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STR. SITE No. 3-575

HWY. No. 416

LOCATION Hwy 416 & Third Line Rd. (Lochhead Rd.)

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

FILE COPY

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FOUNDATION INVESTIGATION REPORT

for

Third Line Road Underpass

W.P. 371-89-03, District 9, Ottawa

Highway 416, Str. Site: 3-575

CONT 96-59

GEOCRES # 31G-212

Submission Date: 1992 03 27

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M.M. Dillon	15 copies
Strata File E-90-036B	1 copy

Nature, to be commanded, must be obeyed

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FOUNDATION INVESTIGATION REPORT

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Third Line Road Underpass

W.P. 371-89-03, District 9, Ottawa

Highway 416, Str. Site: 3-575

1.0 INTRODUCTION

Strata Engineering Corp. has been retained by M.M. Dillon Limited to carry out a foundation investigation at a proposed underpass for Highway 416 at Third Line Rd. The terms of reference were to investigate the site by means of sampled boreholes and dynamic cone penetration tests, and to provide a full geotechnical report.

This report follows a preliminary letter report submitted on 1990 12 20.

2.0 SITE AND GEOLOGY

The site is located in Rideau Township approximately 40 km south of Ottawa along Highway 16, as shown in the Key Plan in Drawing 3718903-A. At present, Third Line Road intersects Highway 16 at an 80° skew at grade.

The topography of the area to the east, south and west of the site is predominantly flat. There are low hills to the north of the site.

Physiographically the area lies within the North Gower Drumlin Field, with the drumlins oriented approximately north-south. This area has been inundated by the Champlain Sea. The drumlins are draped by marine soils consisting of Leda clays.

Bedrock in this area is magnesium limestone to dolostone of the Oxford Group of lower Ordovician age.

3.0 FIELD AND LABORATORY WORK

The field work took place between 1990 10 11 and 22. Eight boreholes were drilled. Five boreholes were located at the proposed pier and abutments. Two boreholes were drilled for the approach ramps of Third Line Road. An additional borehole was drilled between the proposed south east abutment and the centre pier in order to verify the subsurface stratigraphy. The borehole locations are shown on Drawing 3718903-A.

The borehole locations for the structure were staked by M.M. Dillon personnel who also supplied the ground elevations which are referenced to Geodetic datum.

Drilling was done by means of two bombardier mounted drill rigs. Hollow stem augers were used to advance Boreholes 1 to 4, 7 and 8. Boreholes 5 and 6 were advanced by means of wash boring techniques using N sized casing.

The boreholes were sampled at 0.75 m depth intervals within the upper 6 m and at 1.5 m intervals below this depth. Sampling was done by means of the Standard Penetration Test and the N values noted. In cohesive strata, relatively undisturbed samples were obtained by manually or hydraulically pushing thin walled Shelby Tubes. In situ MTO vane tests were carried out to measure the undrained shear strength of the cohesive strata. Remoulded strengths were also measured to assess the sensitivity of the soil.

Six boreholes were accompanied by dynamic cone penetration tests.

Bedrock was cored in three boreholes.

After the last sample was taken in each borehole the groundwater level was measured. Perforated standpipes with bentonite seals were installed in Boreholes 2, 4, 5 and 6. The water levels in the instrumented holes were monitored over a period of time. All boreholes were backfilled with native soil cuttings. The site was restored to its original condition.

Recovered soil samples were transported to our Don Mills Laboratory were they were visually examined and classified. Tests for index properties such as moisture contents, Atterberg Limits and grain size distribution were conducted on representative samples. Unconfined compression tests were conducted on selected thin walled tube samples. One consolidation test was also performed. The field and laboratory results are shown on the Record of Boreholes and Figures 1 to 5 in the Appendix.

4.0 SUBSURFACE CONDITIONS

4.1 General

The soil conditions are variable across the site. To the south east of the existing Highway 16, a surficial deposit of sandy silt overlies an extensive deposit of clayey silt to silty clay above a sand and gravel glacial till. To the north west of Highway 16 there is a silty sand glacial till above the sand and gravel till. The sand and gravel glacial till overlies limestone bedrock.

4.2 Sandy Silt

A brown sandy silt deposit, is present at the south east approach and abutment areas (in Boreholes 1, 2, 3 and 8 only), from the surface to depths ranging from 1.4 m to 2.1 m. The moisture content of this soil is approximately 30 per cent. Two grain size analyses, shown on Figure 1, indicate the stratum consists of fine sand and silt. The soil is non-cohesive. N values of 4 to 8 blows/0.3 m indicate the stratum to be very loose to loose.

4.3 Silty Sand to Sandy Silt (Glacial Till)

To the north west of Highway 16 there is a deposit of silty sand to sandy silt (glacial till) from ground surface down. The thickness of this deposit diminishes from north west to south east. It was 6.7 m thick in Borehole 6 near the north west abutment and 5.2 m in Borehole 4 near the centre pier. There are numerous cobbles and boulders within this deposit.

The moisture content ranged from 10 to 22 per cent, being higher below the groundwater table. The results of grain size analyses are shown in envelope form on Figure 2A. For silty zones within this deposit, the grain size curves are shown on Figure 2B. This glacial till is a heterogenous mixture of sandy silt to silty sand with some gravel with occasional sandy and silty zones.

N values in this deposit ranged from 13 to in excess of 100 blows/0.3 m with average values being about 35 blows/0.3 m. The deposit is therefore compact to very dense.

4.4 Clayey Silt to Silty Clay

Below the sandy silt to the south east part of this site there is a clayey silt to silty clay stratum whose thickness ranges from 8.5 m (Borehole 1) to 5.1 m (Borehole 8). Due to the decreasing thickness of this deposit it can be surmised that it terminates below the existing highway.

The moisture content of this deposit ranged from 25 to 79 per cent. The lower moisture contents were obtained in a desiccated crust which is approximately 3 m thick. Immediately below the crust the moisture contents are the highest and generally decrease with depth. Atterberg limit tests (Figure 3) indicate low to medium plasticity for this soil. The moisture contents are generally higher than the liquid limit indicating a liquidity index in excess of unity.

Field vane tests gave undrained shear strength values ranging from 20 kPa to 90 kPa. The higher values were obtained within the desiccated crust, generally above elev. 84 m. Unconfined compression tests gave values of 16 kPa to 38 kPa. The sensitivity of the soil ranged from 4 to 10 with most values between 6 and 8. The undrained shear strength values below the desiccated crust generally increase with depth, with a c_u/p_o ratio of about 0.28.

A consolidation test (Figure 4) indicates a preconsolidation pressure, p_c, of between 120 kPa and 150 kPa. The compression index C_c was 1.3.

4.5 Sand and Gravel some to trace Silt (Glacial Till)

Below the silty sand to sandy silt (glacial till) to the north west of the existing highway and below the silty clay to clayey silt on the south east side of the highway there is a deposit of poorly sorted sand and gravel with some to trace silt (glacial till). This deposit has randomly occurring cobbles and boulders. Its thickness ranges from 1.7 m to 6.7 m.

The moisture content of this material ranged from 5 to 18 per cent with an average value of 12 per cent. Grain size curves (shown on Figures 5A and 5B) indicate a heterogenous mix of sand gravel and silt sizes with silt content ranging between 5 and 23 per cent.

N values ranged from 42 to in excess of 100 blows/0.3 m indicating the deposit to be dense to very dense.

4.6 Limestone Bedrock

Limestone bedrock was cored in Boreholes 2, 4 and 5. The bedrock elevation ranges from 79.5 m to 77.3 m sloping downwards from north west to south east.

The limestone is thinly bedded and fractured in the top 3 m. Core recoveries were 68 per cent. RQD values ranged from 0 to 48 per cent. Below the upper 3 m the bedrock was of better quality with 100 per cent recoveries and RQD values of 100 per cent.

5.0 GROUNDWATER CONDITIONS

Groundwater level observations are shown below:

Borehole	W.L. Elev.(m)	Depth (m)	Date
1	88.7	0.4	1990/10/18
2	88.8	0.4	1990/10/26
3	88.4	0.4	1990/10/18
4	88.2	1.5	1990/10/26
5	89.1	3.7	1990/10/26
6	88.7	3.7	1991/10/22
7		Dry upon completion	
8	88.7	0.6	1990/10/22

Borehole 7 which was dry was terminated at elevation 89.4 m

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 General

It is proposed to construct southbound lanes west of the existing Highway 16 which will be upgraded to 4 lane freeway standards between Highway 401 and Ottawa. This will involve the construction of an underpass structure to carry Third Line Road over the new highway. The maximum height of the proposed approach fills is 9 m.

This investigation indicates the presence of marine clays of varying thickness on the south east side of existing Highway 16 and poorly sorted till on the north west side which also underlies the marine clay on the south east side. The limestone bedrock is heavily fractured in the upper 3 m. Groundwater was found within 0.5 m of ground surface.

The presence of a variable thickness of relatively weak silty clay to clayey silt deposit at a shallow depth below ground surface in the south east part of this site requires that steps be taken to ensure the overall stability of the south east approach embankment.

6.2 Structure Foundations

6.2.1 Spread Footings

Due to the subsurface conditions encountered, it is not possible to support the entire proposed structure on similar spread footings. The soil conditions at the north west abutment and centre pier are suitable for this option; however the compressible silty clay to clayey silt at the south east abutment precludes the use of spread footings at the south east abutment.

Spread footings of 3 m width at the north west abutment and centre pier may be designed for the following capacities.

Factored capacity at ULS	1050 kPa
Capacity at SLS Type II	400 kPa

A minimum earth cover of 1.8 m to the base of the footings should be provided for protection against frost action.

The capacity for steel H piles at the south east abutment are given in Subsection 6.2.2 below.

6.2.2 Deep Foundations

If a mixture of footing types is not desirable then the structure can be supported entirely on a deep foundation consisting of steel H piles.

Steel H piles (eg HP 310 x 110) may be designed for the following factored load capacities:

N.W. ABUTMENT & PIER		S.E. ABUTMENT ONLY	
ULS	1650 kN	ULS	1200 kN
SLS Type II	1100 kN	SLS Type II	900 kN

HP 310 x 79 may be designed for the following factored load capacities:

N.W. ABUTMENT & PIER		S.E. ABUTMENT ONLY	
ULS	1150 kN	ULS	900 kN
SLS Type II	750 kN	SLS Type II	675 kN

These capacities account for loads due to negative skin friction arising from settlement of the approach fills at the south east abutment. Such piles, driven with an energy of no less than 50 kJ will develop the required capacities at the following minimum toe elevations:

Location	Elevation	On Bedrock
North side of North West Abutment	79.5 m	Yes
South side of North West Abutment	80.5 m	No
Centre Pier	78.4 m	Yes
North side of South East Abutment	77.5 m	Yes
South side of South East Abutment	77.3 m	Yes

Due to the random presence of cobbles and boulders within the glacial till deposits it is recommended that the pile toes be reinforced.

For piles not driven to bedrock the Hiley Formula should be used as the set criteria.

Wing walls of the south east abutment should also be supported on end bearing piles unless they can be adequately cantilevered.

6.3 Earth Pressures

Earth pressures may be computed as per subsection 6-6.1.2.2 of the OHBD code. A yielding foundation condition ie. the active case may be assumed. The Granular A or B backfill should be in accordance with MTO Special Provision No. 109F03 (latest revision). The following parameters are recommended for the granular backfill:

	Granular A	Granular B
Angle of Internal Friction, ϕ	35.0°	30.0°
Unit Weight (kN/m^3), γ	22.8°	21.2°

Surcharge effects if any should be computed as per clause 6-6.1.2.4 of the OHBD Code.

6.4 Approach Embankments

6.4.1 Stability Considerations

Slope stability analyses have been carried out using Bishop's simplified circular arc analyses (method of slices), with seismic force (earthquake) allowance of 0.1 g horizontal force component at bedrock level, to determine the stability of the proposed approach fills. Parameters used in the analyses are shown on Figure 6. The results which are applicable in both the transverse and longitudinal directions are discussed below:

(a) The maximum height of conventional fill without a stabilizing berm and with 2:1 side slopes is 7.8 m.

(b) For a factor of safety of 1.3, fills in excess of 7.8 m will require mid-height berms (as per Figure 6). For example a fill 8.5 m high will require a 5 m wide berm in both the transverse and longitudinal directions.

(c) As the embankment height decreases, the berms should be tapered toward the embankment so that they disappear at embankment heights where they are no longer required.

Design options are either to extend the structure in order to limit the height of fill at the abutment locations, or to consider using lightweight fills which may reduce berm widths or eliminate the need for mid-height berms.

The criteria for lightweight fill are:

1. It should allow the fill to be built to design heights without collapse or excessive compression under self weight and imposed loading.

2. It should result in stresses at the original ground level below those for which a berm is not required, ie. the weight should be equivalent to no more than 7.8 m of conventional fill.

3. It should be easily available, constructible and economic.

<u>Voided Embankment</u>

Corrugated steel pipe culverts placed across the full width could be used to create a voided embankment.

<u>Slag</u>

Blast furnace slag has a unit weight of 15 kN/m^3. At fill heights proposed, the embankment could be constructed to full height with a factor of safety of 1.3, without the need for mid-height berms.

Styrofoam

Styrofoam has a unit weight of 5 kN/m^3, and may be cost competitive with slag. For the proposed grade of Third Line Road it would be necessary to extend the styrofoam to a distance of some 100 m south east of the abutment before the fill height is less than 7.8 m.

A combination of styrofoam at the abutment and conventional fill in the rest of the embankment could also be used. The use of such a combination of fills would eliminate the need for a berm in the longitudinal direction. It would also reduce the volume of lightweight fill needed. In determining the geometry of this combination, the limiting factor is that the berm should extend as close as possible to the south east abutment without encroaching on the NBL of Highway 416. The berm should also taper gradually from zero to full width.

The styrofoam placed at a minimum core height of 2 m should start from the abutment and extend full height to the point at which the berm is full width. From that point it could be tapered off with a gradient of 1:1 or flatter. It would need to be placed practically full width within a 1:1 sloping line from the edge of fill, in the transverse direction. The styrofoam should be covered with a 6-mil polyethylene sheet to protect it from gasoline spills. An adequate cover of earthfill should be placed to hold the styrofoam in place, as well as to provide protection against premature collapse of the foam under equipment construction traffic loading.

No stability problems are anticipated for the north west approach embankment fill.

6.4.2 Settlement Considerations

The loose surficial sandy silt stratum under the south east approach will undergo immediate elastic settlement due to the imposed embankment loading.

For the silty clay stratum, stress distributions were computed using Osterberg charts for the various height and berm configurations. Results of settlement analyses are shown on Figures 7A and 7B.

Figure 7A shows an estimate of settlements to be expected under fill heights using normal 20 kN/m^3 fill material. Figure 7B shows the expected time rate of settlement. These two curves may be used to estimate the settlement magnitude and time rate expected for any given combination of fill heights and berm widths for stable embankments (selected from Figure 6).

Settlement of the lightweight fill will depend on the relative weight of the embankment compared to that of conventional fill. If a combination of fills is used, the differential settlement between the lightweight fill and the conventional fill is expected to be in the order of 70 mm during the service life of the embankment.

Preloading the approaches by advance construction of the embankments may be used to reduce the in-service settlement of the embankment to 300 mm. The time required for preloading will be dependent on the time rate of settlement, as given in Figure 7B.

6.5 Construction Considerations

Due to the high water table, dewatering may be needed for construction of pile caps. On the south east side of existing Highway 16, seepage into excavations made in the sandy silt and silty clay is expected to be minimal, and may be handled by pumping from sumps. Excavations within the desiccated crust may experience moderate seepage of groundwater though fissures in the deposit.

On the north west side of Highway 16, seepage into the excavations made in the silty sand to sandy silt glacial deposit may be adequately handled by pumping from a sump.

7.0 CLOSURE

Field work for this investigation was supervised by A. C. Abel. Drilling equipment was rented from Marathon and F. E. Johnston Drilling companies, Ottawa.

Respectfully submitted:
STRATA ENGINEERING CORP.

A. C. Abel, M. Sc.
Project Engineer

C. Mirza, P. Eng.
Senior Principal

Report Distribution:

M.M. Dillon	15 copies	
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APPENDIX

Explanation of Terms Used in Report

Record of Boreholes 1 to 8

Figures 1 to 7B

Drawing 3718903-A

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	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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No1

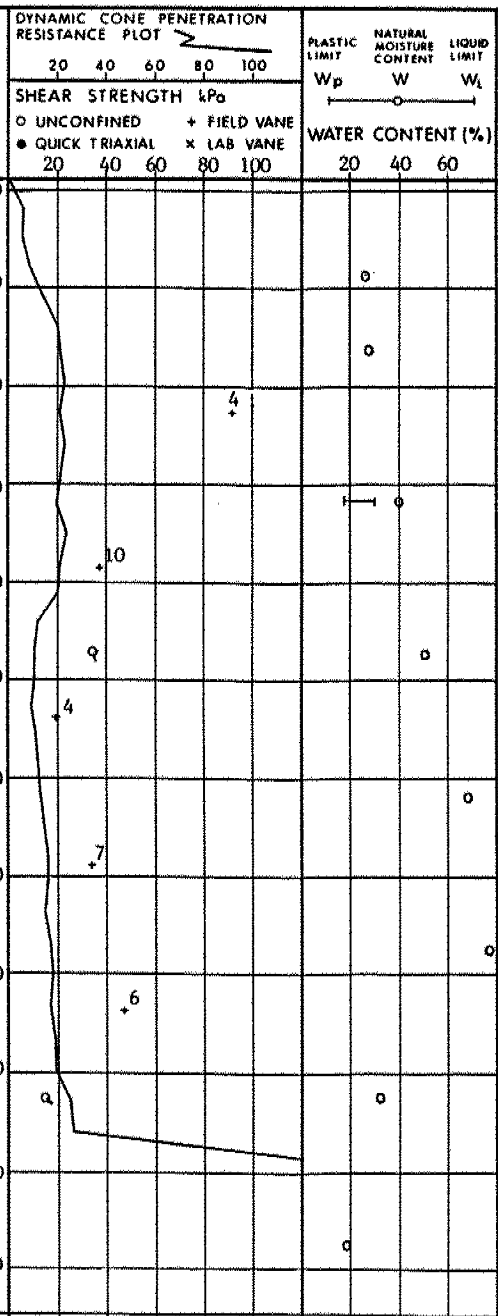
METRIC

W P 371-89-03 | LOCATION N 4,998,513 ; E 369,694 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger; Dynamic Cone Penetration Test | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 15 | CHECKED BY C.M.

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.1	Ground Surface						
0.0	Sandy Silt, Loose, Brown				▼		W.L. on 1990 10 18
		1	SS	6			0 49 (51)
87.7 / 1.4	Clayey Silt to Silty Clay, Desiccated Crust, Stiff	2	SS	3			
	Soft to Firm	3	SS	2			
	Grey	4	TW	PM		15.4	
		5	TW	PM			
		6	TW	PM			
79.2		7	TW	PM		16.8	
9.9	Sand and Gravel trace to some Silt (Glacial Till), Very Dense, Grey	8	SS	103			30 55 (15)
77.5 / 11.6	End of Borehole, Probable Bedrock						



OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

15 -○- 5 (%) STRAIN AT FAILURE (20 above, 10 below)

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 2

METRIC

W P 371-89-03 | LOCATION N 4,998,506 ; E 369,690 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger ; Dynamic Cone Penetration Test | COMPILED BY A. K.

DATUM Geodetic | DATE 1990 10 11 | CHECKED BY C.M.

OFFICE REPORT ON SOIL EXPLORATION

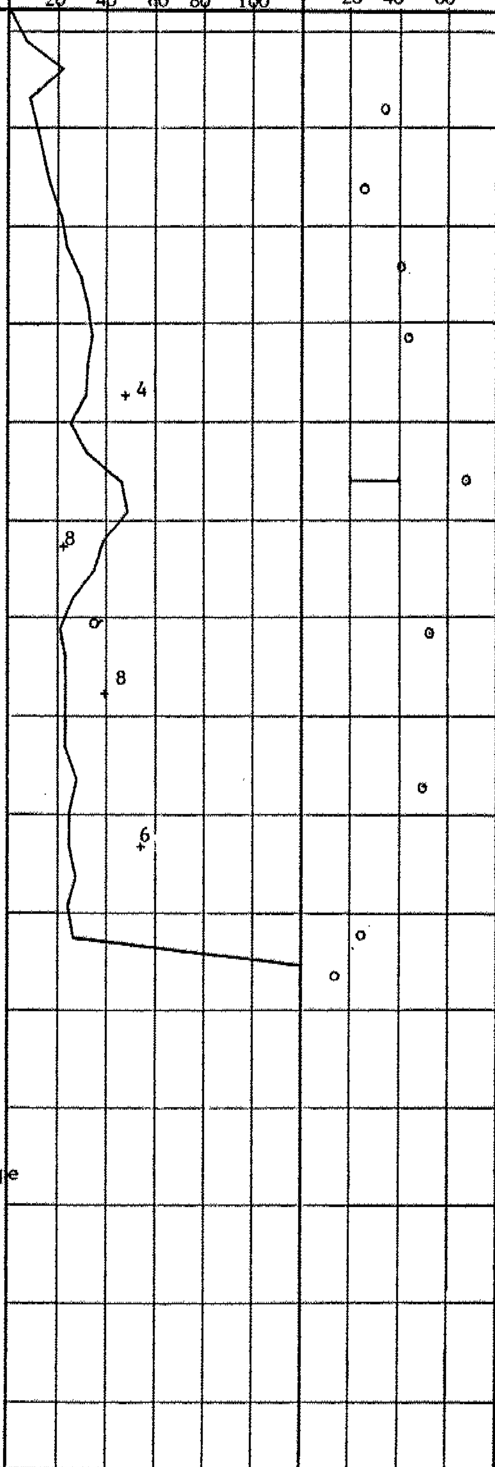
ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.2	Ground Surface							
0.0	Sandy Silt					89.0		W.L. on 1990 10 26
	Very Loose	1	SS	4		88.0		
	Brown	2	SS	4				
87.1 / 2.1	Clayey Silt to Silty Clay Desiccated Crust Firm	3	SS	4		87.0		
		4	SS	2		86.0		
						85.0		
	Soft to Firm	5	TW	PM		84.0		
		6	TW	PM		83.0	15.6	
	Grey					82.0		
		7	TW	PM		81.0		
					Seal	80.0		
79.8 / 9.4	Sand and Gravel trace to some Silt (Glacial Till)	8	SS	9				
		9	SS	88/20 cm		79.0		12 78 (10)
	Very Dense					78.0		
	Grey				Standpipe			
77.3 / 11.9	Limestone Bedrock	10	BX RC	Rec 68%		77.0		RQD = 36%
	Fractured					76.0		
		11	BX RC	Rec 81%				RQD = 13%
		12	BX RC	Rec 100%		75.0		RQD = 16%
74.3 / 14.9	End of Borehole							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT W_p — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 20 40 60



+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3

METRIC

W P 371-89-03 | LOCATION N 4,998,496 ; E 369,706 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test. | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 15 | CHECKED BY C.M.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	ELEVATION SCALE	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
88.8	Ground Surface						
0.0	Sandy Silt, Very Loose, Brown						W.L. on 1990 10 18
					88.0		
		1	SS	4			
		2	SS	12	87.0		
87.1 / 1.7	Clayey Silt to Silty Clay						
		3	SS	5			
					86.0		
		4	TW	PM			
	Firm				85.0		
		5	TW	PM	84.0	15.2	Consol. test Figure 4
	Grey				83.0		
		6	TW	PM		15.6	
					82.0		
		7	TW	PM	81.0		
80.6 / 8.2	End of Sampled Borehole. Probable Clayey Silt to Silty Clay				80.0		
79.6 / 9.2	Probable Sand and Gravel (Glacial Till)				79.0		
78.8 / 10.0	End of Borehole						

Column headings also printed: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60.

+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 4

METRIC

W P 371-89-03 — LOCATION N 4,998,546 ; E 369,660 — ORIGINATED BY A.A.

DIST 9 HWY 416 — BOREHOLE TYPE Hollow Stem Auger; Dynamic Cone Penetration Test — COMPILED BY A.K.

DATUM Geodetic — DATE 1990 10 16 — CHECKED BY C.M.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.7	Ground Surface						
0.0	Silty Sand to Sandy Silt some Gravel (Glacial Till)					89.0	
		1	SS	28			15 40 (45)
	Compact to Very Dense	2	SS	13	▼	88.0	W.L. on 1990 10 26
	Brown	3	SS	17		87.0	
		4	SS	16		86.0	
		5	SS	100			
	trace Gravel	6	SS	32		85.0	9 47 (44)
84.5 / 5.2	Sand and Gravel trace to some Silt (Glacial Till)	7	SS	100		84.0	
		8	SS	42		83.0	13 66 (21)
	Dense to Very Dense					82.0	
		9	SS	51		81.0	
	Grey	10	SS	100/25cm		80.0	
					Standpipe	79.0	
78.4		11	SS	100/16.5cm			19 69 (12)
11.3	Limestone Bedrock Fractured	12	BX RC	Rec 76%		78.0	RQD = 11%
77.5 / 12.2	End of Borehole						

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100

Shear Strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

Plastic Limit W_p — Natural Moisture Content W — Liquid Limit W_L — Water Content (%) 20 40 60

Unit Weight γ

+3, ×5 : Numbers refer to Sensitivity

15 ⌖ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No5

METRIC

W P 371-89-03 | LOCATION N 4,998,586 ; E 369,634 | ORIGINATED BY A.A.

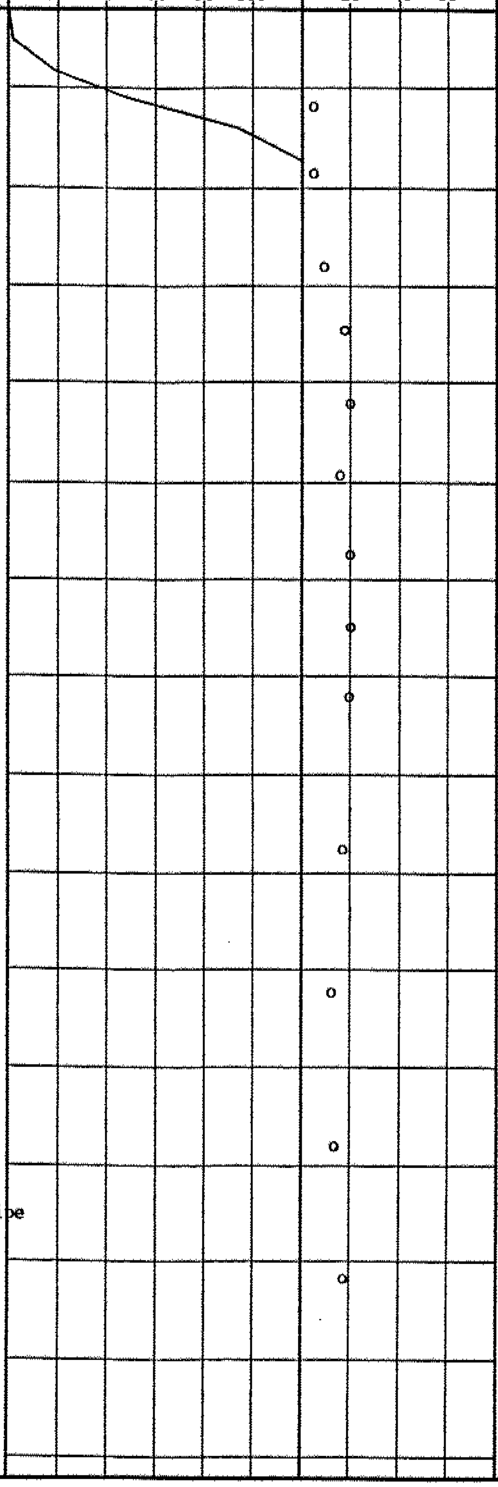
DIST 9 HWY 416 | BOREHOLE TYPE Wash Casing , Dynamic Cone Penetration Test | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 17 | CHECKED BY C.M.

OFFICE REPORT ON SOIL EXPLORATION

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
92.8	Ground Surface						
0.0	Silty Sand to Sandy Silt some Gravel (Glacial Till)					92.0	
		1	SS	104			
		2	SS	50		91.0	18 49 (33)
	Very Dense to Dense	3	BX	Boulder			
		4	SS	40		90.0	
	Brown	5	SS	33			W. L. on 1990 10 26
					▼	89.0	
		6	SS	44			
	Grey	7	SS	47		88.0	
		8	SS	44		87.0	
86.2		9	SS	34			
6.6	Sand and Gravel trace to some Silt (Glacial Till)					86.0	
		10	SS	59			0 87 (13)
						85.0	
	Very Dense	11	SS	58		84.0	
	Grey	12	SS	112		83.0	
						82.0	
		13	SS	65		81.0	
	Gravelly Zone				Standpipe		
79.5		14	SS	100/10cm		80.0	34 44 (22)
13.3	Limestone Bedrock	15	BX RC	Rec 82%		79.0	RQD = 0%
	Fractured	16	BX RC	Rec 94%			RQD = 18%
77.8		17	BX	Rec 100%		78.0	RQD = 48%
15.0							

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 — SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE 20 40 60 80 100 — PLASTIC LIMIT Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT WL — WATER CONTENT (%) 20 40 60 — UNIT WEIGHT γ



Continued on page 2

$+^3, \times^5$: Numbers refer to Sensitivity   15 ⟡ 5 (20/10) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No5 cont'd METRIC

W P 371-89-03 LOCATION N 4,998,586 ; E 369,634 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Wash Casing , Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 17 CHECKED BY C.M.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT W_p NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
77.8	Cont. from page 1										
15.0	Limestone Bedrock Excellent Quality Sound		18	BX RC	Rec 100%		77.0				RQD = 100%
			19	BX RC	Rec 100%		76.0				RQD = 100%
75.4 17.4	End of Borehole										

OFFICE REPORT ON SOIL EXPLORATION

$+^3$, $\times^5$: Numbers refer to Sensitivity

15 ⌖ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No6

METRIC

W P 371-89-03 LOCATION N 4,998,575 ; E 369,626 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Wash Casing COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 17 CHECKED BY C.M.

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
92.4	Ground Surface					
0.0	Silty Sand to Sandy Silt Some Gravel (Glacial Till)				92.0	
		1	SS	100/16cm		
					91.0	
		2	SS	138/28cm		21 52 (27)
	Very Dense	3	BX	Boulder	90.0	
		4	SS	67		
	Brown	5	SS	88	89.0	W.L. on 1990 10 22
	Fine Sand Zone	6	SS	104/20cm		0 68 (32)
					88.0	
		7	SS	100/25cm		
		8	SS	100/22cm	87.0	
	Silty Zone	9	SS	100/25cm	86.0	0 32 (68)
85.7 / 6.7	Sand and Gravel trace to some Silt (Glacial Till)				85.0	
		10	SS	106/18cm		
	Very Dense				84.0	
	Grey	11	SS	110/23cm	83.0	
					82.0	
		12	SS	124		
					81.0	
80.0		13	SS	127/25cm		0 94 (6)
12.4	End of Borehole					

GROUND WATER CONDITIONS: Standpipe

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT W_p — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ

+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 7

METRIC

W P 371-89-03 LOCATION N 4,998,595 ; E 369,619 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 17 CHECKED BY C.M.

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	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) 20 40 60 80 100	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
92.7	Ground Surface										
0.0	Silty Sand with Gravel (Glacial Till)					*					
							92.0				
			1	SS	74				o		
	Very Dense						91.0				
			2	SS	100				o		24 47 (29)
	Brown		3	SS	50/7.5cm				o		
							90.0				
89.4			4	SS	93/23cm				o		
3.3	End of Borehole * Borehole Dry upon Completion										

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

15 -◇- 5 (%) STRAIN AT FAILURE (20 above, 10 below)

Ministry of Transportation Ontario

RECORD OF BOREHOLE No8

METRIC

W P 371-89-03 LOCATION N 4,998,522 ; E 369,688 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 22 CHECKED BY C.M.

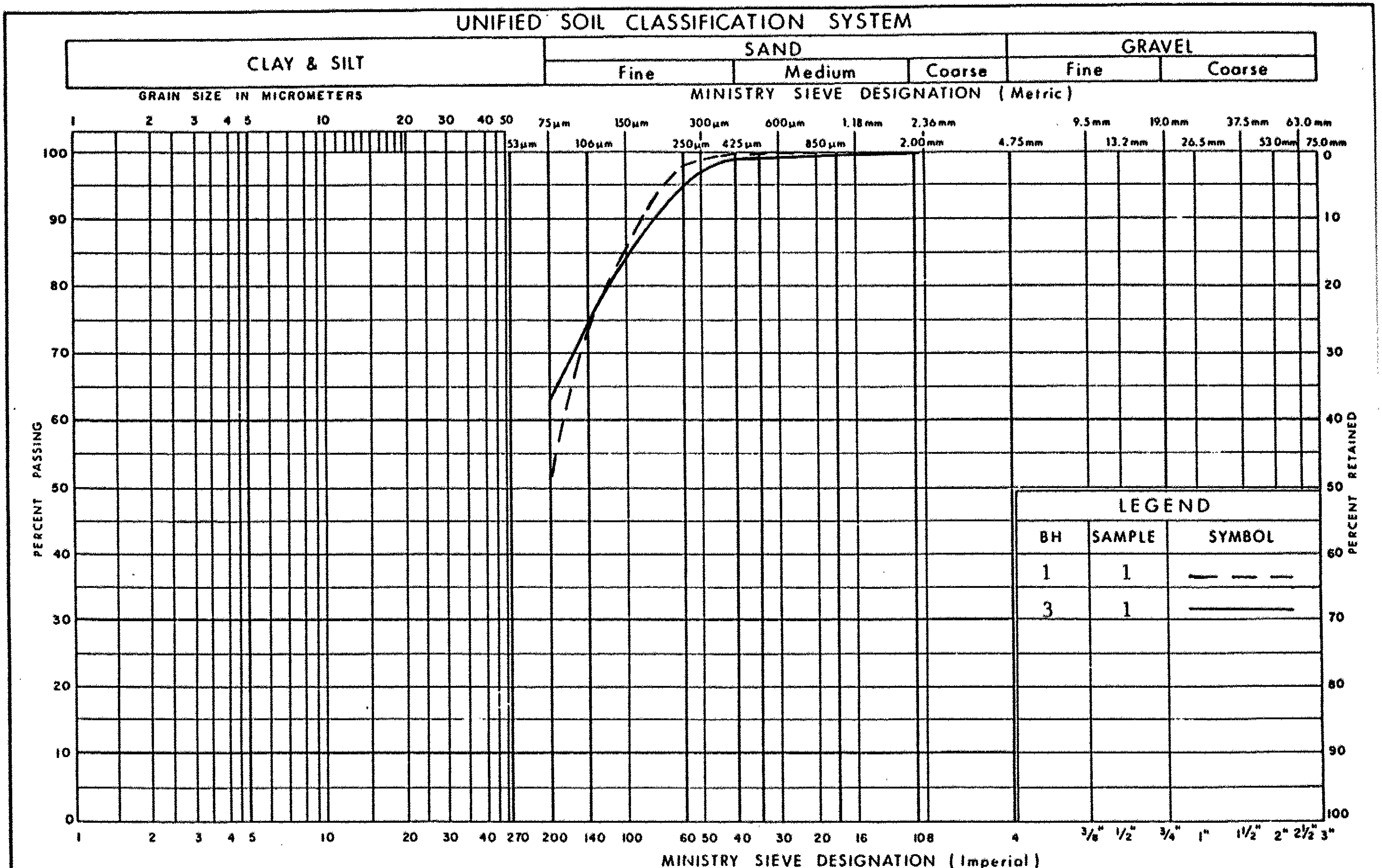
ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.3	Ground Surface									
0.0	Sandy Silt, Loose, Grey				▽	89.0				W.L. on 1990 10 22
						88.0				
		1	SS	8						
87.1 / 2.2	Clayey Silt to Silty Clay, Firm, Grey					87.0				
		2	SS	6		86.0				
		3	SS	1		85.0				
		4	SS	1						
						84.0	+7			
		5	SS	3		83.0				
							+5			
82.0 / 7.3	Sand and Gravel tr. to some Silt(Till) V. Dense Grey					82.0				
81.3		6	SS	100/25 cm						0 96 (4)
8.0	End of Borehole									

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

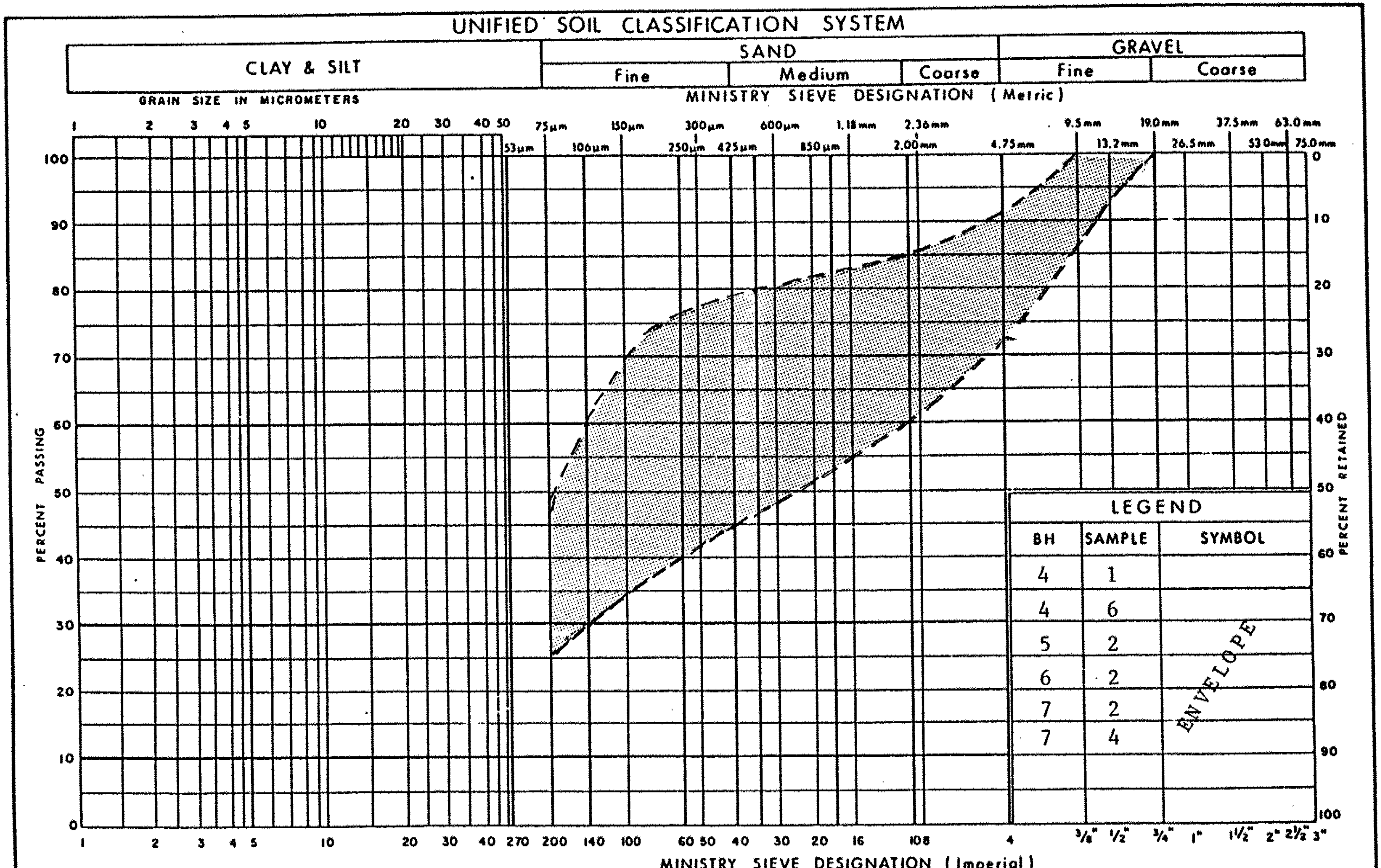
20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

78 12 M



Ministry of Transportation, Ontario	GRAIN SIZE DISTRIBUTION	FIG No 1
	Sandy Silt	W P 371-89-03
		Thirdline Rd. Underpass

78 12 M



Ministry of Transportation

Ontario

GRAIN SIZE DISTRIBUTION

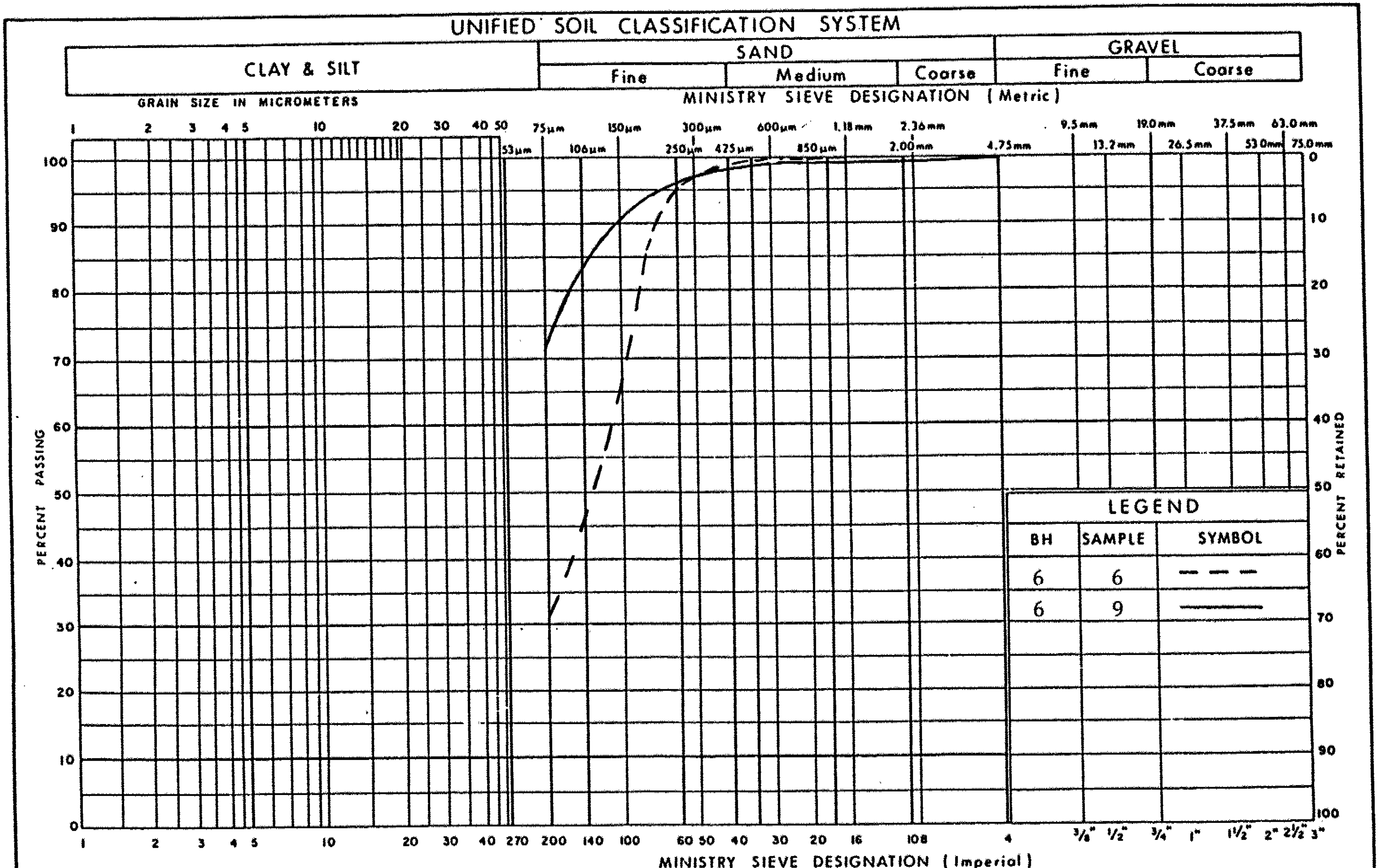
Silty Sand to Sandy Silt
with Some Gravel (Glacial Till)

FIG No 2A

W P 371-89-03

Thirdline Rd. Underpass

78 12 M



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

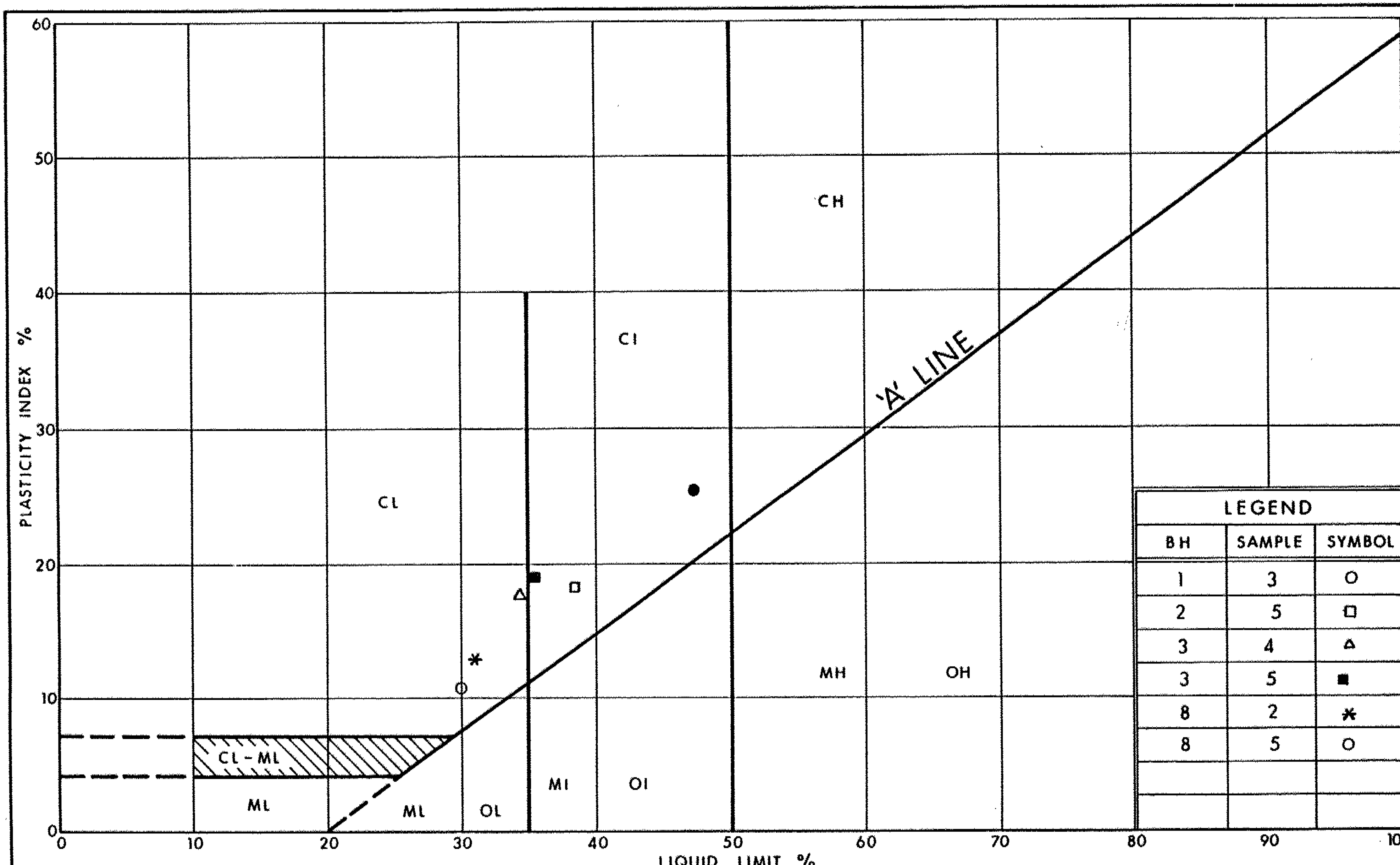
Fine Sand and Silt Zones
within Glacial Till

FIG No 2B

W P 371-89-03

Thirdline Rd. Underpass

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
1	3	○
2	5	□
3	4	△
3	5	■
8	2	*
8	5	○

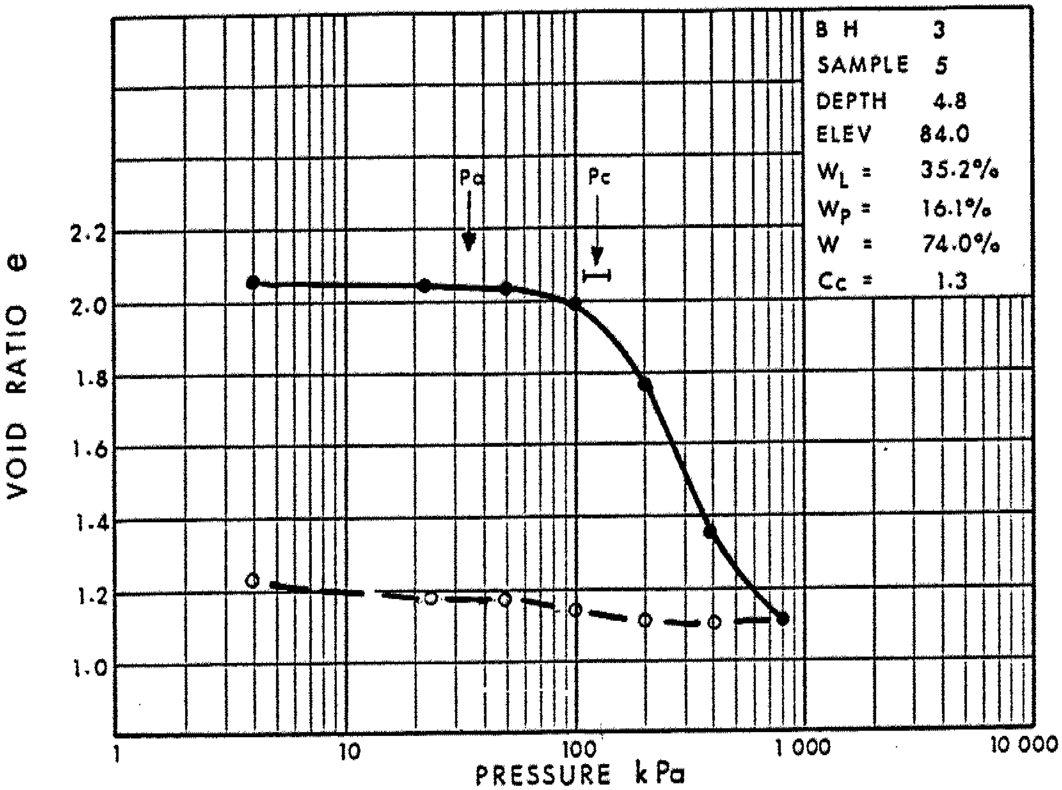
Ministry of Transportation
Ontario

PLASTICITY CHART

Clayey Silt to Silty Clay

FIG No 3
W P 371-89-03
Thirdline Rd. Underpass

VOID RATIO - PRESSURE CURVES



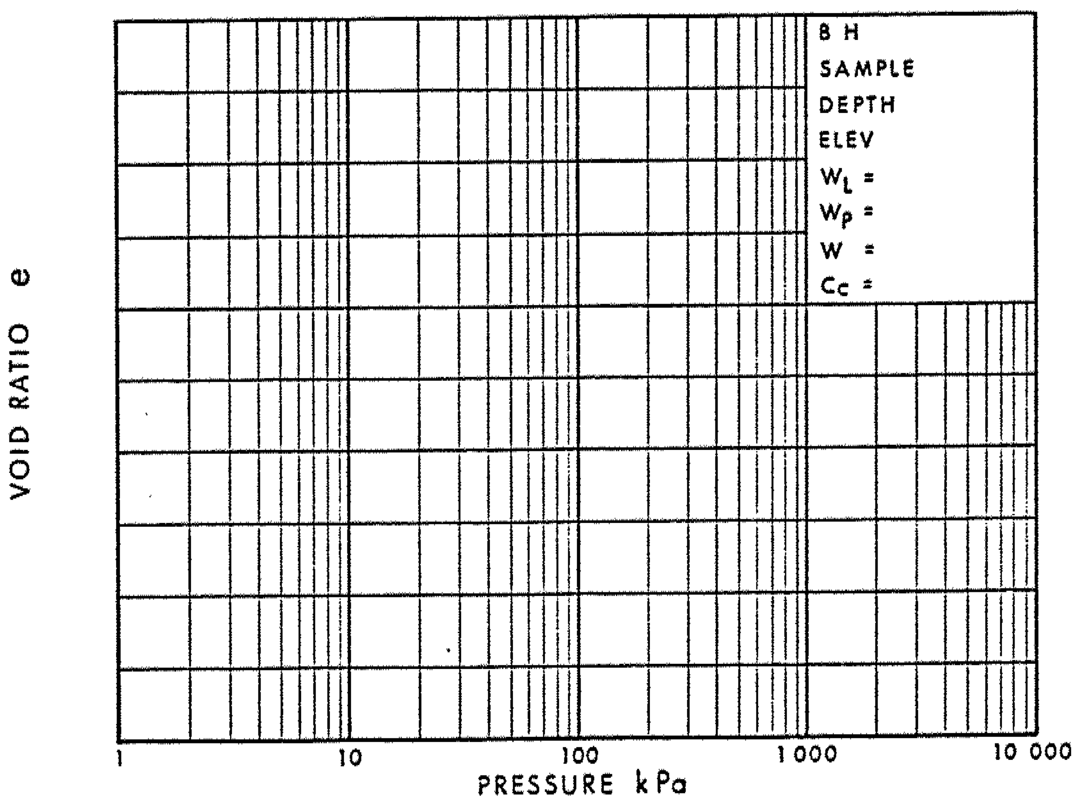
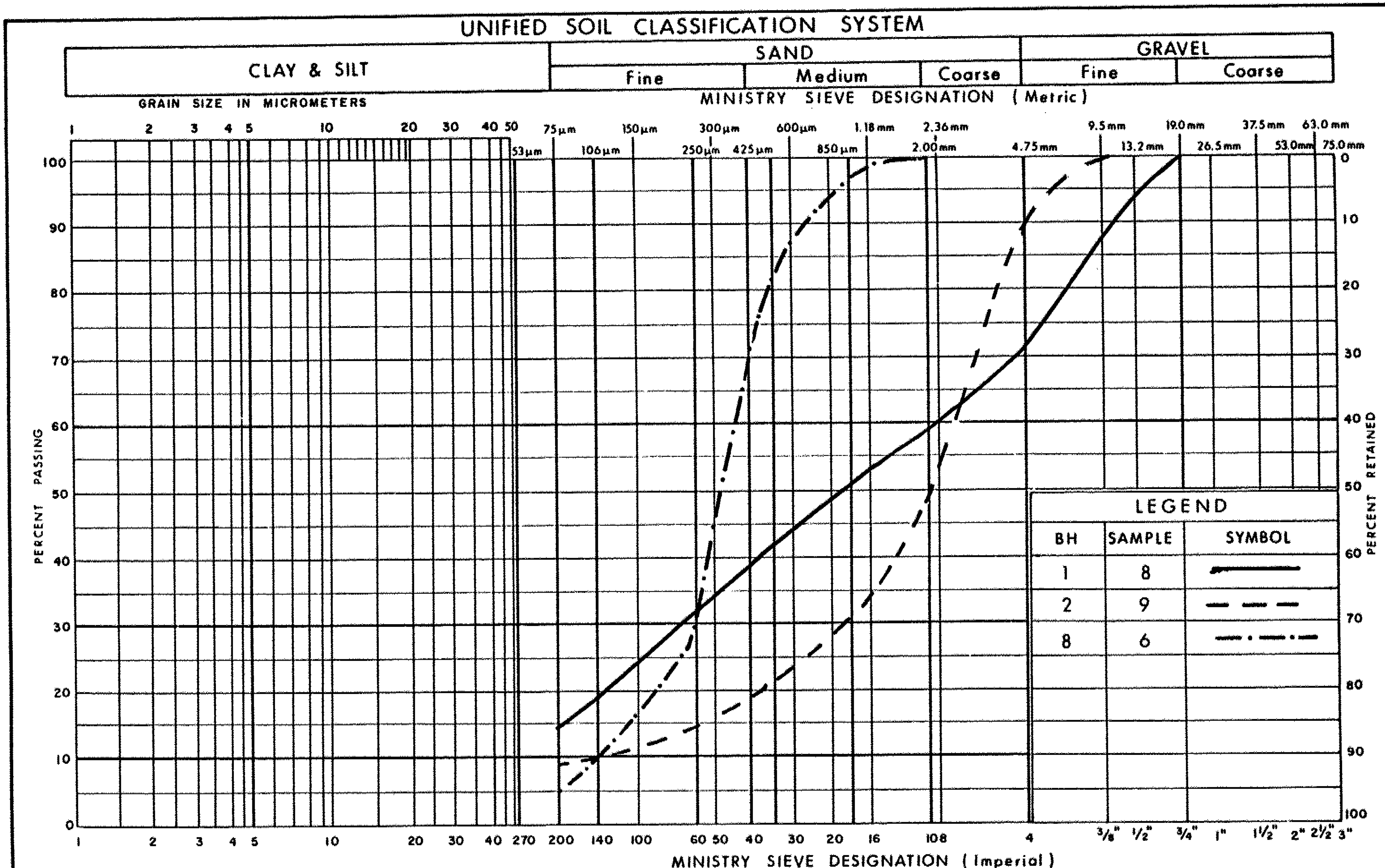


Fig 4

78 12 M



Ministry of Transportation

Ontario

GRAIN SIZE DISTRIBUTION

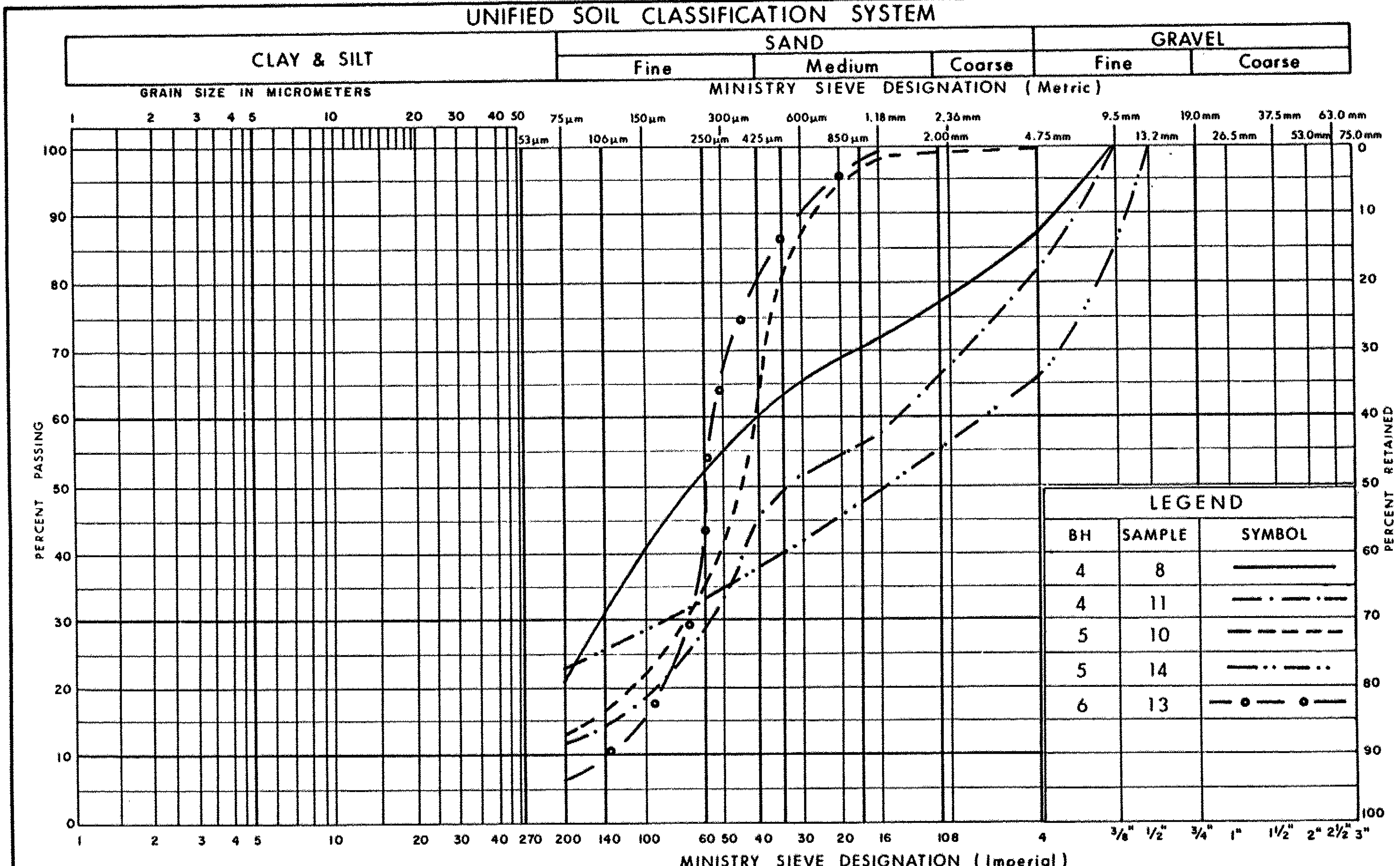
Sand and Gravel
Trace to Some Silt (Glacial Till)

FIG No 5A

W P 371-89-03

Third Line Rd. Underpass

78 12 M



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

Sand and Gravel
Trace to Some Silt (Glacial Till)

FIG No 5B

W P 371-89-03

Thirdline Rd. Underpass

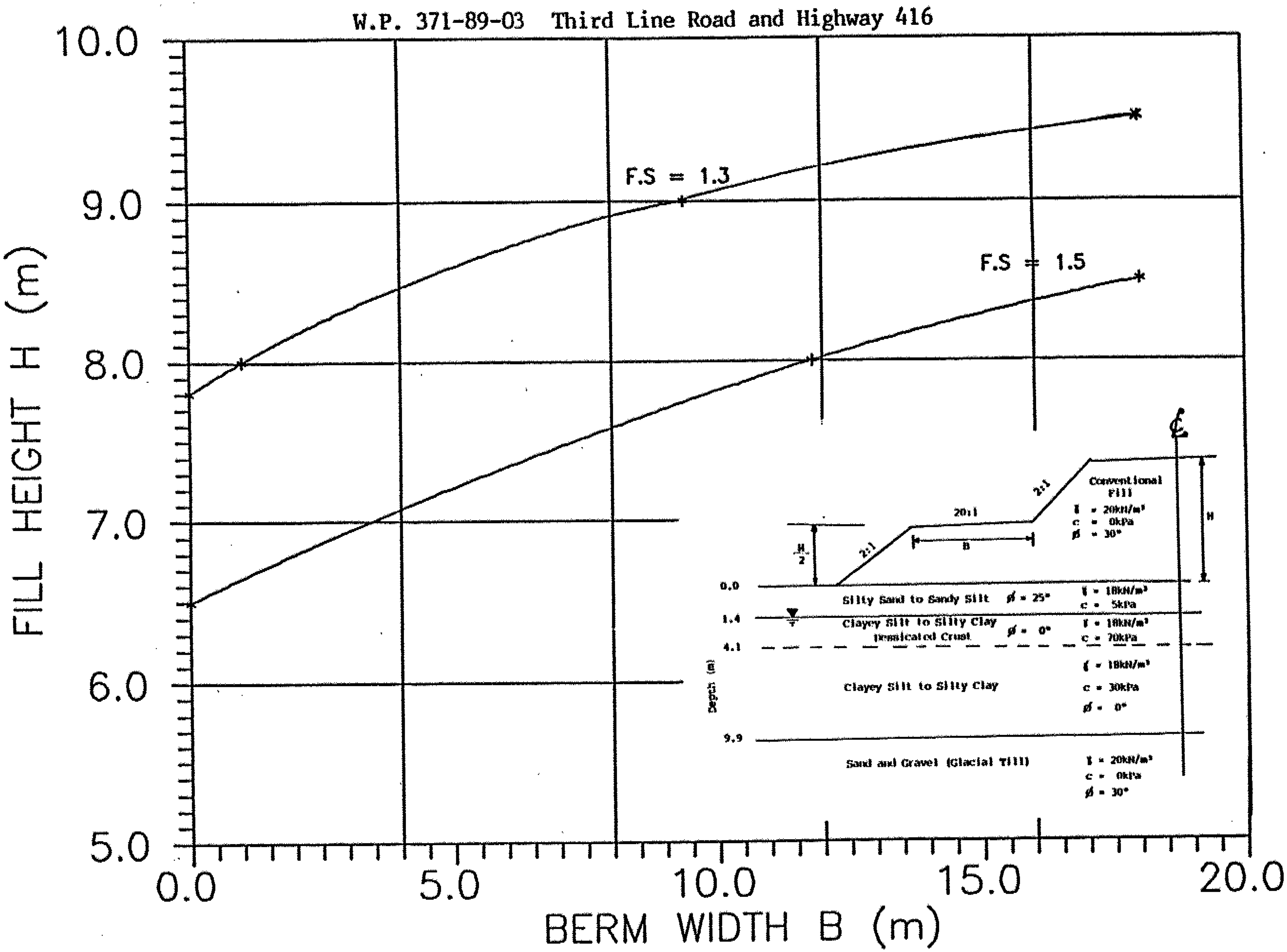
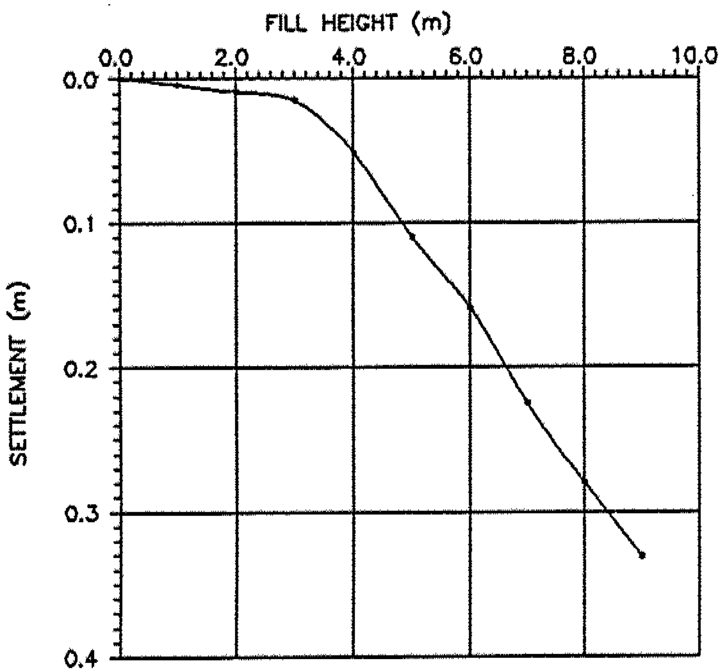


Figure 6 RESULTS OF STABILITY ANALYSES



c_c = 1.3
c_v = 0.0036 cm²/min
p_c = 120 kPa
p_o = 35 kPa
e_o = 2.05
W = 74.0%
W_L = 35.2%
W_p = 16.1%

Figure 7A

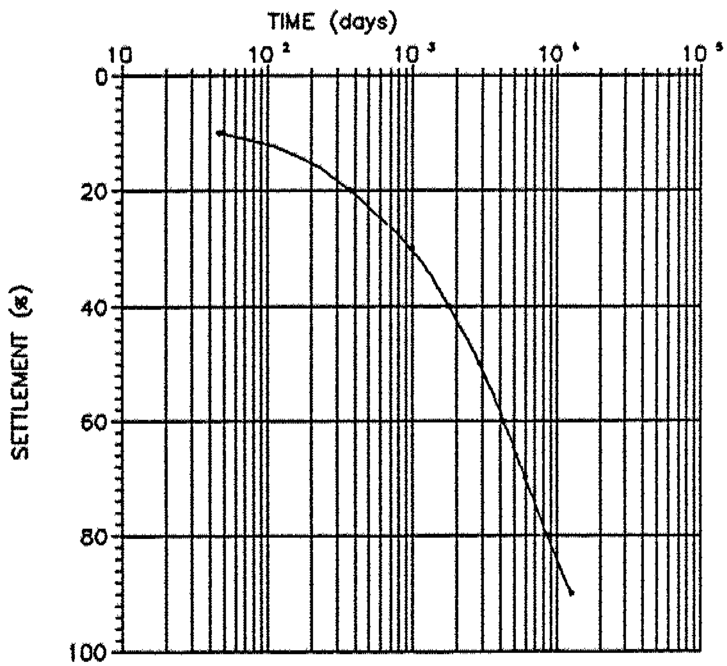


Figure 7B

METRIC

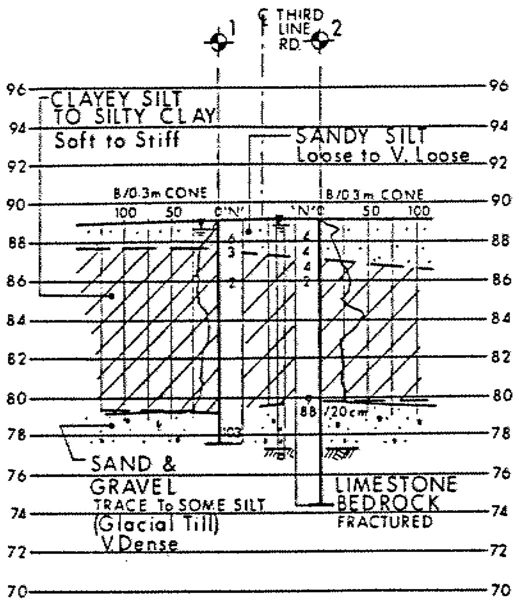
DIMENSIONS ARE IN METRES AND / OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No
WP No 371-89-03

THIRD LINE ROAD U'PASS
BORE HOLE LOCATIONS & SOIL STRATA

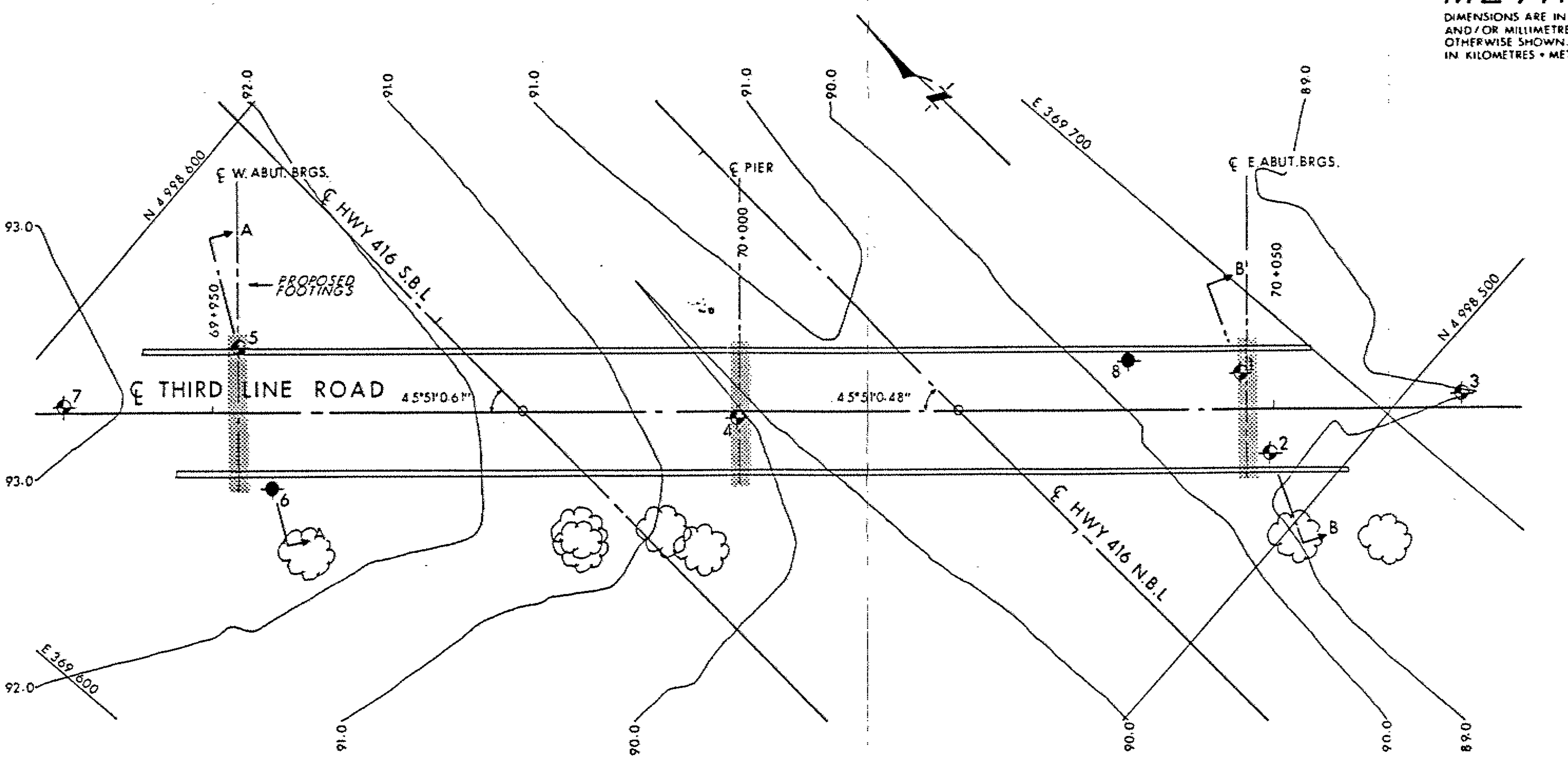
SHEET

STRATA ENGINEERING CORP.

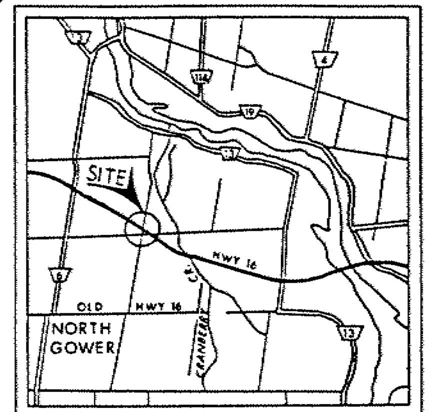


SECTION B-B

SCALE FOR SECTIONS
HOR 5m 0 5m
VERT 5m 0 5m



PLAN
SCALE 5m 0 5m

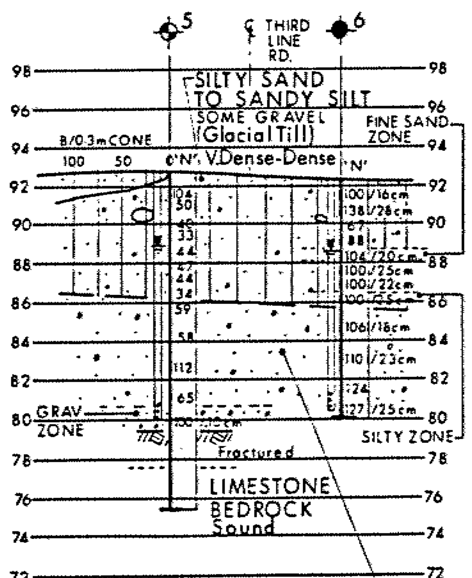


KEY PLAN
SCALE 1km 0 1 2km

LEGEND

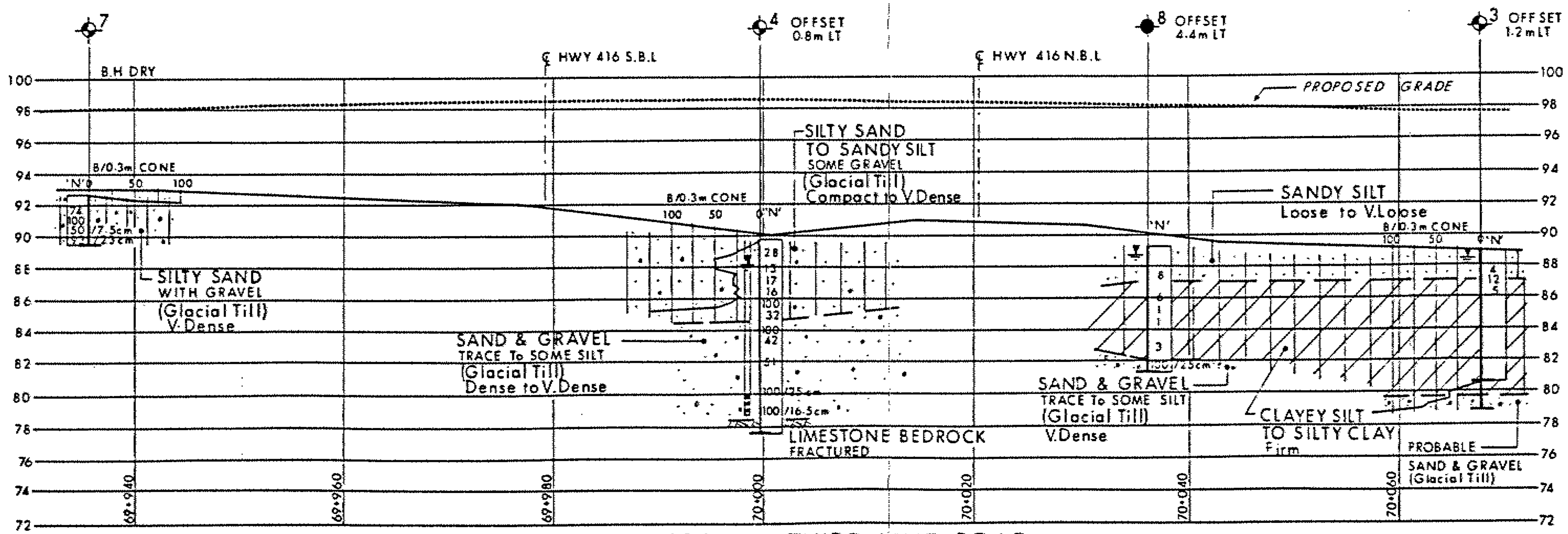
- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N — Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE — Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation Oct 1990
- Stand Pipe

No	ELEVATION	CO-ORDINATES NORTH	CO-ORDINATES EAST
1	89.1	4 998 513	369 694
2	89.2	4 998 506	369 690
3	88.8	4 998 496	369 706
4	89.7	4 998 546	369 660
5	92.8	4 998 586	369 634
6	92.4	4 998 575	369 626
7	92.7	4 998 595	369 619
8	89.3	4 998 522	369 688



SECTION A-A

SAND & GRAVEL
TRACE To SOME SILT
(Glacial Till)
V. Dense



℄ PROFILE THIRD LINE ROAD
SCALE
HOR 5m 0 5m
VERT 5m 0 5m

REF No E-55-416-6: 91 02

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.

REV.	DATE	BY	DESCRIPTION

Geocres No 31G-212

HWY No 416			DIST 9
SUBM'D A A	CHECKED	DATE Apr 04 1991	SITE 3-575
DRAWN A K	CHECKED	APPROVED	DWG 3718903-A