



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

FINAL REPORT

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

30M14-171

GEOTECHNICAL INVESTIGATION

GRADE SEPARATION WESTNEY ROAD

AT HIGHWAY 401 AND C.N.R. TRACKS

EGG0007

AJAX

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1.0 INTRODUCTION

On behalf of GO-ALRT, the Ministry of Transportation and Communications has retained Golder Associates to carry out a geotechnical investigation for the proposed GO-ALRT rapid transit route at Westney Road at Ajax, Ontario. Authorization for the investigation was received in a letter dated July 4, 1983 from the Hon. James Snow, Minister of Transportation and Communications.

Preliminary details of the project were provided during a meeting between Messrs. M. Devata and M. McLean of the Ministry of Transportation and Communications and Mr. F. Heffernan of Golder Associates on July 14, 1983. Plans PD1600209 and PD1600208 titled "Preliminary General Arrangement" prepared by Totten Sims Hubicki Associates, were provided at that time.

The investigation was carried out in accordance with the terms of reference set out in Golder Associates' letter dated July 21, 1983.

The purpose of the investigation was to determine the sub-surface conditions of the site and, based on this information, to provide recommendations pertinent to the geotechnical design of the works.

An interim report of the investigation was prepared in August, 1983 pending detailed plans of the proposed bridge structures. The bridge site plan B-2-GA-2 prepared by M.T.C. was received in December, 1983 whereupon this final report of the investigation was prepared.

2.0 SITE DESCRIPTION

The site is located along Highway 401 between Church Street and Harwood Avenue in the Town of Ajax in the Regional Municipality of Durham (refer to key plan on Drawing 470711611A). At this location the Canadian National Railway's (C.N.R.) main line runs parallel to Highway 401 some 100 m to the south. The top of the railway tracks are about 2.5 m higher than the level of the highway. The area south of the site is used for light industrial uses while north of Highway 401 open fields were present at the time of the investigation. The ground surface in the general area slopes westward to Duffins Creek which is located about 1 km west of the site.

3.0 SUBSURFACE CONDITIONS

3.1 Site Geology

The site is located in the physiographic region known as the Iroquois plain¹ which typically exhibits level to gently undulating topography. The overburden soils consist of glacial drift with a thin surficial glacio-lacustrine deposit which was laid down after the end of the last glacial advance. Remnants of a raised shoreline formed within the glacial Lake Iroquois can be seen immediately to the southwest of the site. The glacial drift below the glacio-lacustrine sediments is described by Caley² to consist of a heterogeneous mixture of gravel, sand, silt and clay with numerous sand and gravel lenses. The bedrock consists of thin bedded grey to black calcareous, bituminous, micaceous shale of the Whitby formation.

3.2 Soil Stratigraphy

3.2.1 Fill

Up to 2.9 m of fill was encountered in the boreholes. The fill in the boreholes put down along Highway 401 typically consists of brown sand to gravelly sand. Near the C.N.R. railway tracks the fill consists of silty sand with some gravel and trace to some clay and contains traces of organic material. The fill is generally in a loose to compact state based on 'N'* values of 9 to 26.

1 Chapman, L.J. and Putnam, D.F., the Physiography of Southern Ontario, University of Toronto Press, Toronto, Ontario.

2 Caley, J.F., Clark, T.H. and Owen, E.G., Groundwater Resources of Pickering Township, Ontario County, Ontario Dept. of Mines and Tech. Surveys, Water Supply Paper 285, 1974.

* 'N' values - Standard Penetration Resistance - refer to Explanation of Terms used in this Report.

3.2.2 Upper Silty Clay

In boreholes located in the low-lying areas of the site up to 2 m of glacio-lacustrine clay was encountered near the ground surface. The clay was found to be varved in most boreholes having alternating light and dark brown layers of 1 to 5 mm in thickness. The clay has a firm to stiff consistency (N values of 4 to 20). Occasional sand lenses were found in the clay at Borehole 18.

Typical grain size distribution curves of the clay are given on Figure 1. The water content of the clay varies from 26 to 38 per cent. The clay has an intermediate plasticity based on liquid limits of 44 to 47 per cent and plasticity indices of 19 to 26 per cent. The bulk unit weight of the clay was measured to be 18.8 kN/cu m in a sample from Borehole 18.

3.2.3 Silty Sand to Silt

The predominant soil deposit encountered in all boreholes is a generally unstructured heterogeneous material mainly composed of sand and silt with some proportion of clay and gravel sized particles contained within its matrix. Distinction between zones of the deposit has been made based on visual observation, grain size distribution and plasticity.

The deposit contains numerous pockets and seams of sand and silt. Pockets of sand with a trace to some silt were noted in Boreholes 1, 2, 3, 7, 10 and 15. Some evidence of stratification was found in the samples taken within the sand and silt pockets. Grain size distribution curves for samples of the deposit are shown on Figure 2 to 5.

The upper portion of the deposit is brown in colour. At depths of 3 to 4 m the colour changes to grey. Rust-stained fissures were found in the upper 3 to 4 m. Some of the gravel in the soil consists of dark grey shale particles and the proportion of shale increases with depth.

The soil is generally very dense and the 'N' values below 3 to 4 m depth are in excess of 50 and usually in excess of 100. At lesser depths the soil is less dense particularly in low-lying areas such as at Borehole 9. This suggests that the soil softens where exposed to groundwater at shallow depth. The 'N' values in the upper 3 to 4 m indicate the soil at shallow depth to be generally compact to dense (N values of 10 to 40 although a very loose pocket (N = 2) was encountered in Borehole 9.

The silty sand to silt deposit has a low to zero plasticity. Liquid limits and plasticity indices of 15 to 18 and 2 to 7 per cent respectively were measured on laboratory samples. The water content of laboratory samples of the soil was generally about 8 to 12 per cent with silty zones having somewhat higher water content. The average bulk unit weight of the soil was measured to be 23.0 kN/cu m.

3.2.4 Sand and Gravel

Along the east side of Westney Road and in several nearby boreholes at a depth of about 12 m, sand and gravel with a trace to some silt underlies the silty sand to silt deposit. The sand and gravel appears to be continuous in the north-south direction along the line of sections A-A (Drawing No. 470771611B). Similar material was also encountered at the same stratigraphic horizon in Boreholes 22 and 23 and it is possible that the sand and gravel extends to the north-east. The sand and gravel is dark

grey in colour, and particles are generally subangular to subrounded in shape. The deposit varies from sand with some gravel to gravelly sand and apparently becomes coarser with depth. Grain size distribution curves of the material are shown in Figure 6. 'N' values within the soil are consistently in excess of 50, indicative of its dense state.

In Borehole 7 a permeability test was undertaken in the piezometer. The water level in the piezometer could only be raised about 10 mm while pouring water into the piezometer at a rate of about 1 litre per minute. Based on this data the permeability (k) of the sand and gravel is in the order of 3×10^{-4} m/sec. Application of the Hazen formula to the gradation curves shown in Figure 6 gives a range of k of 10^{-5} to 3×10^{-4} m/sec.

3.2.5 Lower Silty Clay

Immediately underlying the sand and gravel, or the silty sand to silt deposit where the sand and gravel is missing, silty clay was found at many borehole locations. The clay generally has a large proportion of angular shale and limestone fragments which increases with depth. The clay is dark grey in colour and with depth takes on the appearance of the underlying shale bedrock. The deposit is discontinuous across the site having a maximum thickness of 4.6 m at Borehole 12. In the upper 1 to 2 m at Borehole 11 and 12 the clay appeared to be thinly laminated and contained sandy lenses. A grain size distribution of this material is shown on Figure 7.

The clay has a hard consistency as the 'N' values measured were generally in excess of 50. The soil has a low plasticity based on liquid limit and plasticity index of 26 and 12 per cent respectively. The water content of the silty clay is typically about 10 per cent. The bulk unit weight of the soil was measured to be between 20.5 and 24 kN/cu m.

3.3 Bedrock

Shale bedrock was inferred to be present below the above deposits at between elevations 75.0 and 80.4 in Boreholes 1, 2, 8, 15, 17, 18, 20, 21 and 22. The bedrock was cored in Boreholes 1, 3 and 15 for depths of 2 to 3 m. The rock is grey to dark grey in colour and consists of calcareous to bituminous shale. The rock is moderately fractured to sound and is slightly weathered to fresh. Total core recoveries were in excess of 95 per cent and improved with depth.

3.4 Groundwater Conditions

Groundwater was encountered in all boreholes during drilling. In some boreholes the groundwater flow in the sandy layers within the silty sand to silty deposit was sufficient to cause the borehole walls to collapse. Rapid groundwater flow was experienced on penetrating the sand and gravel. Stabilized groundwater levels measured in the piezometers and stand-pipes were between elevation 88.7 and 91.6 m with an average of 90.7 m.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 Project Description

Details of the proposed bridge structures were provided on Plan B-2-GA-2 entitled "Bridge Site Plan Proposed Crossing at Westney Road, C.N. Rail and GO-ALRT" prepared by M.T.C. The plan was dated 1983 10 and was stamped preliminary.

Details of the proposed grade of the access ramps along Highway 401 were obtained from drawing PDL600034 entitled "GO-A.L.R.T., Pickering to Whitby, Westney Road/Highway 401 Interchange, Preliminary Profiles" prepared by Totten, Sims, Hubicki Limited.

The proposed grade separation will require the construction of three bridges to carry Highway 401, the GO-ALRT track and the C.N.R. track over Westney Road. Ramps will be constructed between the GO-ALRT track and the Highway to provide access from Highway 401 to Westney Road and vice versa. Retaining walls will be constructed on both side of these access ramps. Profiles of the proposed road grades indicate that, at its lowest point Westney Road will be about 8 m below the existing grade.

The construction sequence has not been finalized, however, it is possible that the structures will be constructed in confined spaces and temporary shoring will be required.

4.2 Foundations

Spread footings founded on the very dense soils at the site are considered to be the most suitable foundation for the bridge and retaining wall structures provided measures are taken to permanently lower the water pressure in the underlying sand and gravel aquifer. While the soils are generally very dense, the groundwater elevation is high and

some disturbance could take place during construction, even assuming adequately dewatered excavations. For this reason the bearing capacity at Ultimate Limit States and Serviceability Limit State for spread footings having a width of 4 m and founded on the very dense sandy soils should be limited to 800 kPa and 500 kPa respectively.

Based on the proposed grade of the access ramps, retaining walls along these ramps will generally be founded on the very dense soils. At Boreholes 9, 18 and 22, however, the ground conditions are less competent and it is recommended that in these areas the spread footings be taken down to elevation 85. For 3 m wide retaining wall footings founded on the dense to very dense soils, the bearing capacities at Ultimate Limit State and Serviceability Limit State should be taken as 600 kPa and 300 kPa respectively.

For footings supporting an inclined load (as in the case of retaining walls) the bearing pressure at Ultimate Limit State should be reduced in accordance with Section 6.7.3.3.5 of the Ontario Highway Bridge Code. The reduction factors for granular soil should be used.

Some horizontal layering was noted in the soils at the site and it is recommended that the retaining walls are checked for sliding along the base. For this a factored coefficient of friction of 0.5 can be used for calculating the friction between the base of the concrete structures and layers of silty soil.

All footings should be placed a minimum of 1.2 m below finished grade for frost protection.

Some variation was found in the density of the proposed foundation subsoils and all footing excavations should be inspected by a qualified geotechnical engineer immediately prior to placement of concrete to ensure the competence and uniformity of the soil.

4.3 Earth Pressures

For all earth retaining structures, i.e. retaining walls and bridge abutments, the lateral earth loads will depend on the type and method of placement of the backfill materials and on the subsequent lateral movement of the structure. The following recommendations are made concerning the design of the abutment and retaining walls.

- o Selected "free draining" granular fill, in accordance with MTC specifications should be used as backfill immediately behind the structures. The granular fill should be placed in the wedge-shaped zone defined by a 60 degree line extending up and back from the bottom of the rear face of the structures' footings.
- o All granular fill should be compacted in 200 mm thick lifts to 95 per cent of the standard Proctor density of the material. However, heavy compaction equipment should not be used behind any structure within a lateral distance equal to the current height of the fill above the base of the structure.
- o Longitudinal drains located immediately below the base of the walls should be installed to provide positive drainage of the granular backfill.
- o If the abutment support and retaining walls will permit lateral yielding at the top of the abutment equal to not less than 1/2 per cent of the retained height then 'active' earth pressure conditions should be used in the design. If however the structures are not permitted to yield by 1/2 per cent of their height then 'at rest' pressure conditions should be used. It is anticipated that retained heights of soil behind retaining walls and/or abutments will not exceed 10 m. Accordingly the following equivalent fluid pressures may be used in the design.

At ultimate limit states

'active' condition	8.0 kPa/m
'at rest' condition	10.0 kPa/m

At serviceability limit states

'active' condition	6.5 kPa/m
'at rest' condition	8.5 kPa/m

- o Highway live loads which act on the soil behind the walls within a distance defined by a plane rising at 45 degrees from the underside of the rear of the retaining structure's footing should be considered in the design as an equivalent load due to a height of 600 mm of additional fill. The unit weight of the fill should be taken as 20 kN/cu m.

4.4 Groundwater Control

The primary geotechnical concern at the site is the control of groundwater. Excavations for the structures will probably extend some 9 m through very dense materials which contain numerous pockets of pervious sandy material. Also, the lower deposit of sand and gravel which is under high piezometric pressure will likely be encountered at depth in the excavations. Controlled excavation below the water table must therefore be preceded by dewatering of the site. The consequences of not providing proper groundwater control measures include possible instability of temporary slopes and vertically shored excavation faces, uplift or heave of the excavation base causing loosening of the foundation subsoils and subsequent settlement when footing loads are applied.

Consideration must also be given to providing a system of permanent groundwater control. This will probably include the installation of pressure relief wells into the lower sand

and gravel deposit and a system of drains and/or drainage blanket to lower the groundwater level below the pavement structure.

The design of the temporary dewatering system and the permanent pressure relief wells will depend on the characteristics of the sand and gravel aquifer. Available water well data suggests that the aquifer may have a large lateral extent. Water well records for the area indicate that the majority of wells obtain water from the overburden. While the area is now supplied by a municipal water supply system some wells may still be in operation which may be affected by dewatering of the aquifer. In addition, lowering of the water pressure in the aquifer where it is overlain by loose/soft soil deposits could lead to settlement of structures founded in these loose/soft soils. Extensive deposits of loose/soft soil which are underlain by sand and gravel (possibly the same aquifer) are known to exist north of the site in the area of Highway 2 and Harwood Avenue. It is therefore recommended that a pumping test be undertaken to measure the hydraulic characteristics of the aquifer, including the lateral extent of drawdown which may be induced during and after construction. The test can also be used to design drainage for the works.

4.5 Permanent Cut Slopes

Permanent cut slopes in the existing fill and varved clay deposits should not be steeper than 3 horizontal to 1 vertical (3:1). Permanent cut slopes in the material underlying the varved clay can be designed at 2:1 if adequate drainage is provided to lower the piezometric pressure in the slopes as shown on Figure 11a. Steeper slopes up to 1.5:1 may be obtained by cutting the natural soils to an angle of 2:1 and placing compacted free-draining granular fill to the steeper angle as shown on Figure 11b. The granular fill could be placed at up to 1:1 if it is

reinforced with a geogrid material. Such a scheme is illustrated schematically on Figure 11c. The choice of slope treatment should be based on an economic comparison of the alternatives, including conventional retaining walls. All slopes should be topsoiled and seeded to prevent erosion. Once final grades have been selected, the slope design must be reviewed by geotechnical engineers.

4.6 Excavation

Depending on the construction sequence and consequent detour alignment of the Highway 401 eastbound lanes, excavations for the construction of the structures may be entirely in open cut or may require shoring of the excavation near the centreline of Highway 401.

It should be emphasized that excavation below the groundwater level will result in loosening of the soil and the piezometric level in the soil should at all times be maintained at least 0.6 m below the base of the excavation. This will probably require the installation of vacuum well points in the silt and deep wells in the sand and gravel layer prior to construction but the choice of dewatering system should await the results of the proposed pumping test.

Open cuts within the native soils which will be open for relatively short periods could be excavated as steep as 1.5 horizontal to 1 vertical (1.5:1) in the fill and upper varved clays and 1:1 in the underlying dense materials. However, where pockets of sand or silt are encountered, local sloughing of the slope may take place. Such sloughing could be controlled through the placement of a granular blanket over the affected area. Cross slope ditches are recommended to control water flowing down the slope.

A temporary vertical excavation face may be required near the centre of Highway 401 if the bridge is constructed in two separate parts. Such an excavation face would have to be supported by a soldier pile and lagging wall tied back with anchors. The face of the wall will be in the order of 9 m in height and would support the rerouted traffic lanes close to the face. Therefore, it is important that the construction of this wall be carried out such that lateral deformations of the wall and associated ground subsidence behind the wall are within tolerable limits.

The structural members of the wall and the tie-backs can be designed for the active earth pressure condition and, with proper construction methods, the deformations should be acceptable. The earth pressures acting on the wall should be taken as:

$$p_a = K_a [(\gamma - \gamma_w) H + q] + \gamma_w h_w$$

where K_a = coefficient of active earth pressure
as defined below
 γ = unit weight of soil = 22 kN/m³
 H = depth below top of wall
 q = design surcharge
 γ_w = unit weight of water
 h_w = head of water in soil behind wall

The coefficient of active earth pressure should vary according to the strength of the soil encountered. Near the centreline of Westney Road the upper metre of soil is in a compact state and in the area of Borehole 18 and 19 the upper 5 m of soil is in a very loose to compact state. The coefficient of lateral earth pressure in these weaker soils should be taken as 0.4 while in the underlying very dense material it can be taken as 0.3.

The surcharge loading resulting from traffic should be taken into account. It should be noted that the pressure on the support system is dependent on the water pressure on the potential active failure plane behind the wall and even in the case of a temporary lagging system must be taken into account in the calculation of earth pressure.

Passive pressure in front of the soldier pile below the base of the excavation may be calculated from the expression:

$$p_p = K_p \gamma H \text{ above the water level}$$

and $p_p = K_p (\gamma - \gamma_w) H \text{ below the water level}$

where K_p = coefficient of passive earth pressure
 = 4.0 for very dense silty and sandy soils
 γ = unit weight of soil = 22 kN/m³
 H = depth below base of excavation
 γ_w = unit weight of water

The effective width of the soldier piles can be taken as three times the width of the pile or the concreted pile socket provided the pile spacing is not less than 5 times the pile or socket width.

The load carrying capacity of grouted tie-back anchors in the very dense sandy silty soils can be computed from the following expression:

$$T_L = \sigma Z' A_s K_f$$

where $\sigma Z'$ = effective vertical stress at the midpoint of the load-carrying length

A_s = effective surface area of the ~~surcharge~~

K_f = anchorage coefficient = 10 anchorage

from Canadian Foundation
 Eng Manual pg 28 Section 4

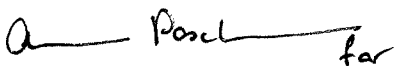
The effective length of the tie-back anchors should be assumed to lie outside a 45 degree slope drawn upward into the retained soil from the bottom of the soldier piles.

If full scale field pull-out tests are carried out (total of 10 per cent of all anchors installed), a factor of safety of 1.5 to 2 can be adopted depending on the consistency of the results and anchorage layout. Otherwise a factor of safety of 3 should be used.

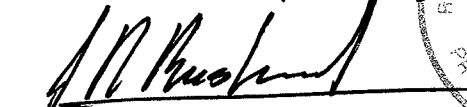
Installation of the soil anchors must be carefully carried out so that no loss of ground occurs into the hole. Where water bearing sands are encountered it may be necessary to case the holes temporarily.

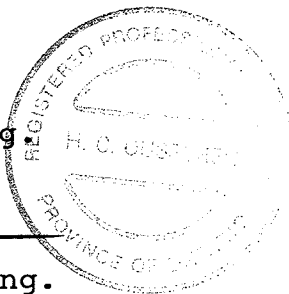
The use of inclined tie-backs will result in a downward load on the wall which will be carried by the soldier piles. Since driving of soldier piles without preaugering in the very dense soil would be difficult, it is assumed that the soldier piles will be installed in preaugered holes and surrounded by lean concrete. For piles founded on the very dense silty and sandy soils an allowable bearing capacity of 1000 kPa can be used to compute the vertical load-carrying capacity of the soldier piles. Side friction along the toes of the piles should be ignored. It should be noted that this design bearing pressure assumed that the foundation materials will not be disturbed during augering operations.

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HCO/JRB/cg

APPENDIX A

INVESTIGATION PROCEDURE

INVESTIGATION PROCEDURE

The field work for this investigation was carried out between July 19 and August 2, 1983. During this period a total of twenty four sampled boreholes were put down at the location shown on Drawing No. 470711611-A. The boreholes were put down to depths of up to 18.4 m using two Bombardier-mounted CME 55 power auger drills supplied and operated by Master Soil Investigations Limited. The fieldwork was supervised by members of Golder Associates' engineering staff who directed the drilling and sampling operations, supervised the in situ testing and logged the boreholes.

The boreholes were advanced through the overburden using continuous flight hollow or solid stem augers. Where pervious sand and gravel was encountered, wash boring techniques were sometimes necessary to advance the holes. At regular intervals of depth samples of the overburden were obtained as part of the Standard Penetration Test using a 51 mm O.D. split-barrel sampler. Auger samples were obtained where required to better define changes in stratigraphy. The shale bedrock was cored in three boreholes using a BQ size core barrel. Filtered standpipes and piezometers were sealed into many of the boreholes to allow monitoring of groundwater levels across the site. The location and elevations of the boreholes were surveyed by Golder Associates. The elevations are referenced to the temporary bench mark on the Bell Canada manhole cover near Borehole 6. It is understood that the Geodetic elevation of this bench mark is 94.266 m.

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

RECORD OF BOREHOLE No 1

W P 470-711-611 LOCATION Co-ordinates N 4,856,356; E 341,771 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Hollow Stem Auger, Solid Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 19 and 20, 1983 CHECKED BY JRB

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				WATER CONTENT (%)				
94.5	Ground Surface							20 40 60 80 100								
0.0	Silty sand, some gravel, trace clay Compact to Dense Brown becoming Grey at Elev. 90.6 m		1	SS	19	Water Level in Open Hole at Elev. 91.3 m Aug 2/83	90								γ = 22.4 kN/m ³	9 61 28 2
			2	SS	16											
			3	SS	28											
			4	SS	50											
89.9			5	SS	31											
			6	SS	84											
4.6	Silt, some fine sand and gravel Very Dense Grey															
88.7																
5.8	Silty sand, trace clay and fine gravel changing to gravelly sand some silt Dense to Very Dense Grey		7	SS	45											
86.6			8	SS	112											
7.9	Silt, some sand and gravel trace clay Very Dense Grey becoming dark grey at elev 85.2 m		9	SS	100/ 150 mm		85									
84.4																
10.1	Sand some gravel and trace silt to silty sand and gravel Very Dense Dark Grey		10	SS	57											
			11	SS	65											
			12	SS	86/ 200 mm		80									
79.3			13	SS	100/ 50 mm											
15.2	Shale bedrock, calcare- ous, moderately frac- tured to sound below elev. 78.8 m, fresh to slightly weathered, grey with occasional black shale beds		14	BQ RC	REC 100%											
76.7			15	BQ RC	REC 100%											
17.8	End of Borehole						75									

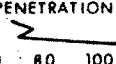
RECORD OF BOREHOLE No 2

W P 470-711-611 LOCATION Co-ordinates N 4,856,349; E 341,757 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Hollow Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 19, 1983 CHECKED BY JRB

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					
94.0	Ground Surface																
0.0	Topsoil																
0.5	Silty clay some sand trace root fibres		1	SS	20												
92.6	Very stiff Brown																
1.4	Silty sand some gravel and trace clay		2	SS	19												
	Compact to Very Dense		3	SS	14												
	Brown		4	SS	66												
89.6			5	SS	100/150												
4.4	Silt trace to some fine sand trace clay becoming gravelly at elev. 86.4		6	SS	100/75												
	Very Dense Grey		7	SS	143												
86.2			8	SS	114/150												
7.8	Sand trace gravel																
85.0	Very Dense Grey		9	SS	100/90												
9.0	Sandy silt with trace gravel and clay		10	SS	100/100												
82.4	Very Dense Dark Grey																
11.6	Silty clay with some gravel-sized shale fragments increasing in frequency with depth		11	SS	127												
	Hard Dark Grey		12	SS	86												
78.8			13	SS	100/												
15.3	End of Borehole																
	Probably shale bedrock with clay partings dark grey																

RECORD OF BOREHOLE No 3

W P 470-711-611 LOCATION Co-ordinates N 4,856,348; E 341,744 ORIGINATED BY HCO
DIST 6 HWY GO-ALRT BOREHOLE TYPE Hollow Stem Auger, Wash Boring COMPILED BY MHW
DATUM Geodetic DATE July 20 and 21, 1983 CHECKED BY JRB

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					
93.8	Ground Surface																
0.0	Fill, silty clay with organic matl. throughout																
92.6	Stiff Black		1	SS	9												
1.2	Silty clay, varved		2	SS	15												
91.7	Stiff Brown																
2.1	Sandy silt to silty sand, trace clay and gravel		3	SS	20												
	Brown becoming Grey with depth		4	SS	24												
89.5	Compact																
4.3	Silty sand trace gravel and clay to sand, some gravel and silt		5	SS	62												
	Very Dense Grey		6	SS	57												
86.1			7	SS	50/75 mm												
7.7	Sandy silt with trace to some gravel		8	SS	50/75 mm												
	Very Dense Grey																
83.3			9	SS	41												
10.5	Silty clay with angular gravel-sized shale and limestone fragments increasing in frequency with depth, some sand, layered in upper portion		10	SS	100/225 mm												
79.9	Hard Grey		11	SS	100/75 mm												
13.9	End of Borehole																
	NOTE: Continuous grinding of augers experienced from elev. 83.9 m to 83.3 m																

RECORD OF BOREHOLE No 4

W P 470-711-611 LOCATION Co-ordinates N 4,856,368; E 341,738 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Hollow Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 20, 1983 CHECKED BY JRB

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									WATER CONTENT (%)
								20 40 60 80 100					10 20 30				
							• UNCONFINED + FIELD VANE • QUICK TRIAXIAL x LAB VANE										
94.4	Ground Surface																
0.0	Topsoil																
0.3	Fill - sandy silt trace clay and gravel, occasional organic material		1	SS	16												
			2	SS	9												
	Loose to Compact Brown		3	SS	11												
91.5			4	SS	42												
2.9	Silty sand, trace to some gravel and trace clay		5	SS	32												
	Compact to Very Dense Brown changing to Grey at ± elev. 89.4 m		6	SS	25												
			7	SS	65												
87.9																	
6.5±	Silt some sand and clay trace gravel		8	SS	100/ 150 mm												
	Very Dense Grey		9	SS	50/ 60 mm												
83.7			10	SS	97/ 150 mm												
10.7	Silty sand, some gravel and trace to some clay																
	Very Dense Dark Grey		11	SS	86/ 150 mm												
80.6			12	SS	103												
13.8																	
14.1	End of Borehole																
	Silty clay some angular shale fragments Hard Dark Grey																

Elev.
90.9 m
Aug 5/83

90

85

80

10 43 32 5

1 21 64 13

RECORD OF BOREHOLE No 5

W P 470-711-611 LOCATION Co-ordinates N 4,856,372; E 341,750 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Hollow Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 20 and 21, 1983 CHECKED BY JRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W _p	W	W _L		
94.5	Ground Surface																
0.1	Topsoil		1	SS	3												
	Fill - sand, clay some silt, gravel trace cobbles and organic material		2	SS	11												
92.4																	
2.1	Silty sand some gravel trace clay		3	SS	25												
	Compact to Dense		4	SS	46												
90.1	Brown		5	SS	48												
4.4	Interlayered sandy silt with traces gravel and clay		6	SS	115/200												
	Gravelly silty sand and silt with trace to some sand. Occasional seams of sand trace silt		7	SS	61												
			8	SS	107/200												
			9	SS	50/25												
			10	SS	118/225												
			11	SS	78												
	Very Dense Dark Grey		12	SS	87												
79.3			13	SS	100/75												
15.2	End of Borehole																
15.3	Silty clay with shale and limestone fragments																
	Hard Dark Grey																

RECORD OF BOREHOLE No 6

W P 470-711-611 LOCATION Co-ordinates N 4,856,376; E 341,765 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Augers COMPILED BY MHW
 DATUM Geodetic DATE July 21 and 22, 1983 CHECKED BY JRB

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					
94.7	Ground Surface																
0.0	Fill - silty sand trace																
94.1	organic matter																
0.6	Silty sand some gravel		1	SS	13												
	trace clay. Silt con-		2	SS	20												
	tent decreasing with		3	SS	37												
	depth, trace organic		4	SS	32												
	matter to elev. 93.7 m		5	SS	130												
90.6	Compact to Dense																
	Brown																
4.1	Silt some fine sand		6	SS	100/												
	some stratification at				250												
	depth																
	Very Dense Grey		7	SS	100/												
87.7					150												
7.0	Silty sand some gravel		8	SS	175/												
	trace clay to gravelly				250												
	sand some silt																
	Very Dense Grey		9	SS	100/												
					75												
			10	SS	50/												
83.1					50												
11.6	Sand and gravel trace		11	SS	96												
	to some silt occasional																
	cobbles																
	Very Dense Dark		12	SS	122												
	Grey																
79.9																	
14.8			13	AS	-												
79.3			14	SS	100/												
15.4	End of Borehole				150												
	Silty clay with angular																
	shale and limestone																
	fragments																
	Hard Dark																
	Grey																

+3, x5: Numbers refer to
 Sensitivity

20
 15
 10
 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 7

W P 470-711-611 LOCATION Co-ordinates N 4,856,401; E 341,760 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY EFO
 DATUM Geodetic DATE July 27 and 28, 1983 CHECKED BY JRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT Σ					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
94.4	Ground Surface																
0.0	Topsoil																
0.1	Silty sand trace to some gravel trace clay, occasional rust stained fissures		1	SS	18												
			2	SS	20												
	Compact to Very Dense Brown		3	SS	65												
			4	SS	61												
90.1			5	SS	120/												
4.3	Sand trace to some silt, trace gravel to silty sand trace gravel and clay		6	SS	67												
	Very Dense Grey		7	SS	66												
			8	SS	125/												
85.9					225												
8.5	Silty sand some gravel trace clay		9	SS	98												
	Very Dense Grey		10	SS	94												
82.7																	
11.7	Sand and gravel some silt		11	SS	63												
	Very Dense Dark Grey		12	SS	110												
79.9																	
14.5	Silty clay with shale fragments		13	AS	-												
79.0	Hard Dark Grey		14	SS	50/												
15.4	End of Borehole				50 mm												

RECORD OF BOREHOLE No 7A

W P 470-711-611 LOCATION Co-ordinates N 4,856,400; E 341,759 ORIGINATED BY HCO
DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger - Piezometer Installation COMPILED BY FFO
DATUM Geodetic DATE July 29, 1983 CHECKED BY JRB

[illegible]

RECORD OF BOREHOLE No 8




W P 470-711-611 LOCATION Co-ordinates N 4,856,392; E 341,730 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Hollow, Solid Stem Auger/BQ Rock Core COMPILED BY MHW
 DATUM Geodetic DATE July 21 and 22, 1983 CHECKED BY JRB

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	NUMBER	TYPE			'N' VALUES	SHEAR STRENGTH					
93.3	Ground Surface											
0.1	Topsoil Silty sand trace to some clay and some gravel Compact to Very Dense Brown becoming Grey at elev. 91.8 m	1	SS	21								
		2	SS	36								
		3	SS	57								
		4	SS	37								
89.6		5	SS	108								
3.7	Fine sandy silt trace clay and gravel Very Dense Grey	6	SS	58								
		7	SS	100/ 50 mm								
		8	SS	115/ 200 mm								
84.8		9	SS	145/ 275 mm								
8.5	Silt to sandy silt some gravel and clay Very Dense Grey to Dark Grey	10	SS	127								
		11	SS	79								
		12	SS	70/ 150 mm								
78.1		13	SS	100/ 100 mm								
15.2	Shale bedrock, grey calcareous lightly fractured, fresh	14	BQ RC	REC 93%								
		15	BQ RC	REC 100%								
75.4												
17.9	End of Borehole											

19 35 33 13

RECORD OF BOREHOLE No 9

W P 470-711-611 LOCATION Co-ordinates N 4,856,375; E 341,682 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 22, 1983 CHECKED BY JRB

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				
90.9	Ground Surface															
90.3	Topsoil															
0.6	Silty clay varved		1	SS	9	 Water Level Elev. 89.9 m Aug. 5/83	90									
	Stiff Brown		2	SS	8											
88.8																
2.1	Silt to sandy silt trace gravel some clay		3	SS	3											
	Very Loose to Very Dense		4	SS	2											
	Grey		5	SS	20											
			6	SS	51		85									
			7	SS	69											
81.7			8	SS	100/											
9.2	End of Borehole				75 mm		80									

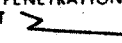
W_L = 43%

γ = 23.7
kN/m³

4 33 43 10

RECORD OF BOREHOLE No 10

W P 470-711-611 LOCATION Co-ordinates N 4,856,357; E 341,623 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 26 and 27, 1983 CHECKED BY JRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 					UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100						
								SHEAR STRENGTH						
93.5	Ground Surface													
0.0	Topsoil													
0.2	Silty sand trace gravel and organic matter		1	SS	10									
91.8	Loose Dark Brown		2	SS	5									
1.7	Interlayered sand and silt occasional rust staining		3	SS	40									
	Loose to Dense		4	SS	31									
89.8	Brown		5	SS	28		90							
3.7	Interlayered silty sand trace gravel, silty fine sand and sand trace silt		6	SS	27		Water Level Elev. 89.4 m Aug 5/83							
	Compact to Very Dense		7	SS	77									
	Brown becoming Grey at elev. 90.6 m becoming Brown at 88.0 m and Grey at 86.2		8	SS	45									
			9	SS	46		85							
82.4			10	SS	65									
11.1	End of Borehole						80							

RECORD OF BOREHOLE No 12

W P 470-711-611 LOCATION Co-ordinates N 4,856,430; E 341,843 ORIGINATED BY HCO
DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Augers COMPILED BY EFO
DATUM Geodetic DATE July 26, 1983 CHECKED BY JRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100		
92.3	Ground Surface													
0.0	Topsoil													
0.3	Silty clay - varved to massive		1	SS	8									
90.2	Stiff Brown		2	SS	7									
2.1	Silty sand to sandy silt trace to some gravel trace clay		3	SS	18									
	Compact to Very Dense		4	SS	51									
	Brown becoming Grey at about elev. 89.3 m		5	SS	99									
86.1			6	SS	104/275									
6.2	Silty clay trace gravel occasional sand lenses, layered		7	SS	43									
	Hard Dark Grey		8	SS	80									
83.5														
8.8	Silty clay with shale and limestone fragments increasing with depth		9	SS	105									
81.5	Hard Dark Grey		10	SS	100/									
10.8	End of Borehole				100									

Water Level
In Open
Hole at Elev.
90.6 m
Aug. 5/83

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

SHEAR STRENGTH
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL x LAB VANE

W_n=42%

0 3 50 47

Y=20.5
kN/m³

RECORD OF BOREHOLE No 13

W P 470-711-611 LOCATION Co-ordinates N 4,856,449; E 341,902 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY EFO
 DATUM Geodetic DATE July 27, 1983 CHECKED BY JRB

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					NATURAL MOISTURE CONTENT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80	100	W _p	W		
93.6	Ground Surface															
0.0	Fill - silty sand some gravel															
0.3	Silty sand trace to some gravel changing to sand some silt and gravel below elev. 90.7 m		1	SS	50											
			2	SS	99/275											
			3	SS	118/200											
	Dense to Very Dense		4	SS	41											
	Brown becoming Grey below elev. 90.7 m		5	SS	43											
			6	SS	46											
			7	SS	52											
			8	SS	100/150											
84.2			9	SS	100/150											
9.5	End of Borehole															
	Silty to sandy clay some gravel															
	Hard Dark Grey															

Water Level Elev. 91.5 m Aug 5/83

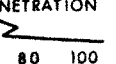
RECORD OF BOREHOLE No 14

RECORD OF BOREHOLE No 15

W P 470-711-611 LOCATION Co-ordinates N 4,856,471; E 341,749 ORIGINATED BY HCO
DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger, Wash Boring, BQ Rock Core COMPILED BY EFO
DATUM Geodetic DATE July 28 and 29, August 2, 1983 CHECKED BY JRB

RECORD OF BOREHOLE No 16

W P 470-711-611 LOCATION Co-ordinates N 4,856,446; E 341,720 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 25, 1983 CHECKED BY JRB

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					WATER CONTENT (%)				
92.3	Ground Surface							20	40	60	80	100					
0.0	Fill - sand trace to some silt trace gravel and organic material		1	SS	26												
90.8	Compact Brown		2	SS	40												
1.5	Silty sand trace to some gravel trace clay, with rusty fissures		3	SS	66												
	Dense to Very Dense		4	SS	55												
88.3	Brown to Grey																
4.0	Silt to sandy silt trace to some gravel and clay, occasional silty sand lenses		5	SS	60												
	Very Dense Grey		6	SS	94												
			7	SS	50/ 50 mm												
			8	SS	122/ 200 mm												
			9	SS	60/ 75 mm												
80.8																	
11.5	Silty sand some gravel trace clay to gravelly silty sand traces clay		10	SS	145												
	Very Dense Grey		11	SS	100/ 225 mm												
			12	SS	31*												
75.4																	
16.9	Silty to sandy clay trace to some gravel		13	SS	138/ 200 mm												
73.9	Hard Dark Grey		14	SS	100/ 75 mm												
18.4	End of Borehole																
	* Low N value likely due to disturbance during augering. Little sample recovered.																

RECORD OF BOREHOLE No 17

W P 470-711-611 LOCATION Co-ordinates N 4,856,454; E 341,744 ORIGINATED BY HCO
DIST 6 HWY GO-ALERT BOREHOLE TYPE Solid Stem Auger COMPILED BY MPW
DATUM Geodetic DATE July 25, 1983 CHECKED BY JRB

RECORD OF BOREHOLE No 18

W P 470-711-611 LOCATION Co-ordinates N 4,856,406; E 341,658 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY EFO
 DATUM Geodetic DATE July 27, 1983 CHECKED BY JRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT \triangleright		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					
91.4	Ground Surface													
0.2	Fill, silty sand trace to some clay trace gravel, gasoline odour		1	SS	5									
90.0	Loose Brown													
1.4	Silty clay, varved with occasional sand lenses		2	SS	6									
	Stiff Brown and Grey		3	SS	9									
88.0			4	SS	4									
3.4	Silty sand some gravel and clay		5	SS	2									
			6	TW	PH									
	Very loose becoming Dense to Very Dense below elevation 85.6 m		7	SS	30									
	Grey		8	SS	66									
			9	SS	57									
81.0														
10.4	Silty clay with shale fragments increasing with depth and changing gradually to shale		10	SS	130/200 mm									
79.0	Bedrock Hard Dark Grey		11	SS	50/50 mm									
12.4	End of Borehole													

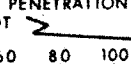
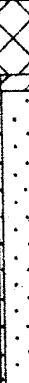

Water Level Elev. 88.7 m Aug 5/83

$\gamma = 18.8 \text{ kN/m}^3$

14 41 37 8

RECORD OF BOREHOLE No 19

W P 470-711-611 LOCATION Co-ordinates N 4,856,416; E 341,689 ORIGINATED BY HCO
 DIST 6 HWY GO-ALERT BOREHOLE TYPE Solid Stem Auger COMPILED BY EFO
 DATUM Geodetic DATE July 27, 1983 CHECKED BY JRB

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									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	x LAB VANE		10			20	30
91.7	Ground Surface																
0.0	Fill - sand trace silt and gravel, gasoline odour		1	SS	5												
90.3	Loose Brown		2	SS	8												
1.4	Silty clay stiff varved		3	SS	8												
1.7	Silty sand some gravel trace clay, with sand and some silt trace gravel at about elev. 86.5 m to 86.0 m		4	SS	61												
			5	SS	13												
			6	SS	35												
			7	SS	89												
84.4																	
7.3	Silty clay with shale fragments increasing with depth		8	SS	87												
	Hard Dark Grey		9	SS	70/ 150 mm												
80.6			10	SS	124/ 200 mm												
11.1	End of Borehole																

γ=23.7
kN/m³

RECORD OF BOREHOLE No 20

W P	470-711-611	LOCATION	Co-ordinates N 4,856,425; E 341,732	ORIGINATED BY	HCO
DIST	6 HWY GO-ALRT	BOREHOLE TYPE	Solid Stem Auger	COMPILED BY	MHW
DATUM	Geodetic	DATE	July 26, 1983	CHECKED BY	JRB

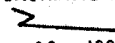
RECORD OF BOREHOLE No 21

W P 470-711-611 LOCATION Co-ordinates N 4,856,434; E 341,750 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 26, 1983 CHECKED BY JRB

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				
92.2	Ground Surface															
0.0	Fill, sand and gravel															
0.3	Fill - sand trace gra- vel and silt		1	SS	28											
91.2																
1.0	Compact Brown Silty sand, trace to some gravel, occasional horizontal layers of silt		2	SS	64											
			3	SS	89											
			4	SS	100/125											
88.7	Very Dense Brown		5	SS	100/230											
3.5	Sandy silt trace to some gravel trace clay		6	SS	100/125											
	Very Dense Grey		7	SS	100/125											
			8	SS	100/125											
83.4																
8.8	Silt, some clay trace sand		9	SS	109/275											
81.9	Very Dense Grey															
10.3	Silty sand to silty sand and gravel		10	SS	57											
	Very Dense Dark Grey		11	SS	61											
78.6																
13.6	Shale bedrock, fissile Dark Grey		12	SS	87/150											
76.9			13	SS	100/75											
15.3	End of Borehole															

RECORD OF BOREHOLE No 22

W P 470-711-611 LOCATION Co-ordinates N 4,856,449; E 341,799 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 26, 1983 CHECKED BY JRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 					UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N' VALUES			20	40	60	80	100		
92.6	Ground Surface													
91.2	Fill - sand and gravel trace silt and organic matter Compact Brown		1	SS	50/ 75 mm		Water Level Elev. 90.4 m July 29/83							
90.5	Organic sandy silt trace gravel and clay Compact Black		2	SS	14									
89.4	Silty clay trace sand varved		3	SS	7									
88.4	Stiff Brown and Grey Silty sand some clay and gravel Loose to Dense Brown becoming Grey below elev. 88.1 m		4A	SS	43									
85.3			5	SS	8									
7.3	Silty to sandy clay trace to some gravel Hard Dark Grey		6	SS	23									
80.4			7	SS	8									
12.3	End of Borehole Shale bedrock - fissile highly weathered, black		8	AS	100/ 125 mm									
			9	SS	79									
			10	SS	100/ 75 mm									
			11	AS	113/ 50 mm									

0 7 55 38

$\gamma=20.7$
kN/m³

RECORD OF BOREHOLE No 23

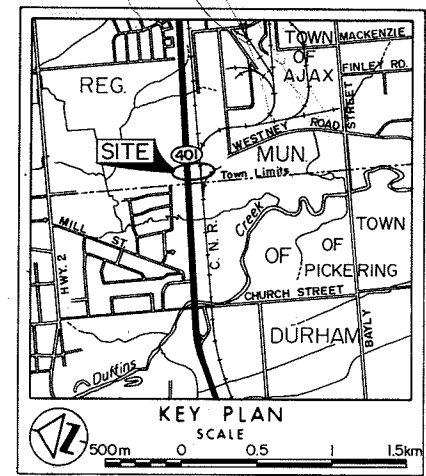
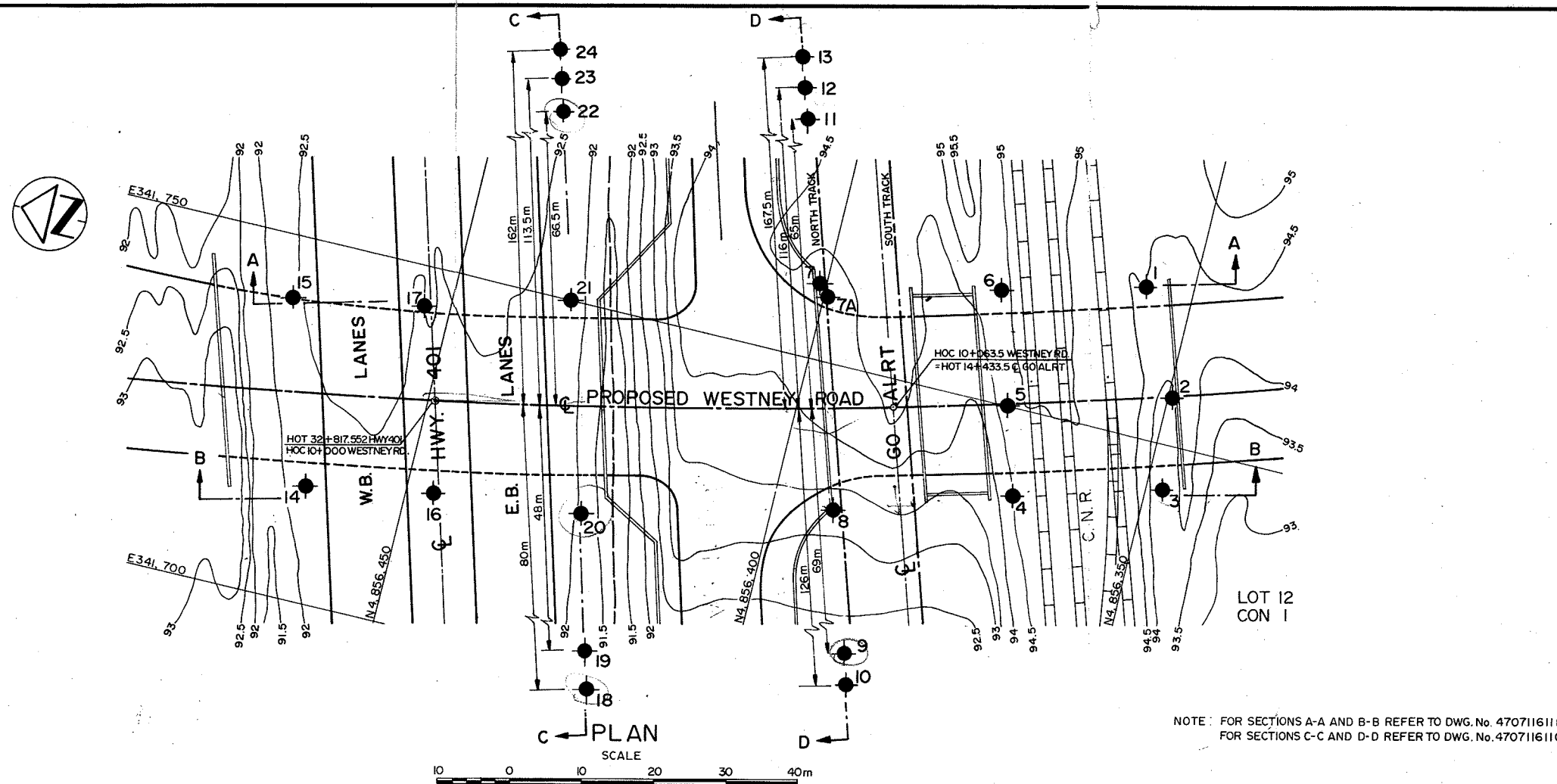
W P 470-711-611 LOCATION Co-ordinates N 4,856,459; E 341,835 ORIGINATED BY HCO
 DIST 6 HWY GO-ALRT BOREHOLE TYPE Solid Stem Auger COMPILED BY MHW
 DATUM Geodetic DATE July 27, 1983 CHECKED BY JRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT Σ					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					
92.9	Ground Surface																
0.0	Fill - sand and gravel																
0.3	Fill silty sand and gravel trace organics		1	SS	13												
91.5	Compact Brown-Grey																
1.4	Silty sand trace to some gravel trace clay		2	SS	9												
90.0	Loose to Very Dense		3	SS	70												
2.9	Sandy silt to silty sand, trace gravel, occasional sandy pockets		4	SS	90												
			5	SS	119/225												
			6	SS	100/150												
	Very Dense Grey		7	SS	100/150												
			8	SS	100/150												
84.1																	
8.8	Sand trace gravel silt and clay		9	SS	116												
83.2	Very Dense Dark Grey																
9.7	Silty clay with some shale and limestone fragments																
81.8	Hard Grey		10	SS	140												
11.1	End of Borehole																

Water Level Elev. 90.6 m Aug 5/83

$\gamma = 23.9$
kN/m³

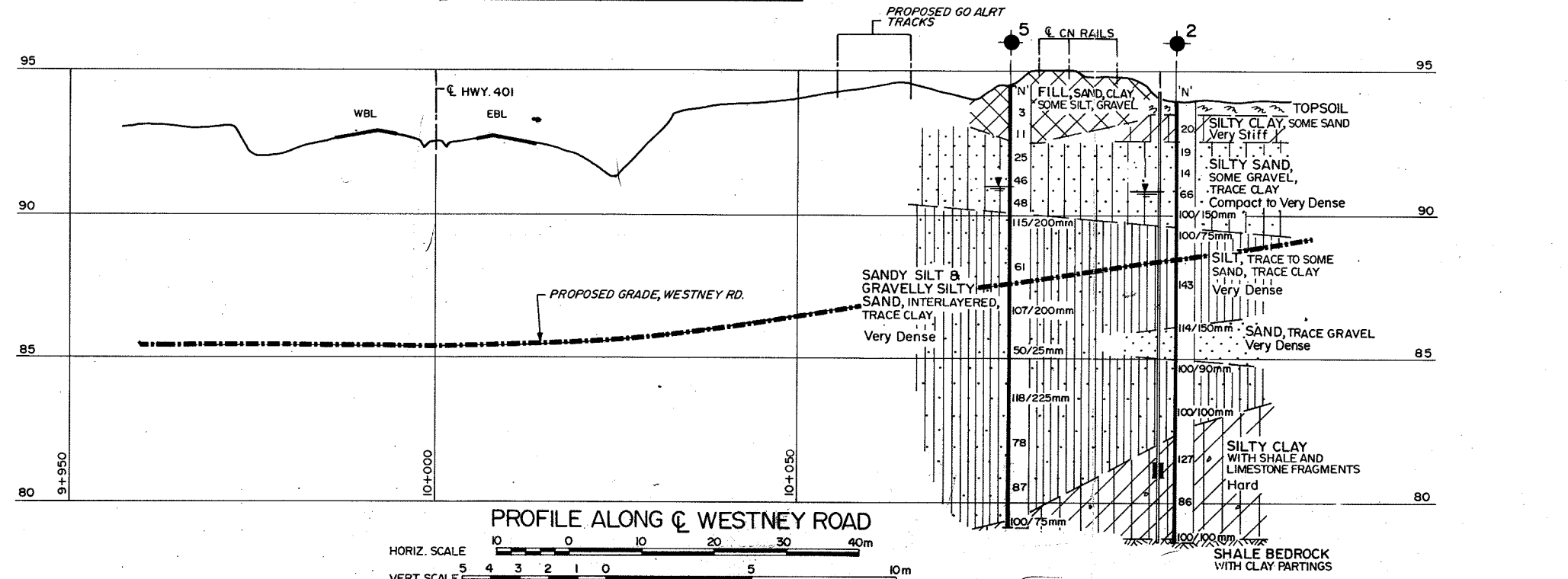
7 80 10 3



LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation, July - Aug. 1983
- Ground Surface
- Bentonite Seal
- Standpipe

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	94.5	4,856,356	341,771
2	94.0	4,856,349	341,757
3	93.8	4,856,348	341,744
4	94.4	4,856,368	341,738
5	94.5	4,856,372	341,750
6	94.7	4,856,376	341,765
7	94.4	4,856,401	341,760
7A	94.4	4,856,400	341,759
8	93.3	4,856,392	341,730
9	90.9	4,856,375	341,682
10	93.5	4,856,357	341,623
11	91.9	4,856,418	341,805
12	92.3	4,856,430	341,843
13	93.6	4,856,449	341,902
14	92.0	4,856,463	341,716
15	92.2	4,856,471	341,741
16	92.3	4,856,446	341,720
17	92.5	4,856,454	341,744
18	91.4	4,856,406	341,658
19	91.7	4,856,416	341,689
20	91.9	4,856,425	341,732
21	92.2	4,856,434	341,750
22	92.6	4,856,449	341,799
23	92.9	4,856,459	341,835
24	93.4	4,856,476	341,890





Geocres No

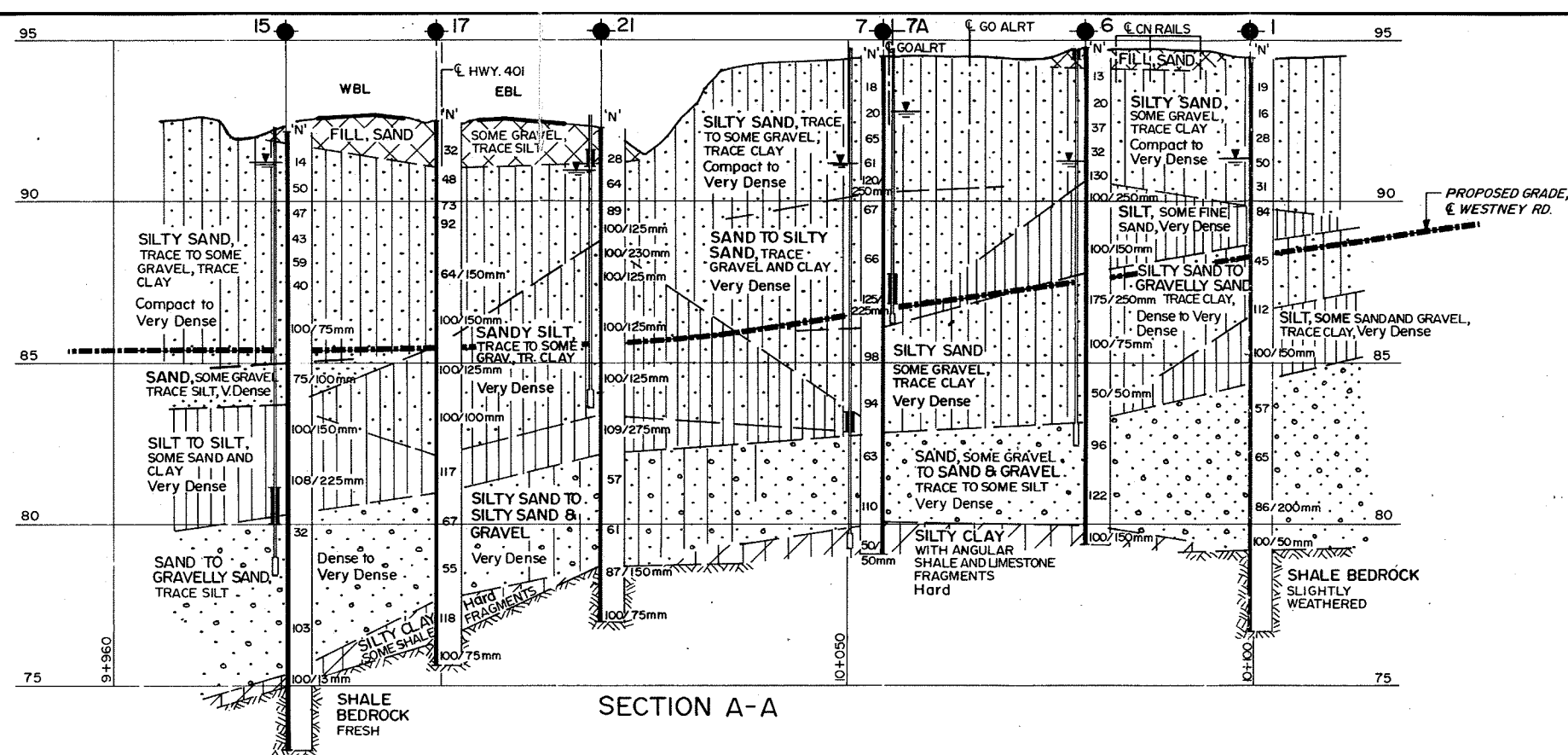
=NOTE=

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

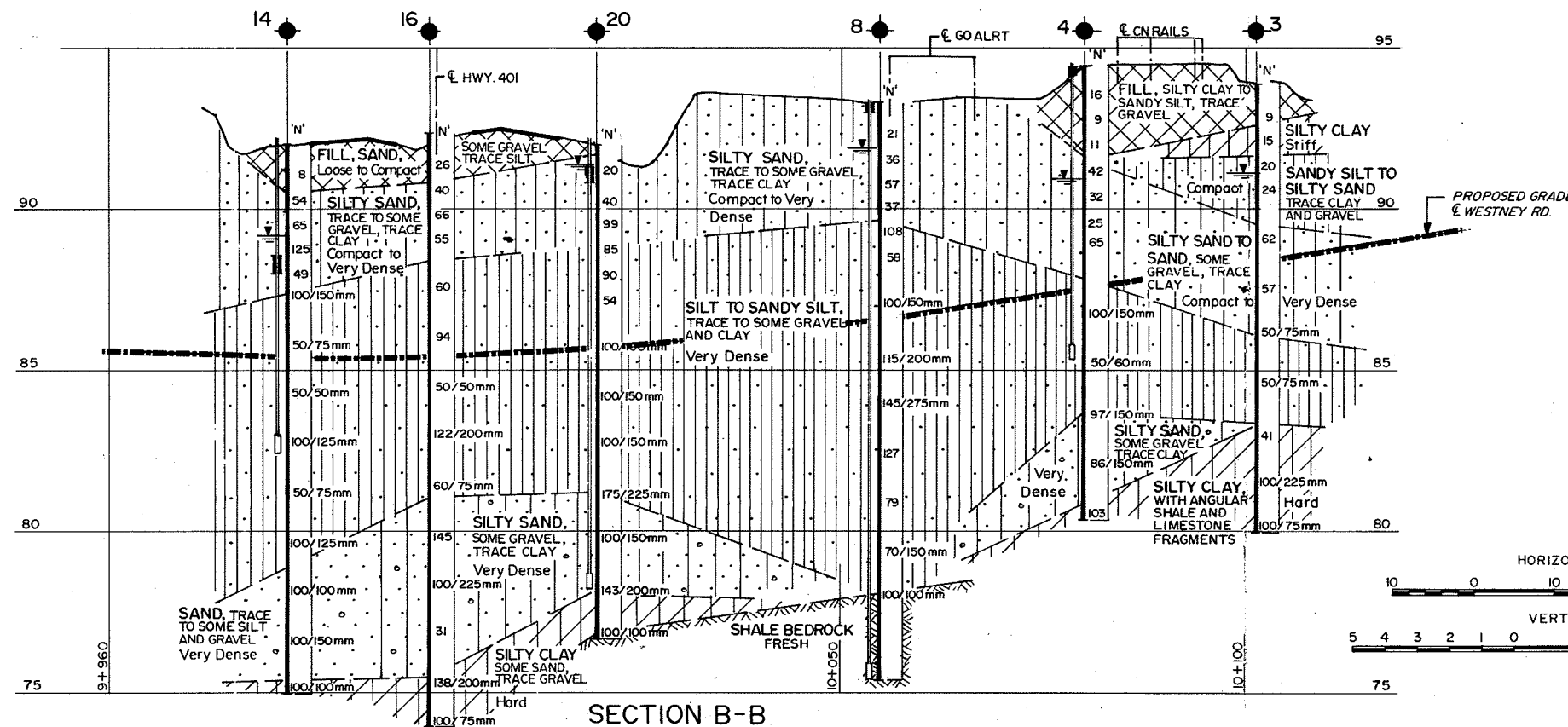
NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

GO-ALRT REF B-2-GA-2

REFERENCE DRAWINGS				REVISIONS		DRAWN BY: EFO, MHW		DESIGNED BY:		 Golder Associates CONSULTING GEOTECHNICAL AND MINING ENGINEERS	 GO-ALRT Ministry of Transportation and Communications	PROPOSED WESTNEY RD. UNDERPASS			
						CHK'D BY: HCO		APPROVED BY: JRB				GO ALRT, HWY. 401 & C.N. RAIL			
						SCALE: FULL SIZE ONLY AS SHOWN						BOREHOLE LOCATIONS & SOIL STRATA			
										PROJECT MANAGER		CONTRACT NO	DWG NO 470711611A	REV	SHEET



SECTION A-A



SECTION B-B

METRIC
ALL DIMENSIONS SHOWN ARE
IN METRES AND/OR MILLI-
METRES UNLESS OTHERWISE
NOTED.

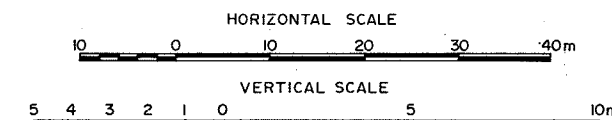
SEE SHEET 1

KEY PLAN
SCALE

LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W.L. at time of investigation, July - Aug. 1983
- Bentonite Seal
- Piezometer



No	ELEVATION
SEE SHEET 1	



Geocres No
=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.

GO-ALRT REF B-2-GA-2

REFERENCE DRAWINGS		REVISIONS		DRAWN BY: MHW	DESIGNED BY:	 Golder Associates CONSULTING GEOTECHNICAL AND MINING ENGINEERS	 GO-ALRT Ministry of Transportation and Communications	PROPOSED WESTNEY RD. UNDERPASS			
				CHK'D BY: HO	APPROVED BY: JRB			GO ALRT, HWY.401 & C.N.RAIL			
				SCALE: FULL SIZE ONLY							
				AS SHOWN							
				PROJECT MANAGER							
								CONTRACT NO	DWG NO 470711611B	REV	SHEET

ALL DIMENSIONS SHOWN ARE
IN METRES AND/OR MILLI-
METRES UNLESS OTHERWISE
NOTED.



KEY PLAN
SCALE



 Bore Hole
 Dynamic Cone Penetration Test (Cone)
 Bore Hole & Cone
 N Blows/0.3m (Std Pen Test, 475 J/blow)
 CONE Blows/0.3m (60° Cone, 475 J/blow)
 W.L. at time of investigation July - Aug. 1983
 Bentonite Seal
 Piezometer

Geocres No

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

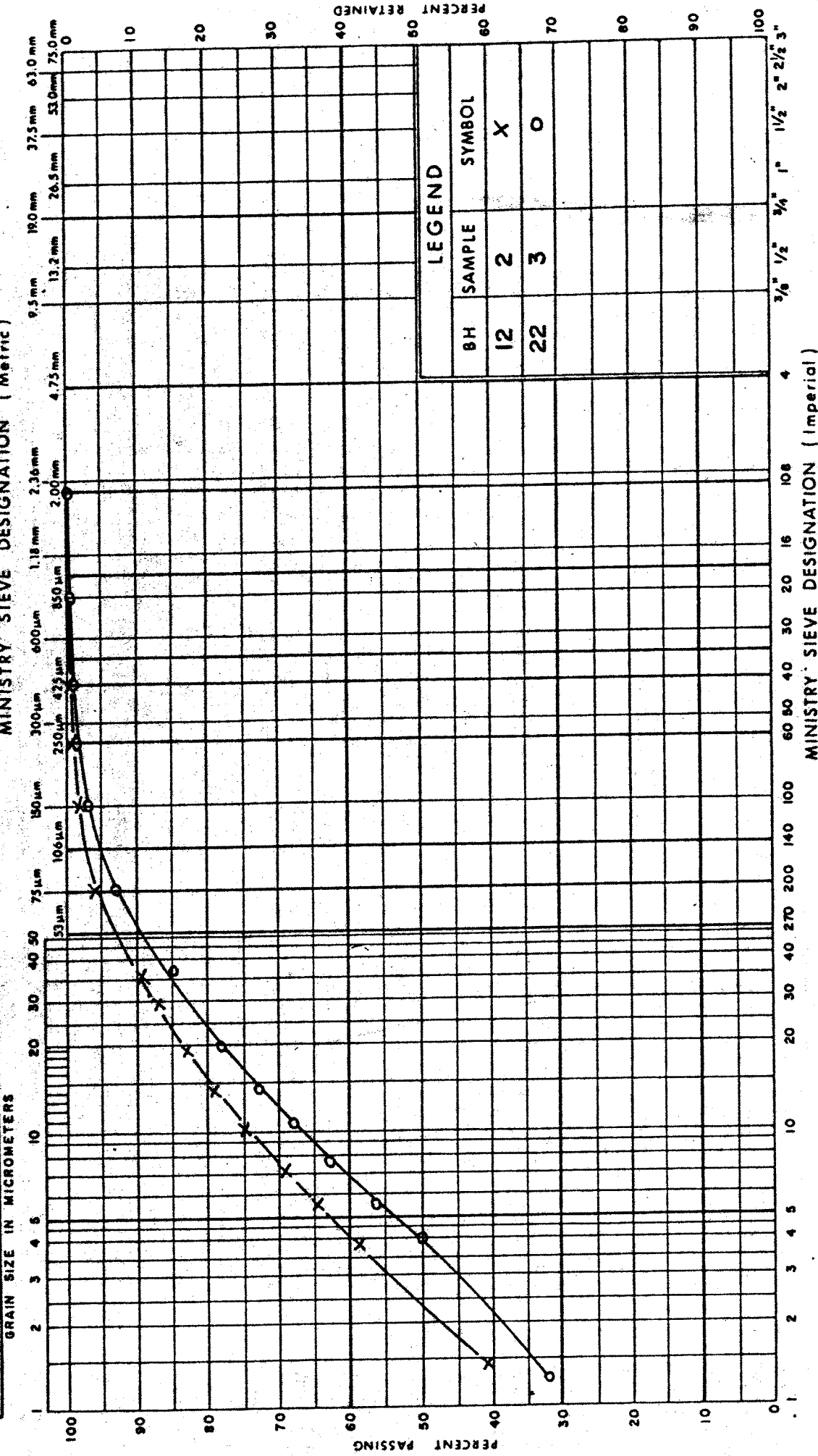
NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

GO-ALRT REF B-2-GA-2

REFERENCE DRAWINGS		REVISIONS		DRAWN BY: EFO, MHW	DESIGNED BY:	 Golder Associates CONSULTING GEOTECHNICAL AND MINING ENGINEERS	 GO-ALRT Ministry of Transportation and Communications	PROPOSED WESTNEY RD. UNDERPASS			
				CHK'D BY: HCO	APPROVED BY: RJB			GO ALRT, HWY. 401 & C.N. RAIL			
				SCALE: FULL SIZE ONLY AS SHOWN				SOIL STRATA			
								CONTRACT NO	DWG NO 470711611C	REV	SHEET
								PROJECT MANAGER			

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT			SAND			GRAVEL		
			Fine	Medium	Coarse	Fine	Coarse	
MINISTRY SIEVE DESIGNATION (Metric)								



GRAIN SIZE DISTRIBUTION UPPER SILTY CLAY

FIG No I
W P 470-711-611

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Communications



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT

GRAIN SIZE IN MICROMETERS

Fine

Medium

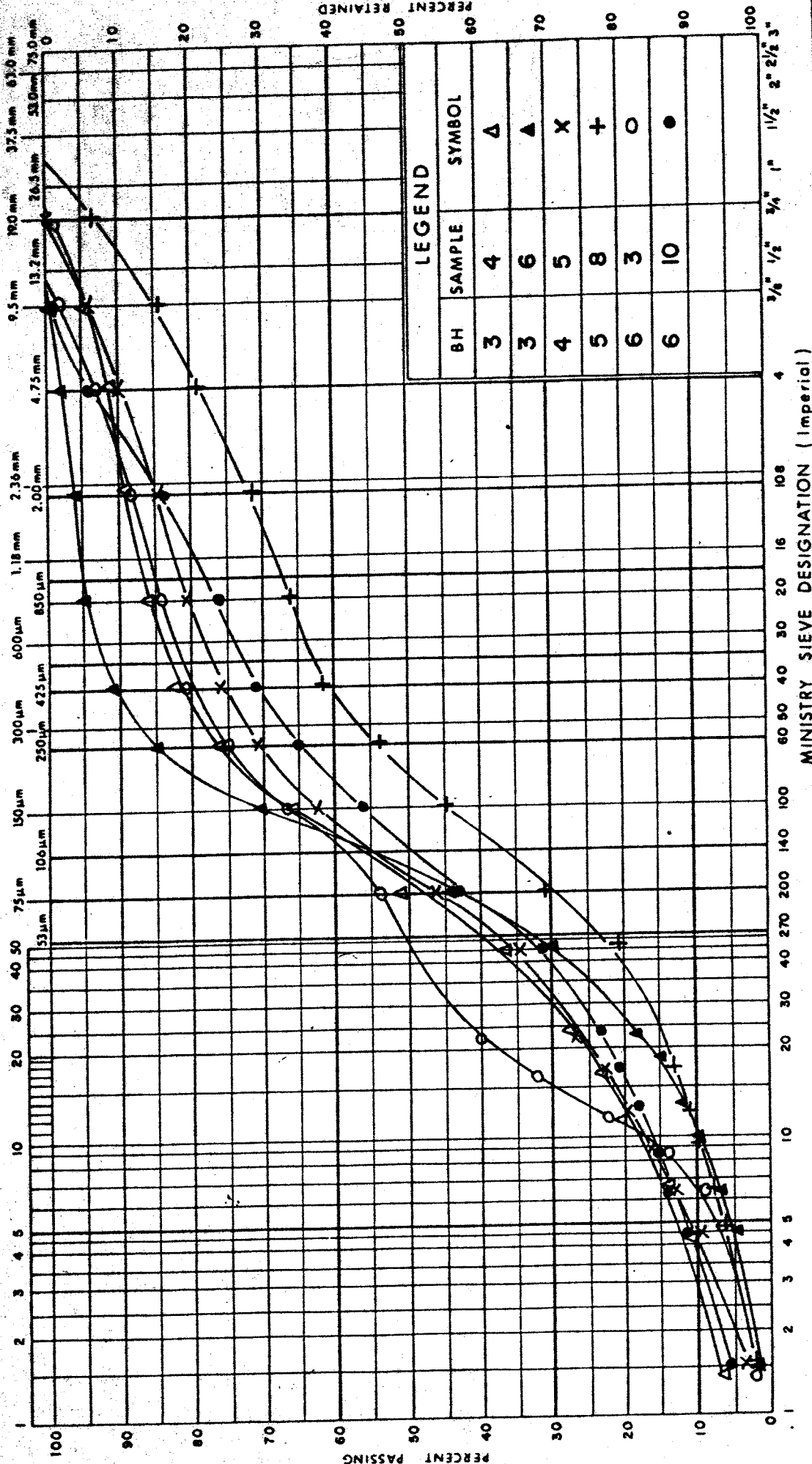
Coarse

GRAVEL

Fine

Coarse

MINISTRY SIEVE DESIGNATION (Metric)



GRAIN SIZE DISTRIBUTION SILTY SAND TO SANDY SILT

Ministry of
Transportation and
Communications



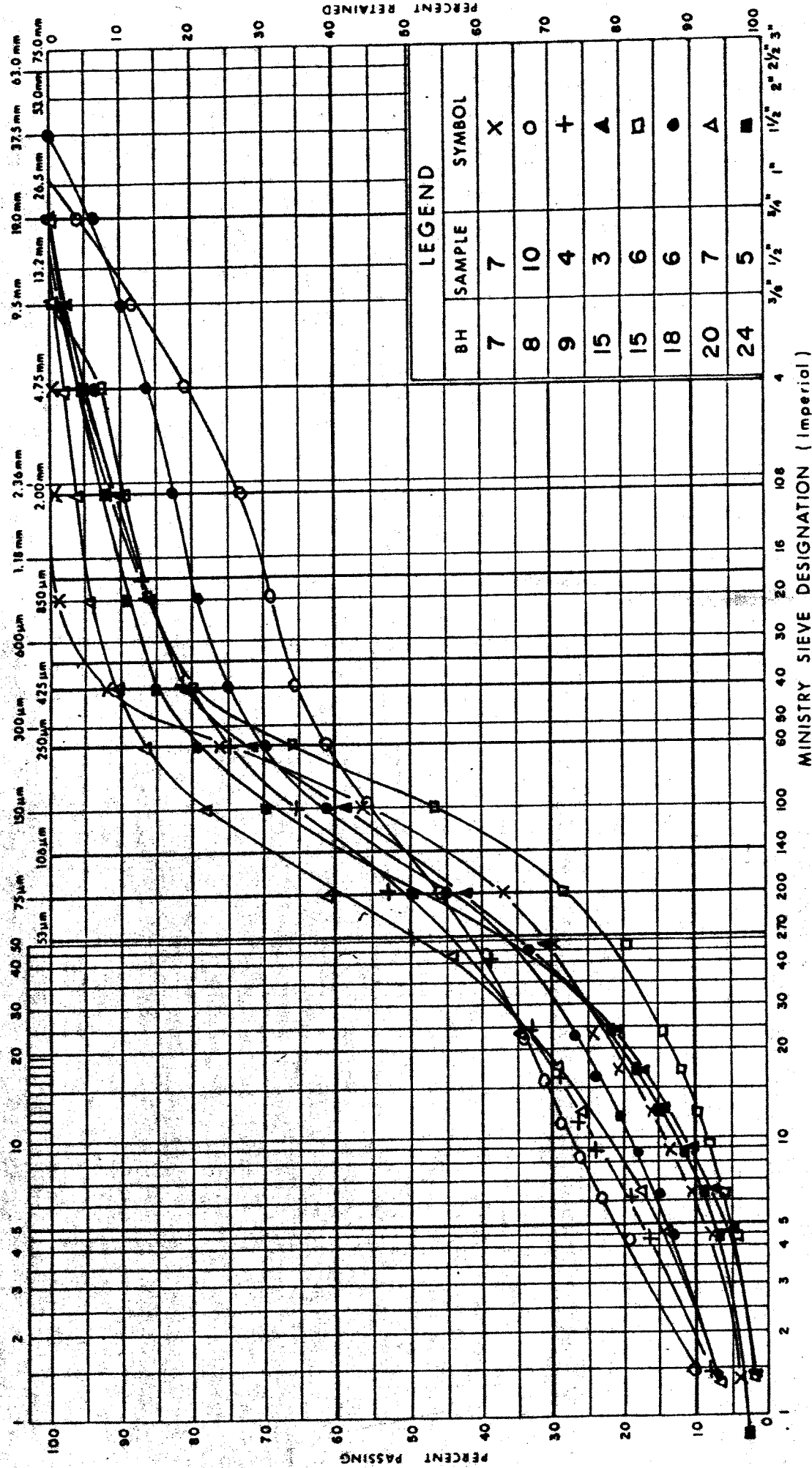
FIG No 2

W P 470-711-611

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT			SAND			GRAVEL		
Fine			Medium			Fine		
MINISTRY SIEVE DESIGNATION (Metric)			Coarse			Coarse		

GRAIN SIZE IN MICROMETERS



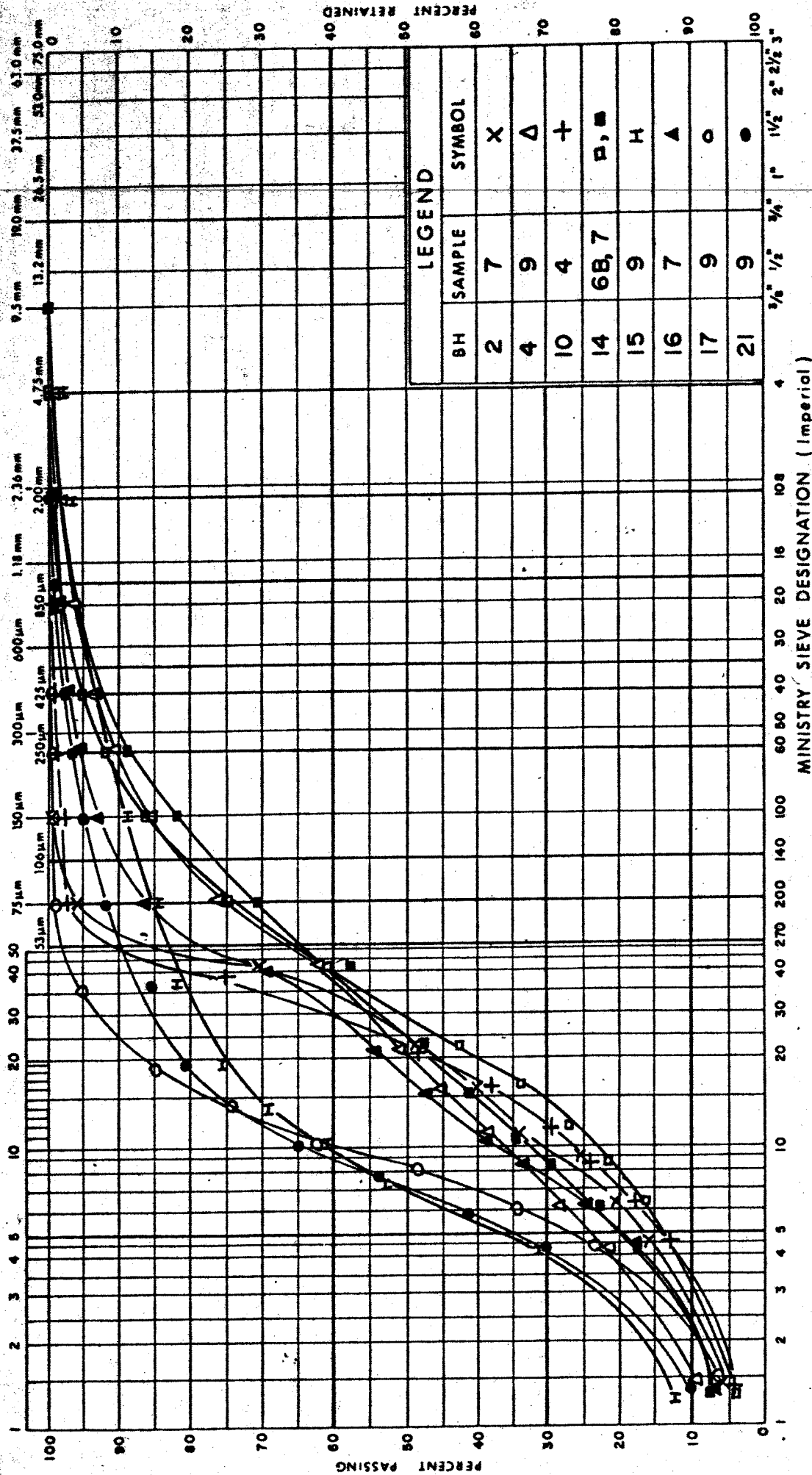
GRAIN SIZE DISTRIBUTION SILTY SAND TO SANDY SILT

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL		
		Fine	Medium	Coarse	Fine	Coarse	

MINISTRY SIEVE DESIGNATION (Metric)

GRAIN SIZE IN MICROMETERS



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Transportation and
Communications



GRAIN SIZE DISTRIBUTION SILT

FIG No 4

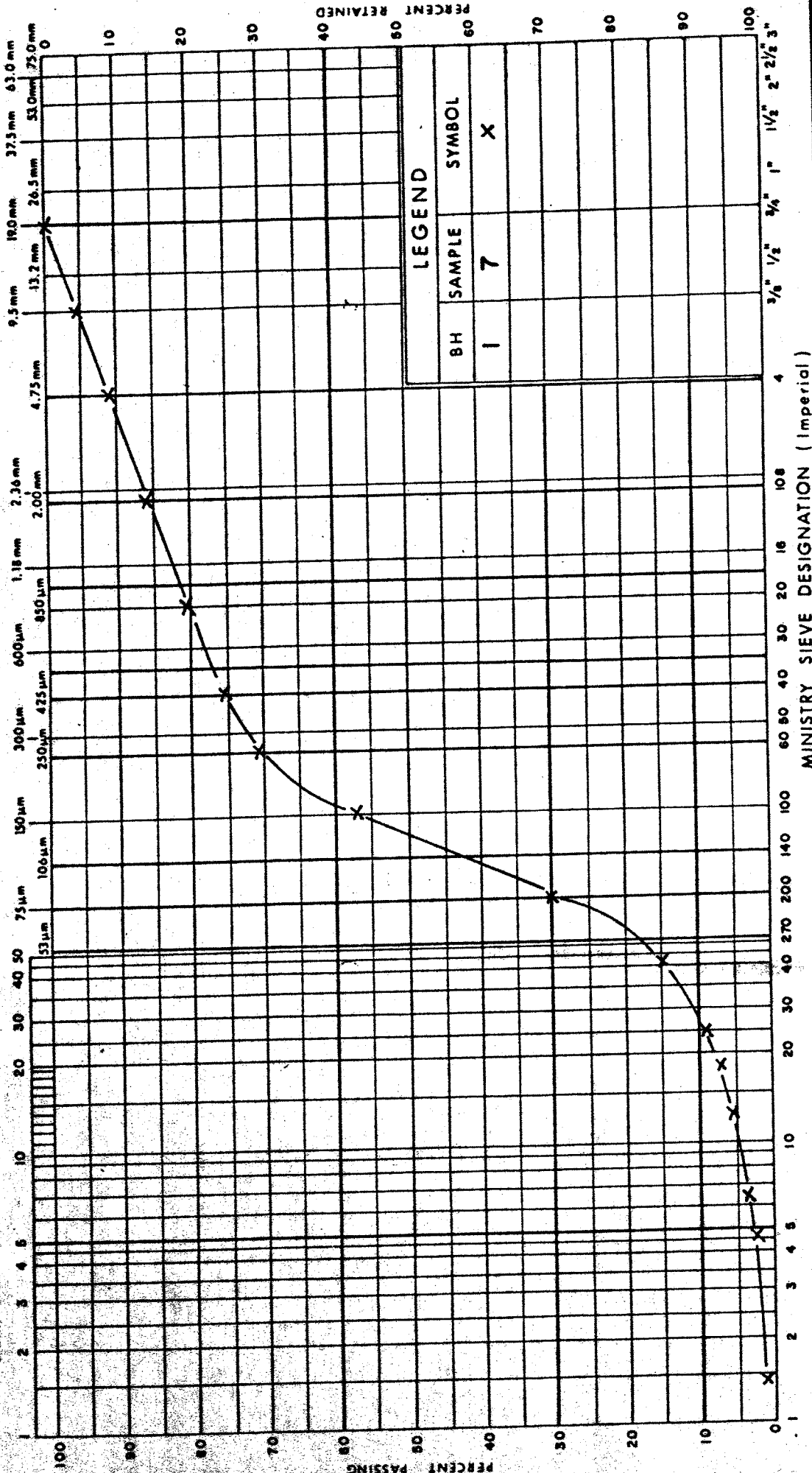
W P 470-711-611

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT			SAND			GRAVEL		
Fine			Medium			Fine		
Coarse			Coarse			Coarse		

MINISTRY SIEVE DESIGNATION (Metric)

GRAIN SIZE IN MICROMETERS



LEGEND

BH	SAMPLE	SYMBOL
1	7	X

GRAIN SIZE DISTRIBUTION SAND

FIG No 5

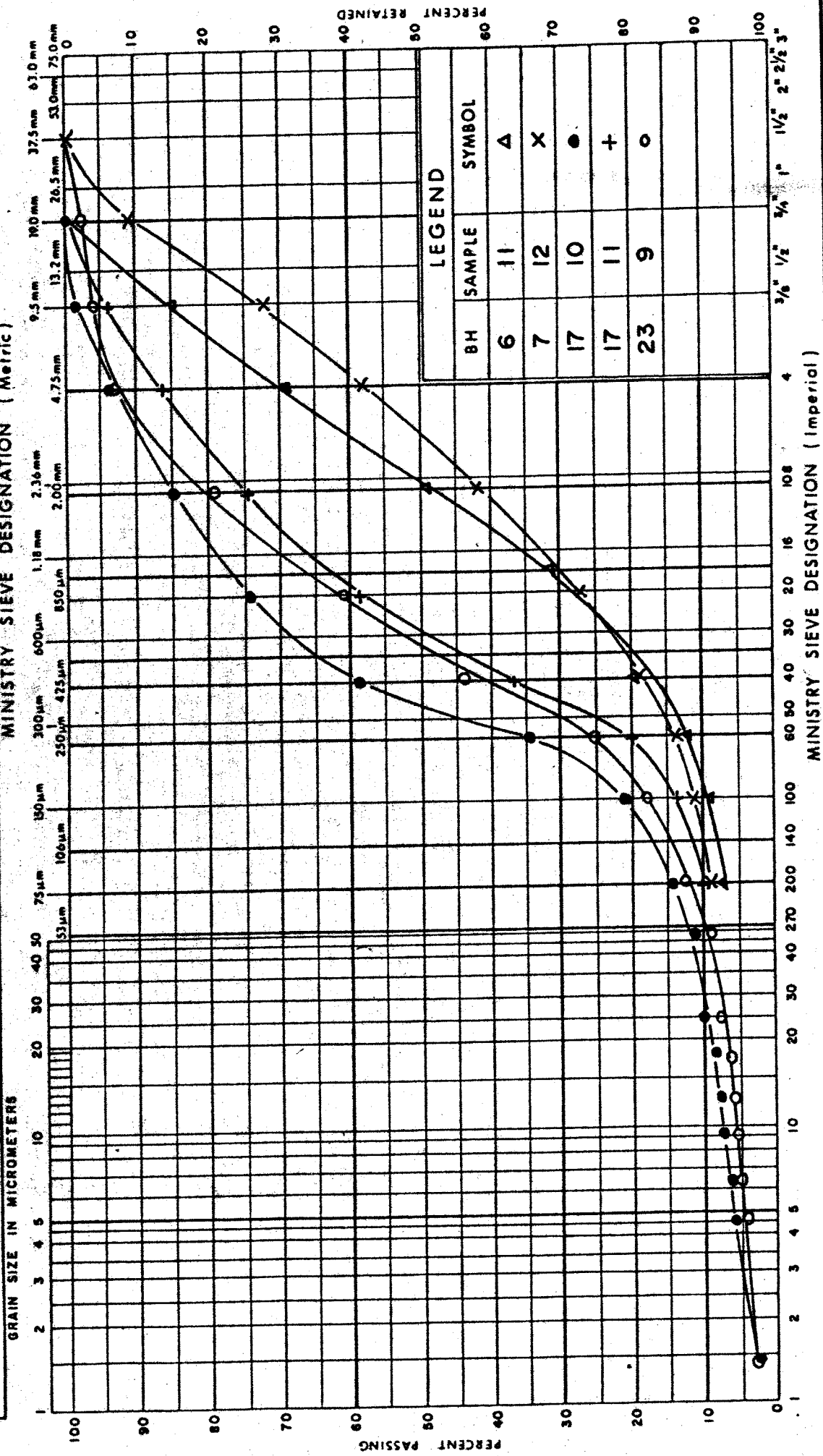
W P 470-711-611

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Transportation and
Communications



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT			SAND			GRAVEL		
Fine			Medium			Fine		
Coarse			Coarse			Coarse		



GRAIN SIZE DISTRIBUTION SAND AND GRAVEL

FIG No 6

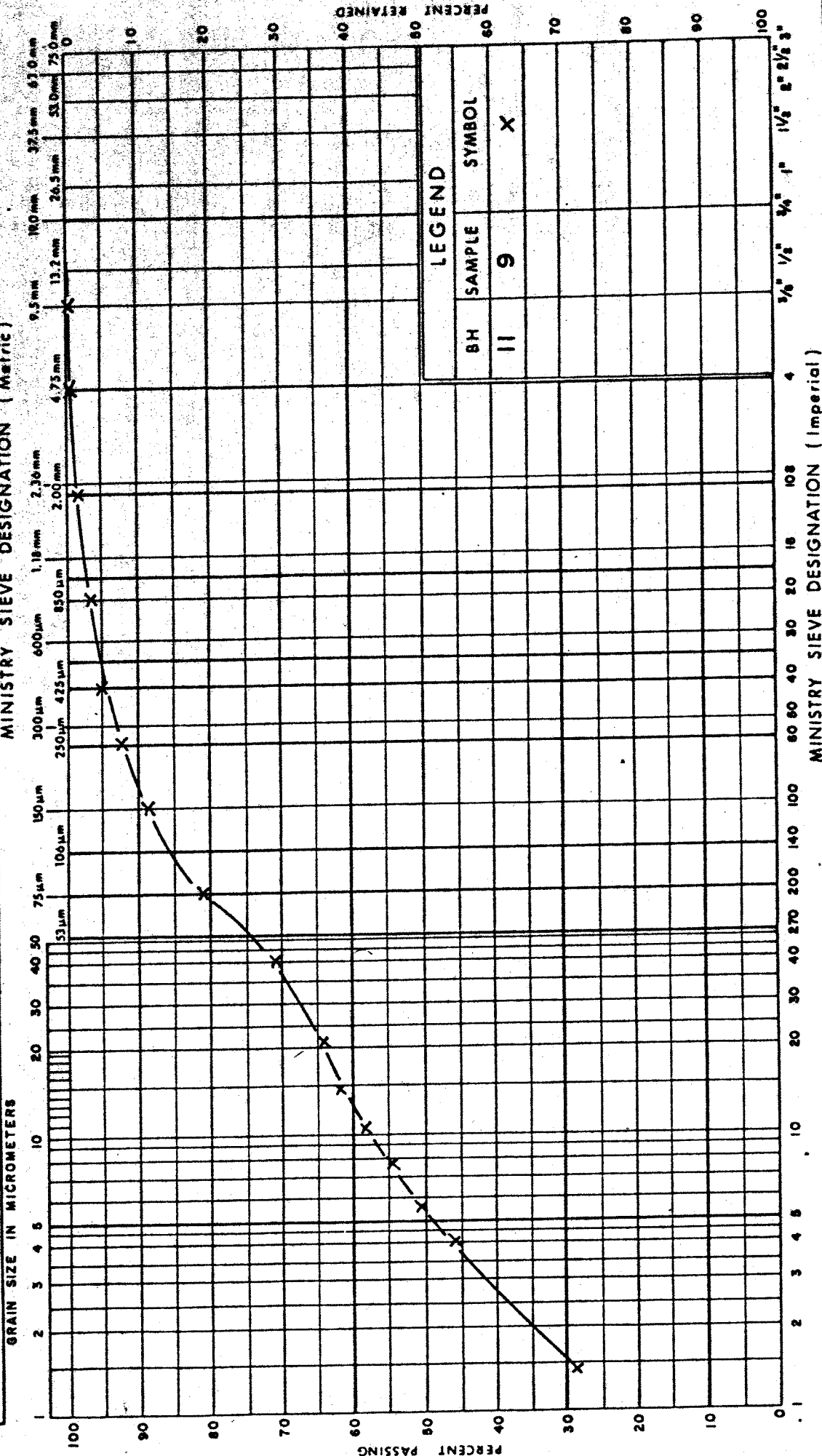
W P 470-711-611

Ministry of
Transportation and
Communications



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT			SAND			GRAVEL		
Fine			Medium			Fine		
MINISTRY SIEVE DESIGNATION (Metric)			MINISTRY SIEVE DESIGNATION (Metric)			MINISTRY SIEVE DESIGNATION (Metric)		

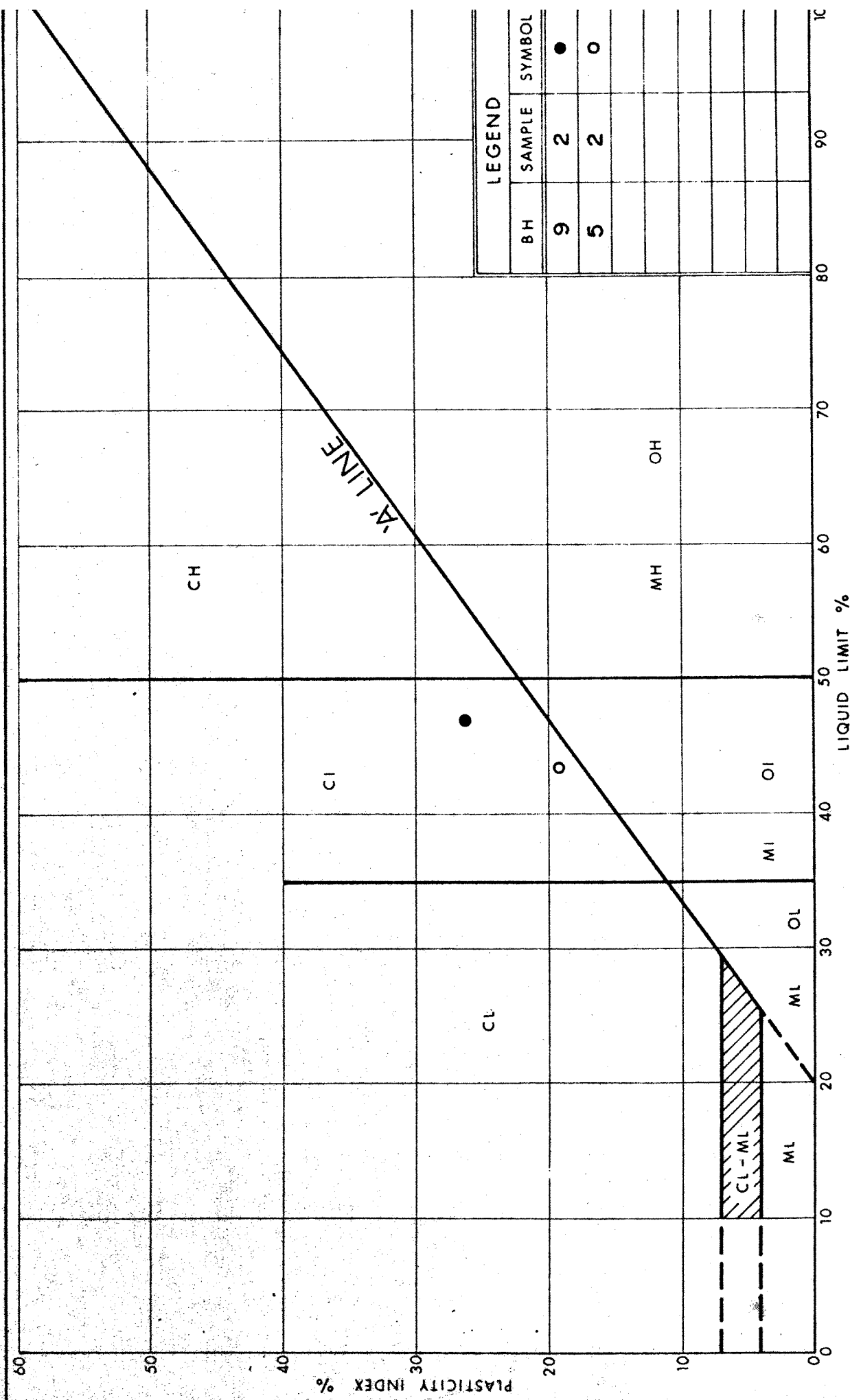


GRAIN SIZE DISTRIBUTION LOWER SILTY CLAY

FIG No 7
W P 470-711-611

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Communications

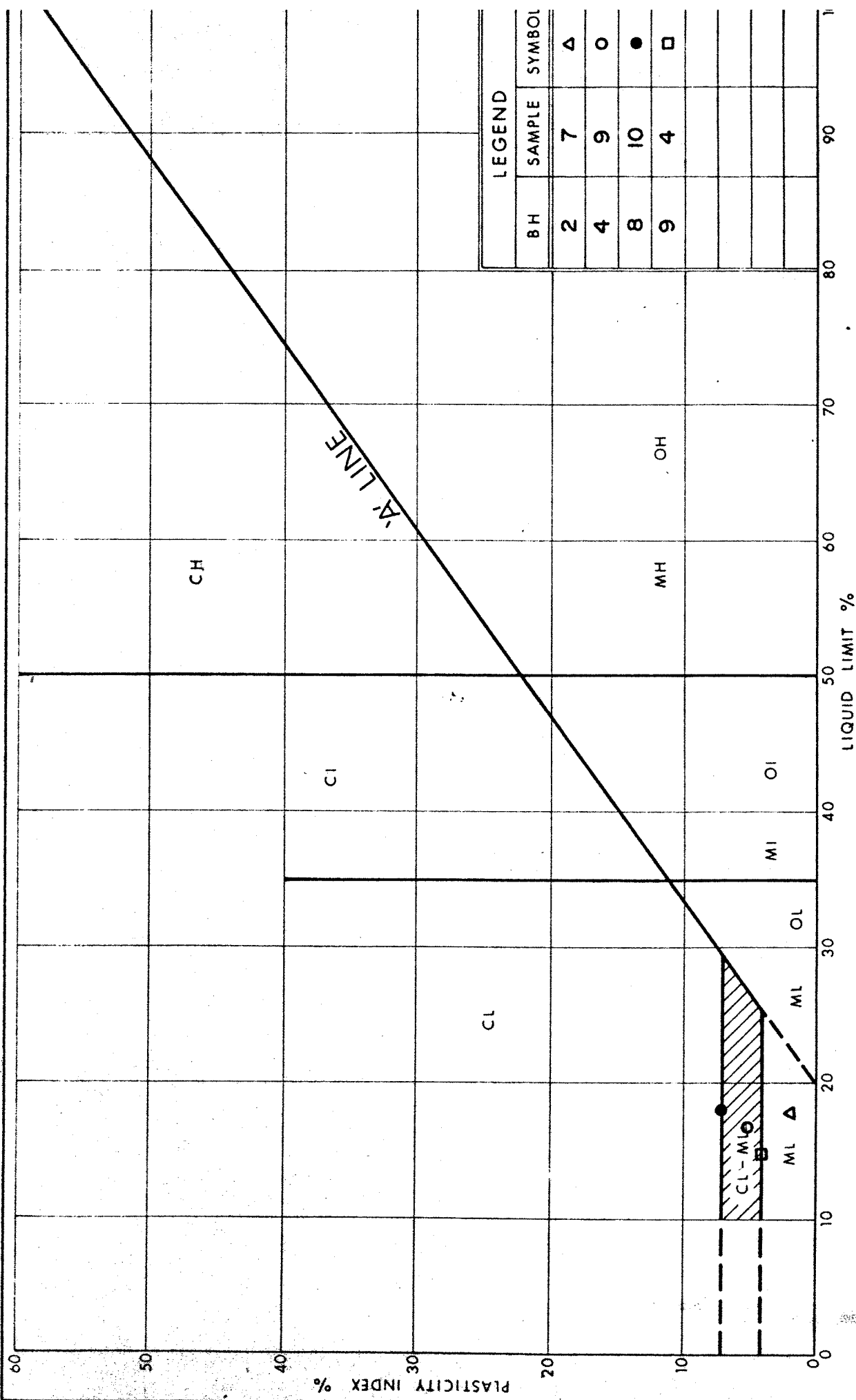




PLASTICITY CHART
UPPER SILTY CLAY

FIG No 8

W P 470-711-611



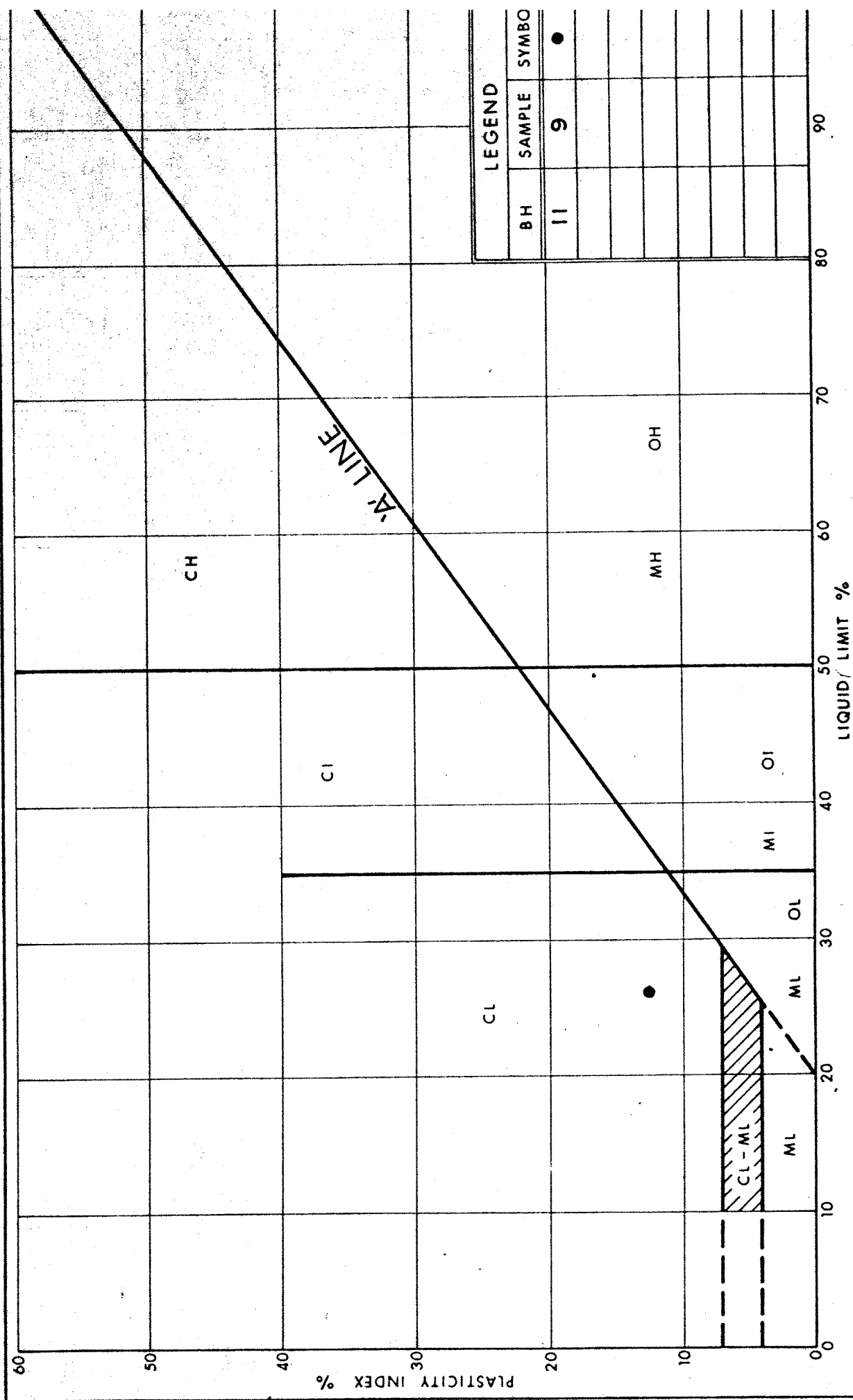
PLASTICITY CHART SILTY SAND TO SANDY SILT

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FIG No 9

W P 470-711-611



LEGEND		
BH	SAMPLE	SYMBOL
11	9	●



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Communications

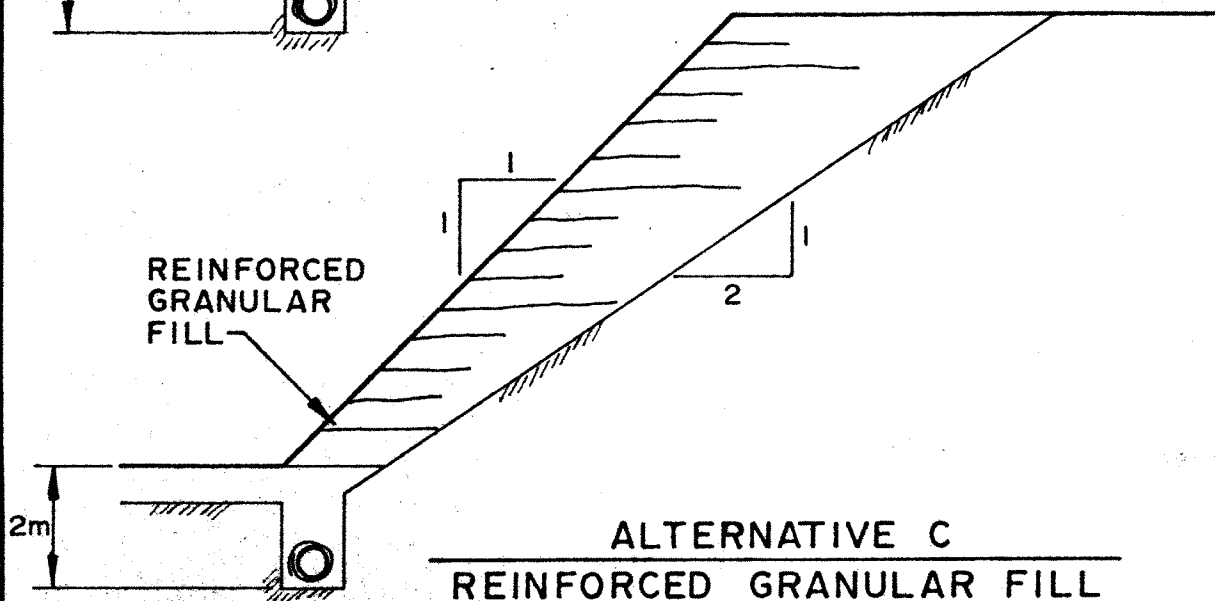
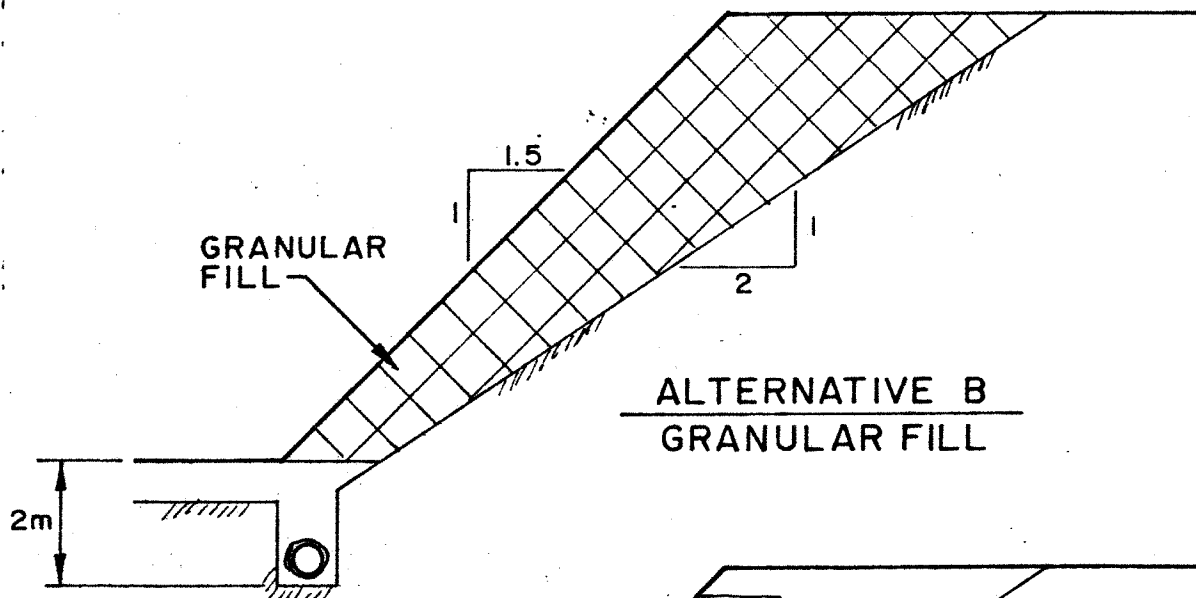
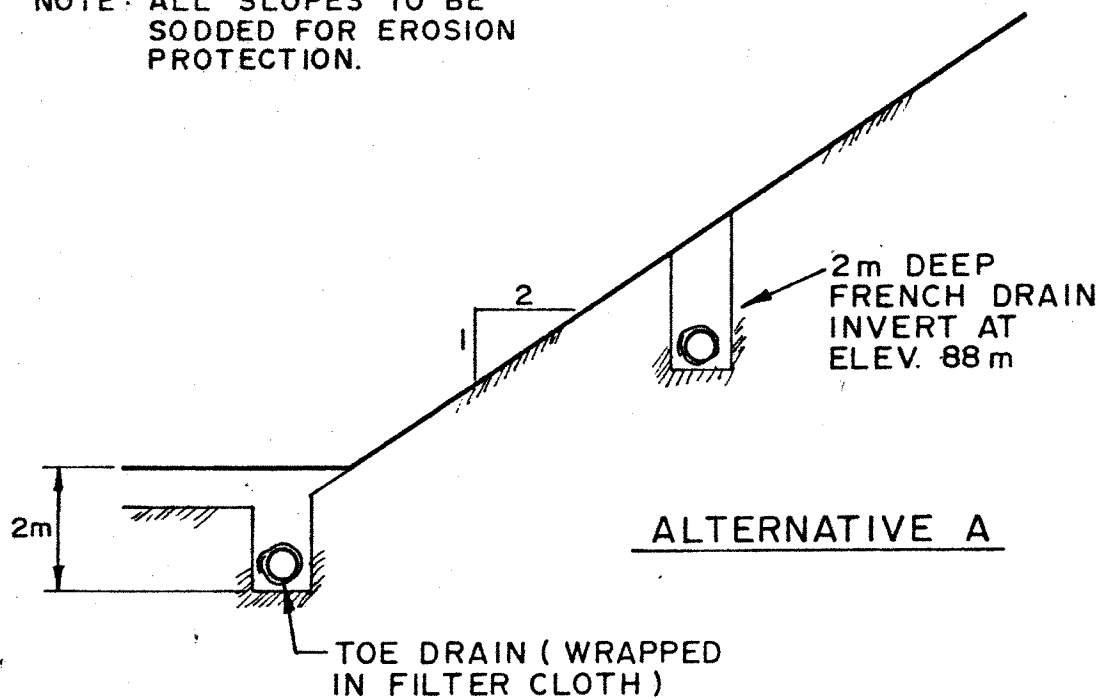
FIG No 10

W P 470 - 711 - 611

PLASTICITY CHART

LOWER SILTY CLAY

NOTE: ALL SLOPES TO BE
SODDED FOR EROSION
PROTECTION.



NOT TO SCALE

FIG No 11

WP 470-711-611

SCHEMATIC ILLUSTRATION OF CUT SLOPE DESIGN

Ministry of
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Communications

