

ENGINEERING MATERIALS OFFICE  
FOUNDATION DESIGN SECTION

WP 128-87-00(C) DIST 9  
HWY 416 STR SITE N/A

Evaluation of Backfill Suitability  
Proposed Hwy. 416  
Between  
Sta. 19+150 and Sta. 19+225

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FOUNDATION INVESTIGATION  
For  
Evaluation of Backfill Suitability  
Proposed Hwy. 416  
Between  
Sta. 19+150 and Sta. 19+225  
W.P. 128-87-00(C), Hwy. 416  
District 9, Ottawa

INTRODUCTION

Subsequent to a request submitted by the Eastern Region Structural Section dated April 4, 1989, an investigation was conducted by this office to determine the suitability of material located in the area delineated in the attached Figure 1 as backfill. The site is located along the proposed Hwy. 416 centreline, approximately 1 km north of the existing Strandherd Dr. between stations 19+150 to 19+225. The following report summarizes the method of investigation undertaken, the results of pertinent laboratory testing and comments are provided evaluating the suitability of the material as borrow material.

SITE DESCRIPTION

The site, located as mentioned above, consists of a generally flat to gently undulating terrain comprised of grassland and numerous surficial boulders. A nursery of low lying shrubs also populated the area. Agricultural farmland exists in the areas adjacent to the site.

FIELD INVESTIGATION

The fieldwork was carried out on 89 05 17 and consisted of two test pits located at stations 19+150 (TP#1) and 19+225 (TP#2). The test pits were excavated using a LS50800 Linkbelt Hydraulic Excavator and extended to depths of 4.1 metres and 5.0 metres at TP#1 and TP#2 respectively.

The exposed subsoil stratigraphy was visually logged and other relevant observations including water seepage, digability characteristics and excavation stability were taken and are summarized on the attached test pit logs in the

Appendix. Chunk samples taken at selected depths were identified in the field and then transported to the laboratory for applicable testing on selected samples.

### LABORATORY ANALYSES

Laboratory tests were carried out to determine the insitu moisture contents, gradation and compactibility characteristics of the subsoil. The test results have been summarized and are included in the attached test pit logs and figures.

### SUBSURFACE CONDITIONS

The natural subsoil stratigraphy consists of a thin veneer of topsoil approximately 0.3 metres in thickness overlying a predominant deposit of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders (glacial till). The glacial till deposit extends to a thickness of approximately 5 metres and is underlain by dolostone bedrock.

The boundaries between the various soil types, laboratory test results and insitu observations are shown on the attached test pit logs. A subsoil stratigraphical section is also attached.

A detailed description of the till deposit is given below:

#### Heterogeneous mixture of silt, sand, gravel, cobbles and boulders (Glacial Till)

The predominant native deposit encountered consists of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. A typical grain size distribution for the material smaller than 75 mm is provided in Figure 3 in envelope form. This material is brown in colouration, well graded and the relatively equal percentages of silt, sand and gravel suggest that this material can be effectively compacted. Random subrounded to rounded cobbles and occasional boulder sizes are also present in the deposit. Photos 1-4 attached illustrate the composition of this till deposit.

Moderate excavation resistance of the material smaller than 75 mm and the fact that vertical cut faces did not cave during excavation suggest that the material is in a compact to dense state of condition. However, considerable resistance to excavation naturally occurred in attempting to excavate the larger boulder sizes.

Natural moisture contents of the material generally range from 6.5% to 9.5%. Higher moisture contents in the 20 to 30% range were present in the surficial one metre thickness and are a product of the perched water that exists.

#### GROUNDWATER CONDITIONS

The natural groundwater table was not encountered during the test pit excavation. However, perched water was present within a surficial thickness of 1 metre and obvious soil ravelling accompanied this condition. Photo 4 illustrates perched water that has seeped in the excavation.

## DISCUSSION AND RECOMMENDATIONS

In conjunction with the excavation requirement for the advancement of Hwy. 416 in the area designated in Figure 1, the suitability of the excavated material as borrow material was requested. Based on the observations and subsequent laboratory analysis, the following conclusions can be derived.

### Earth Borrow Acceptability

The heterogeneous mixture of silt, sand, gravel, cobbles and boulders can be classified as suitable earth borrow in accordance with the material specifications outlined in OPSS 212 series. The deposit can be considered as a coarse grained soil that is inorganic and free-draining.

### Compactibility

The heterogeneous mixture of silt, sand, gravel, cobbles and boulders can be effectively compacted in compliance to the specifications outlined in OPSS 501 series provided that all material over .15 m in greatest dimension is removed and the material is placed with the appropriate moisture content to achieve at least 95% of Proctor maximum dry density. These requirements are in accordance with the layer compaction method outlined in OPSS 206.07.05.02. Natural moisture contents determined reveal a range from 6.5% to 9.5% which is anticipated to be in the range of optimum. If required any material that exceeds the optimum moisture content can be easily dried.

Achievement of the target density shall be quality controlled and correlated to applicable proctor tests.

### Frost Susceptibility

Figure 3 attached reveals that the amount of material between 5  $\mu$ m and 75  $\mu$ m in size ranges from 16 to 30% and consequently the material is not susceptible to frost. Generally materials with amounts exceeding 55% are considered highly susceptible.

MISCELLANEOUS

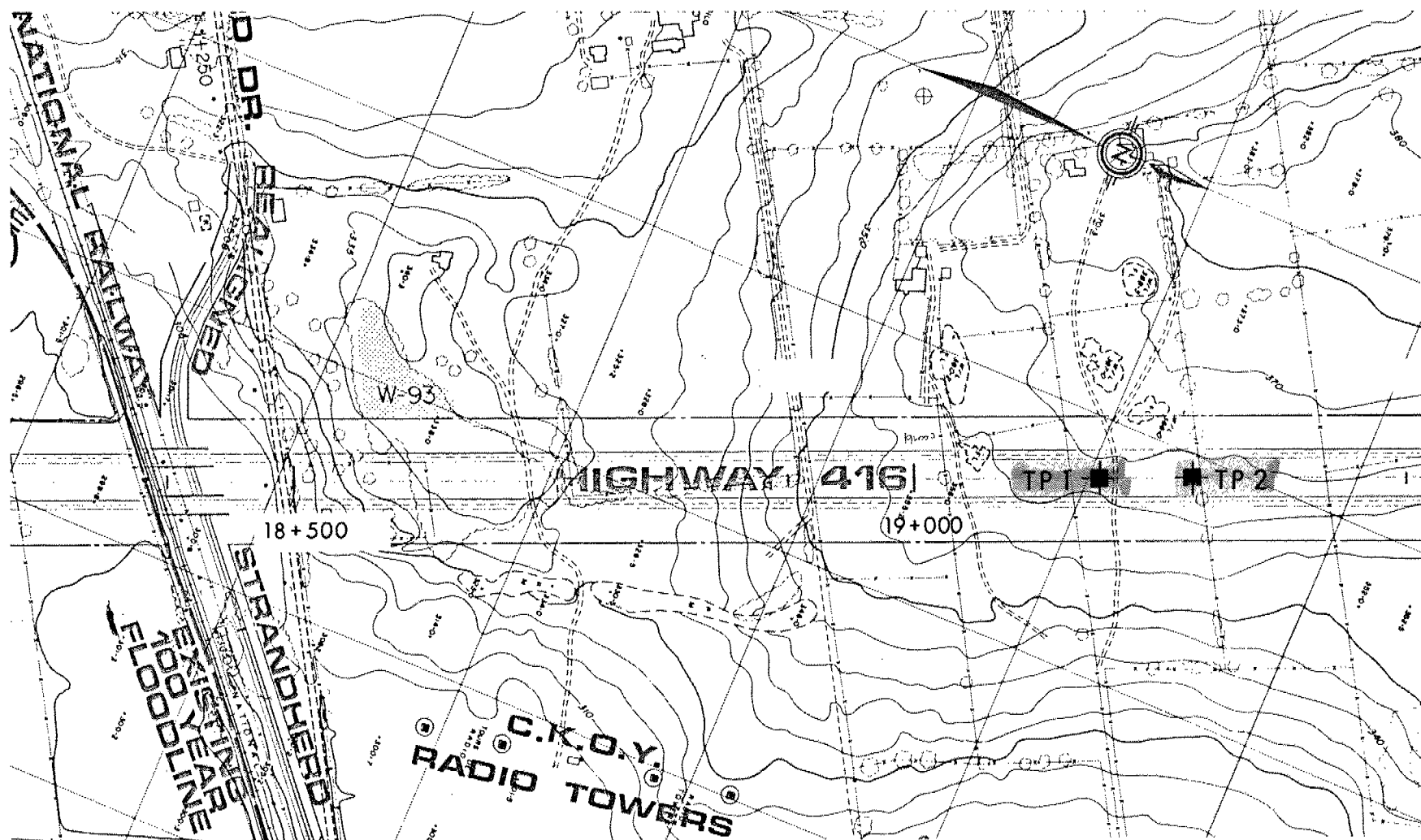
The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, utilizing equipment owned and operated by Vanson Construction Ltd. subcontracted under Marathon Drilling Co. The report was written by T. Sangiuliano and reviewed by Mr. M.S. Devata, Chief Foundation Engineer.



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Foundation Engineer

*M. S. Devata*  
M.S. Devata, P.Eng.  
Chief Foundation Engineer

## **APPENDIX**

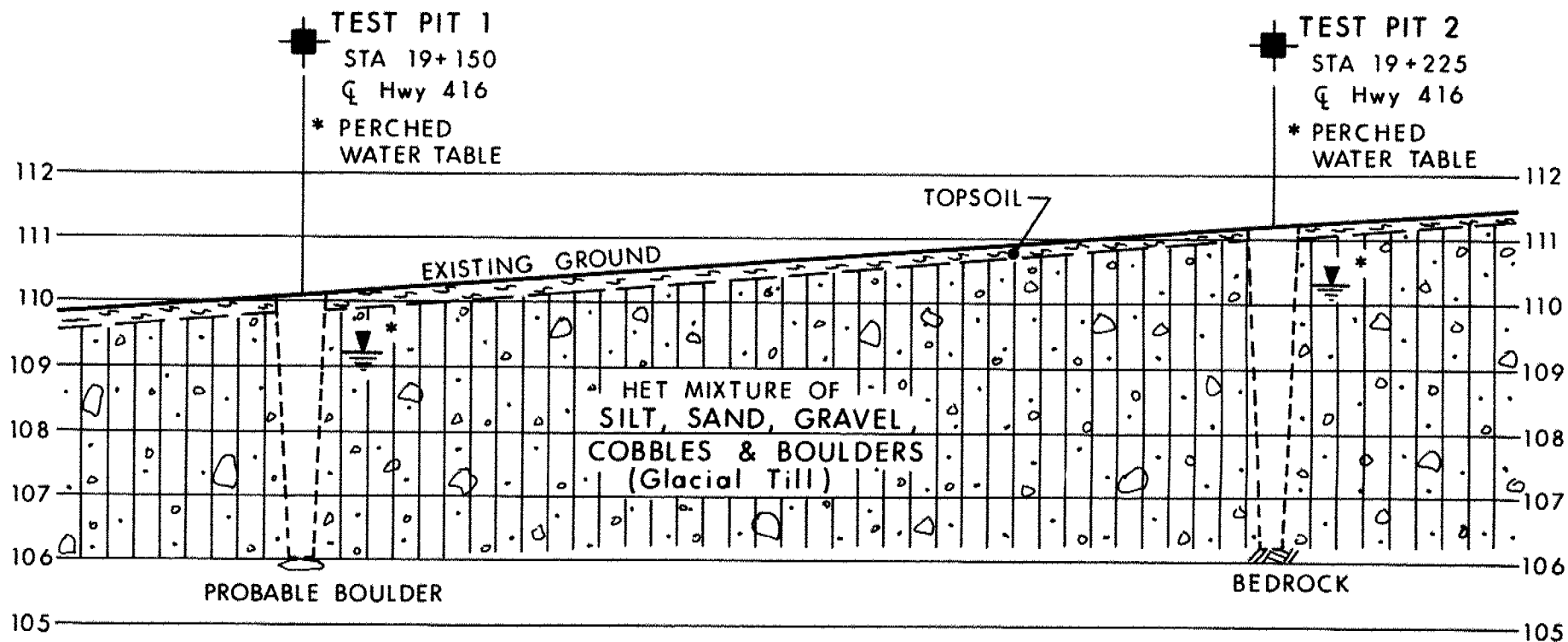


# TEST PIT LOCATIONS

SCALE 1:5000

WP 128-87-00 C  
Geocres No 31G5-164  
Fig No 1

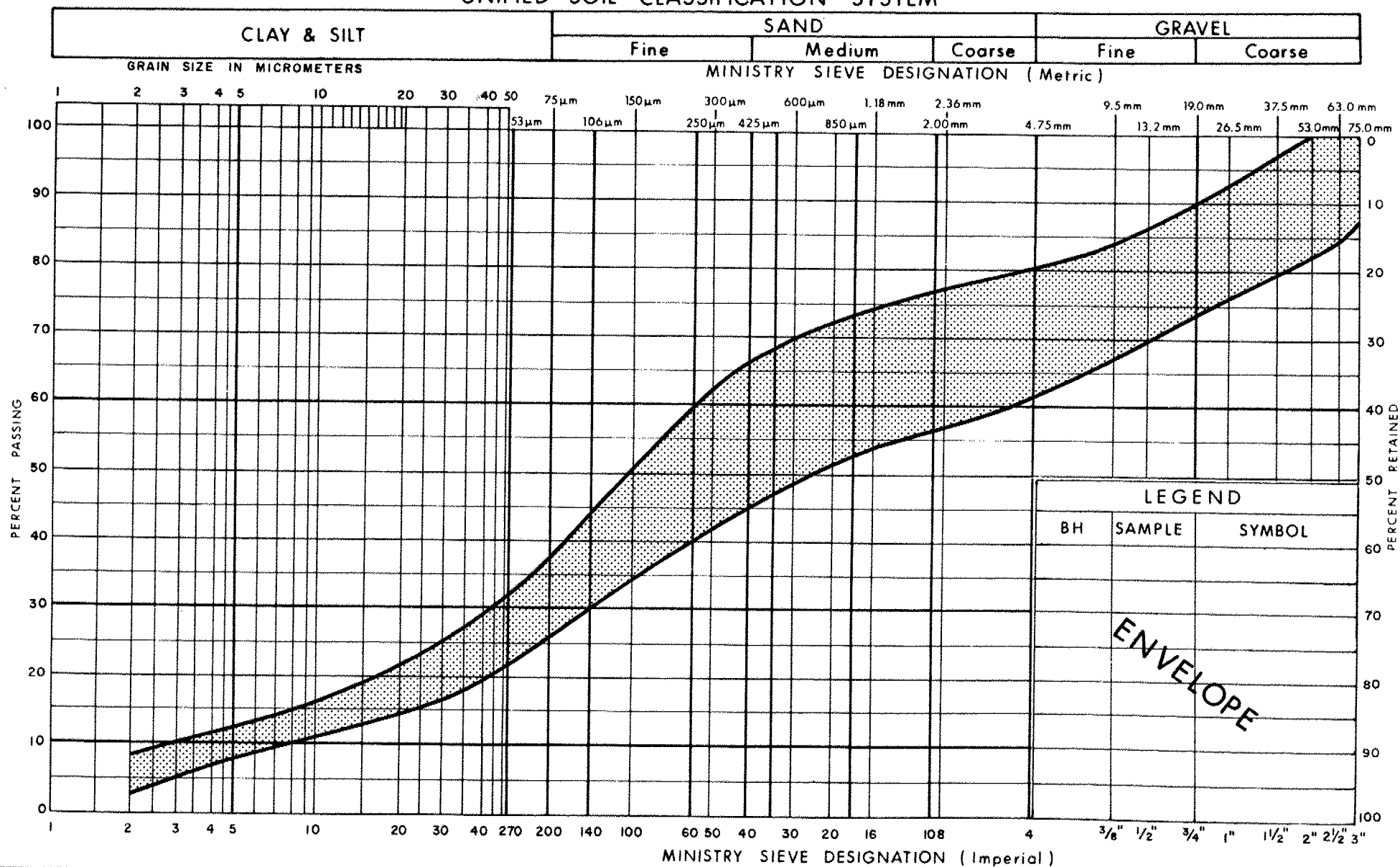




WP 128-87-00 C

Fig 2

## UNIFIED SOIL CLASSIFICATION SYSTEM

Ministry of  
Transportation

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

FIG No 3

W P 128-87-00 C



## METRIC


W P 128-87-00C LOCATION Sta. 19 + 150; ~~E~~ Median Hwy. 416 ORIGINATED BY TS  
DIST 9 HWY 416 HOLE TYPE Test Pit with Backhoe COMPILED BY TS  
DATUM Geodetic DATE 89 05 17 CHECKED BY \_\_\_\_\_

[illegible]



## METRIC

W P 128-87-00C LOCATION Sta. 19 + 225; 4 Median Hwy. 416 ORIGINATED BY TS  
DIST 9 HWY 416 HOLE TYPE Test Pit with Backhoe COMPILED BY TS  
DATUM Geodetic DATE 89 05 17 CHECKED BY \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  W <sub>p</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	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 (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE												
111.2	Ground Surface																			
0.0	Topsoil		1	CS	--	 **	110										27 39 26 8			
	Het. Mixt. of Silt, Sand, Gravel Cobbles and Boulders  (Glacial Till) Brown		2	CS	--													27 41 26 6		
			3	CS	--													32 42 21 5		
			4	CS	--															
			5	CS	--															
106.2																				
5.0	Bedrock End of Test Pit																38 36 21 5			
	* Perched Water Table																			
	** Groundwater Table not Encountered																			

PHOTOS



PHOTO 1 - Stockpile of soil consisting of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders (glacial till) excavated at test pit #1



PHOTO 2 - Close-up of oxidized till deposit illustrating its well-graded composition approximately 1 metre below the ground surface.

PHOTOS



PHOTO 3 - Another photo illustrating the coarser grain sizes (gravels and cobbles). In addition, the photo depicts the perched water seepage.



PHOTO 4 - Enormous boulder sizes are not uncommon in the till deposit. The photo illustrates a 1.5 m boulder.

## 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
$u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	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
$C_\alpha$	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
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

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

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SITE DESCRIPTION

The site, located as mentioned above, consists of a generally flat to gently undulating terrain comprised of grassland and numerous surficial boulders. A nursery of low lying shrubs also populated the area. Agricultural farmland exists in the areas adjacent to the site.

FIELD INVESTIGATION

The fieldwork was carried out on 89 05 17 and consisted of two test pits located at stations 19+150 (TP#1) and 19+225 (TP#2). The test pits were excavated using a LS50800 Linkbelt Hydraulic Excavator and extended to depths of 4.1 metres and 5.0 metres at TP#1 and TP#2 respectively.

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Laboratory tests were carried out to determine the insitu moisture contents, gradation and compactibility characteristics of the subsoil. The test results have been summarized and are included in the attached test pit logs and figures.

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The natural subsoil stratigraphy consists of a thin veneer of topsoil approximately 0.3 metres in thickness overlying a predominant deposit of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders (glacial till). The glacial till deposit extends to a thickness of approximately 5 metres and is underlain by dolostone bedrock.

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A detailed description of the till deposit is given below:

#### Heterogeneous mixture of silt, sand, gravel, cobbles and boulders (Glacial Till)

The predominant native deposit encountered consists of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. A typical grain size distribution for the material smaller than 75 mm is provided in Figure 3 in envelope form. This material is brown in colouration, well graded and the relatively equal percentages of silt, sand and gravel suggest that this material can be effectively compacted. Random subrounded to rounded cobbles and occasional boulder sizes are also present in the deposit. Photos 1-4 attached illustrate the composition of this till deposit.

Moderate excavation resistance of the material smaller than 75 mm and the fact that vertical cut faces did not cave during excavation suggest that the material is in a compact to dense state of condition. However, considerable resistance to excavation naturally occurred in attempting to excavate the larger boulder sizes.

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## DISCUSSION AND RECOMMENDATIONS

In conjunction with the excavation requirement for the advancement of Hwy. 416 in the area designated in Figure 1, the suitability of the excavated material as borrow material was requested. Based on the observations and subsequent laboratory analysis, the following conclusions can be derived.

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Figure 3 attached reveals that the amount of material between 5  $\mu$ m and 75  $\mu$ m in size ranges from 16 to 30% and consequently the material is not susceptible to frost. Generally materials with amounts exceeding 55% are considered highly susceptible.

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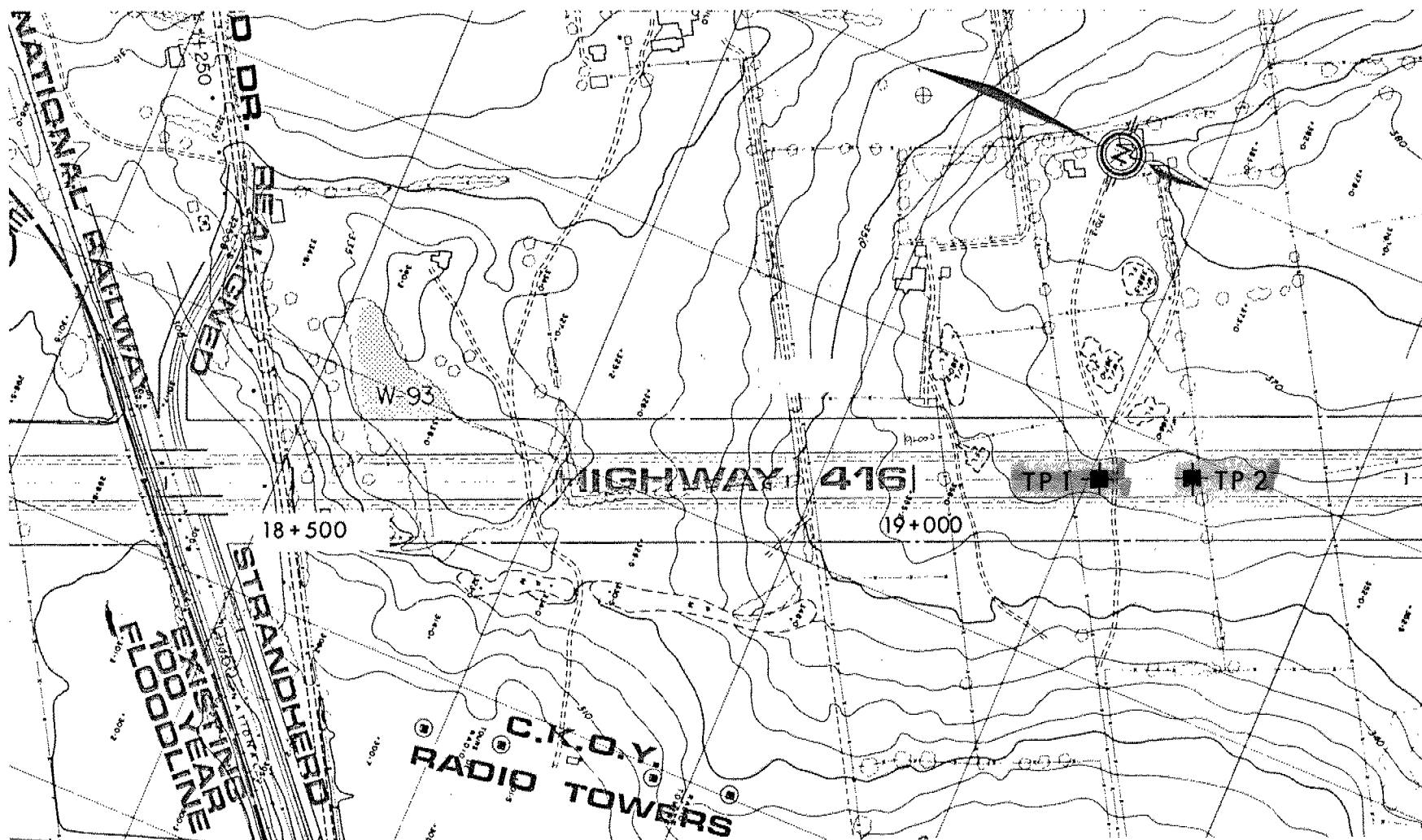
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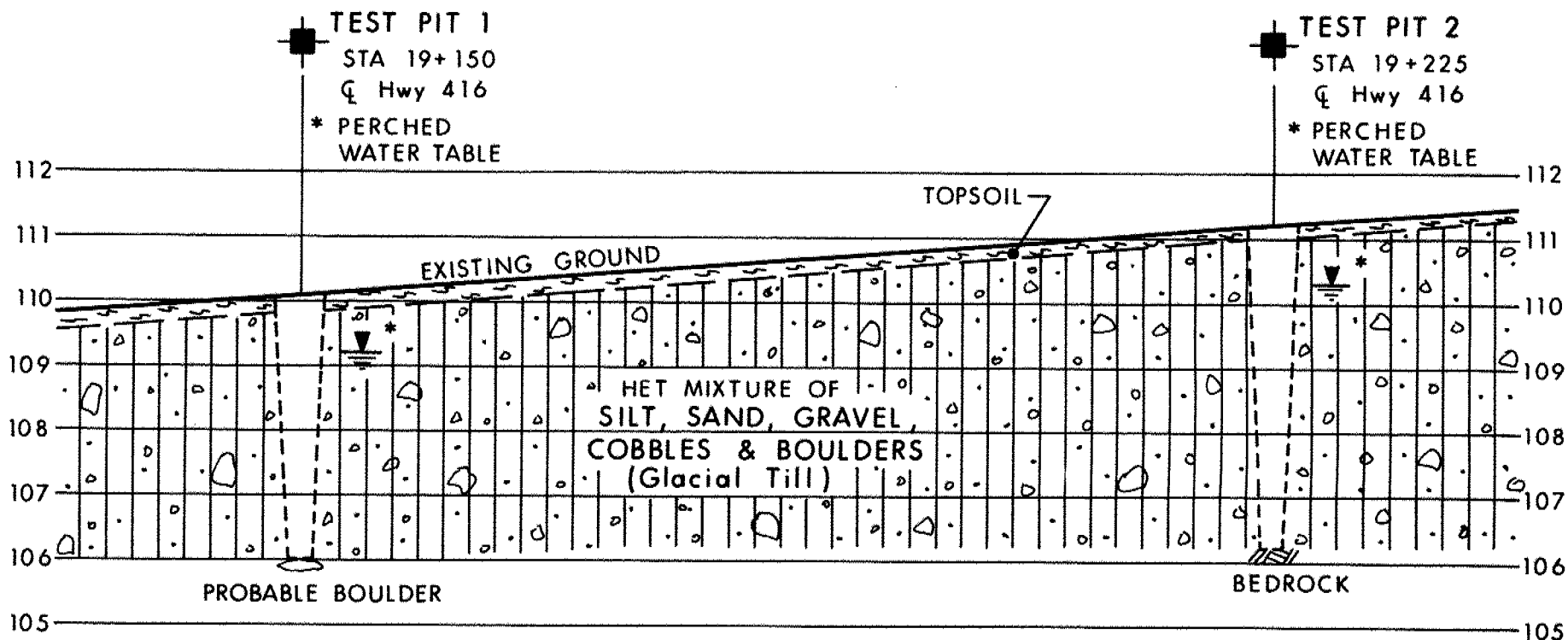
## **APPENDIX**



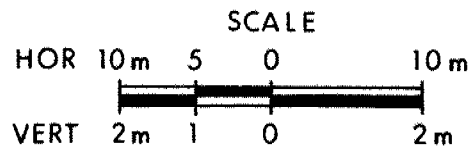
## TEST PIT LOCATIONS

SCALE 1:5000

WP 128-87-00 C  
Geocres No 31G5-164  
Fig No 1



SECTION A-A (ALONG C<sub>L</sub> HWY 416)

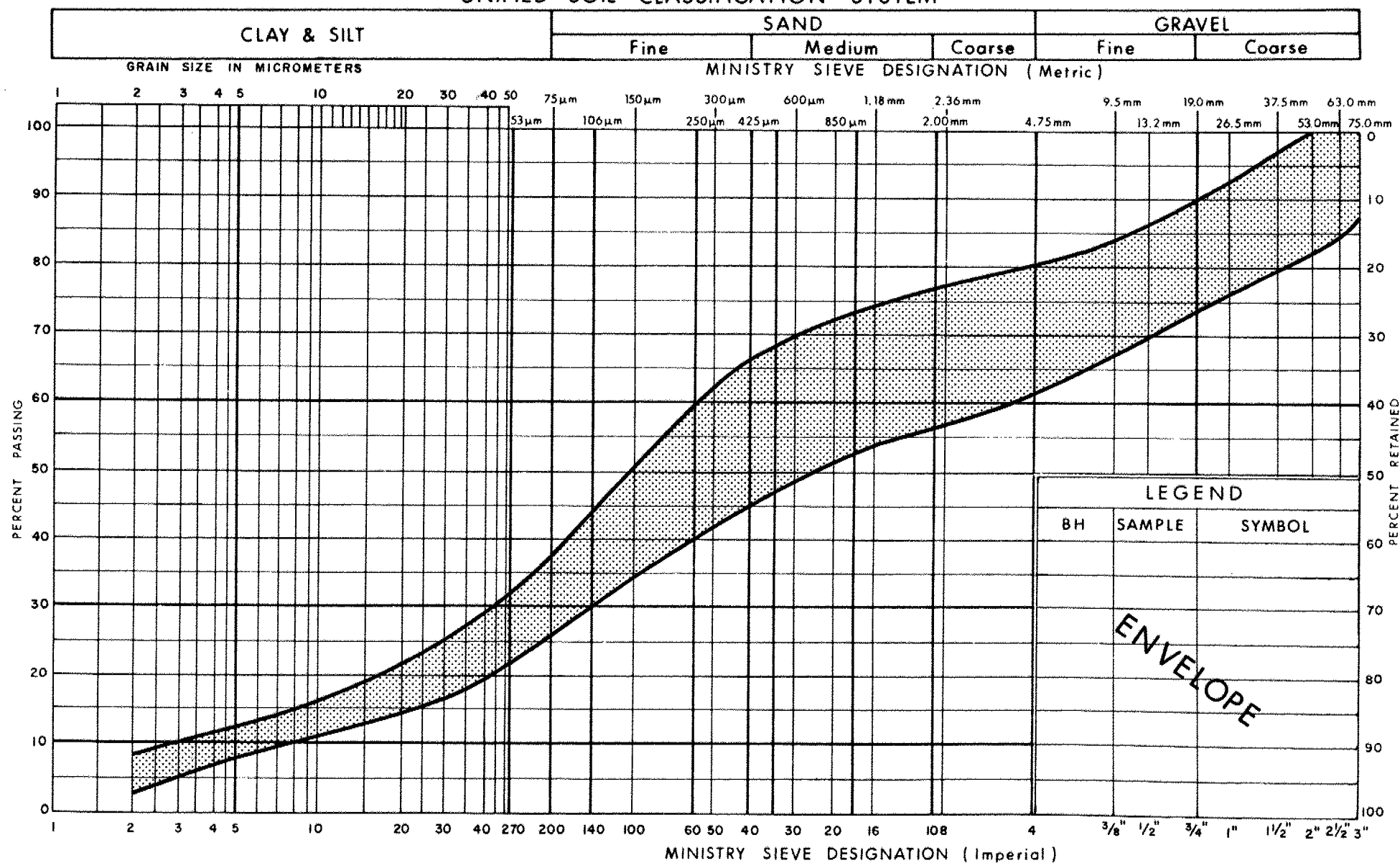


WP 128-87-00 C

Fig 2



## UNIFIED SOIL CLASSIFICATION SYSTEM



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**GRAIN SIZE DISTRIBUTION**  
HET. MIXTURE OF SILT, SAND, GRAVEL  
COBBLES & BOULDERS (Glacial Till)

FIG No 3

W P 128-87-00 C



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PHOTOS



PHOTO 1 - Stockpile of soil consisting of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders (glacial till) excavated at test pit #1



PHOTO 2 - Close-up of oxidized till deposit illustrating its well-graded composition approximately 1 metre below the ground surface.

PHOTOS



PHOTO 3 - Another photo illustrating the coarser grain sizes (gravels and cobbles). In addition, the photo depicts the perched water seepage.



PHOTO 4 - Enormous boulder sizes are not uncommon in the till deposit. The photo illustrates a 1.5 m boulder.

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

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

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

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

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

**JOINTING AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$kPa^{-1}$	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	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
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_r$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### STRESS AND STRAIN

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

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$kg/m^3$	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$kn/m^3$	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\rho_w$	$kg/m^3$	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$kn/m^3$	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	$kg/m^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	$kn/m^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	$kg/m^3$	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	$m^3/s$	RATE OF DISCHARGE
$\gamma_d$	$kn/m^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
$\rho_{sat}$	$kg/m^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{sat}$	$kn/m^3$	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	$kg/m^3$	DENSITY OF SUBMERGED SOIL	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE	j	$kn/m^3$	SEEPAGE FORCE
$\gamma'$	$kn/m^3$	UNIT WEIGHT OF SUBMERGED SOIL						