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31G-206

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T11688D

REPORT TO

FENCO ENGINEERS INC.
WILLOWDALE ONTARIO

HIGHWAY 416
KEMPTVILLE ONTARIO
FOUNDATION INVESTIGATION
PROPOSED VAN BUREN STREET UNDERPASS
(WP 372-89-05; SITE 16-317)
DISTRICT 9, KINGSTON

GEOCRES # 31G-206

Distribution:

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GEOCON (1991)INC.
December, 1991

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1.0 INTRODUCTION

Presented herein are the results of a geotechnical investigation conducted at the above site to establish the prevalent subsurface geotechnical conditions for the design and construction of the proposed Van Buren Street underpass and approach fills. Geocon (1991) Inc. (Geocon) was retained by Fenco Engineers Inc. to perform this work.

The field work for this project was conducted between November 6th and November 16th, 1990 using a CME 55 drill rig equipped with 200 mm diameter hollow stem augers. The investigation consisted of 5 boreholes and 1 test pit. The overburden was sampled using a 52 mm diameter split spoon in conjunction with the Standard Penetration Test (SPT). The underlying bedrock was cored in NXL size. Two standpipe piezometers were installed to monitor the groundwater levels. The test pit was excavated with a backhoe to obtain samples for density determinations and to confirm the matrix and the relative density of the silty sand till stratum.

The locations of the boreholes and one test pit are shown on Drawing 3728905-A. A record of the encountered subsurface conditions at each borehole and the test pit are given on the Record of Borehole Sheets in Appendix A. A summary of borehole depths and elevations is given on Table 1 Appendix A.

2.0 SITE DESCRIPTION AND GEOLOGY

The proposed Van Buren Street underpass is located at the intersection of Van Buren Street and Highway 16 approximately 1.5 kilometers east of Kemptville, Ontario (Figure 1). The proposed underpass will consist of two spans supported on a central pier and two abutments.

The proposed underpass will be located near the crest of a small knoll having gentle slopes dipping from west to east. The difference in elevation across the site is about 3 m. The present Highway 16 and Van Buren Street are located within earth cuts of 1 m to 2.5 m depth. To the east, the alignment is located within agricultural pasture land with some trees. A north flowing drainage ditch intersects the alignment approximately 75 m east of Highway 16.

The proposed Highway 416 is located within the physiographic region of the Ottawa-St. Lawrence lowland. During the last Ice Age this area was glaciated which resulted in the deposition of a layer of till over much of the proposed alignment (Sharpe, 1979). In general the till comprises of a bouldery cobbly silty sand to sandy silt.

Subsequent to glaciation the Ottawa-St. Lawrence lowland was inundated by the Champlain Sea. At the location of the proposed Highway 416 alignment the depth of water was shallow and in general only resulted in minor wave action modification of the surface of the underlying till. However, in localized low lying areas deeper deposits (up to 10 m) of fine grained clayey silt material may be present.

Available surficial geological information along the proposed Van Buren Street realignment (OGS Map 1492A) indicates that it is primarily underlain by till deposits. However, east of Highway 16, the till gives way to deposits of glaciofluvial sands and

silts. In addition, fine grained Champlain Sea deposits may also be present to the east of Highway 16.

The underlying bedrock at the site consists of dolostone bedrock of the Oxford Formation of the Beekmonton Group.

3.0 SUBSURFACE CONDITIONS

The surface conditions at the proposed underpass consist of a thin layer of topsoil overlying a sandy silt till. However, a thin layer of granular roadfill and sandy silt overlie glacial till at Boreholes 11-2 and 11-4, respectively. The factual information which was used to interpret the soil conditions is given in Appendix A and B and Drawing 3728905-A and are described in the following sections.

3.1 Peat and Topsoil

A thin veneer of topsoil, 0.1 to 0.3 m thick was encountered at Boreholes 11-1, 11-4, 11-5 and Test Pit 11-1. At Borehole 11-3, a 0.3 m thick organic deposit was encountered.

3.2 Sandy Silt Till

Sandy silt till was encountered at all boreholes and test pit locations. Where fully penetrated the till was found to be about 12.0 m thick. Based on the results of six grain size analyses performed on selected split spoon samples, this stratum may be described as a sandy silt till to silty sand till with some gravel and a trace clay. However, the results of two grain size analyses performed on bulk samples from the test pit, indicate this layer to be a heterogenous mixture of gravel, sand and silt, some cobbles, trace clay and occasional boulders. Occasional water bearing sand seams were also encountered.

SPT N values within the glacial till are high and variable with refusal recorded at many locations before full test penetration of the split spoon could be obtained. Based on the SPT N values the deposit can be described as having a dense to very dense density. The

dense to very dense relative density of the till is consistent with the high in-situ dry densities of 19.6 kN/m^3 obtained at Test Pit 11-1.

Water contents within the till varied from 7 to 12%.

3.3 Bedrock

Dolostone bedrock was found between El. 83.0 m to El. 82.0 m, approximately 12.0 m below the existing ground surface. The bedrock was proven by coring about 2.8 and 2.6 m into the bedrock in Boreholes 11-2 and 11-4, respectively. The bedrock is judged, by core recovery and RQD percentages to be of fair to excellent quality with the exception of the upper 1.5 m in Borehole 11-2 which is of a poor quality. The cored rock samples indicate the bedrock to be unweathered, grey, fine grained, closely jointed dolostone, having occasional calcite intrusions.

3.4 Groundwater

Groundwater was measured by means of two standpipe piezometers in Boreholes 11-2 and 11-4 and visual observations in the remaining boreholes. The groundwater level was measured between 1 to 28 days after the installation of the piezometers. The groundwater level was observed to be about El. 93.0 m, which is about 1.0 m to 4.5 m below the existing ground surface. The groundwater level could be expected to vary seasonally.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 General

The proposed underpass will have two spans supported on two abutments and a central pier. It is understood that open style abutments perched above the roadway are favoured. At this site, the original ground line at the west abutment location is about 3 m higher than the east abutment ground level. It is expected, therefore, that the east abutment will be supported by spread footings perched within a 3 m high engineered fill. Spread footings placed within the sandy silt till are recommended for the central pier and the west abutment.

4.2 Underpass Foundations

4.2.1 East Abutment

The subsurface conditions at the east abutment location consist of a thin layer of topsoil overlying competent glacial till. In light of this and the favoured open abutment concept, spread footing placed on engineered fill may be considered.

4.2.1.1 Spread Footings Placed on Engineered Fill

For the assumed geometry of this foundation solution (Figure 2), the recommended bearing pressures at the Serviceability Limit State (SLS), Type II and factored Ultimate Limit State (ULS) conditions are 400 kPa and 800 kPa, respectively.

The SLS value is the design load at which the estimated settlement of the footing will be of the order of 25 mm which for the purposes of this design has been assumed as the maximum settlement that may be tolerated. It should be noted that the settlement will be largely elastic and will occur mostly during initial loading of the foundations. An integral part of this proposed foundation design is the construction of an engineered fill on which to place the footing (Figure 2). Frost protection for the footings should be in accordance with Figure 2.

4.2.2 Central Pier and West Abutment

At these locations, the subsurface conditions comprise a thin cover of organic topsoil overlying very dense glacial till. It is anticipated that the proposed west abutment foundation will be located adjacent to an earth cut to accommodate the south bound lanes of the proposed Highway 416. Therefore, spread footings placed on the glacial till may be considered for both the central pier and the west abutment.

4.2.2.1 Spread Footings Placed within the Glacial Till

Spread footings founded on the sandy silt till may be adopted for both the central pier and the west abutment. Design bearing pressures of 500 kPa and 900 kPa at the SLS, Type II, and ULS condition respectively may be used. The recommendation is conditional upon the footings being located at least 1.0 m below the existing ground surface and that the leading edge of the west abutment foundation being located at least one footing width from the crest of the cut slope. Settlements at the SLS condition are anticipated to be of the order of 10 mm.

4.2.3 Differential Settlement

Maximum differential settlements between abutments supported on spread footings founded in engineered fill and the central pier founded on glacial till will be of the order of 15 mm at the SLS condition. Differential settlement between the central pier foundation and the abutments may be reduced by adopting a lower abutment bearing pressure at the SLS condition. Differential settlements at lower SLS bearing pressures may be determined by using a linear relationship between 3 mm at 200 kPa and 15 mm at 400 kPa.

4.3 EMBANKMENT RECOMMENDATIONS

Based on the observed subsurface conditions, and a maximum embankment height of 5 m, it is concluded that embankments constructed with side slopes of 2 Horizontal to 1 Vertical will remain stable.

Embankment fill should meet the requirements of OPSS 212 for borrow material and should be placed and compacted in accordance with OPSS 206. Slopes of 2 Horizontal to 1 Vertical are applicable for sandy earth borrows, rock borrow or select subgrade fill material. If silty or clayey earth borrow is used, the embankment side slope should be 2.5 Horizontal to 1 Vertical or flatter and are to be confirmed by engineering analyses. Embankment slopes should be provided with timely installation of erosion control measures.

Prior to the placement of imported fill, all topsoil and organics and any other deleterious material should be stripped. The glacial till or sandy silt subgrade, should be proof-rolled and any soft areas excavated and replaced with compacted granular material. Settlements

of the main approach embankment and the ramps are estimated to be of the order of 10 mm and which will primarily occur during initial loading of the embankments.

4.4 General Recommendations

4.4.1 Dewatering

Groundwater was observed near the ground surface at all boring locations. Significant excavation within the glacial till stratum will only be required at the central pier. It is anticipated, at this location, that groundwater seepage may be handled by a system of ditches leading to a central sump and a pump.

4.4.2 Excavations

Temporary excavations will be primarily within the glacial till layer. Excavations of more than 1.5 m depth within this layer shall be excavated with 1.5 Horizontal to 1 Vertical slopes. The excavation slopes shall be in compliance with the Ontario Health and Safety Act regulations or other governing regulations within the area. The base of the excavation shall be inspected for any soft areas. If soft soil is encountered, it shall be excavated and replaced with compacted granular fill.

4.4.3 Earth Backfill Pressures

The earth pressure for the design of the abutments should be computed as per Section 6.1.2 of the O.H.B.D.C., and an unyielding foundation condition may be assumed for the computations. If however, movement of the top of the wall is permitted, and is

greater than 0.05% of the overall height of the wall, then a yielding condition may be used in the computations. The Granular 'A' or 'B' backfill should be in accordance with the Special Provision No. 109F03. The following parameters are recommended for the granular backfill:

	Granular 'A'	Granular 'B'
Angle of Internal Friction	$\phi = 35°$	$\phi = 30°$
Unit Weight (kN/m^3)	$\gamma = 22.8$	$\gamma = 21.2$

If the footings are placed on compacted granular backfill, an unfactored coefficient of friction value of tan 30° may be assumed for the estimation of the sliding resistance. However, if the footings are placed on the glacial till, an unfactored coefficient of friction of tan 25° may be used.

4.4.4 Frost Penetration

The anticipated maximum depth of frost penetration at the site is 1.8 m (Canadian Foundation Engineering Manual). Because of the moderately frost susceptible nature of the glacial till at the site, all foundation units should be provided with at least this depth of soil or equivalent cover below finished grade. In addition, where approach fill embankments are less than the anticipated depth of frost penetration additional design measures will be required to ensure the satisfactory performance of the pavement. This aspect of the design will be addressed in more detail in the Pavement Design Report.

4.4.5 Site Supervision

The recommendations given in this report are based on the assumptions that the assumed soil conditions will be verified in any engineered fill and excavations and that all

construction recommendations are followed. It is recommended, therefore, that the foundation and earthworks construction be carried out under suitably qualified geotechnical engineering supervision.

5.0 CLOSURE

The field work portion for the investigation was carried out under the supervision of Mr. N. Khan, P.Eng. The report was written by Mr. I. Corbett, P.Eng. and Mr. N. Khan, P.Eng. and reviewed by Dr. I. Holubec, P.Eng.

This report is subject to the attached General Conditions and Limitations.

Yours very truly
GEOCON (1991) INC.

N. Khan, P.Eng.
Project Engineer

Igor Holubec, Ph.D., P.Eng.
Vice-President

REGISTERED PROFESSIONAL ENGINEER
CIVIL
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PROVINCE OF ONTARIO

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GEOCON (1991) INC.

GEOTECHNICAL REPORT

GENERAL CONDITIONS AND LIMITATIONS

A. USE OF THE REPORT

A.1 The factual data,interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation or if the project is not initiated within eighteen months of the date of the report Geocon (1991) Inc. (Geocon) should be given an opportunity to confirm that the recommendations are still valid.

A.2 The comments given in this report are intended only for the guidance of the design engineer. The number of test holes to determine all the relevant underground conditions which may affect construction costs, techniques and equipment choice, scheduling and sequence of operations would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual test hole data, as to how subsurface conditions may affect their work.

B. FOLLOW-UP

B.1 All details of the design and proposed construction may not be known at the time of submission of Geocon's report. It is recommended that Geocon be retained during the final design stage to review the design drawings and specifications related to foundations, earthworks, retaining systems and drainage, to determine that they are consistent with the intent of Geocon's report.

B.2 Retention of Geocon during construction is recommended to confirm and document that the subsurface conditions throughout the site do not materially differ from those given in Geocon's report and to confirm and document that construction activities did not adversely affect the design intent of Geocon's recommendations.

C. SOIL AND ROCK CONDITIONS

C.1 Soils and rock descriptions in this report are based on commonly accepted methods of classification and identification employed in professional geotechnical practice. Classification and identification of soil and rock involves judgement and Geocon does not guarantee descriptions as exact, but infers accuracy only to the extent that is common in current geotechnical practice.

C.2 The soils and rock conditions described in this report are those observed at the time of the study. Unless otherwise noted, those conditions form the basis of the recommendations in the report. The condition of the soil and rock may be significantly altered by construction activities (traffic, excavation, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil and rock must be protected from these changes or disturbances during construction.

D. LOGS OF TEST HOLES AND SUBSURFACE INTERPRETATIONS

D.1 Soil and rock formations are variable to a greater or lesser extent. The test hole logs indicate the approximate subsurface conditions only at the locations of the test holes. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of boring, the frequency of sampling, the method of sampling and the uniformity of subsurface conditions. The spacing of test holes, frequency of sampling and type of boring also reflect budget and schedule considerations.

D.2 Subsurface conditions between test holes are inferred and may vary significantly from conditions encountered at the test holes.

D.3 Groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities on the site or adjacent sites.

E. CHANGED CONDITIONS

E.1 Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the use or reliance by the client of this report that Geocon is notified of the changes and provided with an opportunity to review the recommendation of this report. Recognition of changed soil and rock conditions requires experience and it is recommended that an experienced geotechnical engineer be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

F. DRAINAGE

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage can have serious consequences. Geocon can take no responsibility for the effects of drainage unless Geocon is specifically involved in the detailed design and follow-up site services during construction of the system.

REFERENCES

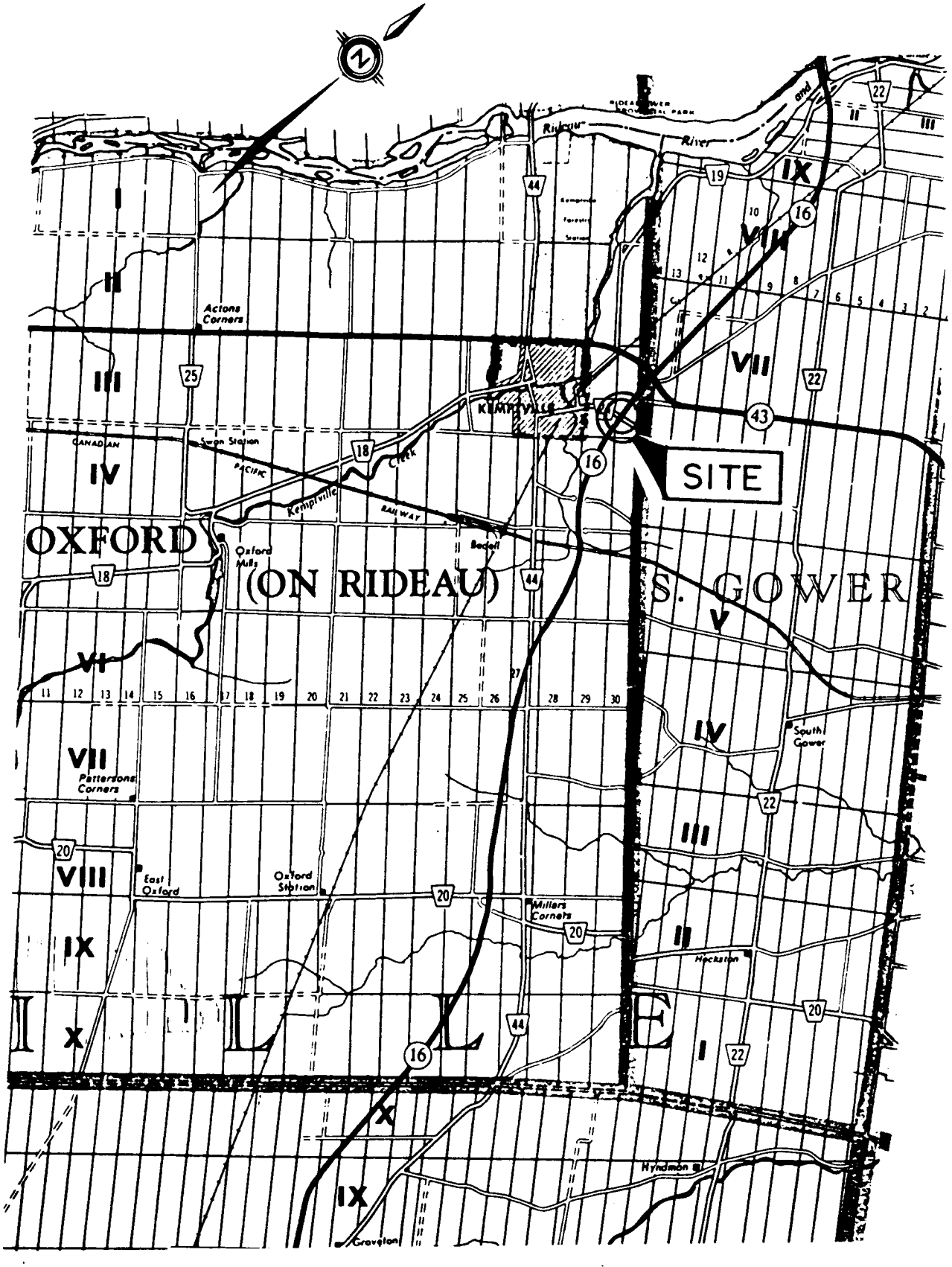
Canadian Foundation Engineering Manual, 1985. Second Edition. Part 1: Fundamentals; Part 2: Shallow Foundations; Part 3: Deep Foundations; Part 4: Excavations and Retaining Structures Part 5: References. Canadian Geotechnical Society, Technical Committee on Foundations, 456 pp.

Sharpe, D.R., 1979. Quaternary Geology of the Merrickville Area, Southern Ontario. Ontario Geological Survey, Report 180, 54P. Accompanied by Maps 2387 and 2388, scale 1:50,000.

Totten Sims Hubicki Associates (1981) Limited Consultants 1990 Structure Data Report, Highway 416 from 0.7 km north of Hwy 401 northerly to 1.0 km north of Hwy 43, District 9 Ottawa. Report prepared for Ministry of Transportation, Ontario.

KEY PLAN

APPENDIX
FIGURE 1
PROJECT WP 372-89-05



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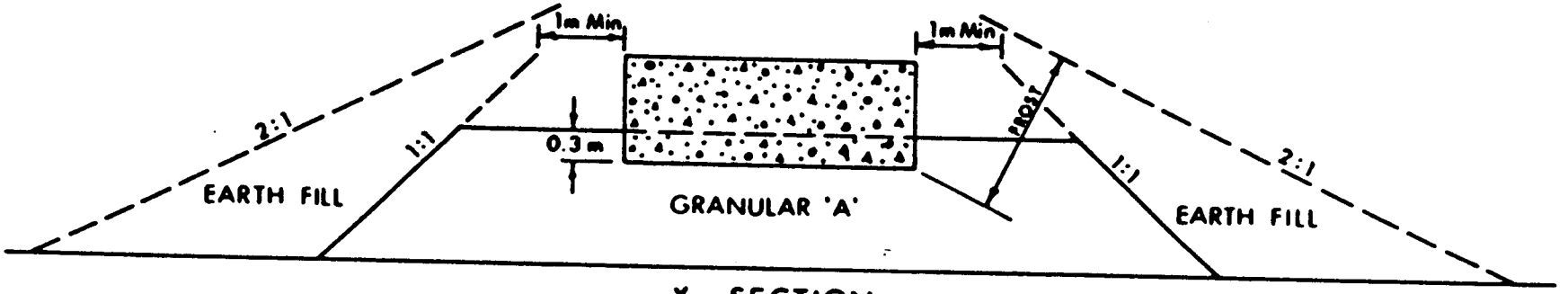
GEOCON



X SECTION

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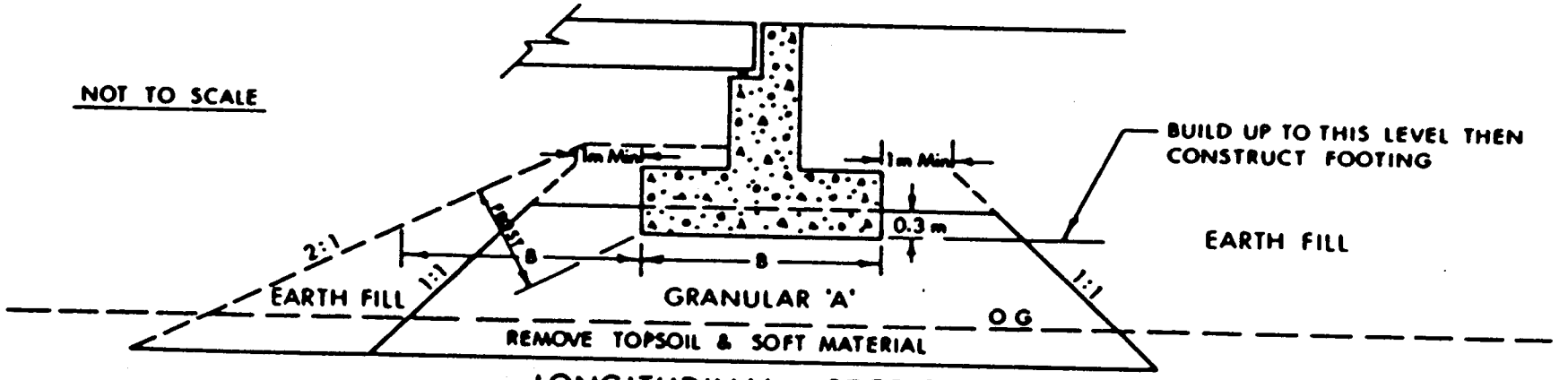


LONGITUDINAL SECTION

NOTES:

1 - REMOVE TOPSOIL &/OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' & EARTH FILL.

2 - PLACE GRANULAR 'A' & EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO CURRENT M T O STANDARDS.

3 - CONSTRUCT CONCRETE FOOTING.

4 - PLACE REMAINDER OF GRANULAR 'A' & EARTH FILL AS REQUIRED.

Ministry of Transportation Ontario	ABUTMENT ON COMPACTED FILL SHOWING GRANULAR 'A' CORE	FIG No 2 W P 372-89-05

APPENDIX A

Borehole Information

Explanation of Terms used in this Report
Explanation of the Term Rock Quality Designation (RQD)
Table 1: Summary of Underpass Borehole Investigation
Record of Borehole Sheets (11-1 to 11-6)
Test Pit Log

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 $\tilde{N}$.

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 (R Q D), 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
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_p	%	PLASTIC LIMIT
w_s	%	SHRINKAGE LIMIT
I_p	%	PLASTICITY INDEX = $w_L - w_p$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
e_{max}	1,%	VOID RATIO IN LOOSEST STATE

e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

EXPLANATION OF THE TERM

ROCK QUALITY DESIGNATION (RQD)

The description of bedrock quality for engineering purposes can be inferred from a modified core recovery logging procedure designated as RQD, developed by D.U. Deere.* This classification is based on a modified diamond drill core recovery percentage in which only the pieces of sound core over 4 inches (10 cm) long are counted as recovery. The core must be carefully examined to discount fresh irregular breaks caused by the drilling process (fresh broken pieces are fitted together and counted as one piece). The remaining fragments less than 4 inches (10 cm) length are considered to be due to very close bedding, jointing, fracturing, shearing, or weathering in the rock mass and are not counted. The procedure penalizes the rock where recovery is poor. This is appropriate because poor core recovery usually depicts poor quality rock. In the case of certain shaley sedimentary or thinly foliated metamorphic rocks, the method is not as exact as for other rock types and rock quality requires interpretation by a specialist for the particular engineering application. To minimize the occurrence of core breaks from drilling procedures RQD logging is normally run on core obtained by double or triple tube core barrels and generally of "N" size or greater.

The table below may be used as a general indicator to correlate (RQD) and rock mass quality.

RQD	DESCRIPTION OF ROCK QUALITY
90 - 100	Excellent - intact, very sound, massive
75 - 90	Good - moderately jointed or sound
50 - 75	Fair - blocky and seamy, fractured
25 - 50	Poor - shattered and very seamy or blocky, severely fractured
0 - 25	Very poor - crushed, very severely fractured

*See, for instance:

K.G. Stagg and O.C. Zienkiewicz, "Rock Mechanics in Engineering Practice". New York, Wiley, 1968, Chapter I.

TABLE 1

HIGHWAY 416 FOUNDATION INVESTIGATION
VAN BUREN STREET UNDERPASS
SUMMARY OF UNDERPASS BOREHOLE INVESTIGATION

	General Information		Stratigraphic Upper Elevation (m) Layer Thickness in Brackets - m)			Piezometer Information	
Borehole No.	Ground Surface Elevation (m)	Total Depth (m)	Peat & Topsoil	Glacial Till	Dolostone Bedrock	Tip Elev. (m)	Groundwater Elev. (m) *
11-1	97.6	3.5	97.6 (0.2)	97.4 [3.5]	Not drilled		
11-2	95.8	15.4	See Note (1)	95.2 (12.0)	83.2 [2.8]	88.4	Piezometer damaged
11-3	94.3	6.3	94.3 (0.3)	94.0 [6.0]	Not drilled		
11-4	94.1	14.4	94.1 (0.1)	94.1 11.7	82.3 [2.6]	85.9	93.1 **
11-5	94.5	6.3	94.5 (0.1)	94.4 [6.3]	Not drilled		
Test Pit 11-1	97.6	4.5	97.6 (0.3)	97.3 [4.2]			

Notes:

1. At this location, the topsoil is replaced by a 0.61 m layer of Roadfill.
2. [ ] Layer thickness not fully penetrated.
3. * At this location Roadfill replaces the topsoil.
4. All elevations are geodetic
   For more detailed information, refer to the Record of Borehole Sheets.
5. ** As detailed in borehole log.

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 11-1

METRIC

W P 372-89-05 LOCATION Co-ords: 4,987,005.7 N; 373,525.8 E ORIGINATED BY N.K.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Augers COMPILED BY N.K.

DATUM Geodetic DATE November 16, 1990 CHECKED BY I.C.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa o UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
97.6	Ground Surface										
0.0 / 97.4	Topsoil Dark Brown					Dry			o		
0.2	Silt & Sand, some gravel, trace clay, occasional cobbles and boulders (Glacial Till)		1	SS	64						
	Very Dense Brown		2	SS	18/ 150mm		96				12 37 44 7
			3	SS	20/ 0mm						
94.1			4	SS	25/ 25mm				o		
3.5	End of Borehole Auger Refusal										

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 11-2

METRIC

W P 372-89-05 LOCATION Co-ords: 4,986,994.4 N; 373,524.3 E ORIGINATED BY N.K.

DIST 9 HWY 416 BOREHOLE TYPE Solid Stem Augers, Tricone, NXL Rock Core COMPILED BY N.K.

DATUM Geodetic DATE November 8, 9 and 10, 1990 CHECKED BY I.C.

OFFICE REPORT ON SOIL EXPLORATION

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
95.8	Ground Surface							20 40 60 80 100	20 40 60		
0.0 / 95.2	Gravelly Sand (Roadfill) Loose Brown		1	SS	9	Not Noted			○		
0.6	Sand and Silt, some gravel, trace clay, some cobbles, occasional boulders (Glacial Till) Very Dense Brown		2	SS	70*		Bentonite Seal				NE 12 38 46 3
			3	SS	46/150mm		94		○		
92.3			4	SS	76/275mm						
3.5	Sandy Silt, some gravel, trace Clay. Some cobbles, occasional boulders (Glacial Till) Very Dense Grey Cored boulders from:- 3.58m - 3.97m; 7.78m - 8.82m						92 Backfill				
			5	SS	62				○		
							90				
			6	SS	64						13 35 57 9
							Piezometer				
			7	SS	28/150mm		88		○		
			8	SS	37/100mm						
							86				
			9	SS	50/110mm				○		
							84				
83.2					52/150mm			RQD%			
12.6	Dolostone Bedrock fine grained, closely jointed, with some calcite intrusions Grey		11	RC NXL	100			59			
			12	RC NXL	69			31			
			13	RC NXL	100			69			
			14	RC NXL	100			100			

Rec%

+3, ×3 : Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 11-2

METRIC

W P 372-89-05' LOCATION Co-ords: 4,986,994.4 N ; 373,524.3 E ORIGINATED BY N.K.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Augers, NXL Rock Core COMPILED BY N.K.

DATUM Geodetic DATE November 16, 1990 CHECKED BY I.C.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE, ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						GR SA SI CL
80.8	Borehole Cont'd										
15.0 / 80.4	See Page 1 for rock Description										
15.4	End of Borehole										

Notes:

1) 00* indicates that the quoted 'N' value is based on the first 0.3m of penetration. (full penetration not achieved)

2) Borehole advanced from 2.5 m to bedrock by Triconing inside an N casing.

3) Piezometer was damaged before a water level was established.

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 11-3

METRIC

W P 372-89-05 LOCATION Co-ords: 4,987,008.9 N; 373, 564.6 E ORIGINATED BY N.K.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Augers COMPILED BY N.K.

DATUM Geodetic DATE November 15, 1990 CHECKED BY I.C.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (o UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
94.3	Ground Surface										
0.0 / 94.0	Peat & Topsoil Soft Black						94				
0.3	Sand and Silt, some gravel, trace clay, occasional cobbles (Glacial Till) Very Dense Brown		1	SS	41*				o		
			2	SS	66						
			3	SS	62*		92		o		14 37 42 7
			4	SS	92/200 mm						
90.0			5	SS	41/275mm	▽			o		
4.3	Sand and Silt, some gravel, trace clay. Occasional cobbles (Glacial Till) Dense Grey Water bearing sand seam at 5.3 - 5.8m		6	SS	38		90		o		
			7	SS	36						
88.0			8	SS	13/150mm						
6.3	End of Borehole										

Notes:

1) Water in open borehole measured at elevation 90.3 m upon completion of drilling.

2) 00* indicates quoted 'N' value is based on the first 0.3m of penetration. (full penetration not achieved)

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 11-4 METRIC

W P 372-89-05 LOCATION Co-ords: 4,987,020.7 N; 373,601.1 E ORIGINATED BY N.K.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Augers, Tricone, NXL Rock Core COMPILED BY N.K.

DATUM Geodetic DATE November 6, 1990 CHECKED BY I.C.

OFFICE REPORT ON SOIL EXPLORATION

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
94.1	Ground Surface										
0.0 / 94.0	Topsoil						94				
0.1	Sandy Silt, some clay trace gravel		1	SS	4			Water level in piezometer measured at elevation 93.1 m on December 4, 1990.			
92.7	Loose to Compact Brown		2	SS	25				○		0 31 52 17
1.4	Sandy Silt, some gravel, trace clay, occasional cobbles (Glacial Till)		3	SS	78*		Bentonite Seal				
	Very Dense Brown		4	SS	64		92		○		
90.7			5	SS	66						
3.5	Sandy Silt, some gravel, trace clay, occasional cobbles						Backfill 90				
	Dense to Very Dense (Glacial Till) Grey		6	SS	32						
	Encountered sand seams at:- 5.01m - 5.34m; 8.13m - 8.31m		7	SS	37		88				
			8	SS	71*						
			9	SS	84						
							Piezometer 86				
			10	SS	92/275mm				○		12 20 62 6
			11	SS	69/225mm		84				
82.3					Rec%			RQD%			
11.8	Dolostone Bedrock fine grained closely jointed		12	RC NXL	95			90			
			13	RC NXL	90			52			
79.7	Grey		14	RC NXL	83			87			
14.4	End of Borehole										

00* indicates that the quoted 'N' value was based on the first 0.3 m of penetration (full penetration not achieved).

+3, ×5 : Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 11-5

METRIC

W P 372-89-05 LOCATION Co-ords: 4,987,014.2 N; 373,602.2 E ORIGINATED BY N.K.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Augers, Triconing COMPILED BY N.K.

DATUM Geodetic DATE November 7, 1990 CHECKED BY I.C.

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT Wp — NATURAL MOISTURE CONTENT W — LIQUID LIMIT WL / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
94.5	Ground Surface										
0.0 / 94.4	Topsoil		1	SS	14	Not Noted	94		○		
0.1	Heterogeneous mixture of Silt, Sand and Gravel, trace clay, occasional cobbles. (Glacial Till) Very Dense Brown		2	SS	73/285mm						
			3	SS	80				○		
			4	SS	31/150mm		92				
			5	SS	80*				○		27 31 36 6
89.9											
4.6	Sandy Silt, some gravel, trace clay, occasional cobbles (Glacial Till) Very Dense Grey		6	SS	64		90				
			7	SS	65						
88.2											
6.3	End of Borehole										

Notes:

1) 00* indicates that the quoted 'N' value is based on the first 0.3m of penetration (full penetration not achieved)

+3, ×5 : Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 11-6

METRIC

W P 372-89-05 LOCATION Co-ords: 4,987,030.1 N; 373,680.4 E ORIGINATED BY G.Y.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Augers COMPILED BY I.C.

DATUM Geodetic DATE March 5, 1991 CHECKED BY I.C.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
92.8	Ground Surface										
0.0 / 92.6	Peat and Topsoil Black										
0.2 / 92.0	Sand Grey						92				
0.8	Clayey Silt. Trace to Some Sand. Silt content increasing with depth. Firm to Very Soft Grey		1	SS	4						0 15 73 12
			2	SS	5						
			3	SS	7		90				0 5 89 6
89.3			4	SS	1						
3.5	Gravelly Sand and Silt Trace Clay. (Glacial Till) Very Dense Grey		5	SS	67						
87.7			6	SS	89		88				
5.0	End of Borehole										

Notes:

1) Water level in open borehole at ground surface upon completion of drilling.

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

15 20/10 5 (%) STRAIN AT FAILURE

Geocon

TEST PIT LOG

PROJECT: Highway 416 - Van Buren Street Underpass — TEST PIT: 11-1

Location: Co-ords. 4,987,015.7N; 373,528.8E — PAGE: 1 OF 1

CONTRACT NO.: WP 372-89-05 — DATE: Dec. 13/91

DATUM: Geodetic

SAMPLE CONDITION: ☒ DISTURBED

W_N - WATER CONTENT - %
GS - GRAIN SIZE ANALYSIS
γ - UNIT WEIGHT - kN/m^3

TYPE OF TEST
P - MODIFIED PROCTOR TEST
W_{OPT} - OPTIMUM WATER CONTENT - %
γ_{MAX} - MAX. DRY UNIT WEIGHT - kN/m^3

W_L - LIQUID LIMIT - %
W_P - PLASTIC LIMIT - %

DEPTH - m	ELEVATION - m / DEPTH - m	DESCRIPTION	SYMBOL	SAMPLES: CONDITION	SAMPLES: NUMBER	TESTS: RESULTS (Gr Sa Si Cl)
0	97.7	Ground Surface				
	0.0 / 97.4	Silty Fine Sand, Some Roots (Topsoil) Dark Brown				
1	0.3	Heterogenous mixture of Gravel, Sand and Silt, Trace Clay, Occasional Cobbles (Glacial Till) Grey/Brown		☒	1	32 30 36 2
2	95.5 / 1.9 / 95.4	Medium Gravel, Some Sand (Water Bearing) Dark Brown				dry @ 2.2m 19.6kN/m³ W_{nat} = 9% S.G. = 2.8
	2.0	Heterogenous mixture of Gravel, Sand and Silt, Trace Clay Some cobbles and boulders. Boulder content increasing with depth. (Glacial Till) Grey/Brown		=		
3						dry @ 3.0m 19.2kN/m³ W_{nat} = 8% S.G. = 2.8
				=		
4				☒	2	32 30 30 8
	92.9 / 4.5	End of Test Pit Machine Refusal				

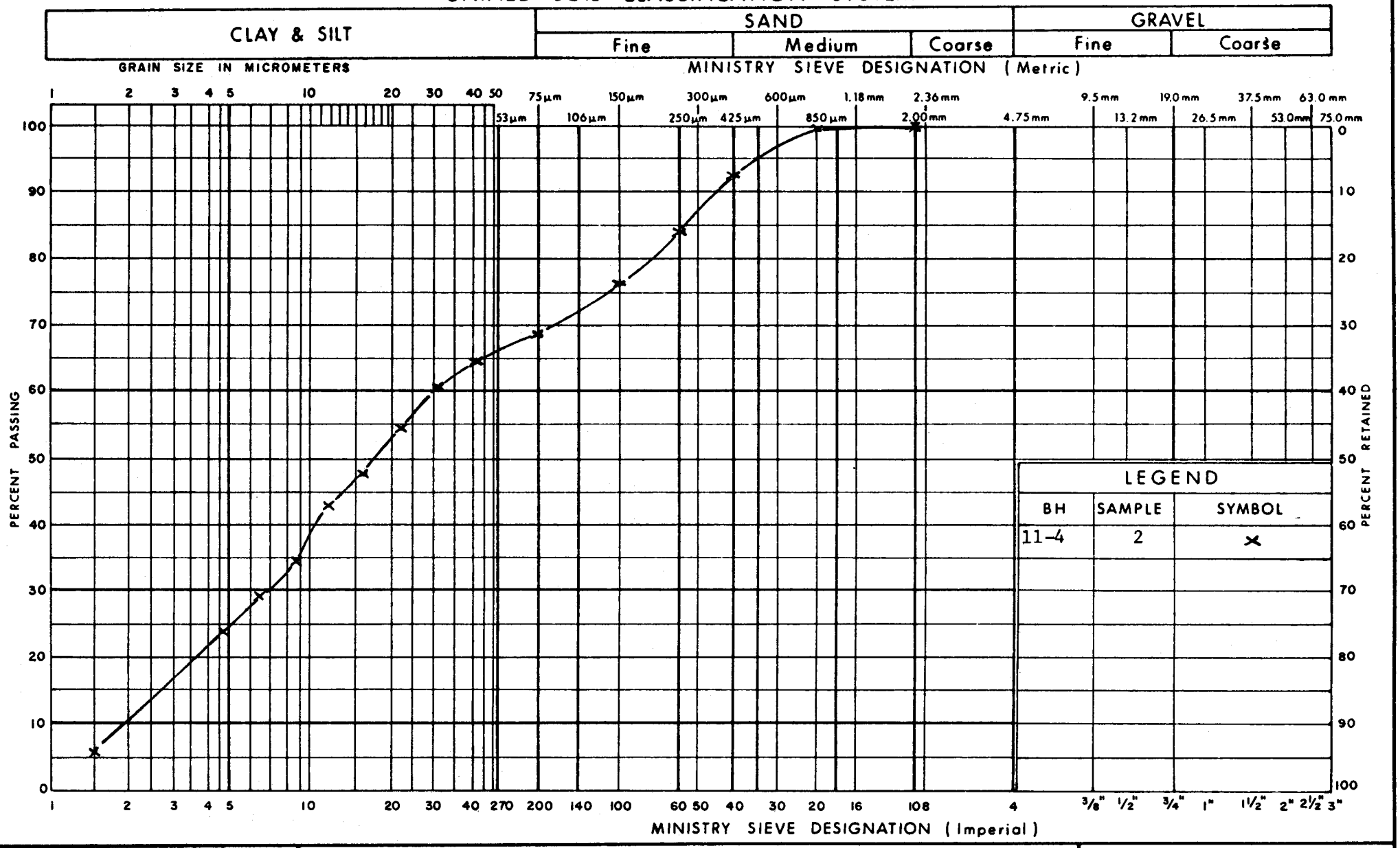
APPENDIX B

Laboratory Test Data

Figures B1 to B4 - Grain Size Curves
Figure B5 - Plasticity Chart

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation and Communications
Ontario

GRAIN SIZE DISTRIBUTION

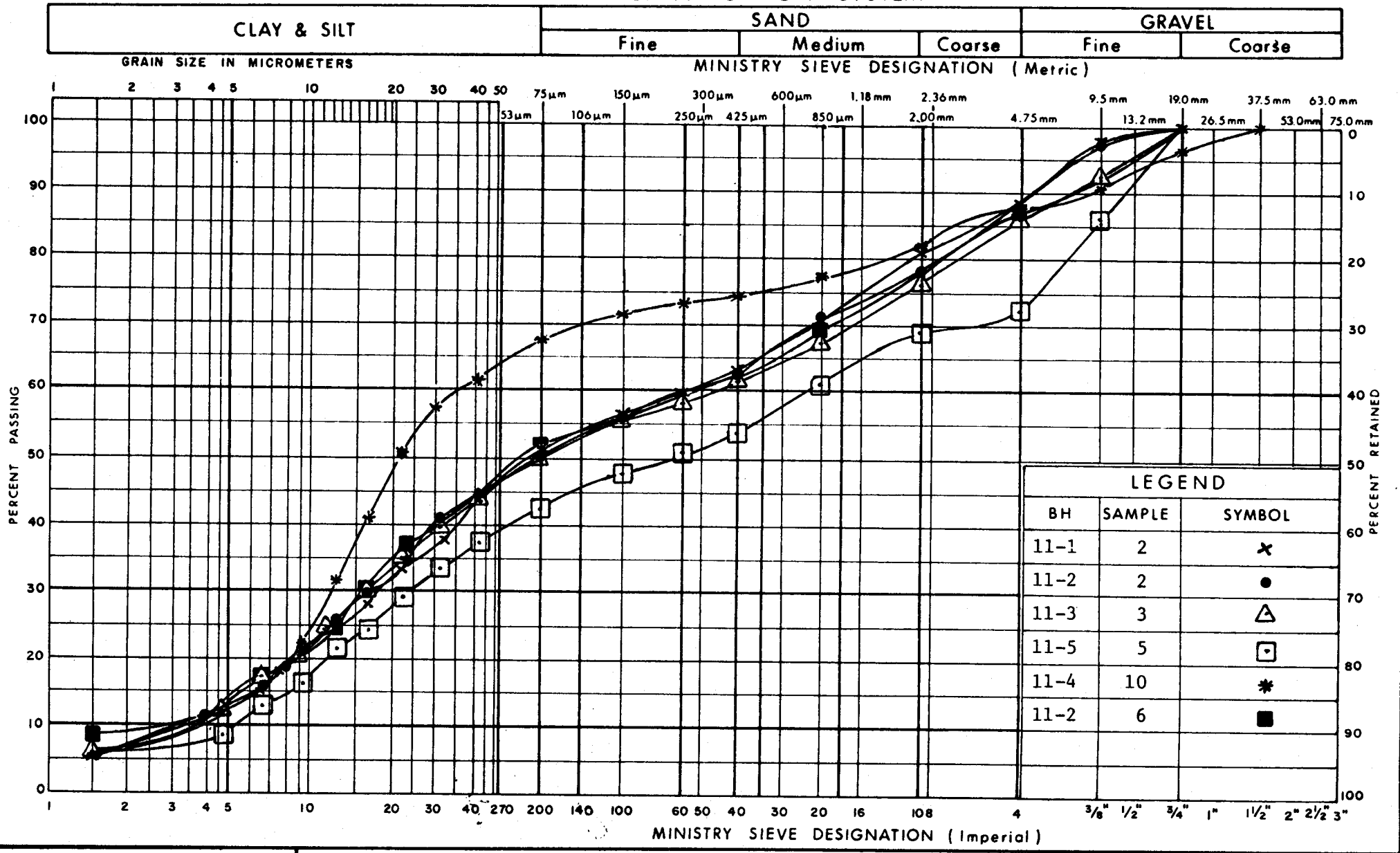
Sandy Silt, Trace Clay

FIG No B1

W P 372-89-05

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM



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Ontario

GRAIN SIZE DISTRIBUTION

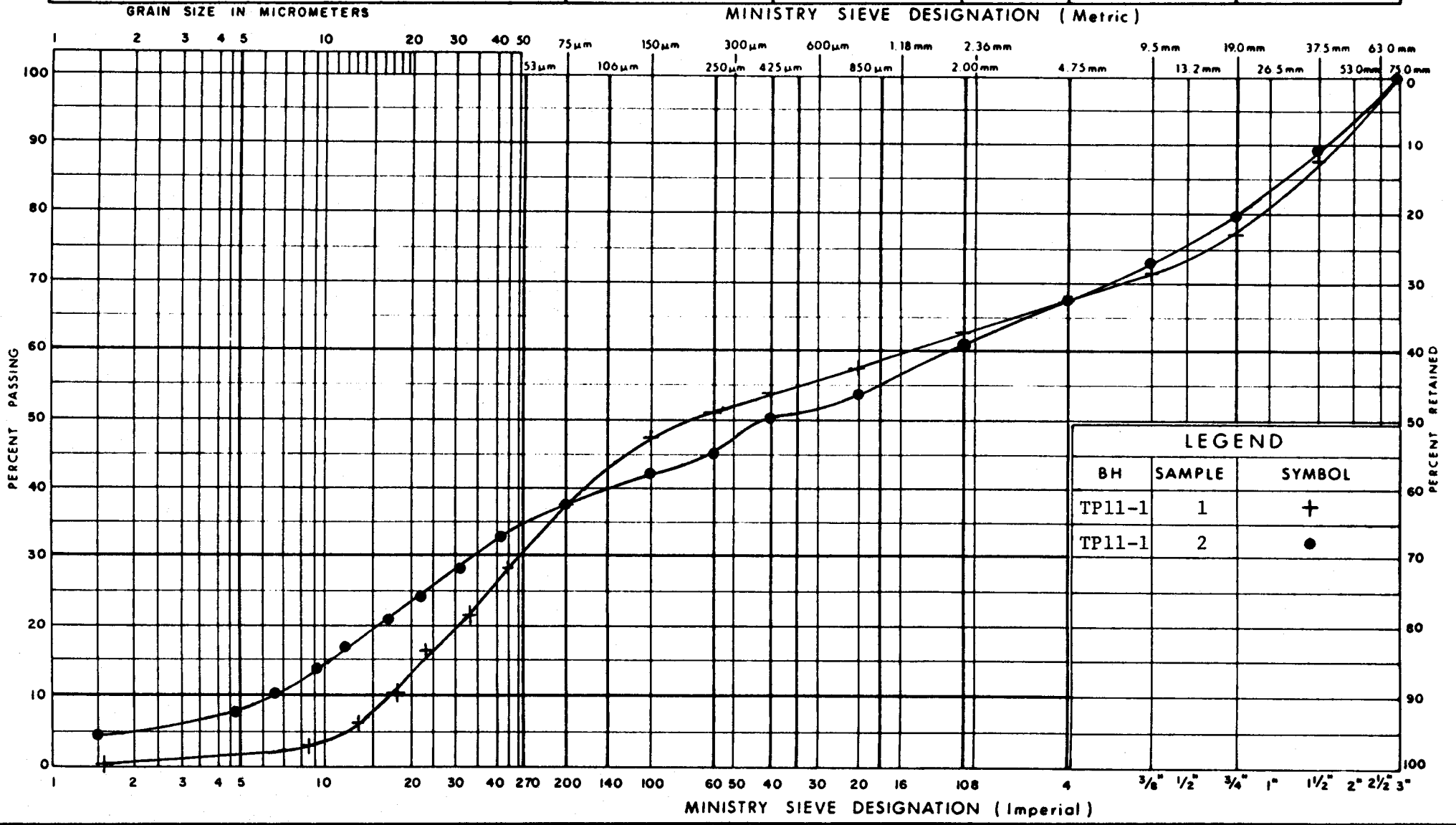
Glacial Till

FIG No B2

W P 372-89-05

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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Ontario

GRAIN SIZE DISTRIBUTION

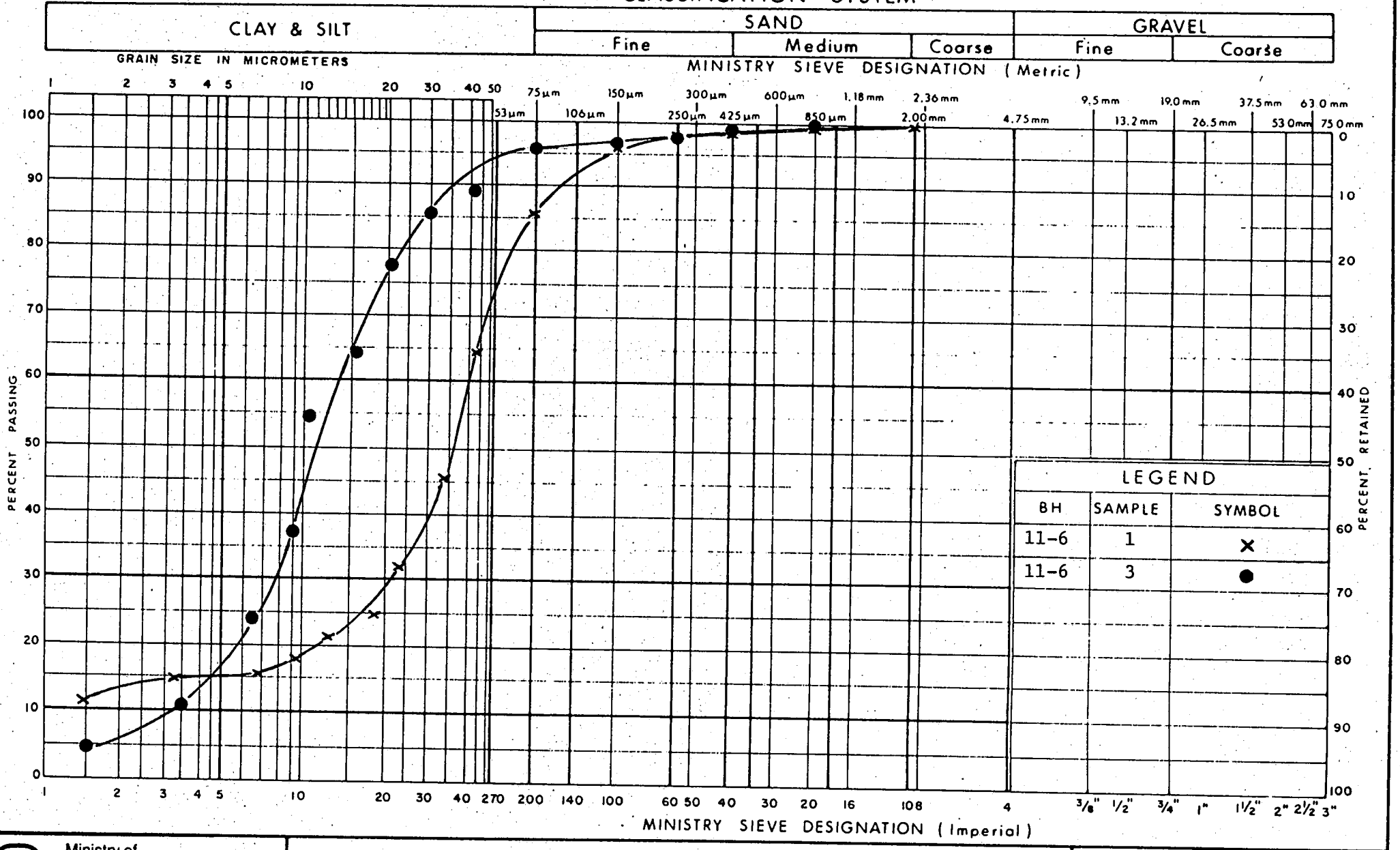
Glacial Till

FIG No B3

W P 372-89-05

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM



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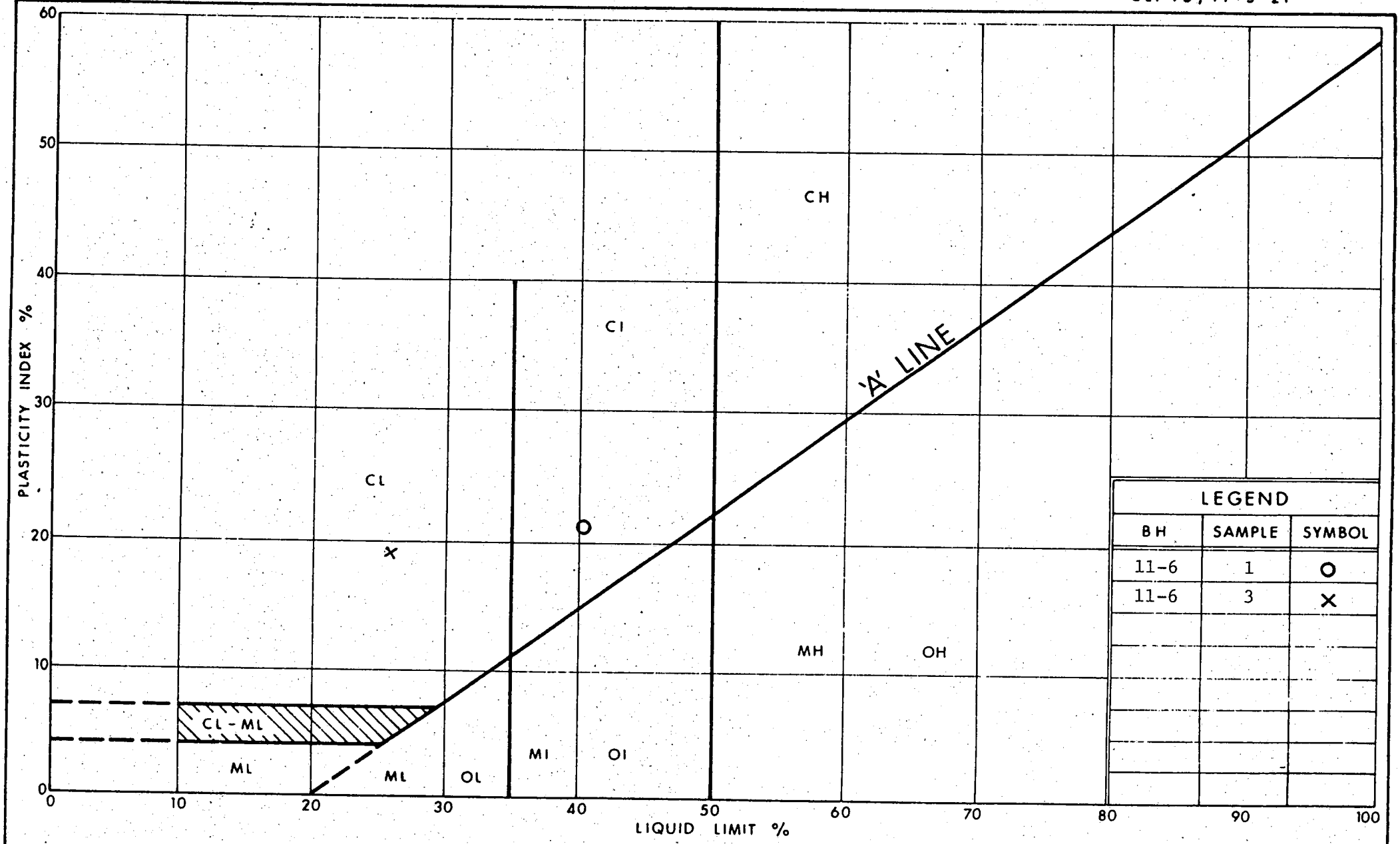
Ontario

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIG No	B4
W P	372-89-05

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
11-6	1	O
11-6	3	×

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Ontario

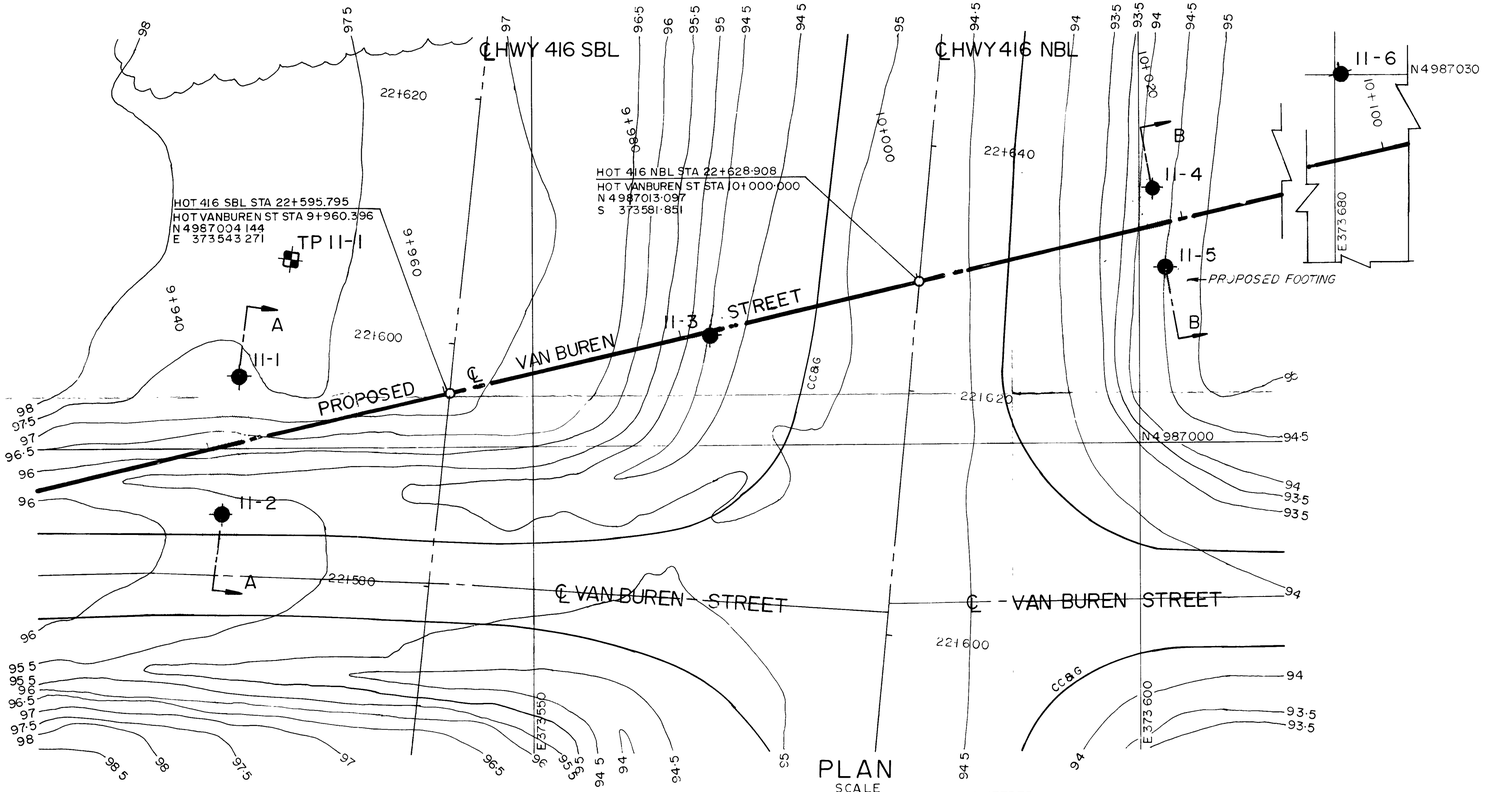
PLASTICITY CHART

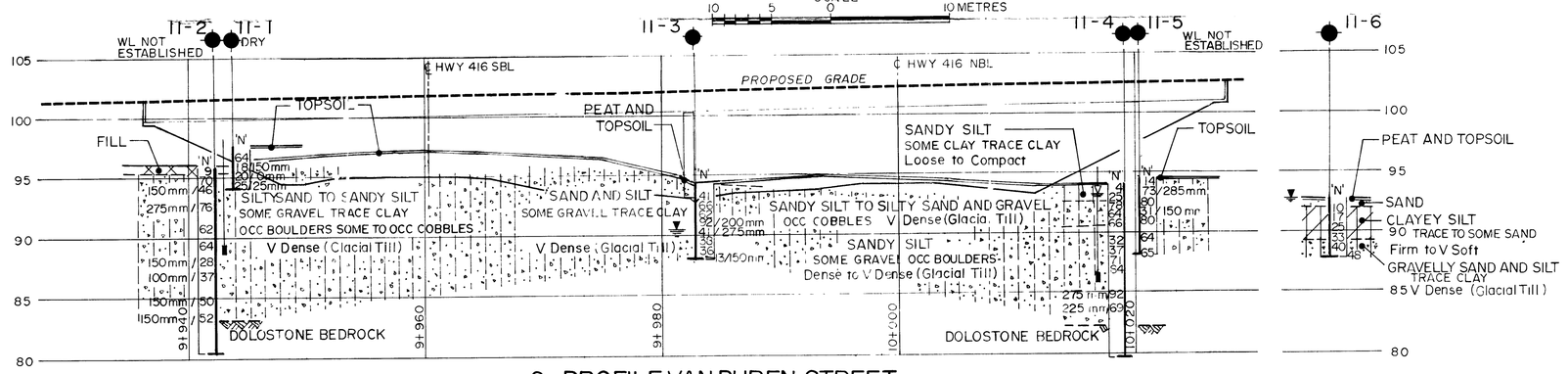
Clayey Silt

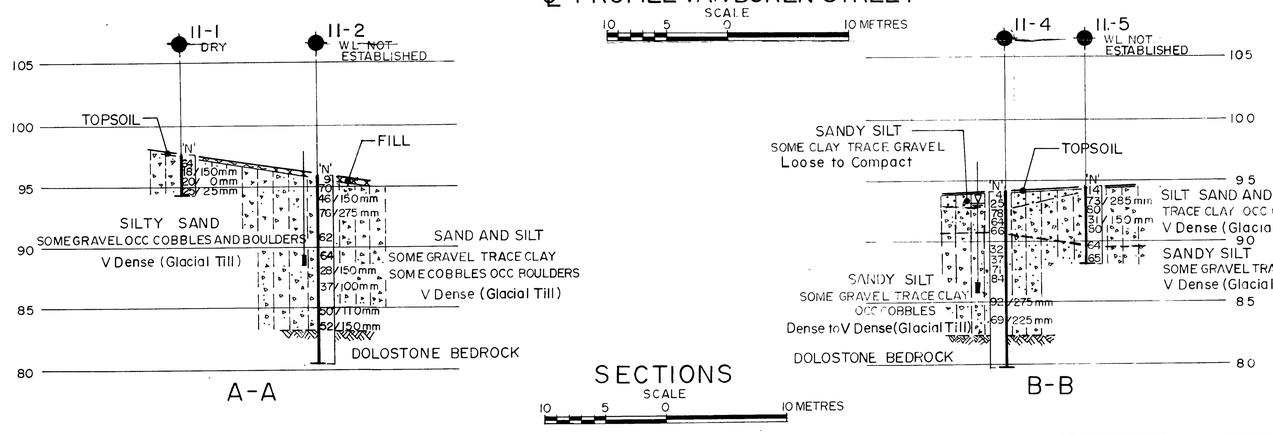
FIG No B5

W P 372-89-05

MINISTRY OF TRANSPORTATION, ONTARIO PH-D-207 88 10







METRIC

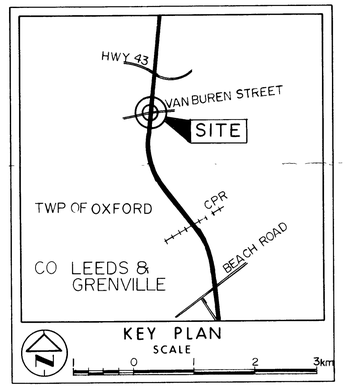
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No
WP No 372-89-05

HIGHWAY 416
VAN BUREN STREET UNDERPASS
BORE HOLE LOCATIONS & SOIL STRATA

SHEET A

GEOCON (1991) INC



LEGEND

- Bore Hole
- 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
- Piezometer
- Test Pit

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	97·6	4 987 005·7	373 525 8
2	95 8	4 986 994·4	373 524 3
3	94 3	4 987 008·9	373 564·6
4	94 1	4 987 020·7	373 601 1
5	94·5	4 987 014·2	373 602·2
6	92 8	4 987 030·1	373 680·4
TP II-1	97 7	4 987 015 7	373 528 8

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

REGISTERED PROFESSIONAL ENGINEER CIVIL I. HOLUBEC PROVINCE OF ONTARIO

REV	DATE	BY	DESCRIPTION

Geocres No 31G-206

HWY No 416			DIST 9
SUBM'D NK	CHECKED NK	DATE 1991 08 26	SITE 16-317
DRAWN MZ	CHECKED RB	APPROVED	DWG 3728905-A

REF No E-53-416-1; 91-05