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**FOUNDATION INVESTIGATION AND DESIGN REPORT
STRUCTURAL CULVERT - SITE 14-487C/W
STATION 19+550, TOWNSHIP OF WARWICK
HIGHWAY 402 AND LAMBTON COUNTY ROAD 79 IMPROVEMENTS
GWP 3158-06-00
WATFORD, ONTARIO**

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TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
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PART A - FOUNDATION INVESTIGATION REPORT

1.0	INTRODUCTION.....	1
2.0	SITE DESCRIPTION.....	2
2.1	Site Geology	2
3.0	INVESTIGATION PROCEDURES.....	3
4.0	SUBSURFACE CONDITIONS.....	4
4.1	Site Stratigraphy.....	4
4.1.1	Fill.....	4
4.1.2	Clayey Silt	4
4.1.3	Silty Clay	5
4.1.4	Clayey Silt Till	5
4.1.5	Silt	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	Foundations	9
6.2.1	Frost Protection	10
6.3	Backfill	10
6.4	Lateral Earth Pressures for Design.....	10
6.5	Construction Considerations	12
6.6	Excavations and Temporary Cut Slopes	12
7.0	MISCELLANEOUS.....	14

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORD OF BOREHOLE SHEETS

FIGURE 1 - Key Plan

DRAWING 1 - Borehole Location and Soil Strata

APPENDIX A - Laboratory Test Data

APPENDIX B - Site Photographs

PART A – FOUNDATION INVESTIGATION REPORT

**STRUCTURAL CULVERT - SITE 14-487C/W
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Delcan Corporation (Delcan) on behalf of Waste Management (WM) to carry out foundation investigations as part of the design of the improvements for the Highway 402/Lambton County Road 79 (Nauvoo Road) interchange and Lambton County Road 79 south of the interchange to the new entrance of the WM Warwick Landfill in the Township of Warwick, Ontario.

The proposed works are being undertaken in conjunction with the Warwick Landfill Expansion Project. The design package is to be completed in accordance with Ministry of Transportation, Ontario (MTO) standards. The scope of work for this project consists of the geotechnical field investigation and design of the following components of the project:

- rehabilitation of the Lambton County Road 79 Underpass Structure (Site 14-355);
- profile grade adjustments (filling) on Lambton County Road 79;
- profile grade adjustments on portions of the existing E-N/S, S-W, N-E and W-N/S ramps;
- replacement of the existing S-E and N-W ramps with new ramps;
- possible pavement upgrades on the existing E-N/S ramp;
- paved shoulders along Lambton County Road 79 from Highway 402 to the landfill entrance;
- roadway improvements along Lambton County Road 79 at the new landfill entrance;
- culvert extensions on Lambton County Road 79; and
- culvert extension on Highway 402.

This report addresses the extension of the north end of the structural culvert (Site Number 14-487C/W) on Highway 402 at Station 19+550 under the westbound lane of Highway 402, Township of Warwick to accommodate the new N-W ramp. The foundation investigation and reporting was conducted in accordance with MTO standards for detail design.

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 WM Project Terms of Reference, in our proposal P71-3118 dated June 26, 2007, and our letter pertaining to foundation engineering services (07-1130-128-4) dated September 10, 2007.

Delcan provided Golder Associates with a base plan for this project in digital format.

2.0 SITE DESCRIPTION

This project consists of the upgrading of the Highway 402/Lambton County Road 79 (Nauvoo Road) interchange with rehabilitation of the underpass structure, profile adjustments on Lambton County Road 79 and the affected ramps, construction of a new S-E ramp and N-W ramp and possible upgrading of the pavement on the E-N/S ramp. In addition, short span and structural culverts in the areas of the roadway improvements are to be extended and Lambton County Road 79 is to be upgraded in the vicinity of the new entrance to the Waste Management landfill. The structural culvert at Station 19+550 on Highway 402, Township of Warwick, is located approximately 630 metres west of the Lambton County Road 79 underpass structure. The location of the project site is shown on the Key Plan, Figure 1.

The surrounding area is predominantly agricultural lands with woodlots immediately north of the interchange. A former construction yard is located immediately north of the interchange and a former gas storage yard is located south of the interchange, both to the west of Lambton County Road 79. The adjacent topography is generally flat with a ground surface elevation ranging from 234 metres to 235 metres.

Lambton County Road 79 is a two lane road. The cross-section of the two span underpass structure over Highway 402 consists of a 18.29 metre wide deck, including curbs and guardrails with a total span length of 83.52 metres. The subject section of Highway 402 is a divided rural freeway with four 3.65 metre wide lanes together with on and off ramps and gravel shoulders.

Two structural culverts in alignment at Station 19+550, Township of Warwick, carry flow from the Morris Drain under the westbound and eastbound lanes of Highway 402. Flow in the culverts is from south to north. Photographs of the culvert under the Highway 402 westbound lanes are shown in Appendix B.

2.1 Site Geology

The project is located in the physiographic region of southern Ontario known as the Horseshoe Moraines, as identified in "The Physiography of Southern Ontario", by Chapman and Putnam (1984). The southwestern limb of the region consists of two, and in some places three, moraine ridges composed of pale brown, hard, calcareous, fine-textured till.

Based on the Ontario Department of Mines and Northern Affairs Preliminary Map P.1972 entitled "Quaternary Geology of the Strathroy Area", the project area is reportedly located in predominantly clayey silt to silty clay till.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out on December 6, 2007 at which time two boreholes were drilled at the locations indicated on Drawing 1.

The as-drilled borehole locations, ground surface elevations and depths of boreholes are as follows:

<u>BOREHOLE</u>	<u>LOCATION (m)</u>		<u>GROUND SURFACE ELEVATION</u>	<u>BOREHOLE DEPTH</u>
	<u>Northing</u>	<u>Easting</u>	(m)	(m)
101	4 761 579.5	354 776.7	227.58	6.55
102	4 761 572.8	354 753.8	229.46	8.84

The existing culvert has the following characteristics:

<u>DIMENSIONS (m)</u>	<u>OBVERT ELEVATION (m)</u>		<u>CONSTRUCTION</u>	<u>MUNICIPAL DRAIN ID</u>
	36.3m (Lt)	10.6m (Lt)		
4.88 x 1.22 x 25.70	228.67	228.73	Concrete, Rigid frame open footing (RFO)	Morris Drain

The soil stratigraphy encountered in the boreholes is shown on the attached Record of Borehole sheets. The investigation was carried out using an all terrain vehicle mounted CME 550 power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at 0.75 and 1.5 metre intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. Groundwater conditions in the boreholes were observed throughout the drilling operations and the boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903. A standpipe was installed in borehole 102 to monitor groundwater conditions.

The field work was supervised on a full-time basis by an experienced member of our engineering staff who directed the drilling, sampling and in situ testing operations, logged the boreholes and determined the ground surface elevations and borehole locations.

The samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and routine classification testing. Index and classification tests consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ 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 types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The locations and elevations of the boreholes, together with an interpreted stratigraphic profile, are shown on the attached Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

The boreholes drilled at the site encountered rip rap or surficial granular fill and clayey silt fill overlying layers of silty clay, clayey silt, clayey silt till and silt.

4.1.1 Fill

A 0.2 metre thick rip-rap layer was encountered at ground surface in borehole 101.

Sand and gravel fill was encountered at ground surface in borehole 102 to a depth of 0.9 metres. The sand and gravel fill is granular roadbase material associated with the roadway shoulder.

A 0.5 metre thick layer of clayey silt fill was encountered beneath the sand and gravel fill in borehole 102 at elevation 228.6 metres. The clayey silt fill was firm with an N value of 6 blows per 0.3 metres.

4.1.2 Clayey Silt

Layers of clayey silt were encountered in both of the boreholes drilled at the site. The clayey silt was found beneath the silty clay at about elevation 225.5 metres in borehole 101 and beneath the clayey silt fill at about elevation 228.1 metres in borehole 102. The layers of clayey silt were 2.3 to 3.8 metres thick.

The clayey silt was stiff to very stiff with N values of 8 to 27 blows per 0.3 metres and had water contents of 15 to 22 per cent with an average water content of about 17 per cent. The average plastic and liquid limits, based on the results of two Atterberg limits determinations, were 16 and

30 per cent, respectively, with an average plasticity index of 14 per cent. The results of the plasticity testing indicate an inorganic clayey soil of low plasticity. The results of the Atterberg limits testing are presented on the Plasticity Chart, Figure A-4.

The results of grain size testing on two samples of clayey silt recovered from the standard penetration testing are presented on Figure A-1.

4.1.3 Silty Clay

Layers of silty clay were encountered in both of the boreholes drilled at the site. The silty clay was found beneath the rip rap at about elevation 227.3 metres in borehole 101 and beneath the clayey silt at about elevation 224.3 metres in borehole 102. The silty clay layers were 1.5 to 1.9 metres thick.

The silty clay was stiff to very stiff with N values of 9 to 20 blows per 0.3 metres and had water contents of 19 to 28 per cent with an average water content of about 23 per cent. The average plastic and liquid limits, based on the results of two Atterberg limits determinations, were 19 and 37 per cent, respectively, with an average plasticity index of 18 per cent. The results of the plasticity testing indicate an inorganic clayey soil of intermediate plasticity. The results of the Atterberg limits testing are presented on the Plasticity Chart, Figure A-4.

The results of grain size testing on two samples of silty clay recovered from the standard penetration testing are presented on Figure A-2.

4.1.4 Clayey Silt Till

Clayey silt till was encountered in both of the boreholes drilled at the site. The clayey silt till was found beneath the clayey silt at about elevation 223.2 metres in borehole 101 and beneath the silty clay at about elevation 222.8 metres in borehole 102. The clayey silt till was 1.2 metres thick where fully penetrated. Borehole 102 was terminated in a deposit of clayey silt till after exploring it for some 2.1 metres.

The clayey silt till was stiff with N values of 8 to 12 blows per 0.3 metres and had water contents of 13 to 16 per cent with an average water content of about 14 per cent. The shear strength of the softer zones of the clayey silt till is greater than 144 kilopascals based on a single in situ vane shear strength test. The plastic and liquid limits, based on the results of a single Atterberg limits determination, were 15 and 27 per cent, respectively, with a plasticity index of 12 per cent. The results of the plasticity testing indicate an inorganic clayey soil of low plasticity. The results of the Atterberg limits testing are presented on the Plasticity Chart, Figure A-4.

The results of grain size testing on a single sample of clayey silt till recovered from the standard penetration testing are presented on Figure A-3.

Although cobbles and boulders were not specifically encountered in the boreholes, the presence of these materials should be expected due to the depositional history of the glacial tills.

4.1.5 Silt

Borehole 101 encountered and was terminated in a layer of silt after exploring it for some 0.9 metres. The silt was found beneath the clayey silt till at about elevation 221.9 metres.

The silt was dense with an N value of 35 blows per 0.3 metres and had a water content of 17 per cent.

The results of grain size testing on a single sample of silt recovered from the standard penetration testing are presented on Figure A-5.

4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Groundwater was encountered in borehole 101 at about 227.5 metres during drilling on December 6, 2007. Borehole 102 was dry during drilling. A standpipe was installed in borehole 102 to monitor the groundwater conditions. After installation on December 6, 2007, the water level in the standpipe was measured at elevation 222.9 metres or a depth of 6.6 metres. On December 19, 2007, the water level in the standpipe was measured at elevation 227.3 metres or a depth of 2.2 metres below the ground surface. On January 30, 2008, the water level in the standpipe was measured at elevation 227.4 metres or a depth of 2.1 metres below the ground surface.

Details of the groundwater conditions encountered and subsequently measured in the installation are provided on the Record of Borehole sheets and are summarized below.

BOREHOLE	GROUND SURFACE ELEVATION (m)	ENCOUNTERED GROUNDWATER LEVEL		INSTALLATION	MEASURED GROUNDWATER LEVEL					
		Depth (m)	Elevation (m)		Dec. 6, 2007		Dec. 19, 2007		Jan. 30, 2008	
					Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
101	227.58	0.8	227.5	-	-	-	-	-	-	-
102	229.46	Dry	Dry	Standpipe	6.55	222.93	2.16	227.30	2.07	227.39

The water level at the outlet of the culvert at Station 19+550 was at elevation 227.5 metres on December 6, 2007.

The interface of the brown to grey clayey silt was at elevation 225.5 metres to 225.7 metres.

Based on the location of the interface of the brown and grey clayey silt, the measured drain water level and the measured water level in the standpipe, the groundwater level elevation is inferred to be near 227.5 metres.

The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by B.U.D. Environmental Services., which 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 routine 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. Dirka U. Prout, P. Eng. under the direction of the Project Manager, 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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PART B – FOUNDATION DESIGN REPORT

**STRUCTURAL CULVERT - SITE 14-487C/W
STATION 19+550, TOWNSHIP OF WARWICK
HIGHWAY 402 AND LAMBTON COUNTY ROAD 79 IMPROVEMENTS
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6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the design of the proposed extension of the culvert (Site 14-487C/W) under the westbound lanes of Highway 402 at Station 19+550, Township of Warwick based on our interpretation of the factual information obtained during the investigation. This culvert is a concrete rigid frame, open footing (RFO) structure. The extension is required to accommodate the new N-W ramp.

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.

6.2 Foundations

The subsoils encountered in the boreholes put down during the investigation typically consist of rip rap or surficial fill underlain by deposits of very stiff to stiff clayey silt to silty clay to about elevation 223 metres. Beneath the clayey silt to silty clay, stiff to very stiff clayey silt till interlayered with silt was found to the borehole termination depths of 6.6 to 8.8 metres. Groundwater was measured at elevation 227.4 metres on January 30, 2008. The water level in the Morris Drain was at elevation 227.5 metres on December 6, 2007.

The culvert information is summarized as follows:

<u>CULVERT LOCATION</u>	<u>SECTION DIMENSIONS</u> (m)	<u>LENGTH</u> (m)	<u>PAVEMENT SURFACE ELEVATION</u> (m)	<u>FOOTING ELEVATION</u> (m)	<u>LONG TERM GROUND- WATER LEVEL</u> (elevation – m)	<u>DRAIN WATER LEVEL</u> (elevation - m)
Station 19+550 (Warwick)	4.88 by 1.22	25.7	230.3	226.2	227.5	227.5

The culvert footing extension should be designed to withstand the appropriate weight of fill and traffic loading. Footing excavations should penetrate all existing fill and topsoil so that foundations bear directly on the native soils. Based on the soil conditions found at the borehole locations and the culvert invert at elevation 227.4 metres, the footings can be founded on spread footings at elevation 226.2 metres in the very stiff to stiff clayey silt and silty clay. Minimal groundwater inflow into the excavations is anticipated.

Assuming a 1.5 metre wide footing at approximately elevation 226.2 metres and a maximum settlement of 25 millimetres, footings may be designed using the following values:

<u>FOUNDING ELEVATION</u> (m)	<u>SOIL TYPE</u>	<u>GEOTECHNICAL RESISTANCE (kPa)</u>		<u>COEFFICIENT OF SLIDING</u> (unfactored)
		<u>Factored ULS</u>	<u>SLS</u>	
226.2	Clayey Silt	225	150	0.5
	Silty Clay	225	150	0.4

6.2.1 Frost Protection

All footings should be provided with a minimum of 1.2 metres of earth cover or thermal equivalent for frost protection purposes.

6.3 Backfill

Backfill for the footings and culvert walls should be carried out in accordance with Ontario Provincial Standard Drawing (OPSD) 3101.150 and incorporate the appropriate frost taper. Culvert backfill material should consist of free-draining, non-frost susceptible granular materials such as Ontario Provincial Standard Specifications (OPSS) Granular A or Granular B, Type III.

Heavy compaction equipment should not be used immediately adjacent to the walls and roof of the culvert. The height of backfill adjacent to the culvert walls should be maintained equal on both sides of the structure during all stages of backfill placement. Adequate erosion protection, as recommended in Section 6.5, should be provided at the outlet.

6.4 Lateral Earth Pressures for Design

The lateral pressures acting on the structure will depend on the backfill soils and, where used, the type and method of placement of the backfill materials behind the wall, as well as the subsequent lateral movement of the structure. The following recommendations are made concerning the design of the culvert walls in accordance with the Canadian Highway Bridge Design Code (CHBDC).

Backfill behind the culvert walls should consist of select, free-draining granular fill meeting the specifications of OPSS Granular A or Granular B, Type III but with less than 5 per cent passing the No. 200 sieve.

Where backfill soils are placed and compacted behind the walls, a compaction surcharge equal to 12 kilopascals should be included in the lateral earth pressures for structural design in accordance with the CHBDC. Compaction equipment should be used in accordance with SP 105S10.

For walls backfilled as noted above, the following parameters (unfactored) may be assumed:

	<u>GRANULAR A</u>	<u>GRANULAR B TYPE III</u>
Fill unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of lateral earth pressure:		
‘active’, K_a (unrestrained case)	0.27	0.31
‘at rest’, K_o (restrained case)	0.43	0.47

If the wall support allows lateral yielding (unrestrained structure), active earth pressures may be used in the geotechnical design of the structure. The granular fill should be placed in a zone greater than 1.2 metres wide at the footing level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical. If the culvert wall support does not allow lateral yielding (restrained structure), at-rest pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.2 metres behind the culvert walls.

The resistance to sliding for a cast-in-place concrete culvert with a concrete working slab may be based on an unfactored angle of interface friction, δ , of 28 degrees between the stiff to very stiff clayey silt and concrete and 24 degrees between the stiff to very stiff silty clay and concrete.

The factored horizontal geotechnical resistance, H_{ri} , should be based on CHBDC 6.7.5 as follows:

$$H_{ri} = 0.8A'c' + 0.8V\tan\delta > H_f$$

Where:

A'	-	effective contact area, square metres
c'	=	0
δ	=	24 degrees (silty clay)
δ	=	28 degrees (clayey silt)
V	-	unfactored vertical force, kilonewtons
H_f	-	factored horizontal load, kilonewtons

The unfactored coefficient of passive pressure for the portion of the culvert wall and footing below the invert may be taken as 3.0 for the clayey silt and 2.6 for the silty clay with effective angles of internal friction of 30 degrees and 26 degrees, respectively.

6.5 Construction Considerations

The founding soils are sensitive to disturbance and softening due to water seepage and/or ponding. Placement of a working slab of lean concrete will be required at the base of the culvert excavation for the footing area. Exposure without protection of the working slab will result in softening of the founding soils. The cleaned excavation base should be inspected by qualified geotechnical personnel prior to placing the working slab. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the geotechnical personnel on site and the working slab be placed immediately after footing inspection. Subgrade preparation and monitoring should be in accordance with SP 902S01.

Outlet cutoffs and filters are not considered necessary as the potential for uplift and piping is low. The provision of camber in the new culvert footings is not required due to the limited fill height and presence of stiff to very stiff foundation soils.

Rip-rap treatment at the culvert outlet and erosion and scour protection for the culvert backfill should be provided, as appropriate, consistent with OPSD 810.010. Consideration could be given to using suitable non-woven geotextile and rip rap, as required, to provide erosion protection based on hydraulic requirements. In addition, sediment control such as silt fences and erosion control blankets may be required during construction and diversion of the watercourse to mitigate migration of fine soil particles.

6.6 Excavations and Temporary Cut Slopes

Excavations for the footing replacements will extend through the existing fills into stiff to very stiff clayey silt and silty clay. Based on the subsurface conditions encountered in the boreholes, the base of the foundation excavations will be below the groundwater level which has been inferred at elevation 227.5 metres. Groundwater seepage into the excavations will be minimal based on the results of the boreholes drilled at the site. Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. In addition to diverting the existing culvert flows, pumping from well filtered sumps located in the base of the excavations may be required. The appropriate non-standard special provision should be added to note that excavations will extend below the groundwater level and the water level in the drain.

Temporary open cut slopes should be maintained no steeper than 1 horizontal to 1 vertical. All excavations should be carried out in accordance with the current edition of the Ontario Occupational Health and Safety Act and Regulations For Construction Projects. The fill materials at this site would be classified as Type 3 soils as would any cohesionless materials below the groundwater level. The native clayey materials would be classified as Type 2 soils.

The consideration with respect to protection of the founding soils, however, as given in Section 6.5 under the heading Construction Considerations must be recognized.

Where space is restricted and will not permit open cuts, a temporary support system should be installed to support the sides of the excavation and permit the use of vertical cuts.

If required, the temporary excavation support system should be designed and constructed in accordance with MTO Special Provision 105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 105S19.

7.0 MISCELLANEOUS

This report was prepared by Ms. Dirka U. Prout, P.Eng. under the direction of the Project Manager, 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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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	l
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 = σ'_p / σ'_{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)

PROJECT <u>07-1130-128-4-1</u>		RECORD OF BOREHOLE No 101		1 OF 1		METRIC	
G.W.P. <u>3158-06-00</u>		LOCATION <u>N 4761579.5 ; E 354776.7</u>		ORIGINATED BY <u>MA</u>			
DIST <u> </u> HWY <u>402</u>		BOREHOLE TYPE <u>POWER AUGER (UNCASED)</u>		COMPILED BY <u>BRS</u>			
DATUM <u>GEODETIC</u>		DATE <u>December 6, 2007</u>		CHECKED BY <u> </u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p	W	W _L		GR	SA	SI	CL
								20	40	60	80	100								
227.58	GROUND SURFACE																			
0.00	RIP RAP																			
0.24	SILTY CLAY, trace sand Very Stiff to Stiff Brown		1	SS	20												0	1		
			2	SS	19															
225.45																				
2.13	CLAYEY SILT, trace sand Stiff Grey		3	SS	14															
			4	SS	15															
223.92																				
3.66	CLAYEY SILT, with silt layers Stiff Grey		5	SS	8												0	0		
223.16																				
4.42	CLAYEY SILT (TILL), trace sand, trace gravel Stiff to Very Stiff Grey		6	SS	8															
221.94																				
5.64	SILT, some clay Dense Grey		7	SS	35												0	0		
221.03																				
6.55	END OF BOREHOLE																			
	Groundwater encountered at about elev. 227.5 m during drilling on December 6, 2007																			

LDN_MTO_01 07-1130-128-4-1.GPJ LDN_MTO.GDT 2/13/08

RECORD OF BOREHOLE No 102

1 OF 1

METRIC

PROJECT 07-1130-128-4-1

G.W.P. 3158-06-00

LOCATION N 4761572.8 ; E 354753.8

ORIGINATED BY MA

DIST HWY 402

BOREHOLE TYPE POWER AUGER (UNCASED)

COMPILED BY BRS

DATUM GEODETIC

DATE December 6, 2007

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								
								20	40	60	80	100				
229.46	GROUND SURFACE															
0.00	FILL, sand and gravel Crushed Brown						0.3m of Rip Rap									
0.24																
228.55	FILL, sand and gravel, trace silt Compact Brown		1	SS	6		Auger Cuttings									
0.91																
228.09	FILL, clayey silt, trace sand, trace gravel Firm Brown		2	SS	20											
1.37																
	CLAYEY SILT, trace sand Very Stiff to Stiff Brown becoming grey below about elev. 225.7m		3	SS	22		Bentonite									0 3 57 40
			4	SS	27											
			5	SS	11											
			6	SS	13		Auger Cuttings									
224.28																
5.18	SILTY CLAY, with silt layers Stiff Grey		7	SS	9											0 0 39 61
			8	SS	12											
222.75																
6.71	CLAYEY SILT (TILL), some sand, trace gravel Stiff Grey		9	SS	9											
			10	SS	11											5 14 67 14
			11	SS	12											
220.62																
8.84	END OF BOREHOLE															
	Borehole dry during drilling on December 6, 2007.															
	Water level measured in standpipe at elev. 222.91m on December 6, 2007.															
	Water level measured in standpipe at elev. 227.30m on December 19, 2007.															
	Water level measured in standpipe at elev. 227.10m on January 7, 2008.															
	Water level measured in standpipe at elev. 227.39m on January 30, 2008.															

Drawing file: 0711301284-1-R01001.dwg Feb 08, 2008 - 9:22am



REFERENCE

DRAWING BASED ON CANMAP STREETFILES
V2005.4

NOTES

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

ALL LOCATIONS ARE APPROXIMATE ONLY.

PROJECT

STRUCTURAL CULVERT 19+550
HIGHWAY 402 & LAMBTON COUNTY ROAD 79 IMPROVEMENTS
GWP 3158-06-00

TITLE

KEY PLAN



**Golder
Associates**
LONDON, ONTARIO

PROJECT No.			FILE No.		
07-1130-128-4			0711301284-1-R01001		
CADD	WDF	FEB 08/08	SCALE	AS SHOWN	REV. 0
CHECK			FIGURE 1		

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

CONT No.
WP No. 3158-06-00

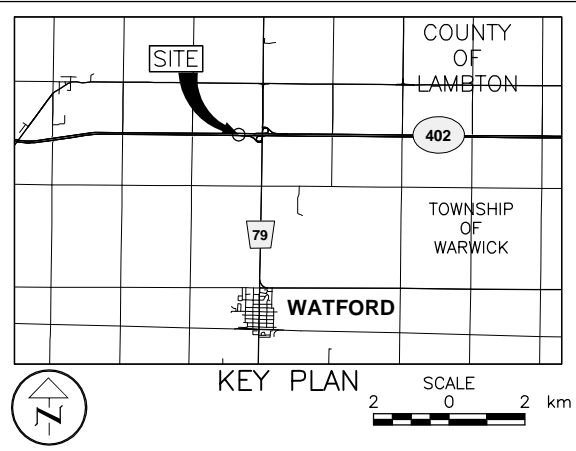


HWY 402/LAMBTON CTY RD 79
IMPROVEMENTS
STUCTURAL CULVERT - STATION 19+550
TOWNSHIP OF WARWICK
BOREHOLE LOCATION AND SOIL STRATA

SHEET



Golder Associates Ltd.
LONDON, ONTARIO, CANADA



LEGEND

- Borehole - Current Investigation
- ⊞ Seal
- ⊞ Standpipe
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ≡ WL in standpipe, measured on JAN 30, 2008.
- ≡ WL encountered during drilling
- DRY Borehole dry during drilling

No.	ELEVATION	CO-ORDINATES (MTM Zone 11)	
		NORTHING	EASTING
101	227.58	4 761 579.5	354 776.7
102	229.46	4 761 572.8	354 753.8

NOTES

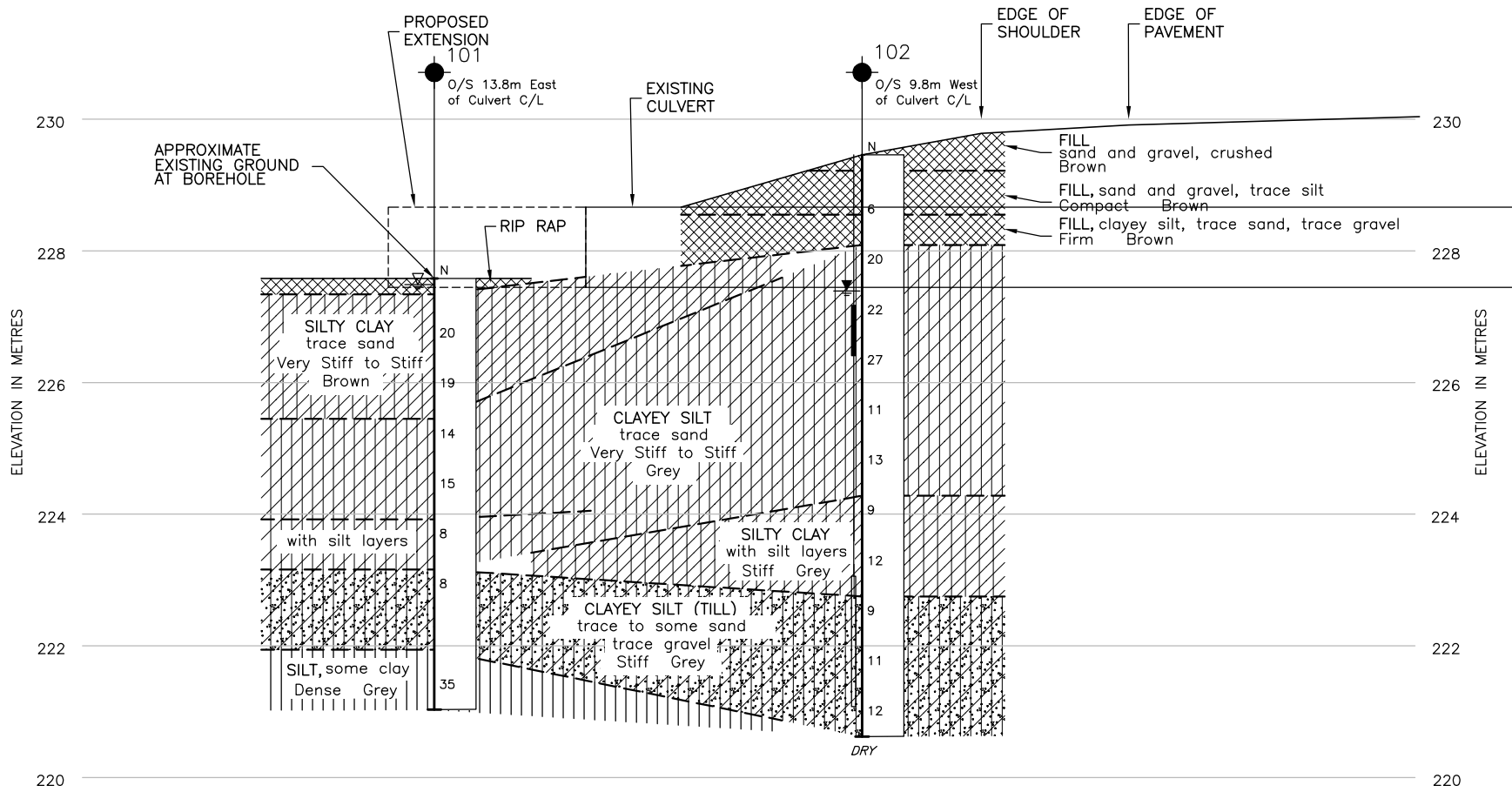
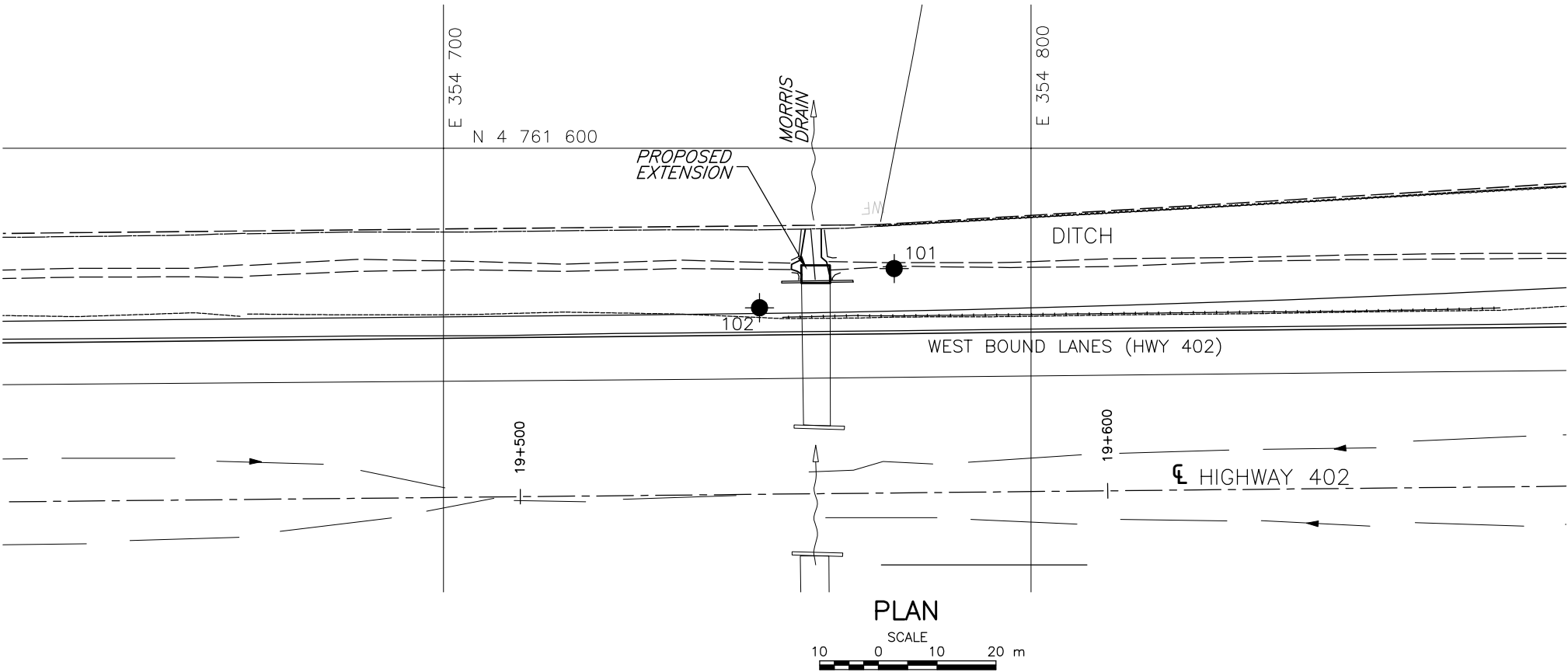
This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

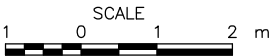
REFERENCE

Base plans provided in digital format by DELCAN

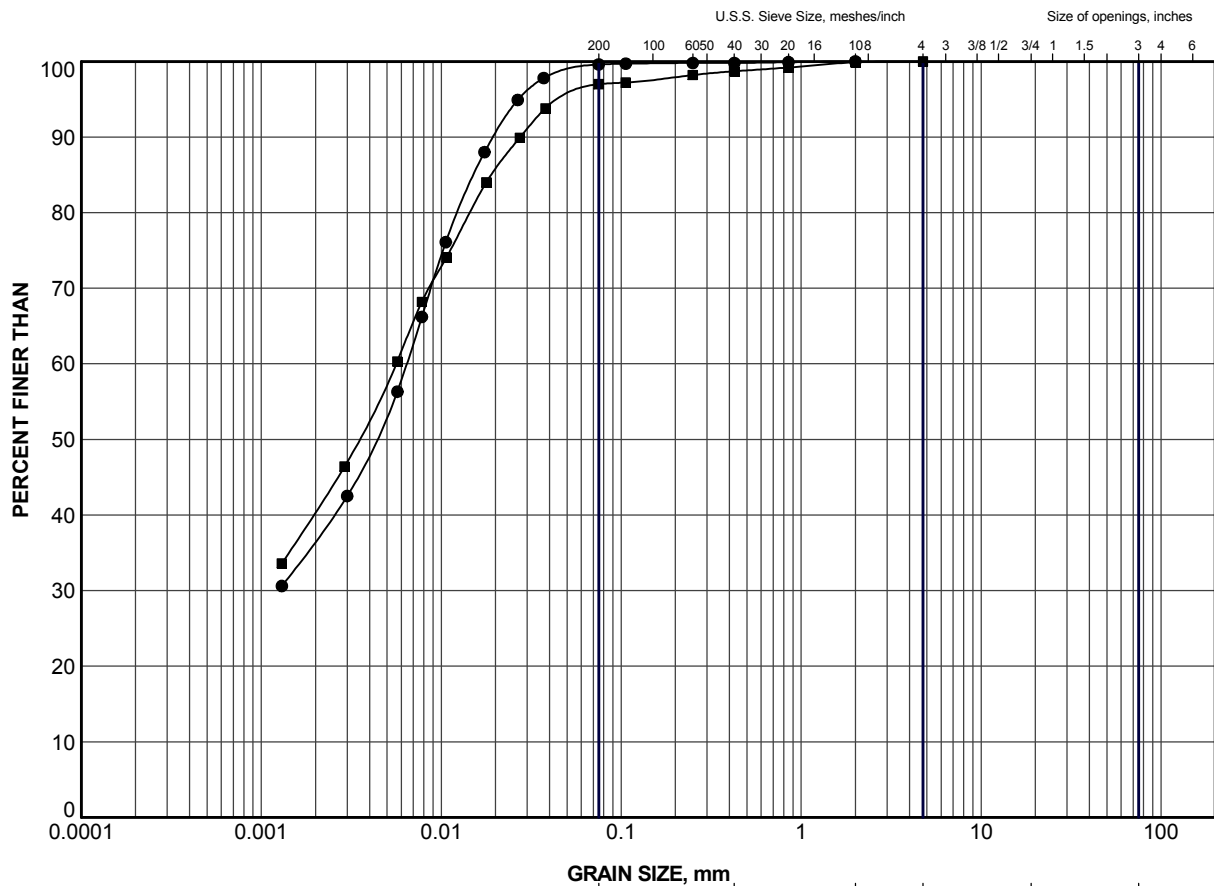
NO.	DATE	BY	REVISION
Geocres No. 40113-52			
HWY.	402	PROJECT NO.	07-1130-128-4
SUBM'D.	DB	CHKD.	DUP
DRAWN:	WDF	CHKD.	DUP
DATE:	FEB 08/08	DIST.	SITE: 14-487C/W
APPD.		DWG.	1



PROFILE ALONG C/L OF CULVERT




APPENDIX A
LABORATORY TEST DATA

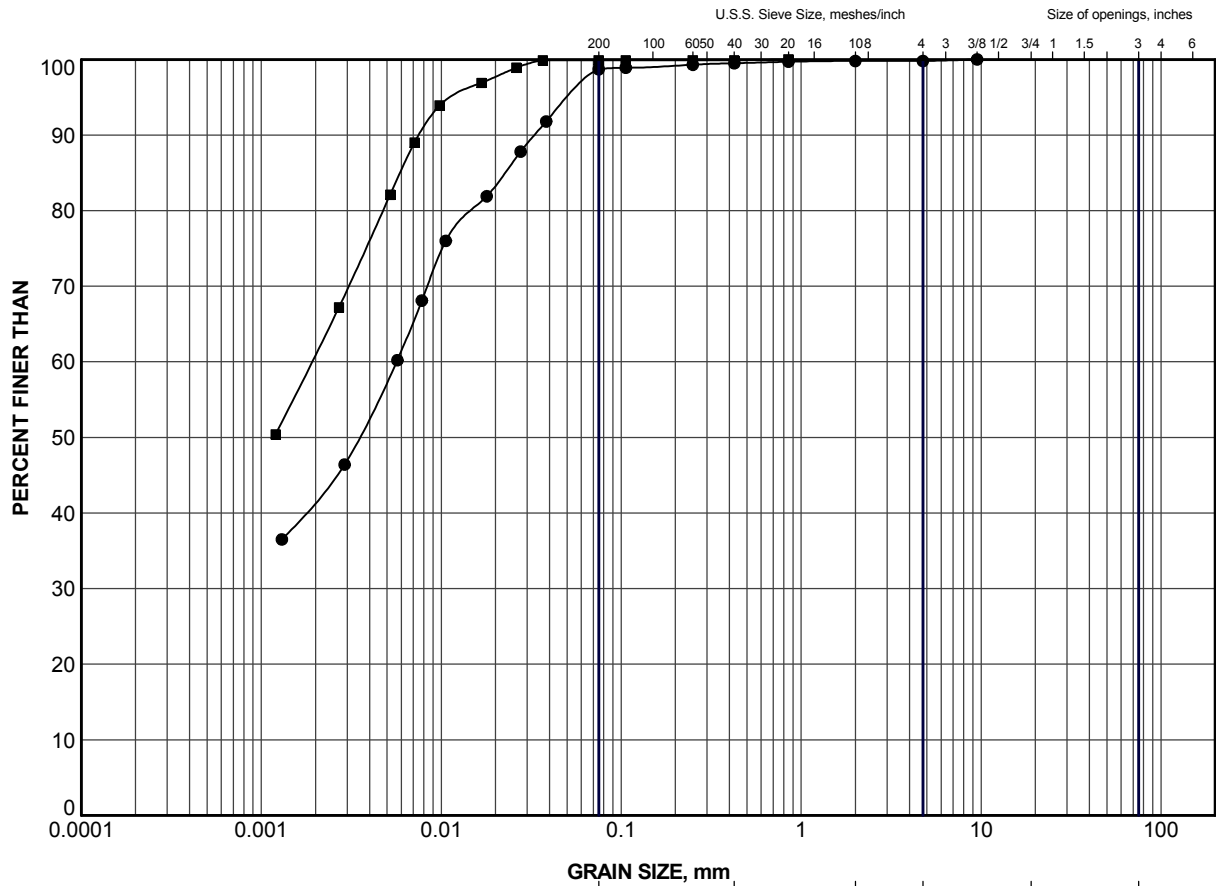


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	5	223.5
■	102	3	226.9

PROJECT				STRUCTURAL CULVERT 19+550 HIGHWAY 402 & LAMBTON COUNTY ROAD 79 IMPROVEMENTS GWP 3158-06-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT			
PROJECT No.		07-1130-128-4		FILE No.		0711301284-1-R010A1	
DRAWN		BRS		SCALE		N/A	
CHECK		Feb 08/08		REV.			
 Golder Associates LONDON, ONTARIO				FIGURE A-1			



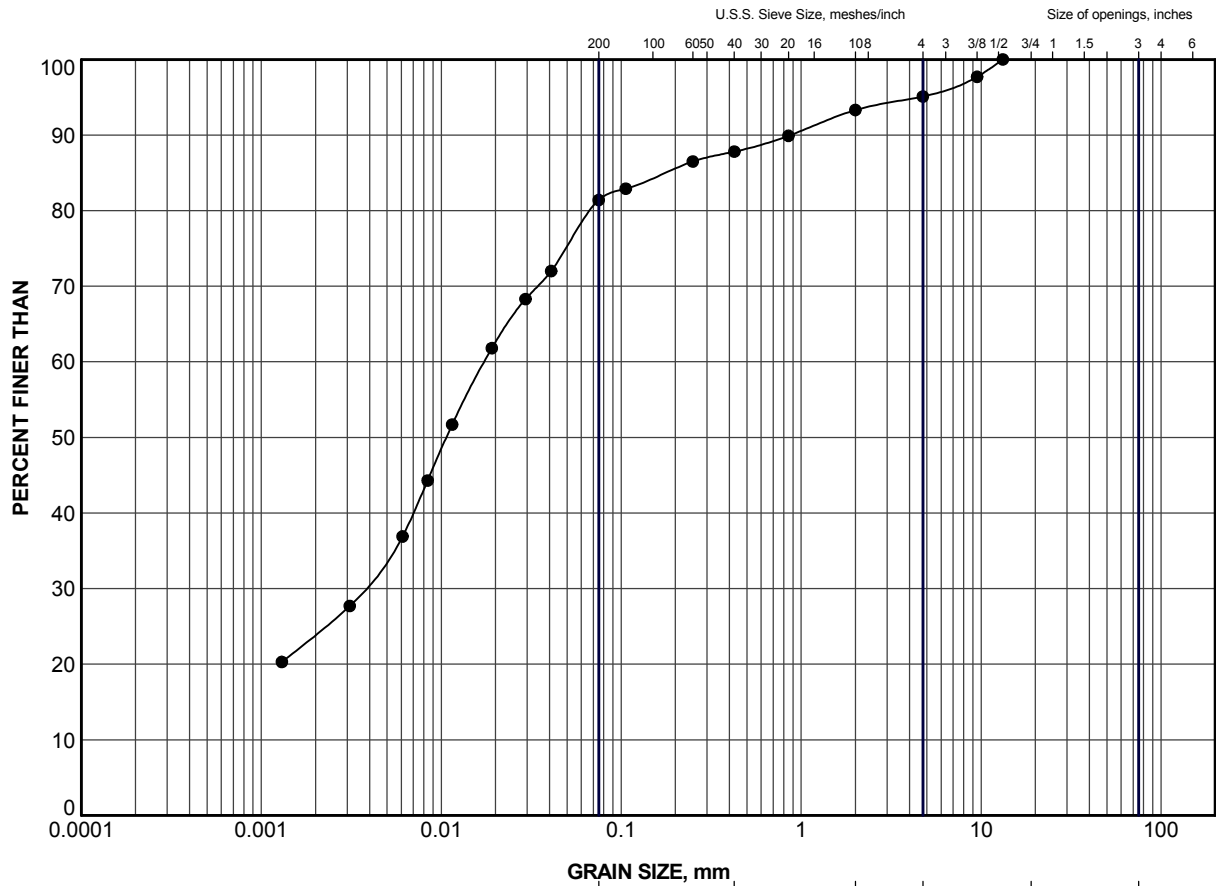
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	1	226.6
■	102	7	223.9

PROJECT				STRUCTURAL CULVERT 19+550 HIGHWAY 402 & LAMBTON COUNTY ROAD 79 IMPROVEMENTS GWP 3158-06-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY CLAY			
PROJECT No.		07-1130-128-4		FILE No.		0711301284-1-R010A2	
DRAWN		BRS		Feb 08/08		SCALE N/A REV.	
CHECK						FIGURE A-2	



LDN_MTO_NEW_GLDR_LDN.GDT

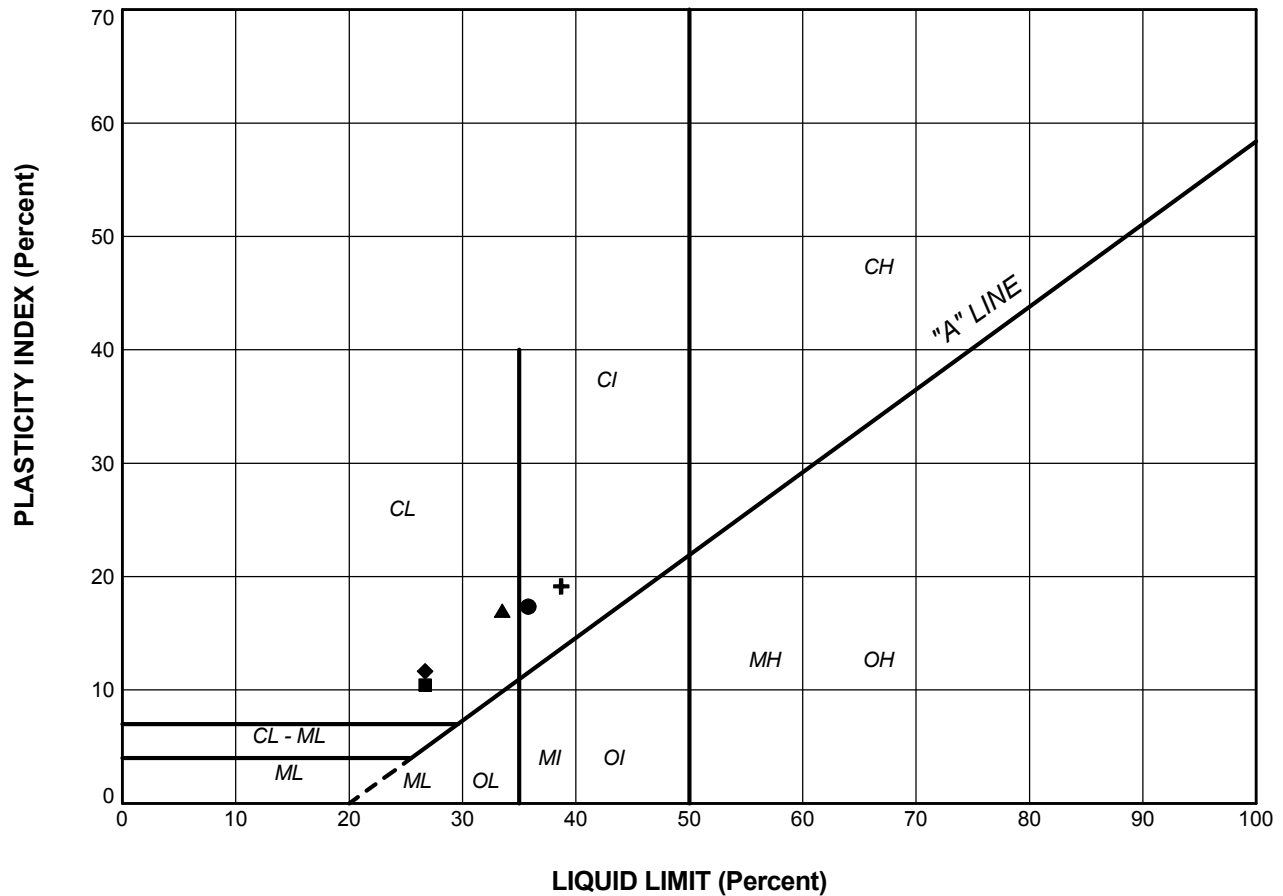


LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	102	10	221.6

PROJECT				STRUCTURAL CULVERT 19+550 HIGHWAY 402 & LAMBTON COUNTY ROAD 79 IMPROVEMENTS GWP 3158-06-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT (TILL)			
PROJECT No.		07-1130-128-4		FILE No.		0711301284-1-R010A3	
DRAWN		BRS		Feb 08/08		SCALE N/A REV.	
CHECK						FIGURE A-3	




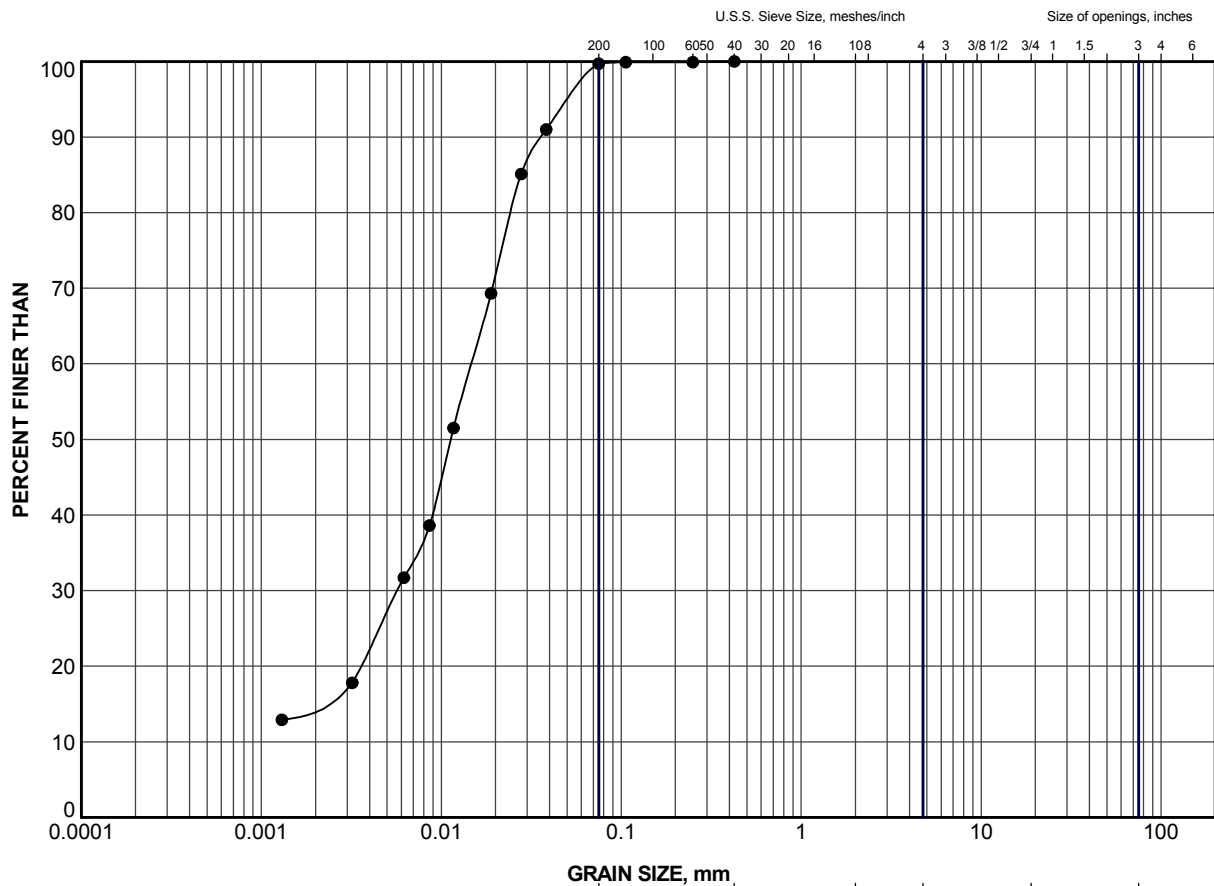
LDN_MTO_NEW_GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
SILTY CLAY					
●	101	1	35.8	18.5	17.4
+	102	7	38.7	19.6	19.2
CLAYEY SILT					
■	101	5	26.7	16.3	10.5
▲	102	3	33.5	16.5	17.0
CLAYEY SILT (TILL)					
◆	102	10	26.7	15.1	11.7


PROJECT		STRUCTURAL CULVERT 19+550 HIGHWAY 402 & LAMBTON COUNTY ROAD 79 IMPROVEMENTS GWP 3158-06-00	
TITLE		PLASTICITY CHART	
PROJECT No. 07-1130-128-4		FILE No. 0711301284-1-R010A4	
DRAWN	BRS	Feb 08/08	SCALE N/A
CHECK			REV.
 Golder Associates LONDON, ONTARIO		FIGURE A-4	



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	7	221.3

PROJECT				STRUCTURAL CULVERT 19+550 HIGHWAY 402 & LAMBTON COUNTY ROAD 79 IMPROVEMENTS GWP 3158-06-00			
TITLE				GRAIN SIZE DISTRIBUTION SILT			
PROJECT No.		07-1130-128-4		FILE No.		0711301284-1-R010A5	
DRAWN		BRS		SCALE		N/A	
CHECK		Feb 08/08		REV.			
 Golder Associates LONDON, ONTARIO				FIGURE A-5			

APPENDIX B
SITE PHOTOGRAPHS

SITE PHOTOGRAPHS



Photo 1: Outlet end of structural culvert 19+550 Highway 402.



Photo 2: Outlet end of structural culvert 19+550 Highway 402.