

**PRELIMINARY FOUNDATION INVESTIGATION  
AND DESIGN REPORT  
DEEP CUTS  
HIGHWAY 24 REHABILITATION  
MINISTRY OF TRANSPORTATION - WEST REGION  
GWP 336-97-00, AGREEMENT NO. 3006-E-0012**

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**PART A – PRELIMINARY FOUNDATION INVESTIGATION  
REPORT**

**DEEP CUTS  
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## 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 preliminary foundation investigations as part of the preliminary design work for GWP 336-97-00. The project involves the preliminary design for the rehabilitation of Highway 24 from Brant County Road 53 to just north of Highway 403 and includes:

- Intersection improvements at the intersection of Highway 24 and Brant County Road 53 including upgrading traffic signals and illumination and extension of left turn lanes;
- Intersection improvements at Highway 24 and Bethel Road including signalization and left turn lanes;
- Minor intersection improvements at the remaining intersections;
- Lane and shoulder widening;
- Minor vertical curve corrections; and
- Replacement of the Whitemans Creek bridge, Site 1-85.

Improvements in the horizontal and vertical alignments are required for future widening to four lanes. Several alignments have been proposed including ones which preserve the crossing of Whitemans Creek at the current location or result in a replacement structure to the west or east of the current bridge. Alignment Alternate 7 is the alignment option currently under consideration. This alignment maintains the creek crossing at the current location.

This report addresses the deep cuts associated with the rehabilitation of Highway 24. Deep cuts in excess of 4.5 metres will be required south of Whitemans Creek Bridge between approximate Stations 16+900 and 17+000 and north of the bridge between Stations 17+700 and 18+080. The deep excavations will result in cut slopes as much as 16 metres in height.

The purpose of the preliminary foundation investigation is to determine the subsurface conditions at the locations of the proposed works by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal, Golder Associates' proposal P61-3103 dated August 11, 2006, revised proposal P61-3103-1 dated February 7, 2007 and our letters dated March 22, 2007 and April 16, 2007 that documented revisions in the scope of work for this project. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated November 7, 2006.

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

## **2.0 SITE DESCRIPTION**

The rehabilitation of Highway 24 to be undertaken as GWP 336-97-00 extends from south of Colborne Street West to north of Highway 403. The site location is shown on the Key Plan in Drawing 1. An existing bridge over Whitemans Creek is situated on Highway 24 approximately 2.8 kilometres south of Highway 403, between Bethel Road and Robinson Road.

Deep cuts exist and are to be deepened along Highway 24 from approximately chainage 16+900 to 17+000 and 17+700 to 18+080. The proposed earthworks will flatten the steep grade changes of the existing roadway on each side of the Whitemans Creek crossing. The existing roadway was built in sections of cut ranging from 2 to 3 metres between 16+915 and 16+925 and from 4 to 11 metres deep between approximate stations 17+740 and 17+890.

The site is located in an area where the land use is rural residential and agricultural. The Apps Mills Conservation Area is situated on the northwest of Robinson Road and Highway 24. Portions of the eastern boundary of the conservation area border on the west road limit of Highway 24. The lands adjacent to Stations 16+900 and 17+000 are primarily agricultural fields with small woodlots. The lands adjacent to the cut between 17+700 to 18+080 are mainly wooded on both sides of the road.

### **2.1 Site Geology**

The area of the proposed Highway 24 rehabilitation lies in the physiographic region of southern Ontario known as the Norfolk Sand Plain<sup>1</sup>. The Norfolk Sand Plain is wedge shaped and extends from the Lake Erie shore to Brantford. The sands and silts were deposited from a significant meltwater discharge from the Grand River as it entered former glacial Lakes Whittlesey and Warren and formed a delta.

Based on the Ontario Department of Mines and Northern Affairs Map 2240 entitled "Pleistocene Geology of the Brantford Area", the creek bed and floodplain of Whitemans Creek are composed of modern alluvium consisting of silty sand, gravel, clay and muck. A narrow band of till and other stratified sediments are present north of the creek. Older gravel and sand alluvium exist in remnants of terraces on the south side of the creek. Glaciofluvial outwash and deltaic deposits of gravel and gravely sand are present in the plateaus beside the Whitemans Creek valley. In many places, the coarse granular materials are overlain by several metres of sand.

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

The bedrock is reported to be shale with lenses of anhydrite and gypsum belonging to the Salina formation of Upper Silurian Age (Geological Survey of Canada, Map 1263A entitled “Geology, Toronto-Windsor Area”, dated 1969). The bedrock surface is near elevation 213 metres according to Ontario Department of Mines Map 2035.

### 3.0 INVESTIGATION PROCEDURES

The field work for this portion of the investigation was carried out on June 21 and 22, 2007, at which time two boreholes, numbered 3 and 4, were drilled to depths of 15.1 and 10.4 metres, respectively.

The investigation was carried out using an all-terrain vehicle mounted CME 850 power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at 0.75 metre intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. Groundwater conditions in the boreholes were observed throughout the drilling operations. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 372/07.

The field work was supervised on a full-time basis by an experienced member of our engineering staff who located the boreholes in the field, directed the drilling, sampling and in situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and 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.

The locations of the boreholes are shown on the Record of Borehole sheets and on Drawing 1. The table below summarizes the borehole locations, ground surface elevations at the borehole locations and borehole depths.

| <u>BOREHOLE</u> | <u>LOCATION (m)</u> |                | <u>GROUND SURFACE</u><br><u>ELEVATION</u> | <u>BOREHOLE DEPTH</u> |
|-----------------|---------------------|----------------|---|-----------------------|
|                 | <u>Northing</u>     | <u>Easting</u> | <u>(m)</u>                                |                       |
| 3               | 4 778 183.0         | 234 128.3      | 250.96                                    | 15.09                 |
| 4               | 4 777 446.1         | 234 423.3      | 244.25                                    | 10.36                 |

## **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 boreholes drilled at the site generally encountered surficial topsoil underlain by strata of sands underlain by layers of silt, clayey silt and sandy silt till.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profiles, 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**

Surficial layers of topsoil 150 and 230 millimetres thick were found at the ground surface of boreholes 4 and 3, respectively.

#### **4.1.2 Sand and Gravel**

Beneath the topsoil in borehole 3, a 0.2 metre thick layer of silty sand and gravel was encountered from elevation 250.7 metres.

#### **4.1.3 Sands**

Layers of compact to very dense sand were encountered beneath the silty sand and gravel in borehole 3 and beneath the surficial topsoil in borehole 4 from elevations 250.5 and 244.1 metres, respectively. The sands ranged in gradation from fine to coarse and contained variable amounts of gravel.

The sands had measured N values, as determined in the standard penetration test, of 11 to 55 blows per 0.3 metres penetration. Natural water contents of samples of sand from above the groundwater level were about 3 per cent.

The results of grain size testing on a sample of sand with some gravel and a sample of fine sand recovered from the standard penetration testing are shown on Figures A-1 and A-2 of Appendix A, respectively.

#### **4.1.4 Silty Fine Sand**

Silty fine sand was encountered beneath the sand in borehole 4 from elevation 240.6 metres. The silty fine sand contained silt seams below elevation 239.1 metres. The silty sand had measured N values of 18 to 27 blows per 0.3 metres penetration. The natural water content of a sample of the silty sand was about 8 per cent.

The results of grain size testing on a sample of silty fine sand recovered from the standard penetration testing are shown on Figure A-3.

#### **4.1.5 Silt**

Layers of compact to dense silt were encountered beneath the sand from approximate elevation 238.2 metres in borehole 3 and beneath the silty fine sand at elevation 238.3 metres in borehole 4. Borehole 4 was terminated within this deposit. The silt had measured N values of 24 to 32 blows per 0.3 metres penetration. The natural water content of a sample of silt was about 20 per cent.

The results of grain size testing on a sample of silt recovered from the standard penetration testing are shown on Figure A-4 of Appendix A.

#### **4.1.6 Clayey Silt**

The silt in borehole 3 was underlain by stiff to very stiff clayey silt from elevation 238.0 metres. The clayey silt had measured N values of 9 and 16 blows per 0.3 metres penetration. The natural water content of a sample of clayey silt was about 22 per cent. The plastic and liquid limits of a single sample were 17 per cent and 32 per cent, respectively, with a plasticity index of 15 per cent based on the results of a single Atterberg limits determination.

The results of the Atterberg limit testing are presented on the Plasticity Chart, Figure A-6. The results of grain size testing on a sample of clayey silt recovered from the standard penetration testing are shown on Figure A-5 of Appendix A.



#### **4.1.7 Sandy Silt Till**

Very dense sandy silt till was encountered in borehole 3 from elevation 236.6 metres. Borehole 3 was terminated in sandy silt till after exploring for some 0.8 metres. The sandy silt till had a measured N value of 52 blows per 0.3 metres penetration.

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

#### **4.2 Groundwater Conditions**

Groundwater conditions were observed during and upon completion of drilling. The groundwater level observations are noted on the profile on Drawing 1 and the Record of Borehole sheets. The following discussion is a summary of the groundwater conditions. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

##### Station 16+900 to 17+000

Borehole 4 remained dry during drilling. Grey soils were not encountered in borehole 4. Therefore it was assumed that the long-term groundwater level at borehole 4 is below the depth of exploration or below elevation 233.9 metres.

##### Station 17+700 to 18+080

Groundwater was encountered in the sand at elevations 239.8 metres in borehole 3 in the early summer period. There is likely a perched groundwater table in the sands. Grey soils were encountered from elevation 237.7 metres in borehole 3. The groundwater level in this segment of Highway 24 has been inferred to be at about elevation 240 metres.

## **5.0 MISCELLANEOUS**

The investigation was carried out using equipment supplied and operated by Aardvark Drilling Inc., 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 – PRELIMINARY FOUNDATION DESIGN REPORT**

**DEEP CUTS  
HIGHWAY 24 REHABILITATION  
MINISTRY OF TRANSPORTATION – WEST REGION  
GWP 336-97-00, AGREEMENT NO. 3006-E-0012**

## **6.0 ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides our recommendations on the geotechnical aspects of the preliminary design of the deep cuts associated with the rehabilitation of Highway 24 (Rest Acres Road) based on our interpretation of the factual information obtained during the preliminary foundation investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

### **6.2 Proposed Deep Cuts**

Two segments with deep cuts are located between approximate stations 16+900 and 17+000 and between 17+700 and 18+080. The changes to the horizontal and vertical alignments are required to provide a profile compatible with the design speed and future 4 lane widening.

#### **6.2.1 Stations 16+900 and 17+000**

This segment of roadway was constructed in a cut 2 to 3 metres deep. The existing centreline profile of Highway 24 varies from elevation 240.9 metres at Station 16+910 to elevation 240.1 metres at Station 16+930.

Borehole 4 was drilled in this cut area. The subsurface conditions encountered at the borehole consisted of surficial topsoil overlying about 3.5 metres of compact to dense sand and 2.2 metres of compact silty fine sand overlying compact to dense silt. Groundwater and grey soils were not encountered in the borehole. The groundwater level is inferred to be below the maximum depth of the exploration which corresponds to elevation 233.9 metres.

The proposed design requires grades to be lowered 1 to 2 metres resulting in cut slopes 3 to 5 metres high. The proposed roadway profile will be between elevations 239.6 and 240.3 metres. The proposed ditch inverts will be between elevations 238.0 and 238.8 metres. Cuts of approximately 5 metres along the west ditch and approximately 3 to 5 metres along the east ditch are anticipated. Standard cut side slopes of 2 horizontal to 1 vertical are proposed. The proposed cut will be above the groundwater level.

Permanent cut slopes with overall side slopes of 2 horizontal to 1 vertical are considered suitable with an adequate factor of safety for long term stability.

### **6.2.2 Stations 17+700 and 18+080**

This segment of Highway 24 is north of the Whitemans Creek bridge and was constructed in a cut 4 to 11 metres deep. Existing grades along the centreline vary between 240.4 metres at station 17+750 and 249.0 metres at station 17+880.

The subsurface conditions encountered in borehole 3, drilled at approximate station 17+765 were surficial topsoil and silty sand and gravel overlying a 12.3 metre thick layer of compact to very dense sand. The sand is underlain by a 0.2 metre thick silt layer and a 1.3 metre thick layer of stiff to very stiff clayey silt followed by very dense sandy silt till to the termination depth of the borehole at elevation 235.9 metres. Apparently, perched groundwater was encountered within the sand at elevation 239.8 metres. The inferred groundwater level in this area is 238 metres.

With the proposed adjustments to the vertical profile, the grade will be lowered 4.2 to 4.6 metres and cut slopes up to 16 metres in height will result. The new centreline of roadway elevations will vary between 236.3 to 244.7 metres. Incremental cut side slopes of 2.0 horizontal to 1 vertical have been proposed with multi-level benches resulting in an overall slope inclination of approximately 2.25 horizontal to 1 vertical.

A granular blanket will be required to control groundwater seepage for the lower portion of the sand layer and to improve the stability of the slope. The granular blanket could consist of a 300 millimetre thickness of 20 millimetre crushed stone or 100 millimetre gabion stone, either placed on a suitable separation geotextile. Flows from the blanket should be collected in a ditch or drain located on a horizontal bench constructed at the sand/clayey silt interface and directed downslope to the roadway ditches by a piped system or a rip rap lined channel.

With proper groundwater control, permanent cut slopes with overall side slopes as proposed are considered suitable with an adequate factor of safety for long term stability.

## **6.3 Excavations and Temporary Dewatering**

Excavations are expected to encounter surficial topsoil and silty sand and gravel, compact to very dense sands and compact silty fine sand in the deep cut area south of Whitemans Creek. North of the creek, compact to very dense sands, silt, stiff to very stiff clayey silt and very dense sandy silt till will be encountered. The sandy silt and saturated sands can be classified as Type 3 soils. Sands and silts above the groundwater level and the clayey silt can be classified as Type 2 materials.

Excavations between Stations 16+900 and 17+000 are not expected to intercept the groundwater table. However following periods of sustained heavy rainfall, saturated soils may be present near the surface of cuts. In the deep cut segment north of Whitemans Creek from about 17+700 to 17+830 groundwater flows should be expected when excavating the sand below approximate elevation 240 metres.

It is anticipated that during construction, the slopes in this area can be adequately dewatered using conventional sumps and drainage ditches. More aggressive dewatering will be required if coarser sand or gravel seams are encountered. The saturated silt layers will be difficult to dewater using gravity drainage methods. The silty layer, as encountered at borehole 3 is approximately 1.6 metres thick. However, if the silt deposit is found to be more extensive, or if flows dictate, it may be necessary to stabilize the slope faces in silt using a vacuum well point system. All sumps must be properly filtered. All dewatering is to be carried out in accordance with Ontario Provincial Standard Specifications (OPSS) 518. Temporary erosion and sediment control measures should be implemented during construction in accordance with OPSS 577.

All excavations should be conducted in accordance with the guideline outlined in the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects.

Mid-height or intermediate height benches some 2 metres wide would be required in areas where the overall slope height is greater than 6 metres. Careful ditching and drainage works should be provided behind the cut and at the mid-height or intermediate height benches to control surface flows and minimize erosion. The completed slope should be topsoiled and provided with an erosion control blanket.

## **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<br>(Relative Density) | N<br>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 cm<sup>2</sup> 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 <sup>1</sup>                                       |
| CIU      | consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup> |
| $D_R$    | 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                                |
| $\ln x$ ,   | 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

|                                |  |
|--------------------------------|--|
| $\gamma$                       | shear strain   |
| $\Delta$                       | change in, e.g. in stress: $\Delta \sigma$                                 |
| $\epsilon$                     | linear strain  |
| $\epsilon_v$                   | volumetric strain  |
| $\eta$                         | coefficient of viscosity   |
| $\nu$                          | 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<br>$= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$                         | 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 $= (e_{max} - e) / (e_{max} - e_{min})$<br>(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)

**RECORD OF BOREHOLE No 3**

1 OF 2

**METRIC**

PROJECT 06-1130-185-2

G.W.P. 336-97-00

LOCATION N 4778183.0; E 234128.3

ORIGINATED BY M.A.

DIST 1 HWY 24

BOREHOLE TYPE POWER AUGER/HOLLOW STEM AUGERS

COMPILED BY BRS

DATUM GEODETIC

DATE June 21, 2007

CHECKED BY

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |     | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|---|---|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | 20  | 40 | 60 | 80 | 100 |   |   |
| 250.96        | GROUND SURFACE   |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 0.00          | TOPSOIL, sandy<br>Brown  |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 0.23          | SILTY SAND AND GRAVEL<br>Brown   |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 0.46          | SAND, fine to coarse, trace gravel,<br>trace silt<br>Compact<br>Brown                                  |            | 1       | SS   | 16         |                            | 250             |   |    |    |    |     |   |   |
|               |  |            | 2       | SS   | 11         |                            | 249             |   |    |    |    |     |   |   |
| 248.83        |  |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 2.13          | SAND, some gravel, trace silt<br>Compact to dense<br>Brown   |            | 3       | SS   | 23         |                            | 248             |   |    |    |    |     |   |   |
|               |  |            | 4       | SS   | 30         |                            |                 |   |    |    |    |     |   | 15 77 6 2   |
|               |  |            | 5       | SS   | 40         |                            | 247             |   |    |    |    |     |   |   |
| 246.72        |  |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 4.24          | SAND, fine to medium, trace gravel<br>Compact to dense<br>Brown  |            | 6       | SS   | 25         |                            | 246             |   |    |    |    |     |   |   |
|               |  |            | 7       | SS   | 18         |                            |                 |   |    |    |    |     |   |   |
|               |  |            | 8       | SS   | 22         |                            | 245             |   |    |    |    |     |   |   |
|               |  |            | 9       | SS   | 42         |                            | 244             |   |    |    |    |     |   |   |
| 243.49        |  |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 7.47          | SAND, fine to coarse, trace to<br>some gravel<br>Compact to dense<br>Brown                             |            | 10      | SS   | 40         |                            | 243             |   |    |    |    |     |   |   |
|               |  |            | 11      | SS   | 24         |                            |                 |   |    |    |    |     |   |   |
| 241.97        |  |            |         |      |            |                            | 242             |   |    |    |    |     |   |   |
| 8.99          | SAND, fine, trace silt<br>Compact<br>Brown   |            | 12      | SS   | 22         |                            |                 |   |    |    |    |     |   | 0 91 5 4  |
| 241.21        |  |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 9.75          | SAND, medium to coarse, trace<br>gravel, trace silt<br>Compact to very dense<br>Brown                  |            | 13      | SS   | 55         |                            | 241             |   |    |    |    |     |   |   |
|               |  |            | 14      | SS   | 19         |                            | 240             |   |    |    |    |     |   |   |
|               |  |            | 15      | SS   | 12         |                            | 239             |   |    |    |    |     |   |   |
|               |  |            | 16      | SS   | 38         |                            |                 |   |    |    |    |     |   |   |
| 238.16        |  |            |         |      |            |                            | 238             |   |    |    |    |     |   |   |
| 12.80         | SILT<br>Brown  |            | 17      | SS   | 16         |                            |                 |   |    |    |    |     |   |   |
| 12.95         | CLAYEY SILT, with silt partings<br>Stiff to very stiff<br>Brown becoming grey at about elev.<br>237.7m |            | 18      | SS   | 9          |                            | 237             |   |    |    |    |     |   | 0 2 48 50   |
| 236.63        |  |            |         |      |            |                            |                 |   |    |    |    |     |   |   |
| 14.33         | SANDY SILT, some clay, trace<br>gravel (TILL)<br>Very dense<br>Grey                                    |            | 19      | SS   | 52         |                            |                 |   |    |    |    |     |   |   |

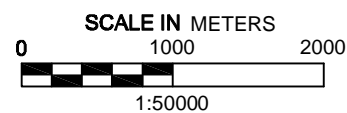
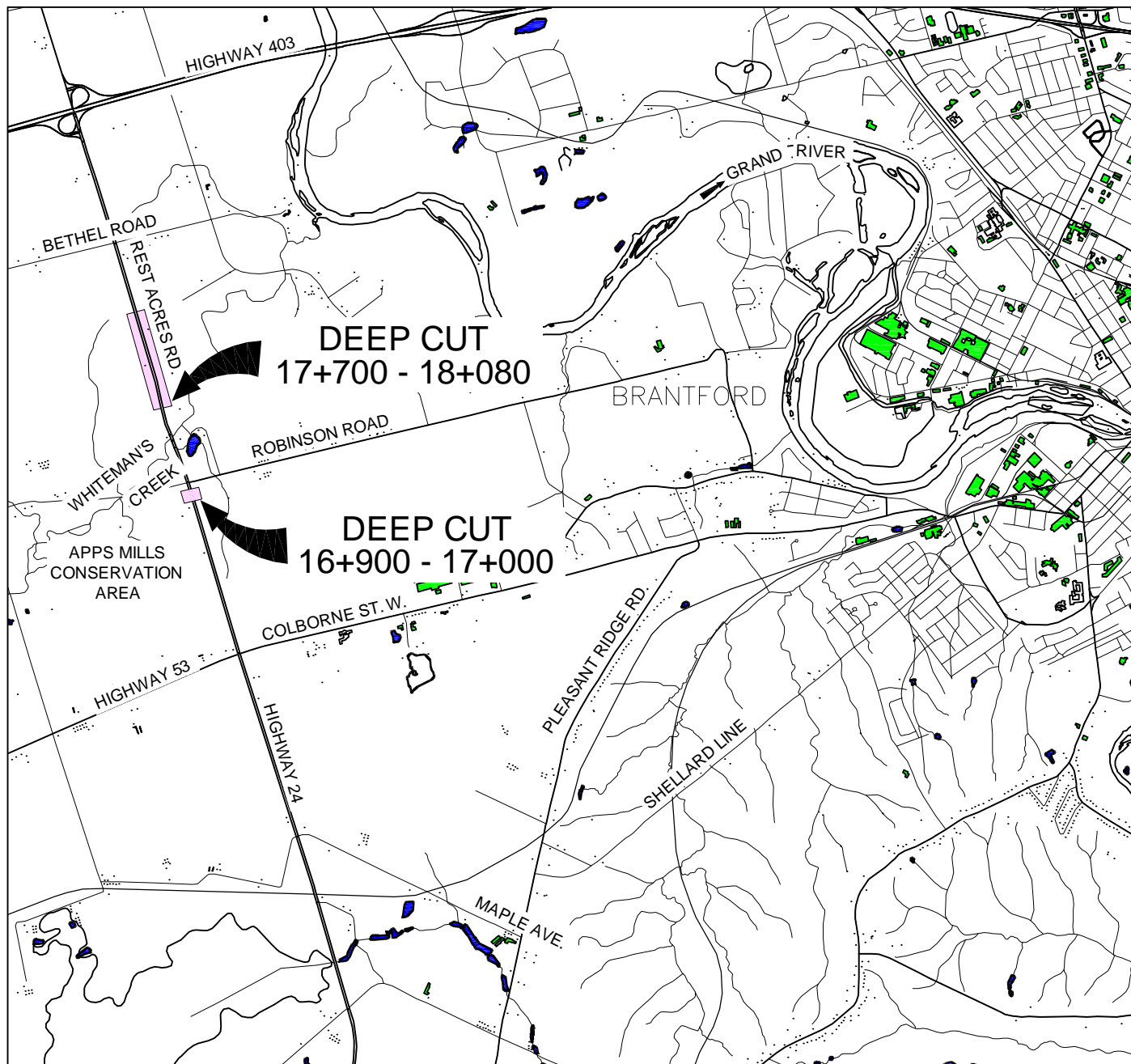
Continued Next Page


+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

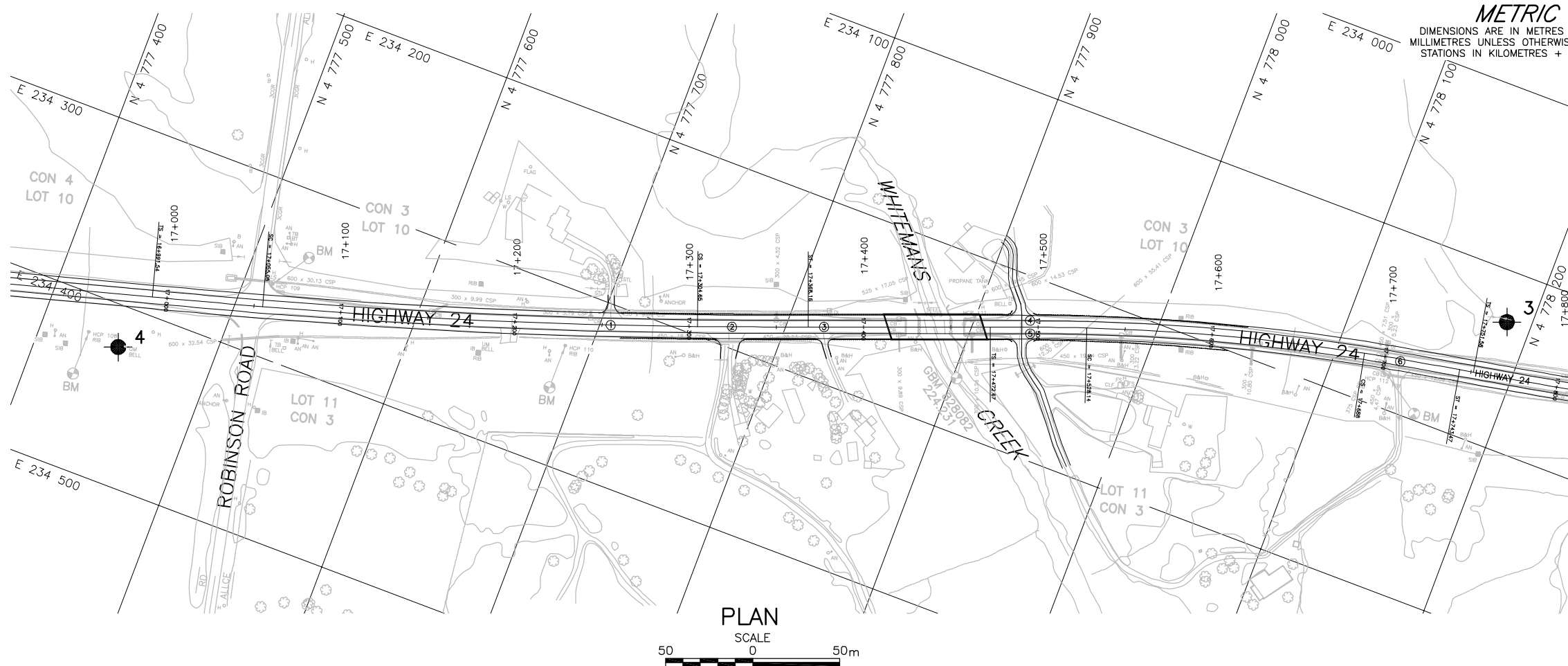
LDN\_MTO\_01 06-1130-185-2.GPJ LDN\_MTO.GDT 3/12/09





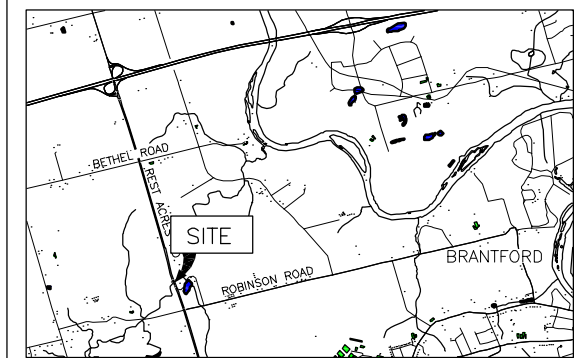


|  |  |  |         |                           |                |        |
|--|--|--|---------|---------------------------|----------------|--------|
| PROJECT  |  | DEEP CUTS<br>HIGHWAY 24 REHABILITATION<br>G.W.P. 336-97-00 |         |                           |                |        |
| TITLE  |  |  |         |                           |                |        |
| KEY PLAN   |  |  |         |                           |                |        |
| <br><b>Golder Associates</b><br>LONDON, ONTARIO |  | PROJECT No. 06-1130-185-2                                  |         | FILE No. 061130185-F02001 |                |        |
|  |  | CADD   | LMK/DCH | Nov. 7/08                 | SCALE AS SHOWN | REV. 0 |
|  |  | CHECK  |         |                           | FIGURE 1       |        |
|  |  |  |         |                           |                |        |

CONT No.  
WP No. 336-97-00HIGHWAY 24 REHABILITATION  
DEEP CUTS

SHEET

BOREHOLE LOCATION AND SOIL PROFILE

**Golder Associates Ltd.**  
LONDON, ONTARIO, CANADAKEY PLAN  
SCALE  
1000 0 1000m

## LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- DRY Borehole / Test Pit dry during drilling / excavation
- WL upon completion of drilling
- Measured WL

| No. | ELEVATION | CO-ORDINATES (MTM Zone 11) |           |
|-----|-----------|----------------------------|-----------|
|     |           | NORTHING                   | EASTING   |
| 3   | 250.96    | 4 778 183.0                | 234 128.3 |
| 4   | 244.25    | 4 777 446.1                | 234 423.3 |

## NOTES

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

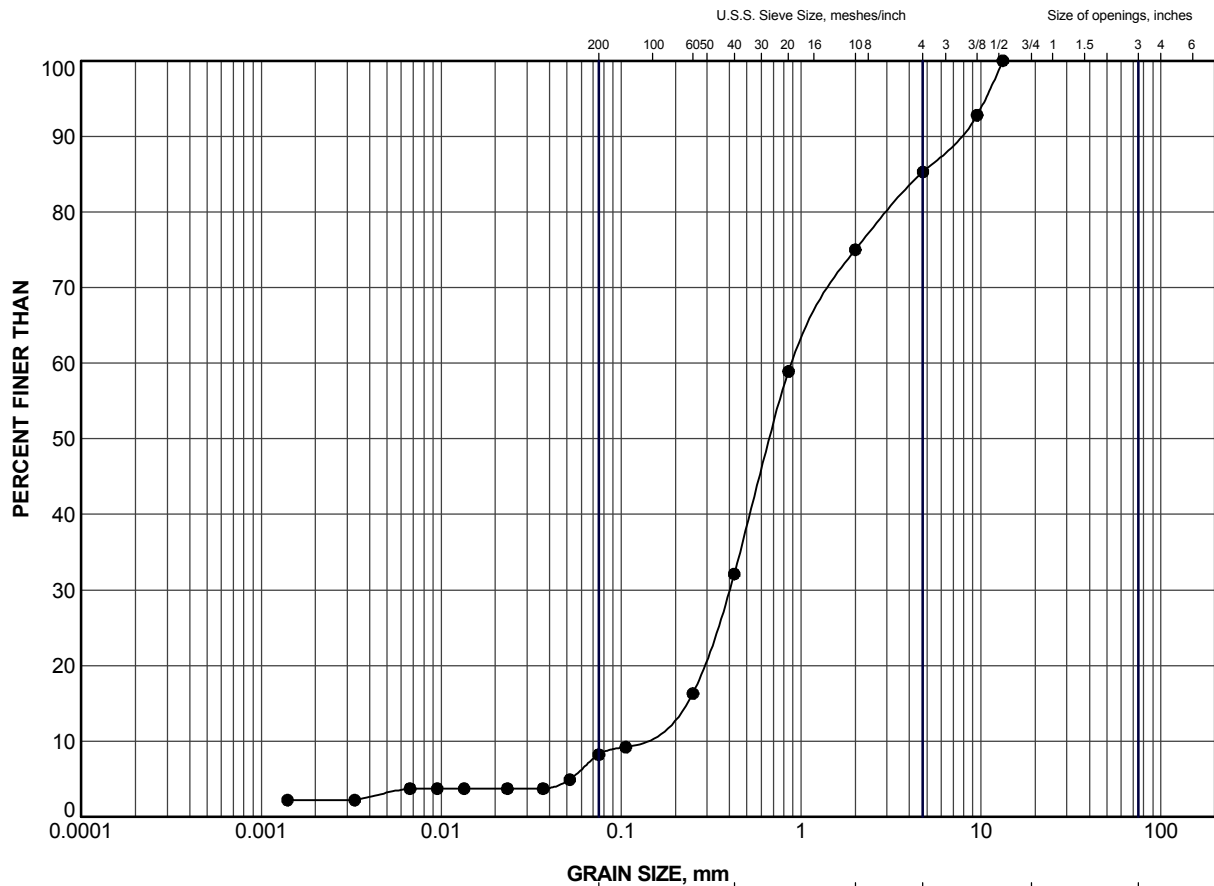
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

## REFERENCE

Base plans provided in digital format by Delcan on July 5, 2007.

| NO.         | DATE     | BY          | REVISION      |
|-------------|----------|-------------|---------------|
| Geocres No. | 40P1-101 |             |               |
| HWY.        | 24       | PROJECT NO. | 06-1130-185-2 |
| SUBM'D.     | DUP      | CHKD.       | DUP           |
| DRAWN:      | DCH/LMK  | CHKD.       | APPD.         |
|             |          | DATE:       | Mar. 9/09     |
|             |          | DIST.       | SITE:         |
|             |          | DWG.        | 1             |


**APPENDIX A**  
**LABORATORY TEST DATA**



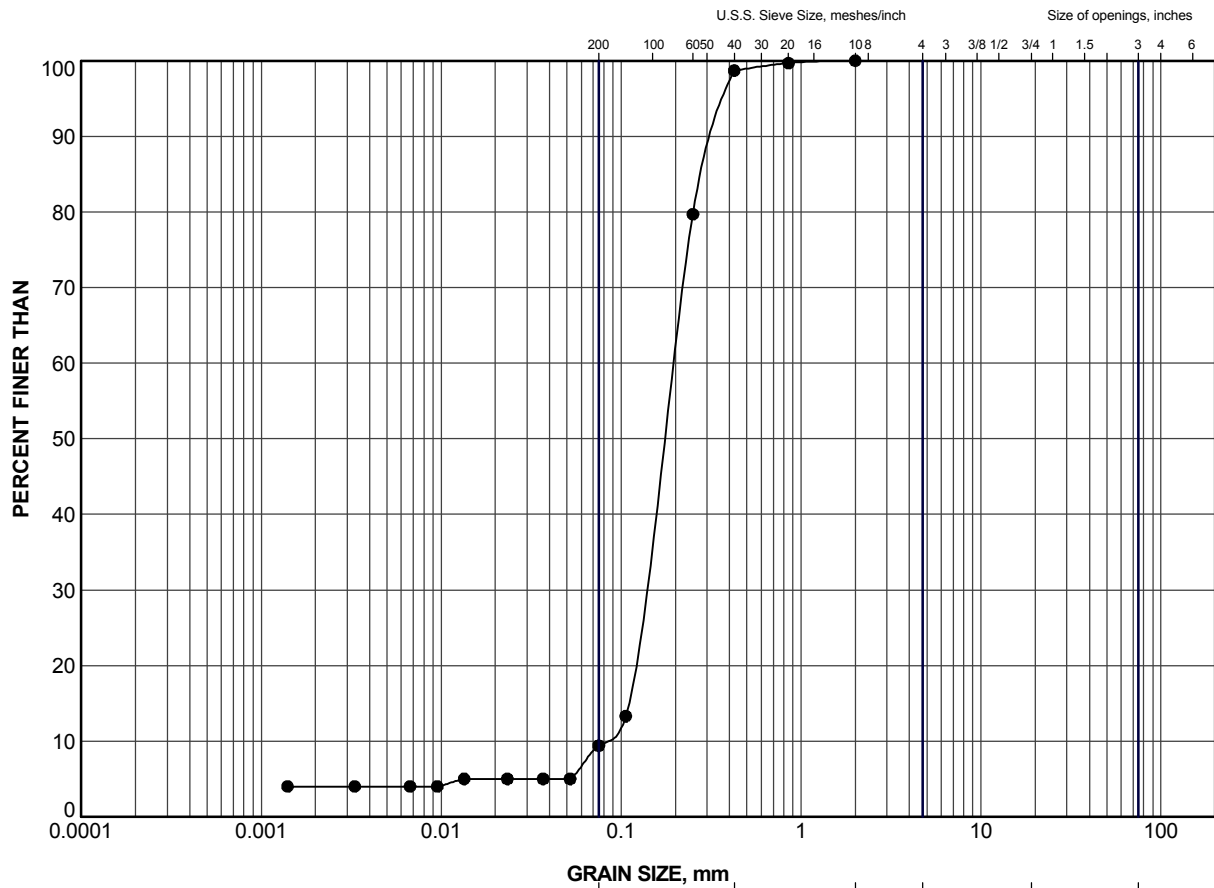
| GRAVEL SIZE, mm |           |        |        |             |        |             |
|-----------------|-----------|--------|--------|-------------|--------|-------------|
| CLAY AND SILT   | fine      | medium | coarse | fine        | coarse | Cobble Size |
|                 | SAND SIZE |        |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

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | 3        | 4      | 247.7    |

|   |  |                 |  |   |  |                    |  |
|---|--|-----------------|--|---|--|--------------------|--|
| PROJECT   |  |                 |  | DEEP CUTS<br>HIGHWAY 24 REHABILITATION<br>G.W.P 336-97-00 |  |                    |  |
| TITLE   |  |                 |  | GRAIN SIZE DISTRIBUTION<br>SAND, some gravel              |  |                    |  |
| PROJECT No.   |  | 06-1130-185-2-2 |  | FILE No.  |  | 061130185-2-F020A1 |  |
| DRAWN   |  | BRS             |  | Oct 27/08   |  | SCALE N/A          |  |
| CHECK   |  |                 |  |   |  | REV.               |  |
|  <b>Golder Associates</b><br>LONDON, ONTARIO |  |                 |  | <b>FIGURE A-1</b>   |  |                    |  |






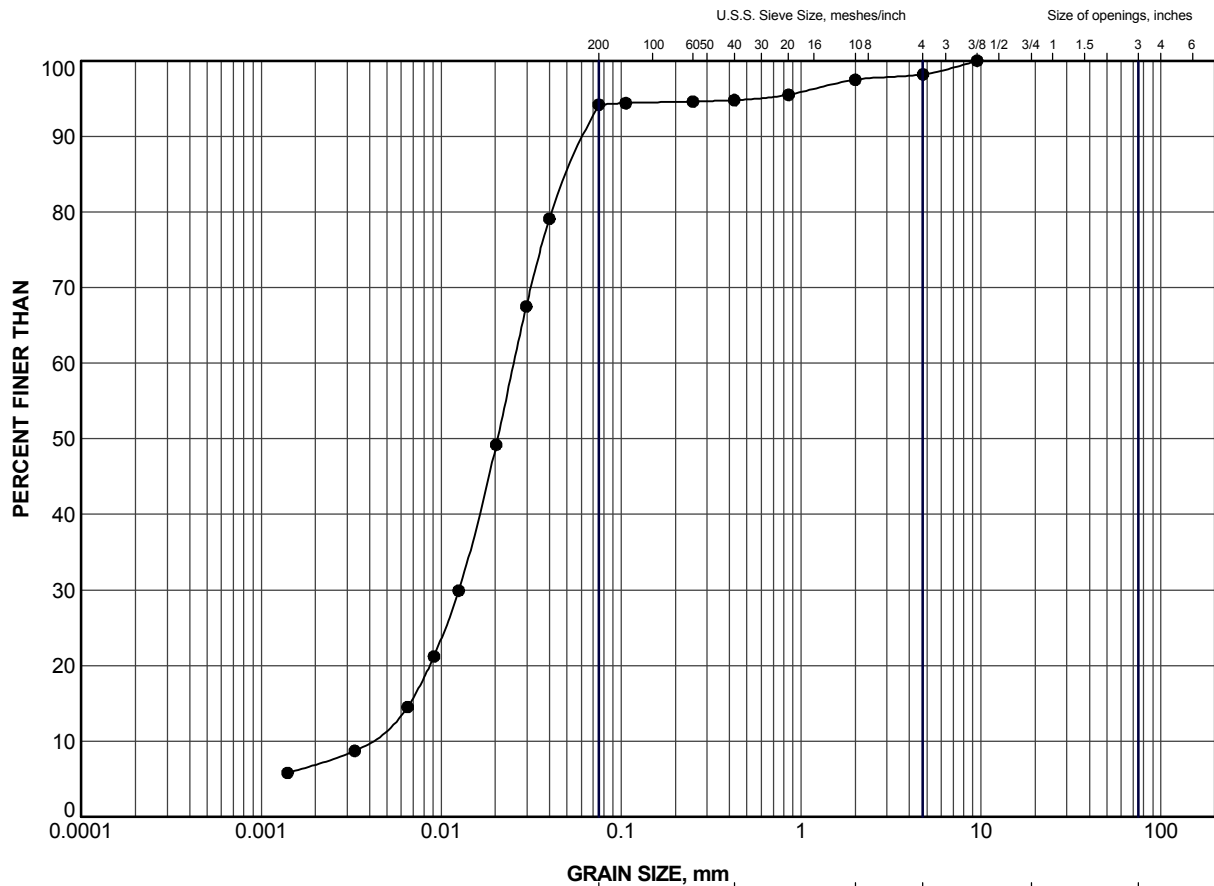
|               |                 |        |        |             |        |                |
|---------------|-----------------|--------|--------|-------------|--------|----------------|
| CLAY AND SILT | GRAVEL SIZE, mm |        |        |             |        | Cobble<br>Size |
|               | fine            | medium | coarse | fine        | coarse |                |
|               | SAND SIZE       |        |        | GRAVEL SIZE |        |                |

#### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | 3        | 12     | 241.6    |

|   |  |                 |  |   |  |                    |  |
|---|--|-----------------|--|---|--|--------------------|--|
| PROJECT   |  |                 |  | DEEP CUTS<br>HIGHWAY 24 REHABILITATION<br>G.W.P 336-97-00 |  |                    |  |
| TITLE   |  |                 |  | GRAIN SIZE DISTRIBUTION<br>FINE SAND                      |  |                    |  |
| PROJECT No.   |  | 06-1130-185-2-2 |  | FILE No.  |  | 061130185-2-F020A2 |  |
| DRAWN   |  | BRS             |  | SCALE   |  | N/A                |  |
| CHECK   |  |                 |  | REV.  |  |                    |  |
|   |  | Oct 27/08       |  |   |  |                    |  |
|  <b>Golder Associates</b><br>LONDON, ONTARIO |  |                 |  | <b>FIGURE A-2</b>   |  |                    |  |




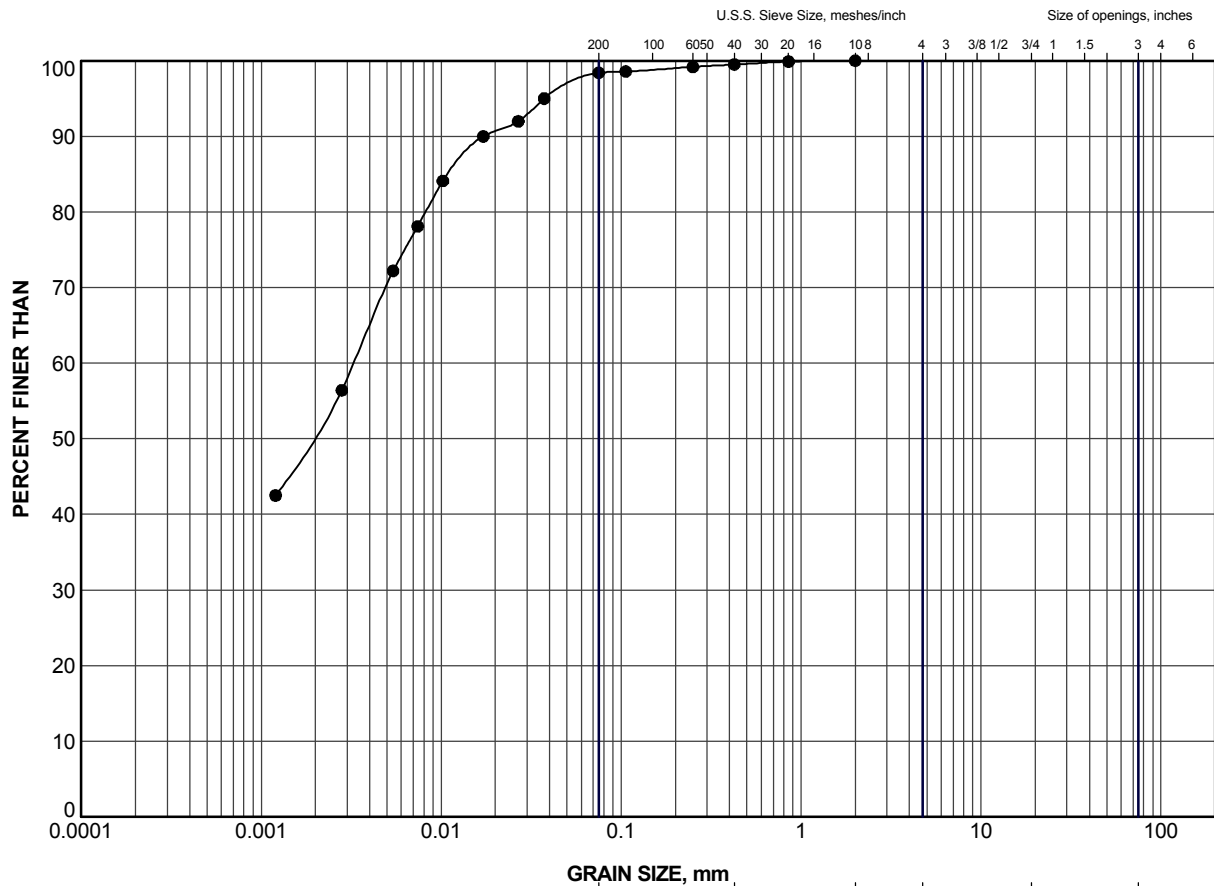


| GRAVEL SIZE, mm |           |        |        |             |        |             |
|-----------------|-----------|--------|--------|-------------|--------|-------------|
| CLAY AND SILT   | fine      | medium | coarse | fine        | coarse | Cobble Size |
|                 | SAND SIZE |        |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

#### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | 4        | 4      | 235.8    |


|  |   |                 |                             |
|--|---|-----------------|-----------------------------|
| PROJECT  | DEEP CUTS<br>HIGHWAY 24 REHABILITATION<br>G.W.P 336-97-00 |                 |                             |
| TITLE  | GRAIN SIZE DISTRIBUTION<br>SILT                           |                 |                             |
|  <b>Golder Associates</b><br>LONDON, ONTARIO | PROJECT No.   | 06-1130-185-2-2 | FILE No. 061130185-2-F020A4 |
|  | DRAWN   | BRS             | Oct 27/08                   |
|  | CHECK   |                 |                             |
|  |   |                 | SCALE N/A REV.              |
|  |   |                 | <b>FIGURE A-4</b>           |



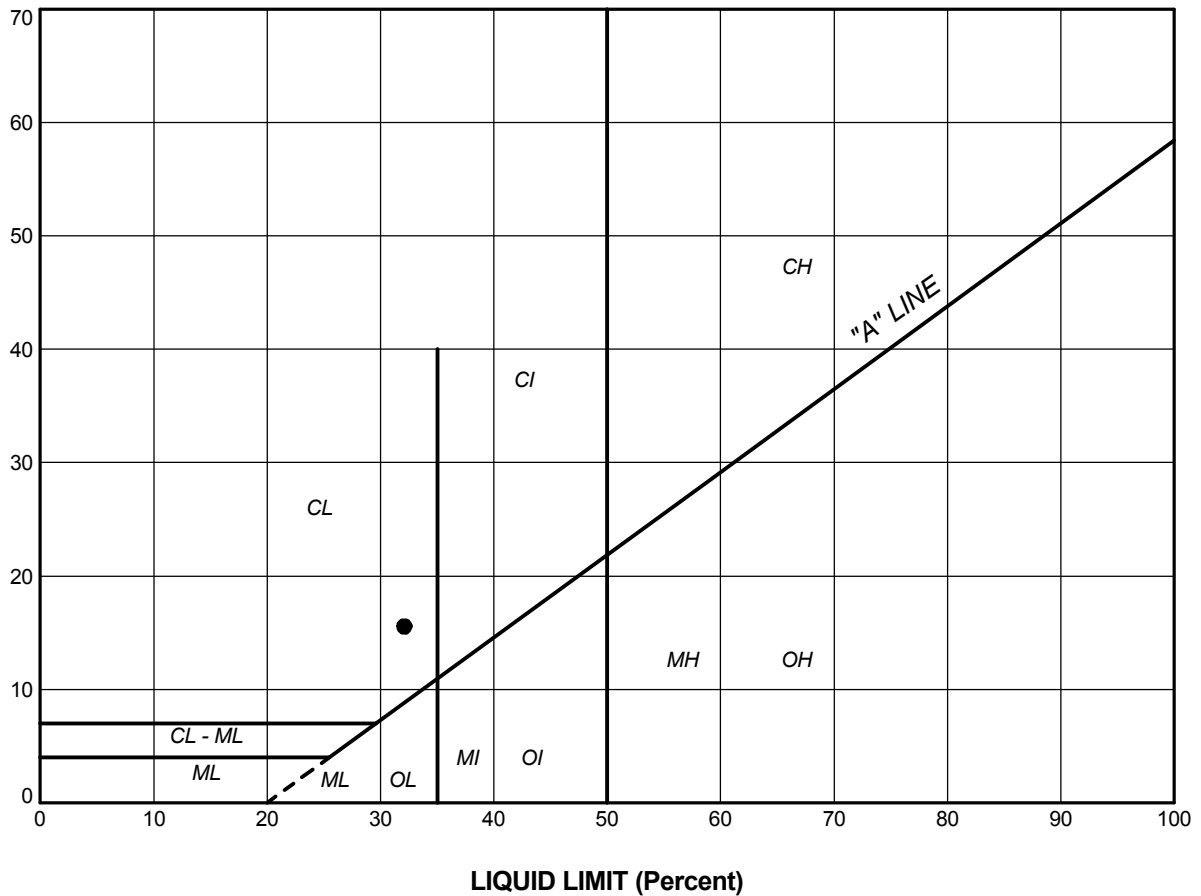
| GRAVEL SIZE, mm |           |        |        |             |        |             |
|-----------------|-----------|--------|--------|-------------|--------|-------------|
| CLAY AND SILT   | fine      | medium | coarse | fine        | coarse | Cobble Size |
|                 | SAND SIZE |        |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

#### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ●      | 3        | 18     | 237.0    |

|   |  |                 |  |   |  |                    |  |
|---|--|-----------------|--|---|--|--------------------|--|
| PROJECT   |  |                 |  | DEEP CUTS<br>HIGHWAY 24 REHABILITATION<br>G.W.P 336-97-00 |  |                    |  |
| TITLE   |  |                 |  | GRAIN SIZE DISTRIBUTION<br>CLAYEY SILT                    |  |                    |  |
| PROJECT No.   |  | 06-1130-185-2-2 |  | FILE No.  |  | 061130185-2-F020A5 |  |
| DRAWN   |  | BRS             |  | SCALE   |  | N/A                |  |
| CHECK   |  | Oct 27/08       |  | REV.  |  |                    |  |
|  <b>Golder Associates</b><br>LONDON, ONTARIO |  |                 |  | <b>FIGURE A-5</b>   |  |                    |  |

PLASTICITY INDEX (Percent)




**SOIL TYPE**  
C = Clay  
M = Silt  
O = Organic

**PLASTICITY**  
L = Low  
I = Intermediate  
H = High

### LEGEND

| SYMBOL | BOREHOLE | SAMPLE | LL(%) | PL(%) | PI   |
|--------|----------|--------|-------|-------|------|
| ●      | 3        | 18     | 32.1  | 16.6  | 15.6 |

|  |     |   |                   |
|--|-----|---|-------------------|
| PROJECT  |     | DEEP CUTS<br>HIGHWAY 24 REHABILITATION<br>G.W.P 336-97-00 |                   |
| TITLE  |     | PLASTICITY CHART  |                   |
| PROJECT No. 06-1130-185-2-2  |     | FILE No. 061130185-2-F020A6                               |                   |
| DRAWN  | DCH | Oct 27/08   | SCALE N/A         |
| CHECK  |     |   | REV.              |
|  <b>Golder Associates</b><br>LONDON, ONTARIO |     |   | <b>FIGURE A-6</b> |