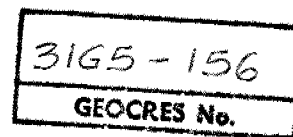


G.I.-30 SEPT. 1976

GEOCRES No. 3165-156DIST. 9 REGION W.P. No. 146-74-00-1CONT. No. W. O. No. STR. SITE No. HWY. No. 416LOCATION Hwy 416 / STONEY CREEKSWAMP AREA AT LYTLE AVENo. of PAGES - =====OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. REMARKS:



Golder Associates Ltd.
CONSULTING ENGINEERS



REPORT TO
MINISTRY OF TRANSPORTATION ONTARIO

GEOTECHNICAL AND GROUNDWATER STUDY

PROPOSED HIGHWAY 416

STONEY SWAMP AREA
W.P. 146-74-00-1-DISTRICT 9 (OTTAWA)

NEPEAN, ONTARIO

Distribution:

- 12 copies - Ministry of Transportation Ontario
Downsview, Ontario
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April 1989

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ABSTRACT

This report presents the results of a subsurface investigation carried out along the proposed route for Highway 416 in the vicinity of the Stoney Swamp and the National Capital Commission (N.C.C.) Log Farm lands located on Cedarview Road near Lytle Avenue in Nepean, Ontario. Based on present plans, this section of the roadway will be in cut section with a grade at about 6 metres below existing ground surface.

The subsurface conditions within this portion of the route consists of shallow discontinuous deposits of sand and gravel and glacial till having a sandy silt or silty sand matrix. Bedrock was encountered at depths of 1.1 to 1.5 metres below ground surface (elevation 100.7 to 106.3 metres) and consists of faintly weathered, very thin to thickly bedded grey sandstone. In situ rising head and pressure packer tests indicate that the upper 6 to 9 metres of the bedrock has a hydraulic conductivity of between 2×10^{-4} and 7×10^{-4} centimetres per second. Pump tests gave average transmissivities of 0.8 and 1.3 metres squared per day. The groundwater level ranges from 0.7 to 3.1 metres below ground surface.

The wetlands area northwest of the proposed highway cut was found to be underlain by 0.3 to 0.9 metres of peat, followed by deposits of silty clay and clayey silt having a thickness of up to 1.0 metre, then by a deposit of glacial till. The groundwater level in the wetlands area is at ground surface.

Analytical and finite element techniques were used in estimating the quantity of groundwater seepage into the proposed cut. Based on a hydraulic conductivity of 4×10^{-4} centimetres per second, the total groundwater seepage into the 800 metre long bedrock cut could be about 150 to 300 cubic metres per day. Groundwater inflow into the proposed cut could induce changes in the groundwater levels in

the bedrock within 200 to 250 metres of the edge of the excavation where the excavation is carried to a depth of about 6 to 6.5 metres below the groundwater level. As such, it is expected that there will be some lowering of the groundwater level in the bedrock immediately to the north of the highway and west of the till and bedrock ridge. Because of the clay and glacial till overburden cover in the wetlands, the total surface water infiltration contributed by the wetlands area should be minor, about 10 cubic metres per day.

Contaminants, such as sodium chloride, are not expected to penetrate significantly into the groundwater system from the roadway cut section. Recommendations are, however, provided to obtain an inventory of local water wells and to obtain baseline data on the groundwater quality prior and subsequent to construction.

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1.0 INTRODUCTION

Golder Associates has been retained by the Ministry of Transportation Ontario (M.T.O.) to carry out a subsurface investigation along the proposed Highway 416 in the vicinity of the Stoney Swamp and the Log Farm located on Cedarview Road near Lytle Avenue in Nepean, Ontario (see Key Plan, Figure 1). The purpose of the investigation was to determine the soil, bedrock and groundwater conditions in the area of the proposed roadway cut and, based on the factual information obtained, to determine the possible effects of the cut on the groundwater regime in the wetlands area and to determine the possible rate of groundwater inflow into the proposed cut. As proposed, Highway 416 would curve through the south and southeast parts of the Log Farm property and the southeast edge of the Stoney Swamp lands. To allow access to the Log Farm, the highway would be in cut section, which would emerge north of the Log Farm. It is expected that the length of the cut will be about 800 metres and that the proposed highway grade will be at most 6 metres below existing grade.

2.0 SITE DESCRIPTION AND GEOLOGY

In general, the site is characterized by a gently sloping topography which decreases in elevation and flattens to a wide clay plain to the northeast. A low till and bedrock ridge which runs approximately north-south at the western limit of Lytle Avenue acts as a surface water divide between the Stoney Swamp subcatchment area to the west and the Log Farm lands and clay plain to the east. The general surface water flow west of the divide is towards the west and northwest; east of the divide the general surface flow is towards the northeast. A small drainage channel which feeds the wetlands area crosses the proposed highway cut immediately west of the ridge.

Geological maps indicate that the study area is underlain by shallow, discontinuous deposits of glacial till followed by interbedded sandstone and sandy dolomite of the March formation. The March formation shows good supplies of potable groundwater from open joints and fractures.

3.0 PREVIOUS INVESTIGATIONS

A hydrogeological assessment of the impacts of the proposed highway cut was undertaken by Water & Earth Sciences Associates Ltd. for the N.C.C. The results of this work are provided in their report entitled, "Hydrogeological Assessment of the Proposed Highway 416 Corridor, Stoney Swamp Conservation Area", dated August 1984. This hydrogeological study was based on a number of sampled, overburden boreholes advanced in the area of the cut and on local water well information. Based on field observations of low infiltration in the Stoney Swamp Wetland area west of the roadway cut, the study concludes that the upper 6 to 8 metres of the bedrock does not contain water producing strata of significance and that the hydraulic connection between the wetlands and the proposed highway cut will be minimal. Dewatering of the swamp is not expected to occur apart from a narrow band of land parallel to the cut and extending about 50 metres from the edge of the excavation. The report also concludes that dissolved contaminants are not expected to penetrate deeply into the groundwater system from the roadway cut, since groundwater is expected to flow into the cut and not away from it.

4.0 PROCEDURE

The field work for this investigation was carried out between October 17 and 25, 1988. During this time, three (3) boreholes, numbered 88-9, 88-10 and 88-11, were put down at the site using a track mounted hollow stem auger machine supplied and operated by Marathon Drilling Co. Ltd. of Gloucester, Ontario. The boreholes were advanced to depths ranging from 6.8 to 9.7 metres below ground

surface (elevation 92.5 to 99.8 metres). Within the overburden deposits, standard penetration tests were carried out at regular intervals of depth and samples of the soils encountered were recovered using drive open sampling equipment. The underlying bedrock was cored using NX and NXL type diamond drilling equipment. During the core drilling operations, a careful record was kept of the rock core recovery and Rock Quality Designation (R.Q.D.) In situ rising head testing was carried out in all of the boreholes to determine the hydraulic conductivity of the bedrock. Pressure packer testing was also carried out at borehole 88-9 to supplement and confirm the rising head test results. In addition, short duration variable discharge rate pump tests were carried out at boreholes 88-9 and 88-10 to determine the transmissivity of the upper part of the bedrock.

Following an examination of the data obtained, an additional five (5) shallow hand augerholes were advanced in the wetlands area to determine the type and thickness of overburden materials present.

The field work was supervised throughout by members of our engineering staff who located the boreholes, directed the drilling, sampling and pump test operations and logged the overburden and bedrock samples.

Samples of the soil and bedrock encountered were taken to our laboratory for detailed examination and testing. Samples of the soils recovered from the augerholes were tested for grain size distribution.

Detailed logs of the soil, bedrock and groundwater conditions encountered in the boreholes are given on the Record of Borehole sheets following the text of this report. The results of the hand augerholes are given on the attached Record of Augerholes, Table 1.

The approximate locations of the boreholes and augerholes with respect to existing and proposed site features are given on the site plan and profile, Drawing 1467400-A1. The results of the in situ rising head tests and the pressure packer test are provided on the Summary of In Situ Hydraulic Conductivity Tests, Table 2, following the text of this report. The results of the laboratory testing are given on the Grain Size Distribution curves, Figures 2 and 3.

The borehole and hand augerhole locations were determined by our staff and are referenced to existing site features. The ground surface elevations at the borehole locations were also determined by members of our engineering staff and are referenced to N.C.C. Benchmark No. 705 located on Cedarview Road approximately 1.3 kilometres north of Fallowfield Road. The published Geodetic elevation of this point is 118.26 metres.

5.0 SUBSURFACE CONDITIONS

As previously indicated, the detailed soil, bedrock and groundwater conditions determined from the boreholes and augerholes are given on the Record of Borehole sheets and on Table 1 following the text of this report. The following presents a brief description of the conditions encountered.

5.1 Overburden

The boreholes advanced along the proposed roadway alignment and on the ridge north of the roadway encountered between about 1.1 and 1.5 metres of overburden. The overburden was shown to be composed of topsoil followed by discontinuous and variable deposits of glacial till having a sandy silt or silty sand matrix and sand and gravel. Standard penetration tests carried out within the sandy silt/silty sand glacial till encountered at boreholes 88-9 and 88-10 and within the sand and gravel at borehole 88-11 gave N values of 36 and 52 blows per 0.3 metres, which reflect the dense to very

dense state of packing of these materials near the overburden/bedrock contact.

The hand augerholes advanced within the swamp area to the north and west of the proposed highway cut indicate that the area is underlain by between 0.3 and 0.9 metres of peat, followed by variable and discontinuous deposits of silty clay and clayey silt having a thickness of up to about 1.0 metre. These deposits are in turn underlain by a deposit of glacial till which can be generally described as a sandy silt containing some gravel and clay. Grain size distribution curves for silty clay/clayey silt and glacial till encountered at augerhole 5 are given on Figures 2 and 3, respectively.

5.2 Bedrock

Bedrock was encountered in the boreholes at depths of between 1.1 and 1.5 metres below ground surface (elevation 100.7 to 106.3 metres). The bedrock consists of faintly weathered, very thin to thickly bedded grey sandstone bedrock with occasional completely weathered seams. Fracturing of the core occurs mostly along the nearly horizontal bedding planes. A secondary fracture system consisting of steeply dipping joints was also observed in some of the boreholes.

The sandstone bedrock was found to be of good quality, as evidenced by core recovery values of 93 to 100 percent (average of 99 percent) and RQD values of 33 to 96 percent (average of 76 percent).

In situ rising head and pressure packer tests were carried out in the boreholes to determine the hydraulic conductivity characteristics of the bedrock. The results of the testing, summarized on the attached Table 2, indicate that the upper 6 to 9 metres of the bedrock has a hydraulic conductivity of between about 2×10^{-4} and 7×10^{-4} centimetres per second. Pump tests

carried out at boreholes 88-9 and 88-10 gave average transmissivity results of 1.3 and 0.8 metres squared per day, respectively which agree with the conductivity test results.

5.3 Groundwater

The groundwater levels in the open boreholes were found to range from a minimum of 0.7 metres below ground surface (elevation 101.1 metres) at borehole 88-9 to 3.1 metres below ground surface (elevation 104.4 metres) at borehole 88-11.

The groundwater level within the wetlands area northwest of the roadway was found to be at ground surface which, based on topographic information, would give a corresponding water level of between about elevation 104.4 and 104.5 metres. The water level in the wetlands area, therefore, is similar to that measured in borehole 88-11 put down on the bedrock and till ridge. Based on the measured groundwater levels, the general direction of groundwater flow in the bedrock is from the wetlands area north and east towards Cedarview Road and the farmlands east of Cedarview Road.

It should be noted that the groundwater levels in the bedrock and overburden could be higher during wet periods of the year such as the early spring.

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 Seepage into the Proposed Highway Cut

Based on the current profile grade information and the subsurface information obtained, it is expected that the proposed roadway cut will extend up to about 6 metres within the sandstone bedrock of the March formation, including an allowance for 1.0 to 1.5 metre deep drainage ditches. For the most part, the cut will be between about 4 and 6.5 metres below the measured water table.

Seepage into the excavation will occur from the sides and bottom of the cut. In estimating the quantity of groundwater seepage into the proposed cut, a vertical and horizontal hydraulic conductivity of 4×10^{-4} centimetres per second was used for the bedrock. Analytical and two dimensional finite element methods of analyses indicate that the total groundwater seepage from the bedrock into the 800 metre long cut could be of the order of about 150 to 300 cubic metres per day.

The following points should be considered in regard to seepage into the bedrock cut:

- The hydraulic conductivity of the sandstone bedrock is controlled by flow through fractures, along bedding planes and possibly along fault zones (should they be intersected). The potential for significant increased localized flow exists if a particularly open fracture system or fault zone is intersected.
- There is a potential for localized increased upward flow into the bedrock cut if an open well connected fracture system exists beneath the base of the cut.
- Some localized groundwater inflow should also be anticipated from the overburden/bedrock contact where the bedrock is

sometimes weathered and fractured or the glacial till washed of fines.

- The rate of groundwater inflow during excavation and construction could be significantly higher due to transient flow conditions.

6.2 Effect of the Highway Cut on the Wetlands

Groundwater inflow into the highway cut is expected to induce changes in the groundwater and surface water regimes near the cut. Based on the hydraulic conductivity results, it is expected that the zone of influence will be about 200 to 250 metres from the edge of the excavation, where the excavation is carried out to about 6 to 6.5 metres below the existing groundwater level. The width of the zone of influence will be proportionately less at the west and north limits of the site where the roadway exits from the cut. Therefore, it is expected that there will be some lowering of the groundwater level in the bedrock in the wetlands area immediately to the north of the highway and west of the till and bedrock ridge. However, since the wetlands area was shown to be underlain by deposits of silty clay, clayey silt and glacial till which will retard vertical groundwater flow, the amount of water seepage into the bedrock from the swamp will be less than would otherwise be expected, provided there is some continuity of these surficial soil conditions. It is anticipated that the total infiltration contributed by the wetlands area would be about 10 cubic metres per day, which represents about 3 to 7 percent of the total groundwater inflow into the highway cut.

In evaluating the potential impact of the highway cut on the wetlands, the additional groundwater withdrawal of 10 cubic metres per day together with the sources of surface water loss to the swamp (the small creek to the west of the ridge and minor overland flow) should be weighed against the other components of the water balance associated with the subcatchment area. Although a

hydrological study of the wetlands area is beyond the scope of this report, it is expected that the groundwater loss could cause shrinkage of the small wetlands subcatchment area northwest of the proposed cut.

6.3 Contamination of the Groundwater

The principal contaminant associated with the use of the highway will be sodium chloride, which is commonly used as a deicing agent. Contaminants, such as sodium chloride and gasoline, and other contaminants usually associated with the construction and the use of such a roadway, are not expected to significantly penetrate into the groundwater system from the cut section since the local groundwater flow direction will be towards the roadway cut. However, groundwater contamination may occur from the at grade roadway section southwest of the study area. Since the groundwater flow direction is towards the northeast, some of the wells along Lytle Avenue may be affected. Therefore, it would be prudent to obtain an inventory of local water wells and to carry out a program of water well sampling and testing to obtain baseline data on the groundwater quality prior and subsequent to the highway construction.

6.4 Effect of the Highway Cut on Local Wells

As discussed previously, groundwater inflow into the highway cut will result in a lowering of the local groundwater level. Therefore, the water level in some of the wells along Lytle Avenue may be lowered as a consequence of construction and it may be necessary to provide additional deeper wells for some of the residences. Alternatively, it may be possible to extend the existing watermain in the Cedarhill subdivision to Lytle Avenue.

6.5 Construction Monitoring

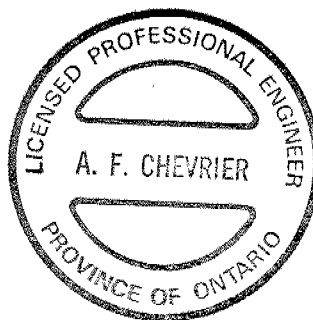
To verify the results of this study, it is recommended that additional boreholes be advanced between the proposed roadway cut and Lytle Avenue and near the wetlands area. The boreholes should be instrumented with single and multi-level piezometers to allow monitoring of the groundwater level during and after construction.

Yours truly,

GOLDER ASSOCIATES LTD.



A.F. Chevrier, P. Eng.



F.J. Heffernan, P. Eng.

AFC/FJH/yh
Disk 1

TABLE 1

RECORD OF HAND AUGERHOLES

<u>Augerhole Number</u>	<u>Depth (metres)</u>	<u>Soil Description</u>
1	0.00 - 0.56	PEAT
	0.56 - 1.52	Grey brown to grey SILTY CLAY , some sandy silt layers
	1.52 - 1.68	Grey sandy silt, trace gravel and clay (GLACIAL TILL)
	1.68	Auger Refusal End of Augerhole Note: Water level at ground surface.
2	0.00 - 0.67	PEAT
	0.67 - 1.01	Grey brown sandy silt, trace to some gravel, trace clay (GLACIAL TILL)
	1.01	Auger Refusal End of Hole Note: Water level at ground surface.
3	0.00 - 0.91	PEAT
	0.91 - 1.07	Grey brown SANDY SILT , trace gravel and clay
	1.07 - 1.37	Stiff grey SILTY CLAY
	1.37 - 1.52	Grey sandy silt, trace to some gravel, trace clay (GLACIAL TILL)
	1.52	End of Hole

<u>Augerhole Number</u>	<u>Depth (metres)</u>	<u>Soil Description</u>
4	0.00 - 0.30	PEAT
	0.30 - 0.76	Very stiff grey brown SILTY CLAY (weathered crust)
	0.76 - 0.91	Grey brown sandy silt, trace gravel and clay (GLACIAL TILL)
	0.91	Auger Refusal End of Hole
		Note: Water level at ground surface.
5	0.00 - 0.15	WATER
	0.15 - 1.07	PEAT
	1.07 - 1.43	Grey CLAYEY SILT and SILTY CLAY , trace to some sand
	1.43 - 1.74	Grey sandy silt, some gravel and clay (GLACIAL TILL)
	1.74	Auger Refusal End of Hole

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TABLE 2

**SUMMARY OF IN SITU HYDRAULIC
CONDUCTIVITY TESTS**

<u>Borehole Number</u>	<u>Depth (metres)</u>	Hydraulic Conductivity (cm/s)	
		<u>Rising Head Test</u>	<u>Pressure Packer Test</u>
88-9	1.49 - 3.32		4×10^{-4}
	1.49 - 6.46	2×10^{-4}	--
	1.49 - 9.30	3×10^{-4}	--
88-10	3.20 - 6.10	3×10^{-4}	--
	3.20 - 6.80	7×10^{-4}	--
88-11	3.11 - 5.09	2×10^{-4}	--
	3.11 - 9.70	4×10^{-4}	--

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 1" SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: NON-COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $\frac{w_L - w_p}{w_p}$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						



RECORD OF BOREHOLE No 88-9

METRIC

W P 146-74-00 LOCATION Approx. Co-ords N 5017 310 E 360 120 ORIGINATED BY DJS
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, NXL Rock Core COMPILED BY AC
DATUM Geodetic DATE October 25, 1988 CHECKED BY AC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	PIASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
101.8	Ground Surface												GR SA SI CL
0.0	Topsoil												
0.2	Silty sand, some gravel												
0.5	Sandy silt, some gravel & clay. (Glacial Compact Brown Till)		1	SS	12/13								
1.1	Sandstone bedrock, faintly weathered very thin to medium bedded grey, bedding near horizontal. (March Formation)		2	RC NXL	REC= 100% RQD= 90%								
			3	RC NXL	REC= 100% RQD= 93%								
			4	RC NX	REC= 100% RQD= 79%								
	Fractured Core (4.57m)		5	RC NX	REC= 100% RQD= 93%								
	13 mm completely weathered seam (5.76m)		6	RC NX	REC= 98% RQD= 67%								
	Open Seam (7.06m)		7	RC NX	REC= 100% RQD= 96%								
92.5													
9.3	End of Borehole												

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 88-10

METRIC

W P 146-74-00 LOCATION Co-ords N 5 017 126; E 359 884 ORIGINATED BY PH
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, NX & NXI Rock Core COMPILED BY AC
DATUM Geodetic DATE October 22 & 24, 1988 CHECKED BY AC

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					
106.6	Ground Surface																
0.0	Topsoil.																
0.2	Silty sand, some gravel trace clay. (Glacial Till)		1	SS	52												
105.1	Compact to Grey Brown Very Dense																
1.5	Sandstone bedrock, faintly weathered very thin to thickly bedded grey, some moderately to highly weathered seams, bedding near horizontal (March Formation)		2	RC NX	REC= 100% RQD= 38%												
			3	RC NXL	REC= 100% RQD= 83%												
			4	RC NXL	REC= 98% RQD= 95% REC=												
			5	RC NXL	100% RQD= 83%												
99.8	End of Borehole																
6.8																	

OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 88-II

METRIC

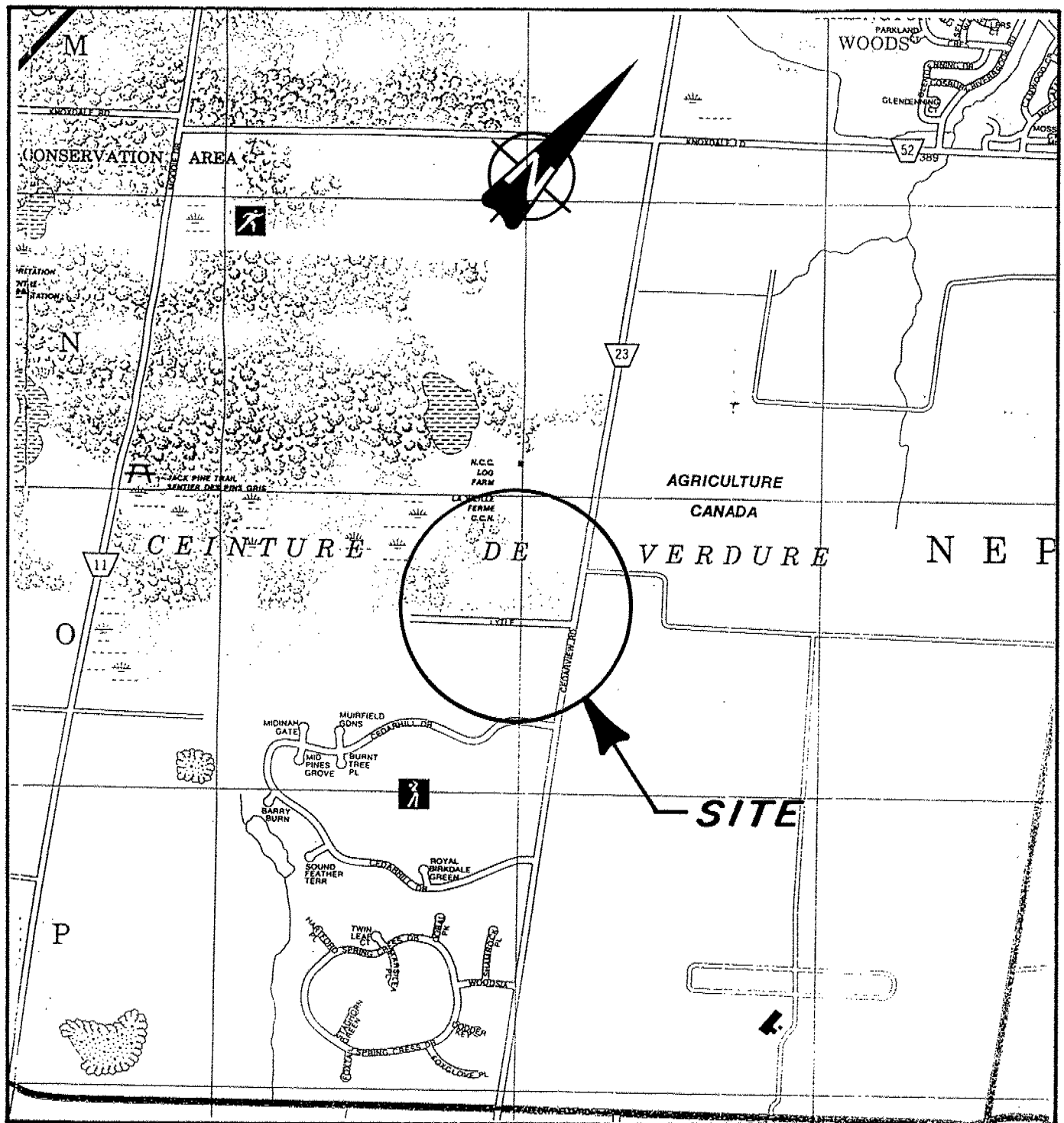
W P 146-74-00 LOCATION Co-ords N 5 017 136; E 359 795 ORIGINATED BY PH
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, NX Rock Core COMPILED BY AC
DATUM Geodetic DATE October 17 & 18, 1988 CHECKED BY AC

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	F L O C S W B S	REMARKS & GRAIN SIZE DISTRIBUTION (%)
FIELD DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
107.5	Ground Surface																
0.0	Topsoil.																
0.2	Sand & gravel, some silt.																
106.3	Compact to Dense Brown		1	SS	36												
1.2	Sandstone bedrock, faintly weathered, very thin to thickly bedded grey, some shale partings throughout core, some near vertical rough open joints. (March Formation)		2	RC NX	REC= 100% RQD= 56%												
	Fractured Zone - (3.6m)		3	RC NX	REC= 100% RQD= 75%												
	Vertical Open Joint (4.1 - 4.2m)		4	RC NX	REC= 99% RQD= 81%												
			5	RC NX	REC= 100% RQD= 90%												
	Vertical Open Joint (7.3 - 8.2m)		6	RC NX	REC= 91% RQD= 33%												
			7	RC NX	REC= 98% RQD= 70%												
97.8	Completely (9.02m) Weathered Seam																
9.7	End of Borehole																

OFFICE REPORT ON SOIL EXPLORATION

KEY PLAN

FIGURE 1



SCALE 1:25000

SPECIAL NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION
WITH ACCOMPANYING REPORT.

Date JAN 24, 1989

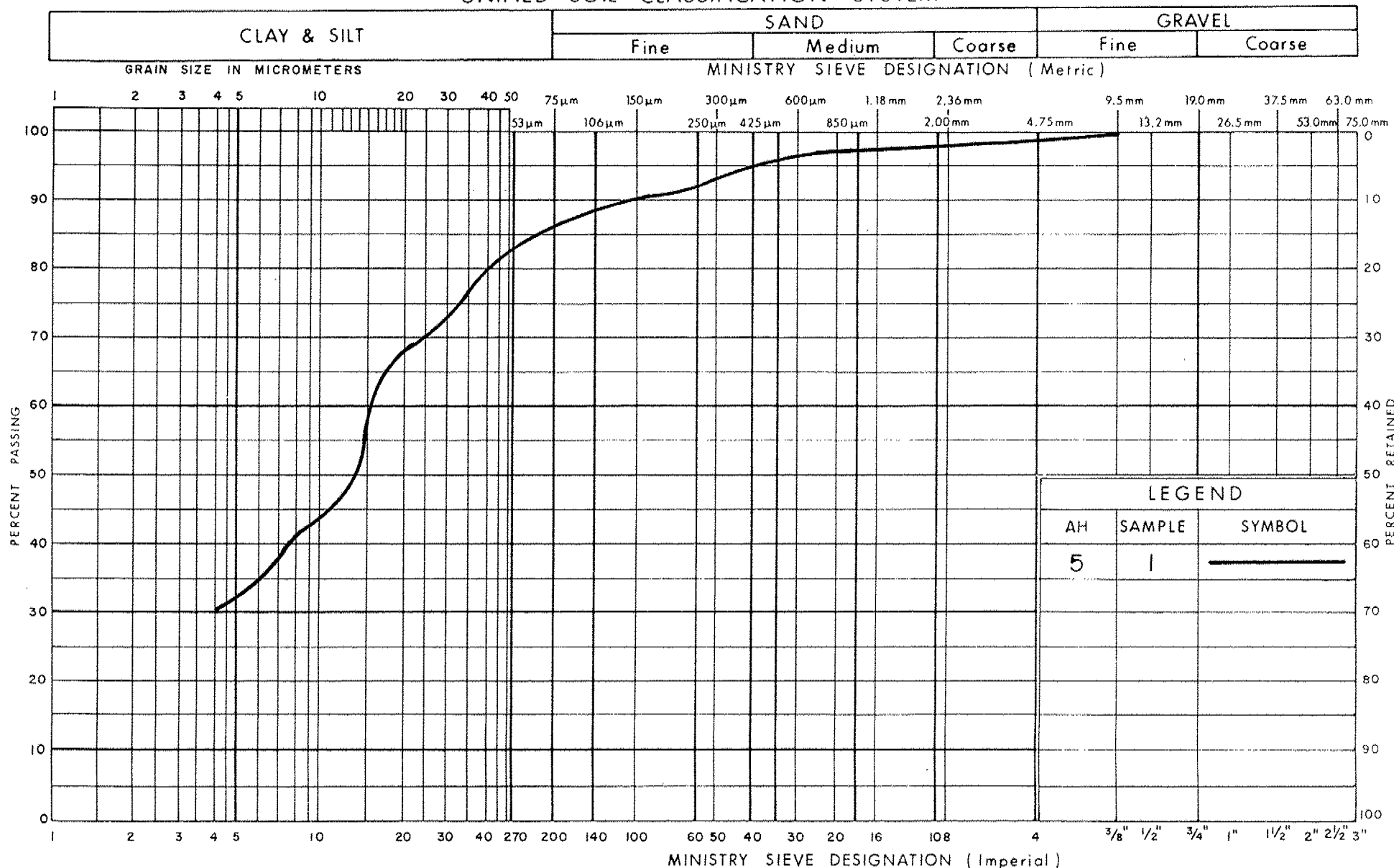
Project 881-2294-1

Golder Associates

Drawn JC

Chkd. AC

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

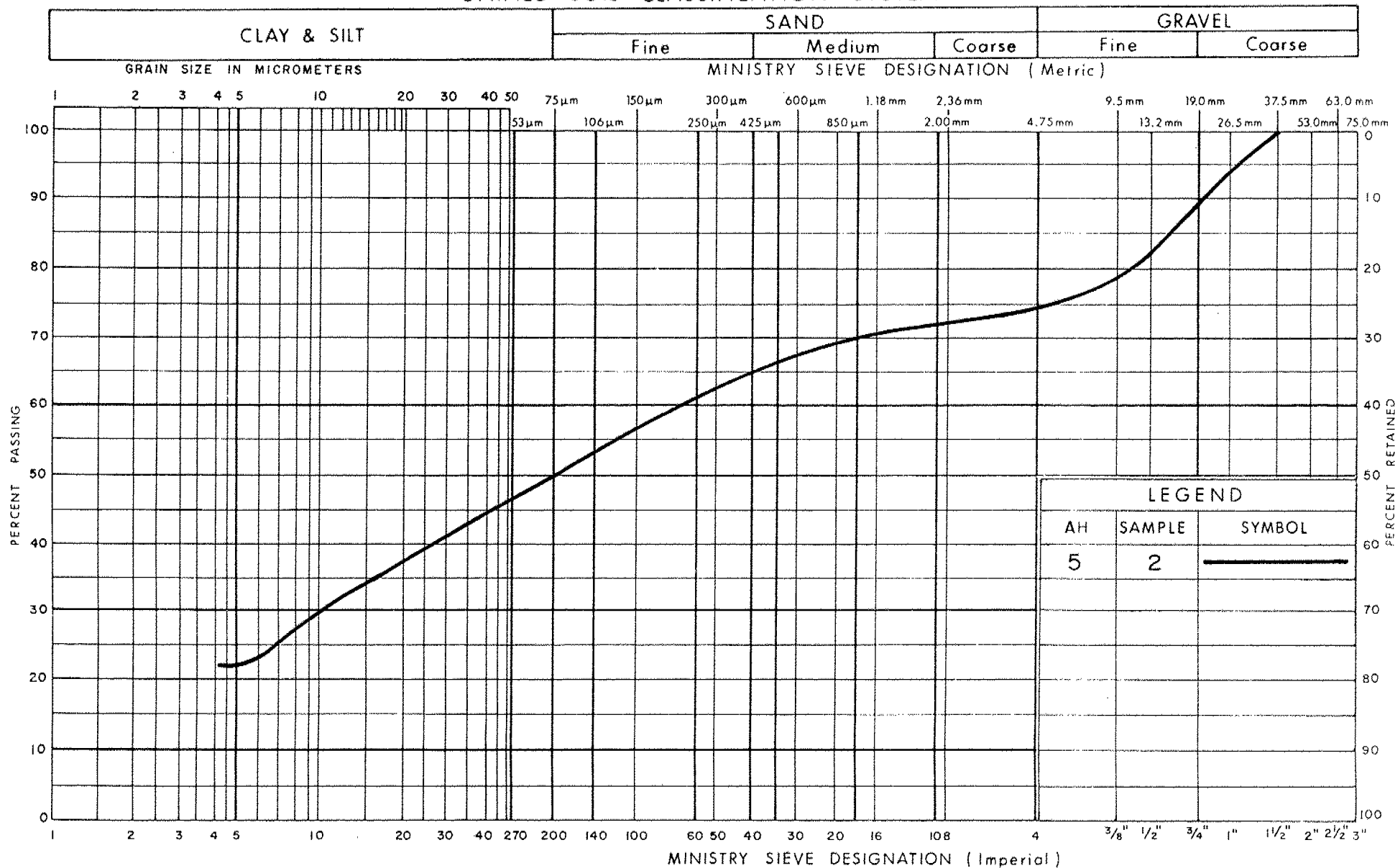
GRAIN SIZE DISTRIBUTION

CLAYEY SILT AND SILTY CLAY

FIG No 2

W P 146-74-00

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

GLACIAL TILL

FIG No 3

W P 146-74-00

DRAFT

October 27, 1988

Our Ref: 881-2294

Ministry of Transportation Ontario
Foundation Design Section
1201 Wilson Avenue
Room 315, Central Building
Downsview, Ontario
M3M 1J8

ATTENTION: Mr. M.S. Devata, P.Eng.

RE: INTERIM REPORT, GROUNDWATER AND GEOTECHNICAL INVESTIGATIONS,
PROPOSED HIGHWAY 416, CEDARVIEW CORRIDOR, NEPEAN, ONTARIO

Dear Sirs:

This interim report provides general information of the findings of the above investigation to date and a preliminary opinion of their implication on design and construction of sections of Highway 416. The following discussions are divided into the four separate sections of the alignment which are being investigated.

a) Silver Springs Farm

Two water well rig boreholes are yet to be constructed to 20 metre depth as described in our proposal; this work is scheduled to be carried out on November 1 and 2, 1988. Since this work has not yet been carried out, and since the available subsurface information is inconclusive, it is not possible to predict at this time what effect the Highway 416 bedrock cut may have on the quality and quantity of the Silver Springs Farm well.

b) Lynwood Subdivision

The proposed boreholes for this section have been recently completed and reviewed in conjunction with the previous data and proposed roadway profile. Our borehole 88-4 put down to the south of the CN rail line between the Highway 416 cut and the Lynwood subdivision indicates that a portion of the cut in this area will extend some 2 to 3 metres into a saturated sand deposit which has a piezometric head about 7 metres above the proposed bottom of excavation level. The deposit was not previously detected in the deep boreholes advanced by the

G.I.-30 SEPT. 1976

GEOCRES No. 3145-156DIST. 9 REGION W.P. No. 146-74-00-4CONT. No. W. O. No. STR. SITE No. HWY. No. 416LOCATION Hwy 416 / RICHMOND RD
(NEAR SILVER SPRINGS FARM)No of PAGES - =====OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. REMARKS:



Golder Associates Ltd.
CONSULTING ENGINEERS

3165-156
GEOCRES No.

REPORT TO
MINISTRY OF TRANSPORTATION ONTARIO

GROUNDWATER STUDY

PROPOSED HIGHWAY 416
CEDARVIEW ROAD CORRIDOR
NEAR RICHMOND ROAD
W.P. 146-74-00-4-DISTRICT 9 (OTTAWA)
NEPEAN, ONTARIO

Distribution:

- 12 copies - Ministry of Transportation Ontario
Downsview, Ontario
- 2 copies - Golder Associates Ltd.
Ottawa, Ontario

April 1989

881-2294-4

ABSTRACT

This report presents the results of a groundwater study carried out along the proposed Highway 416 corridor near Richmond Road in Nepean, Ontario. The purpose of the investigation was to determine the effects of the proposed Highway 416 cut in this area on the quality and quantity of groundwater resources at the Silver Springs Farm.

To determine the bedrock and groundwater conditions, a test well was advanced in the area of the proposed highway cut and another was put down on the Silver Springs Farm property. The subsurface conditions at the test wells was shown to consist of between 4.0 and 4.3 metres of silty clay and glacial till overburden, followed by sandstone bedrock. The test wells were found to be capable of yielding between about 7 and 20 cubic metres of water per day. Water bearing zones were encountered at 15.8 and 24.7 metres below ground surface in the area of the proposed highway cut while test well 88-1, advanced on the Silver Springs Farm property, showed a limited water bearing zone at 13.7 metres depth. Water well records indicate that the Silver Springs Farm well encountered water bearing zones between 24.4 and 42.7 metres below ground surface.

The measured static water levels in the wells indicate that the direction of groundwater flow is from the Silver Springs Farm area towards the proposed cut; the hydraulic gradient between the boreholes is about 0.65 percent.

Chemical analyses were carried out to obtain baseline data on the quality of the groundwater currently being supplied by the Silver Springs Farm vending stall on Richmond Road and of the groundwater in the area of the proposed highway cut.

The study indicates that the significant water bearing zones in the bedrock are expected to be at least 8 metres below the bottom of the proposed highway cut and therefore the proposed highway cut should have little effect on the quantity of water currently being supplied by the Silver Springs Farm wells. Since the highway cut is downgradient from the Silver Springs Farm and since the local groundwater flow will be towards the cut, there should be no impact from highway contaminants on the quality of the groundwater currently being obtained.

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DRAWING 1467400-A4

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2. Borehole Locations and Soil Strata - Drawing 1467400-A4

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1. Results of Chemical Analyses
2. Results of BTEX and Phenol Analyses

1.0 INTRODUCTION

Golder Associates has been retained by the Ministry of Transportation Ontario (MTO) to carry out a groundwater study along the proposed Highway 416 corridor near Richmond Road in Nepean, Ontario (see Key Plan, Figure 1). The purpose of the investigation was to determine the effects of the proposed highway cut in the vicinity of Richmond Road on the quality and quantity of groundwater resources at the Silver Springs Farm.

As proposed, the Highway 416 alignment will be approximately 250 metres east of the Silver Springs Farm facilities. In the study area, the proposed roadway will be in cut section having a depth of between about 8.5 and 9.5 metres below existing ground surface, including an allowance for 1.0 to 1.5 metre deep drainage swales. The proposed roadway will slope downward at about a 2 percent grade from south to north.

2.0 SITE DESCRIPTION AND GEOLOGY

The Silver Springs Farm is located on Richmond Road west of the proposed highway cut. Currently, the facility has three drilled wells on site which supply water to the greenhouse operation, the on site residences, and the bottled water vending stall on Richmond Road. Based on discussions with the manager of the farm, it is understood that the well supplying the vending stall is located immediately to the east of the farm house (about 220 metres from the proposed highway cut) whereas the remaining two wells are located behind the new residences.

Based on previous work carried out by the Ministry of Transportation Ontario (MTO), it is expected that the subsurface conditions along the proposed roadway cut consist of shallow deposits of sensitive silty clay and glacial till. Geological information indicates that the bedrock in this area consists of

dolostone and limestone of the Oxford formation underlain by interbedded sandstone and sandy dolostone of the March formation.

3.0 PROCEDURE

To determine the effects of the proposed cut on the quality and quantity of the groundwater supply at the Silver Springs Farm, two deep test wells (numbered 88-1 and 88-2) were advanced at the locations shown on Drawing 1467400-A4. One of the borings was advanced on the Silver Springs Farm property while the other was advanced within the area of the proposed highway cut. The borings have a diameter of 15 centimetres and were advanced using an air percussion drill rig supplied and operated by Henry Mains Well Drilling of Richmond, Ontario. A steel casing was installed in the upper part of the borings and sealed with cement grout. The test wells were developed by surging and blowing with compressed air. One hour pump tests were carried out on both of the wells.

Water samples were collected from the Silver Springs Farm vending stall in November, 1988 and January, 1989 and from borehole 88-2 in January, 1989, and sent to Bondar-Clegg and Company Ltd. of Ottawa, Ontario for chemical analysis to obtain baseline water quality information.

An additional water sample was obtained from the Silver Springs Farm vending stall on February 22, 1989 and sent to Zenon Environmental Inc. of Toronto, Ontario for detailed chemical analysis. Gas chromatograph and mass spectrometer analyses were performed to determine the concentration of benzene, toluene, ethyl benzene, and xylene (BTEX) and phenols in the existing well water. In addition, fluoride, chloride, potassium and total nitrogen concentrations were determined to supplement the baseline water quality information for the Silver Springs Farm well determined from the previous sampling.

The water sampling from borehole 88-2 was carried out using a clean bailer; all of the water samples were filtered, fixed, stored and shipped in accordance with established standard protocol.

In addition to the borings, a review was carried out of the Ministry of Environment (MOE) water well records to determine the depth of the water bearing zone(s) for the Silver Springs Farm wells.

Logs of the soil, bedrock and groundwater conditions obtained from the borings are given on the Record of Borehole sheets following the text of this report. The approximate locations of these borings, together with other boreholes put down by Golder Associates and MTO in this area, are given on the site plan and profile, Drawing 1467400-A4. The results of the basic chemical analyses on the groundwater samples are presented in Table 1, together with the Ontario Drinking Water Objectives (ODWO). The results of the BTEX and phenol analyses are given on Table 2.

The borehole locations were determined by our staff and were referenced to existing features at the site. The ground surface elevations at the borehole locations were determined by members of our engineering staff and are referenced to the fire hydrant located at the northwest corner of the intersection of Dante Street and Cedarview Road. The elevation of the arrowhead on the hydrant was provided by the City of Nepean as 87.73 metres, Geodetic datum.

4.0 SUBSURFACE CONDITIONS

As previously indicated, the soil, bedrock and groundwater conditions determined from the borings are given on the Record of Borehole sheets. It should be noted that the overburden and bedrock conditions have been inferred from air percussion drilling results; therefore, the soil description and the depth to planes of geological change are approximate only and should be interpreted

accordingly. The following presents a summarized account of the subsurface conditions encountered.

4.1 Overburden

The overburden at the borehole locations likely consists of sensitive silty clay and glacial till. The overburden was shown to extend to depths of between 4.0 and 4.3 metres below ground surface at boreholes 88-2 and 88-1, respectively (elevation 73.6 and 75.2 metres).

4.2 Bedrock

The bedrock encountered in the borings consists of sandstone with limestone layers, which is typical of the March formation. The MOE water well records indicate that the Silver Springs Farm well was also advanced through sandstone to a depth of 43 metres below ground surface. Detailed bedrock information obtained south of Baseline Road in borehole 88-3 indicates that the sandstone may be overlain by limestone or dolostone.

4.3 Groundwater

4.3.1 Well Water Quantity

Test well 88-1 advanced on the Silver Springs Farm property encountered a limited water bearing zone within the sandstone bedrock at 13.7 metres below ground surface and was terminated at a depth of about 25 metres. A short duration pump test indicated that the well could develop about 6.6 cubic metres per day [1 Imperial gallon per minute (Igpm)]. Within the proposed highway cut (test well 88-2), water bearing zones were encountered 15.8 and 24.7 metres below ground surface. A one hour pump test indicated that the well could potentially develop about 19.7 cubic metres per day (3 Igpm). During the pump tests on the two test

wells, the water levels were drawn down to about 24.4 metres below ground surface.

The MOE water well records indicate that the Silver Springs Farm well put down in November 1970 encountered water bearing zones between 24.4 and 42.7 metres below ground surface and was tested at a rate of 78.6 cubic metres per day (12 Igpm) for a period of one hour.

4.3.2 Static Water Levels

The static water level in the open wells was measured on November 21, 1988. At that time, the groundwater level ranged from 1.8 metres below ground surface (elevation 77.7 metres) at borehole 88-1 to 1.0 metre below ground surface (elevation 76.6 metres) at borehole 88-2. This shows that the groundwater flow direction is from the Silver Springs Farm area towards the cut; the hydraulic gradient between borehole 88-1 and 88-2 is about 0.65 percent.

4.3.3 Groundwater Quality

Water samples were collected from the test well put down along the proposed Highway 416 alignment and on three separate occasions from the bottled water vending stall on Richmond Road.

The results of the chemical analyses, given on Table 1, indicate that the Silver Springs Farm well and the test well have hard to very hard water with respect to water softening classification. In addition, the Silver Springs Farm well has elevated levels of manganese (i.e. between 0.06 and 0.09 milligrams per litre) in comparison with the Ontario Drinking Water Objectives (ODWO) of 0.05 milligrams per litre. Both the Silver Springs Farm well and the test well showed sodium levels of between 45 and 58 milligrams per litre, which are above the ODWO level of 20 milligrams per litre. All other parameters tested fall within the guidelines given by ODWO.

The levels of BTEX and phenols in the groundwater sample obtained from the Silver Springs Farm well are below the minimum detection limits (see Table 2). It appears that this water supply has not been contaminated by petroleum products at the time of testing in February, 1989.

5.0 DISCUSSION

The results of the investigation and the available information for the Silver Springs Farm well indicate that the significant water bearing zones in the bedrock are expected to be below a depth of about 24 metres, with some localized minor water bearing zones between 13 and 24 metres below ground surface. Based on the static groundwater elevations, the existing groundwater flow direction is considered to be towards the north and east. The hydraulic gradient between the test well on the Silver Springs Farm property and borehole 88-2 advanced in the area of the cut was found to be about 0.65 percent.

Since the cut is expected to be carried out to depths of between 8.5 to 9.5 metres (minimum elevation of 65 metres, approximately), the bottom of the proposed highway cut will be at least 8 metres above the main water bearing zone supplying the wells. Therefore, the proposed highway cut is expected to have little effect on the quantity of water currently being supplied by the Silver Springs Farm wells and on the static water level in the wells. Since the proposed cut is downgradient from the Silver Springs Farm wells and since the local groundwater flow direction will be towards the roadway cut, contaminants usually associated with the construction and the use of the highway (such as sodium chloride and gasoline) should not impact on the quality of the groundwater currently being obtained. It is not considered necessary to line the ditches of the cut to prevent contamination of the groundwater supply at the Silver Springs Farm. Soil lined ditches could be considered to improve the hydraulic characteristics of the swale or to facilitate cleanup of any possible large spills along the highway; in this case, granular or pipe drains would have to be installed beneath the soil liner in the ditches to allow drainage of the bedrock.

Although it is not likely that the highway cut would affect other local wells due to the depth of the water bearing zone, it would be prudent to obtain an inventory of local wells within about 0.5

kilometres of the proposed highway and to carry out a program of water well sampling and testing to obtain baseline data on the groundwater quality in other wells in the area prior and subsequent to the highway construction.

Yours truly,

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED BY

A.F. Chevrier, P. Eng.

ORIGINAL SIGNED BY

F.J. Heffernan, P. Eng.

AFC/FJH/yh
Disk 2

TABLE 1

RESULTS OF CHEMICAL ANALYSES

Parameter	Silver Springs Farm Well			Borehole 88-2	ODWO*
	Sampled 88/11/21	Sampled 89/01/06	Sampled 89/02/22	Sampled 89/01/06	
Alkalinity (as CaCO ₃)	176	172	--	152	--
Hardness (as CaCO ₃)	151	152	--	142	--
Calcium	29	30	--	27	--
Iron	<0.05	0.04	--	0.02	0.3
Magnesium	19	20	--	18	--
Manganese	0.09	0.06	--	0.03	0.05
Sodium	45	50	--	58	20
Chloride	35	36	49	44	250
Fluoride	--	--	--	--	2.4
Nitrate (as N)	1.21	<0.10	--	<0.10	10.0
Nitrite (as N)	<0.10	<0.10	--	<0.10	1.0
Sulphate	31	38	--	42	500
pH (pH units)	8.18	7.99	--	8.21	6.5-8.5
Conductivity (μ S/cm)	--	--	--	--	--
Total Dissolved Solids	256	252	--	270	500
Total Nitrogen	--	--	<0.2	--	--
Fluoride	--	--	0.38	--	2.4
Potassium	--	--	8.6	--	--

All values are expressed in mg/l except as noted.

*ODWO - Ontario Drinking Water Objectives.

TABLE 2
RESULTS OF BTEX
AND
PHENOL ANALYSES

Parameter	Minimum Detection Limit ($\mu\text{g/L}$)	Silver Springs Farm Well Sampled 89/02/22
Benzene	0.5	<*
Toluene	0.5	<
Ethyl Benzene	0.5	<
m,p-Xylenes	0.5	<
o-Xylene	0.5	<
2,3,4,5-Tetrachlorophenol	0.8	<
2,3,4,6-Tetrachlorophenol	1.4	<
2,3,5,6-Tetrachlorophenol	1.4	<
2,3,4-Trichlorophenol	1.0	<
2,3,5-Trichlorophenol	0.8	<
2,4,5-Trichlorophenol	1.2	<
2,4,6-Trichlorophenol	2.4	<
2,4-Dimethylphenol	3.4	<
2,4-Dinitrophenol	9.6	<
2,4-Dichlorophenol	2.4	<
2,6-Dichlorophenol	2.2	<
4,6-Dinitro-o-cresol	3.0	<
2-Chlorophenol	5.4	<
4-Chloro-3-methylphenol	2.8	<
4-Nitrophenol	2.8	<
m-Cresol	6.0	<
o-Cresol	3.4	<
p-Cresol	7.0	<
Pentachlorophenol	2.2	<
Phenol	2.2	<

* < - less than minimum detection limit

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	F H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_f	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

STRESS AND STRAIN

u	kPa	PORE WATER PRESSURE
λ	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{\min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

[illegible]

OFFICE REPORT ON SOIL EXPLORATION

+3, x5 : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



METRIC

ORIGINATED BY RB

COMPILED BY AC

CHECKED BY AC

+3, x5: Numbers refer to Sensitivity

OFFICE REPORT ON SOIL EXPLORATION



RECORD OF BOREHOLE No 88-3

METRIC

W P 146-74-00 LOCATION Co-ords N 5 021 430; E 358 840 ORIGINATED BY PH
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, NX & BXL Rock Core COMPILED BY AC
DATUM Geodetic DATE October 19, 1988 CHECKED BY AC

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 (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100											
								SHEAR STRENGTH kPa											
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE											
81.0	Ground Surface																		
0.0	Topsoil.																		
0.2	Clayey silt and sandy silt, trace gravel, occasional sand layer.																		
79.5	Loose Grey Brown		1	SS	5														
1.5	Silty clay and clayey silt, trace sand & gravel.		2	SS	3														
78.4	Very Stiff Grey Brown		3	SS	3														
2.6	Sandy silt to silty sand, some gravel, trace clay. (Glacial Till)		4	SS	5														
76.0	Loose Grey Brown to Grey		5	SS	10														
5.0	Dolostone bedrock, fresh, very thin to medium bedded grey, some sandy layers, occasional shale partings. (March Formation)		6	RC NX	REC= 100% RQD= 55%														
74.6	Sandstone bedrock, fresh, thin to thickly bedded grey, occasional grey dolostone layer. (March Formation)		7	RC BXL	REC= 95% RQD= 84%														
6.4			8	RC BXL	REC= 100% RQD= 98%														
70.6			9	RC BXL	REC= 100% RQD= 100%														
10.4	End of Borehole																		

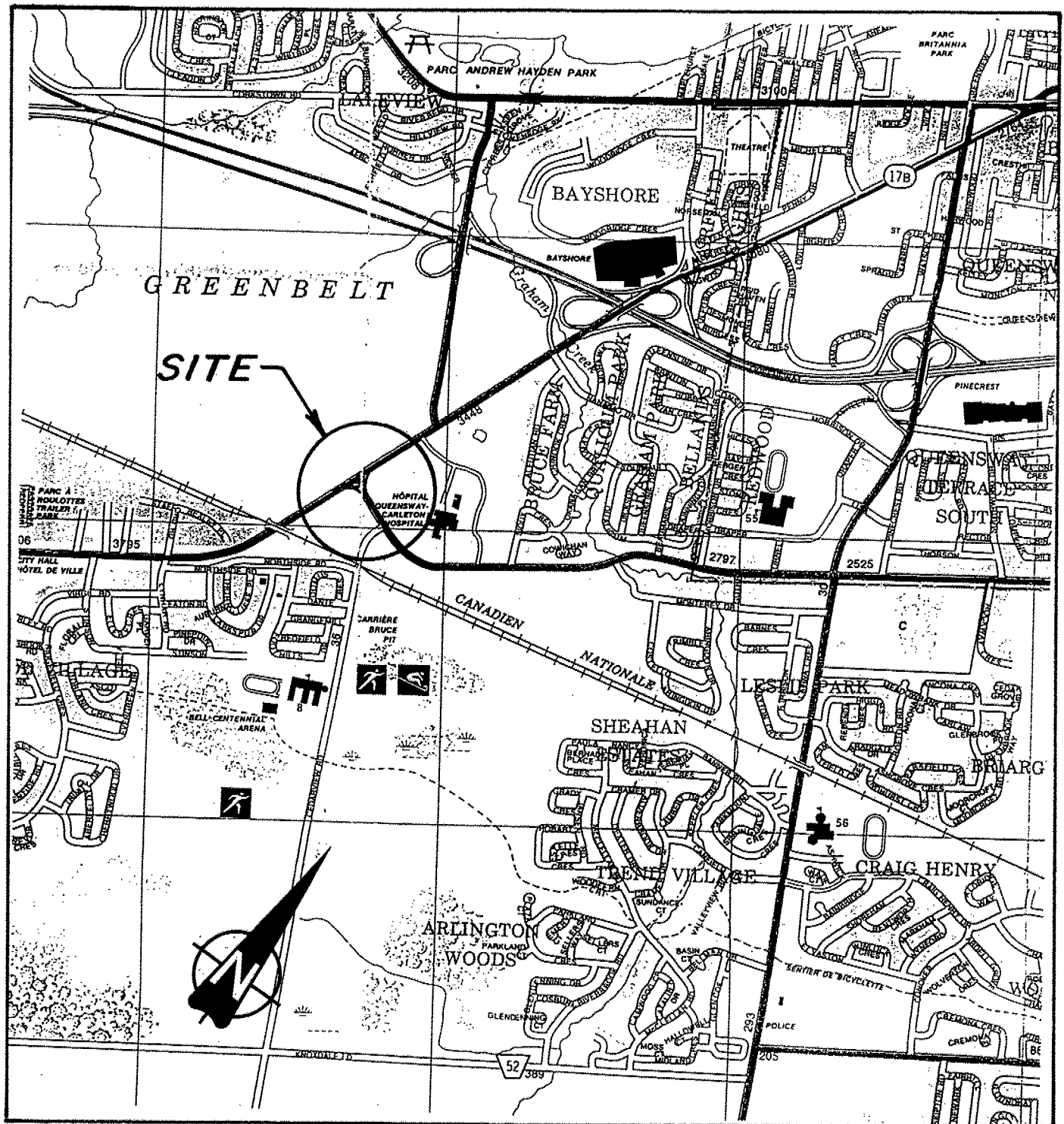
OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

KEY PLAN

FIGURE 1



SCALE 1:25000

SPECIAL NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION
WITH ACCOMPANYING REPORT.

Date JAN. 24, 1989

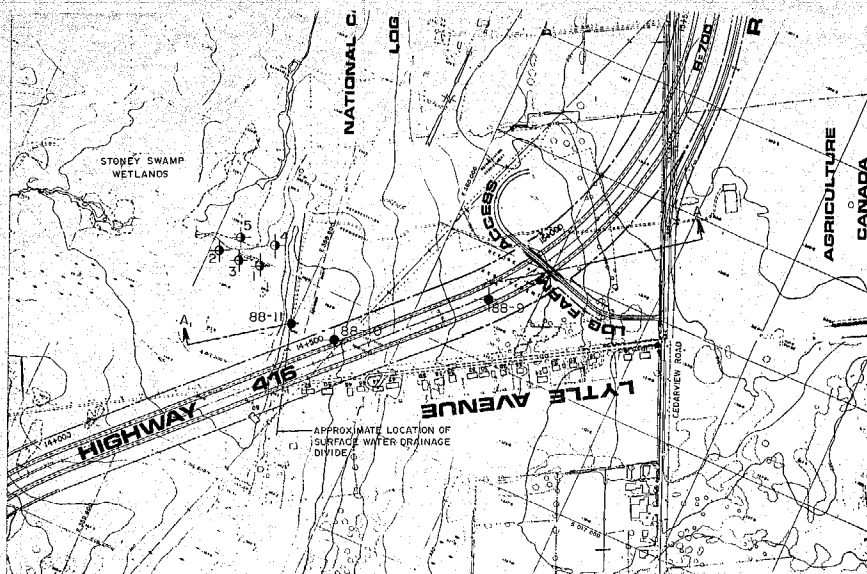
Project 881-2294-4

Golder Associates

Drawn JC

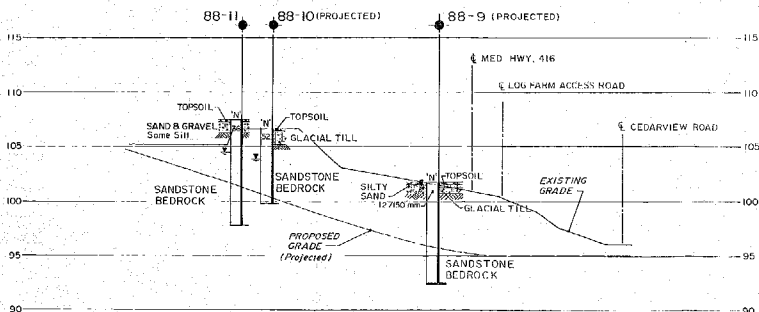
Chkd AC

OVERSIZE DRAWING



PLAN

SCALE.



SECTION A-A

SCALE



METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES • METRES.

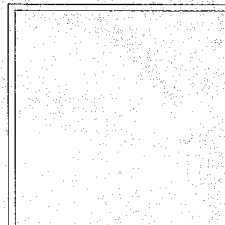
CONT No
WP No 146-74-00

HIGHWAY 416

AT LYTLE AVENUE
BORE HOLE LOCATIONS & SOIL STRATA








SHEET



KEY PLAN

SCALE

LEGEND

-  Bore Hole by Golder Associates
-  Dynamic Cone Penetration Test (Cone)
-  Bore Hole & Cone
- N Blows/0.3m (Sid Pant Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
-  Wt or time of investigation: Nov.1988
-  Auger Hole by Golder Associates

No	ELEVATION	NORTH	EAST
88-9	101.8 m	5 017 310	360 120
88-10	106.6 m	5 017 126	359 884
88-11	107.5 m	5 017 136	359 795

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

NOTE:
For detailed soil and bedrock descriptions
refer to RECORD OF BOREHOLE sheet

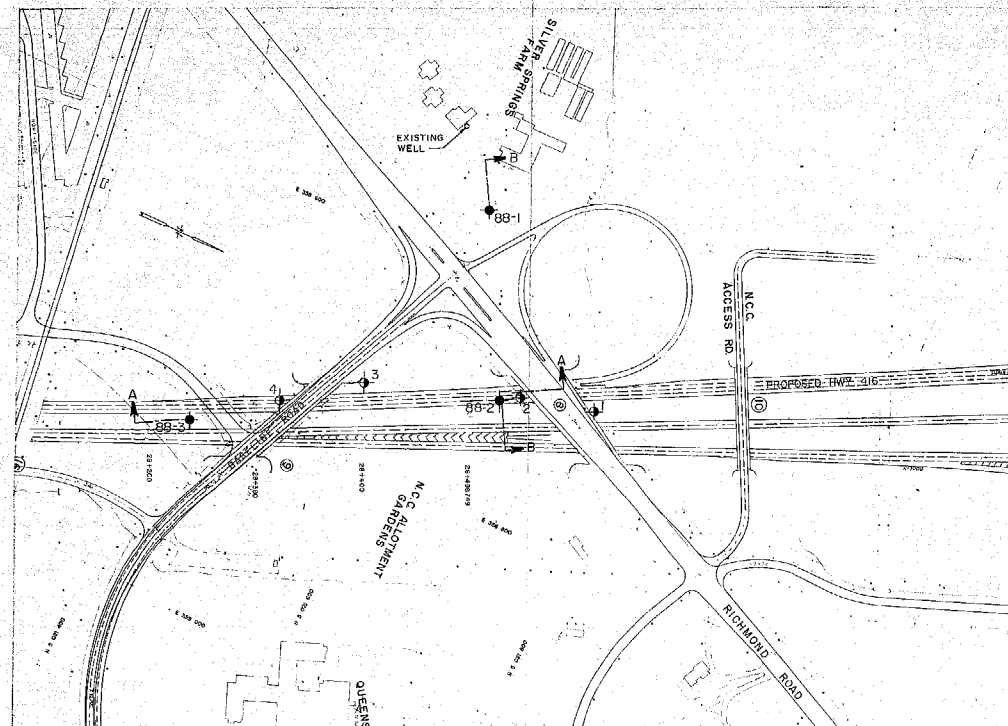
For details of augerholes see table 2

REV	DATE	BY	DESCRIPTION
Geocres No 31G5-156			
HWY No 416			Dist 9
SUBAND	CHECKED	DATE 3/1/89	SITE
DRAWN JC	CHECKED	DATE 3/1/89	DWG 1467400-A1

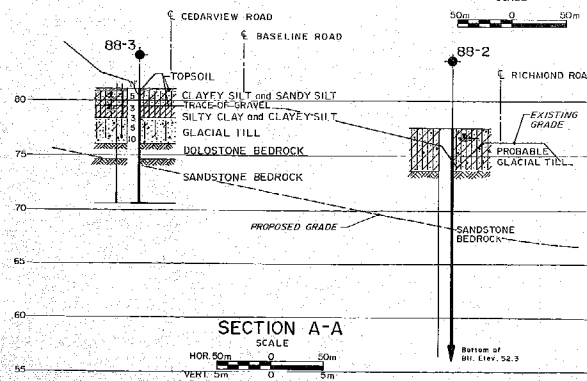
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SPECIFIED. STATIONS
IN KILOMETRES - METRES.

CONT No
WP No 146-74-00
HIGHWAY 416
NEAR SILVER SPRINGS FARM
BORE HOLE LOCATIONS & SOIL STRATA

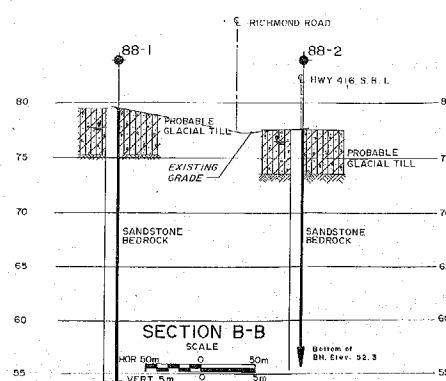
SHEET



PLAN
SCALE



SECTION A-A
SCALE



SECTION B-B
SCALE



KEY PLAN
SCALE

LEGEND

- Bore Hole by Golder Associates
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W.L. at time of investigation Nov. 1986
- ⊕ Previous borehole by MTO
Geocres no. 31G5-158

No	ELEVATION	NORTH	EAST
88-1	79.5m	5 021 601	358 540
88-2	77.6m	5 021 686	358 700
88-3	81.0m	5 021 430	358 840
1	76.3m	5 021 769.8	358 673.2
2	74.8m	5 021 707.4	358 688.5
3	78.7m	5 021 561.5	358 735.7
4	78.5m	5 021 500.0	358 786.5

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102.2 of Form 100.

NOTE
For detailed soil and bedrock descriptions refer to RECORD OF BOREHOLE SHEETS.

No	DATE	BY	DESCRIPTION
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Geocres No. 31G5-158
HWY No. 416
SHEET 8
DRAWN J.C. CHECKED J.P.P. DATE 3/1/89
DWC 1467400-A4