ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

CONT. 90-36

WP 120-87-03 DIST 9

HWY 417 STR SITE 3-537

Graham Creek Structure North Section
Structure #14

DISTRIBUTION

E.C. Lane (2)
T.W. Murphy
D.J. Kimmett
E. Zavitski (2)
K.G. Bassi
D. Aspinwall
T. Yakutchuk
G. Szekreny
L. Saulnier (Cover Only)
M. MacLean (Cover Only)
File

GEOCRES 31G5-150 DATE JAN 0 5 1989

FOUNDATION INVESTIGATION REPORT
For
Graham Creek Structure North Section
Structure #14
WP 120-87-03, Site 3-537
Hwy. 417, District 9, Ottawa

INTRODUCTION

This report summarizes the results obtained from a Foundation Investigation implemented at the aforementioned site. It is proposed to remove and replace the existing Graham Creek culvert that underpasses the existing Hwy. 417 and Richmond Road ramp. The most northen 44 m of the existing culvert will be modified by removing the top slab and west retaining wall. This report is applicable to the structure foundations, approaches and related earthworks.

SITE DESCRIPTION AND GEOLOGY

The site is situated at the location of the existing Graham Creek culvert that underpasses the existing Hwy. 417 and Richmond Road ramp approximately 200 metres east of the Hwy. 417/Acres Road underpass in the City of Nepean Ottawa-Carleton Municipality. The northerly flowing waters of Graham Creek meander in a valley approximately 20 metres wide immediately adjacent and south of the existing structure. Gabion retaining walls exist on the slopes at the outlet of the culvert. Approximately 5 metres of fill cover the roof of the existing culvert.

The surrounding terrain is generally flat and consists primarily of grassland. A condominium complex exists approximately 500 metres northeast of the culvert outlet.

Physiographically, the site lies in the area known as the Ottawa Valley Clay Plains founded in the Lowlands of the St. Lawrence. The deposit 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.

The bedrock in the area is of the Gull River Formation of the Middle Ordovician Period. It consists of interbedded silty dolostone, shaley limestone and fine grained quartz sandstone. The overburden was deposited during and immediately

following the Wisconsin 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

The fieldwork for the investigation was carried out between 88 07 21 and 88 07 28 and consisted of four sampled boreholes accompanied by dynamic cone penetration tests. Continuous flight hollow stem auger equipment and washboring techniques were used to advance the boreholes in the overburden. Subsoil samples were retrieved at selected intervals by a split spoon sampler in accordance with the Standard Penetration Test (ASTM D1586). Samples were identified in the field and then returned to the laboratory for applicable testing. Bedrock was proven at BH #14-2 using conventional rock coring methods.

Water levels were obtained in the open boreholes until approximate stabilized levels were observed.

Survey information related to location and elevation of boreholes was provided by Eastern Region Surveys and Plans.

LABORATORY ANALYSES

To identify the behaviour, gradation and properties of the soil, various laboratory testing were performed. These tests included:

1) Atterberg Limit Tests
2) Grain Size Analyses
3) Natural Moisture Contents
4) Direct Shear Tests

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

SUBSURFACE CONDITIONS

Underlying approximately 5 metres of fill consisting of a mixture of clayey silt, silt, sand and gravel used in the construction of the existing culvert, the main deposit at the site consists of a significant thickness of a cohesionless sand. This deposit has a thickness ranging from 15.2 metres to 19.4 metres and contains traces of silt and gravel. Its relatively density ranges from loose to very dense but generally it can be classified as dense. Underlying the sand layer is a heterogeneous mixture of sand, gravel and boulders (glacial till) that in turn overlies the bedrock composed of silty dolostone with interbedded limestone. The vertical extent of the till deposit was not established across the site but is 2.1 metres in thickness in the area of BH 14.2.

The boundaries between the various soil types, in situ and laboratory test results as well as stabilized ground water levels, are shown on the attached Record of Borehole Sheets in the Appendix. A plan of the site illustrating the locations and elevations of the boreholes and subsoil stratigraphical sections are also provided on Dwg. 1208703-A. The plan includes locations and stratigraphical profiles of borholes advanced in conjunction with structure 6 (culvert extension).

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

Fill Material (Mixture of Clayey Silt-Silt, Sand and Gravel)

The surficial fill material used in the construction of the existing culvert varies in composition and behaviour at different locations along the length of the culvert. Basically, the fill south of the existing Richmond Road ramp is a cohesionless mixture of sand, silt and gravel. The surficial fill material north of the Richmond Road ramp contains a greater percentage of fines and consequently exhibits a cohesive behaviour. It consists of a mixture of clayey silt, sand and gravel and is of low plasticity. The thickness of the fill ranges from 3.5 to 5.0 metres.

Grain size distribution curves illustrating the composition of the fill is provided on Figure 1. Atterberg Limits performed on the fine grained portion of the fill are plotted on Figure 2.

Based on 'N' values obtained from the Standard Penetration Test, this fill material is generally in a compact state of condition.

Sand

The predominant deposit at the site and underlying the fill material is a poorly graded cohesionless sand that ranges in thickness from 15.2 m to 19.4 m. This sand layer also contains traces of gravel and silt. Typical grain size distribution curves are plotted in envelope form on Figure No. 3.

The relative density of the cohesionless deposit varies from loose to very dense with 'N' values obtained from the Standard Penetration Test ranging from 5 blows/0.3 m to 120 blows/0.25 m. Generally, the deposit is in a compact to dense state of condition.

Direct shear tests were performed on selected samples of the deposit in the laboratory to determine the angle of internal friction. Results revealed values ranging from 31 to 33.5° and are summarized in Table 1 below.

Table 1

Sample	Angle of Internal Friction (°)
BH 14-2, SS6	31
BH 14-2, SS9	33.5
BH 14-4, SS5A	32.5

Heterogeneous Mixture of Sand, Gravel and Boulders (Glacial Till)

Underlying the predominant deposit of the deposit of sand exists a heterogeneous mixture of sand, gravel and boulders of glacial origin. This stratum was not explored to its vertical extent over the entire site but a thickness of 2.1 metres exists in the area of BH 14-2. Rock Coring methods were required to penetrate the larger sizes of the deposit.

Bedrock

The glacial till deposit is underlain by bedrock of the Gull River Formation and was proven at BH 14-2 by obtaining 1.4 metres of rock core samples. The bedrock consists of a silty dolostone which is a clastic sedimentary rock. Detailed descriptions of the bedrock are attached in the Appendix, entitled "Description of Rock Core".

Core recoveries and rock quality designations (RQD) were determined in situ and also in the laboratory to evaluate the competence and integrity of the rock. Based on the results and thorough visual laboratory examination, the rock can be classified as medium strong to strong and unweathered.

Groundwater Conditions

Observation of the groundwater level was carried out by measuring the water level in the open boreholes. Measurements revealed stabilized levels at an elevation ranging from 60.5 m to 61.0 m which corresponds approximately to the surface of the native sand deposit.

DISCUSSION AND RECOMMENDATIONS

It is proposed to replace, modify and extend the existing Graham Creek Culvert that transmits the waters of Graham Creek at the Hwy. 417 crossing. The existing culvert is a 5.5 m x 2.4 m x 123 m reinforced concrete box culvert. It is conceived that both the culvert replacement and extension will be reinforced concrete box frame structures.

This report provides recommendations pertaining to the removal of the existing culvert and its replacement along the original alignment (Stage 2 construction) and its modification (stage 3 construction - removal of top slab and west wall). For the modification, excavated slopes that extend from the base of the existing culvert to the existing ground surface are proposed for the west side at the culvert outlet following removal of the west wall. The east wall will remain as a retaining wall for a sloped surface. This proposal is for the most northerly section of the existing culvert and is approximately 44 m in length. Presently, the sloped surfaces at the culvert outlet are retained by gabion retaining structures.

The proposed Hwy. 417 WB and Richmond Road ramp to 417 WB will overpass the culvert at a grade of 72.0 m which translates into fills up to 7.0 m at the approaches and 13.5 metres at the creek channel.

The major geotechnical related areas of discussion contained in this report are:

1) Structure Foundations
2) Stability and Settlement of Approaches
3) Lateral Earth Pressures
4) Cut Slopes at Culvert Outlet
5) Construction Considerations

STRUCTURE FOUNDATIONS

The proposed concrete culvert structure may be founded on spread footings located within the native sand layer that predominates the site. For purposes of the O.H.B.D.C., the following design values are recommended:

Structure	Recommended Footing El. (m)	Bearing Capacity at S.L.S. Type II (kPa)	Factored Bearing Capacity at U.L.S. (kPa)
Concrete Culvert	<59.0	250	450

A footing width (B) equal to 6.0 m was used in the calculation of the capacities.

The underside of all footings should be provided with a minimum 1.80 metres of earth cover for frost protection. In addition, to protect the footings against scour, a properly designed rip-rap meeting the hydrological requirements at the site, should be placed at the culvert channel outlet.

Settlement of the foundation subsoil as a result of the applied footing pressure will be elastic in nature - i.e. take place during or immediately following the construction period. The magnitude of this settlement is anticipated to be within 25 mm, provided the subsoil is not loosened by construction or related activites. It is recommended that a working slab be placed to protect the footing founding soil within 4 hours of exposure.

Sliding resistance between the concrete and the foundation soil should be calculated in accordance with Section 6.7.3.3.2 of the O.H.B.D.C. assuming a coefficient of friction of 0.6.

STABILITY AND SETTLEMENT OF APPROACH FILLS

Stability computations were carried out to evaluate the effect of the approach fills to the overall stability both in the longitudinal and transverse directions. Bishop's total stress analysis was implemented incorporating a minimum factor of safety of 1.3. The properties of the fill material and subsoil and the surface geometries used in these computations are shown on Figure 4. The proposed fill height is in the order of 7 m above the existing ground surface at the approaches beyond the anticipated excavation cut for the culvert replacement. Within the anticipated excavation cut, fills up to 13.5 metres will be required. Based on the analyses, the following conclusions have been derived:

1) Due to the competent nature of the subsoil, no deep seated failures are anticipated for fills constructed with standard 2H:1V slopes.

2) Fills up to 8 metres above the original ground surface will maintain internal stability provided they are constructed with standard 2H:1V slopes.

3) A nominal 2 m midheight stabilizing berm will be required for fills exceeding 8 metres in height above the ground surface. Berms should be constructed with a nominal slope such that surface run-off does not pond on the berm.

Any softened and/or organic soil should be removed within the planned limits of the fill prior to its placement.

Settlement of the native subsoil as a result of the approach embankment loading will be elastic in nature (occur during or immediately after construction) and within a magnitude of 25 mm. In addition, settlement of the fill under its own weight can be expected. In general, the following settlements within the fill can be expected:

Height of Fill (H_{FILL}) (m)	Total Settlement (S_T)
0-7	0.5% x H_{FILL}
7-10	0.75% x H_{FILL}
10-12	1% x H_{FILL}

Cohesive soils will settle with time and consequently it is recommended that cohesive fills be placed as far in advance of the roadway paving as scheduling permits.

LATERAL EARTH PRESSURES ON CULVERT/RETAINING WALLS

To prevent hydrostatic pressure build-up, backfill to culvert walls and retaining walls should consist of Granular 'A' or Granular 'B'. Design parameters of the soil are given below:

	Granular 'A'	Granular 'B'
Angle of Internal Friction (ϕ)	35°	30°
Unit Weight (kN/m^3), γ	22.8	21.2

Lateral earth pressures should be computed in accordance with Section 6.6.1.2.1 of the O.H.B.D.C.. The active condition (K_A) will govern earth pressure design if the structure is yielding while the at rest condition (K_O) will govern for an unyielding structure. Weep holes should be designed to drain accumulation of water in the backfill.

CUT SLOPES AT CULVERT OUTLET

The critical condition for stability of the open cut slopes proposed at the culvert outlet will be the long term (drained) condition and consequently an effective stress analysis was implemented using Bishop's method and incorporating a minimum factor of safety of 1.3.

Various cut geometries were evaluated and the results are summarized below.

1) An analysis assuming a 2H:1V slope with 0, 0.6 and 1.2 m thick rip-rap blankets produced unacceptable factors of safety. (see Figure 5).

2) An analysis assuming a 2.5H:1V slope with 0, 0.6 and 1.2 m thick rip-rap blankets resulted in acceptable factors of safety. (see Figure 6).

3) An analysis assuming a 2H:1V slope with a 1.2 m wide bench located at mid-depth and with 0, 0.6 and 1.2 m thick rip-rap blankets resulted in acceptable factors of safety (see Figure 7).

It can be concluded from the results that alternatives 1 or 2 be adopted. The alternative that is most economical and practical should be selected.

CONSTRUCTION CONSIDERATIONS

1) Temporary excavation cuts for foundation elements should be sloped at slopes no steeper than 2H:1V in view of the high water table.

2) Temporary diversion of the Graham Creek waters will be required during construction.

3) Temporary excavations for the construction of the box culvert will extend some 3 metres below the groundwater level in the cohesionless sand deposit. This may cause the base of the excavation to "boil" due to unbalanced hydrostatic water pressure head within the sand stratum. Consequently, a dewatering scheme will be required. Two methods of dewatering that is recommended are:

a) Oversized Excavation

Figure 8 illustrates this proposed scheme that involves a "benched" excavated slope with temporary slopes not steeper than 2H:1V and a mid-height bench width of 2 m. Drainage ditches should be excavated at the toe of the slopes to drain the accumulated water.

b) Cofferdam Construction

The excavation can be carried out from within an enclosure formed of interlocking steel sheeting. In order to prevent 'boiling' at the base of the excavation, it is recommended that the sheeting be driven to a depth below the footing base equal to the unbalanced hydrostatic head existing above this level (see Figure 9).

4) Backfill to the culvert should be constructed in accordance with appropriated O.P.S.D. Standards (O.P.S.D. 803 series). The backfill should be constructed in 300 mm lifts on alternating 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 J. Fellenius, Student Engineer and T. Sangiuliano, Foundation Engineer, utilizing equipment owned and operated by Marathon Drilling Co. and Johnston Drilling Co. Rock Core Descriptions were provided by Mr. S. Senior, Geologist. This report was written by T. Sangiuliano and reviewed by Mr. M.S. Devata, Chief Foundation Engineer.

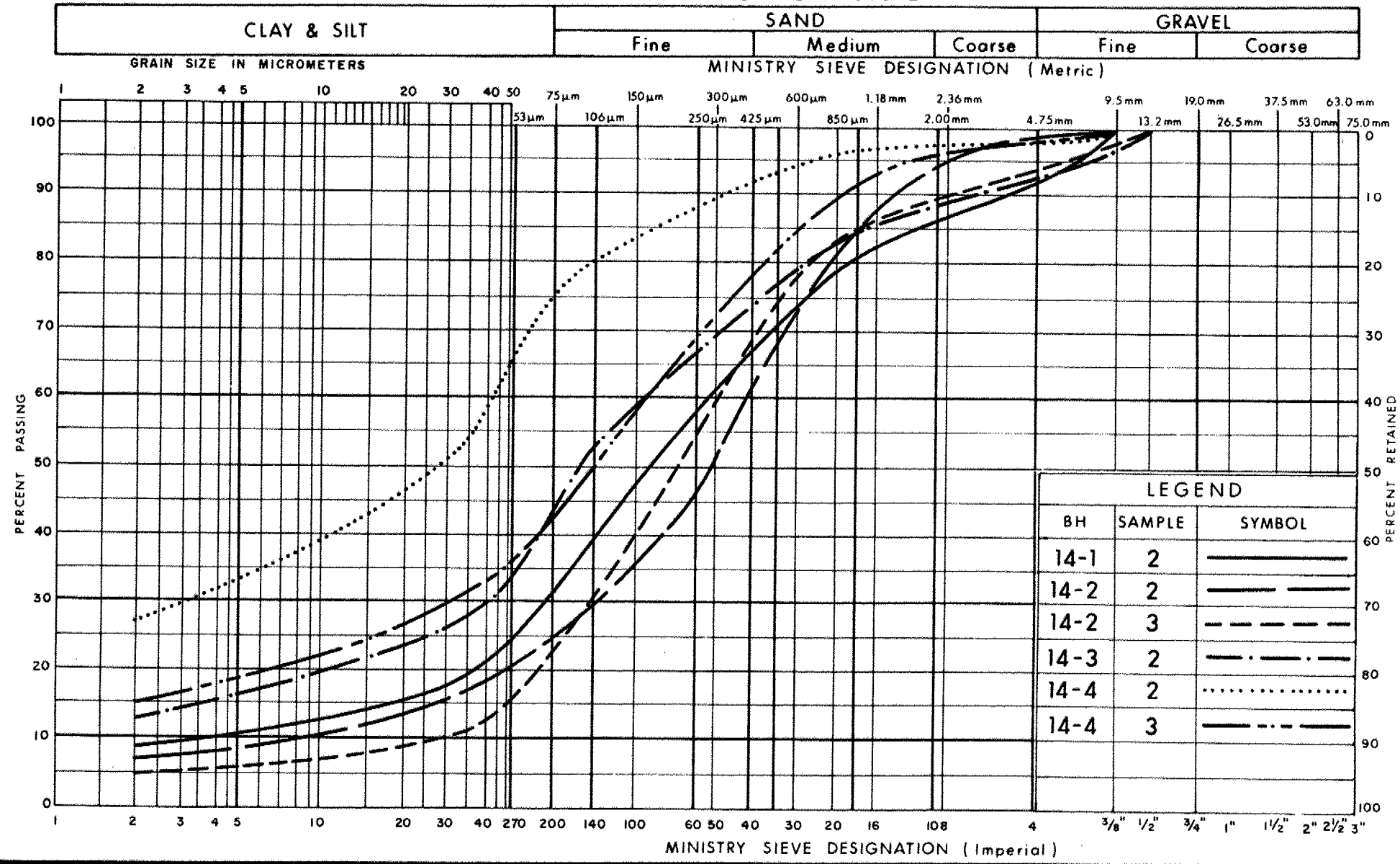
LICENSED PROFESSIONAL ENGINEER
A. J. Sangiuliano
PROVINCE OF ONTARIO

T. Sangiuliano, P.Eng.
Foundation Engineer

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

APPENDIX

UNIFIED SOIL CLASSIFICATION SYSTEM

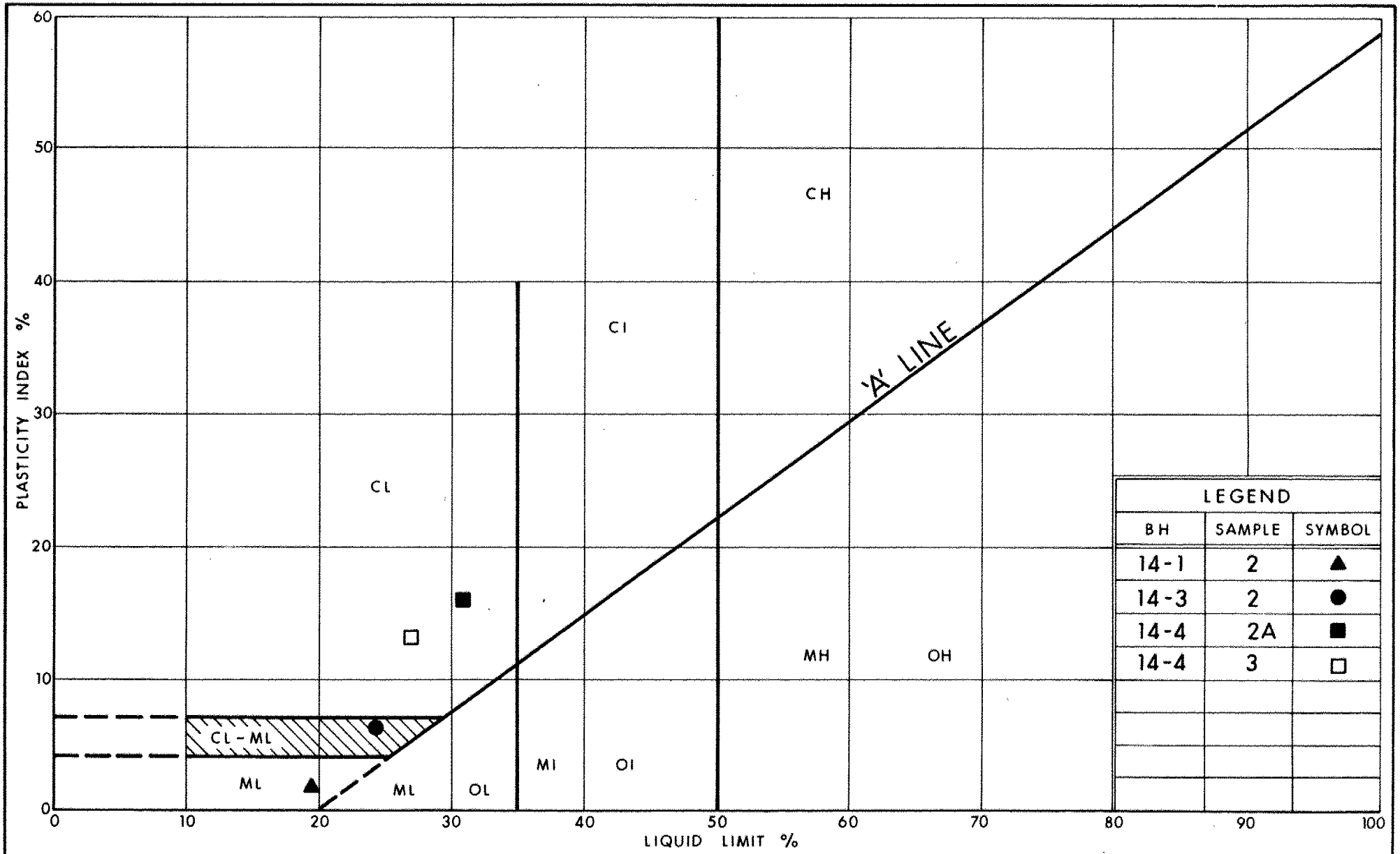


Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION
MIXTURE OF
CLAYEY SILT, SILT, SAND & GRAVEL (Fill)

FIG No 1
W P 120-87-03

Oct 75, FF-S-21

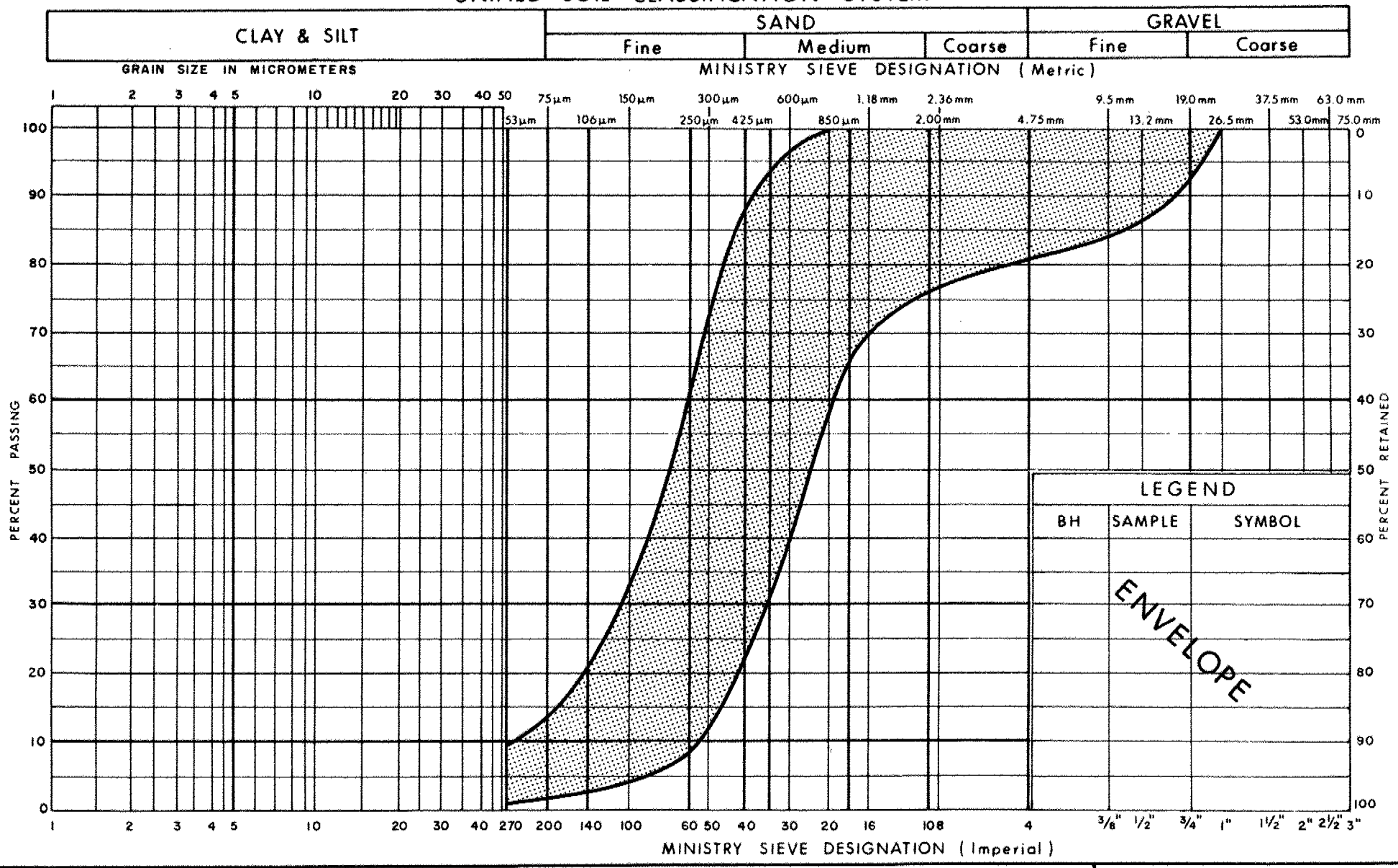


Ministry of Transportation
Ontario

PLASTICITY CHART
MIXTURE OF
CLAYEY SILT, SILT, SAND & GRAVEL (Fill)

FIG No 2
W P 120-87-03

UNIFIED SOIL CLASSIFICATION SYSTEM



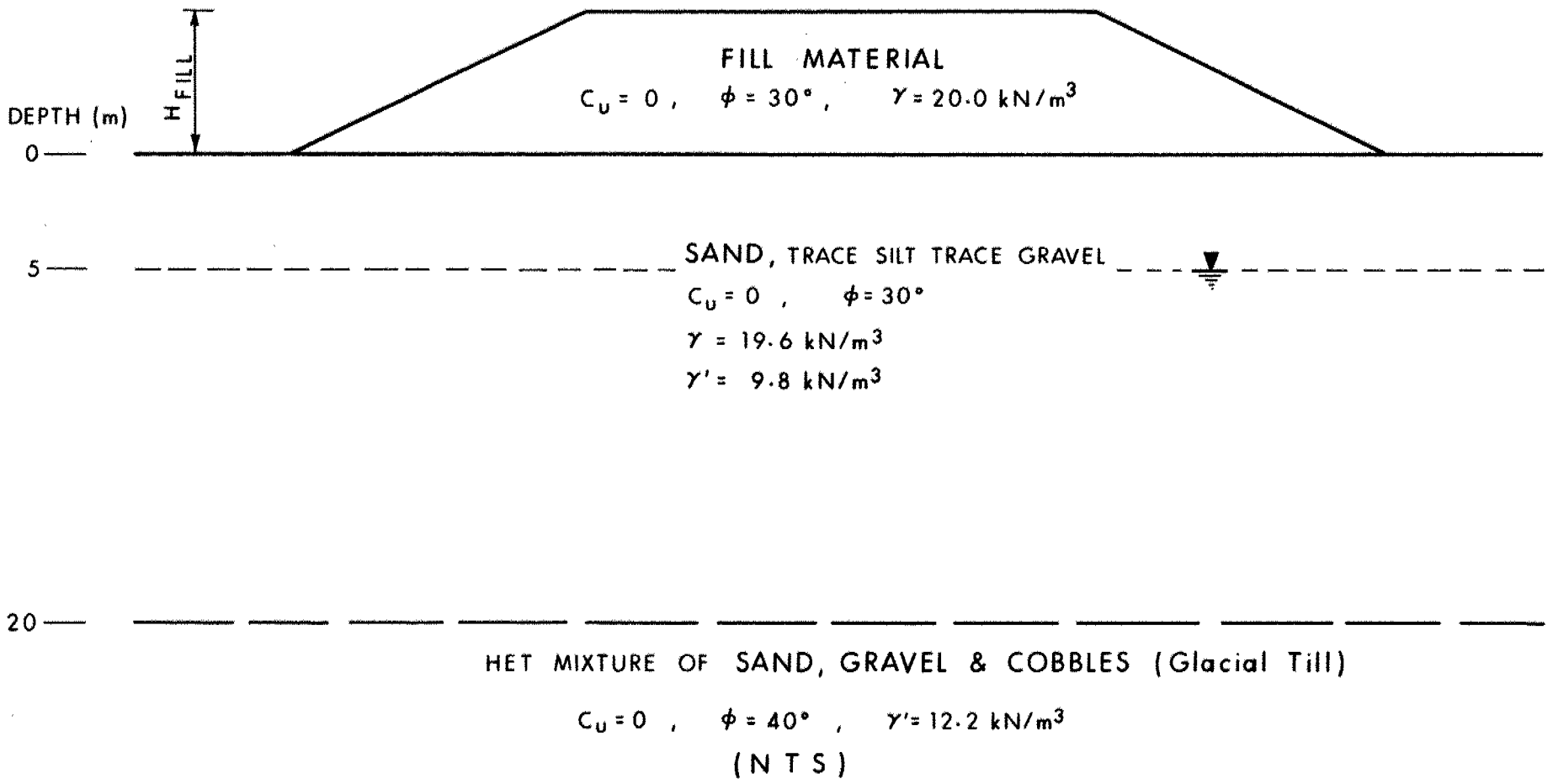
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

SAND, TRACE OF SILT, TRACE GRAVEL

FIG No 3

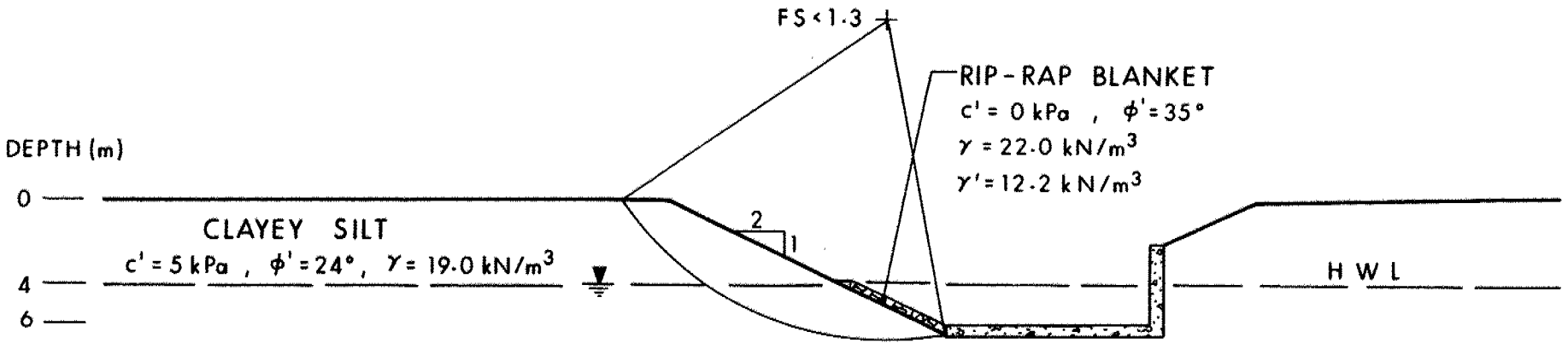
W P 120-87-03



(N T S)

APPROACH EMBANKMENT STABILITY ANALYSIS - TRANSVERSE DIRECTION

WP 120-87-03
FIG 4



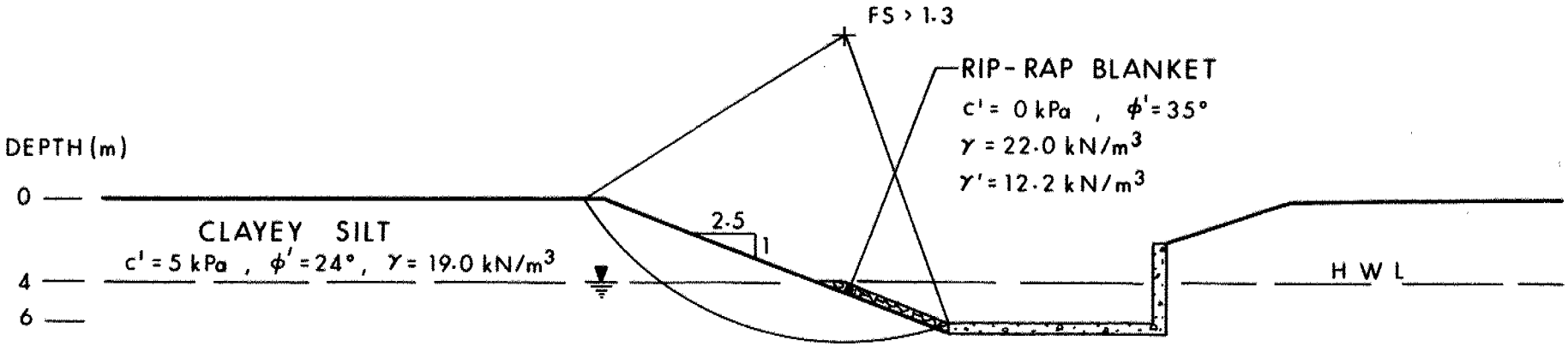
(N T S)

EFFECTIVE STRESS ANALYSIS (2 H : 1V CUT SLOPE)

WITH 0, 0·6 or 1·2 m THICK RIP - RAP BLANKET

WP 120 - 87 - 03

FIG 5



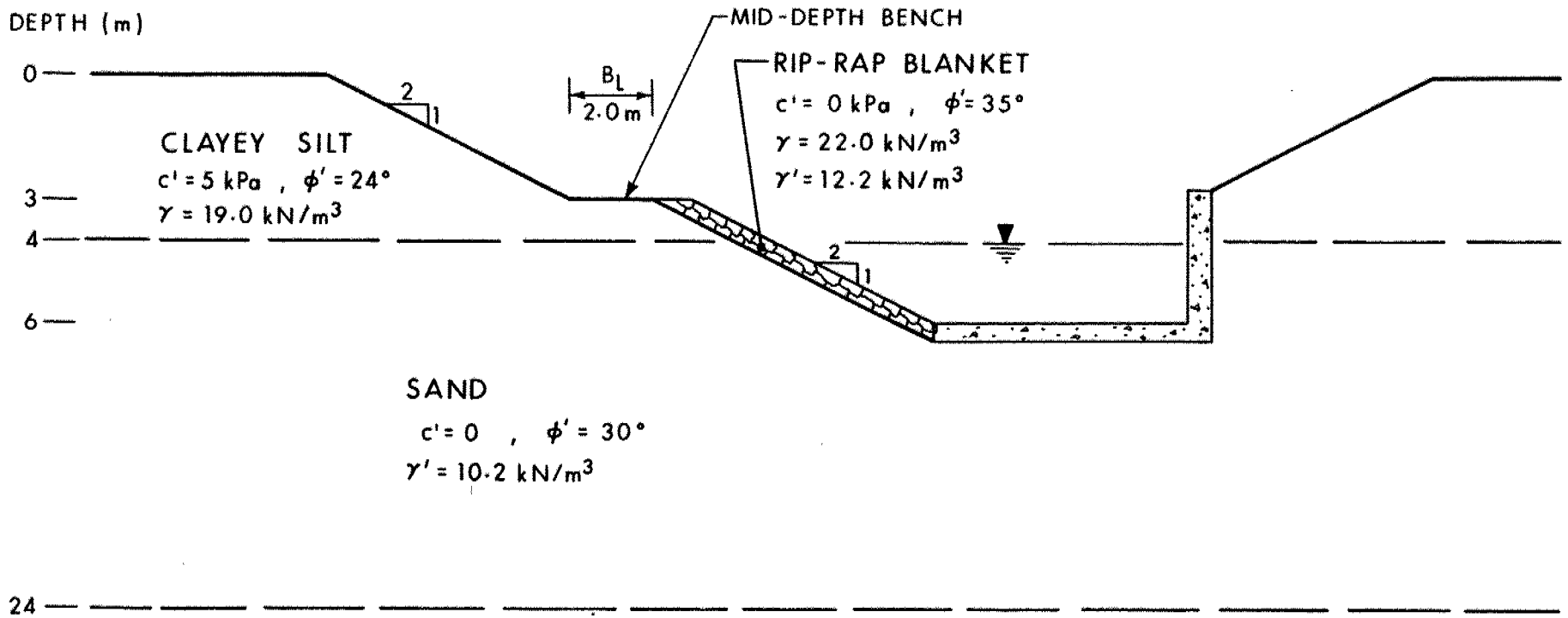
(NTS)

EFFECTIVE STRESS ANALYSIS (2·5H:1V CUT SLOPE)

WITH 0, 0·6 or 1·2 m THICK RIP-RAP BLANKET

WP 120-87-03

FIG 6

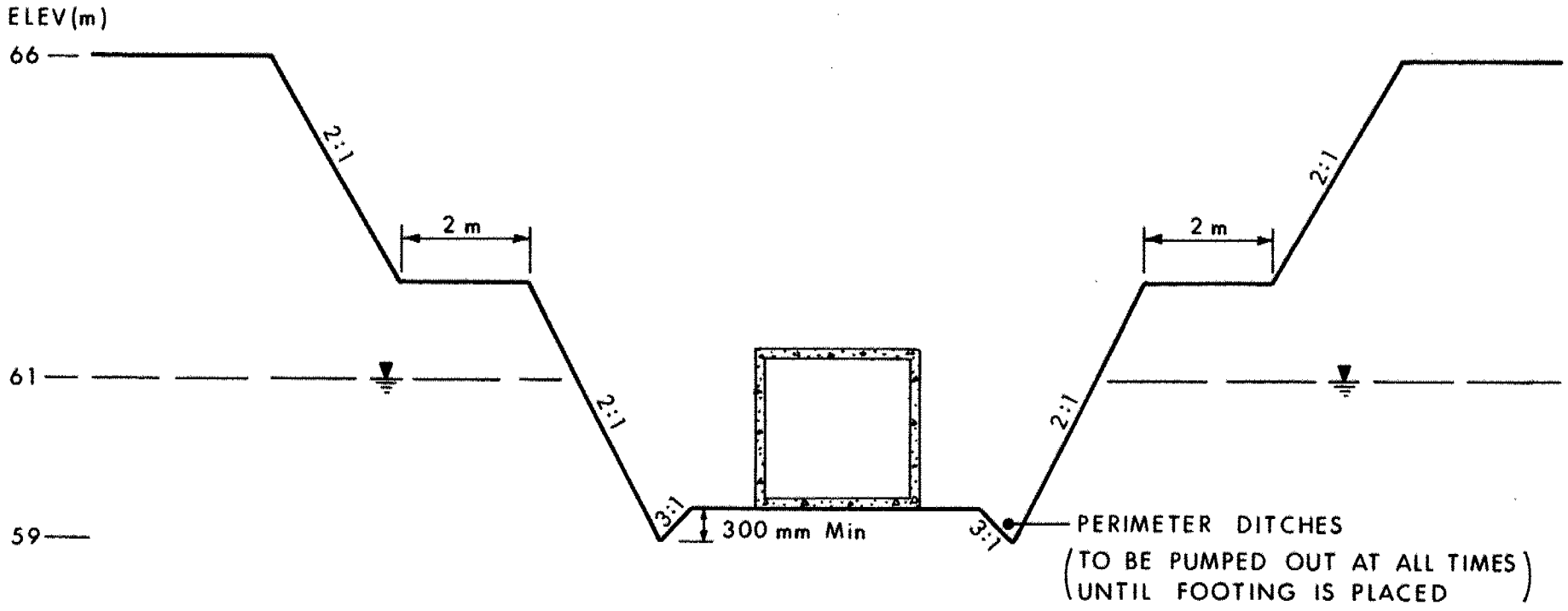


(N T S)

EFFECTIVE STRESS ANALYSIS (2H : 1V SLOPE)

WITH MID-DEPTH BENCH (2.0 m LENGTH) AND 0 & 0.6 m RIP-RAP BLANKET

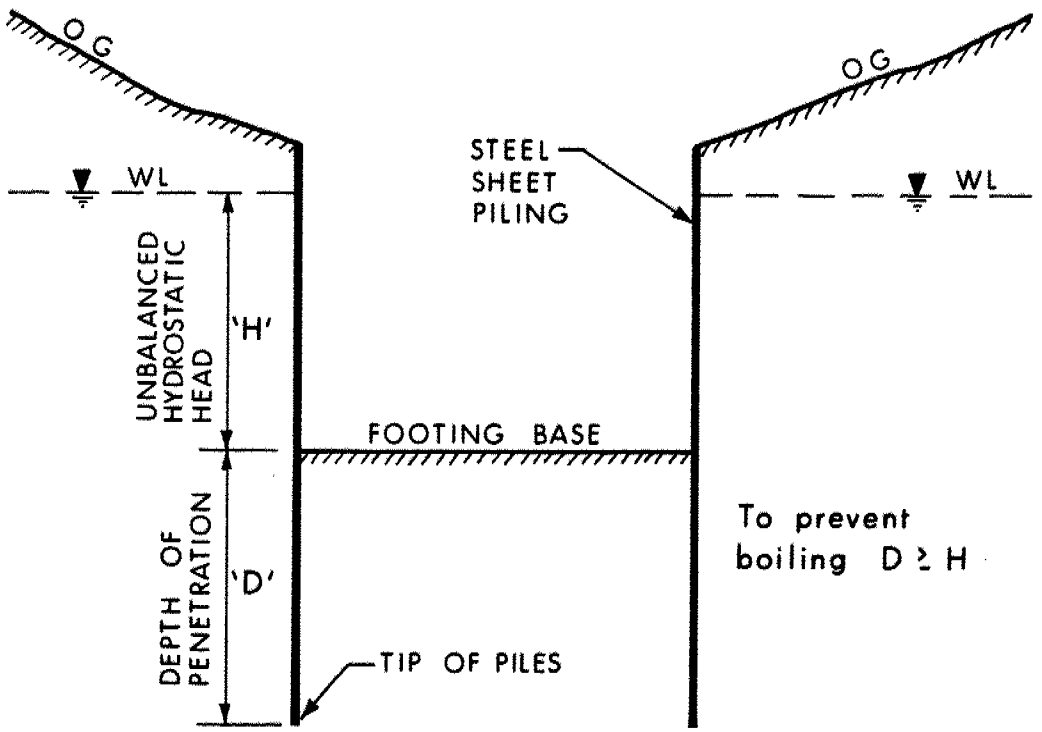
WP 120-87-03
FIG 7



(NTS)

TEMPORARY EXCAVATION / DEWATERING SCHEME

WP 120-87-03
FIG 8



COFFERDAM CONSTRUCTION

WP 120-87-03
FIG 9

DESCRIPTION OF ROCK CORE - WP 120-87-03

	CORE RECOVERY			CORE DESCRIPTION	
HOLE #	DEPTH (m)	%CR*	%RQD*	DEPTH (m)	DESCRIPTION
14-2	26.21-26.82 26.82-27.76	100 95	41 64	26.21-27.76	**SILTY DOLOSTONE**, medium grey to dark grey, fine grained thinly bedded; medium strong to strong rock; slightly weathered to unweathered; close to moderately close spaced fractures: flat, rough, irregular; minor **SANDSTONE** bed (2 cm) at 26.26 m

NOTE: Depths are approximated in zones of poor core recovery.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

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 (R Q D), FOR MODIFIED RECOVERY, IS:

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ_p'	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_p	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_p	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 6-1 METRIC

W P 120-87-09 LOCATION Co-Ords N 5 022 702.0; E 358 757.4 ORIGINATED BY JBF

DIST 9 HWY 417 BOREHOLE TYPE H-S Augers "B" Casing, Washboring & Cone Test COMPILED BY TS

DATUM Geodetic DATE 88 07 21 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
65.9	Ground Surface										
0.0	Clayey Silt Some Sand, trace Gravel Brown, stiff to hard		1	SS	30	*			o —		1 35 39 25
63.6	Occ.Zones of Organics		2	SS	14		64		o —		1 29 55 15
2.3			3	SS	11						
			4	SS	8		62		o		8 68 14 10
			5	SS	17						
	Brown Grey Sand		6	SS	19		60				
	Trace Silt, Trace Gravel		7	SS	27				o		0 96 (4)
	Loose to		8	SS	18		58				
	Very Dense		9	SS	32		56		o		0 83 (17)
			10	SS	41		54				
			11	SS	56		52				
							50				
47.2	Het.mixture of sand, Gravel, Boulders (Glacial Till)		12	SS	76		48		o		0 96 (4)
18.7 / 46.1			13	RC	-						
19.8	END OF BOREHOLE										

* Water Level Not Established

+3, ×5 : Numbers refer to Sensitivity

15 20/10 5 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 6-2 METRIC

W P 120-87-09 LOCATION Co-Ords N 5 022 707.2; E 358 733.3 ORIGINATED BY JF

DIST 9 HWY 417 BOREHOLE TYPE Washboring, "N"-Casing & BXL Rock Core COMPILED BY TS

DATUM Geodetic DATE 88 07 25 to 28 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
61.4	Ground Surface										
0.0	Brown Grey Sand Trace Silt Trace Gravel Loose to Very Dense		1	SS	9	▼	60		○		10 85 (5)
			2	SS	7						
			3	SS	23						
			4	SS	28		58				
			5	SS	25				○		6 91 (3)
			6	RC	-						
			7	SS	39		56				
			8	SS	35				○		2 71 (27)
			9	SS	55		54				
			10	SS	69		52		○		0 92 (8)
			11	SS	71		50				
			12	SS	59		48				
			13	SS	75/15cm		46				
44.3											
17.1	Het. mixture of Sand, Gravel and Boulders (Glacial Till)		14	RC	-		44				
							42				
39.6			15	SS	100		40				47 43 (10)
21.8	Bedrock		16	RC	REC 48%						RQD = 19%
	Dolostone		17	BXL RC	REC 85%						
37.8	Unweathered		18	RC	REC 94%		38				RQD = 55% RQD = 45%
23.6	END OF BOREHOLE										

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 6-3 METRIC

W P 120-87-09 LOCATION Co-Ords N 5 022 721.6; E 358 699.2 ORIGINATED BY JBF
DIST 9 HWY 417 BOREHOLE TYPE Hollow Stem Augers, Washboring COMPILED BY TS
DATUM Geodetic DATE 88 07 21-22 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
62.0	Ground Surface										
0.0			1	SS	2						0 59 31 10
			2	SS	5		60				
			3	SS	20						0 98 (2)
			4	SS	22						
	Sand						58				
	Trace of Silt										
	Grey										
	occasional		5	SS	44						0 98 (2)
	Zones of Silty										
	Sand						56				
			6	SS	47						1 97 (2)
	Loose to										
	Very Dense										
			7	SS	89		54				
			8	SS	94						0 49 50 1
							52				
							50				
			9	SS	72						
							48				
			10	SS	103/15cm						0 97 (3)
							46				
	Some Gravel		11	SS	124		44				17 74 (9)
							42				
40.2			12	SS	113						
21.8	END OF BOREHOLE										

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 6-4 METRIC

W P 120-87-09 LOCATION Co-Ords N 5 022 729.9; E 358 737.4 ORIGINATED BY IBF

DIST 9 HWY 417 BOREHOLE TYPE Hollow Stem Augers, Washboring & Cone Test COMPILED BY TS

DATUM Geoderic DATE 88 07 22 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
65.7	Ground Surface										
0.0						*					
			1	SS	19		64	100/10 cm			
	Brown Grey		2	SS	73		62		○		14 71 (15)
			3	SS	37				○		0 93 (7)
	Sand Trace of Silt Trace of Gravel Compact to Very Dense		4	SS	16		60		○		1 98 (1)
			5	SS	38		58				
			6	SS	60						
			7	SS	53		56		○		0 92 (8)
53.1			8	SS	36		54				
12.6	END OF BOREHOLE										

* Water Level not established

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

15 20/10 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 14-1 METRIC

W P 120-87-03 LOCATION Co-Ords N 5 022 737.7; E 358 692.0 ORIGINATED BY JBF
DIST 9 HWY 417 BOREHOLE TYPE Hollow Stem Augers, Washboring & Cone Test COMPILED BY JBF
DATUM Geodetic DATE 88 07 21 CHECKED BY

OFFICE REPORT ON SOIL EXPLORATION

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
66.1	Ground Surface						66				
0.0	Mixture of Sand, Silt and Gravel (Fill) Brown loose to Compact		1	SS	5		64				
			2	SS	17						9 59 24 8
61.5							62				
4.6	Brown Grey Sand Trace Silt Trace Gravel Compact to Very Dense		3	SS	27						5 88 (7)
			4	SS	44	▼					19 73 (8)
			5	SS	62		60				
			6	SS	95						0 90 (10)
			7	SS	46						2 91 (7)
			8	SS	49		58				
			9	SS	16						
			10	SS	18						
			11	SS	31		56				0 98 (2)
			12	SS	55						
							54				
							52				
			13	SS	53						
							50				
			14	SS	120/ 25cm						
46.3							48				
19.8	Het. Mixture of Sand, Gravel, Boulders (Glacial Till) Grey, very dense										
44.3			15	SS	73		46				
21.8	END OF BOREHOLE										

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 14-2 METRIC

W P 120-87-03 LOCATION Co-Ords N 5 022 758.9; E 358 645.1 ORIGINATED BY TS

DIST 9 HWY 417 BOREHOLE TYPE Cone Test, H-S Auger, B-Casing, Washbore & BXL Rock Core COMPILED BY TS

DATUM Geodetic DATE 88 07 22-23 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
65.6	Ground Surface										
0.0	Mixture of Clayey Silt and Gravel (Fill) Brown, compact		1	SS	18	*	64				
			2	SS	15		62				2 72 19 7
60.6			3	SS	21						6 70 20 4
5.0	Sand Brown / Grey; Trace Silt; Trace Gravel; Compact to Very Dense		4	SS	5		60				5 88 (7)
			5	SS	12						4 90 (6)
			6	SS	23		58				1 90 (9)
			7	SS	25						
			8	SS	19						
			9	SS	30		56				1 90 (9)
			10	SS	55						
			11	SS	38		54				
			12	SS	33		52				0 91 (9)
			13	SS	32		50				
			14	SS	36		48				
			15	SS	97		46				
41.2							44				13 78 (9)
24.4	Het Mixture of Sand, Gravel and Boulders, Very Dense (Glacial Till)		16	SS	54		42				
39.1							40				
26.5	Bedrock Dolostone Unweathered		17	RC	REC	100%					RQD = 41%
37.9			18	BXL RC	REC 95%		38				RQD = 64%
27.7	END OF BOREHOLE * Water Level not established. Hole caved in at 2.1m depth.										

OFFICE REPORT ON SOIL EXPLORATION

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

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 14-3 METRIC

W P 120-87-03 LOCATION Co-Ords N 5 022 791.6; E 358 619.6 ORIGINATED BY JBF
DIST 9 HWY 417 BOREHOLE TYPE Hollow Stem Auger, Washboring, & Cone Test COMPILED BY JBF
DATUM Geodetic DATE 88 07 23 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
65.4	Ground Surface										
0.0	Mixture of Clayey Silt, Sand, and Gravel Brown, Very Stiff (Fill)		1	SS	27	*	64				
61.9			2	SS	17		62		○		6 48 32 14
3.5	Sand trace Silt Occ. Gravelly Zones		3	SS	18		60				
	Compact to Very Dense Grey		4	SS	30		58		○		29 58 13 0
			5	SS	50		56		○		0 89 (11)
			6	SS	19		54				
			7	SS	61		52		○		0 94 (6)
52.8			8	SS	26		50				
12.6	END OF BOREHOLE						48				
							46				
43.8							44				
21.6	END OF CONE TEST										

* Water level not established. Hole caved in at 4.6m depth

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 14-4 METRIC

W P 120-87-03 LOCATION Co-Ords N 5 022 787.1; E 358 600.4 ORIGINATED BY TS
DIST 9 HWY 417 BOREHOLE TYPE Cone Test, H-S Auger, Washbore COMPILED BY JBF
DATUM Geodetic DATE 88 07 22 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
65.6	Ground Surface							
0.0	Mix of Clayey Silt, Sand and Gravel Grey , Firm (Fill)		1	CS	-	*	64	
			2	SS	7			2 19 51 28
61.6			3	SS	5		62	2 55 28 15
4.0	Brown Grey Sand Trace Silt Trace Gravel Compact to Dense		4	SS	19		60	1 90 5 4
			5	SS	8			1 97 (2)
			6	SS	29		58	
			7	SS	29		56	0 90 (10)
			8	SS	47		54	
53.0			9	SS	33			
12.6	END OF BOREHOLE						52	
							50	
							48	
							46	
							44	
41.2							42	
24.4	END OF CONE TEST							

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT Wp | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W_L
WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ

* Water level not established. Hole caved in at 4.6m depth.

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

15 20 10 5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS, ONTARIO PH-0-207 82 04

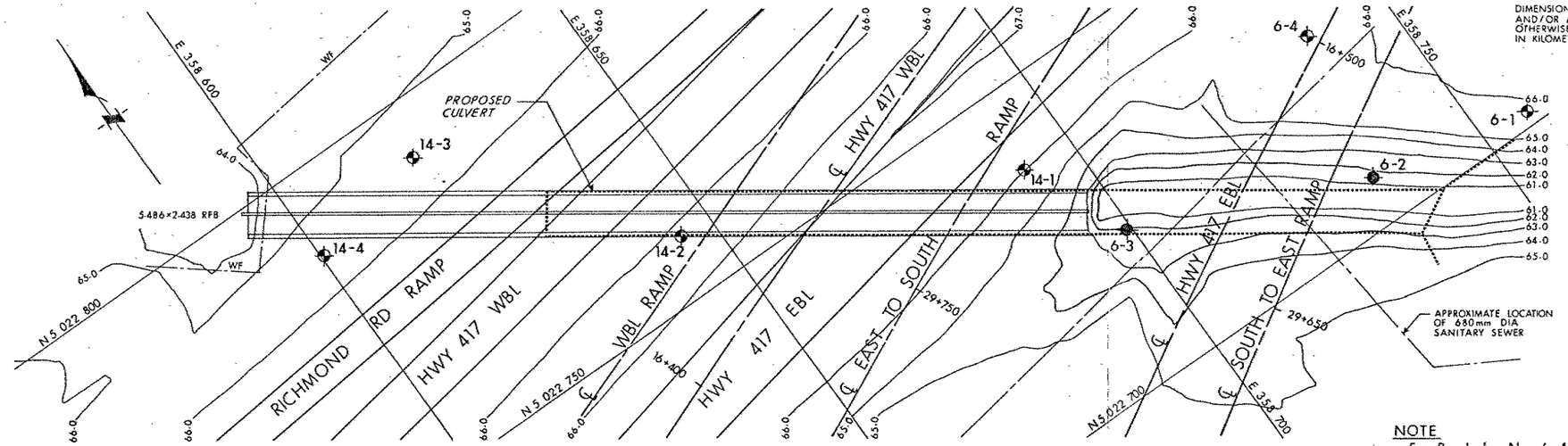
METRIC

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

CONT No
WP No 120-87-03

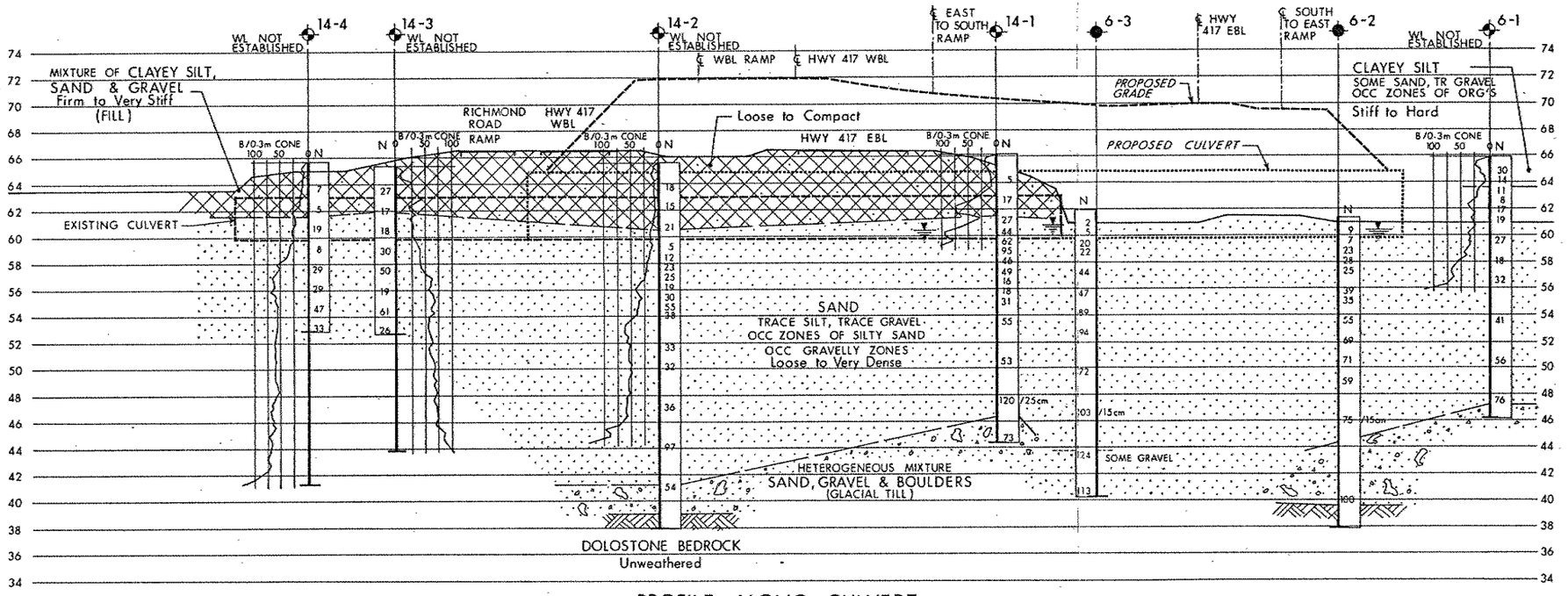
SHEET

HWY 417 & GRAHAM CREEK
(NORTH CULVERT) STR 14
BORE HOLE LOCATIONS & SOIL STRATA

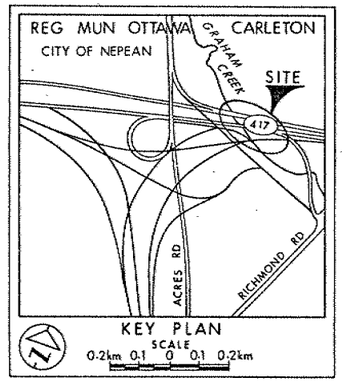


PLAN
SCALE
8m 4 0 8m

NOTE
For Borehole No 6-4 see Record of Borehole Sheet



PROFILE ALONG CULVERT
SCALE
8m 4 0 8m Hor
4m 2 0 4m Vert



KEY PLAN
SCALE
0·2km 0·1 0 0·1 0·2km

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N Blows/0·3m (Std Pen Test, 475 J/blow)
- CONE Blows/0·3m (60° Cone, 475 J/blow)
- WL at time of investigation 88 07

No	ELEVATION	CO-ORDINATES NORTH	EAST
6-1	65.9	5 022 702.0	358 757.4
6-2	61.4	5 022 707.2	358 733.3
6-3	62.0	5 022 721.6	358 699.2
6-4	65.7	5 022 729.9	358 737.4
14-1	66.1	5 022 737.7	358 692.0
14-2	65.6	5 022 758.9	358 645.1
14-3	65.4	5 022 791.6	358 619.6
14-4	65.6	5 022 787.1	358 600.4

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 31G5-150

HWY No 417			DIST 9
SUBM'D TS	CHECKED	DATE 88 11 03	SITE 3-537
DRAWN DT	CHECKED	APPROVED	DWG 1208703-A