till which consists of stony, sandy silt glacial till. The HOV sign at Station 17+280 is located within the Catfish Creek Till. The surficial materials at the OHS at Station

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



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17+700 Rt consist of the Speed River flood plain stream deposits. The surficial materials at the OHS at Station 18+593 Rt, at the HOV sign at Station 18+793, and at the OHS at Station 10+305 (Hespeler W-N/S ramp) consist of outwash gravel, where the OHS at Station 18+593 Rt is located near an eroded scarp which forms the transition between the outwash gravel and the stream deposits.²

The underlying bedrock surface in this area generally slopes upwards from about elevation 259 metres at Fountain Street to 282 metres at Hespeler Road.³ The rock formation is mapped and described as cream and brown, fine to medium crystalline dolomite of the Guelph Formation.⁴

² Karrow, P.F., 1987: Quaternary Geology of the Cambridge Area, Southern Ontario. Ontario Geological Survey, Map 2508, scale 1:50,000.

³ Ontario Department of Mines, 1960: Bedrock Topography, Galt Area, Southern Ontario. Map 2030, scale 1:50,000

⁴ Sanford, B.V., 1969: Geology, Toronto-Windsor Area, Ontario. Geological Survey of Canada, Map 1263A, scale 1:250,000.



3.0 INVESTIGATION PROCEDURES

The field work for the investigation was carried out between June 13, 2012 and May 8, 2014, during which time ten boreholes specific to the OHSs (boreholes 1 to 4 and 6) and HOV signs (boreholes 20 to 24) were drilled. These boreholes were supplemented with boreholes advanced for other components of this project, specifically:

- Borehole 721 advanced for high fills, Geocres Report No. 40P8-223; and
- Borehole 904 advanced for a high mast light location, Geocres Report No. 40P8-221.

The bedrock was later cored in borehole 721A, adjacent to borehole 721, in order to meet the minimum exploration depth requirement. The borehole locations are shown on the Borehole Location Plan, Drawing 1. The table below summarizes the locations, ground surface elevations, and depths of the boreholes.

Borehole	Structure	Site No.	Station	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
				Northing	Easting		
1	OHS	33-830-E-S	17+700 Rt	4 808 505	236 241	277.52	4.60
2		33-416-W-S	16+500 Lt	4 808 290	235 084	297.97	15.70
3		33-417-W-S	15+703 Lt	4 807 787	234 439	304.31	8.53
4		33-418-W-S	15+159 Lt	4 807 561	233 975	305.84	6.55
6		33-833-E-S	10+305*	4 808 469	237 534	296.00	6.31
721		33-829-E-S	18+593 Rt	4 808 495	237 138	286.31	4.82
721A				4 808 495	237 136	286.31	7.47
20	HOV	33-835-E-S	15+750	4 807 790	234 524	302.65	6.55
21		33-839-W-S	16+691	4 808 370	235 265	283.80	6.55
22		33-836-E-S	17+059	4 808 510	235 601	279.85	7.71
23		33-837-E-S	17+280	4 808 528	235 820	279.00	6.19
24		33-838-E-S	18+793	4 807 554	237 332	295.00	6.55
904		33-834-E-S	15+350	4 807 595	234 172	305.50	10.21

* Refers to Hespeler Road W-N/S ramp chainage.

The investigation was carried out using truck and track mounted drilling equipment supplied and operated by specialist drilling contractors. In the boreholes, samples of the overburden were obtained at generally 0.76 or 1.52 metre intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures of ASTM D1586. The bedrock in boreholes 1, 22, 23 and 721A was cored using NQ-sized rock coring equipment.



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The recorded SPT N values are noted on the Record of Borehole sheets. According to ASTM D1586, the SPT resistance, or N value, is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split-spoon sampler a distance of 300 millimetres, after an initial 150 millimetres of penetration. In cases where it was not possible to achieve a full 450 millimetres of drive, a penetration resistance representing the number of blows to drive the sampler is recorded on the Record of Borehole. The penetration resistance obtained in the first 150 millimetres is normally neglected unless the sampler could only be driven 150 millimetres or less, in which case SPT testing was terminated after 100 blows. The results of the SPT testing as presented on the Record of Borehole sheets and in Section 4 are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.).

The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles 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 fill materials and native granular soils as discussed in the text of this report.

The boreholes were terminated between 4.6 and 15.7 metres below the existing pavement or ground surface. Groundwater conditions in the boreholes were observed throughout the drilling operations. A groundwater observation piezometer was installed in borehole 2 as indicated on the corresponding Record of Borehole sheets. The boreholes were backfilled in general accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The field work was monitored on a full-time basis by experienced Golder Associates' staff who also located the boreholes in the field, monitored the drilling, sampling, and in situ testing operations, and logged the boreholes. 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 soil samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.



4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the 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 samples and observations of drilling resistance and, therefore, may represent transitions between soil and rock types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered the existing pavement structure or topsoil underlain in some areas by fill materials, over various layers of native granular and cohesive soils. The native granular soils consisted of sand and gravel, sands, silts and glacial till. The native cohesive soils consisted of silty clay, clayey silt and clayey silt glacial till. The underlying bedrock surface was encountered at five of the sign locations.

The locations and elevations of the boreholes are shown on Drawing 1. Detailed descriptions of the subsurface conditions encountered in the boreholes are provided on the Record of Borehole sheets and are summarized in subsequent report sections.

4.1.1 Pavement Structure

Boreholes 20 through 24 and 904 were advanced through the paved shoulders adjacent to the median barrier wall at HOV locations and encountered some 90 to 150 millimetres of asphaltic concrete over 250 to 460 millimetres of sand and gravel road base materials. The granular base in boreholes 21, 22, 23 and 904 was underlain by between 0.5 and 1.7 metres of sand and gravel subbase materials. At borehole 24 the granular subbase materials could not be discerned from the underlying fill materials. Measured N values from standard penetration testing carried out in the subbase materials ranged from 27 to 63 blows per 0.3 metres, indicating compact to very dense relative density. Samples of the subbase materials had measured water contents of 2 per cent. A grain size distribution curve for a sample of the sand and gravel subbase is presented on Figure A-1.

4.1.2 Topsoil

Between 80 and 550 millimetres of surficial topsoil was encountered in boreholes 1, 2, 3, 4, 6 and 721. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.



4.1.3 Fill

Sand and gravel fill materials were encountered beneath the topsoil at OHS boreholes 6 and 721. The sand and gravel fill was 0.4 and 4.3 metres thick, respectively, and was encountered at elevations 295.8 and 286.2 metres. The sand and gravel fill in borehole 6 was silty and cobbles and boulders were encountered within the sand and gravel fill in boreholes 6 and 721.

Granular fill materials were encountered beneath the pavement structure in boreholes 20, 21 and 24 advanced at HOV sign locations, and consisted of sand, silty sand and gravel, sand and gravel, and silty sand to sandy silt and contained cobbles. The granular fill in these boreholes was between 1.1 and 3.9 metres thick and was encountered between elevations 271.1 and 294.5 metres.

Measured N values in the granular fill materials ranged from 6 to 96 blows per 0.3 metres, indicating loose to very dense relative density. Water contents of samples of the granular fill ranged from 2 to 8 per cent. Grain size distribution curves for samples of the granular fill are presented on Figure A-1.

4.1.4 Silty Sand

Layers of silty sand were encountered beneath the topsoil in borehole 1, beneath a layer of sandy silt till in borehole 2, and beneath the pavement structure in borehole 23. The silty sand layers were between 0.3 and 8.4 metres thick and were encountered between elevations 277.3 and 303.7 metres. Measured N values from the very dense silty sand in borehole 2 ranged from 82 to greater than 100 blows per 0.3 metres, and in the compact to dense silty fine sand in borehole 23 were 22 and 33 blows per 0.3 metres. Samples of the silty sand had water contents of between 4 and 19 per cent. Grain size distribution curves for samples of the silty sand are shown on Figure A-2.

4.1.5 Sandy Silt

Loose to very dense sandy silt layers were encountered in borehole 2 beneath the topsoil, in borehole 3 beneath the topsoil and layers of silty sand and gravel and clayey silt till, and in borehole 904 beneath layers of sand, clayey silt till, and clayey silt. The sandy silt in borehole 2 was 1.5 metres thick and was encountered at elevation 297.9 metres. In borehole 3, the sandy silt layers were encountered between elevations 296.8 and 304.1 metres and were 0.5 and 0.8 metres thick, where fully penetrated. Borehole 3 was terminated in the sandy silt after 1.1 metres of exploration. In borehole 904, the sandy silt layers were between 0.6 and 0.8 metres thick and were encountered between elevations 298.8 and 304.1 metres.

Measured N values from the sandy silt ranged from 7 to greater than 100 blows per 0.3 metres. The water contents of select samples of the sandy silt ranged from 1 to 9 per cent. Grain size distribution curves for samples of the sandy silt are presented on Figure A-3.



4.1.6 Sand

Layers of sand were encountered beneath a layer of clayey silt till in borehole 2, beneath a sandy silt layer in borehole 3, beneath the topsoil in borehole 4, beneath a layer of sand and gravel in borehole 6, beneath fill materials in borehole 21, and beneath the pavement structure in boreholes 23 and 904. The sand layers were encountered between elevations 276.9 and 305.3 metres and were 0.2 to 0.9 metres thick where fully penetrated. Borehole 21 was terminated in the sand after exploring the layer for 2.1 metres. Measured N values in the compact to very dense sand ranged from 18 to greater than 100 blows per 0.3 metres. Grain size distribution curves for samples of the sand are presented on Figure A-4.

4.1.7 Silt

A 0.8 metre thick layer of very loose silt was encountered in borehole 22 beneath a layer of silty sand till at elevation 277.7 metres. A single measured N value in the silt layer was 3 blows per 0.3 metres.

4.1.8 Sandy Silt Till

Very dense sandy silt glacial till was encountered beneath the sand and silty sand layers in borehole 2, beneath a layer of silty sand and gravel in borehole 3, and beneath a layer of silty clay in borehole 20. The sandy silt till layers were encountered between elevations 285.2 and 299.3 metres and were 0.8 to 1.5 metres thick, where fully penetrated. Borehole 20 was terminated in the sandy silt till after exploring the layer for 2.1 metres. Measured N values from the sandy silt till ranged from 67 to greater than 100 blows per 0.3 metres. The water contents of samples of the sandy silt till were 8 and 18 per cent. Grain size distribution curves for samples of the sandy silt till are shown on Figure A-5. While not specifically encountered in the boreholes, cobbles and boulders are known to be present in the glacial till materials and should be anticipated within the sandy silt till.

4.1.9 Silty Sand Till

Compact to very dense silty sand glacial till was encountered in borehole 4 beneath a layer of clayey silt till at elevation 303.7 metres and in borehole 904 beneath a layer of sandy silt at elevation 298.2 metres. The silty sand till in borehole 4 was 2.3 metres thick. Borehole 904 was terminated in the silty sand till after exploring the layer for 2.9 metres. Measured N values in the silty sand till layer ranged from 21 to greater than 100 blows per 0.3 metres. The water content of samples of the silty sand till were 5 and 7 per cent. The grain size distribution curves for samples of the silty sand till are shown on Figure A-6. While not specifically encountered in the boreholes, cobbles and boulders are known to be present in the glacial till materials and should be anticipated within the silty sand till.



4.1.10 Sand and Gravel

Compact to very dense sand and gravel layers were encountered in borehole 2 beneath a layer of sandy silt till, in borehole 3 beneath layers of sandy silt and sand, in borehole 6 beneath the fill materials and a layer of sand, in boreholes 20, 24 and 721 beneath the fill materials, and in borehole 22 beneath layers of silt and clayey silt. The sand and gravel in boreholes 2, 3, 22 and 721 was noted to be silty. Cobbles were noted within the sand and gravel in boreholes 6, 24 and 721. The sand and gravel layers were encountered between elevations 276.0 and 303.8 metres and were between 0.3 and 2.0 metres thick, where fully penetrated. Boreholes 6 and 24 were terminated in sand and gravel layers after 3.4 and 2.1 metres of penetration, respectively. Measured N values from the sand and gravel layers ranged from 29 to greater than 100 blows per 0.3 metres. Water contents of samples of the sand and gravel ranged from 2 to 13 per cent. Grain size distribution curves for samples of the silty sand and gravel and sand and gravel are shown on Figures A-7 and A-8, respectively.

4.1.11 Silty Clay

A 0.3 metre thick layer of hard silty clay was encountered in borehole 20 beneath a layer of sand and gravel at elevation 298.5 metres. A single measured N value in the silty clay layer was 33 blows per 0.3 metres.

4.1.12 Clayey Silt

Clayey silt layers were encountered in boreholes 22 and 904 beneath layers of silty sand and gravel and sandy silt, respectively. The clayey silt layers in boreholes 22 and 904 were 0.2 and 3.1 metres thick and were encountered at elevations 276.2 and 301.8 metres, respectively. Measured N values in the clayey silt layer in borehole 904 ranged from 20 to 46 blows per 0.3 metres. The water contents of samples of the clayey silt were 15 and 18 per cent. A sample of the clayey silt had plastic and liquid limits of 14 and 28 per cent, respectively, and a plasticity index of 14 per cent, indicating low plasticity. Results of the Atterberg limits determination are shown on Figure A-11. The grain size distribution curve for a sample of the clayey silt is shown on Figure A-9.

4.1.13 Clayey Silt Till

Stiff to hard clayey silt glacial till was encountered in borehole 2 beneath the sandy silt, in borehole 3 beneath the sandy silt till, in borehole 4 beneath the sand and silty sand till layers, and in borehole 904 beneath the sandy silt layer. The clayey silt till layers were encountered between elevations 296.4 and 305.1 metres and were 0.8 to 1.7 metres thick where fully penetrated. Borehole 4 was terminated in the lower clayey silt till after exploring it for about 2.1 metres. Measured N values from the clayey silt till ranged from 13 to greater than 100 blows per 0.3 metres. Water contents of select samples of the clayey silt till ranged from 8 to 13 per cent. Three Atterberg



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limits determinations carried out on samples of the clayey silt till yielded liquid limits of between 18 and 34 per cent, plastic limits of between 11 and 19 per cent, and plasticity indices of between 6 and 15 per cent, indicating low plasticity. Results of Atterberg limits determinations are shown on Figure A-11. The grain size distribution curves for samples of the clayey silt till are shown on Figure A-10. While not specifically encountered in the boreholes, cobbles and boulders are known to be present in the glacial till materials and should be anticipated within the clayey silt till.

4.1.14 Bedrock

The bedrock surface was encountered in boreholes 1, 2, 22, 23, 721 and 721A. Boreholes 2 and 721 were terminated on bedrock due to auger and/or split spoon refusal and borehole 2 penetrated the bedrock 0.5 metres. The bedrock in boreholes 1, 22, 23 and 721A was cored for between 3.1 and 4.1 metres. The encountered bedrock depths and elevations are presented in the following table.

Site No.	Borehole	Encountered Bedrock	
		Elevation (m)	Depth (m)
33-830-E-S	1	277.1	0.5
33-416-W-S	2	282.7	15.2
33-836-E-S	22	275.7	4.2
33-837-E-S	23	276.0	3.0
33-829-E-S	721	281.5	4.8
	721A	281.9	4.4

The Total Core Recovery (TCR), Solid Core Recovery (SCR) and Rock Quality Designation (RQD) for 11 runs of core are presented in the following table.

Borehole	Run	TCR (%)	SCR (%)	RQD (%)
1	1	91	91	13
	2	61	57	0
	3	96	96	0
22	1	94	72	0
	2	97	93	85
	3	97	97	88
23	1	90	82	76
	2	93	90	82
	3	100	100	100
721A	1	90	85	70
	2	75	70	62



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Based on the RQD values which range from 0 to 100 per cent, the bedrock quality is described as poor to excellent.

The bedrock core from boreholes 1, 22, 23 and 721A was examined by a geologist and was typically described as tan to grey, massive to thickly bedded, medium to microcrystalline dolostone to dolomitic limestone. The bedrock core from borehole 1 was described as fresh, and was observed to be pitted and vuggy throughout the sample. The upper 0.8 metres of rock core from borehole 22 was weathered. Below about elevation 274.9 metres in borehole 22, the rock core was fresh and was observed to contain localized calcite filled voids and fractures. In borehole 23, the rock core was described as fresh with a rubbly interval between about elevations 274.1 and 274.4 metres. The bedrock core from borehole 721A was described as fresh, fossiliferous and more porous below about elevation 280.2 metres.

The strength of the bedrock in boreholes 1, 22, 23 and 721A was estimated by the geologist after examination of the core as R3 to R5, but typically about R4, in accordance with the Canadian Foundation Engineering Manual 2006 (CFEM) rock strength classification system.

Unconfined compressive tests and point load tests were carried out on samples of rock core obtained for other aspects of this project and have been utilized in the preparation of this report. The test results are summarized in the following table.

Location	Station	Sample Depth Below Bedrock Surface (m)	Unconfined Compressive Strength (MPa)	Point Load Index, $I_{s'50}$ (MPa)
Speedsville Road Underpass, Geocres No. 40P8-204	17+400	3.1	111	-
	17+444	2.7	64	-
Speed River Bridges, Geocres No. 40P8-220	17+754	3.8	-	6.0
		1.5	-	5.3
	17+770	5.1	-	4.1
		1.8	45	-
	17+825	2.6	-	7.7
		1.1	196	-
CNR Overhead, Geocres No. 40P8-225	18+230	1.1	196	-
	18+540	2.6	47	-
	18+555	0.8	53	-
	18+800	0.9	53	-

4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Groundwater was encountered in boreholes 2, 20 through 23, 721 and 904 during drilling; however, on the second day of drilling borehole 2 was found to be dry to the termination depth. A piezometer was installed in borehole 2. The



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piezometer was found to be dry on January 24, 2013 and November 20, 2013. The encountered groundwater levels are summarized in the table below.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Level	
		Elevation (m)	Depth (m)
1	277.5	*	*
2	298.0	285.2**	12.8**
3	304.3	*	*
4	305.8	*	*
6	296.0	*	*
721	286.3	282.0	4.3
721A	286.3	*	*
20	302.7	299.9	2.8
21	283.8	278.6	5.2
22	279.9	276.0	3.9
23	279.0	276.1	2.9
24	295.0	*	*
904	305.5	298.5	7.0

* Groundwater level not established.

** Groundwater level encountered during first day of drilling on June 26, 2012; but was not encountered on second day of drilling on June 27, 2012.

The above-noted water levels are not considered to be representative of the long-term, stabilized groundwater conditions as the readings were taken only during the relatively short duration of drilling. Based on the measured and encountered groundwater levels and the soil colour change from brown to grey, of boreholes both at and adjacent to the proposed sign locations, the inferred groundwater level generally varies with the overall ground surface elevation along the length of the project, and ranges from elevation 302.0 metres just west of Fountain Street, to about elevation 277.0 metres in the area of Speedsville Road, to about 285.0 metres near Hespeler Road.

Groundwater levels are expected to fluctuate seasonally and to be higher during periods of sustained precipitation or during spring melt conditions. The inferred groundwater levels are expected to vary across the site as follows:



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Site No.	Station	Borehole	Ground Surface Elevation (m)	Inferred Groundwater Level	
				Elevation (m)	Depth (m)
33-830-E-S	17+700 Rt	1	277.5	277.0	0.5
33-416-W-S	16+500 Lt	2	298.0	285.0	13.0
33-417-W-S	15+703 Lt	3	304.3	301.0	3.3
33-418-W-S	15+159 Lt	4	305.8	302.0	3.8
33-833-E-S	10+305 ¹	6	296.0	Below 287.5 ²	Below 8.5
33-829-E-S	18+593 Rt	721/721A	286.3	283.0 ³	3.3
33-835-E-S	15+750	20	302.7	300.0	2.7
33-839-W-S	16+691	21	283.8	279.0	4.8
33-836-E-S	17+059	22	279.9	277.0	2.9
33-837-E-S	17+280	23	279.0	277.0	2.0
33-838-E-S	18+793	24	295.0	285.0	10.0
33-834-E-S	15+350	904	305.5	302.5	3.0

¹ Refers to Hespeler Road W-N/S ramp chainage.

² Groundwater level not encountered in BH6 or nearby BH901 above elevation 287.4 m.

³ Possible perched groundwater in fill materials up to elevation 292 m based on adjacent CNR site.



5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Lantech Drilling Services Inc. and Aardvark Drilling Inc., Ontario Ministry of Environment licensed well contractors. The field operations were supervised by Mr. Michael Arthur, Mr. Daniel Babcock, P.Eng., and Mr. Brett Thorner, E.I.T. under the direction of Mr. David J. Mitchell, the Field Investigation Manager.

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 Ms. Nicole A. Gould, P.Eng. under the direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng. This report was reviewed by Mr. Azmi M. Hammoud, P.Eng., an Associate with Golder Associates. An independent quality review of this report was carried out 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
OVERHEAD AND HOV SIGNS**

PART B

FOUNDATION DESIGN REPORT

OVERHEAD AND HOV SIGNS

RECONSTRUCTION AND WIDENING OF HIGHWAY 401

FROM 0.5 KM WEST OF REGIONAL ROAD 8/KING STREET EASTERLY TO

0.5 KM EAST OF REGIONAL ROAD 24/HESPELER ROAD – 5.5 KM

GWP 4-00-00

MINISTRY OF TRANSPORTATION - WEST REGION



6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the design of the overhead and high-occupancy vehicle signs to be constructed as part of the Highway 401 reconstruction and widening. The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, and scheduling.

Six OHSs and six HOV signs have been proposed for this project. The OHSs are to be constructed with two supports, either one median mounted and the other shoulder mounted, or both shoulder mounted installed along the highway shoulders. The HOV signs are to be constructed with a single median mounted support.

Based on the information provided, the boreholes were located at the approximate sign locations as follows:

Site No.	Sign Station	Location	Borehole
33-416-W-S	16+500 Lt	1050 m east of Fountain Street, over Highway 401 westbound lanes	2
33-417-W-S	15+703 Lt	253 m east of Fountain Street, over Highway 401 westbound lanes and King Street E-N speed change lane	3
33-418-W-S	15+159 Lt	291 m west of Fountain Street, over King Street E-N speed change lane	4
33-829-E-S	18+593 Rt	607 m west of Hespeler Road, over Highway 401 eastbound lanes	721/721A
33-830-E-S	17+700 Rt	300 m east of Speedsville Road, over Highway 401 eastbound lanes	1
33-833-E-S	10+305*	230 m west of Hespeler Road, over Hespeler Road W-N/S ramp	6
33-834-E-S	15+350	100 m west of Fountain Street	904
33-835-E-S	15+750	300 m east of Fountain Street	20
33-836-E-S	17+059	341 m west of Speedsville Road	22
33-837-E-S	17+280	120 m west of Speedsville Road	23
33-838-E-S	18+793	407 m west of Hespeler Road	24
33-839-W-S	16+691	1241 m east of Fountain Street	21

*Hespeler Road W-N/S ramp chainage.

6.2 Foundation Design

Caisson foundations for overhead and HOV sign supports should be designed in accordance with the requirements in MTO's Sign Support Manual. The design of HOV signs is governed by Division 3 – Cantilever



FOUNDATION INVESTIGATION AND DESIGN REPORT OVERHEAD AND HOV SIGNS

Static Sign Supports and the design of OHSs is governed by Division 4 – Tri-Chord Static Sign Supports. For both OHSs and HOV signs reference should be made to Drawings SS118-3, SS118-4 and SS118-5 in the Manual. The Sign Support Manual includes a standard caisson foundation design that is applicable to both OHSs and HOV signs in which the caissons are extended 5 metres below the design frost depth (i.e. a total length of 6.4 metres below grade for this project), except where bedrock is encountered within this depth. The standard design is based on the following minimum soil conditions:

- **Case 1 (Cohesionless Soils):** Sand with a friction angle of 28 degrees surrounding the upper two-thirds of the portion of the caisson foundation below the frost depth, and sand with a friction angle of 30 degrees surrounding the lower third of the portion of the caisson below the design frost depth.
- **Case 2 (Cohesive Soils):** Soft clay with an undrained shear strength of 25 kilopascals surrounding the upper two-thirds of the portion of caisson foundation below the frost depth, and “soft” clay with an undrained shear strength of 50 kilopascals surrounding the lower third of the portion of the caisson below the design frost depth.

Caissons for overhead and HOV signs at Stations 17+059, 17+280, 17+700 Rt and 18+593 Rt will be terminated in bedrock. As indicated in the Sign Support Manual, for sign supports in bedrock the footing depth below the frost depth (1.4 metres for this site) may be taken as:

$$d = Y + (5 - Y)/2$$

where d = footing depth below the frost depth, m

Y = depth below frost depth to “sound” rock, m

To account for the presence of weathered rock at the bedrock surface, the depth to resisting rock in the following table may be used for the design of caissons terminating in bedrock:

Station	Approximate Proposed Pavement Elevations (m)		T_w (m)	W (m)	V (m)
	Lt*	Rt*			
17+059	279.5	279.2	4.18	0.76	4.94
17+280	279.0	279.6	2.99	0.00	2.99
17+700 Rt	280.2	280.2	0.46	0.12	0.58
18+593 Rt	294.0	293.8	4.42	0.00	4.42

Notes: T_w = thickness of soil above rock (overburden), m
 W = thickness of weathered rock, m
 V = $T_w + W$, depth to resisting rock below ground surface (must be checked against limiting length less additional eccentricity due to drainage if anchored foundations are used)

* Denotes Left (Lt) and Right (Rt) sides of the median for HOV signs, and Lt and Rt ends of the sign for OHSs, when facing the direction of increasing chainage.



FOUNDATION INVESTIGATION AND DESIGN REPORT OVERHEAD AND HOV SIGNS

Based on the strength classification of the rock core obtained from the boreholes and comparison with the results of testing carried out on rock core from other portions of this project as described in Section 4.1.14 above, the unconfined compressive strength (q_u) and ultimate bond strength of the bedrock that can be used for design are:

Location	Unconfined Compressive Strength (MPa)	Ultimate Bond Strength (MPa)
17+059	64	4.2*
17+280	64	4.2*
17+700 Rt	50	4.2*
18+593 Rt	50	4.2*

* Ultimate Bond Strength = $q_u/10$, with a maximum of 4.2 MPa.

Varying amounts of granular fill materials were encountered below the frost depth at the following sign/borehole locations:

- OHS at Station 18+593 Rt, borehole 721/721A;
- HOV sign at Station 15+750, borehole 20;
- HOV sign at Station 16+691, borehole 21;
- HOV sign at Station 17+059, borehole 22; and,
- HOV sign at Station 18+793, borehole 24.

Based on a review of the materials below the frost depth at these sign locations a standard foundation design, as provided in the Sign Support Manual, can be used provided that the caissons penetrate all fill material and are terminated in native deposits.

Case 1 applies to the signs at Stations 10+305 (Hespeler Road W-N/S ramp), 18+593 Rt, 16+500 Lt, 16+691, 17+280 and 18+793. Based on a review of the subsurface information, the granular subsurface soils have friction angles that meet or exceed the input parameters used in modelling of the standard caisson foundation. Therefore, standard caisson foundation designs are suitable for these three sites. Based on the proposed pavement elevation at Station 16+500 Lt, a caisson extending to 5 metres below the frost depth may encounter the inferred bedrock elevation of 282.7 metres; however, it is anticipated that any rock penetration that may be required at this location will be minimal and that the native granular soils are adequate to provide lateral support as required for Case 1.

The subsurface soil conditions below the frost depth at the signs at Stations 15+703 Lt, 15+159 Lt, 15+350, 15+750 and 17+059 consist of both cohesive and granular materials. The granular and cohesive materials at these locations have friction angles and shear strengths, respectively, that meet or exceed the input parameters



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used in modelling of the standard caisson foundations for both Cases 1 and 2. Therefore, the standard caisson foundation design is suitable for these sites.

The following unfactored parameters may be used for the design of the sign support foundations founded wholly or partially in soils:

Soil Type	Friction Angle, ϕ (°)	Undrained Shear Strength, c_u (kPa)	Unit Weight, γ (kN/m ³)	Passive Earth Resistance Coefficient, K_p	Adhesion Factor, α	Shaft Resistance Factor, β	Bearing Capacity Factor, N_t
Granular Fill	30	-	20	3.00	-	0.50	60
Silty Sand	30	-	20	3.00	-	0.35	40
Sandy Silt	29	-	20	2.88	-	0.25	20
Sand	30	-	20	3.00	-	0.45	60
Silt	28	-	19	2.77	-	0.25	20
Sandy Silt Till	32	-	21	3.25	-	0.50	75
Silty Sand Till	33	-	21	3.39	-	0.50	75
Silty Sand and Gravel	35	-	21	3.69	-	0.60	125
Sand and Gravel	37	-	22	3.00	-	0.60	125
Silty Clay	25	30	18	2.46	0.90	0.27	4
Clayey Silt	25	50	18	2.46	0.75	0.30	5
Clayey Silt Till	28	50	19.5	2.77	0.75	0.32	10

6.2.1 Axial Resistance

Lateral loading governs over axial loading for the design of OHS and HOV sign foundations. However, the axial resistance can be checked using the recommendations made in this section.

Based on the subsurface conditions encountered in the boreholes, the unfactored ultimate axial capacity of the caisson, R , in kilonewtons (kN), may be calculated using the following equation:

$$R = F_b + F_s$$

considering the shaft resistance,

$$F_s = \sum F_{sn} d C$$

where $F_{sn} = \alpha c_u$ for cohesive soils (silty clay, clayey silt and clayey silt till)
 $= \beta \sigma_v'$ for cohesionless soils (granular fills, sands, silts, sand and gravel, sand and silt tills)



FOUNDATION INVESTIGATION AND DESIGN REPORT OVERHEAD AND HOV SIGNS

$$= b P_a \left(\frac{q_u}{P_a} \right)^{0.5} \quad \text{for rock}$$

and, F_b = unfactored end bearing capacity of the caisson, kN

F_s = unfactored axial capacity of the caisson, kN

F_{sn} = nominal unit side resistance, kPa

d = thickness of resisting layer, m

C = circumference of the caisson, m

α = adhesion coefficient

c_u = average undrained shear strength within resisting layer, kPa

β = a combined shaft resistance factor

σ_v' = vertical effective stress adjacent to the pile at depth z , kPa

b = empirical factor (1.4)

P_a = atmospheric pressure, kPa

q_u = unconfined compressive strength of rock, kPa

The vertical effective stress (σ_v') in the cohesionless layer adjacent to the caisson may be calculated based on the inferred groundwater levels given in Section 4.2.

The upper 1.4 metres below the ground surface should be neglected to account for frost action. Although not specifically encountered in the boreholes below the frost depth, any portion of the caissons within organic materials is also to be neglected. Sections in fill are also to be neglected, with the exception of locations where a significant portion of the caisson would be situated in fill as identified in Section 6.2 above. At these locations, it will be necessary to utilize the fill to resist the applied loadings calculated using the parameters for the fill given above.

The component of vertical load carrying capacity that may be derived from end bearing may be calculated using the following equation:

$$F_b = q_{BN} A_b$$

where q_{BN} = $6 c_u$ for cohesive soils

= $N_t \sigma_b'$ for cohesionless soils

= $2.5 q_u$ for rock

and, q_{BN} = unit base resistance, kPa

A_b = cross-sectional area of the caisson, m²



N_t = bearing capacity factor

σ_b' = vertical effective stress at toe of caisson, kPa

The bearing capacity at the base of the caisson may be calculated using the vertical effective stress at the caisson base in kPa using the preceding table of design groundwater elevations. A resistance factor of 0.4 should be applied to obtain the factored axial resistance at Ultimate Limit States (ULS). The axial resistance at Serviceability Limit States (SLS) is greater than at ULS and ULS values will govern design.

The proceeding recommendations pertain to sign support foundations on level ground. If any sign support is to be constructed on a slope, the geotechnical engineer must be contacted to revise the recommendations.

Where the depth to bedrock is fairly shallow, the foundations may be embedded or anchored into the rock surface. The minimal length of caisson embedment is 2.5 metres below the frost penetration depth. The rock is generally strong based on the average uniaxial compressive strength and has a compressive strength greater than that of concrete (σ'_c). Therefore, the value of σ'_c must be used as the allowable vertical bearing capacity of the rock for foundations anchored to rock. A testing program should be carried out to assess the allowable bond stress for rock anchors if used in the design.

Where there is more extensive overburden over the bedrock, such as at Stations 18+593 Rt, 17+059 and 17+280, it may be sufficient to only socket the caisson tip into the bedrock. The minimum caisson length for rock socketed piles is to be 2.0 metres, with a minimum socket length equivalent to the depth of the weathered rock, where present, or not less than one half the pile diameter.

6.2.2 Lateral Loads

It is recognized that the procedure outlined in the Sign Support Manual gives specific procedures to determine the lateral load capacity and the appropriate caisson length. The following recommendations can be used to check the lateral capacity.

The lateral resistance of the cohesive soils along the shaft is represented by a constant distribution with depth and given by $9c_u B$, where c_u is the undrained shear strength in kPa and B is the shaft diameter in metres. The unfactored lateral force resisted by a shaft of length L metres is given by:

$$P = 9 c_u B (L - 1.5B)$$

Where the lateral loading exerted by the caissons will be resisted by cohesionless soils, the unfactored passive lateral earth pressure, P_p , distributed along the length of the caisson foundation may be calculated using the following equations:

$$P_p = K_p \gamma d \quad \text{above the groundwater table}$$

$$P_p = K_p \gamma d_w + K_p \gamma' (d - d_w) \quad \text{below the groundwater table}$$



where	K_p	=	passive earth pressure coefficient
	γ	=	bulk unit weight, kN/m^3
	γ'	=	effective unit weight below the groundwater level ($\gamma' = \gamma - \gamma_w$), kN/m^3
	d	=	depth below the ground surface, m
	d_w	=	depth to the groundwater level, m

The lateral earth pressures may be assumed to act over an equivalent width equal to three times the caisson diameter. Also, large deformations (lateral movement) would be required to fully mobilize lateral shaft resistance.

Where an undrained shear strength, c_u , is provided, the undrained capacity of the caisson should be checked to determine whether the drained or undrained case will govern. The lateral resistance for the length of the caisson within cohesive soil should be calculated assuming an unfactored passive lateral pressure distribution varying linearly from $2 c_u$ at the surface to $9 c_u$ at a depth of three pile diameters and beyond acting over the actual width of the caisson.

There is no simplified approximate method to compute the lateral resistance of piles in rock. The $p - y$ method or finite element method is recommended for design. Since the dolostone bedrock at this site is quite strong relative to concrete, the value of σ'_c must be used for the allowable lateral bearing (b_{horiz}) resistance for caissons embedded or socketed into the bedrock. In the case of foundations anchored to rock, the anchorage must be designed to transfer the factored applied moment from the caisson base to the rock.

A resistance factor of 0.5 should be applied to the calculated lateral resistance in order to obtain the factored lateral geotechnical resistance. As with calculation of the axial resistance, the upper 1.4 metres below the ground surface should be neglected in the calculation of the passive resistance in front of the caisson to account for frost action. Any portion of the caisson within fill and/or organic materials would also normally be neglected. However, as indicated above, there are several locations where signs will be within areas of deep fill, therefore, at these locations, it will be necessary to utilize the fill to resist the applied loadings with the parameters for the fill given in Section 6.2, above.

6.3 Construction Considerations

Based on the groundwater levels observed in the boreholes, excavations for most of the caissons will extend below the groundwater level in predominantly granular soils. Caisson excavations at Stations 16+500 Lt, 18+793, and 10+305 (Hespeler W-N/S ramp) are expected to remain dry. Proper proactive dewatering will be required at locations where the groundwater is encountered.

With proactive dewatering, a temporary liner will be required to support the sides of the excavation and permit cleaning and inspection of the bases. 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



FOUNDATION INVESTIGATION AND DESIGN REPORT OVERHEAD AND HOV SIGNS

installed using mud drilling techniques (augering with the hole filled with bentonite slurry) and placement of concrete by tremie. Occasional obstructions due to cobbles and boulders within the fill materials, glacial tills and sand and gravel should be expected. Surface water run off should be directed away from the excavations. The caissons should be constructed and inspected in accordance with Ontario Provincial Standard Specifications 903. A Non Standard Special Provision should be provided in the Contract Documents to highlight the potential for cobbles and boulders in the fill materials, glacial tills and sand and gravel strata.

It may be necessary to core through larger boulders located in the overburden. Coring for caisson construction in bedrock may be problematic due to the tendency for fractured rock to jam coring equipment. Double wall core barrels are expected to be more effective than single barrel core barrels. As an alternative to core barrels, full-faced rotary tools or down-hole hammers may also be used in areas where the rock is very hard.



7.0 MISCELLANEOUS

This report was prepared by Ms. Nicole A. Gould, P.Eng. under the direction of the Project Engineer, Ms. Dirka U. Prout, P.Eng. This report was reviewed by Mr. Azmi M. Hammoud, P.Eng., an Associate with Golder Associates. An independent quality review of this report was carried out by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

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 1

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808505.0 , E 236240.8 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM / NQ ROCKCORE COMPILED BY LMK
DATUM GEODETIC DATE June 13, 2012 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							
277.52	GROUND SURFACE														
0.00	TOPSOIL, sandy, with roots														
0.21	Brown														
0.46	SILTY SAND, some gravel														
	Brown														
	Tan to light grey, fine crystalline, fossiliferous DOLOSTONE TO DOLOMITIC LIMESTONE. Remnant fossils throughout, with calcite replacement. Very thinly laminated (at 90 degrees to core axis) to massive. Vuggy - calcite filled throughout last half of interval. Final 40cm of interval is gradational into dark brown dolostone. Common, irregular fracture-filling sulphide mineralization. Mechanical fracturing at 85 to 90 degrees to core axis. Natural fractures at 75 degrees to core axis. Natural fracture surfaces have calcite filling with local sulphide mineralization. Pitted / vuggy appearance throughout. Looks like possible bioherm containing rugose/tabulate coral; Strength R4		1	NQ RC											
			2	NQ RC											
			3	NQ RC											
272.92	END OF BOREHOLE														
4.60	Groundwater not established during drilling on June 13, 2012.														

RECORD OF BOREHOLE No 2

1 OF 2

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808289.7, E 235084.3 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE June 26, 2012 - June 27, 2012 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100		W _P W W _L				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
297.97	GROUND SURFACE							20 40 60 80 100	10 20 30				GR SA SI CL	
0.00 0.12	TOPSOIL, sandy Brown SANDY SILT, trace to some clay, trace gravel Loose Brown		1	SS	7		Concrete Cuttings							
296.35														
1.62	CLAYEY SILT TILL, some sand, trace gravel, trace sand seams Very stiff to hard Brown		2	SS	19		Bentonite			○			5 27 37 31	
			3	SS	36									
295.07														
2.90	SAND, fine, some silt, trace gravel Dense Brown		4	SS	39									
294.31														
3.66	SANDY SILT TILL, some clay, trace to some gravel Very dense Brown		5	SS	67					○			11 29 42 18	
293.55														
4.42	SILTY SAND, trace to some gravel, trace clay Very dense Brown		6	SS	63/ 100mm									
			7	SS	61/ 100mm					○			4 62 24 10	
			8	SS	100/ 100mm									
			9	SS	100/ 25mm									
			10	SS	100/ 25mm									
289.89							Grout							
8.08	SILTY SAND, fine to medium, trace to some gravel, some clay Very dense Brown		11	SS	102					○			3 65 21 11	
			12	SS	101									
			13	SS	42/ 50mm									
			14	SS	40/ 75mm									
			15	SS	82									
285.93														
12.04	SILTY SAND, with clayey silt seams Very dense Brown		16	SS	100/ 250mm					○			0 52 38 10	
285.17														
12.80	SANDY SILT TILL, some gravel Very dense Brown		17	SS	95									
			18	SS	45/ 75mm									
283.64							Bentonite							
14.33	SILTY SAND AND GRAVEL Very dense Brown		19	SS	100/ 150mm		Sand							

Continued Next Page



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

RECORD OF BOREHOLE No 2

2 OF 2

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808289.7 , E 235084.3 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE June 26, 2012 - June 27, 2012 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										w _p	w	w _L	WATER CONTENT (%)
								20	40	60	80	100									
282.73			20	SS	100/ 100mm		Sand Piezometer														
15.24	Inferred BEDROCK																				
282.27																					
15.70	END OF BOREHOLE																				
	Auger refusal at about elev. 282.3m																				
	Groundwater encountered at about elev. 285.2m during drilling on June 26, 2012.																				
	Groundwater not established during drilling on June 27, 2012.																				
	Piezometer dry on January 24, 2013.																				
	Piezometer dry on November 20, 2013.																				

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4807787.1, E 234438.6 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE July 5, 2012 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					
304.31	GROUND SURFACE																
0.00	TOPSOIL, silty Brown																
0.21																	
303.79	SANDY SILT, some gravel Brown																
0.52																	
	SILTY SAND AND GRAVEL Very dense to compact Brown		1	SS	66												
			2	SS	29												
302.18																	
2.13	SANDY SILT, trace gravel, some clay Dense Brown		3	SS	40												
301.41																	
2.90	SAND, fine, some silt, trace gravel Very dense Brown		4	SS	57/ 125mm												
300.80																	
3.51	SILTY SAND AND GRAVEL, trace clay Very dense Brown		5	SS	69												
			6	SS	100/ 275mm												
299.28																	
5.03	SANDY SILT TILL, some gravel Very dense Brown		7	SS	38/ 50mm												
298.52																	
5.79	CLAYEY SILT TILL, some sand, trace gravel Hard Grey		8	SS	100/ 275mm												
			9	SS	88												
296.84																	
7.47	SANDY SILT, some clay, trace gravel Very dense Grey		10	SS	56/ 125mm												
295.78																	
			11	SS	100												
8.53	END OF BOREHOLE																
	Groundwater not established during drilling on July 5, 2012.																

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

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4807561.1, E 233975.1 ORIGINATED BY DB
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE October 4, 2012 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										
								○ UNCONFINED + FIELD VANE										
								● QUICK TRIAXIAL × LAB VANE										
305.84	GROUND SURFACE							20	40	60	80	100		10	20	30	kN/m ³	GR SA SI CL
0.00	TOPSOIL, silty Brown																	
305.29																		
0.55	SAND, fine, trace silt Brown																	
0.76	CLAYEY SILT TILL, trace sand, trace gravel Stiff to very stiff Brown		1	SS	13		305											
			2	SS	29		304											
303.71																		
2.13	SILTY SAND TILL, some gravel, trace to some clay Compact to very dense Brown becoming grey at about elev. 302.2m		3	SS	21		303											
			4	SS	104									○				14 45 24 17
			5	SS	45		302											
301.42																		
4.42	CLAYEY SILT TILL, some sand, trace gravel, trace sand layers Hard Grey		6	SS	37		301											
			7	SS	64									φ	—			2 22 28 48
							300											
			8	SS	49													
299.29																		
6.55	END OF BOREHOLE																	
	Groundwater not established during drilling on Oct. 4, 2012.																	

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

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808468.9 , E 237533.5 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE May 5, 2014 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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
296.00	GROUND SURFACE						296	20	40	60	80	100					GR SA SI CL			
0.00	TOPSOIL, sandy Brown							20	40	60	80	100								
0.24	FILL, silty sand and gravel, with cobbles Brown																			
295.39																				
0.61																				
	SAND AND GRAVEL, trace silt Very dense to dense Brown		1	SS	52															
			2	SS	46															
293.87																				
2.13	SAND, fine to coarse, some silt Compact Brown		3	SS	24															
293.10																				
2.90	SAND AND GRAVEL, trace to some silt, with cobbles Dense to very dense Brown		4	SS	82															
			5	SS	45															
			6	SS	53															
			7	SS	90															
			8	SS	73/75mm															
289.69	END OF BOREHOLE						290													
6.31	Groundwater not established during drilling on May 5, 2014.																			

RECORD OF BOREHOLE No 20

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4807789.7 , E 234523.6 ORIGINATED BY DB
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE May 7, 2014 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										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
302.65	PAVEMENT SURFACE						20	40	60	80	100						GR SA SI CL			
0.09	ASPHALT																			
302.10	FILL, sand and gravel, crushed, trace silt																			
0.55	FILL, sand, fine to medium, some gravel, trace silt Compact to loose Brown		1	SS	24															
			2	SS	6															
300.52																				
2.13	SAND AND GRAVEL, some silt Dense to very dense Brown		3	SS	30															
			4	SS	68															
298.54			5	SS	33															
4.11	SILTY CLAY, trace sand, trace gravel Very stiff Brown																			
298.23																				
4.42	SANDY SILT TILL, some clay, some gravel Very dense Brown to grey at about elev. 296.9m		6	SS	67															
			7	SS	100/ 225mm															
			8	SS	75															
296.10	END OF BOREHOLE																			
6.55	Groundwater encountered at about elev. 299.9m during drilling on May 7, 2014.																			

RECORD OF BOREHOLE No 21

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808369.7 , E 235264.7 ORIGINATED BY DB
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE May 7, 2014 - May 8, 2014 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										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
283.80	PAVEMENT SURFACE															GR SA SI CL				
0.10	ASPHALT																			
283.34	FILL, sand and gravel, crushed, trace silt																			
0.46	Brown																			
282.43	FILL, sand and gravel, trace silt		1	SS	29		283													
	Compact Brown																			
1.37	FILL, silty sand and gravel, with cobbles		2	SS	96		282													
	Very dense Brown																			
281.30	FILL, silty sand to sandy silt, some clay, some gravel		3	SS	32		281													
2.50	Compact to dense Brown		4	SS	11															
			5	SS	12		280													
279.38	SAND, fine to medium, trace to some silt, trace gravel		6	SS	32		279													
4.42	Compact to dense Brown		7	SS	18															
			8	SS	21		278													
277.25	END OF BOREHOLE																			
6.55	Groundwater encountered at about elev. 278.6m during drilling on May 7 & 8, 2014.																			

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

RECORD OF BOREHOLE No 22

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808510.1, E 235600.9 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM / NQ ROCKCORE COMPILED BY LMK
DATUM GEODETIC DATE May 6, 2014 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									
279.85	PAVEMENT SURFACE					20	40	60	80	100							
0.00	ASPHALT																
0.12	FILL, sand and gravel, crushed, trace silt																
0.40	FILL, sand and gravel, trace to some silt, with cobbles Dense to very dense Brown		1	SS	43							○				55 35 (10)	
			2	SS	63												
277.72																	
2.13	SILT, some sand, trace clay, topsoil layers Very loose Brown and black		3	SS	3												
276.95																	
2.90	SILTY SAND AND GRAVEL, some clay Compact Brown		4	SS	13							○				27 37 24 12	
276.19																	
3.66	CLAYEY SILT, trace sand Stiff Brown		5	SS	90/ 75mm							○	○				
3.90												○					
4.18	SILTY SAND AND GRAVEL Very dense Brown		6	NQ RC			94		72	0							
	Weathered, tan brown, thickly bedded to massive DOLOSTONE upper 0.76m, into fresh, alternating blue-grey microcrystalline DOLOSTONE and buff or tan, massive, sucrosic DOLOSTONE. Soft, mm scale blue grey muddy interbeds within the microcrystalline dolostone and localized stylolites common. Common muddy mm scale beds between elev. 273.97m and elev. 273.37m. Localized calcite filled voids and fractures from elev. 272.6m to end of borehole. Overall Strength R4, locally R4/R5 within massive interval (sucrosic)		7	NQ RC													
			8	NQ RC													
272.14	END OF BOREHOLE																
7.71	Groundwater encountered at about elev. 276.0m during drilling on May 6, 2014.																

RECORD OF BOREHOLE No 23

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808527.6 , E 235820.4 ORIGINATED BY MA
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM / NQ ROCKCORE COMPILED BY LMK
DATUM GEODETIC DATE May 7, 2014 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				
								20	40	60	80	100				
279.00	PAVEMENT SURFACE															
0.00	ASPHALT															
0.12	FILL, sand and gravel, crushed, trace silt															
278.57	FILL, sand and gravel, trace silt Dense Brown		1	SS	33											
277.87	SILTY FINE SAND Compact Brown		2	SS	22											
1.13																
276.87																
2.13	SAND, fine, trace to some silt Compact Brown		3	SS	16											
276.01			4	SS												
2.99	Fresh, fine to medium crystalline, massive, light to dark grey DOLOSTONE, with localized mm scale green-grey muddy interbeds and fracture fillings. Common stylolites throughout perpendicular to core axis with mechanical fractures along planes of weakness. Localized natural fracturing perpendicular (horizontal to bedding) to core axis with black muddy coating infill. Rubbly interval from elev. 274.43m to elev. 274.06m within muddy fracture filling interval, Strength R4 - hard		5	NQ RC	100/0mm											
			6	NQ RC												

RECORD OF BOREHOLE No 24

1 OF 1

METRIC

PROJECT 10-1132-0056
W.P. 4-00-00 LOCATION N 4808553.5 , E 237332.1 ORIGINATED BY DB
DIST HWY 401 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY LMK
DATUM GEODETIC DATE May 8, 2014 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										WATER CONTENT (%)		
295.00	PAVEMENT SURFACE						20	40	60	80	100						GR SA SI CL			
0.00	ASPHALT																			
0.15	FILL, sand and gravel, crushed, trace silt																			
294.45																				
0.55	FILL, sand and gravel, trace to some silt, with cobbles Dense to very dense Brown		1	SS	42															
			2	SS	39															
			3	SS	40															
			4	SS	56															
			5	SS	35															
290.58			6	SS	100/ 225mm															
4.42	SAND AND GRAVEL, trace silt, with cobbles Very dense Brown		7	SS	100															
			8	SS	87															
288.45	END OF BOREHOLE																			
6.55	Groundwater not established during drilling on May 8, 2014.																			

PROJECT <u>10-1132-0056</u>		RECORD OF BOREHOLE No 721		1 OF 1	METRIC
W.P. <u>4-00-00</u>	LOCATION <u>N 4808494.7 , E 237138.1</u>	ORIGINATED BY <u>MA</u>			
DIST <u></u> HWY <u>401</u>	BOREHOLE TYPE <u>POWER AUGER, HOLLOW STEM</u>	COMPILED BY <u>LMK</u>			
DATUM <u>GEODETIC</u>	DATE <u>June 26, 2013</u>	CHECKED BY <u></u>			

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 (%)				GR	SA	SI	CL
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×	LAB VANE	W _p	W		W _L			
286.31	GROUND SURFACE																			
0.08	TOPSOIL, sandy, gravelly Brown FILL, sand and gravel, trace silt, with cobbles and boulders Loose to very dense Grey		1	SS	88															
			2	SS	32							○						55	36 (9)	
			3	SS	28															
			4	SS	15															
			5	SS	8							○						60	35 (5)	
281.89																				
4.42	SILTY SAND AND GRAVEL, with cobbles		6	SS	93/ 100mm								○					38	36 (26)	
281.49	Very dense Grey																			
4.82	END OF BOREHOLE																			
	Auger & Split-spoon refusal on inferred bedrock.																			
	Groundwater encountered at about elev. 282.0m during drilling on June 26, 2013.																			

RECORD OF BOREHOLE No 721A

1 OF 1

METRIC

PROJECT 10-1132-0056

W.P. 4-00-00

LOCATION N 4808494.7, E 237136.0

ORIGINATED BY BT

DIST HWY 401

BOREHOLE TYPE POWER AUGER, HOLLOW STEM / NQ ROCKCORE

COMPILED BY LMK/WDF

DATUM GEODETIC

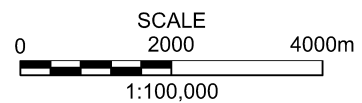
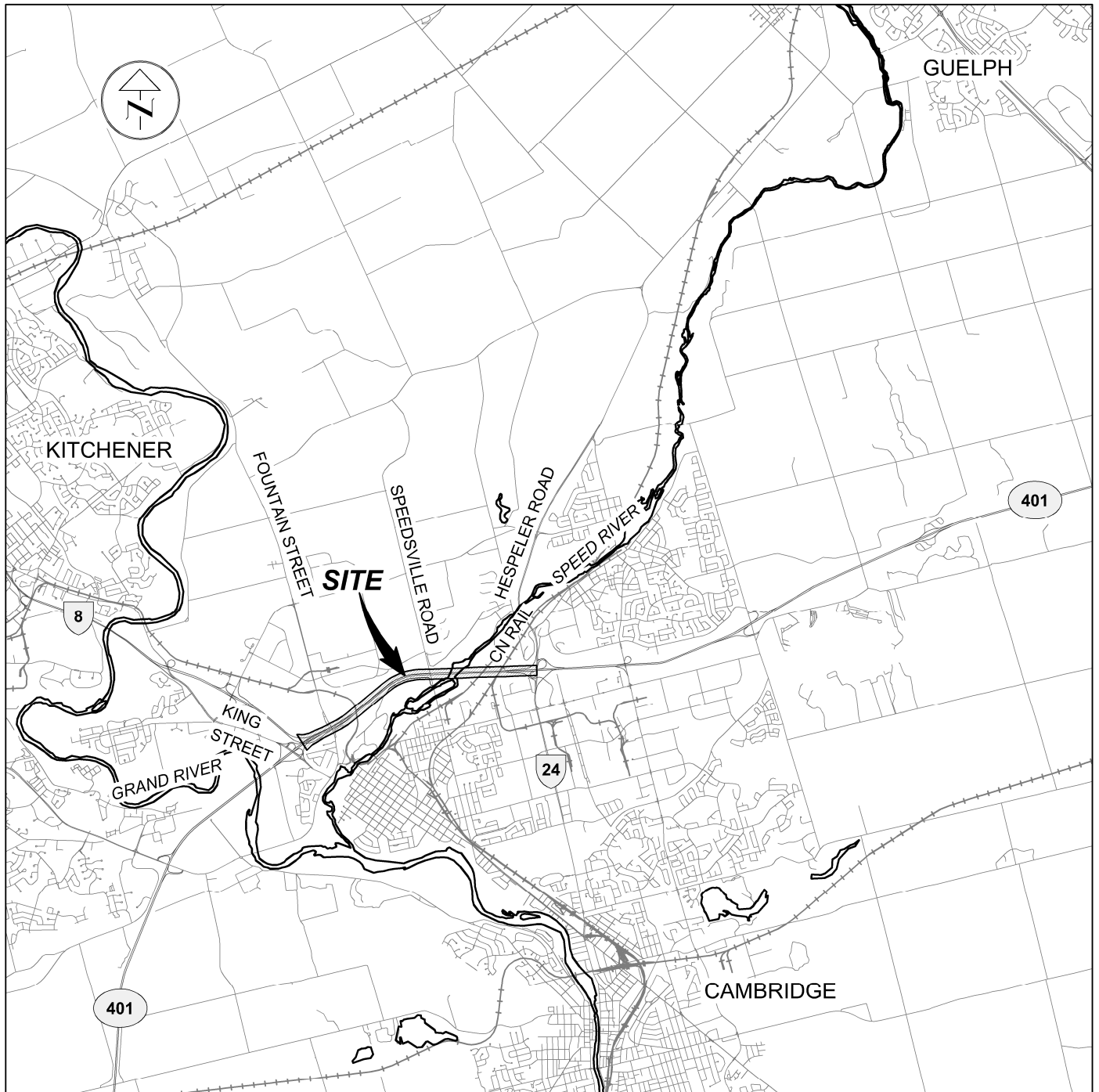
DATE December 18, 2013

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										WATER CONTENT (%)		
								○ UNCONFINED	+	FIELD VANE	×	LAB VANE								
286.31	GROUND SURFACE						20	40	60	80	100									
0.08	TOPSOIL, sandy, gravelly Brown FILL, sand and gravel, some silt, with cobbles and boulders Loose to very dense Grey																			
281.89																				
4.42	Fresh, tan brown becoming blue grey, fine to microcrystalline, DOLOSTONE. Massive to about elev. 281.0m then turning to medium to thickly bedded blue-grey to approximately elev. 280.2m. Below elev. 280.2m is more porous, sucrosic, mottled tan and grey fossiliferous Dolostone, with abundant carbonate filled vugs and remnant fossils, localized stylolites. Mechanically fractured throughout with rare natural fissures perpendicular to core axis. Strength R3.		1	NQ RC																
			2	NQ RC																
278.84																				
7.47	END OF BOREHOLE Groundwater not established during drilling on December 18, 2013.																			

PROJECT 10-1132-0056		RECORD OF BOREHOLE No 904		1 OF 1 METRIC	
W.P. 4-00-00	LOCATION N 4807594.7 , E 234172.4			ORIGINATED BY DB	
DIST HWY 401	BOREHOLE TYPE POWER AUGER, HOLLOW STEM			COMPILED BY WDF/LMK	
DATUM GEODETIC	DATE August 19, 2013			CHECKED BY	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT 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							w _p w w _L		
							20 40 60 80 100					10 20 30					
305.50	PAVEMENT SURFACE																
0.00	ASPHALT																
0.12	FILL, sand and gravel, crushed Brown																
0.37	FILL, sand and gravel, trace silt Brown																
304.62	FILL, sand and gravel, trace silt Brown																
0.88	SAND, fine, some silt Compact Brown		1	SS	27												
304.13	SANDY SILT, some clay, trace gravel Loose Brown		2	SS	8												
1.37	CLAYEY SILT TILL, trace sand, trace gravel Very stiff Brown		3	SS	19												
303.36	SANDY SILT, trace clay Very dense Grey		4	SS	52												
2.14	CLAYEY SILT, trace gravel, trace sand Very stiff to hard Grey		5	SS	25												
302.60	CLAYEY SILT, trace gravel, trace sand Very stiff to hard Grey		6	SS	37												
2.90	CLAYEY SILT, trace gravel, trace sand Very stiff to hard Grey		7	SS	20												
301.84	CLAYEY SILT, trace gravel, trace sand Very stiff to hard Grey		8	SS	46												
3.66	CLAYEY SILT, trace gravel, trace sand Very stiff to hard Grey		9	SS	55												
298.79	SANDY SILT, some clay, with silt layers at about elev. 298.5m Very dense Grey		10	SS	80/150mm												
6.71	SANDY SILT, some clay, with silt layers at about elev. 298.5m Very dense Grey		11	SS	20/50mm												
298.18	SANDY SILT, some clay, with silt layers at about elev. 298.5m Very dense Grey		12	SS	65/150mm												
7.32	SANDY SILT, some clay, with silt layers at about elev. 298.5m Very dense Grey																
295.29	END OF BOREHOLE																
10.21	Groundwater encountered at about elev. 298.5m during drilling on August 19, 2013.																



REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

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

PROJECT

OVERHEAD AND HOV SIGNS
HIGHWAY 401 IMPROVEMENTS
GWP 4-00-00

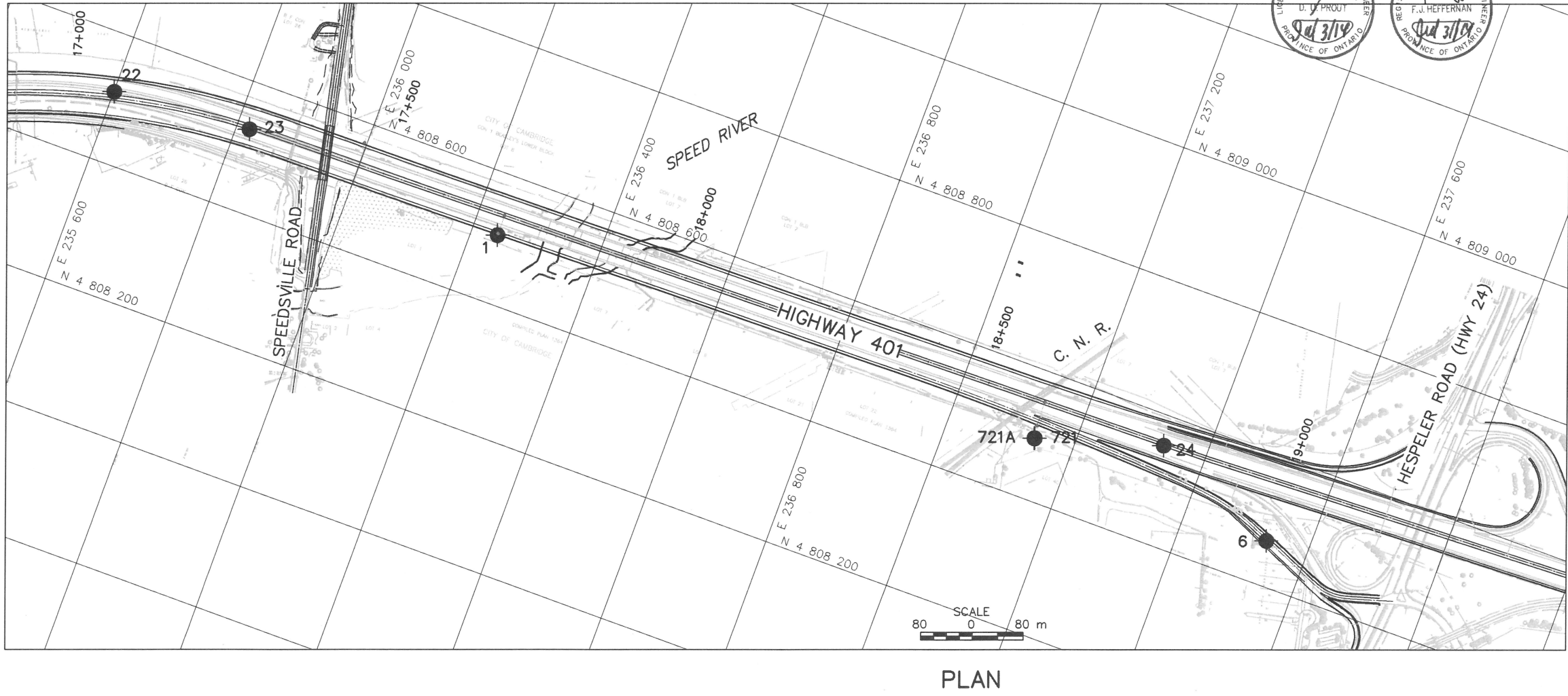
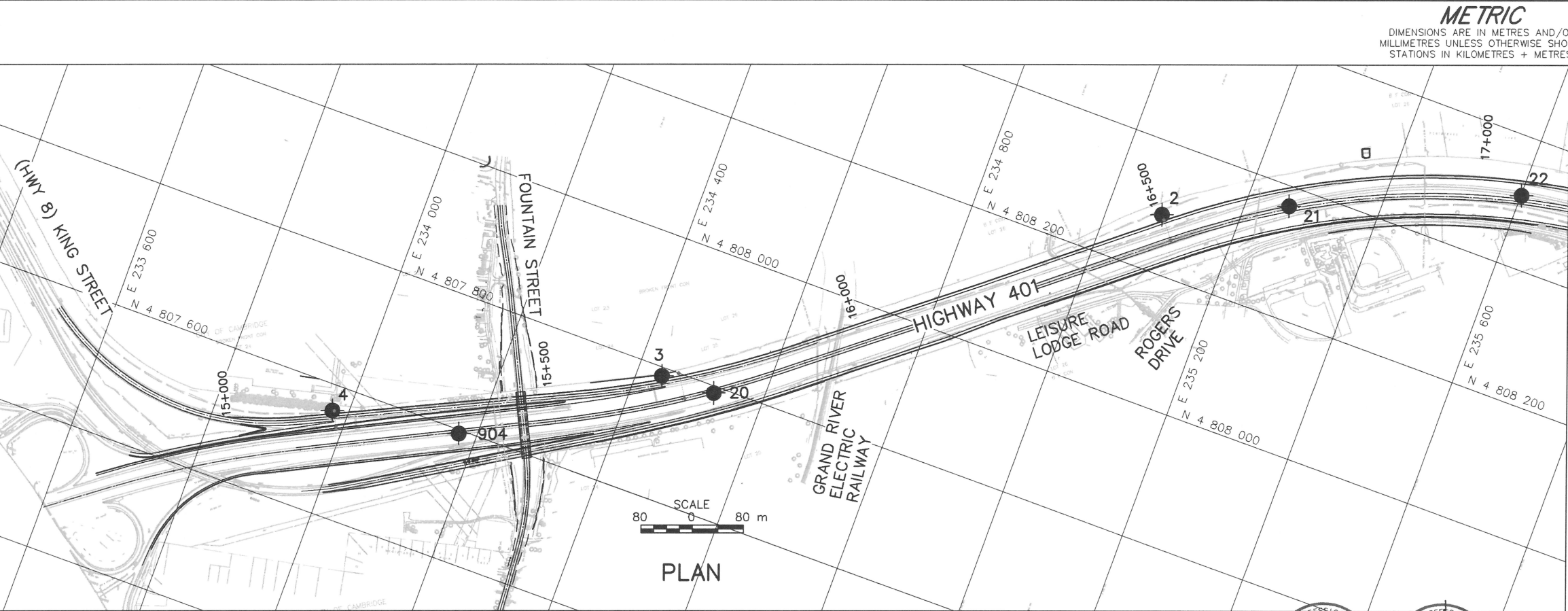
TITLE

KEY PLAN



PROJECT No. 10-1132-0056		FILE No. 1011320056-2000-F11001	
CADD	WDF	June 5/14	SCALE AS SHOWN
CHECK			REV. 0

FIGURE 1

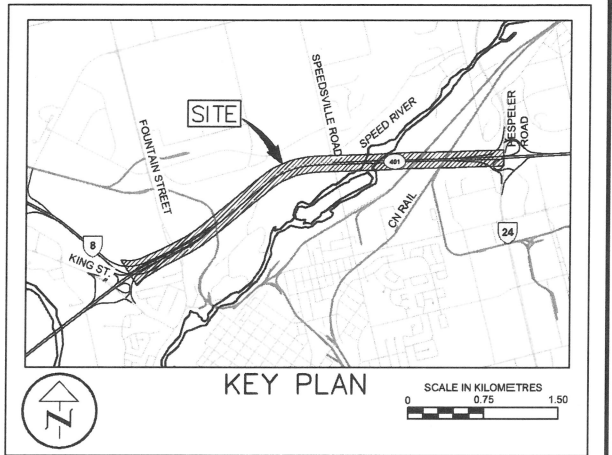


CONT No.
WP No. 4-00-00

OVERHEAD AND HOV SIGNS

HIGHWAY 401 IMPROVEMENTS
BOREHOLE LOCATIONS

SHEET



LEGEND

● Borehole - Current Investigation

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
1	277.52	4 808 505.0	236 240.8
2	297.97	4 808 289.7	235 084.3
3	304.31	4 807 787.1	234 438.6
4	305.84	4 807 561.1	233 975.1
6	296.00	4 808 468.9	237 533.5
20	302.65	4 807 789.7	234 523.6
21	283.80	4 808 369.7	235 264.7
22	279.85	4 808 510.1	235 600.9
23	279.00	4 808 527.6	235 820.4
24	295.00	4 808 553.5	237 332.1
(GEOCRES No. 40P8-223)			
721	286.31	4 808 494.7	237 138.1
721A	286.31	4 808 494.7	237 136.0
(GEOCRES No. 40P8-221)			
904	305.50	4 807 594.7	234 172.4

NOTES

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

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

REFERENCE

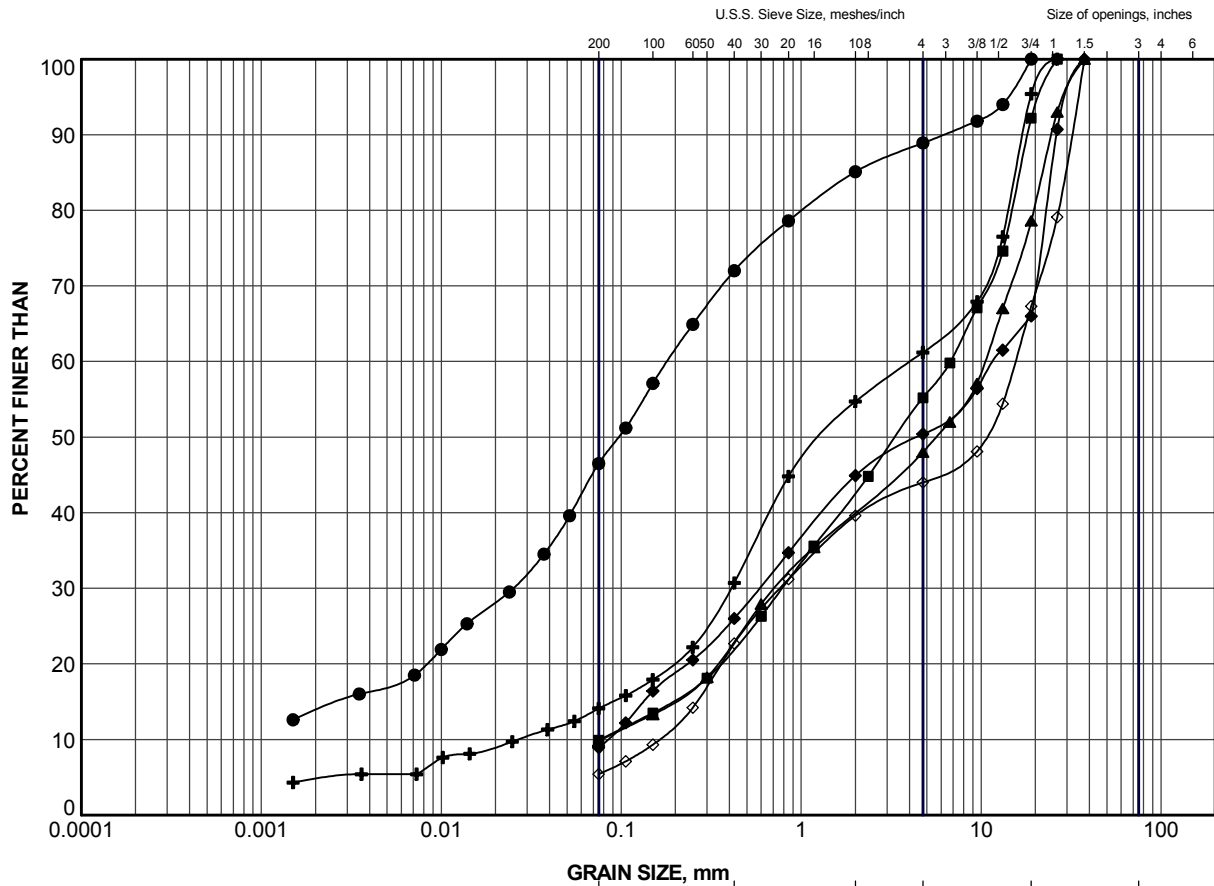
Base plans provided in digital format by Delcan.

NO.	DATE	BY	REVISION
Geocres No. 40P8-226			
HWY.	401	PROJECT NO.	10-1132-0056
SUBM'D.	NAG	CHKD.	NAG
DRAWN:	WDF	CHKD.	AMH
DATE:	July 28/14	APPD.	FJH
SITE:		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)
●	21	4	280.5
■	22	1	278.9
▲	24	2	293.3
+	24	5	291.0
◆	721	2	284.6
◇	721	4	283.0

PROJECT

OVERHEAD AND HOV SIGNS
HIGHWAY 401 IMPROVEMENTS
GWP 4-00-00

TITLE

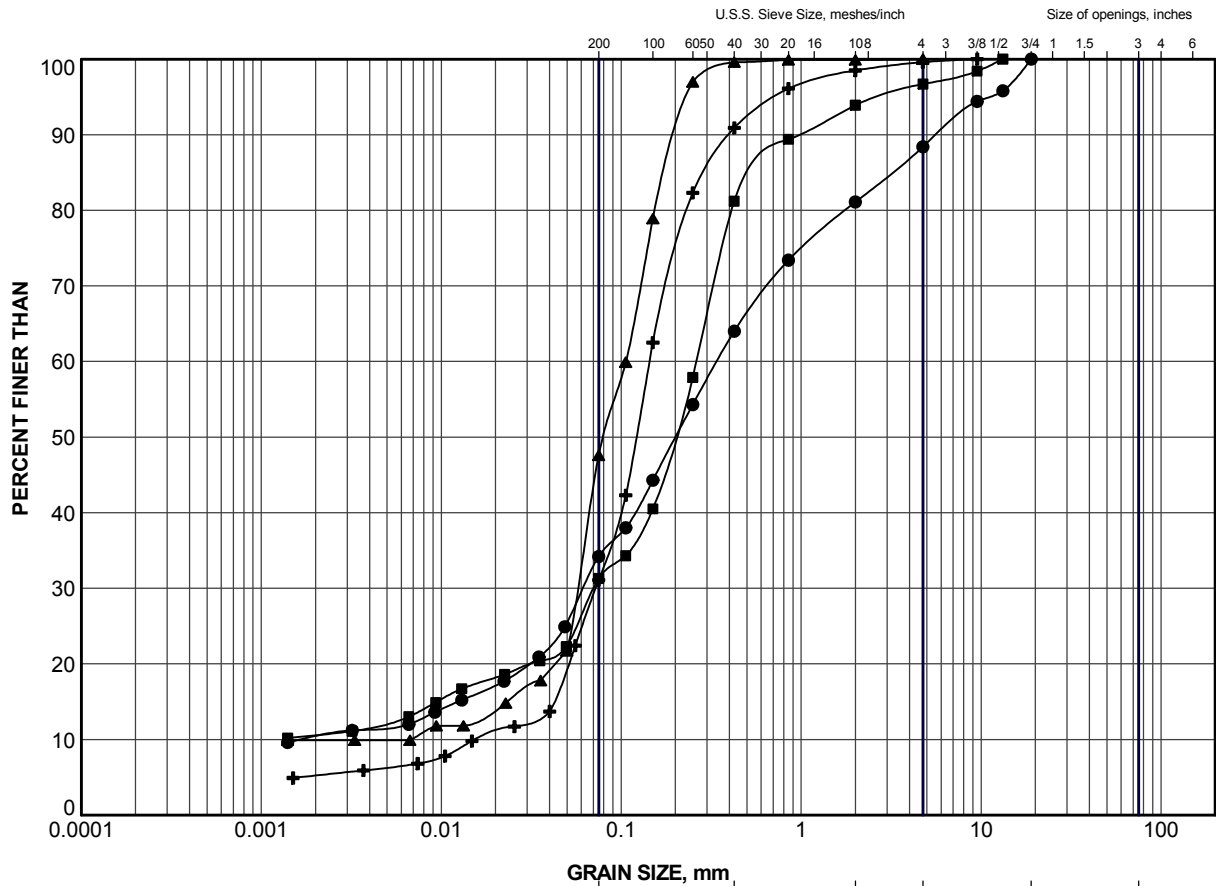
GRAIN SIZE DISTRIBUTION
FILL



Golder Associates
LONDON, ONTARIO

PROJECT No.	10-1132-0056	FILE No.	1011320056-2000-F110A1
DRAWN	WDF	Jun 03/14	SCALE N/A REV.
CHECK			

FIGURE A-1



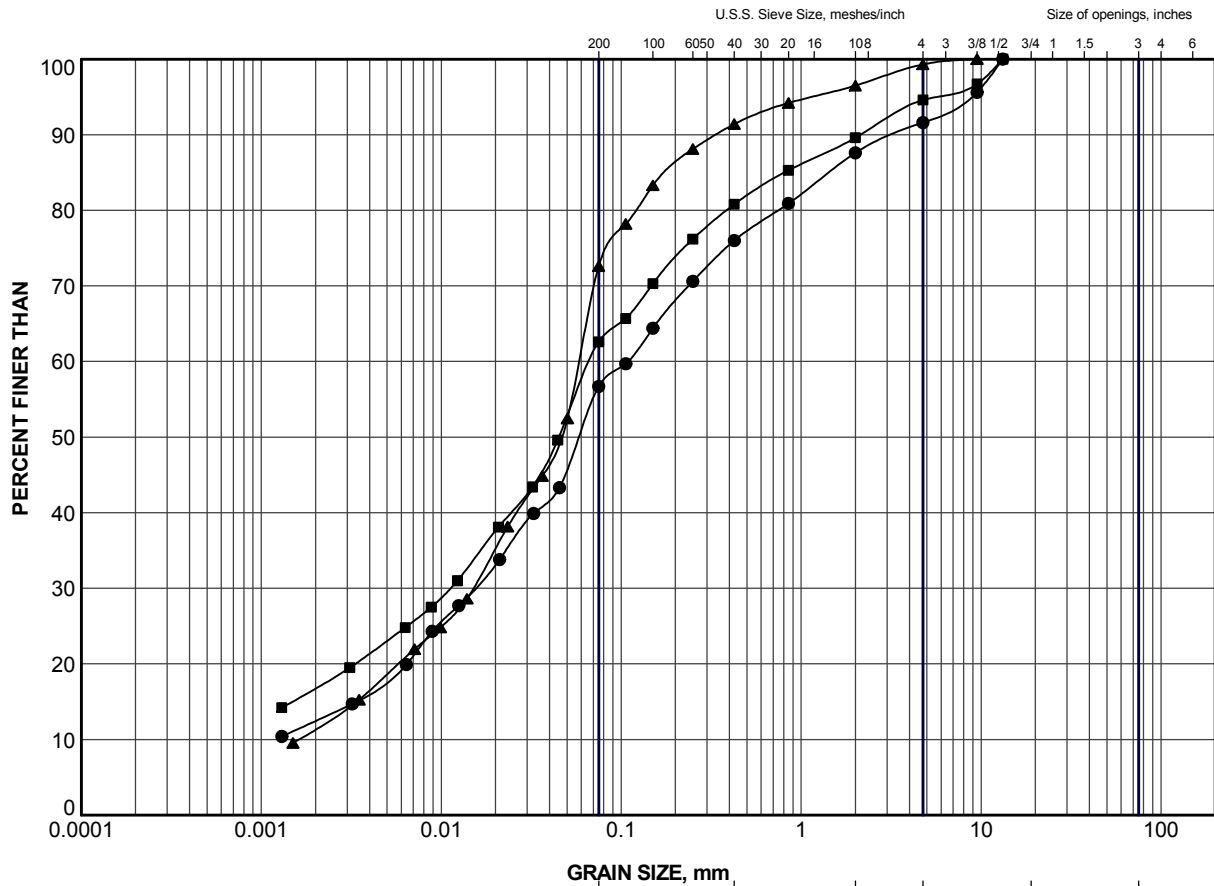
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	2	7	292.5
■	2	11	289.4
▲	2	16	285.6
+	23	2	277.3

PROJECT				OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY SAND			
PROJECT No.		10-1132-0056		FILE No. 1011320056-2000-F110A2			
DRAWN		WDF		Jun 03/14		SCALE N/A REV.	
CHECK						FIGURE A-2	




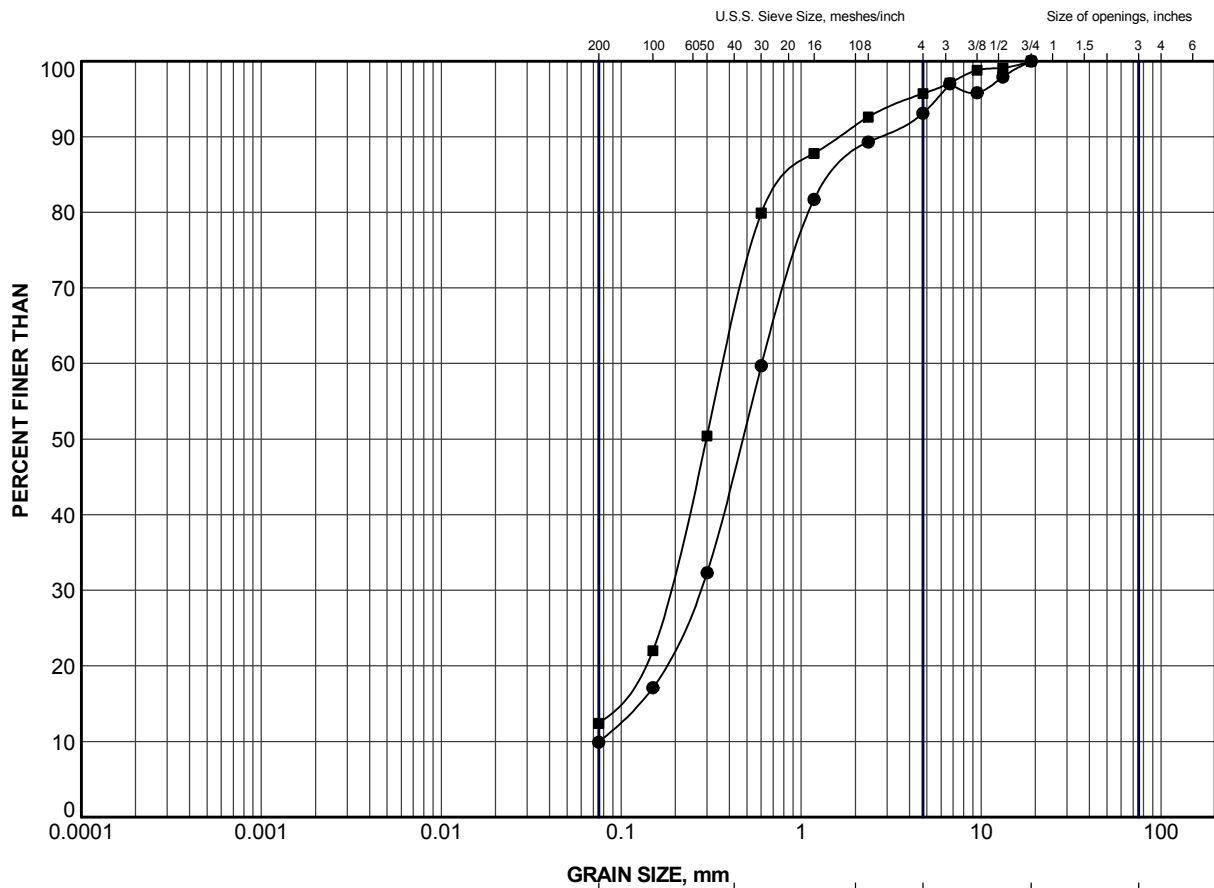


CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	3	3	301.8
■	3	10	296.6
▲	904	9	298.4

PROJECT				OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F110A3	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Jun 03/14					
 Golder Associates LONDON, ONTARIO				FIGURE A-3			



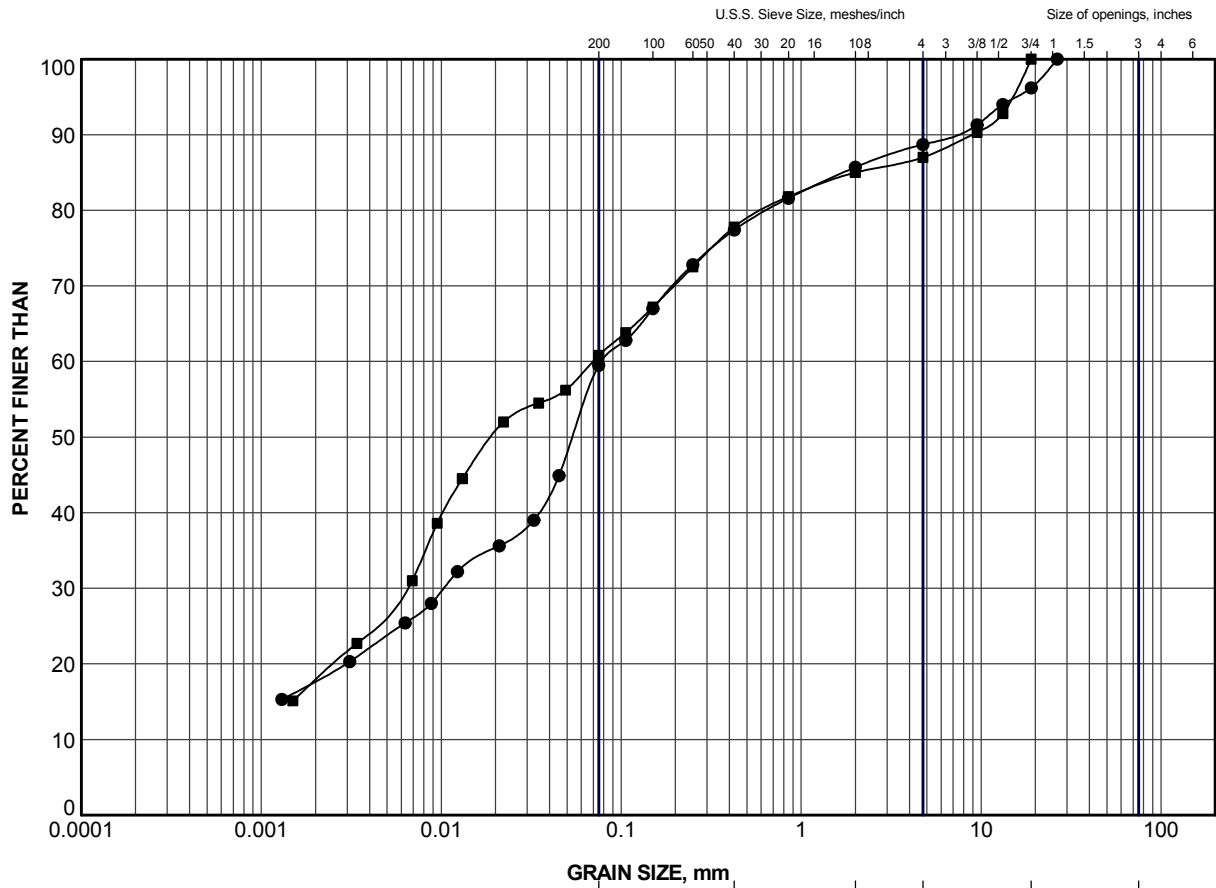
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	6	3	293.5
■	21	7	278.2


PROJECT				OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND			
PROJECT No.		10-1132-0056		FILE No.		4	
DRAWN		WDF		Jun 03/14		SCALE N/A REV.	
CHECK						FIGURE A-4	



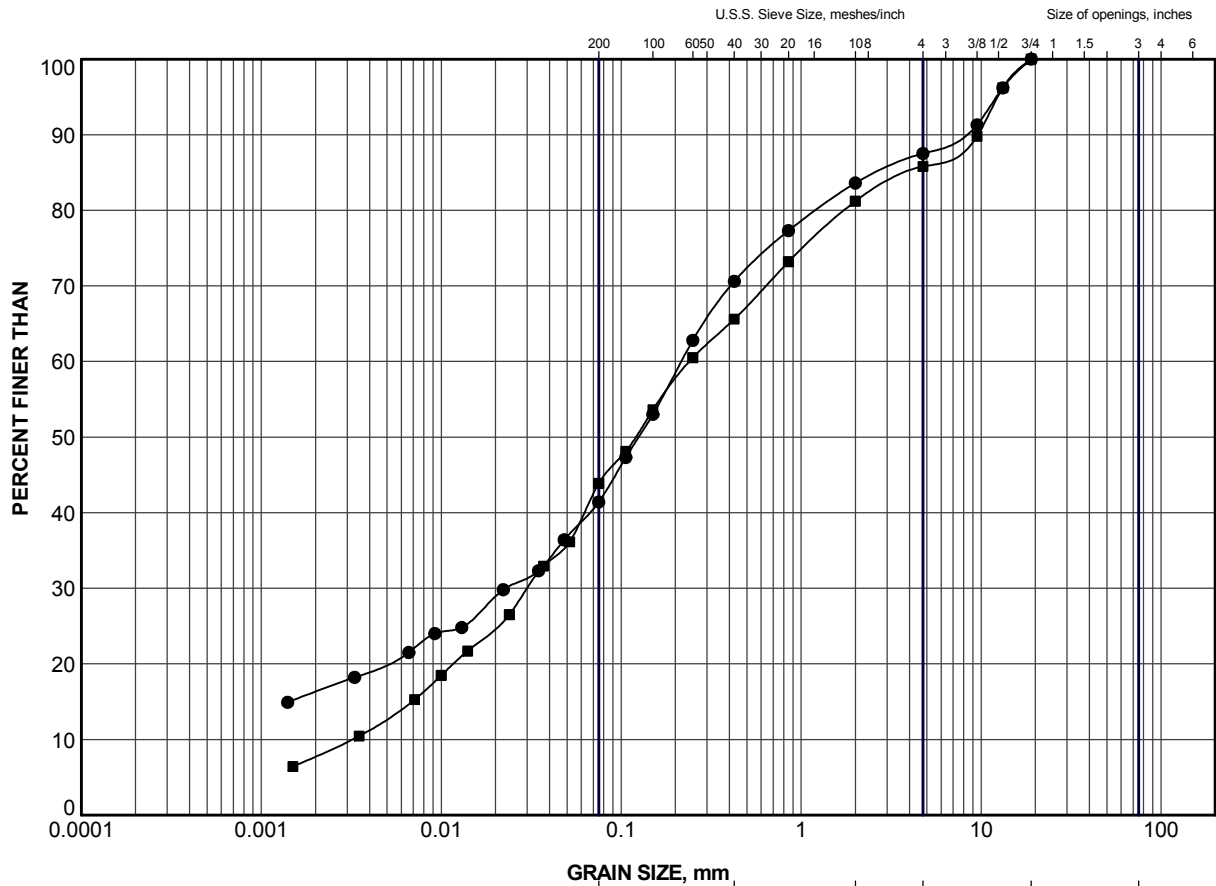


CLAY AND SILT	SAND SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	2	5	293.9
■	20	6	297.9

PROJECT		OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00				
TITLE		GRAIN SIZE DISTRIBUTION SANDY SILT TILL				
 Golder Associates LONDON, ONTARIO		PROJECT No.		10-1132-0056		
		FILE No.		1011320056-2000-F110A5		
		SCALE	N/A		REV.	
		DRAWN	WDF	Jun 03/14		
		CHECK				
		FIGURE A-5				


LDN_MTO_GSD_GLDR_LDN.GDT 03/06/14

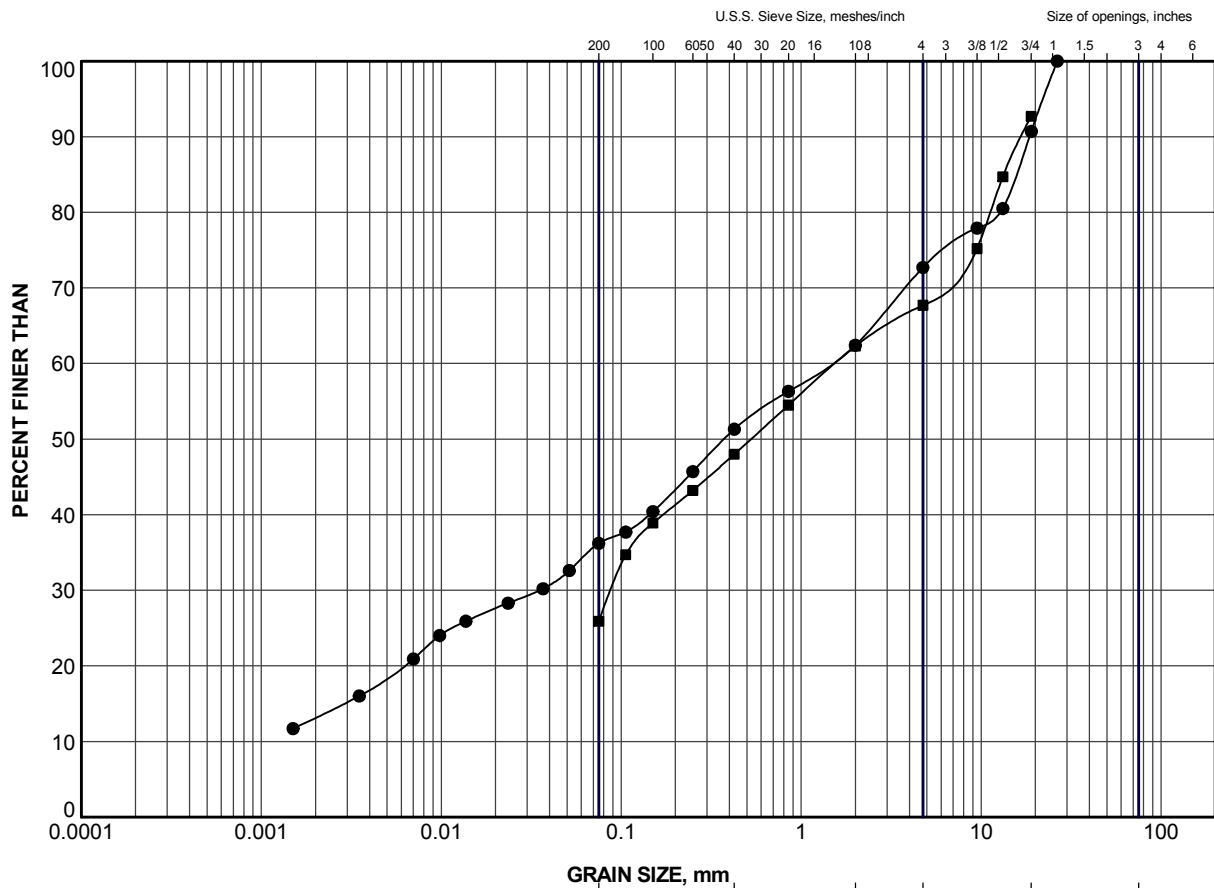


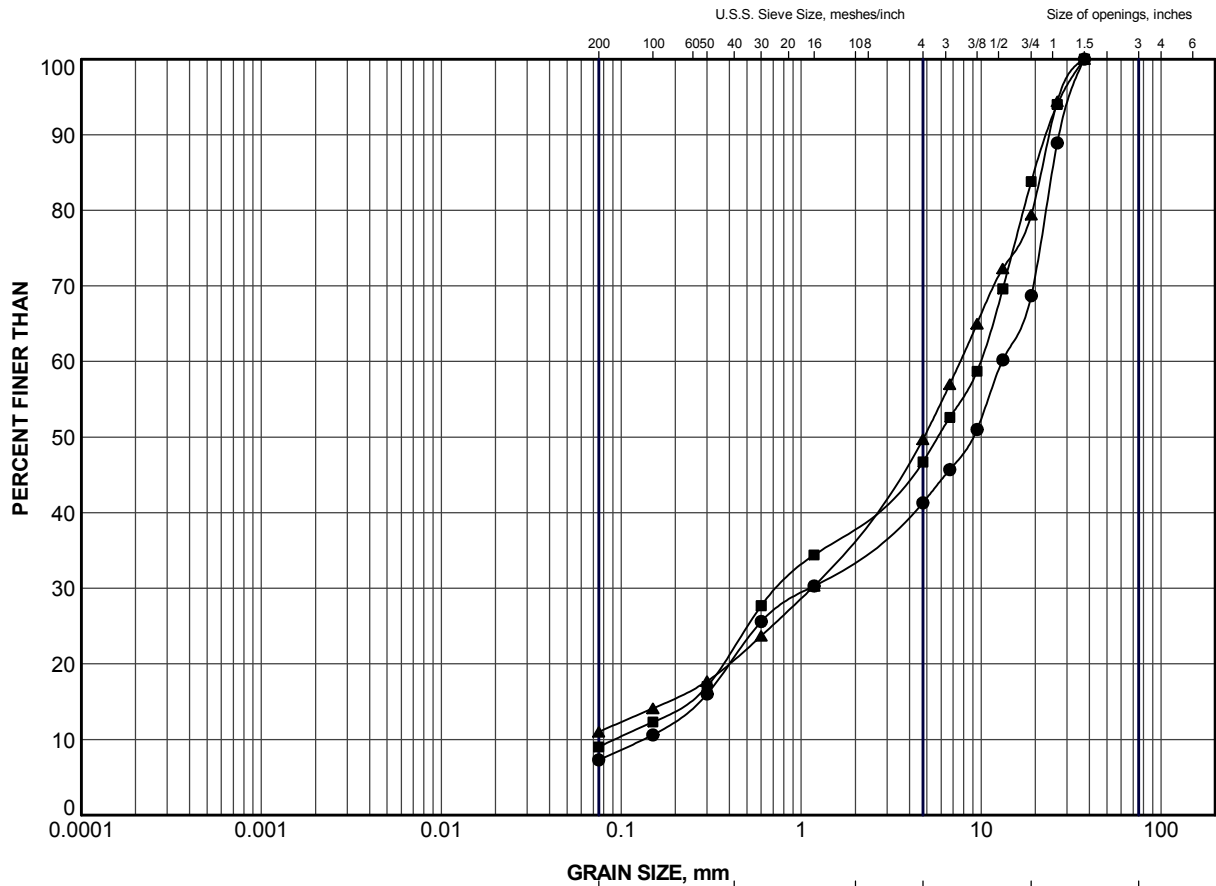
CLAY AND SILT	SAND SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	4	4	302.6
■	904	10	297.7

PROJECT				OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY SAND TILL			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F110A6	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Jun 03/14					
 Golder Associates LONDON, ONTARIO				FIGURE A-6			





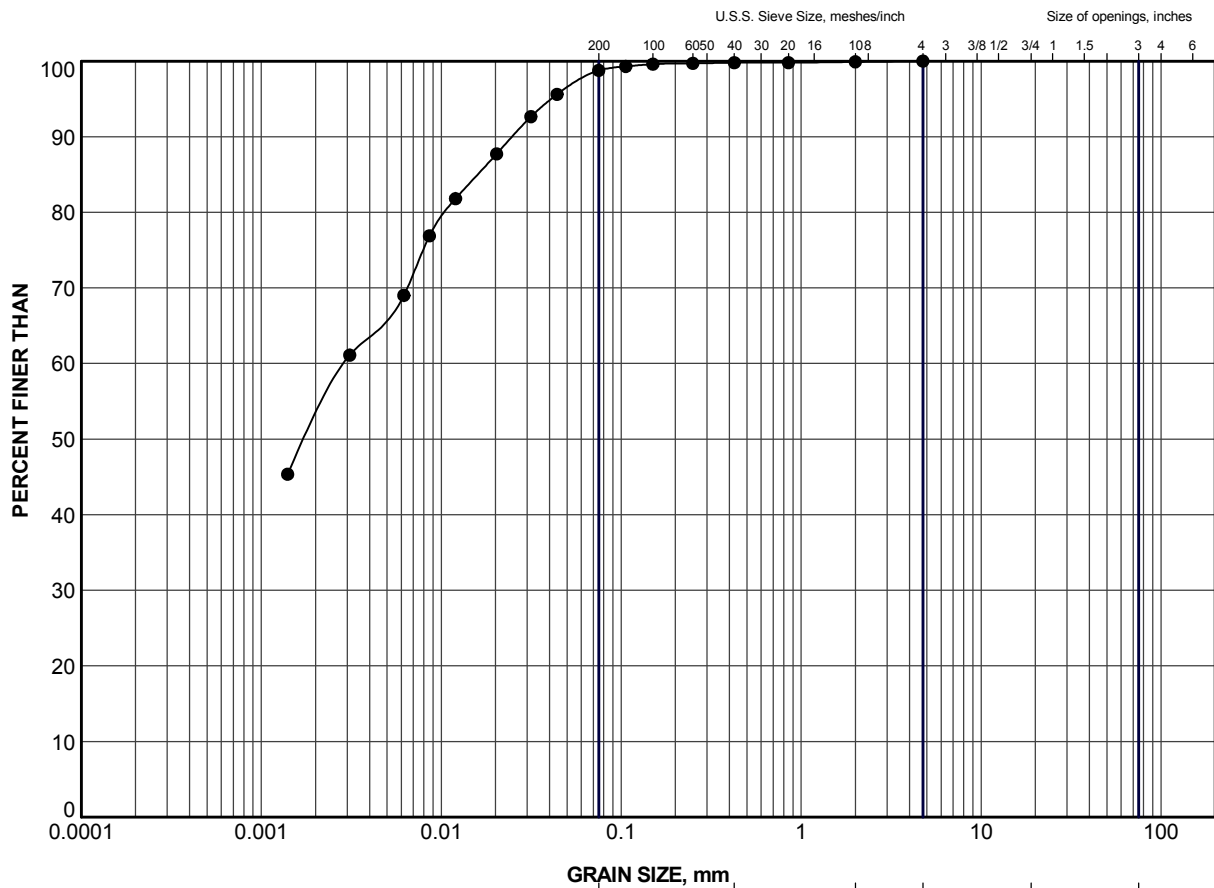
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	6	2	294.3
■	6	4	292.7
▲	20	4	299.4

PROJECT				OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION SAND AND GRAVEL			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F110A8	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Jun 03/14		FIGURE A-8			




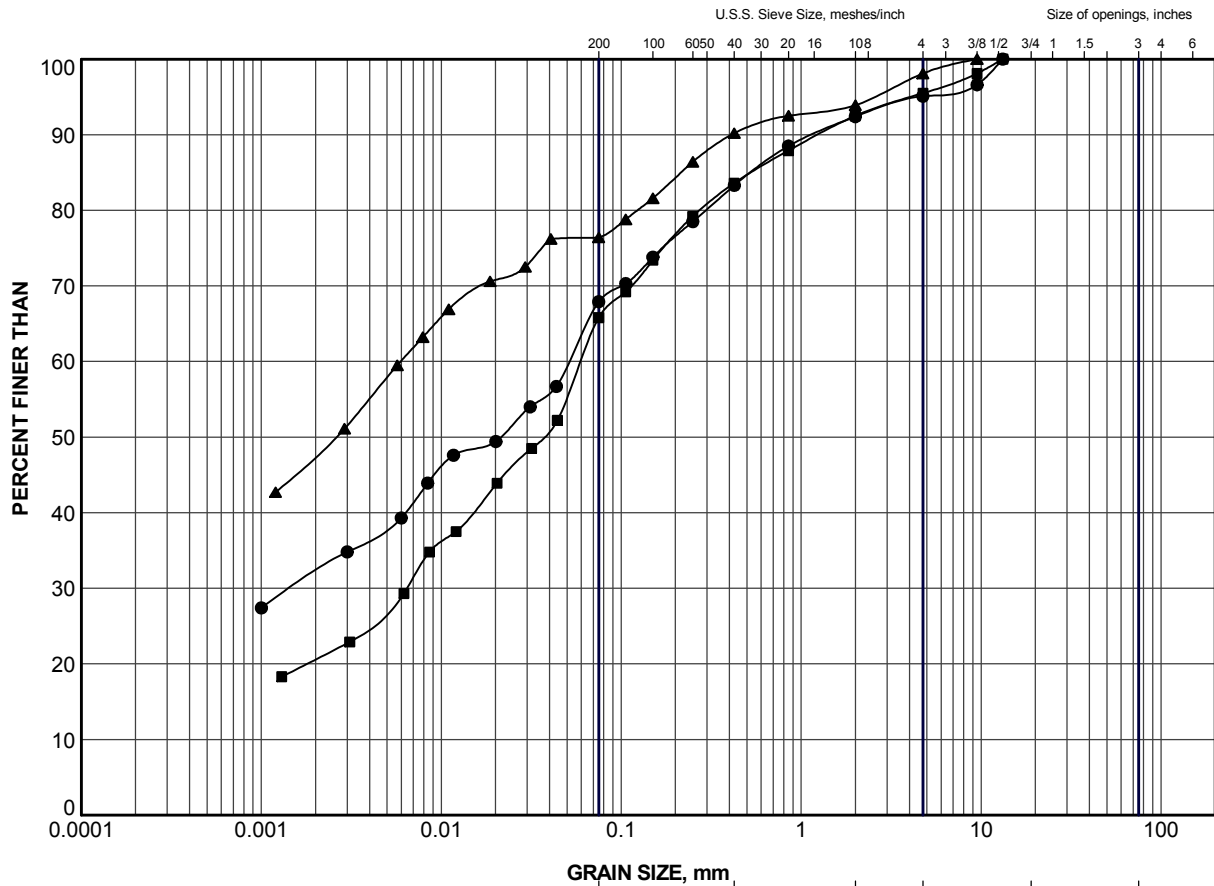


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	904	6	300.7

PROJECT				OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT			
PROJECT No.		10-1132-0056		FILE No.		1011320056-2000-F110A9	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Jun 03/14					
 Golder Associates LONDON, ONTARIO				FIGURE A-9			



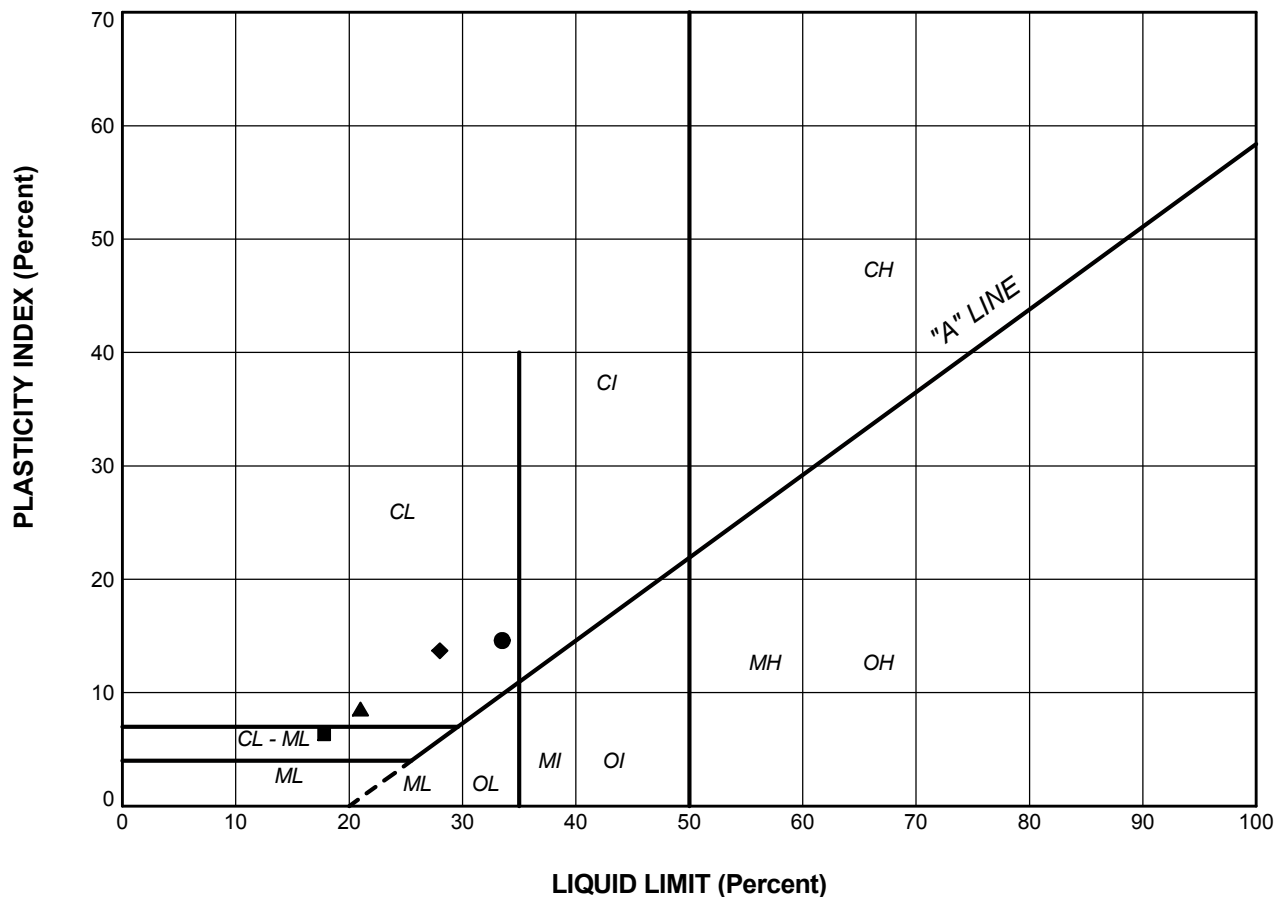
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	2	2	296.2
■	3	8	298.0
▲	4	7	300.3

PROJECT				OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL			
PROJECT No.		10-1132-0056		FILE No		1011320056-2000-F110A10	
DRAWN		WDF		SCALE		N/A	
CHECK				REV.			
		Jun 03/14		FIGURE A-10			





LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	2	2	33.5	18.9	14.6
■	3	8	17.8	11.5	6.4
▲	4	7	21.0	12.5	8.6
◆	904	6	28.0	14.3	13.7

PROJECT		OVERHEAD AND HOV SIGNS HIGHWAY 401 IMPROVEMENTS GWP 4-00-00	
TITLE		PLASTICITY CHART	
PROJECT No. 10-1132-0056		FILE No 1011320056-2000-F110A11	
DRAWN	WDF	Jun 03/14	SCALE N/A REV.
CHECK			FIGURE A-11



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