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**FOUNDATION INVESTIGATION AND DESIGN REPORT
STRUCTURAL CULVERT
SITE 6-410-C
HIGHWAY 3 WIDENING
GWP 315-98-00
MINISTRY OF TRANSPORTATION - SOUTHWESTERN REGION**

Submitted to:

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March 8, 2007

06-1130-177-0-4
Geocres No. 40J2-91



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PART A
FOUNDATION INVESTIGATION REPORT

**STRUCTURAL CULVERT
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HIGHWAY 3 WIDENING
GWP 315-98-00
MINISTRY OF TRANSPORTATION - SOUTHWESTERN REGION**

1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Delcan Corporation (Delcan) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 315-98-00. The project involves the first phase of the reconstruction and widening of Highway 3 (Talbot Trail) between Windsor and Leamington. The project limits extend along Highway 3 from just west of Essex Road 34 (Talbot Street North) easterly to just east of Essex Road 8 (Maidstone Avenue West) in Essex County, Ontario.

In conjunction with the widening, the scope of work for this project includes:

- rehabilitation or replacement of selected culverts within the project limits;
- slotted left turn lanes at all intersections;
- Revision or upgrading of illumination at four intersections;
- Revision or upgrading of traffic signals at two intersections;
- Replacement or relocation of existing traffic counting stations;
- Drainage improvements; and
- Upgrading of existing signage.

It has been proposed to widen five structural culverts and four short span culverts and to replace two short span culverts.

This report addresses the foundation investigation for the extension of the right/south end of the structural culvert located at Station 10+060 on Highway 3 approximately 60 metres east of Manning Road (Essex County Road 19). Extensions were originally considered for both ends; however, it is currently proposed to extend this culvert approximately 20 metres to the south side.

The purpose of the foundation investigation is to determine the subsurface conditions at the location of the proposed works by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P61-3113-1 dated August 17, 2006 and our letter dated November 14, 2006. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated September 18, 2006.

Delcan provided Golder Associates with a base plan and profile for this project in digital format which included the top elevations of the culverts.

2.0 SITE DESCRIPTION

GWP 315-98-00 extends along Highway 3 from 0.5 kilometres west of Essex Road 34 (Talbot Street North) within the Town of Tecumseh easterly to 0.6 kilometres east of Essex Road 8 (Maidstone Avenue West) in the Town of Essex. West of Manning Road, Highway 3 is within South Sandwich Township. East of Manning Road, it is within Maidstone Township. The chainage equation at Manning Road is 20+981.675 South Sandwich (SS) = 10+000.000 Maidstone (M). The west project limit is located at Station 17+700 SS and the east project limit is situated at Station 13+600 M.

Culvert Site 6-410-C is located on Highway 3 at Station 10+060 M and approximately 60 metres east of Manning Road. This culvert conveys flows of the West Townline Drain from the right/south side of Highway 3 to the left/north side. The location of the project is shown on the Key Plan, Figure 1, and in the photograph in Appendix B.

The land use in the vicinity of the site is predominantly agricultural. The adjacent topography is generally flat to slightly rolling with ground surface elevations between 191 and 195 metres.

2.1 Site Geology

The site is situated on the Essex Clay Plain, a subregion of the physiographic region of southern Ontario known as the St. Clair Clay Plain.¹ This subregion is described as a beveled till plain with little relief that has been locally smoothed by shallow deposits of lacustrine clay deposited in depressions in the till. The prevailing soil type is reported to be the Brookston clay loam.

The available surficial geology mapping for the project area indicates that the predominant surficial soils are clayey silt till.² The till is reportedly underlain by limestone, dolomite and shale of the Middle Devonian era and by dolomite of the Upper Silurian era. The overburden thickness within the project area ranges from 27 to 41 metres.³

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

² Vagners, U. J., 1972. *Quaternary Geology of the Windsor-Essex Area (Western and Eastern Parts)*, Southern Ontario; Ontario Department of Mines and Northern Affairs, Preliminary Maps P. 749 and P.750, Geological Series.

³ Vagners, U.J., Sado, E.V., and Yundt, S.E. 1973. *Drift Thickness of the Windsor-Essex Area (Western and Eastern Parts)*, Southern Ontario; Ontario Division of Mines, Preliminary Maps P.814 and P.815, Drift Thickness Series.

3.0 INVESTIGATION PROCEDURES

The field work for this portion of the investigation was carried out on November 27 to 29, 2006, at which time four boreholes were drilled at each end of the proposed culvert extension. Boreholes 1 and 2 were drilled in the area of the proposed extensions and boreholes 3 and 4 were drilled at the north end. The boreholes were 7.5 to 9.0 metres deep.

The investigation was carried out using a Deidrich 50 track-mounted power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at intervals of 0.75 metres up to a depth of 4.6 metres and at 1.5 metre intervals below this 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 these observations are provided on the corresponding Record of Borehole sheets. A standpipe piezometer was installed in borehole 3 to monitor the groundwater levels at this location. Boreholes were backfilled in accordance with current regulations, MTO recommended procedures and Ontario Regulation 128/03.

The field work was supervised on a full-time basis by an experienced member of our engineering staff who arranged for utility locates, directed the drilling, sampling and in-situ testing operations, logged the boreholes and cared for the samples obtained. The soil samples were identified in the field, placed in labeled containers and transported to Golder Associates' London laboratory for further examination and testing. Index and classification tests consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations were carried out on selected samples. The results of the field and laboratory testing are given on the Record of Borehole sheets and in Appendix A.

Temporary traffic control was carried out in accordance with the Ontario Traffic Manual, Temporary Conditions, Book 7, dated March 2001.

The as-drilled borehole locations and ground surface elevations are shown on the Record of Borehole sheets and on Drawing 1.

The table below summarizes the culvert location and coordinates, ground surface elevations and depths of the boreholes.

<u>BOREHOLE</u>	<u>LOCATION (m)</u>		<u>GROUND SURFACE ELEVATION</u>	<u>BOREHOLE DEPTH</u>
	<u>Northing</u>	<u>Easting</u>	(m)	(m)
1	4 673 018.1	273 772.3	191.42	8.23
2	4 673 040.8	273 777.3	192.20	8.99
3	4 673 064.8	273 805.2	190.60	7.47
4	4 673 064.0	273 795.2	192.32	8.99

The existing culvert has the following characteristics:

<u>DIMENSIONS (m)</u>	<u>TOP ELEVATION (m)</u>		<u>CONSTRUCTION</u>
	(Lt)	(Rt)	
3.65 x 1.28 x 39.75	190.73	190.78	Concrete, non-rigid frame, open footing

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes together with the results of the in situ and laboratory testing carried out on selected samples are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling resistance and represent transitions between soil types rather than exact planes of geological change. Subsurface conditions will vary between and beyond the borehole locations.

In general, the boreholes drilled at the proposed culvert extension typically encountered surficial topsoil and fill materials underlain by an extensive deposit of clayey silt till.

The locations of the boreholes 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.

4.1.1 Topsoil and Fill

Topsoil layers were encountered at the ground surface of boreholes 1 and 3. The topsoil thicknesses were 100 and 210 millimetres at boreholes 1 and 3, respectively.

Fill layers were encountered at the surface of boreholes 2 and 4 and beneath the topsoil in borehole 3 from elevation 190.4 metres.

Granular fill materials were present in boreholes 2, 3 and 4. The granular fill layers consisted of sand and gravel or sand about 0.4 to 0.7 metres thick.

Stiff cohesive fills were encountered beneath the granular fills in borehole 2 from elevation 191.7 metres and from elevation 191.8 metres in borehole 4. The clayey silt fill in borehole 2 had N values of 8 and 9 blows per 0.3 metres. N values in the silty clay fill in borehole 4 varied from 10 to 13 blows per 0.3 metres with a water content of 25 per cent. The results of a grain size analysis conducted on the silty clay fill is presented in Figure A-1 in Appendix A. Based on a single sample, the silty clay fill is of intermediate plasticity based on liquid and plastic limits of 39 and 18 per cent, respectively, and a plasticity index of 21 per cent. The results of the Atterberg limits testing are shown on the Plasticity Chart, Figure A-3, in Appendix A.

4.1.2 Clayey Silt Till

Clayey silt till was encountered beneath the topsoil layer in borehole 1 from elevation 191.3 metres and below the fill layers in boreholes 2, 3 and 4 from elevations 189.4 to 190.0 metres. The results of grain size analyses conducted on six samples obtained from the standard penetration testing are shown in Figure A-2.

The clayey silt till is stiff to hard with N values ranging from 9 blows to 50 blows per 0.3 metres. Water contents in the clayey silt till ranged from 16 to 20 per cent. The clayey silt till is of low to intermediate plasticity based on an average plastic and liquid limits of 16 and 33 per cent and an average plasticity index of 17 per cent. The results of the Atterberg limits testing are shown on the Plasticity Chart, Figure A-3.

Cobbles and boulders were not encountered in any of the boreholes for this investigation. However, the presence of cobbles and boulders should be anticipated in the clayey silt till.

4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. All of the boreholes were dry during and upon completion of drilling.

A standpipe piezometer was installed in borehole 3 on December 14, 2006 to monitor the groundwater conditions. On this date, the groundwater level was measured at elevation 187.0 metres or at a depth of 3.6 metres below the ground surface. The most recent measurement taken on February 26, 2007 indicated a groundwater level at 1.6 metres below the ground or at elevation 189.0 metres. The long-term groundwater level is inferred to be at elevation 189 metres based on the change in soil colour and the water level readings.

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

The water level in the West Townline Drain was measured at elevation 189.54 metres at the inlet/south side on November 27, 2006 and at elevation 189.52 metres at the outlet/north side on November 28, 2006.

5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by London Soil Test Limited which is an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Mike Arthur under the direction of Mr. David J. Mitchell. The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing of 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 6-410-C
HIGHWAY 3 WIDENING
GWP 315-98-00
MINISTRY OF TRANSPORTATION - SOUTHWESTERN 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 proposed extension of the structural culvert situated in the project area at Station 10+060 M on Highway 3 approximately 60 metres east of Manning Road (Essex County Road 19). This culvert is a non-rigid frame, open footing (NRFO) structure.

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

A series of improvements is planned for Highway 3 from 0.5 kilometres west of Essex County Road 34 (Talbot Road) to 0.6 kilometres east of Essex County Road 8 (Maidstone Avenue West). The major improvement will be widening of Highway 3 from 2 lanes to 4 lanes including the addition of slotted left turn lanes at all intersections. This will require drainage upgrades within the project limits including extension of the inlet/south end of the West Townline Drain culvert under Highway 3 (Site 6-410-C).

The subsoils encountered in the boreholes advanced during the investigation typically consist of surficial topsoil and fills over stiff to hard clayey silt till. The long-term groundwater level was estimated to be between elevation 188 and 189.5 metres. On February 26, 2007, the groundwater level was measured at elevation 189.0 metres. The water level in the West Townline Drain at the culvert location was measured at about elevation 189.5 metres on November 27 and 28, 2006.

The culvert 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 elevation at about 189.5 metres at the inlet, the culvert extension can be founded on spread footings at or below elevation 188.3 metres in the very stiff to hard but typically very stiff clayey silt till. Minimal groundwater inflow into the excavations is anticipated.

The recommended factored geotechnical resistance at Ultimate Limit States (ULS) and the unfactored geotechnical resistance at Serviceability Limit States (SLS) are 375 kilopascals and 250 kilopascals, respectively, assuming a maximum allowable settlement of 25 millimetres and a

1.5 metre footing width for design of the culvert foundations at both the left and right ends. An unfactored coefficient of sliding of 0.53 may be used for design of cast-in-place footings.

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 around the culvert extension should be carried out in accordance with Ontario Provincial Standard Drawing (OPSD) 803.010. 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.

Heavy compaction equipment should not be used immediately adjacent to the walls and roof of the culverts. The height of backfill adjacent to the culvert walls should be maintained equal on both sides of the structures 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 proposed culvert extension 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 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 OPSS 501.06.

For walls backfilled using granular materials, the following parameters (unfactored) may be assumed:

Fill unit weight:	22 kN/m ³
Coefficients of lateral earth pressure:	
‘active’ or unrestrained, K_a	0.31
‘at rest’ or restrained, K_o	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 friction of 28 degrees between the very stiff to hard clayey silt till and concrete interface. The factored horizontal geotechnical resistance, H_{ri} should be based on CHBDC 6.7.5 as follows:

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

Where:

A'	-	effective contact area, square metres
c'	=	0
ϕ'	=	28 degrees
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.

6.5 Construction Considerations

The founding soils are sensitive to disturbance and softening due to water seepage and/or ponding. If cast-in-place culverts are to be constructed, placement of a working slab of lean concrete will be required at the base of the culvert excavations 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 that the working slab be placed immediately after footing inspection.

Inlet seals are not considered necessary as the potential for uplift and piping at this location is low. The provision of camber in the culvert extension is not required due to the minimal height of overlying fill, presence of very stiff soils at the foundation level which will result in low post-construction settlements.

Erosion and scour protection for the culvert backfill should be provided, as appropriate. 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.

Subgrade preparation should be performed and monitored in accordance with SP902S01.

6.6 Excavations and Temporary Cut Slopes

Excavations for the culvert extension will encounter surficial topsoil and fills and the stiff to hard clayey silt till. The presence of cobbles and boulders which may be present in the clayey silt till should be anticipated. It is expected that the excavations will intercept the groundwater table. However, the overall amount of groundwater inflow is expected to be minimal.

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 at the base of the excavations and outside of the footprint of the foundations may be required to provide groundwater control during foundation excavations.

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. Sumps should be maintained outside of the actual footing limits. Surface water runoff should be directed away from the excavations at all times. The appropriate Non Standard Special Provision (NSSP) should be included in the contract documents.

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. The temporary support system could consist of soldier piles and lagging where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds. Support to the soldier pile and lagging wall system could be in the form of struts and walers in the case of footing excavations or rakers and anchors in the case of roadway protection excavations.

The design of braced soldier pile and lagging walls should be based on a rectangular earth pressure distribution using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system.

In the cohesive soils, the unfactored triangular earth pressure distribution (p in kN/m^2 ; increasing with depth), can be calculated as follows:

$$p = K_a (\gamma H + q)$$

where H = the height of the excavation at any point in metres
 K_a = 0.4 for level ground behind excavation
 γ = soil unit weight = 20 kN/m^3
 q = surcharge loads

In granular soils, such as backfill for the existing culvert, the unfactored rectangular earth pressure distribution (p in kN/m^2 ; constant with depth), can be calculated as follows:

$$p = 0.65K_a (\gamma' H + q)$$

where H = the height of the excavation
 K_a = 0.3 for level ground behind excavation
 γ = soil unit weight = 20 kN/m^3
 γ' = $\gamma - \gamma_w$ where $\gamma_w = 9.8 \text{ kN/m}^3$
 q = surcharge loads

Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter. The coefficient of passive lateral earth pressure, K_p , for the socket within very stiff to hard clayey soils may be taken as 2.8. The soil unit weight should be taken as 20 kN/m^3 and the unit weight of water should be taken as 9.8 kN/m^3 . A groundwater level at ground surface should be assumed for design.

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.

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 silt till materials would be classified as Type 2 soils. Temporary open cut slopes should be maintained no steeper than 1 horizontal to 1 vertical.

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
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 $= (\text{compressive strength})/2$
 - * 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 06-1130-177 LOCATION N 4673018.1 ; E 273772.3 ORIGINATED BY MA
G.W.P. 315-98-00 DIST HWY 3 BOREHOLE TYPE Power Auger, Solid Stem COMPILED BY LMK
DATUM GEODETIC DATE November 27, 2006 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						
191.42	GROUND SURFACE																
0.10	TOPSOIL, clayey Brown CLAYEY SILT, trace sand, trace gravel (TILL) Stiff to Hard Mottled Brown and Grey becoming Grey at about elev. 188.2m																
			1	SS	9												
			2	SS	18												
			3	SS	35												
			4	SS	25												
			5	SS	18												
			6	SS	14												
			7	SS	14												
			8	SS	11												
			9	SS	16												
183.19	END OF BOREHOLE																
8.23	Borehole dry during drilling November 27, 2006																

ONL_MTO_06-1130-177-DD.GPJ LDN_MTO.GDT 12/20/06

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

PROJECT 06-1130-177
G.W.P. 315-98-00 LOCATION N 4673028.2 ; E 273767.5 ORIGINATED BY MA
DIST HWY 3 BOREHOLE TYPE Power Auger, Solid Stem COMPILED BY LMK
DATUM GEODETIC DATE November 27, 2006 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE								○				
								● QUICK TRIAXIAL × LAB VANE												
192.20	GROUND SURFACE						20	40	60	80	100	10	20	30						
0.10	FILL, sand and gravel Grey																			
191.70	FILL, sand and gravel Brown																			
0.50	FILL, clayey silt, trace sand, trace gravel Stiff to Hard Grey		1	SS	8															
			2	SS	9															
189.73			3	SS	22															
2.47	CLAYEY SILT, trace sand, trace gravel (TILL) Very Stiff to Hard Brown becoming Grey at about elev. 187.8m																			
			4	SS	36															
			5	SS	38															
			6	SS	21															
			7	SS	16															
			8	SS	13															
			9	SS	18															
183.21	END OF BOREHOLE																			
8.99	Borehole dry during drilling November 27, 2006																			

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

PROJECT 06-1130-177
G.W.P. 315-98-00 LOCATION N 4673064.8 ; E 273805.2 ORIGINATED BY MA
DIST HWY 3 BOREHOLE TYPE Power Auger, Solid Stem COMPILED BY LMK
DATUM GEODETIC DATE November 28, 2006 - November 29, 2006 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					
190.60	GROUND SURFACE						20	40	60	80	100	10	20	30		
0.00	TOPSOIL, clayey Brown															
0.21	FILL, silty sand with gravel Brown															
190.00	CLAYEY SILT, trace sand, trace gravel (TILL) stiff to very stiff Brown becoming Grey at about elev. 187.8m		1	SS	11											
0.60			2	SS	29											
			3	SS	23											
			4	SS	16											
			5	SS	16											
			6	SS	13											
			7	SS	17											
			8	SS	15											
183.13	END OF BOREHOLE															
7.47	Borehole dry during drilling November 28 & 29, 2006. Water level measured in standpipe at elev. 187.00m Dec. 14, 2006. Water level measured in standpipe at elev. 189.02m on February 26, 2007.															

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

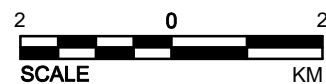
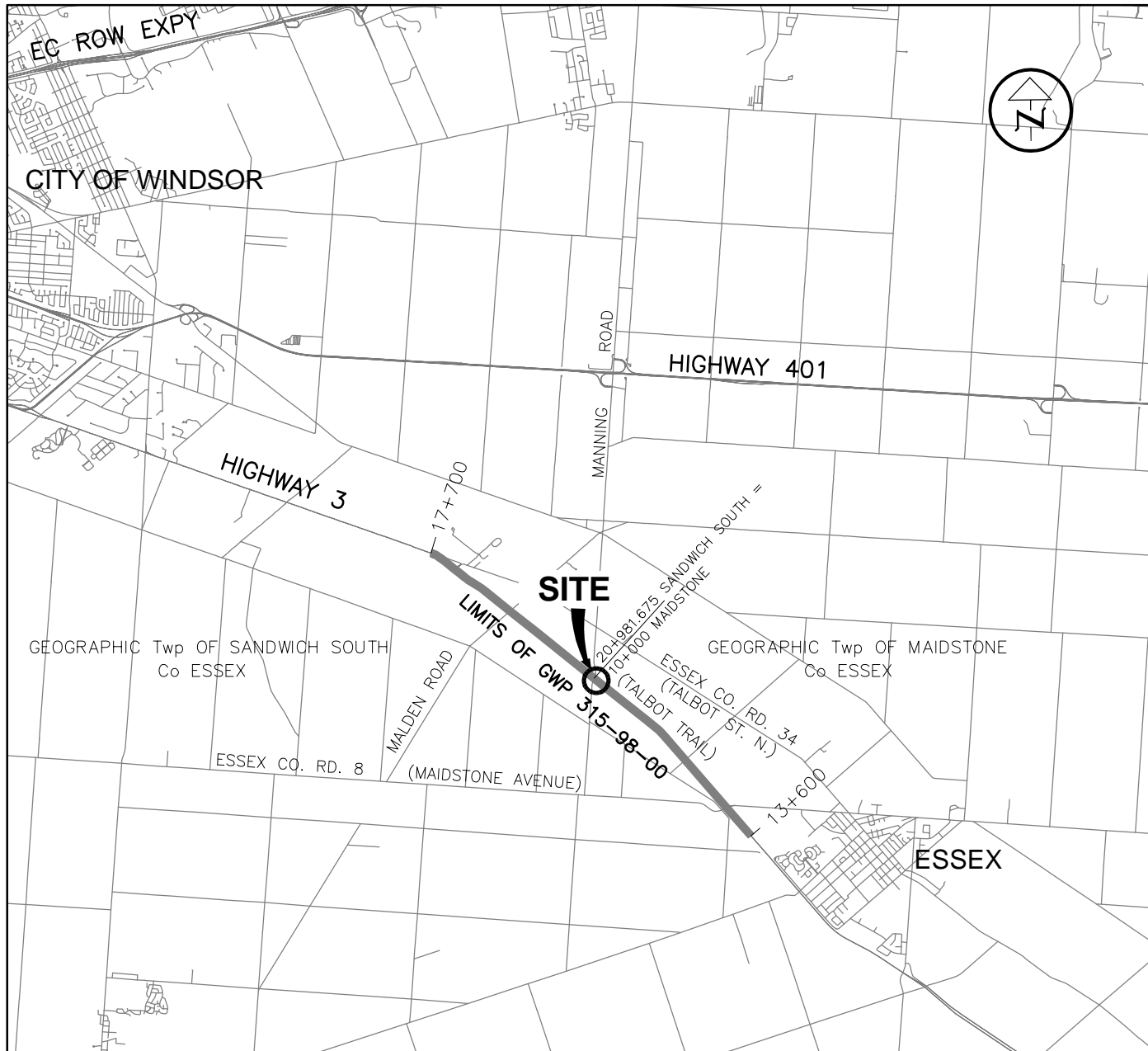
RECORD OF BOREHOLE No 4

1 OF 1

METRIC

PROJECT 06-1130-177 LOCATION N 4673064.0 ; E 273795.2 ORIGINATED BY MA
G.W.P. 315-98-00 DIST HWY 3 BOREHOLE TYPE Power Auger, Solid Stem COMPILED BY LMK
DATUM GEODETIC DATE November 28, 2006 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE									
								● QUICK TRIAXIAL	× LAB VANE									
192.32	GROUND SURFACE						20	40	60	80	100	10	20	30				
0.00	FILL, sand and gravel Grey																	
191.76																		
0.66	FILL, sand, some gravel, trace silt Brown		1	SS	11													
	FILL, silty clay, trace sand, trace gravel, trace topsoil Stiff Brown and Grey		2	SS	10													
			3	SS	13													
189.42																		
2.90	CLAYEY SILT, trace sand, trace gravel (TILL) Stiff to Hard Brown becoming Grey at about elev. 188.1m		4	SS	50													
			5	SS	29													
			6	SS	19													
			7	SS	13													
			8	SS	16													
			9	SS	20													
183.33	END OF BOREHOLE																	
8.99	Borehole dry during drilling November 28, 2006.																	



NOTE

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

PROJECT

STRUCTURAL CULVERT - SITE 6-410-C
HIGHWAY 3 WIDENING
GWP 315-98-00

TITLE

KEY PLAN



**Golder
Associates**
LONDON, ONTARIO

PROJECT No. 06-1130-177-0-4

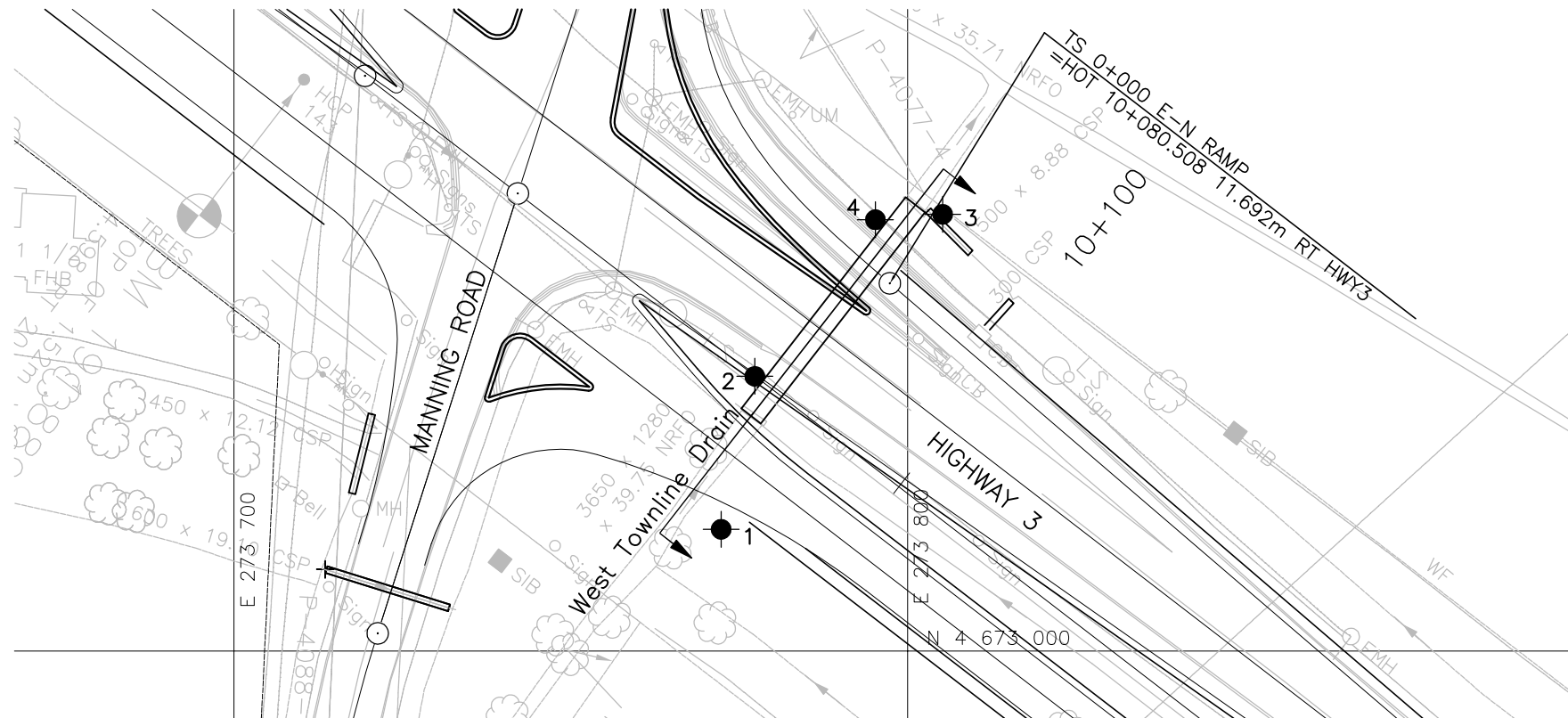
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CADD WDF Dec. 19/06

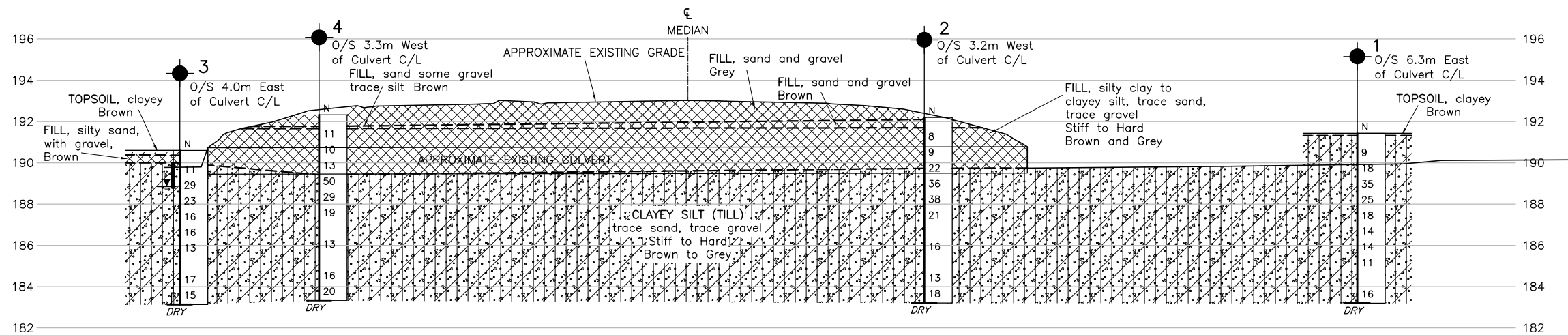
CHECK

SCALE AS SHOWN REV. 0

FIGURE 1



PLAN
SCALE
10 0 10 m



PROFILE ALONG C/L OF CULVERT

SCALE
2.5 0 2.5 m

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

CONT No.
WP No. 315-98-00

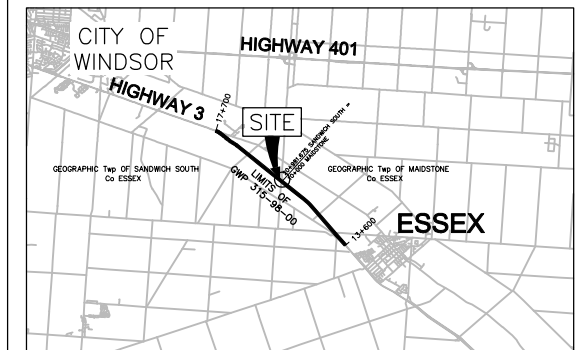
STRUCTURAL CULVERT
SITE 6-410-C
HIGHWAY 3 WIDENING
BOREHOLE LOCATION AND SOIL STRATA



SHEET



Golder Associates Ltd.
LONDON, ONTARIO, CANADA



KEY PLAN
SCALE
3000 0 3000m

LEGEND

- Borehole - Current Investigation
- Standard Penetration Test Value
- Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- Seal
- Standpipe
- WL in standpipe, measured on Feb. 26, 2007.
- DRY Borehole dry during drilling

No.	ELEVATION	CO-ORDINATES (MTM Zone 11)	
		NORTHING	EASTING
1	191.42	4 673 018.1	273 772.3
2	192.20	4 673 040.8	273 777.3
3	190.60	4 673 064.8	273 805.2
4	192.32	4 673 064.0	273 795.2

NOTES

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

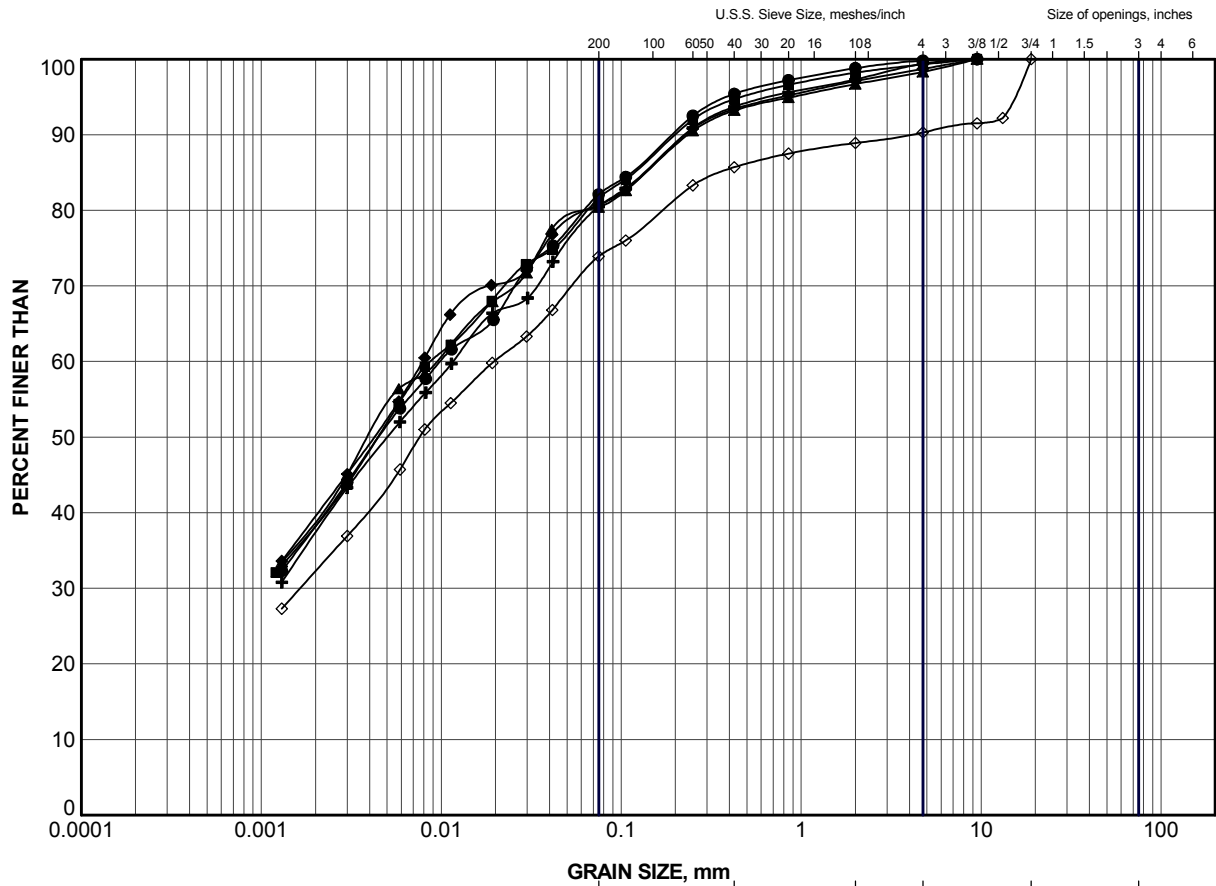
The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by DELCAN.

NO.	DATE	BY	REVISION
Geocres No.	40J2-91		
HWY.	3	PROJECT NO.	06-1130-177-0-4
SUBM'D.	DUP	CHKD.	DUP
DRAWN:	WDF	CHKD.	APPD.
		DATE:	Dec. 20/06
		SITE:	6-410-C
		DWG.	1


APPENDIX A
LABORATORY TEST DATA

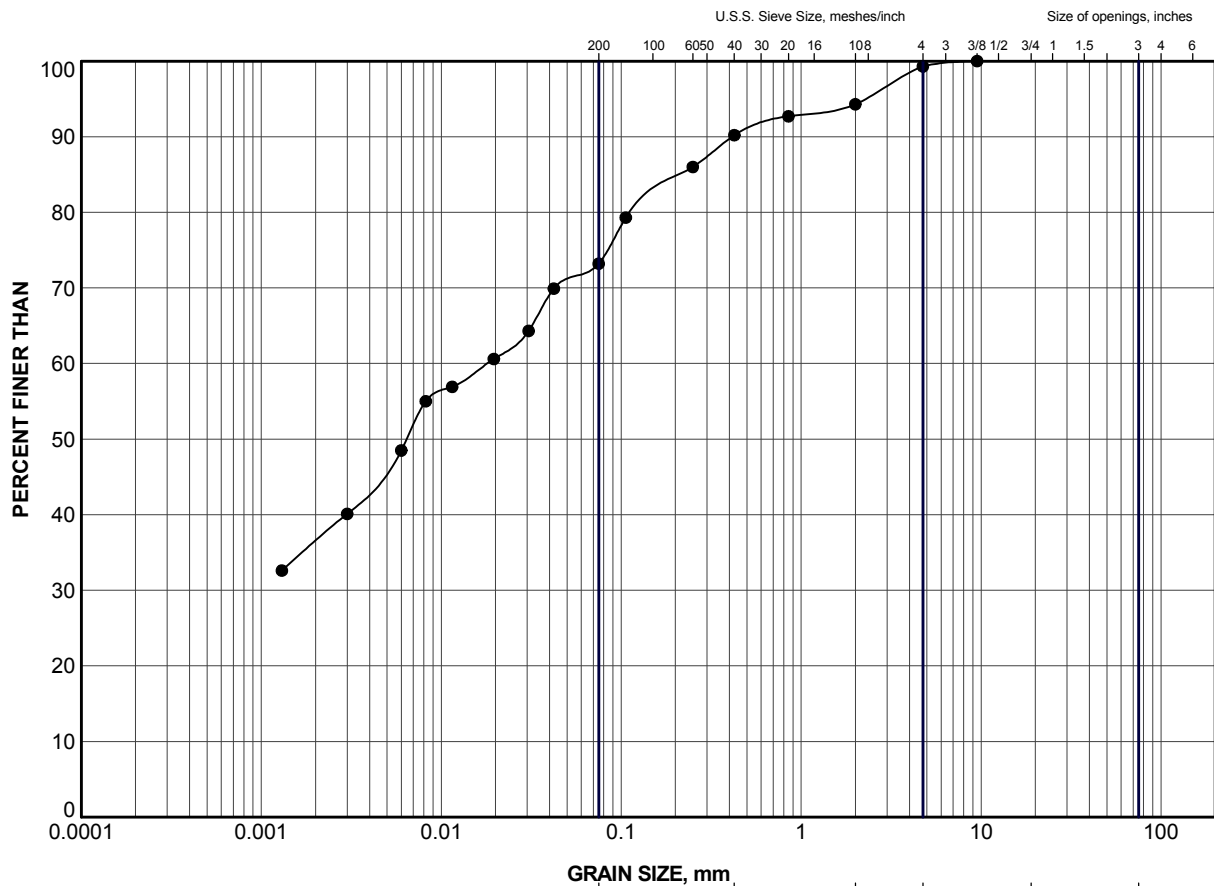


CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	1	5	187.4
■	2	4	188.9
▲	2	7	185.9
+	3	4	187.3
◆	4	5	188.3
◇	4	8	184.5


PROJECT		STRUCTURAL CULVERT - SITE 6-410-C HIGHWAY 3 WIDENING GWP 315-98-00					
TITLE		GRAIN SIZE DISTRIBUTION CLAYEY SILT (TILL)					
 Golder Associates LONDON, ONTARIO		PROJECT No.	06-1130-177		FILE No.	06-1130-177-DD.GPJ	
		DRAWN	WDF	Dec 17/06	SCALE	N/A	REV.
		CHECK					
		FIGURE A-1					

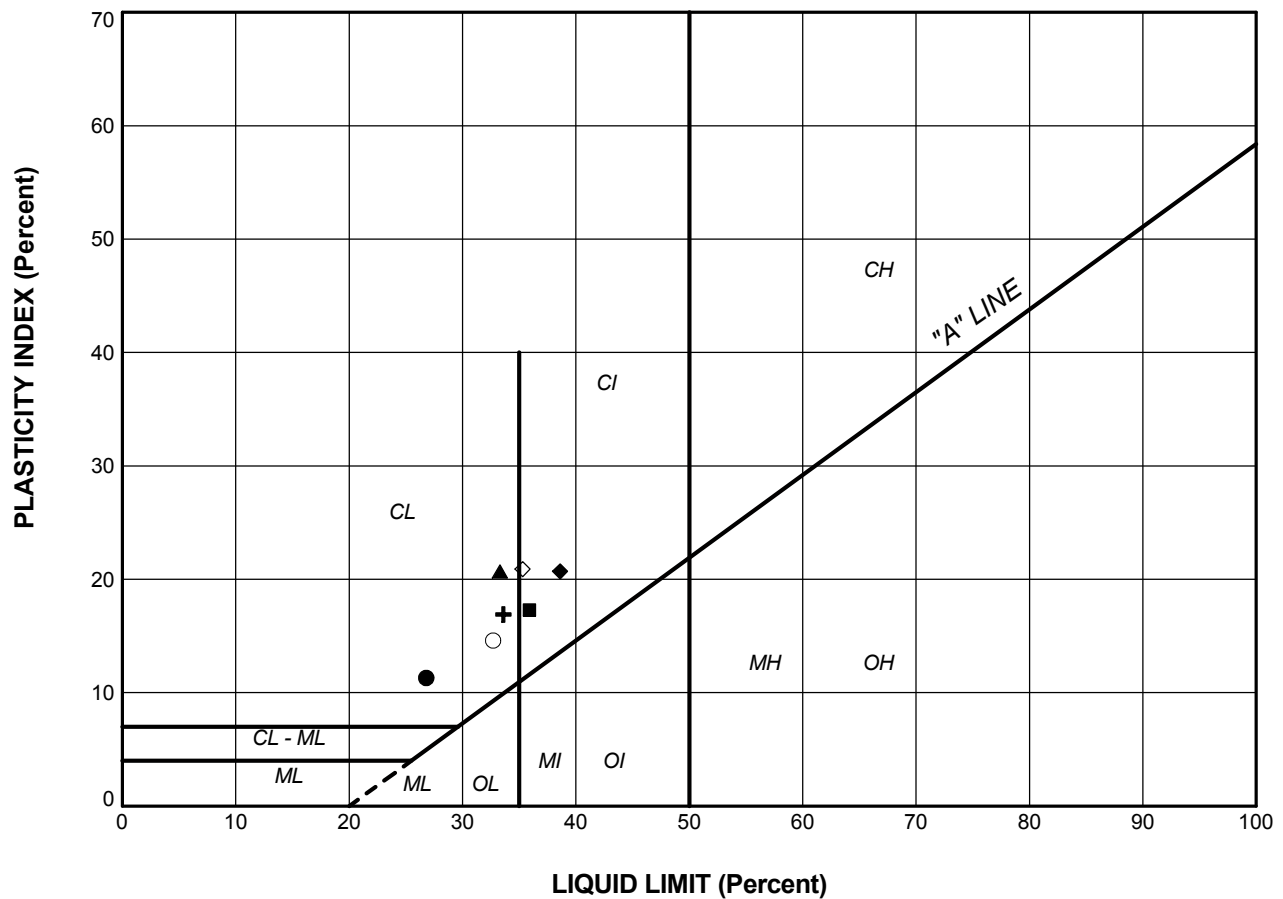


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	4	3	189.8

PROJECT	STRUCTURAL CULVERT - SITE 6-410-C HIGHWAY 3 WIDENING GWP 315-98-00			
TITLE	GRAIN SIZE DISTRIBUTION FILL, silty clay			
 Golder Associates LONDON, ONTARIO	PROJECT No.	06-1130-177	FILE No.	06-1130-177-DD.GPJ
	DRAWN	WDF	Dec 17/06	SCALE N/A REV.
	CHECK			
			FIGURE A-2	



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
CLAYEY SILT (TILL)					
●	1	5	26.8	15.5	11.3
■	2	4	35.9	18.6	17.3
▲	2	7	33.3	12.6	20.7
+	3	4	33.6	16.7	16.9
◇	4	5	35.3	14.4	20.9
○	4	8	32.7	18.1	14.6
FILL, silty clay					
◆	4	3	38.6	17.9	20.7

PROJECT				STRUCTURAL CULVERT - SITE 6-410-C HIGHWAY 3 WIDENING GWP 315-98-00			
TITLE				PLASTICITY CHART			
PROJECT No.		06-1130-177		FILE No.		06-1130-177-DD.GPJ	
DRAWN	WDF	Dec 17/06	SCALE	N/A	REV.		
CHECK			FIGURE A-3				



APPENDIX B
SITE PHOTOGRAPH

March 2007

06-1130-177-0-4

SITE PHOTOGRAPH



Photo 1: Culvert Site 6-410-C at Station 10+060 Maidstone. View of inlet looking north towards Highway 3.