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Golder Associates

# FOUNDATION INVESTIGATION AND DESIGN REPORT
## RUSCOM RIVER BRIDGE WIDENING
## SITE 6-88
## HIGHWAY 401 RECONSTRUCTION
## GWP 63-00-00, AGREEMENT NO. 3004-E-0006
## MINISTRY OF TRANSPORTATION - SOUTHWESTERN REGION

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## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundations engineering services as part of the detail design work for the section of Highway 401 described by GWP 63-00-00. This section of Highway 401 is some 9.9 kilometres in length and extends from 2.5 kilometres east of Essex Road 27 easterly to 1.2 kilometres west of Highway 77 in the Township of Lakeshore, County of Essex, Ontario.

The purpose of this portion of the foundation investigation was to determine the subsurface conditions for the widening of the Ruscom River bridge by drilling boreholes, carrying out in-situ tests and laboratory tests on selected samples. In addition, the relevant background information collected by others was reviewed. The terms of reference for the scope of work are outlined in the MTO's request for proposal and in Golder Associates proposal P41-3106, dated December 24, 2004 and letter dated June 27, 2005. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering Detail Design Services dated March 9, 2005.

## 2.0 SITE DESCRIPTION

### 2.1 General

GWP 63-00-00 comprises the reconstruction and widening of some 9.9 kilometres of Highway 401 extending from 2.5 kilometres east of Essex Road 27 in the Township of Rochester easterly to 1.2 kilometres west of Highway 77 in the Township of Tilbury West, County of Essex, Ontario. The location of the project is shown on the Key Plan, Figure 1. The project chainage extends from Highway 401 Station 13+000, Township of Rochester to Station 12+700, Township of Tilbury West.

This report addresses the subsurface conditions for the widening of the Ruscom River bridge. The location of the bridge is shown on the Key Plan, Figure 1.

The existing structure is a single span rigid frame bridge about 42 metres long (24.4 metres between the abutments) and 30.6 metres wide. The bridge currently carries four lanes of Highway 401 traffic (two in each direction) over the Ruscom River. In each direction, two 3.35 metre wide lanes with 3.58 metre outer shoulders and 4.57 metre wide inner shoulders are present. Based on the information provided, the existing spread footings for the bridge are at about elevation 176.5 metres and the bridge deck is at about elevation 184 metres.

### 2.2 Site Geology

The project lies within the Essex Clay Plain, a subregion of the physiographic region of southern Ontario known as the St. Clair Clay Plains, identified in "The Physiography of Southern Ontario" by Chapman and Putnam (1984). The clay plain is described as a till plain that has been smoothed by shallow deposits of lacustrine clay which settled in the depressions of the till. The prevailing soil type is reportedly the Brookston clay.

Based on the Ontario Department of Mines and Northern Affairs Preliminary Maps P.749 and P.750 entitled "Quaternary Geology of the Windsor-Essex Area" Western and Eastern Parts, respectively, the project area is reportedly located in predominantly clayey silt till. The mapping also indicates that unsubdivided modern alluvium is present in the river channel area.

Based on the available bedrock geology mapping, the subcropping bedrock consists of limestone of the Dundee formation of Middle Devonian age.

## 3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between July 29 and August 4, 2005 at which time three boreholes were drilled at the locations indicated on the Location Plan, Drawing 1. Borehole 2A was drilled to obtain additional shear strength data and a thin walled tube sample from the softer zone of clayey soil identified in borehole 2.

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

| BOREHOLE | LOCATIONS (m) Northing | LOCATIONS (m) Easting | GROUND SURFACE ELEVATION (m) | BOREHOLE DEPTH (m) |
|---|---|---|---|---|
| 1 | 4676968 | 295168 | 181.17 | 11.13 |
| 2 | 4676968 | 295202 | 181.55 | 34.14 |
| 2A | 4676968 | 295200 | 181.55 | 7.32 |

The soil stratigraphy encountered in the boreholes is shown on the attached Record of Borehole sheets and on Drawings 1 and 2.

The boreholes were advanced using an all terrain vehicle mounted power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at suitable intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures and thin walled tube samples were obtained for laboratory consolidation testing. In situ vane testing was carried out, where feasible, within the cohesive strata. Where bedrock was encountered in borehole 2, the borehole was advanced in to the bedrock using mud rotary tricone techniques. Groundwater conditions were observed in the boreholes throughout the drilling operations. All of the boreholes were backfilled in accordance with current regulations and MTO recommended procedures.

The field work was supervised on a full-time basis by an experienced member of our engineering staff who arranged for underground 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 routine testing. Index and classification tests consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations were carried out on selected samples. Selected thin walled tube samples were transported to Golder Associates' Mississauga laboratory for consolidation testing. 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, Book 7, dated March 2001.

The locations of the boreholes are indicated on the Record of Borehole sheets and are shown on Drawing 1, attached.

In addition, the results of a previous investigation carried out by Peto MacCallum Ltd. for the proposed widening of the Ruscom River bridge have been included in this report. The relevant boreholes are identified as:

- Boreholes 88-1, 88-2, 88-3 and 88-4 from Peto MacCallum Ltd. Report No. 01TF073H entitled "Foundation Investigation Report for Widening of Ruscom River Bridge, G.W.P. 60-00-00, Site 6-88, Highway 401, Town of Lakeshore, Ontario", dated November 2002, MTO Geocres No. 40J2-51.

The records of these boreholes are provided in Appendix B. The boreholes were drilled between May 7 and May 9, 2002 to depths of 9.6 metres. The approximate locations of these boreholes are shown on Drawing 1 and the subsurface conditions encountered in the boreholes have been included on Drawings 1 and 2.

## 4.0 SUBSURFACE CONDITIONS

### 4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are provided on the attached Record of Borehole sheets following the text of this report and in Appendices A and B. 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. Further, the subsurface conditions may vary significantly between and beyond the borehole locations.

In summary, the boreholes drilled for the Ruscom River bridge widening encountered topsoil and fill materials, stiff to hard silty clay till with layers of clayey silt, sand and sandy silt, overlying a stratum of firm to stiff silty clay and bedrock.

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 Materials

Topsoil was encountered at ground surface in boreholes 1 and 2. The topsoil was about 0.1 to 0.2 metres thick at the borehole locations.

Beneath the topsoil in borehole 2 and at ground surface in boreholes 88-1 through 88-4, inclusive, stiff to very stiff fill materials were encountered. The fill materials consisted of clayey silt and silty clay and were 1.4 to 2.6 metres thick at the borehole locations. The fill had N values, as determined in the standard penetration testing, of 9 to 18 blows per 0.3 metres with in situ water contents of 14 to 30 per cent with an average water content of about 22 per cent.

Buried topsoil was encountered beneath the fill in borehole 88-3 at elevation 179.4 metres. The topsoil was about 0.4 metres thick and had an N value of 9 blows per 0.3 metres.

#### 4.1.2 Silty Clay Alluvium

A layer of soft to firm silty clay was encountered beneath the buried topsoil in borehole 88-3 at elevation 179.0 metres. The silty clay was about 1.5 metres thick and had N values of 4 to 7 blows per 0.3 metres and water contents of 23 to 26 per cent.

#### 4.1.3 Clayey Silt

A layer of stiff clayey silt about 1.5 metres thick was encountered beneath the fill in borehole 2 at elevation 179.5 metres. The clayey silt had N values of 11 to 12 blows per 0.3 metres and a natural water content of 16 per cent.

#### 4.1.4 Clayey Silt Till

Hard clayey silt till was encountered beneath the silty clay till in borehole 88-2 at elevation 179.1 metres. The clayey silt till was about 0.8 metres thick at the borehole location. The clayey silt till had an N value of 30 blows per 0.3 metres with a natural water content of 13 per cent.

#### 4.1.5 Silty Clay Till

Firm to hard silty clay till was encountered beneath the topsoil in borehole 1, beneath the clayey silt in borehole 2, beneath the fill in boreholes 88-1, 88-2 and 88-4, beneath the silty clay alluvium in borehole 88-3 and beneath the clayey silt till in borehole 88-2. The surface of the till was encountered between elevations 177.5 and 181.1 metres. Where fully penetrated in boreholes 1 and 2, the silty clay till was 4.3 to 6.6 metres thick. Boreholes 88-1 through 88-4, inclusive, were terminated in the silty clay till after exploring it for 6.0 to 7.7 metres. The silty clay till had N values of 5 to 32 blows per 0.3 metres with natural water contents of 14 to 24 per cent with an average water content of 20 per cent. Grain size distribution curves for the samples of the silty clay till recovered from the standard penetration testing are shown on Figure A-1. The silty clay till had corresponding average plastic and liquid limits of 20 and 41 per cent, respectively, based on five Atterberg limits determinations. The silty clay till is identified on the Plasticity Chart, Figure A-3, as an inorganic clay of low to intermediate plasticity.

The results of the laboratory consolidation testing carried out on sample 1 from borehole 2A are provided on Figures A-4 to A-6. The results indicate that the silty clay till is overconsolidated some 320 kilopascals (kPa) beyond the existing overburden pressure. The following table summarizes the relevant oedometer test results.

| BOREHOLE AND SAMPLE | DEPTH (m) | $\sigma'_{po}$ (kPa) | $\sigma'_{p}$ (kPa) | $\sigma'_{Pc} - \sigma'_{Po}$ (kPa) | OCR | $e_o$ | $C_r$ | $C_c$ | $C_v$ (cm²/sec) |
|---|---|---|---|---|---|---|---|---|---|
| 2A - 1 | 6.1 to 6.6 | 450 | 130 | 320 | 3.5 | 0.63 | 0.06 | 0.23 | 0.025 |

#### 4.1.6 Sandy Silt

A 0.3 metre thick layer of sandy silt was encountered beneath the silty clay till in borehole 2 at elevation 173.6 metres.

#### 4.1.7 Silty Clay

Beneath the silty clay till in borehole 1 at elevation 174.5 metres and the sandy silt in borehole 2 at elevation 173.3 metres, silty clay was encountered. Borehole 1 was terminated in the silty clay after exploring it for 4.4 metres. Where fully penetrated in borehole 2, the silty clay was 23.9 metres thick. The silty clay had N values of 5 to 13 blows per 0.3 metres. In situ vane shear strength testing carried out in the silty clay till indicated undrained shear strengths of 69 to greater than 144 kPa and vane sensitivities of 1.4 to 2.4. The silty clay had natural water contents of 11 to 31 per cent with an average water content of about 22 per cent. The results of grain size distribution analyses of samples of the silty clay are shown on Figure A-2. The silty clay had corresponding average plastic and liquid limits of 16 and 31 per cent, respectively, based on four Atterberg limits determinations. The silty clay is identified on the Plasticity Chart, Figure A-3, as an inorganic clay of low to intermediate plasticity.

#### 4.1.8 Bedrock

Borehole 2 encountered and was terminated in the bedrock after exploring it for some 2.0 metres using mud rotary tricone drilling techniques. The inferred surface of the bedrock is at elevation 149.4 metres or some 32 metres below ground surface. Based on examination of the rock cuttings recovered from the mud rotary drilling, the bedrock consists of light grey limestone.

### 4.2 Groundwater Conditions

Groundwater conditions were observed in the boreholes during drilling. Groundwater was encountered in borehole 1 about 8.6 metres below ground surface or at elevation 172.9 metres during drilling on July 29, 2005. Borehole 2 remained dry during drilling on August 2 and 3, 2005. The groundwater was measured in the piezometer/standpipe at elevation 172.5 metres on

August 5, 2005 and elevation 173.5 metres on August 11, 2005. These elevations may not represent long-term stable groundwater levels.

Groundwater levels were not established in boreholes 88-1 and 88-2. Groundwater was encountered in boreholes 88-3 and 88-4 about 6.6 and 7.6 metres below ground surface, respectively, or between elevation 174.2 and 174.6 metres. This information is summarized below:

| BOREHOLE | GROUND SURFACE ELEVATION (m) | ENCOUNTERED GROUNDWATER ELEVATION (m) |
|---|---|---|
| 1 | 181.17 | 173.5 |
| 2 | 181.55 | Dry |
| 2A | 181.55 | Dry |
| 88-1 | 181.19 | Not established |
| 88-2 | 181.24 | Not established |
| 88-3 | 181.12 | 174.2 |
| 88-4 | 181.72 | 174.6 |

The water level in the Ruscom River was at elevation 176.75 metres during the field work. Based on the background information provided, the corresponding high river water level is at about elevation 180.9 metres.

## 5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Lantech Drilling Services Inc., 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 laboratory testing was carried out at Golder Associates' London and Mississauga laboratories under the direction of Mr. Chris M. Sewell and Dr. J. Paul Dittrich, P.Eng. The laboratories are accredited participants in the MTO Soil and Aggregate Proficiency Program and are certified by the Canadian Council of Independent Laboratories and MTO. This report was prepared by Mr. Michael E. Beadle, 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
# RUSCOM RIVER BRIDGE WIDENING
# SITE 6-88
# HIGHWAY 401 RECONSTRUCTION
# GWP 63-00-00, AGREEMENT NO. 3004-E-0006
# 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 widening of the Ruscom River bridge. The recommendations are based on our interpretation of the factual information obtained during the investigation and on the available background information collected by others. 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.

Based on the information provided, it is understood that it is proposed to widen the existing Ruscom River bridge structure by 2.7 metres on each side. The widening will facilitate three lanes of Highway 401 traffic in each direction. The lane configurations will consist of 3.75 metre wide outer and centre lanes, a 3.5 metre wide median lane and 3.0 metre wide outer and median shoulders in each direction. The eastbound and westbound traffic will be separated by a new concrete median barrier wall.

Based on the information provided, the existing spread footings for the rigid frame bridge are at about elevation 176.5 metres and are some 1.5 metres in width. The bridge deck is at about elevation 184 metres.

### 6.2 Bridge Foundations

The subsurface conditions encountered in the boreholes drilled during this investigation and the previous investigation typically consisted of surficial topsoil and fill overlying stiff to hard silty clay till which is, in turn, underlain by firm to stiff silty clay. Borehole 2 encountered and was terminated in the bedrock, the surface of which was encountered at elevation 149.4 metres. Groundwater was encountered in a sand layer in borehole 1 at elevation 172.5 metres during drilling.

### 6.3 Subsurface Model

As part of this assignment, selected existing Ruscom River bridge elements were surveyed and the data compared to the available design/as-built information on the drawings provided by MTO to determine the actual post construction settlements experienced by the structure. This information was utilized in conjunction with the field and laboratory data to construct a calibrated model of the settlement behaviour of the clayey soils at the site.

### 6.3.1 Survey Data

The results of the survey of the structure are summarized below:

| LOCATION | ELEVATION (m) As-Built | ELEVATION (m) Survey | SETTLEMENT (mm) |
|---|---|---|---|
| Northwest corner | 181.189 | 181.001 | 188 |
| Southwest corner | 181.184 | 181.061 | 123 |
| Northeast corner | 181.184 | 181.039 | 145 |
| Southeast corner | 181.189 | 181.019 | 170 |

The survey was carried out by the survey subconsultant, Archibald, Gray & McKay Engineering Ltd. using precise levelling techniques. The survey points correspond to the intersection of the haunch with the abutments. Since these points would not have been affected by any bridge rehabilitation works, the measured settlements are therefore considered to be a realistic quantification of the post construction structure settlements. Similar precise levelling was used for another MTO assignment to measure house settlements in a subdivision adjacent to dewatering operations for Highway 416 and provided reproducible results over several survey periods.

### 6.3.2 Field and Laboratory Data

The results of the field testing and laboratory testing are described in Section 4 of this report and details are provided on the Records of Boreholes sheets and in Appendix A.

Based on the borehole information, the general soil conditions consist of firm to hard silty clay till to about elevation 174 metres overlying firm to stiff silty clay. Bedrock was encountered at elevation 149.4 metres. Based on the information provided, the existing underside of bridge footing elevation is 176.5 metres.

A review of the laboratory oedometer test data and our analyses indicates the following settlement characteristics:

| STRATUM | ELEVATION (m) | $\sigma'_{pc}$ (kPa) | OCR | $e_o$ | $C_r$ | $C_c$ |
|---|---|---|---|---|---|---|
| Silty Clay Till | 175 to 175.5 | 450 | 3.5 | 0.63 | 0.06 | 0.23 |

The above-noted parameters were derived from the field and laboratory data, checked using empirical relationships and are also based on our previous experience in the area.

### 6.3.3 Model Calibration

The model was calibrated using the above-noted settlement parameters, the existing geometry of the bridge footings and standard stress distribution theory to calculate the theoretical long-term settlement of the existing bridge footings based on the estimated sustained bridge (SLS) loading of 400 kPa provided by Dillon.

The results of the settlement analyses of the existing structure indicated settlements of 160 millimetres which agree well with those measured. Based on this calibrated model, the SLS loading (for 25 millimetres of settlement) was calculated to be about 100 kPa.

In addition to the above, this calibrated model was utilized to calculate the anticipated settlements of the proposed widenings, taking into account the loading and settlement history as well as the original footing configuration.

## 6.4 Shallow Foundations

Based on the results of the investigation, the proposed bridge widenings could be founded on conventional spread footings at elevation 176.5 metres similar to the existing structure.

### 6.4.1 Axial Geotechnical Resistance

Based on the results of the investigation, the proposed widenings could be supported on spread footings founded at about elevation 176.5 metres on the stiff to hard silty clay till and some 3.5 metres above the firm to stiff silty clay. Spread footings constructed in this manner may be designed using a factored geotechnical resistance of 150 kPa at Ultimate Limit States (ULS). As part of this assignment, the existing bridge was surveyed and these elevations were compared to the design/as-built elevations to determine the actual settlement experienced by the structure. This information was utilized, in conjunction with the results of the field investigation and oedometer testing, to construct a calibrated model of the settlement behaviour of the clayey soils at the site.

Based on the survey data, as given above, the corners of the existing bridge have settled 125 to 190 millimetres with an average settlement of 160 millimetres. Utilizing the existing bridge footing geometry and the calibrated model, the computed geotechnical resistance at Serviceability Limit States (SLS) for the existing bridge is 100 kPa for 25 millimetres of settlement, exclusive of embankment effects. Based on the information provided, and as confirmed by the measured settlements and our calculations, the existing bridge footings are currently loaded beyond both the factored ULS and the SLS geotechnical resistances. Therefore, the proposed founding method for the new footing extensions should ensure that no additional loads are transferred to existing footings.

Assuming that the new footing extensions will be approximately 3 metres wide and 3 metres long and using the calibrated model, it is anticipated that footings proportioned in this manner will provide a geotechnical resistance at SLS of 75 kPa for 25 millimetres of settlement for footings independent from the existing footings.

Additional, settlements of the roadway platform/approaches may occur due to additional embankment widening. Modifications to the existing approach embankments could be constructed well in advance to reduce the effects of these potential additional settlements.

Alternatively, deep foundations should be utilized if the potential for differential movements and related deformations/distresses is to be minimized or eliminated.

### 6.4.2 Resistance to Lateral Forces

Resistance to lateral forces/sliding resistance between the concrete spread footings and the subsoil should be calculated in accordance with Section 6.7.5 of the CHBDC. Assuming that the founding soils are not softened/disturbed during excavation and footing construction, the following angle of friction between the concrete and the founding soils, and corresponding coefficient of friction, tan δ, may be used:

| | | |
|---|---|---|
| Footings on silty clay till | angle of friction | 28° |
| | tan δ | 0.53 |

### 6.4.3 Frost Protection

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

### 6.4.4 Construction Considerations

The founding soils are susceptible to softening upon exposure to water and the placement of a 75 millimetre thick working slab of lean concrete will be required at the base of the excavation for the footing area. The prepared 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 the footing excavation is inspected.

## 6.5 Deep Foundations

End bearing piles driven to practical refusal on the limestone bedrock at about elevation 149 metres are considered feasible to support the proposed widenings.

### 6.5.1 Geotechnical Axial Resistance

For design purposes, the factored axial geotechnical resistance at ULS for HP 310 x 110 piles driven to refusal on the bedrock may be taken as 2000 kilonewtons (kN) per pile. This value is based on the structural limitations on the pile. The bedrock is considered to be an unyielding layer and, as such, the geotechnical resistance at SLS does not apply. The pile should be equipped with a suitable driving shoe to avoid damage to the pile tip as it is seated into the bedrock and, in the case of battered piles, to avoid slipping on the surface of the bedrock during driving. These end bearing piles are the preferred option for the support of the bridge widening.

Provision should be made to re-tap the piles to confirm the set after adjacent piles have been driven in accordance with Special Provision 903S01.

### 6.5.2 Downdrag Load (Negative Skin Friction)

Some minor widening of the adjacent embankment will be required which will cause some consolidation settlement of the underlying extensive clayey deposits. The consolidation settlement is time-dependent and depends on the sequencing of construction and therefore may not completely occur during the construction period. That is, post-construction settlement of the clayey deposits may take place and settlement of the clayey soils relative to the piles will result in the development of negative skin friction acting on the piles. Therefore, negative skin friction or downdrag loads will need to be taken into account during design of the piles supporting the abutments. If the approach widenings are constructed well in advance of the piling, the downdrag loads may be eliminated. Alternatively, lightweight fill and/or bitumen coating of the piles could be considered to reduce downdrag loads; however, neither of these measures is considered to be cost effective or warranted given the small number of piles and high total capacity available.

The magnitude of the downdrag load acting on a pile is a function of the adhesion (skin friction) that develops between the pile and the clay, the surface area of the pile within the clay deposit and the loading. The load calculated in this manner is a nominal (unfactored) load. This load should be multiplied by a load factor of 1.25, as defined in the CHBDC, and included as part of the load effects acting on the pile as described in the CHBDC considering the limited height of the embankment widening. The negative skin friction is estimated to be 100 kilonewtons per pile.

### 6.5.3 Resistance to Lateral Loads

The lateral loading could be resisted fully or partially by the use of battered piles. If vertical piles are used, the resistance to lateral loading will have to be derived from the soil in front of the piles.

The piles for the abutment widening will be driven through the predominant cohesive materials. The resistance to lateral loading may be based on the following assessed values:

| SOIL TYPE | HORIZONTAL RESISTANCE VALUES (kN) PER PILE | |
|---|---|---|
| | Factored ULS | SLS |
| Silty clay/silty clay till | 100 | 35 |

Group action for lateral loading should be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor R as follows:

| *Pile Spacing in Direction of Loading, d = Pile Diameter* | *Subgrade Reaction Reduction Factor R* |
|---|---|
| 8d | 1.00 |
| 6d | 0.70 |
| 4d | 0.40 |
| 3d | 0.25 |

### 6.5.4 Frost Protection

The pile caps should be provided with a minimum of 1.2 metres of soil cover for frost protection.

## 6.6 Lateral Earth Pressures

The lateral pressures acting on the bridge abutments and associated retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls. The following recommendations are made concerning the design of the abutments, in accordance with the CHBDC:

- Select, free-draining granular fill meeting the specifications of Ontario Provincial Standard Specifications (OPSS) Granular A or Granular B with less than 5 per cent passing the 200 sieve should be used as backfill behind the abutments and walls. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the abutment granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSD 3501.00 and 3504.00.

- A compaction surcharge equal to 12 kPa should be included in the lateral earth pressures for the structural design of the abutment wall, in accordance with CHBDC Figure 6.9.3. Compaction equipment should be used in accordance with OPSS 501.06.
- The granular fill may be placed either in a zone with a width equal to at least 1.2 metres behind the back of the stem (Case i from Commentary on CHBDC Figure C6.9.1(l)) or within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical extending up and back from the rear face of the footing (Case ii from Commentary on CHBDC Figure C6.9.1(l)).
- For Case i, the pressures are based on the embankment/approach fill materials and the following parameters (unfactored) may be assumed for granular fill:

| | |
|---|---|
| Soil unit weight: | 21 kN/m$^3$ |
| Coefficients of lateral earth pressure: | |
| Active, $K_a$ | 0.33 |
| At rest, $K_o$ | 0.50 |

- For Case ii, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

| | GRANULAR A | GRANULAR B (Type III) |
|---|---|---|
| Soil unit weight: | 22 kN/m$^3$ | 21 kN/m$^3$ |
| Coefficients of lateral earth pressure: | | |
| Active, $K_a$ | 0.27 | 0.31 |
| At rest, $K_o$ | 0.43 | 0.47 |

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures may be used in the geotechnical design of the structure. If the wall support does not allow lateral yielding, at rest earth pressures should be assumed for geotechnical design.

It should be noted that the above design parameters assume level backfill and ground surface behind the wall.

### 6.7 Embankments

Widening of the existing approaches will be required to accommodate the new Highway 401 cross-section. Based on the design drawings provided by Dillon, the widenings will be about 3 metres on each side with final side slope inclinations of about 2.7 horizontal to 1 vertical. Utilizing this data, and assuming that about 1 metre of fill will be required to construct the widening, some 50 millimetres of total settlement of the widenings and adjacent pavements are anticipated. The magnitude of the settlement of the new embankment and the loading effect on the existing footings could be reduced by the use of lightweight fill, such as expanded polystyrene, for example.

Based on the embankment geometry provided, stability analyses were carried out. The results of our analyses indicate that embankments constructed as outlined above will have a long-term factor of safety of greater than 1.3.

The widening should be constructed by removing the existing shoulder pavement structure, together with the associated stripping of the topsoil from ditch areas, filling to subgrade level with approved, compacted earth borrow, and constructing the new pavement and shoulder structures. Where subexcavation depths vary, such as towards the ditches, the new fill should be benched into the existing soils in accordance with OPSS 200 series.

### 6.8 Excavations and Temporary Cut Slopes

Excavations for pile cap construction and/or spread footings will extend through the existing fill materials and will encounter clayey silt and silty clay till. Based on the subsurface conditions encountered in the boreholes, it is not likely that excavations will encounter groundwater. Temporary open cut slopes should be maintained no steeper than 1 horizontal to 1 vertical.

Some surficial water seepage into the excavations should be expected, and will be heavier during periods of sustained precipitation. Pumping from well filtered sumps located at the base of the excavations may be required to provide groundwater control during foundation construction. 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 roadway protection 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 or driven steel sheet piling. Support to the 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.

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.

The temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision 539S01. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 539S01.

All excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Ontario Occupational Health and Safety Act and Regulations For Construction Projects. The surficial topsoil and fill materials at this site would be classified as Type 3 soils and the underlying native cohesive soils deposits would be classified as Type 2 soils.

## 7.0 MISCELLANEOUS

This report was prepared by Mr. Michael E. Beadle, 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.**

Michael E. Beadle, P. Eng.
Senior Geotechnical Engineer

Philip R. Bedell, P. Eng.
Principal

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

MEB/PRB/FJH/cr
n:\active\2005\1130 - geotechnical\1130-000\05-1130-031-1 dillon - foundation eng - hwy 401\reports\foundation reports\05-1130-031-1-1\dec 20 05 (final)- ruscom river bridge.doc

# LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole", on the figures and in the text of the report, are as follows:

## I. SAMPLE TYPES

| | |
|---|---|
| *AS* | auger sample |
| *CS* | chunk sample |
| *DO* | drive open |
| *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 |
| *SS* | split spoon |

## II. PENETRATION RESISTANCES

Dynamic Penetration Resistance:
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 0.3 m (12 in.).

Standard Penetration Resistance, 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.) drive open sampler for a distance of 0.3 m (12 in.).

*WH* sampler advanced by static weight-weight, hammer

*PH* sampler advanced by hydraulic force

*PM* sampler advanced by manual force

## III. SOIL DESCRIPTION

### (a) *Cohesionless Soils*

| Relative Density | "N" Blows/0.3 m or Blow/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 | "Cu" = "Su" kPa | psf. |
|---|---|---|
| Very soft | 0 to 12 | 0 to 250 |
| Soft | 12 to 25 | 250 to 500 |
| Firm | 25 to 50 | 500 to 1000 |
| Stiff | 50 to 100 | 1000 to 2000 |
| Very stiff | 100 to 200 | 2000 to 4000 |
| Hard | over 200 | over 4000 |

## IV. SOIL TESTS

| | |
|---|---|
| *C* | consolidation test |
| *H* | hydrometer analysis |
| *M* | sieve analysis |
| *MH* | combined analysis, sieve and hydrometer [1] |
| *Q* | undrained triaxial [2] |
| *R* | consolidated undrained triaxial [2] |
| *S* | drained triaxial |
| *U* | unconfined compression |
| *V* | field vane test |
| *Chem* | chemical analysis |

NOTES:

1. Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.
2. Undrained triaxial tests in which pore pressures are measured are shown as Q or R.

# LIST OF SYMBOLS

## I. GENERAL

$\pi = 3.1416$
e = base of natural logarithms 2.7183
$\log_e$ a or ln a, natural logarithm of a
$\log_{10}$ a or log a, logarithm of a to base 10

| | |
|---|---|
| $t$ | time |
| $g$ | acceleration due to gravity |
| V | volume |
| W | weight |
| m | mass |
| M | moment |
| F | factor of safety |

## II. STRESS AND STRAIN

| | |
|---|---|
| u | pore pressure |
| $\sigma$ | normal stress |
| $\sigma'$ | normal effective stress ($\sigma$ is also used) |
| $\tau$ | shear stress |
| $\varepsilon$ | linear strain |
| $\varepsilon_{sy}$ | shear strain |
| $\upsilon$ | Poisson's ration ($\mu$ is also used) |
| E | modulus of linear deformation (Young's modulus) |
| G | modulus of shear deformation |
| K | modulus of compressibility |
| $\eta$ | coefficient of viscosity |

## III. SOIL PROPERTIES

### (a) *Unit weight*

| | |
|---|---|
| $\gamma$ | unit weight of soil (bulk density) |
| $\gamma_s$ | unit weight of solid particles |
| $\gamma_w$ | unit weight of water |
| $\gamma_d$ | unit dry weight of soil (dry density) |
| $\gamma'$ | unit weight of submerged soil |
| $G_s$ | specific gravity of solid particles $G_s = \gamma_s/\gamma_w$ |
| e | void ratio |
| $n$ | porosity |
| $w$ | water content |
| $S_r$ | degree of saturation |

### (b) *Consistency*

| | |
|---|---|
| $w_L$ | liquid limit |
| $w_P$ | plastic limit |
| $I_P$ | plasticity index |
| $w_S$ | 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 |
| $D_r$ | relative density = $(e_{max} - e)/(e_{max} - e_{min})$ |

### (c) *Permeability*

| | |
|---|---|
| $h$ | hydraulic head or potential |
| $q$ | rate of discharge |
| $v$ | velocity of flow |
| $i$ | hydraulic gradient |
| $\kappa$ | coefficient of permeability |
| $j$ | seepage force per unit volume |

### (d) *Consolidation (one-dimensional)*

| | |
|---|---|
| $m_v$ | coefficient of volume change $= -\Delta e/(1+e)\Delta\sigma'$ |
| $C_c$ | compression index = $-\Delta e/\Delta \log_{10}\sigma'$ |
| $c_v$ | coefficient of consolidation |
| $T_F$ | time factor = $c_v t/d^2$ (d, drainage path) |
| U | degree of consolidation |

### (e) *Shear strength*

| | | |
|---|---|---|
| $\tau_f$ | shear strength | in terms of effective stress $\tau_f = c' + \sigma'\tan\phi$ |
| $c'$ | effective cohesion intercept | |
| $\phi'$ | effective angle of shearing resistance, or friction | |
| $S_u$ | apparent cohesion* | in terms of total stress $\tau_f = cu + \sigma\tan\phi_u$ |
| $\phi_u$ | apparent angle of shearing resistance, or friction | |
| $\mu$ | coefficient of friction | |
| $S_t$ | sensitivity | |

*For the case of a saturated cohesive soil, $\phi_u = 0$ and the undrained shear strength $\tau_f = S_u$ is taken as half the undrained compressive strength.

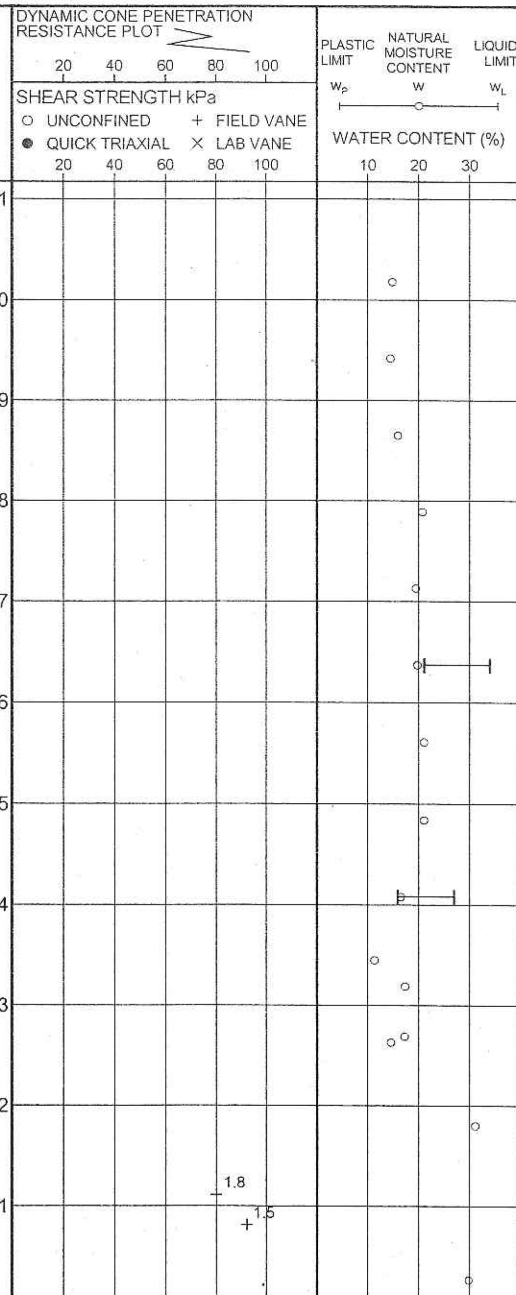
Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 1

 **METRIC**

PROJECT 05-1130-031-1-1
G.W.P. 63-00-00 LOCATION N 4676968.0 ;E 295168.0 ORIGINATED BY MA
DIST 1 HWY 401 BOREHOLE TYPE POWER AUGER/HOLLOW STEM AUGERS COMPILED BY DCH
DATUM GEODETIC DATE July 29, 2005 CHECKED BY [signature]

| ELEV / DEPTH | SOIL PROFILE – DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 181.17 | GROUND SURFACE | | | | | |
| 0.08 | **TOPSOIL**, clayey, brown<br>**SILTY CLAY**, trace sand, trace **(TILL)**,<br>Stiff to Very Stiff,<br>Brown becoming grey at 3.6m depth | | | | 181 | |
| | | 1 | SS | 22 | 180 | |
| | | 2 | SS | 25 | | |
| | | 3 | SS | 19 | 179 | |
| | | 4 | SS | 11 | 178 | |
| | | 5 | SS | 10 | 177 | |
| | | 6 | SS | 14 | | 1 11 44 44 |
| | | 7 | SS | 13 | 176 | |
| | | 8 | SS | 10 | 175 | |
| 174.46<br>6.71 | **SILTY CLAY**, trace sand, gravel with fine sand layers,<br>Stiff,<br>Grey | 9 | SS | 13 | 174 | 1 12 48 39 |
| 173.25<br>7.92 | **SAND** fine, trace silt,<br>Compact,<br>Grey | 10 | SS | 16 | 173 | |
| 172.57<br>8.60 | **SILTY CLAY**, trace sand, trace gravel,<br>Firm to Very Stiff,<br>Grey | 11 | SS | 7 | | |
| | | 12 | SS | 6 | 172 | |
| | | | | | 171 | |
| | | 13 | SS | 8 | | |
| 170.04<br>11.13 | END OF BOREHOLE<br><br>Groundwater encountered during drilling at elevation 172.94m July 29, 2005<br><br>Groundwater measured at elevation 172.54m Aug. 4, 2005<br><br>Groundwater measured at elevation 173.52m Aug. 11, 2005 | | | | | |




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

Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 2

 **METRIC**

PROJECT 05-1130-031-1-1
G.W.P. 63-00-00 LOCATION N 4676968.0 ;E 295202.0 ORIGINATED BY MA
DIST 1 HWY 401 BOREHOLE TYPE POWER AUGER/HOLLOW STEM AUGERS - WASH BORING/NW CASING COMPILED BY DCH
DATUM GEODETIC DATE August 2, 2005 - August 3, 2005 CHECKED BY [signature]

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × 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

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|
| 181.55 | GROUND SURFACE | | | | | | | |
| 0.00 | **TOPSOIL**, clayey, brown | | | | | | | |
| 0.18 | **FILL** clayey silt, trace to some sand, trace gravel, Stiff to Very Stiff, Brown and grey | 1 | SS | 18 | | | | |
| | | 2 | SS | 13 | | | | |
| 179.42 / 2.13 | **CLAYEY SILT**, trace sand, trace gravel, Stiff, Brown | 3 | SS | 12 | | | | |
| | | 4 | SS | 11 | | | | |
| 177.89 / 3.66 | **SILTY CLAY**, trace sand, trace gravel, **(TILL)**, Stiff to Very Stiff, Brown to grey at about 4.4m depth | 5 | SS | 17 | | | | |
| | | 6 | SS | 18 | 1 | 12 | 43 | 44 |
| | | 7 | SS | 15 | 1 | 12 | 43 | 44 |
| | | 8 | SS | 10 | | | | |
| | | 9 | SS | 10 | | | | |
| 173.63 | | 10 | TO | PH | | | | |
| 7.92 | **SANDY SILT**, trace gravel, grey | | | | | | | |
| 173.32 / 8.23 | **SILTY CLAY**, trace sand with fine sand layers, Stiff, Grey | 11 | SS | 14 | | | | |
| 172.56 / 8.99 | **SILTY CLAY**, trace sand , trace gravel, Firm to Stiff, Grey | 12 | SS | 6 | 1 | 25 | 54 | 28 |
| | | 13 | SS | 6 | | | | |
| | | 14 | TO | PH | | | | |
| | | 15 | SS | 9 | | | | |

Plot annotations: liquid limit values 42 (sample 6) and 43 (sample 7); field vane sensitivities 2.0, 1.6, 1.5, 1.4, 1.8, 2.0.

Elevation scale: 181, 180, 179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169, 168, 167

Continued Next Page

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

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London, Ontario

# RECORD OF BOREHOLE No 2

 **METRIC**

PROJECT 05-1130-031-1-1
G.W.P. 63-00-00
DIST 1 HWY 401
DATUM GEODETIC
LOCATION N 4676968.0 ;E 295202.0
BOREHOLE TYPE POWER AUGER/HOLLOW STEM AUGERS - WASH BORING/NW CASING
DATE August 2, 2005 - August 3, 2005
ORIGINATED BY MA
COMPILED BY DCH
CHECKED BY [signature]

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | SHEAR STRENGTH kPa | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|
| | **SILTY CLAY**, trace sand , trace gravel, Firm to Stiff, Grey | | | | | + 2.4; 2.0 | | |
| | | | | | 166 | | | |
| | | 16 | TO | PH | | | | |
| | | | | | 165 | | | |
| | | 17 | SS | 5 | 164 | | w ≈ 24 | |
| | | | | | 163 | | | |
| | | 18 | SS | 8 | | | $w_p$ ≈ 13, $w_L$ ≈ 30 | 1 20 43 36 |
| | | | | | 162 | | | |
| | | 19 | SS | 8 | 161 | | w ≈ 23 | |
| | | | | | 160 | | | |
| | | | | | 159 | | | |
| | | 20 | SS | 7 | 158 | | | |
| | | | | | 157 | | | |
| | | | | | 156 | | | |
| | | 21 | SS | 13 | 155 | | w ≈ 22 | |
| | | | | | 154 | | | |
| 153.25<br>28.30 | **SILTY CLAY**, trace sand, gravel with fine sand layers, Stiff, Grey | | | | 153 | | | |
| | | | | | 152 | | | |
| | | 22 | SS | 8 | | | | |

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; UNIT WEIGHT γ kN/m³

Continued Next Page

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

Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 2



**METRIC**

| | | | |
|---|---|---|---|
| PROJECT 05-1130-031-1-1 | | | |
| G.W.P. 63-00-00 | LOCATION N 4676968.0 ;E 295202.0 | | ORIGINATED BY MA |
| DIST 1 HWY 401 | BOREHOLE TYPE POWER AUGER/HOLLOW STEM AUGERS - WASH BORING/NW CASING | | COMPILED BY DCH |
| DATUM GEODETIC | DATE August 2, 2005 - August 3, 2005 | | CHECKED BY |

| ELEV / DEPTH | SOIL PROFILE – DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **SILTY CLAY**, trace sand, gravel with fine sand layers, Stiff, Grey | | | | | | 151 | | | | |
| | | | | | | | 150 | | | | |
| 149.39 / 32.16 | **LIMESTONE**, Light grey | | ~~23~~ | ~~SS~~ | 100/ 25mm | | 149 | | | | |
| | | | 24 | WS | - | | 148 | | | | |
| 147.41 / 34.14 | BOTTOM OF BOREHOLE<br>Borehole dry during drilling August 2 & 3, 2005 | | | | | | | | | | |

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

Golder Associates
London, Ontario

# RECORD OF BOREHOLE No 2A



**METRIC**

PROJECT 05-1130-031-1-1
G.W.P. 63-00-00
LOCATION N 4676968.0 ;E 295200.0
ORIGINATED BY MA
DIST 1 HWY 401
BOREHOLE TYPE POWER AUGER/HOLLOW STEM AUGERS
COMPILED BY DCH
DATUM GEODETIC
DATE August 4, 2005
CHECKED BY [signature]

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 181.55 | GROUND SURFACE | | | | | | | | | | |
| 0.00 | For stratigraphy, see BH2 | | | | | | 181–176 | >144+ (at 176) | | | |
| | | | 1 | TO | PH | | 175 | | Wp–w–WL plotted (approx. 19 / 21 / 37) | | C 1 11 46 42 |
| | | | | | | | | 138+ 1.6; 138+ 1.4 | | | |
| 174.23 / 7.32 | END OF BOREHOLE | | | | | | | | | | |

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. PLASTIC LIMIT $W_P$; NATURAL MOISTURE CONTENT W; LIQUID LIMIT $W_L$.

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

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


| PROJECT | RUSCOM RIVER BRIDGE<br>WP 63-00-00<br>HWY 401 | | |
|---|---|---|---|
| TITLE | KEY PLAN | | |
| Golder Associates<br>LONDON, ONTARIO | PROJECT No. 05-1130-031-1-1 | FILE No. 051130031-1-1-F001 | |
| | | SCALE AS SHOWN | REV. 0 |
| | CADD WDF AUG 30/05 | FIGURE 1 | |
| | CHECK | | |

Drawing file: 051130031-1-1-F001.dwg Dec 13, 2005 - 1:08pm

# METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

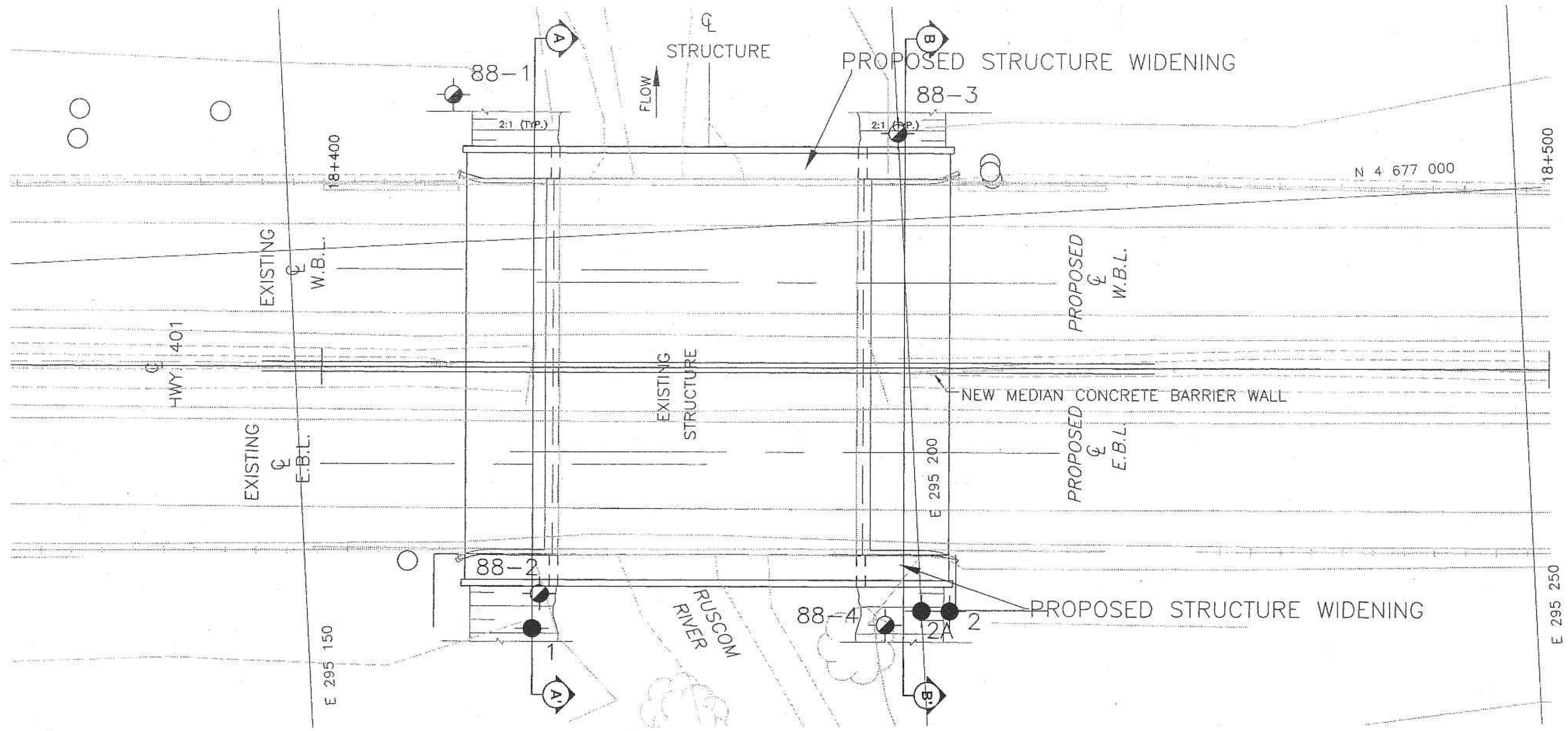
DIST 1 HWY. 401
CONT. No.
WP No. 63-00-00

## RUSCOM RIVER BRIDGE
## BOREHOLE LOCATIONS & SOIL STRATA

SHEET

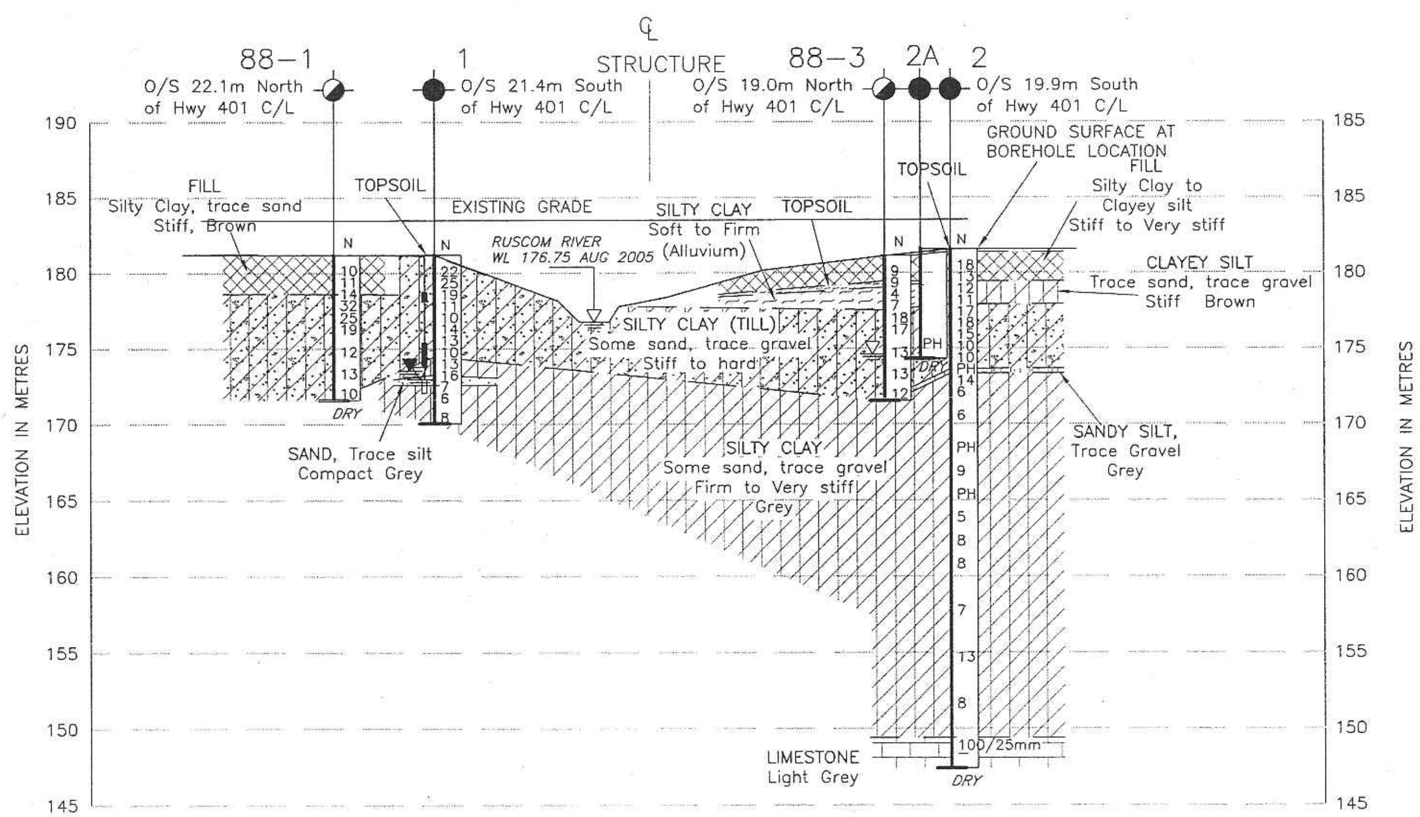
Golder Associates

Golder Associates Ltd.
LONDON, ONTARIO, CANADA




PLAN

SCALE 5 0 5 10 m




PROFILE ALONG CENTRELINE HWY 401

SCALE 5 0 5 10 m


KEY PLAN

0 2.5 km 5.0 km
KILOMETRES

LICENSED PROFESSIONAL ENGINEER M. E. BEADLE PROVINCE OF ONTARIO

F. J. HEFFERNAN PROVINCE OF ONTARIO

## LEGEND

- Borehole (Current Investigation – Golder Associates)
- Borehole (Previous Investigation – By Others)
- Seal
- Piezometer
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL encountered during drilling
- WL in piezometer, Aug. 11, 2005.
- *DRY* — Borehole dry during drilling

| No. | ELEVATION (metres) | CO-ORDINATES NORTH | CO-ORDINATES EAST |
|---|---|---|---|
| 1 | 181.17 | 4 676 968 | 295 168 |
| 2 | 181.55 | 4 676 968 | 295 202 |
| 2A | 181.55 | 4 676 968 | 295 200 |
| 88-1 | 181.19 | 4 677 012 | 295 164 |
| 88-2 | 181.24 | 4 676 971 | 295 169 |
| 88-3 | 181.12 | 4 677 007 | 295 200 |
| 88-4 | 181.72 | 4 676 967 | 295 197 |

## NOTES

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

This drawing is for subsurface information only. The proposed structure details are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents

## REFERENCE

REFERENCE : DRAWING BY DILLON CONSULTING
ENTITLED: RUSCOM RIVER BRIDGE PRELIMINARY GENERAL ARRANGEMENT
SITE No. : 6-88
DATED: JULY 2005

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

Geocres No. 40J2-73

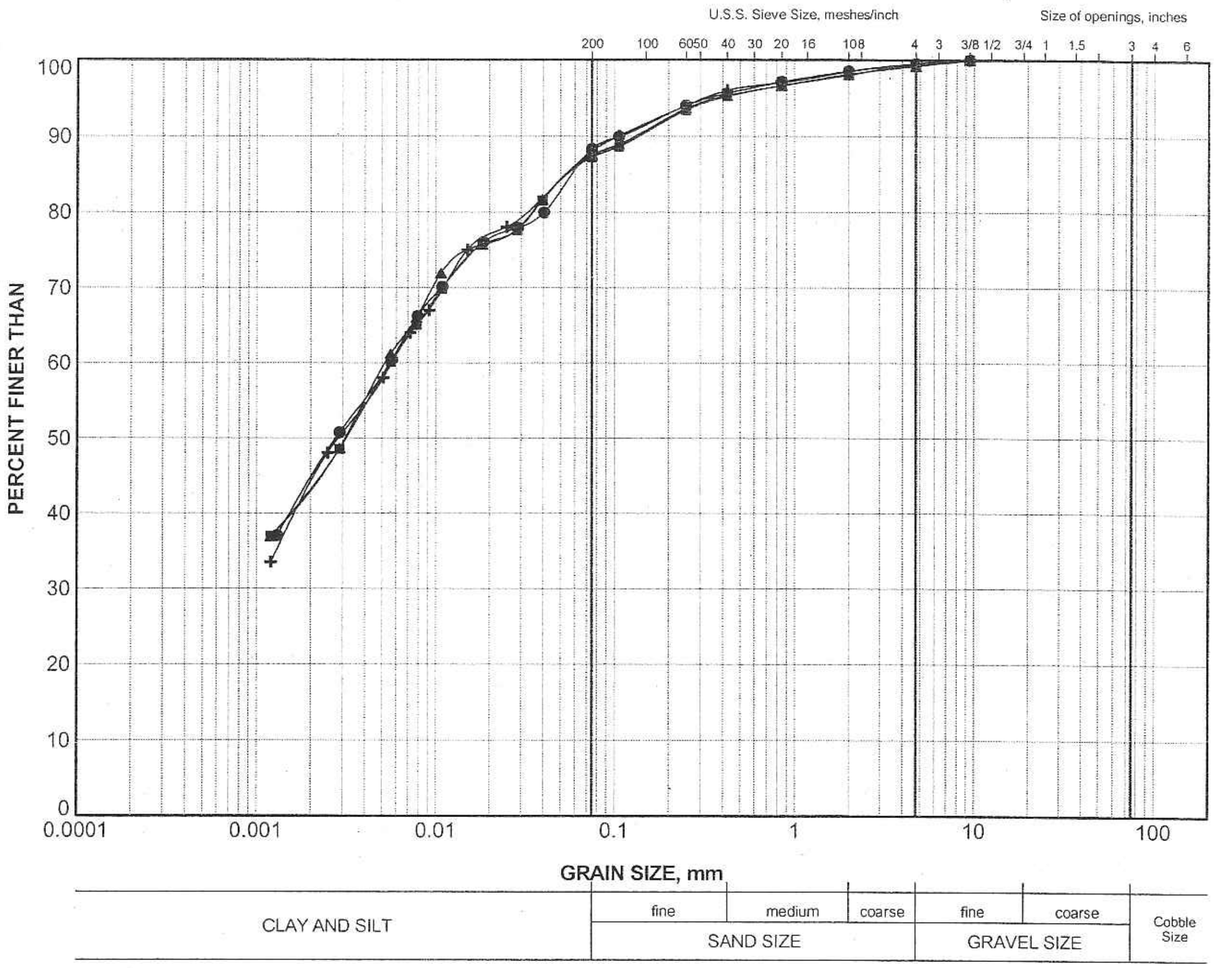
| | | | |
|---|---|---|---|
| HWY. No. 401 | PROJECT NO.: 05-1130-031-1-1 | | |
| SUBM'D. – | CHKD: | DATE: AUG 29/05 | |
| DRAWN: WDF | CHKD. | APPD. | DWG. 1 |

PLOT DATE: December 14, 2005
FILENAME: 05113003\1-1-1000\1.dwg

1 = 1 metric D size dwg 22" x 34" 11" x 17" plot half scale

# APPENDIX A

## LABORATORY TEST DATA (FIGURES A-1 to A-6)




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|---|---|---|---|
| ● | 1 | 6 | 176.4 |
| ■ | 2 | 6 | 176.8 |
| ▲ | 2 | 7 | 176.0 |
| + | 2A | 1 | 175.2 |

PROJECT
RUSCOM RIVER BRIDGE
WP 63-00-00
HWY 401

TITLE

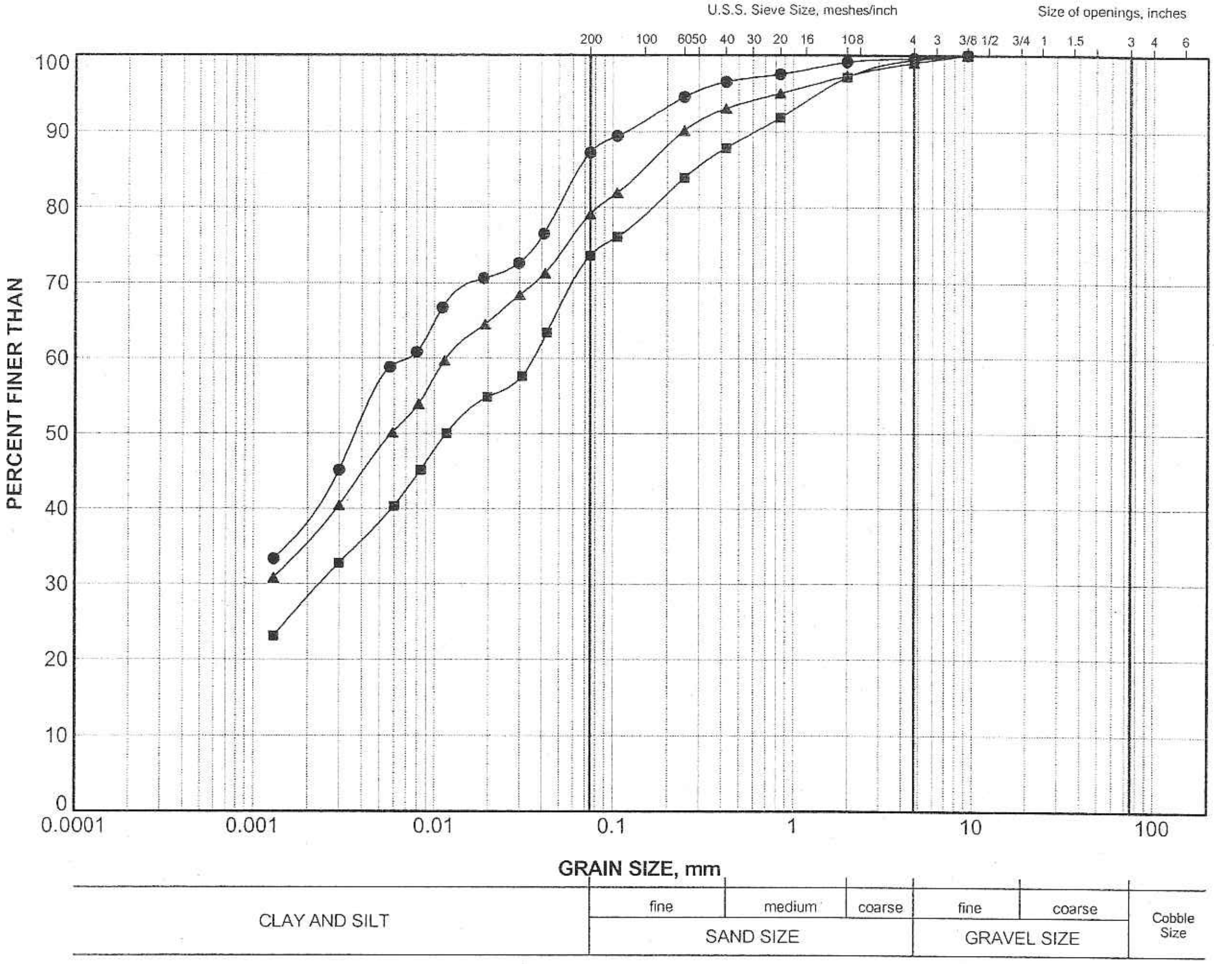
# GRAIN SIZE DISTRIBUTION

## SILTY CLAY TILL

Golder Associates
LONDON, ONTARIO

| | | | | |
|---|---|---|---|---|
| PROJECT No. 05-1130-031-1-1 | | | FILE No. 051130031-1-1.GPJ | |
| | | | SCALE N/A | REV. |
| DRAWN | WDF | Dec. 13/05 | **FIGURE A-1** | |
| CHECK | | | | |

LDN_MTO_NEW GLDR_LDN.GDT




**LEGEND**

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|---|---|---|---|
| ● | 1 | 9 | 174.1 |
| ■ | 2 | 12 | 172.2 |
| ▲ | 2 | 18 | 162.4 |

PROJECT

RUSCOM RIVER BRIDGE
WP 63-00-00
HWY 401

TITLE

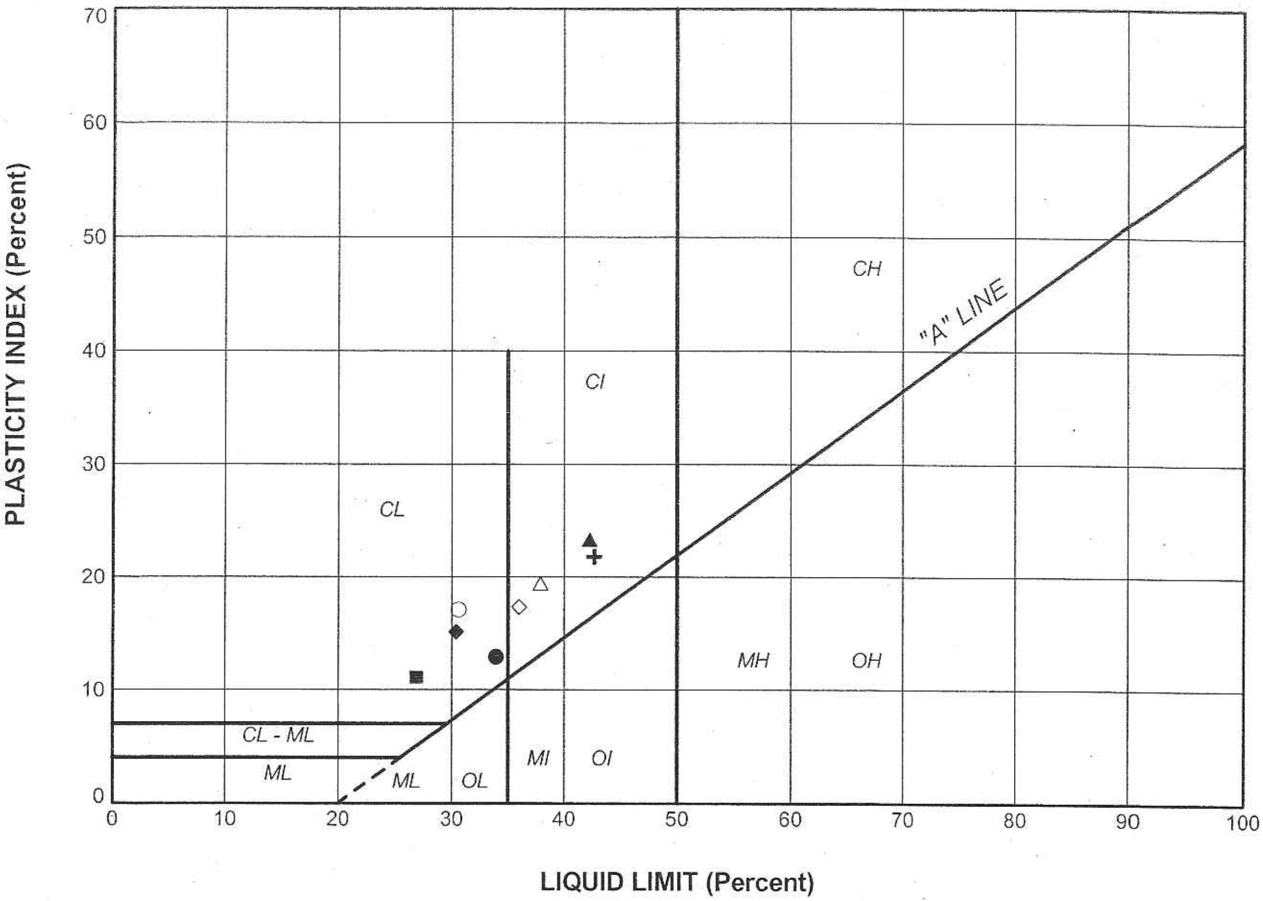
# GRAIN SIZE DISTRIBUTION

## SILTY CLAY

Golder Associates
LONDON, ONTARIO

| PROJECT No. 05-1130-031-1-1 | | | FILE No. 051130031-1-1.GPJ | |
|---|---|---|---|---|
| | | | SCALE N/A | REV. |
| DRAWN | WDF | Dec. 13/05 | **FIGURE A-2** | |
| CHECK | [signature] | | | |

LDN_MTO_NEW GLDR_LDN.GDT




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

## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | LL(%) | PL(%) | PI |
|---|---|---|---|---|---|
| **SILTY CLAY TILL** | | | | | |
| ● | 1 | 6 | 33.9 | 21.0 | 12.9 |
| ▲ | 2 | 6 | 42.3 | 19.0 | 23.3 |
| + | 2 | 7 | 42.7 | 20.9 | 21.8 |
| △ | 2A | 1 | 37.9 | 18.5 | 19.4 |
| SILTY CLAY | | | | | |
| ◆ | 2 | 12 | 30.4 | 15.3 | 15.1 |
| ◇ | 2 | 15 | 36.0 | 18.7 | 17.3 |
| ○ | 2 | 18 | 30.6 | 13.5 | 17.1 |
| ■ | 1 | 9 | 26.9 | 15.8 | 11.1 |

PROJECT

RUSCOM RIVER BRIDGE
WP 63-00-00
HWY 401

TITLE

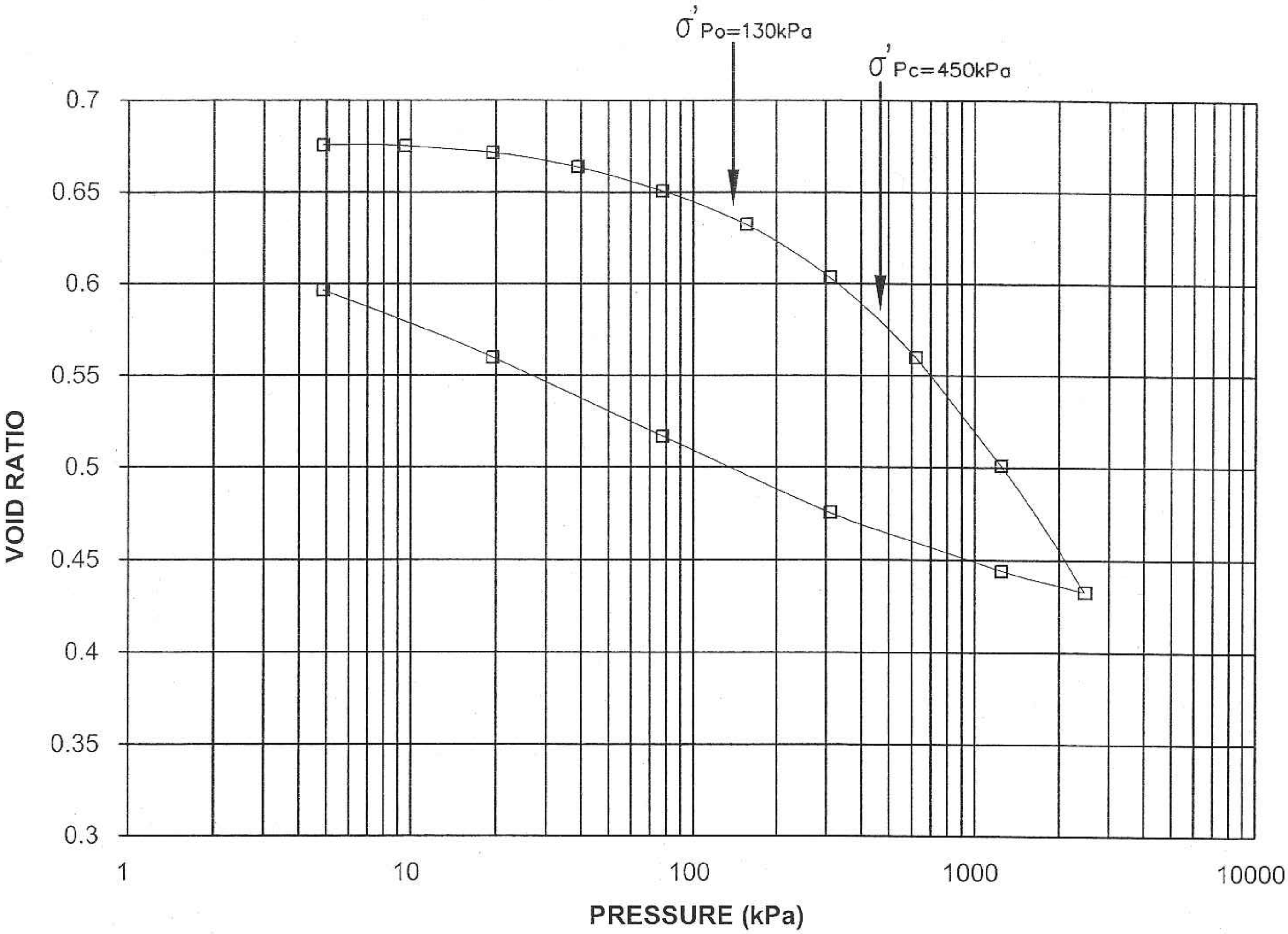
# PLASTICITY CHART

Golder Associates
LONDON, ONTARIO

| PROJECT No. | 05-1130-031-1-1 | | FILE No. | 051130031-1-1.GPJ |
|---|---|---|---|---|
| | | | SCALE N/A | REV |
| DRAWN | WDF | Dec. 13/05 | **FIGURE A-3** | |
| CHECK | [signature] | | | |

MTO_PI GLDR_LDN.GDT

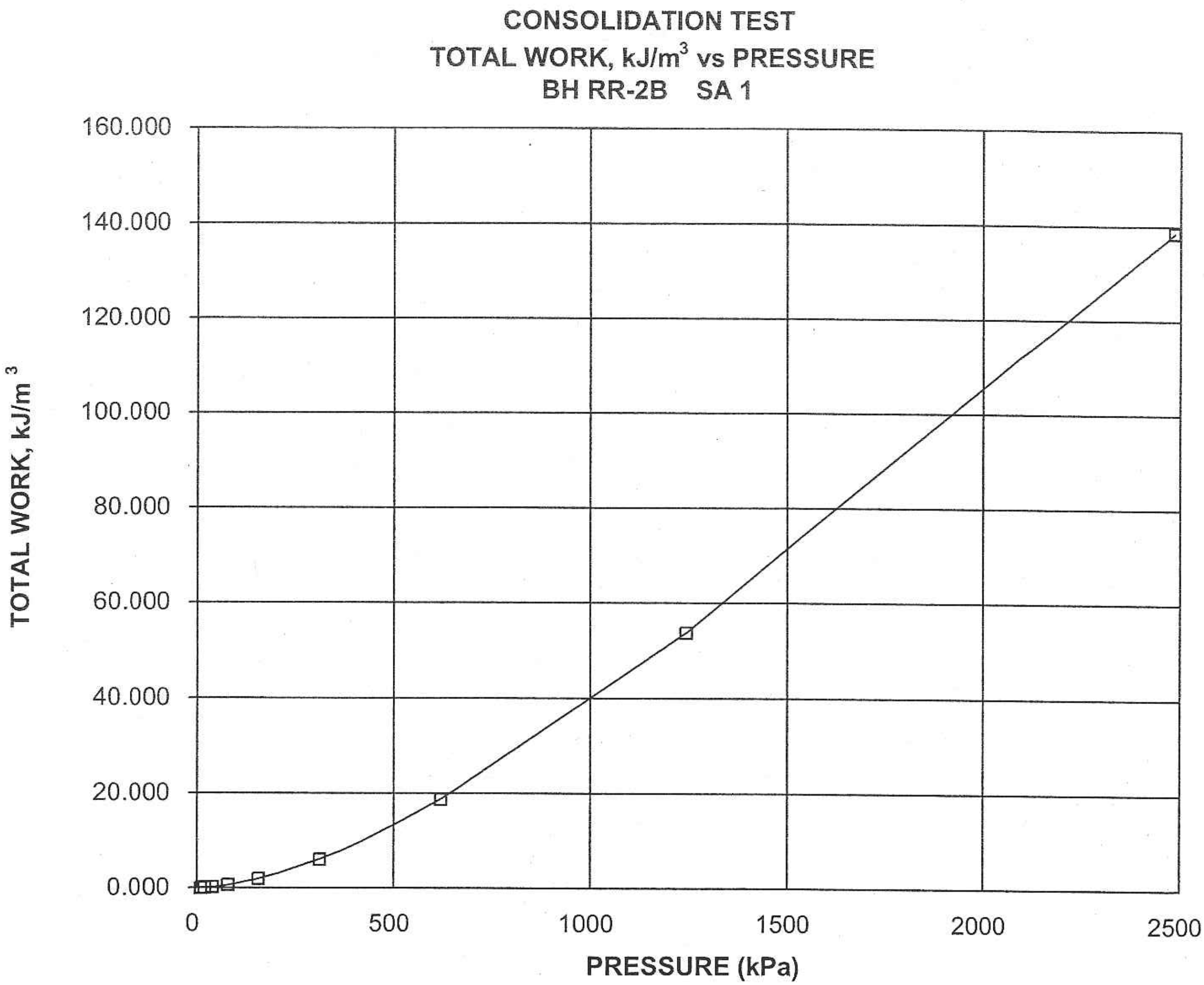
## CONSOLIDATION TEST
## VOID RATIO vs PRESSURE
## BH RR-2B SA 1




| | |
|---|---|
| PROJECT | RUSCOM RIVER BRIDGE<br>WP 63-00-00<br>HWY 401 |
| TITLE | **VOID RATIO VS. LOG PRESSURE CONSOLIDATION TEST** |

| Golder Associates LONDON, ONTARIO | PROJECT No. 05-1130-031-1-1 | FILE No. 051130031-1-1-App |
|---|---|---|
| | | SCALE AS SHOWN REV. 0 |
| | CADD WDS AUG 30/05 | |
| | CHECK | **FIGURE A-4** |

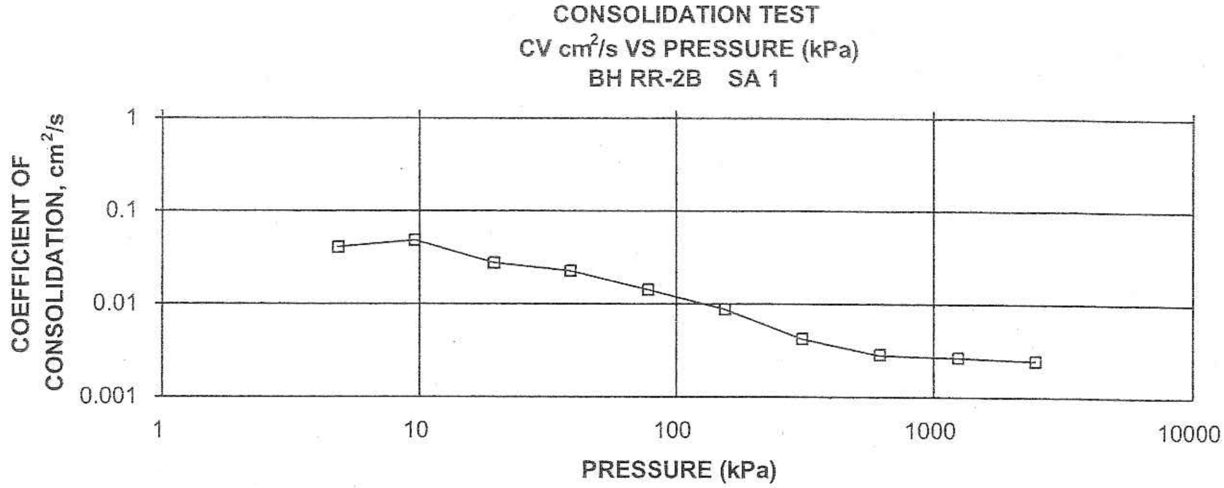
Drawing file: 051130031-1-1-App.dwg Dec 13, 2005 - 1:24pm

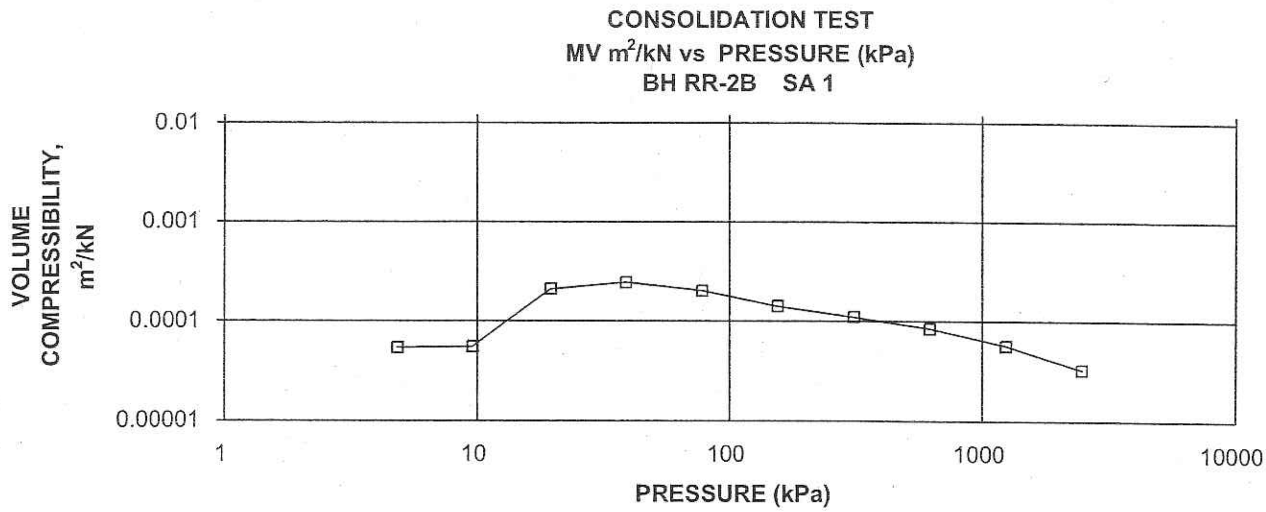


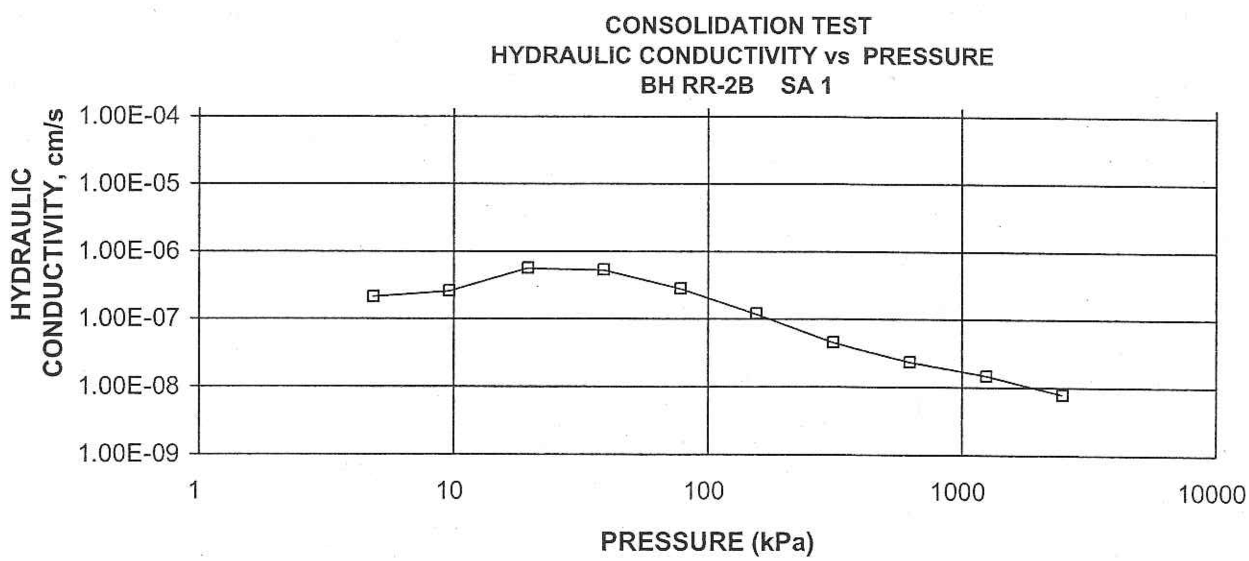

| | |
|---|---|
| PROJECT | RUSCOM RIVER BRIDGE<br>WP 63-00-00<br>HWY 401 |
| TITLE | CONSOLIDATION TEST |

| | | | | |
|---|---|---|---|---|
| Golder Associates<br>LONDON, ONTARIO | PROJECT No. 05-1130-031-1-1 | | FILE No. 051130031-1-1-App | |
| | | | SCALE AS SHOWN | REV. 0 |
| | CADD | WDF | AUG 30/05 | FIGURE A-5 |
| | CHECK | | | |

Drawing file: 051130031-1-1-App.dwg Aug 31, 2005 - 8:57am




PROJECT
RUSCOM RIVER BRIDGE
WP 63-00-00
HWY 401

TITLE

# OEDOMETER CONSOLIDATION SUMMARY

Golder Associates
LONDON, ONTARIO

| | | | | |
|---|---|---|---|---|
| PROJECT No. 05-1130-031-1-1 | | | FILE No. 051130031-1-1-App | |
| | | | SCALE AS SHOWN | REV. 0 |
| CADD | WDF | AUG 30/05 | FIGURE A-6 | |
| CHECK | W | | | |

Drawing file: 051130031-1-1-App.dwg Aug 31, 2005 - 8:59am

# APPENDIX B

# RECORDS OF BOREHOLES BY OTHERS

Ministry of Transportation Ontario

Peto MacCallum Ltd.
Foundation Design

# RECORD OF BOREHOLE No 88-1

 METRIC

G W P. 60-00-00 | LOCATION Co-ords. 4 677 012 N; 335 164 E. | ORIGINATED BY [illegible]

DIST 31 | HWY 401 | BOREHOLE TYPE Continuous Flight Solid Stem Augers | COMPILED BY [illegible]

DATUM Geodetic | DATE May 09, 2002 | CHECKED BY MBA

| ELEV / DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | REMARKS |
|---|---|---|---|---|---|
| 181.19 | Ground Level | | | | |
| 0.00 | Silty clay, trace of sand, Stiff, Brown (Fill) | 1 | SS | 10 | |
| | | 2 | SS | 11 | |
| | with mottling topsoil | 3 | SS | 11 | |
| 178.59 / 2.60 | Silty clay, some sand, trace of gravel, Very Stiff to Hard, Brown (Till) | 4 | SS | 32 | |
| | | 5 | SS | 25 | |
| | | 6 | SS | 19 | Water content 125 |
| | Stiff, Grey | 7 | SS | 12 | |
| | | 8 | SS | 13 | |
| 171.59 / 9.60 | | 9 | SS | 10 | |

Elevation scale: 181, 180, 179, 178, 177, 176, 175, 174, 173, 172

Dynamic Cone Penetration Resistance Plot: 20, 40, 60, 80, 100
Shear Strength kPa: O Unconfined, + Field Vane, ● Quick Triaxial, X Lab Vane: 20, 40, 60, 80, 100
Plastic Limit $w_P$, Natural Moisture Content $w$, Liquid Limit $w_L$; Water Content (%): 20, 40, 60
Unit Weight $\gamma$ kN/m³
Remarks & Grain Size Distribution (%): GR SA SI CL

End of Borehole

Borehole dry on completion of drilling

■ Penetrometer Test



$+^7 \times^5$: Numbers refer to Sensitivity

20 / 15 -○- 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

**Peto MacCallum Ltd.**
Foundation Design

# RECORD OF BOREHOLE No 88-2

 METRIC

G W P. 60-00-00 LOCATION Co-ords. 4 876 371 N; 293 164 E. ORIGINATED BY MR

DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY GP

DATUM Geodetic DATE May 07, 2002 CHECKED BY MRA

| ELEV DEPTH | SOIL PROFILE DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE |
|---|---|---|---|---|---|
| 181.24 | Ground Level | | | | |
| 0.00 | Silty clay, trace of sand<br>Stiff<br>Brown Mottled<br>(Fill) | | | | 181 |
| | | 1 | SS | 10 | 180 |
| 179.84<br>1.40 | Silty clay, some sand, trace of gravel<br>Stiff to Very Stiff<br>Brown<br>(Till) | 2 | SS | 15 | |
| 179.14<br>2.10 | Clayey sandy silt, trace of gravel<br>Compact/Very Stiff<br>Brown<br>(Till) | 3 | SS | 30 | 179 |
| 178.34<br>2.90 | Silty clay, some sand, trace of gravel<br>Very Stiff<br>Brown<br>(Till) | 4 | SS | 23 | 178 |
| | | 5 | SS | 25 | 177 |
| | Grey | 6 | SS | 20 | 176 |
| | Stiff | 7 | SS | 12 | 175 |
| | | | | | 174 |
| | | 8 | SS | 9 | 173 |
| | Firm | | | | 172 |
| 171.64<br>9.60 | | 9 | SS | 7 | |
| | End of Borehole<br>Borehole dry on completion of drilling<br>■ Penetrometer Test | | | | |

Column headings: GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

150

ON_MOT 01TF073H.GPJ ON_MOT.GDT 11/21/2002 2:24:40 PM

$+^7, \times^5$: Numbers refer to Sensitivity    20 / 15 -O- 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

**Peto MacCallum Ltd.**
Foundation Design

# RECORD OF BOREHOLE No 88-3

 **METRIC**

G W P. 60-00-00 LOCATION Co-ords. 4 627 007 N; 295 200 E. ORIGINATED BY MR

DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY JP

DATUM Geodetic DATE May 09, 2002 CHECKED BY MRA

## SOIL PROFILE

| ELEV / DEPTH | DESCRIPTION |
|---|---|
| 181.12 | Ground Level |
| 181.12 / 0.00 | Silty clay, trace of sand; Stiff; Brown Mottled (Fill) |
| 179.42 / 1.70 | Silty clay; Dark Brown; Topsoil |
| 179.02 / 2.10 | Silty clay, trace of sand; Soft to Firm; Blueish Grey; Alluvium; with occ. thin partings of silt and fine sand at 3.0m |
| 177.52 / 3.60 | Silty clay, some sand, trace of gravel; Very Stiff; Brown (Till); Stiff; Grey |
| 171.52 / 9.60 | End of Borehole |

## SAMPLES

| NUMBER | TYPE | "N" VALUES | Elevation (approx.) | Shear strength (kPa) | Natural moisture content | Remarks & grain size distribution (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 1 | SS | 9 | 180.1 | | o | |
| 2 | SS | 9 | 179.4 | | o | |
| 3 | SS | 4 | 178.6 | | o | |
| 4 | SS | 7 | 177.9 | | o | |
| 5 | SS | 18 | 177.1 | ■ 150 | o | |
| 6 | SS | 17 | 176.4 | ■ 125 | o (with liquid limit) | 2 12 43 43 |
| 7 | SS | 13 | 174.8 | ■ | o | |
| 8 | SS | 13 | 173.3 | ■ | o | |
| 9 | SS | 12 | 171.8 | ■ | o (with plastic and liquid limits) | 1 12 41 46 |

GROUND WATER CONDITIONS: water level ▼ at approx. elevation 174.7

ELEVATION SCALE: 181, 180, 179, 178, 177, 176, 175, 174, 173, 172

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; X LAB VANE — 20 40 60 80 100

PLASTIC LIMIT $w_P$ — NATURAL MOISTURE CONTENT $w$ — LIQUID LIMIT $w_L$; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

▼ Water level measured after drilling

■ Penetrometer Test



$+^3, \times^5$: Numbers refer to Sensitivity

20 / 15 —o— 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

Peto MacCallum Ltd.
Foundation Design

# RECORD OF BOREHOLE No 88-4

 METRIC

G W P. 60-00-00 LOCATION Co-ords. 4 676 967 N; 295 197 E. ORIGINATED BY MR

DIST 31 HWY 401 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 08, 2002 CHECKED BY MRA

| ELEV / DEPTH | SOIL PROFILE – DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | REMARKS |
|---|---|---|---|---|---|---|---|
| 181.72 | Ground Level | | | | | | |
| 0.00 | Silty clay, trace of sand; Stiff; Brown Mottled (Fill) | 1 | SS | 13 | | 181 | |
| | | 2 | SS | 12 | | 180 | |
| 179.82 / 1.90 | Silty clay, some sand, trace of gravel; Stiff to Very Stiff; Brown (Till) | 3 | SS | 12 | | 179 | |
| | | 4 | SS | 23 | | 178 | |
| | | 5 | SS | 20 | | | Plastic limit column: 187 |
| | Stiff; Grey | 6 | SS | 11 | | 177 | |
| | | 7 | SS | 9 | | 176, 175 | |
| | Firm; Brown | 8 | SS | 5 | ▼ | 174 | |
| | | 9 | SS | 7 | | 173 | |
| 172.12 / 9.60 | End of Borehole | | | | | | |

▼ Water level measured after drilling

■ Penetrometer Test

Column headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT w, LIQUID LIMIT $W_L$; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL



+⁷ ×⁵: Numbers refer to Sensitivity; 20 / 15–○–5 / 10 (%) STRAIN AT FAILURE

## APPENDIX C

## SITE PHOTOGRAPHS

## SITE PHOTOGRAPHS

Photo 1

Photo 2

# SITE PHOTOGRAPHS

Photo 3

Photo 4

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

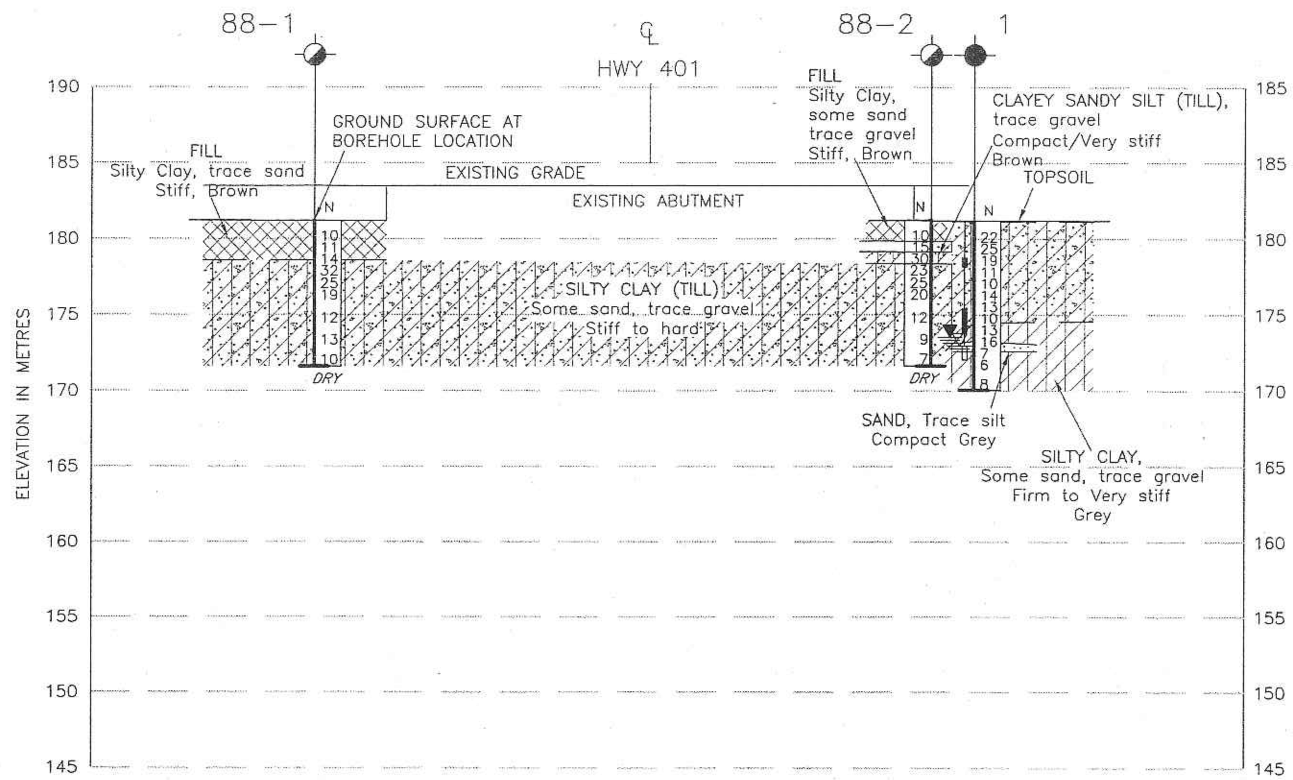
DIST 1 HWY. 401
CONT. No.
WP No. 63-00-00

# RUSCOM RIVER BRIDGE
## SOIL STRATA

SHEET

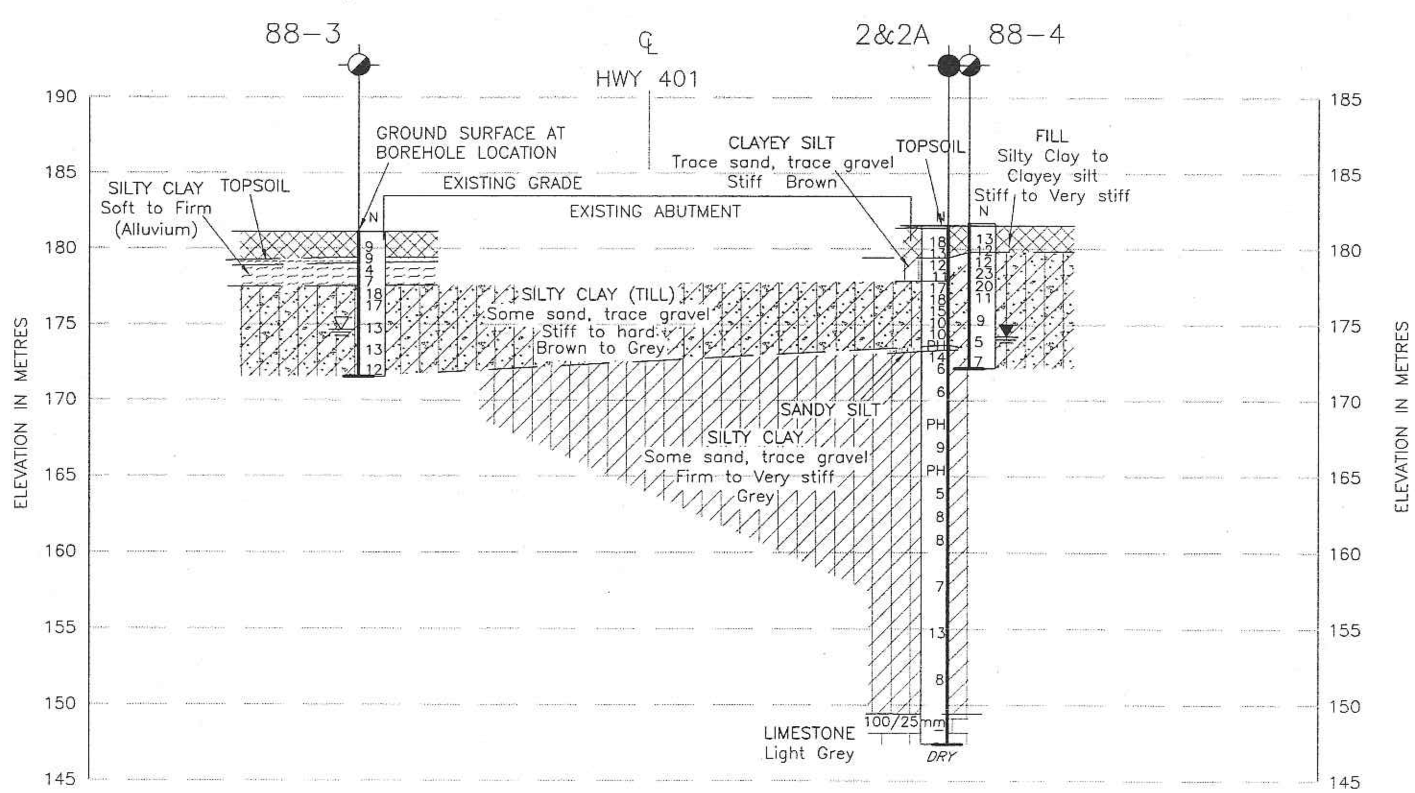
Golder Associates

Golder Associates Ltd.
LONDON, ONTARIO, CANADA




SECTION A-A'

SCALE 5 0 5 10 m

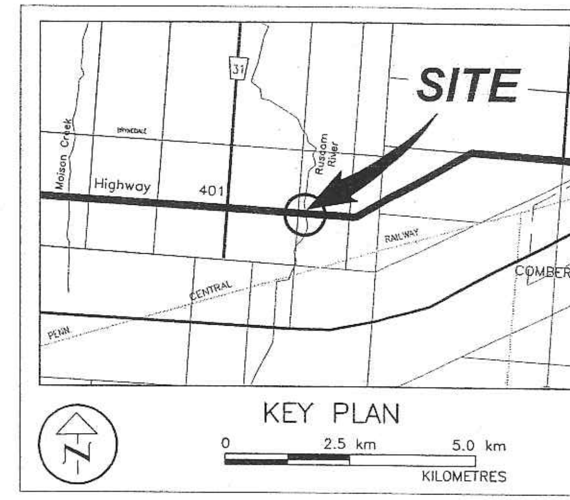



SECTION B-B'

SCALE 5 0 5 10 m

LICENSED PROFESSIONAL ENGINEER M. E. BEADLE PROVINCE OF ONTARIO

PROFESSIONAL ENGINEER F.J. HEFFERNAN PROVINCE OF ONTARIO




KEY PLAN

0 2.5 km 5.0 km KILOMETRES

## LEGEND

- Borehole (Current Investigation – Golder Associates)
- Borehole (Previous Investigation – By Others)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL encountered during drilling
- WL in piezometer, Aug. 11, 2005.
- DRY Borehole dry during drilling

| No. | ELEVATION (metres) | CO-ORDINATES NORTH | CO-ORDINATES EAST |
|---|---|---|---|
| 1 | 181.17 | 4 676 968 | 295 168 |
| 2 | 181.55 | 4 676 968 | 295 202 |
| 2A | 181.55 | 4 676 968 | 295 200 |
| 88-1 | 181.19 | 4 677 012 | 295 164 |
| 88-2 | 181.24 | 4 676 971 | 295 169 |
| 88-3 | 181.12 | 4 677 007 | 295 200 |
| 88-4 | 181.72 | 4 676 967 | 295 197 |

## NOTES

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

This drawing is for subsurface information only. The proposed structure details are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

## REFERENCE

REFERENCE : DRAWING BY DILLON CONSULTING
ENTITLED: RUSCOM RIVER BRIDGE PRELIMINARY GENERAL ARRANGEMENT
SITE No. : 6-88
DATED: JULY 2005

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

Geocres No. 40J2-73

| | | | |
|---|---|---|---|
| HWY. No. 401 | PROJECT NO.: 05-1130-031-1-1 | | |
| SUBM'D. – | CHKD: | DATE: AUG 29/05 | |
| DRAWN: WDF | CHKD. | APPD. | DWG. 2 |

1 = 1 metric D size dwg 22" x 34" 11" x 17" plot half scale

051130031-1-1D001.dwg