

Golder Associates Ltd.

2390 Argentia Road
Mississauga, Ontario, Canada L5N 5Z7
Telephone: (905) 567-4444
Fax: (905) 567-6561



REPORT ON

**FOUNDATION INVESTIGATION AND DESIGN
CULVERT EXTENSIONS
G.W.P. 275-99-00, HIGHWAY 406 TWINNING
FROM 2.2 KM NORTH OF REGIONAL ROAD 20 TO
0.2 KM NORTH OF PORT ROBINSON ROAD
CITY OF THOROLD, CENTRAL REGION**

Submitted to:

Morrison Hershfield Ltd.
Suite 600, 235 Yorkland Boulevard
Toronto, Ontario
M2J 1T1

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PART A

**FOUNDATION INVESTIGATION REPORT
CULVERT EXTENSIONS
G.W.P. 275-99-00, HIGHWAY 406 TWINNING
FROM 2.2 KM NORTH OF REGIONAL ROAD 20 TO
0.2 KM NORTH OF PORT ROBINSON ROAD
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Appendix B Consolidation Test Data

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (Morrison Hershfield) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the twinning of Highway 406 in the City of Thorold, Regional Municipality of Niagara. The project includes a new bridge structure and interchange at Regional Road 20, a pedestrian subway at the abandoned CN Rail, culvert extensions and high fill areas. The limits of the project extend from 0.2 km north of Port Robinson Road northerly to 2.2 km north of Regional Road 20.

This report addresses the proposed culvert extensions within the project limits. A foundation investigation was carried out to determine the subsurface conditions at each proposed culvert extension by drilling a limited number of boreholes, and carrying out in-situ testing and laboratory testing on selected samples.

The work was carried out in accordance with Golder Associates' Quality Control Plan for Foundation Design Services, dated August 2002. A plan of the culvert extensions was provided to Golder by Morrison Hershfield in January 2003.

The subsurface information found in the following reports prepared by Golder as part of the overall project requirements was utilized in the preparation of this report to supplement the subsurface data obtained during the investigations at the culvert locations:

- Draft Foundation Investigation and Design Report titled "Regional Road 20 Underpass Structure", G.W.P. 275-99-00, Highway 406 Twinning from 2.2 km North of Regional Road 20 to 0.2 km North of Port Robinson Road, City of Thorold, Central Region. Report No. 021-1143-1, dated December 2002
- Draft Foundation Investigation and Design Report titled "Pedestrian Subway Crossing Structure", G.W.P. 275-99-00, Highway 406 Twinning from 2.2 km North of Regional Road 20 to 0.2 km North of Port Robinson Road, City of Thorold, Central Region. Report No. 021-1143-2, dated January 2003

In addition, the subsurface information found in the following reports prepared by the MTO was utilized in the preparation of this report to supplement the subsurface data obtained during the current investigation:

- Foundation Design Report titled "Hwy 20 Overpass at Hwy 406", W.P. 88-63-00, Site 34-297, District 4, Hamilton, dated August 1980. Geocres No. 30M3-175
- Foundation Design Report titled "CNR Overhead at Hwy 406", W.P. 167-66-01, Site 34-210, District 4, Hamilton, dated August 1980. GEOCREs No. 30M3-176.

2.0 SITE DESCRIPTION

The site is located in the City of Thorold, Regional Municipality of Niagara. Near the north limit of the project, the existing Highway 406 is carried over the abandoned section of the CN Rail line via a three-span pre-cast concrete girder bridge that was constructed under Contract 69-137. After CN abandoned the rail line, the City of Thorold transformed the corridor into a recreational trail. The existing embankment at this location is up to about 9 m high and, based on the contours shown on the topographic map, the side slopes are inclined at about 2 horizontal to 1 vertical (2H:1V). The remaining embankments within the project limits are between about 1 m and 2 m high.

In this area, Highway 406 and Regional Road 20 are presently a two lane, undivided highways with a posted speed limits of 80 km/hr and 60 km/hr, respectively. The intersection of these highways is controlled with overhead lights.

The topography of the general area is characterized by low relief. In addition to the many wet sloughs that cover the plain as a result of poor drainage, several shallow watercourses traverse the area with direct surface drainage into several parallel streams that include Twenty Mile Creek, Forty Mile Creek and the Welland River. These watercourses are carried beneath the existing Highway 406 within the project limits with rigid frame, open footing concrete culverts that range in size from 1.2 m by 1.2 m to 2.5 m by 1.5 m.

The land within the project limits is mainly used for agricultural purposes. The perimeter of the open fields typically holds stands of mature trees. Long grass and occasional bushes cover the highway right-of-ways within the project limits.

3.0 INVESTIGATION PROCEDURES

A subsurface investigation was carried between October 23 and 31, 2002. At that time, two (2) boreholes were advanced at the location of each of the six (6) culvert extensions for a total of twelve (12) boreholes. The borehole numbers and locations are summarized in the following table.

| Culvert Number | Station | Borehole Number |
|----------------|---------|-----------------|
| 1 | 5+850 | C-1, C-1A |
| 2 | 6+207 | C-2, C-2A |
| 3 | 7+282 | C-3, C-3A |
| 4 | 8+525 | C-4, C-4A |
| 5 | 9+582 | C-5, C-5A |
| 6 | 10+406 | C-6, C-6A |

These boreholes were extended to depths of between 3.7 m and 7 m below the existing ground surface. The information from the boreholes put down within the project limits as part of the

current project (see Section 1 for references) at the proposed interchange at Highway 406 and Regional Road 20 (Boreholes 20-1 to 20-3) and the proposed Pedestrian Subway structure at Station 10+120 (Boreholes P-1, P-1A, and P-2) was utilized to assess the subsurface conditions at depth.

The boreholes were advanced with a track-mounted CME-75 drill rig equipped with an automatic hammer using 114 mm diameter solid stem augers supplied and operated by GeoEnvironmental Ltd. of Milton, Ontario. In the boreholes, overburden samples were obtained at 0.75 m to 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedure. Field vane testing was also carried out in order to measure the in-situ, undrained shear strength of the subsoils, where appropriate. The groundwater conditions in the open boreholes were observed throughout the drilling operations, and piezometers were installed in selected boreholes to permit monitoring of the groundwater level at these locations. The piezometers consist of a 25 mm outside diameter pipe with a 0.3 m long slotted tip that is sealed at a selected depth within the boreholes. The boreholes were backfilled to ground surface with bentonite mixed with soil cuttings.

The field work was supervised on a full-time basis by a member of our engineering staff who cleared the area of buried utilities, located the boreholes in the field, directed the drilling, sampling, and in-situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to our laboratory in Mississauga for further examination and testing. Index and classification tests consisting of Atterberg limits tests and water content determinations were carried out on selected soil samples. The results of these tests were supplemented with the test results from our investigations carried for other aspects of the project, where appropriate. The supplemental test information includes Grain size analysis and Atterberg limits testing. In addition, one-dimensional consolidation (oedometer) tests were carried out on two selected samples of the clayey deposit as part of the analysis for the Pedestrian Subway structure. Reference is also made to the subsurface information obtained as part of the previous MTO investigations within the projects limits, as appropriate. The relevant record of boreholes from the previous MTO investigations are provided in Appendix A.

The borehole locations were established relative to the staked limits of the proposed culvert extensions. The as-drilled borehole locations and elevations were surveyed by Callon Dietz Inc. of London, Ontario. It is understood that the northing and easting coordinates are referenced to the MTM coordinate system and that the elevations are referenced to Geodetic Datum. The borehole locations are shown on Drawing 1.

4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY

4.1 Site Geology

From published literature, the site is located within the physiographic region known as the Haldimand Clay Plain (“The Physiography of Southern Ontario”, 3rd Edition, Chapman and Putnam, 1984). This region was submerged by glacial Lake Warren and as such much of the subsoil is comprised of stratified lacustrine silts and clays. In some areas the stratified clay overlies clayey till while in other areas the subsoil is represented by an interlayered / intermixed deposit of lacustrine silt / clay and till. The overburden is generally less than about 20 m thick, with a trend of increasing thickness towards Lake Erie. The underlying bedrock consists of a succession of Paleozoic beds dipping slightly southward under Lake Erie. Dolostone is the predominate type of rock within the plain with softer, shaley rock found in the southwest area of the plain.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets and on Figures 1 to 9 following the text of this report. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoils at the site consist of surficial layers of topsoil and fill underlain by an upper deposit of silty clay, which in turn is underlain by clayey silt with occasional silty clay to silt seams / layers. A ‘softened’ silty clay deposit was encountered beneath the upper silty clay in the area of the two culverts near the north limit of the project. Bedrock was not encountered in the boreholes put down at the proposed culvert extensions; however, dolomite bedrock was found beneath the clayey silt at about 23 m depth (Elevation 160.5) in the area of the Highway 406 / Regional Road 20 intersection (Golder Report No. 021-1143-1, dated July 2003). Bedrock was also encountered at about 11 m depth (Elevation 170 m) in the area of the CN Rail corridor (Golder Report No. 021-1143-2, dated July 2003). Based on the readings made in the deep piezometers installed in other areas within the project limits, the aquifer in the bedrock controls the primary groundwater level. However, perched conditions within the silty clay and upper portions of the clayey silt were also observed as part of the current Golder and previous MTO investigations. Water was measured in the piezometers at between about 1 m and 5 m below the groundwater surface at the culvert locations, which likely reflects perched conditions in the silty clay and clayey silt deposits.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections. The locations and elevations of the boreholes are shown on the attached Drawing 1.

4.2.1 Topsoil

A layer of topsoil was encountered surficially in all boreholes, except in Boreholes C-2, C-2A, C-5, and C-5A. The topsoil is generally about 0.2 m thick at the borehole locations.

4.2.2 Fill

A 1.3 m thick layer of mottled brown to brown silty clay fill was encountered below the topsoil in Boreholes C-4 and C-4A. Trace sand, gravel, and topsoil were noted within the fill. Standard Penetration testing (SPT) carried out within the fill measured 'N' values of 7 blows to 27 blows per 0.3 m of penetration, which indicates a firm to very stiff consistency. The water content of a selected sample of the silty clay fill was measured at about 22 percent.

The silty clay fill is likely reworked native material as part of the agricultural operations carried out in the area of Culvert 4.

4.2.3 Upper Silty Clay

A deposit of reddish brown / grey silty clay, trace sand and gravel was encountered below the topsoil and fill in all the boreholes. Occasional organics were noted in the upper portion of the deposit in Boreholes C-1, C-1A. At the location of Boreholes C-5 and C-5A, the upper 0.4 m and 0.7 m, respectively, of the silty clay is mixed with organics that gives this portion of the deposit a very dark to black colour. The silty clay is typically weathered throughout its 2 m to 4 m thickness where oxidation staining and fissuring were noted in the samples. Grain size distribution curves of two selected samples of the silty clay as part of the current Golder investigations at the Regional Road 20 / Highway 406 intersection (Borehole 20-1) and at the CN Rail Corridor (Borehole P-1) are shown on Figure 1.

Standard Penetration Testing (SPT) measured 'N' values ranging from 2 blows to 27 blows per 0.3 m of penetration, which indicates a soft to very stiff consistency. In general, the upper silty clay is very stiff as a result of weathering that has formed a crust. The lower 'N' values were measured in the areas of the deposit where organics are present. Field vane testing was attempted within the deposit; however, it was found that the vane could not be turned. This indicates that the undrained shear strength exceeds 96 kPa (i.e. the upper limit of shear strength measurement of the vane). The results of the unconfined shear strength testing carried out on selected samples from this stratum as part of the previous MTO investigation at the CN Rail corridor (Boreholes 80-1A to 80-6A) measured shear strength values of 287 kPa to 156 kPa, with a general trend of decreasing strength with depth throughout the deposit.

Atterberg Limits testing conducted on three selected samples obtained from this stratum at the culvert locations show liquid limits (w_L) of between about 36 percent and 49 percent and plasticity indices (I_p) of between about 20 percent and 22 percent. The results of the Atterberg Limits testing are shown plotted on the plasticity chart on Figure 2 along with the results from

other current Golder investigations carried out within the project limits (Boreholes 20-1 and P-1). Based on the results, the silty clay is of intermediate to high plasticity. In general, the silty clay is of intermediate plasticity. The natural water content measured on selected samples from this stratum range from about 20 percent to 99 percent. The highest water content was measured in the upper portion of the deposit in Borehole C-1 and reflects the presence of organics in the sample tested. Excluding this high value, the water content ranges from about 20 percent to 30 percent, with an average of about 23 percent. In general, the water contents were found to be at or slightly above the measured plastic limits, corresponding to a liquidity index of less than 1.

Boreholes C-1A, C-3A, and C-4A were terminated at about 2.2 m to 3.7 m within the silty clay deposit.

4.2.4 'Softened' Silty Clay

A deposit of grey / brown to grey silty clay containing trace of sand and gravel and occasional silt seams / layers was encountered below the upper silty clay in Boreholes C-5, C-5A, C-6, and C-6A. These boreholes were terminated within the softened silty clay deposit. It is possible that this deposit represents the unweathered portion of the upper silty clay or a softer layer within / near the creek channels where the boreholes were put down. Standard Penetration Testing (SPT) carried out within the silty clay measured 'N' values of between 4 blows and 20 blows per 0.3 m of penetration; typically 4 blows to 12 blows per 0.3 m of penetration. Field vane testing carried out within the silty clay gave undrained shear strength values of 28 kPa to 78 kPa, indicating that the deposit has a firm to stiff consistency. The higher vane strength values were measured in Borehole C-5 where the higher 'N' values were also recorded. The sensitivity of the deposit, as estimated from the field vane tests, is about 1.5 and 3, implying that the clayey stratum in this area is of low to medium sensitivity based on the classification system provided in CFEM (1992).

Atterberg Limits testing conducted on two samples obtained from this stratum show liquid limits (w_L) of 41 percent and 49 percent and plasticity indices (I_p) of 22 percent and 28 percent, respectively. The results of the Atterberg Limits testing classify the soil in this stratum as inorganic silty clay of intermediate plasticity. The results of the Atterberg Limits testing are shown plotted on the plasticity chart on Figure 2 (Borehole C-5, Elevation 176.3 m and Borehole C-6, Elevation 174.8 m). The natural water content of selected samples from this stratum range from about 20 percent to 49 percent. The highest water content was measured on a sample from Borehole C-6 submitted for Atterberg limits testing and is equal to its liquid limit.

4.2.5 Lower Clayey Silt

The predominant deposit at the site was encountered beneath the silty clay stratum and consists of brown to reddish grey clayey silt with occasional silty clay and silt seams / layers and containing trace of sand and gravel. Grain size distribution curves for selected samples of the clayey silt and

silty clay seams / layers as part of the current Golder investigation within the project limits are shown on Figures 3 and 5, respectively.

Standard Penetration Testing (SPT) measured 'N' values within this deposit ranging from 6 to 30 blows per 0.3 m at penetration. The highest 'N' value was measured in Borehole C-4 where a silt layer is present. Typically, at the culvert borehole locations, the measured 'N' values range from 6 blows to 20 blows per 0.3 m of penetration. SPT 'N' values measured in the deposit for the Golder investigation in the area of Highway 406 and Regional Road 20 range from 13 blows to greater than 50 blows per 0.3 m of penetration. Field vane testing was attempted within the deposit at this location; however, it was found that the vane could not be turned, which indicates that the undrained shear strength exceeds 96 kPa. The sensitivity of the deposit, as estimated from the field vane tests, ranges from about 1.5 to 4, implying that the clayey stratum in this area is of low to medium sensitivity based on the classification system provided in CFEM (1992).

Atterberg Limits testing conducted on selected clayey silt samples obtained from this stratum in the area of the culvert extensions, Regional Road 20 / Highway 406 intersection, and CN Rail corridor indicate liquid limits (w_L) of between about 20 percent and 31 percent and plasticity indices (I_p) of between about 4 percent and 15 percent. Atterberg limits testing was also carried out on two silty clay to silt seams found within the Shelby tube samples obtained in Borehole P-1A for the Golder investigation at the CN Rail corridor. The results indicate liquid limits (w_L) of about 31 percent and 34 percent and plasticity indices (I_p) of about 13 percent and 17 percent for the silty clay to silt seams / layers. The results of the Atterberg Limits testing classify this stratum as an inorganic clayey silt of low plasticity with the silt / clay seams / layers having low plasticity. The results of the current Atterberg Limits testing are shown on the plasticity chart on Figures 4 and 4A (clayey silt) and 6 (silt / clay seams / layers). The natural water content measured on selected samples from this stratum typically range from about 17 percent to 37 percent, with an average of about 25 percent. These water contents vary significantly with respect to relationship with the liquid limits and plastic limits; likely reflecting the wide range of soil types and the interlayering of the deposit.

The measurements of mass and dimensions conducted to estimate the natural bulk unit weight of two carefully trimmed samples from this stratum that were collected during the CN Rail corridor investigation resulted in values of about 20 kN/m³. The specific gravity measured on these two samples produced an average value of 2.73.

Consolidation tests (oedometer) were performed on two samples from this stratum as part of the Golder investigation for the pedestrian subway structure (Golder No. 021-1143-2, dated July 2003). The results are summarized below.

| Borehole (Sample) | Elevation (Depth) (m) | σ_{vo}' (kPa) | σ_p' (kPa) | OCR | e_o | C_r | C_c | c_v (cm ² /s) |
|----------------------|-----------------------------|-------------------------|----------------------|-----|-------|-------|-------|-------------------------------|
| P-1A (1) | 176 (5) | 100 | 505 | 5.1 | 0.562 | 0.031 | 0.151 | 1.1×10^{-1} |
| P-1A (2) | 172.9 (8.1) | 156 | 455 | 2.9 | 0.661 | 0.024 | 0.144 | 5.3×10^{-2} |

where: σ_{vo}' is the effective overburden pressure in kPa
 σ_p' is the pre-consolidation pressure in kPa
OCR is the overconsolidation ratio
 e_o is the initial void ratio
 C_r is the recompression index
 C_c is the compression index
 c_v is the estimated coefficient of consolidation for anticipated stress range at sample depth in cm²/s

The results of the consolidation tests are provided in Appendix B. Plots showing the Void Ratio versus Pressure for Samples 1 and 2 are shown on Figures 7 and 8, respectively. Figure 9 is a plot of the preconsolidation stress values for the two oedometer tests in relation to the effective stress profile in the area of the CN Rail corridor.

Boreholes C-1, C-2, C-3, and C-4 were terminated about 3 m to 4 m within the clayey silt deposit. The clayey silt was fully penetrated in Boreholes 20-1 and 20-2 in the area of Highway 406 and Regional Road 20 where the deposit was found to be about 17 m thick, corresponding to an elevation of about 162.5 m at the base of the deposit. The deposit was also fully penetrated in Borehole P-1 in the area of the CN Rail corridor where it was found to be about 7 m thick, corresponding to an elevation of about 169.9 m at the base of the deposit.

4.2.6 Silty Clay with Sand and Gravel

Beneath the clayey silt stratum in Boreholes 20-1 and 20-2 exists a heterogeneous deposit of reddish grey silty clay with sand and gravel that is 2 m and 2.8 m thick, respectively, at these borehole locations. Standard Penetration Testing (SPT) measured 'N' values of 90 blows and greater than 100 blows per 0.3 m of penetration, indicating a hard consistency. The deposit was also encountered beneath the clayey silt in some of the previous MTO boreholes put down in the area of the Highway 406 / Regional Road 20 intersection and the CN Rail corridor.

4.2.7 Bedrock

Bedrock was encountered at Elevation 160.5 m in Boreholes 20-1 and 20-2 at Highway 406 / Regional Road 20. Bedrock was also encountered in Borehole P-1 at Elevation 169.9 m and inferred in Borehole P-2 at Elevation 169.5 m based on auger grinding / refusal at the CN Rail corridor. The results of these boreholes and of the previous MTO investigations indicate that the bedrock surface is relatively flat at these locations. Boreholes 20-1, 20-2, and P-1 were advanced

about 3 m to 4 m into the bedrock by coring in NQ size. The rock core samples consist of slightly weathered to fresh, grey, medium to coarse-grained, strong to very strong, mainly massive with some thin bedding dolostone.

4.2.8 Groundwater Conditions

Water levels were noted in the open boreholes during and upon completion of the drilling operation; these levels are shown on the attached Record of Borehole sheets. Piezometers were sealed in Boreholes C-1 to C-6 to permit the monitoring of the groundwater levels at these locations. Details of the piezometer installations and the groundwater level measurements are shown on the attached Record of Borehole sheets. The water levels in the open boreholes and piezometers are summarized in the table below.

| Culvert Number | Borehole Number | Water Level in Open Borehole | | Piezometer Tip Elev. (m) | Water Level in Piezometer | | | |
|----------------|-----------------|------------------------------|---------------|---------------------------------|---------------------------|---------------|------------------|---------------|
| | | Depth (m) | Elevation (m) | | November 15, 2002 | | January 31, 2003 | |
| | | | | | Depth (m) | Elevation (m) | Depth (m) | Elevation (m) |
| 1 | C-1 | Wet at base | 172.8 | 173 | 1.0 | 178.8 | 0.8 | 179.0 |
| | C-1A | Dry | --- | --- | N/A | N/A | N/A | N/A |
| 2 | C-2 | Dry | --- | 173 | 1.4 | 178.4 | Frozen @ g.s. | 179.8 |
| | C-2A | Dry | --- | --- | N/A | N/A | N/A | N/A |
| 3 | C-3 | Dry | --- | 177 | 4.8 | 179.2 | 2.4 | 181.6 |
| | C-3A | Dry | --- | --- | N/A | N/A | N/A | N/A |
| 4 | C-4 | 6.4 | 174.5 | 174 | 3.1 | 177.8 | 1.5 | 179.4 |
| | C-4A | Wet at base | 177.7 | --- | N/A | N/A | N/A | N/A |
| 5 | C-5 | 5.2 | 174.8 | 174 | 4.7 | 175.3 | 2.0 | 178.4 |
| | C-5A | 0.6 | 179.3 | --- | N/A | N/A | N/A | N/A |
| 6 | C-6 | Dry | --- | 172.9 | Dry | --- | Wet at base | 172.9 |
| | C-6A | Dry | --- | --- | N/A | N/A | N/A | N/A |

Piezometers were also sealed in the bedrock and the lower portion of the clayey silt deposit in Boreholes 20-1 and 20-2 (at Highway 406 / Regional Road 20 between Culverts 3 and 4), and in Borehole P-1 (at the CN Rail corridor between Culverts 5 and 6). Water was measured in the piezometers at depths of about 4.9 m (Elevation 178.9 m), 6.7 m (Elevation 176.4 m), and 7.5 m (Elevation 173.5 m) in Boreholes 20-1, 20-2, and P-1 about 2 weeks after completion of drilling. A second set of readings made in these piezometers about three months after completion of drilling measured the water at 6.5 m depth (Elevation 176.6 m) in Borehole 20-2 and at 2.3 m depth (Elevation 178.7 m) in Borehole P-1; the water level was unchanged in Borehole 20-1. A piezometer was also sealed within the clayey silt in Borehole P-2 with tip at 173.5 m where the water level was measured at 5.1 m depth (Elevation 177.1 m) about two weeks after installation. Water was noted at about 1.8 m to 2.5 m in some of the previous MTO boreholes that were left open for a period of time after drilling.

The readings indicate that a perched water condition exists within the silty clay and upper portion of the clayey silt. The perched water level follows the ground surface within the project limits and is generally within about 2.5 m of the ground surface. The regional groundwater level is

located at a greater depth and appears to be controlled by the bedrock and the more pervious sand and gravel layer that overlies the bedrock.

The groundwater information in the Preliminary Design and Environmental Assessment Report (dated September 2001) for this project indicates that there are no significant shallow aquifers within the study area and that the primary aquifer(s) is found within the bedrock. Well records in the area (compiled as part of the previous study) indicate water levels generally below 8 m depth.

It should be noted that groundwater levels are expected to fluctuate seasonally and are expected to be higher during wet periods of the year.

GOLDER ASSOCIATES LTD.

Dan K. Breeze, P.Eng.,
Geotechnical Engineer

Anne S. Poschmann, P.Eng.,
Principal

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

DKB/ASP/FJH/ mmh

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PART B

**FOUNDATION DESIGN REPORT
CULVERT EXTENSIONS
G.W.P. 275-99-00, HIGHWAY 406 TWINNING
FROM 2.2 KM NORTH OF REGIONAL ROAD 20 TO
0.2 KM NORTH OF PORT ROBINSON ROAD
CITY OF THOROLD, CENTRAL REGION**

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides foundation design recommendations for the five (5) proposed culvert extensions that will be placed beneath the proposed SBL of Highway 406 twinning within the project limits. The recommendations are based on interpretation of the factual data obtained from a limited number of boreholes advanced during the current and previous MTO subsurface investigations at this site. The interpretation and recommendations provided are intended only to provide the designers with sufficient information to assess the feasible foundation alternatives for design of the proposed culvert extensions and staging of this construction. As such, where comments are made on construction they are provided only in order to highlight those aspects which could affect the planning of the project.

The limits of this project extend from 0.2 km north of Port Robinson Road northerly to 2.2 km north of Regional Road 20. Within these limits, it is understood that Highway 406 will be twinned with the existing two lanes of the highway converted to the northbound lanes and the construction of two new southbound lanes. The existing culverts beneath Highway 406 must therefore be extended past the proposed SBL in order to facilitate drainage across the Highway.

It is understood that the SBL will be constructed first and that traffic will be moved to this section while work proceeds on the existing embankment to form the NBL.

The type, locations, and extension length of the culverts and proposed extensions are given in the table below. Subsequent to drilling of the boreholes, it is understood that the extension at Culvert 1 is not required.

| Culvert Number | Station | Existing Culvert Type | Proposed Extension Type | Extension Length |
|-----------------------|----------------|-------------------------------------|-------------------------------------|-------------------------|
| 2 | 6+207 | 2.5 x 1.5 m (Concrete Open Footing) | 2.5 x 1.5 m (Concrete Open Footing) | 26.17 m LT |
| 3 | 7+282 | 1.8 x 1.0 m (Concrete Open Footing) | 1.8 x 1.0 m (Concrete Open Footing) | 27.42 m LT |
| 4 | 8+525 | 2.4 x 1.4 m (Concrete Open Footing) | 2.4 x 1.4 m (Concrete Open Footing) | 34.62 m LT |
| 5 | 9+582 | 1.2 x 1.2 m (Concrete Open Footing) | 1.2 x 1.2 m (Concrete Open Footing) | 34.79 m LT |
| 6 | 10+406 | 1.2 x 1.2 m (Concrete Open Footing) | 1.2 x 1.2 m (Concrete Open Footing) | 31.08 m LT |

As the information in the tables indicates, the proposed culvert extensions will match the existing culverts. The embankment fill in the area of the culverts will be about 2 m high, except at the location of Culvert 6 where the fill will be up to about 4.5 m high in order to provide an approach to the proposed Pedestrian Subway structure at Station 10+120.

5.2 Culvert Foundations

Apart from the existing embankment fill, the subsoils at the site consist of a surficial layer of topsoil / organics / fill underlain by an upper stratum of generally very stiff silty clay of medium to high plasticity that is about 2 m to 4 m thick at the borehole locations. The silty clay is in a weathered state and therefore forms a “crust” layer. At the location of the proposed extensions to Culverts 5 and 6, the silty clay crust is underlain by a layer of firm to stiff silty clay of medium plasticity. At the other culvert locations, the crust is underlain by the predominant deposit at the site which is comprised of generally firm to stiff clayey silt of low plasticity. Silty clay to silt seams / layers are randomly found throughout the deposit. Based on the Golder boreholes put down, the clayey silt deposit is about 17 m to 19 m thick in the area of the Highway 406 / Regional Road 20 intersection and about 7 m thick in area of the CN Rail corridor. In some of the boreholes, a 0.6 to 2.8 m thick deposit of hard silty clay with sand and gravel was encountered beneath the clayey silt. Dolostone bedrock is found at about Elevation 160.5 m in the area of Regional Road 20 and Highway 406 and at about Elevation 170 m in the area of the CN Rail corridor.

The water level readings indicate that a perched water condition exists within the silty clay and upper portion of the clayey silt. The perched water level follows the ground surface within the project limits as is generally within about 2.5 m of the ground surface. The regional groundwater level is located at a greater depth and appears to be controlled by the bedrock and the more pervious sand and gravel layer that overlies the bedrock.

Based on the subsurface information available at the culvert locations, consideration may be given to supporting the structures on shallow spread footings. The use of deep foundations is not recommended at any of the culvert sites due to the presence of suitable material at or just below the founding elevation of the existing culverts.

5.2.1 Axial Geotechnical Resistance

The invert elevation and founding soil type for each culvert extension are identified in the following table. The information for the existing culverts provided in the Drainage and Storm Water Management Report was used to estimate the invert elevations along the proposed culverts assuming a 0.5% grade along the culvert extensions. The elevation provided is for the mid-point of the culvert extension. The elevation given for the base of the footings assumes that they will

be placed at least 1.2 m below the invert level. At the location of Culvert 4, fill is present at 1.2 m below the invert. This fill should be subexcavated and the footings placed at the lower elevation shown in the table. The footing size was obtained from the MTO Drawing titled “Standard Concrete Culverts, Open Type-Without Headwalls”, dated July 1957 that was provided by Morrison Hershfield.

The factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical resistance at Serviceability Limit States (SLS) that may be used for design of each culvert where founded on the properly prepared native soil are also given in the table. It should be noted that settlements of greater than 25 mm will occur due to the embankment loading discussed in Section 5.2.3.

The geotechnical resistances provided herein are 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 the *Canadian Highway Bridge Design Code (CHBDC)*.

| Culvert Number | Culvert Station | Relevant Boreholes | Invert Elevation for Extension (m) | Footing Elevation for Extension (m) | Founding Soil Type |
|----------------|-----------------|--------------------|------------------------------------|-------------------------------------|--------------------------------|
| 2 | 6+207 | C-2, C-2A | 179.2 | 178.0 | Stiff to Very Stiff Silty Clay |
| 3 | 7+282 | C-3, C-3A | 183.7 | 182.5 | |
| 4 | 8+525 | C-4, C-4A | 181.0 | 179.5* | |
| 5 | 9+582 | C-5, C-5A | 180.5 | 179.3 | |
| 6 | 10+406 | C-6, C-6A | 179.3 | 178.1 | |

| Culvert Number | Footing Width, B (m) | Factored Geotechnical Resistance at ULS (kPa) | Settlement | | Angle of Friction, ϕ' | Coefficient of Friction, $\tan\phi'$ |
|----------------|----------------------|---|----------------|----------------|----------------------------|--------------------------------------|
| | | | SLS (kPa) 25mm | SLS (kPa) 50mm | | |
| 2 | 0.7 | 125 | 150 | 200 | 24 | 0.45 |
| 3 | 0.6 | 150 | 175 | 225 | 24 | 0.45 |
| 4 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| 5 | | | | | | |
| 6 | | | | | | |

*Value greater than 1.2 m below invert to reflect subexcavation of fill material required - see Section 5.3.1.

5.2.2 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the base of the concrete footings and the undisturbed native materials should be calculated in accordance with Section 6.7.5 of the *CHBDC*. Assuming cast-in-place footings which also assumes intimate contact with the foundings soils the coefficient of friction value, $\tan \phi'$, for the footings placed on undisturbed native soils is provided in the table above. Since the founding deposit is similar at all culvert locations, the same values applies to all culverts. The value provided is unfactored; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

5.2.3 Settlement Assessment

Consolidation settlement of the clayey subsoils as a result of placement of embankment fill will occur, which will correspondingly result in settlement of the proposed culvert extensions. At the location of Culvert 6, rebound of the existing culvert will occur as a result of the reduction in the existing embankment height for the proposed NBL profile.

A settlement assessment was carried out for the proposed embankments using UNISETTLE (V3.0), a commercially available computer software program. The analysis was carried out assuming that the new SBL embankment will be at the same height as the existing embankment for Culverts 1 to 5. The existing embankment height at these locations is about 2 m. At the location of Culvert 6, the existing embankment height will be reduced by about 1 m to 4.5 m as part of the approach configuration to the proposed Pedestrian Subway structure at Station 10+120. This will result in a net off-loading at this location and therefore rebound of the clayey subsoils will occur.

The settlement assessment was carried out using the compression and recompression indices (C_c and C_r) profiles which were derived based correlations with the laboratory data (Atterberg Limits) in conjunction with the two consolidation (oedometer) tests. Two distinct set of profiles were observed after the correlations were made. The first profile relates to the information compiled between about Stations 5+600 and 8+600, where Culverts 1 to 4 are located. The second profile includes the information compiled between about Stations 9+550 to 10+450, where Culverts 5 and 6 are located. The analysis was carried out to reflect these two profiles.

The deposit is overconsolidated based on the results of the consolidation test data. It was found that the resulting effective stress after the proposed new embankment loading is still less than the preconsolidation pressures at all culvert locations (i.e. only the C_r profile applies). The results of the settlement analysis are provided in the following table.

| Culvert No. | Proposed Embankment Height (m) | Max. Settlement (mm) | Max. Rebound (mm) | C_v cm ² /s | Calculated Time for 70% Consolidation (months) | Calculated Time for 90% Consolidation (months) |
|-------------|--------------------------------|----------------------|-------------------|--------------------------|--|--|
| 2 | 2 | 40 | N/A | 0.035 | 6 | 12 |
| 3 | 2 | 40 | N/A | 0.035 | 6 | 12 |
| 4 | 2 | 40 | N/A | 0.035 | 6 | 12 |
| 5 | 2 | 50 | N/A | 0.035 | 4 | 8 |
| 6 | 4.5 | 75 | 25 | 0.04 | 3.5 | 7 |

At the location of Culvert 6, the critical differential settlement for design will be along the length of the culvert structure extending between the median and the inside crest of the SBL embankment. The total differential settlement that should be taken into consideration for design is in the order of 100 mm. The C_r profile used in the analysis for Culverts 1 to 4 and the calculated settlement profile along the culvert extensions are shown on Figure 10. The C_r profile used in the analysis for Culverts 5 and 6 and the calculated settlement profiles (and rebound for Culvert 6) along the culvert extensions are shown on Figure 11. These settlement profiles should be considered in the design of the culverts.

As indicated in the table, it is estimated that 70 percent of the consolidation / rebound will occur within about 3.5 months of construction and that 90 percent of the consolidation / rebound will occur within 7 months at the location of Culvert 6. Therefore, if the SBL is constructed first and the NBL construction is at least 3.5 months following completion of the SBL embankment at the subway location, then the maximum post construction differential along the length of the culvert between the embankment centrelines will be $(75 - 70\% \text{ of } 75) + 25 \text{ (rebound)} \cong 50 \text{ mm}$. The maximum post construction differential would be about 40 mm (i.e. 60 mm consolidation having occurred) in about 4 months.

It is understood that surcharge embankment is proposed and will be 6 m high, 8 m wide of the crest, and have side slopes of 1.5 H:IV. It is also understood that the surcharge embankment will encompass the full proposed culvert extension length of 22.8 m. In order to induce consolidation settlement of 60 mm (i.e. residual consolidation of 40 mm), the surcharge embankment must be left in place for a period of at least 2.5 months. In order to reduce this time to 2 months, the surcharge embankment must be at least 6.5 m high (as opposed to 6 m).

The settlement related to the compression of the properly placed and compacted fill materials comprising the new SBL embankment is anticipated to be minor, and will occur during construction.

5.2.4 Frost Protection

The culvert footings should be provided with a minimum of 1.2 m of earth cover for frost protection purposes.

5.3 Culvert Extension Construction

5.3.1 Backfill

The backfill requirements for the culvert extensions should be in accordance with OPSD 803.02 for concrete rigid frame culverts. The culvert extensions should be designed for the full overburden pressure and live load, assuming an embankment fill unit weight of 21 kN/m³.

Backfill to the culvert walls should consist of granular fill meeting the specifications for OPSS Granular 'A' or Granular 'B', Type II (but with less than 5 per cent passing the 200 sieve). The backfill should be placed in lifts not exceeding 200 mm loose thickness and compacted to 95 per cent Standard Proctor dry density. Reference should be made in the contract documents to special provision 422S01.

5.3.2 Lateral Earth Pressures for Design

The lateral earth pressures acting on the culvert 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 magnitude of surcharge including construction loadings, 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 walls:

- Select free-draining granular fill meeting the specifications of Ontario Provincial Standard Specifications (OPSS) Granular 'A' or Granular 'B' but with less than 5 per cent passing the 200 sieve should be used as backfill behind the walls. This fill should be compacted in loose lifts not greater than 200 mm in thickness to 95 per cent of the material's Standard Proctor maximum dry density in accordance with OPSS 501. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD 3501.00 and 3504.00.
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the structure, in accordance with *CHBDC* Section 6.9.3 and Figure 6.9.3. Compaction equipment should be used in accordance with OPSS 501.06. Other surcharge loadings should be accounted for in the design, as required.
- The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the walls (Case I in Figure C6.9.1(I) of the *Commentary to the CHBDC*) or within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II in Figure C6.9.1(I) of the *Commentary to the CHBDC*).
- For Case I, the pressures are based on the proposed embankment fill materials and the following parameters (unfactored) may be assumed based on the use of Select Subgrade Material:

| | |
|-------------------------------|----------------------|
| Soil unit weight: | 21 kN/m ³ |
| Coefficients of lateral earth | |
| Active, K_a | 0.35 |
| 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 II |
| 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 lateral yielding of the culvert walls is allowed, active earth pressures may be used in the design of the structure. If the culvert support / wall does not allow lateral yielding, at-rest pressures should be assumed for design.

It should be noted that the above design parameters assume level backfill and ground surface behind the culvert walls. Where there is sloping ground behind the walls (i.e. sloping upwards away from the culvert), the coefficient of lateral earth pressure must be increased to account for the slope.

5.3.3 Erosion Protection

Typically, the subsoils at the invert level of the culverts consists of a stiff to very stiff silty clay deposit. The cohesive material would be classified low scourability. If the creek velocities warrant, provision should be made for scour and erosion protection.

Erosion protection should be provided to the culverts as appropriate. Consideration could be given to the use of suitable non-woven geotextiles and rip-rap to provide erosion protection based on hydraulic requirements. The rip-rap should extend to an elevation that is 0.5 m above the high water level (i.e. the flood level) and laterally to at least the width of culvert on both sides of the inlet / outlet.

In addition, sediment control such as silt fences and / or erosion control blankets may be required during construction and diversion of creek to mitigate migration of fine soil particles into the water courses.

5.3.4 Groundwater and Surface Water Control

The founding soils for the culverts are susceptible to disturbance due to water ponding and / or construction traffic. Groundwater seepage into the excavations is expected to be minimal. In general, pumping from properly filtered sumps or a filtered drain placed at the base of the excavation should provide sufficient groundwater control during foundation works. Surface water should be directed away from the excavations at all times.

5.3.5 Subgrade Preparation

It is noted that the soils in which the excavations will be formed are susceptible to disturbance from ponded water and construction traffic. For protection of the founding soils, a working mat of lean concrete should be placed as soon as practical after reaching the base of the excavation and following inspection by qualified geotechnical personnel. Where drainage or levelling is required additional granular bedding should be provided.

5.3.6 Excavations

Excavations works 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 native silty clay is classified as a Type I soil and therefore temporary open-cut slopes can be carried out at 1 horizontal to 1 vertical (1H:1V).

6.0 CLOSURE

This report was prepared by Dan Breeze, P.Eng., Project Engineer under the supervision of Anne Poschmann, P.Eng., Project Manager. The overall review and quality control of this project was carried out by Fin Heffernan, P.Eng. Designated MTO Contact.

GOLDER ASSOCIATES LTD.

Dan K. Breeze, P.Eng.,
Geotechnical Engineer

Anne S. Poschmann, P.Eng.,
Principal

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

DKB/ASP/FJH/ mmh

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LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

| | |
|----|---------------------|
| AS | Auger sample |
| BS | Block sample |
| CS | Chunk sample |
| 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 |

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

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

(b) Cohesive Soils

c_u, s_u

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

IV. SOIL TESTS

| | |
|----------|---|
| w | water content |
| w_p | plastic limit |
| w_l | liquid limit |
| C | consolidation (oedometer) test |
| CHEM | chemical analysis (refer to text) |
| CID | consolidated isotropically drained triaxial test ¹ |
| CIU | consolidated isotropically undrained triaxial test with porewater pressure measurement ¹ |
| D_R | relative density (specific gravity, G_s) |
| DS | direct shear test |
| M | sieve analysis for particle size |
| MH | combined sieve and hydrometer (H) analysis |
| MPC | Modified Proctor compaction test |
| SPC | Standard Proctor compaction test |
| OC | organic content test |
| SO_4 | concentration of water-soluble sulphates |
| UC | unconfined compression test |
| UU | unconsolidated undrained triaxial test |
| V | field vane (LV-laboratory vane test) |
| γ | unit weight |

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

LIST OF SYMBOLS

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

I. General

| | |
|-------------|---------------------------------------|
| π | 3.1416 |
| $\ln x$, | natural logarithm of x |
| \log_{10} | x or log x, logarithm of x to base 10 |
| g | acceleration due to gravity |
| t | time |
| F | factor of safety |
| V | volume |
| W | weight |

II. STRESS AND STRAIN

| | |
|--------------------------------|--|
| γ | shear strain |
| Δ | change in, e.g. in stress: $\Delta \sigma$ |
| ϵ | linear strain |
| ϵ_v | volumetric strain |
| η | coefficient of viscosity |
| ν | poisson's ratio |
| σ | total stress |
| σ' | effective stress ($\sigma' = \sigma - u$) |
| σ'_{vo} | initial effective overburden stress |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stress (major, intermediate, minor) |
| σ_{oct} | mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| τ | shear stress |
| u | porewater pressure |
| E | modulus of deformation |
| G | shear modulus of deformation |
| K | bulk modulus of compressibility |

III. SOIL PROPERTIES

(a) Index Properties

| | |
|--------------------|--|
| $\rho(\gamma)$ | bulk density (bulk unit weight*) |
| $\rho_d(\gamma_d)$ | dry density (dry unit weight) |
| $\rho_w(\gamma_w)$ | density (unit weight) of water |
| $\rho_s(\gamma_s)$ | density (unit weight) of solid particles |
| γ' | unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$) |
| D_R | relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s) |
| e | void ratio |
| n | porosity |
| S | degree of saturation |

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

| | |
|------------------|--|
| τ_p, τ_r | peak and residual shear strength |
| ϕ' | effective angle of internal friction |
| δ | angle of interface friction |
| μ | coefficient of friction $= \tan \delta$ |
| c' | effective cohesion |
| c_u, s_u | undrained shear strength ($\phi = 0$ analysis) |
| p | mean total stress $(\sigma_1 + \sigma_3)/2$ |
| p' | mean effective stress $(\sigma'_1 + \sigma'_3)/2$ |
| q | $(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$ |
| q_u | compressive strength $(\sigma_1 + \sigma_3)$ |
| S_t | sensitivity |

- Notes:**
- 1 $\tau = c' + \sigma' \tan \phi'$
 - 2 shear strength $= (\text{compressive strength})/2$
 - * density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

RECORD OF BOREHOLE No C-1

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4767231.9; E 326346.4

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 30, 2002

CHECKED BY ASP

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | UNIT WEIGHT | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|---|------------|--------|------|-------------------------|-----------------|--|-----------------|---|-------------------|-------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | 20 40 60 80 100 | 20 40 60 80 100 | W _p W W _L | WATER CONTENT (%) | | |
| 179.8 | GROUND SURFACE | | | | | | | | | | | |
| 0.0 | Topsoil | | 1 | SS | 3 | | | | | | 99.4 | |
| 0.2 | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured, trace organics in upper 0.3m. Soft to very stiff. Reddish brown/grey. Moist to Wet. | | 2 | SS | 10 | | | | | | 4.3 | |
| | | | 3 | SS | 22 | | | | | | | |
| | | | 4 | SS | 21 | | | | | | | |
| | | | 5 | SS | 20 | | | | | | | |
| 175.7 | Clayey Silt, trace sand and gravel. Firm to stiff. Grey. Moist to wet. | | 6 | SS | 10 | | | | | | | |
| 4.1 | | | | | | | | | | | | |
| | | | 7 | SS | 6 | | | | | | | |
| 172.8 | END OF BOREHOLE | | | | | | | | | | | |
| 7.0 | Notes: 1. Open borehole wet at base on completion of drilling. 2. Water level measured in piezometer at 1.0m depth (El. 178.8m) on Nov. 15, 2002. 3. Water level measured in piezometer at 0.8m depth (El. 179.0m) on Jan. 31, 2003. | | | | | | | | | | | |

| PROJECT <u>021-1143</u> | | | | RECORD OF BOREHOLE No C-1A | | | | 1 OF 1 | | METRIC | | | | | | | |
|------------------------------|---|---|---------|-----------------------------------|------------|----------------------------|-----------------|---|----|---------------|----|-----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| W.P. <u>275-99-00</u> | | LOCATION <u>N 4767231.7; E 326339.4</u> | | | | ORIGINATED BY <u>PKS</u> | | | | | | | | | | | |
| DIST <u>4</u> HWY <u>406</u> | | BOREHOLE TYPE <u>Solid Stem Augers</u> | | | | COMPILED BY <u>DKB</u> | | | | | | | | | | | |
| DATUM <u>Geodetic</u> | | DATE <u>October 30, 2002</u> | | | | CHECKED BY <u>ASP</u> | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| 179.8 | GROUND SURFACE | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 0.0 | Topsoil | | 1 | SS | 5 | | 179 | | | | | | | | | | |
| 0.2 | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured, occasional rootlets, trace organics in upper 0.3m Firm to very stiff Brown/grey Moist | | 2 | SS | 13 | | 179 | | | | | | | | | | |
| | | | 3 | SS | 26 | | 179 | | | | | | | | | | |
| | | | 4 | SS | 18 | | 177 | | | | | | | | | | |
| | | | 5 | SS | 18 | | | | | | | | | | | | |
| 176.1 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| 3.7 | Note: 1. Open borehole dry upon completion of drilling. | | | | | | | | | | | | | | | | |

ON_MOT 021-1143.GPJ ON_MOT.GDT 4/2/03

RECORD OF BOREHOLE No C-2

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4767589.4; E 326346.9

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 30, 2002

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | | |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|--|-----|---|--|----|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED | | WATER CONTENT (%) w _p w w _L | | | | | | |
| 179.8 0.0 | GROUND SURFACE Silty Clay, trace sand and gravel, occasional oxidation staining, fissured Stiff to very stiff Reddish brown/grey Moist | | 1 | SS | 8 | | 20 | 40 | 60 | 80 | 100 | 10 | 20 | 30 | | |
| | | | 2 | SS | 16 | | 179 | | | | | | | | | |
| | | | 3 | SS | 24 | | 178 | | | | | | | | | |
| | | | 4 | SS | 21 | | 177 | | | | | | | | | |
| 176.8 3.0 | Clayey Silt, trace sand and gravel Stiff Grey Moist | | 5 | SS | 16 | | 20 | 40 | 60 | 80 | 100 | 10 | 20 | 30 | | |
| | | | | | | | 176 | | | | | | | | | |
| | | | 6 | SS | 10 | | 175 | | | | | | | | | |
| | | | | | | | 174 | | | | | | | | | |
| 172.8 7.0 | END OF BOREHOLE Notes: 1. Open borehole dry upon completion of drilling. 2. Water level measured in piezometer at 1.4m depth (El.178.4m) on Nov.15, 2002. 3. Water frozen in piezometer at ground surface on Jan.31, 2003. | | 7 | SS | 10 | | 20 | 40 | 60 | 80 | 100 | 10 | 20 | 30 | | |

RECORD OF BOREHOLE No C-2A

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4767586.8; E 326337.5

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 30, 2002

CHECKED BY ASP

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|---|------------|--------|------|----------------------------|-----------------|---|--------------------|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | "N" VALUES | SHEAR STRENGTH kPa | | | | | | | | |
| 179.5 | GROUND SURFACE | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 0.0 | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured Firm to very stiff Reddish brown/grey Moist | | 1 | SS | 7 | | | | | | | | | | | |
| | | | 2 | SS | 12 | | | | | | | | | | | |
| | | | 3 | SS | 21 | | | | | | | | | | | |
| | | | 4 | SS | 19 | | | | | | | | | | | |
| 176.5 | Clayey Silt, trace sand and gravel Very stiff Grey Moist | | 5 | SS | 17 | | | | | | | | | | | |
| 175.8 | END OF BOREHOLE | | | | | | | | | | | | | | | |
| 3.7 | Note: 1. Open borehole dry upon completion of drilling. | | | | | | | | | | | | | | | |

+³.X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

| PROJECT <u>021-1143</u> | | | | RECORD OF BOREHOLE No C-3 | | | | 1 OF 1 | | METRIC | | | | | | |
|------------------------------|--|---|--------|----------------------------------|----------------------------|--------------------------|---|--------------------|--|---------------|--|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| W.P. <u>275-99-00</u> | | LOCATION <u>N 4768664.9; E 326355.9</u> | | | | ORIGINATED BY <u>PKS</u> | | | | | | | | | | |
| DIST <u>4</u> HWY <u>406</u> | | BOREHOLE TYPE <u>Solid Stem Augers</u> | | | | COMPILED BY <u>DKB</u> | | | | | | | | | | |
| DATUM <u>Geodetic</u> | | DATE <u>October 30, 2002</u> | | | | CHECKED BY <u>ASP</u> | | | | | | | | | | |
| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | "N" VALUES | SHEAR STRENGTH kPa | | | | | | | | |
| | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED | | | | | WATER CONTENT (%) | | | | |
| | | | | | | | 20 40 60 80 100 20 40 60 80 100 10 20 30 | | | | | | | | | |
| 184.0 | GROUND SURFACE | | | | | | | | | | | | | | | |
| 0.0 | Topsoil | | 1 | SS | 10 | | | | | | | | | | | |
| 0.2 | Silty Clay, trace sand and gravel, occasional silt layers, occasional oxidation staining, fissured. Stiff to very stiff. Brown/grey. Moist. | | 2 | SS | 23 | | | | | | | | | | | |
| | | | 3 | SS | 23 | | | | | | | | | | | |
| | Silt layer from 2.2m to 3m, non-plastic atterberg limits measured for sample 4. | | 4 | SS | 27 | | | | | | | | | | | |
| | | | 5 | SS | 16 | | | | | | | | | | | |
| 179.9 | Clayey Silt, trace sand and gravel. Stiff to firm. Brown to grey. Moist to wet. | | 6 | SS | 17 | | | | | | | | | | | |
| 4.1 | | | | | | | | | | | | | | | | |
| | | | 7 | SS | 8 | | | | | | | | | | | |
| 177.0 | END OF BOREHOLE | | | | | | | | | | | | | | | |
| 7.0 | Notes: 1. Open borehole dry upon completion of drilling. 2. Water level measured in piezometer at 4.8m depth (El.179.2m) on Nov.15, 2002. 3. Water level measured in piezometer at 2.4m depth (El. 181.6m) on Jan.31, 2003. | | | | | | | | | | | | | | | |

| PROJECT 021-1143 | | | | RECORD OF BOREHOLE No C-3A | | | | 1 OF 1 | | METRIC | | | | | | | |
|------------------|--|---------------|---------|-----------------------------------|------------|----------------------------|-----------------|---|----|---------------|----|-----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| W.P. 275-99-00 | | | | LOCATION N 476866.3; E 326342.9 | | | | ORIGINATED BY PKS | | | | | | | | | |
| DIST 4 HWY 406 | | | | BOREHOLE TYPE Solid Stem Augers | | | | COMPILED BY DKB | | | | | | | | | |
| DATUM Geodetic | | | | DATE October 30, 2002 | | | | CHECKED BY ASP | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| 184.3 | GROUND SURFACE | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 8.9 | Topsoil | [Hatched Box] | 1 | SS | 11 | 184 | | | | | | | | | | | |
| | Silty Clay, trace sand and gravel, occasional silt layers, occasional oxidation staining, fissured | | 2 | SS | 20 | 183 | | | | | | | | | | | |
| | Stiff to very stiff | | 3 | SS | 21 | 182 | | | | | | | | | | | |
| | Brown/grey | | 4 | SS | 20 | 181 | | | | | | | | | | | |
| | Moist | | 5 | SS | 12 | | | | | | | | | | | | |
| 180.6 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| 3.7 | Note: 1. Open borehole dry upon completion of drilling. | | | | | | | | | | | | | | | | |

ON_MOT 021-1143.GPJ ON_MOT.GDT 4/2/03

RECORD OF BOREHOLE No C-4

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4769918.9; E 326360.3

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 24, 2002

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|--|--|--|---|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED | | WATER CONTENT (%) w _p w w _L | | | | |
| 180.9 0.0 | GROUND SURFACE | | | | | | | 20 40 60 80 100 | | | | | | |
| 0.2 | Topsoil | | 1 | SS | 7 | | | | | | | | | |
| | Silty Clay, trace sand and gravel, trace topsoil (Fill) Firm to very stiff Mottled brown Moist | | 2 | SS | 27 | | | | | | | | | |
| 179.5 1.5 | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured Very stiff Reddish brown Moist to wet below 3m depth | | 3 | SS | 22 | | | | | | | | | |
| | | | 4 | SS | 13 | | | | | | | | | |
| | | | 5 | SS | 12 | | | | | | | | | |
| 176.8 4.1 | Clayey Silt, trace sand and gravel, occasional silt layers Very stiff to firm Brown to grey Wet Silt layer from 4.6m to 5.2m depth. | | 6 | SS | 30 | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | 7 | SS | 7 | | | | | | | | | |
| 173.9 7.0 | END OF BOREHOLE | | | | | | | | | | | | | |
| | Notes: 1. Water level measured in open borehole at 6.4m depth (El.174.5m) upon completion of drilling. 2. Water level measured in piezometer at 3.1m depth (El.177.8m) on Nov.15,2002. 3. Water level measured in piezometer at 1.5m depth (El. 179.4m) on Jan.31, 2003. | | | | | | | | | | | | | |

RECORD OF BOREHOLE No C-4A

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4769908.6; E 326350.2

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 24, 2002

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT | | | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | | |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|---|--|--|---|---|----|----|----|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED | | | | | WATER CONTENT (%) w _p w w _L | | | | GR | SA | SI | CL |
| 181.4 | GROUND SURFACE | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | | | |
| 0.0 | Topsoil | | 1 | SS | 7 | | 181 | | | | | | | | | | | | | |
| 0.2 | Silty Clay, trace sand and gravel (Fill) Firm to very stiff Brown Moist | | 2 | SS | 21 | | 18C | | | | | | | | | | | | | |
| 180.0 | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Silty Clay, trace sand and gravel, occasional silt layers, occasional oxidation staining, fissured Stiff to very stiff Brown to grey Moist to wet | | 3 | SS | 27 | | 17S | | | | | | | | | | | | | |
| | | | 4 | SS | 18 | | 17C | | | | | | | | | | | | | |
| | | | 5 | SS | 10 | | | | | | | | | | | | | | | |
| 177.7 | END OF BOREHOLE | | | | | | | | | | | | | | | | | | | |
| 3.7 | Note: 1. Base of borehole wet upon completion of drilling. | | | | | | | | | | | | | | | | | | | |

N. MOT 021-1143.GPJ ON MOT.GDT 4/2/03

RECORD OF BOREHOLE No C-5

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4770955.1; E 326321.8

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 24, 2002

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|---|------------|---------|------|------------|-------------------------|-----------------|--|----------|---|--|--|-------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | WATER CONTENT (%) | | | | |
| 180.4 | GROUND SURFACE | | | | | | 20 40 60 80 100 | 20 40 60 80 100 | 10 20 30 | W _P W W _L | | | | |
| 0.0 | Silty Clay, with organics, trace sand | | 1 | SS | 2 | | | | | | | | | |
| 179.7 | Very soft | | | | | | | | | | | | | |
| 0.7 | Dark grey | | 2 | SS | 12 | | | | | | | | | |
| | Wet | | | | | | | | | | | | | |
| | Silty Clay, trace sand and gravel, occasional silt layers, occasional rootlets and oxidation staining, fissured | | 3 | SS | 15 | | | | | | | | | |
| | Stiff to very stiff | | | | | | | | | | | | | |
| | Brown/grey | | 4 | SS | 16 | | | | | | | | | |
| | Wet | | | | | | | | | | | | | |
| 177.4 | Silty Clay, trace sand, occasional silt seams/layers | | | | | | | | | | | | | |
| 3.0 | Firm to Stiff | | 5 | SS | 12 | | | | | | | | | |
| | Grey | | 6 | SS | 12 | | | | | | | | | |
| | Wet | | | | | | | | | | | | | |
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RECORD OF BOREHOLE No C-5A

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4770961.1; E 326308.5

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 24, 2002

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _P | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED | | | | | | | | | |
| 180.6 | GROUND SURFACE | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 180.2 | Silty Clay with organics Black Wet | | 1 | SS | 2 | ▽ | 180 | | | | | | | | | | |
| 0.4 | Silty Clay, trace sand and gravel, occasional silt layers, occasional oxidation staining, fissured Stiff to very stiff Grey Wet | | 2 | SS | 12 | | 179 | | | | | | | | | | |
| | | | 3 | SS | 18 | | 170 | | | | | | | | | | |
| | | | 4 | SS | 16 | | 177 | | | | | | | | | | |
| | | | 5 | SS | 8 | | | | | | | | | | | | |
| 177.6 | Silty Clay, trace sand and gravel, occasional silt seams/layers Firm Grey Wet | | | | | | | | | | | | | | | | |
| 176.6 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| 4.0 | Note: 1. Water level measured in open borehole at 0.6m depth (El.179.3m) upon completion of drilling. | | | | | | | | | | | | | | | | |

+ 3, X 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

| PROJECT <u>021-1143</u> | | RECORD OF BOREHOLE No C-6 | | 1 OF 1 | | METRIC | | | | | | |
|---|---|---|--------|----------------------------|-----------------|---|------------|---------------------------------|-------------------------------------|--------------------------------|---------------------|---|
| W.P. <u>275-99-00</u> | | LOCATION <u>N 4771775.7; E 326184.4</u> | | ORIGINATED BY <u>PKS</u> | | | | | | | | |
| DIST <u>4</u> HWY <u>406</u> | | BOREHOLE TYPE <u>Solid Stem Augers</u> | | COMPILED BY <u>DKB</u> | | | | | | | | |
| DATUM <u>Geodetic</u> | | DATE <u>October 23, 2002</u> | | CHECKED BY <u>ASP</u> | | | | | | | | |
| SOIL PROFILE | | SAMPLES | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | | | TYPE | "N" VALUES | | | | | |
| 179.0 0.0 | GROUND SURFACE | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED | | | | | | |
| | Topsoil | | 1 | SS | 15 | | | | | | | |
| | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured Very stiff Mottled brown/grey Moist | | 2 | SS | 29 | | | | | | | |
| | | | 3 | SS | 24 | | | | | | | |
| | | | 4 | SS | 16 | | | | | | | |
| 176.6 3.0 | Silty Clay, trace sand and gravel, occasional silt seams/layers Firm Grey/brown to grey Wet | | 5 | SS | 6 | | | | | | | |
| | | | 6 | SS | 4 | | | | | | | |
| | | | 7 | SS | 7 | | | | | | | |
| 172.9 6.7 | END OF BOREHOLE | | | | | | | | | | | |
| Notes: 1. Open borehole dry upon completion of drilling. 2. Piezometer dry on Nov.15, 2002. 3. Base of piezometer wet on Jan.31, 2003. | | | | | | | | | | | | |

| PROJECT 021-1143 | | | | RECORD OF BOREHOLE No C-6A | | | | 1 OF 1 | | METRIC | | | | | | | |
|--|--|----------------------------------|---------|-----------------------------------|------------|----------------------------|-----------------|--|--|---------------|--|--|---|--|--|---|--|
| W.P. 275-99-00 | | LOCATION N 4771772.2; E 326171.3 | | | | ORIGINATED BY PKS | | | | | | | | | | | |
| DIST 4 HWY 406 | | BOREHOLE TYPE Solid Stem Augers | | | | COMPILED BY DKB | | | | | | | | | | | |
| DATUM Geodetic | | DATE October 23, 2002 | | | | CHECKED BY ASP | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | W _p W W _L | | | | |
| 180.4 | GROUND SURFACE | | | | | | | 20 40 60 80 100 O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED | | | | | 20 40 60 80 100 WATER CONTENT (%) | | | | |
| 177.4 | Topsoil | | 1 | SS | 15 | | 180 | | | | | | | | | | |
| 176.7 | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured | | 2 | SS | 20 | | 170 | | | | | | | | | | |
| 176.7 | Very stiff | | 3 | SS | 27 | | 178 | | | | | | | | | | |
| 176.7 | Mottled brown/grey | | 4 | SS | 29 | | 177 | | | | | | | | | | |
| 176.7 | Moist | | 5 | SS | 10 | | | | | | | | | | | | |
| 176.7 | Silty Clay, trace sand and gravel | | | | | | | | | | | | | | | | |
| 176.7 | Stiff | | | | | | | | | | | | | | | | |
| 176.7 | Brown/grey | | | | | | | | | | | | | | | | |
| 176.7 | Moist to wet | | | | | | | | | | | | | | | | |
| 176.7 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| Note: 1. Open borehole dry upon completion of drilling. | | | | | | | | | | | | | | | | | |

| PROJECT 021-1143 | | | RECORD OF BOREHOLE No 20-1 | | | 1 OF 2 | | | METRIC | | | | | | | | |
|------------------|-------|--|----------------------------------|--------|------|--|-------------------------|-----------------|---|-----------------|---------------------------------|-------------------|---|-------------|---------------------------------------|--|--|
| W.P. 275-99-00 | | | LOCATION N 4769665.3; E 326326.6 | | | ORIGINATED BY PKS | | | | | | | | | | | |
| DIST 4 HWY 406 | | | BOREHOLE TYPE Solid Stem Augers | | | COMPILED BY DKB | | | | | | | | | | | |
| DATUM Geodetic | | | DATE October 25&28, 2002 | | | CHECKED BY ASP | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT | | | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | |
| ELEV | DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | 20 40 60 80 100 | 20 40 60 80 100 | W _p W W _L | WATER CONTENT (%) | γ | GR SA SI CL | | | |
| 183.8 | | GROUND SURFACE | | | | | | | | | | | | | | | |
| 9.0 | | Topsoil | | 1 | SS | 23 | | 183 | | | | | | | | | |
| 183.1 | | Silty Clay, trace sand and gravel, trace topsoil (Fill) | | 2 | SS | 25 | | 182 | | | | | | | | | |
| 0.7 | | Very stiff Brown Moist | | 3 | SS | 35 | | 181 | | | | | | | | | |
| | | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured | | 4 | SS | 35 | | 180 | | | | | | | | | |
| | | Very stiff to hard Reddish brown/grey Moist | | 5 | SS | 65 | | 179 | | | | | | | | | |
| 179.7 | | Clayey Silt, trace sand and gravel, occasional silty clay seams/layers | | 6 | SS | 20 | | 178 | | | | | | | | | |
| 4.1 | | Very stiff Brown to reddish grey Moist to Wet below 4.9m depth | | 7 | SS | 29 | | 177 | | | | | | | | | |
| 178.2 | | Clayey Silt, trace sand and gravel | | 8 | SS | 20 | | 176 | | | | | | | | | |
| 5.6 | | Very stiff to hard Reddish grey Wet | | 9 | SS | 22 | | 175 | | | | | | | | | |
| | | | | 10 | SS | 22 | | 174 | | | | | | | | | |
| | | | | 11 | SS | 25 | | 173 | | | | | | | | | |
| | | | | 12 | SS | 21 | | 172 | | | | | | | | | |
| | | | | 13 | SS | 20 | | 171 | | | | | | | | | |
| | | | | 14 | SS | 50 | | 170 | | | | | | | | | |
| | | | | 15 | SS | 32 | | 169 | | | | | | | | | |
| | | | | | | | | 168 | | | | | | | | | |
| | | | | | | | | 167 | | | | | | | | | |
| | | | | | | | | 166 | | | | | | | | | |
| | | | | | | | | 165 | | | | | | | | | |
| | | | | | | | | 164 | | | | | | | | | |

ON_MOT 021-1143.GPJ ON_MOT.GDT 4/2/03

Continued Next Page

+³, X³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

| PROJECT <u>021-1143</u> | | | | RECORD OF BOREHOLE No 20-1 | | | | 2 OF 2 | | METRIC | | | | | | |
|--------------------------------------|---|---|--------|-----------------------------------|----------------------------|--------------------------|---|--|--|---------------|--|---|-------------------------------|--|---|--|
| W.P. <u>275-99-00</u> | | LOCATION <u>N 4769665.3; E 326326.6</u> | | | | ORIGINATED BY <u>PKS</u> | | | | | | | | | | |
| DIST <u>4</u> HWY <u>406</u> | | BOREHOLE TYPE <u>Solid Stem Augers</u> | | | | COMPILED BY <u>DKB</u> | | | | | | | | | | |
| DATUM <u>Geodetic</u> | | DATE <u>October 25&28, 2002</u> | | | | CHECKED BY <u>ASP</u> | | | | | | | | | | |
| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | "N" VALUES | SHEAR STRENGTH kPa 20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED | | | | | WATER CONTENT (%) 10 20 30 | | | |
| --- CONTINUED FROM PREVIOUS PAGE --- | | | | | | | | | | | | | | | | |
| 162.5 | Clayey Silt, trace sand and gravel Very stiff to hard Reddish grey Wet | 16 | SS | 32 | | | | | | | | | | | | |
| 21.3 | Heterogenous mixture of SILTY CLAY, SAND and GRAVEL Hard/Very Dense Reddish grey Wet | 17 | SS | 100/0.2 | | | | | | | | | | | | |
| 160.5 | | 18 | SS | 100/0.05 | | | | | | | | | | | | |
| 23.3 | Fresh to slightly weathered, strong, grey, medium to coarse grained DOLOSTONE, very few fractures, some vugs, some fossils, massive to thinly bedded. | | | | | | | | | | | | | | | |
| 156.7 | For bedrock coring details refer to Record of Drillhole 20-1. | | | | | | | | | | | | | | | |
| 27.1 | END OF HOLE Notes: 1. Water level not obtained in open borehole upon completion of drilling due to use of water for coring. 2. Water level measured in piezometer at 9.1m depth (El. 174.4m) on Nov. 15, 2002 and on Jan. 31, 2003. | | | | | | | | | | | | | | | |

ON_MOT_021-1143.GPJ ON_MOT.GDT 4/2/03

SHEET 3 OF 3

DATUM: Geodetic

DRILLING CONTRACTOR: Geo-Environmental Ltd.

[illegible]

DRILLHOLE 1143-ROCK.GPJ GLDR CAN.GDT 4/2/03 PS/MMZ

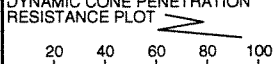
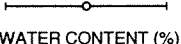
DEPTH SCALE

1 : 50

LOGGED: PKS

CHECKED: LCC

| | | | | | |
|------------------------------|--|---|--|--------------------------|---------------|
| PROJECT 021-1143 | | RECORD OF BOREHOLE No 20-2 | | 1 OF 2 | METRIC |
| W.P. 275-99-00 | | LOCATION N 4769691.8; E 326359.7 | | ORIGINATED BY PKS | |
| DIST 4 HWY 406 | | BOREHOLE TYPE Solid Stem Augers | | COMPILED BY DKB | |
| DATUM Geodetic | | DATE October 28, 29, 2002 | | CHECKED BY ASP | |

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED | PLASTIC LIMIT w_p NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L  | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|--------------|---|------------|---------|------|------------|-------------------------|-----------------|---|--|---|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | *N* VALUES | | | | | | |
| 183.1 | GROUND SURFACE | | | | | | | | | | |
| 0.0 | Rockfill | | | | | | | | | | |
| 0.3 | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured Very stiff Reddish brown/grey Moist | | 1 | SS | 29 | | | | | | |
| | | | 2 | SS | 25 | | | | | | |
| | | | 3 | SS | 20 | | | | | | |
| 180.1 | Clayey Silt, trace sand and gravel Very stiff to hard Brown to Grey to Reddish grey Moist to wet below 6.7m depth | | 4 | SS | 26 | | | | | | |
| 3.0 | | | 5 | SS | 30 | | | | | | |
| | | | 6 | SS | 27 | | | | | | |
| | | | 7 | SS | 24 | | | | | | |
| | | | 8 | SS | 28 | | | | | | |
| | | | 9 | SS | 27 | | | | | | |
| | | | 10 | SS | 22 | | | | | | |
| | | | 11 | SS | 38 | | | | | | |
| | | | 12 | SS | 100/10 | | | | | | |
| | | | 13 | SS | 48 | | | | | | |
| | Silt layer from 16.3m to 17.5m depth. Non-plastic Atterberg Limits result measured for Sample 13 | | 14 | SS | 31 | | | | | | |
| | | | 15 | SS | 100/10 | | | | | | |
| 163.3 | | | | | | | | | | | |

CN_MOT 021-1143.GPJ ON MOT.GDT 4/2/03

Continued Next Page

 +³, x³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

| PROJECT 021-1143 | | | | RECORD OF BOREHOLE No 20-2 | | | | 2 OF 2 | | METRIC | | | | | | | | | | | | | | | | |
|------------------------------------|--|----------------------------------|---------|-----------------------------------|------------|-------------------------|--|--------|--|---------------|--|---|--|--|-------------------|--|--|-------------|--|--|---------------------------------------|--|--|--|--|--|
| W.P. 275-99-00 | | LOCATION N 4769691.8; E 326359.7 | | | | ORIGINATED BY PKS | | | | | | | | | | | | | | | | | | | | |
| DIST 4 HWY 406 | | BOREHOLE TYPE Solid Stem Augers | | | | COMPILED BY DKB | | | | | | | | | | | | | | | | | | | | |
| DATUM Geodetic | | DATE October 28, 2002 | | | | CHECKED BY ASP | | | | | | | | | | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | | | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | WATER CONTENT (%) | | | UNIT WEIGHT | | | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | | | | |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | | | | | | | | | | | | | | | | |
| -- CONTINUED FROM PREVIOUS PAGE -- | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19.8 | Heterogenous mixture of SILTY CLAY, SAND and GRAVEL Hard/Very Dense Reddish grey Wet | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 16 | SS | 88 | | | | | | | | | | | | | | | | | | | | | |
| 160.5 22.6 | Fresh to slightly weathered, strong, grey, medium to coarse grained DOLOSTONE, very few fractures, some vugs, some fossils, mainly massive, some thin bedding, stylolites. For bedrock coring details refer to Record of Drillhole 20-2. | | | | | | | | | | | | | | | | | | | | | | | | | |
| 157.3 25.8 | END OF HOLE Notes: 1. Water level not obtained in open borehole upon completion of drilling due to introduction of water for coring. 2. Water level measured in piezometer at 7.8m depth (El. 175.3m) on Nov. 15, 2002. 3. Water level measured in piezometer at 6.5m depth (El. 176.6m) on Jan. 31, 2003. | | | | | | | | | | | | | | | | | | | | | | | | | |

PROJECT: 021-1143

RECORD OF DRILLHOLE: 20-2

SHEET 3 OF 3

LOCATION: N 4769691.8; E 326359.7

DRILLING DATE: October 29, 2002


DATUM: Geodetic

INCLINATION: -90°

AZIMUTH: ---

DRILL RIG: CME - 75

DRILLING CONTRACTOR: Geo-Environmental Ltd.

| DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. | | RUN No. | PENETRATION RATE (m/min) | FLUSH | COLOUR % RETURN | FR/FX-FRACTURE-FAULT | | | | SM-SMOOTH | | | | FL-FLEXURED | | | | BC-BROKEN CORE | | | | DIAMETRAL POINT LOAD INDEX (MPa) | NOTES WATER LEVELS INSTRUMENTATION |
|-----------------------|-----------------|---|---|----------------------------|-------------------------|---------------------------------|-----------------------------|-------|--------------------|----------------------|----|----------------|----|------------|----|-----------|----|----------------|----|----|----|----------------|----|--|--|--|--|
| | | | | DEPTH (m) | | | | | | CL-CLEAVAGE | | J-JOINT | | R-ROUGH | | UE-UNEVEN | | MB-MECH. BREAK | | | | | | | | | |
| | | | | | | | | | | SH-SHEAR | | P-POLISHED | | ST-STEPPED | | W-WAVY | | B-BEDDING | | | | | | | | | |
| | | | | | | | | | | VN-VEIN | | S-SLICKENSIDED | | PL-PLANAR | | C-CURVED | | | | | | | | | | | |
| RECOVERY | | R.Q.D. | | FRACT. INDEX PER 0.3 | DISCONTINUITY DATA | | HYDRAULIC CONDUCTIVITY | | | | | | | | | | | | | | | | | | | | |
| TOTAL CORE % | SOLID CORE % | % | | | DIP w.r.t. CORE AXIS | TYPE AND SURFACE DESCRIPTION | K, cm/sec | | | | | | | | | | | | | | | | | | | | |
| 80 | 80 | 80 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| 40 | 40 | 40 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | | | |
| 20 | 20 | 20 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | | | |
| 0 | 0 | 0 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | | | | |
| 23 | | GROUND SURFACE Fresh to slightly weathered, strong, grey medium to coarse grained DOLOSTONE, very few fractures, some vugs, some fossils, mainly massive, some thin bedding, stylolites. |  | 22.60 | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | END OF HOLE | | 25.80 | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | |

DRILLHOLE 1143-ROCK.GPJ GLDR CAN.GDT 4/2/03 PS/MMZ

DEPTH SCALE

1 : 50



LOGGED: PKS

CHECKED: LCC

RECORD OF BOREHOLE No 20-3

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4769677.3; E 326361.1

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 25, 2002

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|---|--|--|---|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | WATER CONTENT (%) | | | | |
| 183.2 0.0 | GROUND SURFACE | | | | | | | 20 40 60 80 100 | | w _p w w _L | | | | |
| 0.2 | Topsoil | | 1 | SS | 4 | | 183 | ○ UNCONFINED + FIELD VANE | | | | | | |
| | Silty Clay, trace sand and gravel, occasional oxidation staining, trace rootlets, fissured Firm to hard Brown/grey Moist | | 2 | SS | 22 | | 182 | ● QUICK TRIAXIAL X REMOULDED | | ○ | | | | |
| | | | 3 | SS | 28 | | 181 | | | | | | | |
| | | | 4 | SS | 28 | | 180 | | | ○ | | | | |
| | | | 5 | SS | 77 | | 179 | | | | | | | |
| 179.1 4.1 | Clayey Silt, trace sand and gravel, occasional silty clay layers Very stiff Brown to reddish grey | | 6 | SS | 27 | | 178 | | | ○ | | | | |
| 178.2 5.0 | Wet Clayey Silt, trace sand and gravel Very stiff Reddish grey Wet | | 7 | SS | 26 | | 177 | | | | | | | |
| 176.5 6.7 | END OF BOREHOLE | | | | | | | | | | | | | |
| | Note: 1. Open borehole dry upon completion of drilling. | | | | | | | | | | | | | |

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON MOT 021-1143.GPJ ON MOT.GDT 4/2/03

RECORD OF BOREHOLE No P-1

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION N 4771501.6; E 326279.7

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

DATE October 31, 2002

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|-------------------------|-----------------|--|--|---|--|--|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | WATER CONTENT (%) | | | | |
| 181.0 | GROUND SURFACE | | | | | | | 20 40 60 80 100 | | 10 20 30 | | | | |
| 0.0 | Topsoil | | 1 | SS | 15 | | | ○ UNCONFINED + FIELD VANE | | | | | | |
| 0.2 | Silty Clay, trace sand and gravel, occasional oxidation staining, fissured Very stiff to hard Brown/grey Moist | | 2 | SS | 21 | | 180 | | | | | | | |
| | | | 3 | SS | 37 | | 179 | | | | | | | |
| | | | 4 | SS | 33 | | 178 | | | | | | | |
| | | | 5 | SS | 31 | | 177 | | | | | | | |
| 176.7 | Clayey Silt, trace sand and gravel with occasional silt to silty clay seams/layers Firm to stiff Grey to reddish grey Wet | | 6 | SS | 6 | | 176 | X + | | | | | | |
| 4.3 | | | 7 | SS | 9 | | 175 | | | | | | | |
| | | | 8 | SS | 5 | | 174 | X + | | | | | | |
| | | | 9 | SS | 3 | | 173 | X + | | | | | | |
| | | | 10 | SS | 29 | | 172 | X + | | | | | | |
| 169.9 | Slightly weathered to fresh, strong to very strong, grey, medium to coarse grained DOLOSTONE, very few fractures, mainly massive, some vugs, some stylolites. | | | | | | 171 | X + | | | | | | |
| 11.1 | | | | | | | 170 | | | | | | | |
| | | | | | | | 169 | | | | | | | |
| | | | | | | | 168 | | | | | | | |
| | | | | | | | 167 | | | | | | | |
| 165.9 | For bedrock coring details refer to Record of Drillhole P-1. | | | | | | 166 | | | | | | | |
| 15.1 | END OF HOLE | | | | | | | | | | | | | |
| | Notes: 1. Water level measured in piezometer at 7.5m depth (El.173.5m) on Nov.15, 2002. 2. Water level measured in piezometer at 2.3m depth (El. 178.7m) on Jan.31, 2003. | | | | | | | | | | | | | |

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON MOT 021-1143.GPJ ON MOT.GDT 4/2/03

SHEET 2 OF 2

DATUM: Geodetic

DRILLING CONTRACTOR: Geo-Environmental Ltd.

[illegible]

DEPTH SCALE

1 : 50

LOGGED: PKS

CHECKED: MR

DRILLHOLE 1143-ROCK.GPJ GLDR_CAN.GDT 4/2/03 PS/MMZ

+³, X³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

RECORD OF BOREHOLE No P-2

1 OF 1

METRIC

PROJECT 021-1143

W.P. 275-99-00

LOCATION Sta. 10+120 O/S 12m LT.

ORIGINATED BY PKS

DIST 4 HWY 406

BOREHOLE TYPE Solid Stem Augers

COMPILED BY DKB

DATUM Geodetic

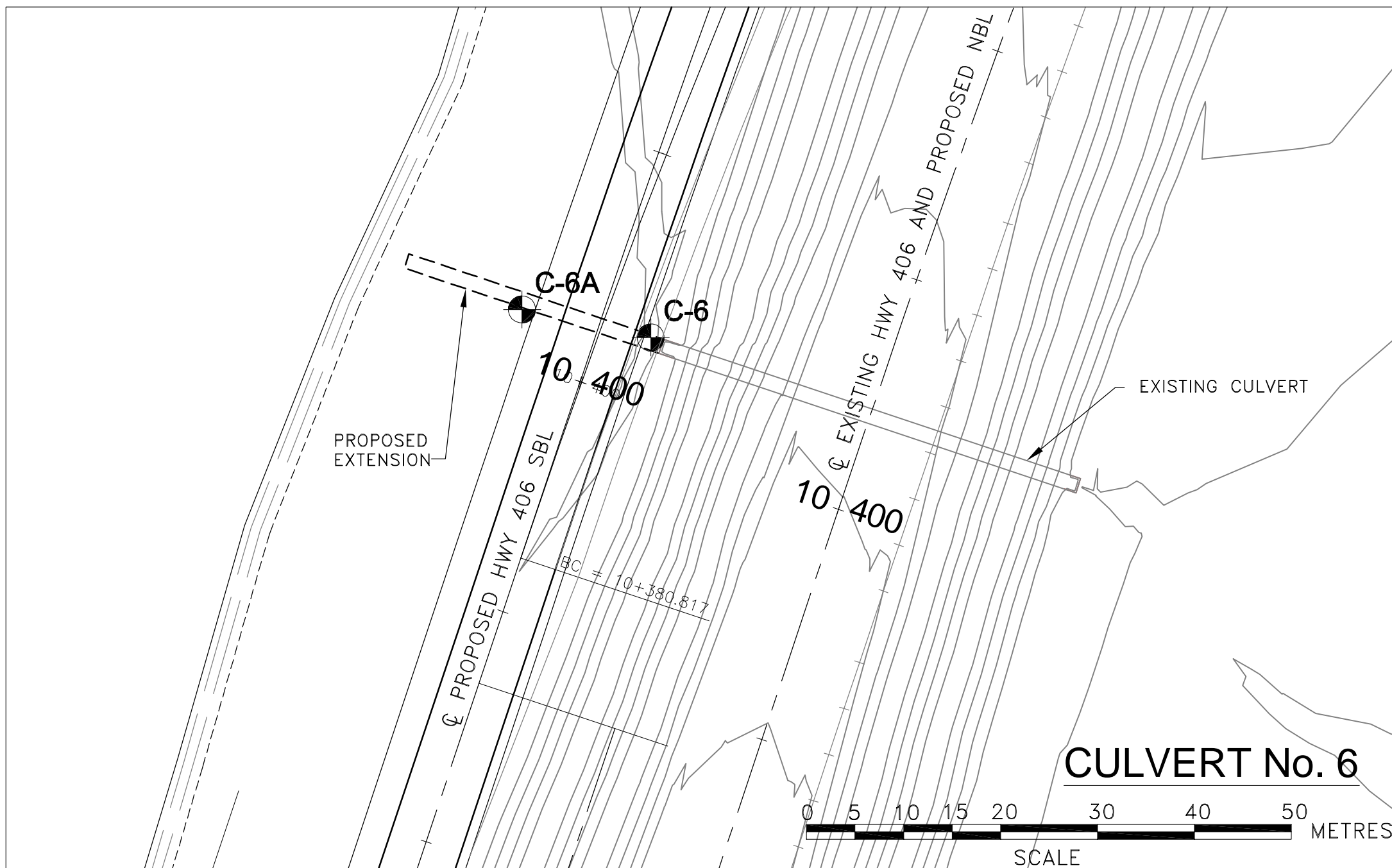
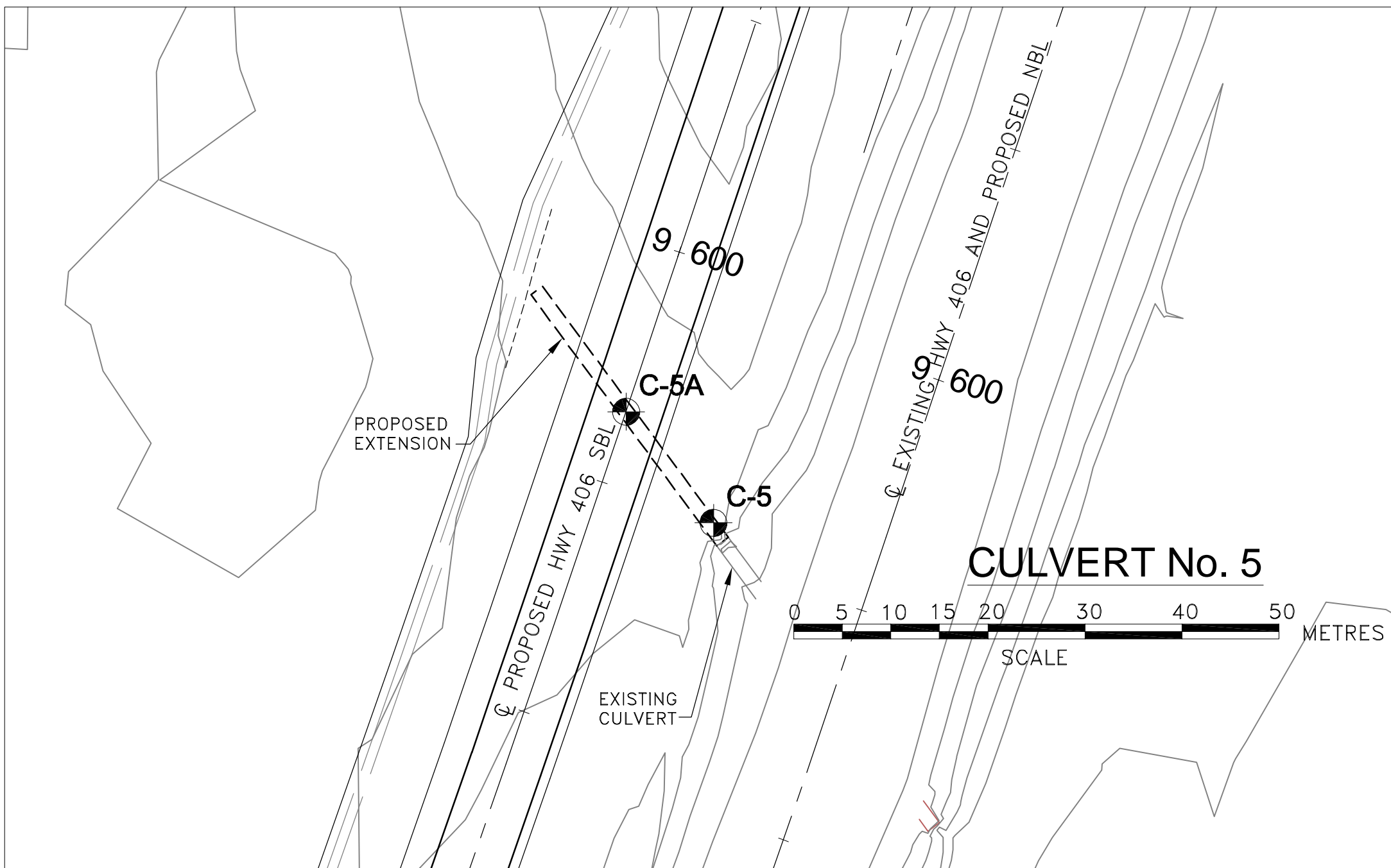
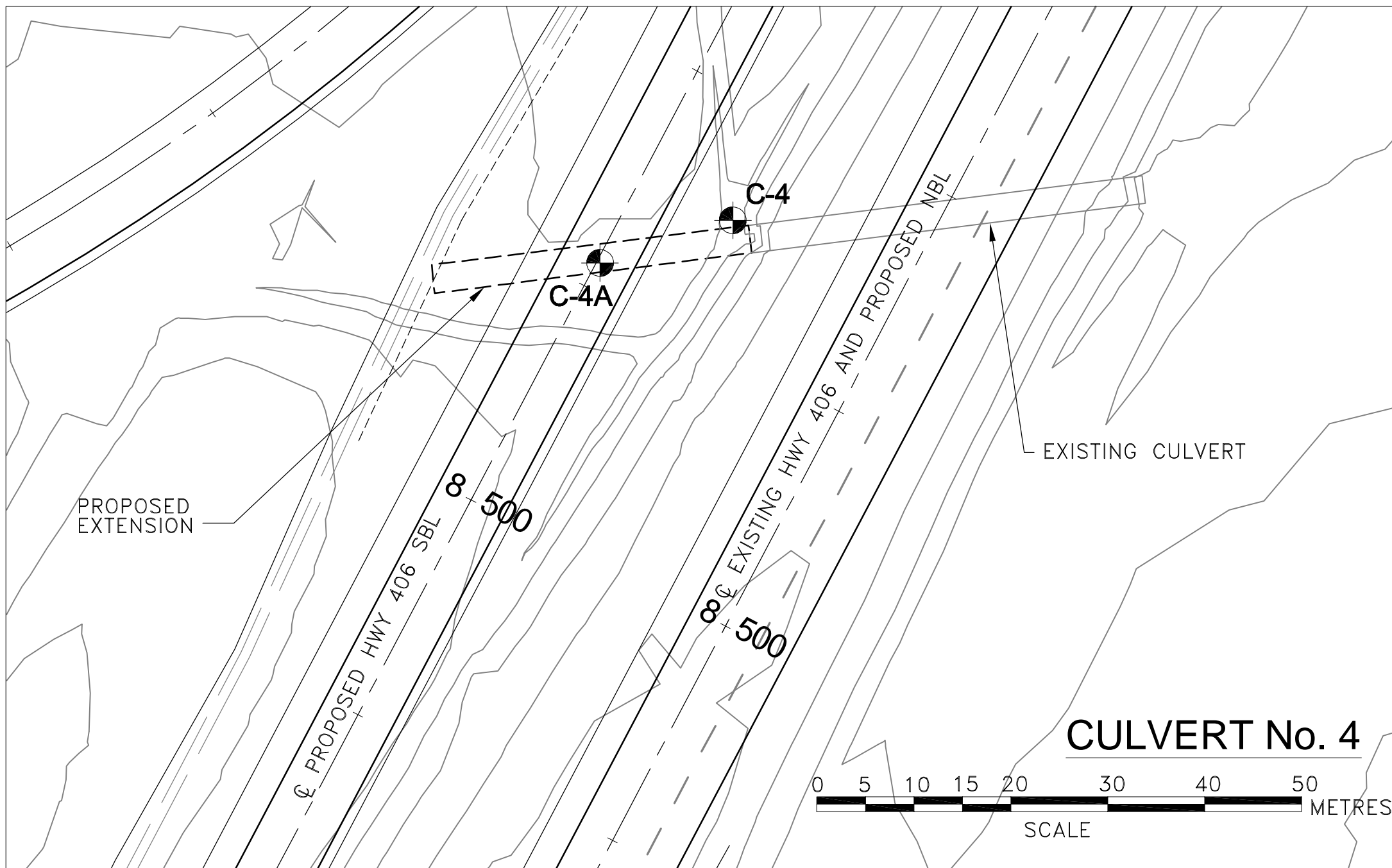
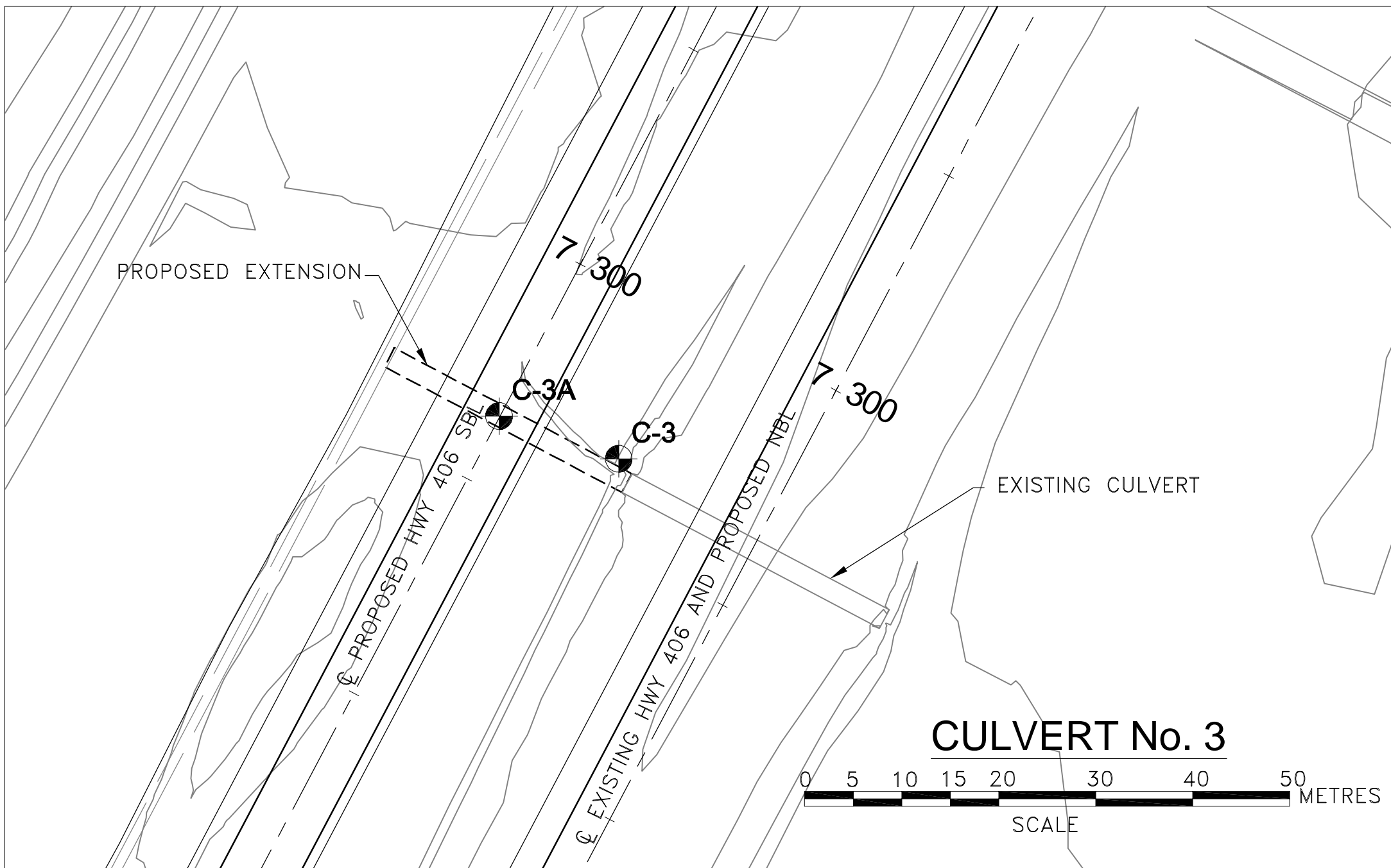
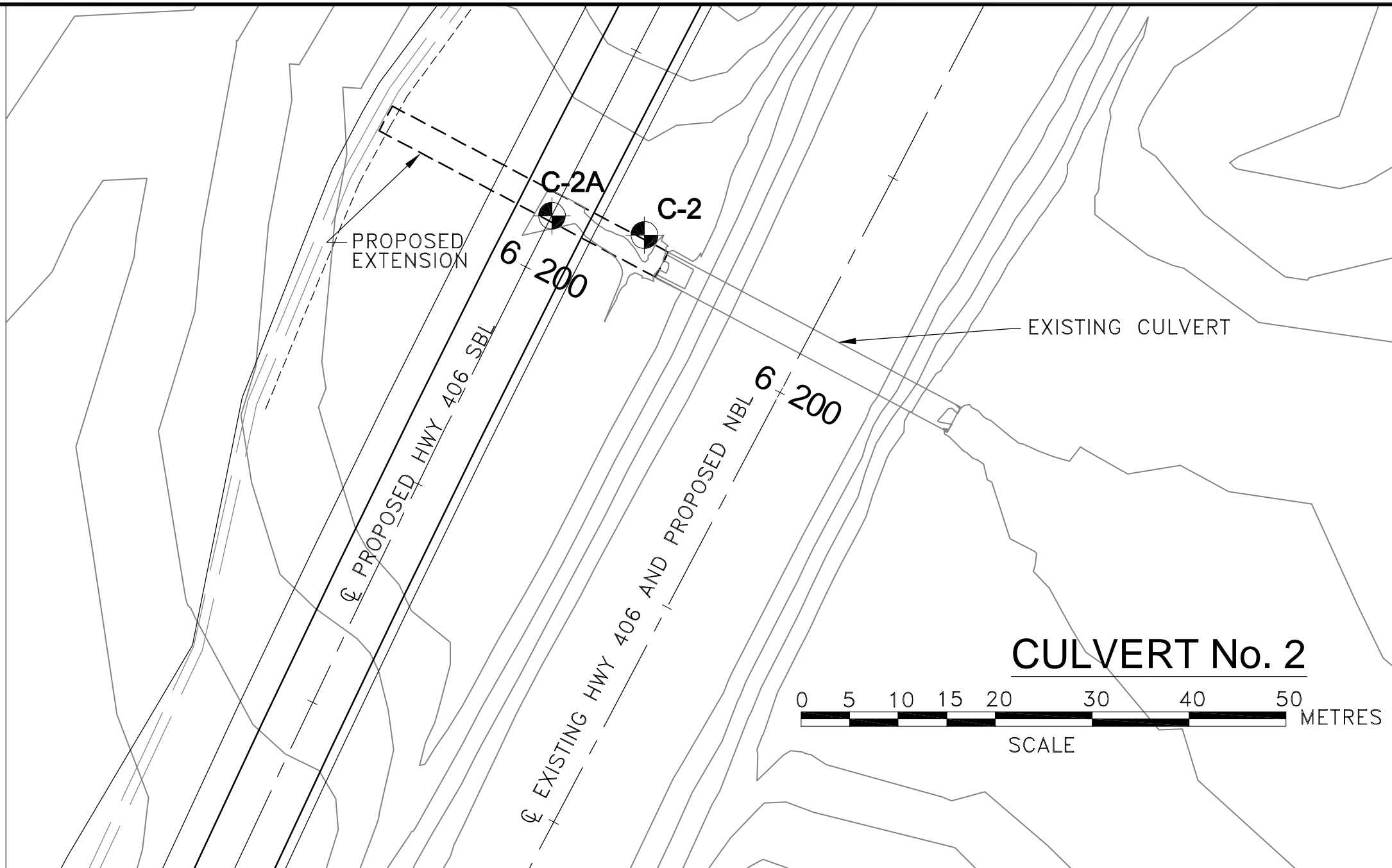
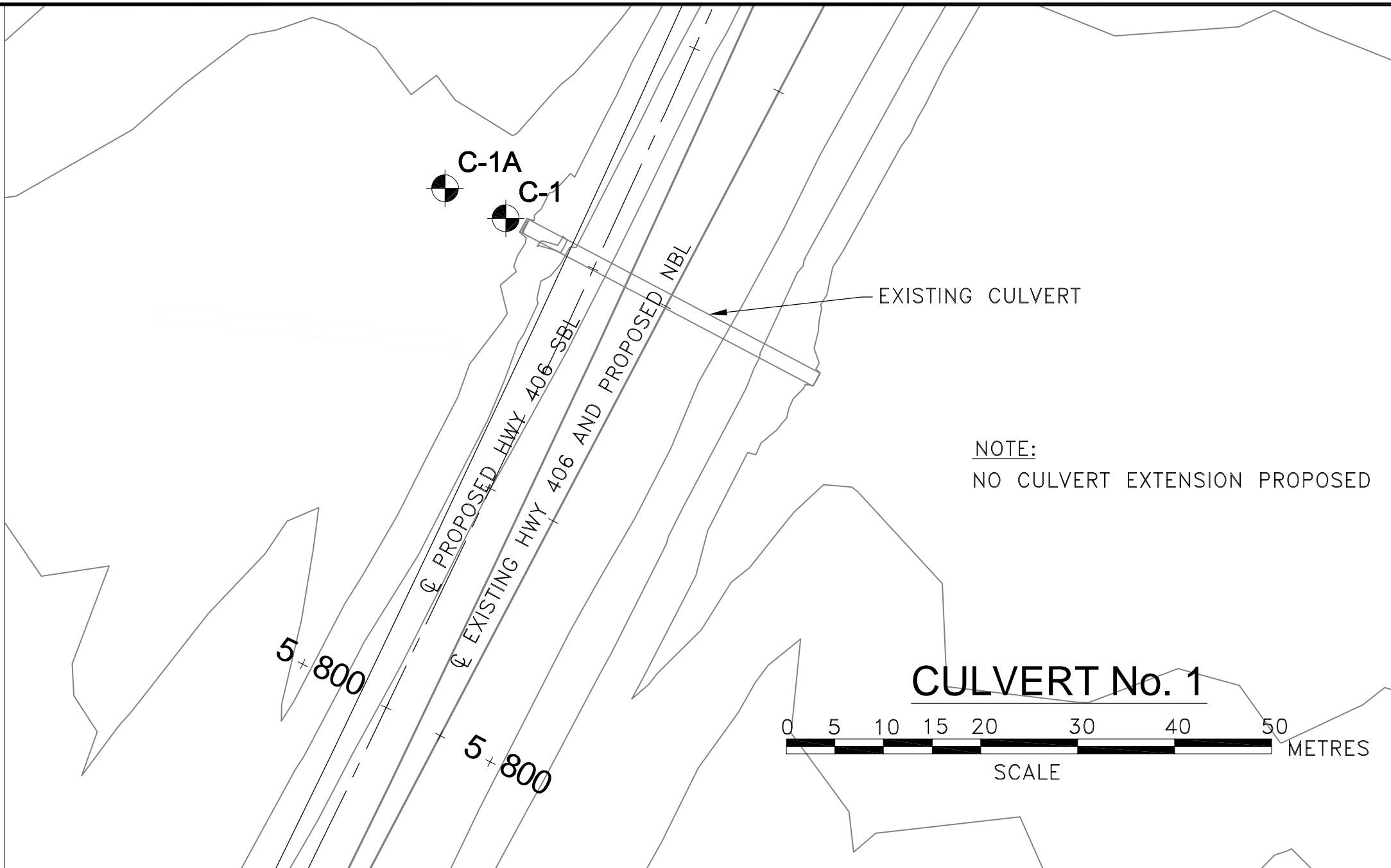
DATE January 14, 2003

CHECKED BY ASP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|---|--|--|---|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | WATER CONTENT (%) | | | | |
| | | | | | | | | 20 40 60 80 100 | | W _p W W _L | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | | | |
| 182.2 | GROUND SURFACE | | | | | | | | | | | | | |
| 182.2 | TOPSOIL | | 1 | SS | 7 | | | | | | | | | |
| | Silty clay, trace sand and gravel, Stiff Brown Moist (FILL) | | 2 | SS | 4 | | | | | | | | | |
| 180.8 | | | | | | | | | | | | | | |
| 1.4 | Silty Clay, trace sand and gravel , occ. oxidation staining, fissured Stiff to very stiff Brown/Grey Moist | | 3 | SS | 14 | | | | | | | | | |
| | | | 4 | SS | 25 | | | | | | | | | |
| | | | 5 | SS | 21 | | | | | | | | | |
| 178.5 | | | | | | | | | | | | | | |
| 3.7 | Clayey Silt, trace sand and gravel with occ. silt to silty clay seams/layers Firm to Stiff Grey Wet | | 6 | SS | 15 | | | | | | | | | |
| | Note: 0.8m thick silt layer present at 3.7m depth. | | 7 | SS | 8 | | | | | | | | | |
| | | | 8 | SS | 7 | | | | | | | | | |
| | | | 9 | SS | 7 | | | | | | | | | |
| | | | 10 | SS | 3 | | | | | | | | | |
| | | | 11 | SS | 4 | | | | | | | | | |
| 171.1 | Silty Clay, some sand and gravel Hard Grey Wet | | | | | | | | | | | | | |
| 169.5 | END OF BOREHOLE Refusal on probable bedrock | | | | | | | | | | | | | |
| 12.7 | Notes: 1. Open borehole dry upon completion of drilling. 2. Water level measured in piezometer at 5.1m depth (El. 177.1m) on Jan.31, 2003. | | | | | | | | | | | | | |

+³, X³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

PLOT DATE: August 19, 2003
FILENAME: T:\Projects\2002\021-1143\REPORT-3\RA0203\RI 143-2007.dwg



DIST. 4 HWY. 406
CONT No.
WP No. 275-99-00

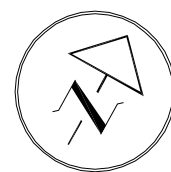
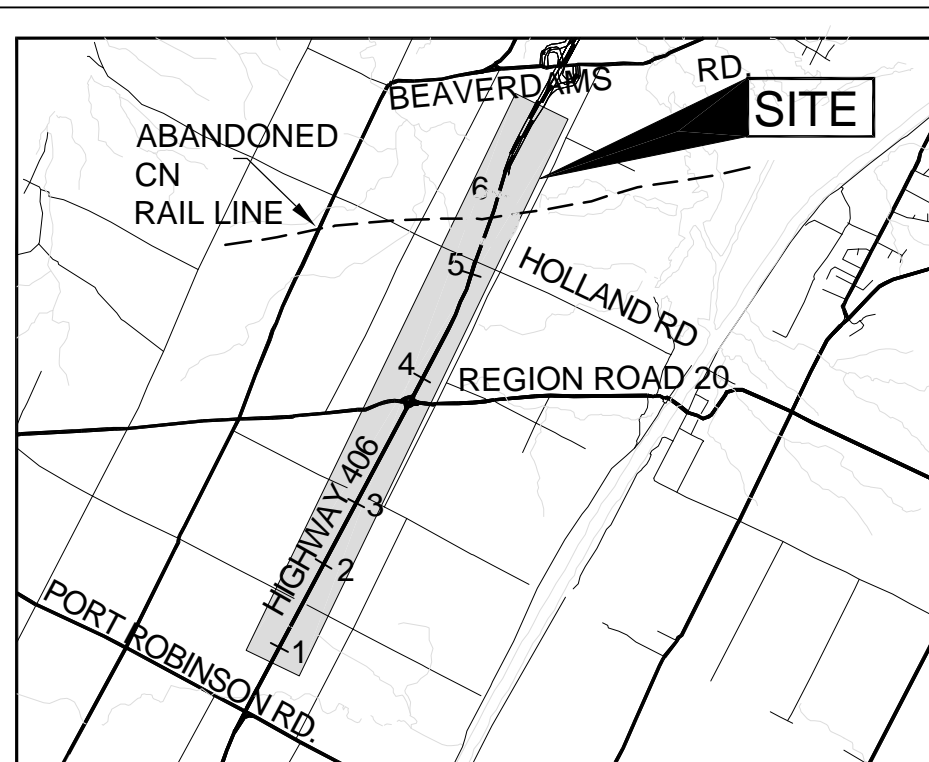
HIGHWAY 406 TWINNING
CULVERT EXTENSIONS
BOREHOLE LOCATIONS



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



KEY PLAN

LEGEND



Borehole - Current Golder Associates Ltd.
Investigation

| No. | ELEVATION | LOCATION | |
|------|-----------|-----------|----------|
| | | NORTHING | EASTING |
| C-1 | 179.8 | 4767231.9 | 326346.4 |
| C-1A | 179.8 | 4767231.7 | 326339.4 |
| C-2 | 179.8 | 4767589.4 | 326346.9 |
| C-2A | 179.5 | 4767586.8 | 326337.5 |
| C-3 | 184.0 | 4768664.9 | 326355.9 |
| C-3A | 184.3 | 4768663.1 | 326342.9 |
| C-4 | 180.9 | 4769918.9 | 326360.3 |
| C-4A | 181.4 | 4769908.6 | 326350.2 |
| C-5 | 180.4 | 4770955.1 | 326321.8 |
| C-5A | 180.6 | 4770961.1 | 326308.5 |
| C-6 | 179.6 | 4771775.7 | 326184.4 |
| C-6A | 180.4 | 4771772.2 | 326171.3 |

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REFERENCE

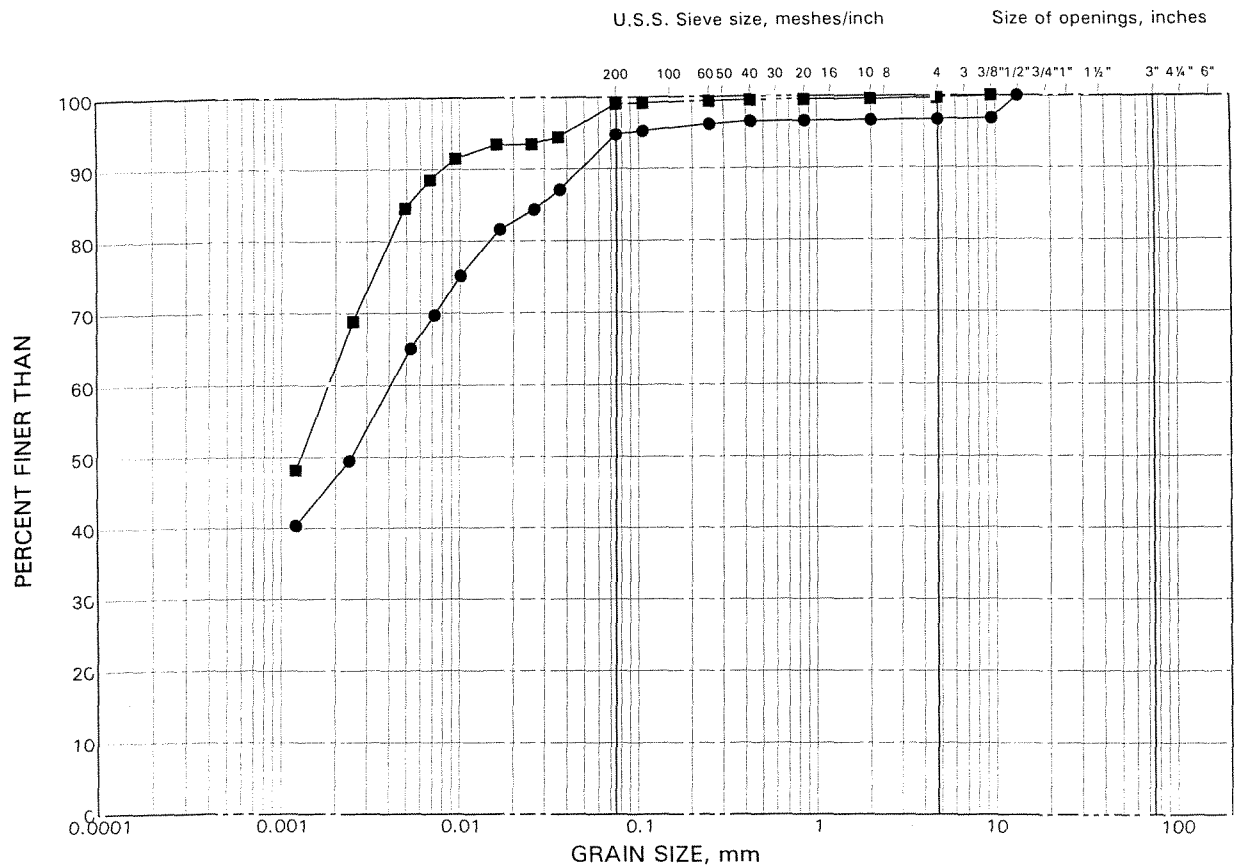
Base Plans provided in digital format by Morrison Hershfield Ltd. drawing file No. drawing file No. shm-golder-revisedalignment1.dwg received Dec. 9, 2002

| NO. | DATE | BY | REVISION |
|---------------------|-----------|------------------------|----------|
| Geocres No. | | | |
| HWY. 406 (TWINNING) | | PROJECT NO. 021-1143-3 | DIST. 4 |
| SUBM'D. DKB | CHKD. DKB | DATE: APRIL 2003 | SITE: |
| DRAWN: JFC | CHKD. ASP | APPD. FJH | DWG. 1 |

GRAIN SIZE DISTRIBUTION

Silty Clay, trace sand and gravel

FIGURE 1



| | | | | | | | | |
|---------------------|--|-----------|--|--------|-------------|------|--------|--------|
| SILT AND CLAY SIZES | | FINE | | MEDIUM | COARSE | FINE | COARSE | COBBLE |
| FINE GRAINED | | SAND SIZE | | | GRAVEL SIZE | | SIZE | |

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEVATION (m) |
|--------|----------|--------|---------------|
| ● | 20-1 | 4 | 180.9 |
| ■ | P-1 | 4 | 178.1 |

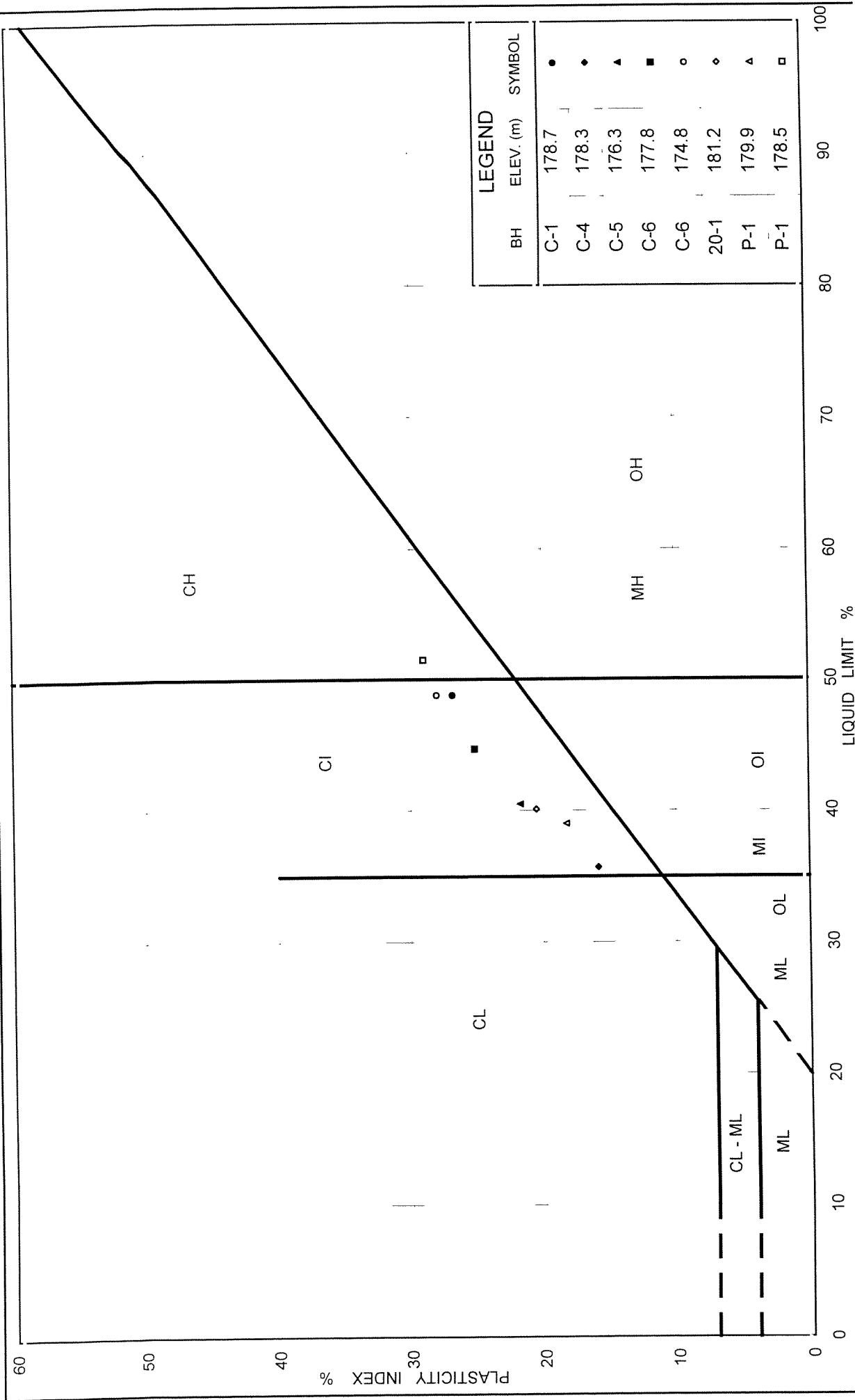


FIG No. 2

PLASTICITY CHART
Silty Clay

Ministry of Transportation

Project No. 021-1143-3

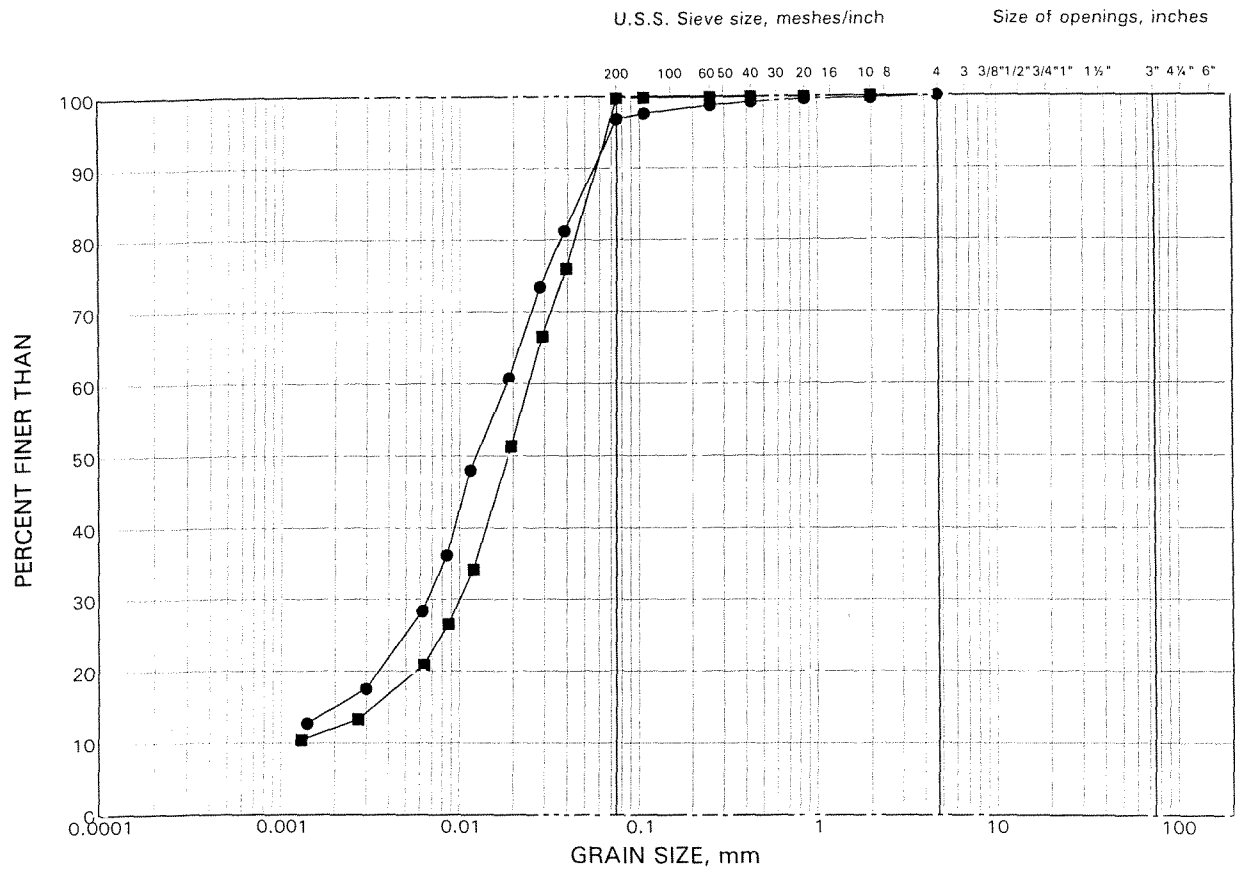


Ontario

GRAIN SIZE DISTRIBUTION

Clayey Silt, trace sand

FIGURE 3



| | | | | | | | |
|---------------------|--|-----------|--------|--------|-------------|--------|--------|
| SILT AND CLAY SIZES | | FINE | MEDIUM | COARSE | FINE | COARSE | COBBLE |
| FINE GRAINED | | SAND SIZE | | | GRAVEL SIZE | | SIZE |

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEVATION (m) |
|--------|----------|--------|---------------|
| ● | 20-1 | 12 | 169.5 |
| ■ | P-1A | 1 | 176.0 |

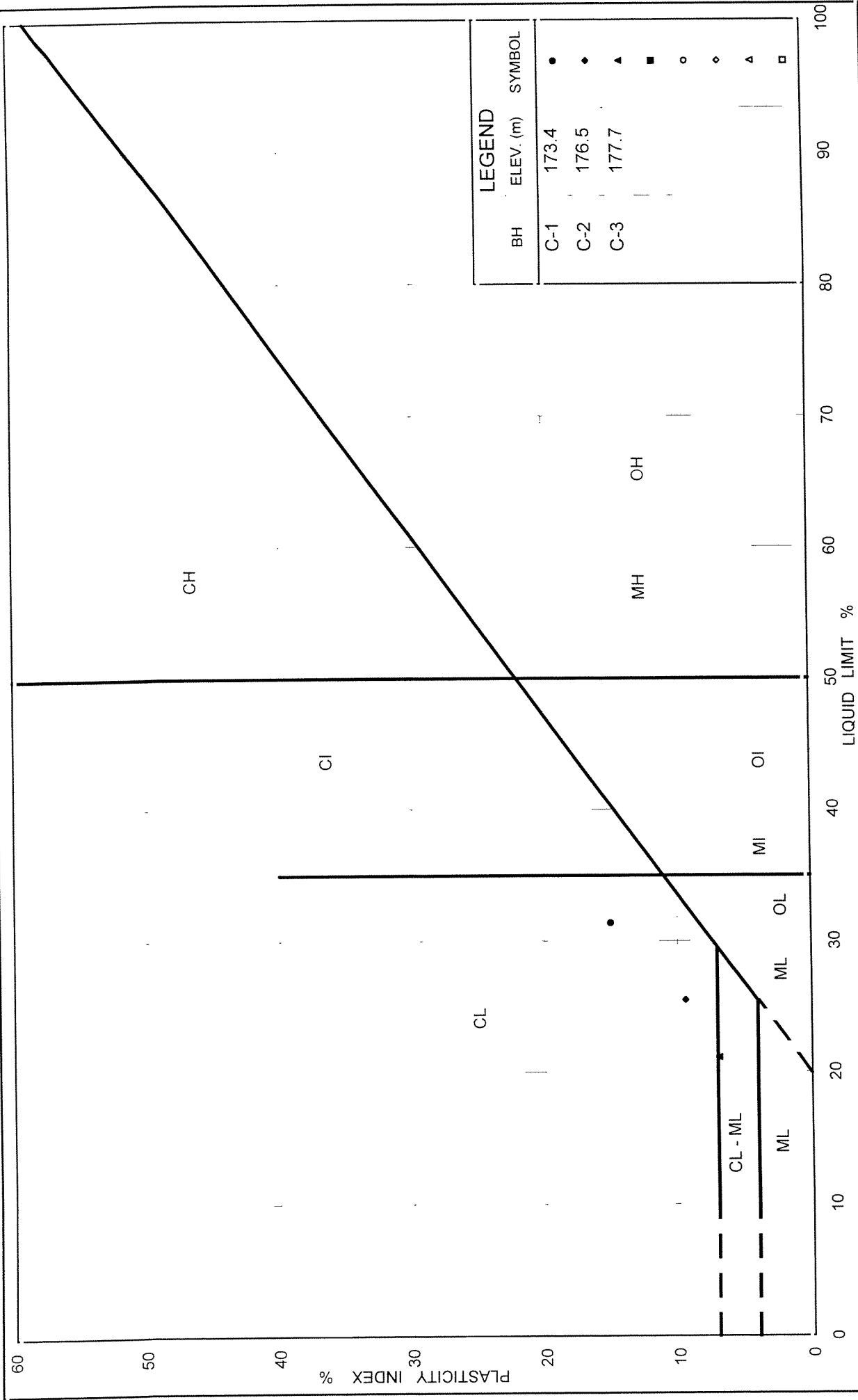


FIG No. 4

PLASTICITY CHART

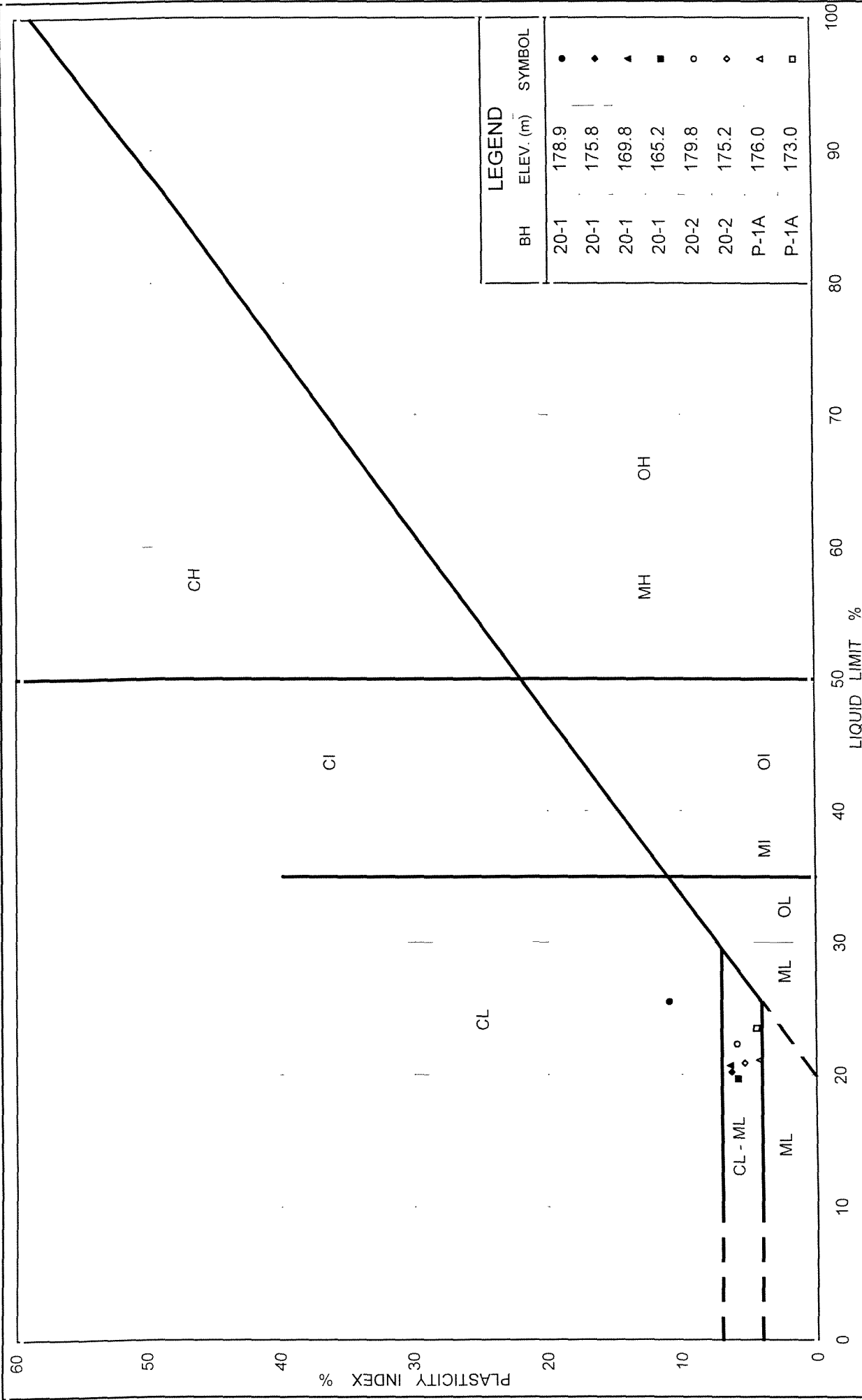
Clayey Silt

Ministry of Transportation



Ontario

Project No. 021-1143-3



PLASTICITY CHART
Clayey Silt

FIG No. 4A

Project No. 021-1143-3

Ministry of Transportation

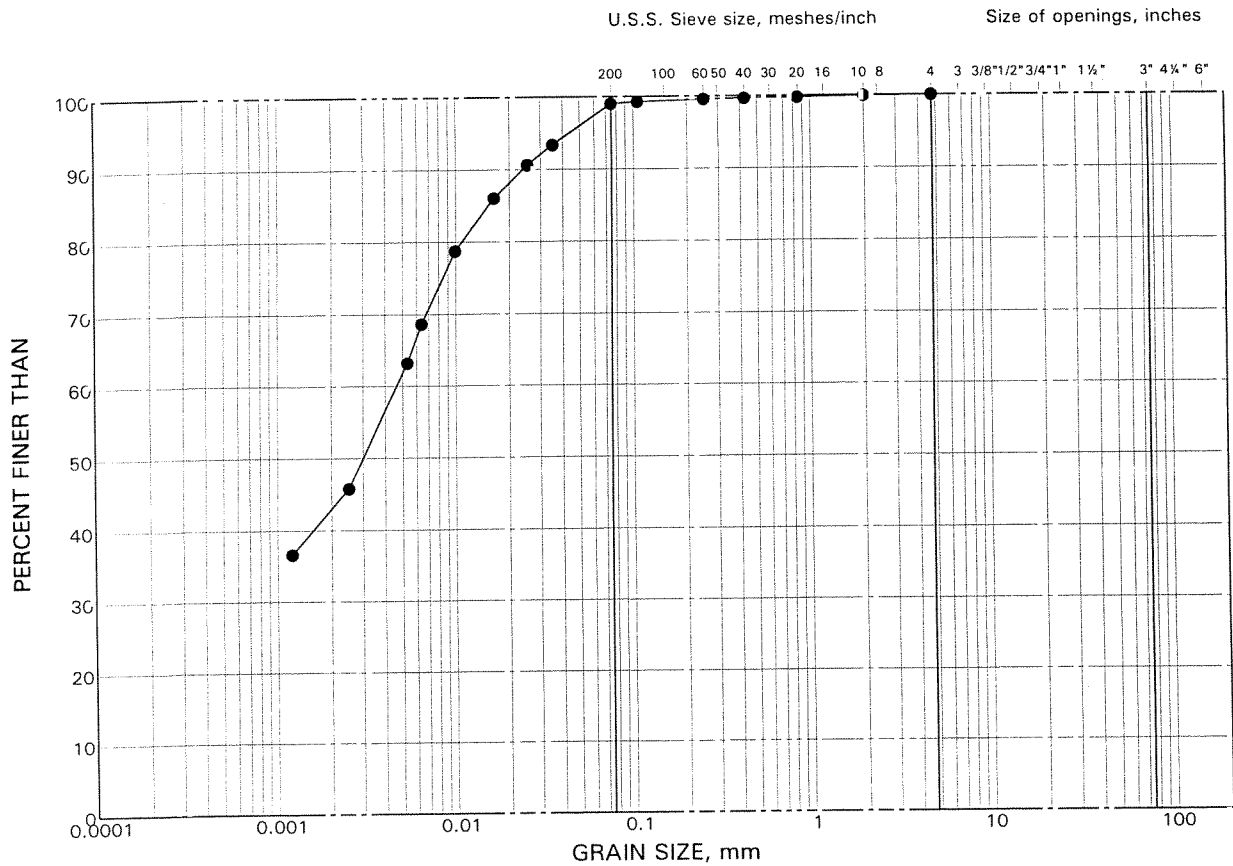


Ontario

GRAIN SIZE DISTRIBUTION

Clayey Silt, trace sand (seam / layer)

FIGURE 5



| | | | | | | | | |
|---------------------|--|-----------|--|--------|--------|-------------|--------|--------|
| SILT AND CLAY SIZES | | FINE | | MEDIUM | COARSE | FINE | COARSE | COBBLE |
| FINE GRAINED | | SAND SIZE | | | | GRAVEL SIZE | | SIZE |

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEVATION (m) |
|--------|----------|--------|---------------|
| • | P-1A | 2 | 172.9 |

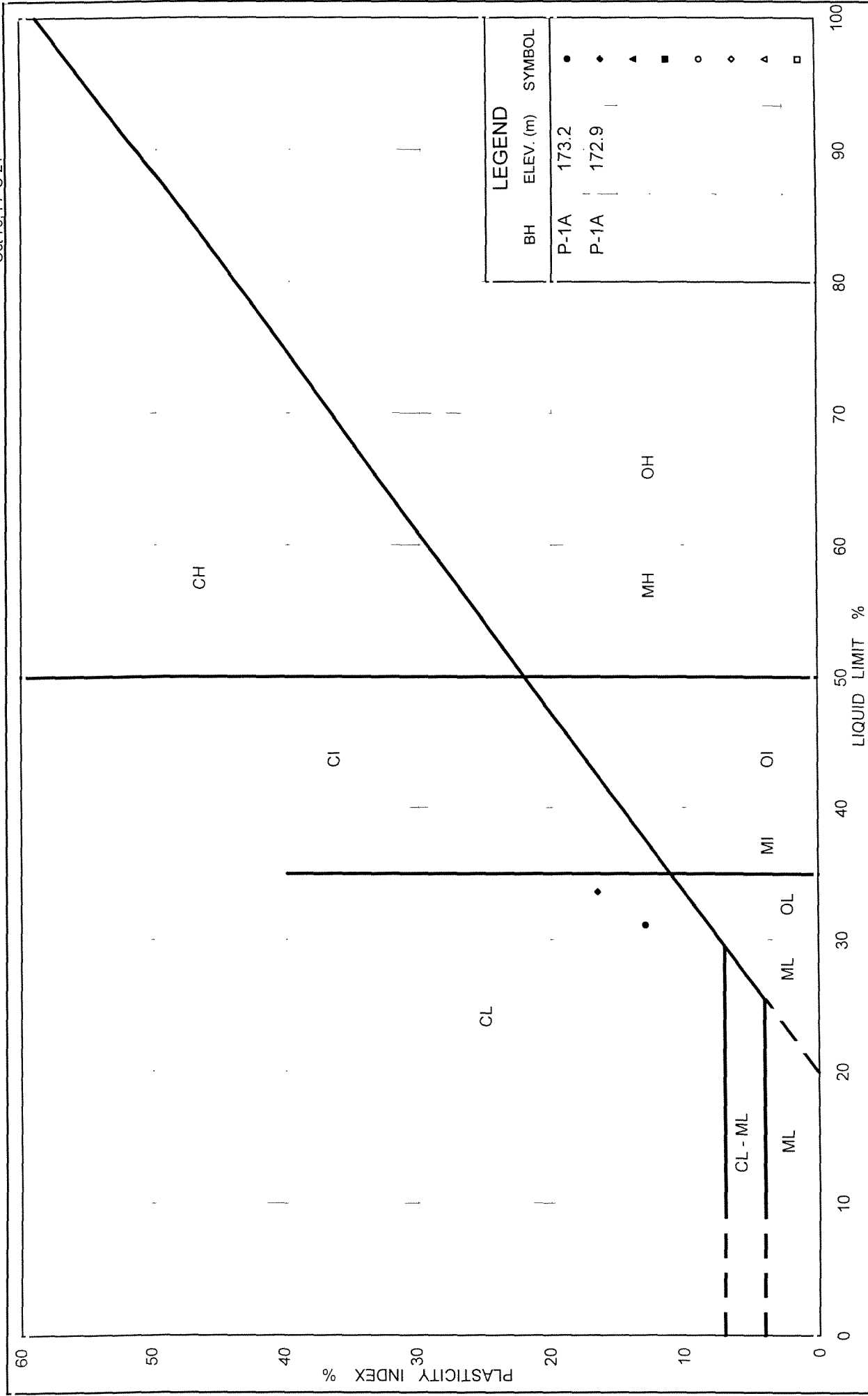


FIG No. 6

PLASTICITY CHART

Clayey Silt (seam / layer)

Ministry of Transportation

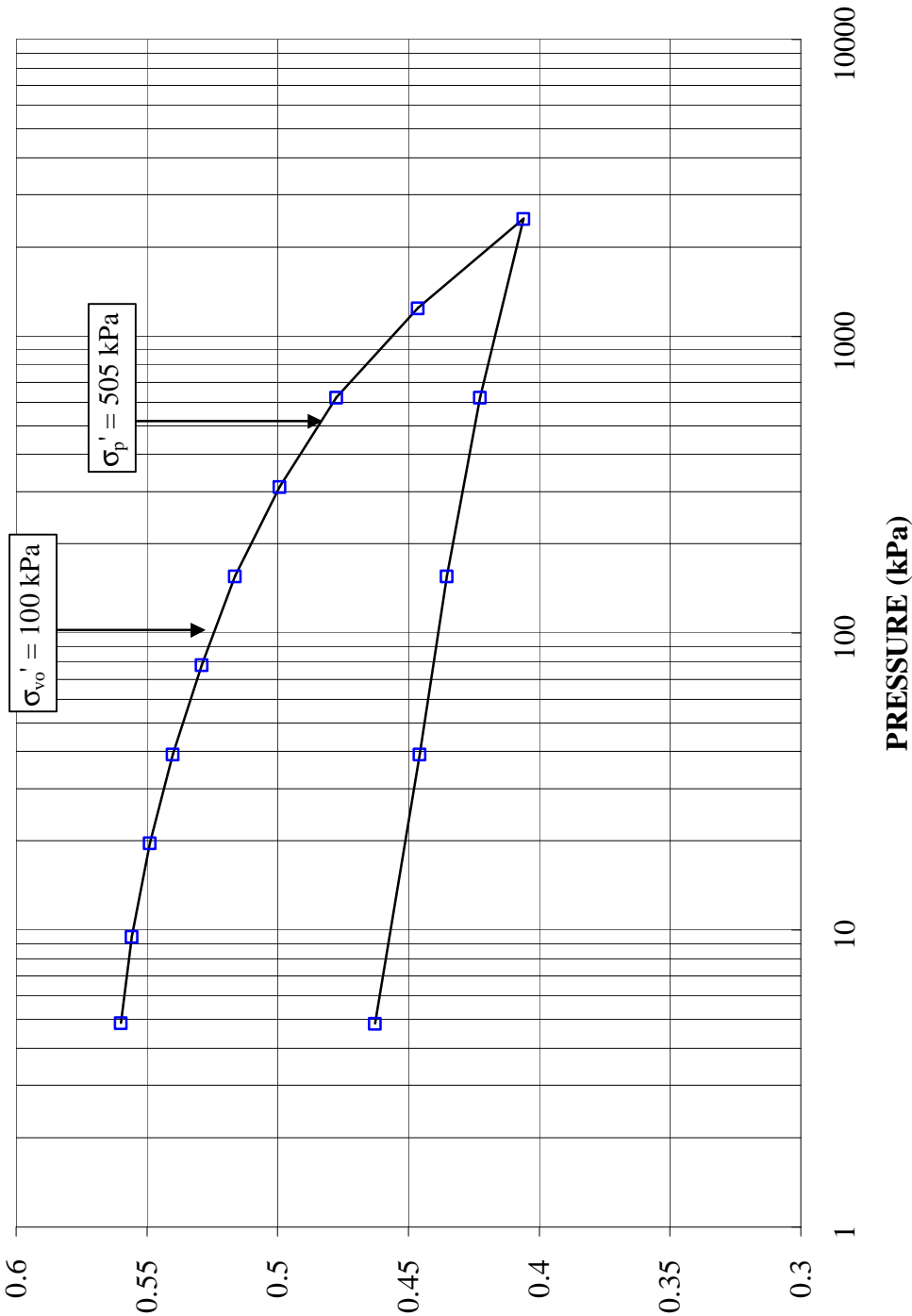


Ontario

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

FIGURE 7

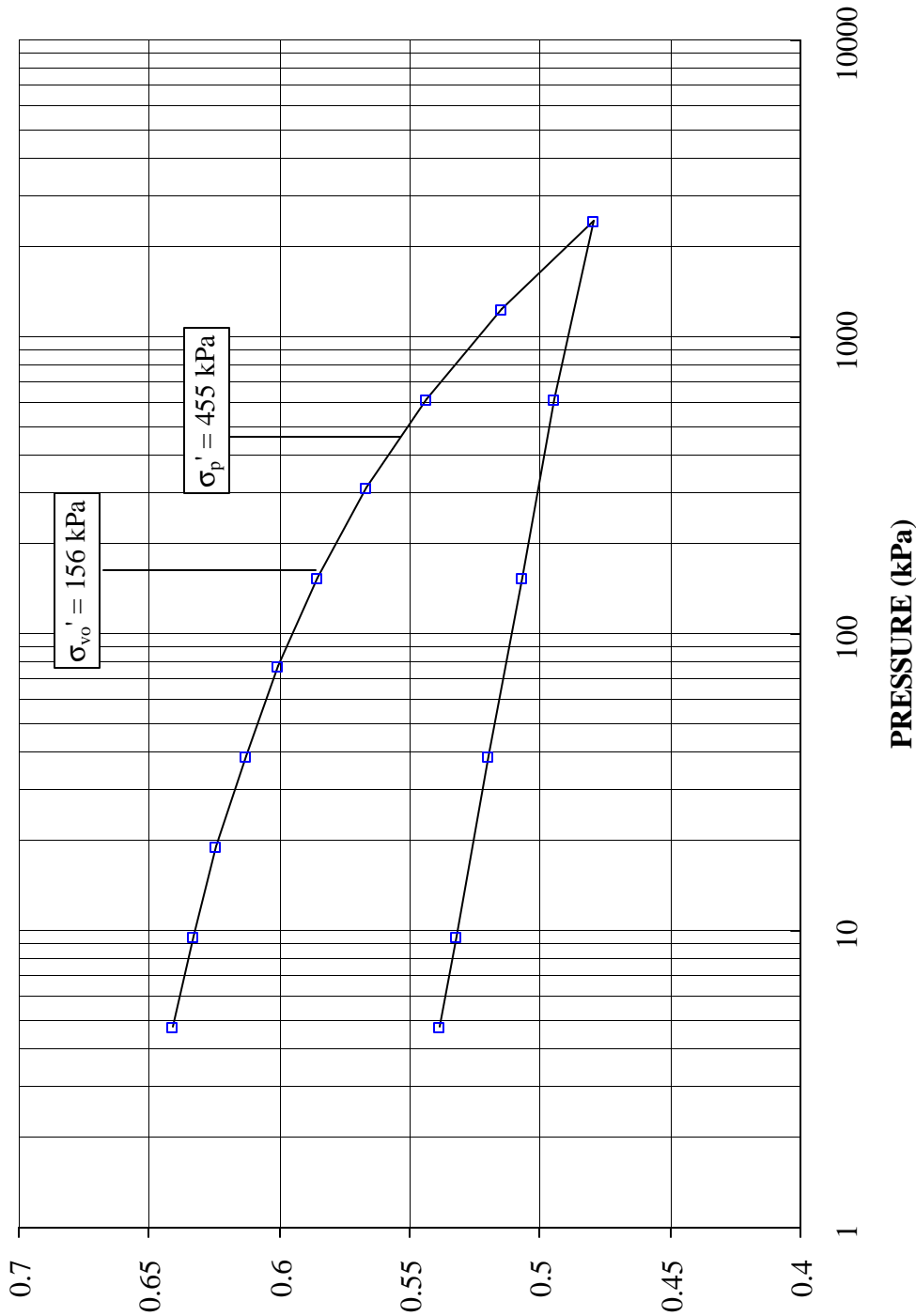
CONSOLIDATION TEST
VOID RATIO vs PRESSURE
BH P-1A - ELEVATION 176 m



CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

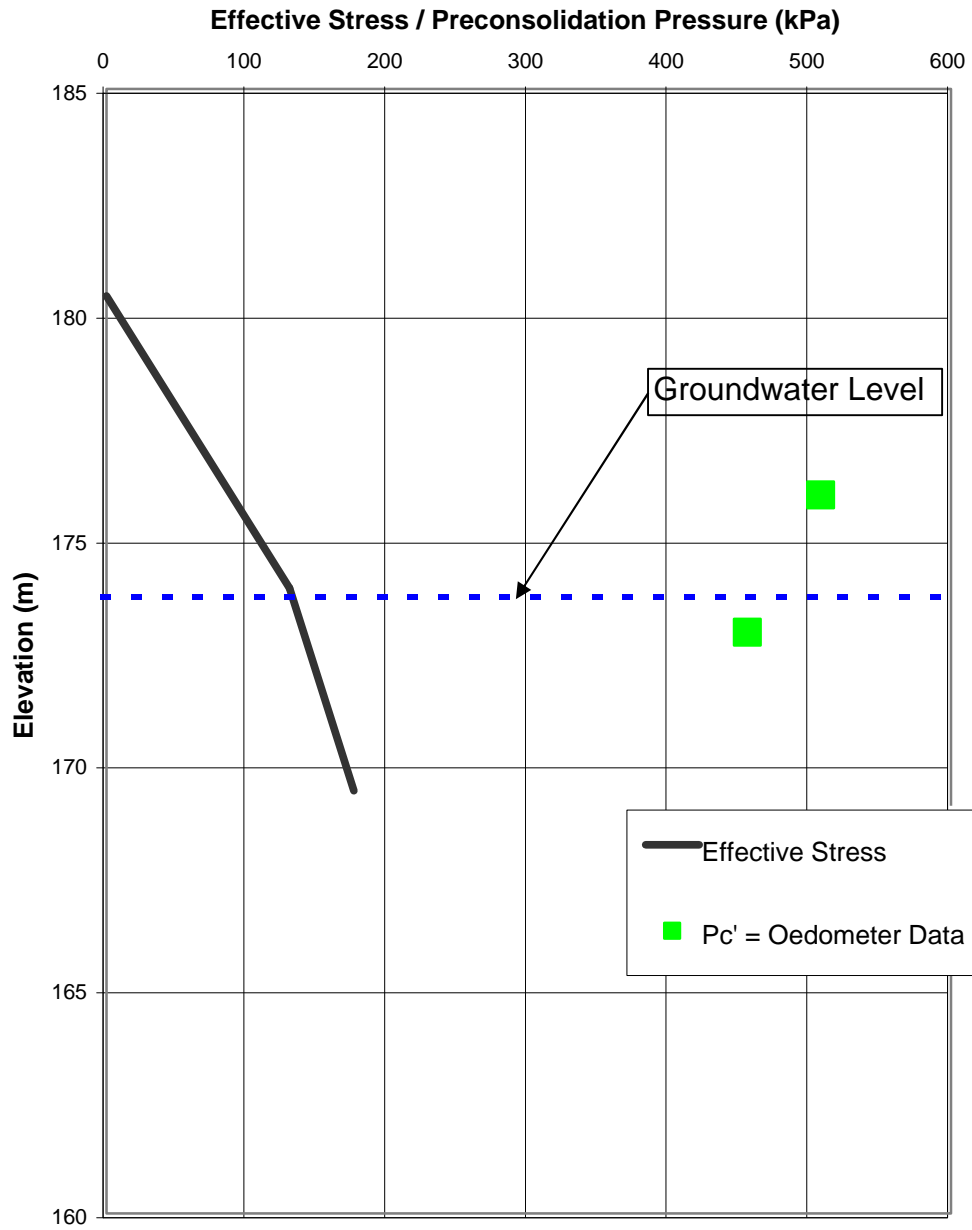
FIGURE 8

CONSOLIDATION TEST
VOID RATIO vs PRESSURE
P-1A - ELEVATION 172.9 m



Effective Stress and Preconsolidation Pressure

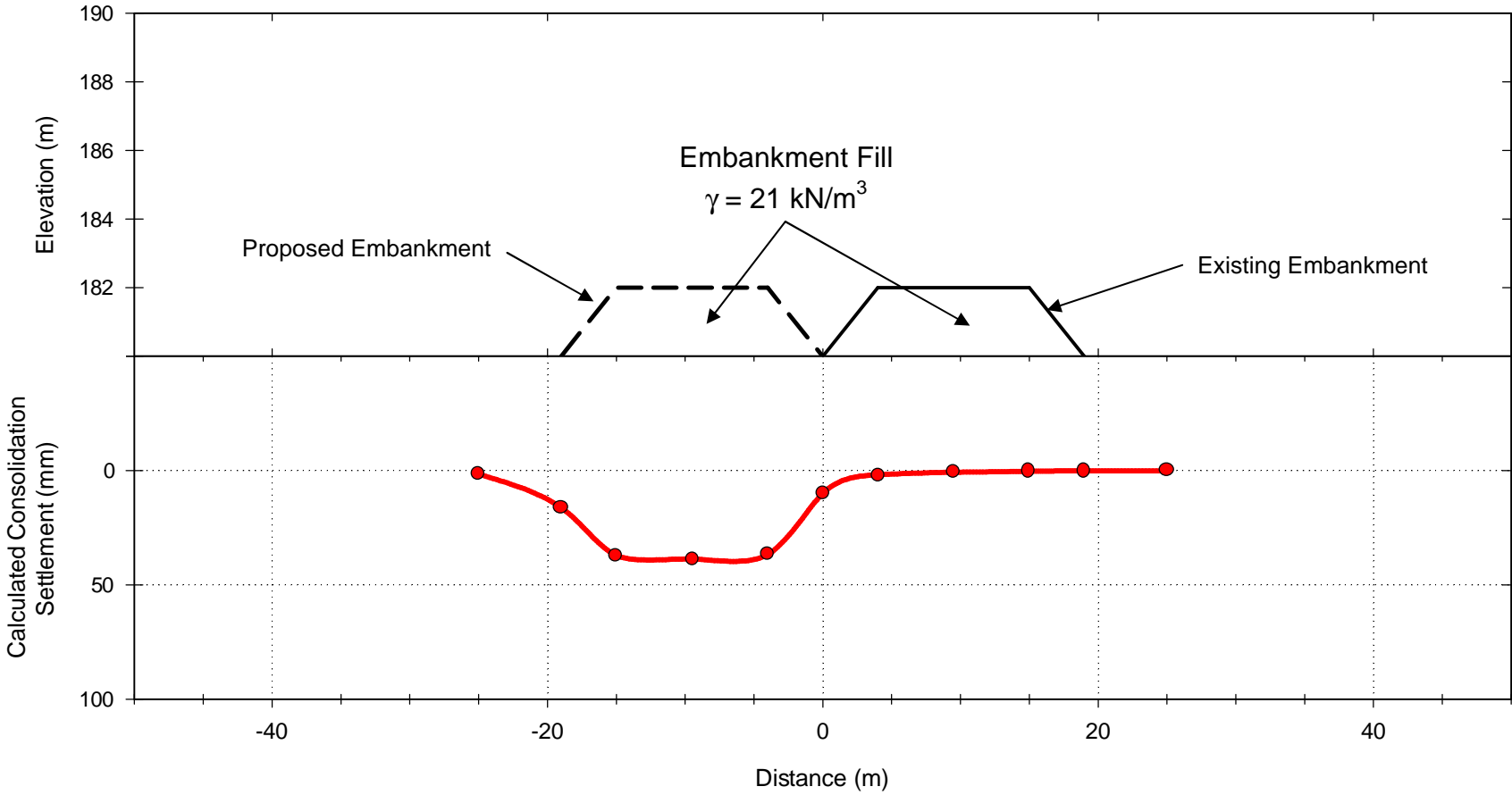
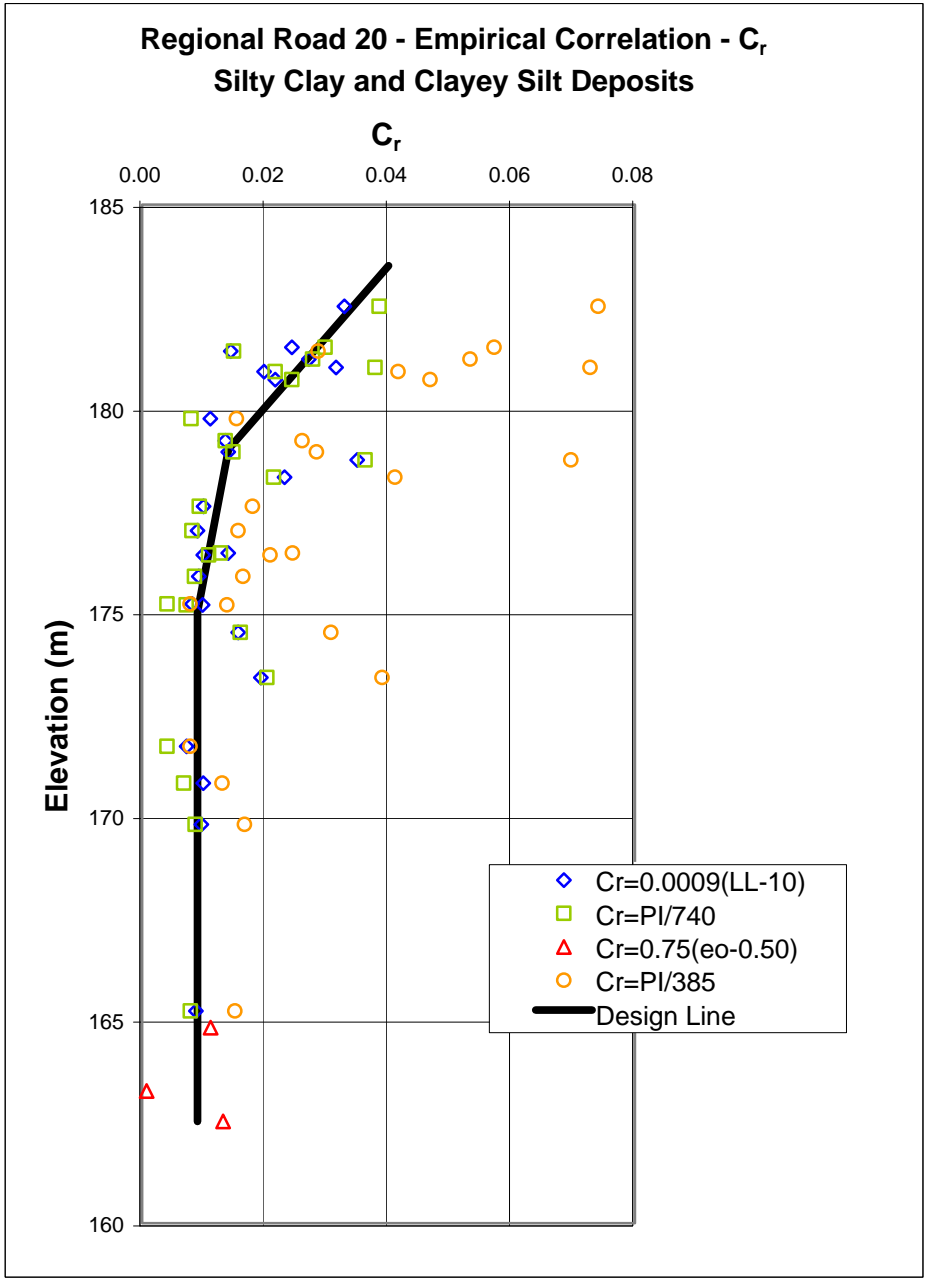
FIGURE 9



Date: January 2003
Project: 021-1143-3

Drawn: DKB
Checked: ASP

Golder Associates Ltd.

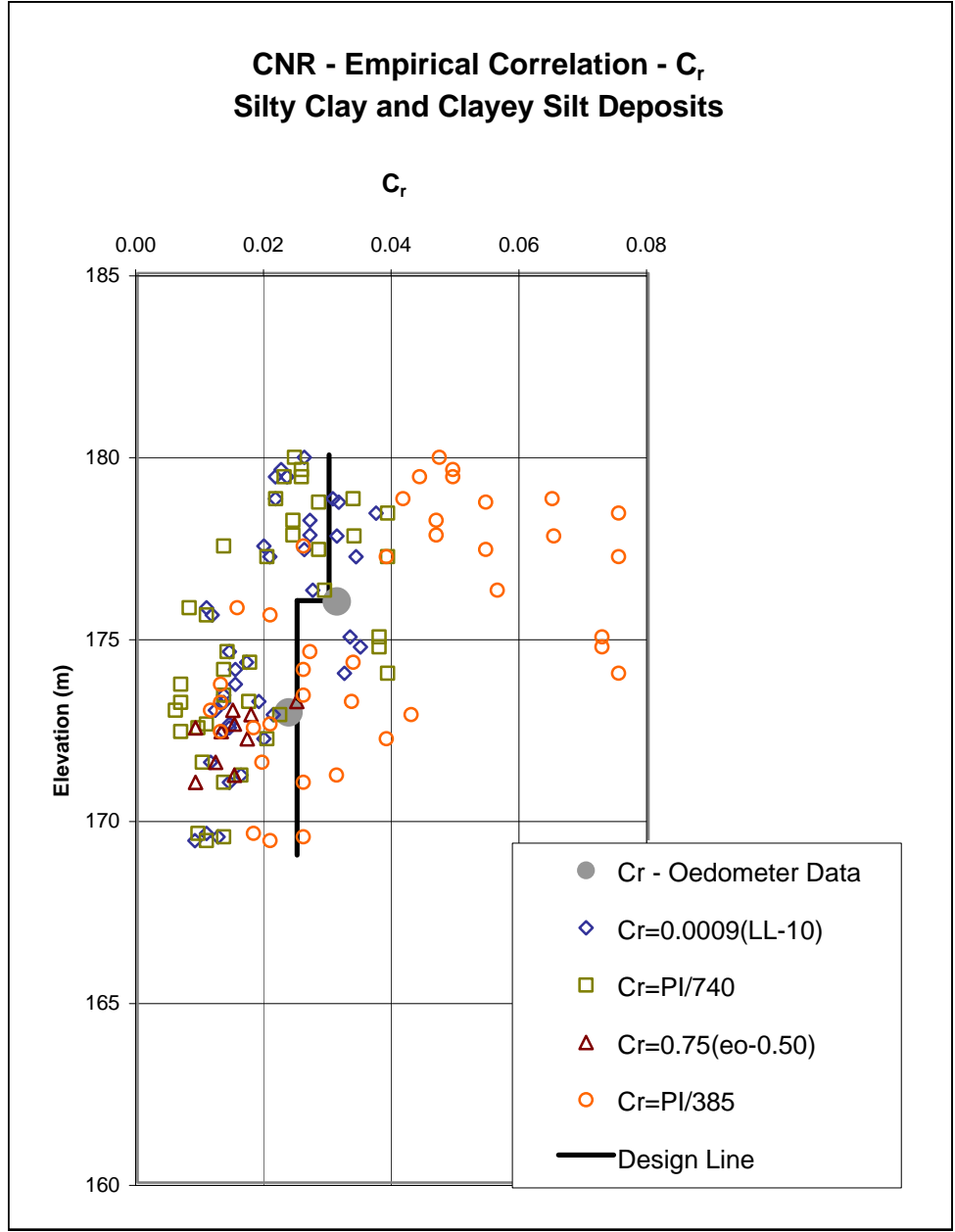


notes: -Correlations for C_r based on accepted relationships found in the published literature.
-Data used includes current and previous investigations between Stations 5+550 and 8+600 where similar soil conditions were encountered.

Date January 2003
Project 021-1143-3

Golder Associates Ltd.

Drawn DKB / CN
Checked ASP



notes: -Correlations for C_r based on accepted relationships found in the published literature.
-Data used includes current investigations between Stations 9+550 and 10+450 where similar soil conditions were encountered.

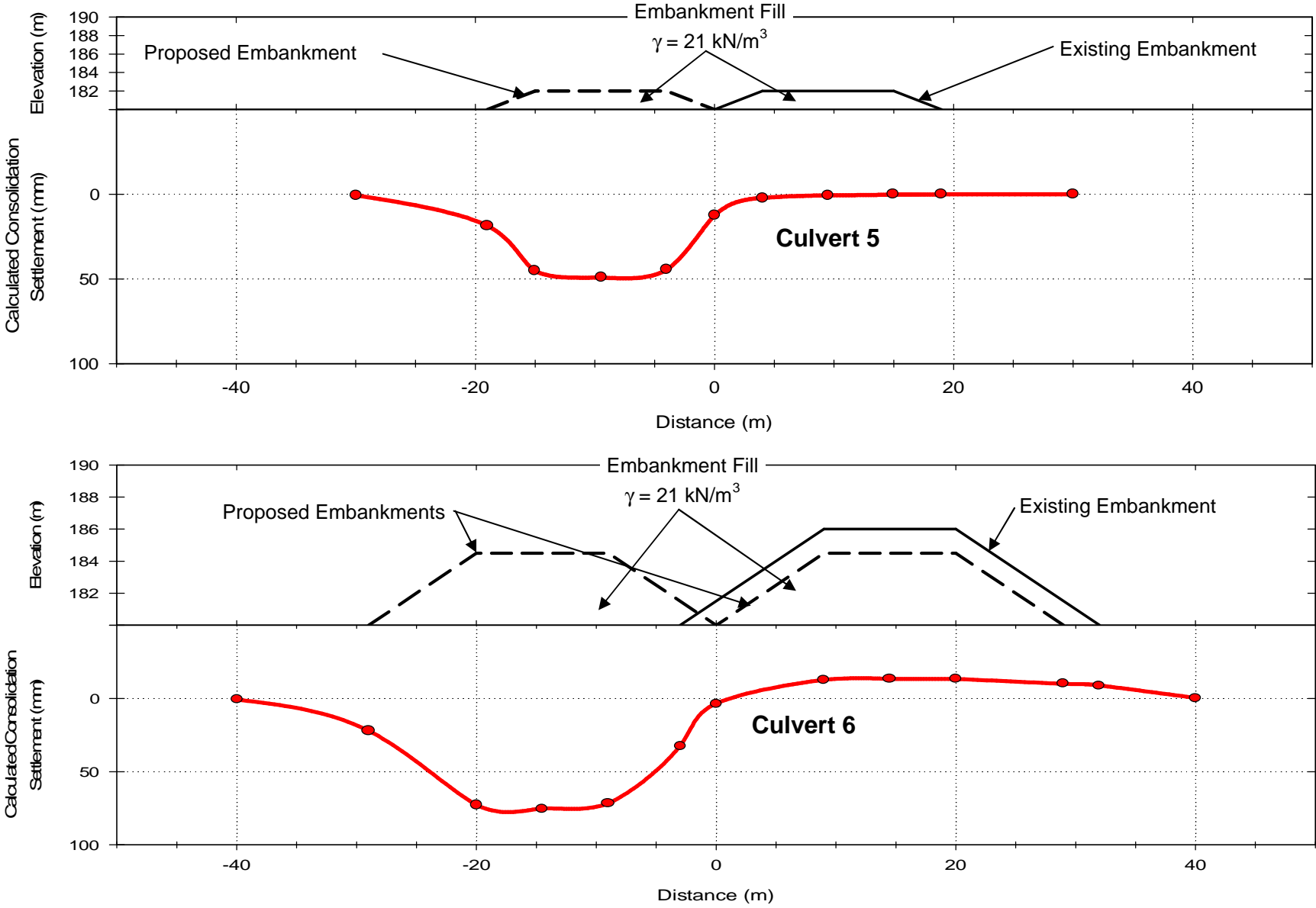
Date January 2003
Project 021-1143-3

Golder Associates Ltd.

Drawn DKB / CN
Checked ASP

Settlement Assessment
Proposed Culvert Extensions
Culverts 5 and 6

FIGURE 11



APPENDIX A

**RELEVANT RECORD OF BOREHOLE SHEETS
(MTO GEOCRES NOS 30M3-175 AND 30M3-176, DATED AUGUST 1980)**

RECORD OF BOREHOLE No 1

80-1

W P 88-63-00 LOCATION Co-ords N 4 769 463 E 326 341 ORIGINATED BY SC
 DIST 4 HWY 406&20 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
 DATUM Geodetic DATE June 3, 1980 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|---|------------|---------|------|------------|-------------------------|-----------------|--|----------|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | 'N' VALUES | | | 20 40 60 80 100 | 10 20 30 | | | | | |
| 183.3 | Ground Level | | | | | | | | | | | | | |
| 0.0 | Roadway Fill (Sand & Gravel) | | | | | | | | | | | | | |
| 182.6 | | | | | | | | | | | | | | |
| 0.7 | Silty Clay (Medium and Low Plasticity) | | 1 | SS | 12 | | 182 | | | | | | | |
| | Traces of Sand and Gravel | | 2 | SS | 28 | | | | | | | | | |
| | Stiff to Hard | | 3 | SS | 24 | | | | | | | | | 4 7 54 35 |
| | | | 4 | SS | 80 | | 180 | | | | | | | 4 2 80 14 |
| | | | 5 | SS | 111 | | | 120/127 mm | | | | | | |
| 178.1 | | | 6 | SS | 42 | | | | | | | | | |
| 5.2 | Layers of Silty Clay (of Low Plasticity) and Silt | | 7 | SS | 27 | | 178 | | | | | | | |
| | | | 8 | SS | 26 | | | | | | | | | |
| | | | 9 | SS | 29 | | 176 | | | | | | | |
| | Trace of Sand | | 10 | SS | 18 | | | | | | | | | |
| | Stiff to Very Stiff | | 11 | SS | 13 | | 174 | | | | | | | |
| | | | 12 | SS | 16 | | 172 | | | | | | | |
| | | | 13 | SS | 22 | | 170 | | | | | | | |
| | | | 14 | SS | 23 | | 168 | | | | | | | |
| | | | 15 | SS | 30 | | 166 | | | | | | | |
| | | | 16 | SS | 15 | | 164 | | | | | | | 0 0 95 5 |
| 162.9 | | | | | | | 162 | | | | | | | |
| 20.4 | Het. Mixture of Silty Clay | | | | | | | | | | | | | |
| 161.7 | Sand and Gravel | | 17 | SS | 21 | | | | | | | | | 23 39 28 10 |
| 21.6 | End of Borehole | | | | | | | | | | | | | |
| | Refusal to Auger Probable Bedrock | | | | | | 160 | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to 20
 Sensitivity 15 φ 5 (%) STRAIN AT FAILURE
 10

RECORD OF BOREHOLE No 2

W-2

W P 88-63-00 LOCATION Co-ords N 4 769 436 E 326 298 ORIGINATED BY SC
 DIST 4 HWY 406 & 20 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
 DATUM Geodetic DATE June 4, 1980 CHECKED BY

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | UNIT WEIGHT | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|------------------------------|------------|--------|------|-------------------------|-----------------|--|--|---|--|-------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | 20 40 60 80 100 | | W _p W W _L | | | |
| 183.5 | | | | | | | | | | | | |
| 0.0 | Roadway Fill | | | | | | | | | | | |
| 182.5 | (Sand and Gravel) | | | | | | | | | | | |
| 1.0 | | | 1 | SS | 12 | | | | | | | |
| | Silty Clay | | 2 | SS | 17 | | | | | | | |
| | (Low to Medium Plasticity) | | 3 | SS | 24 | | | | | | | |
| | Traces of Sand and Gravel | | 4 | SS | 32 | | | | | | | |
| | Very Stiff to Hard | | 5 | SS | 55 | | | | | | | |
| | | | 6 | SS | 25 | | | | | | | |
| 177.5 | | | 7 | SS | 19 | | | | | | | |
| 6.0 | | | 8 | SS | 23 | | | | | | | |
| | Layers of Silty Clay | | 9 | SS | 17 | | | | | | | |
| | (of Low Plasticity) and Silt | | | | | | | | | | | |
| | Trace of Sand | | 10 | SS | 17 | | | | | | | |
| | Stiff to Hard | | | | | | | | | | | |
| | | | 11 | SS | 13 | | | | | | | |
| | | | 12 | SS | 18 | | | | | | | |
| | | | 13 | SS | 25 | | | | | | | |
| | | | 14 | SS | 39 | | | | | | | |
| | | | | | | | | | | | | |
| | | | 15 | SS | 19 | | | | | | | |
| | | | | | | | | | | | | |
| 162.9 | | | | | | | | | | | | |
| 20.6 | Het. Mixture of Silty | | 16 | SS | 17 | | | | | | | |
| 162.2 | Clay, Sand & Gravel | | | | | | | | | | | |
| 21.3 | Dolstone Bedrock | | 17 | RC | 69% | | | | | | | |
| 160.8 | Slightly Pitted | | 18 | RC | 98% | | | | | | | |
| 22.7 | End of Borehole | | | | | | | | | | | |

+3, x5: Numbers refer to 20
 Sensitivity 15-5 (%) STRAIN AT FAILURE
 10

RECORD OF BOREHOLE No 3

80-3

W P 88-63-00 LOCATION Co-ords. N 4 769 499; E 326 398 ORIGINATED BY SC
 DIST 4 HWY 406 & 20 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
 DATUM Geodetic DATE June 5, 1980 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|---------|------|------------|-------------------------|-----------------|--|----------|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | 'N' VALUES | | | 20 40 60 80 100 | 10 20 30 | | | | | |
| 183.5 0.0 | Ground Level Topsoil | | | | | | | | | | | | | GR SA SI CL |
| | Silty Clay (Low to Medium Plasticity) Traces of Sand and Gravel Stiff to Hard | | 1 | SS | 23 | | 182 | | | | | | | 9 7 42 42 |
| | | | 2 | SS | 14 | | | | | | | | | |
| | | | 3 | SS | 19 | | | | | | | | | |
| | | | 4 | SS | 23 | | | | | | | | | |
| | | | 5 | SS | 29 | | | | | | | | | |
| 178.3 5.2 | | | 6 | SS | 86 | | | 120/250 mm | | | | | | |
| | | | 7 | SS | 27 | | 178 | | | | | | | |
| | Layers of Silty Clay (of Low Plasticity) and Silt Trace of Sand Very Stiff to Hard | | 8 | SS | 19 | | | | | | | | | |
| | | | 9 | SS | 24 | | 176 | | | | | | | |
| | | | 10 | SS | 22 | | | | | | | | | |
| | | | 11 | SS | 21 | | 174 | | | | | | | |
| | | | 12 | SS | 20 | | 172 | | | | | | | |
| | | | 13 | SS | 81 | | 170 | | | | | | | 0 1 91 8 |
| | | | 14 | SS | 20 | | 168 | | | | | | | |
| | | | 15 | SS | 24 | | 166 | | | | | | | |
| 163.0 20.5 | | | | | | | 164 | | | | | | | |
| 162.0 21.5 | Het. Mixture of Silty Clay, Sand and Gravel Hard | | 16 | SS | 119/ | 280 mm | 162 | | | | | | | 41 16 34 9 |
| 160.1 23.4 | Dolstone Bedrock Sound | | 17 | RC | 85% | | 160 | | | | | | | |
| | End of Borehole | | | | | | | | | | | | | |

+3, x5: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 1

W P 167-66-01 LOCATION Co-ords. N 4 771 224; E 326 199 ORIGINATED BY SC
DIST 4 HWY 406 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
DATUM Geodetic DATE 1980 06 06 CHECKED BY

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZ DISTRIBUTIO (%) |
|---------------|--|---------|------|------------|----------------------------|--------------------|---|--|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | 'N' VALUES | | | 20 40 60 80 100 | | | | | | |
| 180.8 | Ground Level | | | | | | | | | | | | |
| 0.0 | Topsoil | | | | | | | | | | | | |
| | Silty Clay of Medium Plasticity | 1 | SS | 13 | | 180 | | | | | | 20.6 | |
| | Trace of Sand | 2 | TW | PH | | | | | | | | | |
| | Brown & Grey | 3 | SS | 22 | | | | | | | | | |
| 177.1 | Stiff to Hard | 4 | SS | 26 | | 170 | | | | | | | 0 1 60 3 |
| 3.7 | | 5 | SS | 18 | | | | | | | | | |
| | Layers of Inorganic Silt and Silty Clay (Low to Medium Plasticity) | 6 | SS | 9 | | | | | | | | | |
| | Traces of Sand and Gravel | 7 | SS | 6 | | | | | | | | | |
| | Firm to Stiff | 8 | SS | 9 | | | | | | | | | |
| | Grey & Brown | 9 | TW | PH | | | | | | | | | |
| | | 10 | SS | 7 | | | | | | | | | |
| | | 11 | TW | PH | | | | | | | | | |
| | | 12 | SS | 2 | | | | | | | | | |
| | | 13 | TW | PH | | | | | | | | | 1 8 83 |
| 168.4 | | | | | | | | | | | | | |
| 12.4 | End of Borehole (Refusal to Auger) Probable Bedrock | | | | | | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 2

W P 167-66-01 LOCATION Co-ords. N 4 771 193; E 326 188 ORIGINATED BY SC
DIST 4 HWY 406 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
DATUM Geodetic DATE 80 06 09 CHECKED BY

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | UNIT WEIGHT Y | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|---------|------|------------|----------------------------|--------------------|---|----|----|----|-----|---------------------|---|
| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | 'N' VALUES | | | 20 | 40 | 60 | 80 | 100 | | |
| 180.6 | Ground Level | | | | | | | | | | | | |
| 176.9 | Topsoil | | | | | | | | | | | | |
| 176.9 | Silty Clay of Medium Plasticity | 1 | SS | 17 | | 180 | | | | | | | 0 2 60 38 |
| | Trace of Sand | 2 | SS | 24 | | 178 | | | | | | | |
| | Brown & Grey | 3 | SS | 35 | | | | | | | | | |
| | V. Stiff to Hard | 4 | TV | PH | | | | | | | | | |
| 176.9 | Layers of Inorganic Silt and Silty Clay | 5 | SS | 8 | | 176 | | | | | | | 0 0 88 12 |
| 3.7 | (Low to Medium Plasticity) | 6 | TV | PH | | | | | | | | | |
| | Traces of Sand and Gravel | 7 | SS | 5 | | 174 | | | | | | | |
| | Firm to Hard | 8 | TV | PH | | | | | | | | | |
| | | 9 | SS | 5 | | 172 | | | | | | | 0 5 91 4 |
| | | 10 | TV | PH | | | | | | | | | |
| | | 11 | SS | 1 | | | | | | | | | |
| | | 12 | SS | 4 | | | | | | | | | |
| 168.9 | Grey Dolomite | 13 | TV | PH | | 170 | | | | | | | |
| 11.7 | Medium Texture | | | | | | | | | | | | |
| 166.9 | (Sound) | 14 | RC | 80Z | | 168 | | | | | | | |
| 13.7 | End of Borehole | | | | | | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 3

W P 167-66-01 LOCATION Co-ords. N 4 771 256; E 326 201 ORIGINATED BY SC
DIST 4 HWY 406 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
DATUM Geodetic DATE 1980 06 10 CHECKED BY

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT Y | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|--------|------|----------------------------|--------------------|---|----|----|----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | 20 | 40 | 60 | 80 | 100 | | | | |
| 180.4 | Ground Level | | | | | | | | | | | | | | |
| 0.0 | Topsoil | | | | | | | | | | | | | | |
| | Silty Clay of Medium Plasticity | | 1 | SS | 18 | | | | | | | | | | |
| | Trace of Sand | | 2 | TW | PH | | | | | | | | | | |
| | Brown & Grey | | 3 | SS | 31 | | | | | | | | | | |
| 176.8 | V. Stiff to Hard | | 4 | SS | 23 | | | | | | | | | | |
| 3.6 | | | 5 | SS | 25 | | | | | | | | | | |
| | Layers of Inorganic Silt and Silty Clay (Low to Medium Plasticity) | | 6 | SS | 20 | | | | | | | | | | |
| | Traces of Sand and Gravel | | 7 | SS | 10 | | | | | | | | | | |
| | Firm to V. Stiff | | 8 | TW | PH | | | | | | | | | | |
| | | | 9 | SS | 16 | | | | | | | | | | |
| | | | 10 | TW | PH | | | | | | | | | | |
| | | | 11 | SS | 2 | | | | | | | | | | |
| | | | 12 | SS | 18 | | | | | | | | | | |
| 168.2 | | | | | | | | | | | | | | | |
| 12.2 | End of Borehole (Refusal to Auger) Probable Bedrock | | | | | | | | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 4

W P 167-66-01 LOCATION Co-ords. N 4 771 237; E 326 186 ORIGINATED BY SC
DIST 4 HWY 406 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
DATUM Geodetic DATE 80 06 10 CHECKED BY

| SOIL PROFILE | | STRAT PLOT | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|---------------------|--|
| ELEV DEPTH | DESCRIPTION | | NUMBER | TYPE | 'N' VALUES | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 180.4 | Ground Level | | | | | | | | | | | | | | | | |
| U.U. | Topsoil | | | | | | | | | | | | | | | | |
| | Silty Clay of Medium Plasticity | | 1 | SS | 29 | | 180 | | | | | | | | | | |
| | Trace of Sand | | 2 | SS | 34 | | | | | | | | | | | | |
| | Brown & Grey | | 3 | SS | 31 | | 178 | | | | | | | | | | 0 1 61 38 |
| | V. Stiff to Hard | | 4 | SS | 23 | | | | | | | | | | | | |
| 176.7 | | | 5 | SS | 22 | | | | | | | | | | | | |
| 3.7 | Layers of Inorganic Silt and Silty Clay (Low to Medium Plasticity) | | 6 | SS | 20 | | 176 | | | | | | | | | | |
| | Traces of Sand and Gravel | | 7 | SS | 9 | | | | | | | | | | | | |
| | | | 8 | TW | PH | | 174 | | | | | | | | | 20.25 | 0 0 76 24 |
| | Firm to V. Stiff | | 9 | SS | 33 | | | | | | | | | | | | |
| | | | 10 | TW | PH | | 172 | | | | | | | | | 20.4 | |
| | | | 11 | SS | 2 | | 170 | | | | | | | | | | |
| | | | 12 | TW | PH | | | | | | | | | | | 22.0 | |
| 168.5 | End of Borehole (Refusal to Auger) | | | | | | | | | | | | | | | | |
| 11.9 | Probable Bedrock | | | | | | | | | | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 5

W P 167-66-01 LOCATION Co-ords. N 4 771 278; E 326 191 ORIGINATED BY SC
DIST 4 HWY 406 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
DATUM Geodetic DATE 80 06 10 & 11 CHECKED BY

| SOIL PROFILE | | STRAT PLOT | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT | | | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|---|------------|---------|------|------------|-------------------------|-----------------|--|---------|---|----------|-------------|------------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | | NUMBER | TYPE | 'N' VALUES | | | 20 40 60 80 100 | 100 200 | W _p W W _L | 15 30 45 | GR SA SI CL | | |
| 180.6 | Ground Level | | | | | | | | | | | | | |
| 0.0 | Topsoil and Organics | | | | | | | | | | | | | |
| 179.6 | | | | | | | | | | | | | | |
| 1.0 | Silty Clay of Medium Plasticity. Trace of Sand. Brown and Grey Firm to V. Stiff | | 1 | SS | 10 | | | | | | | | | |
| | | | 2 | SS | 8 | | | | | | | | | |
| 177.7 | | | 3 | SS | 22 | | | | | | | | | |
| 2.9 | | | 4 | SS | 13 | | | | | | | | | |
| | Layers of Inorganic Silt and Silty Clay (Low to Medium Plasticity) | | 5 | SS | 11 | | | | | | | | | |
| | Traces of Sand & Gravel | | 6 | SS | 8 | | | | | | | | | |
| | | | 7 | SS | 8 | | | | | | | | | |
| | | | 8 | TW | PH | | | | | | | | | |
| | | | 9 | SS | 9 | | | | | | | | | |
| | Firm to V. Stiff | | 10 | SS | 5 | | | | | | | | | |
| | | | 11 | TW | PH | | | | | | | | | |
| 169.8 | | | | | | | | | | | | | | |
| 10.7 | Silty Clay with Sand & Gravel Hard | | 12 | SS | 90 | | | | | | | | | |
| 168.6 | | | | | | | | | | | | | | |
| 12.0 | End of Borehole (Refusal to Auger) Probable Bedrock | | | | | | | | | | | | | |

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 6

W P 167-66-01 LOCATION Co-ords. N 4 771 307; E 326 202 ORIGINATED BY SC
 DIST 4 HWY 406 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SC
 DATUM Geodetic DATE 80 06 10 CHECKED BY _____

OFFICE REPORT ON SOIL EXPLORATION

| SOIL PROFILE | | STRAT. PLOT | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|--|-------------|---------|------|------------|-------------------------|-----------------|--|----|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| ELEV. DEPTH | DESCRIPTION | | NUMBER | TYPE | 'N' VALUES | | | 20 | 40 | | | | | |
| 180.5 | Ground Level | | | | | | | | | | | | | |
| 0.0 | Topsoil | | | | | | | | | | | | | |
| | Silty Clay of Medium Plasticity | | 1 | SS | 17 | | 180 | | | | | | | 0 2 64 34 |
| | Trace of Sand | | 2 | SS | 26 | | | | | | | | | |
| | Brown & Grey | | 3 | SS | 22 | | 178 | | | | | | | |
| | Very Stiff | | 4 | SS | 26 | | | | | | | | | |
| 176.8 | | | 5 | SS | 13 | | 176 | | | | | | 18.70 | 0 2 26 72 |
| 3.7 | Layers of Inorganic Silt and Silty Clay (Low to Medium Plasticity) | | 6 | SS | 7 | | | | | | | | | |
| | Traces of Sand and Gravel | | 7 | TW | PH | | 174 | | | | | | | |
| | Firm to Very Stiff | | 8 | SS | 12 | | | | | | | | | |
| | | | 9 | SS | 5 | | 172 | | | | | | 19.95 | |
| | | | 10 | TW | PH | | | | | | | | | |
| | | | 11 | SS | 2/500 | | 170 | | | | | | | |
| 169.8 | Silty Clay with Sand and Gravel Hard | | 12 | SS | 129 | | | | | | | | | 27 25 41 7 |
| 10.7 | | | 13 | RC | 967 | | 168 | | | | | | | |
| 169.2 | Dolomite Medium Texture Sound | | 14 | RC | 872 | | | | | | | | | |
| 11.3 | | | 15 | RC | 962 | | | | | | | | | |
| 167.7 | End of Borehole | | | | | | | | | | | | | |
| 12.8 | | | | | | | | | | | | | | |

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

APPENDIX B
CONSOLIDATION TEST DATA

OEDOMETER CONSOLIDATION SUMMARY

SAMPLE IDENTIFICATION

| | | | |
|-----------------|----------|-----------------|---|
| Project Number | 021-1143 | Sample Number | 1 |
| Borehole Number | P1-A | Sample Depth, m | 5 |

TEST CONDITIONS

| | | | |
|------------------|---------------------|-------------------|-----------|
| Test Type | Quick Consolidation | Load Duration, hr | (0.1-0.2) |
| Oedometer Number | 7 | | |
| Date Started | 02-11-26 | | |
| Date Completed | 02-11-26 | | |

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

| | | | |
|-------------------------|--------|------------------------------------|-------|
| Sample Height, cm | 1.91 | Unit Weight, kN/m ³ | 20.20 |
| Sample Diameter, cm | 6.35 | Dry Unit Weight, kN/m ³ | 16.95 |
| Area, cm ² | 31.67 | Specific Gravity, assumed | 2.70 |
| Volume, cm ³ | 60.49 | Solids Height, cm | 1.223 |
| Water Content, % | 19.14 | Volume of Solids, cm ³ | 38.73 |
| Wet Mass, g | 124.57 | Volume of Voids, cm ³ | 21.76 |
| Dry Mass, g | 104.56 | Degree of Saturation, % | 91.9 |

TEST COMPUTATIONS

| Pressure kPa | Corr. Height cm | Void Ratio | Average Height cm | t ₉₀ sec | cv. cm ² /s | mv m ² /kN | k cm/s |
|-----------------|-----------------------|---------------|-------------------------|------------------------|---------------------------|--------------------------|-----------|
| 0.00 | 1.910 | 0.562 | 1.910 | | | | |
| 4.83 | 1.907 | 0.560 | 1.909 | 4 | 1.93E-01 | 3.03E-04 | 5.74E-06 |
| 9.47 | 1.902 | 0.555 | 1.905 | 22 | 3.50E-02 | 5.87E-04 | 2.01E-06 |
| 19.53 | 1.894 | 0.549 | 1.898 | 5 | 1.53E-01 | 4.32E-04 | 6.47E-06 |
| 38.96 | 1.883 | 0.540 | 1.888 | 11 | 6.87E-02 | 2.94E-04 | 1.98E-06 |
| 77.66 | 1.869 | 0.529 | 1.876 | 24 | 3.11E-02 | 1.83E-04 | 5.56E-07 |
| 155.07 | 1.854 | 0.516 | 1.862 | 7 | 1.05E-01 | 1.06E-04 | 1.09E-06 |
| 310.31 | 1.833 | 0.499 | 1.843 | 6 | 1.20E-01 | 6.98E-05 | 8.21E-07 |
| 618.44 | 1.806 | 0.477 | 1.820 | 4 | 1.75E-01 | 4.54E-05 | 7.80E-07 |
| 1238.68 | 1.768 | 0.446 | 1.787 | 15 | 4.52E-02 | 3.20E-05 | 1.42E-07 |
| 2477.19 | 1.719 | 0.406 | 1.744 | 32 | 2.01E-02 | 2.09E-05 | 4.13E-08 |
| 618.44 | 1.739 | 0.422 | 1.729 | | | | |
| 155.07 | 1.755 | 0.435 | 1.747 | | | | |
| 38.96 | 1.767 | 0.445 | 1.761 | | | | |
| 4.83 | 1.788 | 0.463 | 1.778 | | | | |

Notes:

void ratio for each increment has been calculated based on dial reading at the end of the increment
k calculated using cv based on t₉₀ values.

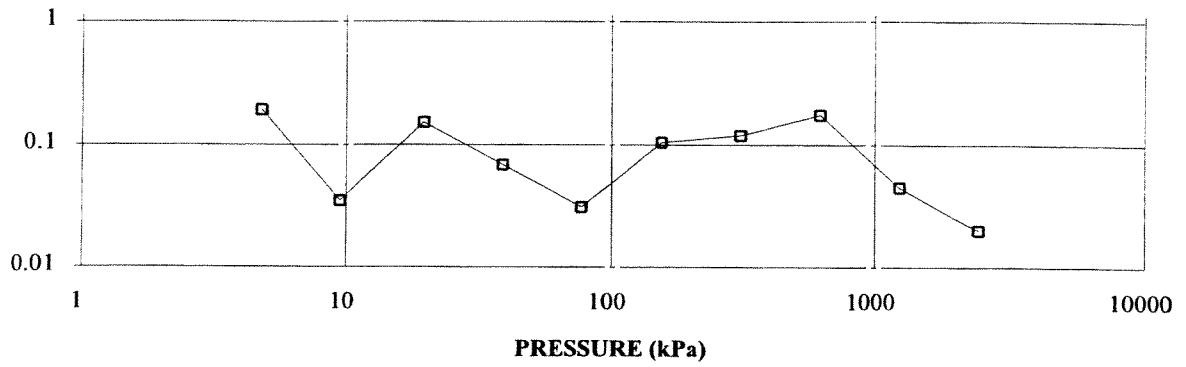
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

| | | | |
|-------------------------|--------|------------------------------------|-------|
| Sample Height, cm | 1.79 | Unit Weight, kN/m ³ | 21.56 |
| Sample Diameter, cm | 6.35 | Dry Unit Weight, kN/m ³ | 18.10 |
| Area, cm ² | 31.67 | Specific Gravity, assumed | 2.70 |
| Volume, cm ³ | 56.64 | Solids Height, cm | 1.223 |
| Water Content, % | 19.06 | Volume of Solids, cm ³ | 38.73 |
| Wet Mass, g | 124.49 | Volume of Voids, cm ³ | 17.91 |
| Dry Mass, g | 104.56 | | |

OEDOMETER CONSOLIDATION SUMMARY

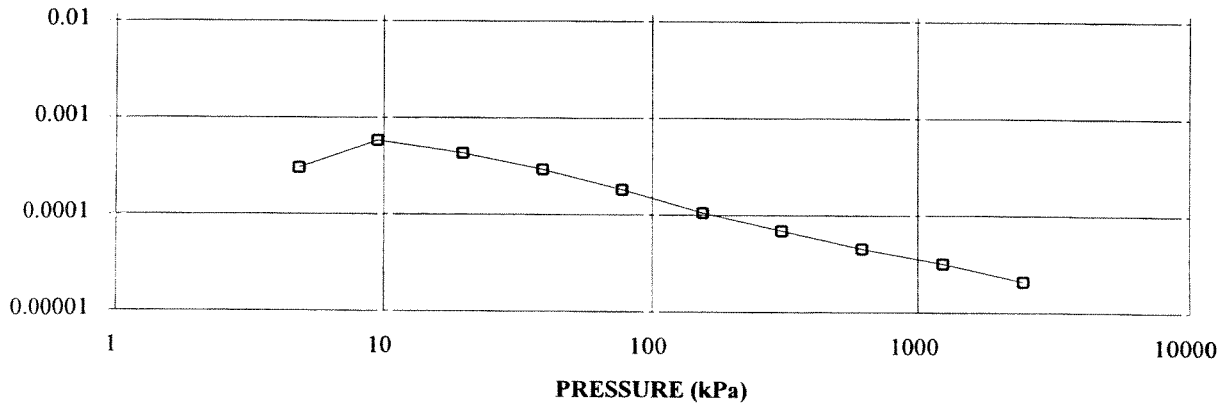
COEFFICIENT OF CONSOLIDATION, cm^2/s

CONSOLIDATION TEST
 c_v cm^2/s vs PRESSURE (kPa)
 BH P-1A 5 m



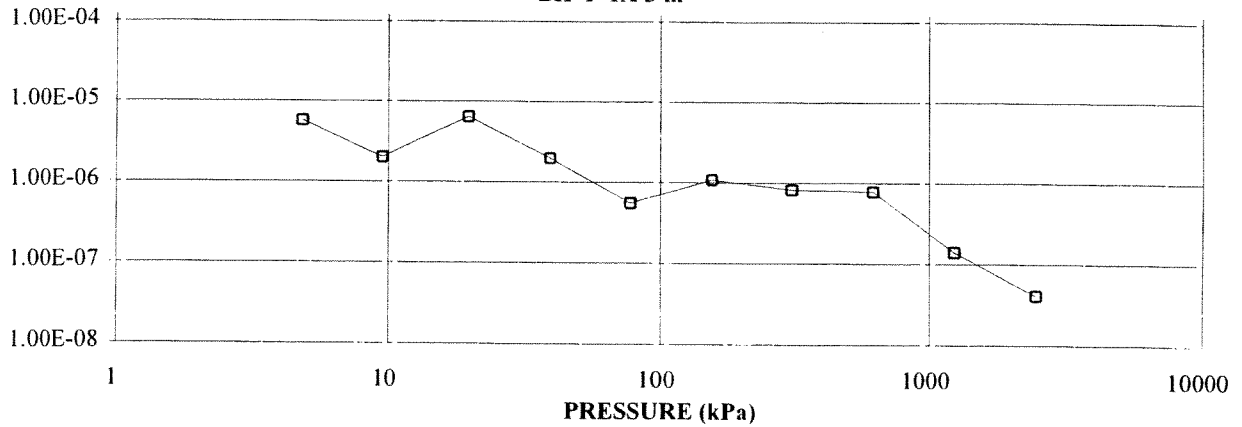
VOLUME
COMPRESSIBILITY,
 m^2/kN

CONSOLIDATION TEST
 m_v , m^2/kN vs PRESSURE (kPa)
 BH P-1A 5 m



HYDRAULIC
CONDUCTIVITY, cm/s

CONSOLIDATION TEST
 HYDRAULIC CONDUCTIVITY vs PRESSURE
 BH P-1A 5 m

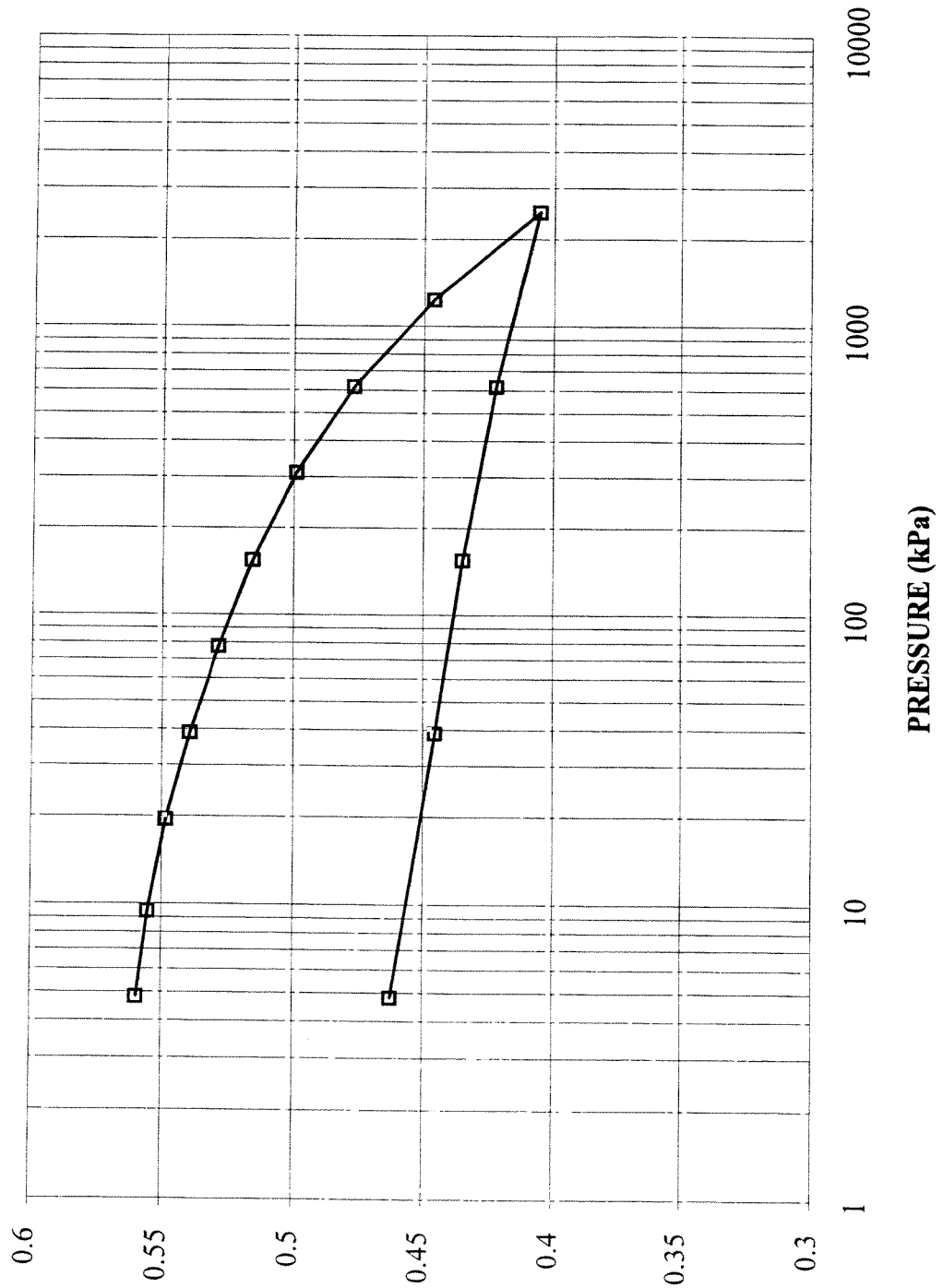


Project No. 021-1143

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

FIGURE

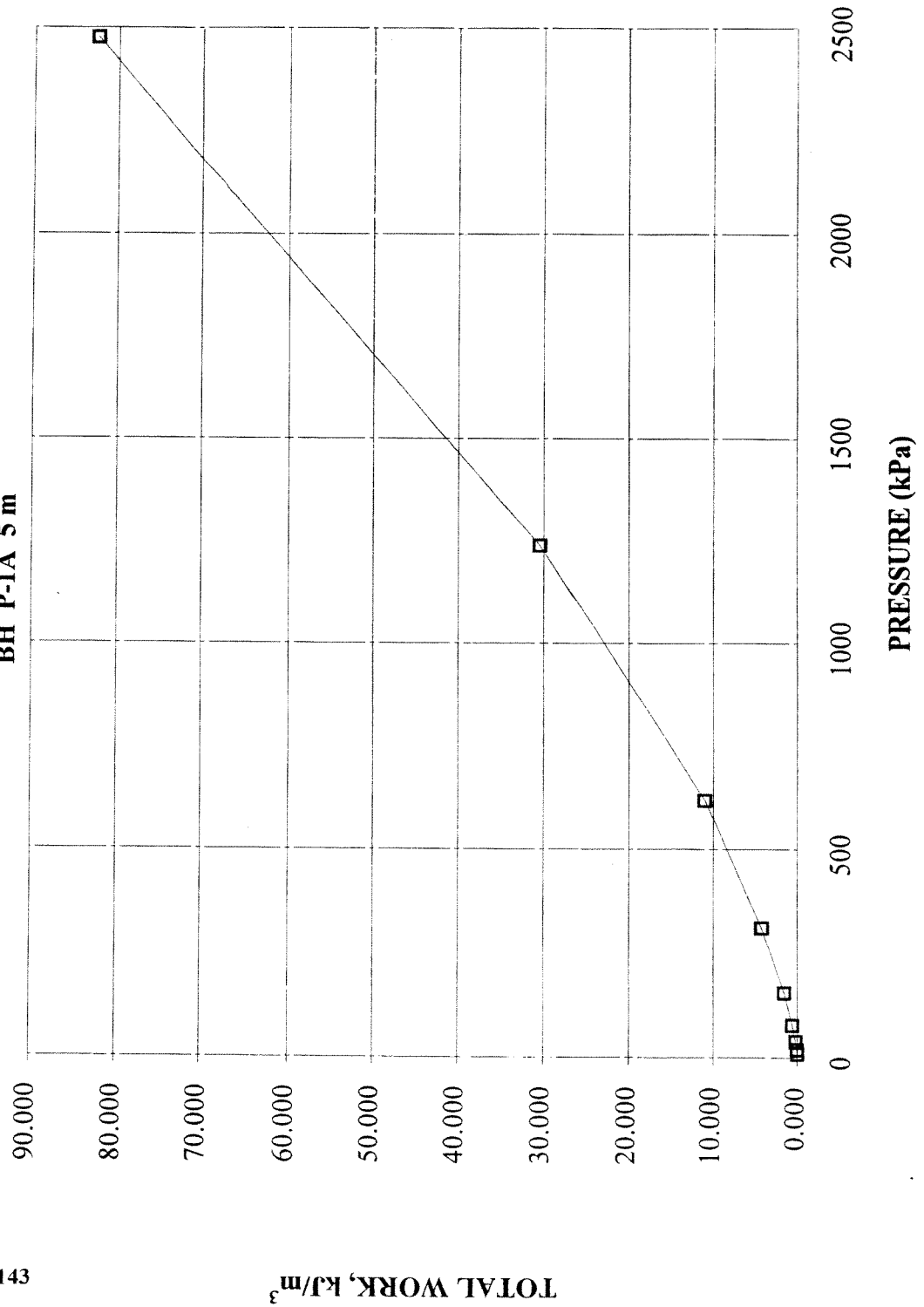
CONSOLIDATION TEST
VOID RATIO vs PRESSURE
BH P-1A 5 m



Project No. 021-1143

VOID RATIO

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs PRESSURE
BH P-1A 5 m



OEDOMETER CONSOLIDATION SUMMARY

SAMPLE IDENTIFICATION

| | | | |
|-----------------|----------|-----------------|-----|
| Project Number | 021-1143 | Sample Number | 2 |
| Borehole Number | P-1A | Sample Depth, m | 8.1 |

TEST CONDITIONS

| | | | |
|------------------|----------|-------------------|-----------|
| Test Type | Quick | Load Duration, hr | (0.1-0.2) |
| Oedometer Number | 6 | | |
| Date Started | 02-11-07 | | |
| Date Completed | 02-11-07 | | |

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

| | | | |
|-------------------------|--------|------------------------------------|-------|
| Sample Height, cm | 1.91 | Unit Weight, kN/m ³ | 20.15 |
| Sample Diameter, cm | 6.34 | Dry Unit Weight, kN/m ³ | 16.12 |
| Area, cm ² | 31.61 | Specific Gravity, measured | 2.73 |
| Volume, cm ³ | 60.37 | Solids Height, cm | 1.150 |
| Water Content, % | 24.99 | Volume of Solids, cm ³ | 36.35 |
| Wet Mass, g | 124.04 | Volume of Voids, cm ³ | 24.02 |
| Dry Mass, g | 99.24 | Degree of Saturation, % | 103.2 |

TEST COMPUTATIONS

| Pressure kPa | Corr. Height cm | Void Ratio | Average Height cm | t ₉₀ sec | cv. cm ² /s | mv m ² /kN | k cm/s |
|-----------------|-----------------------|---------------|-------------------------|------------------------|---------------------------|--------------------------|-----------|
| 0.00 | 1.910 | 0.661 | 1.910 | | | | |
| 4.76 | 1.887 | 0.641 | 1.899 | 576 | 1.33E-03 | 2.51E-03 | 3.26E-07 |
| 9.56 | 1.878 | 0.633 | 1.883 | 116 | 6.48E-03 | 1.01E-03 | 6.44E-07 |
| 19.29 | 1.868 | 0.624 | 1.873 | 21 | 3.54E-02 | 5.33E-04 | 1.85E-06 |
| 38.75 | 1.855 | 0.613 | 1.862 | 43 | 1.71E-02 | 3.47E-04 | 5.81E-07 |
| 77.53 | 1.841 | 0.601 | 1.848 | 25 | 2.90E-02 | 1.93E-04 | 5.48E-07 |
| 154.98 | 1.823 | 0.585 | 1.832 | 18 | 3.95E-02 | 1.19E-04 | 4.61E-07 |
| 309.76 | 1.802 | 0.567 | 1.812 | 12 | 5.80E-02 | 7.31E-05 | 4.16E-07 |
| 619.50 | 1.775 | 0.543 | 1.788 | 10 | 6.78E-02 | 4.55E-05 | 3.02E-07 |
| 1239.04 | 1.742 | 0.515 | 1.758 | 10 | 6.56E-02 | 2.75E-05 | 1.76E-07 |
| 2477.70 | 1.702 | 0.480 | 1.722 | 22 | 2.86E-02 | 1.72E-05 | 4.82E-08 |
| 619.50 | 1.719 | 0.494 | 1.710 | | | | |
| 154.98 | 1.733 | 0.507 | 1.726 | | | | |
| 38.75 | 1.747 | 0.519 | 1.740 | | | | |
| 9.56 | 1.762 | 0.532 | 1.755 | | | | |
| 4.76 | 1.769 | 0.538 | 1.766 | | | | |

Notes:

k calculated using cv based on t₉₀ values.

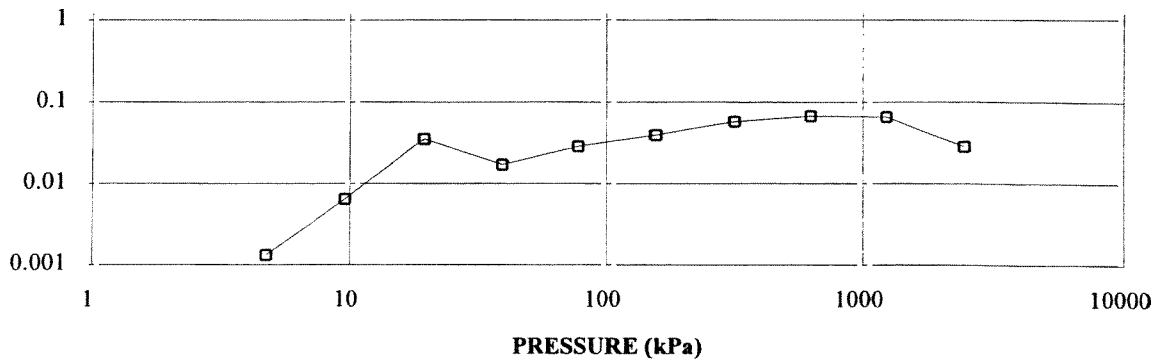
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

| | | | |
|-------------------------|--------|------------------------------------|-------|
| Sample Height, cm | 1.77 | Unit Weight, kN/m ³ | 20.94 |
| Sample Diameter, cm | 6.34 | Dry Unit Weight, kN/m ³ | 17.40 |
| Area, cm ² | 31.61 | Specific Gravity, measured | 2.73 |
| Volume, cm ³ | 55.92 | Solids Height, cm | 1.150 |
| Water Content, % | 20.33 | Volume of Solids, cm ³ | 36.35 |
| Wet Mass, g | 119.41 | Volume of Voids, cm ³ | 19.57 |
| Dry Mass, g | 99.24 | | |

OEDOMETER CONSOLIDATION SUMMARY

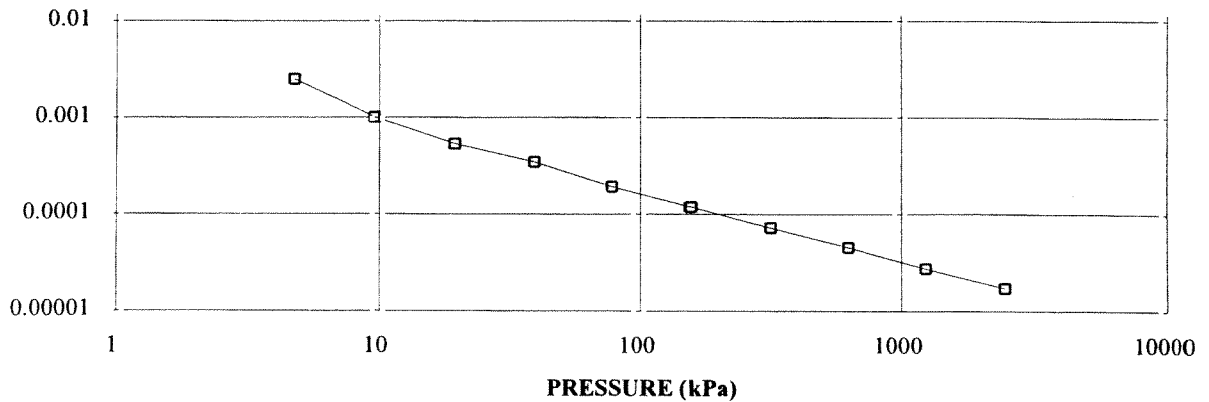
COEFFICIENT OF CONSOLIDATION, cm^2/s

CONSOLIDATION TEST
 $c_v \text{ cm}^2/\text{s}$ vs PRESSURE (kPa)
P-1A 8.1m



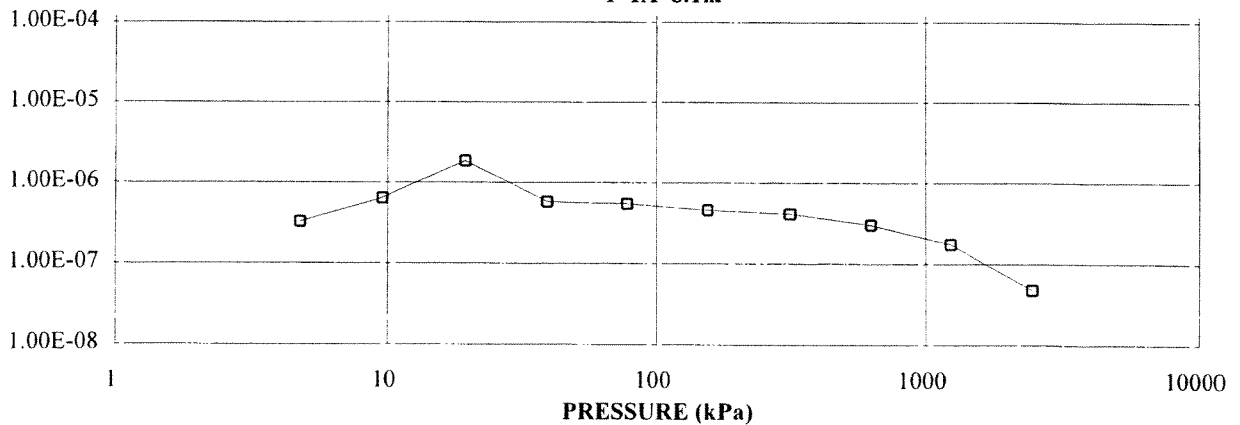
VOLUME
COMPRESSIBILITY,
 m^2/kN

CONSOLIDATION TEST
 $m_v, \text{m}^2/\text{kN}$ vs PRESSURE (kPa)
P-1A 8.1m



HYDRAULIC
CONDUCTIVITY, cm/s

CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
P-1A 8.1m

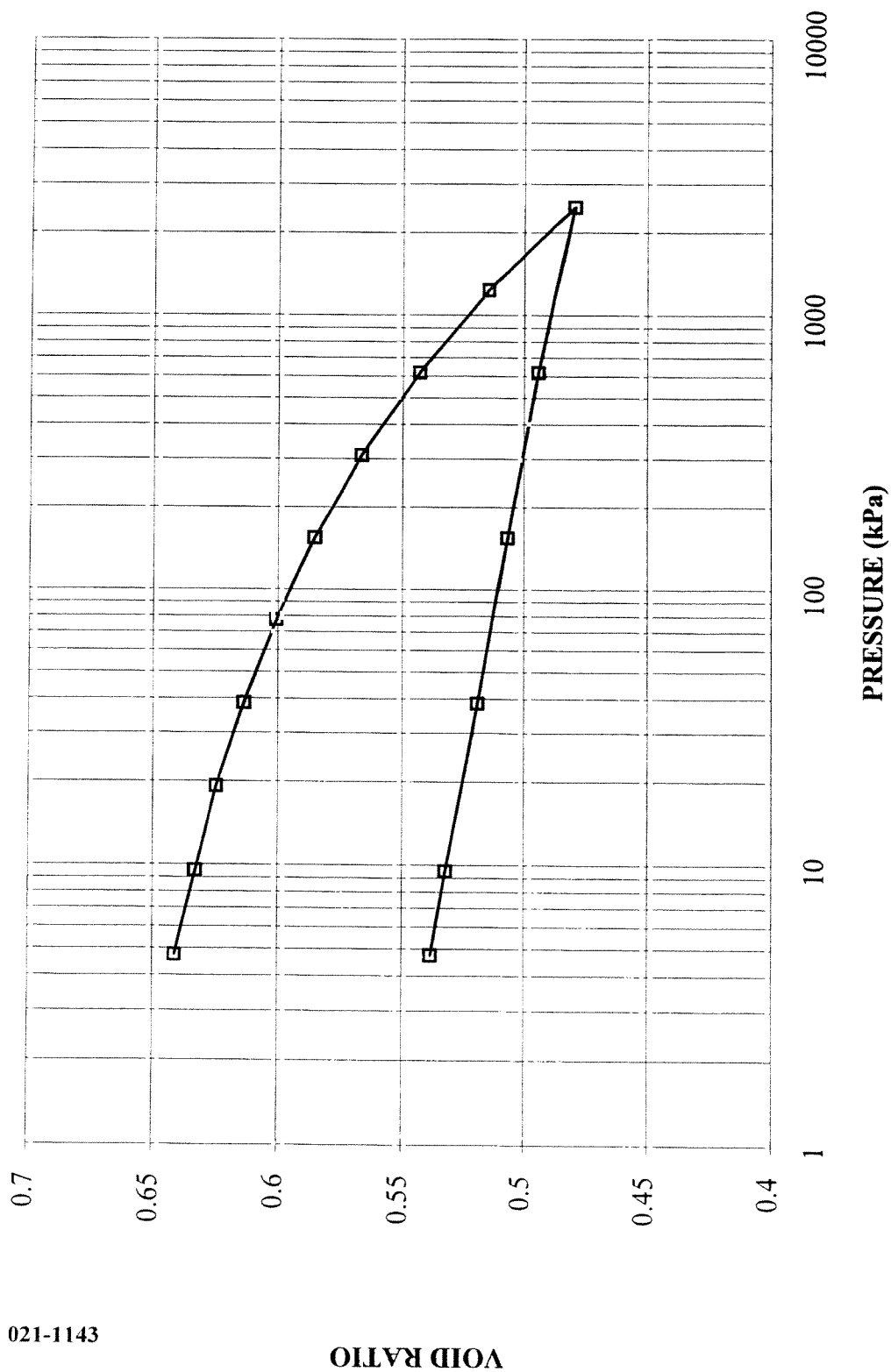


Project No. 021-1143

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

FIGURE

CONSOLIDATION TEST
VOID RATIO vs PRESSURE
P-1A 8.1m



Project No. 021-1143

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs PRESSURE
P-1A 8.1m

