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**FOUNDATION INVESTIGATION AND DESIGN
RETAINING WALL STATION 18+600 TO 19+080
HIGHWAY 17
NORTH BAY TO STURGEON FALLS
DISTRICT 54, SUDBURY
G.W.P. 812-76-01**

Submitted to:

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GEOCRES No. 31L-94

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PART A

**FOUNDATION INVESTIGATION REPORT
RETAINING WALL STATION 18+600 TO 19+080
HIGHWAY 17
NORTH BAY TO STURGEON FALLS
DISTRICT 54, SUDBURY
G.W.P. 812-76-01**

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (McCormick Rankin) on behalf of the Ministry of Transportation (MTO) to carry out a foundation investigation for a proposed retaining wall in the area of the proposed widening and upgrading of Highway 17 between North Bay and Sturgeon Falls, Ontario (see Drawing 1).

The purpose of the investigation is to determine the subsurface conditions along the proposed wall by the Ministry of Transportation of Ontario by drilling boreholes, carrying out in-situ tests and performing laboratory tests on selected samples. The initial terms of reference for the scope of work are outlined in Golder's proposal letter dated March 27, 2003. The work was carried out in accordance with Golder's Quality Control Plan for this project.

The following report, prepared by Golder, was used in preparation of this report:

- Foundation Investigation and Design, High Embankments and Culvert, Highway 17, North Bay to Sturgeon Fall, District 54, Sudbury, G.W.P. 812-76-01, April 2001.

2.0 SITE DESCRIPTION

The project area covered by this report extends along the proposed Highway 17 widening route, from approximately Station 18+600 to 19+080 in the Township of Commanda (referred to as Area 6 in the 2001 report). The site is situated approximately 20 km west of North Bay, Ontario between Highway 64 and Highway 11.

The ground surface along the centreline of existing Highway 17 within the project area and along the proposed retaining wall location generally lies between about Elevation 217 m and 226 m dipping towards the east. Lake Nipissing is located well south of the highway.

3.0 INVESTIGATION PROCEDURES

A subsurface investigation was carried out for the proposed Highway 17 widening on July 29 and 30, 2004, at which time seven boreholes (Boreholes 04-01 to 04-07) were advanced at the site. Boreholes 04-01 to 04-04 were advanced using a truck-mounted CME-40 drill rig, while Boreholes 04-05 to 04-07 were advanced using a truck mounted CME-55 drill rig, both supplied and operated by Colbar Resources Drilling Services of Sudbury, Ontario. The boreholes were advanced on the south shoulder of the existing Highway 17.

A subsurface investigation was previously carried out in the area by Golder Associates in 1999 and Borehole 99-30 was advanced in the vicinity of the proposed retaining wall.

The boreholes were advanced using hollow stem augers to depths ranging from 1.4 m to 4.6 m below the existing ground surface. Samples of the overburden were obtained at 0.75 m to 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure. The water level in the open boreholes was observed throughout the drilling operations. The boreholes were backfilled using bentonite pellets and some soil cuttings.

The field work was supervised on a full-time basis by members of Golder's staff who 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 Golder's laboratory in Mississauga for further examination and testing. Index and classification tests consisting of water content determinations, Atterberg limits testing and grain size distribution analyses were carried out on selected soil samples.

The borehole locations were measured by Golder Associates relative to site features, and the ground surface elevations at the borehole locations were determined from the alignment drawings for this project. The borehole locations (including MTM NAD83 northing and easting coordinates) and ground surface elevations (referenced to geodetic datum) are summarized in the following table and are shown on Drawing 1.

<i>Borehole Number</i>	<i>MTM NAD83 Northing (m)</i>	<i>MTM NAD83 Easting (m)</i>	<i>Ground Surface Elevation (m)</i>
99-30	5132703.2	303274.9	220.2
04-01	5132696.6	302957.5	225.2
04-02	5132697.1	303007.4	225.5
04-03	5132697.8	303057.5	225.4
04-04	5132699.0	303107.5	224.8
04-05	5132699.8	303157.4	223.9
04-06	5132700.7	303207.4	222.7
04-07	5132701.5	303257.5	220.9

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The site lies within the Canadian Shield in an area where the bedrock is overlain by overburden materials of variable thickness. To the west of the site, the area can be characterized as a flat plain. The bedrock in the general area is igneous and metamorphic rock of early Precambrian age. A former glacial lake basin existed in the area and, consequently, the site is underlain by deposits of fine-grained lake sediments. The overburden typically consists of surficial sands and silts overlying clay deposit of variable thickness. Some of the clay deposits are varved.

4.2 Site Stratigraphy

As part of the subsurface investigation at this site, seven boreholes were advanced adjacent to the proposed retaining wall. The borehole locations and interpreted stratigraphy are shown on Drawing 1. The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets and Figures 1 to 4. 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 site is covered by a thin layer of granular fill, associated with the existing Highway 17, underlain by deposits ranging from sand and gravel to clayey silt, with the most prominent deposit being the silty sand to sandy silt deposit. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Fill material was encountered at the ground surface in all boreholes. The fill, consisting of mainly sand and gravel containing trace silt, varied in thickness from 0.5 m to 1.5 m, being thickest towards the east end of the site. The measured SPT 'N' values within the fill range from 13 to 40 blows per 0.3 m of penetration, indicating that this existing fill has a compact to dense relative density. The water content of the fill ranged from 2.1 to 4.4 per cent.

4.2.2 Clayey Silt

Underneath the fill material, a clayey silt with sand deposit containing trace gravel was encountered in Borehole 99-30, 04-01 and 04-06. In Borehole 04-01 the deposit also contained sandy silt seams throughout. The thickness of the deposit ranged between 1.0 m and 4.1 m, with the surface of the deposit between Elevation 219.1 m and Elevation 224.4 m. In Borehole 04-06,

the sand content of the deposit decreased with depth, and at a depth notably below Elevation 221.2 m.

The measured SPT 'N' values ranged from 12 to greater than 100 blows per 0.3 m of penetration, indicating that the deposit is stiff to hard, generally hard.

The results of three Attenberg limit tests indicated the samples tested to be of low plasticity (see Figure 1). The results from two grain size distribution tests of the clayey silt with sand are shown on Figure 2. The results from one grain size distribution test from the lower clayey silt, trace sand to some sand portion of the deposit is shown on Figure 3. The water content of the deposit ranged from 8.1 to 19.2 per cent.

4.2.3 Sand and Silt

Granular deposits ranging in composition from sand and gravel to sandy silt were encountered below the fill in all the boreholes except 04-01, 04-06, and 99-30. The deposits contain trace to some gravel, trace to some clay and occasional clay seam. The elevation of the surface of these deposits ranges between Elevation 219.4 m and Elevation 224.9 m. The deposit ranges from 0.8 to 4.0 m in total thickness.

The measured SPT 'N' values ranged from 12 to greater than 100 blows per 0.3 m of penetration, indicating that the deposit is compact to very dense, generally very dense.

The results from one grain size distribution test of sand and silt some gravel is shown on Figure 4. The water content of the deposit ranged from 2.1 to 9.0 per cent.

4.2.4 Cobbles

Cobbles were encountered at the bottom of Borehole 04-05 at Elevation 222.7 m.

4.2.5 Refusal

Auger refusal was encountered in all of the boreholes between 1.4 and 4.6 m below the ground surface on what is probably at or near the surface of bedrock. The elevation of auger refusal is given in the table below. In Borehole 04-07, the borehole was not terminated due to auger refusal, however, it was not possible to take a spoon sample at depth, suggesting that refusal had been encountered.

<i>Borehole</i>	<i>Auger Refusal Depth (m)</i>	<i>Auger Refusal Elevation (m)</i>
99-30	2.8	217.4
04-01	3.8	221.4
04-02	4.6	220.9
04-03	2.1	223.3
04-04	1.9	222.9
04-05	1.4	222.5
04-06	4.6	218.1
04-07*	4.0	216.9

Note: * Borehole 04-07 was by sampler refusal.

4.3 Groundwater Conditions

No piezometers were installed in the area of the proposed wall. In addition, no visible water was observed in any of the boreholes, and the boreholes were dry upon completion of drilling. In addition, the ground slopes downwards towards the east end of the site and likely serves to drain this area. In Boreholes 04-01, 04-05 and 04-06, the holes caved just above the base of the borehole, indicating the presence of perched water in these boreholes.

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

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NK/SEP/FJH/nk

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PART B

**FOUNDATION DESIGN REPORT
RETAINING WALL STATION 18+600 TO 19+080
HIGHWAY 17
NORTH BAY TO STURGEON FALLS
DISTRICT 54, SUDBURY
G.W.P. 812-76-01**

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides our recommendations on the foundation aspects of design of the proposed retaining wall on Highway 17 between North Bay and Sturgeon Falls, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at this site. The interpretation and recommendations provided are intended only to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed structure foundations. As such, where comments are made on construction they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

5.2 Retaining Wall Foundation

It is understood that the proposed high retaining wall will extend from Station 18+675 to the west side of Couchie Industrial Park Road, and from the east side of Couchie Industrial Park Road to Station 19+050 along the south side of Highway 17 to accommodate the proposed widening. Based on the ditch grade and the grade of the adjacent property, the walls are estimated to be between 2.5 and 4.0 m in height. It is understood that the exact alignment of the wall is not known, and could be located somewhere between the proposed widened ditch line and the adjacent private property.

The subsurface conditions encountered in the seven boreholes put down in the area of the retaining wall during this investigation typically consist of a 0.5 m to 1.5 m thick layer of sand and gravel fill, underlain primarily by granular deposits although clayey silt deposits were encountered in some areas. The most prominent soil deposit being the silty sand to sandy silt. The surfaces of the native deposits are encountered between Elevation 219.1 m to Elevation 224.9 m. Auger refusal was encountered in most boreholes at depths between 1.4 m and 4.6 m (between Elevation 216.9 m to Elevation 223.3 m).

Consideration can be given to the use of a retained soil system (RSS) wall, or a concrete cantilever wall. The use of deep foundations has not been considered due to the presence of competent founding soils at relatively shallow depth.

5.2.1 Retained Soil System (RSS) Walls

Depending on the space restrictions at the proposed site, a retained soil system wall could be considered. A mechanically-reinforced soil retaining wall system (RSS wall) consists of granular

fill, placed and compacted in layers, and reinforced with metal or fabric strips or grids. A facing material, typically pre-cast concrete panels mechanically fastened to the reinforcing strips or grids, is used to form the face of the reinforced soil structure and to prevent the loss of fill material. This facing material is often supported on a narrow strip footing on a small granular levelling pad. Provision should be made in the contract for subexcavation of any loose/soft material from beneath the footing or RSS mass to be backfilled with compacted granular material.

RSS walls could be adopted at this site, although it is noted that a geotextile or appropriately-graded filter material (for example, "Ottawa sand") will be required between the native soils and the RSS wall fill, in order to prevent loss of fine soil particles into the voids within the granular fill.

Depending upon the finished grades along the wall alignment, RSS walls at this site would be between about 2.5 m to 4.0 m high. Assuming that the wall could be located adjacent to the ditch line, the RSS walls should be founded at least 0.5 m below the proposed cut of the south ditch of Highway 17. In this case the RSS walls would be founded on either the stiff to hard clayey silt deposit or the compact to very dense granular materials. The following table lists the approximate founding elevations and the founding soil type at regular intervals along the wall.

<i>Station</i>	<i>Borehole</i>	<i>Ground Surface Elevation (m)</i>	<i>Elevation of Surface of Native Soil (m)</i>	<i>Proposed Founding Elevation (m)</i>	<i>Founding Stratum</i>
18+700	04-01	225.2	224.4	222.5	Clayey Silt
18+750	04-02	225.5	224.9	222.5	Sand and Silt
18+800	04-03	225.4	224.8	222.7	Probable Rock
18+850	04-04	224.8	224.2	222.6	Probable Rock
18+900	04-05	223.9	223.3	220.8	Probable Rock
18+950	04-06	222.7	222.2	219.8	Clayey Silt
19+000	04-07	220.9	219.4	218.3	Sand and Silt

*Based on cross sections provided by MRC

Assuming that the RSS wall acts as a unit and utilizes the full width of the reinforced soil mass, which is taken as two-thirds of the height of the wall, the following factored geotechnical resistances at ULS and the geotechnical resistance at SLS (for 25 mm of settlement) may be used for design of RSS walls founded on the properly prepared founding soils.

<i>Wall Height</i>	<i>Assumed Footing Width</i>	<i>Factored Geotechnical Resistance at ULS</i>	<i>Geotechnical Resistance at SLS</i>
2.5 m	1.7 m	375 kPa	250 kPa
4.0 m	2.7 m	400 kPa	275 kPa

If the alignment of the wall is such that a higher elevation is desired, the footings could be placed as high as the surface of the native materials given in the table above, using the resistances as described above. It is not recommended that the wall be founded on the fill material at this site.

The resistance to lateral forces / sliding resistance between the compacted granular fill (assumed to be Granular “A”) and the subgrade soils should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction, $\tan \delta'$, between the compacted Granular “A” and the properly prepared subgrade may be taken as 0.45. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

The internal stability of the mechanically-reinforced soil walls should be checked by the RSS supplier / designer. The factor of safety related to global stability under static loading for properly designed and constructed RSS walls at this site is greater than 1.3.

Since the wall foundation will be located adjacent to and below the Highway 17 ditch, the foundation (strip footing) should be protected from scour in this area. Erosion protection such as rip-rap or other suitable material should line the ditch in order to prevent scour below the footing.

5.2.2 Concrete Cantilever Wall

A conventional cast-in-place concrete cantilever wall could also be considered for design for the proposed retaining wall at this site. However, in order to ensure adequate performance of this type of wall, the footings should be placed at 2.0 m below the final grade in front of the wall (based on OPSD 3400.010) to provide protection against the detrimental effects of frost action.

The founding levels of the wall in this case will be below the auger refusal, as measured in the boreholes. However, if bedrock is encountered before reaching the founding level indicated below, the footings may be founded on the bedrock subsurface. In this regard, the footings should be stepped up and concrete used to level the footing area. The proposed founding elevations for this type of wall are given in the following table at regular intervals along the wall.

<i>Station</i>	<i>Borehole</i>	<i>Proposed Ditch Grade (m)</i>	<i>Proposed Founding Elevation (m)</i>	<i>Elevation of Auger Refusal (m)</i>	<i>Founding Stratum</i>
18+700	04-01	223.0	221.0	221.4	Probable Rock
18+750	04-02	223.0	221.0	220.9	Probable Rock
18+800	04-03	223.2	221.2	223.3	Probable Rock
18+850	04-04	222.2	220.2	222.9	Probable Rock
18+900	04-05	221.4	219.4	222.5	Probable Rock
18+950	04-06	220.3	218.3	218.1	Probable Rock
19+000	04-07	218.9	216.9	216.9	Probable Rock

Based on an assumed footing width of 2.0 m, a factored geotechnical resistance at ULS of 700 kPa may be used for design of the wall footings founded on the sand and silt or the clayey silt strata. A geotechnical resistance at SLS (for 25 mm of settlement) of 400 kPa may be used for design.

The geotechnical resistance provided assumes that the loads will be applied perpendicular to the surface of the footing. The inclination of the load should be taken into account in accordance with *CHBDC* when the load is not applied perpendicular to the surface of the footing.

The resistance to lateral forces / sliding resistance between the cast-in-place concrete retaining wall foundation and the subgrade soils should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction, $\tan \delta'$, between the concrete retaining wall foundation and the properly prepared native soil subgrade may be taken as 0.62. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

The stability of the wall system against overturning should be checked. The retaining wall should be designed to resist lateral earth pressures in accordance with the *CHBDC* and the recommendations as provided in the following section.

5.3 Lateral Earth Pressures for Design

The lateral earth pressures acting on the retaining wall 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. It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- 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 wall stem, 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 wall stem (Case I in Figure C6.9.1(l) 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(l) of the *Commentary to the CHBDC*).
- For Case I, the pressures are based on the soils behind the granular fill and the following parameters (unfactored) may be used:

Soil unit weight:	21 kN/m ³
Coefficients of static lateral earth pressure:	
Active, K_a	0.31
At rest, K_o	0.47

- 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 static lateral earth pressure:		
Active, K_a	0.27	0.31
At rest, K_o	0.43	0.47

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

5.4 Construction Considerations

Excavation will be required for both the RSS wall, and the concrete cantilever walls; the extent of excavation will be more for the concrete cantilever wall. Excavations for the RSS walls are anticipated to be less than 0.3 m and will extend through mainly granular fill. Excavations for the concrete walls could be as deep as 2.0 m and will extend through fill, stiff to hard clayey silt, and compact to very dense sand and silt.

Excavations 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 following table specifies the OHSA soil classifications for the soils at the site:

<i>Soil Type</i>	<i>OSHA Soil Classification</i>
Clayey Silt	Type 2
Sand and Silt	Type 2

Temporary excavations (i.e. those which are only open for a relatively short period) through these overburden soils should be made with side slopes no steeper than 1.5 horizontal to 1 vertical (1.5H:1V).

Excavation support for roadway protection as well as space restrictions adjacent to the existing properties may be required at this site property in order to permit installation of the RSS strips or to construct the spread footing. Where required, the temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision 539S01. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 539S01.

Groundwater flow through the granular deposits is expected to be minimal. It is anticipated that for open-cut excavations open for a short period of time, any water inflow to excavations through these deposits could be adequately controlled by pumping from properly filtered sumps.

The native soils at the site are expected to contain cobbles and boulders. The presence of cobbles and/or boulders was generally inferred from the augers grinding during borehole advance, as noted at the base of Borehole 04-05.

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LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (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

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

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)

PROJECT <u>991-1164</u>				RECORD OF BOREHOLE No 04-01				1 OF 1		METRIC											
W.P. <u>812-76-01</u>		LOCATION <u>N 5132696.6 E 302957.5</u>				ORIGINATED BY <u>ID</u>															
DIST <u>54</u> HWY <u>17</u>		BOREHOLE TYPE <u>80 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>NK</u>															
DATUM <u>Geodetic</u>		DATE <u>July 29, 2004</u>				CHECKED BY <u>SEMP</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													
							<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL x REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 10 20 30 </div> <div style="display: flex; justify-content: space-between;"> WATER CONTENT (%) </div>									
225.2 0.0	GROUND SURFACE Sand and gravel (FILL) Compact		1	50 DO	13																
224.4 0.8	Clayey Silt with Sand, trace gravel, containing sandy silt seams Stiff to hard Grey Moist		2	50 DO	12																
			3	50 DO	28																
			4	50 DO	49																
			5	50 DO	40																
221.4 3.8	END OF BOREHOLE AUGER REFUSAL Note: 1. Borehole dry on completion of drilling. Borehole caved below 3.0 m depth.																				

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PROJECT 991-1164

RECORD OF BOREHOLE No 04-02

1 OF 1

METRIC

W.P. 812-76-01

LOCATION N 5132697.1 :E 303007.4

ORIGINATED BY ID

DIST 54

HWY 17




BOREHOLE TYPE 80 mm I.D. Hollow Stem Augers

COMPILED BY NK

DATUM Geodetic

DATE July 29, 2004

CHECKED BY SEMP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80	100		
225.5 0.0	GROUND SURFACE Sand and gravel (FILL) Compact		1	50 DO	24								
224.9 0.6	Silty Sand to Sandy Silt Compact to very compact Grey Moist		2	50 DO	22								
			3	50 DO	79								
			4	50 DO	60								
			5	50 DO	92								
221.2 220.9 4.6	Silty Sand to Sand Very dense Light brown/grey Moist END OF BOREHOLE AUGER REFUSAL Note: 1. Borehole dry on completion of drilling. Borehole caved below 4.3 m depth.		6	50 DO	107								




+³, X³

Numbers refer to
Sensitivity




○ 3%

STRAIN AT FAILURE

PROJECT 991-1164		RECORD OF BOREHOLE No 04-03		1 OF 1	METRIC
W.P. 812-76-01		LOCATION N 5132697.8 ; E 303057.5		ORIGINATED BY ID	
DIST 54 HWY 17		BOREHOLE TYPE 80 mm I.D. Hollow Stem Augers		COMPILED BY NK	
DATUM Geodetic		DATE July 29, 2004		CHECKED BY SEMP	

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 (%)				
225.4 0.0	GROUND SURFACE Sand and gravel (FILL) Dense		1	50 DO	32												
224.8 0.6	Sand and Gravel, some silt to silty sand, some gravel, containing clay seams Compact to very dense Light brown/grey Moist		2	50 DO	14												
223.3 2.1	END OF BOREHOLE AUGER REFUSAL Note: 1. Borehole dry on completion of drilling. Borehole caved below 2.0 m depth.		3	50 DO	51												

PROJECT 991-1164		RECORD OF BOREHOLE No 04-04		1 OF 1	METRIC
W.P. 812-76-01		LOCATION N 5132699.0; E 303107.5		ORIGINATED BY ID	
DIST 54 HWY 17		BOREHOLE TYPE 80 mm I.D. Hollow Stem Augers		COMPILED BY NK	
DATUM Geodetic		DATE July 29, 2004		CHECKED BY SEMP	







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 × REMOULDED					WATER CONTENT (%) w _p w w _L				
224.8 0.0	GROUND SURFACE Sand and gravel (FILL) Compact		1	50 DO	22												
224.2 0.6	Silty Sand to Sand and Silt, some gravel, trace clay Compact to very dense Grey Moist to wet		2	50 DO	12												
222.9 1.9	END OF BOREHOLE AUGER REFUSAL Note: 1. Borehole dry on completion of drilling. Borehole caved below 1.6 m depth.		3	50 DO	58											22 39 31 8	




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

PROJECT 991-1164			RECORD OF BOREHOLE No 04-05			1 OF 1			METRIC			
W.P. 812-76-01			LOCATION N 5132699.8 E 303157.4			ORIGINATED BY ID						
DIST 54 HWY 17			BOREHOLE TYPE 80 mm I.D. Hollow Stem Augers			COMPILED BY NK						
DATUM Geodetic			DATE July 30, 2004			CHECKED BY SEMP						
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT REMARKS			
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L	γ	GRAIN SIZE DISTRIBUTION (%)
223.9	0.0	GROUND SURFACE										
		Sand and gravel (FILL)		1	50 DO	23						
223.3	0.6	Sandy Silt, trace clay, trace gravel										
		Compact										
222.7		Grey		2	50 DO	29		223				
		Moist to wet										
		Cobbles										
1.4		END OF BOREHOLE										
		AUGER REFUSAL										
Note: 1. Borehole dry on completion of drilling. Borehole caved below 1.3 m depth.												

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PROJECT <u>991-1164</u>		RECORD OF BOREHOLE No 04-06		1 OF 1	METRIC
W.P. <u>812-76-01</u>		LOCATION <u>N 5132700.7 E 303207.4</u>		ORIGINATED BY <u>ID</u>	
DIST <u>54</u> HWY <u>17</u>		BOREHOLE TYPE <u>80 mm I.D. Hollow Stem Augers</u>		COMPILED BY <u>NK</u>	
DATUM <u>Geodetic</u>		DATE <u>July 30, 2004</u>		CHECKED BY <u>SEMP</u>	

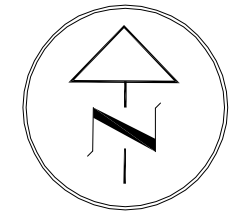
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) w _p w w _L				
222.7 0.0	GROUND SURFACE Sand and gravel (FILL) Compact to dense		1	50 DO	30												
222.2 0.5	Clayey Silt with Sand Very stiff Light grey Wet		2	50 DO	18												
221.7 1.5	Clayey Silt, trace to some sand Hard Grey Dry to moist		3	50 DO	87												
			4	50 DO	50/08												
			5	50 DO	50/08												
			6	50 DO	52												
218.1 4.6	END OF BOREHOLE AUGER REFUSAL Note: 1. Borehole dry on completion of drilling. Borehole caved below 4.5 m depth.																

PROJECT <u>991-1164</u>				RECORD OF BOREHOLE No 04-07				1 OF 1		METRIC						
W.P. <u>812-76-01</u>		LOCATION <u>N 5132701.5 ; E 303257.5</u>				ORIGINATED BY <u>ID</u>										
DIST <u>54</u> HWY <u>17</u>		BOREHOLE TYPE <u>80 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>NK</u>										
DATUM <u>Geodetic</u>		DATE <u>July 30, 2004</u>				CHECKED BY <u>SEMP</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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
220.9 0.0	GROUND SURFACE Sand and gravel (FILL) Compact to dense		1	50 DO	26											
			2	50 DO	40											
219.4 1.5	Sand with clay pockets Very dense Brown		3	50 DO	55											
218.8 2.1	Sandy Silt, trace clay, trace gravel Very dense Dark grey Moist		4	50 DO	99											
			5	50 DO	83											
216.9 4.0	END OF BOREHOLE SAMPLER REFUSAL Note: 1. Borehole dry on completion of drilling.															

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

DIST 54 HWY 17
CONT. No.
WP No. 812-76-01

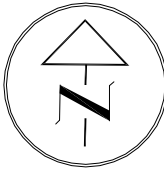
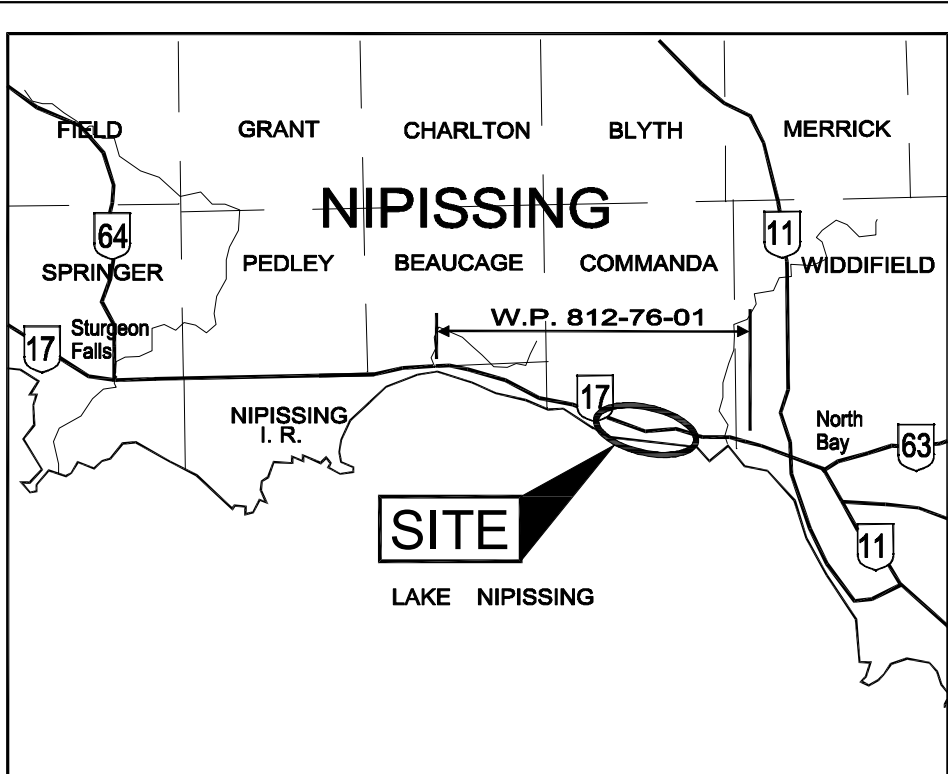


HIGHWAY 17
STA. 18+600 TO STA. 19+080
BOREHOLE LOCATIONS & SOIL STRATA

SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

LEGEND

- 2004 Borehole
- 1999 Borehole
- Blows/0.3m
- WL during drilling

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
99-30	220.2	5132703.2	303274.9
04-01	225.2	5132696.6	302957.5
04-02	225.5	5132697.1	303007.4
04-03	225.4	5132697.8	303057.5
04-04	224.8	5132699.0	303107.5
04-05	223.9	5132699.8	303157.4
04-06	222.7	5132700.7	303207.4
04-07	220.9	5132701.5	303257.5

NOTES

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

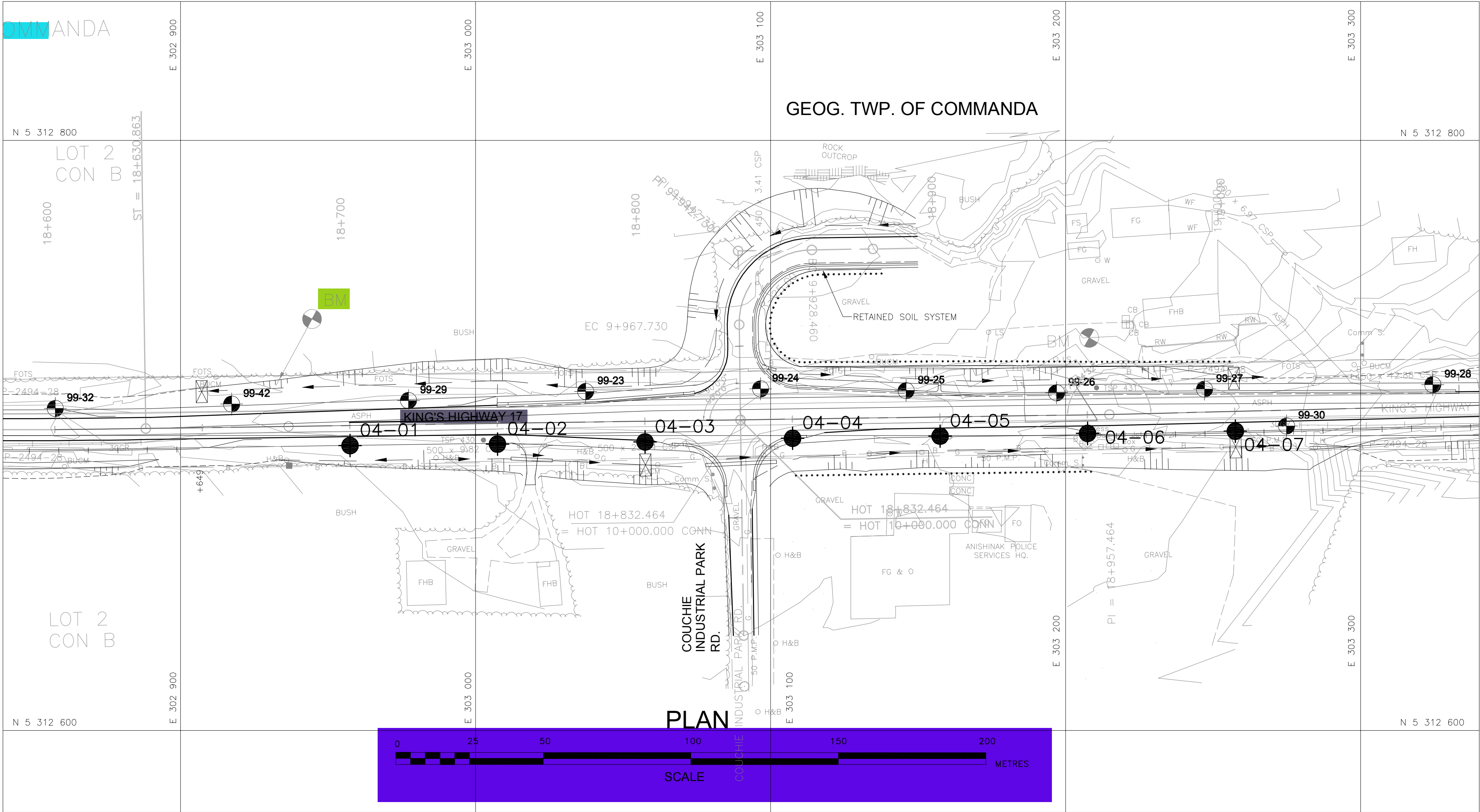
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

For subsurface information only.

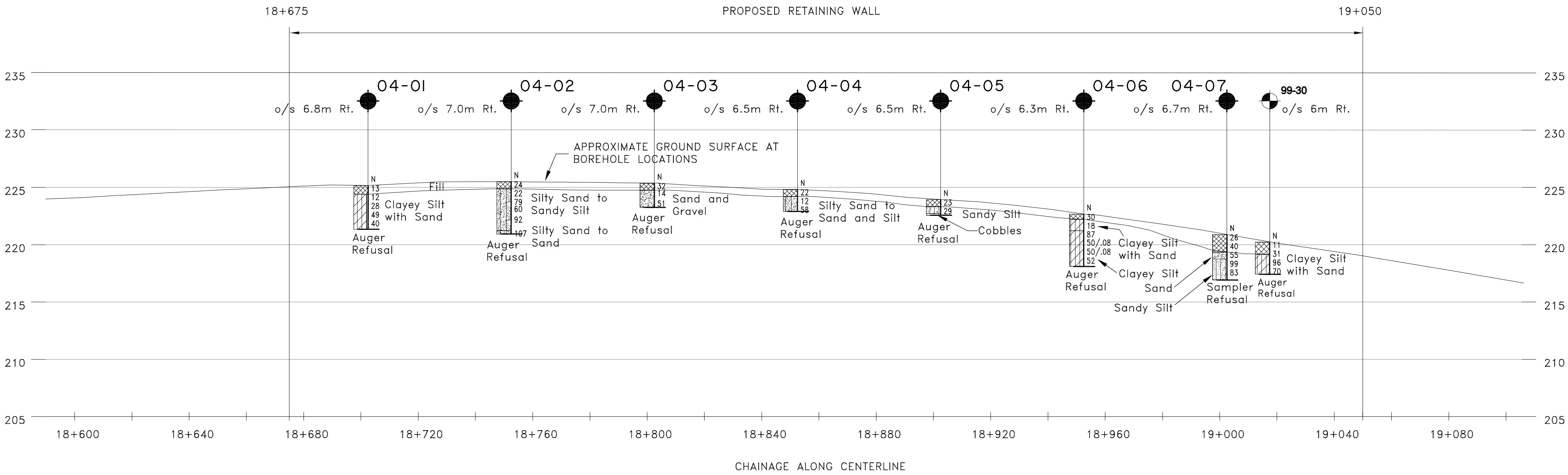
REFERENCE

This drawing was created from digital files provided by McCormick Rankin Corp.

NO.	DATE	BY	REVISION
Geocres No. 31L-94			
HWY. No.	17	PROJECT NO.: 991-1164	
SUBM'D.	NK	CHKD: FJH	DATE: NOV., 2004
DRAWN:	JDR	CHKD. SEP	APPD.
			DIST. 54
			DRAWING 1

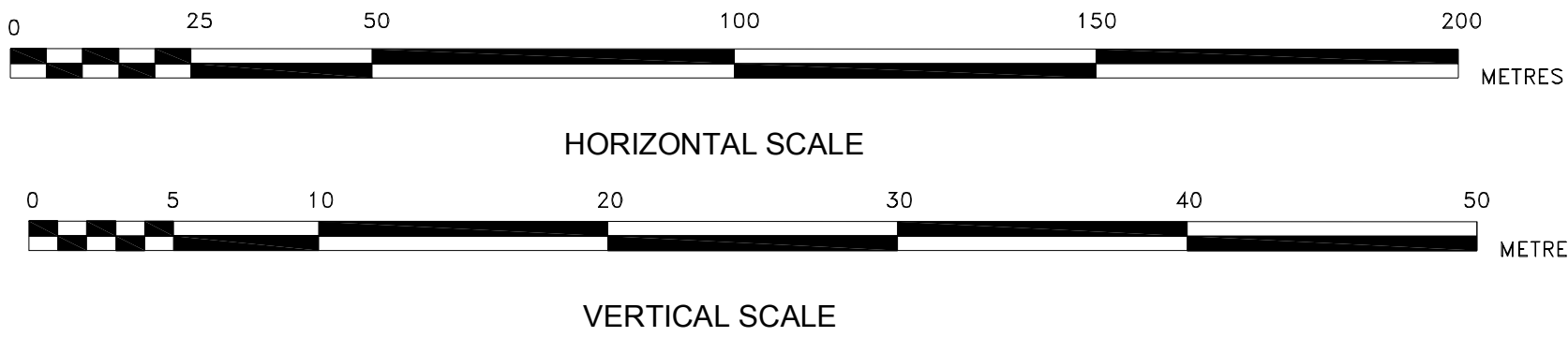


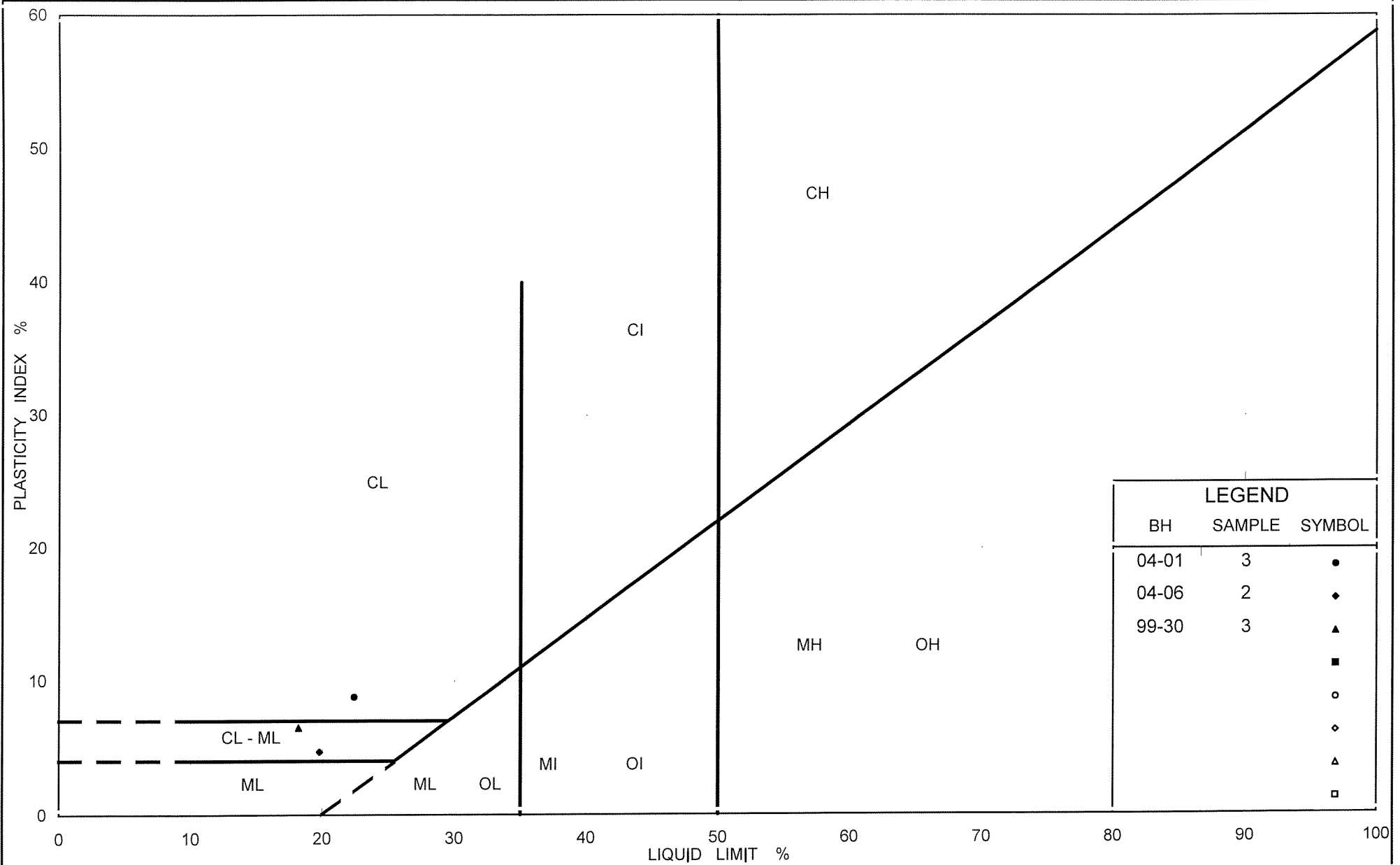
ELEVATION IN METRES



ELEVATION IN METRES

PROFILE ALONG HWY 17 CENTERLINE





Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt with Sand

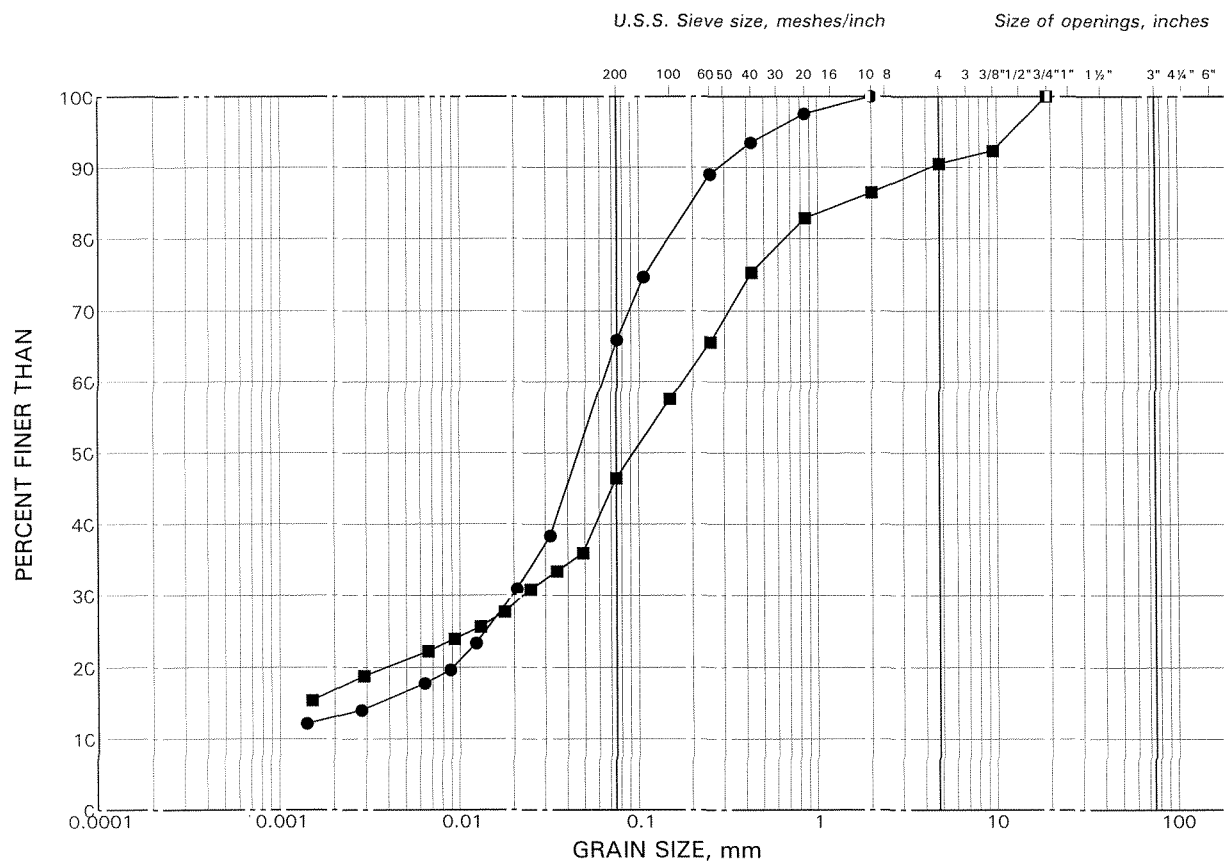
FIG No. 1

Project No. 991-1164

GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand

FIGURE 2



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

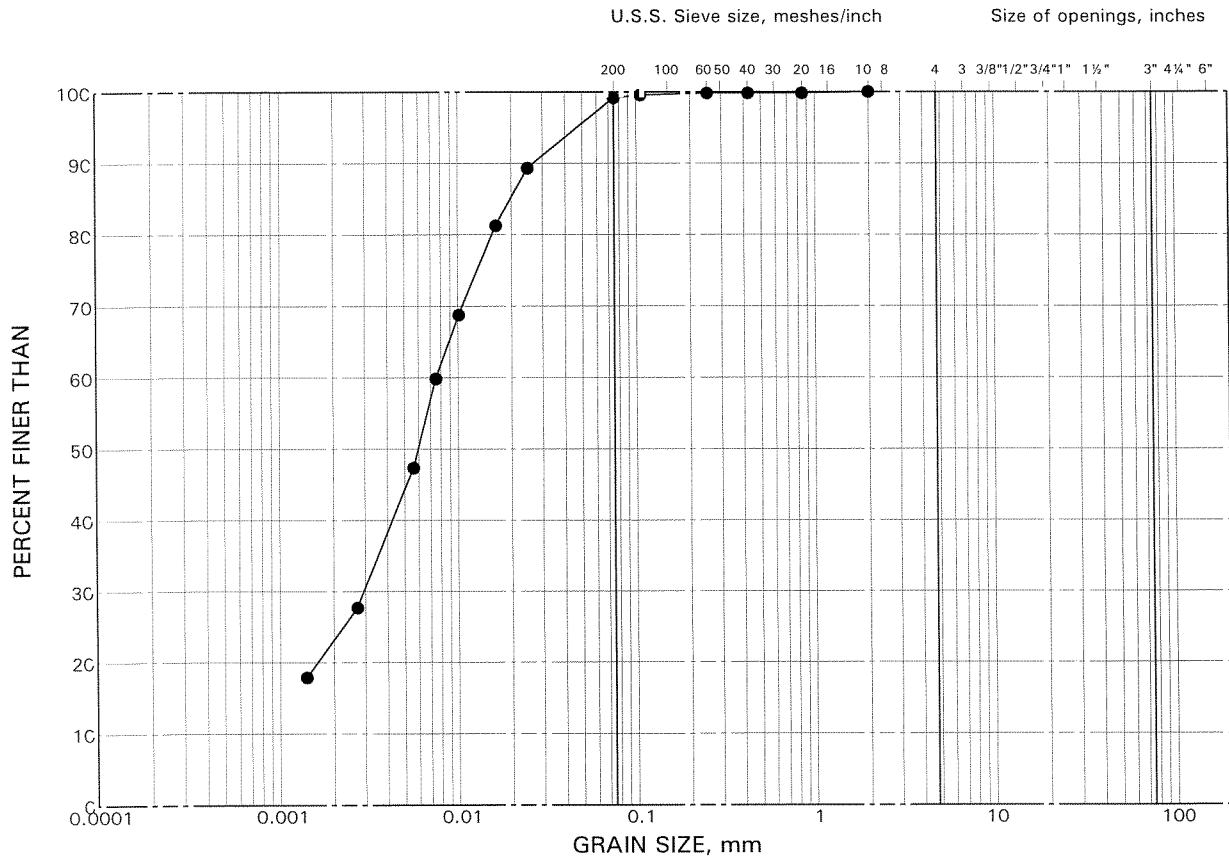
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	04-01	5	221.9
■	99-30	3	-

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE 3



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

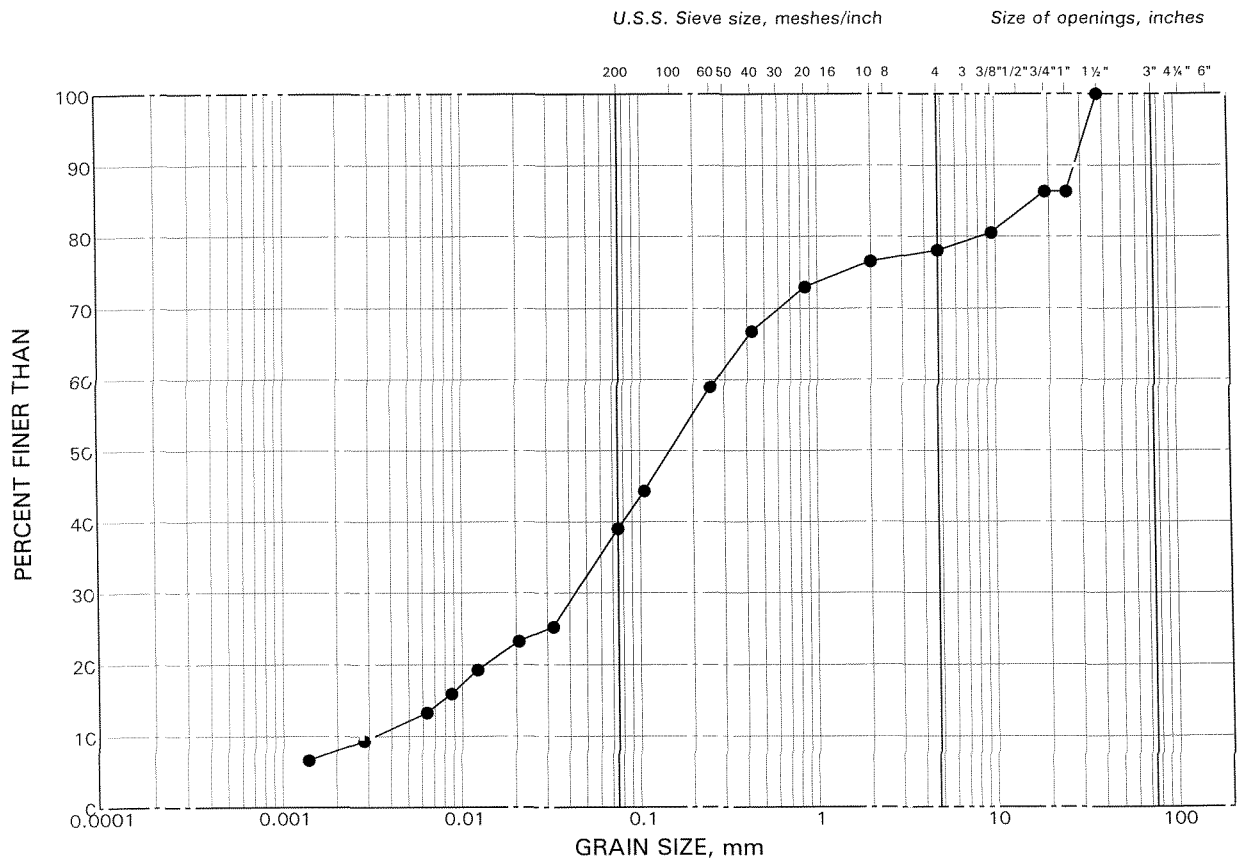
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
•	04-06	5	219.4

GRAIN SIZE DISTRIBUTION

Sand and Silt, some clay

FIGURE 4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
•	04-04	3	223.1