**Golder Associates Ltd.**

309 Exeter Road, Unit #1
London, Ontario, Canada N6L 1C1
Telephone: (519) 652-0099
Fax: (519) 652-6299

# FOUNDATION INVESTIGATION REPORT
# STRUCTURAL CULVERT, STATION 17+709
# SITE 6-457-C, COWAN D&W DRAIN
# HIGHWAY 77 REHABILITATION
# GWP 139-98-00, AGREEMENT NO. 3006-E-0013
# MINISTRY OF TRANSPORTATION - SOUTHWESTERN REGION

Submitted to:

Philips Engineering Ltd.
3215 North Service Road
P.O. Box 220
Burlington, Ontario
L7R 3Y2

DISTRIBUTION:

9 Copies - Philips Engineering Ltd.
2 Copies - Golder Associates Ltd.

February 1, 2008

06-1130-202-0 (-4)
Geocres No. 40J2-106

# TABLE OF CONTENTS

SECTION PAGE

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Philips Engineering Ltd. (Philips) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 139-98-00. Highway 77 will be rehabilitated from its southern terminus in Leamington to Staples approximately 11.7 kilometres. The southern project limit is just south of Highway 3 in Leamington and the northern limit is near the junction with Essex County Road 8 in Staples. The project also includes reconstruction and widening of an approximately 350 metre long section of Essex County Road 8 within the Highway 77/Essex County Road 8 interchange area. The scope of work for the proposed rehabilitation project includes:

- Pavement rehabilitation;
- Cross section revisions;
- Minor road widening and grade raise;
- Improvements to surface and subsurface drainage;
- Improvements to drainage structures;
- Intersection improvements including turning lanes and illumination;
- Entrance upgrades;
- Guide rail replacement; and,
- Subsurface utility engineering.

The improvements to the drainage structures will include the replacement, extension or rehabilitation of five structural culverts. This report addresses the foundation investigation for the partial replacement of the structural culvert located on Highway 77 at Station 17+709 (Site 6-457-C).

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, in Golder Associates' proposal P61-3143-1 dated September 14, 2006 and our letter dated November 8, 2007. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering originally issued on December 13, 2006 and revised February 19, 2007.

Philips provided Golder Associates with a general arrangement drawing for the proposed structure and a base plan for this project in digital format as well as hard copies of the Contract Drawings for this project.

## 2.0 SITE DESCRIPTION

Along Highway 77, the project limits of GWP 139-98-00 extend from Station 11+652 at the south side of Highway 3 northerly to Station 23+022 at the intersection with Essex County Road 8. The project also includes reconstruction of the Highway 77 S-E Ramp at the Essex County Road 8 intersection and reconstruction and some widening of Essex County Road 8 from Station 9+960 to Station 10+310. Approximately 11.4 kilometres of Highway 77 is within the Municipality of Leamington. Within the Community of Staples, the remaining 0.3 kilometres runs along Essex County Road 8 which marks the border between the Municipality of Leamington and the Town of Lakeshore. Highway 77 is co-signed with Essex County Road 8 in the short east-west section which joins the northern leg to Highway 401 and the southern leg leading to Leamington.

Culvert Site 6-457-C is located at Station 17+709 on Highway 77 and approximately 8 metres south of the centreline of Mersea Township Road 8 in the Community of Blytheswood. At this location, the Cowan D&W Drain crosses under Highway 77 from west to east. The location of the project is shown on the Key Plan, Figure 1, and in the photographs in Appendix B.

In the vicinity of the culvert, the Cowan D&W Drain flows in a grassed channel which parallels Mersea Township Road 8. The land use in the vicinity of the site is primarily residential with some commercial properties. The adjacent topography is generally flat to gently undulating with ground surface elevations ranging from 192 to 197 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 Plains.[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. Near Leamington, there is a small morainic hill composed primarily of sand and gravel.

The available surficial geology mapping for the project area indicates that it is predominantly an area of till (sandy silt and/or clayey silt) and glaciofluvial gravel or gravelly sand.[2] The

[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.

overburden thickness within the project area ranges from 32.0 to 34.7 metres.[3] Immediately underlying the overburden is a medium brown limestone followed by a brown and tan limestone containing quartz sand grains and chert belonging to the Dundee Formation of the Hamilton Group.

[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 investigation at this site was conducted on November 20 and 22, 2007 at which time three boreholes, numbered 6, 7 and 17, were drilled in the area of the proposed culvert replacement. Borehole 6 was advanced to a depth of 8.8 metres, borehole 7 to 8.1 metres and borehole 17 to a depth of 3.1 metres.

Boreholes 6 and 7 were advanced using a truck-mounted P57 power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. Borehole 17 was drilled by staff from Golder Associates using manual drilling equipment. The SPT testing in the manually drilled borehole was conducted using a non-standard hammer weight of 31 kilograms and the SPT N values shown on the Record of Borehole have been adjusted to approximate standard values.

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 was installed in borehole 7 to monitor the groundwater levels at this location. The boreholes were backfilled in accordance with current regulations, MTO recommended procedures and Ontario Regulation 903.

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 labelled 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 the coordinates, ground surface elevations and depths of the associated boreholes.

| BOREHOLE | LOCATION (m) | | GROUND SURFACE ELEVATION | BOREHOLE DEPTH |
|---|---|---|---|---|
| | Northing | Easting | (m) | (m) |
| 6 | 4664753.8 | 296936.9 | 193.63 | 8.84 |
| 7 | 4664762.8 | 296966.2 | 193.63 | 8.08 |
| 17 | 4664761.9 | 296914.3 | 192.48 | 3.05 |

The existing culvert has the following characteristics:

| DIMENSIONS (m) | OBVERT ELEVATION (m) | | CONSTRUCTION |
|---|---|---|---|
| | (Lt) | (Rt) | |
| 2.74 x 1.22 x 45.72 | 193.03 | 193.03 | Non-Rigid Frame Open Footing (NRFO) |

# 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 may 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 encountered surficial asphalt and granular road base in the shoulder areas and topsoil near the drain. Layers of clayey fill were found beneath the topsoil and pavement. The fill was underlain by predominantly clayey silt deposits interlayered with silty fine sand, sandy silt and sand.

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 Pavement Structure

A 120 millimetre thick layer of asphalt was encountered at the ground surface in borehole 6. The asphalt was underlain by a 0.25 metre thick layer of granular road base material from elevation 193.5 metres. A 0.3 metre thick layer of granular road base was encountered at ground surface in borehole 7.

### 4.1.2 Topsoil and Fill

A 130 millimetre thick topsoil layer was encountered at the ground surface in borehole 17.

Granular fill materials were encountered at elevation 193.3 metres beneath the granular road base in boreholes 6 and 7. The fill consisted of silty sand to elevation 193.1 metres in borehole 6 and fine to medium sand to elevation 193.2 metres in borehole 7.

Clayey silt fill was encountered beneath the granular fill in boreholes 6 and 7 from elevations 193.1 and 193.2 metres, respectively, and beneath the topsoil in borehole 17 from elevation 192.4 metres. The clayey silt fill layers were 0.9, 1.0 and 2.0 metres thick in boreholes 6, 7 and 17,

respectively. The cohesive fill layers were soft to firm with N values ranging from 3 to 7 blows per 0.3 metres. The natural water contents of the clayey silt fill were about 28 per cent.

### 4.1.3 Clayey Silt

Clayey silt was encountered beneath the clayey silt fill in boreholes 6 and 7 from elevation 192.3 metres and beneath a layer of sand in borehole 17 from elevation 189.6 metres.

The clayey silt was firm to very stiff with N values ranging from 7 blows per 0.3 metres to 25 blows per 0.3 metres. The results of in situ vane testing indicated an undrained shear strength of over 144 kilopascals. The natural water contents of the clayey silt varied between about 17 and 19 per cent. The clayey silt is of low to intermediate plasticity based on average plastic and liquid limits of 17 and 35 per cent, respectively, and an average plasticity index of 18 per cent. The results of the Atterberg limits determinations are shown on Figure A-2.

The results of grain size analyses conducted on samples of the clayey silt are shown on Figure A-1.

### 4.1.4 Silty Fine Sand

A 0.3 metre thick layer of silty fine sand was encountered in the clayey silt stratum in borehole 7 from elevation 190.5 metres. The results of grain size testing on a sample of silty fine sand are presented in Appendix A on Figure A-3. The silty fine sand was compact with an N value of 24 blows per 0.3 metres. The natural water content of a sample of the silty fine sand was about 15 per cent.

### 4.1.5 Sand

A 0.8 metre thick layer of fine to medium sand was encountered beneath the clayey silt fill in borehole 17 from elevation 190.4 metres. The results of grain size testing on a sample of sand are shown on Figure A-5. The sand was compact with an N value of 24 blows per 0.3 metres. The natural water content of a sample of the sand was about 20 per cent.

### 4.1.6 Sandy Silt

A 1.7 metre thick layer of sandy silt was encountered beneath the silty fine sand in borehole 7 from elevation 190.1 metres. The results of grain size testing on samples of sandy silt are shown on Figure A-4. The sandy silt was compact with N values of 13 and 15 blows per 0.3 metres. As shown on Figure A-2, the sandy silt is of slight plasticity based on plastic and liquid limits of 11.8

and 15.4 per cent, respectively, and a plasticity index of 3.7 per cent. The natural water content of a sample of the sandy silt was about 10 per cent.

## 4.2 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Groundwater was encountered at a depth of 1.4 metres or at elevation 191.1 metres in borehole 17 and at a depth of 5.0 metres or at elevation 188.6 metres in borehole 7. Borehole 6 was dry during and upon completion of drilling.

A standpipe was installed in borehole 7 to monitor the groundwater conditions. The most recent groundwater reading was obtained on December 28, 2007 where the groundwater level was measured at elevation 192.4 metres or at a depth of 1.2 metres below the ground surface.

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

| BOREHOLE | GROUND SURFACE ELEVATION (m) | ENCOUNTERED GROUNDWATER LEVEL | | INSTALLATION | MEASURED GROUNDWATER LEVEL | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Nov. 20, 2007 | | Nov. 28, 2007 | | Dec. 28, 2007 | |
| | | Depth (m) | Elevation (m) | | Depth (m) | Elevation (m) | Depth (m) | Elevation (m) | Depth (m) | Elevation (m) |
| 6 | 193.63 | Dry | Dry | - | - | - | - | - | - | - |
| 7 | 193.63 | 5.03 | 188.60 | Standpipe | 7.57 | 186.06 | 1.40 | 192.23 | 1.24 | 192.39 |
| 17 | 192.48 | 1.37 | 191.11 | - | - | - | - | - | - | - |

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

The prevailing groundwater level has been inferred at approximately elevation 192.5 metres. The water level in the Cowan D&W Drain was measured at elevation 191.99 metres on November 20, 2007.

## 5.0 MISCELLANEOUS

The investigation was carried out using power equipment supplied and operated by B.U.D. Environmental Services Ltd. which is an Ontario Ministry of Environment licensed well contractor and manually operated equipment owned by Golder Associates. The field operations were supervised by Mr. Mike Arthur and Mr. Dennis Verschoor 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.

**GOLDER ASSOCIATES LTD.**

Dirka U. Prout, P. Eng.
Geotechnical Engineer

Philip R. Bedell, P. Eng.
Principal

Fintan J. Heffernan, P. Eng.
Designated MTO Contact

TP/DUP/PRB/FJH/cr
n:\active\2006\1130 - geotechnical\1130-200\06-1130-202 philips - fdns gwp 139-98-00 - hwy 77\reports\-4) 17+709\feb 1 08 - (final) part a fdn inv & dsgn rpt - st 17+709 cowan d&w drain.doc

# 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 |

## 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.)

**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, 60º 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 $cm^2$ 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.

## 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 |

### (b) Cohesive Soils

| Consistency | $c_u, s_u$ kPa | $c_u, s_u$ psf |
|---|---|---|
| Very soft | 0 to 12 | 0 to 250 |
| Soft | 12 to 25 | 250 to 500 |
| Firm | 25 to 50 | 500 to 1,000 |
| Stiff | 50 to 100 | 1,000 to 2,000 |
| Very stiff | 100 to 200 | 2,000 to 4,000 |
| Hard | over 200 | over 4,000 |

## 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) |
| $\gamma$ | 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

| | |
|---|---|
| $\pi$ | 3.1416 |
| in 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

| | |
|---|---|
| $\gamma$ | shear strain |
| $\Delta$ | change in, e.g. in stress: $\Delta\sigma$ |
| $\varepsilon$ | linear strain |
| $\varepsilon_v$ | volumetric strain |
| $\eta$ | coefficient of viscosity |
| v | poisson's ratio |
| $\sigma$ | total stress |
| $\sigma'$ | effective stress ($\sigma' = \sigma - u$) |
| $\sigma'_{vo}$ | initial effective overburden stress |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stress (major, intermediate, minor) |
| $\sigma_{oct}$ | mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$ |
| $\tau$ | 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 |
| $\gamma'$ | 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 |
| $\sigma'_p$ | pre-consolidation pressure |
| OCR | over-consolidation ratio = $\sigma'_p/\sigma'_{vo}$ |

### (d) Shear Strength

| | |
|---|---|
| $\tau_p, \tau_r$ | peak and residual shear strength |
| $\phi'$ | effective angle of internal friction |
| $\delta$ | angle of interface friction |
| $\mu$ | 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 $\rho$. Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 6

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-4
G.W.P. 139-98-00
LOCATION N 4664753.8 ;E 296936.9
ORIGINATED BY MA
DIST HWY 77
BOREHOLE TYPE POWER AUGER (SOLID STEM)
COMPILED BY LMK
DATUM GEODETIC
DATE November 20, 2007
CHECKED BY

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT w / LIQUID LIMIT $w_L$ / WATER CONTENT (%) (10 20 30) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 193.63 | GROUND SURFACE | | | | | | | | | | |
| 0.00 | ASPHALT | | | | | | | | | | |
| 0.12 | FILL, sand and gravel, trace silt (crushed) | | | | | | | | | | |
| 0.37 | FILL, silty sand, trace gravel Brown | | | | | | | | | | |
| 0.50 | FILL, clayey silt, trace sand, trace gravel | | 1 | SS | 7 | | 193 | | | | |
| 192.26 | Firm | | | | | | | | | | |
| 1.37 | Grey and brown CLAYEY SILT, trace sand, trace gravel Firm to very stiff Brown becoming grey at about elev. 190.6m | | 2 | SS | 7 | | 192 | | | | |
| | | | 3 | SS | 18 | | 191 | | | | |
| | | | 4 | SS | 25 | | 190 | | | | |
| | | | 5 | SS | 14 | | | | | | 0 15 48 37 |
| | | | 6 | SS | 11 | | 189 | | | | |
| | | | 7 | SS | 9 | | 188 | | | | 0 19 43 38 |
| | | | 8 | SS | 8 | | 187 | | | | |
| | | | | | | | | > 144 kPa | | | |
| | | | 9 | SS | 9 | | 186 | | | | |
| 184.79 | | | 10 | SS | 9 | | 185 | | | | |
| 8.84 | END OF BOREHOLE | | | | | | | | | | |

Borehole dry during drilling on November 20, 2007.

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

LDN_MTO_01 0611302020-4.GPJ LDN_MTO.GDT 2/1/08

Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 7

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-4
G.W.P. 139-98-00
LOCATION N 4664762.8 ;E 296966.2
ORIGINATED BY MA
DIST HWY 77
BOREHOLE TYPE POWER AUGER (SOLID STEM)
COMPILED BY LMK
DATUM GEODETIC
DATE November 20, 2007
CHECKED BY

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ / WATER CONTENT (%) (10 20 30) | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 193.63 | GROUND SURFACE | | | | | | | | | | |
| 0.00 | FILL, sand and gravel, some silt (crushed) | | | | | | Cuttings | | | | |
| 0.40 | FILL, sand fine to medium, trace silt | | | | | | 193 | | | | |
| | FILL, clayey silt, trace sand, gravel, topsoil<br>Firm<br>Grey and brown | | 1 | SS | 6 | | Bentonite | | | | |
| 192.26 | | | | | | | | | | | |
| 1.37 | CLAYEY SILT, trace sand, trace gravel<br>Very stiff<br>Brown becoming grey at about elev. 190.6m | | 2 | SS | 16 | | 192 | | | | |
| | | | 3 | SS | 20 | | 191 | | | | |
| 190.46 | | | | | | | | | | | |
| 3.17 | SILTY FINE SAND<br>Compact | | 4 | SS | 24 | | | | ○ | | 1 55 31 13 |
| 190.13 | Brown | | | | | | 190 | | | | |
| 3.50 | SANDY SILT, trace to some clay, trace gravel<br>Compact<br>Grey | | 5 | SS | 13 | | Cuttings | | | | |
| | | | 6 | SS | 15 | | 189 | | ○⊢ | | 5 45 39 11 |
| 188.45 | | | | | | | | | | | |
| 5.18 | CLAYEY SILT, trace sand, trace gravel<br>Stiff<br>Grey | | 7 | SS | 13 | | 188 | | | | |
| | | | 8 | SS | 10 | | 187 | | | | |
| | | | 9 | SS | 12 | | Filter sand | | | | |
| | | | 10 | SS | 12 | | 186 | | | | |
| 185.55 | | | | | | | | | | | |
| 8.08 | END OF BOREHOLE | | | | | | | | | | |

Groundwater encountered at about elev. 188.6m during drilling on November 20, 2007.

Water level measured at elev. 186.1m immediately after installation on November 20, 2007.

Water level measured at elev. 192.23m on November 28, 2007.

Water level measured at elev. 192.35m on December 11, 2007.

Water level measured at elev. 192.39m on December 28, 2007.

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 17

1 OF 1

**METRIC**

PROJECT 06-1130-202-0-4
G.W.P. 139-98-00
DIST HWY 77
DATUM GEODETIC

LOCATION N 4664761.9 ;E 296914.3
BOREHOLE TYPE MANUAL DRILLING
DATE November 22, 2007

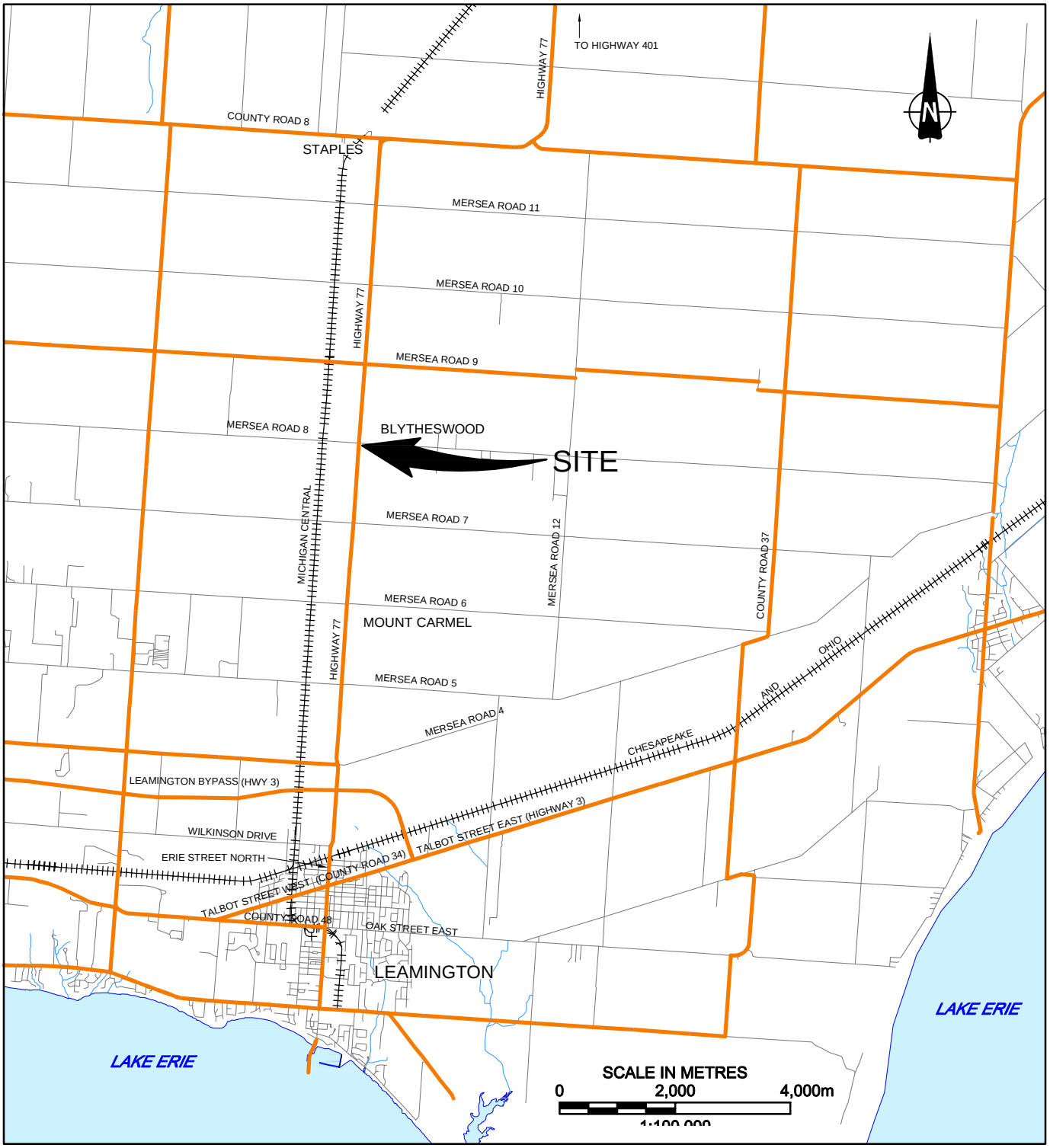
ORIGINATED BY DV
COMPILED BY LMK
CHECKED BY

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100 | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) 10 20 30 | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 192.48 | GROUND SURFACE | | | | | | | | | | |
| 0.00 | TOPSOIL, silty<br>Brown | | | | | | | | | | |
| 0.13 | FILL, clayey silt, trace sand, gravel, topsoil<br>Soft<br>Brown and grey | | 1 | SS | 3 | ▽ | 192 | | ○ | | |
| | | | 2 | SS | 3 | | 191 | | ○ | | |
| 190.35 | | | | | | | | | | | |
| 2.13 | SAND, fine to medium, trace silt<br>Compact<br>Brown | | 3 | SS | 24 | | 190 | | ○ | | 0 94 2 4 |
| 189.58 | | | | | | | | | | | |
| 2.90 | CLAYEY SILT, trace sand, trace gravel<br>Hard<br>Brown | | | | | | | | ○ | | |
| 3.05 | END OF BOREHOLE | | | | | | | | | | |

Groundwater encountered at about elev. 191.1m during drilling on November 22, 2007.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

LDN_MTO_01 0611302020-4.GPJ LDN_MTO.GDT 2/1/08




## 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.

PROJECT

**STRUCTURAL CULVERT 17+709**
**HIGHWAY 77 REHABILITATION**
**GWP 139-98-00**

TITLE

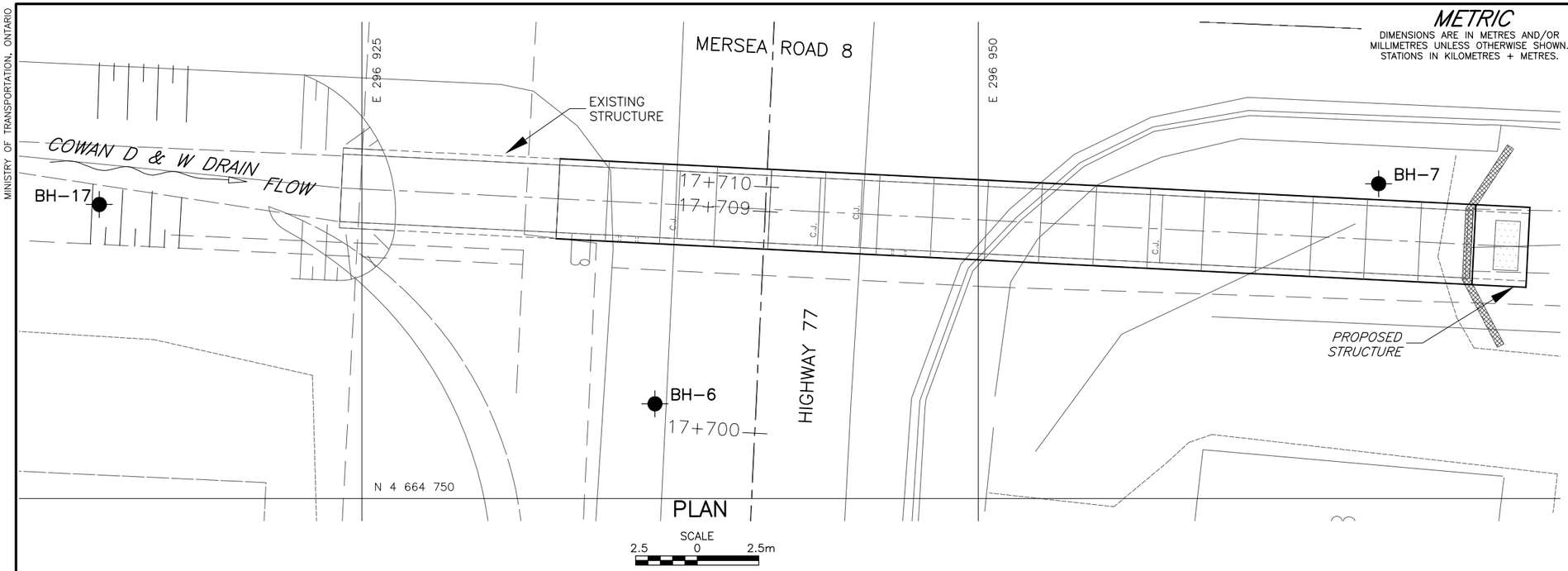
**KEY PLAN**

Golder Associates
LONDON, ONTARIO

| | | | |
|---|---|---|---|
| PROJECT No. 06-1130-202 | | | FILE No. 0611302020-4-F01001 |
| | | | SCALE AS SHOWN REV. |
| CADD | DCH | Dec. 19/07 | **FIGURE 1** |
| CHECK | | | |

Drawing file: 0611302020-4-F01001.dwg Feb 01, 2008 - 1:24pm

MINISTRY OF TRANSPORTATION, ONTARIO




PLAN

SCALE 2.5 0 2.5m

METRIC

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

CONT No.

WP No. 139–98–00

SHEET

HIGHWAY 77 REHABILITAION
STRUCTURAL CULVERT 17+709
CULVERT WIDENING
BOREHOLE LOCATION AND SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA

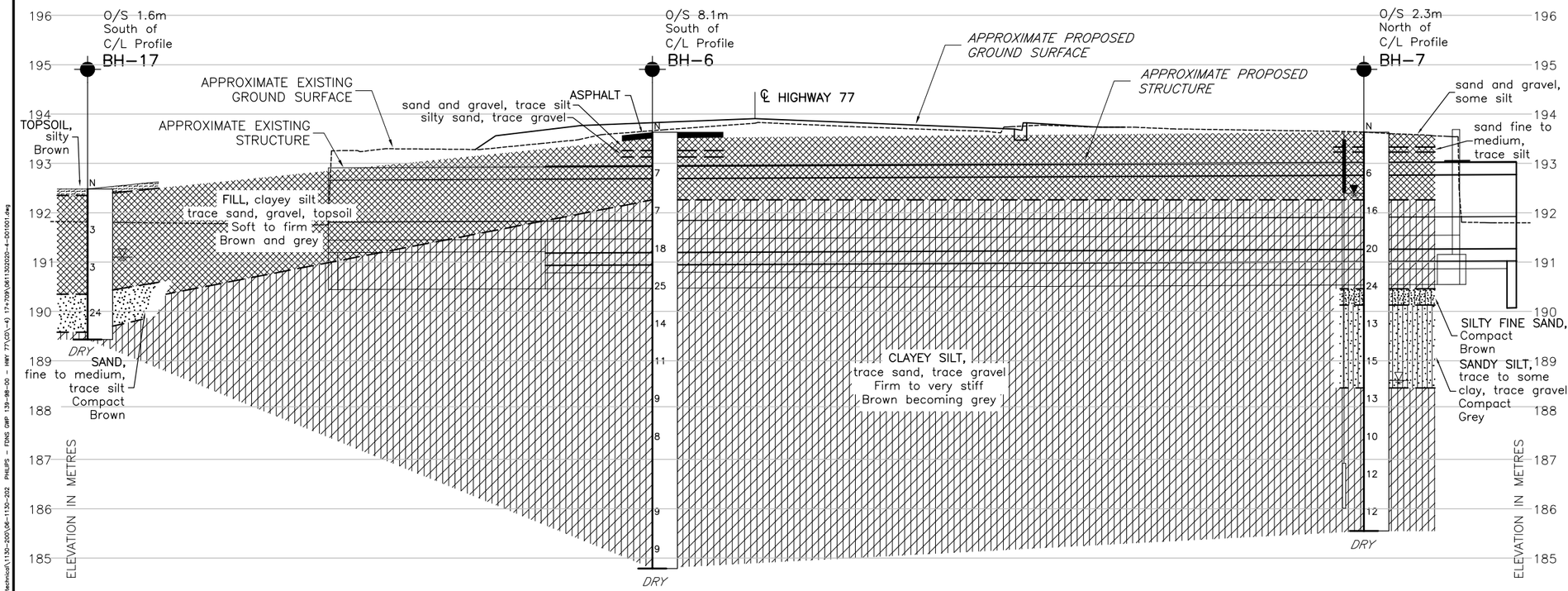

KEY PLAN

SCALE 2000 0 2000m

## LEGEND

- Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on December 28, 2007
- WL encountered during drilling

| No. | ELEVATION | CO–ORDINATES (MTM Zone 11) | |
|---|---|---|---|
| | | NORTHING | EASTING |
| 6 | 193.63 | 4 664 753.8 | 296 936.9 |
| 7 | 193.63 | 4 664 762.8 | 296 966.2 |
| 17 | 192.48 | 4 664 761.9 | 296 914.3 |




PROFILE ALONG C/L OF CULVERT AT STA. 17+709

HORIZONTAL SCALE 3 0 3m

VERTICAL SCALE 6 0 6m

## 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

Preliminary base plans provided in digital format by Dillon.

| NO. | DATE | BY | REVISION |
|---|---|---|---|
| | | | |
| | | | |

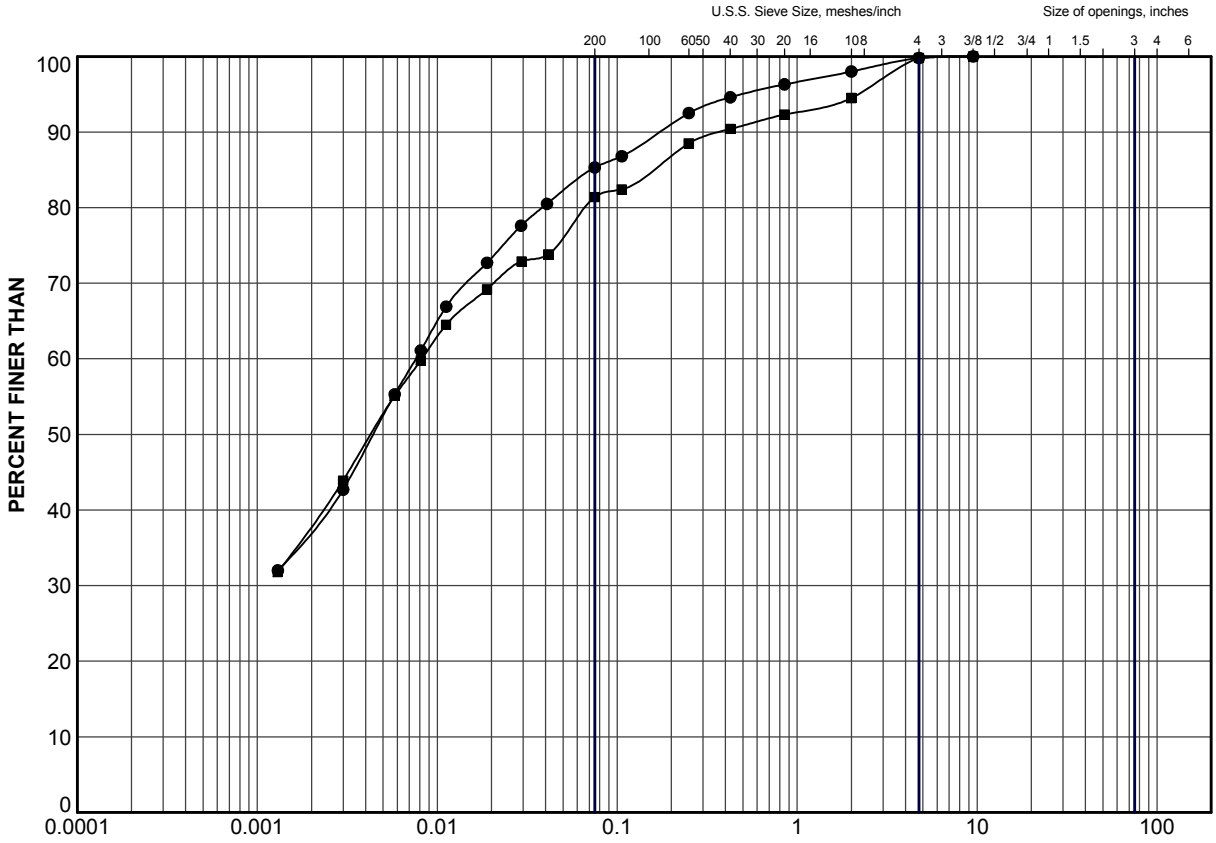
Geocres No. 40J2–106

| | | | | | |
|---|---|---|---|---|---|
| HWY. 77 | | | PROJECT NO. 06–1130–202–0–4 | | DIST. |
| SUBM'D. DUP | CHKD. DUP | | DATE: Dec. 18/07 | | SITE: 6–457C |
| DRAWN: DCH | CHKD. DUP | | APPD. | | DWG. 1 |

PLOT DATE: February 01, 2008
FILENAME: N:\active\2006\1130 - Geotechnical\1130-2006-1130-202 PHILIPS - FDNS GWP 139-98-00 - HWY 77\CD\-4) 17+709\061130202D-4-D01001.dwg

# APPENDIX A

# LABORATORY TEST DATA




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|---|---|---|---|
| ● | 6 | 5 | 189.6 |
| ■ | 6 | 7 | 188.1 |

PROJECT

STRUCTURAL CULVERT 17+709
HIGHWAY 77 REHABILITATION
GWP 139-98-00

TITLE

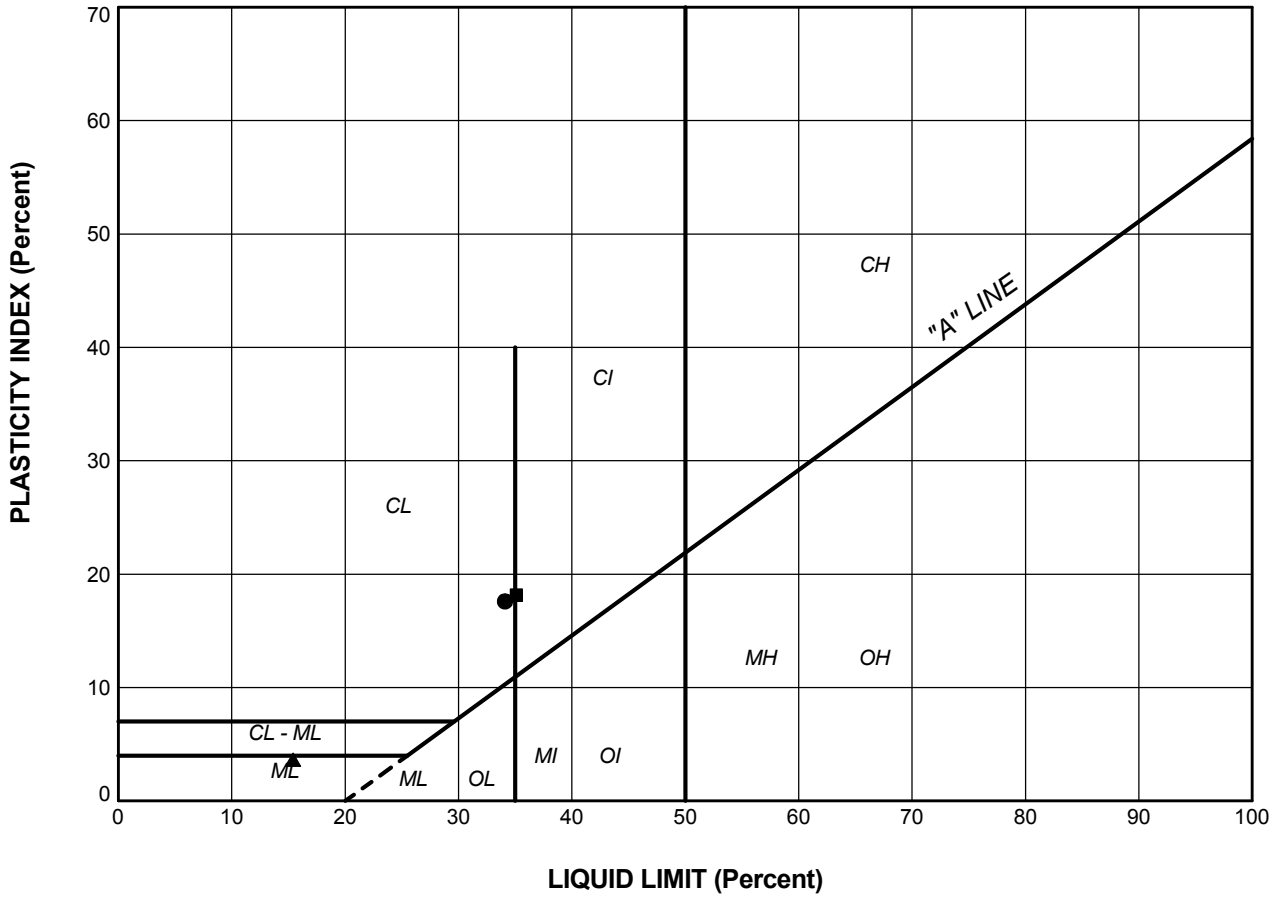
# GRAIN SIZE DISTRIBUTION

## CLAYEY SILT

Golder Associates
LONDON, ONTARIO

| | | | | |
|---|---|---|---|---|
| PROJECT No. 06-1130-202-0-4 | | | FILE No. 0611302020-4-F010A1 | |
| | | | SCALE N/A | REV. |
| DRAWN | LMK | Dec 19/07 | FIGURE A-1 | |
| CHECK | | | | |

LDN_MTO_NEW GLDR_LDN.GDT




**LIQUID LIMIT (Percent)**

| **SOIL TYPE** | **PLASTICITY** |
|---|---|
| C = Clay | L = Low |
| M = Silt | I = Intermediate |
| O = Organic | H = High |

## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | LL(%) | PL(%) | PI |
|---|---|---|---|---|---|
| CLAYEY SILT | | | | | |
| ● | 6 | 5 | 34.1 | 16.5 | 17.6 |
| ■ | 6 | 7 | 35.1 | 17.0 | 18.2 |
| SANDY SILT | | | | | |
| ▲ | 7 | 6 | 15.4 | 11.8 | 3.7 |

PROJECT

STRUCTURAL CULVERT 17+709
HIGHWAY 77 REHABILITATION
GWP 139-98-00

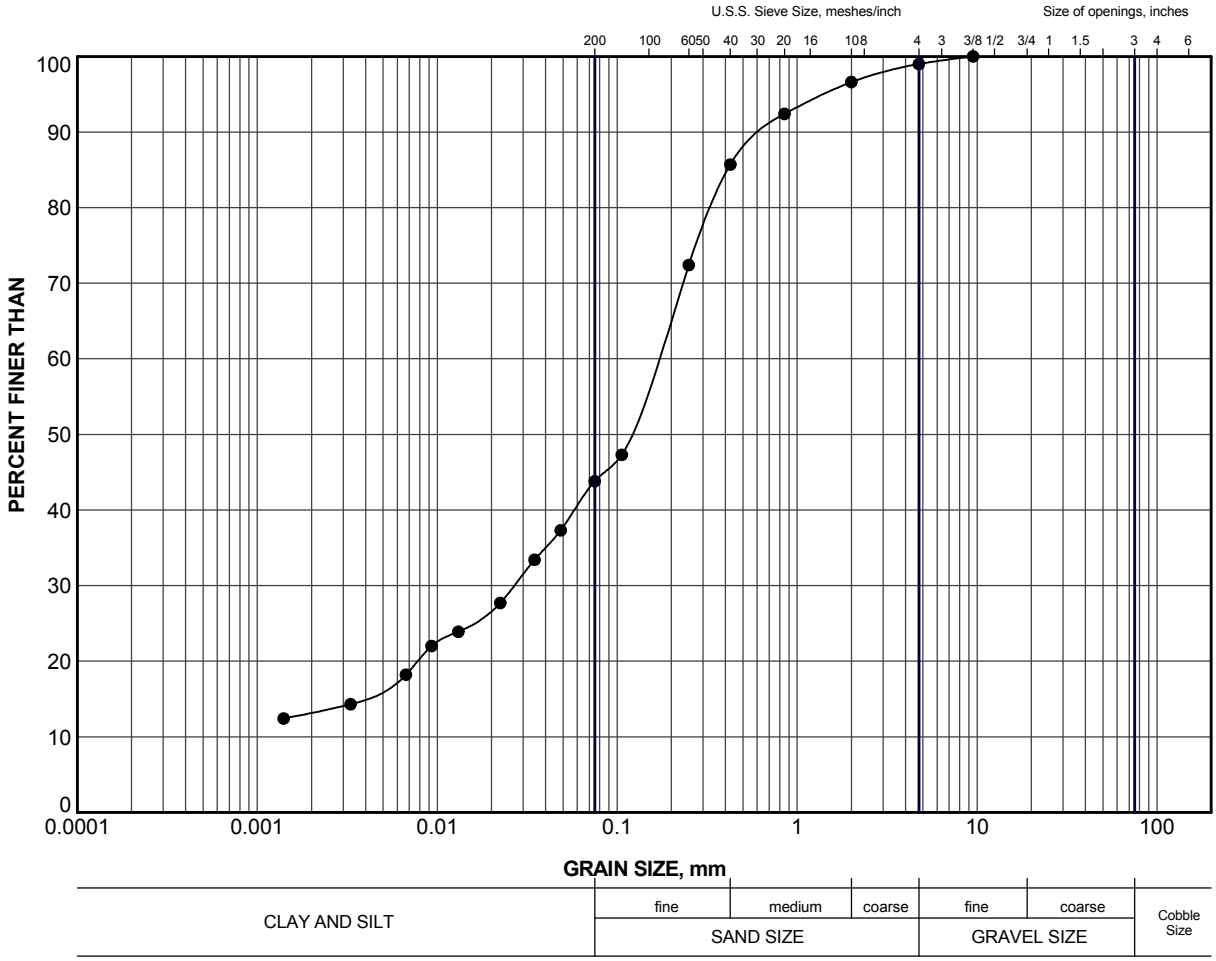
TITLE

# PLASTICITY CHART

Golder Associates
LONDON, ONTARIO

| | | | | |
|---|---|---|---|---|
| PROJECT No. 06-1130-202-0-4 | | | FILE No. 0611302020-4-F010A2 | |
| | | | SCALE N/A | REV. |
| DRAWN | LMK | Dec 19/07 | | |
| CHECK | | | **FIGURE A-2** | |

MTO_PI_GLDR_LDN.GDT




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|---|---|---|---|
| ● | 7 | 4 | 190.3 |

PROJECT

STRUCTURAL CULVERT 17+709
HIGHWAY 77 REHABILITATION
GWP 139-98-00

TITLE

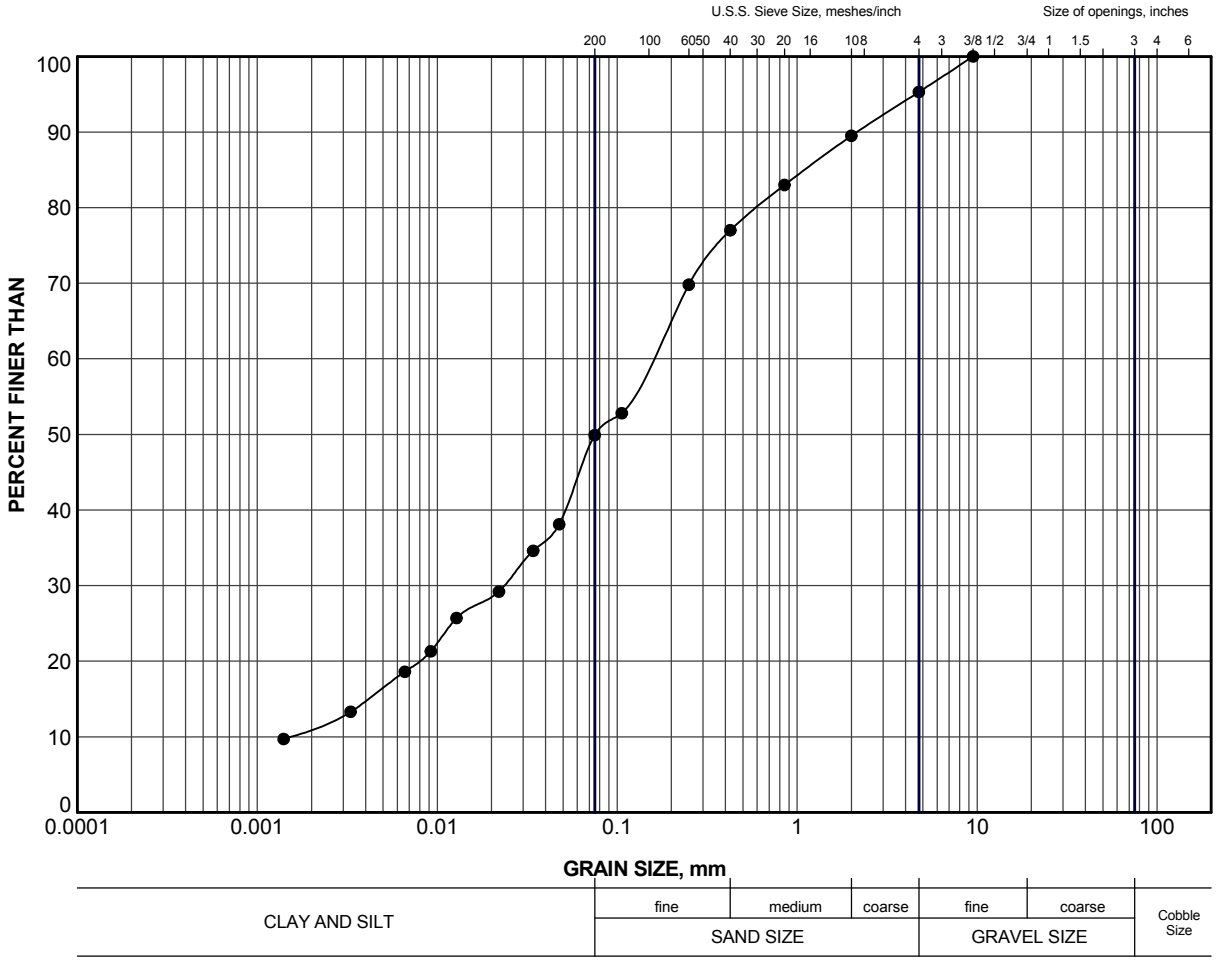
# GRAIN SIZE DISTRIBUTION

## SILTY FINE SAND

Golder Associates
LONDON, ONTARIO

| | | | | |
|---|---|---|---|---|
| PROJECT No. 06-1130-202-0-4 | | | FILE No. 0611302020-4-F010A3 | |
| | | | SCALE N/A | REV. |
| DRAWN | LMK | Jan 8/08 | | |
| CHECK | | | **FIGURE A-3** | |

LDN_MTO_NEW GLDR_LDN.GDT




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|---|---|---|---|
| ● | 7 | 6 | 188.8 |

PROJECT

STRUCTURAL CULVERT 17+709
HIGHWAY 77 REHABILITATION
GWP 139-98-00

TITLE

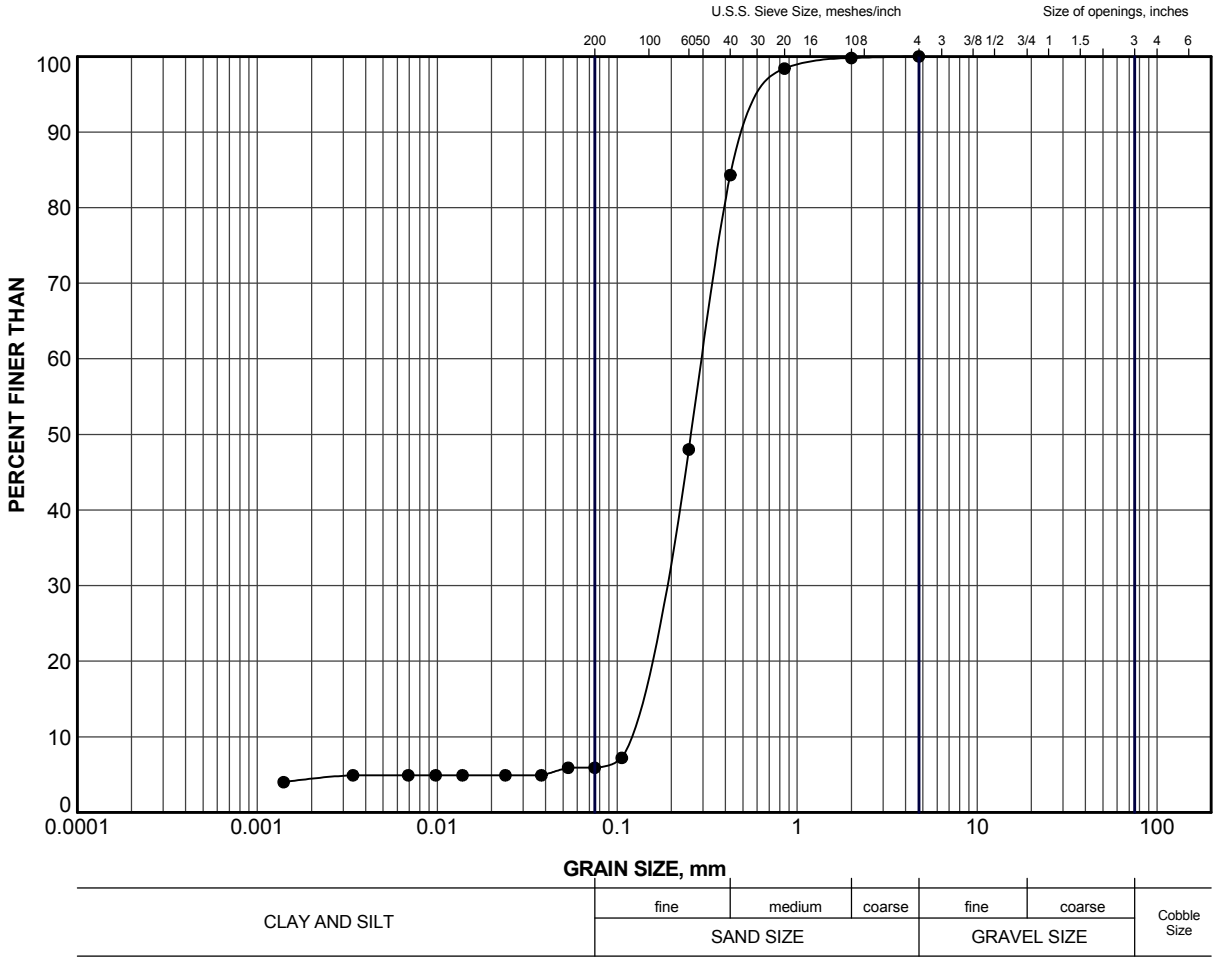
# GRAIN SIZE DISTRIBUTION

## SANDY SILT

Golder Associates
LONDON, ONTARIO

| PROJECT No. | 06-1130-202-0-4 | | FILE No. | 0611302020-4-F010A4 |
|---|---|---|---|---|
| | | | SCALE | N/A |
| DRAWN | LMK | Dec 19/07 | REV. | |
| CHECK | | | **FIGURE** | **A-4** |

LDN_MTO_NEW GLDR_LDN.GDT




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|---|---|---|---|
| ● | 17 | 3 | 189.8 |

PROJECT

STRUCTURAL CULVERT 17+709
HIGHWAY 77 REHABILITATION
GWP 139-98-00

TITLE

# GRAIN SIZE DISTRIBUTION

## SAND

Golder Associates
LONDON, ONTARIO

| PROJECT No. | 06-1130-202-0-4 | | FILE No. | 0611302020-4-F010A5 |
|---|---|---|---|---|
| | | | SCALE | N/A |
| DRAWN | LMK | Jan 8/08 | REV. | |
| CHECK | | | | |

**FIGURE A-5**

LDN_MTO_NEW GLDR_LDN.GDT

# APPENDIX B

# SITE PHOTOGRAPHS

## SITE PHOTOGRAPHS

Photo 1: Station 17+809, inlet (west end) of Cowan D&W Drain. Looking west along Mersea Township Road 8.


Photo 2: Looking east along Mersea Township Road 8 at intersection with Highway 77 in B1.