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W.P. No.

CONT. No.

W. O. No. 84-05-0022

STR. SITE No.

HWY. No. 11

LOCATION HWY 11 & 534

(TOWN OF POWASSAN)

PROPOSED INTERCHANGE

=====

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:



Ministry of
Transportation and
Communications

foundation investigation and design report

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WO 84-05-0022

DIST 13

HWY 11 & 534

STR SITE

Preliminary Foundation Investigation
for Proposed Interchange at Hwys. 11 & 534

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PRELIMINARY FOUNDATION INVESTIGATION

For

Proposed Interchange at Hwys. 11 and 534

W.O. 84-05-0022

District 13, North Bay

INTRODUCTION

This report summarizes the subsurface information obtained from a preliminary foundation investigation carried out at the above-noted site between 85-03-18 and 85-03-26.

The fieldwork for this investigation consisted of 8 sampled boreholes advanced by means of hollow stem augers. The boreholes ranged from 3.7 m to 32.3 m in depth below the existing ground surface.

Five boreholes were advanced for the structure in Scheme "A" (BH1 - BH4, and BH1-A), two for the structure in Scheme "B" (BH5, BH6), and an additional borehole at the existing culvert north of the Scheme "B" structure.

SITE DESCRIPTION

The site is located in the Town of Powassan, Township of North Himsforth, District of Parry Sound. As reported by Gartner, J. F. in "Northern Ontario Engineering Geology Terrain Study", this site is situated near the boundary of glaciofluvial and glaciolacustrine deposits. It is however, likely that the material encountered across this site is of glaciolacustrine origin.

Topography across the area is generally flat to rolling. Surface drainage is poor in many areas. Specifically at this site, however, surface drainage is facilitated by roadside ditches and a creek immediately north of the site.

SUBSURFACE CONDITIONS

General

The Record of Borehole Sheets in the Appendix illustrate the soil conditions at each borehole location. The location of the boreholes are shown in plan in Figure A in the Appendix.

Subsurface Conditions - Scheme "A" (BH1 - BH4)

=====

Extending from the ground surface down to a maximum depth of 8.7 m is a deposit of soft to firm silty clay, trace sand. The bottom of this deposit varies in elevation from Elev. 243.5 in BH4 to Elev. 236.7 in BH3. This indicates a slope downward from west to east.

Underlying this cohesive deposit is a silt, trace sand, clay stratum. This non-cohesive deposit varies in thickness from 1.5 m to 3.8 m and is generally in a very loose to loose state.

Below this silt layer is a deposit of sand and silt of an undetermined depth. This non-cohesive material is very loose to loose in the upper zones, however, it becomes more dense with depth. As determined in BH1, the gravel content of this material increases at about Elev. 228.

The following is a description of the soils encountered in BH1, 1-A, 2, 3, and 4.

Sand and Gravel (Shoulder Fill)

This non-cohesive material was found in the shoulder area of Clarke Street and had a thickness of approximately 0.8 m. No field or laboratory tests were conducted on this material.

Silty Clay, trace sand

This cohesive material was encountered in all five boreholes. It forms the surficial deposit in all holes except BH1 where it underlies the Sand and Gravel fill described above. The thickness of this layer ranges from 4.1 m to 8.7 m. The bottom of this deposit varies in elevation from Elev. 243.5 in BH4 to Elev. 236.7 in BH3. This indicates a downwards slope to the east.

The results of Atterberg Limits testing carried out on seven samples of this material are shown on Figure 1, in the Appendix. The material ranges from a plastic silt to a silty clay of low plasticity (ML-CL group) to a clay of high plasticity (CI group). The test results can be summarized as follows:

		<u>Range</u>
Natural Moisture Content (W)		27 - 55%
Liquid Limit	(W _L)	24 - 53%
Plastic Limit	(W _p)	18 - 24%
Plasticity Index	(I _p)	4 - 33%

Based on the results of field vane tests, unconfined compression tests and Standard Penetration Test 'N' values, this material is assessed to have a consistency of soft to stiff.

The values of undrained shear strength obtained using the field vane range from 34 to 64 kPa with a range in sensitivity of 4 to 8.

The grain size distribution of this material is shown in envelope form on Figure 2 and can be summarized as follows:

	<u>Range</u>
Gravel	0%
Sand	1 - 7%
Silt	36 - 83%
Clay	13 - 63%

The unit weight of this material, as measured in three undisturbed samples, ranges from 16.7 to 17.8 kN/m³.

It is to be noted that within this generally cohesive deposit, occasional thin seams of silt are encountered.

Silt, trace sand, trace clay

This non-cohesive deposit was encountered in all boreholes with the exception of BH1-A which was terminated in the silty clay zone described above. This layer was shown to have a thickness of 3.8 m in BH1 and 1.5 m in BH4. Boreholes BH2 and BH3 were terminated in this deposit and thus its extent was not proven.

The grain size distribution of this material is shown in envelope form on Figure 3. The distribution can be summarized as follows:

	<u>Range</u>
Gravel	0%
Sand	2 - 7%
Silt	90 - 93%
Clay	3 - 6%

The measured natural water content of this material ranges from 25.5% to 26.5%.

Based on the interpretation of Standard Penetration Test 'N' values ranging from 4 to 15 blows/0.3 m this material is assessed to be in a loose to compact state.

Sand and Silt

This non-cohesive material was encountered in BH1 and BH4 only. The extent of this material was not proven as both boreholes were terminated in this material. In BH1 the material was proven for 14.6 m.

The grain size distributions of three samples of this material are shown on Figure 4.

The information can be summarized as follows:

	<u>Range</u>
Gravel	0 - 46%
Sand	38 - 59%
Silt	13 - 159%
Clay	0 - 3%

It should be noted that below Elev. 228, the gravel content increases with depth.

The natural water content of this material ranges from 6.5 to 25% with an average of 17%, based on the results of three tests.

Based on an interpretation of Standard Penetration Test 'N' values ranging from 1 to 96 blows/0.3 m this material is assessed to be in a very loose to very dense state. Above Elev. 228, the material is in a very loose state. Below Elev. 228, the material ranges from compact to very dense.

Groundwater Conditions

The groundwater level in BH1, BH3, and BH4 was determined by measuring the stabilized water level in open boreholes. The groundwater level ranged from Elev. 236.5 in BH1 to Elev. 241 in BH4.

Subsurface Conditions - Scheme 'B' (BH5, BH6)

=====

In BH5, silty clay, trace sand was encountered from the ground surface down to a depth of 4.9 m. Occasional silt seams were also encountered within this cohesive material.

Underlying this silty clay deposit in BH5, and existing as the surficial material in BH6 is a deposit of silt, trace sand, clay. The full extent of this non-cohesive deposit was not investigated in BH5. However, in BH6 this material extended down to a depth of 4.1 m (or Elev. 244.7).

Below this silt is a 25.2 m thick deposit of sand, trace silt clay. The denseness of this material changes throughout the stratigraphy.

Extending from Elev. 219.6 to an undetermined depth, and underlying the sand deposit is a mixture of a very dense mixture of gravel and sand.

The following is a description of the soils encountered in BH5 and BH 6.

Silty Clay

This material was encountered in BH5 extending from the ground surface down to a depth of 4.9 m (Elev. 240.5).

The results of two Atterberg Limits tests are shown on Figure 5. Based on the results of these two tested samples, it appears that this material ranges from a plastic silt (ML group) to a silty clay of intermediate plasticity (CI group).

Based on the interpretation of field vane tests, unconfined compression tests and Standard Penetration Test 'N' values, this cohesive material is assessed to have a consistency of firm to stiff.

The value of the undrained shear strength of this material obtained using the field vane is approximately 75 kPa, with the associated sensitivity of 5 to 6.

A grain size distribution test was conducted on one sample of this material and the results are shown on Figure 6. The distribution can be summarized as follows:

Clay	46%
Silt	53%
Sand	1%
Gravel	0%

The unit weight of this material, as measured in one undisturbed sample, is 17.0 kN/m³.

It is to be noted that within this generally cohesive deposit, occasional thin seams of silt are encountered.

Silt, trace sand, clay

Underlying the silty clay deposit in BH5 and existing as the surficial deposit in BH6 is a deposit of silt, trace sand, clay. The full extent of this non-cohesive deposit was not investigated in BH5. However, in BH6, this material extended down to a depth of 4.1 m (or to Elev. 244.7).

The results of grain size distribution tests carried out on two samples of this material are shown on Figure 7 and can be summarized as follows:

	<u>BH5, #4</u>		<u>BH6, #5</u>
Gravel	0%	,	0%
Sand	6%	,	6%
Silt	88%	,	90%
Clay	6%	,	4%

Based on the interpretation of 'N' values, this material is in a compact state in BH6, while in BH5 this silt is in a very loose state.

It is to be noted that "boiling" will result if this material is subjected to an unbalanced hydrostatic pressure.

Sand, trace silt, clay

This material was encountered in BH6 underlying the silt. This non-cohesive deposit extends from Elev. 244.1 to Elev. 219.6.

The results of grain size distribution tests conducted on three samples of this material are shown in envelope form on Figure 8.

The results can be summarized as follows:

	<u>Range</u>
Gravel	0%
Sand	86% - 93%
Silt	6% - 13%
Clay	1%

Based on 'N' values of 14-30 blows/0.3 m this material is in a compact to dense state between Elev. 244.7 and Elev. 240. Based on 'N' values of 2 to 16 blows/0.3 m, this material is in a loose to compact state between Elev. 240 and Elev. 224. At Elev. 228.5 an 'N' value of 56 blows/0.3 m was obtained. However, it is believed that this value is not typical of this deposit. This unrealistically high 'N' value could be a result of an encountered piece of gravel or cobble. Between Elev. 224 and Elev. 219.6 this material is considered to be in a compact to dense state.

It should be noted that seams of silt and sand mixture and possibly only silt are included in this deposit.

Gravel and Sand

Extending from Elev. 219.6 to an undetermined depth, and underlying the sand deposit is a very dense mixture of gravel and sand.

The result of one grain size distribution test, carried out on one sample of this material can be summarized as follows:

<u>BH6, #15</u>	
Gravel	55%
Sand	36%
Silt	8%
Clay	1%

Groundwater Conditions

The groundwater level was not established in either BH5 or BH6. For estimating purposes it can be assumed that the groundwater level occurs approximately between Elev. 236 and 239. The precise level should, however, be determined prior to any design work.

Subsurface Conditions at BH7

Extending from the ground surface down to an undetermined depth is a non-cohesive deposit of sand with silt. The full extent of this deposit was not investigated as the borehole was terminated at a depth of 12.6 m below the existing ground surface.

The results of grain size distribution tests carried out on samples of this sand with silt are shown on Figure 9 and can be summarized as follows:

	<u>BH7, #2</u>	<u>BH7, #6</u>
Gravel	2%	1%
Sand	69%	66%
Silt	26%	31%
Clay	3%	2%

This deposit becomes more dense with depth. Based on 'N' values ranging from 2 to 20 blows/0.3 m, this material is in a very loose to compact state.

Groundwater Conditions

The groundwater level was encountered at Elev. 237.8+.

DISCUSSION AND RECOMMENDATIONS

In conjunction with the proposed widening of Hwy. 11, a full interchange is proposed for Hwys. 11 and 534. Currently, Hwy. 534 terminates at Hwy. 11 (west side) and Clarke Street continues to the east. Two schemes are presently under consideration.

Scheme 'A' requires a structure carrying Hwy. 534 over Hwy. 11 on the existing Clarke Street alignment. Scheme 'B' requires a structure carrying Hwy. 534 over Hwy. 11 approximately 200 m north of Clarke Street. Both schemes require approach fills of up to 6.5 m in height, and associated ramp fills of various heights.

The following recommendations are based on the preliminary investigation. These recommendations are presented for assessment purposes only and are not intended for the design of the structure foundations or construction of the fills. When a final scheme is selected a detailed foundation investigation will be required for both the structure foundations and the high fills.

Scheme 'A'

1. Slope Stability

Bishop's total stress analysis was used to determine the stability of a 6.5 m high fill (maximum unit weight of $2.2 \text{ t/m}^3 (21.5 \text{ kN/m}^3)$) constructed at the location of the structure approach. Figure B indicates the parameters and geometry used in the analysis. Using Bishop's method of analysis it appears that embankments having a height of 6.5 m will be stable with 2:1 front and side slopes.

Longitudinal or lateral berms are not required.

2. Settlements

Three consolidation tests were carried out on samples of the native silty clay. Based on the results of these tests estimated settlements of 100 to 150 mm can be anticipated under 6.5 m of fill. The majority of the settlement will occur within six months after construction. If necessary, the settlements could be accelerated by surcharging the fills. Otherwise the fills would have to remain in place for at least six months prior to paving.

3. Structure Foundations

The structure can be founded on piles using the following design parameters:

<u>Type</u>	<u>Size</u>	<u>U.L.S.</u> kN/pile	<u>S.L.S. II</u> kN/pile	<u>Tip Elevation</u> (m)
Steel H	310 x 110	1600	1150	220 ±
Steel H	310 x 79	1150	850	220 ±
Timber	36	290	200	227 ±

H-Pile driving should be controlled by using the Hiley Equation as per MTC standards, using on ultimate pile capacity of 3 x S.L.S. II value.

Depending on when the piles are driven, a reduction in the pile capacities may have to be applied to compensate for the effects of the anticipated downdrag.

Scheme 'B'

1. Slope Stability

Bishop's total stress analysis was used to determine the stability of a 6.5 m high fill (maximum unit weight of $2.2 \text{ t/m}^3 (21.5 \text{ kN/m}^3)$) constructed at the location of the structure approach. Figure B indicates the parameters and geometry used in the analysis. Using Bishop's method of analysis, it appears that embankments having a height of 6.5 m will be stable with 2:1 front and side slopes.

Longitudinal or lateral berms are not required.

2. Settlements

One consolidation test was carried out on a sample of the native silty clay. Based on the result of this test estimated settlements of 50 to 100 mm can be anticipated under 6.5 m of fill. The majority of the settlement will occur within two months after construction. The approach fills should remain in place at least two months prior to paving.

3. Structure Foundations

The structures can be founded on piles using the following parameters:

<u>Type</u>	<u>Size</u>	<u>U.L.S.</u> kN/pile	<u>S.L.S. II</u> kN/pile	<u>Tip Elevation</u> (m)
Steel H	310 x 110	1600	1150	214 ±
Steel H	310 x 79	1150	850	214 ±
Timber	36	290	200	227 ±

H-Pile driving should be controlled by using the Hiley Equation as per MTC standards, using an ultimate pile capacity of 3 x S.L.S. II value.

Depending on when the piles are driven, a reduction in the pile capacities may have to be applied to compensate for the effects of the anticipated downdrag.

General (for both Schemes 'A' and 'B')

- * Backfill to structures should consist of granular material in accordance with MTC Standard Special Provision #121 (83 10). Computation of earth pressures should be in accordance with Section 6.6.1.2 of the 1983 O.H.B.D.C. For design purposes, the physical properties of the backfill are as follows:

<u>Material</u>	<u>Ø</u>	<u>Unit Weight</u>
Granular 'A'	35 ⁰	22.0 kN/m ³
Granular 'B'	30 ⁰	21.2 kN/m ³

- * Active conditions apply for the design of the abutment.
- * For frost protection, earth cover of 1.9 m, or equivalent, is required.
- * All surficial organic material within 15 m back of the abutment and within the plan limits of the approach fills should be subexcavated and replaced with well-compacted granular material.
- * Any fill required below the prevailing groundwater level should consist of free draining, granular material.
- * In view of the existance of denser seams of material, pile tips should be reinforced or per MTC standards.
- * Dewatering most likely will not be required.

CLOSURE

The recommendations presented in this report are based on a preliminary investigation and are intended to be used for assessment purposes only. When a scheme is selected a standard foundation investigation will be required so that detailed analysis can be made and design parameters recommended for both the structure foundations and the approach fills.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of S. Winchester, Student Engineer, utilizing equipment owned and operated by Atcost Soil Drilling Inc. of Toronto. This report was prepared by L. Politano and I. Richardson, and reviewed by M.Devata, Chief Foundations Engineer (East).



A handwritten signature in black ink, appearing to read "L. Politano", followed by a horizontal line.

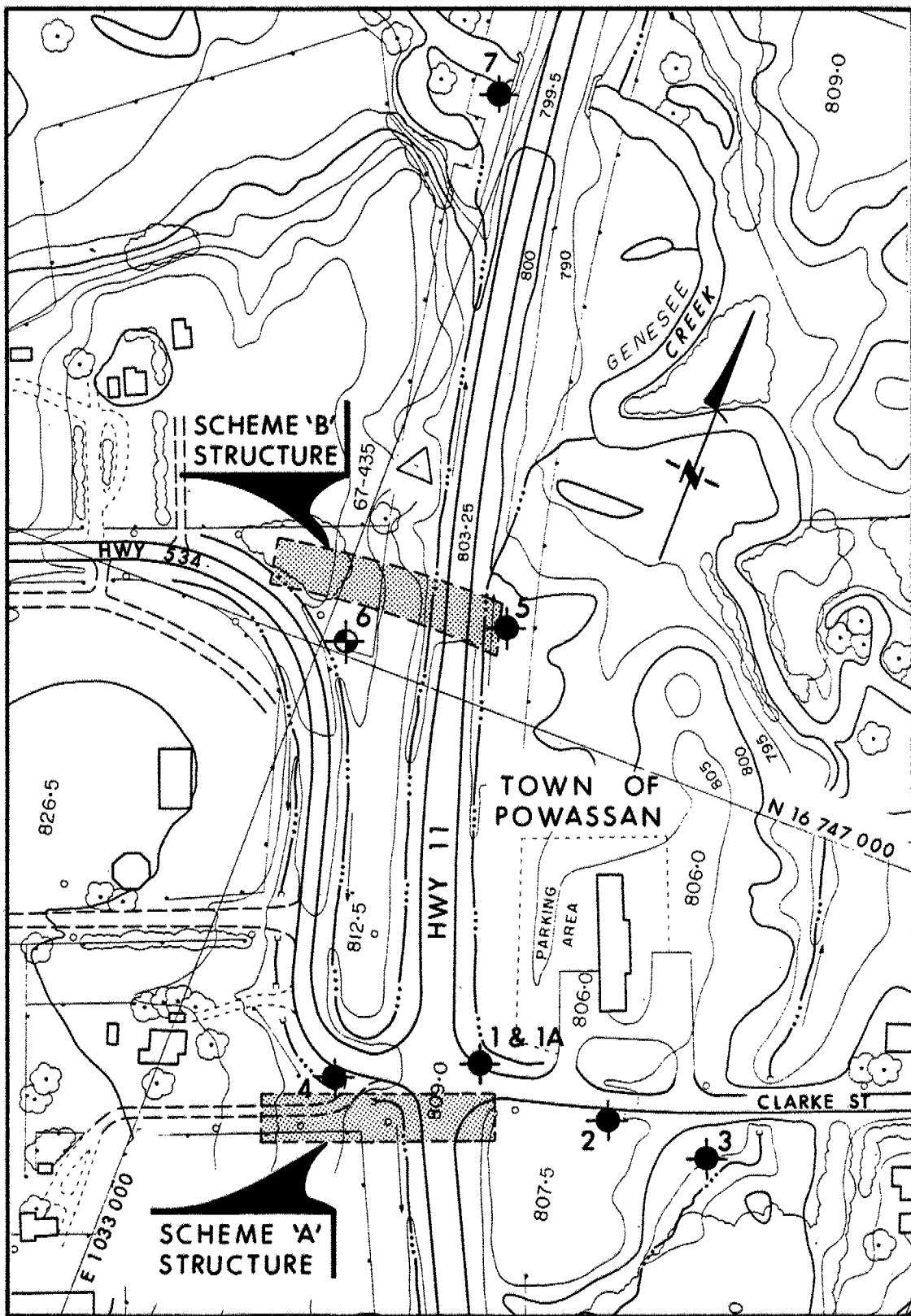
L. Politano, P. Eng.
Project Foundations Engineer

A handwritten signature in black ink, appearing to read "D. H. Dundas", with the word "for" written below it.

M. Devata, P. Eng.
Chief Foundations Engineer
(East)

August 1985

APPENDIX



IMPERIAL PLAN SCALE 1" = 200'

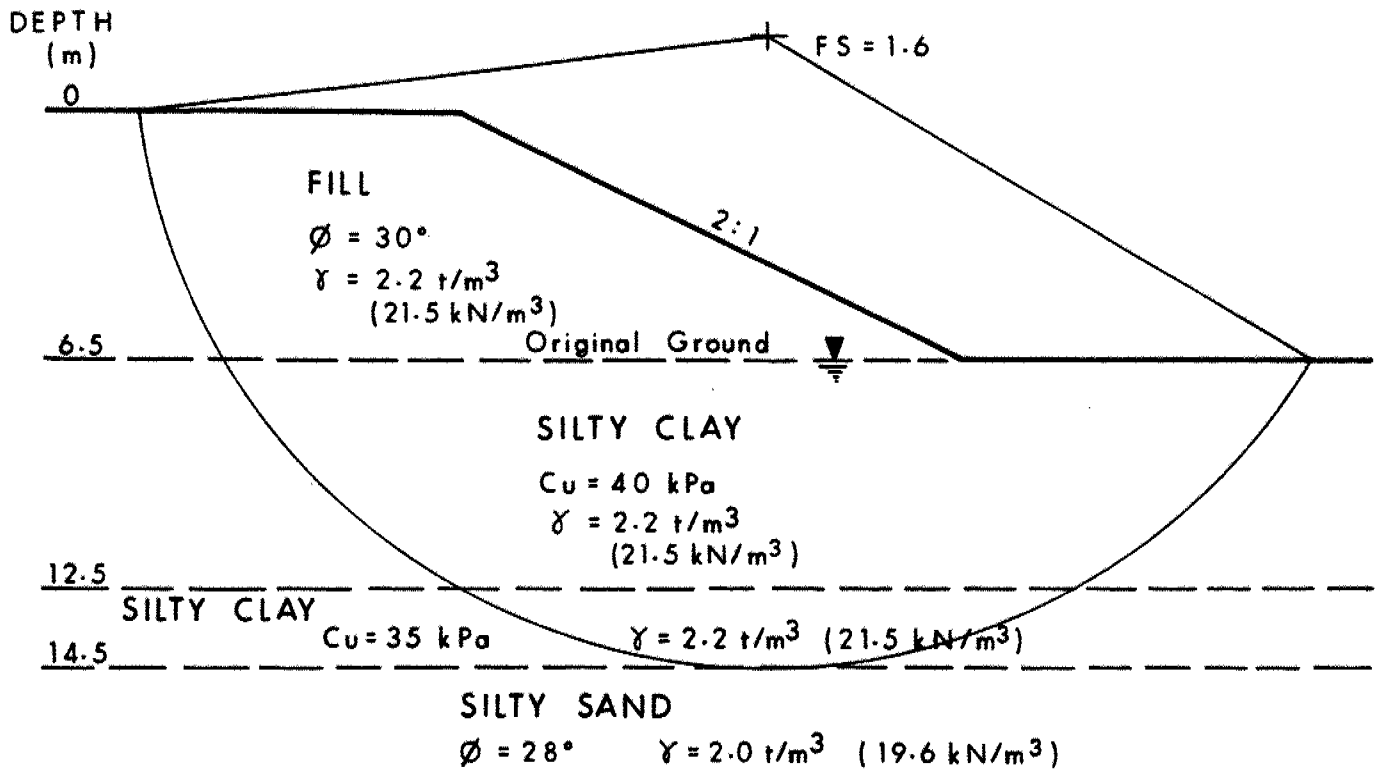
PROPOSED INTERCHANGE Hwy 11 & 534

Fig A

Dist of PARRY SOUND
Twp of N. HIMSWORTH
Town of POWASSAN
Hwy 11 ; Dist 13
W O 84-05-0022
Geocres No 31L-52

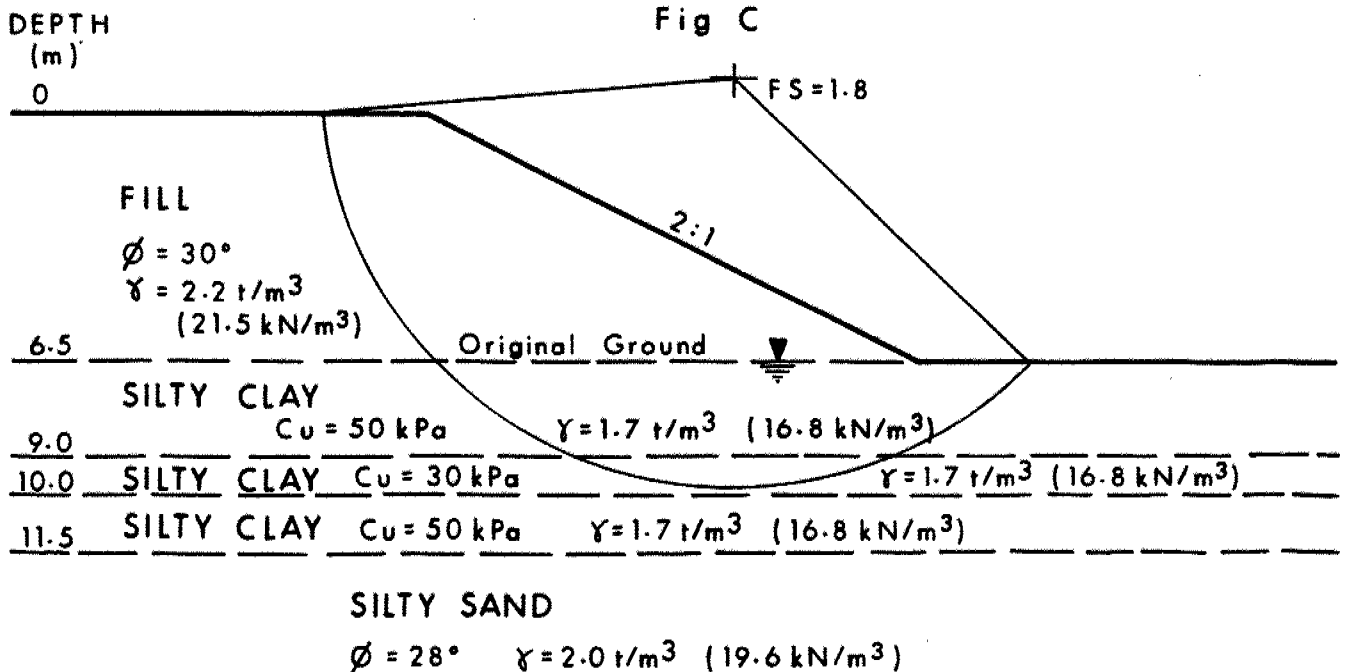
SCHEME 'A'

Fig B



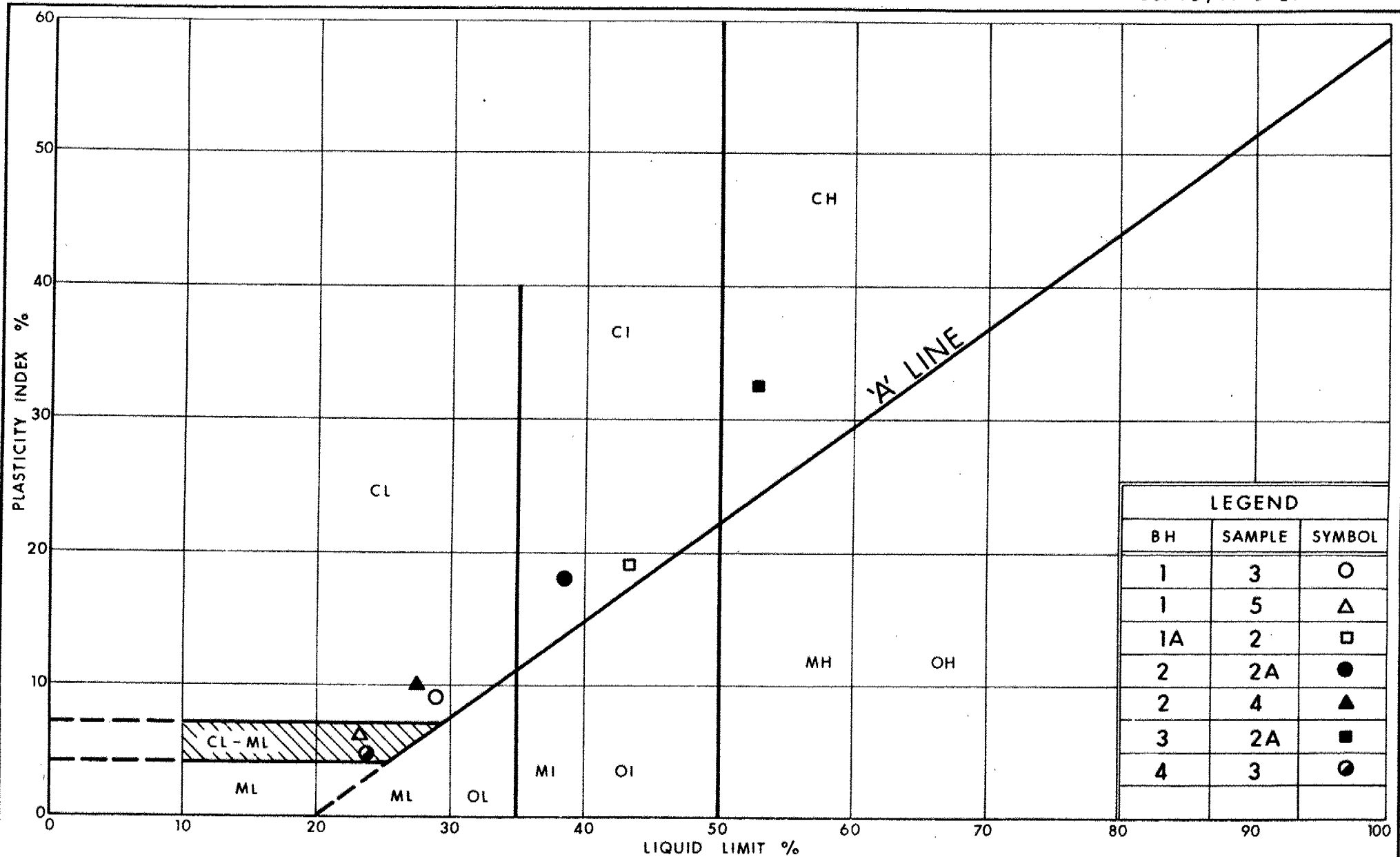
SCHEME 'B'

Fig C



BISHOPS TOTAL STRESS ANALYSIS

W O 84-05-0022



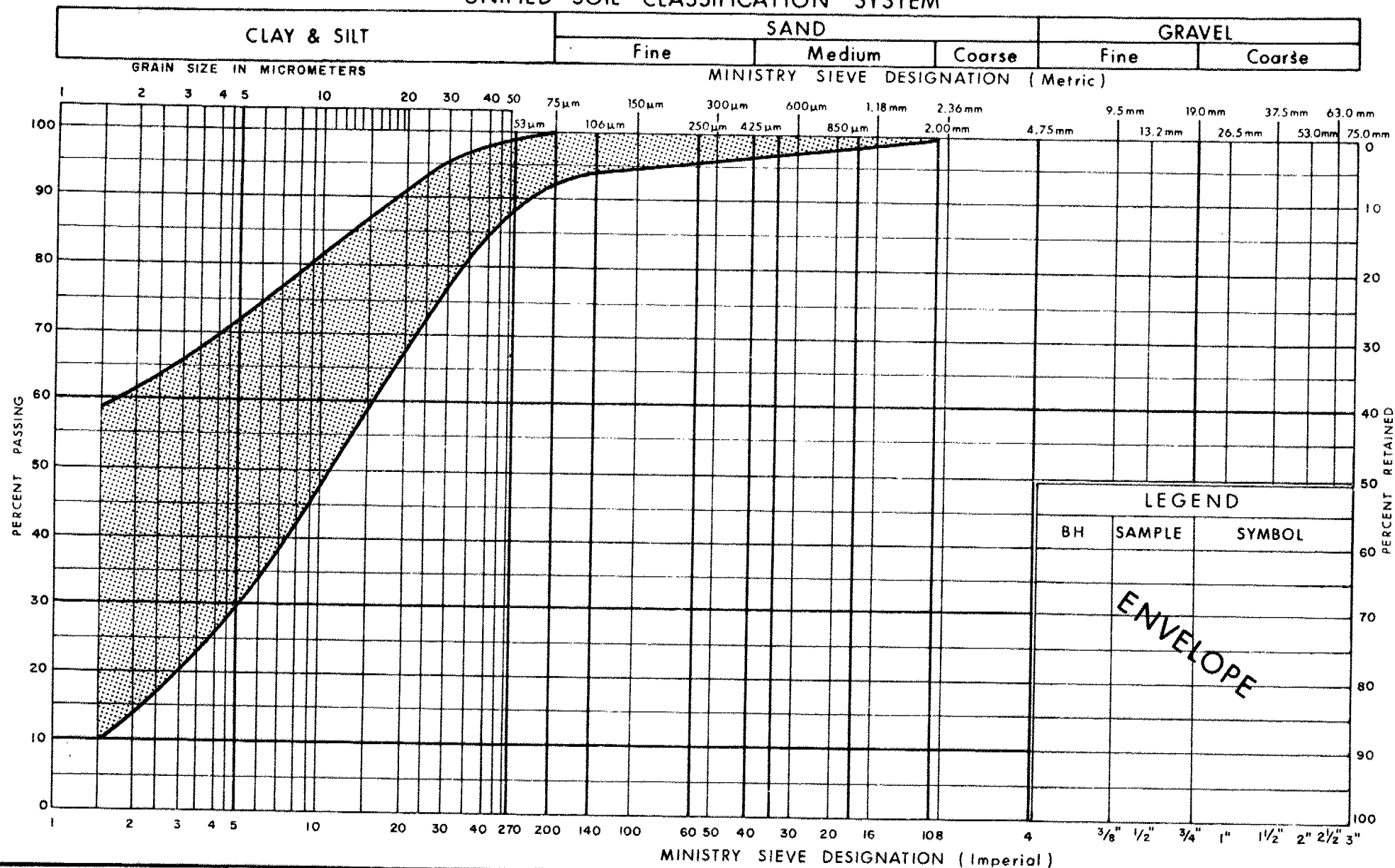
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PLASTICITY CHART SILTY CLAY, TRACE OF SAND (SCHEME 'A')

FIG No 1

W O 84-05-0022

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

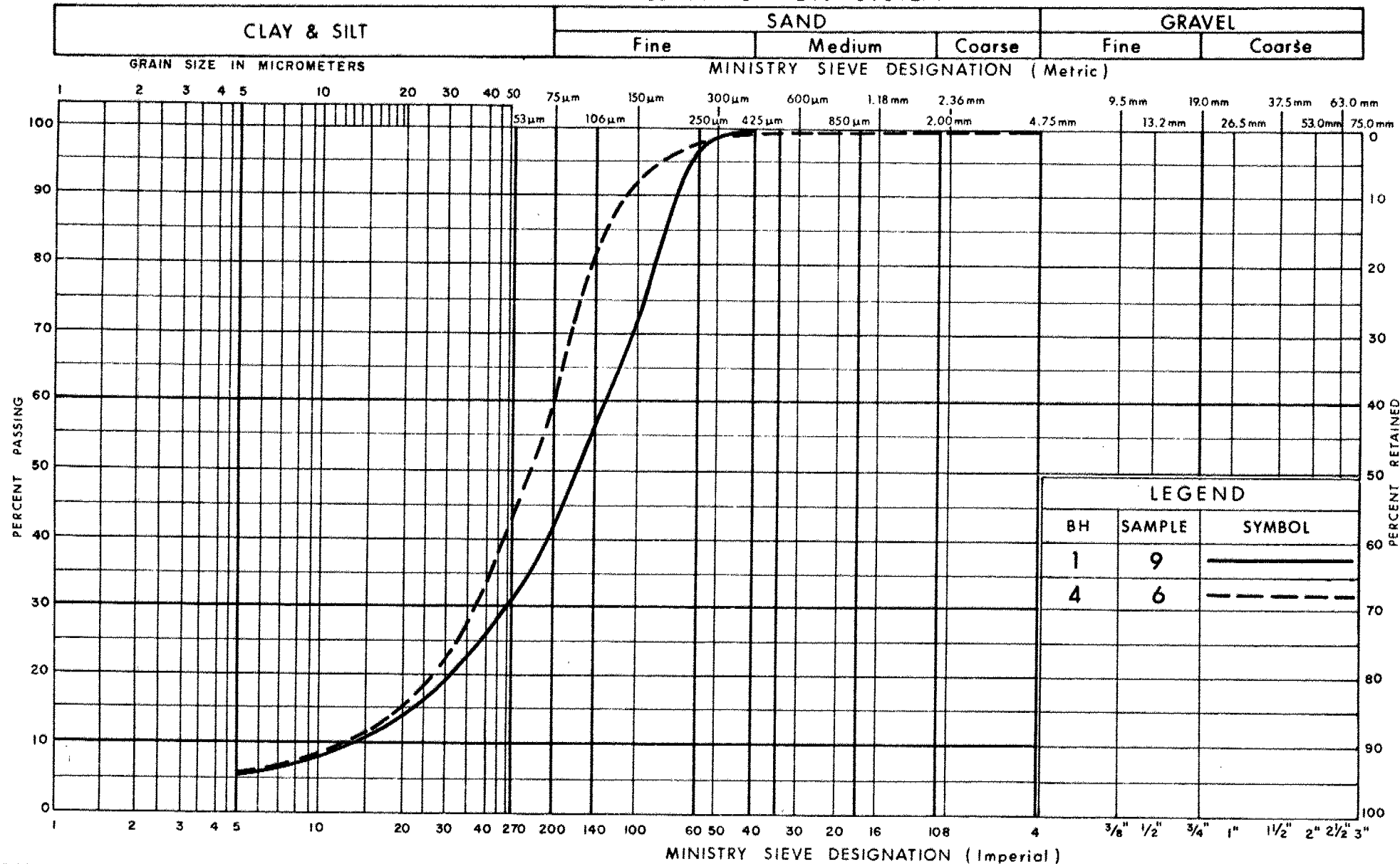
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Communications

GRAIN SIZE DISTRIBUTION
SILTY CLAY, TRACE OF SAND
(SCHEME 'A')

FIG No 2

W O 84-05-0022

UNIFIED SOIL CLASSIFICATION SYSTEM

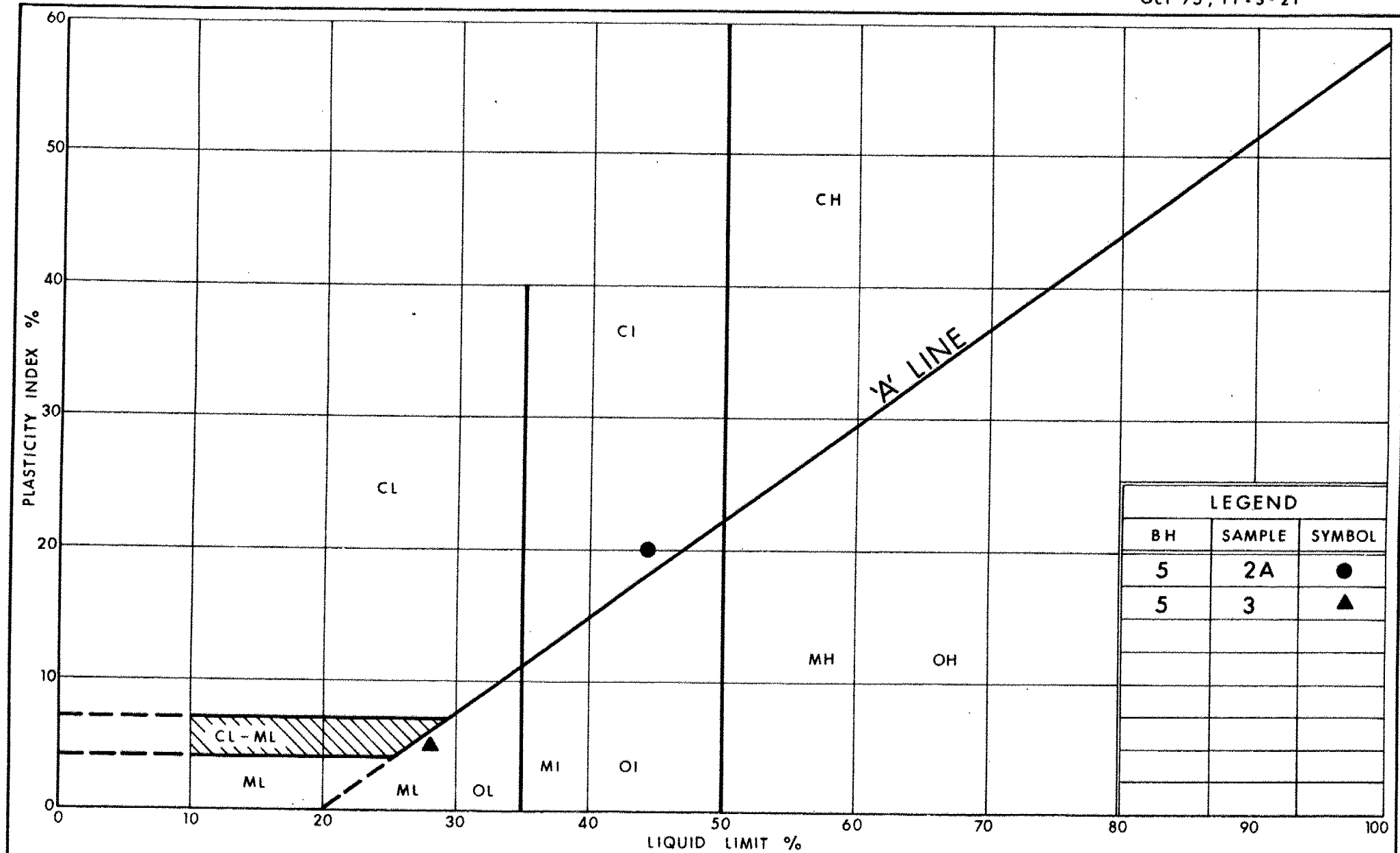


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**GRAIN SIZE DISTRIBUTION
SAND & SILT
(SCHEME 'A')**

FIG No 4

W O 84-05-0022



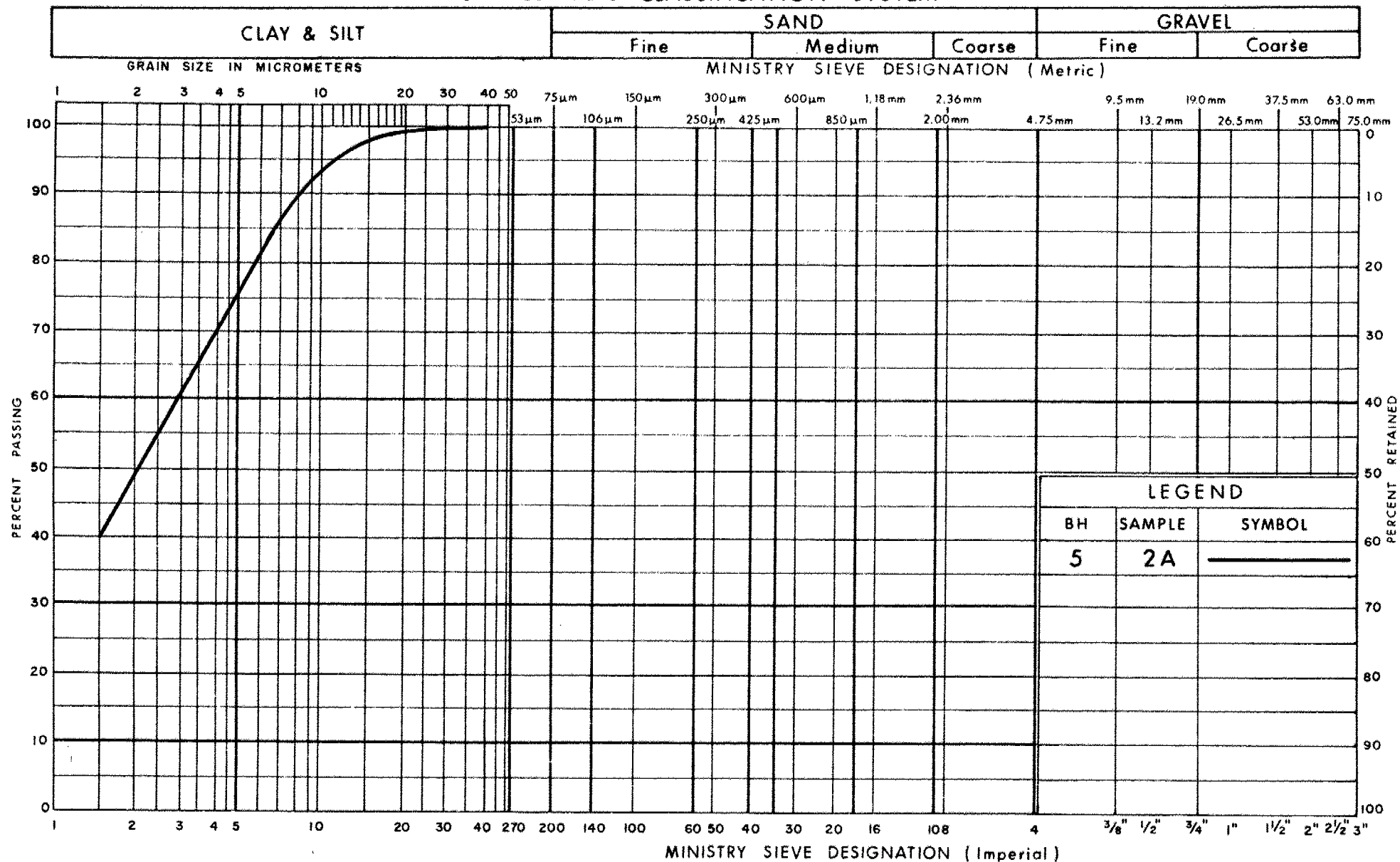
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PLASTICITY CHART SILTY CLAY (SCHEME 'B')

FIG No 5

W O 84-05-0022

UNIFIED SOIL CLASSIFICATION SYSTEM



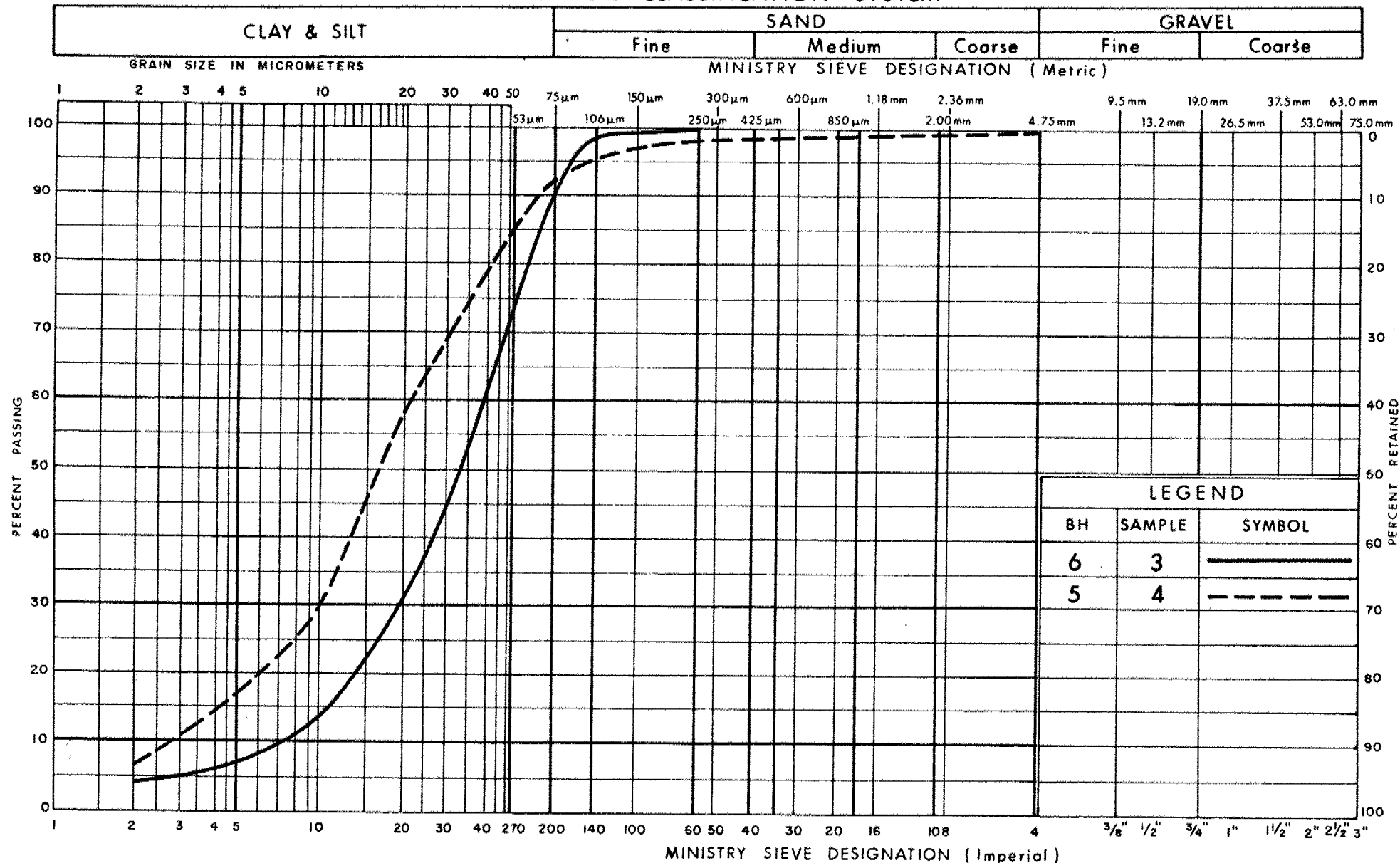
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GRAIN SIZE DISTRIBUTION
SILTY CLAY
(SCHEME 'B')

FIG No 6

W O 84-05-0022

UNIFIED SOIL CLASSIFICATION SYSTEM



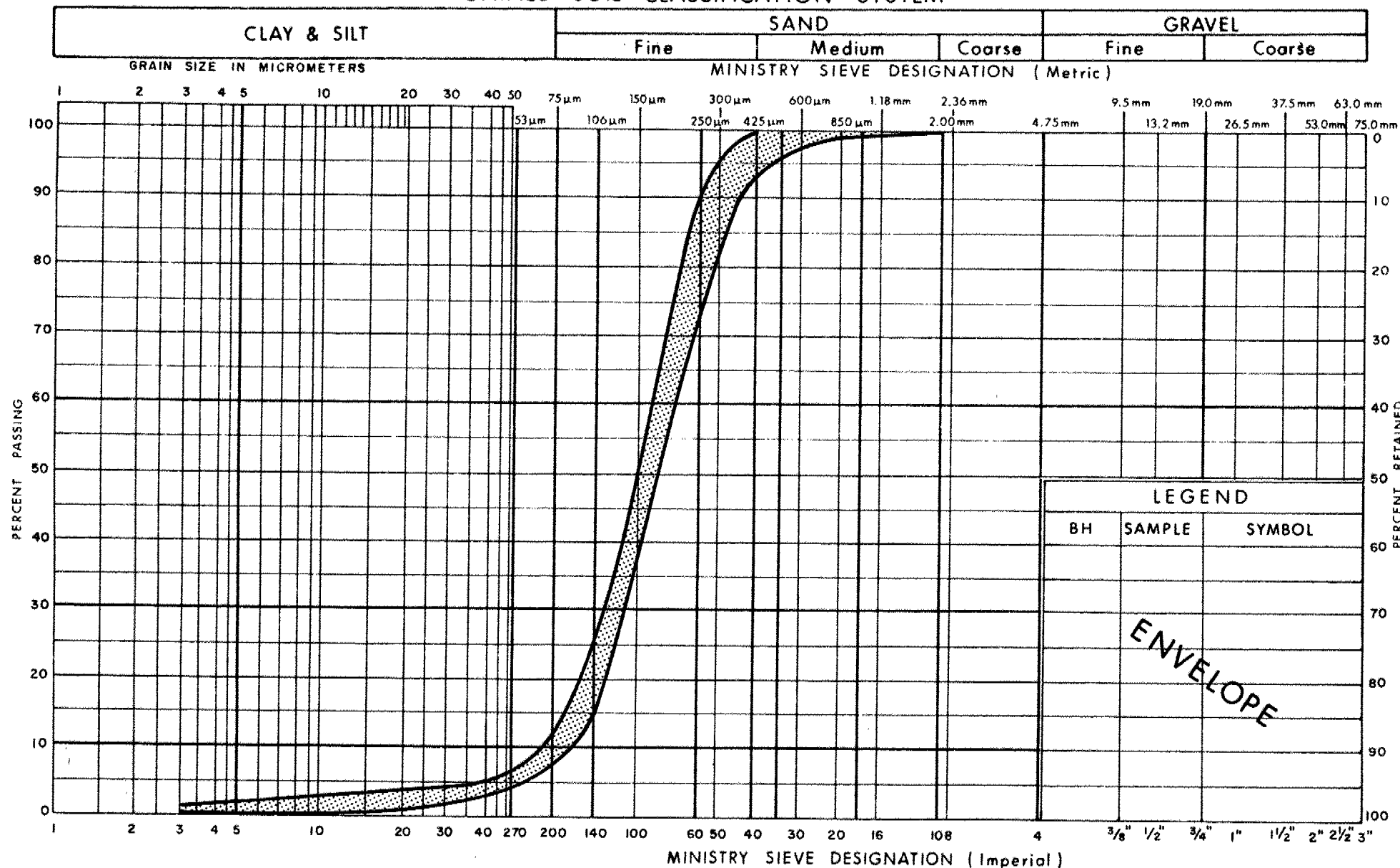
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GRAIN SIZE DISTRIBUTION
SILT, TRACE OF SAND
(SCHEME 'B')

FIG No 7

WO 84-05-0022

UNIFIED SOIL CLASSIFICATION SYSTEM



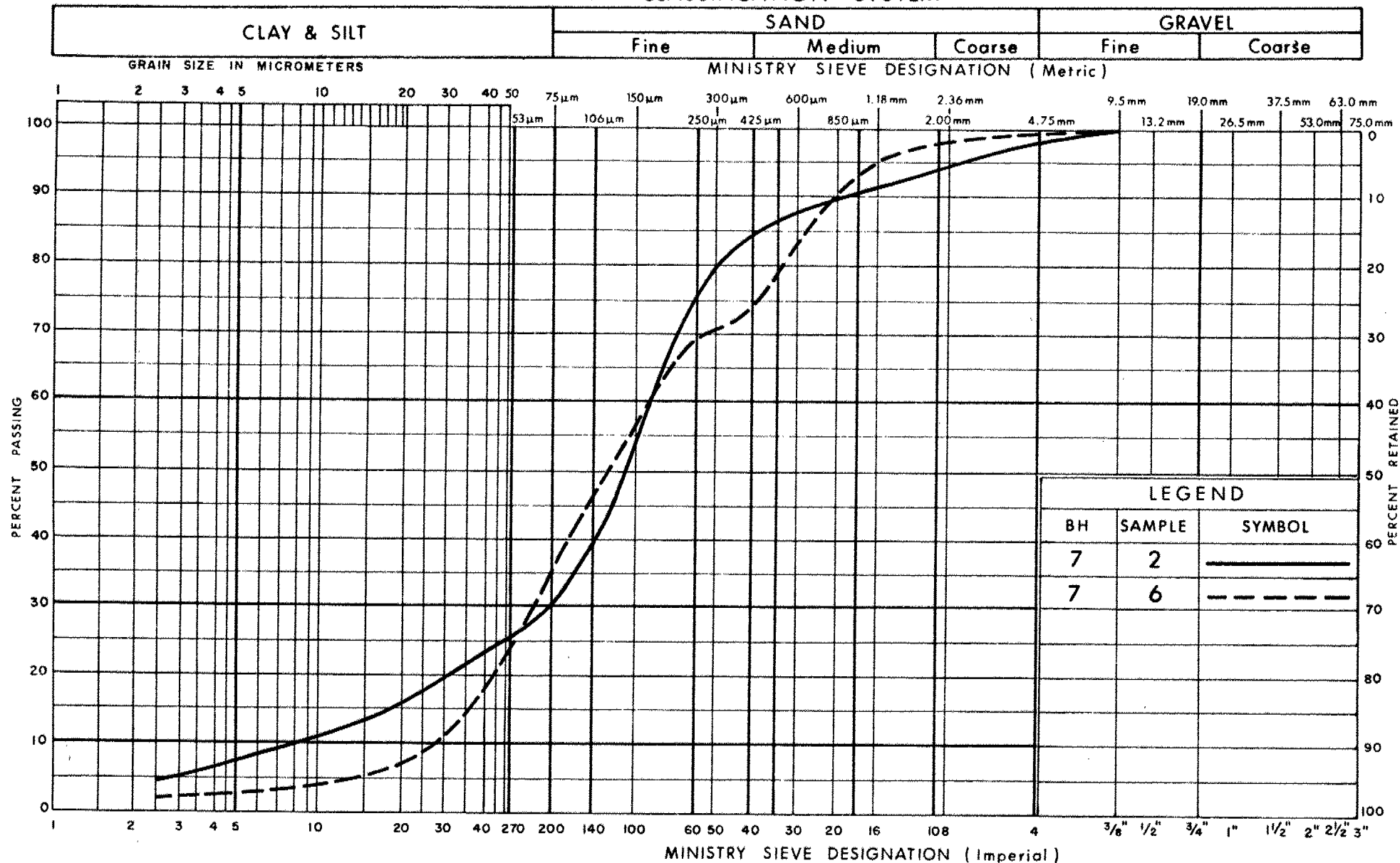
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GRAIN SIZE DISTRIBUTION
SAND, TRACE OF SILT
(SCHEME 'B')

FIG No 8

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UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION
SAND WITH SILT
(BH 7)

FIG No 9

WO 84-05-0022

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

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	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_f	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 = $w_L - w_p$	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 ³	SEEPAGE FORCE
γ'	kn/m ³	UNIT WEIGHT OF SUBMERGED SOIL						



RECORD OF BOREHOLE No 1 (Sheet 1 of 2) METRIC

W P 84-05-0022 LOCATION 5.4 m North of Clarke St.; 0/S 13.1 m East of Hwy. 11 ORIGINATED BY SW
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SW
DATUM Geodetic DATE 85 03 18 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
246.1	Ground Level													
0.0	Sand and Gravel (Shoulder Fill)						246							
245.3							245							
0.8							244							
	Silty Clay		1	SS	7		243							
	trace sand		2	SS	5		242							
	Soft to Firm		3	SS	3		241							
	Occasional thin silt seams		4	SS	5		240							
	Brown		5	SS	2		239							
239.7							238							
6.4							237							
	Silt, trace sand, clay		6	SS	9		236							
	Loose						235							
	Grey		7	SS	5		234							
235.9							233							
10.2							232							
	Sand and Silt		8	SS	5									
	Very Loose		9	SS	3									
	Grey													
231.0														
15.1														

Continued

+³, x⁵: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 1 (Sheet 2 of 2) METRIC

W P 84-05-0022 LOCATION 5.4 m North of Clarke St.; O/S 13.1 m East of Hwy. 11 ORIGINATED BY SW
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger COMPILED BY SW
DATUM Geodetic DATE 85 03 18 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	W _p	W	W _L		
								SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE			WATER CONTENT (%) 10 20 30		
231.0 15.1	Continued		10	SS	4								
	Sand and Silt						230						
	Very Loose												
	Grey						229						
	Gravel content increasing below Elev. 228½ and material becoming Compact to Very Dense		11	SS	23		228						
			12	SS	51		227						
							226						46 39 13 2
			12A	SS	13		225						
							224						
	Greyish-Brown												
			13	SS	68		223						
							222						
221.3			14	SS	96								
24.8	End of Borehole												

+3, x5 : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 1A

METRIC

W P 84-05-0022 LOCATION 5.4 m North of Clarke St.; O/S 16.8 m East of Hwy. 11
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger
DATUM Geodetic DATE 85 03 19

ORIGINATED BY SW

COMPILED BY SW

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
246.1	Ground Level																
0.0	Silty Clay trace sand					*	246										
	Firm to Stiff		1	SS	6		245										
	Brown		2	TW	PH		244				+4						
242.4							243				+5					17.8	0 1 70 29
3.7	End of Borehole * Water Level not Established																

+3, x5: Numbers refer to
Sensitivity

20
15 \diamond 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 2

METRIC

W P 84-05-0022 LOCATION 17.8 m South of Clarke St.; O/S 64.5 m East of Hwy. 11
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger
DATUM Geodetic DATE 85 03 19

ORIGINATED BY SW
COMPILED BY SW
CHECKED BY *JP*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
245.4	Ground Level																
0.0	Silty Clay trace sand Soft to Firm Brown with occasional thin silt seams Brown Grey		1	SS	4	*	245									17.8	0 7 59 34
			2A	TW	PH		244										
			2	SS	5		243										
			3	SS	4		242										
			4	SS	4		241										
			5	SS	3		240										
236.7			6	SS	8		239									W=43%	
8.7	Silt, trace sand clay Very Loose to Loose Grey		7	SS	4		238										
234.3							237										
11.1	End of Borehole * Water Level not Established						236										0 7 90 3
							235										

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 3

METRIC

W P 84-05-0022 LOCATION 36.2 m South of Clarke St.; 0/S 102.2 m East Hwy. 1
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger ORIGINATED BY SW
DATUM Geodetic DATE 85 03 20 COMPILED BY SW
CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
242.2	Ground Level																
0.0	Silty Clay trace sand Soft to Firm with occasional thin silt or sand seams — Brown Grey		1	SS	11		242									16.7	
			2	SS	5		241										
			2A	TW	PH		240	+7								W = 55% W _L = 53% W _p = 20%	0 1 36 63
			3	SS	2		239	4									
			4	SS	2		238									W = 41%	
236.7							237	+6									
5.5	Silt, trace sand clay Loose Grey		5	SS	10		236										
							235										
234.0			6	SS	5												0 5 90 5
8.2	End of Borehole																

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 4

METRIC

W P 84-05-0022 LOCATION 1.4 m North of Clarke St.; O/S 40.5 m West of Hwy. 11
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger
DATUM Geodetic DATE 85 03 20

ORIGINATED BY SW

COMPILED BY SW

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
247.6	Ground Level																
0.0	Silty Clay trace sand						247										
	with occasional silt seams		1	SS	28		246										
	Stiff		2	SS	9		245										
	Brown		3	SS	5		244										0 4 83 13
243.5																	
4.1	Silt, trace sand clay		4	SS	15		243										0 2 92 6
	Compact Brown						242										
242.0																	
5.6	Sand and Silt trace clay		5	SS	1		241										
	Very Loose Brown						240										0 38 59 3
239.5			6	SS	4												
8.1	End of Borehole																

+3, x5: Numbers refer to
Sensitivity

20
15 x 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 5

METRIC

W P 84-05-0022 LOCATION 177.8 m North of Clarke St.; O/S 20.4 m East of Hwy. 11
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger
DATUM Geodetic DATE 85 03 20

ORIGINATED BY SW
COMPILED BY SW
CHECKED BY *[Signature]*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
245.3	Ground Level																
0.0						*	245										
	Silty Clay trace sand						244										
	Firm to Stiff		1	SS	9												
	with occasional silt seams		2	SS	5		243										
	Brown		2A	TW	PH		242										
							241										
240.5			3	SS	12		240										
4.9							239										
	Silt trace sand clay						238										
	Very Loose		4	SS	5												
	Grey																
237.1			5	SS	3												
8.2	End of Borehole																
	* Water Level not established																

RECORD OF BOREHOLE No 6 (Sheet 2 of 3) METRIC

w p 84-05-0022

LOCATION 166.3 m North of Clarke St. O/S 41.5 m West of Hwy. 11

ORIGINATED BY SW

DIST 13 HWY 11 & 534

BOREHOLE TYPE Hollow Stem Auger & NX Washbore

COMPILED BY SW

DATUM Geodetic

DATE 85 03 21 to 85 03 26

CHECKED BY

[illegible]

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Continued

+3, x5 : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 6 (Sheet 3 of 3) METRIC

W P 84-05-0022 LOCATION 166.3 m North of Clarke St.; O/S 41.5 m West of Hwy. 11
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger & NX Washbore
DATUM Geodetic DATE 85 03 21 to 85 03 26
ORIGINATED BY SW
COMPILED BY SW
CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL											
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	SHEAR STRENGTH						WATER CONTENT (%)										
218.6	Continued		15	SS	73																				
30.2															Gravel and Sand trace silt clay										55 36 8 1
															Very Dense										
216.6	Grey																								
32.3	End of Borehole																								
	* Water Level not Established																								

+3, x5: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 7

METRIC

W P 84-05-0022 LOCATION 381.5 m North of Clarke St.; O/S 19.4 m West of Hwy. 11 ORIGINATED BY SW
DIST 13 HWY 11 & 534 BOREHOLE TYPE Hollow Stem Auger & NX Washboring COMPILED BY SW
DATUM Geodetic DATE 85 03 22 CHECKED BY gfo

[illegible]

+3, x5: Numbers refer to Sensitivity

20
15
10