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GEOCRES No:  
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**FOUNDATION  
INVESTIGATION AND DESIGN REPORT  
OVERHEAD SIGNS  
HIGHWAY 401 WIDENING  
FROM 2.7 KM WEST OF HIGHWAY 38  
EASTERLY TO HIGHWAY 15  
W.P. 76-99-01**

Submitted to:

Ministry of Transportation, Ontario – Eastern Region  
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July 2003

021-1142-1

## **PART A**

**FOUNDATION INVESTIGATION REPORT  
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Figure 1            Mapping Data and Photographs, Highway 401 – County Road 38 Interchange

Figure 2            Photographs, Highway 401 – County Road 38 Interchange

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations for the following components associated with the widening of Highway 401 from 2.7 km west of County Road 38 to Highway 15, in the vicinity of Kingston, Ontario:

- Two cantilever signs at the County Road 38 (formerly Highway 38) interchange; and
- Extension of the Collins Creek culvert, located at Station 16+837, on the south side of Highway 401.

This report addresses the cantilever signs located at the County Road 38 interchange.

The terms of reference for this work are outlined in the MTO's Request for Proposal (RFP) and in Golder Associates' Proposal No. P21-1231, dated June 2002.

## 2.0 SITE DESCRIPTION

The terrain in the vicinity of the site is generally flat, with a regional slope downward to the south, toward Lake Ontario. The existing Highway 401 is a four-lane divided highway, that trends northwest-southeast at the County Road 38 underpass site.

The Highway 401 grade is at about Elevation 111 m to 112 m below the County Road 38 underpass structure, with the highway grade rising in the eastbound direction. Highway 401 has been constructed in cut through the bedrock in the immediate vicinity of this underpass structure. The bedrock cut face is between 2 m and 4 m high along the south side of Highway 401, and up to about 2.5 m high in the northwest quadrant of the Highway 401 – County Road 38 interchange. There is no bedrock cut face in the northeast quadrant; however, the natural grade is slightly higher than the highway grade, and bedrock is exposed at ground surface in some portions of this quadrant.

### **3.0 INVESTIGATION PROCEDURES**

A field investigation was carried out at the County Road 38 interchange site in September 2002, at which time one borehole was advanced at the location of a proposed overhead sign in the northeast quadrant of the interchange. In the southwest quadrant of the interchange, where bedrock outcrops in the vicinity of a second overhead sign, structural mapping of the exposed rock face was carried out in lieu of borehole drilling, in accordance with Golder Associates Ltd.'s Proposal No. P21-1231, dated June 2002.

#### **3.1 Borehole Investigation Program**

One borehole (Borehole 2) was drilled in the northeast quadrant of the site using a bombardier-mounted drill rig supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. The borehole was advanced using hollow stem augers, to auger refusal which occurred at 1.2 m depth. Samples of the overburden were obtained at 0.75 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven with an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure. Below the overburden, the borehole was advanced 3.1 m into the bedrock using NQ-size coring equipment. The groundwater conditions in the open borehole were observed throughout the drilling operations.

The field work was supervised on a full-time basis by members of Golder Associates' staff who located the borehole in the field, directed the drilling, sampling, and in-situ testing operations, and logged the borehole. The soil and bedrock samples were identified in the field, placed in labelled containers and transported to Golder Associates' laboratory in Mississauga for further examination.

The borehole location was established relative to site features, and the ground surface elevation at the borehole location was determined by Golder Associates relative to established ground surface elevations along the Highway 401 centreline. The borehole location, including MTM NAD83 northing and easting coordinates and ground surface elevation referenced to geodetic datum, is shown on Drawing 1.

#### **3.2 Rock Cut Mapping**

A geological engineer inspected the exposed rock cut along the south side of Highway 401, in the southwest quadrant of the Highway 401 – County Road 38 interchange. The rock cut examination was carried out to determine the geotechnical properties of the bedrock, and to carry out discontinuity mapping and assessment of joint and bedding properties, including spacing, roughness, aperture size, and the presence of infilling materials.

## 4.0 SITE GEOLOGY AND STRATIGRAPHY

### 4.1 Regional Geological Conditions

The site is located in the physiographic region of Southern Ontario known as the Napanee Plain, as delineated in *The Physiography of Southern Ontario*<sup>1</sup>. The Napanee Plain is flat to undulating, and is characterized by relatively shallow soil deposits overlying bedrock. Geologic mapping<sup>2</sup> indicates that the bedrock within the Napanee Plain consists of grey limestone/dolostone of the Gull River Formation, which contains some shale partings and seams.

The overburden soils within the Napanee Plain generally consist of glacial till, although alluvium is present in river and stream valleys and, in the southern portion of the Plain, low-lying areas are typically covered with deposits of stratified clay. Well records indicate that the average depth to bedrock within the Napanee Plain is approximately 2 m. However, in many areas, bedrock outcrops at ground surface, while deeper soil deposits (on the order of 10 m) are present in the northern portion of the Plain, and within and adjacent to river valleys throughout the Plain.

### 4.2 Site Stratigraphy

Highway 401 has been constructed in cut through a limestone bedrock outcrop at this site. Exposed rock faces are present along the south side of the highway, and in the northwest quadrant of the interchange. Bedrock is also exposed in the northeast quadrant although at the proposed sign location, fill is present overlying the bedrock; this fill is likely associated with the Highway 401 embankment and storm sewer system in the immediate vicinity of the proposed sign location. One borehole was advanced in this area at the location shown on Drawing 1. The detailed subsurface soil, bedrock, and groundwater conditions encountered in the borehole are given on the Record of Borehole / Drillhole sheets. The stratigraphic boundaries shown on the borehole record are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. Subsurface conditions will vary beyond the borehole location.

In the northeast quadrant of the site, Borehole 2 encountered a thin layer of topsoil overlying about 1.2 m of fill, overlying limestone bedrock. The upper portion of the limestone bedrock at this location is highly fractured, possibly related to blasting for construction of the existing Highway 38 underpass structure and / or a nearby drainage catchbasin. A more detailed description of the subsurface conditions encountered in the borehole and observed in the structural geological mapping is provided in the following sections.

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<sup>1</sup> Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario*. Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.

<sup>2</sup> Map 2544, Ministry of Northern Development and Mines, 1991.



#### 4.2.1 Topsoil

Approximately 50 mm of topsoil was encountered at the location of Borehole 2, in the northeast quadrant of the interchange.

#### 4.2.2 Fill

In Borehole 2, the topsoil is underlain by about 0.6 m of fill which ranges in composition from silty sand containing trace clay and some gravel, to clayey silt with sand and some gravel. This fill is, in turn, underlain by about 0.5 m of crushed limestone gravel. Standard Penetration Test (SPT) "N" values of 13 and 24 blows per 0.3 m of penetration were measured within the fill, indicative of a compact density.

#### 4.2.3 Limestone/Dolostone Bedrock

Limestone/dolostone bedrock was encountered below the topsoil and fill at about 1.2 m depth (Elevation 109.4 m) in Borehole 2, in the northeast quadrant of the site. This borehole was advanced about 3.1 m into the bedrock using NQ coring equipment. The recovered rock core samples consist of slightly weathered to fresh, grey, fine-grained, medium-bedded limestone/dolostone, containing shale partings, seams and interbeds. The upper 1.5 m of the bedrock core was highly fractured, with a Rock Quality Designation (RQD) measurement of 0 per cent for the first run. In the second run (lower 1.5 m of cored bedrock, below Elevation 107.9 m), the measured RQD was 100 per cent, indicating that this portion of the rock mass is of excellent quality. The rock is classified as medium strong to strong (Grade R3 to R4), according to the *Canadian Foundation Engineering Manual*<sup>3</sup>.

In addition to the bedrock coring carried out in Borehole 2, structural geological and geotechnical mapping was conducted for the rock cut face on the south side of Highway 401, west of the County Road 38 underpass structure. Annotated photographs of this rock outcrop and the cut face are shown on Figures 1 and 2. The rock mass exposed in the rock cut comprises interbedded units of limestone/dolostone and shale. Overall, the rock cut in the southwest quadrant of the interchange ranges from about 3.5 m to 4 m in height; the limestone units range in thickness from about 1 m to 2 m, while the shale beds are less than 0.5 m thick. The limestone/dolostone unit is generally grey, slightly to moderately weathered at the cut face, fine-grained, medium-bedded and medium strong to strong. The shale beds are grey, slightly weathered, very fine-grained, thinly-bedded and weak. The rock cut exhibits slight blast damage and minor ravelling due to frost action.

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<sup>3</sup> *Canadian Foundation Engineering Manual*. Third Edition, 1992. Canadian Geotechnical Society, Technical Committee on Foundations.

In total, 34 discontinuities were mapped at the rock cut face on the south side of Highway 401. Three discontinuity sets are present: two sub-vertical joint sets (J1 and J2) and the near-horizontal bedding set; some random sub-vertical jointing is also evident. The J1 and J2 sets are roughly orthogonal to each other, with the J2 set trending in a northwest-southeast orientation approximately parallel to Highway 401 and dipping toward the southwest, and the J1 set trending northeast-southwest and dipping toward the southeast. Each of these discontinuity sets is annotated on the pole, contour and rosette stereographic plots that are shown on Figure 1. As expected in structural mapping of well-bedded sedimentary rock masses, the near-horizontal bedding planes are the most common structural feature encountered, accounting for about 47 per cent of all features measured. There is very little difference in the frequency of occurrence between the J1 and J2 sets. The J1 set is slightly more common, comprising roughly 24 per cent of the total features, while the J2 set comprises about 21 per cent. In the upper limestone unit exposed in the rock cut (i.e. in the upper 1 m to 1.5 m of the rock cut), the sub-vertical joints (J1 and J2) are often open, with apertures of up to 100 mm as shown on Figure 2.

The physical attributes of the discontinuity sets are summarized in the following table. It should be noted that all measurements are with respect to magnetic north; for approximate true north readings, add 10 degrees to the magnetic north values.

Discontinuity Set	Number of Poles	Average Dip / Dip Direction <sup>#</sup>	Spacing (Average) (m)	Roughness	Filling	Aperture (mm)	Continuity (m)
J1	8	86/149 (SE)	0.5-3.0 (0.75)	Smooth Planar	Generally clean, minor calcite and iron oxide staining	1-100	1-10
J2	7	87/232 (SW)	1.0-3.0 (1.0)	Smooth Planar	Generally clean, minor calcite and iron oxide staining	1-100	0.5-10
Bedding	16	00/000 (Flat)	0.1-0.5 (0.4)	Smooth Planar	Generally clean, minor calcite	Tight	2->20

### 4.3 Groundwater Conditions

The overburden soil in Borehole 2 was dry on completion of the drilling operations, and no seepage was observed from the rock cut faces adjacent to Highway 401.

Due to the location of Borehole 2 adjacent to a catchbasin and stormwater drainage system, it is anticipated that "perched" groundwater conditions could exist within the fill and the upper, fractured zone of the bedrock during wet periods of the year.

**GOLDER ASSOCIATES LTD.**



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LCC/ASP/FJH/lcc

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**PART B**

**FOUNDATION DESIGN REPORT  
OVERHEAD SIGNS  
HIGHWAY 401 WIDENING  
FROM 2.7 KM WEST OF HIGHWAY 38  
EASTERLY TO HIGHWAY 15  
W.P. 76-99-01**

## 5.0 ENGINEERING RECOMMENDATIONS

### 5.1 General

This section of the report provides foundation design recommendations for two proposed overhead signs at the Highway 401 – County Road 38 interchange. The recommendations are based on interpretation of the factual data obtained from the borehole advanced during the subsurface investigation and structural mapping of the exposed rock face at this site. The interpretation and recommendations provided are intended only to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed overhead sign foundations. As such, 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, scheduling and the like.

### 5.2 Overhead Sign Foundation Options

The following table summarizes the subsurface conditions encountered at the two cantilever overhead sign locations:

<i><b>Proposed Sign Location</b></i>	<i><b>Subsurface Conditions</b></i>
Station 17+982 Offset 21 m Right	Limestone / dolostone bedrock outcrops at this location; top of outcrop at about 4 m above Highway 401 grade.
Station 18+010 Offset 20 m Left	Compact fill overlying limestone / dolostone bedrock at a depth of about 1.2 m below ground surface.

Based on the presence of bedrock at ground surface or at relatively shallow depth in the southwest and northeast quadrants of the interchange, respectively, consideration could be given to founding the proposed cantilever overhead signs either on a mass concrete footing placed on the surface of the bedrock, or on caisson extended into the bedrock. Further discussion regarding each of these options is provided in the following sections, and the advantages, disadvantages, risks and consequences associated with these two options are summarized in Table 1 following the text of this report.

Based on this comparison, it is considered that mass concrete footings (using rock dowels if necessary to supplement the horizontal or uplift resistance) founded on the surface of the bedrock are the most appropriate foundation option for this site. This is primarily because installation of caissons into the medium-bedded, medium strong to strong limestone / dolostone bedrock would require bedrock coring or churn drilling, which would be more expensive and time-consuming

than overburden excavation, rock surface preparation and dowel installation (if necessary) for spread footings.

### 5.3 Spread Footings

The cantilever overhead signs may be supported on spread footings founded on the limestone / dolostone bedrock at this site. The surface of the bedrock was encountered at the following depths / elevations at the two proposed sign locations:

<i><b>Proposed Sign Location</b></i>	<i><b>Borehole Number</b></i>	<i><b>Depth to Bedrock</b></i>	<i><b>Bedrock Surface Elevation</b></i>
Station 17+982 Offset 21 m Right	N/A (Bedrock Outcrop)	0 m	Top of rock outcrop Approx. 115 m
Station 18+010 Offset 20 m Left	2	1.2 m	Approx. 110.6 m

For the sign in the southwest quadrant of the interchange (Station 17+982, Offset 21 m Right), the footing may be placed on the surface of the bedrock, or may be placed with nominal embedment into the bedrock, although such embedment would require the use of hoe ramming and/or line drilling with controlled blasting in the medium strong to strong bedrock at this site. For the sign in the northeast quadrant, where the upper 1.5 m of the bedrock is fractured (an RQD value of 0 per cent for the first run), subexcavation of any loose, fractured bedrock will be required prior to construction of the footing. MTO's Special Provision SP902S01 should be included in the Contract Documents requiring inspection and approval of the foundation area by the Quality Verification Engineer prior to footing construction, to ensure that all loose and/or fractured rock has been removed from the foundation areas.

Variation in the bedrock surface should be anticipated at both of the proposed sign locations, and provision should be made in the Contract Documents for mass concrete placement to accommodate variations in the bedrock surface. In addition, mass concrete placement may be necessary to accommodate the open jointing that was observed on the top of the rock outcrop in the southwest quadrant.

#### 5.3.1 Bearing Resistance

Spread footings placed on the surface of or with nominal embedment into the properly prepared limestone/dolostone bedrock may be designed based on a factored bearing resistance at Ultimate Limit States (ULS) of 3 MPa. The geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement will be greater than the factored bearing resistance at ULS, since the limestone bedrock is considered to be an unyielding material; as such, ULS conditions will govern for this foundation type.



The geotechnical resistance provided above is given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Sections 6.7.2 and 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC)* and its *Commentary*.

### **5.3.2 Resistance to Lateral Loads**

Resistance to lateral forces / sliding resistance between the concrete footings and the limestone/dolostone bedrock should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction,  $\tan \delta'$ , may be taken as 0.70 for cast-in-place concrete footings constructed on the bedrock. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

For the overhead sign footing in the northeast quadrant, where the upper 1.5 m of the bedrock at the borehole location was found to be highly fractured, some horizontal resistance will also be derived from the embedment of the footing within the bedrock as a result of subexcavation to remove loose, fractured rock from within the foundation area. For design, the depth of subexcavation may be assumed to be 0.5 m. The horizontal passive resistance derived from the surrounding fractured rock may be taken as 8 kN per metre length of the footing, assuming an embedment depth within the bedrock of 0.5 m.

If necessary, the sliding resistance can be supplemented by dowelling into the bedrock. The horizontal resistance of the dowels is dependent on the strength of the bedrock, grout and steel. Where the rock mass is as strong as or stronger than concrete, the design of the dowels in the rock may be handled in the same way as the dowel embedment into the concrete, assuming that the unconfined compressive strength of the grout is similar to that of the concrete. This may be assumed to be the case for the rock mass at the southwest overhead sign location, as well as for the rock mass below the subexcavated zone at the northeast overhead sign location. The rock dowels should have a minimum embedded length within the bedrock of 1 m, and the structural strength of the dowel and the compressive strength of the grout should not be exceeded.

### **5.3.3 Uplift Resistance**

Rock dowels could also be used for to provide uplift resistance, to supplement the weight of the sign footing if necessary. For uplift of the dowels, a factored value of 700 kPa may be assumed for the grout-to-rock bond stress for ULS design. The actual bond stress along the rock-grout interface may vary from the design value given and it should, therefore, be verified in the field by pull-out testing; in this case, a Special Provision will have to be included in the Contract Documents to cover this testing. Alternatively, a factored value of 500 kPa may be assumed for

the grout-to-rock bond stress for ULS design, and the requirement for pull-out testing of the dowels can be deleted.

Notwithstanding the above design values, where rock dowels are required to supplement the uplift resistance, they should have a minimum embedded length within the bedrock of 2 m, to extend approximately 1 m below the highly fractured bedrock encountered at the sign location in the northeast quadrant, and to extend below the upper shale unit observed in the exposed rock face in the southwest quadrant.

Provision should also be made in the contract for longer dowels or for tensioned bolts for the footing in the southwest quadrant, in the event that there are adversely oriented joints in the rock under the final footing location that could potentially result in a sliding failure toward the cut face. In terms of kinematic stability, wedge and planar type failures are unlikely at this location due to the typically sub-vertical joint sets, and the nearly horizontal bedding planes. However, there is a slight possibility of a shallow toppling failure, since the J2 joint set is nearly parallel to the orientation of the rock cut. It is, therefore, recommended that the spread footing for this overhead sign be placed a minimum of 2 m behind the existing or future cut face.

#### 5.4 Caissons

For design of caisson foundations, both sign locations should be treated as bedrock sites, with the bedrock surface taken at the depths / elevations indicated in the following table:

<i>Proposed Sign Location</i>	<i>Borehole Number</i>	<i>Depth to Bedrock</i>	<i>Approximate Bedrock Surface Elevation</i>
Station 17+982 Offset 21 m Right	N/A (Outcrop)	0 m	Top of rock outcrop
Station 18+010 Offset 20 m Left	2	1.2 m	110.6 m

For caissons socketted into the bedrock a minimum depth equal to three caisson diameters, the caissons may be designed based on a factored axial resistance at Ultimate Limit States (ULS) of 6 MPa. The geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement will be greater than the factored axial resistance at ULS, since the limestone bedrock is considered to be an unyielding material; as such, ULS conditions will govern for this foundation type.



For the sign support at Station 17+982 in the southwest quadrant of the interchange, the caisson foundation, if adopted, should be maintained a minimum distance,  $D$  (m), behind the existing or future rock cut face, as follows:

$$D = 3B + 2 \text{ m} \quad \text{where } B \text{ is the caisson diameter (m).}$$

Installation considerations related to advancing the caisson into the medium-bedded, strong to moderately strong bedrock are discussed further in Section 5.5.2 (Construction Considerations – Caisson Installation in Bedrock) and in Table 1 following the text of this report.

## **5.5 Construction Considerations**

### **5.5.1 Excavation and Groundwater / Surface Water Control**

The surface of the limestone bedrock was encountered at about 1.2 m depth in Borehole 2, which was advanced at the proposed location for the overhead sign in the northeast quadrant of the interchange. Excavation for construction of a spread footing on bedrock at this sign location would extend through about 0.6 m of compact silty sand to stiff clayey silt fill, overlying about 0.5 m of compact, crushed gravel fill. Although these fill soils were dry during the borehole investigation, it is likely that water could be “perched” within the fill atop the bedrock during wet periods of the year.

Excavation should be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act (OHSA) for Construction Activities. The potentially water-bearing fill soils are classified as Type 3 soil, according to the OHSA. Temporary excavations (i.e. those which are only open for a relatively short period) through these overburden soils should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V). It is considered that pumping from sumps at the base of the excavation should provide sufficient control of surface water and any groundwater “perched” within the fill. Shallower side slopes may be required to minimize surficial sloughing if the construction is carried out at times of high “perched” water levels.

If a caisson foundation is adopted for the overhead sign in the northeast quadrant, use of a temporary liner will be required to support the approximately 1.2 m of overburden soils during caisson installation.


### **5.5.2 Caisson Installation in Bedrock**


The limestone / dolostone bedrock at the site is medium strong to strong which, according to the *Canadian Foundation Engineering Manual*, corresponds to unconfined compressive strengths ranging from 25 MPa to 100 MPa. If caisson foundations are adopted for support of the overhead

signs, rock coring or churn drilling would be required in order to advance the caisson into the bedrock. The bedrock is also medium-bedded, which corresponds to bedding thicknesses ranging from 200 mm to 600 mm; this bedding thickness could pose difficulties for both methods of caisson advancement, since there are fewer planes of weakness along which the bedrock will fracture to permit removal of the rock from the caisson hole.


Based on the above, it is considered that caisson installation within the bedrock is more difficult and less practicable than construction of spread footings (dowelled if necessary) on the bedrock surface for these two overhead signs. This is outlined further in Table 1 following the text of this report.

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**TABLE 1**  
**COMPARISON OF FOUNDATION ALTERNATIVES**

<i><b>Foundation Option</b></i>	<i><b>Advantages</b></i>	<i><b>Disadvantages</b></i>	<i><b>Relative Costs</b></i>	<i><b>Risks and Consequences</b></i>
Mass concrete footings on surface of bedrock	<ul style="list-style-type: none"> <li>Excavation and bedrock surface preparation (including subexcavation at northeast sign location) can be done with conventional excavation equipment</li> <li>Dowelling of footing into bedrock provides a more economical alternative to socketting steel H-piles or drilled shafts into the medium strong to strong bedrock to resist lateral or uplift loading, if required</li> </ul>	<ul style="list-style-type: none"> <li>Fractured bedrock is present at northeast sign location and subexcavation will be necessary prior to construction of footing; however, this should be relatively easy because of the fractured nature of the bedrock</li> <li>Appropriate dewatering required during excavation and construction at northeast overhead sign location</li> </ul>	Excavation / rock surface preparation costs less than for caisson foundations	Low risk and consequences
Caisson foundations	<ul style="list-style-type: none"> <li>Caisson would extend through zone of fractured bedrock at northeast sign location, avoiding subexcavation that would be required for mass concrete footing option</li> </ul>	<ul style="list-style-type: none"> <li>Socketting into medium-bedded, medium strong to strong bedrock will require coring or churn drilling, which requires mobilization of specialized equipment to site and is expected to be more difficult and time-consuming than placement of footing on surface of bedrock</li> </ul>	Bedrock coring / churn drilling costs higher than preparation costs associated with mass concrete footings	Low risk and consequences

## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS Auger sample  
BS Block sample  
CS Chunk sample  
SS Split-spoon  
DS Denison type sample  
FS Foil sample  
RC Rock core  
SC Soil core  
ST Slotted tube  
TO Thin-walled, open  
TP Thin-walled, piston  
WS Wash sample

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Consistency

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

#### (b) Cohesive Soils

#### Dynamic Cone Penetration Resistance; $N_4$ :

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<sub>p</sub> plastic limit  
w<sub>l</sub> 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<sub>R</sub> relative density (specific gravity, G<sub>s</sub>)  
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<sub>4</sub> concentration of water-soluble sulphates  
UC unconfined compression test  
UU unconsolidated undrained triaxial test  
V field vane (LV-laboratory vane test)  
γ unit weight

**Note: 1** Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. General

$\pi$	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 $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
*	Density symbol is $\rho$ . Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

#### (a) Index Properties (continued)

w	water content
$w_l$	liquid limit
$w_p$	plastic limit
$I_p$	plasticity index $= (w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index $= (w - w_p) / I_p$
$I_C$	consistency index $= (w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_a$	coefficient of secondary consolidation
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction $= \tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 + \sigma_3)$
$S_i$	sensitivity

- Notes: 1  $\tau = c' + \sigma' \tan \phi'$   
2 Shear strength = (Compressive strength)/2

# LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

## WEATHERING STATE

**Fresh:** no visible sign of weathering.

**Faintly weathered:** weathering limited to the surface of major discontinuities.

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock texture and structure are preserved.

## BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	> 2 m
Thickly bedded	0.6 m to 2m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	< 6 mm

## JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	> 3 m
Wide	1 - 3 m
Moderately close	0.3 - 1 m
Close	50 - 300 mm
Very close	< 50 mm

## GRAIN SIZE

Term	Size*
Very Coarse Grained	> 60 mm
Coarse Grained	2 - 60 mm
Medium Grained	60 microns - 2 mm
Fine Grained	2 - 60 microns
Very Fine Grained	< 2 microns

Note: \* Grains >60 microns diameter are visible to the naked eye.

## CORE CONDITION

### Total Core Recovery

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid sticks.

## DISCONTINUITY DATA

### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

### Dip with Respect to (W.R.T.) Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.




### Description and Notes

An abbreviated description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

### Abbreviations

B - Bedding	P - Polished
FO - Foliation/Schistosity	S - Slickensided
CL - Cleavage	SM - Smooth
SH - Shear Plane/Zone	R - Ridged/Rough
VN - Vein	ST - Stepped
F - Fault	PL - Planar
CO - Contact	FL - Flexured
J - Joint	UE - Uneven
FR - Fracture	W - Wavy
MF - Mechanical Fracture	C - Curved
- Parallel To	
⊥ - Perpendicular To	

PROJECT <u>021-1142</u>		<b>RECORD OF BOREHOLE No 2</b>		1 OF 1	<b>METRIC</b>
W.P. <u>76-99-01</u>		LOCATION <u>N 4902595 3 E 267741.5</u>		ORIGINATED BY <u>PKS</u>	
DIST <u>41</u> HWY <u>401</u>		BOREHOLE TYPE <u>108mm ID Hollow Stem Auger</u>		COMPILED BY <u>JFC</u>	
DATUM <u>Geodetic</u>		DATE <u>September 27, 2002</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
110.6	GROUND SURFACE													
109.9	Silty Sand, trace clay to clayey silt with sand, some gravel, some styrofoam pieces (FILL) Compact/Stiff		1	SS	13									
109.4	Crushed limestone gravel (FILL) Compact		2	SS	24									
1.2	Limestone/Dolostone (BEDROCK)													
	For bedrock coring details, refer to Record of Drillhole 2.													
106.3														
4.3	NOTE: Borehole dry on completion of overburden drilling.													

MISS MTO 021-1142.GPJ ON MOT.GDT 8/4/03

PROJECT: 021-1142

## RECORD OF DRILLHOLE: 2

SHEET 1 OF 1

LOCATION: N 4902595.300 E 267741.500

DRILLING DATE: September 27, 2002

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME-55 Bombardier

DRILLING CONTRACTOR: Marathon

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (mm/min)	FLUSH % RETURN	FR/FX-FRACTURE-F-FAULT CL-CLEAVAGE J-JOINT R-SMOOTH SH-SHEAR P-POLISHED R-ROUGH VN-VEIN S-SUCKENSIDED PL-PLANAR C-CURVED										BC-BROKEN CORE MB-MECH. BREAK B-BEDDING				NOTES WATER LEVELS INSTRUMENTATION
								RECOVERY		R Q D %	FRACT INDEX PER D 3	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec						
								TOTAL CORE %	SOLID CORE %			DIP w.r.t CORE AXIS		TYPE AND SURFACE DESCRIPTION		10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>			
								80 90 92	80 90 92			0 30 60	0 30 60	0 30 60	0 30 60	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>			
								DIP w.r.t CORE AXIS				TYPE AND SURFACE DESCRIPTION		HYDRAULIC CONDUCTIVITY K, cm/sec				DIAMETRAL POINT LOAD INDEX (MPa)				
2	CME-55 BOMBARDIER 108mm ID HOLLOW STEM AUGER	Refer to Previous Page		1.24	1	0.1	50															
3		Limestone/Dolostone (Bedrock) with shale seams Slightly weathered to fresh Medium strong to strong Grey			2	0.1	100															
4		END OF BOREHOLE		4.30																		
5																						
6																						
7																						
8																						
9																						
10																						
11																						

DEPTH SCALE

1 : 50



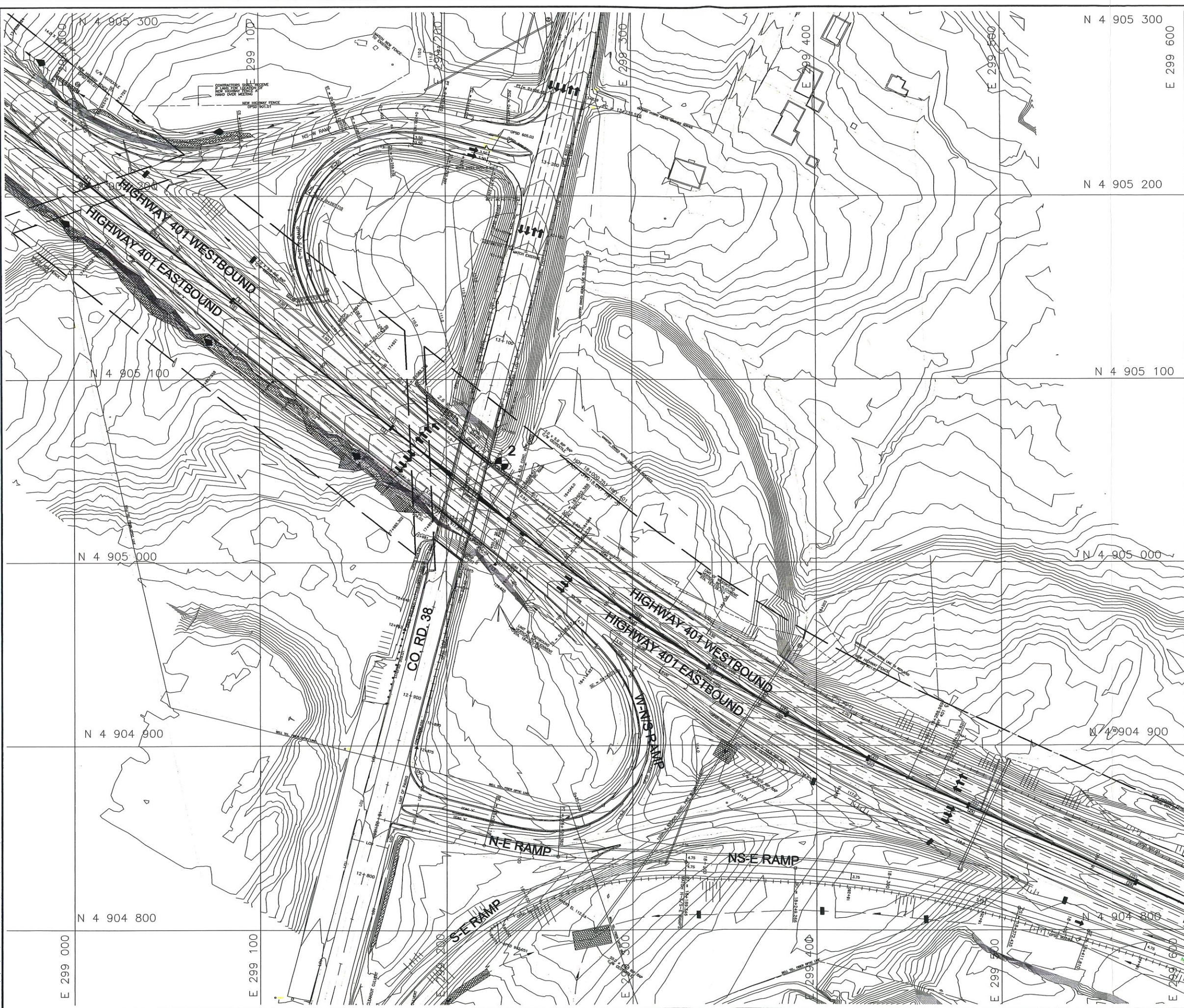
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CHECKED: LCC

MISS. ROCK 1142 ROCK GPJ GLDR CAN GDT 8/4/03 JFC



PLOT DATE: April 02, 2003  
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DIST. 42
HWY. 401

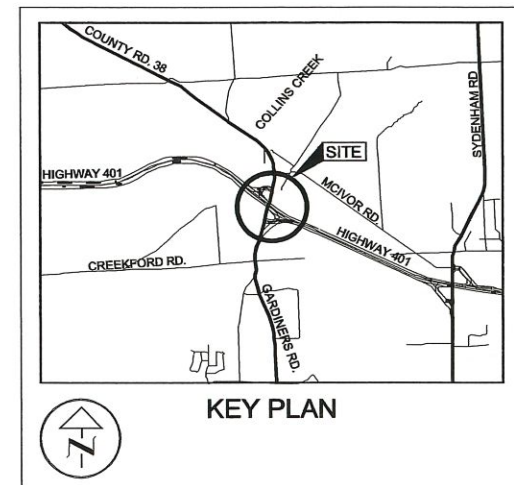
CONT No.
WP No. 76-99-01

OVERHEAD SIGNS AT  
COUNTRY ROAD 38  
BOREHOLE LOCATION

**Golder Associates Ltd.**  
MISSISSAUGA, ONTARIO, CANADA

SHEET

**METRIC**  
 DIMENSIONS ARE IN METRES  
 AND/OR MILLIMETRES  
 UNLESS OTHERWISE SHOWN



LEGEND			
Borehole			
No.	ELEVATION	LOCATION	
		NORTHING	EASTING
2	110.6	4902595.3	267741.5



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

**REFERENCE**  
 This drawing was prepared using a base plan supplied in digital format by MTO Eastern Region

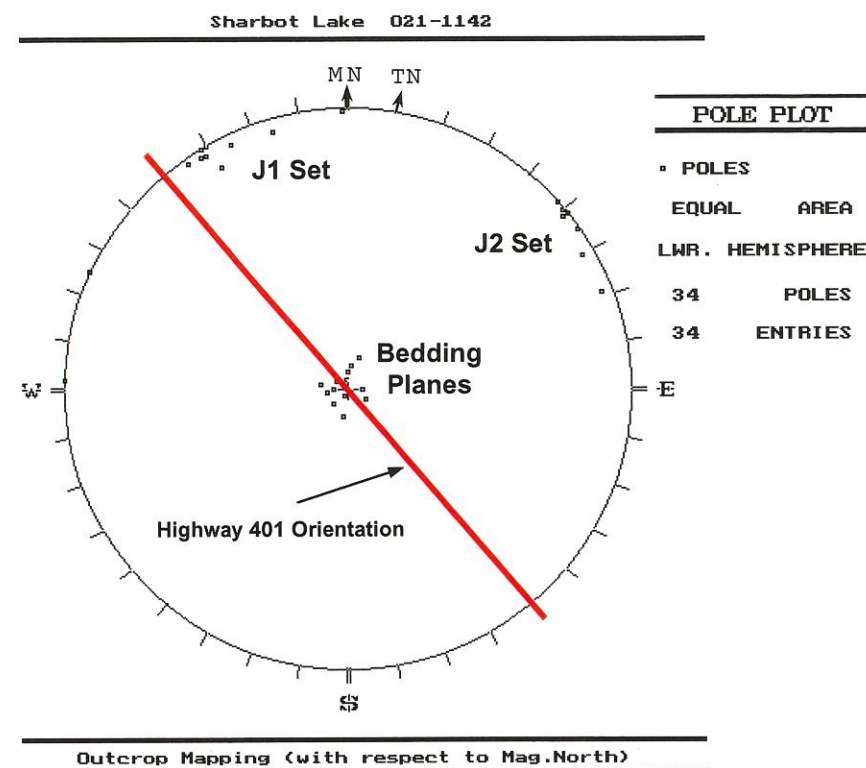
NO.	DATE	BY	REVISION
Geocres No.			
HWY. 401	PROJECT NO. 021-1142-1		DIST. 42
SUBM'D. LCC	CHKD. LCC	DATE: MARCH 2003	SITE:
DRAWN: MMZ	CHKD. LCC	APPD. ASP	DWG. 1



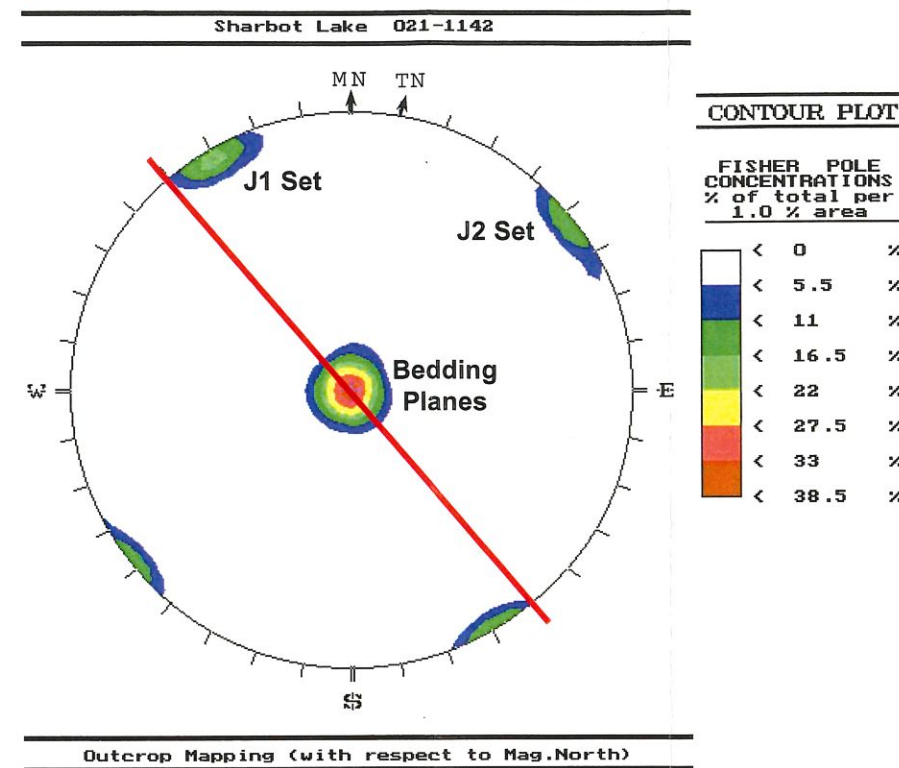
# MAPPING DATA AND PHOTOGRAPHS HIGHWAY 401 – COUNTY ROAD 38 INTERCHANGE

FIGURE 1

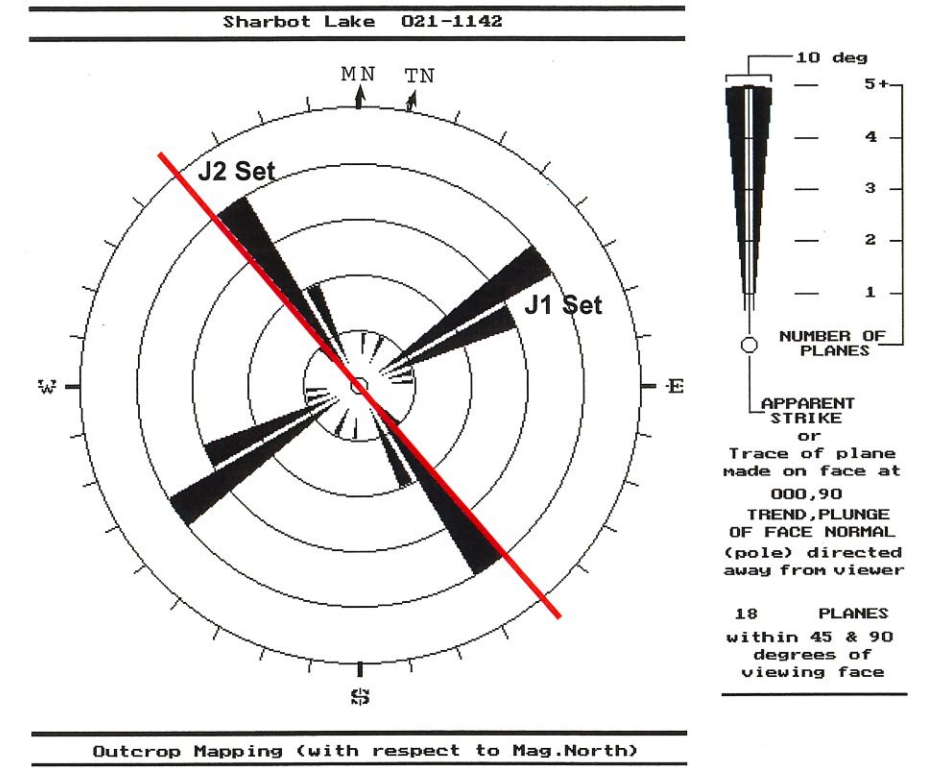
A) Pole Plot of Structural Geological Mapping Data



B) Contour Plot of Structural Geological Mapping Data



C) Rosette Plot of Structural Geological Mapping Data



D) Photomosaic of Rock Cut Face on South Side of Highway 401, West of County Road 38 Underpass Structure



Date: April 2003  
Project: 021-1142

Golder Associates

Drawn: PdG  
Chkd: LCC



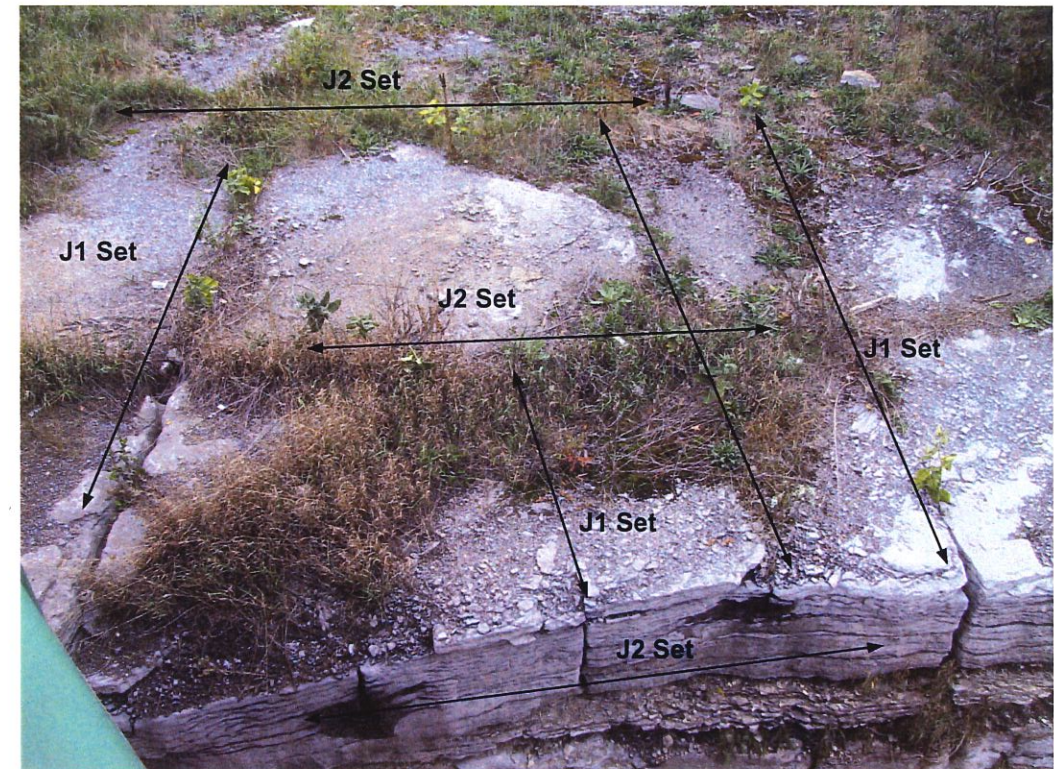
PHOTOGRAPHS  
HIGHWAY 401 – COUNTY ROAD 38 INTERCHANGE

FIGURE 2

A) Exposed Rock Face Immediately West of County Road 38 Underpass, South of Highway 401



B) Top View of Rock Outcrop West of County Road 38 Underpass



C) Close-Up of Typical Near-Surface Open Jointing

