

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

CONT. 90-36

WP 120-87-00A

DIST 9

HWY 416/417

STR SITE

Culvert Structures Underneath Ramp Hwy. 417 W

-Hwy. 416 S and Hwy. 417 E.B.L.

Culvert Nos. ~~#1 and #2~~

4

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FOUNDATION INVESTIGATION REPORT
For
Culvert Structures Underneath Ramp Hwy. 417 W
-Hwy. 416 S and Hwy. 417 E.B.L.
Culvert Nos #1 and #2
W.P. 120-87-00A
District 9, Ottawa

INTRODUCTION

This report summarizes the information obtained from a foundation investigation carried out at the above-mentioned site during the period of 89 11 01 to 89 11 03. Two 3.5 m span culvert structures are proposed to construct underneath Hwy. 417 Eastbound (Culvert #2) and Ramp Hwy. 417 W to Hwy. 416 Southbound (Culvert #1).

Six boreholes (BH #C1-1 to BH #C1-3 and BH #C2-1 to BH #C2-3) were advanced and sampled with a conventional diamond drill (BW casing and BXL Rock Core barrel) adopted for rock sampling purposes. In addition, cone penetration tests were carried out at five locations to delineate the inferred bedrock surface for alternative alignment of the proposed culverts. These boreholes extended down to depths ranging from 0.4 to 9.0 metres below the existing ground surface.

This report contains factual information obtained from this investigation together with discussion and recommendations pertaining to structure foundations, approach embankments and related earthworks for Culvert Nos. #1 and #2 as shown on Drawing No. 1208700A-A.

SITE DESCRIPTION AND GEOLOGY

The proposed structure site is located in the corn field and cattle ranch immediately south of the existing Hwy. 417 between the Acres Road and Moodie Drive in the City of Nepean, Ottawa-Carleton Municipality. The topography of the area is generally flat to gently undulating with the land in the immediate vicinity being used for agricultural and dairy farming purposes. A new municipal pumping station exists north of the site.

Physiographically, the site lies in the area known as the Ottawa Valley Clay Plains founded in the lowlands of the St. Lawrence. The subsoil consists of clay plains interrupted by ridges of rock or sand. Fault scarps are also evident within the area; an illustration of the numerous normal faults that dominate the region. It appears that the site is divided by a fault. The bedrock in the area is of the March Formation west of the fault, and the Rockcliffe and Gull River Formation east of the fault which are of the middle Ordovician period. The March Formation consists of interbedded quartz sandstone and sandy dolostone, whereas the Rockcliffe and Gull River Formation consists of interbedded fine grained quartz sandstone, silty dolostone, and limestone. The site is transversed by a north-south trending fault which is a geologic structure reportedly common to the area. The overburden was deposited during and immediately following the Wisconsinian glaciation at which time the area was depressed from the effect of the glaciation. Following the retreat of the glacier, the brackish waters of the Champlain Sea flooded the area and then gradually receded as the land rebounded with the deposition of sediments to its present level.

FIELD INVESTIGATION AND LABORATORY ANALYSIS

The fieldwork for the site investigation was carried out between November 1 and November 3, 1989 and consisted of six (6) sampled boreholes accompanied by dynamic cone penetration tests and additional five (5) dynamic cone test holes. Among these, three (3) boreholes and four (4) dynamic cone holes were put down for the Culvert No. #1 and three (3) boreholes and one (1) dynamic cone hole were driven for the Culvert No. #2. Soil samples were retrieved generally at 1.5 m interval by a split spoon sampler according to the Standard Penetration Test (ASTM D1586). In situ vane tests were also carried out in cohesive soil. Samples were identified in the field and then returned to the laboratory for appropriate testing. Bedrock was cored at three borehole locations from about 1.6 m to 1.8 m depths using conventional rock coring methods.

Water levels were obtained in the open boreholes during the fieldwork and in two piezometers installed afterwards. Survey information related to location and elevation of boreholes was provided by Eastern Region Surveys and Plans.

To identify the properties of the soil, the following laboratory tests were performed:

1. Atterberg Limit Tests
2. Grain Size Analysis
3. Natural Moisture Content

Laboratory test results have been summarized and are included in the Appendix of this report.

SUBSURFACE CONDITIONS

As previously mentioned, the site is transversed by a north-south trending geologic structure of fault as shown on Drawing No. 1208700A-A. Based on observed surficial features and information from the site investigation, the ground surface at the proposed Culverts #1 and #2 to the east of the fault is comprised of approximately 60 percent exposed bedrock or bedrock covered with less than 0.4 metre of overburden. The bedrock consists of sandstone of the March Formation. The area west of the fault is underlain by 1.5 to 5.8 m of soft to firm clayey silt underlain by a thin layer of loose silty sand (0.7 to 1.6 m). Further underlying this layer is a deposit of loose to very dense heterogeneous mixture of silt, sand, and gravel and boulders (cohesionless Glacial Till). Approximately 1.6 to 4.1 m of the till deposit was found before encountering the interbedded quartz sandstone bedrock.

It should be noted that in the vicinity of southern part of the Culvert #1 and Northern part of Culvert #2, the proposed culverts will seat on a loose Glacial Till up to 4.5 m at the southern end and 1.0 m at the Northern end, respectively. Topsoil, consisted of organic sandy silt, was found at BH #C1-2.

A detailed description of the subsurface conditions encountered is given below.

Topsoil

Topsoil was encountered at one borehole location. The material consists of a dark brown organic sandy silt. The thickness of this layer is about 0.4 m at

BH #C1-2 as shown on Record of Borehole sheets. Grain size distribution test was carried out on this material. Figure 1 in the Appendix shows the test result. Through the grain size distribution curve and visual observation, the material classified as a sandy silt.

Clayey Silt with Interbedded Sandy Silt

This stratum occurred from the ground surface to a depth of 1.5 to 5.8 m. This material changes in colour from brown to grey at approximate elevation 65.0 m.

Atterberg Limit tests were performed on these samples and the results are plotted on Figure 2 and summarized as follows:

<u>Property</u>	<u>Range (%)</u>	<u>Average (%)</u>
Natural Moisture Content (w)	24.5-38.0	29.5
Liquid Limit (w _L)	25.0-38.0	30.4
Plastic Limit (w _p)	13.0-16.5	14.5
Plasticity Index (I _p)	12.0-21.5	15.9

From the plasticity chart, it is evident that the layer can be classified as an inorganic clayey silt with interbedded sandy silt of low plasticity (CL or CL-ML). Grain size distribution tests were carried out on these materials. Figure 3 in the Appendix shows the results in an envelope form.

Undrained shear strength of the soil was determined by in situ vane tests. The results are plotted on the Record of Borehole sheets in the Appendix and summarized as follows:

<u>Undrained Shear Strength</u>	<u>Cu (kPa)</u>	<u>Sensitivity</u>
Field Vane	20-60 (Avg. 47 kPa)	3.2-6.5

Due to the irregular nature of the deposit, which reveals numerous seams and layers of sandy silt interbedded within the clayey silt, the results provided

in the above table are not necessarily indicative of the shear strength of the clayey silt portion. In view of this consideration, the consistency of the clayey silt portion can be described as soft to stiff. The sandy silt portion was generally very loose in denseness. For design purposes an undrained shear strength of 45 kPa can be assumed for this stratum.

Silty Sand

This deposit was encountered below the clayey silt with interbedded sandy silt layer. The thickness of this layer ranges from 0.7 m at BH #C1-3 to 1.6 m at BH #C1-1 and BH #C2-2.

This deposit contains a minor variation in gravel content throughout its thickness. Generally, the deposit contains trace of gravel, but at some locations, considerable gravel was encountered. Grain size distribution curve indicates that the soil can be classified to a silty sand. This layer is basically non-plastic. Figure 4 in the Appendix shows the result of Grain Size Distribution test.

In this stratum, the 'N' values ranged from 3 to 32 blows/0.3 m indicating a state of compaction described as very loose to dense.

Heterogeneous mixture of Silt, Sand and Gravel and Boulders (Glacial Till)

Underlying the silty sand, a heterogeneous mixture of silt, sand and gravel, and boulders of glacial origin was encountered. The thickness of this stratum ranges from 1.6 m at BH #C2-2 to 3.2 m at BH #C1-1. Figure 5 shows the results of Grain size distribution tests in an envelope form for this material.

In this stratum, the 'N' values ranged from 2 to over 26 blows/0.3 m indicating a state of compaction described as very loose to compact.

Bedrock

As discussed previously, a north-south trending geologic structure transverses

the site with an approximately 60 percent exposed bedrock or bedrock covered with a thin veneer of overburden at the east of the fault. Exposed bedrock was cored at one location. Up to 1.6 m of rock core samples was obtained at BH #C2-1.

The bedrock consists of a March Formation comprised of interbedded quartz sandstone.

Detailed descriptions of the bedrock are attached in the Appendix, entitled "Description of Rock Core". Core Recoveries (CR) and Rock Quality Designation (RQD) values were determined in situ and also in the laboratory to evaluate the competence and integrity of the rock. Core Recoveries (CR) range between 78 and 100 percent and Rock Quality Designation (RQD) values range from 23 to 81 percent. Based on the results and through visual laboratory examination, the rock can be classified as medium strong to strong and predominantly unweathered.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water level in the open boreholes and two piezometers installed in BH #C1-1 and BH #C2-3. Groundwater levels in the boreholes were found to range between elevation 63.6 m at BH #C2-3 and elevation 64.7 m at BH #C1-3. This corresponds to depths of 1.4 m to 0.9 m below the existing ground surface.

DISCUSSION AND RECOMMENDATIONS

The recommendations in this report apply to the concrete culvert and related approaches.

It is proposed to construct two 3.5 m span culverts underneath Hwy. 417 eastbound (Culvert #2) and Ramp Hwy. 417 W to Hwy. 416 Southbound (Culvert #1). The proposed culverts will be a 3.5 x 1.6 m box culvert with an approximate length of about 59 m for Culvert #1 and 57 m for Culvert #2.

Based on the site investigation, the foundation recommendations for the design of concrete box culverts are as follows:

STRUCTURE FOUNDATION FOR CONCRETE CULVERTS

Culvert #1

As previously mentioned, the proposed Culvert #1 will be laid on a loose glacial till layer up to 4.5 m at the southern half of culvert. In consideration of the weak nature of the foundation soil, this material may be excavated down to 1.5 m below the proposed base elevation of Culvert #1 (approximate Elev. 60.2) as shown on a section in Drawing 1208700A-A. It should be noted that rock underneath the northern half of Culvert #1 be also excavated approximately 1.5 m below the proposed base elevation in order to minimize the differential settlement of the proposed culvert.

The excavated area can be backfilled with well compacted Granular 'A' material to the base of the proposed concrete culvert. The following design values are recommended for the purpose of the O.H.B.D.C.

<u>Structure</u>	<u>Allowable Bearing Capacity at S.L.S. Type II (kPa)</u>	<u>Factored Bearing Capacity at U.L.S. (kPa)</u>
Concrete	200	400

A footing width (B) equal to 3.5 m was used in the calculation of the capacities.

Culvert #2

Similarly, the proposed Culvert #2 will be laid on a loose to compact till layer up to 1.0 m at the northern half of the culvert. In consideration of the weak nature of the foundation soil, this material may be excavated down to 0.5 m below the proposed base elevation of Culvert #2 (approximate Elev. 60.9 m) as shown in Drawing 1208700A-A. Rock underneath the southern half of Culvert #2 should be also excavated approximately 0.5 m below the proposed base elevation.

The excavated area can be backfilled with well compacted Granular 'A' material to the base of the proposed concrete culvert. The following design values are recommended for the purpose of the O.H.B.D.C.

<u>Structure</u>	<u>Allowable Bearing Capacity at S.L.S. Type II (kPa)</u>	<u>Factored Bearing Capacity at U.L.S. (kPa)</u>
Concrete Culverts	250	500

To protect the footings against scour, a properly designed rip-rap meeting the filter design criteria and hydrological requirements at site, should be placed at the culvert channel inlet and outlet.

Resistance of sliding of the footings can be calculated assuming a coefficient of friction of 0.7 between the underside of the concrete culverts and the Granular 'A' core.

STABILITY AND SETTLEMENT OF APPROACH EMBANKMENTS

Stability Considerations

Stability analyses in transverse direction and the internal stability of fills were carried out to evaluate the overall stability of the approach fill in the vicinity of the proposed culvert. A minimum factor of safety 1.3 was incorporated for the analysis. It should be noted that all stability calculations were made for the static condition only. The properties of the fill material, subsoil and the subsurface geometries used in these computations

are shown on Figure 6. The proposed fill height is in the order of 8 m above the existing ground surface at the approaches beyond the anticipated excavation cut for the culvert construction. Within the anticipated excavation cut, fills up to 12.0 m will be required. Based on the analyses, the following conclusions have been derived:

- 1) Fills up 8 m above the original ground surface will maintain internal stability provided they are constructed with standard 2H:1V slopes.
- 2) A nominal midheight stabilizing berm or a flatter slope will be required for fills exceeding 8 m in the height above the ground surface for the Ramp Hwy. 417 Westbound to Hwy. 416 Southbound. Berms, if this option is adopted, should be constructed with a nominal slope such that surface run-off does not pond on the berm.
- 3) A nominal 2 m midheight stabilizing berm or a flatter slope of 2.25H:1V will be required for fills exceeding 10 m in height above the excavated ground surface and above the concrete box Culvert #1. Consequently, the Culvert #1 should be extended by 2.5 m at both sides of slopes.

Detailed stability analyses for the approach fill beyond the Culvert #1 are included in our previous report (W.P. 120-87-01).

Settlement Considerations

Settlement of the native subsoil, as a result of the approach embankment load, was estimated in detail in our previous report (W.P. 120-87-01) and not repeat in this report.

However, it should be noted that to minimize post construction maintenance consideration be given in constructing the approach fills as far in advance of the structure foundations as scheduling, feasibility and economics permit. The final paving operations should also be delayed as long as possible.

Differential settlement of the native glacial till underneath the Granular 'A' pad is estimated to be in the order of 25 mm at the southern half of Culvert #1. Based on the above estimation, it is recommended that a special flexible joint should be installed for Culvert #1 between a section seating on the bedrock and the section seating on the native soil in order to accomodate the differential settlement of the culvert. No special consideration would be required for Culvert #2.

LATERAL EARTH PRESSURES ON CULVERT WALLS

Free draining material such as Granular 'A' or Granular 'B' is recommended as appropriate backfill to the culvert walls to prevent hydrostatic pressure build-ups. Design parameters of the soil are given below.

	<u>Granular 'A'</u>	<u>Granular 'B'</u>
Angle of Internal Friction (ϕ)	35°	30°
Unit Weight (kN/m ³) γ	22.8	21.2
Coefficient of Earth Pressure at Rest (K_0)*	0.43	0.5

*for horizontal backfill only.

The earth pressure coefficient at rest is to be used in design if the culvert structure is rigid and unyielding.

CUT SLOPES AT CULVERT INLET, OUTLET AND DRAINAGE CHANNEL

The critical condition for stability of the open cut slopes proposed at the culvert inlet, outlet and drainage channel will be the long term condition and consequently an effective stress analysis was implemented incorporating a minimum factor of safety of 1.3.

Based on the analyses, the following conclusions have been derived:

- 1) Excavation down to 5.0 metres in depth will be stable provided they are maintained with 2H:1V slope, while deeper cuts to 7.0 m will require a flatter slope of $2\frac{1}{2}$ H:1V.

CONSTRUCTION CONSIDERATIONS

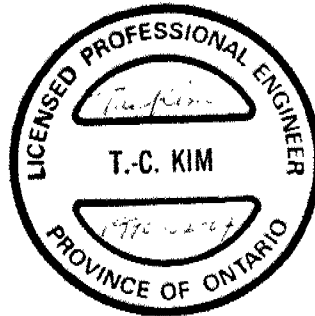
- 1) Temporary excavation cuts for foundation elements should be at slopes no steeper than 2H:1V in view of the high water table.
- 2) Temporary excavations for the construction of the box culvert will extend some 2.7 m for Culvert #2 and some 3.7 m for Culvert #1 below the groundwater level in the cohesionless glacial till deposit. This may cause the base of the excavation to "boil" due to unbalanced hydrostatic water pressure within the cohesionless stratum. Consequently, an advance dewatering scheme will be required for deep excavation.
- 3) In order to get a gravitational drainage system in the the vicinity of the upstream of Culvert #1, it is recommended that excavation for Culvert #2 and construction of drainage channel through the bedrock be implemented prior to excavation for the Culvert #1 foundation.
- 4) Rock blasting should be controlled carefully in order to avoid overbreaking of rock.
- 5) Backfill to the culvert should be constructed in accordance with appropriate O.P.S.D. Standards (O.P.S.D. 803 series). The backfill should be constructed in 300 mm lifts on alternatively sides of the culvert so that the maximum differential in backfill at any time does not exceed 300 mm. Excessive vibratory equipment loadings should be prevented from inducing undue lateral pressures on the culvert walls.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of Tae C. Kim, Foundation Design Engineer, and Dale Colquhoun, Visiting Engineer

from Jamaica. The equipment was owned and operated by Marathon Drilling Co. and Johnston Drilling Co., Ottawa.

The project was carried out by Tae C. Kim under the general supervision of Dr. B. Iyer. This report was written by Tae C. Kim, Foundation Design Engineer, reviewed by Dr. B. Iyer, Sr. Foundation Engineer and approved by M. Devata, Chief Foundation Engineer.



Tae C. Kim

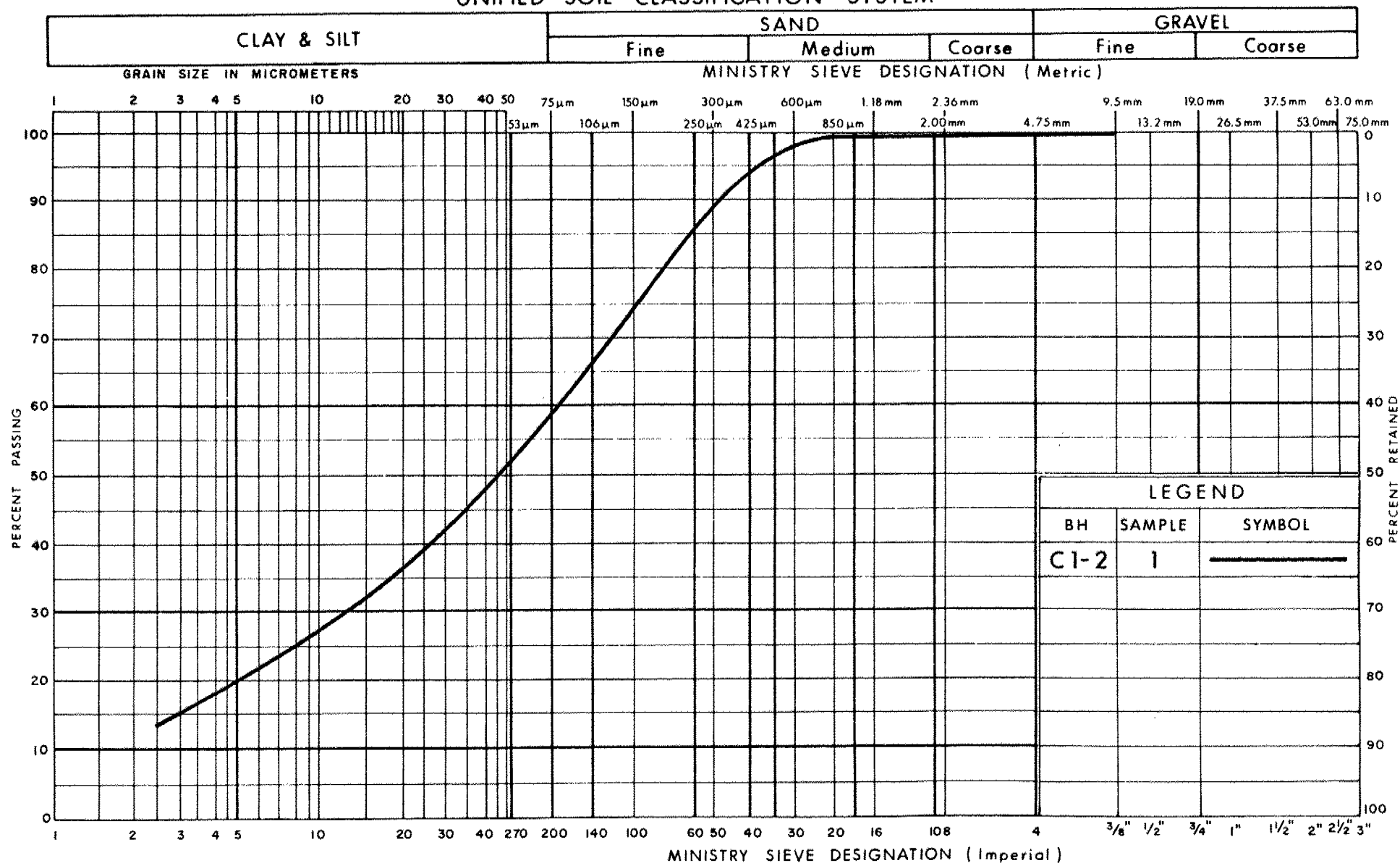
Tae C. Kim, P.Eng.
Foundation Design Engineer

M. Devata

M. Devata, P.Eng.
Chief Foundation Engineer

APPENDIX

UNIFIED SOIL CLASSIFICATION SYSTEM

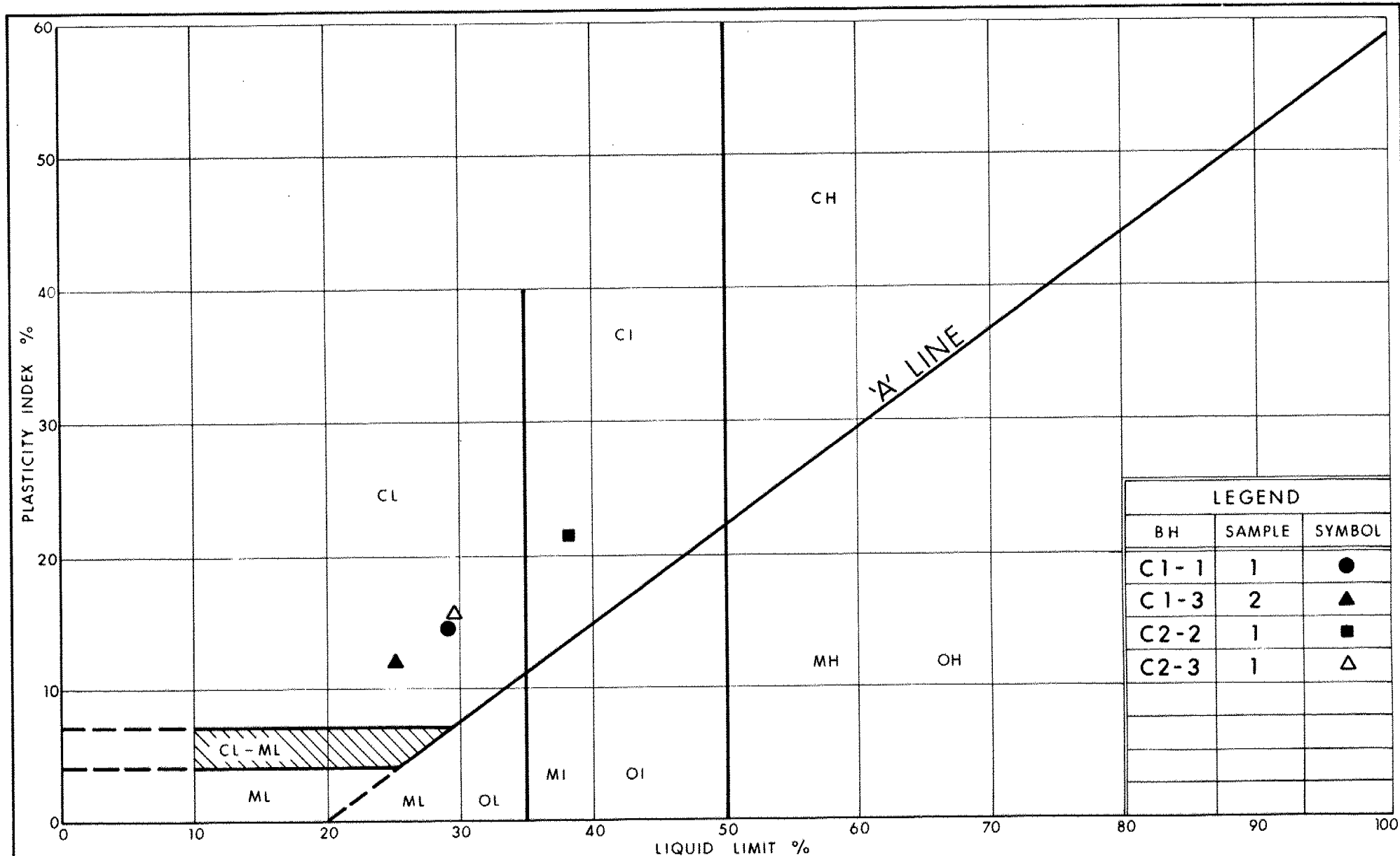


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GRAIN SIZE DISTRIBUTION ORGANIC SANDY SILT (Topsoil)

FIG No 1

W P 120-87-00A



Ontario

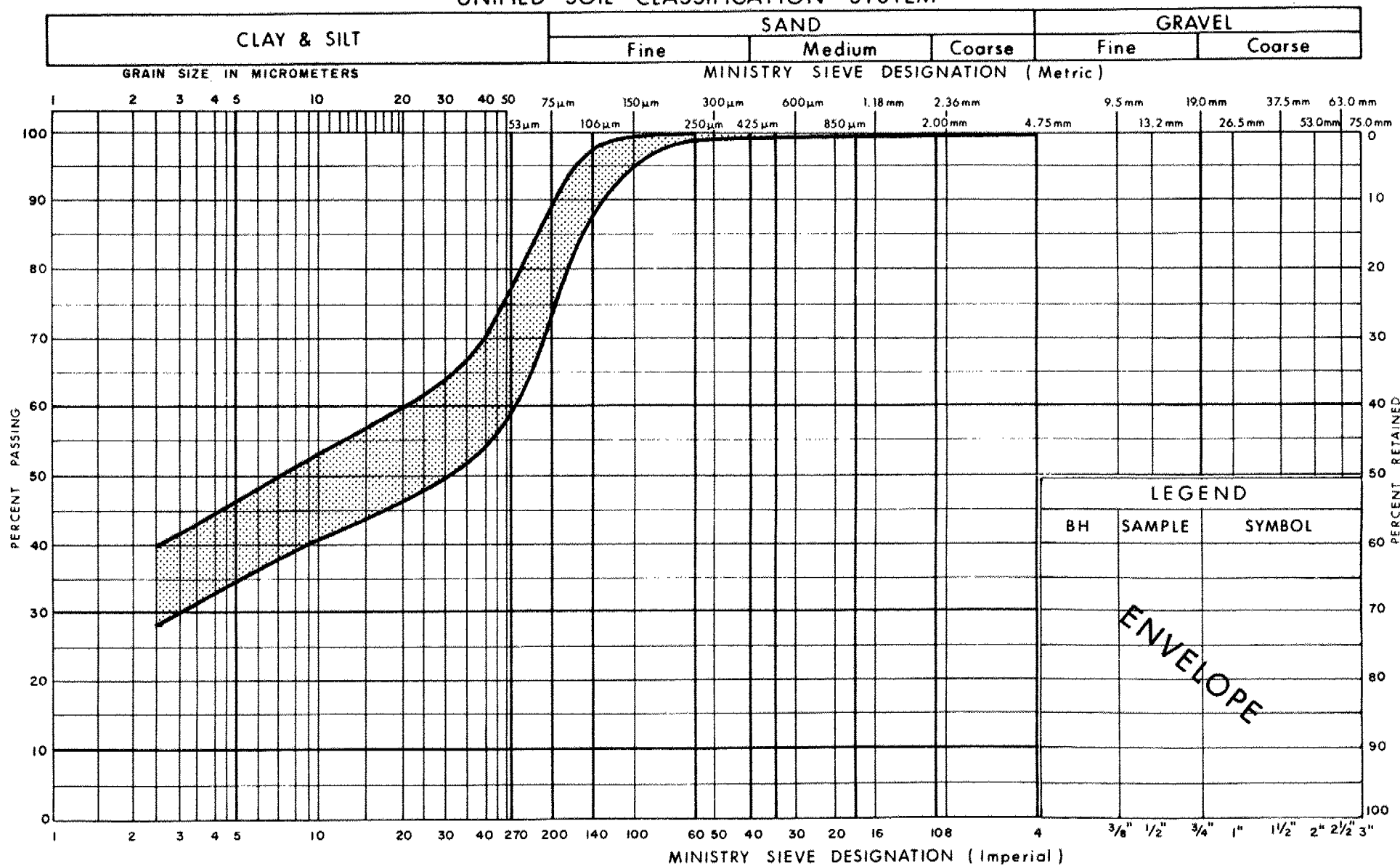
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PLASTICITY CHART CLAYEY SILT, WITH INTERBEDDED SANDY SILT

FIG No 2

W P 120-87-00A

UNIFIED SOIL CLASSIFICATION SYSTEM



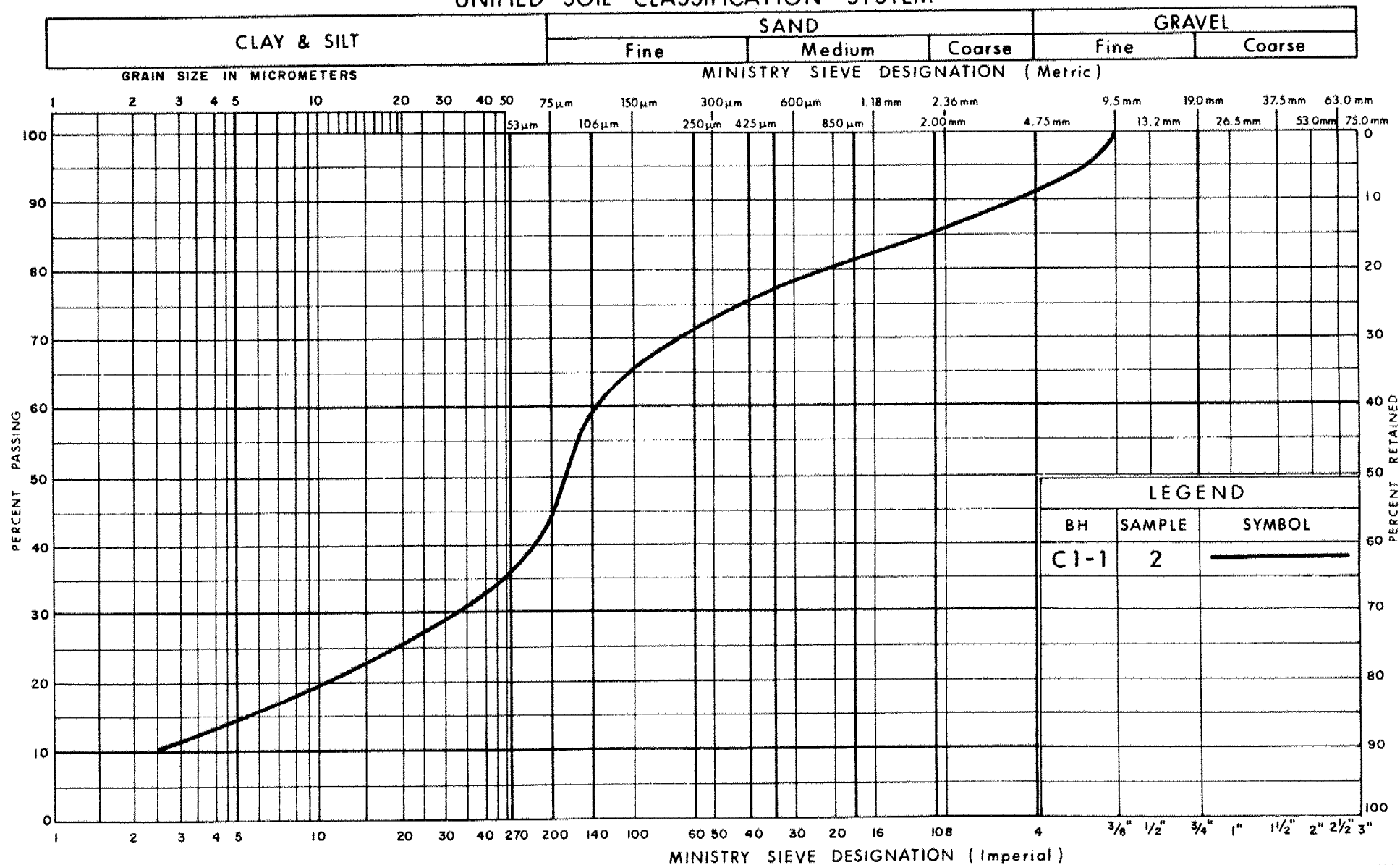
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GRAIN SIZE DISTRIBUTION
CLAYEY SILT, WITH INTERBEDDED SANDY SILT

FIG No 3

W P 120-87-00A

UNIFIED SOIL CLASSIFICATION SYSTEM



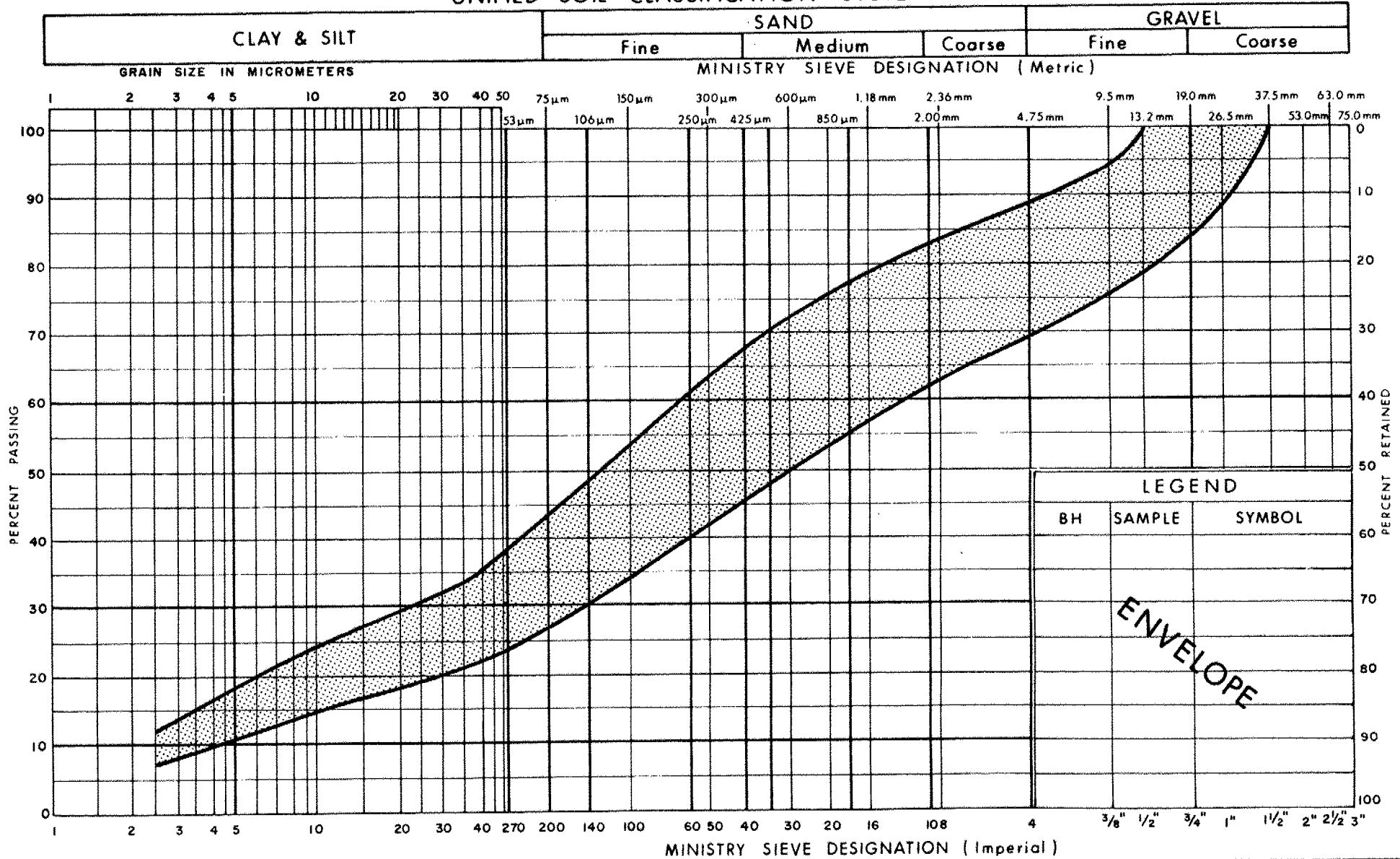
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GRAIN SIZE DISTRIBUTION
SILTY SAND

FIG No 4

W P 120-87-00A

UNIFIED SOIL CLASSIFICATION SYSTEM

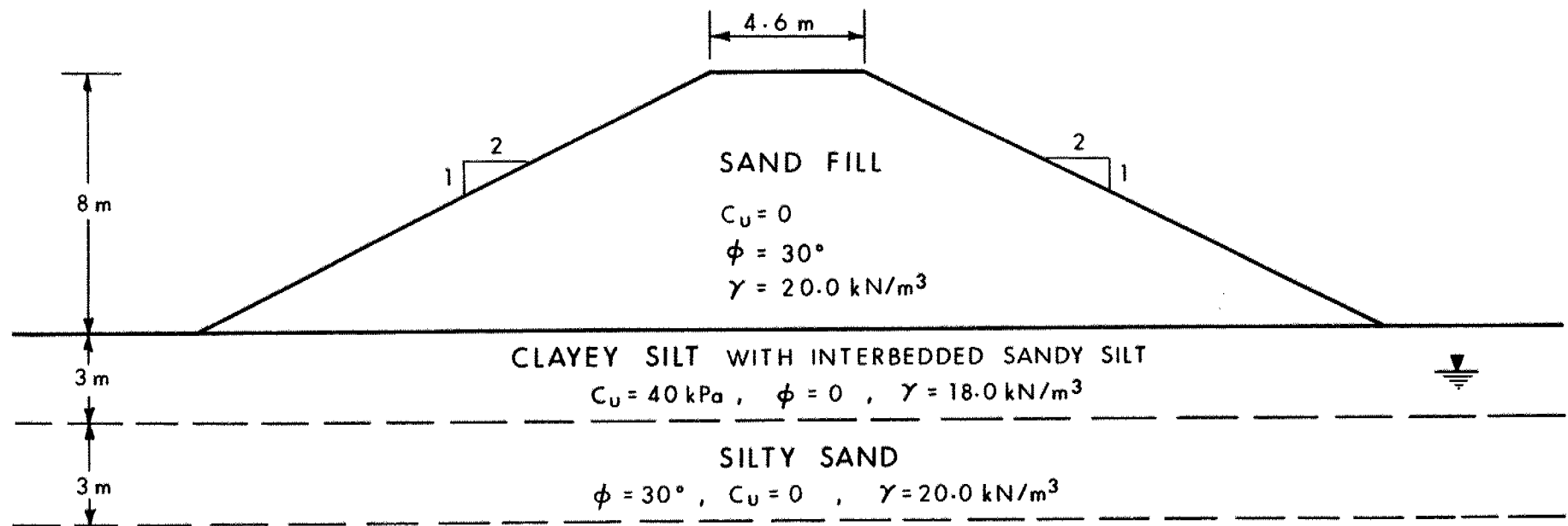


Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
HET MIXTURE OF
SILT, SAND & GRAVEL (Glacial Till)

FIG No 5

W P 120-87-00A



STABILITY ANALYSIS

WP 120-87-00A

Fig 6

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

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 = $\frac{c_u}{\tau_r}$

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
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

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	p	%	PLASTICITY INDEX = $\frac{w_L - w_p}{w_p}$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL		1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL		1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL		1		j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE			

ROCK CORE DESCRIPTION

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Page 1 of 1.

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
C1-1	6	6.63-6.73	100	0	6.63-8.41	SANDSTONE , medium light to very light grey, stained moderate yellow brown, laminated dark grey; medium grained; medium strong to strong rock; slightly weathered to unweathered; very close spaced fractures: horizontal, rough, irregular.
	7	6.73-8.41	92	23		
C2-1	1	0.00-1.63	95	81	0.00-1.63	SANDSTONE , very light to light grey, stained moderate yellow brown, laminated dark grey; medium grained; medium strong to strong rock; slightly weathered to unweathered; very close to moderately close spaced fractures: horizontal, rough, irregular.
C2-2	6	5.26-6.96	78	63	5.26-6.96	SANDSTONE , very light to medium grey, stained moderate yellow brown, laminated dark grey; medium to fine grained; medium strong to strong rock; slightly weathered to unweathered; close to moderately close spaced fractures: horizontal, rough, irregular.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: SAS, Soils and Aggregates Section.

RECORD OF BOREHOLE No C1-1

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 399.2; E 358 171.9 ORIGINATED BY DC
 DIST 9 HWY 416/417 BOREHOLE TYPE H.S. Auger, BW Casing, BXL Core & Cone Test COMPILED BY TCK
 DATUM Geodetic DATE 89 11 02 CHECKED BY TCK

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 x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) 10 20 30	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
65.6	Ground Surface										
0.0	Clayey Silt With Interbedded Brown Sandy Silt Grey Soft to Firm		1	SS	2						0 17 45 38
63.8											
1.8	Silty Sand V. Loose		2	SS	3						9 47 36 8
62.2											
3.4	Het. Mixture of Silt, Sand and Gravel (Glacial Till) Loose to V. Dense		3	SS	16						
			4	SS	6						
59.0			5	SS	40/						11 45 36 8
6.6	Sandstone Bedrock		6	RC	100%						RQD = 0%
57.2			7	RC	92%						RQD = 23%
8.4	End of Borehole										
<p><u>Piezometer Installation</u> <u>P-1 (Tip at 4.57m BGS)</u> 0 - 1.52m Backfill 1.52 - 1.83m Bentonite Seal 1.83 - 4.12m Backfill 4.12 - 4.57m Pea Gravel 4.57 - 8.40m Backfill</p>											

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No C1-2

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 451.5; E 358 190.5 ORIGINATED BY DC
 DIST 9 HWY 416/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TCK
 DATUM Geodetic DATE 89 11 02 CHECKED BY TCK

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					
65.8	Ground Surface													
65.4	Organic Sandy Silt (Topsoil)		1	CS	-	*								0 42 47 11
0.4	End of Borehole													
	Auger Refusal at Bedrock													
	* Borehole Dry													

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No C1-3

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 419.7; E 358 178.8 ORIGINATED BY DC
 DIST 9 HWY 416/417 BOREHOLE TYPE H.S. Auger and Cone Test COMPILED BY TCK
 DATUM Geodetic DATE 89 11 02 CHECKED BY TCK

OFFICE REPORT ON SOIL EXPLORATION

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			SHEAR STRENGTH kPa	WATER CONTENT (%)					
65.6	Ground Surface													
0.0	Brown - Grey Clayey Silt With Interbedded Sandy Silt Layer		1	SS	2		64	+6.5						0 23 52 25
			2	SS	2		62	+3.2						
	Soft to Stiff		3	SS	2									
61.0														
4.6	Silty Sand		4	SS	PH									
60.3	V. Loose													
5.3	Het. Mixture of Silt, Sand and Gravel (Glacial Till)		5	SS	4		60							30 43 22 5
	V. Loose to V. Dense		6	SS	2		58							
57.3														
8.3	End of Borehole							26/Bouncing at 8.2m BGS						
	Auger Refusal at Probable Bedrock													

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No C1-5

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 455.6; E 358 178.8 ORIGINATED BY DC
DIST 9 HWY 416/417 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY TCK
DATUM Geodetic DATE 89 11 02 CHECKED BY TCK

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 x LAB VANE	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE						
65.2	Ground Surface									
0.0	Inferred Clayey Silt									
63.5	With Interbedded Sandy Silt Layers					64				
1.7	End of Cone Test						50/Bouncing at 1.7m BGS			
	Cone Refusal at Probable Bedrock									

OFFICE REPORT ON SOIL EXPLORATION



METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 429.3; E 358 169.4 ORIGINATED BY DC
DIST 9 HWY 416/417 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY TCK
DATUM Geodetic DATE 89 11 02 CHECKED BY TCK

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 kPa	WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE		○					
								● QUICK TRIAXIAL x LAB VANE		x					
65.2	Ground Surface														
0.0															
	Inferred Clayey Silt With Interbedded Sandy Silt Layers														
59.4															
5.8															
58.5	Inferred Silty Sand														
6.7															
	Inferred Het. Mixture of Silt, Sand and Gravel (Glacial Till)														
56.2															
9.0	End of Cone Test														
	Cone Refusal at Probable Bedrock														
								24/Bouncing at 9.0m BGS							

+3, x5: Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No C1-7

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 402.7; E 358 161.5 ORIGINATED BY DC
 DIST 9 HWY 416/417 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY TCK
 DATUM Geodetic DATE 89 11 03 CHECKED BY TCK

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								
65.6	Ground Surface												
0.0	Inferred Clayey Silt With Interbedded Sandy Silt												
62.6													
3.0	Inferred Silty Sand												
61.6													
4.0	Inferred Het. Mixture of Silt, Sand and Gravel (Glacial Till)												
57.5													
8.1	End of Cone Test												
	Cone Refusal at Probable Bedrock												

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No C2-1

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 484.5; E 358 201.5 ORIGINATED BY DC
 DIST 9 HWY 416/417 BOREHOLE TYPE BXL Rock Core Barrel COMPILED BY TCK
 DATUM Geodetic DATE 89 11 02 CHECKED BY TCK

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					
66.3	Ground Surface																GR SA SI CL
0.0	Sandstone Bedrock		1	BXL RC	REC 95%	*	66										RQD = 81%
64.7																	
1.6	End of Borehole																
	* Borehole Dry																

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No C2-2

METRIC

W P 120-87-00A LOCATION: Co-ords: N 5 022 535.5; E 358 219.2 ORIGINATED BY DC
 DIST 9 HWY 416/417 BOREHOLE TYPE H.S. Auger, BW Casing, BXL Core and Cone Test COMPILED BY TCK
 DATUM Geodetic DATE 89 11 01 and 02 CHECKED BY TCK

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 x LAB VANE 20 40 60 80 100	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								
65.7	Ground Surface												
0.0	Clayey Silt With Interbedded Sandy Silt Layers, Grey Soft to Stiff		1	SS	7								0 11 54 35
63.6													
2.1	Silty Sand Loose		2	SS	4								
62.0													
3.7	Het. Mixture of Silt, Sand and Gravel (Glacial Till) Loose to Compact		3	SS	4								25 44 20 11
60.4													
5.3	Sandstone Bedrock		4	SS	5								
60.4													
5.3			5	SS	26								
5.3													
5.3			6	BXL RC	REC 78%								RQD = 63%
58.7													
7.0	End of Borehole												
<p>Piezometer Installation P-1 (Tip at 4.3m BGS)</p> <p>0 - 1.52m Backfill 1.52 - 1.83m Bentonite Seal 1.83 - 3.35m Backfill 3.35 - 4.36m Pea Gravel 4.36 - 7.00m Cased with Natural Material</p>													

OFFICE REPORT ON SOIL EXPLORATION

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 510.4; E 358 210.0 ORIGINATED BY DC
DIST 9 HWY 416/417 BOREHOLE TYPE H.S. Auger and Cone Test COMPILED BY TCK
DATUM Geodetic DATE 89 11 02 CHECKED BY TCK

[illegible]

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No C2-4

METRIC

W P 120-87-00A LOCATION Co-ords: N 5 022 488.0; E 358 191.0 ORIGINATED BY DC

DIST 9 HWY 416/417 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY TCK

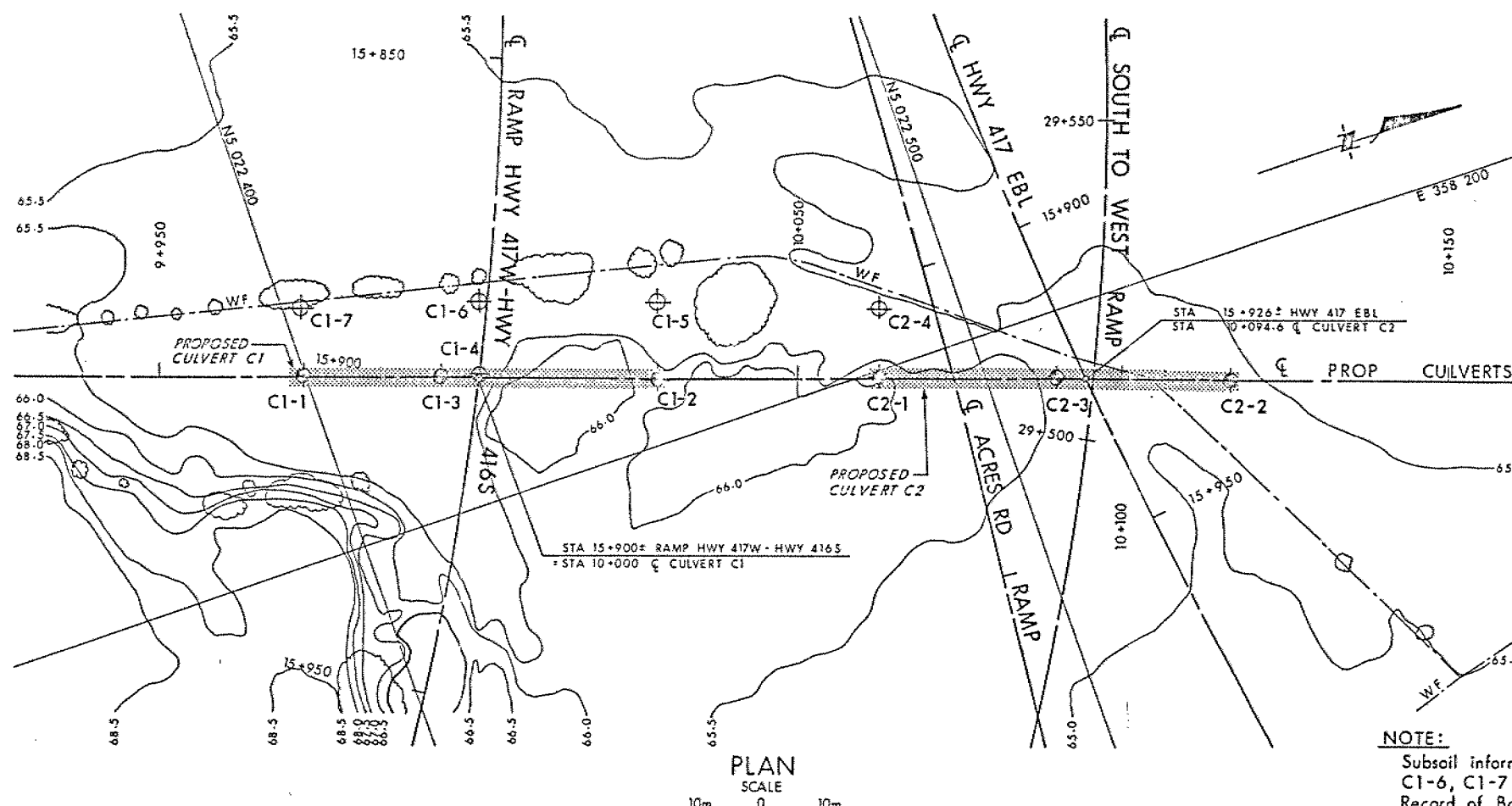
DATUM Geodetic DATE 89 11 03 CHECKED BY TCK

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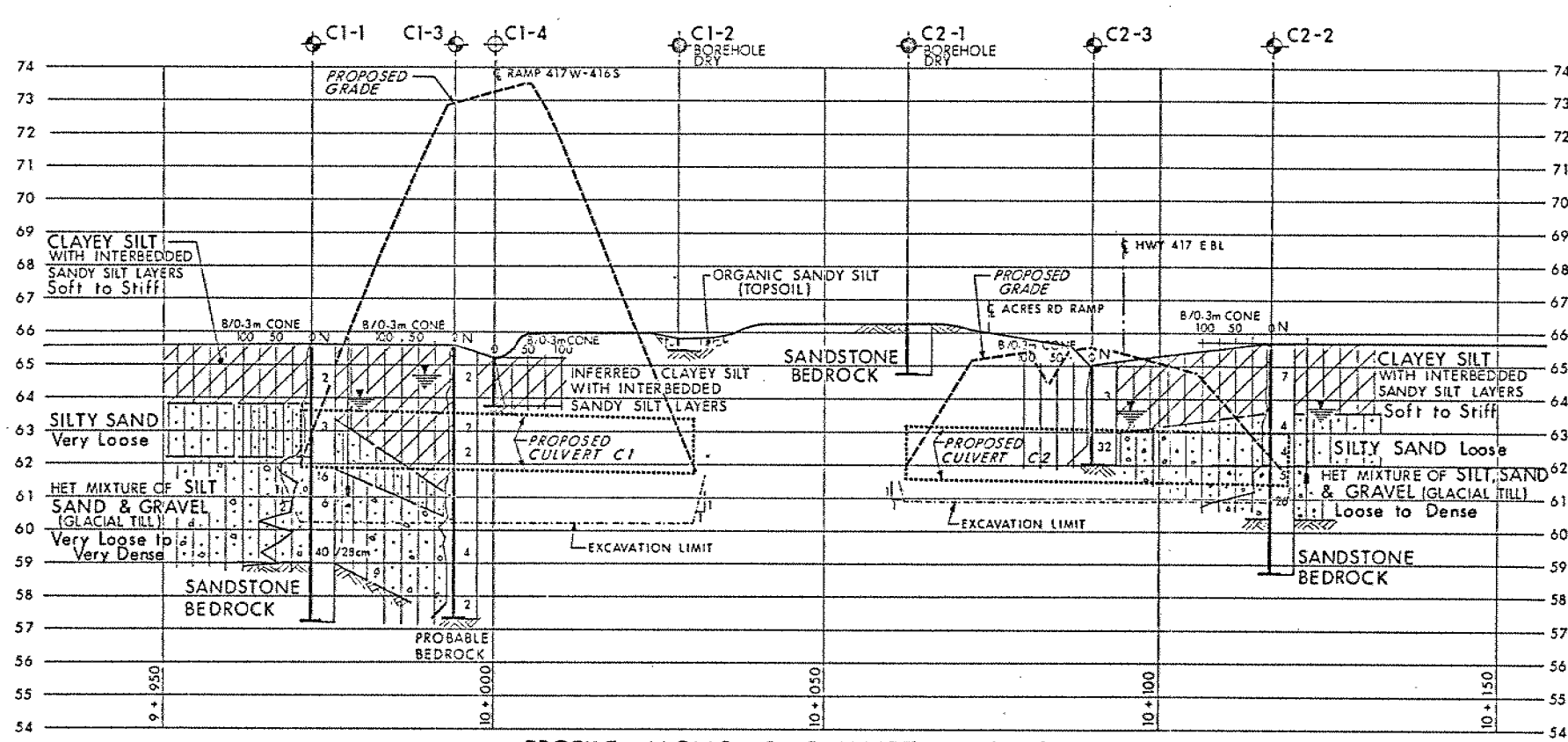
OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to Sensitivity

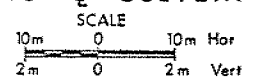
20
15 ϕ 5 (%) STRAIN AT FAILURE
10



NOTE:
Subsoil information for BH C1-5, C1-6, C1-7 & C2-4 refer to Record of Borehole sheets

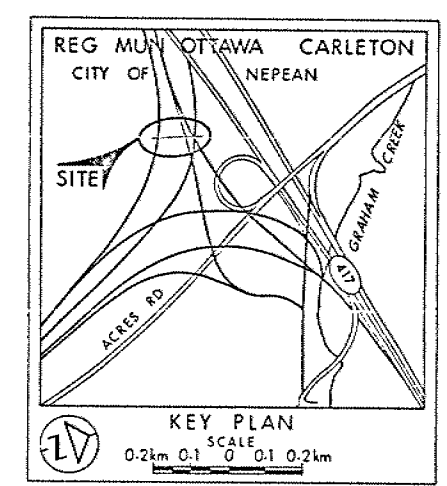


PROFILE ALONG CULVERT No 1 & 2



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

CONT No WP No 120-87-00A		SHEET
RAMP 417W-416S & 417 EBL CULVERT No 1 & 2		
BORE HOLE LOCATIONS & SOIL STRATA		



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)		
	WL at time of investigation 89 11		
	Piezometer		
No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C1-1	65.6	5 022 399.2	358 171.9
C1-2	65.8	5 022 451.5	358 190.5
C1-3	65.6	5 022 419.7	358 178.8
C1-4	65.2	5 022 425.5	358 181.0
C1-5	65.2	5 022 455.6	358 178.8
C1-6	65.2	5 022 429.3	358 169.4
C1-7	65.6	5 022 402.7	358 161.5
C2-1	66.3	5 022 484.5	358 201.5
C2-2	65.7	5 022 535.5	358 219.2
C2-3	65.0	5 022 510.4	358 210.0
C2-4	65.0	5 022 488.0	358 191.0

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 31G5-171

HWY No 416/417	DIST 9
SUBMD TCK: CHECKED TCK DATE 90 01 31	SITE
DRAWN DT: CHECKED DT	DWG 120 8700 A-A