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LOCATION Hwy 407 ℄ from Islington to Pine Valley Dr.

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ENGINEERING MATERIALS OFFICE

FOUNDATION DESIGN SECTION

CONT. 92-40

WP 141-87-00A DIST 6

HWY 407 STR SITE N/A

Hwy. 407 Excavation Cuts
Between
Stations 15 + 550+/- to 16 + 100+/-
(Islington Avenue to Pine Valley Drive)

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FOUNDATION INVESTIGATION REPORT
For
Hwy. 407 Excavation Cuts
Between
Stations 15+550+/- to 16+100 +/-
(Islington Avenue to Pine Valley Drive)
W.P. 141-87-00A, Hwy. 407
District 6, Toronto

INTRODUCTION

Subsequent to requests submitted by the Central Region Geotechnical Section dated 89 09 22 and 90 02 08, an investigation was carried out by this office to determine the geometry of the proposed cut slope including the drainage ditch on the north side of Hwy. 407, and to provide recommendations to facilitate the excavation at the aforementioned site. In addition, comments addressing the feasibility of utilizing the excavated material as borrow fill is contained in this report.

Excavation cuts ranging in magnitude from approximately 4 to 10 m in the native overburden will be required to satisfy the proposed Hwy. 407 profile grade and adjoining drainage channel. The proposed Hwy. 407 grade slopes at a 3% gradient from approximate El. 156.5 m at Sta. 15+750± to El. 151.5 m at Sta. 15+550±. The proposed profile grade of Hwy. 407 east of Sta. 15+750 slopes at approximately 0.64% with an elevation grade of approximately 158 m at the eastern boundary of the site. The proposed drainage channel extends along the north side at the toe of the proposed excavated slopes. The drainage channel is a hydrological component that will direct storm water from the highway westwardly and eventually outflowing to the Humber River located west of the site. Excavation cuts ranging from 6 to 10 m will be required along the length of the north side of Hwy. 407 at the site to facilitate this drainage channel. The natural ground surface is relatively flat to gently sloping, increasing slightly from 160.0 to 161.0 m towards the east.

The investigation procedure, including the fieldwork procedures and laboratory analyses, and a detailed description of the subsurface conditions are also included in this report.

SITE DESCRIPTION AND GEOLOGY

The site is located along the proposed Hwy. 407 right-of-way bounded by Islington Avenue to the west and Pine Vally Drive to the east in the Town of Vaughan, Regional Municipality of York. Existing Hydro transmission towers intersect the site approximately 300 m east of Pine Valley Drive. Immediately north of the site, a one storey building used as a warehouse for agricultural supplies, equipment and products exists. A residential home neighbours this building and the hydro corridor mentioned earlier runs parallel to these buildings at that location.

A residential subdivision is located approximately 0.5 km north of the site and CNR tracks, supported by approximately 7 m of embankment fill, are located approximately 0.5 km south of the site.

The land at the site is generally flat to gently sloping. The natural ground surface increases slightly in elevation in an easterly direction.

Land use at the site is agricultural farmland. Major crops annually harvested include radishes, onions, spinach and parsley.

Physiographically, the site is located in the geological domain known as the Bolton area. At the site, deltaic and glaciolacustrine sands and silts, the products of Lake Peel (Karrow 1963), a body of water confined between a lobe of ice projecting up the Humber Valley and the surrounding higher elevation grounds, overly a glaciolacustrine Wildfield Till complex consisting of stratified silty clays, clayey silts and silt nodules, also depositions of Lake Peel. These deposits levelled out the former gently undulating surface of ground moraine, known as the "Peel Plain" (Putnam and Chapman, 1936).

The Bolton area features overburden deposited during the Wisconsinan glaciation of the Pleistocene era. The overburden is underlain by shale bedrock of the Dundas-Meaford formation. Water well records indicate that the bedrock is found at depths ranging from 40 to 60 m.

INVESTIGATION PROCEDURE

Soil data and inherent properties were obtained by in situ and laboratory testing. The procedures employed are discussed below.

Field Investigation

The fieldwork for the investigation was carried out between 90 01 11 and 90 01 17 and on 90 02 23 and consisted a total of 10 sampled boreholes advanced to depths ranging from 12.6 m to 18.7 m. The second mobilization was in response to a requested extension of the original scope of work. Three of the boreholes were accompanied by dynamic cone penetration tests, two of which were advanced at the bottom of the open borehole to overall depths ranging from 22.4 m to 23.0 m from the original ground surface. A dynamic cone test advanced from the natural ground surface penetrated to a depth of 17.3 m.

The boreholes were advanced in the overburden using conventional hollow stem augering techniques. Track mounted continuous flight auger drilling rigs were employed for the operation.

In general, subsoil samples were retrieved at 0.7 m intervals for the surficial 6 m and at 1.5 m intervals thereafter. Disturbed subsoil samples were retrieved by a split spoon sampler in accordance with the Standard Penetration Test (ASTM D1586). A longer split spoon sampler (0.6 m) was used in an attempt to retrieve additional volumes of soil to facilitate pertinent backfill suitability tests (Standard Proctor Tests). Relatively undisturbed samples were also randomly retrieved in the cohesive clayey silt to silty clays and underlying moraine till deposit using a shelby tube sampler in accordance with standard practice (ASTM D1587). In situ vane tests were also conducted in the cohesive soils, generally at 1.5 m intervals, to determine the undisturbed and remoulded undrained shear strengths of the soil. The test was conducted employing the standard MTO 'N' vane in accordance with ASTM D2573.

All subsoil samples were identifed in the field and returned to the laboratory for further examination and applicable testing.

Water levels were obtained in the open boreholes and also in sealed piezometers installed at BH's A-6 and A-1. Groundwater levels were monitored throughout the duration of the investigation. All boreholes were backfilled at the completion of the fieldwork.

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

Laboratory Analyses

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

1) Atterberg Limits
2) Grain Size Distributions
3) Unit Weights
4) Natural Moisture Contents
5) Multi-stage consolidated undrained tests with pore pressure measurements.

Laboratory test results have been summarized in the subsequent section of this report entitled Suburface Conditions, and are illustrated on corresponding figures and boreholes included in the attached Appendix.

SUBSURFACE CONDITIONS

The soil stratigraphy at the site consists of a surficial veneer of topsoil, brown in colour and of thickness equivalent to approximately 0.7 m. The topsoil is underlain by a cohesionless brown sand that contains traces/some silt and traces/some gravel. This deposit has a thickness ranging from 0.7 m to 2.9 m and generally has a compact denseness. A cohesionless deposit of non plastic, brown silt underlies the sand deposit and extends for a relatively shallow thickness ranging from 0.3 m to 1.6 m. Thicknesses of the sands and silts generally decline in an easterly direction across the site. The non plastic silt is underlain by a glacio-lacustrine deposit consisting of a cohesive, grey clayey silt to silty clay containing interbedded layers and random nodules of silt within the soil matrix. The stratum can be categorized as having a stiff consistency and ranges in thickness from 2.6 m to 4.8 m.

The glaciolacustrine stratum is underlain by a cohesive unstratified glacial till deposit consisting of a clayey silt host material with traces/some sand and traces of gravel. The extent of this deposit was not fully explored across the entire site. For the area bounded by BH's 8 and BH's 7 (Sta. 15+975 to 15+500), the deposit was penetrated up to a maximum thickness of 11.1 m. At BH's 9 and 10, the thickness of the deposit is in the order of 5 to 6 m and is underlain by a cohesionless deposit of sand to silty sand. The extent of the underlying cohesionless deposit was not determined during the investigation.

The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation, 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 provided on Dwg. 1418700-A.

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

<u>Topsoil</u>

A thin veneer of topsoil that is brown in colour, moist, and contains a rich, earthy odour is spread across the site. The thickness of this veneer is approximately 0.8 m.

<u>Sand, trace Silt, trace/some Gravel</u>

The surficial topsoil is underlain by a brown, cohesionless sand that contains traces of silt and traces/some gravel. A grain size distribution envelope for this deposit as determined by mechanical sieve analysis is provided in Figure 1 in the Appendix. The thickness of this native deposit varies from 0.7 m to 2.9 m extending to elevations ranging from El. 159.4 m to 156.4 m. The thickness decreases in an easterly direction and is typically in the 0.7 to 0.9 m ranges east of BH 8.

This cohesionless deposit was partially submerged below the groundwater table at the time of investigation and soil cave was witnessed in the open borehole. Natural moisture contents determined in the laboratory range from 6.5 to 15.5%.

Standard Penetration Tests carried out in this deposit revealed 'N' values ranging from 6 blows/0.3 m to 28 blows/0.3 m indicating that the deposit ranges in denseness from loose to compact. In general, the deposit can be categorized as compact.

A Standard Proctor Test was carried out on material obtained by conglomerating individual samples into one representative volume batch. A grain size curve illustrating the gradation of the batch sample is illustrated on Figure 2. The Standard Proctor Test was carried out in accordance with Procedure 1 of the Method of Test for Moisture-Density Relationship of Soils outlined in the MTO Laboratory Testing Manual (LS 607). The results of the test are illustrated in Figure 3 in the Appendix. Based on the results, the soil has an optimum moisture content (w_{opt}) of 8.5% and a maximum dry density (γ dry) of 1.96g/cm^3 (19.2 kN/m^3). These results have been corrected to account for the effect of stone content.

SILT

The cohesionless sand deposit is underlain by a thin stratum of plastic silt ranging in thickness from 0.3 m to 1.6 m and found to extend to elevations ranging from 154.7 m to 158.4 m. The stratum is generally brown in colour although the stratum has been oxidized to grey at some locations. Figure 4 in the Appendix illustrates the gradation of this deposit on typical grain size distribution curves determined by mechanical sieve and hydrometer analysis.

The plasticity of the silt was confirmed by performing Atterberg Limit tests and the results are tabulated in Table 1 below and illustrated in Figure 5 in the Appendix. Natural moisture contents determined in the laboratory are also summarized in Table 1 and reveal values ranging from 21 to 22%.

Table 1 - Silt

	Range	# of Tests
Natural Moisture Content (w%)	21-22	5
Liquid Limit (w_L%)	19-21	3
Plasticity Index (I_p)	3-4.5	3

The silt stratum was submerged beneath the groundwater table at the time of the investigation and soil sloughing in the open borehole is expected to have developed concurrent with the overlying sand deposit.

Standard Penetration tests carried out in this deposit revealed 'N' values ranging from 9 blows/0.3 m to 47 blows/0.3 m indicating a range of denseness of loose to dense. In general, 'N' values were in the 15 blows/0.3 m to 25 blows/0.3 m equivalent to a compact denseness.

Clayey Silt to Silty Clay with random nodules/seams of Silt

Underlying the cohesionless silt deposit, a layer of clayey silt to silty clay with random nodules or zones and interbedded seams of silt exists. The surface of this stratum is at an elevation ranging from 158.4 m to 154.7 m and extends to an elevation ranging from 154.1 m to 151.7 m. The thickness of the stratum varies from 2.6 m to 4.8 m. The stratum is grey in colour with the silt nodules and seams present at a lighter grey hue.

A grain size distribution envelope for this deposit as determined by mechanical sieve and hydrometer analysis is given in Figure 6 in the Appendix. The envelope illustrates that clay and silt percentages in the deposit range from 25-40% and 60-75% respectively.

Atterberg Limit tests were carried out to define the behaviour and plasticity of the soil and the results are plotted in Figure 7. A summary of the indices is provided in Table 2. Unit weights are also included.

Table 2 - Clayey Silt to Silty Clay

	Range	# of Tests
Natural Moisture Content (w%)	20-34	14
Liquid Limit (w_L%)	23-46.5	12
Plasticity Index (I_P)	9.5-28.5	12
Unit Weight (kN/m^3)	17.2-22.6	7
Undrained Shear Strength (cu) (kPa) - Field Vane	30->120	10
Senstivity	2-4	10
SPT 'N' values (blows/0.3 m)	5-24	24

The test results reveal that the deposit varies randomly in plasticity ranging from low (clayey silt) to intermediate (silty clay). Natural moisture contents range from 20-34% but are generally in the 20-25% range.

Undrained shear strength measurements (cu) of the soil were obtained by conducting in situ vane tests. Results are plotted on the Record of Borehole sheets in the Appendix and summarized in Table 2 above. The results reveal undrained shear strength values ranging from 30->120 and hence the soil can be classified as having a consistency ranging from firm to very stiff. In general, the soil can be categorized as stiff.

The sensitivity of the soil as defined by the ratio of the undrained strength in the undisturbed state to the undrained strength, at the same water content, in the remoulded state was also determined by the field vane test and the results are tabulated in Table 2 and identified on the Record of Borehole sheets. Sensitivity values range from 2 to 4 indicating that the soil has a low sensitivity.

Standard Penetration tests carried out in this stratum revealed 'N' values ranging from 5 blows/0.3 m to 24 blows/0.3 m as tabulated in Table 2. The range of values confirms the firm to very stiff categorization determined from the in situ vane test.

Consolidated undrained multi-stage triaxial tests with pore pressure measurements were conducted in the laboratory to determine the effective strength parameters of the material. The effective shear strength parameters determined from the test are summarized in Table 3 below.

Table 3 - Effective Strength Parameters

Sample	BH A-5, Tw8
Elevation (m)	154.1
Liquid Limit (w_L%)	43
Plasticity Index (I_p%)	24
Natural Moisture Content	27
Effective Angle of Internal Friction (0°)	29
Effective Shear Strength Intercept (c')(kPa)	0

For design purposes, a reduced angle of internal friction (0) of 26° was selected to account for the fact that the sample tested was not saturated.

Two Standard Proctor Tests were carried out on material obtained by conglomerating individual samples into two representative volume batches. Grain size curves illustrating the gradation of the batch samples are illustrated in Figure 8.

The Standard Proctor Tests were carried out in accordance with Procedure 1 of the Method of Test for Moisture-Density Relationship of Soils outlined in the MTO Laboratory Testing Manual (LS 607). The results of the tests are illustrated in Figure 9 in the Appendix. Based on the results, the soil has an optimum moisture content (w_{opt}) of 13.2 to 13.8% and a maximum dry density (γ dry) of 1.89 to 1.92 g/m^3 (18.6 to 18.8 kN/m^3).

Clayey Silt, trace/some sand, trace gravel (Glacial Till)

The clayey silt to silty clay stratum is underlain by a glacial till deposit consisting of a clayey silt host material combined with varying percentages (trace to some) of sand and traces of gravel. The extent of the deposit was not determined throughout the site area. For the area bounded by BH's 8 and 7, the deposit was explored to a maximum thickness of 11.1 m. At BH's 9 and 10, the thickness of the deposit is in the order of 5 to 6 m.

A grain size distribution envelope for this deposit as determined by mechanical sieve and hydrometer analysis is given in Figure 10 in the Appendix. The envelope illustrates that clay and silt percentages in the deposit range from 26-41% and 58-65% respectively. The envelope also depicts percentages of sand up to 32% also comprise the deposit.

Atterberg Limit Tests were carried out to define the behaviour and plasticity of the fine grained portion of the soil and the results are plotted in Figure 11 in the Appendix. A summary of the indices is provided in Table 4 below. Unit weights are also included.

Table 4 - Clayey Silt Till

	Range	# of Tests
Natural Moisture Content (w%)	15-25	8
Liquid Limit (w_L%)	19-34	8
Plasticity Index (I_p)	7-15	8
Unit Weight (kN/m^3)	18.3-20.8	6
Undrained Shear Strength (cu) (kPa)		
- Field Vane	30->120	32
Sensitivity	2-4	32
SPT 'N' values (blows/0.3 m)	3-29	

The test results reveal that the fine grained portion of the deposit is predominantly of low plasticity and hence can be classified as clayey silt.

Undrained shear strength measurements (cu) of the soil were obtained by conducting in situ vane tests. Results are plotted on the Record of Borehole sheets in the Appendix and summarized in Table 4 above. A shear strength (cu) vs Elevation (m) profile is also provided in Figure 12 in the Appendix. Based on shear strength values ranging from 30->120 kPa, the consistency of the soil ranges from firm to very stiff. In consideration that the higher shear strength values determined may not be representative because of the presence of the sand and gravel components of the till, the deposit can be generally categorized as having a stiff consistency. As Figure 12 illustrates, however, the consistency does become stiffer with depth.

The sensitivity of the soil as defined by the ratio of the undrained strength in the undistributed state to the undrained strength, at the same water content, in the remoulded state was also determined by the field vane test and the results are tabulated in Table 4 and identified in the Record of Borehole sheets. Sensitivity values range from 2 to 4 indicating that the soil has a low sensitivity.

Standard Penetration tests carried out in the stratum revealed 'N' values ranging from 3 blows/0.3 m to 29 blows/0.3 m as illustrated on the 'N' values vs Elevation (m) graph in Figure 13 in the Appendix. 'N' values generally increase with depth in the deposit indicating that the consistency of the soil becomes stiffer with depth.

Consolidated undrained multi-stage triaxial tests with pore pressure measurements were conducted in the laboratory to determine the effective strength parameters of the material. The effective shear strength parameters determined from the test are summarized in Table 5 below.

Table 5 - Effective Strength Parameters

Sample	BH A-6, Tw8
Elevation (m)	147.6
Liquid Limit (w_L%)	26
Plasticity Index (I_P%)	12
Natural Moisture Content	19
Effective Angle of Internal Friction (0°)	29
Effective Shear Strength Intercept (c')(kPa)	10

For design purposes, a reduced angle of internal friction (0) of 26° and a shear strength intercept of 5 kPa was selected to account for the fact that the sample tested was not saturated.

Sand to Silty Sand

At BH's A-9 and A-10, the till deposit is underlain by a cohesionless sand to silty sand deposit. The deposit exists at an elevation ranging from 149.5 m to 148.7 m or depths of 10.7 to 11.4 m below the natural ground surface. The extent of this deposit was not determined during the investigation.

The fact that sloughing of the borehole occurred upon penetration into this deposit indicates that the deposit is under subartesian head. "Blow back" in the order of 2 to 3 m was observed when sampling through this material. A head of water was required to balance the unbalanced hydrostatic head so that penetration through this soil could be achieved.

Standard Penetration tests carried out in this deposit revealed 'N' values in the order of 5-6 blows/0.3 m indicating a loose material denseness.

Groundwater Conditions

Observation of the groundwater level was carried out by measuring the water level in the open boreholes and monitoring water levels in piezometers installed in the surficial sand and silt deposits. The piezometers were installed with the tips at an approximate elevation of 156 m with a bentonite seal of 0.3 m thickness below the piezometer tip and a bentonite seal at the surface of equal thickness. Pea gravel (10 mm) was used to fill the annular space between the piezometer and the borehole.

Measurements obtained from the aforementioned sources at the time of the investigation revealed water levels ranging from 2 to 2.5 m below the natural ground surface (Elevation 157.8 m to 158.8 m). At BH's A-7 and A-4, water levels could not be obtained because of the sloughing of the boreholes at depths of 1.5 m to 2.1 m respectively.

Groundwater levels, in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

DISCUSSION AND RECOMMENDATIONS

To facilitate the advancement of the Hwy. 407 between Pine Valley Drive and Islington Avenue, excavation cuts up to 10 m below existing grade will be required. The scope of this report includes excavation cuts exceeding 4 m in depth and hence the eastern boundary limit of the investigation was established at Sta. 15+850± or approximately 350 m west of Pine Valley Drive for the south side of the Hwy. 407. Deeper cuts ranging from 6 m to 10 m will be required for the north side of Hwy. 407 at the site to facilitate a hydrological storm drainage channel proposed at the toe of the north slope. The storm water will flow in a westerly direction and eventually outflow to the Humber River situated beyond the site. Th drainage channel is illustrated in Figure 1418700A-A. The proposed Hwy. 407 grade slopes with increasing elevation at a 0.64% gradient east of Sta. 15+850±. West of this limit and towards Islington Avenue, the proposed Hwy. 407 grade slopes at a 3% gradient from approximate elevation 156.5 m to elevation 151.5 m at Sta. 15+550±.

Recommendations pertaining to the following geotechnical considerations are contained in the purview of this report.

1) Excavated Slope Stability Design
2) Construction of Excavated Slopes
3) Backfill Suitability of Excavated Material

1) Excavated Slope Stability Design

The critical condition examined in the evalution of cuts such as those proposed at the site location is the long term (drained) condition. Consequently, an effective stress analysis was implemented using Bishop's method on an in-house mainframe program incorporating a factor of safety of 1.3. The properties of the subsoil and the geometry used in the analysis is summarized in Figure 14 in the Appendix. The analysis was carried out employing static loading conditions and circular slip surfaces.

The results of the analysis is summarized in Table 6 below. Based on the results, all excavation cut slopes less than 4.0 m can be constructed at 2H:1V whilst slopes exceeding 4.0 m in depth will require stabilizing benches and/or flatter slopes. The recommended slope geometry requirements for various depths of cut are tabulated in Table 6 below. An 8.0 m cut required at the site will require a 3 m bench and 2.5H:1V slopes.

Table 6 - Slope Geometries

Depth of Cut (m)		Recommended Geometry
0-4.0	inclusive	2H:1V
>4-5	inclusive	2H:1V, 2 m Bench
>5-7	inclusive	2H:1V, 3 m Bench
>7-9.5	inclusive	2.5H:1V, 3 m Bench
>9.5-10.5	inclusive	2.5H:1V, 2 m Double bench at 1/3 depths*

Alternate 3H:1V Slopes

Depth of Cut (m)	Recommended Geometry
0-4	2H:1V
>4-8	3H:1V
>8-11	3H:1V, 2m Bench

Drained stability analysis of slopes are very sensitive to groundwater levels and pore pressures that can develop in the slope. Therefore drainage measures will be required to control groundwater and hence ensure the long-term stability of the slopes. By employing a 0.6 m thick granular blanket consisting of free draining material such as Granular 'A' material, development of excess pore water pressures can be prevented. The granular blankets should be designed in conjunction with a permanent drainage system that will discharge drained water from the slope. It is recommended that longitudinal toe/bench drains be constructed consisting of a perforated pipe encased with a suitable geotextile filter fabric and in turn surrounded by a suitable granular soil filter material. The toe drains should then be connected to an appropriate integrated drainage system. At the site, the toe drains can be constructed in conjunction with the highway perimeter drainage system. An illustration of the proposed drainage scheme is shown on Figure 14.

The granular blanket also protects the slope from surficial erosion that can be caused by freeze-thaw cycles and surface runoff. Normal slope vegetation should be established as soon as possible after completion of the cut to augment the control of surficial erosion.

Construction of Excavated Slopes

It is anticipated that considerable difficulty could be experienced by the Contractor in excavating the surficial cohesionless sands and silts and maintaining side slopes below the prevailing water table. Consequently, an advanced dewatering scheme in conjunction with a controlled excavation is recommended to drawdown the water level to facilitate the slope construction. Two alternatives are summarized below. The alternative that is the most economical and practically feasible should be selected. The dewatering scheme shall conform to OPSS 517 series and subject to review by this office.

Gravity Drainage

A gravity drainage system consisting of trench drains and sump pumping methods can be employed. One recommended method is to firstly advance the excavation to the elevation of the water table and then install a temporary longitudinal trench drain at the toe of the cut. Subsequent to this installation and observation of draw/down in the native soil, the excavation can proceed down to the depth of the designed stabilizing bench where an additional permanent trench drain is to be installed. Finally, the excavation can then proceed down to the proposed grade where another permanent trench drain is to be installed at the toe of the slope. Figure 16a in the Appendix illustrates this gravity drainage method.

Gravity drainage can also be conducted by working from the centre of the proposed excavation and progressing laterally to either excavation slope. This can be accomplished by excavating sump pits and staging the excavation as illustrated in Figure 16b in the Appendix. The advantage of this gravity drainage method is that any soil sloughing created by seepage are effectively contained within the limits of the excavation. Consequently, this method becomes a more efficient gravity drainage construction technique.

Wells and/or Well points

Alternatively, vacuum wellpoints and/or wells consisting of large pumps with gravel filters installed concentrically in cased holes can be used to drawdown the water table. The wellpoints and wells should be properly filtered to prevent migration of fines and subsequent potential clogging. This can be achieved by surrounding the wellpoints and/or wells with properly graded free draining soil filter. Grain size distribution curves for the native cohesionless soils should be applied in establishing the filtration and permeability criteria for the soil filter.

Backfill Suitability of Excavated Material

Although excavation cuts up to 10 m will be required to facilitate the drainage channel, most of the area will be subject to earth removal up to a maximum 8 m.

Excavation cuts up to 8 m will necessitate the removal of the soil type and corresponding depths as tabulated in Table 7 below.

Table 7 - Excavated Soil

Soil Type	Thickness (m)
Topsoil	0.8
Sand, trace Silt,trace/some gravel	1.2-2.9
Silt	0.5-1.6
Clayey Silt to Silty Clay	2.6-4.8

The clayey silt till deposit is in most cases beneath the 8 m excavation. Discussion regarding the suitability of utilizing the excavated material as backfill is discussed below.

Topsoil

The brown topsoil CAN be used as a blanket in conjunction with natural vegetation cover as a form of surficial erosion protection.

Sand, trace silt, trace/some Gravel

Although this cohesionless deposit has in situ moisture contents as high as 15%, which exceeds its optimum moisture content of 8.5%, because of its free draining nature, this material is acceptable as borrow material in accordance with the material specifications outlined in OPSS 212 series. This material can be easily dried and the moisture content modified to obtain its optimum.

The material from this deposit can be effectively compacted provided the material is placed with the appropriate moisture content to achieve 100% of the Proctor maximum dry density as outlined in OPSS 501.08.02 (Method A). Field density measurements shall be conducted in conformance with this specification and compared to the maximum dry density as obtained in the laboratory (see Figure 3) to confirm achievement of the target density.

As illustrated in the grain size distribution envelope for this deposit, the amount of material between 5 mm and 75 mm (silt) in size is generally less than 10%. Conseqently, this material is not susceptible to frost. Generally materials with amounts exceeding 55% are considered highly susceptible.

Silt

Silty materials are very sensitive to moisture content and hence wet silty soils tend to "roll" under compactive energy if the moisture content exceeds the optimum even by a small percentage. Silty soils can also attract water by capillarity and hence the increase in water content further aggravates the problem of compacting silty materials. Furthermore, silty materials are frost susceptible. Consequently, for these reasons, this material is NOT recommended as suitable structural backfill material.

Clayey Silt to Silty Clay with random nodules/seams of Silt

As indicated in Table 2, in situ moisture contents for this material range from 20 to 34%. Although the moisture contents are generally in the 20 to 25% range, these values exceed the optimum moisture contents of 13.2-13.8%, as shown in Figure 9, as much as up to 11.8%. Hence, this material has moisture contents that are far in excess of the range that will produce 95% of the maximum dry density as specified in OPSS 501.08.02.

Reducing the water content of this material to acceptable levels is difficult, time consuming and in our opinion not practicable. Furthermore, this stratum has silt percentages that exceed 55% and hence the soil is frost susceptible. Consequently, for these reasons this material is considered unsuitable for backfill application.

Construction Considerations

The aforementioned discussion indicates that the surficial topsoil and the cohesionless sandy soil are salvagable materials at the site whilst the underlying silts and clayey silt to silty clay materials are not. It is therefore recommended that these surficial materials be scraped off using a dozer separate from the underlying deposits using a dozer.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, B. Cung, Engineering Trainee and J. Petruzziello, Engineering Technician, utilizing equipment owned and operated by Marathon Drilling and Master Soils Investigation.

The project was carried out by T. Sangiuliano under the general supervision of Dr. B. Iyer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by Dr. B. Iyer and approved by Mr. M.S. Devata, Chief foundation Engineer.

LICENSED PROFESSIONAL ENGINEER
A. J. Sangiuliano
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APPENDIX

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

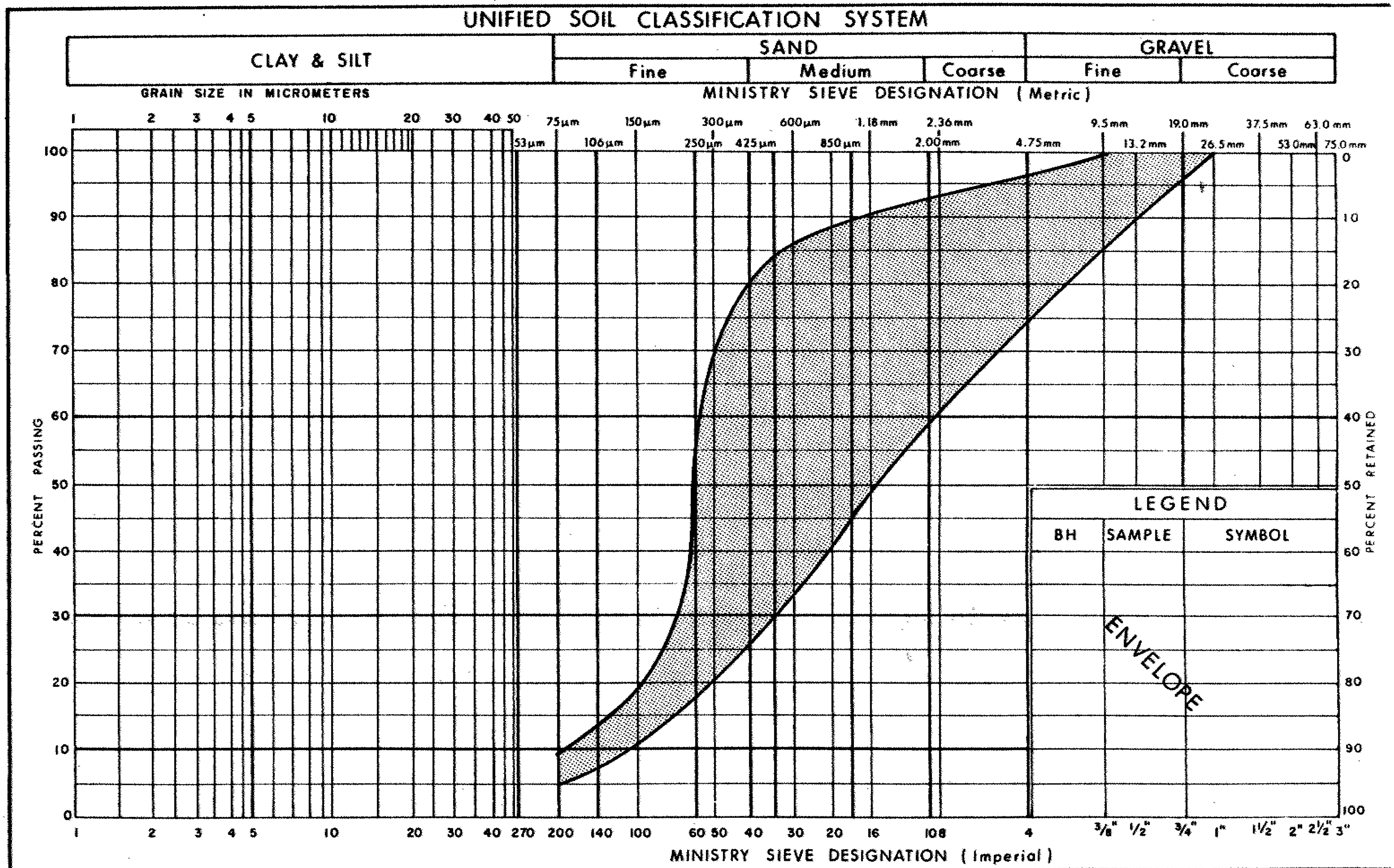
PHYSICAL PROPERTIES OF SOIL

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

78 12 M



Ministry of Transportation

Ontario

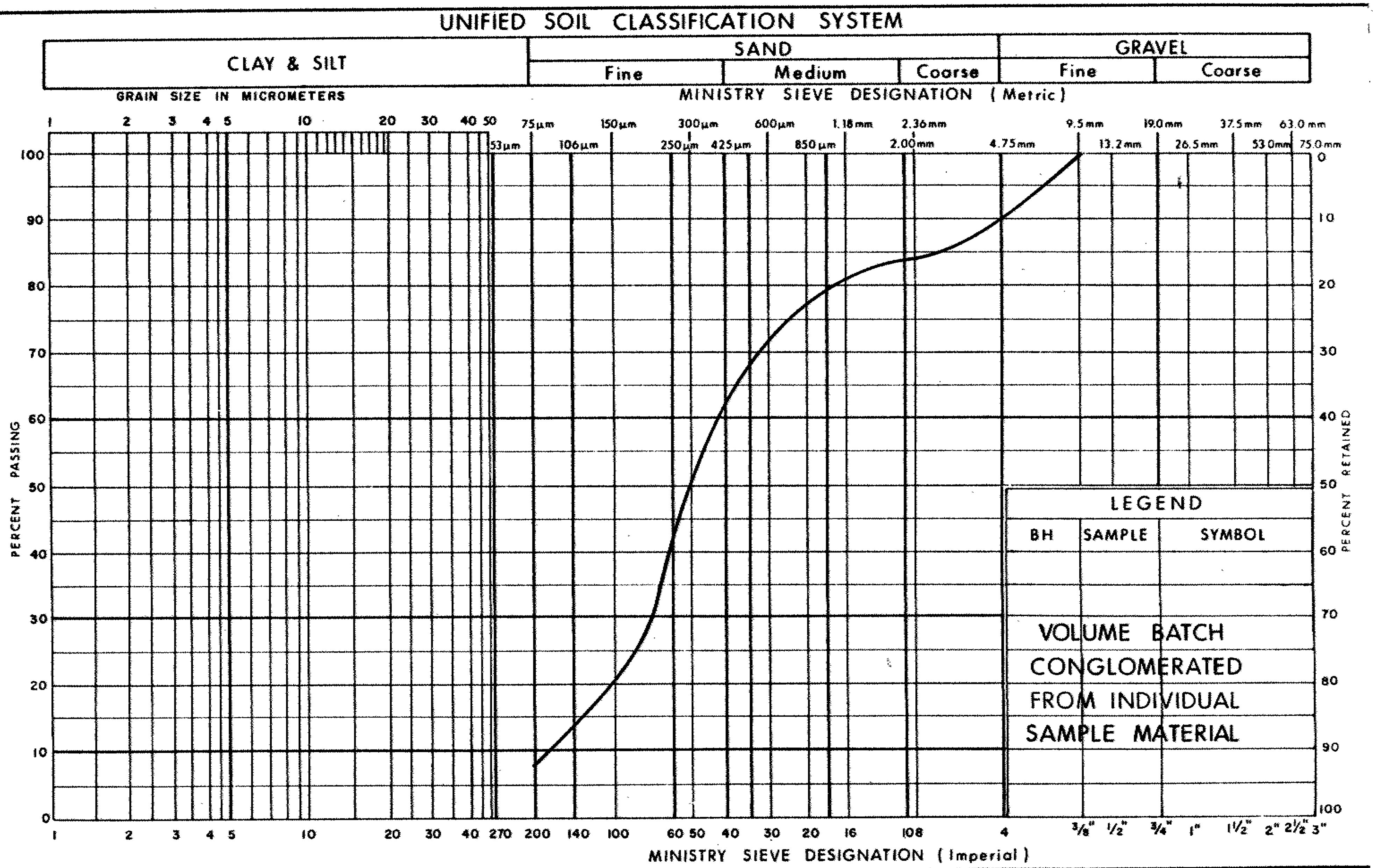
GRAIN SIZE DISTRIBUTION

SAND, TRACE SILT, TRACE /SOME GRAVEL

FIG No 1

W P 141-87-00 (A)

78 12 M



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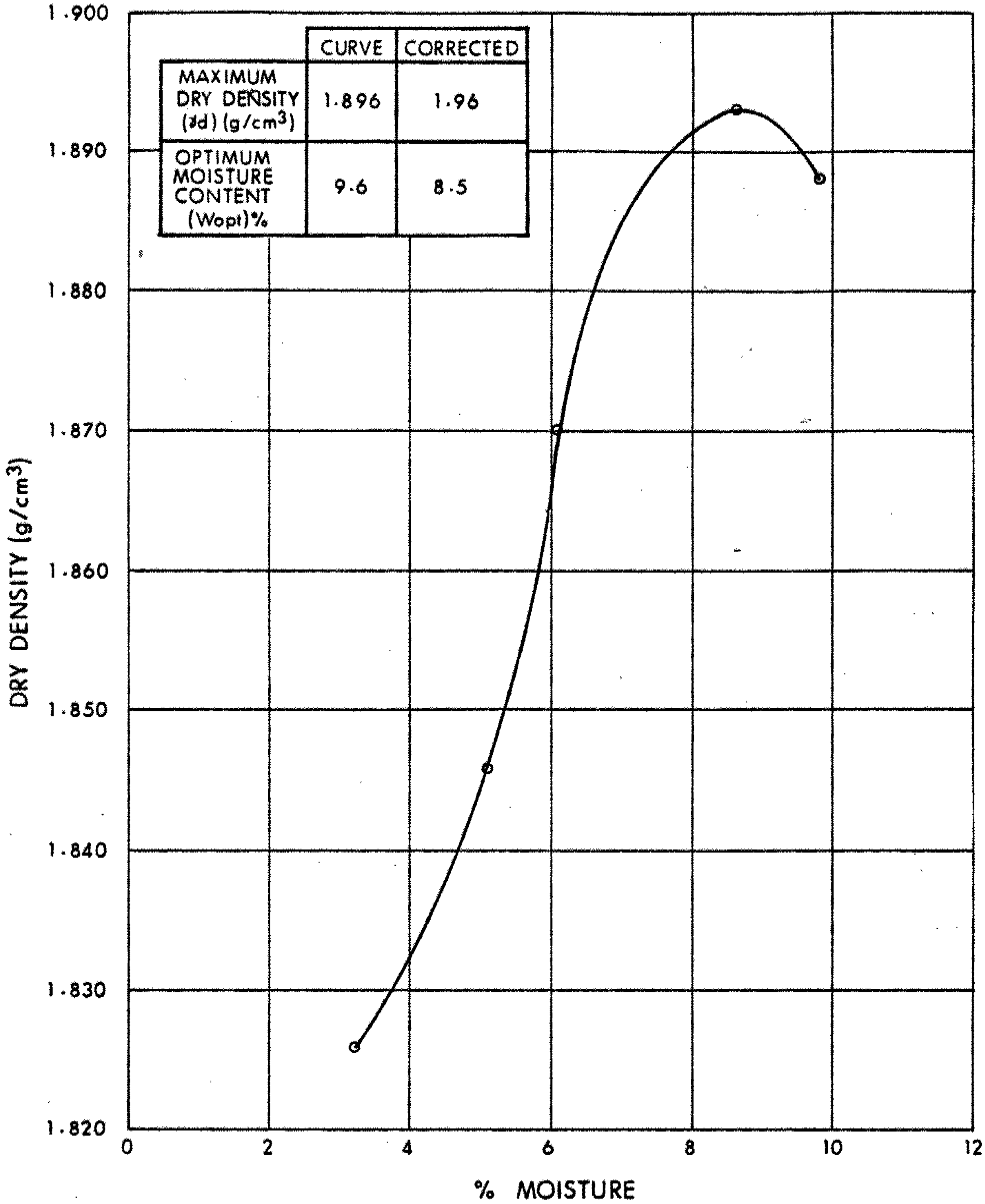
GRAIN SIZE DISTRIBUTION

SAND, TRACE SILT, TRACE / SOME GRAVEL

FIG No 2

W P 141 - 87 - 00 (A)

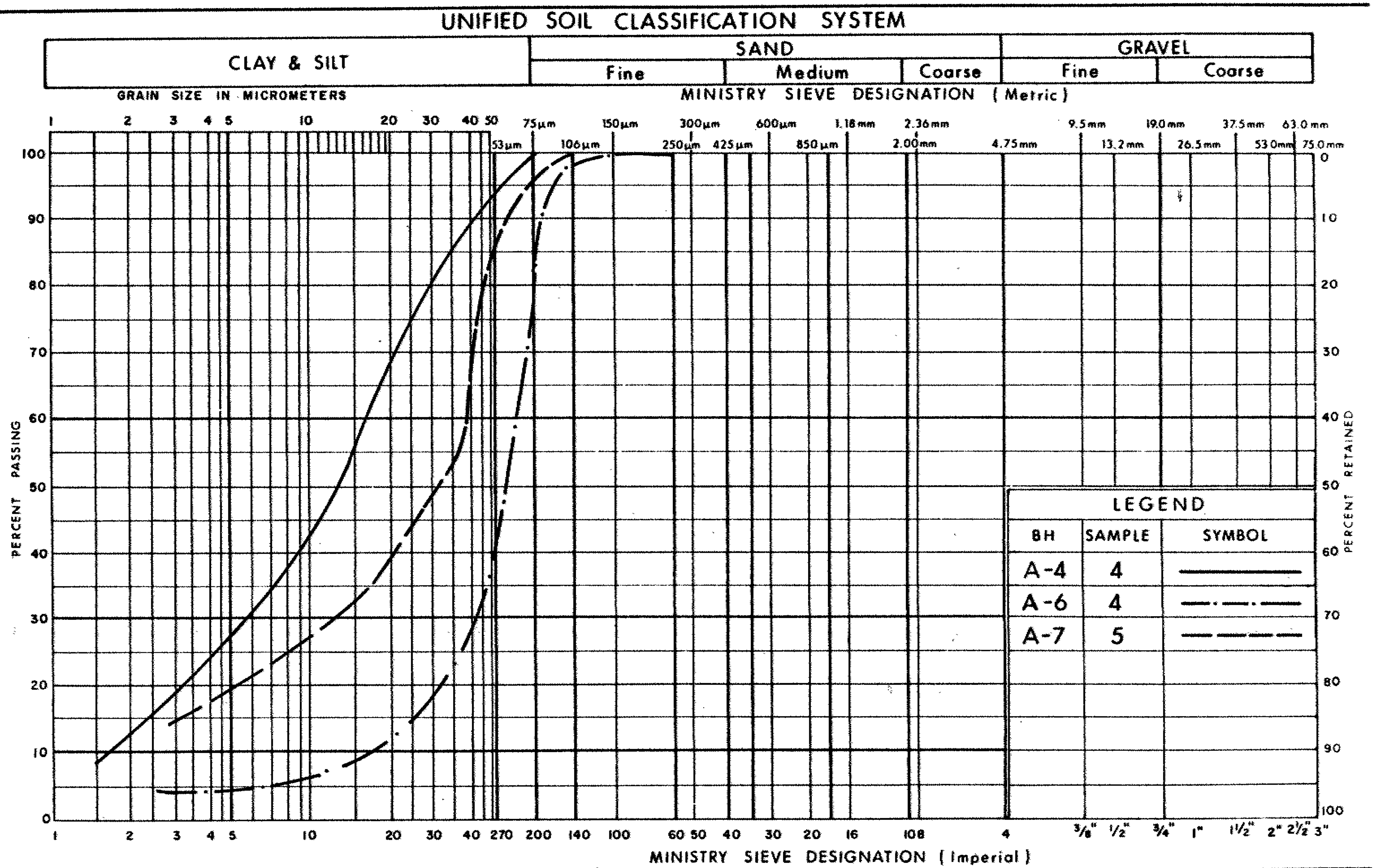


	CURVE	CORRECTED
MAXIMUM DRY DENSITY (γd) (g/cm^3)	1.896	1.96
OPTIMUM MOISTURE CONTENT (Wopt)%	9.6	8.5

MOISTURE-DENSITY RELATIONSHIP
SAND, TRACE SILT, TRACE GRAVEL

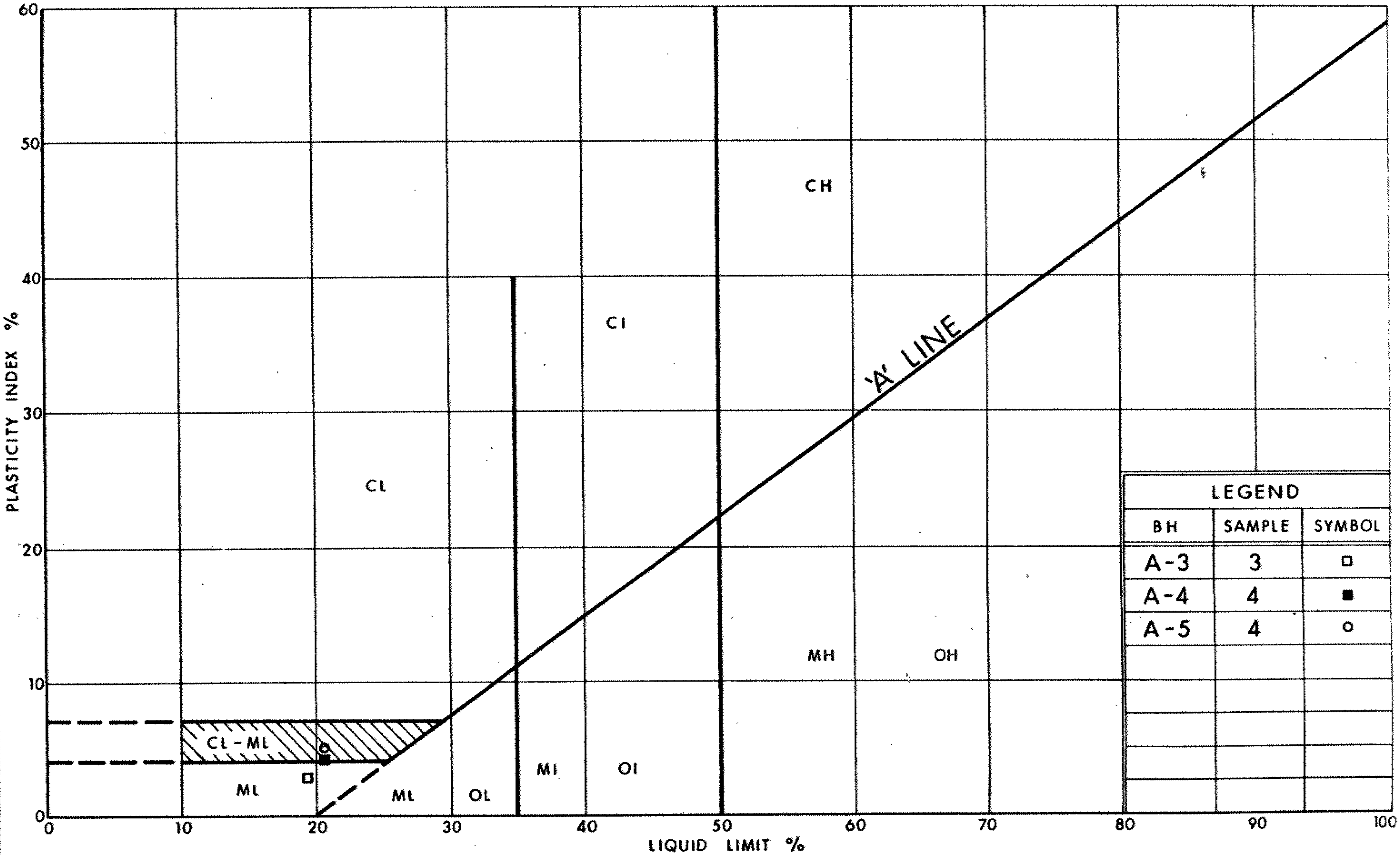
FIG - 3
WP 141-87-00(A)

78 12 M



Ministry of Transportation Ontario	GRAIN SIZE DISTRIBUTION SILT	FIG No 4 WP 141-87-00 (A)

Oct 75, FF-S-21



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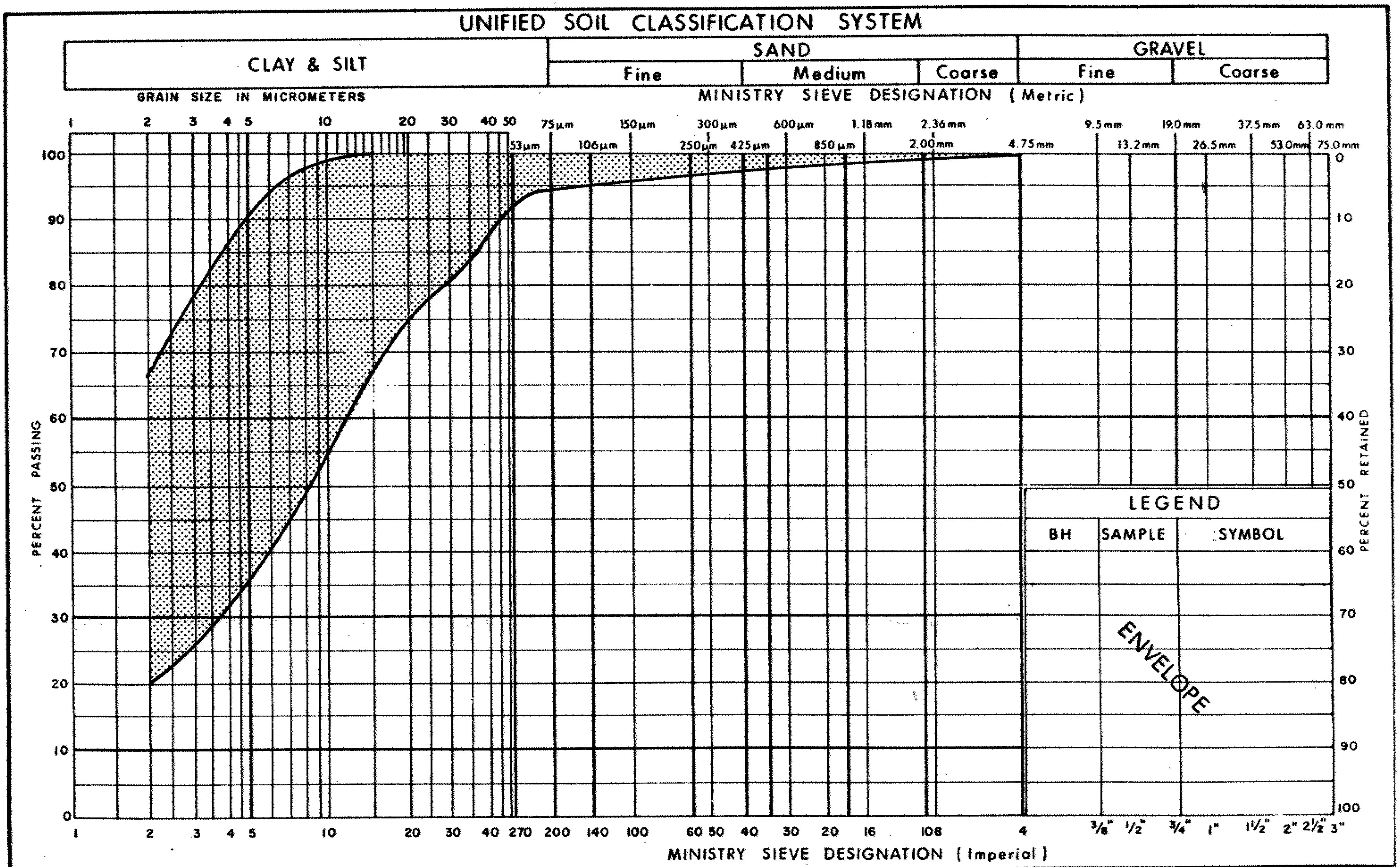
PLASTICITY CHART
SILT

FIG No 5
W P 141 - 87 - 00 (A)

78 12 M



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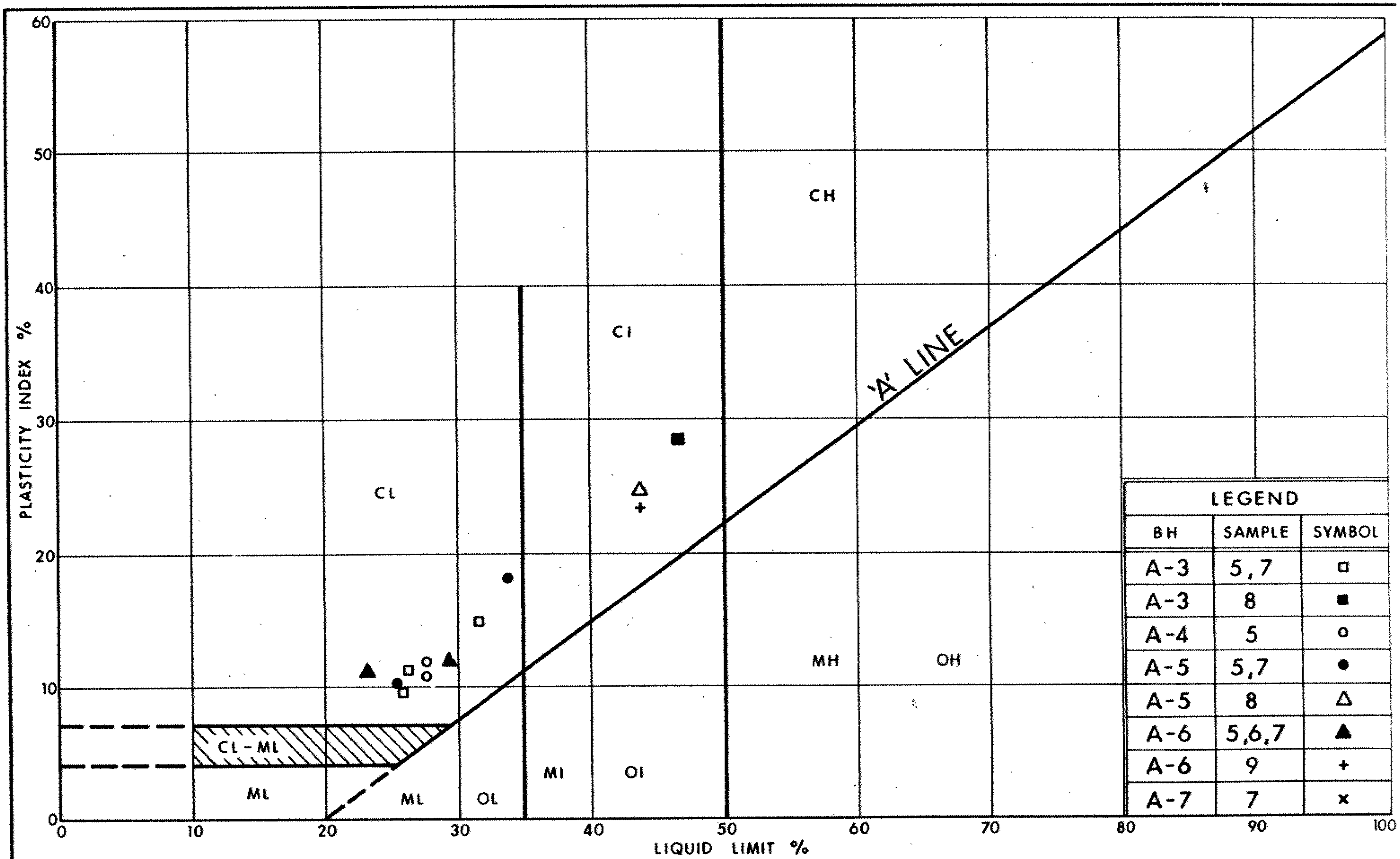
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM NODULES/SEAMS OF SILT

FIG No 6

W P 141-87-00 (A)

Oct 75, FF-S-21



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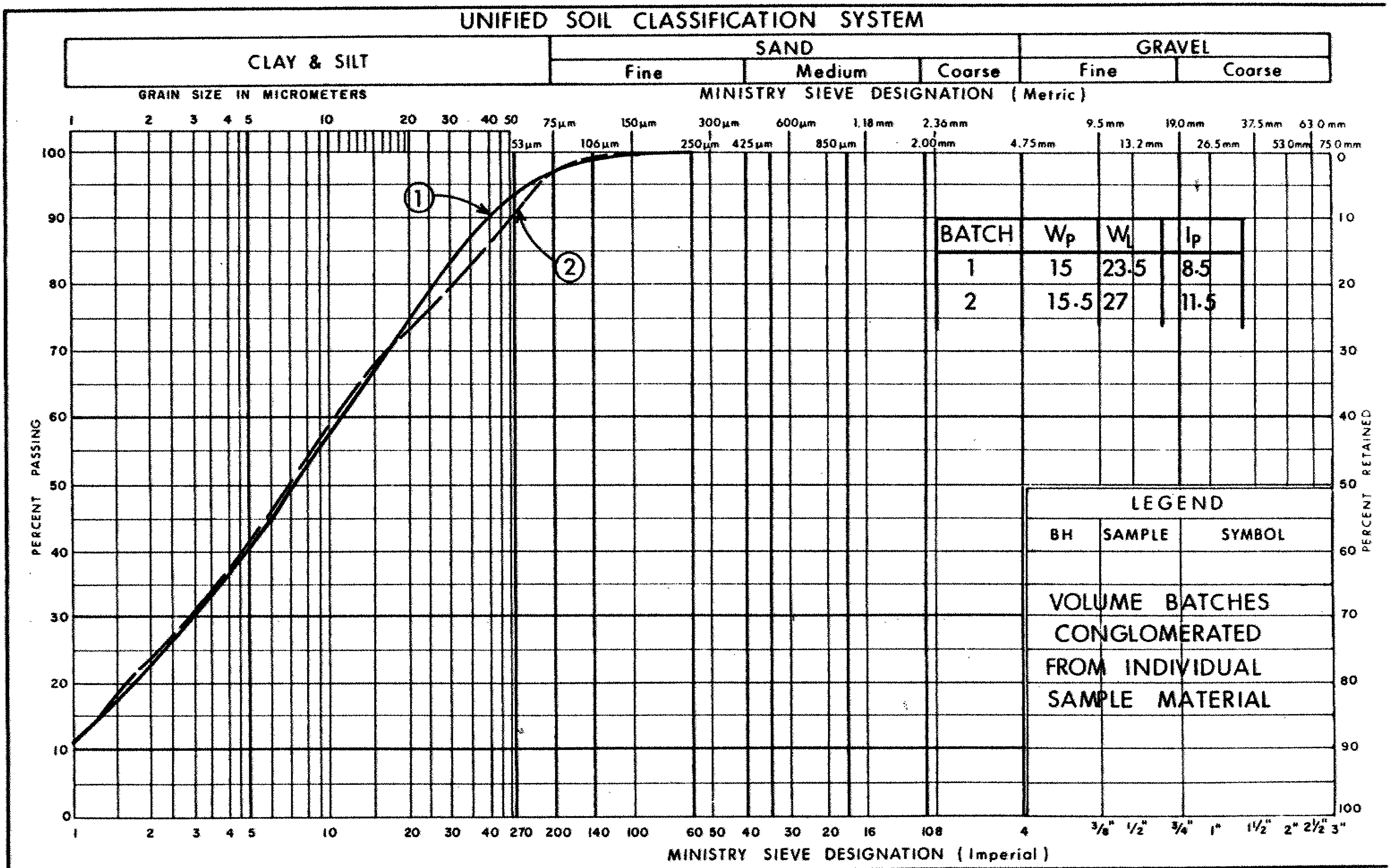
PLASTICITY CHART
CLAYEY SILT TO SILTY CLAY
WITH RANDOM NODULES/SEAMS OF SILT

FIG No 7
W P 141-87-00 (A)

78 12 M



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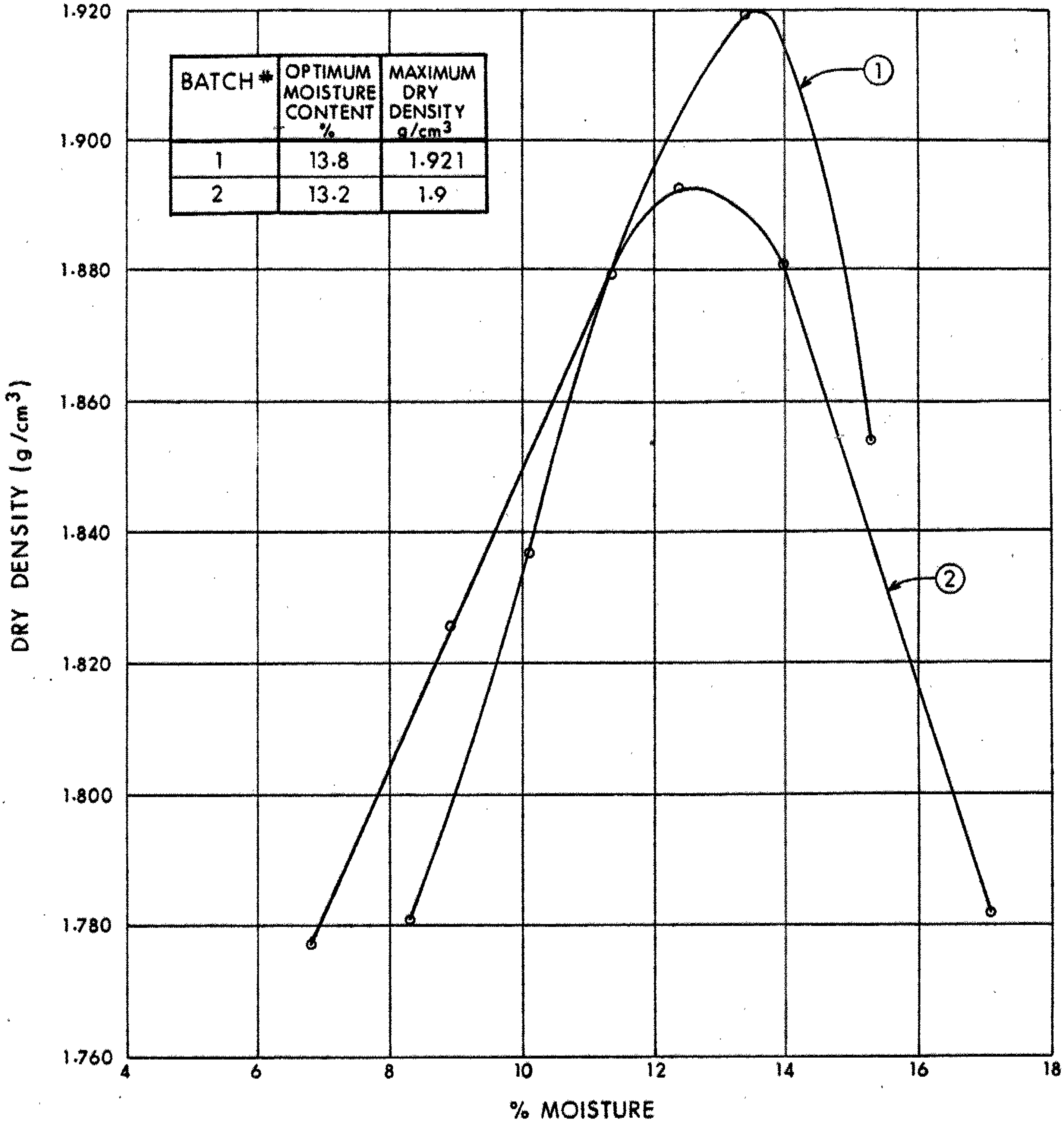
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM NODULES / SEAMS OF SILT

FIG No 8

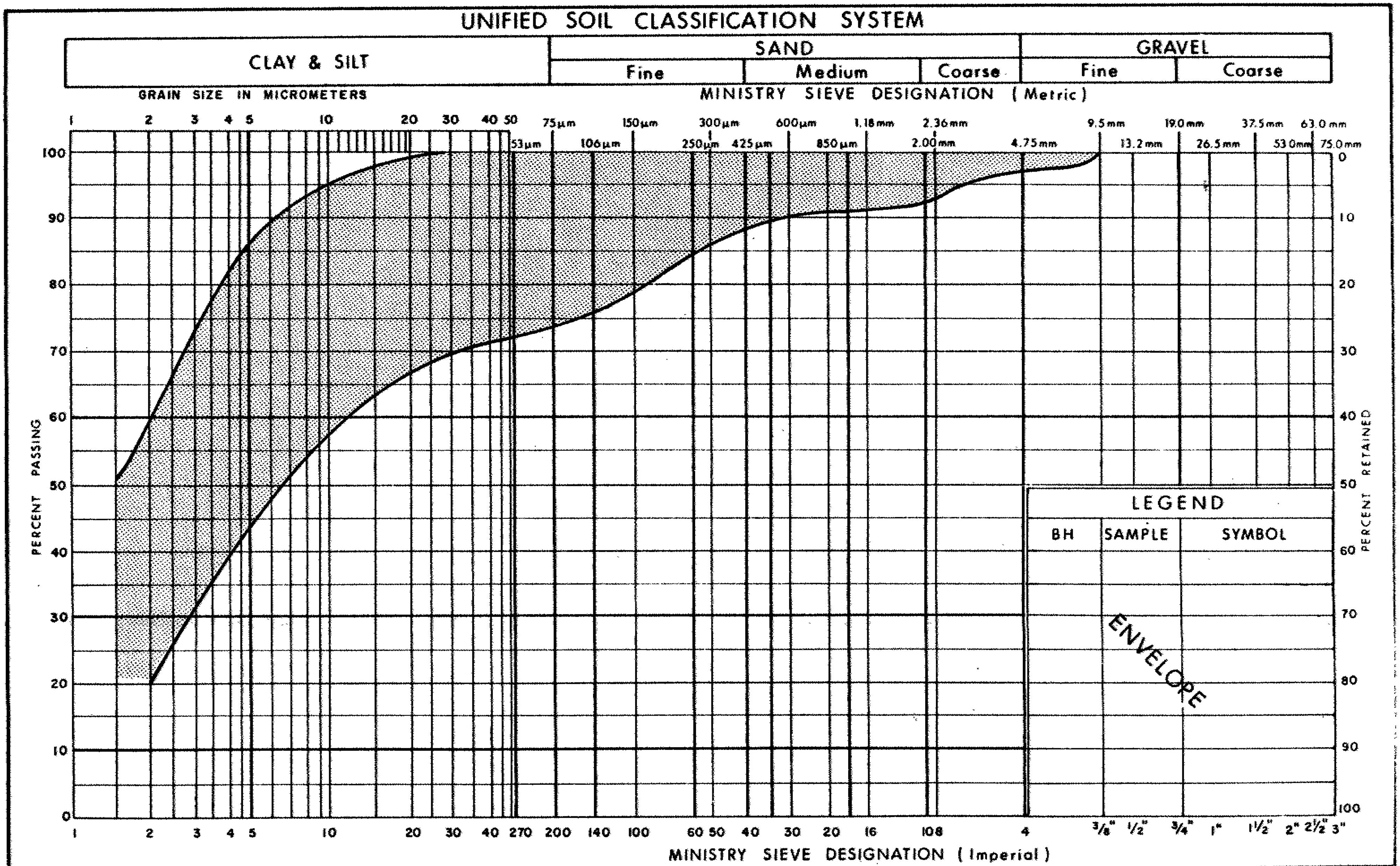
W P 141-87-00 (A)



MOISTURE-DENSITY RELATIONSHIP
CLAYEY SILT TO SILTY CLAY
WITH RANDOM NODULES/SEAMS OF SILT

FIG-9
WP 141-87-00(A)

78 12 M



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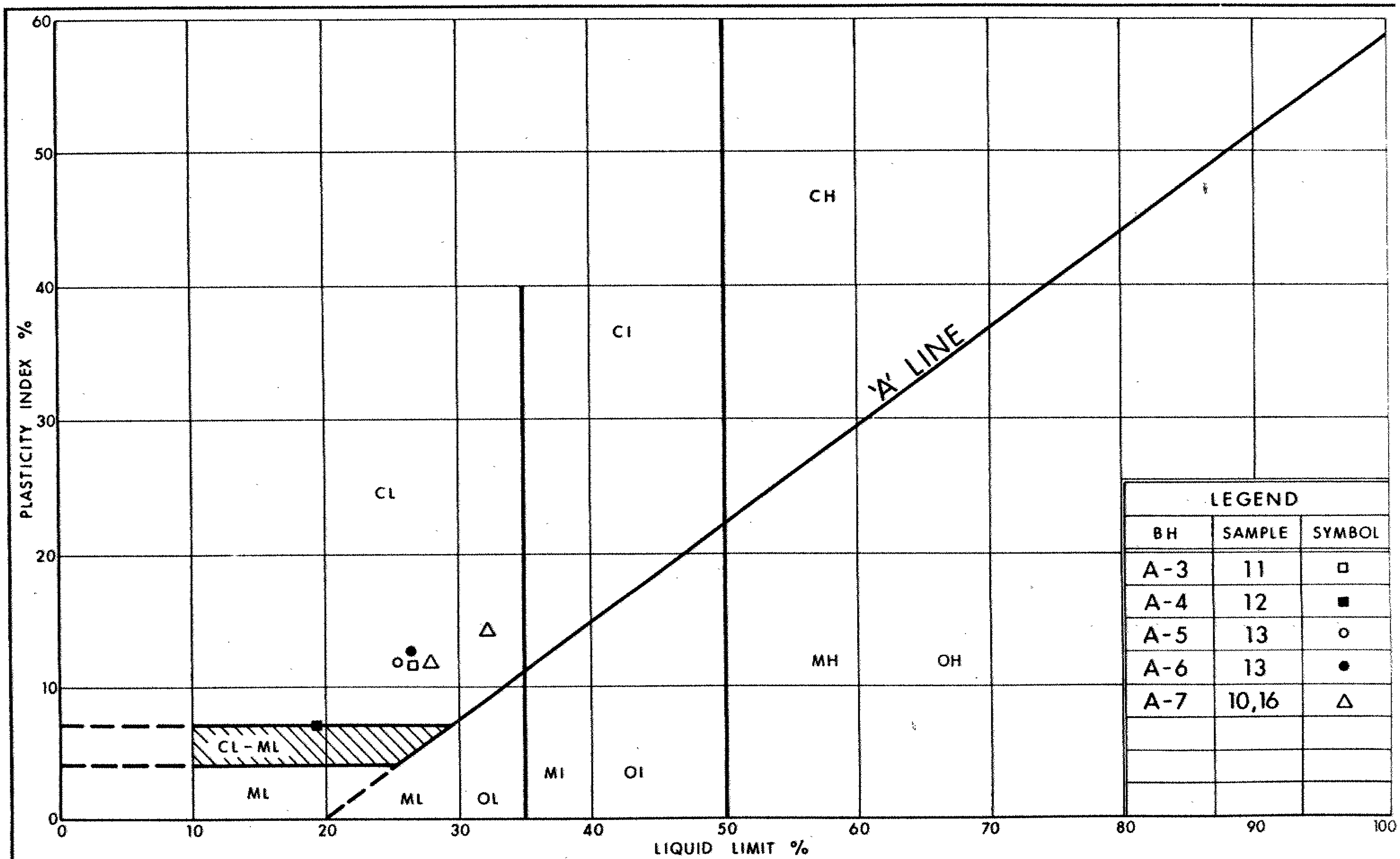
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, SOME / TRACE SAND, TRACE GRAVEL (GLACIAL TILL)

FIG No 10

W P 141-87-00 (A)

Oct 75, FF-S-21



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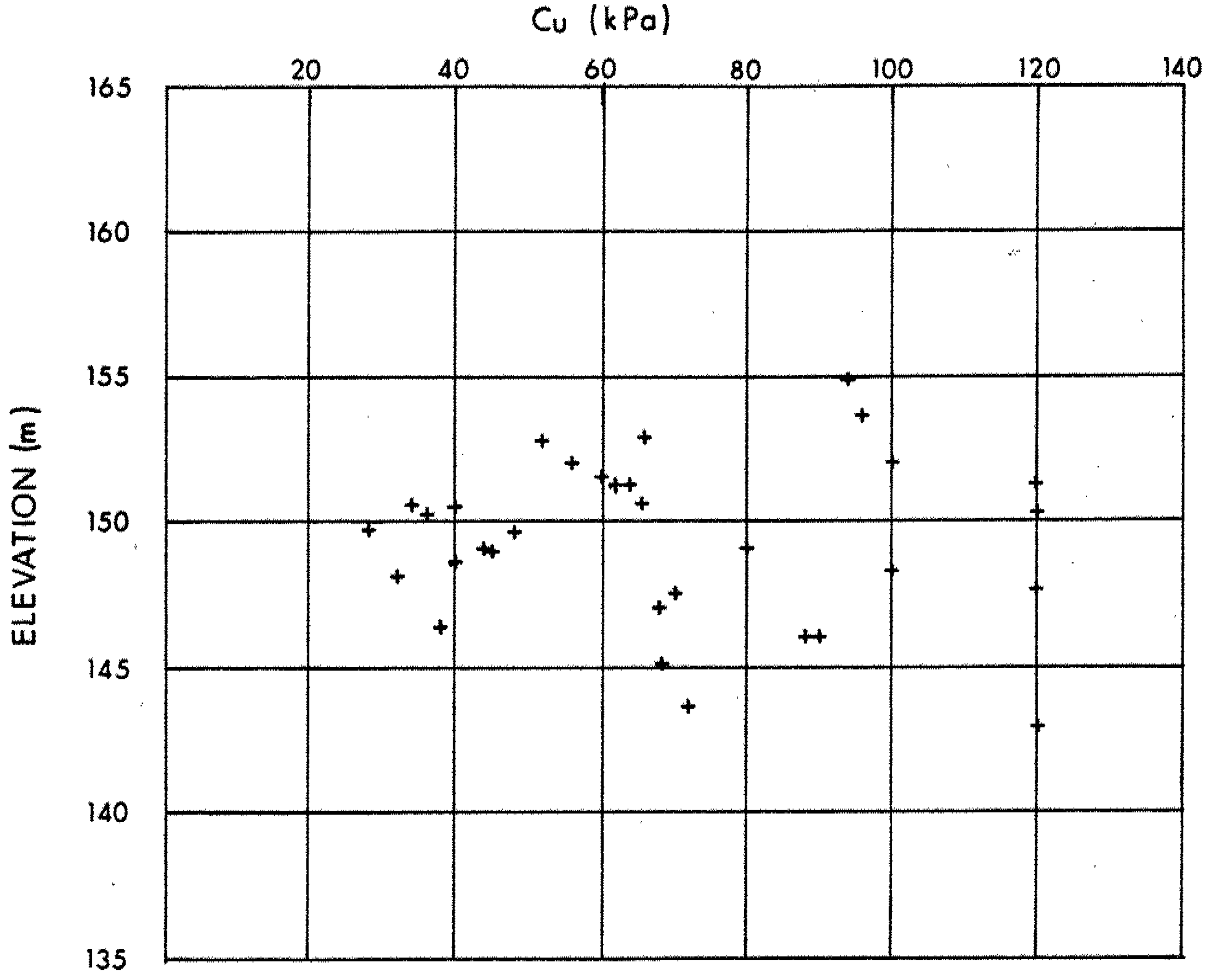
PLASTICITY CHART

CLAYEY SILT, SOME / TRACE SAND, TRACE GRAVEL (GLACIAL TILL)

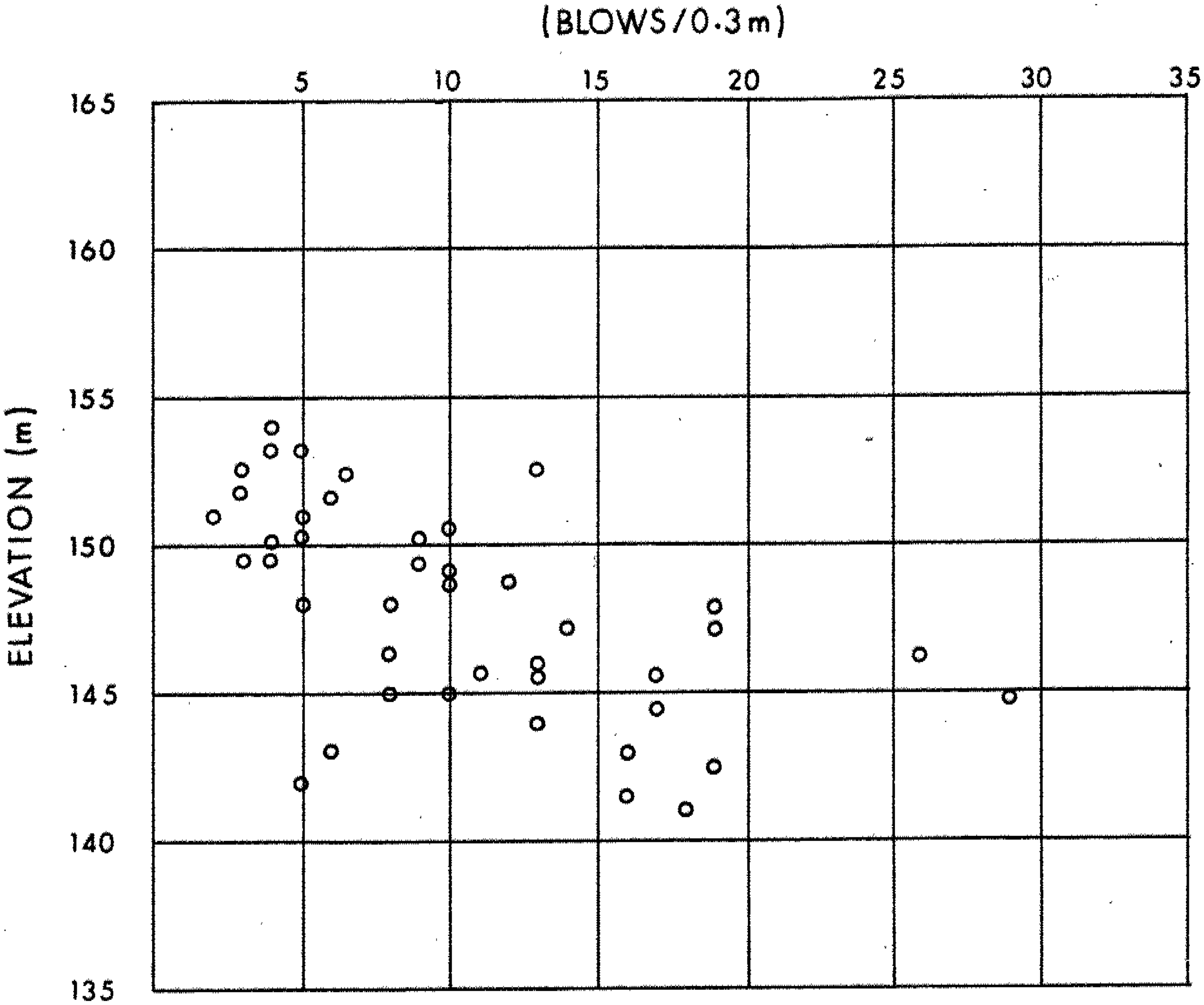
FIG No 11

W P 141-87-00 (A)



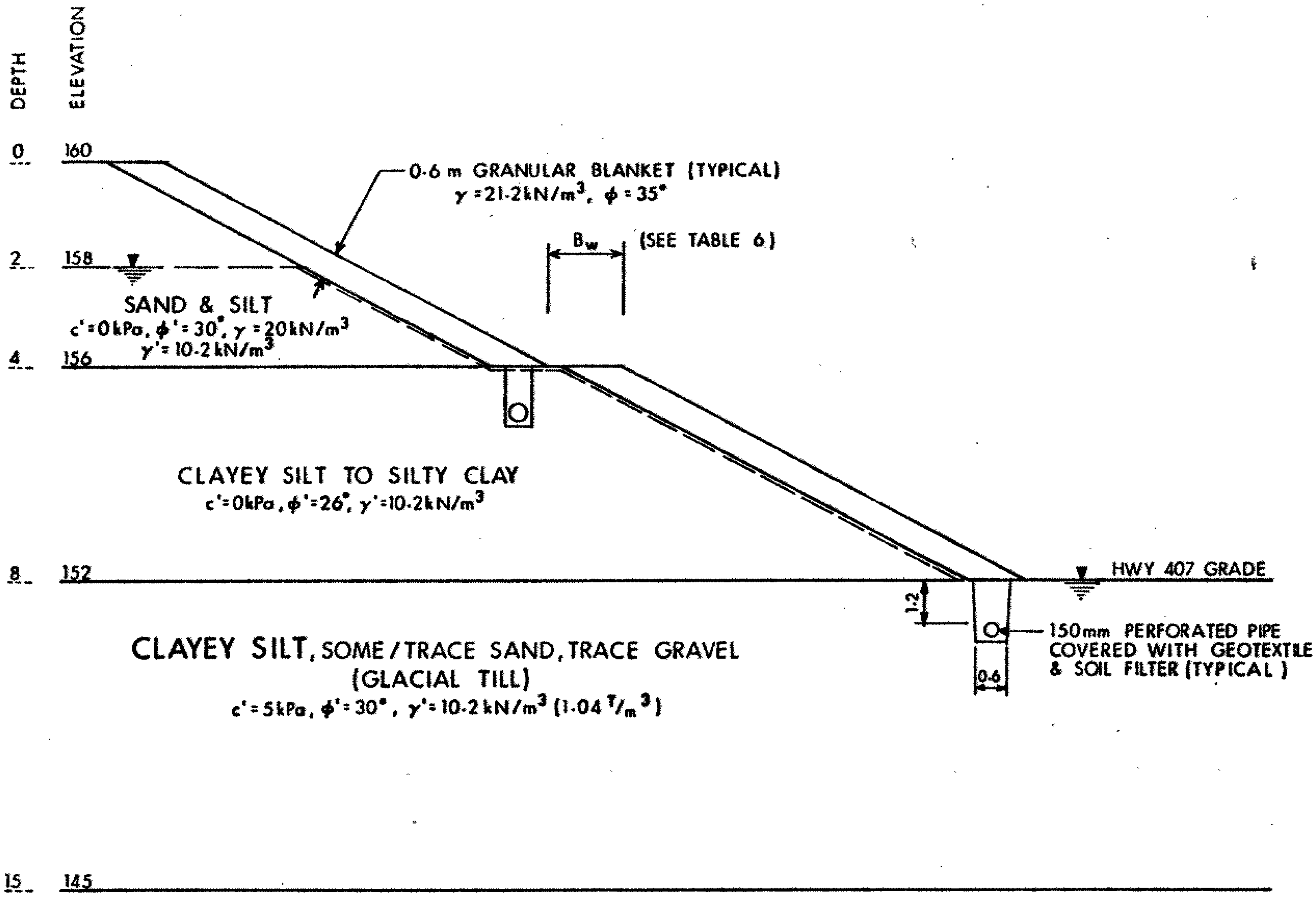
UNDRAINED SHEAR STRENGTH (C_u) KPa VS ELEVATION (m)
CLAYEY SILT, SOME / TRACE SAND, TRACE GRAVEL
(GLACIAL TILL)

FIG-12
WP 141-87-00(A)



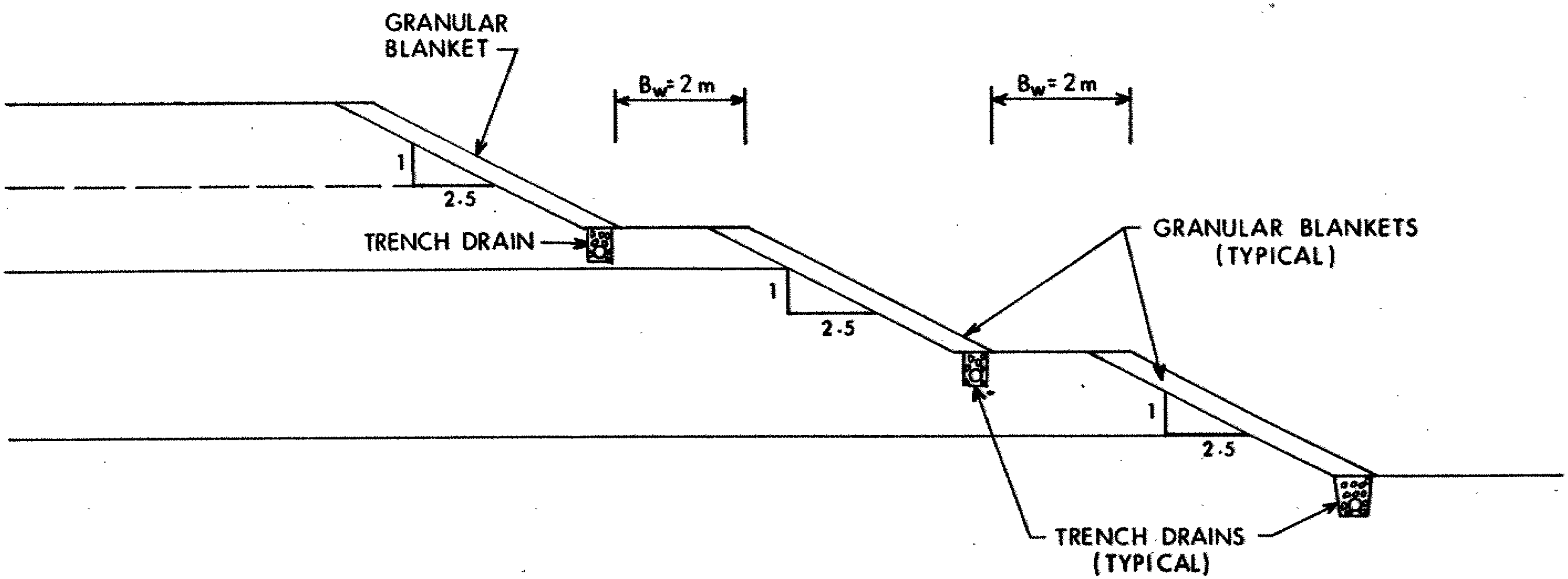
SPT 'N' VALUES (BLOWS/0.3m) VS ELEVATION (m)
CLAYEY SILT, SOME / TRACE SAND, TRACE GRAVEL
(GLACIAL TILL)

FIG-13
WP 141-87-00(A)



EXCAVATED SLOPE STABILITY DESIGN
(NTS)

FIG - 14
WP 141-87-00(A)



NOTE
(FOR SOIL STRATIGRAPHY & PARAMETERS, SEE FIG 14)

DOUBLE BENCH DESIGN
NTS

FIG - 15
WP 141-87-00(A)

GRAVITY DRAINAGE SCHEME
METHOD A

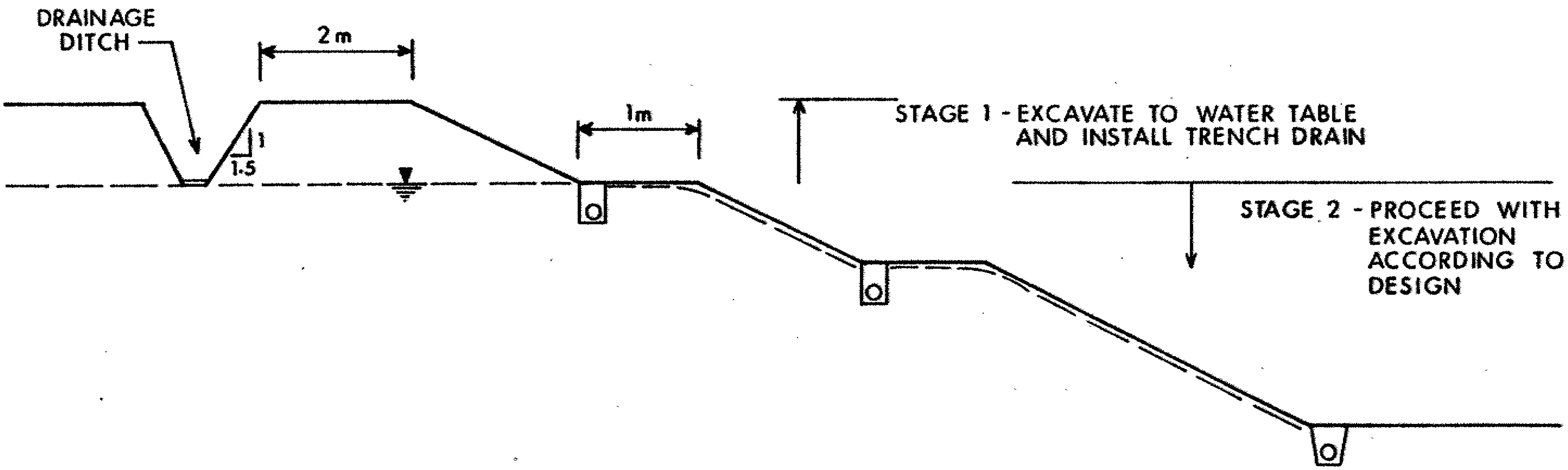
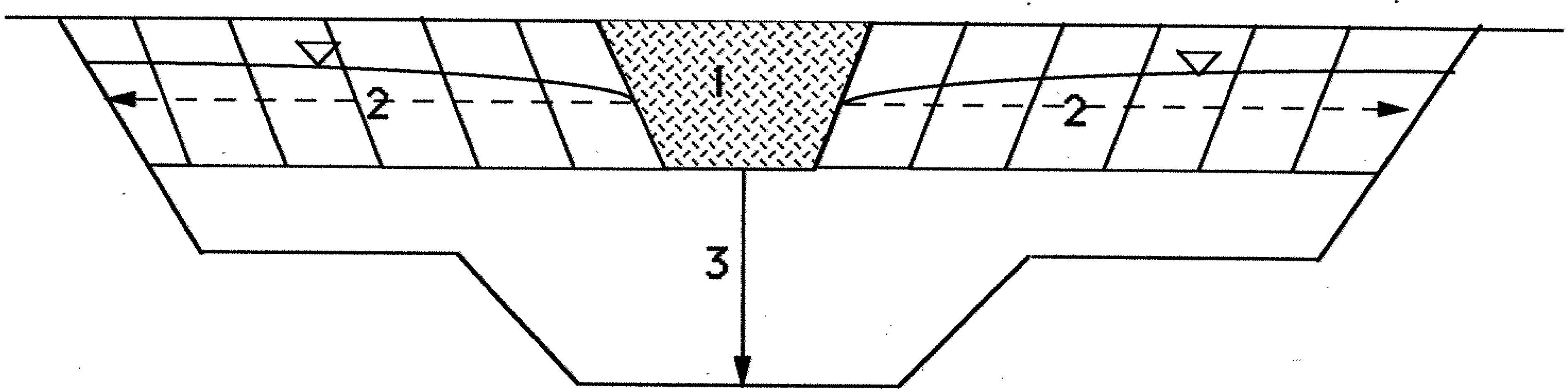


FIG -16A
WP 141-87-00 (A)

FIG. 16b - GRAVITY DRAINAGE SCHEME
METHOD B



1 EXCAVATE INITIAL SUMP PUMP TRENCH AND ALLOW GRAVITY DRAINAGE

2 EXCAVATE LATERALLY TO EDGE OF EXCAVATION, ALLOWING GRAVITY DRAINAGE IN PROCESS

3 PROGRESS TO DESIGNED DEPTH BY REPEATING (1) AND (2)

WP 141-87-00A

RECORD OF BOREHOLE No A-1

METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 751.6 ; E 298 751.3 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 16-17 CHECKED BY BC

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
160.2	Ground Surface
159.4	Topsoil
0.8	Sand, Tr. Gravel Brown, Compact
157.2	
156.7	Silt, Brown, Compact
3.5	Clayey Silt with Random Nodules/ Seams of Silt Grey, Stiff to Very Stiff
154.1	
6.1	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Firm to Very Stiff
144.5	
15.7	End of Borehole

SAMPLES

NUMBER	TYPE	'N' VALUES
1	AS	-
2	SS	14
3	SS	9
4	SS	9
5	SS	7
6	SS	6
7	SS	5
8	SS	4
9	SS	3
10	SS	5
11	SS	3
12	SS	8
13	SS	8
14	SS	8

GROUND WATER CONDITIONS

ELEVATION SCALE: 158, 156, 154, 152, 150, 148, 146

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

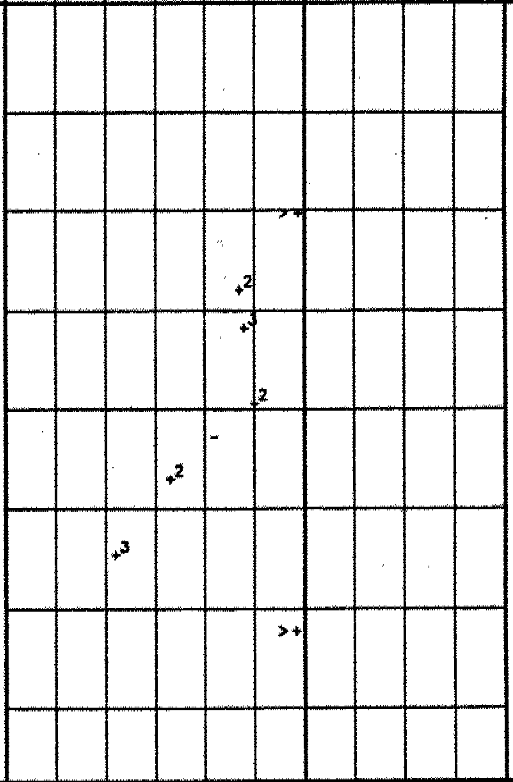
SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, • QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL



* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	158.2

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

15 ◇ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No A-2

METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 790.6 ; E 298 676.7 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 16-17 CHECKED BY BC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	REMARKS
160.1	Ground Surface							
159.3	Topsoil							
0.8	Sand, Tr. Gravel Brown, Compact	1	SS	18				
		2	SS	21				
		3	SS	15	▼	158		
156.4		4	SS	25				
155.8	Silt, Brown, Very Dense	5	SS	47		156		
4.3	Clayey Silt with Random Nodules/ Seams of Silt Grey, Stiff to Very Stiff	6	SS	24				
		7	SS	19		154		
152.5		8	SS	7				
7.6	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Firm to Very Stiff	9	SS	6		152	+3	
		10	SS	5			+3	
		11	SS	9		150	+2	
		12	SS	19		148		
		13	SS	26		146		
144.4		14	SS	29				
15.7	End of Borehole							

Header legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

15 ◇ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No A-3

 METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 713 ; E 298 662.2 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 16 CHECKED BY BC

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
160.9	Ground Surface								
160.2	Topsoil								
0.7	Sand, Tr. Gravel, Brown, Loose	1	SS	7					
		2	SS	6					
158.9 / 2.0	Silt, Brown / Grey, Compact	3	SS	13					
		4	SS	12		0	1	79	20
157.4 / 3.5	Clayey Silt to Silty Clay with Random Nodules/Interbeds of Silt, Grey, Stiff to Very Stiff	5	SS	12					
		6	SS	5	17.2	0	1	63	36
		7	SS	12		0	5	39	56
		8	TW	PH					
153.3 / 7.6	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till), Grey, Stiff to Very Stiff	9	SS	5					
		10	SS	3					
					19.6	3	24	53	20
		11	SS	9					
		12	SS	10					
		13	SS	19					
		14	SS	13					
145.2 / 15.7	End of Borehole								

Elevation scale: 158, 156, 154, 152, 150, 148, 146

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30

Plot annotations: +2, 46.5, >+, +3, >+, >+

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

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

$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No A-4

 METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 740.9 ; E 298 588.6 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 16 CHECKED BY BC

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
160.9	Ground Surface				*					
160.1	Topsoil									
0.8 / 158.9	Sand, Tr. Gravel, Tr. Silt, Brown, Compact	1	SS	24						3 86 (11)
		2	SS	28						
2.0 / 157.4	Silt, Compact (Brown / Grey)	3	SS	27		158				
		4	SS	17					20.4	
3.5	Clayey Silt with Random Nodules/ Seams of Silt, Stiff to Very Stiff	5	SS	15						
		6	SS	13		156				
		7	SS	14						
		8	SS	11		154				
153.3		9	SS	4			+2			
7.6	Clayey Silt, Some Sand, Tr. Gravel (Glacial Till) Grey, Firm to Stiff	10	TW	PH		152	+3			
		11	SS	5		150	+3			
							+2			7 32 (61)
		12	SS	12		148				
		13	SS	14		146				
145.2		14	SS	17						
15.7	End of Borehole									

* Hole caved-in at 2.1m (GWL not established)

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

$+^3$, $\times^3$: Numbers refer to Sensitivity $15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No A-5

1 OF 1 METRIC

W.P. 141-87-00A | LOCATION Co-ords: N 4 847 660.1 ; E 298 576.7 | ORIGINATED BY TS

DIST 6 HWY 407 | BOREHOLE TYPE HS Auger | COMPILED BY TS

DATUM Geodetic | DATE 90 01 15 | CHECKED BY BC

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
160.2	Ground Surface
159.4	Topsoil
0.8	Sand, Some Gravel Brown, Compact
157.2	
156.4	Silt, Brown, Compact
3.8	Clayey Silt to Silty Clay with Random Nodules/Interbeds of Silt Grey, Stiff
152.6 7.6	Clayey Silt, Some Sand, Tr. Gravel (Glacial Till) Grey, Firm to Stiff
141.5 18.7	End of Borehole
137.3 22.9	End of Cone Test

SAMPLES

NUMBER	TYPE	'N' VALUES
1	SS	11
2	SS	10
3	SS	17
4	SS	14
5	SS	10
6	SS	11
7	SS	5
8	TW	PH
9	SS	13
10	SS	2
11	SS	4
12	SS	5
13	SS	8
14	SS	10
15	SS	6
16	SS	5

GROUND WATER CONDITIONS: water level symbol at approx. elev. 158

ELEVATION SCALE: 158, 156, 154, 152, 150, 148, 146, 144, 142

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; x LAB VANE — 20 40 60 80 100

Field vane sensitivities plotted: +4, +3, +4, +3, +2, +2, +3

PLASTIC LIMIT w_p — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30 (value 43.5 noted)

UNIT WEIGHT γ kN/m³ and REMARKS & GRAIN SIZE DISTRIBUTION (%)

Unit weight	GR	SA	SI	CL
	11	82	(7)	
	25	68	(7)	
18.8	0	0	(100)	
22.6				
	0	0	32	68
18.4	1	15	(84)	

* c'=0, ø'=29°

$^{+3}$, ^{x5} : Numbers refer to Sensitivity

15 -o- 5 (20 above, 10 below) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No A-6

METRIC

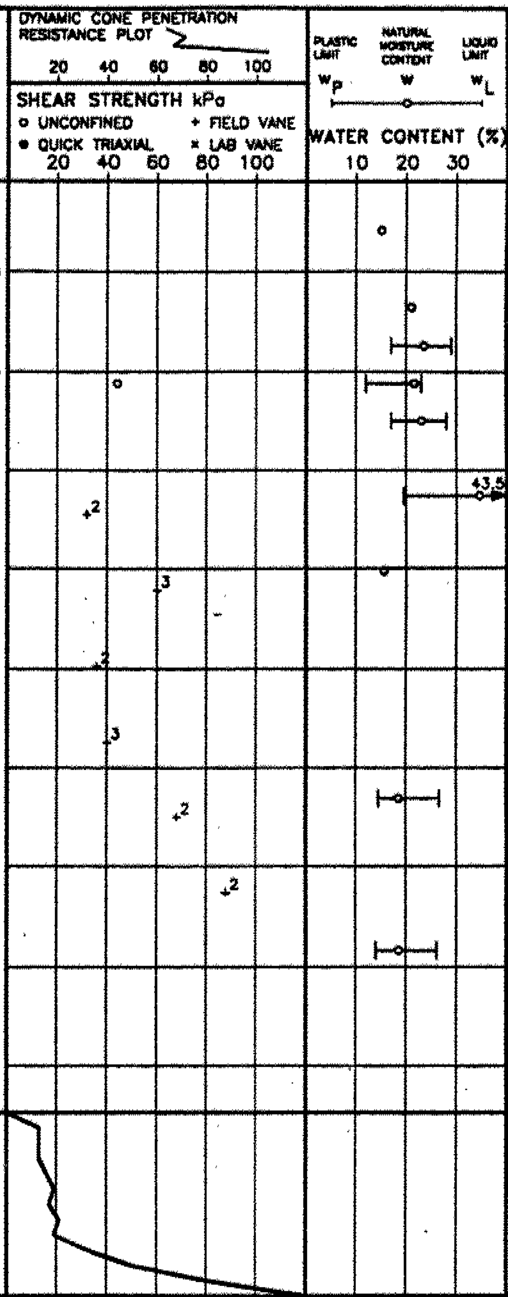
W.P. 141-87-00A LOCATION Co-ords: N 4 847 691.2 ; E 298 501.7 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 12-15 CHECKED BY BC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
159.8	Ground Surface								
159.0	Topsoil	1	AS	-					
0.8	Sand, Tr. Silt, Some Gravel	2	SS	26		14	79	(7)	
157.5	Brown, Compact	3	SS	18					
2.3 / 156.8	Silt Brown, Compact	4	SS	21		0	19	76	5
3.0	Clayey Silt to Silty Clay with Random Nodules/Interbeds of Silt Firm to Stiff	5	SS	18		0	0	60	40
		6	SS	16	20.0	0	0	77	23
		7	SS	12	22.2				
		8	SS	8	19.8				
152.0		9	SS	5					
7.8	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Stiff to Very Stiff	10	TW	PH					
		11	SS	10					
		12	SS	10					
		13	TW	PH	20.3	1	11	62	26
		14	SS	13					
		15	SS	17	20.8	1	20	49	30
		16	SS	16					
141.1		17	SS	16					
18.7	End of Borehole								
137.5 / 22.3	End of Cone Test								

Remarks (Sample 13): * c' = 10 kPa, ø' = 29°



* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	157.5

+³, ×³ : Numbers refer to Sensitivity

15 ◇ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No A-7

METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 615.4 ; E 298 488.6 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 11-12 CHECKED BY BC

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
159.3	Ground Surface									
158.5	Topsoil	1	AS	-	*					
0.8	Sand, Tr. Silt, Tr. Gravel, Brown, Compact	2	SS	16						
		3	SS	22			5	89	(5)	
156.3		4	SS	16						
3.0	Silt, Compact, Brown / Grey	5	SS	26			0	3	86	11
154.7		6	SS	16						
4.6	Clayey Silt with Random Nodules/Seams of Silt, Grey, Stiff	7	TW	PH						
		8	SS	8			0	0	75	25
		9	SS	9		17.7				
151.7										
7.6	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Firm to Stiff	10	SS	6			0	0	65	35
		11	SS	4		17.0				
		12	TW	PH		18.4	0	0	58	42
		13	TW	PM						
		14	SS	11						
		15	SS	13						
		16	SS	19		20.8	0	10	56	34
140.6		17	SS	17						
18.7	End of Borehole									

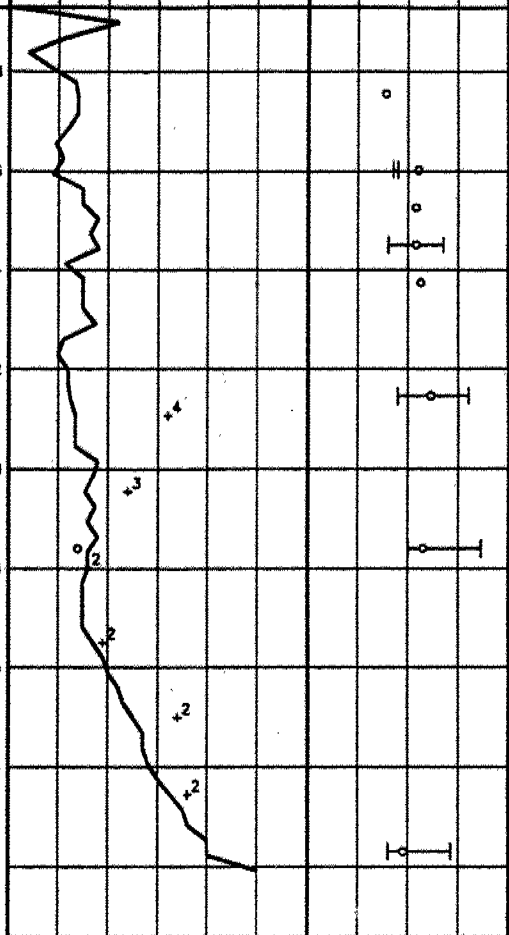
* Hole Cave-in at 1.5m
(GWL not established)

ELEVATION SCALE: 158, 156, 154, 152, 150, 148, 146, 144, 142

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED; + FIELD VANE; • QUICK TRIAXIAL; × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30



+3, ×3 : Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No A-8

METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 881 ; E 298 813 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 02 23 CHECKED BY BC

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
160.2	Ground Surface										
159.4	Topsoil										
0.8 158.7	Sand, Tr. Gravel										
1.5	Silt, Brown, Compact		1	SS	12	▼					
1.8	Clayey Silt with Random Nodules/ Seams of Silt Grey, Stiff		2	SS	10		158				
			3	SS	7		156				
154.1											
6.1	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Stiff to Very Stiff		4	SS	3		154	>+			
			5	SS	3		152	>+			
			6	SS	7		150				
			7	SS	12						
147.6			8	SS	16		148				
12.6	End of Borehole										

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

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

Ontario

RECORD OF BOREHOLE No A-9 — 1 OF 1 — METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 921 ; E 298 877 ORIGINATED BY TS
DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 90 02 23 CHECKED BY BC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (+ FIELD VANE)	REMARKS
160.1	Ground Surface							
159.3 / 0.8	Topsoil							
158.6 / 1.5	Sand, Tr. Gravel Brown							
157.8 / 2.3	Silt Brown, Compact	1	SS	16	▼	158		
154.0 / 6.1	Clayey Silt with Random Nodules/ Seams of Silt Grey, Stiff to Very Stiff	2	SS	14		156		
		3	SS	7			+2	
148.7 / 11.4	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Firm to Very Stiff	4	SS	3		154	+2	
		5	SS	3		152	+2	
		6	SS	5		150	+2	
		7	SS	8			>+	
147.5 / 12.6	Sand, Tr. Silt Loose	8	SS	6		148		
12.6	End of Borehole							

Column headings: SOIL PROFILE (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 o UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

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

Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No A-10

1 OF 1 METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 953 ; E 298 923 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 02 23 CHECKED BY BC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	REMARKS
160.0	Ground Surface							
159.4	Topsoil							
0.6 / 158.5	Sand, Tr. Gravel, Brown, Compact							
1.5 / 157.7	Silt, Brown, Compact	1	SS	14	▽	158		
2.3 / 153.9	Clayey Silt with Random Nodules/Seams of Silt, Grey, Very Stiff	2	SS	6		156		
		3	SS	11				
6.1 / 149.3	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till), Grey, Firm to Stiff	4	SS	6		154	+ (sensitivity 3)	
		5	SS	5		152	+ (sensitivity 2)	
		6	TW	PH		150	+ (sensitivity 2)	
10.7 / 147.4	Silty Sand, Grey, Loose	7	SS	5		148		
		8	SS	5				
12.6	End of Borehole							

Legend: Dynamic Cone Penetration Resistance Plot (20, 40, 60, 80, 100); Shear Strength kPa: o Unconfined, + Field Vane, ● Quick Triaxial, × Lab Vane (20, 40, 60, 80, 100); Plastic Limit w_P, Natural Moisture Content w, Liquid Limit w_L; Water Content (%) 10 20 30; Unit Weight γ kN/m³; Remarks & Grain Size Distribution (%) GR SA SI CL.

+3, ×5 : Numbers refer to Sensitivity

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

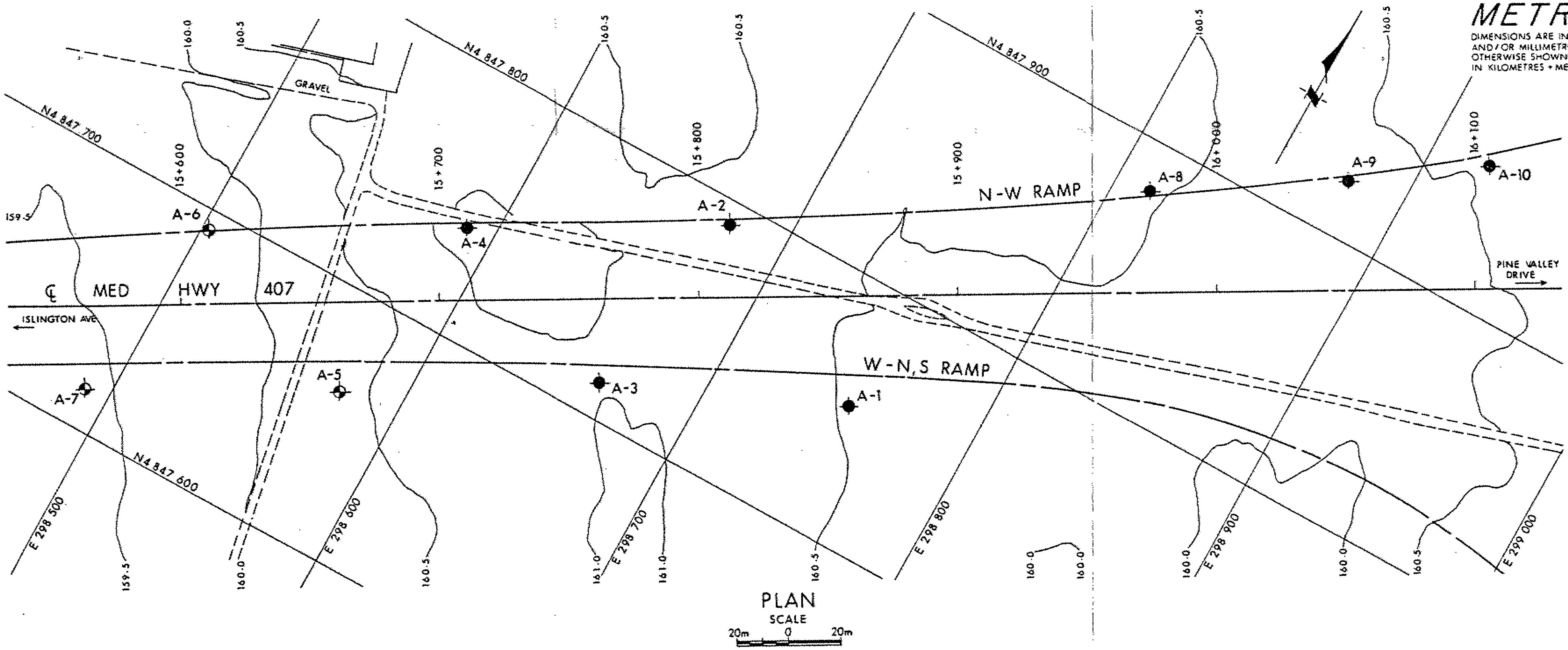
METRIC

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

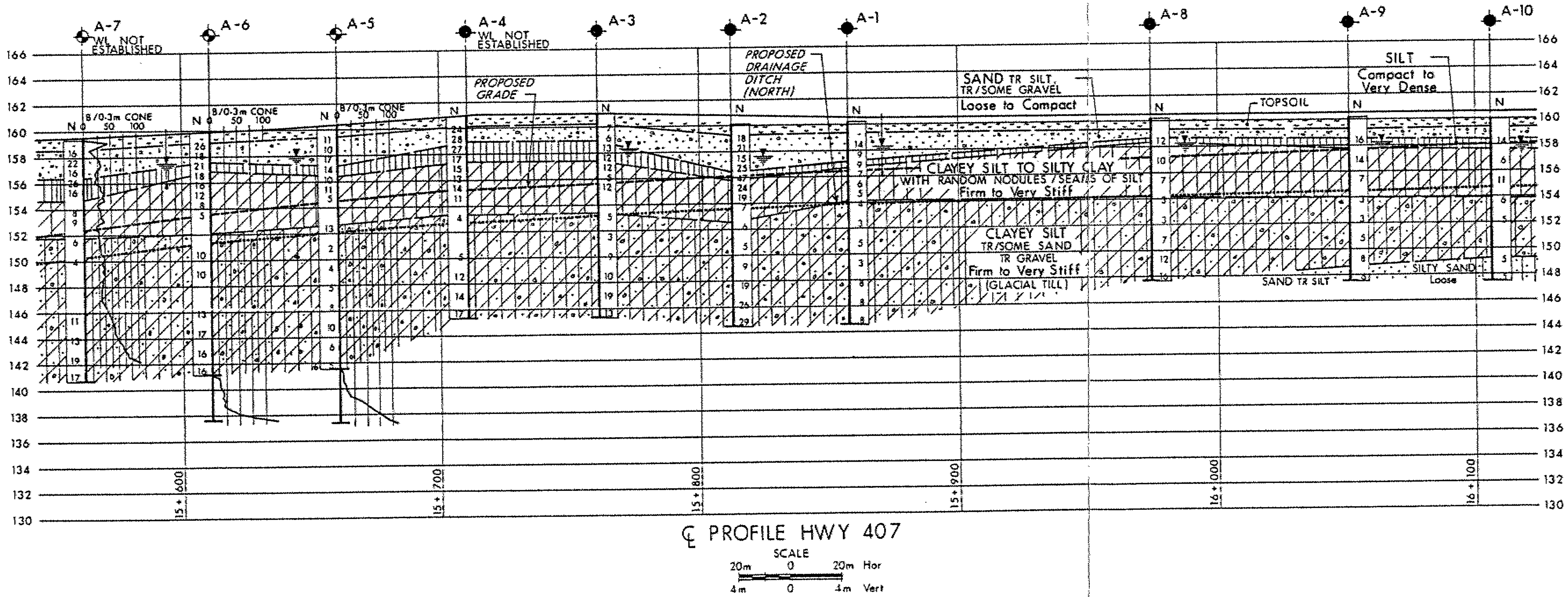
CONT No
WP No 141-87-00A

HWY 407
(FROM ISLINGTON AVE TO PINE VALLEY DR)
BORE HOLE LOCATIONS & SOIL STRATA

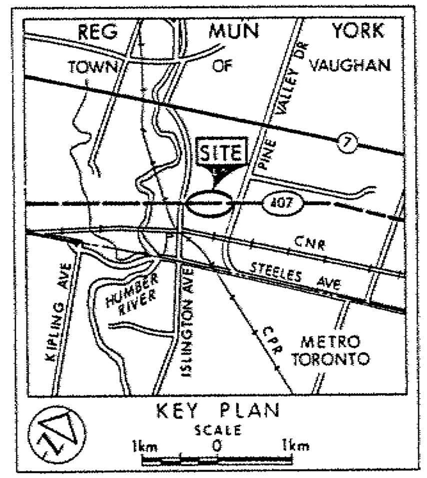
SHEET



PLAN
SCALE
20m 0 20m



℄ PROFILE HWY 407
SCALE
20m 0 20m Hor
4m 0 4m Vert



KEY PLAN
SCALE
1km 0 1km

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 90 01 and 90 02
- WL in Piezometer
- Piezometer

No	ELEVATION	CO-ORDINATES NORTH	CO-ORDINATES EAST
A-1	160·2	4 847 751·6	298 751·3
A-2	160·1	4 847 790·6	298 676·7
A-3	160·9	4 847 713·0	298 662·2
A-4	160·9	4 847 740·9	298 588·6
A-5	160·2	4 847 660·1	298 576·7
A-6	159·8	4 847 691·2	298 501·7
A-7	159·3	4 847 615·4	298 488·6
A-8	160·2	4 847 881·0	298 813·0
A-9	160·1	4 847 921·0	298 877·0
A-10	160·0	4 847 953·0	298 923·0

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

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

REV	DATE	BY	DESCRIPTION

Geocres No 30M13-102

HWY No 407			DIST 6
SUBM'D TS	CHECKED	DATE 90 05 29	SITE
DRAWN DT	CHECKED	APPROVED	DWG 1418700A-A

ENGINEERING MATERIALS OFFICE

FOUNDATION DESIGN SECTION

CONT. 92-40

WP 141-87-00(A) DIST 6

HWY 407 STR SITE

Proposed Hwy. 407 Cut and Detention Pond
Islington Avenue to Pine Valley Drive

DISTRIBUTION

V.F. Boehnke (3)
G. Cautillo
J. Cullen (2)
A. Wittenberg
K.G. Bassi
S.J. Dunham
E.A. Joseph
I. Harrod (Cover Only)
F. Bacchus (Cover Only)
File ✓

GEOCRES 30M13-125 DATE DEC 03 1991

FOUNDATION INVESTIGATION REPORT

For

Proposed Hwy. 407 Cut & Detention Pond

Islington Avenue to Pine Valley Drive

W.P. 141-87-00(A), Hwy. 407

District 6, Toronto

INTRODUCTION

Subsequent to requests submitted by the Central Region Geotechnical Section, an investigation was carried out by this office to determine the subsurface conditions for the proposed Hwy. 407 cuts east of Islington Avenue and west of Pine Valley Drive and for a proposed detention pond and stockpile located within this region.

Excavation cuts of up to 10 m will be required to satisfy the proposed Hwy. 407 profile grade. The proposed Hwy. 407 profile grade sloped westward from 156 m to 151 m with the natural ground surface relatively flat on the east side of Islington Avenue with an elevation of 160 m.

The investigating procedure, including the fieldwork procedures and laboratory analysis and a detailed description of the subsurface conditions are also included in this report.

SITE DESCRIPTION AND GEOLOGY

The site is located ½ km north of Steeles east of Islington Avenue in the City of Vaughan, Region of York. The area consists of farmland with hydro power towers to the east and north, CNR tracks south and an industrial building to the north. At the time of the investigation the farmers field contained short grassy vegetables. Boreholes were located along narrow farmer roads located between crops.

Physiographically, the site is located in the geological domain known as the "Peel Plain". The "Peel Plain" is the product of the advances and retreat of the wisconsinan ice sheet which covered the area during the pleistocene epoch. It consists of a bevelled till plain with a gently undulating rolling surface and limited relief. At some locations, the till is overlain by the deposits of varved clay. Till sheets of varying composition comprise the "Peel Plain". Generally, the surficial till sheets exhibit a cohesive behaviour whilst the lower till sheets are cohesionless. As characteristics of till material, these deposits contain a wide range of grain sizes ranging from boulders to clay. The till sheets are usually separated from one another by interbeds of stratified silt or sand of variable thickness. Bedrock in the area has been found at depths ranging from 25 to 35 m below ground surface and consists of interbedded shale and limestone of the Dundas-Meaford formation ordivician period.

INVESTIGATION PROCEDURES

Soil data and inherent properties were obtained by in situ and laboratory testing. The procedures employed are discussed below.

FIELD INVESTIGATION

The fieldwork for the investigation was carried out between 91 07 24 to 91 07 31 and consisted of five sampled boreholes located within the proposed stock pile and retention pond east of Islington.

3 boreholes were advanced 21 m below natural ground surface and 2 boreholes were advanced deeper, down to 48 m to collect data for a future possible retaining wall alternative if found necessary.

Vanes and undisturbed shelby tube samples were taken when plastic cohesive material was encountered. Cone penetration tests were taken down at the invert or each borehole and at two boreholes from the surface.

Track mounted CME 55 equipment employing hollow stem and wash boring techniques were used to advance all boreholes in the overburden. In general, disturbed subsoil samples were retrieved at 0.75 m intervals for the surficial 4.5 m and 1.5 m thereafter. All samples were identified in the field and then returned to the laboratory for applicable testing. Sample retrieval was conducted in accordance with the Standard Penetration Test (ASTM D1586).

Groundwater levels were obtained by monitoring the levels in the open boreholes throughout the duration of the field investigation, two piezometers were utilized at opposite ends of the site. All boreholes were backfilled at the completion of the fieldwork.

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

LABORATORY ANALYSIS

The following laboratory tests were carried out on select soil samples:

1) Atterberg Limit Tests
2) Grain Size Distributions
3) Unit Weights
4) Natural Moisture Contents

Laboratory test results have been summarized in the subsequent section of this report and are illustrated on corresponding figures and boreholes included in the attached appendix.

SUBSURFACE CONDITIONS

General

The stratigraphy encountered consisted mainly of 2.1 m to 4.4 m of a non-cohesive silty sand which contained surficial interbeds of organics. This stratum generally has a compact state of denseness. Underlying the above is a cohesive 1.2 m to 5.7 m thick deposit of clayey silt, trace sand which is inturn underlyed by a clayey silt (Glacial Till) trace sand, trace gravel which was found to extend down to 31.5 m to 30 m below the ground surface, within the two deeper boreholes (BH's 17 and 18). The two deposits have a very soft to stiff and very soft to hard consistency but generally the clayey silt layer has a stiff consistency. A non-cohesive heterogeneous mixture of clay, silt and sand, trace gravel was encountered in the two deep boreholes to extend from 31.5 m to

47.3 m. Bits of shale with probable bedrock was encountered at the terminated depths of these two deep boreholes. This deposit generally has a very dense state of denseness.

The boundaries between the various soil types, in situ and laboratory test results as well as groundwater level established at the time of the investigation, 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 are provided on Dwg. No. 1418700(A)-A.

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

<u>Silty Sand</u>

The native surficial deposit at the site consists of a non-cohesive silty sand that extends to a depth of 2.1 m to 4.4 m below the existing ground surface.

A grain size distribution envelope as determined by mechanical sieve and hydrometer analysis is provided in Figure 1 in the Appendix. The envelope illustrates that a large percentage of the deposit consists of sand and silt. This deposit comprised of 2-10% gravel, 68-83% sand, 9-20% sand and 1-13% clay.

Natural moisture contents for this stratum are in the 6.5-21% range. The deposit has been oxidized and hence is brown in colour.

Standard Penetration Tests carried out in this deposit revealed 'N' values ranging from 2 to 19 blows/0.3 m. Based on these 'N' values, the material can be described as having a denseness of very loose to compact.

<u>Clayey Silt, trace Sand</u>

The surficial non-cohesive deposit is underlain by a cohesive stratum consisting of clayey silt, trace sand. A Grain Size Distribution envelope is provided in Figure 2 in the Appendix. The thickness of the stratum ranges from 1.2 m to 5.7 m. The envelope illustrates that a large percentage of the deposit is finer than 75 micrometers and hence is in the clay and silt range. This deposit comprises of 0% gravel, 1-3% sand, 37-84% silt and 13-60% clay.

The deposit is unoxidized and hence is grey in colour. The oxidation delineation was found within the surficial layer.

The fine grained portion of the deposit dictates the behaviour of this cohesive deposit. Hence, Atterberg Limit Tests were carried out to define the behaviour and plasticity of the fine grained portion of the soil and the results are plotted in Figure 3 in the Appendix. A summary of the indices is provided in Table 1 below.

Table 1 - Clayey Silt

	Range	# of Tests
Natural Moisture Content (w%)	22.5-34	6
Liquid Limit (w_L%)	19-37	6
Plastic Index (I_P%)	8-20	6
Unit Weights (kN/m^3)	19.3-23.3	6

The results reveal that the fine grained portion of the deposit is primarily of low plasticity and hence can be classified as a clayey silt.

Standard Penetration Tests carried out in this deposit revealed 'N' values ranging from 0 to 9 blows/0.3 m. Based on these 'N' values, the material can be described as having a consistency of very soft to firm.

Clayey Silt, trace Sand, trace Gravel, (Glacial Till)

Underlying the above layer is a deposit of clayey silt, trace sand, trace gravel (Glacial Till). A Grain Size Distribution envelope is provided in Figure 4 in the Appendix.

This layer extends down to 31.5 m to 30 m below the ground surface. The envelope illustrates a large percentage of clay and silt with a trace of gravel and sand. This deposit comprises of 0-8% gravel, 5-34% sand, 36-87% silt and 12-63% clay. The material within the till is unsorted and unstratified and has been completely oxidized and is grey in colour.

Atterberg Limit Tests were carried out to define the behaviour and plasticity of the fine grained portion of the soil and the results are plotted in Figure 5 in the Appendix. A summary of the indices is provided in Table 2 below.

Table 2 - Clayey Silt (Till)

	Range	# of Tests
Natural Moisture Content (w%)	13-29	14
Liquid Limit (w_L%)	24-38	14
Plastic Index (I_P%)	10-19	14
Unit Weights (kN/m^3)	20.6-21.7	14

The results indicate that the fine grained portion of the deposit ranges in plasticity from low to intermediate and hence can be categorized as a clayey silt (till).

Standard Penetration Tests carried out in this deposit revealed 'N' values ranging from 1 to 40 blows/0.3 m, however the 'N' values were generally between 1 to 20 blows/0.3 m. Therefore, the deposit can be considered to have a soft to very stiff consistency with random hard zones.

Heterogeneous mixture of Silt and Sand, trace Clay, trace Gravel

Underlying the above material is a heterogeneous mixture of silt and sand, trace gravel, trace clay which was found at a depth of 31.5 m to 47.3 m and extending down to unknown depths. This layer was only encountered in the two deep boreholes. Near the terminated depths of the two boreholes pieces of shale with a greater percentage of gravel. At depths of 49 m refusal with possible bedrock was encountered. A Grain Size Distribution envelope is provided in Figure 6 in the Appendix. The envelope illustrates a large percentage of silt, sand and gravel. This deposit comprised of 0-22% gravel, 10-15% sand, 15-83% silt and 6-46% clay.

Atterberg Limit Tests were carried out to define the behaviour and plasticity of the fine grained proportion of the soil and the results are plotted in Figure 7 in the Appendix. A summary of the indices is provided in Table 3 below.

Table 3 - Heterogeneous mixture of Silt, Sand, Tr. Gravel, Tr. Clay

	Range	# of Tests
Natural Moisture Content (w%)	6-22	6
Liquid Limit (w_L%)	16-25	5
Plastic Index (I_P%)	0-3	5
Unit Weights (kN/m^3)	20.3-22.9	3

The results indicate the material is an inorganic silt or sandy silt of slight plasticity.

Standard Penetration Tests carried out in this deposit revealed 'N' values ranging from 40 to >120 blows/0.3 m which gives it a very dense state of relative density.

GROUNDWATER CONDITIONS

Observations of the groundwater level was carried out by measuring the water level in the open boreholes and two piezometers placed at opposite ends of the site. Groundwater levels determined at the time of the investigation ranged from 2.7 m to 3.5 m below the ground surface or at an elevation of 156.6 m.

Soil cave-in witnessed in the heterogeneous mixture of silt and sand deposit confirms that the stratum is under some sub-artesian head. However, no excess head was observed.

Groundwater levels, in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

DISCUSSION AND RECOMMENDATIONS

It is proposed to construct Hwy. 407 between Islington Avenue and Pine Valley Drive within cuts ranging from 8 m to 3 m. A detention pond will be constructed and designed to hold storm water just south of Hwy. 407 within this cut. South of the cut a proposed stockpile is to be placed with a height of 5 m.

The existing elevation of the ground surface is relatively flat at approximately 160 m while the proposed elevations of Hwy. 407 and the invert of the stormwater storage pond are 154 m and 149 m respectively.

The excavation cuts of up to 15 m will be required in the soil consisting of varying thicknesses of silty sand, clayey silt and glacial tills as described in previous sections in this report. An effective stress analysis was implemented using Bishop's method on an in-house, desktop computer using the sarma program. The analysis was carried out employing static loading conditions with a circular slip surface. A static surcharge load was placed on Hwy. 407 but no load effects due to the transitway was included.

The results of the analysis are summarized in the Table below.

Slope Geometries

Depth of Cut	Recommended Geometry
6 m	3H:1V
9 m	3H:1V + 3 m wide bench
12 m	3H:1V + 6 m wide bench
15 m	3H:1V + Two 5 m wide benches

Landscaping requirements also specify that sideslopes of a maximum 3:1 be maintained.

Eastward towards Pine Valley Drive structures the stratigraphy improves allowing slopes of 2H:1V while westward towards Islington Avenue the weaker material requires 3H:1V slopes, 3 m bench. The amount of excavation cut also decreases towards the east with cuts of 4 m.

The proposed stock pile with a height of 5 m should be placed 10 m from the crest (top) of any slope cuts).

The slope stability analysis for the above recommended geometries did not include the presence of the proposed transit-way to be located on the south slope, south of the retention pond. Possible proposals could include a retaining wall to make room for the transit way along the embankment. If there are any new developments please contact this office for further comment concerning the effects of this load on the stability of this slope.

CONSTRUCTION CONSIDERATIONS

If any pockets of loose material are encountered remove and replace with Granular Fill.

Water table depths remained at an elevation of 156.4 m throughout the site within the cohesive clayey silt layer. Dewatering should not be a major problem due to the presence of a cohesive subsoil. Conventional pumping techniques will suffice in discharge any local seepage.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of M. Michalek, Junior Foundation Engineer and P. Thase, Student Engineer. The equipment was owned and operated by Malones Soil Samples Ltd., Toronto.

The report was written by M. Michalek under the general supervision of B. Iyer, Senior Foundation Engineer and reviewed by M. Devata, Chief Foundation Engineer.

REGISTERED PROFESSIONAL ENGINEER
CIVIL
M. DEVATA
PROVINCE OF ONTARIO

M. Michalek
Junior Foundation Engineer

M. Devata, P.Eng.
Chief Foundation Engineer

APPENDIX

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/0.3 m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

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

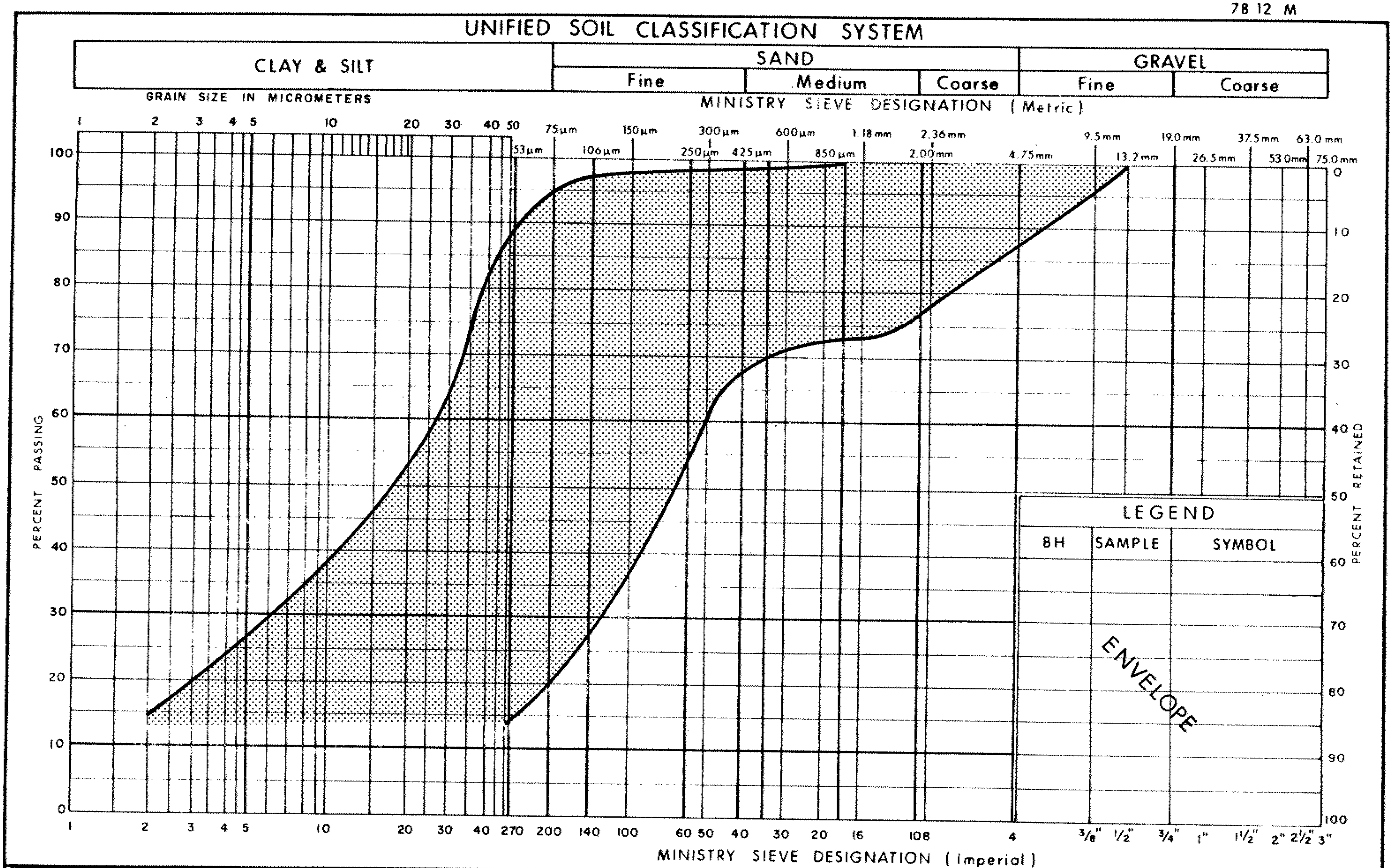
MECHANICAL PROPERTIES OF SOIL

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

78 12 M



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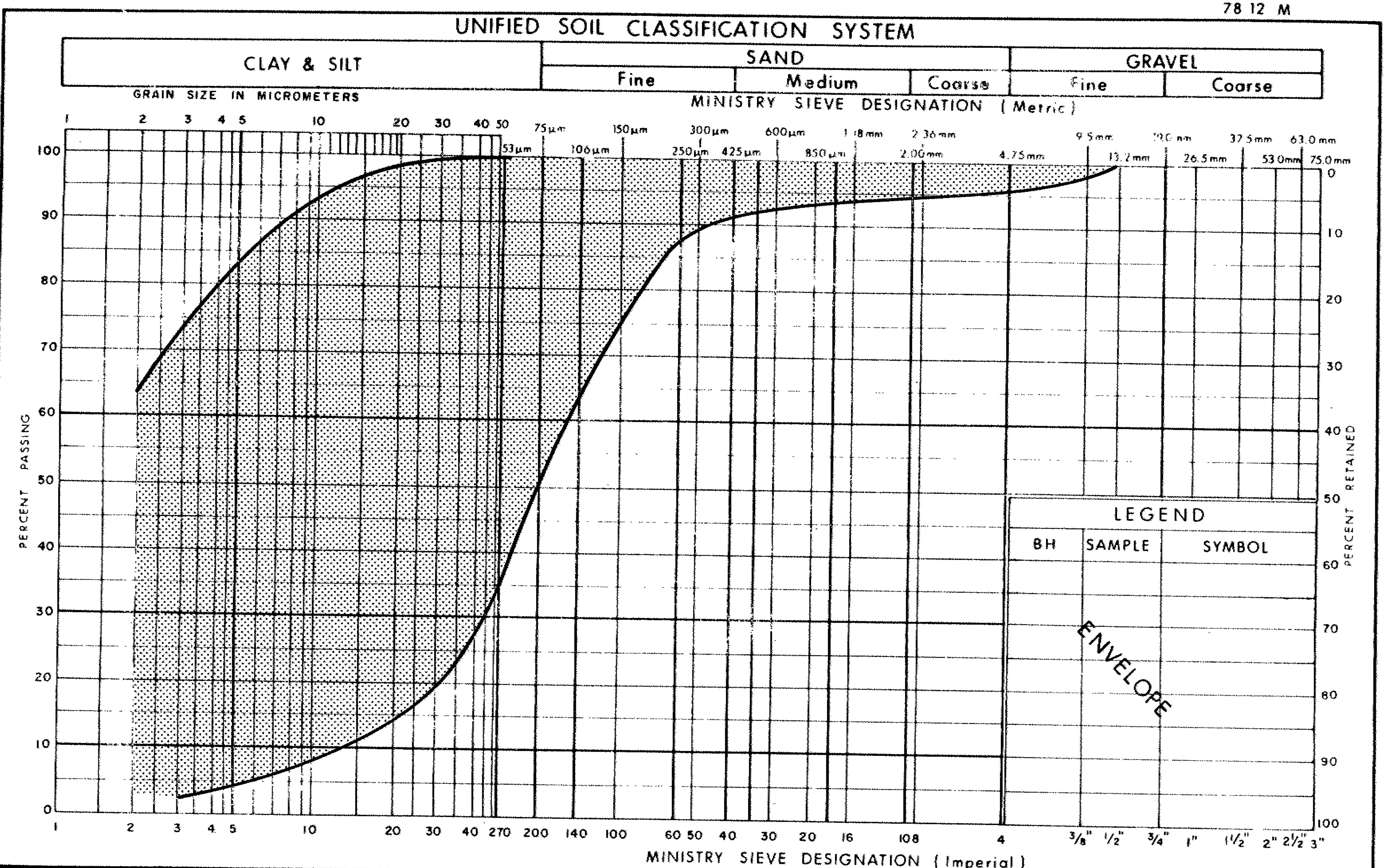
GRAIN SIZE DISTRIBUTION
SILTY SAND

FIG No 1

W P 141-87-00A

78 12 M



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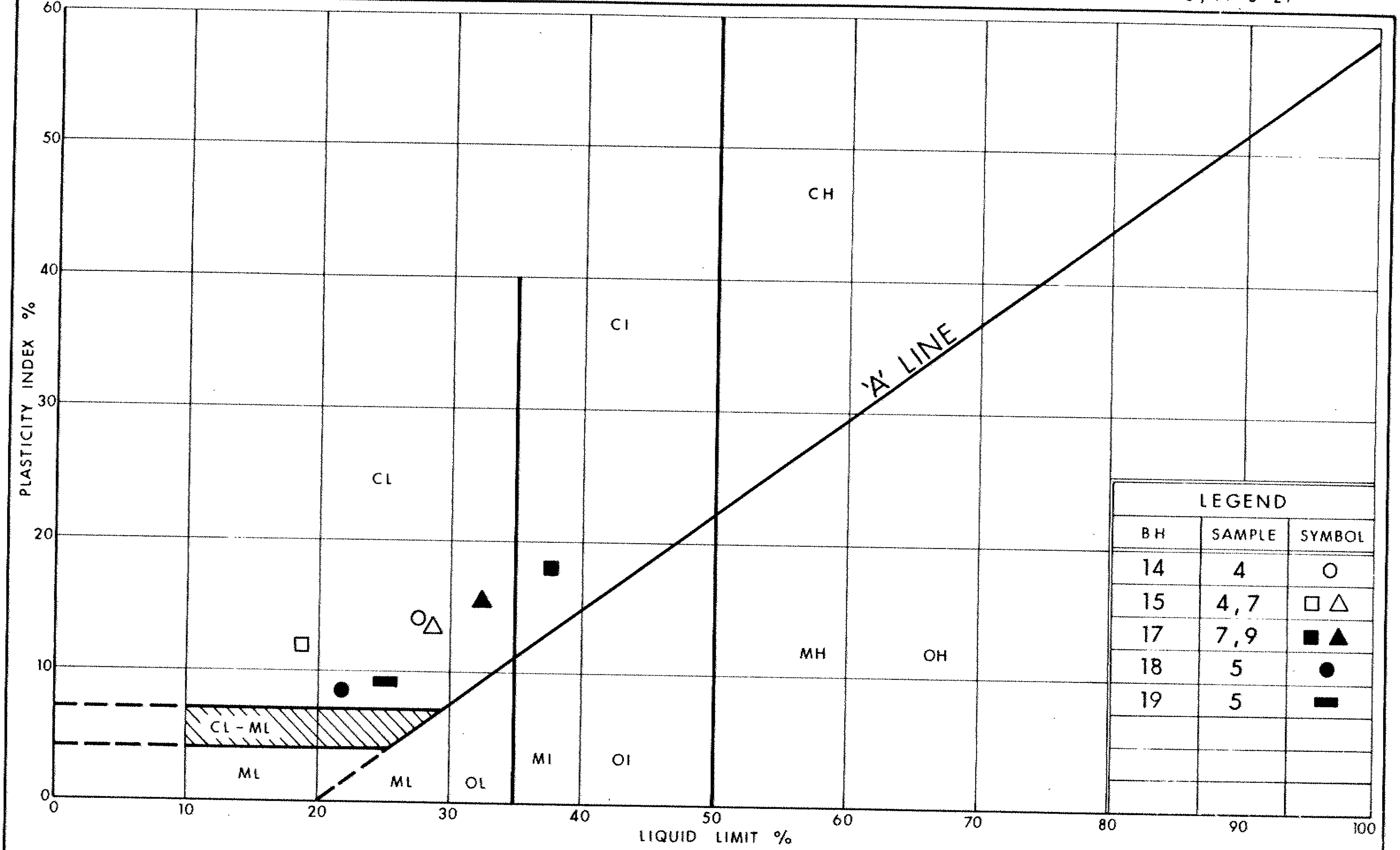
GRAIN SIZE DISTRIBUTION
CLAYEY SILT

FIG No 2

W P 141-87-00A

Oct 75, FF-S-21



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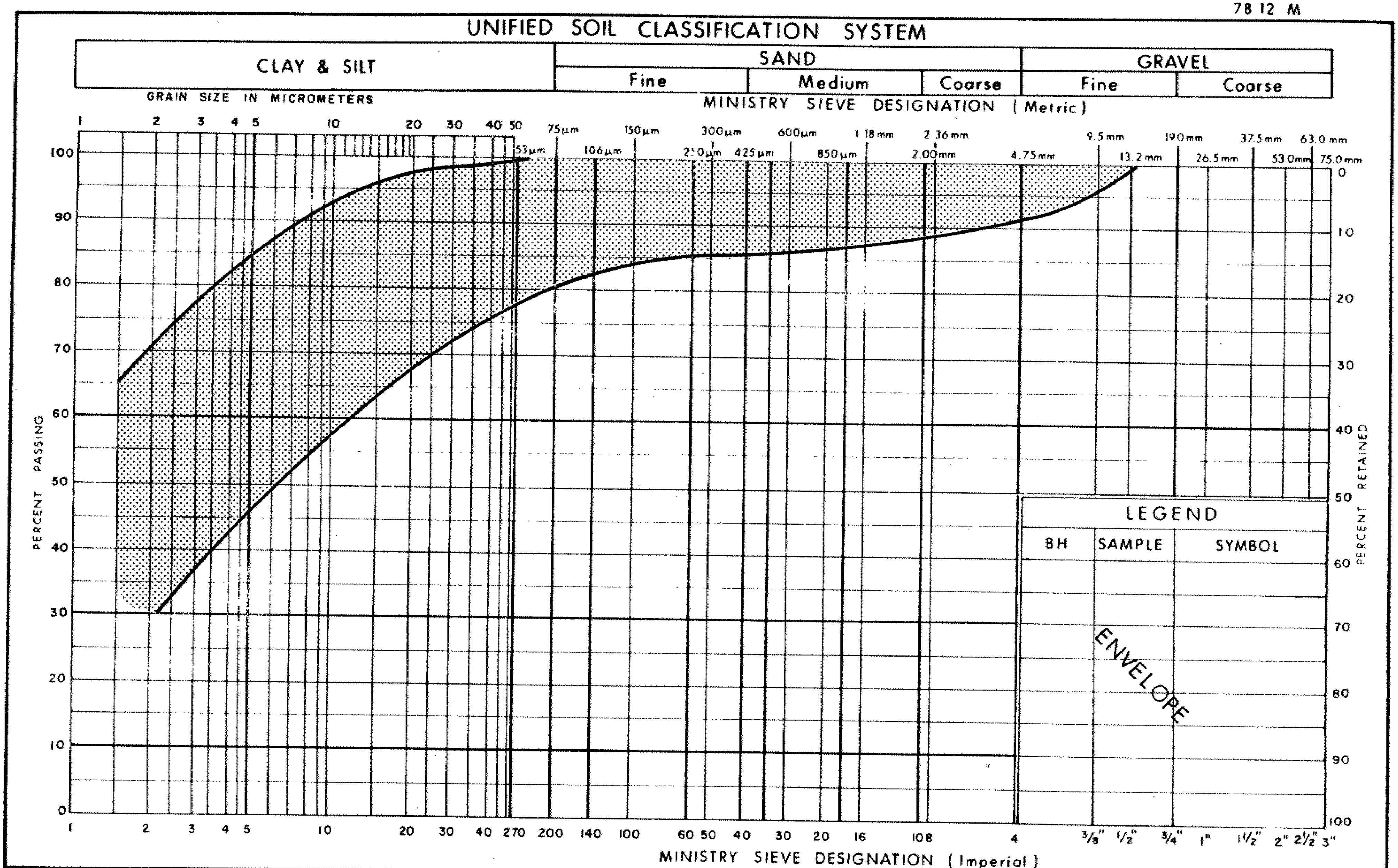
PLASTICITY CHART
CLAYEY SILT

FIG No 3
W P 141-87-00A

78 12 M



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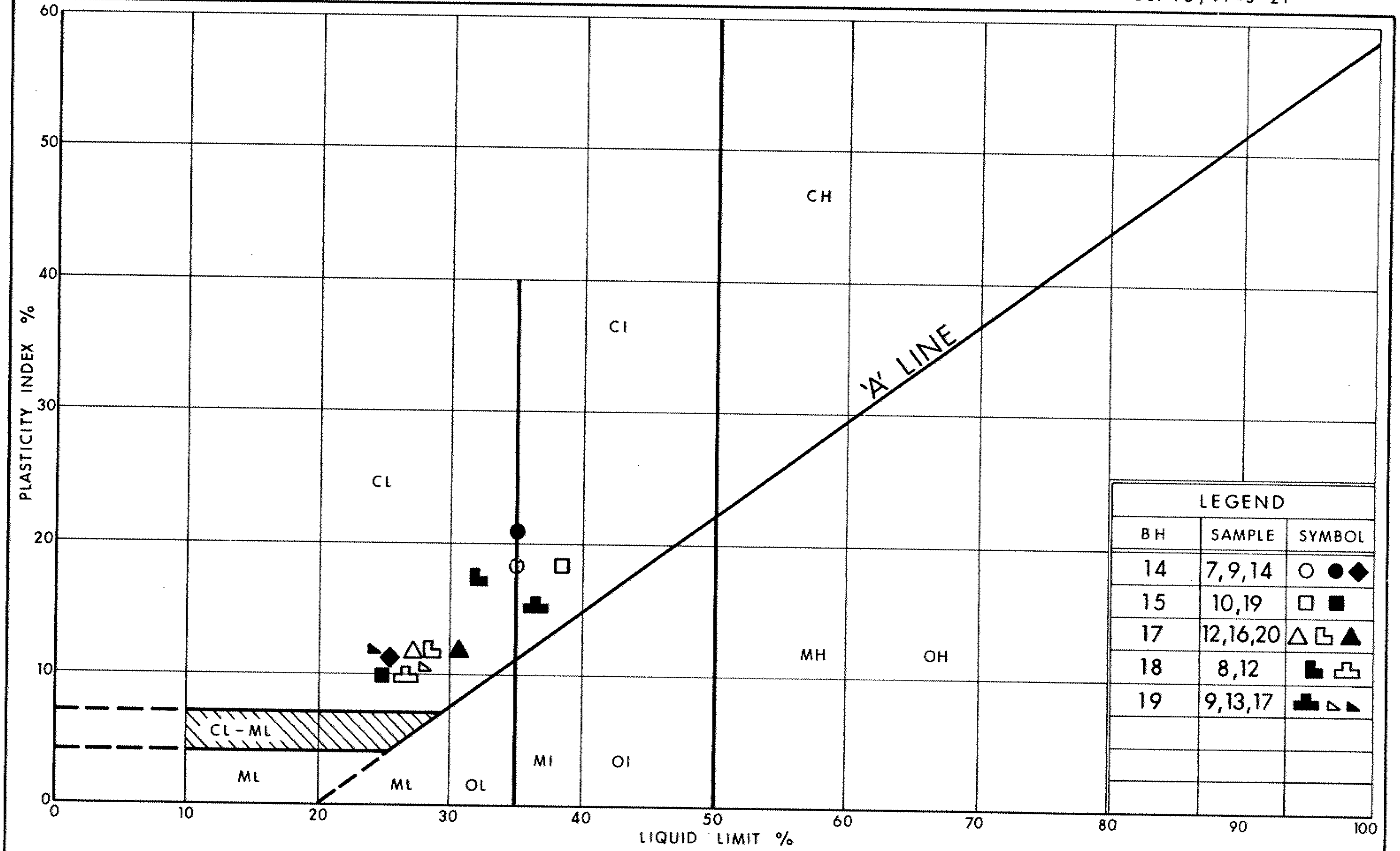
GRAIN SIZE DISTRIBUTION
CLAYEY SILT
(GLACIAL TILL)

FIG No 4

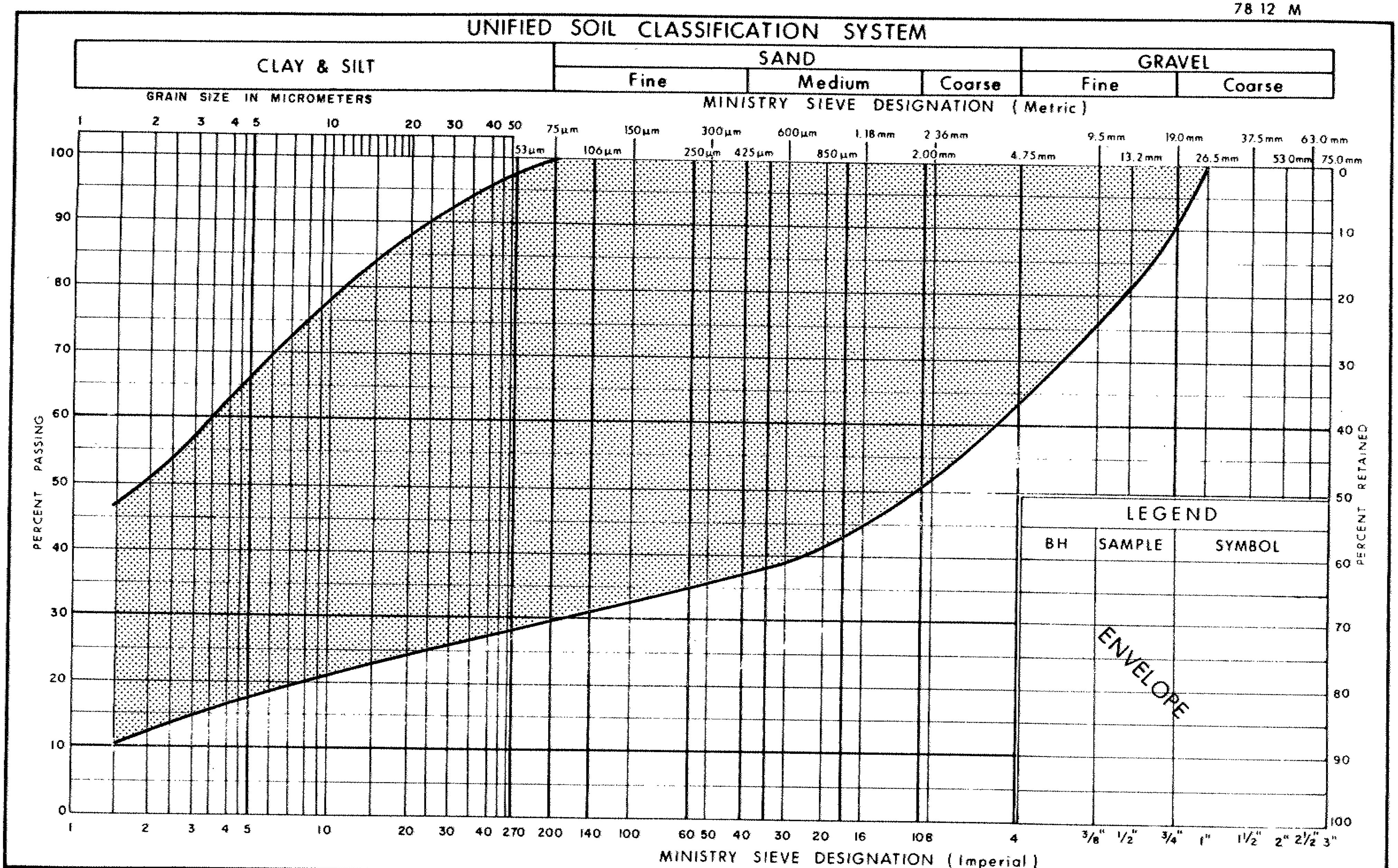
W P 141-87-00A

Oct 75, FF-S-21



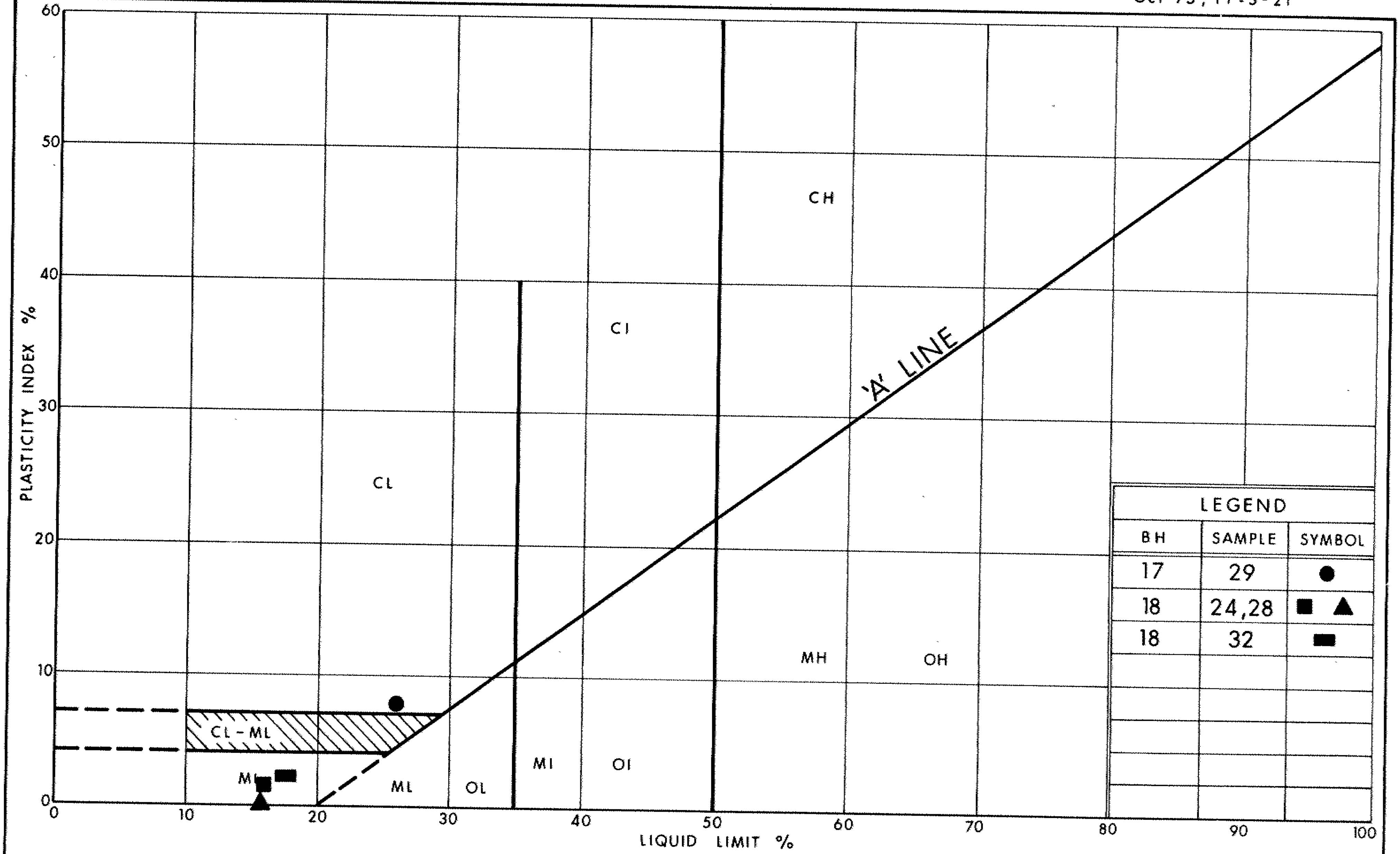
Ministry of Transportation Ontario	PLASTICITY CHART **CLAYEY SILT** (GLACIAL TILL)	FIG No 5 W P 141-87-00 A

78 12 M



Ministry of Transportation Ontario	**GRAIN SIZE DISTRIBUTION** HETEROGENEOUS MIXTURE OF SILT & SAND TRACE GRAVEL, TRACE CLAY	FIG No 6 W P 141-87-00A

Oct 75, FF-S-21



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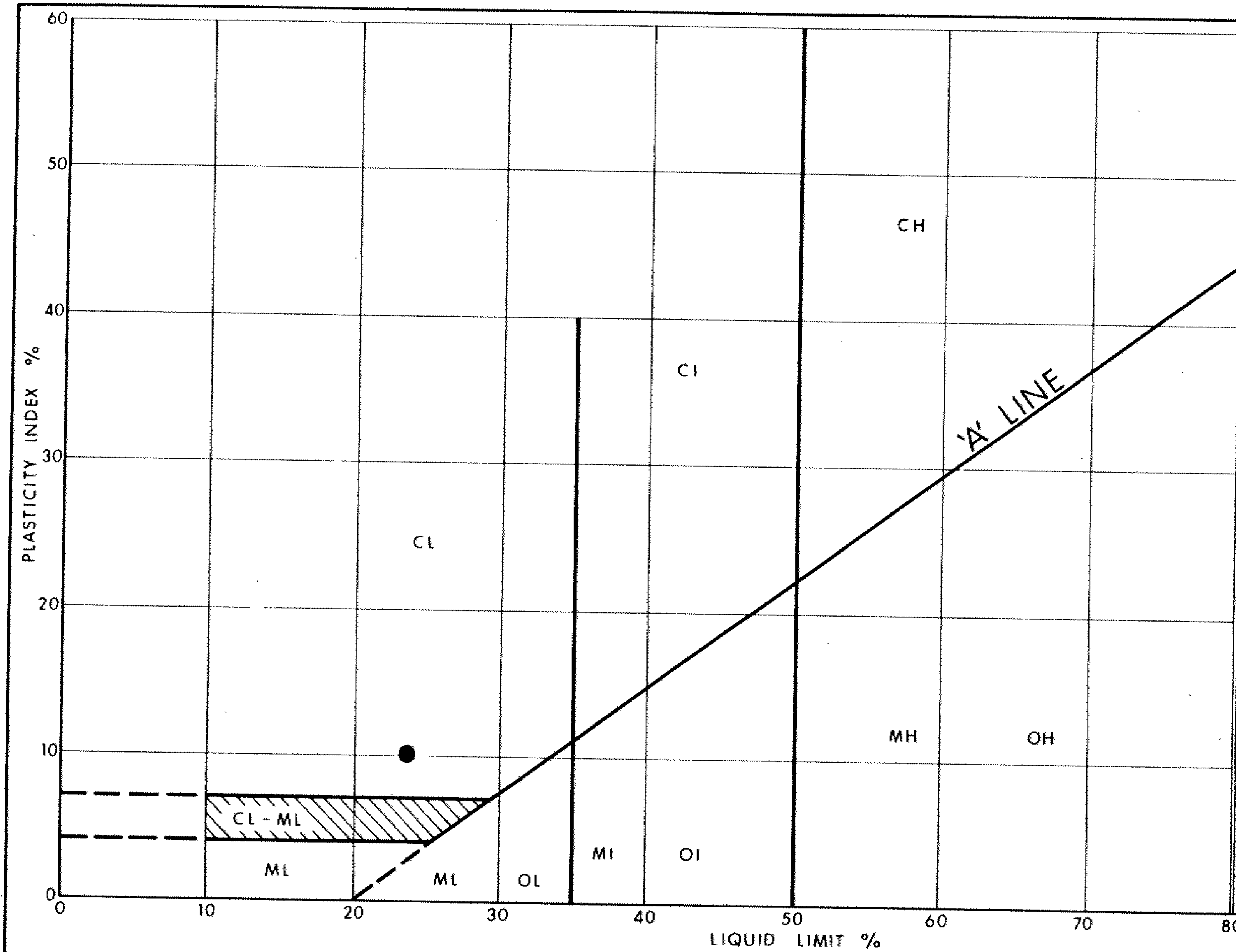
PLASTICITY CHART
HETEROGENEOUS MIXTURE OF SILT & SAND
TRACE GRAVEL, TRACE CLAY

FIG No 7

W P 141-87-00A



LEGEND		
BH	SAMPLE	SYMBOL
18	3	●

Ministry of Transportation
Ontario

PLASTICITY CHART
SILTY SAND

FIG No 8
W P 141-87-00A

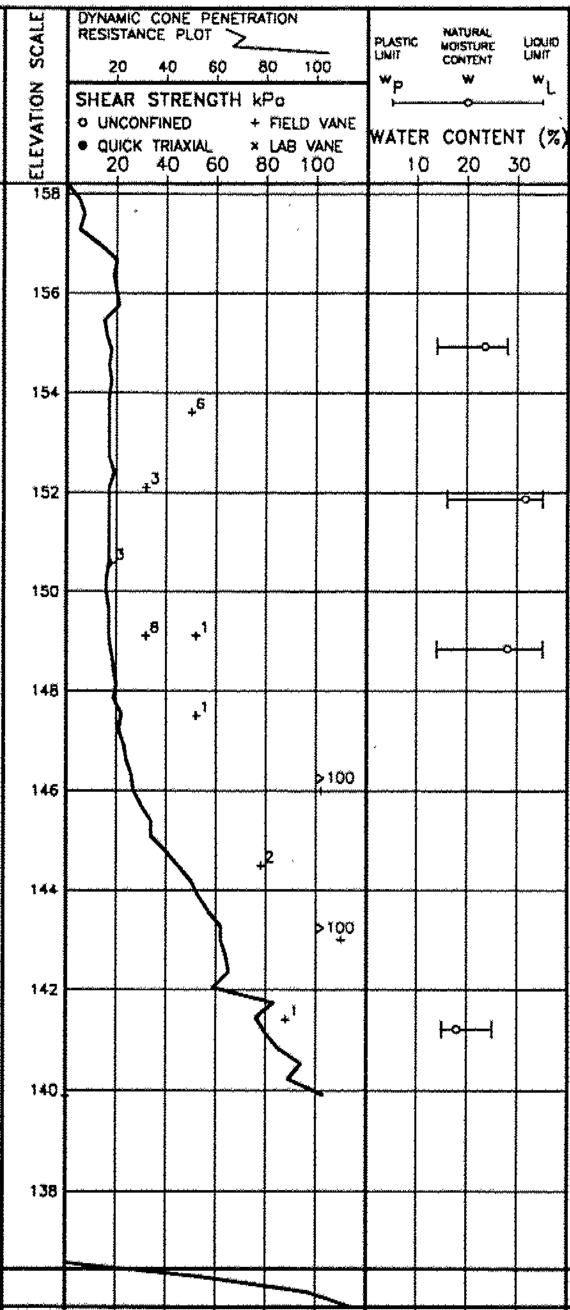
RECORD OF BOREHOLE No 14

METRIC

W.P. 141-87-00	LOCATION Coords: N 4 847 628, E 298 878		ORIGINATED BY M.M.
DIST 6	HWY 407	BOREHOLE TYPE Hollow Stem Auger, Cone Penetration Test	COMPILED BY M.M.
DATUM Geodetic	DATE 91/07/15		CHECKED BY B.I.

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
158.2	GROUND SURFACE								
0.0	SILTY SAND, COMPACT, TRACE ORGANICS, BROWN	1	SS	0		2	75	18	5
		2	SS	16					
	GREY	3	SS	7					
155.3 / 2.9	CLAYEY SILT, TRACE SAND, FIRM	4	SS	5	19.5	0	0	63	37
		5	SS	4					
		6	TW	PH					
152.6 / 5.6	CLAYEY SILT, TRACE SAND, TRACE GRAVEL (GLACIAL TILL), VERY SOFT TO VERY STIFF	7	SS	1		1	12	37	50
		8	SS	1					
		9	SS	1		3	15	36	46
		10	SS	2					
		11	TW	PH					
		12	SS	4		2	17	53	28
		13	SS	5					
		14	SS	6	21.2	2	14	52	32
		15	SS	7					
		16	SS	11		1	19	53	27
136.4		17	SS	29					
21.8	End of Borehole								
135.6 / 22.6	End of Cone Test								

GROUND WATER CONDITIONS: /30cm



91/07/12

* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	138.2

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

15-○-5 (%) STRAIN AT FAILURE (20 above, 10 below)

RECORD OF BOREHOLE No 15

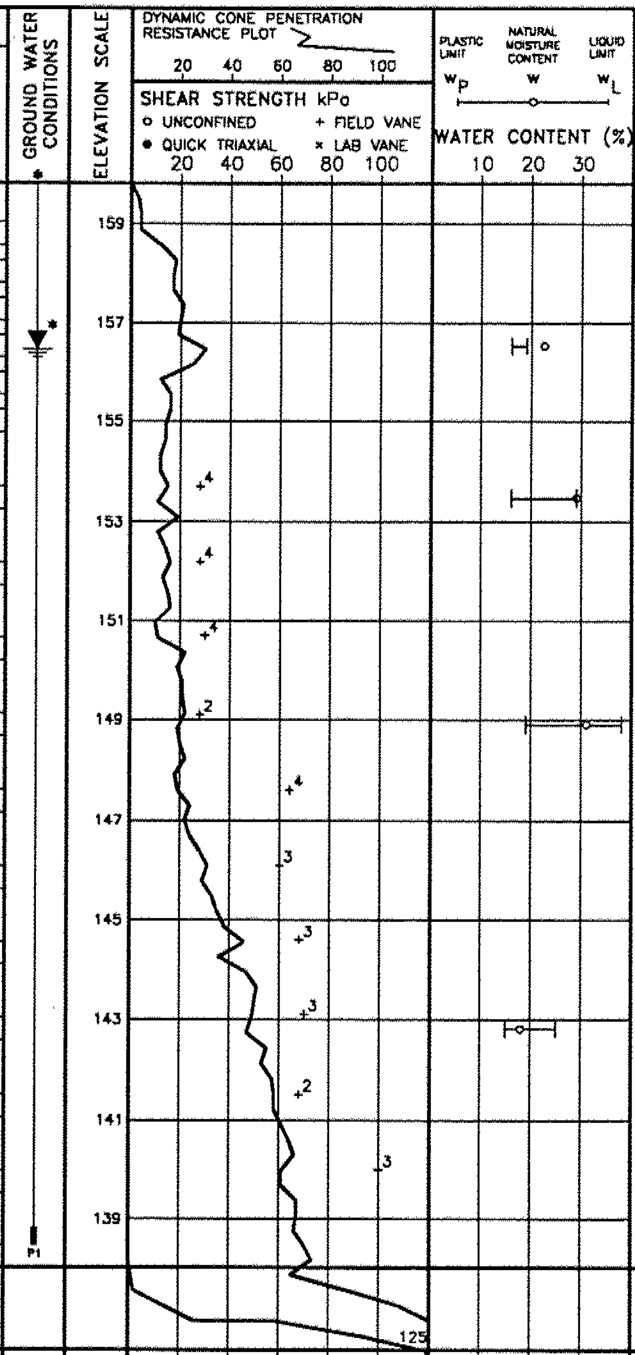
METRIC

W.P. 141-87-00 | LOCATION Coords: N 4 847 528, E 298 538 | ORIGINATED BY M.M.

DIST 6 HWY 407 | BOREHOLE TYPE Hollow Stem Augers, Cone Penetration Test | COMPILED BY M.M.

DATUM Geodetic | DATE 91/07/17 | CHECKED BY B.I.

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
159.8	GROUND SURFACE					
0.0	TRACE ORGANICS; SILTY SAND LOOSE TO COMPACT; BROWN / GREY	1	SS	4		10 68 9 13
		2	SS	13		
156.9		3	SS	13		
2.9	CLAYEY SILT TRACE SAND SOFT TO STIFF	4	SS	9		0 3 84 13
		5	SS	2		
		6	TW	PH		
152.9		7	SS	2		
6.9	CLAYEY SILT TRACE SAND TRACE GRAVEL (GLACIAL TILL) VERY SOFT TO FIRM	8	SS	1		
		9	SS	1		
		10	SS	1		1 8 36 55
		11	SS	2		
		12	TW	PH		
		13	SS	6		
		14	SS	6	20.6	4 8 53 35
		15	SS	4		
		16	SS	3		
138.0		17	SS	9		0 22 61 17
21.8	End of Borehole					
135.7						
24.1	End of Cone Test					



91/07/29
* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	143.3

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

$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 17

 METRIC

W.P. 141-87-00 LOCATION Coords: N 4 847 549, E 298 618 ORIGINATED BY M.M.

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Augers, Wash-boring COMPILED BY M.M.

DATUM Geodetic DATE 91/07/18 CHECKED BY B.I.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
160.1	GROUND SURFACE									
0.0	TRACE ORGANICS; SILTY SAND, VERY LOOSE TO COMPACT; BROWN / GREY	1	SS	14			19	72	6	3
		2	SS	19	158					
		3	SS	13						
		4	SS	4			0	1	91	8
155.7		5	SS	2	156					
4.4	CLAYEY SILT, TRACE SAND, VERY SOFT	6	SS	0						
		7	SS	0	154		1	2	37	60
		8	TW	PH	152					
		9	SS	1						
150.0					150					
10.1	CLAYEY SILT, TRACE SAND, TRACE GRAVEL (GLACIAL TILL), VERY SOFT TO HARD	10	SS	1			10	24	38	28
		11	SS	3	148					
		12	SS	5	146		1	11	52	36
		13	TW	PH	144					
		14	SS	8						
		15	SS	9	142					
		16	SS	9	140		1	12	53	34
		17	SS	14	138					
		18	SS	17	136					
		19	SS	27						
		20	SS	24	134	21.0	1	1	65	33
		21	SS	11	132					
		22	SS	30	130		2	34	51	13

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%): 10 20 30

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued

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

20 / 15 -o- 5 / 10 (%) STRAIN AT FAILURE

Continued

RECORD OF BOREHOLE No 17

METRIC

W.P. 141-87-00 LOCATION Coords: N 4 847 549, E 298 618 ORIGINATED BY M.M.

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Augers, Wash-boring COMPILED BY M.M.

DATUM Geodetic DATE 91/07/18 CHECKED BY B.I.

Continued

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
30.5		23	SS	11								
128.6 / 31.5	HETEROGENEOUS MIXTURE OF CLAY, SILT AND SAND TRACE GRAVEL FIRM	24	SS	8		128			4	29	55	12
127.1 / 33.0	CLAYEY SILT TRACE SAND HARD	25	SS	106		126						
		26	SS	50			plotted	23.3				
		27	SS	50		124						
		28	SS	55		122						
121.0 / 39.1	HETEROGENEOUS MIXTURE OF CLAY, SILT AND SAND TRACE TO SOME GRAVEL HARD	29	SS	39		120	plotted	20.3	0	1	53	46
		30	SS	61		118						
		31	SS	176								
		32	SS	120	/15cm	116			34	38	22	6
		33	SS	200	/5cm	114						
112.4 / 47.7	CHUNKS OF SHALE	34	SS	200	/8cm		plotted		2	23	50	25
	End of Borehole											
	* Water Level Not Established											

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10, 20, 30; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 18

METRIC

W.P. 141-87-00 | LOCATION COORDS: N 4 847 606, E 298 587 | ORIGINATED BY M.M.

DIST 6 HWY 407 | BOREHOLE TYPE HOLLOW STEM AUGERS | COMPILED BY A.H.

DATUM GEODETIC | DATE 91/05/15 | CHECKED BY B.I.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	WATER CONTENT / LIMITS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
160.1 / 0.0	SILTY SAND COMPACT, BROWN	1	SS	15						
		2	SS	12			8	83	8	1
157.2		3	SS	11	plotted	20.0				
2.9	CLAYEY SILT TRACE SAND FIRM TO STIFF, GREY	4	SS	10						
		5	SS	6	plotted	19.3	0	0	74	26
154.5		6	SS	5						
5.6	CLAYEY SILT TRACE SAND TRACE GRAVEL (GLACIAL TILL) SOFT TO HARD	7	SS	5			0	1	58	41
		8	SS	3	plotted					
		9	TW	PH						
		10	SS	3			0	5	32	63
		11	SS	6						
		12	SS	8	plotted		0	9	54	37
		13	SS	9						
		14	SS	6						
		15	TW	PH						
		16	SS	11						
		17	SS	13	plotted		20	42	29	9
		18	SS	33						
		19	SS	40						
		20	SS	25			1	7	45	47
		21	SS	15			0	2	86	12
130.2 / 29.9		22	SS	3						

Elevation scale: 158, 156, 154, 152, 150, 148, 146, 144, 142, 140, 138, 136, 134, 132, 130

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100. Shear Strength kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. Water content (%): 10 20 30; Plastic limit w_P, Natural moisture content w, Liquid limit w_L.

Continued

Continued

+³, ×⁵ : Numbers refer to Sensitivity

15-○-5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 18

METRIC

W.P. 141-87-00 LOCATION COORDS: N 4 847 606, E 298 587 ORIGINATED BY M.M.

DIST 6 HWY 407 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY A.H.

DATUM GEODETIC DATE 91/05/15 CHECKED BY B.I.

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
30.5	Continued: HETEROGENEOUS MIXTURE OF CLAY, SILT AND SAND TRACE GRAVEL VERY STIFF TO HARD	23	SS	19							
		24	SS	44	128	o H	22.9	11	20	52	17
		25	SS	90	126						
		26	SS	63				1	19	70	10
		27	SS	51	124						
		28	SS	50	122	I o		0	10	83	7
		29	SS	100	120						
		30	SS	78	118						
		31	SS	164							
		32	SS	127	116	o H		22	56	15	7
		33	SS	144	114						
		34	SS	169	112						
110.9	CHUNKS OF SHALE										
49.2	End of Borehole * Water Level Not Established										

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100. PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30. GROUND WATER CONDITIONS. STRAT PLOT. REMARKS & GRAIN SIZE DISTRIBUTION (%).

$+^3$, $\times^3$: Numbers refer to Sensitivity   15 ◇ 5 (20 / 10) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

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RECORD OF BOREHOLE No 19

METRIC

W.P. 141-87-00 LOCATION Coords: N 4 847 578, E 298 713 ORIGINATED BY M.M.

DIST 6 HWY 416 BOREHOLE TYPE Hollow Stem Augers, Cone Penetration Test COMPILED BY A.H.

DATUM Geodetic DATE 91/06/16 CHECKED BY B.I.

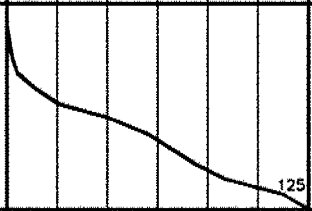
ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR SA SI CL
160.3	GROUND SURFACE							
0.0	SILTY SAND COMPACT	1	SS	11				10 80 10 0
		2	SS	19				
158.2 / 2.1	CLAYEY SILT TRACE SAND STIFF (BROWN / GREY)	3	SS	19				
		4	SS	11	▼			0 8 75 17
		5	SS	10		plotted		
		6	SS	9				0 0 82 18
154.8 / 5.5	CLAYEY SILT TRACE SAND TRACE GRAVEL (GLACIAL TILL) VERY SOFT TO STIFF	7	SS	3				
		8	TW	PH				
		9	SS	1	/30cm	plotted		0 5 40 55
		10	SS	1	/30cm			
		11	TW	PH				
		12	SS	4				
		13	SS	8		plotted		1 11 53 35
		14	SS	13				
		15	SS	14				
		16	SS	4				
138.5		17	SS	5		plotted	21.7	8 21 41 30
21.8	End of Borehole							
134.4 / 25.9	End of Cone Test							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

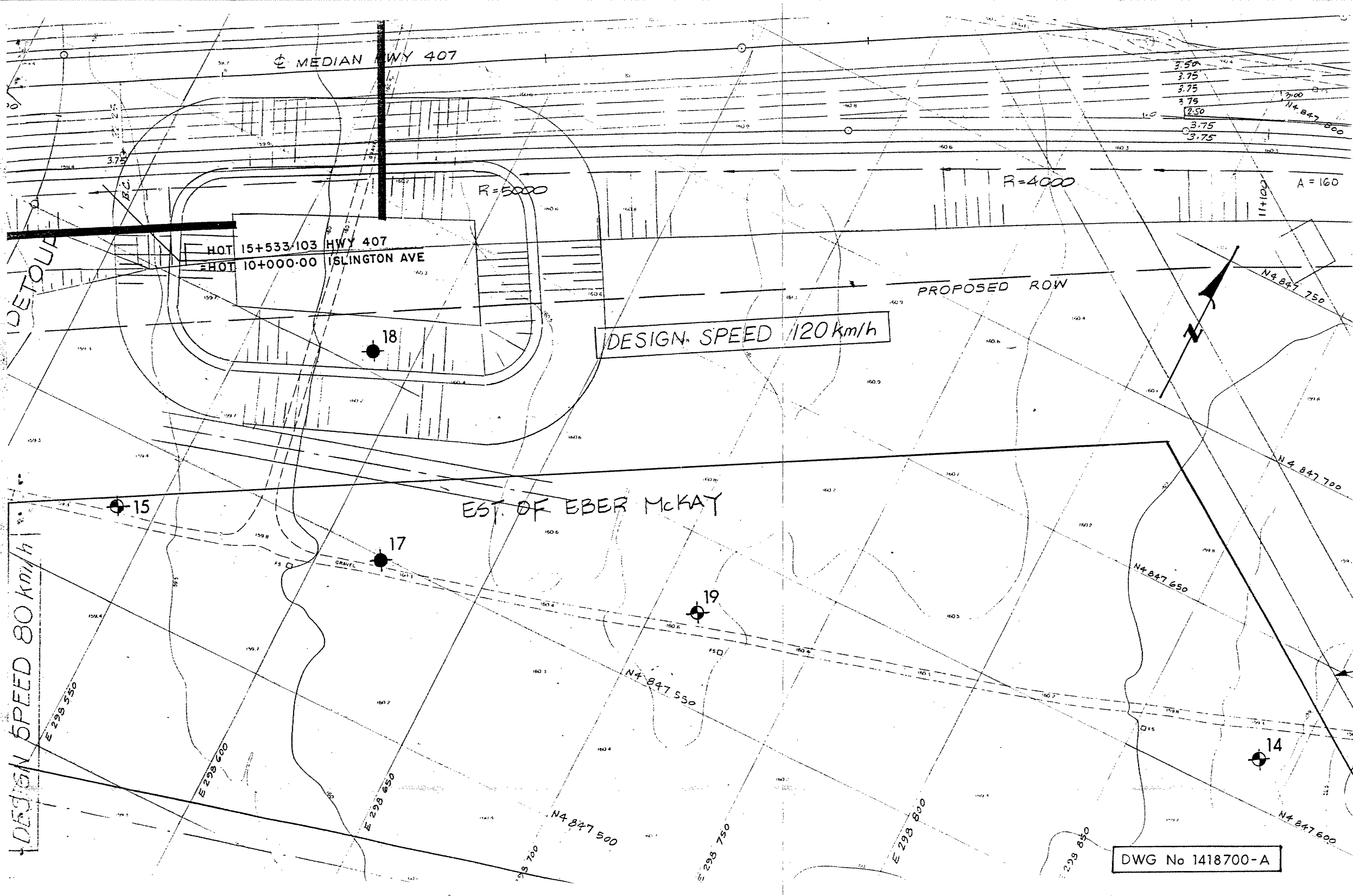
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

ELEVATION SCALE: 160, 158, 156, 154, 152, 150, 148, 146, 144, 142, 140



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

15-◇-5 (20 above, 10 below) (%) STRAIN AT FAILURE



℄ MEDIAN HWY 407
R=5000
R=4000
A = 160
HOT 15+533.103 HWY 407
=HOT 10+000.00 ISLINGTON AVE
DETOUR
PROPOSED ROW
DESIGN SPEED 120 km/h
DESIGN SPEED 80 km/h
EST. OF EBER McKAY
18
15
17
19
14
N4 847 750
N4 847 700
N4 847 650
N4 847 600
N4 847 550
N4 847 500
N4 847 800
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E 298 650
E 298 700
E 298 750
E 298 800
E 298 850
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STR. SITE No.

HWY. No. 407

LOCATION Watermain Relocation at 407 & Islington Ave.

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

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STABILITY STUDY
PROPOSED GAS MAIN RELOCATION
ISLINGTON AVENUE - FUTURE HIGHWAY 407
TOWN OF VAUGHAN, ONTARIO

Ref. No. G-91.0106
September 1991

Prepared for:

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APPENDIX

CONTENTS (Continued)

ENCLOSURES

REPORT

ON

STABILITY STUDY

FOR

PROPOSED GAS MAIN RELOCATION

ISLINGTON AVENUE - FUTURE HIGHWAY 407

TOWN OF VAUGHAN, ONTARIO

1.0 INTRODUCTION

Geo-Canada Ltd. has been retained by Consumers' Gas Company to conduct a Geotechnical Investigation at the site of a gas main installation. This installation will involve constructing a gas main at a depth of about 14 m. The objectives of the study have been to determine the subsurface conditions in the study area, and to prepare recommendations regarding the geotechnical design of the installation.

2.0 DESCRIPTION OF SITE AND PROPOSED CONSTRUCTION

The site of the proposed construction is located on the east side of Islington Avenue, about 500 m north of Steeles Avenue West in the Town of Vaughan.

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In the near future, it is proposed to construct the new Highway 407 to pass under Islington Avenue in an east-west direction. The finished road grade of Highway 407 in that area will be about 8 m below the existing grades. In order to accommodate the proposed construction, it will be necessary to relocate the gas main which lies on the east side of Islington Avenue to an alignment which is parallel to the existing pipeline route, but which is about 40 m further to the east. As the relocated gas main will have to underlie Highway 407, it will be necessary to set the pipeline at an invert elevation of 146.0 m. To relocate the gas main, an excavation approximately 13 to 14 m deep will therefore be required. Presently, the site and the surrounding area are used for agricultural purposes.

Following the installation of the relocated gas main, Islington Avenue will be temporarily diverted above the main to facilitate the construction of a bridge.

Running in a north to south direction at about 200 m east of Islington Avenue is an existing unpaved road which is used as an access route by the local farmers. This road will remain open during the gas main relocation work. It is expected that the excavated materials from the gas main construction will be stockpiled in the area west of the road.

Figure 1, attached shows the site, the route of the proposed gas main, and the area for stockpile of the excavated soil. The works area will be entirely within the right of way of Highway 407, and is bounded by private properties on the north and south sides.

.../...

Two methods of construction are being considered. The first method is by open excavation. In this case, it is proposed that the general excavation will be taken to El. 149 m, i.e. about 11 m below present grade and the gas main will be installed in a 3 m deep trench at the base of the general excavation. In the second method, access pits will be excavated at the two ends of the relocated section of gas main to allow the gas main to be installed in tunnel.

3.0 METHODOLOGY OF STUDY

The study consisted of a field investigation to establish the soil and groundwater conditions at the site, laboratory tests to determine the index and engineering properties of the soils, and geotechnical analyses to determine a safe slope angle for cuts as well as design parameters for the tunnel and work shaft.

3.1 Field Investigation

Considerable geotechnical information was available for the general area from previous geotechnical studies carried out for the proposed Highway 407. In order to provide specific data for the geotechnical design of the pipeline, three additional boreholes were put down at the site to confirm the soil stratigraphy and properties at the actual location of the gas main construction. The locations of the boreholes drilled for this study (Boreholes G1, G2 and G3) and the previously drilled boreholes are shown on Figure 1, attached. The boreholes were laid out in the field with the assistance of a site plan provided to us by Consumers Gas. The borehole elevations were established by surveying with respect to a Geodetic Benchmark located on the west abutment wall of the CN Railway bridge just south of the site. The elevation of this benchmark is 158.680 m above the geodetic datum.

.../...

The boreholes were drilled on June 25 to 27, 1991, using a Bombardier mounted power auger drill rig equipped with hollow stem augers. An engineer from our office supervised the fieldwork and logged the soil profile. In the boreholes, samples were taken at 1.5 m intervals of depth using the standard penetration test method. In cohesive soils and where the standard penetration blow counts (SPT 'N'-values) were less than 15 blows/0.3 m, in situ vane tests were carried out to measure the undrained shear strength of the soils. Several relatively undisturbed soil samples were taken by pushing thin walled 'Shelby' tube samplers into the soil.

At the completion of the boreholes, in each borehole two piezometers were installed to monitor the groundwater level. One of the piezometer tips was installed at a relatively shallow depth and the other near the base of the borehole in order to determine the direction of the groundwater flow and the seepage gradient at each location.

The water levels in the piezometers were read on three different occasions during the month following the completion of the drilling.

3.2 Laboratory Testing

The samples were brought to our laboratory where they were re-examined by a senior engineer. Representative samples were selected for index and strength tests. The index tests included the measurement of natural moisture contents, consistency (Atterberg) limits, particle size distribution, and unit weight. The soil samples recovered in the Shelby tubes were tested in unconfined compression to determine their undrained or short term shear

.../...

strength. Consolidated undrained triaxial compression tests with pore pressure measurements were also performed to establish the long term strength parameters of the cohesive soils.

The results of the laboratory tests are shown on Figures 2 to 8, and also on the Borehole Logs.

3.3 Stability Analysis

A series of analyses was carried out to evaluate the stability of the proposed excavation with various assumed slope angles and depths.

The analyses were carried out with the assistance of a computer programme (PC-SLOPE, by Geo-Slope International Ltd., Calgary, Alberta) which uses the generalized limit equilibrium method. This programme can calculate the factor of safety (F.S.) of any slope by a variety of widely accepted analytical methods (e.g. Janbu, Bishop Simplified, Morgenstern and Price, etc.) along a wide range of potential sliding surfaces. The F.S.'s quoted in this study however, are for circular sliding surfaces using the "Simplified Bishop Method".

The slope angles and soil profiles used in the analyses are shown on Figures 11 to 14. For each slope angle a large number of trial failure surfaces were analyzed in order to establish the minimum F.S. for that profile. Both the short and long term conditions were analyzed to examine the F.S. immediately after the excavation was completed (short term case), and at some time later when the pore water pressure in the soil had adjusted itself to the new stress conditions (i.e. long term case). For the short term analyses, the undrained shear

.../...

strength of the cohesive soils were used, ($\phi = 0$ analysis), while for the long term condition, the effective shear strength parameters established in the triaxial compression tests were employed.

4.0 RESULTS OF STUDY

4.1 Subsurface Conditions

A study of the existing borehole information (M.T.O. W.P. 88-78-18, Boreholes 1 to 6, A5, A6) revealed that the stratigraphy at the site consists of loose to compact sand and silt strata overlying a layered deposit of soft to stiff clayey silt or silty clay, which in turn overlies clayey silt (glacial till) of firm to very stiff consistency followed by compact to very dense silt and sand. The boreholes drilled for this study confirmed the general stratigraphy described above.

The details of the subsurface conditions are shown on the Borehole Logs, Enclosures 1 to 3B. For the sake of completeness the logs of the boreholes drilled by others in the general vicinity of the construction site are also attached to this report as Enclosures 4 to 12. Two simplified inferred soil profiles drawn through the site in an east-west direction are shown on Figures 9 and 10.

In the following paragraphs the relevant properties of the various soil strata are briefly discussed. In this report, clayey soils which have liquid limits between 35 and 50% are classified as silty clays, while soils with liquid limits below 35%, and a plasticity index greater than 7 are classified as clayey silts.

.../...

4.1.1 Sand

A 1.0 to 2.7 m thick layer of sand was encountered in each borehole drilled for this study.

The composition of the sand ranges from a relatively poorly graded fine to medium sand to gravelly sand. Figure 2 shows three grading curves of the sand. The tested samples are composed of 2 to 40% gravel, 48 to 84% sand, and 2 to 12% silt and clay. Samples from previously drilled boreholes were found to contain 5 to 25% gravel.

The moisture contents of the sand are between 9 and 11%.

The SPT 'N'-values recorded in the sand vary from 3 to 20 blows per 0.3 m, indicating very loose to compact conditions.

Based on its grain size distribution and compactness condition, the effective angle of shearing resistance (φ') of the sand is estimated to be 33°.

4.1.2 Silt and Sandy Silt

A layer of silt or sandy silt underlies the sand in every borehole. Typically it is an approximately 1.5 m thick layer although locally (e.g. Boreholes 1 and 2) it attains a greater thickness (3.5 to 7 m).

.../...

This is a poorly graded soil, as can be seen from the two grading curves shown on Figure 3. These two samples contain 3 to 15% sand, 77 to 89% silt, and 8% clay. Tests done by others found 21 to 35% sand in the silt. It also contains occasional clayey silt seams. The deposit exhibits no plasticity, it is dilatant and moisture contents range from 21 to 22%.

SPT 'N'-values of 8 to 16 blows/0.3 m, were recorded in the silt during the present investigation and up to 26 during the previous studies. These results indicate loose to compact conditions.

The effective angle of shearing resistance of the sandy silt is estimated to be 30°.

4.1.3 Clayey Silt to Silty Clay

This soil unit underlies the sandy silt and is 4.3 to 5.3 m thick at the new borehole locations (Boreholes G1, G2 and G3). In Boreholes 1 and 2, which were put down previously, the deposit is up to 10 m thick. In Boreholes G2 and G3, a second layer of similar deposit was found below El. 140 m.

This is a layered deposit consisting of alternate layers of clayey silt and silty clay, and occasional silt seams. The individual layers are a few millimetres to a few centimetres thick. Due to this fine layering, it was not practical to test separately the silt and the clay layers.

.../...

Figure 4 shows three typical grading curves of this deposit. The tested samples are composed of 0 to 2% sand, 34 to 74% silt, and 26 to 65% clay. Tests carried out by others found a trace of sand (0 to 3%), 32 to 82% silt, and 11 to 68% clay.

The natural moisture contents of this layered deposit are between 22 and 34%. Its liquid limits, plastic limits and plasticity indices are 21 to 47%, 15 to 18%, and 6 to 29, respectively. One sample taken from Borehole G1 was found to be non plastic. These test results are very similar to those found by others and they indicate clayey silt or silty clay of low to medium plasticity.

The SPT 'N'-values of this deposit range from 2 to 8 blows/0.3 m. Occasionally higher values (up to 16) were recorded in some of the previously drilled boreholes. Undrained shear strength values, measured by in situ vane shear tests, range from 28 to over 100 kPa; most of the values are between 28 and 44 kPa. The sensitivity (the ratio of undisturbed to remoulded shear strength) of the soil is between 1.4 and 2.5. An undrained shear strength of 35 kPa was obtained in an unconfined compression test and the same soil sample had a unit weight of 21.7 kN/m^3. These results indicate a soft to stiff consistency.

A set of three consolidated undrained triaxial compression tests with pore pressure measurement obtained an effective cohesion (c') of 5 kPa and an effective shearing angle, ϕ', of 24° for the layered clayey silt to silty clay (Figure 7). A previous test carried out by others, gave a ϕ' angle of 29° with no effective cohesion (c' = 0).

.../...

4.1.4 Clayey Silt to Silty Clay (Glacial Till)

This glacial deposit underlies the layered clayey silt to silty clay and extends to between about El. 140 and 134. In Borehole G3, (at El. 146 m) the clayey silt is interbedded with an approximately 4 m thick layer of silt. A second clayey silt till deposit was also found at the bottom of Borehole G2 at about El. 134 m.

Figure 5 shows two grading curves of this soil unit. It is composed of 1 to 22% sand, 40 to 50% silt, and 28 to 59% clay. It also contains a trace of gravel.

This soil unit has moisture contents ranging from 14 to 31% and its liquid limits, plastic limits, and plasticity indices are 27 to 40%, 16 to 20%, and 11 to 20, respectively.

The SPT 'N'-values observed in the clayey silt till during the present investigation vary from 1 to 12 blows/0.3 m. In situ vane shear tests obtained undrained shear strengths values which increased with depth from 28 to over 100 kpa. The sensitivity of the soil is between 1.2 and 2.4. These results indicate that the clayey silt till is soft to very stiff. Previous investigations have found that this soil unit is soft to hard, with 'N'-values ranging from 2 to over 50 blows/0.3 m.

In a set of consolidated undrained triaxial compression tests, with pore pressure measurements an effective cohesion, c', of 10 kPa and an effective shearing angle, ϕ', of 28^o were obtained (Figure 8). Previous investigations reported a c' of 10 kPa and a ϕ' of 30^o for this deposit.

.../...

4.1.5 Silt

A loose to compact silt deposit was encountered in Boreholes G1 and G3. In Borehole G1 it underlies the clayey silt till at El. 134± m, while in Borehole G3 it is interbedded in the till between about El. 146 and 141.5 m. The silt contains thin seams of sandy silt and clayey silt.

Three samples of this soil were tested and found to contain 0 to 2% gravel, 9 to 22% sand, 59 to 73% silt, and 13 to 26% clay. These grading curves are shown in Figure 6.

The silt is saturated (moisture contents of 18 to 20%) and it is dilatant. The clayey silt seams give the soil a slight plasticity (liquid limit 22%, plastic limit 17%, and plasticity index of 5).

The 'N'-values recorded in the silt ranged from 6 to 12 blows/0.3 m, indicting loose to compact conditions.

4.1.6 Groundwater Conditions

The groundwater levels observed in the piezometers are shown on the Borehole Logs and are summarized in Table 1.

The results show three different phreatic and piezometric surfaces within the soil profile. The piezometers in the near surface sand, sandy silt and the layered clayey silt and silty clay recorded a water level between El. 157.9 and 158.3 m. The piezometric head in the clayey silt till appears to be at El. 150.8 m. The piezometers installed below the clayey silt till recorded a piezometric surface at El. 142.3 to 142.7 m. These results agree with the water

.../...

levels observed in the other investigation carried out for Highway 407. These observations indicate that the groundwater has a pronounced vertically downward flow component.

In the stability analyses, the piezometric heads in the near surface soils (sand, sandy silt, and the layered clayey silt to silty clay), in the clayey silt till, and in the materials below the clayey silt till are taken as El. 158, 151 and 142, respectively.

4.2 Stability Analysis Results

The results of the stability analyses are shown in Figures 11 to 14.

Figure 11 shows an excavation with 2.5H:1V side slopes to El. 146 m. It also shows the soil stratigraphy and the soil parameters used in the analysis as well as the F.S. in the short term (i.e. when the cut reaches its maximum depth). The section shown in Figure 11, was taken through Borehole G1 because the weakest soils were recorded in this borehole. In the analysis of the short term condition both the layered clayey silt and the clayey silt till were treated as purely cohesive soils (i.e. $\phi' = 0$), possessing only undrained shear strength with values as shown on Figure 15.

Figure 15 shows the undrained shear strength values obtained by the field vane, laboratory vane and unconfined compression tests. Also shown on this figure is the shear strength profile used in the stability analyses except where the layered clayey silt extends below El. 148 m the strength of this material was taken as 30 kPa throughout the deposit. In view of the low plasticity indices of the soils, no correction has been applied to the vane shear test results.

.../...

The minimum short term F.S. for the proposed 2.5:1 cut is 1.17 which is marginally adequate provided that the slope is monitored during construction. The critical potential slip surface associated with this minimum F.S. is shown on Figure 11. As shown it daylights at some distance above the toe of the cut, and is situated totally above the base of the cut. It was found that the F.S. of sliding surfaces which extend deeper than about El. 149± m increase due to the increase of the shear strength with depth. Although Figure 11 shows the base of the cut at El. 146 m, it was found that the minimum F.S. would not increase if the base of cut is raised to El. 149 m and a 3 m deep trench with cross braced shoring is excavated below the base of the general excavation level.

It should be noted however that this short term F.S. will diminish with the progression of time at a rate which is governed by the rate of the pore water pressure dissipation in the soil. The F.S. will approach the long term F.S. as discussed further below.

In the event that the cut slope is steepened to 2:1, the minimum short term F.S. drops to 1.04. Since Islington Avenue has to remain open to the traffic and in view of its proximity to the edge of the excavation this short term F.S. is inadequate.

Figure 12 shows the F.S. of the same 2.5:1 cut in the long term, i.e. after the negative pore water pressures in the soil deposits have dissipated and adjusted themselves to the new stress conditions in the soil. The soil parameters used in the analysis are also shown on the Figure.

.../...

For the long term condition, the water level in the layered clayey silt deposit was assumed to be at the surface of this stratum. This is a valid assumption since it will be necessary to install wellpoints around the excavation to stabilize the surface soils (see Section 5.9).

As is often the case with clay cuts, the long term condition is more critical due to the generally low effective angle of shearing resistance (φ') of the clayey soils. In the present case the minimum long term F.S. for the 2.5:1 cut is 1.02, indicating only marginally stable conditions. However, since the construction period is expected to be short (approximately two months) it is unlikely that the pore water pressures would completely dissipate within this period of time. The actual F.S. at the end of the construction is therefore expected to be higher, probably around 1.1.

We have also analyzed the stability of 7 to 8 m high temporary cuts (i.e. base elevation at 152 m) using 2H:1V side slopes. The results are shown in **Figures 13 and 14**. We found that immediately after the cuts are made, the computed minimum short term F.S. is 1.28. In the long term however, the calculated minimum F.S. is only 0.82.

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5.0 DISCUSSION OF RESULTS

In this section of the report, various alternative construction schemes are examined and the safety and possible restrictions imposed on these methods are discussed.

5.1 Overview of Design Alternatives

The relocated 300 mm diameter gas main will be laid at El. 146 m, i.e. about 14 m below present grade.

In consultation with the Client, a number of design (construction) alternatives were examined:

1. Open cut excavation to El. 146 m;

2. Open cut excavation to El. 149 m, combined with a 3 m deep braced excavation to El. 146 m;

3. Tunnelling with access shafts constructed by the open cut method to El. 152 m and a vertical shaft with shoring between El. 152 and 146 m; and

4. Tunnelling with shored vertical shafts from present grade to El. 146 m.

These various alternatives are examined in the following sections of this report.

.../...

There are a number of conditions which if met, impose restrictions on the construction. These are:

- During construction, both Islington Avenue and the unpaved farm road located about 190 m to the east will have to be kept open for traffic, thus restricting the effective construction area to about 150 m by 190 m in plan.

- The stockpiling of the excavated material will be allowed only within the above construction area.

- The stockpiled material will have to be placed in a stable configuration.

- The excavation will have to be backfilled with earth fill material, with a degree of compaction not less than 95% of the standard Proctor maximum dry density (S.P.M.D.D.) to the finished grade of the future Highway 407.

The effect of these restrictions on the proposed construction were analyzed and are discussed when examining the various alternatives in the following sections of this report.

5.2 Overview of Geotechnical Conditions

The subsurface profile, details of which are presented on the individual Borehole Logs and on Figures 9 and 10, can be summarized as follows. Covered by a thin veneer of topsoil, the surface deposits consist of granular cohesionless soils, comprising gravelly sand, sand, sandy

.../...

silt and silt in a loose to compact condition. Typically, the combined thickness of these deposits is 4 m however locally, especially near Islington Avenue, they extend deeper (up to 7 m).

The granular surficial soils are underlain by two major clayey (cohesive) soil deposits comprising a layered clayey silt and silty clay, and a clayey silt till stratum. These deposits extend to between El. 135 and 130 m and have a soft to stiff consistency. For the purpose of the design, the undrained shear strength of these two strata was taken as 30 kPa above El. 148 m, and 40 to 70 kPa below El. 148 m (see Figure 15).

Below about El. 135 to 130 m, the subsoil is compact to very dense silt, sandy silt, or silty sand.

The design and performance of the excavation will be governed by the properties and behaviour of the two major clayey deposits which typically occupy the soil profile between about El. 155 and 135 m.

5.3 Selection of Factor of Safety

Because neither the properties of the materials nor the loading conditions can be accurately established, all engineering works incorporate a safety factor as a safeguard against unknown or unexpected conditions. This is particularly true for earthworks due to variations in the soil conditions and the resulting scatter in the soil properties. Safety factors normally used in earthworks range between 1.2 and 1.3. For temporary works (e.g. construction) lower safety

.../...

factors can be accepted provided that the behaviour of the soil is carefully monitored throughout the duration of the construction. With appropriate monitoring systems in place, theoretical safety factors as low as 1.01 can be accepted as long as provisions for quick remedial action, if necessary, are available.

In the present case for the proposed construction alternatives, the following safety factors will have to be analyzed and their adequacy examined:

- the stability of the side slopes of open cut excavations;
- the stability of the base of the excavation against bottom heave; and
- the stability of the face of the tunnel.

The factor of safety of the side slopes of an open cut excavation is affected by the geometry of the cut, (e.g. the height and slope angles) the shear strength properties of the soil, the position of the groundwater table or piezometric surface, and in case of cohesive soils, also by time. The safety factor decreases with the increasing steepness and height of the slope. Similarly an increase in the height of the water table or the piezometric surface has a destabilizing effect on the slopes. The safety factor is also directly proportional to the shear strength of the soil. Furthermore for cut slopes in cohesive soils, the safety factor decreases with time. The rate at which the safety factor decreases is a function of the rate at which the pore pressures in the slope readjust themselves to the new stress conditions, unfortunately however, it is difficult, if not impossible to predict this with sufficient accuracy. Because of this uncertainty, it is customary to analyze the stability of slopes both for the short and long

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term using undrained shear strength for the short term, and effective shear strength parameters for the long term.

5.4 Excavated Material (Stockpiling and Recompaction)

An important aspect of construction that will have a bearing on the viability of some construction alternatives is the manner at which the excavated material can be stockpiled and re-used for the backfilling of the excavations.

The bulk of the excavated material will be clayey silt or silty clay. These materials have moisture contents often approaching the liquid limit of the soil and are also sensitive to disturbance. The sensitivity of the soil is generally between 1.5 and 2 indicating that the shear strength of the disturbed excavated material could be as low as half of its undisturbed shear strength. This will impose a limit on the maximum height to which the excavated material can be stockpiled at a reasonable slope angle of about 2 to 2.5H:1V.

Our analysis indicates that the maximum height to which the excavated material can be safely stockpiled (F.S. = 1.1) with 2.5 to 1 side slopes is 9 m. In order to assure the stability of the excavation the stockpile must be set back at least 30 m from the top edge of the excavation.

We have also examined the suitability of the excavated material to backfill the excavation. Since the natural moisture contents are generally well above the plastic limit of the clayey soils, it is unlikely that these materials can be compacted to densities higher than about 90% of the S.P.M.D.D. In order to provide adequate support for the future Highway 407, the

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degree of compaction will have to be not less than 95% S.P.M.D.D. It follows from the above that the excavated soils with the possible exception of the surficial sand and gravelly sand could not be re-used to backfill the excavations and that imported fill material will have to be used below El. 152± m. When evaluating the financial viability of any of the alternatives, this should be taken into consideration.

5.5 Open Cut Excavation to 146 m

We have examined the stability and the safety factor of an open pit excavation carried out with 2H:1V side slopes to El. 146 m. Our analysis indicates that the short term factor of safety for this alternative is only 1.04. Since this factor of safety is expected to decrease with time and since the edge of the excavation will be close to Islington Avenue, this factor of safety is inadequate, even if the slope is closely monitored during construction.

The minimum short term factor of safety for an excavation to the same depth but with 2.5H:1V side slopes, was found to be 1.17 (Figure 11). For the same slope, the long term factor of safety was calculated to be 1.02 (Figure 12). Assuming that the excavation will not be open for a period longer than two months, we estimate that the factor of safety during this period of time will not diminish to a value less than about 1.1. This factor of safety in conjunction with an adequate monitoring system is in our opinion, acceptable.

Our calculations indicate that there is insufficient room in the restricted construction site to stockpile all the excavated material while maintaining adequate separations between the excavation and the stockpile, and the excavation and Islington Avenue. However since a

.../...

large portion of the excavated material could not be re-used for backfilling, the stockpiling of all the excavated material on site will not be necessary and therefore, the open cut alternative is technically feasible but due to the cost of the backfilling, it may not be economical.

5.6 Open Cut Excavation to Elevation 149 m

This alternative was examined to determine if a reduction in the depth of the excavation will permit the use of steeper slope angles. The computer analysis however indicates that all potential failure surfaces which have safety factors less than 1.2, are located above El. 149 m and therefore reducing the depth of excavation to this level does not result in the desired benefit of using steeper slope angles. The possible advantage of this alternative is a reduction in the total volume of excavation and hence in the total volume of imported backfill needed. The minimum short and long term factors of safety are identical to those discussed in Section 5.5, above.

5.7 Tunnelling

At El. 146 m, the tunnel for the gas pipe is expected to be driven predominantly through cohesive clayey materials although it is possible that locally, silts similar to those encountered in Borehole G3 just below El. 146 m, may intrude into the tunnel opening. The shear strengths of the clayey silt or silty clay materials between El. 146 and 147 m appears to range 40 and over 100 kPa, with most probable values around 50 to 60 kPa (Figure 15). For these conditions, the stability factor

$$N = \gamma H / c_u$$

.../...

was calculated to range between 5.3 and 4.4. Experience indicates that where the stability number is 5 or less, the squeezing and loss of soil into the tunnel opening is insignificant. The face of tunnel could therefore be advanced by conventional jacking and boring methods. Where non cohesive silt zones are encountered, (e.g. Borehole G3) these would tend to flow into the tunnel opening. To maintain stability and to minimize loss of ground, during jacking a sufficiently long earth plug should be left in the liner at the head of the tunnel.

For the evaluation of the jacking force required the adhesion between the liner and soil can be obtained from the undrained shear strength profile shown on Figure 15.

5.8 Work Shaft

Two alternative shaft constructions were examined:

(a) combination of open cut and vertical shaft; and

(b) vertical shaft.

(a) The Client's proposal for the shaft was open cut excavation with 2H:1V side slopes to El. 152 m and an adequately shored vertical shaft below El. 152 m.

We have examined the stability of the upper open cut portion of the shaft and found that the minimum short term factor of safety is 1.28 and the minimum long term factor of safety of 0.82. Although the rate at which the safety factor will diminish cannot be estimated with sufficient accuracy, we are of the opinion that during the anticipated two month construction period, the factor of safety will not diminish to a value less than 1.1 which, in conjunction with an adequate monitoring system, is

.../...

considered to be acceptable. Since requirements for the compaction of the backfill above El. 152 m (the proposed grade of future Highway 407) are less strict, on site excavated material will most likely be suitable for backfilling. Under the road bed of the temporary detour of Islington Avenue, the top 1 m below the subgrade level should however be compacted to a density in excess of 95% S.P.M.D.D., some imported material in this zone may therefore be required.

As the volume of the excavated material is considerably less than for a fully open cut excavation, in our estimate, there should be sufficient room in the construction area to stockpile all the excavated material.

(b) A vertical work shaft could be sunk either from the present grade (El. 160) or from the base of the proposed cut to El. 152 m. The shaft will probably be 10 m long and 3 to 4 m wide. Support to the sides of the shaft could be provided by either steel sheet piling or soldier piles and lagging, both with waler beams and cross struts for lateral support. The toe of the sheet piles or the soldier piles should be at an adequate depth below the base of the excavation to assure safe toe support. The factor of safety against bottom heave due to the shear failure of the soil below the base of the excavation is 1.6 at El. 146 m. During the sinking of the shaft between El. 151 and 148 m the safety factor however will be only 1.2. At safety factors less than 1.5, some bottom heave and surface settlement adjacent to the excavation can be expected. If the shafts are located sufficiently far from existing structures (30 m or more) the settlements should have no adverse affect on the safety of these structures.

.../...

Soil parameters for the design of the shoring and the earth pressure distribution on the support system are given in Section 7.0 and are shown on Figure 17.

5.9 Dewatering of Excavations

The majority of the excavation will be through relatively impervious clay deposits. Both the rate and volume of water seepage through these materials are expected to be small and could be handled by gravity drainage into collector ditches installed along the base of the excavations and pumping from temporary sumps.

Moderate to heavy seepage can however be expected through the silt and the overlying sand strata as well as from possible silt zones in the clayey till, similar to that encountered in Borehole G3 at about El. 146 m. In addition to the heavier volume of water expected from these deposits, these soils will also be unstable as a result of the seepage forces. To preserve their stability and to prevent flowing ground conditions, the sand and silt strata will have to be stabilized by wellpoints. In the sand, conventional wellpoints would be sufficient, however the silt could be dewatered (stabilized) only by a vacuum wellpoint system. The wellpoints should be surrounded with a sand wick and the spacing of the wellpoints will have to be at close intervals (1.5 m or less). A specialist dewatering contractor, experienced with the installation and operation of vacuum wellpoint systems, should be employed.

.../...

6.0 CONCLUSIONS

From the foregoing discussion the following conclusions can be drawn.

(1) Open cut excavation to El. 149 or 146 m is feasible with 2.5H:1V side slopes with the following restrictions:

(a) The safety and the stability of the cut will have to be closely monitored using slope indicators and surface observation points.

(b) The bulk of the on-site excavated material will have to be removed due to inadequate room for the stockpiling of the material within the construction site and the unsuitability of the excavated material for backfilling below El. 152 m (proposed grade of future Highway 407).

(c) The excavated material should be stockpiled to a height no greater than 9 m and side slopes no steeper than 2.5H:1V.

(d) The minimum separation required between the toe of the stockpile and the top edge of the excavation is 30 m.

(2) Tunnelling by the jacking and boring method is technically feasible at El. 146 m.

.../...

(3) Open cut excavation for the work shaft to El. 152 m is feasible with 2H:1V side slopes provided that the behaviour of the slope is closely monitored for the entire duration of the excavation using slope indicators and surface observation points.

7.0 RECOMMENDATIONS

1. Maximum (steepest) side slopes for cuts and fills are:

    - cuts up to 8 m, 2H:1V
    - cuts up to 14 m, 2.5H:1V
    - fills up to 9 m, 2.5H:1V

2. During construction, the safety of the cut side slopes must be monitored by slope indicators and surface observation points. The tip of the slope indicator should be at or below El. 130 m. The slope indicator should be monitored daily during the excavation of the cuts and for at least a week after the excavation has reached its maximum depth. Depending on the movements observed, the frequency of the observations after this could be reduced, but not to less than once a week. Slope indicators will not be required for an adequately supported vertical shaft when not constructed in conjunction with open cut.

.../...

3. For the design of the shaft support, the following soil parameters can be used:

- unit weight of soil, $\gamma = 19\ kN/m^3$
- coefficient of lateral earth pressure

  $K_a = 0.4$

8.0 STATEMENT OF LIMITATION

The Statement of Limitation, as quoted in Appendix "A", is an integral part of this report.

GEO-CANADA LTD.

James Ng, P.Eng.

Ivan P. Lieszkowszky, P.Eng.

JN:IPL/jt

Ref. No. G-91.0106

TABLE 1

WATER LEVEL READINGS

Borehole	G1	G1	G2	G2	G3	G3
Piezometer Tip Elev.	132.2	156.1	134.1	154.5	141.3	154.5
Soil	Silt	Sand	Clayey Silt	Clayey Silt to Silty Clay	Clayey Silt (till)	Clayey Silt to Silty Clay
Date (1991)	Water Level					
	Elev. / Depth	Elev. / Depth	Elev. / Depth	Elev. / Depth	Elev. / Depth	Elev. / Depth
06.25					144.4 / 15.2	Dry
06.26	137.1 / 21.6	157.6 / 1.1			Dry	157.8 / 1.8
06.27	139.9 / 18.8	158.0 / 0.7	135.3 / 24.1	155.2 / 4.2	147.3 / 12.3	158.4 / 1.2
07.03	142.4 / 16.3	158.0 / 0.7	142.6 / 16.8	158.2 / 1.2	150.5 / 9.1	158.3 / 1.3
07.16	142.3 / 16.1	158.0 / 0.7	142.7 / 16.7	158.1 / 1.3	150.8 / 8.8	158.4 / 1.2
07.30	blocked	157.9 / 0.8	blocked	157.9 / 1.5	150.9 / 8.7	158.3 / 1.3

APPENDIX

APPENDIX
"A"
Statement of Limitation

The conclusions and recommendations in this report are based on information determined at the borehole locations. Soil and groundwater conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and conditions may become apparent during construction which could not be detected or anticipated at the time of the soil investigation.

The design recommendations given in this report are applicable only to the project described in the text, and then only if constructed substantially in accordance with details of alignment and elevations stated in the report. Since all details of the design may not be known to us, in our analysis certain assumptions had to be made. The actual conditions may, however, vary from those assumed, in which case changes and modifications may be required to our recommendations.

We recommend, therefore, that we be retained during the final design stage to review the design drawings and to verify that they are consistent with our recommendations or the assumptions made in our analysis. We recommend also that we be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the boreholes. In cases where these recommendations are not followed, the company's responsibility is limited to interpreting accurately the information encountered at the boreholes.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the design engineer. The number of boreholes may not be sufficient to determine all the factors that may affect construction methods and costs. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work.

E N C L O S U R E S

LOG OF BOREHOLE G1

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 26 1991

REF. No: G-91.0106
ENCL. No: 1

(m) ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) Gr Sa Si Cl
158.7	Ground Surface									
0.0	290 mm Topsoil GRAVELLY SAND trace to some silt brown loose to compact	1A/1B	SS	8	Seal			~11		38 60 (2)
					W.L. at 157.9 91.07.30	158				
		2	SS	20	Piezometer 2			~11		40 48 (12)
156.0 / 2.7	SILT some clayey silt layers grey loose				Seal	156				
		3	SS	8				~22		0 3 89 8
154.6 / 4.1	CLAYEY SILT to SILTY CLAY layered grey soft to firm	4	SS	7		154				
		5	TW	PH			O ~37	N.P. ~23	21.7	
		6	SS	3		152				
							+ 1.8			
		7	SS	3			+ 2.0			
						150				
149.3 / 9.4	CLAYEY SILT some sand trace of gravel grey soft (glacial till)	8	SS	2			+ 2.0			
148.0 / 10.7	Continued					148				

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE — 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30

LOG OF BOREHOLE G1 (CONT.)

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 26, 1991

REF. No: G-91.0106
ENCL. No: 1A

ELEV (m) / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	'N' BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (+ FIELD VANE)	WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) Gr Sa Si Cl
148.0	Continuation										
10.7	CLAYEY SILT some sand, trace of gravel, grey (glacial till)	T	9	SS	3						
		T						+ 1.3			
			10	SS	1		146				
		T						+ 2.0			
	sand seams		11	SS	3						
		T	12	TW	PH		144				
								+ 1.3			
		T	13	TW	PH				W ≈ 22 (Wp–WL)	21.4	0 22 50 28; C'=10kPa; Ø'=28°
	soft / stiff					W.L. 142.3 m 91.07.16		+ 1.4			
		T					142				
			14	SS	12						
		T						+ 1.2			
		T	15	SS	9		140				
								+ 1.4			
		T	16	SS	8						
		T					138				
137.4 / 21.3	Continued										

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

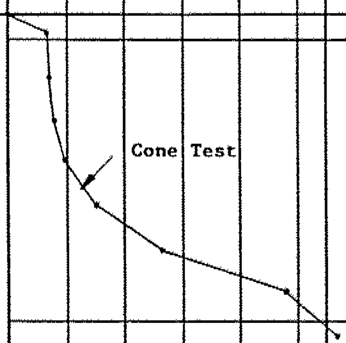
LOG OF BOREHOLE G1(CONT.)

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 26, 1991

REF. No: G-91.0106
ENCL. No: 1 B

SOIL PROFILE (m) ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT W_p / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) Gr Sa Si Cl
137.4	Continuation										
21.3	CLAYEY SILT as above stiff (glacial till)	T	17	SS	8						
							136				
		T	18	SS	10						
134.4		T									
24.3	SILT some sandy silt and clayey silt seams saturated compact		19	SS	12		134				0 9 73 18
132.2			20	SS	12	Piezometer 1					
26.5	END OF BOREHOLE						132				
							130				
129.8											
28.9	END OF CONE TEST										



Date (1991)	W.L. Piez1	Piez2
06.26	137.1	157.6
06.27	139.9	158.0
07.03	142.4	158.0
07.16	142.3	158.0
07.30	blocked	157.9

LOG OF BOREHOLE G2

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 27, 1991

REF. No: G-91.0106
ENCL. No: 2

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' BLOWS 0.3 m	GROUND WATER CONDITIONS / ELEVATION SCALE	SHEAR STRENGTH kPa (+ Field Vane)
159.4	Ground Surface					
0.0	250 mm Topsoil **SAND** trace gravel damp, brown very loose	1	SS	3		
158.4 1.0	**SANDY SILT** some clayey silt seam dilatant brown compact				W.L. at 157.9 m 91.07.. ; 158	
		2	SS	16	Seal	
156.9 2.5	**CLAYEY SILT** to **SILTY CLAY** layered grey soft	3	SS	4	156	
						+ 1.4
					Piezometer 2	
		4	SS	3	154	+ 1.7
		5	SS	2		
					Seal	+ 2.5
152.2 7.2	**CLAYEY SILT** some sand trace of gravel grey very soft to soft (glacial till)				152	
		6	SS	2		
						+ 2.2
		7	SS	1	150	
						+ 1.3
148.7 10.7	Continued					

Other column headings: STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa — ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%); UNIT WEIGHT γ; REMARKS & GRAIN SIZE DISTRIBUTION (%) Gr Sa Si Cl

LOG OF BOREHOLE G2(CONT.)

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 27, 1991

REF. No: G-91.0106
ENCL. No: 2 A

(m) ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (+ FIELD VANE)	WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) Gr Sa Si Cl
148.7	Continuation										
10.7	CLAYEY SILT some sand trace gravel grey soft to firm (glacial till)		8	SS	2		148	1.4			
			9	SS	6			1.4			
							146				
			10	SS	6			1.4			
							144				
			11	SS	5			1.3			
						W.L. 142.7 m 91.07.16					
			12	SS	5		142	1.4			
			13	SS	5			1.7			
							140				
			14	SS	5			2.0			
138.3											
138.1	CLAYEY SILT										
21.3	Continued										

LOG OF BOREHOLE G2(CONT.)

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 27, 1991

REF. No: G-91.0106
ENCL. No: 2 B

ELEV (m) / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' BLOWS 0.3 m	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) (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) Gr Sa Si Cl
138.1	Continuation										
21.3	CLAYEY SILT TO SILTY CLAY layered grey		15	SS	33		138				
	v. stiff / hard										
			16	SS	19		136				
	firm / v. stiff										
			17	SS	5	Piezometer 1					
134.0							134	+			
25.4	CLAYEY SILT some sand trace gravel grey, stiff (glacial till)	T	18	SS	14						
132.9		T									
26.5	END OF BOREHOLE										

Date (1991)	W.L.(m) Piez1	Piez2
06 27	135.3	155.2
07.03	142.6	158.2
07.16	142.7	158.1
07.30	blocked	157.9

LOG OF BOREHOLE G3

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 25, 1991

REF. No: G-91.0106
ENCL. No: 3

(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) Gr Sa Si Cl
159.6	Ground Surface									
0.0	310 mm Topsoil SAND some silt trace of gravel brown very loose	1	SS	3						4 84 (12)
					Seal					
					W.L. 158.3 m 91.07.30					
158.1 1.5	SILT some sand trace of clay brown compact	2	SS	12		158				0 15 77 8
156.7 2.9	CLAYEY SILT to SILTY CLAY layered grey stiff to soft	3	SS	8		156				
		4	SS	5	Piezometer 2					0 0 74 26
						154				
		5	SS	3						
		6	TW	PH	Seal				19.8 W_L=47%	0 1 34 65 C'=5kPa ø'=24°
152.4 7.2	CLAYEY SILT trace of sand occasional gravel (glacial till) grey very soft					152	2.4			
		7	SS	2			1.8			
					W.L. 150.9 m 91.07.30					
		8	SS	1		150				0 1 40 59
							1.7			
148.9 10.7	Continued									

LOG OF BOREHOLE G3(CONT.)

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 25, 1991

REF. NO: G-91.0106
ENCL. NO: 3A

ELEV (m) / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH (kPa)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	Gr	Sa	Si	Cl
148.9	Continuation												
10.7	CLAYEY SILT some sand trace of gravel grey very soft to firm (glacial till)	9	SS	1									
						148	1.9 +						
		10	SS	5									
145.9						146							
13.7	SILT some sandy silt and clayey silt seams dilatant grey compact to loose	11	SS	10						2	22	63	13
							1.7 +						
		12	SS	7		144							
		13	TW	PH			1.5 +		21.5 / 22.4	0	15	59	26
		14	SS	6									
141.6						142	1.6 +						
18.0	CLAYEY SILT some sand trace of gravel grey stiff (glacial till)				Piezometer 1								
		15	SS	7									
							1.7 +						
139.8						140							
19.8	CLAYEY SILT to SILTY CLAY layered trace of sand grey very stiff	16	SS	26					21.7				
138.3 / 21.3	Continued												

LOG OF BOREHOLE G3 (CONT.)

CLIENT: Consumers Gas
PROJECT: Gas Main Relocation
LOCATION: Vaughan, Ontario
DATUM ELEVATION: Geodetic

DRILLING DATA
Method: Hollow Stem Augering
Diameter: 150 mm
Date: June 25, 1991

REF. NO: G-91.0106
ENCL. NO: 3 B

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' BLOWS / 0.3 m	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ	GRAIN SIZE DISTRIBUTION (%) Gr	Sa	Si	Cl
138.3	Continuation										
21.3	CLAYEY SILT to SILTY CLAY layered trace of sand grey very stiff to stiff	17	SS	28	138						
		18	SS	18	136						
		19	SS	12		46	19.6	0	2	51	47
		20	SS	12	134						
133.1											
26.5	END OF BOREHOLE										

Date (1991)	W.L. (m) Piez1	Piez2
06.26	dry	157.8
06.27	147.3	158.4
07.03	150.5	158.3
07.16	150.8	158.4
07.30	150.9	158.3

Ministry of Transportation Ontario

Enclosure 4

RECORD OF BOREHOLE No 1

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 645 E 298 404 ORIGINATED BY HCO

DIST 6 HWY 407 BOREHOLE TYPE Wash Boring,Hollow Stem Augers,Solid Stem Augers COMPILED BY RWR

DATUM Geodetic DATE June 20 to 23, 1983 CHECKED BY HCO

SOIL PROFILE

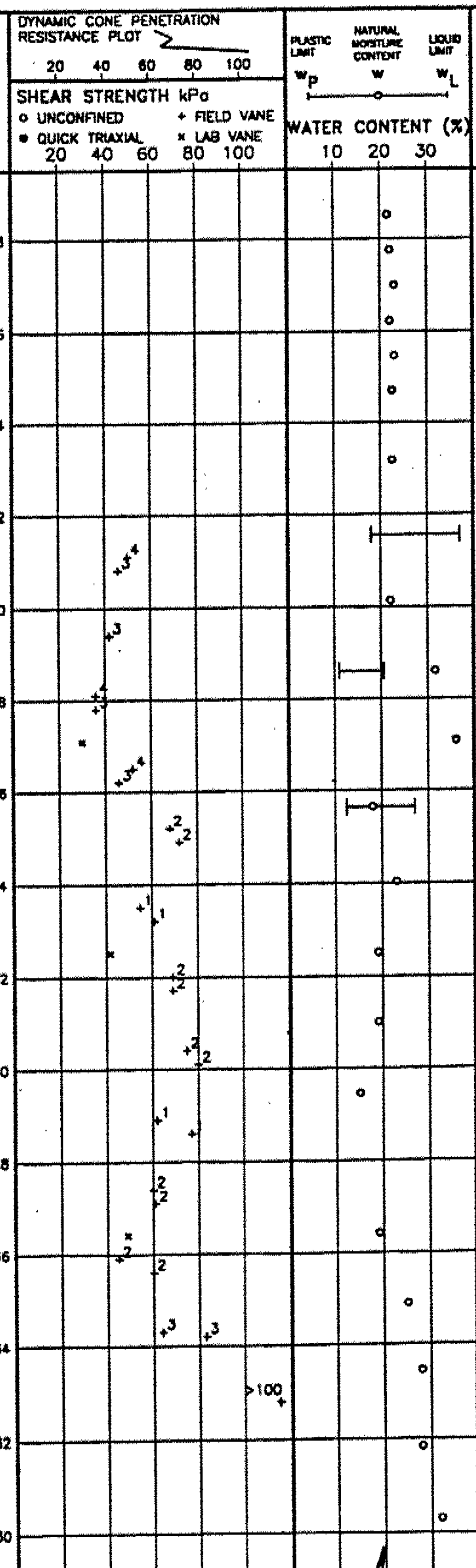
ELEV DEPTH	DESCRIPTION
159.5	Ground Surface
159.1	Topsoil – Brown, Sandy
0.4	Brown / Grey; Sandy Silt (Compact) with interbedded layers of Clayey Silt
152.2 7.3	Clayey Silt with random layers/nodules of silt, occasional Sand and Gravel pockets; Firm to Stiff; Grey
143.2 16.3	Clayey Silt, Some Sand, Trace Gravel (Glacial Till); Stiff; Grey
133.9 25.6	Clayey Silt; Stiff to Very Stiff; Grey
129.3 30.2	

SAMPLES

NUMBER	TYPE	'N' VALUES
1	SS	15
2	SS	18
3	SS	18
4	SS	15
5	SS	11
6	SS	14
7	SS	15
8	SS	4
9	SS	WR
10	SS	PH
11	TW	PM
12	SS	1
13	SS	WR
14	TW	PH
15	SS	13
16	SS	21
17	SS	14
18	TW	PH
19	SS	10
20	SS	22
21	SS	27
22	SS	11

GROUND WATER CONDITIONS: P1

ELEVATION SCALE: 158, 156, 154, 152, 150, 148, 146, 144, 142, 140, 138, 136, 134, 132, 130



UNIT WEIGHT γ kN/m³ / REMARKS & GRAIN SIZE DISTRIBUTION (%)

Elevation (approx.)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
~155		0	22	73	5
~152	Wn=44%				
~147	18.5				
~143	21.2				
~140		1	12	57	30
~137	21.4				

Continued

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

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

Continued

Ministry of Transportation Ontario

Enclosure 4A

RECORD OF BOREHOLE No 1 — 2 OF 2 — METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 645 E 298 404 ORIGINATED BY HCO

DIST 6 HWY 407 BOREHOLE TYPE Wash Boring,Hollow Stem Augers,Solid Stem Augers COMPILED BY RWR

DATUM Geodetic DATE June 20 to 23, 1983 CHECKED BY HCO

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m³	GR	SA	SI	CL
30.5	Continued	23	SS	23			o					
		24	SS	16		128	o					
	Compact / Very Dense	25	SS	131		126	o		10	71	15	4
	Sandy Silt to Silty Sand, Trace Gravel, Occasional Sand Seams	26	SS	94	/23cm	124						
		27	SS	127	/23cm	122						
		28	SS	109		120						
119.4 / 40.1	End of Borehole	29	SS	162	/27cm							

** Water Level Elev. 157.5 m July 7 /83
Piezometer dry Aug. 24 /83

*** Water Level Elev. 141.4 m Aug. 4 /83

* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	157.5
2	141.4

Legend: Dynamic Cone Penetration Resistance Plot 20 40 60 80 100; Shear Strength kPa: o Unconfined, + Field Vane, ● Quick Triaxial, × Lab Vane; 20 40 60 80 100; Plastic Limit w_p, Natural Moisture Content w, Liquid Limit w_L; Water Content (%) 10 20 30; Remarks & Grain Size Distribution (%)

$+^3$, $\times^5$: Numbers refer to Sensitivity; 20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

Enclosure 5

RECORD OF BOREHOLE No 2

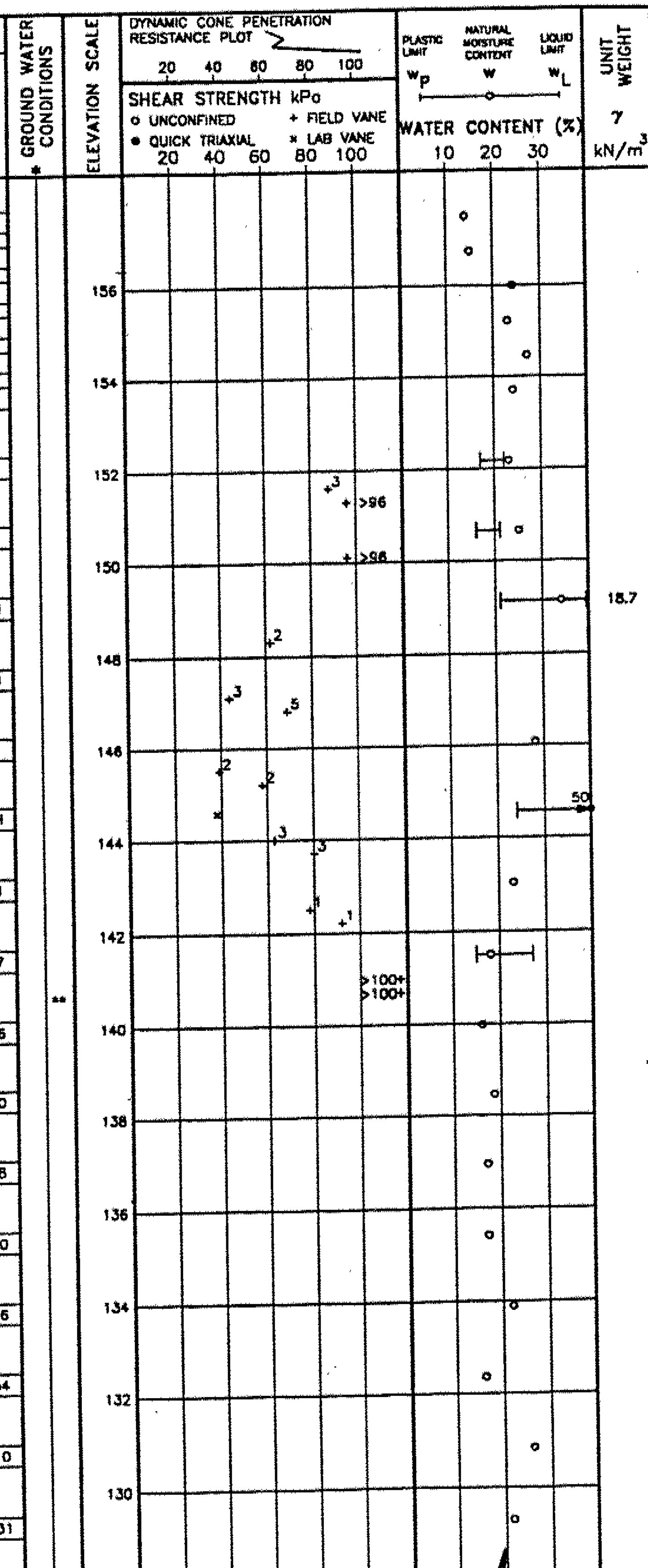
METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 575 E 298 428 ORIGINATED BY HCO

DIST 6 HWY 407 BOREHOLE TYPE Wash Boring COMPILED BY EFO

DATUM Geodetic DATE July 7-11, 1983 CHECKED BY HCO

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
158.5	Ground Surface				
0.0	Sand, Some Gravel, Compact	1	SS	15	
		2	SS	20	
	Silt to Sandy Silt, Compact, Brown	3	SS	12	
		4	SS	21	
	Grey	5	SS	10	0 21 74 5
		6	SS	15	
153.0 / 5.5	Clayey Silt to Silty Clay with interbedded zones and nodules of Silt, Traces of Gravel, Stiff to Very Stiff	7	SS	13	
		8	SS	13	0 1 66 33
	Firm to Stiff	9	SS	PH	0 1 44 55 (Unit weight 18.7)
		10	TW	PH	
		11	SS	6	
		12	TW	PH	
143.3 / 15.2	Clayey Silt with / some Sand and Trace Gravel (Glacial Till) Very Stiff to Hard, Grey	13	SS	11	
		14	SS	17	0 13 57 30
		15	SS	26	
		16	SS	20	
		17	SS	18	
		18	SS	20	
		19	SS	16	
		20	SS	54	
131.0 / 27.5	Clayey Silt, Trace / Some Fine Sand, Very Stiff to Hard, Grey	21	SS	10	
		22	SS	31	
128.0 / 30.5					



Continued

$+^3$, x^3: Numbers refer to Sensitivity

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

Continued

Ministry of Transportation Ontario

Enclosure 5A

RECORD OF BOREHOLE No 2

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 575 E 298 428 ORIGINATED BY HCO

DIST 6 HWY 407 BOREHOLE TYPE Wash Boring COMPILED BY EFO

DATUM Geodetic DATE July 7-11, 1983 CHECKED BY HCO

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
128.0 / 30.5	Continued. Limestone Cobbles with Silty Sand. Dense to Very Dense, Grey	23	SS	33			
		24	SS	100/15cm			
		25	WS	–			
125.3 / 33.2	Silt, Some Sand and Gravel, Trace Clay, Occasional Sand layers. Very Dense, Grey	26	SS	48			
		27	SS	97/23cm			
		28	SS	63			0 46 50 4
		29	SS	60			
		30	SS	33		19.8	
118.7 / 39.8	Clayey Silt, layered. Hard, Grey	31	SS	117			0 1 59 40
116.4 / 42.1	Sand and Silt. Very Dense, Grey	32	SS	91			
		33	SS	100/9cm			
114.1 / 44.4	End of Borehole						

** Water Level Elev. 140.7 m Aug 24 /83.

Elevation scale: 126, 124, 122, 120, 118, 116

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100

Shear Strength kPa: ○ Unconfined, + Field Vane, ● Quick Triaxial, × Lab Vane — 20 40 60 80 100

Water Content (%): Plastic Limit w_P, Natural Moisture Content w, Liquid Limit w_L — 10 20 30

* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	140.7

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

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 617 E 298 429 ORIGINATED BY HCO

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Auger, Wash Boring COMPILED BY EFO

DATUM Geodetic DATE July 12-13, 1983 CHECKED BY HCO

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
159.6	Ground Surface				
0.0 / 158.8	Sand and Gravel (Fill)				
0.8	Sandy Silt with interbedded layers of Clayey Silt. Very Loose to Compact. Brown / Grey	1	SS	5	
		2	SS	7	0 2 86 12
		3	SS	15	
		4	SS	5	
		5	SS	4	
154.7		6	SS	3	
4.9	Clayey Silt with random Silt zones and Traces of Sand. Firm to Stiff, Grey	7	SS	6	0 0 67 33
151.7		8	TW	PH	
7.9	Clayey Silt, Some Sand, Trace Gravel (Glacial Till) Firm to Stiff, Grey	9	TW	PH	
		10	SS	6	
		11	SS	6	
		12	SS	9	
		13	SS	16	
		14	SS	12	
		15	SS	10	
		16	SS	12	
137.1		17	SS	11	
22.5	Clayey Silt with Occasional layers and pockets of Sand. Very Stiff to Hard	18	SS	34	
		19	SS	58	0 2 73 25
		20	SS	36	
		21	SS	30	
129.8		22	SS	19	
29.8 / 129.1	As below				
30.5					

Unit weight at sample 8: 18.8 kN/m³

Shear strength annotations: +>96

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS (P1); ELEVATION SCALE (158–130); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, x LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued

$+^3$, x^5: Numbers refer to Sensitivity

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

Continued

Ministry of Transportation Ontario

Enclosure 6A

RECORD OF BOREHOLE No 3

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 617 E 298 429 ORIGINATED BY HCO

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Auger, Wash Boring COMPILED BY EFO

DATUM Geodetic DATE July 12-13, 1983 CHECKED BY HCO

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	UNIT WEIGHT kN/m³	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
129.1	Continued					
30.5	Sandy Silt to Silty Sand, Compact to Very Dense	23	SS	19		
		24	SS	48		
		25	SS	20		
		26	SS	69		
123.0						2 26 65 7
36.6	Clayey Silt, Hard	27	SS	67		2 8 57 33
121.0		28	SS	49	22.2	
38.6	Sandy Silt, Some Gravel, Very Dense					
118.5		29	SS	76		
40.1	End of Borehole					

Water Level Elev. 154.9 m Aug.24 /83

Elevation scale: 128, 126, 124, 122, 120

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100

Shear Strength kPa: o Unconfined, + Field Vane, ● Quick Triaxial, × Lab Vane — 20 40 60 80 100

Plastic Limit w_P, Natural Moisture Content w, Liquid Limit w_L — Water Content (%) 10 20 30

• GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	154.9

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

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

Ministry of Transportation Ontario

Enclosure 7

RECORD OF BOREHOLE No 4

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 569.3 E 298 444.7 ORIGINATED BY IR

DIST 6 HWY 407 BOREHOLE TYPE HS Auger and Washboring COMPILED BY HS

DATUM Geodetic DATE 84 07 23 CHECKED BY JP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
159.4	Ground Surface
157.3 / 0.0 – 2.1	Clayey Silt with random zones of silt, Firm to Stiff, Brown
154.5 / 2.1 – 4.9	Sand, Trace Silt, Compact, Grey
143.2 / 4.9 – 16.2	Clayey Silt to Silty Clay, Firm, Grey
133.5 / 16.2 – 25.9	Clayey Silt, some Sand, trace Gravel (Glacial Till) Stiff to Very Stiff
128.9 / 25.9 – 30.5	Clayey Silt, trace sand, occasional cobbles, very stiff to hard

SAMPLES

NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	5	
2	SS	16	23 66 9 2
3	SS	16	
4	SS	8	0 0 82 18
5	SS	9	
6	SS	5	
7	SS	5	
8	SS	8	
9	SS	13	
10	SS	15	
11	SS	78	

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (158 to 130); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

Water content plot value annotation: 45

Continued

Continued

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

15 ◇ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

Enclosure 7A

RECORD OF BOREHOLE No 4

 METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 569.3 E 298 444.7 ORIGINATED BY IR

DIST 6 HWY 407 BOREHOLE TYPE HS Auger and Washboring COMPILED BY HS

DATUM Geodetic DATE 84 07 23 CHECKED BY JP

ELEV DEPTH	DESCRIPTION	Sample NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
30.5	Continued As Above	12	SS	67		128		
125.9		13	SS	17		126		
33.5	Sand (cemented) some Silt, Occasional Cobbles Very Dense					124		
		14	SS	100/28cm			o	1 74 19 6
122.2 37.2	Clayey Silt Hard, Grey					122		
		15	SS	163/25cm		120		
		16	SS	54		118		
117.3		17	SS	32				
42.1	Sandy Gravel some silt to Silty Sand Very Dense	18	SS	150/5cm		116		
		19	SS	61			o	53 36 9 2
		20	SS	150/23cm		114		
		21	SS	200/23cm		112		
110.9		22	SS	150/5cm				
48.5	End of Borehole							

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa o UNCONFINED + FIELD VANE • QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m^3; STRAT PLOT.

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

$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

Enclosure 8

RECORD OF BOREHOLE No 5

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 813 E 294 415 ORIGINATED BY IR

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Auger and Wash Boring COMPILED BY HS

DATUM Geodetic DATE July 25, 1984 CHECKED BY TS

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
159.3	Ground Surface				
0.0	Silt with/some Sand Compact, Brown	1	SS	18	0 12 84 4
		2	SS	10	0 35 64 1
154.7 / 4.6	Clayey Silt with interbedded silt zones and nodules Firm	3	SS	8	
		4	SS	5	
152.0 / 7.3	Clayey Silt some Sand, trace Gravel (Glacial Till)	5	SS	3	
		6	SS	5	
	Firm	7	SS	4	
	Stiff	8	SS	11	
		9	SS	10	
		10	SS	14	
	Hard	11	SS	16	
		12	SS	34	
135.2 / 24.1	Clayey Silt trace Sand, trace Gravel Very Stiff to Hard	13	SS	45	
		14	SS	30	
		15	SS	22	
128.8 / 30.5	Continued				

GROUND WATER CONDITIONS: P1

ELEVATION SCALE: 159, 157, 155, 153, 151, 149, 147, 145, 143, 141, 139, 137, 135, 133, 131, 129

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

Continued

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

$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 5

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 613 E 294 415 ORIGINATED BY IR

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Auger and Wash Boring COMPILED BY HS

DATUM Geodetic DATE July 25, 1984 CHECKED BY TS

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
128.8 / 30.5	Continued	16	SS	76				
						127		
		17	SS	10		125		
	Silt, some Sand, trace Gravel, occasional cobbles, Very Dense					123		
		18	SS	212		121		
		19	SS	157		119	o	10 15 71 4
		20	SS	38		117		
		21	SS	116				
114.5 / 44.8		22	SS	95		115	o	0 17 80 3
	Silty Sand to Sandy Gravel, some Silt, Very Dense	23	SS	195 /23cm		113		
		24	SS	98			o	33 45 18 4
		25	SS	186 /23cm		111		
110.3 / 49.0	End of Borehole	26	SS	185 /18cm				

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

1985 04 25

* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	157.8

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

$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 6

 METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 664 E 294 398 ORIGINATED BY IR

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Auger and Wash Boring COMPILED BY HS

DATUM Geodetic DATE July 31, 1984 CHECKED BY TS

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
159.4	Ground Surface						
0.0	Silt, trace Sand to Sandy Silt, Compact, Brown				P1		
		1	SS	17		~21	0 13 86 1
		2	SS	17			
		3	SS	12		~19	0 4 90 6
153.9 / 5.5	Silty Clay with random zones of Silt and occasional sand pockets, Soft to Firm	4	SS	6			
		5	SS	3		~31 (wp ~22, wL ~36)	
		6	SS	3			
146.0 / 13.4	Clayey Silt, some Sand, some Gravel (Glacial Till), Stiff to Very Stiff	7	SS	9			
		8	SS	18		~18 (wL ~26)	
		9	SS	14			
		10	SS	*			
		11	SS	25			
133.8 / 25.6	Clayey Silt with interbedded layers of Silt, Stiff, Grey	12	SS	*			
		13	SS	*			
		14	SS	14		~13	

Continued — Continued

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

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 6

METRIC

W.P. 88-78-18 LOCATION Co-ords: N 4 847 664 E 294 398 ORIGINATED BY IR

DIST 6 HWY 407 BOREHOLE TYPE Hollow Stem Auger and Wash Boring COMPILED BY HS

DATUM Geodetic DATE July 31, 1984 CHECKED BY TS

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
128.6 30.5	Continued													
30.8	Silty Sand to Gravelly Sand some Silt		15	SS	100									
	Clayey Silt		16	SS	67									
	Very Dense		17	SS	101				o		26	55	15	4
			18	SS	185 /20cm									
121.6 37.8	Silt with occasional Clayey Silt seams		19	SS	184				o		0	16	64	20
119.3	Very Dense		20	SS	174 /28cm									
40.1	End of Borehole													

Legend: Dynamic cone penetration resistance plot: 20, 40, 60, 80, 100. Shear strength kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100. Plastic limit w_P, Natural moisture content w, Liquid limit w_L; water content 10, 20, 30. Remarks & grain size distribution (%).

1984 08 12

• GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	dry

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

$15 \diamond 5$ (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

Enclosure 10

RECORD OF BOREHOLE No A-5

METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 660.1 ; E 298 576.7 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 15 CHECKED BY BC

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
160.2	Ground Surface					
159.4	Topsoil					
0.8	Sand, Some Gravel Brown, Compact	1	SS	11		11 82 (7)
		2	SS	10		
157.2		3	SS	17		25 68 (7)
156.4	Silt, Brown, Compact	4	SS	14	18.8	0 0 (100)
3.8	Clayey Silt to Silty Clay with Random Nodules/Interbeds of Silt Grey, Stiff	5	SS	10		
		6	SS	11	22.6	
		7	SS	5		
152.6		8	TW	PH		0 0 32 68 * c'=0 ø'=29°
7.6	Clayey Silt, Some Sand, Tr. Gravel (Glacial Till) Grey, Firm to Stiff	9	SS	13		
		10	SS	2		
		11	SS	4		
		12	SS	5		
		13	SS	8	18.4	1 15 (84)
		14	SS	10		
		15	SS	6		
141.5		16	SS	5		
18.7	End of Borehole					
137.3 / 22.9	End of Cone Test					

Ground water conditions: water level symbol at approx. elev. 158.

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (o UNCONFINED, + FIELD VANE, • QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30. Elevation scale 158 to 142.

Field vane readings (sensitivity): +4, +3, +4 (clayey silt to silty clay); +3, +2, +2, +3, >+ (glacial till). Liquid limit annotation: 43.5.

+3, ×3 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

Enclosure 11

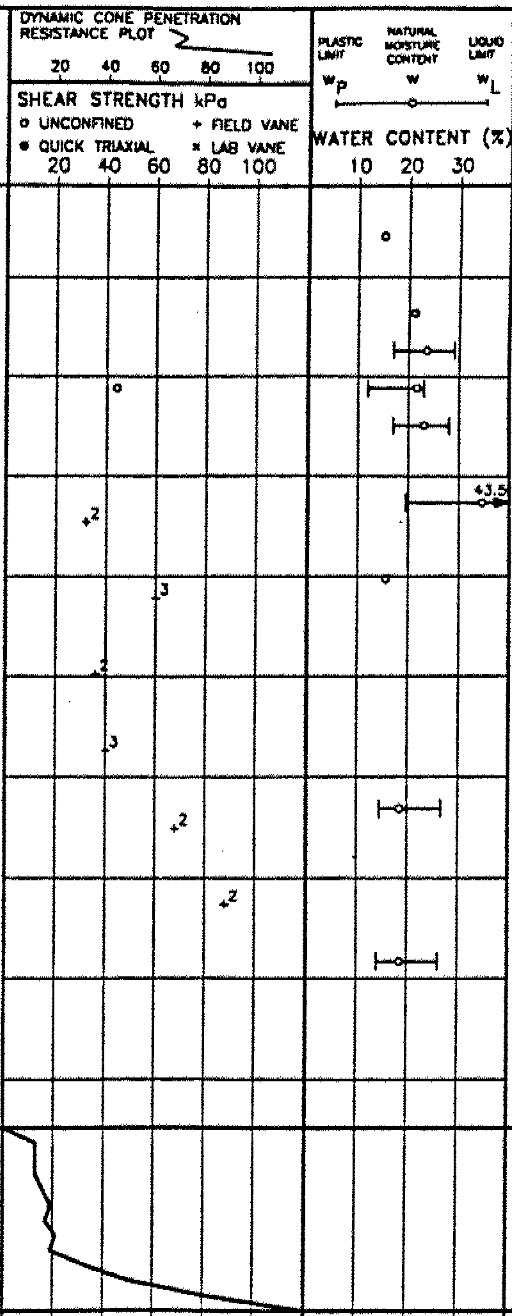
RECORD OF BOREHOLE No A-6   1 OF 1   METRIC

W.P. 141-87-00A   LOCATION Co-ords: N 4 847 691.2 ; E 298 501.7   ORIGINATED BY TS

DIST 6   HWY 407   BOREHOLE TYPE HS Auger   COMPILED BY TS

DATUM Geodetic   DATE 90 01 12-15   CHECKED BY BC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
159.8	Ground Surface					
159.0	Topsoil	1	AS	-		
0.8	Sand, Tr. Silt, Some Gravel	2	SS	26		14 79 (7)
157.5	Brown, Compact	3	SS	18		
2.3 / 156.8	Silt Brown, Compact	4	SS	21		0 19 76 5
3.0	Clayey Silt to Silty Clay with Random Nodules/Interbeds of Silt Firm to Stiff	5	SS	18		0 0 60 40
		6	SS	16	20.0	0 0 77 23
		7	SS	12	22.2	
		8	SS	8	19.8	
152.0		9	SS	5		
7.8	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Stiff to Very Stiff	10	TW	PH		
		11	SS	10		
		12	SS	10		
		13	TW	PH	20.3	1 11 62 26 * c'= 10 kPa ø'= 29°
		14	SS	13		
		15	SS	17	20.8	1 20 49 30
		16	SS	16		
141.1		17	SS	16		
18.7	End of Borehole					
137.5						
22.3	End of Cone Test					



* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	157.5

+3, ×5 : Numbers refer to Sensitivity   20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

Transportation Ontario

RECORD OF BOREHOLE No A-7

METRIC

W.P. 141-87-00A LOCATION Co-ords: N 4 847 615.4 ; E 298 488.6 ORIGINATED BY TS

DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 90 01 11-12 CHECKED BY BC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
159.3	Ground Surface									
158.5	Topsoil	1	AS	-						
0.8	Sand, Tr. Silt, Tr. Gravel Brown, Compact	2	SS	16	*					
		3	SS	22			5	89	(5)	
156.3		4	SS	16						
3.0	Silt Compact (Brown / Grey)	5	SS	26			0	3	86	11
154.7		6	SS	16						
4.6	Clayey Silt with Random Nodules/ Seams of Silt Grey, Stiff	7	TW	PH						
		8	SS	8			0	0	75	25
151.7		9	SS	9		17.7				
7.6	Clayey Silt, Tr. Sand, Tr. Gravel (Glacial Till) Grey, Firm to Stiff	10	SS	6			0	0	65	35
		11	SS	4		17.0				
		12	TW	PH		18.4	0	0	58	42
		13	TW	PM						
		14	SS	11						
		15	SS	13						
		16	SS	19		20.8	0	10	56	34
140.6		17	SS	17						
18.7	End of Borehole									

* Hole Cave-in at 1.5m

Elevation scale: 158, 156, 154, 152, 150, 148, 146, 144, 142

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

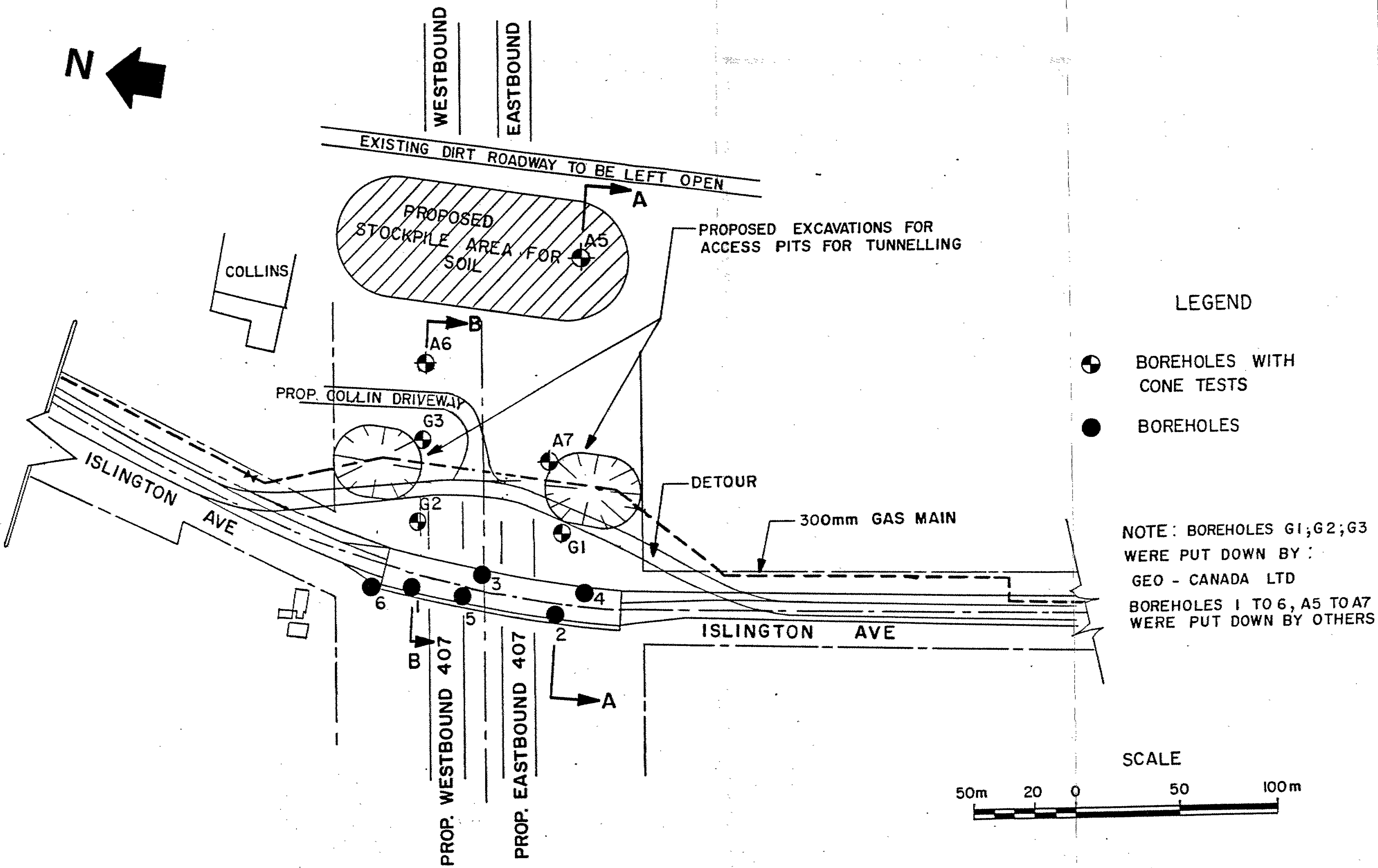
SHEAR STRENGTH kPa: o UNCONFINED + FIELD VANE; ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100

Field vane sensitivities plotted: +4, +3, 2, +2, +2, +2

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%): 10 20 30

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

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

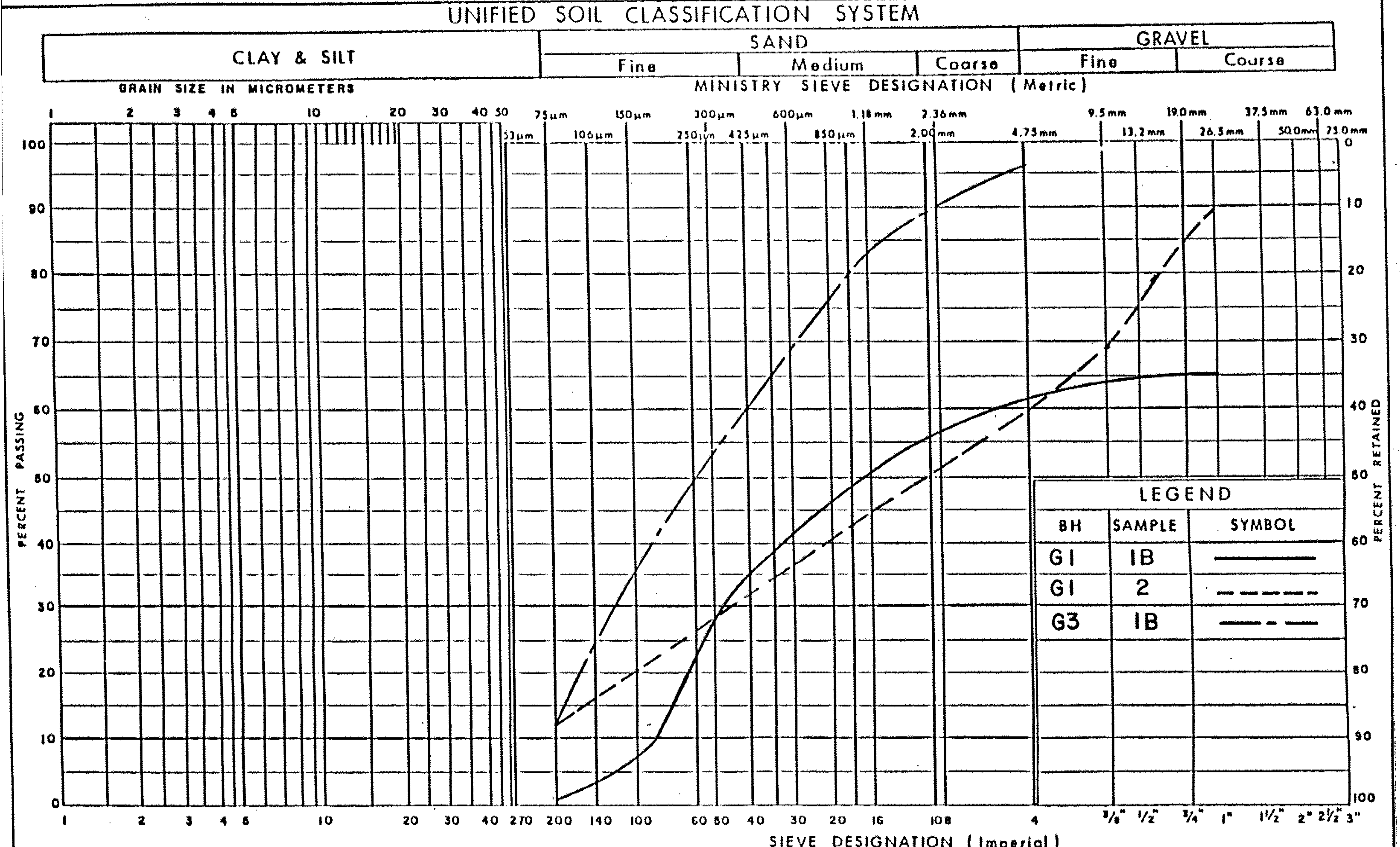


BOREHOLE LOCATION PLAN

G-91.0106

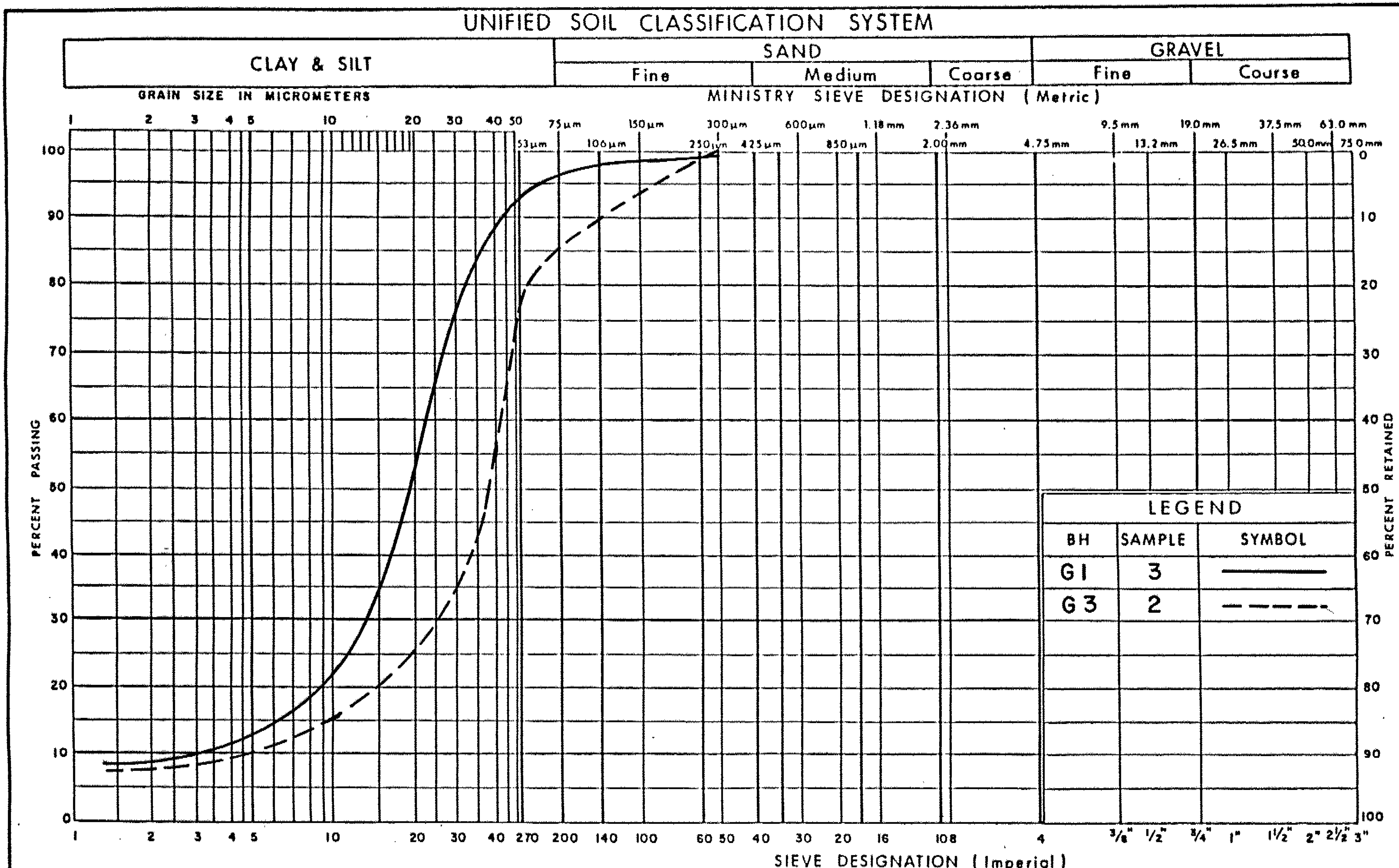
FIG. 1.

78 12 M

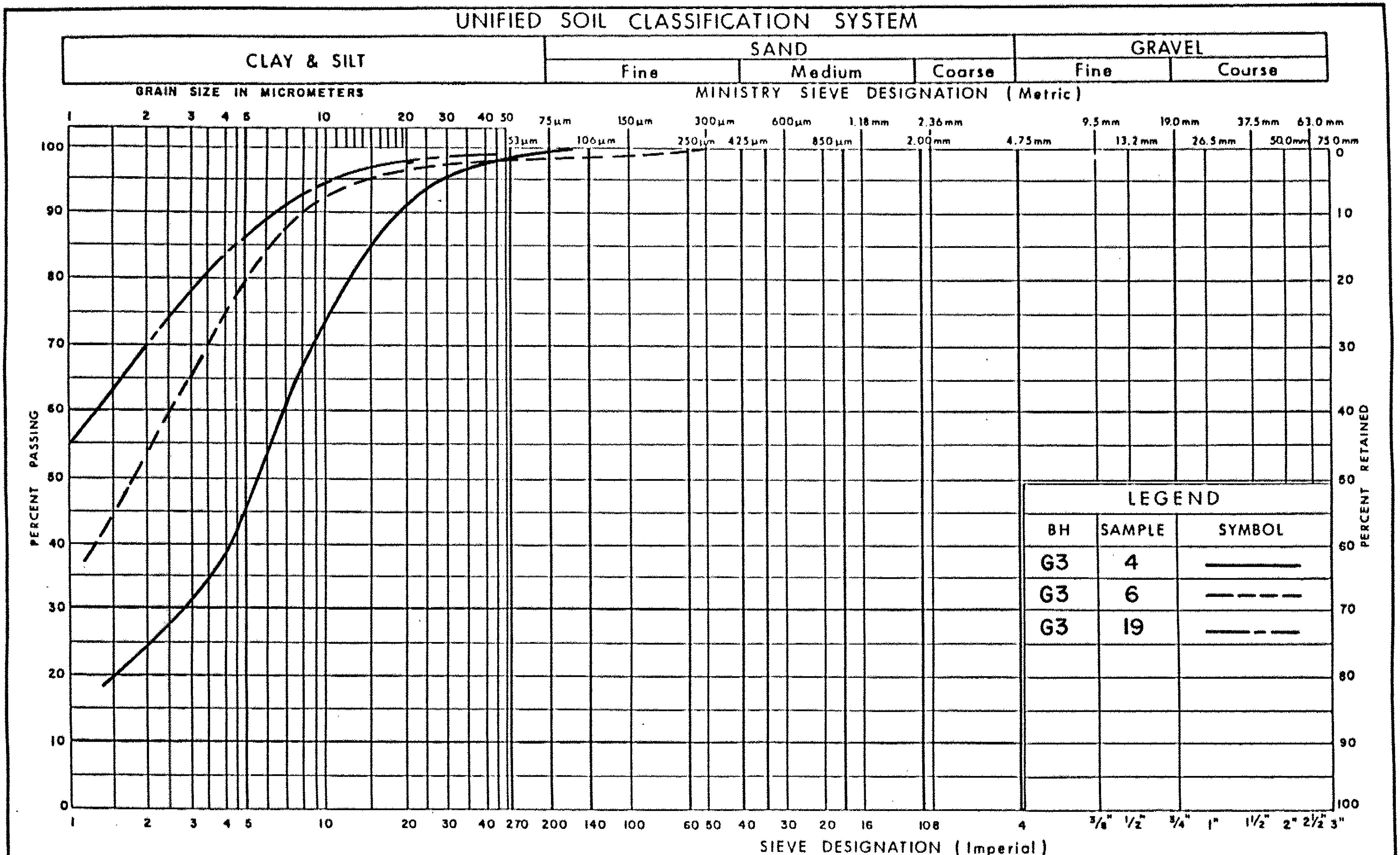


GEO-CANADA	GRAIN SIZE DISTRIBUTION GRAVELLY SAND some silt	FIG No 2 REF. No G-91.0106 DATE AUG. 1991.

78 12 M



GEO-CANADA	GRAIN SIZE DISTRIBUTION SILT trace to some sand, trace clay	FIG No 3 REF. No G-91.0106 DATE AUG. 1991.

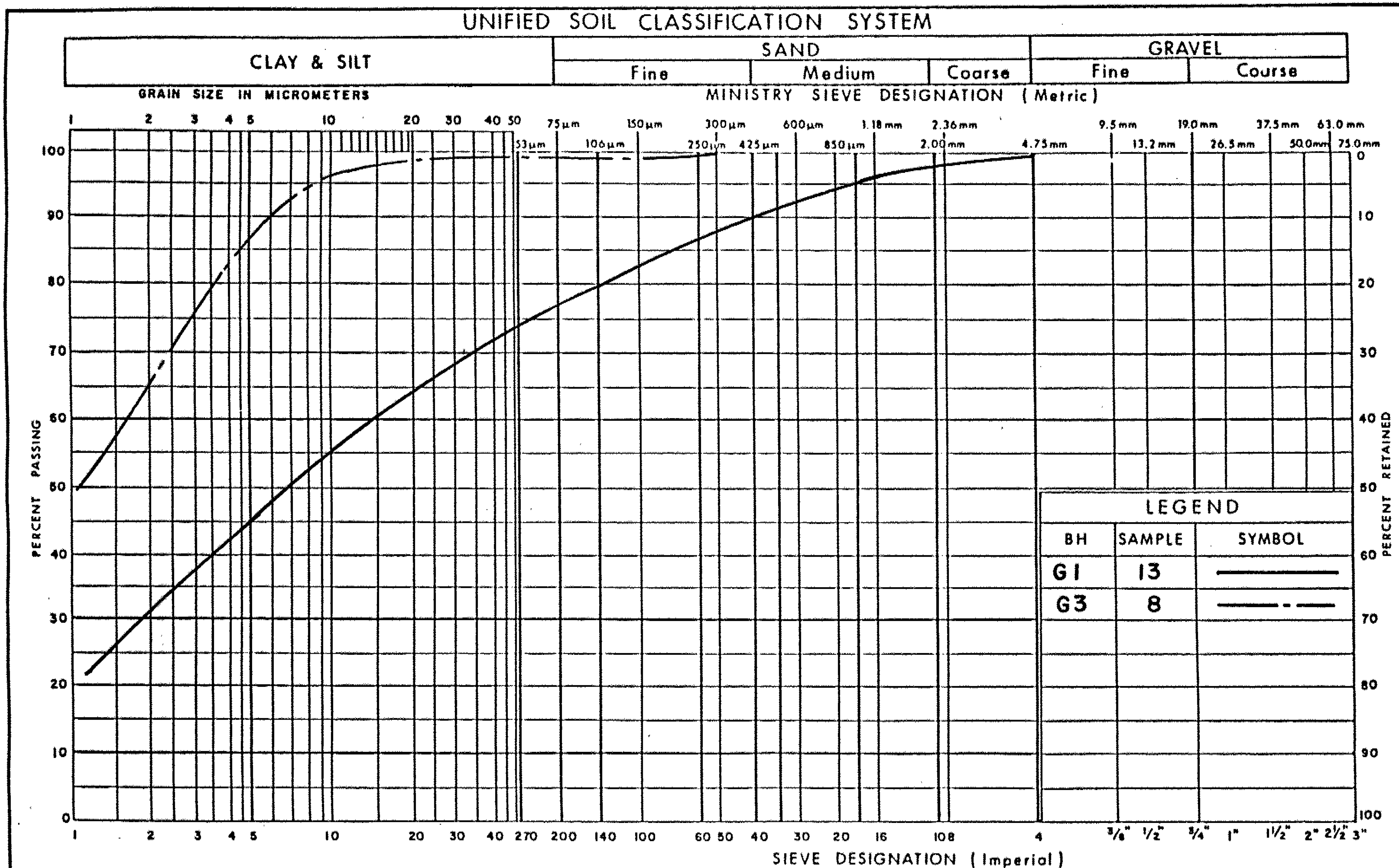


78 12 M

GEO-CANADA

GRAIN SIZE DISTRIBUTION
LAYERED CLAYEY SILT TO SILTY CLAY

FIG No 4
REF. No G-91.0106
DATE AUG. 1991.

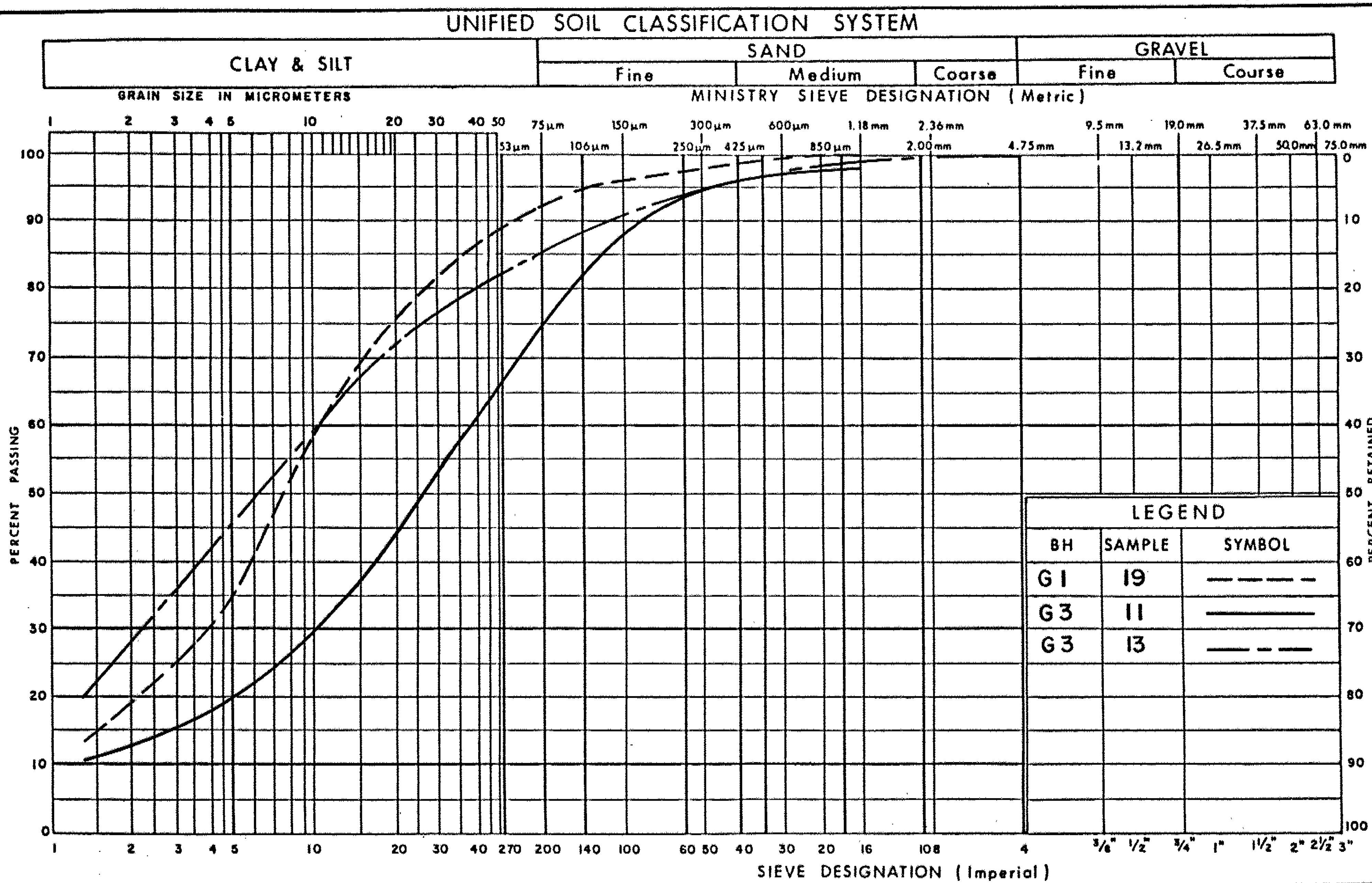


GEO-CANADA

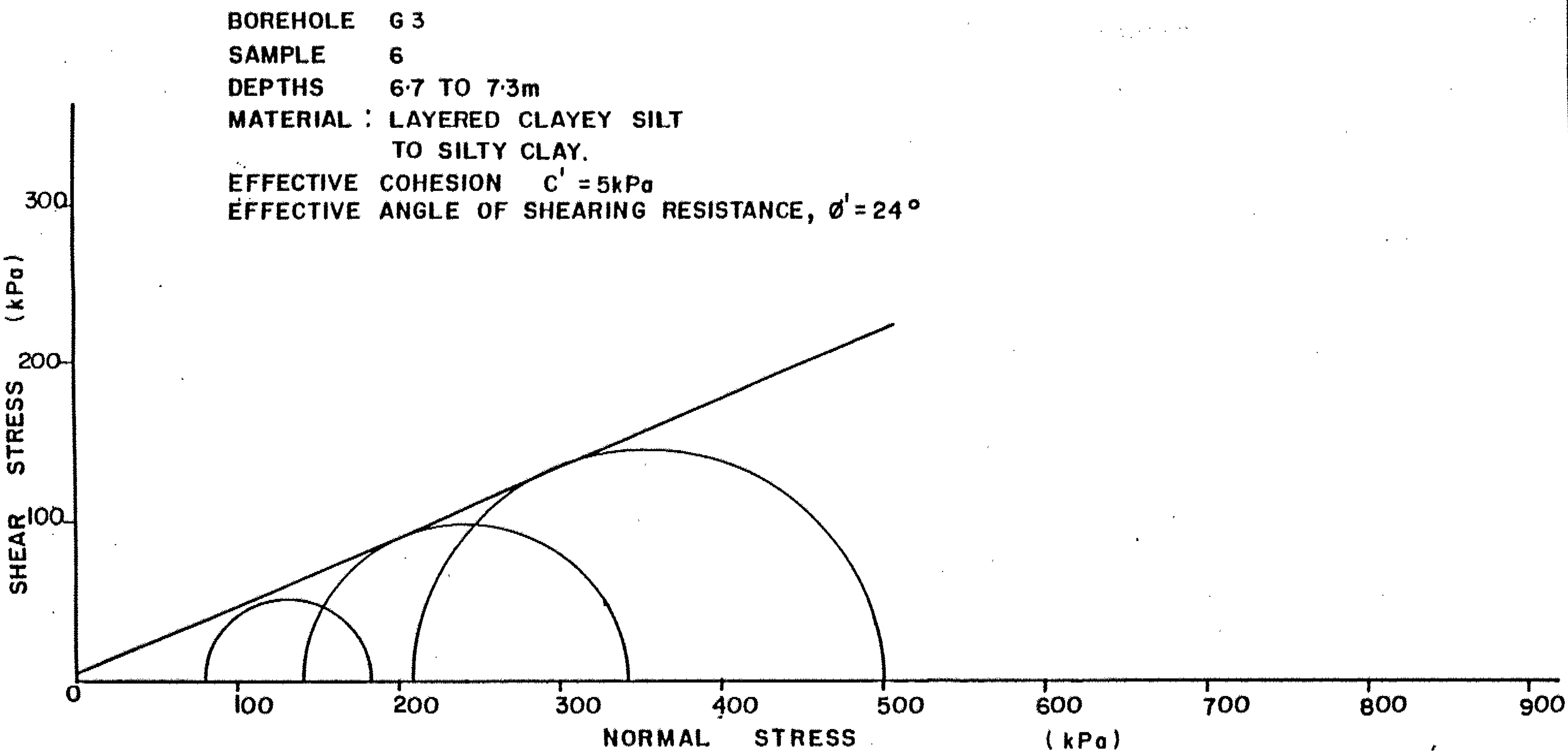
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY (TILL)

FIG No 5
REF. No G-91.0106
DATE AUG. 1991.

78 12 M



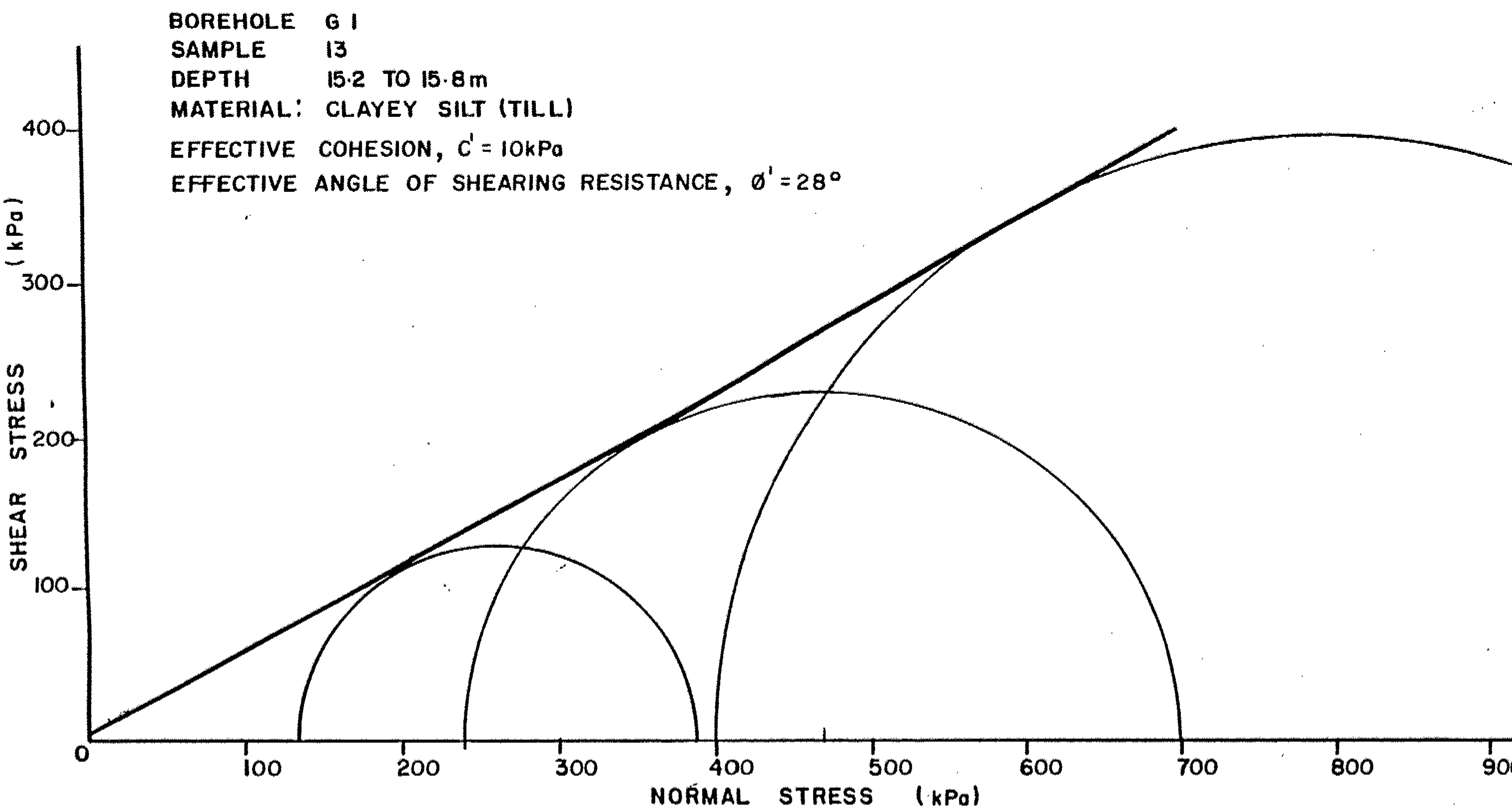
GEO-CANADA	GRAIN SIZE DISTRIBUTION **SILT** some sand, trace to some clay	FIG No 6 REF. No G-91.0106 DATE AUG. 1991



RESULTS OF SETS OF CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TESTS CARRIED OUT WITH PORE PRESSURE MEASUREMENT

G-91.0106

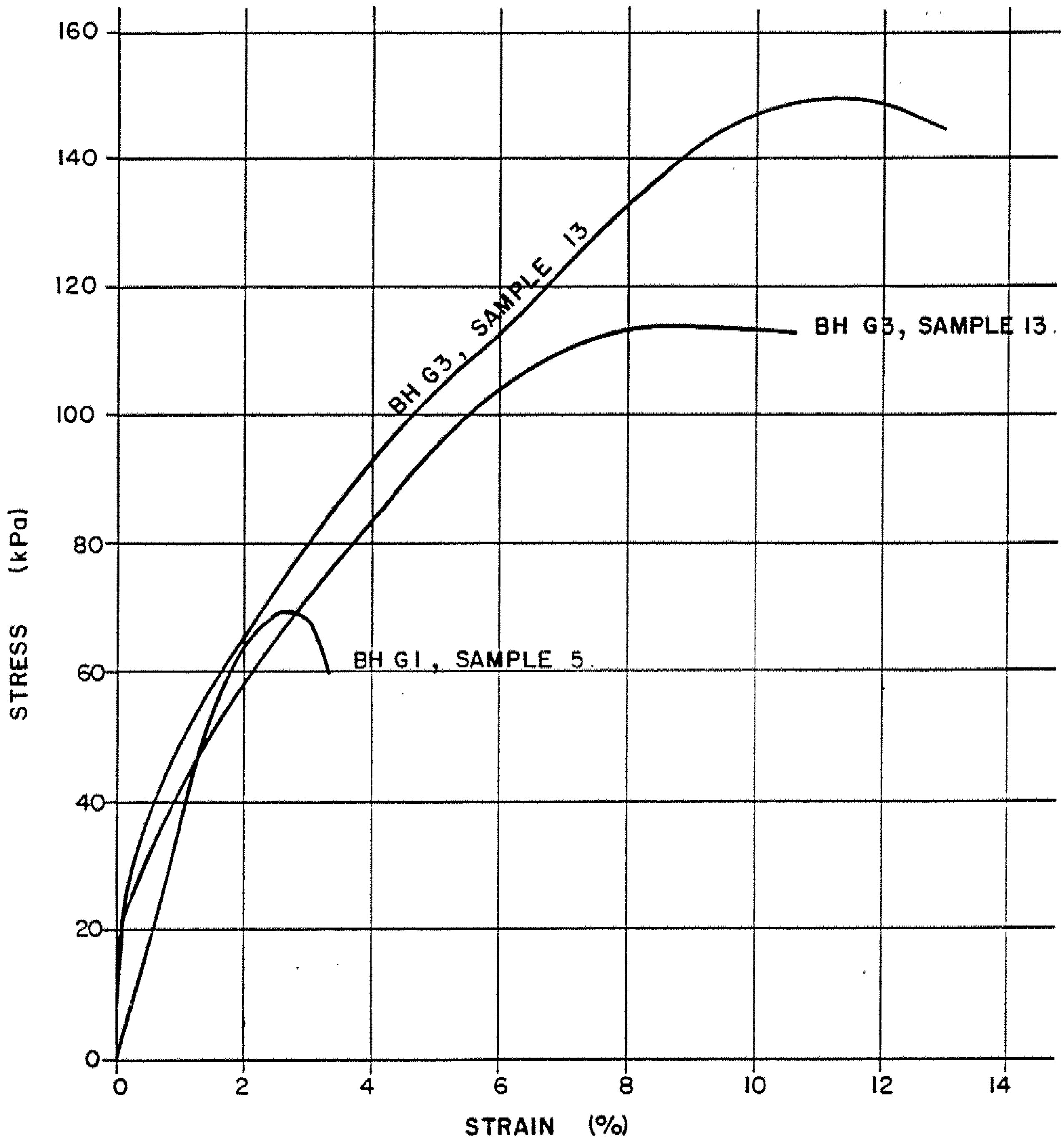
FIG. 7 .



RESULTS OF SETS OF CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TESTS CARRIED OUT WITH PORE PRESSURE MEASUREMENT

G-91.0106

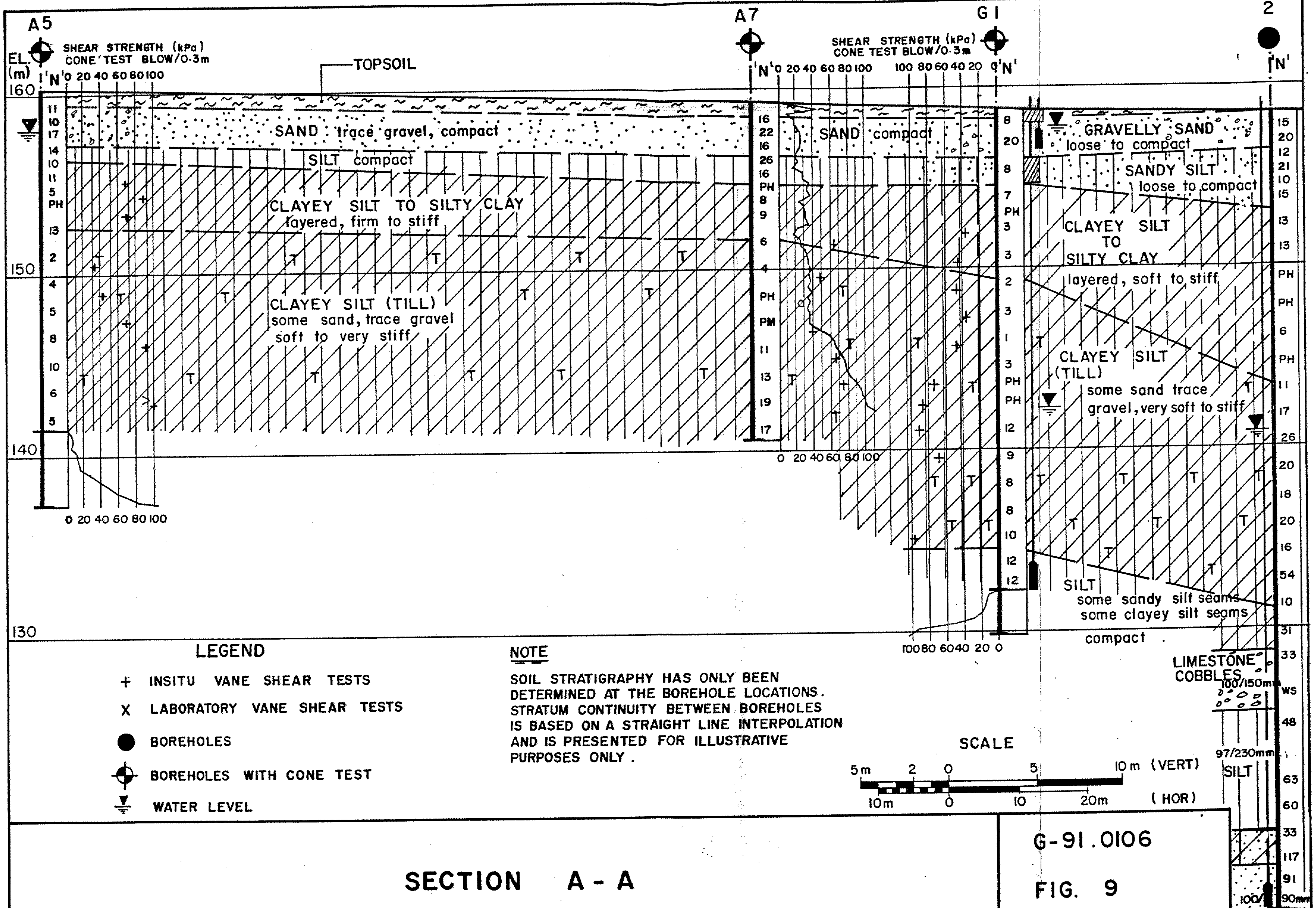
FIG. 8.



RESULTS OF UNCONFINED COMPRESSION TESTS

G-91.0106

FIG. 8A



LEGEND

- \+ INSITU VANE SHEAR TESTS
- X LABORATORY VANE SHEAR TESTS
- ● BOREHOLES
- ⊕ BOREHOLES WITH CONE TEST
- ▽ WATER LEVEL

NOTE

SOIL STRATIGRAPHY HAS ONLY BEEN DETERMINED AT THE BOREHOLE LOCATIONS. STRATUM CONTINUITY BETWEEN BOREHOLES IS BASED ON A STRAIGHT LINE INTERPOLATION AND IS PRESENTED FOR ILLUSTRATIVE PURPOSES ONLY.

SCALE

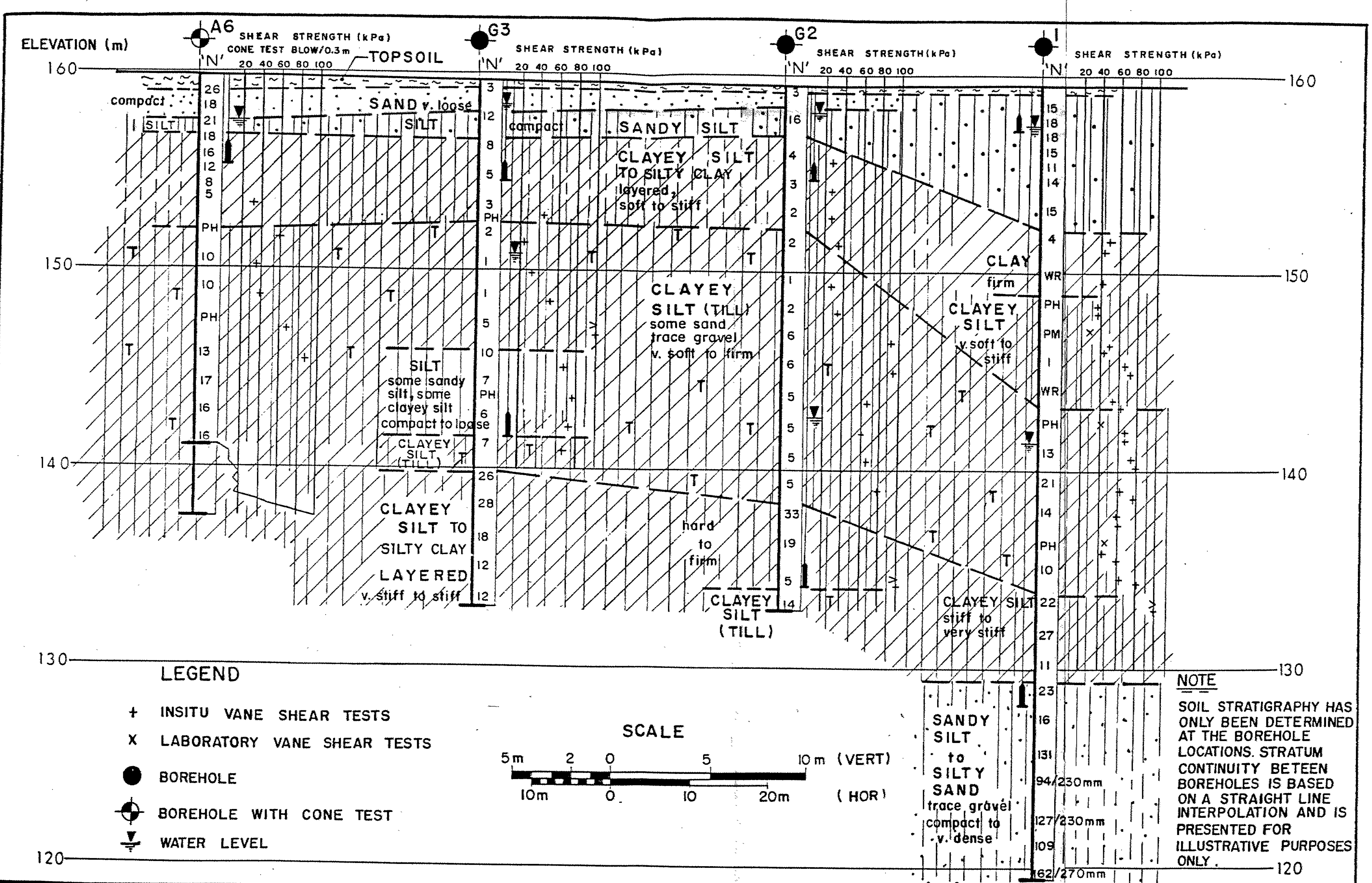
5m 2 0 5 10 m (VERT)

10m 0 10 20m (HOR)

SECTION A - A

G-91.0106

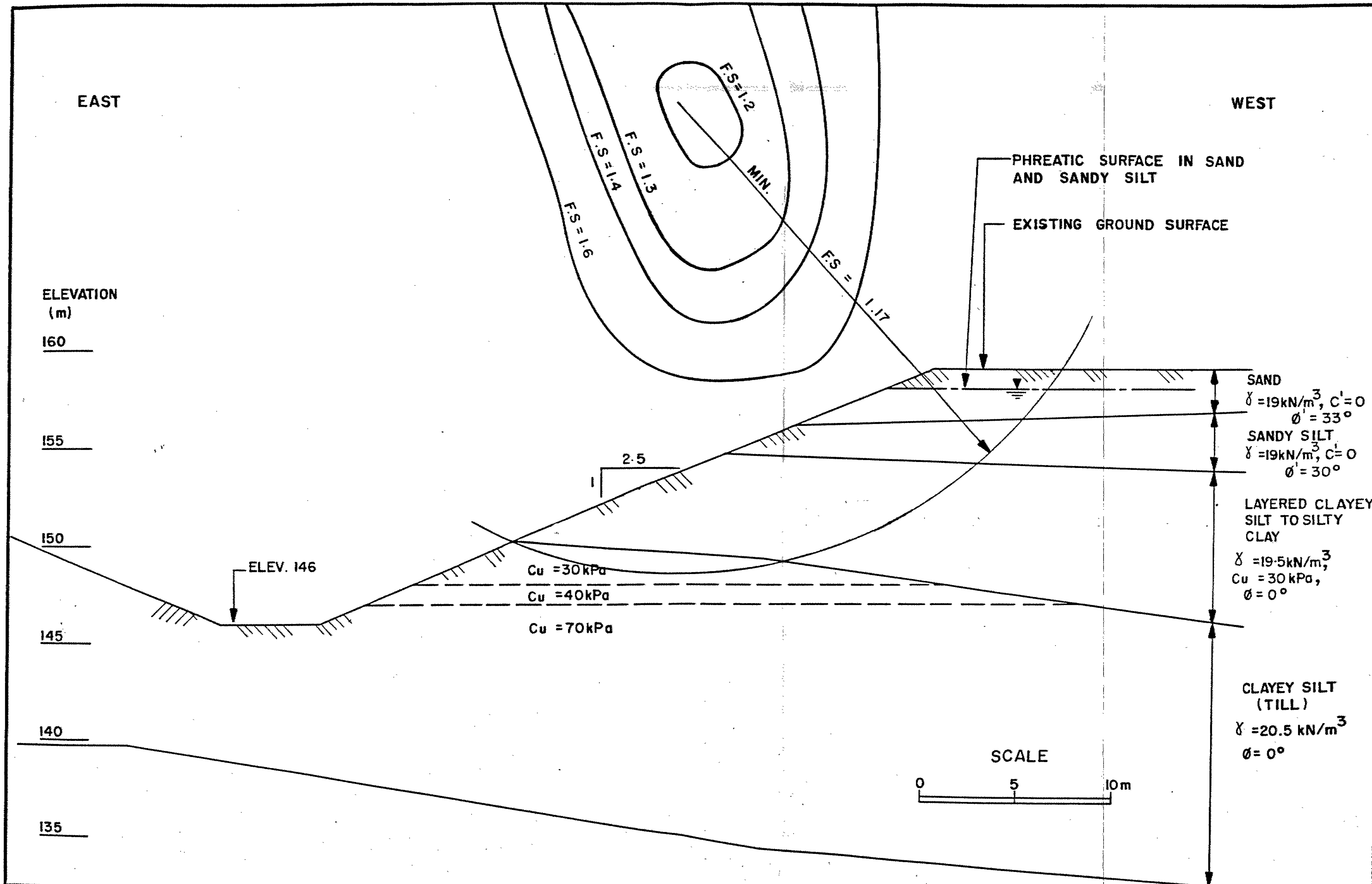
FIG. 9



SECTION B-B

G-91.0106

FIG. 10

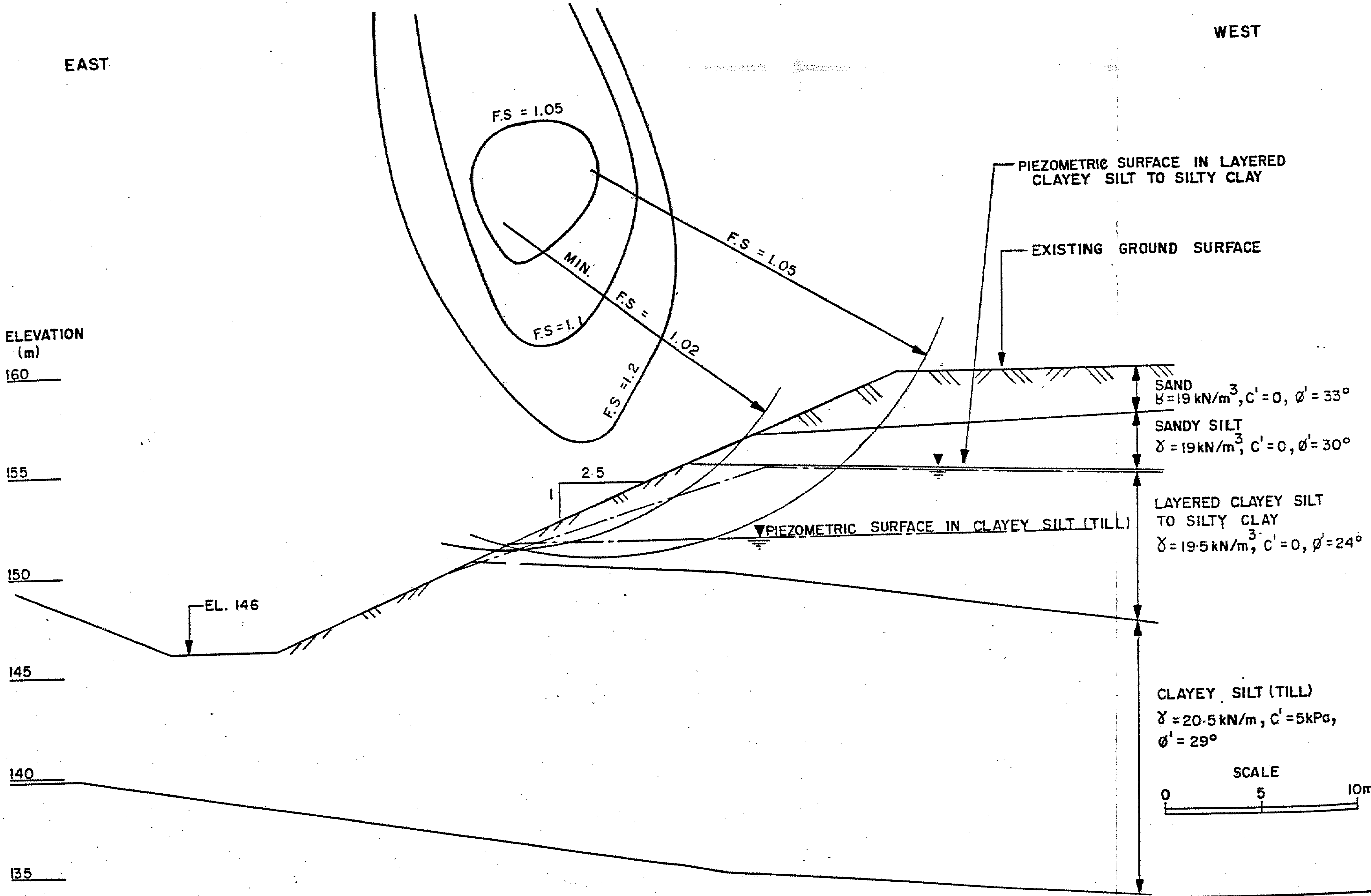


STABILITY ANALYSIS RESULTS - SHORT TERM CONDITION

EXCAVATED TO ELEVATION 146m

G-91. 0106

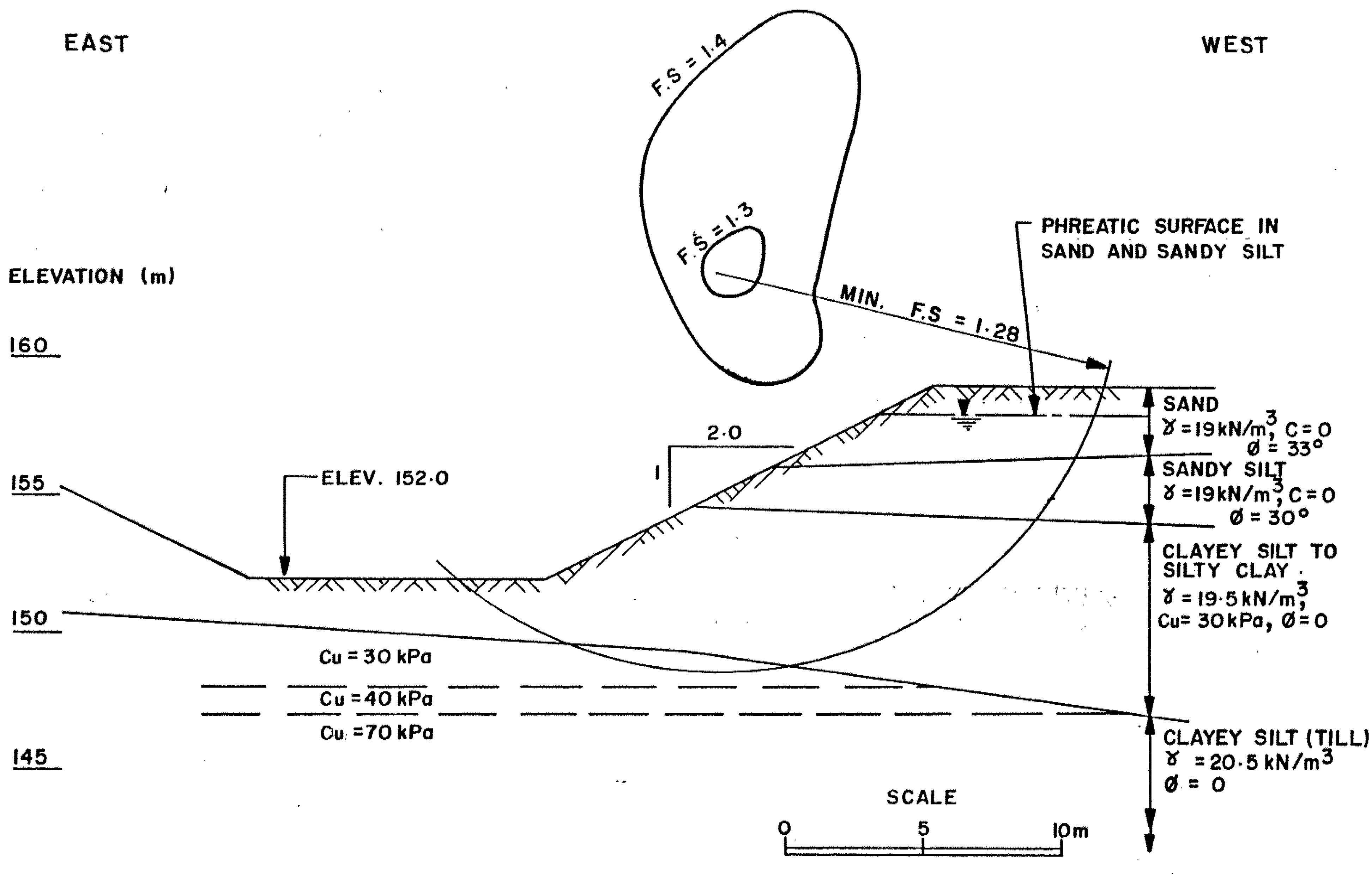
FIG. 11



STABILITY ANALYSIS RESULTS - LONG TERM CONDITION
EXCAVATED TO ELEVATION 146

G-91.0106

FIG. 12

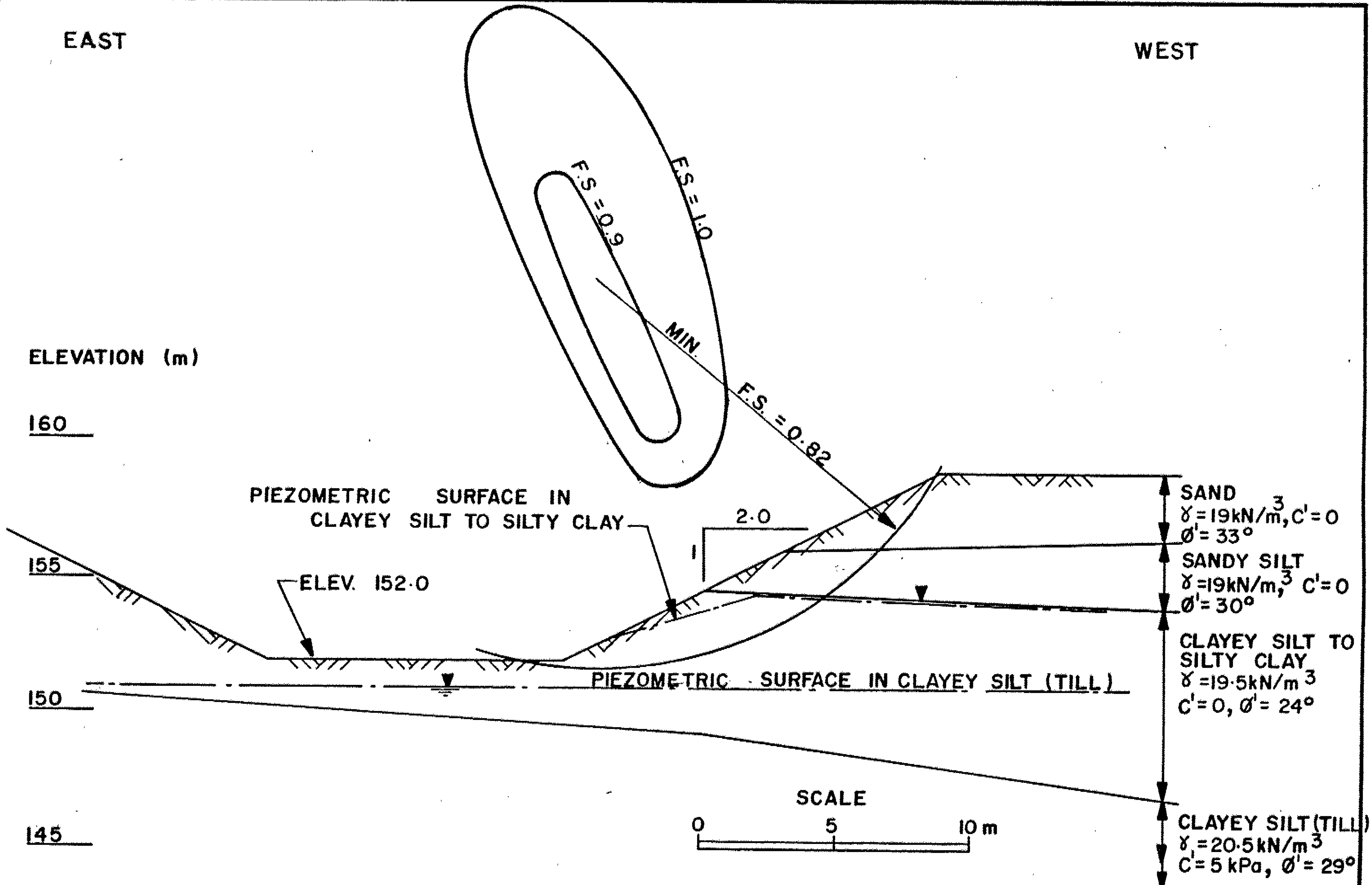


STABILITY ANALYSIS RESULTS - SHORT TERM CONDITION

2H : 1V CUT TO ELEVATION 152.0 m

G-91.0106

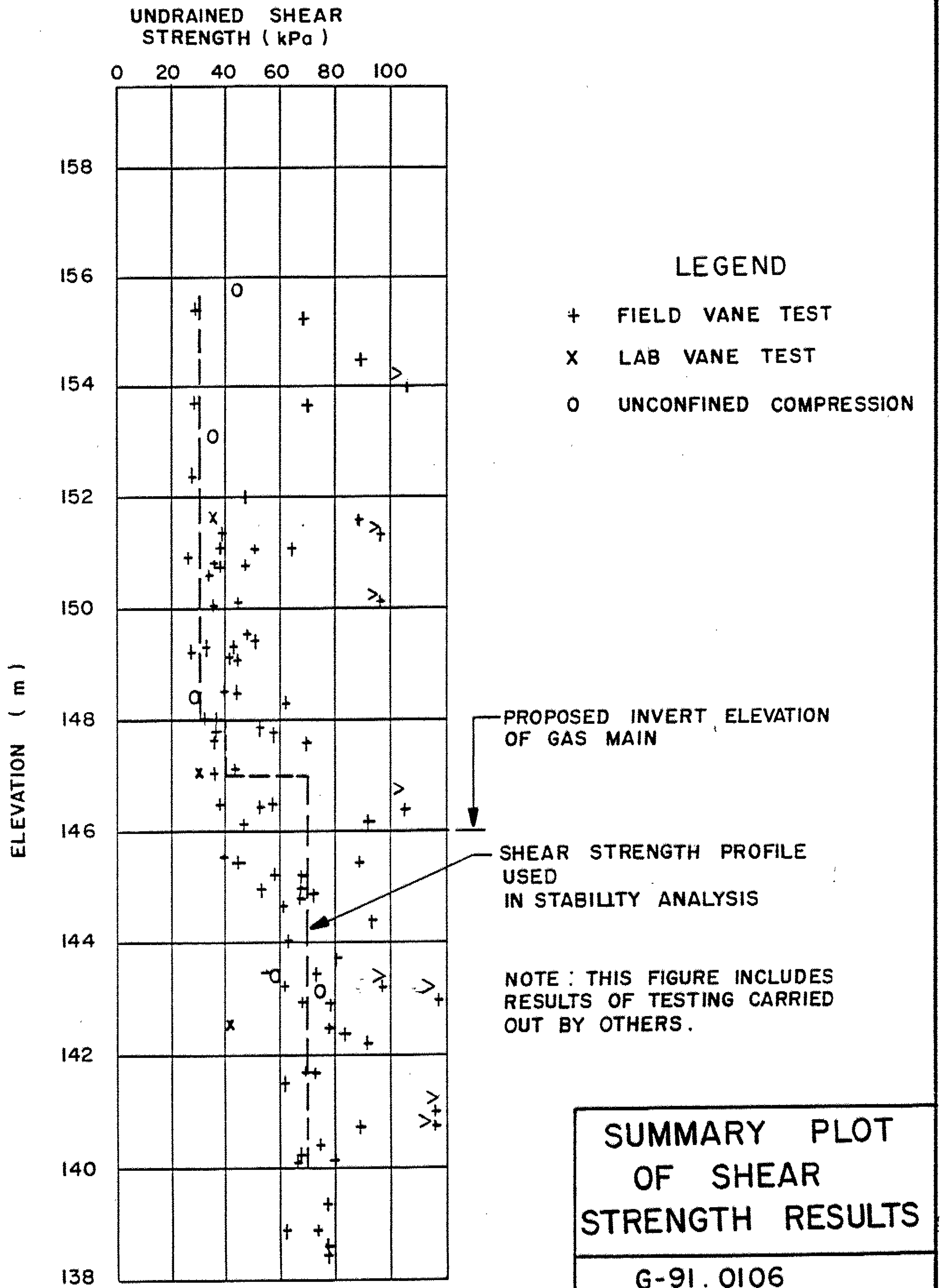
FIG. 13



STABILITY ANALYSIS RESULTS - LONG TERM CONDITION
2:1 CUT TO ELEVATION 152.0 m

G-91.0106

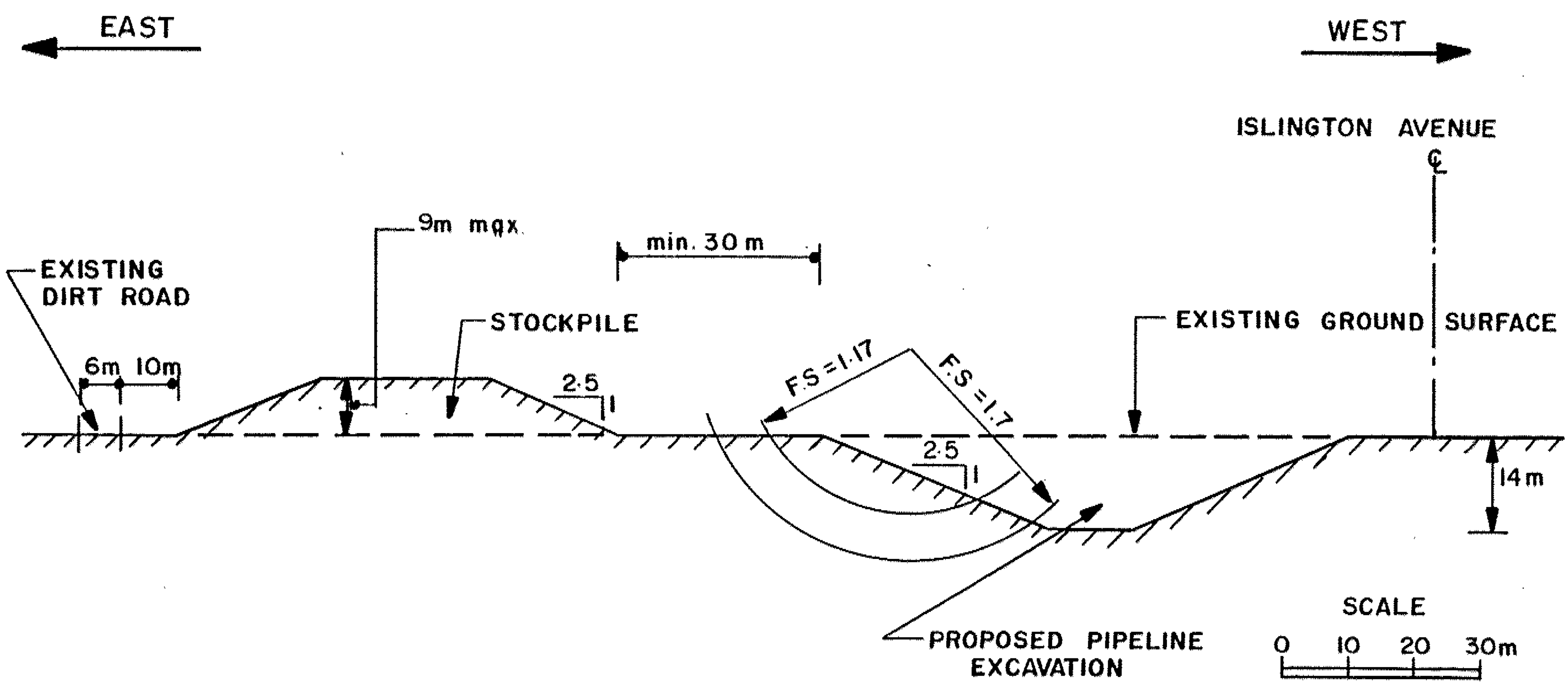
FIG. 14



SUMMARY PLOT OF SHEAR STRENGTH RESULTS

G-91.0106

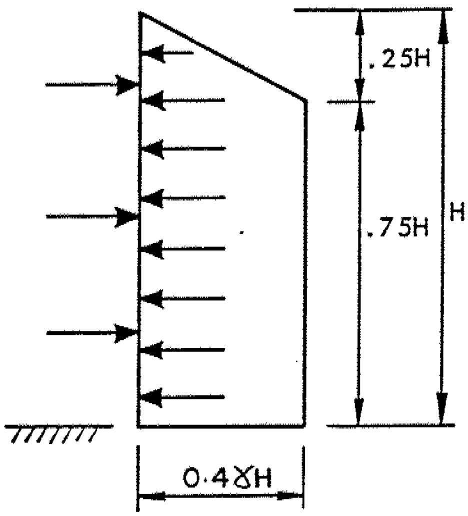
FIG. 15



CROSS SECTION SHOWING STOCKPILE AND EXCAVATION

G-91.0106

FIG. 16



CLAY

CLAYEY SILT

γ = 19.0 KN/m^3

NOTES:

1. CHECK SYSTEM FOR PARTIAL EXCAVATION CONDITION
2. IF THE FREE WATER LEVEL IS ABOVE THE BASE OF THE EXCAVATION THE HYDROSTATIC PRESSURE MUST BE ADDED TO THE ABOVE PRESSURE DISTRIBUTION IN SANDS
3. IF SURCHARGE LOADINGS ARE PRESENT AT OR NEAR THE GROUND SURFACE THESE MUST BE INCLUDED IN THE LATERAL PRESSURE CALCULATION.

EARTH PRESSURE DISTRIBUTION ON BRACED SHEETING	G-91.0106 FIG. 17

GEO-CANADA LTD.

memorandum

Ontario

To: W.R. Lankinen
Planning & Design Section
4th floor, Atrium Tower

Date: 1991 11 26

From: Foundation Design Section
Room 315, Central Building

Re: Water Main Relocation at
Hwy. 407 - Islington Ave.
W.P. 141-87-00
District 6, Toronto

We have reviewed the proposed watermain relocation at the above site. As mentioned at our earlier meeting, we have some concerns regarding the method of execution of the excavation and bedding placement along the slope. We find that no mention is made to this fact on the drawing or in the specifications.

We have no other comments.

B Iyer

Dr. B. Iyer, P. Eng.
Sr. Foundation Engineer

BI/jb

cc: R. Jeffries

7540-1021

SEND TO L. Crowder
Geotechnical

FROM W. Faulkner **DEPT.** P & D. **DATE** 91/11/19

SUBJECT W.P. 141-87-00, Hwy. 407 - Pine Valley Dr. to Humber R.
Proposed Consumers Gas Relocation Option 'B', West of Islington Ave.

We forward for your review & comment the preliminary proposal by Consumers Gas for an alternative relocation scheme on the west side of Islington Ave. Please discuss with the Foundation Design Section the need or desireability to jack and bore the section beneath the 407 roadbed in conjunction with the open cut method

REPLY on the slopes.

The permanent relocation for this option would be installed during construction after completion of the 407 cut by our contractor.

Your reply by 91/11/27 please. Thankyou.

R. Jeffries
cc. H. Wendland

W. Faulkner.

REPLY FROM

REPLY DATE

Consumers Gas

500 Elgin Mills Road East
Richmond Hill, Ontario L4C 5G1

1991-09-26

Ministry of Transportation
1201 Wilson Avenue
Atrium Tower
Downsview, Ontario
M3M 1J8

Attention: Mr. H. Wendland
Utilities Coordinator

RE: PROPOSED GAS MAIN RELOCATION
ISLINGTON AVE. AND HIGHWAY 407
OUR JOB #30-4636-91

Dear Sir:

This is further to our meeting of September 18, 1991 at the offices of Giffels and Associates.

We recommend the gas main relocation be completed using the directional boring method, (Option A). This is based on the soils report by Geo Canada Limited and discussions with our contractor, R.B. Somerville Ltd. The work can commence on or about October 7, 1991 when the equipment is available and should be completed in about four weeks. The estimated cost of this proposal including overheads is $745,000 with the Ministry responsible for 100%. R.B. Somerville Ltd. has agreed to confirm the location of the pipeline upon completion by digging any necessary and reasonable test holes. Furthermore if this relocation method is unsuccessful, R.B. Somerville Ltd. has agreed that no payment will be made to them.

If it is determined that Option A cannot be completed for any reason, R.B. Somerville Ltd. would proceed as quickly as possible with Option B on a forced account basis. This option would involve a temporary relocation around the bridge site and a permanent relocation after the bridge is built and the detour road is removed. The total estimated cost of this work including overheads is $775,000. with the Ministry responsible for 100%.

We have enclosed two copies of our revised plan, Drawing #30-3083, Sheets 1, 2 and 3, for your review and comment. Upon the receipt of any other revisions from you and your consultants we will process the encroachment permit application through our Land Department. We will also require a purchase order or letter of authorization regarding the cost of this work and written confirmation regarding property clearance.

If there are any other questions, please call me as soon as possible.

Yours truly,

G. Ashby, C.E.T. B.A.,
Manager, Planning & Technical Services
Northern Region

c.c. Mr. W. Lankinen, M.T.O.
Mr. W. Lachmaniuk, Giffels & Associates
Mr. E. Durey, M.T.O.
Mr. B. Henriques, Vaughan Hydro
Mr. R. Ashby
Mr. R. Burdey
Mr. R. Drysdale
Mr. N. DeKoning, R.B. Somerville Ltd.

G A/kb