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ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

CONT 94-55

WP 114-87-00(D) DIST 4

HWY 403 STR SITE -

Big Creek Culvert
Between Alberton Rd. & Sunnyridge Rd.

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FOUNDATION INVESTIGATION REPORT

FOR

BIG CREEK CULVERT

WP 114-87-00(D), Hwy 403

District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted in conjunction with the proposed triple cell culvert and associated embankment fills at the Hwy 403 - Big Creek crossing. The Big Creek crossing is one of many structures proposed in connection with the new Hwy 403 between Ancaster and Brantford.

SITE DESCRIPTION AND GEOLOGY

The site is situated along the proposed Hwy 403 alignment between Jerseyville Rd. and Hwy 2 in the north-south direction and between Alberton Rd. and Sunnyridge Rd. in the east-west direction. The site is located within the Town of Ancaster, Regional Municipality of Hamilton-Wentworth.

The site is located within a pronounced valley that houses the existing meandering Big Creek. The Big Creek which is approximately 3 metres in width and 2 metres in depth, flows in a southerly direction. At the time of the investigation, the water level in the creek was approximately 1 metre.

Ridges of overburden confine the relatively flat valley terrain. The ridges are approximately 15 to 20 metres higher than the valley floor. The ridges are covered by either agricultural crops, tall deciduous trees or grassland. The valley terrain is covered by tall grasses.

The area surrounding the site is occupied by farmland. Both dairy farming and agricultural farming is evident on this farmland.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsin Glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound. Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness of approximately 25m.

INVESTIGATION PROCEDURE

General

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and the laboratory testing program are discussed below.

Field Investigation

The fieldwork for this project was carried out under two separate stages. The initial stage was planned as part of a preliminary investigation study and consisted of one (1) sampled borehole advanced to a depth of 24.8 metres. The borehole was advanced between 76 03 23 and 76 03 24.

A more detailed investigation was recently conducted between 92 07 06 and 92 07 08. The investigation consisted of a total of five (5) sampled boreholes. Two of the boreholes were positioned at the proposed culvert structure location. One of these boreholes (BH3) was accompanied by a dynamic cone penetration test. The three (3) remaining boreholes were advanced at the proposed embankment fill locations adjacent the culvert structure. The boreholes were advanced to depths ranging from 24.1m to 28.3m below the ground surface. The dynamic cone penetration test was advanced to a depth of 22.1 metres.

All boreholes were advanced using track mounted drilling units equivalent to Central Mining Equipment (CME) 55 machines. Conventional hollow stem augering techniques were used to advance the boreholes in the overburden. Conventional rock coring techniques using BW and NW casing and BXL and NXL core barrels were used to retrieve up to 3 metres of rock core at the two (2) structure foundation locations.

Subsoil samples were generally retrieved at 1.5m intervals for the surficial 18m or so and at 3m intervals thereafter. Both disturbed and undisturbed subsoil samples were retrieved throughout the overburden. Disturbed subsoil samples were retrieved in accordance with the Standard Penetration Test (ASTM D1586) using a standard split spoon sampler driven into the soil and

undisturbed subsoil samples were retrieved using a thin wall sampler pushed hydraulically into the soil in accordance with procedures outlined in ASTM D1587.

All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents in the soil. Disturbed samples were placed in sealed plastic containers and thin wall samples were capped and waxed. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

In situ vane tests were also carried out to determine the undrained shear strength at selected intervals between the subsoil sample retrieval. The test was carried out in accordance with ASTM D2573 employing the standard MTO 'N' vane. Remoulded shear strengths were also obtained allowing the determination of soil sensitivity.

Rock core samples were also identified in the field and physical index properties were determined by visual examination and also by measurement of rock quality designations (RQD's) and rock core recovery. All rock core were placed in standard rock core boxes and carefully transported to the laboratory.

Groundwater levels were determined by monitoring the water levels in the open boreholes throughout the duration of the field investigation. All boreholes were backfilled upon completion of the fieldwork.

The survey related to the location and elevation of the individual boreholes was provided by Central Region Surveys and Plans.

Laboratory Analyses

All subsoil samples were carefully visually examined in the laboratory in accordance with the procedures outlined in the Visual Method described in Chapter 2 of the MTO Soil Classification Manual. The behaviour, gradation and other pertinent physical and mechanical properties of the soil were determined by conducting the appropriate laboratory tests on representative samples as identified in Table 1 below.

Table 1 - Physical/Mechanical Property Tests

Physical Properties	Mechanical Properties
1) Atterberg Limit Tests	1) Consolidation Tests
2) Particle Size Analysis	2) Unconfined Compression Tests
3) Natural Moisture Contents	3) Undrained Unconsolidated Tests
4) Bulk Unit Weights	

Sample preparation and testing were conducted in accordance with the MTO Laboratory Testing Manual.

Detailed rock core logging was conducted in the laboratory by an in-house resident geologist. The rock core logging includes descriptions of colour, grain size, bedding, jointing and strength.

Laboratory test results have been summarized below in the subsequent section of this report entitled "Subsurface Conditions" and are illustrated on the corresponding boreholes and figures included in the Appendix to this report.

SUBSURFACE CONDITIONS

General

Subsurface conditions across the site are uniform and consist of four (4) distinct layers of overburden overlying bedrock. The surficial deposit consists of a shallow veneer of cohesive clayey silt that extends to depths ranging from 2.7m to 5.0m below the ground surface. The deposit which has a firm to very stiff consistency also contains random interbeds of plastic silt approximately 25mm to 100mm in thickness.

The surficial cohesive clayey silt deposit is underlain by a plastic silt that has a very loose to loose denseness and contains random interbedded seams or layers of cohesive clayey silt. This deposit has a thickness ranging from 7.2m to 10.7m.

The plastic silt stratum is in turn underlain by a deposit consisting of layers of plastic silt interbedded with a cohesive clayey silt to silty clay. Pronounced and distinct stratified layers up to 300mm are present within this deposit. The deposit has a thickness ranging from 9.1m to 12.2m.

A very thin deposit comprised of a heterogeneous mixture of silt, sand and gravel underlies the layered silt and clayey silt to silty clay stratum. The deposit has a thickness of approximately

0.4m to 2.8m and extends to the bedrock surface which exists at an elevation of 183.0m to 184.4m.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. No. 1148700D-A in the Appendix. A subsoil stratigraphical profile and a stratigraphical section at the proposed structure that illustrates the subsurface conditions at the site are also provided. 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 stratigraphical profile and section and also on the individual Record of Boreholes sheets in the Appendix.

Clayey Silt with random layers of Silt

The surficial stratum at the site consists of a cohesive clayey silt that extends for a thickness ranging from 2.7 to 5.0 metres. The deposit also contains thin layers or seams of plastic silt generally 25mm to 100mm in thickness. The deposit has been oxidized for the surficial 2.3 to 4.3 metres, which is most of the deposit, and is brown in colour within this depth. Below this depth, the deposit is unoxidized and grey in colour. A grain sized distribution envelope produced by mechanical sieve and hydrometer analysis is shown in Figure 1 in the Appendix. The envelope clearly illustrates that the stratum is composed primarily of grain sizes smaller than 75 micrometres. The grain size distribution envelope for this material illustrates large percentages of silt, ranging from 62% to 85% and clay percentages ranging from 15% to 38%. In general, silt percentages exceed 75% and the clay fraction is in the order of 15% to 22%. In view of the fact that more than 50% of the material is finer than 75 micrometres, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil as discussed below.

Atterberg Limit Test were carried out on the fine grained soil (less than 425 micrometres) and the results are plotted on Figure 2 in the Appendix and summarized on Table 2 below. Natural Moisture Contents and the Bulk Unit Weight of the soil have also been included in the table.

Table 2 - Atterberg Limit Test Results - Clayey Silt

Test	Range	# of Tests
Natural Moisture Content (w%)	23 - 31	8
Liquid Limit (w_L %)	23 - 42	8
Plastic Limit (w_P %)	16 - 20	8
Plasticity Index (I_p %)	7 - 23	8
Bulk Unit Weight (kN/m^3) γ	18.8 - 20	4

The test results clearly reveal that the soil has a liquid limit ranging from 23% to 42% but generally, the liquid limit is less than or equal to 30%. Therefore, the soil generally has a low plasticity and can hence be categorized as a clayey silt (CL). Natural moisture contents are generally close to the liquid limit of the soil.

Random layers of silt are also present within the surficial deposit. The silt interbeds typically display quick dilatancy, no toughness and a low dry strength.

The consistency and undrained shear strength of the soil were determined by conducting in situ vane tests. The results of these tests are plotted on the individual Record of Borehole Sheets and summarized on the Undrained Shear Strength vs. Elevation graph shown on Figure 3 in the Appendix. In situ vane test results are erratic and undrained shear strengths ranged from as low as 24 kPa, determined in isolated zones only, to as high as exceeding 120 kPa (depths at which

the vane could not be torqued). It is believed that the lower values may have been the result of disturbance induced during the testing and the larger values were the result of silt interbeds. As Figure 3 illustrates, undrained shear strengths generally range from 50 kPa to 100 kPa, indicating a stiff consistency.

The sensitivity of the soil is 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. Sensitivities of this soil ranged from 2 to 5 indicating a low to moderately sensitive material.

The 'N' values as determined by the Standard Penetration Test ranged from 1 blow/0.3m to 8 blows/0.3m suggesting a low penetration resistance and hence confirming the lower strengths and weaker consistencies of this soil.

Silt with Interbedded seams/layers of Clayey Silt

A cohesionless silt of quick dilatancy interbedded with thin seams and also layers of cohesive clayey silt exists below the surficial clayey silt deposit and extends to depths ranging from 12.2m to 13.7m below the ground surface. The thickness of this stratum ranges from 7.2m to 10.7m and the cohesive interbedded seams are approximately 25mm to 75mm in thickness, whilst the layers are up to 150mm in thickness. The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

Random thin layers of sand and gravel are also present within this deposit. These layers are generally less than 0.5 metres in thickness.

Grain size distribution envelopes as determined by mechanical sieve and hydrometer analysis illustrating the gradations of the cohesionless silt material and the cohesive seams/layers are shown on Figure 4 in the Appendix. The envelope illustrates that the host silt has percentages of silt ranging between 83% and 89% with clay fractions ranging from 10% to 16%. The cohesive interlayers and seams have silt percentages ranging from 39% to 83% and clay fractions ranging from 13% to 61%. The silty soil does however exhibit plasticity and the results of Atterberg Limit Tests carried out on some representative samples of this material and also the cohesive interbeds are summarized in Table 3 below and illustrated in Figure 4.

Table 3 - Atterberg Limit Test Results - Silt with interbedded seams/
layers of Clayey Silt

a) Silt

Test	Range	# of Tests
Natural Moisture Content ($w\%$)	22 - 29	6
Liquid Limit ($w_L\%$)	19 - 24	6
Plastic Limit ($w_p\%$)	16 - 20	6
Plasticity Index ($I_p\%$)	2 - 5	6
Liquidity Index ($I_L\%$)	0.5 - 3.5	6

b) Clayey Silt

Test	Range	# of Tests
Natural Moisture Content (w%)	26 - 42	7
Liquid Limit (w_L %)	21 - 34	7
Plastic Limit (w_p %)	14 - 18	7
Plasticity Index (I_p %)	7 - 16	7
Liquidity Index (I_L %)	1.1 - 1.9	7

The test results reveal that the host soil is a plastic silt (ML to CL-ML categorization) and the interbedded seams/layers are of low plasticity and hence can be categorized as a clayey silt. Natural moisture contents exceed the liquid limit of the soil for both soils as reflected by liquidity indices exceeding unity.

Due to the percentages of clay and the seams/layers of interbedded clayey silt, vanes could be torqued and in situ tests were conducted. The results revealed undrained shear strength values ranging from approximately 60 to >120 kPa. The results, in general, were erratic and devoid of any pattern which is perhaps indicative of the high silt percentages.

The 'N' values as derived from the Standard Penetration test reveal values ranging from 3 to 10 blows/0.3m. This is representative of a very loose to loose state of denseness.

Layered Silt and Clayey Silt to Silty Clay

The plastic silt deposit is underlain by a deposit that consists of alternate layers of plastic silt and cohesive clayey silt to silty clay. The stratification of these layers is readily evident with the silt

layers being lighter grey in colour and quickly dilatant. The cohesive layers, on the other hand, are darker grey in colour and exhibit no dilatancy.

The thickness of the entire stratum ranges from 9.1m to 12.2m across the site. The stratified layers range from approximately 100mm to 300mm in thickness.

Grain size distribution envelopes for both layered materials are shown on Figure 6 in the Appendix. The envelopes illustrate that the silt layers contain silt percentages ranging from 88% to 90% and clay percentages ranging from 9% to 12%. The cohesive interbeds, as expected have larger clay percentages ranging from 22% to 58% and smaller silt percentages ranging from 42% to 78%.

In accordance with the MTO Soil Classification system, materials with gradations of this nature are categorized by their behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 7 and summarized in Table 4 below. Natural Moisture Contents are also included in the Table below.

Table 4 - Atterberg Limit Test Results
Layered Silt and Clayey Silt to Silty Clay

a) Silt

Test	Range	# of Tests
Natural Moisture Content (w%)	25 - 29	3
Liquid Limit (w_L %)	20 - 24	3
Plastic Limit (w_p %)	18 - 22	3
Plasticity Index (Ip%)	2 - 3	3
Liquidity Index (I_L %)	3.3 - 5.5	3

b) Clayey Silt to Silty Clay

Test	Range	# of Tests
Natural Moisture Content (w%)	25 - 38	10
Liquid Limit (w_L %)	24 - 50	10
Plastic Limit (w_p %)	15 - 22	10
Plasticity Index (Ip%)	10 - 28	10
Liquidity Index (I_L %)	0.8 - 1.6	10

The test results reveal interbeds of inorganic silt of low plasticity (ML) and clayey silt to silty clay (CL to CI). Liquidity indices for both materials are close or exceed unity indicating that natural moisture contents are high and exceed the liquid limit of the soil.

In situ vane tests were conducted within this deposit to determine the consistency and undrained shear strength of the cohesive material. Undrained shear strengths ranged from 70 kPa to in excess of 120 kPa. Interpretation of the larger undrained shear strength values must consider the influence of the silt interbeds. These interbeds inhibit the advancement of the test and therefore erratic shear strength profiles are produced. In general, it can be concluded that the cohesive interbeds have a stiff to very stiff consistency.

The compressibility characteristics of the clayey silt to silty clay layers were determined by conducting a one dimensional consolidation test on a representative sample of the material. The results of the test are shown graphically on Figure 8 in the Appendix. The consolidation curve is plotted on semi-logarithmic paper with the void ratio (e) plotted against the applied load ($\log p$). This form of plotting the load-deformation properties of the soil has the advantage of enabling the determination of the preconsolidation pressure (p_c) which is defined as the maximum pressure that the soil has experienced in its stress history. Considerable consolidation settlements can occur once the threshold preconsolidation pressure is exceeded.

The consolidation curve reveals a preconsolidation pressure of approximately 650 kPa. The effective overburden pressure for the sample tested is approximately 160 kPa. Therefore, the soil has been preconsolidated in the past to an effective pressure approximately 490 kPa in excess of the existing effective overburden pressure. The compression index of the material (C_c) is of small magnitude and equivalent to 0.64.

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

Underlying the layered silt and clayey silt to silty clay stratum and immediately overlying the bedrock, a deposit comprised of a heterogeneous mixture of silt, sand and gravel exists. This deposit is a glacial till and as is inherent of these types of materials, is unsorted and unstratified. The thickness of this deposit is relatively small and ranges from 0.4m to 2.8m.

The main component of this deposit is the silt material and this is illustrated on the grain size distribution curves shown on Figure 9 in the Appendix. The envelope includes particle sizes up to 26.5mm (coarse gravel) and hence excludes the boulder and cobble sizes. The envelope reveals that the silt material comprises up to approximately 76% of the deposit and the remainder of the deposit is comprised of traces of clay, some sand and traces/some gravel. Although boulders and cobbles were not encountered during the investigation, they are characteristic components of glacial tills and hence can be encountered in this deposit.

Atterberg Limit tests were conducted on the fine grained portion of the deposit (less than 425 micrometres) to determine if the material exhibits any plasticity. The results are plotted on the individual borehole logs (see BH's 2 and BH's 3) and confirm that the fine grained portion of the deposit has a low plasticity and can be categorized as a plastic silt (ML).

Bedrock

The bedrock, consisting of a "vuggy" dolostone of the Amabel Formation underlies the heterogeneous mixture of silt, sand and gravel deposit at an elevation of approximately 183m to 184.4m. The bedrock was cored at two borehole locations, BH1 and BH3 in BXL and NXL sizes respectively. Up to 3 metres of core was retrieved.

The dolostone bedrock is a chemical sedimentary rock that typically is composed of magnesium carbonate compounds and is fine to medium grained. The rock is unweathered that is featured by a porous "vug" texture. The rock is light-grey to medium dark grey in colour and contains thin horizontal beds and very close to closely spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix in a report entitled "Description of Rock Core".

An assessment of the quality and strength of the rock was carried out by measuring core recoveries and Rock Quality Designations (RQD) in the field and physical index property testing. Recoveries ranged from 97% to 100% and RQD's ranged from 83% to 98% indicating that the rock is of good to excellent quality. Rock strengths can be described as medium strong.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes throughout the duration of the field investigation. Groundwater levels determined at the time of the more recent investigation were approximately 2 metres below the ground surface (Elevation 206.5m).

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 a triple cell reinforced concrete culvert structure that will carry the proposed Hwy 403 over the existing Big Creek. The existing Big Creek meanders at the site and will be realigned at the proposed structure location.

Dwg. 1148700D-A in the Appendix illustrates a plan of the proposed culvert structure. The plan identifies the proposed culvert location, positioned at a 105° skew to the centreline. The dimensions of each cell is 5.0m x 3.6m producing a cross sectional area equivalent to 54m². The length of the proposed culvert structure is approximately 100 m.

The proposed grade for the Hwy 403, which initially will be a four lane median divided highway with ultimate widening plans, is approximately 220.5 metres at the eastern limit of the site and slopes downward to an approximate elevation of 220 metres at a 0.3% gradient at the western limit of the site. The culvert invert elevation is 208.0 metres at the culvert inlet and 207.0 metres at the culvert outlet, indicating a bed slope gradient of approximately 1%. The ground surface elevation is flat and equivalent to approximately 208.5m. Therefore, approximately 12 metres of embankment fill will be required above the ground surface at the site.

Embankment fills as proposed at the site must be designed in consideration of regional storm events. At the site, the following regional storm water levels have been provided.

Table 5 - Regional Storm Water Levels

Flood Level Period (year)	Elevation (m.)
50	209.6
100	213.0

To facilitate the design and construction of the proposed structure foundations and related earthworks, the following foundation and geotechnical recommendations are provided in the scope of this report.

1. Structure Foundations
2. Erosion Protection at Culvert Inlet/Outlet
3. Backfill to Structure
4. Approach Embankments
5. Construction Considerations

1) STRUCTURE FOUNDATIONS

The surficial native soils at the site are not considered suitable for the support of conventional, economical shallow foundations because of the weaker nature of the material. A closed box culvert type of structure is hence not considered feasible. It is therefore recommended that the culvert be of an open footing type of culvert supported on end-bearing deep foundation steel H-piles driven to the bedrock surface. For purposes of the O.H.B.D.C., the deep foundation units can be designed employing the axial capacities tabulated in Table 6 below.

Table 6 - Axial Capacities - Steel H-piles

Pile Type	Factored Capacity at U.L.S (kPa)	Axial Capacity at S.L.S (kPa)	Estimated Pile Tip Elevation (m)
HP 310 x 110	1600	1150	183
HP 310 x 79	1150	890	183

Axial capacities provided in Table 6 are for vertical piles only. Reductions of axial capacities for inclined loadings shall conform to factors provided in Section 6.8.3.4.3 of the O.H.B.D.C.

It is recommended that to facilitate the pile driving process, all piles be equipped with reinforced tips. Driving shoe details are given on OPSD 3301.00.

In view of the pile embedment lengths required to reach bedrock, splicing of the piles will be required. Splicing shall be carried out in accordance with OPSS 903.07.01.03 and as illustrated on OPSD 3301.00.

Pile spacing shall conform with Section 6.8.3.10 of the O.H.B.D.C. For centrally loaded piles equal load sharing on the deep foundation units can be assumed. The design of eccentric loaded deep foundation units shall comply with section 6.8.3.4.2 of the O.H.B.D.C.

The lateral resistance for both vertical and battered piles shall be computed in accordance with Section 6.8.3.8 of the O.H.B.D.C. Pertinent unfactored soil parameters to facilitate the design of vertical piles is given in Table 7 below.

Table 7 - Horizontal Capacity Soil Parameters

Soil	Elevation (m)	Undrained Shear Strength (c_u) (kPa)	Angle of Internal Friction (ϕ)	Bulk Unit Weight (kN/m^3)
Clayey Silt with random layers of Silt	208.5 - 204	50		19
Silt with random seams/ layers of Clayey Silt	204 - 195		30°	20
Layered Silt and Clayey Silt to Silty Clay	195 - 184	70		19
Heterogeneous Mixture of Silt, Sand and Gravel	184 - 183		30°	20

Pile caps shall be protected against frost penetration by providing a minimum 1.2m earth cover or equivalent frost protection.

2. EROSION PROTECTION AT CULVERT INLET AND OUTLET

A smooth transition should be provided at the inlet and outlet of each culvert to minimize the potential for erosion caused by the scouring forces of the creek water. Aprons and rip-rap should be constructed to provide the necessary erosional resistance. Rip-rap shall be placed over the transitional area and also throughout the stream bed within the culvert length in accordance with the hydrology and hydraulic requirements. These requirements include the rip-rap gradation and the height of rip-rap coverage.

To inhibit flow within the backfill adjacent to the culvert walls, it is recommended that headwalls be constructed in conjunction with the rip-rap protection. Impervious clay liners can also be used at the culvert inlet as a sealer behind the rip-rap. The impervious clay blanket shall be 1 metre thick and consist of material as specified in OPSS 1205.

3) BACKFILL TO STRUCTURE

Material

It is recommended that Granular 'A' or Granular 'B' be used behind the culvert structure walls placed as shown on OPSD 800 series. The application of granular material combined with weep holes in the culvert walls to drain any accumulation of water in the backfill will prevent hydrostatic pressure build-up. Design parameters of the soil are given in Table 8 below.

Table 8 - Backfill Properties

	Granular 'A'	Granular 'B'
Angle of Internal Friction (ϕ) (unfactored)	35°	30°
Unit Weight (kN/m ³) , γ	22.8	21.2
*Coefficient of Active Earth Pressure (Ka)		
- S.L.S	0.27	0.33
- U.L.S	0.33	0.40
*Coefficient of Earth Pressure at Rest (Ko)		
- S.L.S	0.43	0.50
- U.L.S	0.50	0.58

*These earth pressure coefficients apply to horizontal backfill surfaces only. The appropriate consideration shall be given to account for sloping backfill.

Backfilling and Compaction

In the placement of the backfill material, all softened material should be excavated for their full depth within the plan limits prior to fill placement. Backfill shall be placed simultaneously behind both sides of the structure walls and at no time shall the difference in elevation be greater than 500mm. The backfill shall be constructed in 300mm lifts in accordance with OPSS 902 series and applicable OPSD series. The backfill shall be compacted to achieve the target maximum dry density as outlined in OPSS 501.07.08.

Heavy vibratory equipment should be avoided in the backfill construction adjacent to the structure. It is therefore recommended that hand compaction equipment be employed in backfilling the sides of the culvert within a lateral distance equal to the current height of fill above the wall footing in order to minimize deflection or possible damage of the wall.

4) APPROACH EMBANKMENTS**General**

The site is located in a low lying valley and consequently approach fills up to approximately twelve (12) metres will be required adjacent to the culvert structure and approximately ten (10) metres of fill will be required above the roof of the culvert. The design of embankments such as those proposed at the site must address the following considerations:

- 1) Stability
- 2) Settlement

A further important consideration at this site is safeguarding the embankment from the consequences of regional storm water levels. As mentioned earlier, fifty (50) and one hundred (100) year storm water levels will reach elevations of 209.6m and 213.0m respectively.

Therefore, embankment material, geometry and drainage must be appropriately designed to prevent loss of material and subsequent imminent embankment failure.

The embankment design considerations and recommendations are discussed below. Construction of the embankment is also discussed.

Stability

Global

The critical condition examined in the evaluation of the global stability of embankment fills as proposed at the site location is the short term (undrained) condition and consequently a total stress analysis was conducted. In all cases, stability computations were carried out using an in-house MTOslope application software package which is based on Sarma's method of limiting equilibrium. The formulation of Sarma's method is described in a paper entitled "Stability Analysis of Embankments and Slopes", Sarma, S.K. (1973), Geotechnique 23, No. 3, pp 423-433.

The process of stability analyses involves the selection of pertinent shear strength parameters and physical soil properties such as unit weight, inputting the subsurface and groundwater conditions and then designing a surface geometry that produces an acceptable factor of safety of 1.3 using the MTOslope program.

Figure 10 in the Appendix illustrates the subsurface conditions and relevant subsoil parameters used in the stability analyses. Both circular and non circular slip surfaces were evaluated and a critical slip surface was searched.

Both a granular fill material and a cohesive clay material were selected in the stability analyses and the final results were similar. The advantage of the granular material however, is that pore pressures which can develop from the rise in the water level as is expected during the regional storm will dissipate quickly and hence preserve the stability of the embankment.

The results of the analysis reveals that the critical slip surface is located within the surficial clayey silt with random layers of silt deposit at the site. It is therefore recommended that the transverse slopes of the embankment fills be constructed with a nominal mid-height four (4) metre berm and 2H:1V slopes as shown on Figure 10. To promote surface runoff, it is recommended that the berm be constructed with a 2% downward gradient towards the toe of the embankment.

Internal

The internal stability of the embankment fill must be ensured during the regional storm period. Consequently, soil migration and piping within the embankment fill must be prevented. Based on a headwater and tailwater head difference of 0.3m as given in previous correspondence (see internal memo - P. Jankowski - 92 06 19), no major seepage or piping problems are anticipated. However, it is recommended that the base material of the embankment be protected from the external water with a minimum 1 metre thick rip-rap or gabion stone material as outlined in OPSS 1004.050.06. It is further recommended that filter materials be placed between the rock protection and the base embankment material. Specifications for the gradation and thickness of the filter material are dependent on the gradation of the base embankment material. This office can provide recommendations for the filter material once the gradation of the base material is known. The rock protection and filter material shall extend to a minimum 0.3m above the high water level (100 year flood level, Elevation 213.0m).

Consideration can also be given to employing a cohesive predominantly clay material as the base core embankment material or as an impervious core material. An impervious core shall extend a minimum 0.3 m above the high water elevation. Suitable filters and rock protection are recommended for the clay material as discussed above.

Normal slope vegetation cover shall be established as per conventional MTO standards as soon as possible to provide surface erosion protection for the slopes above the rock protection.

Native slopes exist at the western and eastern limits of the site. Longitudinal embankment fill slopes shall be benched into the existing slopes as per OPSD 208.01.

Embankment Construction

Embankment material and construction shall conform to OPSS 212 and OPSS 206 series respectively. The embankment material shall be compacted as outlined in OPSS 501 series.

All softened and/or organic material should be excavated for their full depth within the plan limits prior to fill placement.

Embankment Settlement

The overburden materials at the site are weaker in nature and hence will experience settlement as a result of the applied loadings. In view of the preconsolidation nature of the cohesive clayey silt to silty clay layers and the predominant cohesionless silt deposit and silt interlayers it is expected that approximately 120mm of settlement will be realized as a result of the compression of the native soil. This settlement is expected to be elastic in nature and hence should be realized during or shortly after the construction period.

Settlements within the embankment fill material are also anticipated. It is expected that approximately 75mm to 100mm of settlement within the fill will be realized as a result of loading under its own weight. These settlements are expected to occur almost instantaneously and should occur during or immediately following construction for a granular material. In the case of a cohesive fill material, settlements are expected to require longer durations to be realized but these settlements are anticipated within a three (3) month period following construction.

Any additional vertical shearing forces created by the relative movements of the embankment fill and the culvert foundation must be considered in deducing the applied loadings.

It is recommended that in view of the cumulative embankment settlements, that the final surface paving be delayed as much as scheduling permits in order to minimize post construction maintenance. Most of the settlements should be realized within a three (3) month period following construction.

CONSTRUCTION CONSIDERATIONS

Recommendations for construction methods and procedures are given below. In all cases, the most economical alternative shall be adopted.

Construction Procedure

a) Temporary Diversion

To facilitate the construction of the culvert, a temporary diversion of the Big Creek will be required. This can be accomplished by temporary realigning the creek. Impervious earth dikes

composed of suitable clay material (CH-see OPSS 1205) can be used upstream to prevent water inflow into the foundation excavation.

b) Interlocking Steel Sheet Pile Wall (Cofferdam Construction)

Alternatively, the culvert construction can take place within an enclosure formed by interlocking steel sheet piling. In order to prevent basal heave at the base of the excavation, it is recommended that the sheeting be driven to a depth below the footing base equal to the unbalanced hydrostatic head existing above this level (see Figure 11).

Excavation and Dewatering

Excavation to facilitate the construction of the culvert structure will require the removal of up to approximately 1.5 metres of the surficial thickness of clayey silt with random layers of silt. In order to prevent conditions of unbalanced hydrostatic head within the underlying silt deposit and the resulting 'boiling' action of the material and to control the sloughing of the interbedded layers within the clayey silt, two methods are recommended depending on the construction procedure that is selected.

a) Oversized Excavation

Figure 12 illustrates the proposed oversized excavation scheme that is to be used in conjunction with the temporary diversion construction procedure. The oversized excavation is composed of perimeter ditches and a sump pumping discharge system to drain accumulated water. Soil migration during the dewatering process must be adequately controlled to prevent potential undermining of the footing bed. A properly designed filter fabric placed on the excavated slopes can be used to achieve the retention of soil migration.

b) Interlocking Steel Sheet Pile Wall

Excavation can take place within an interlocking steel sheet pile wall as described above. Any water within the enclosure can be discharged using conventional sump pump methods.

Temporary Slopes

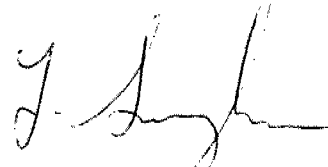
Temporary excavation slopes within the surficial clayey silt with random layers of silt stratum shall not be steeper than 1.5H:1V.

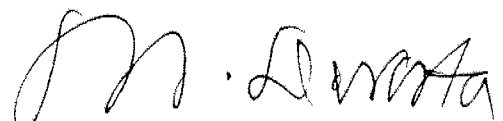
MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and L. Dametto, Student Engineer, utilizing equipment owned and operated by Malone's Soil Samples and Dominion Soil Investigation. Logging of rock core in the laboratory was carried out by D. Williams, Petrographer.

The project was carried out by T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by Mr. M. Devata, Chief Foundation Engineer.

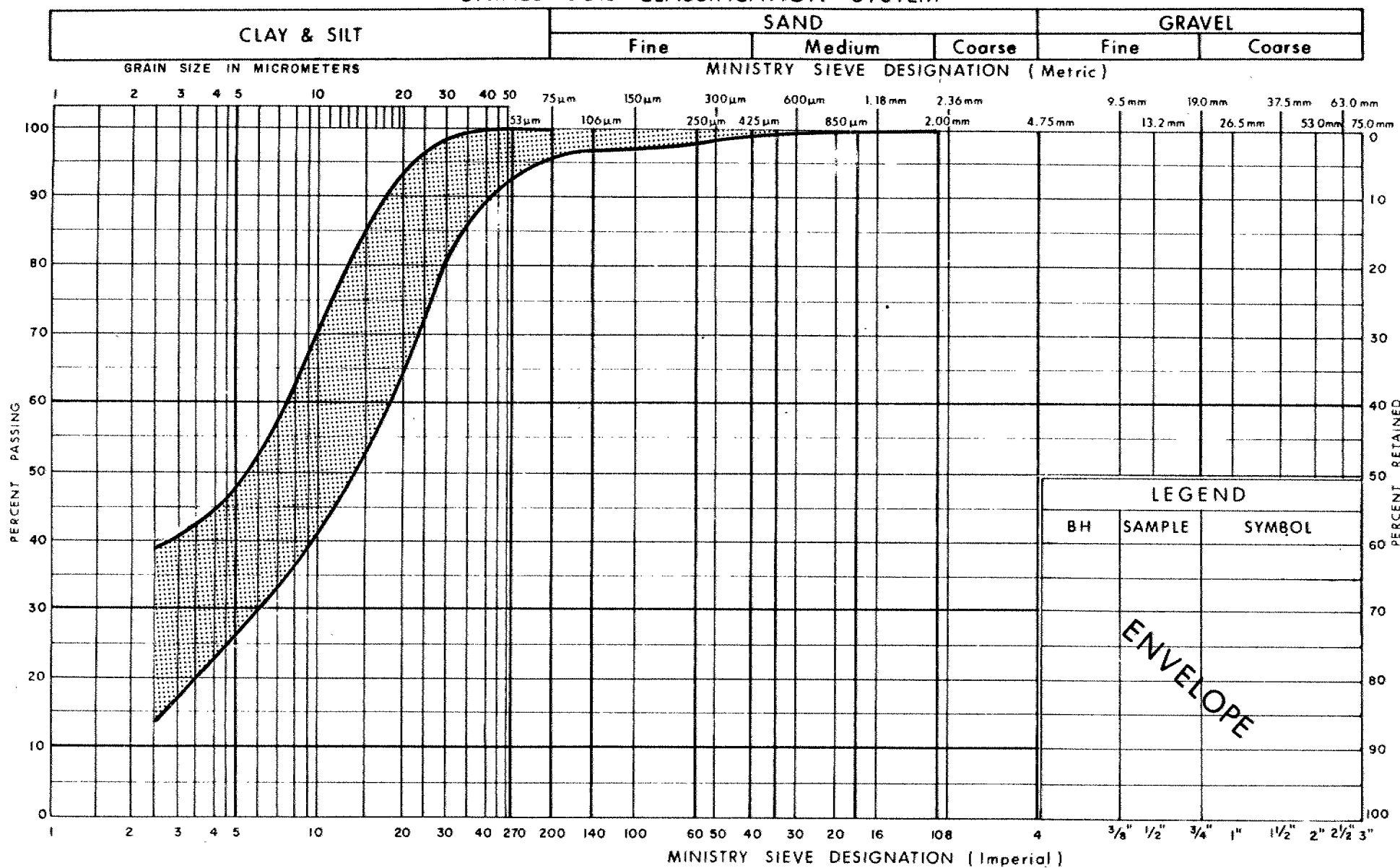



T. Sangiuliano, P. Eng
Foundation Engineer


M. Devata, P. Eng.
Chief Foundation Engineer

APPENDIX

UNIFIED SOIL CLASSIFICATION SYSTEM



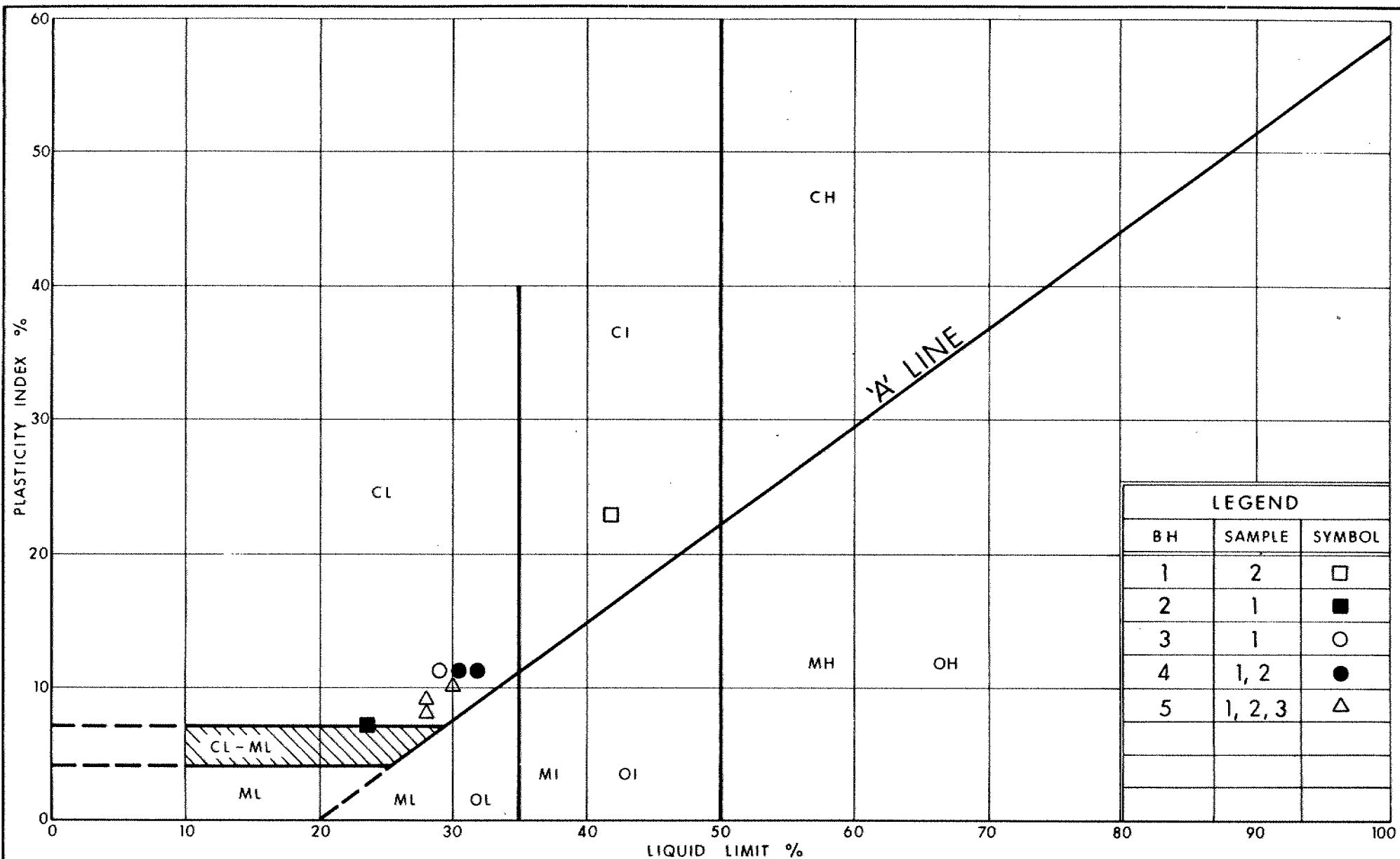
Ontario

Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
CLAYEY SILT
 WITH RANDOM LAYERS OF SILT

FIG No 1

W P 114 - 87 - 00 (D)



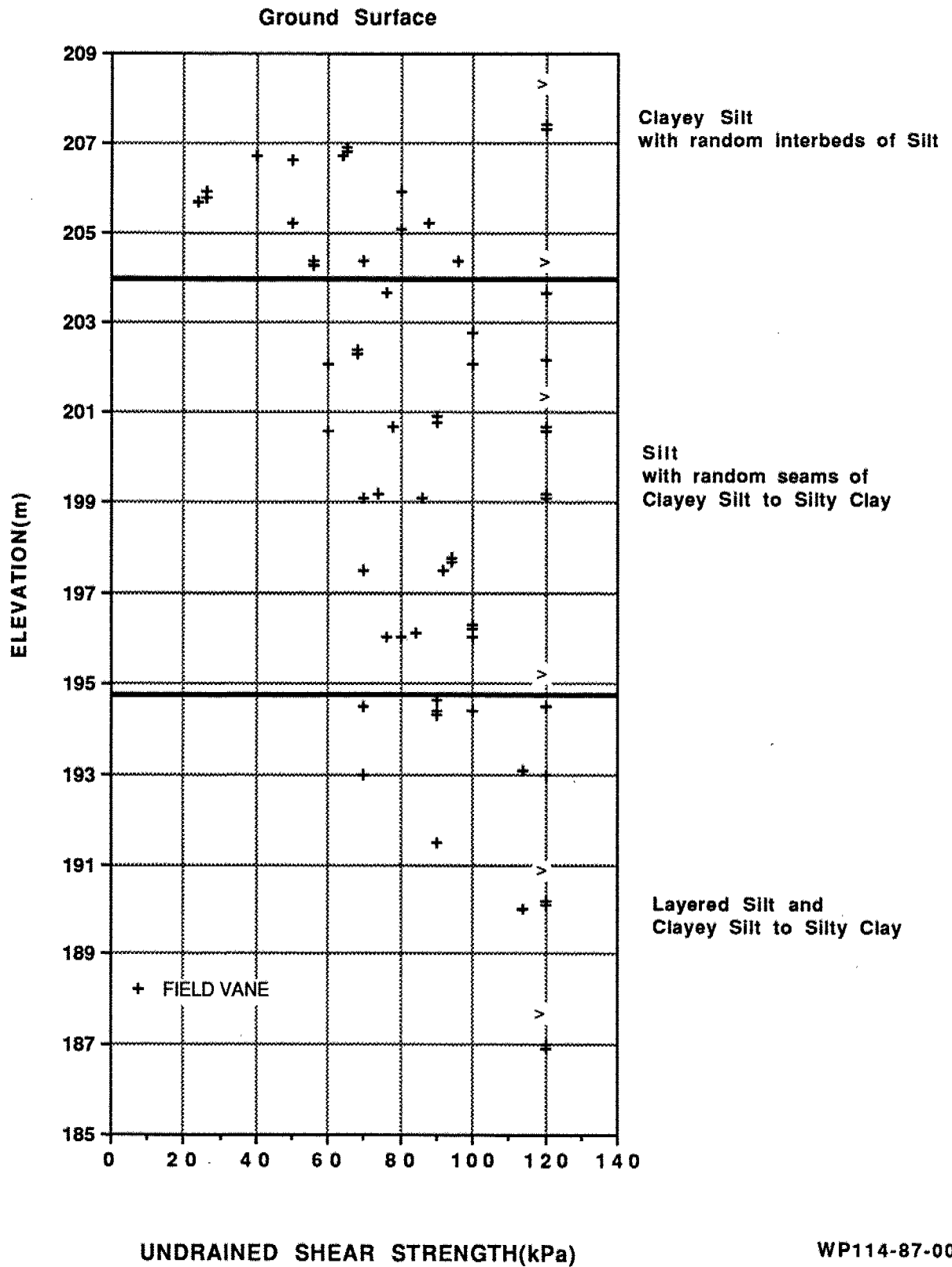
Ministry of
Transportation
Ontario

PLASTICITY CHART CLAYEY SILT WITH RANDOM LAYERS OF SILT

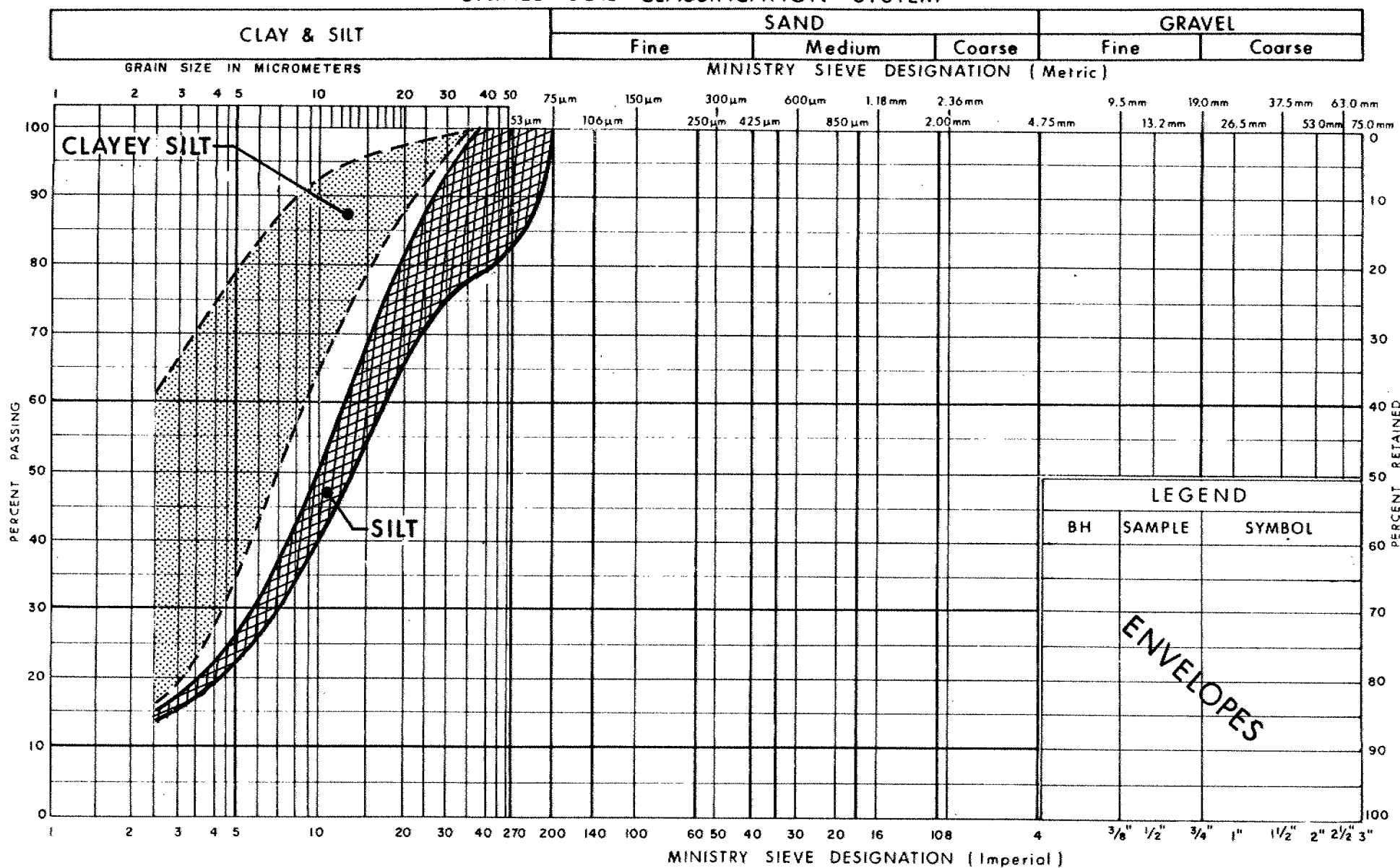
FIG No 2

W P 114-87-00(D)

FIGURE 3
ELEVATION VS SHEAR STRENGTH PROFILE



UNIFIED SOIL CLASSIFICATION SYSTEM

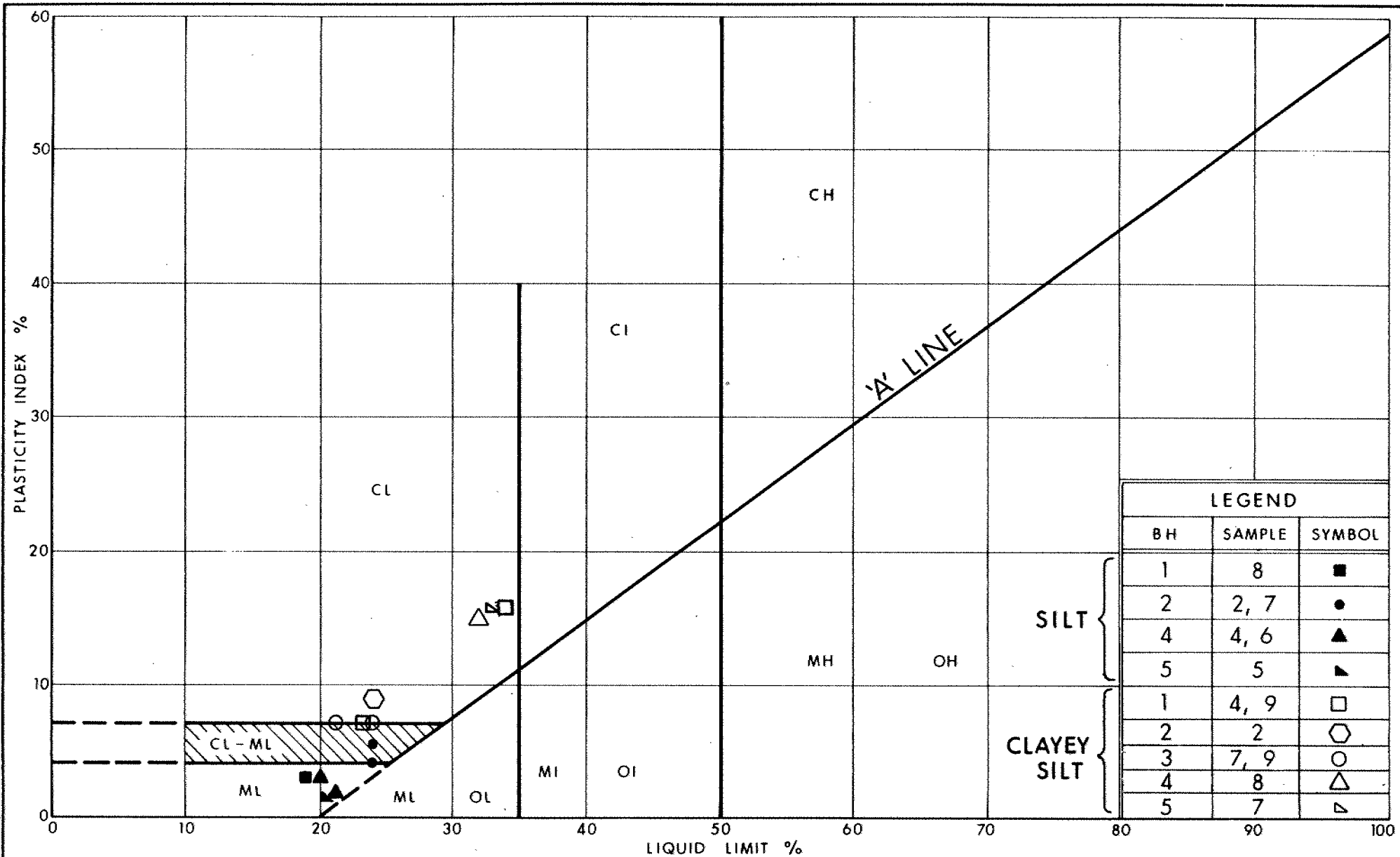
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION SILT

WITH INTERBEDDED SEAMS/LAYERS OF CLAYEY SILT

FIG No 4

W P 114 - 87 - 00 (D)



Ministry of
Transportation

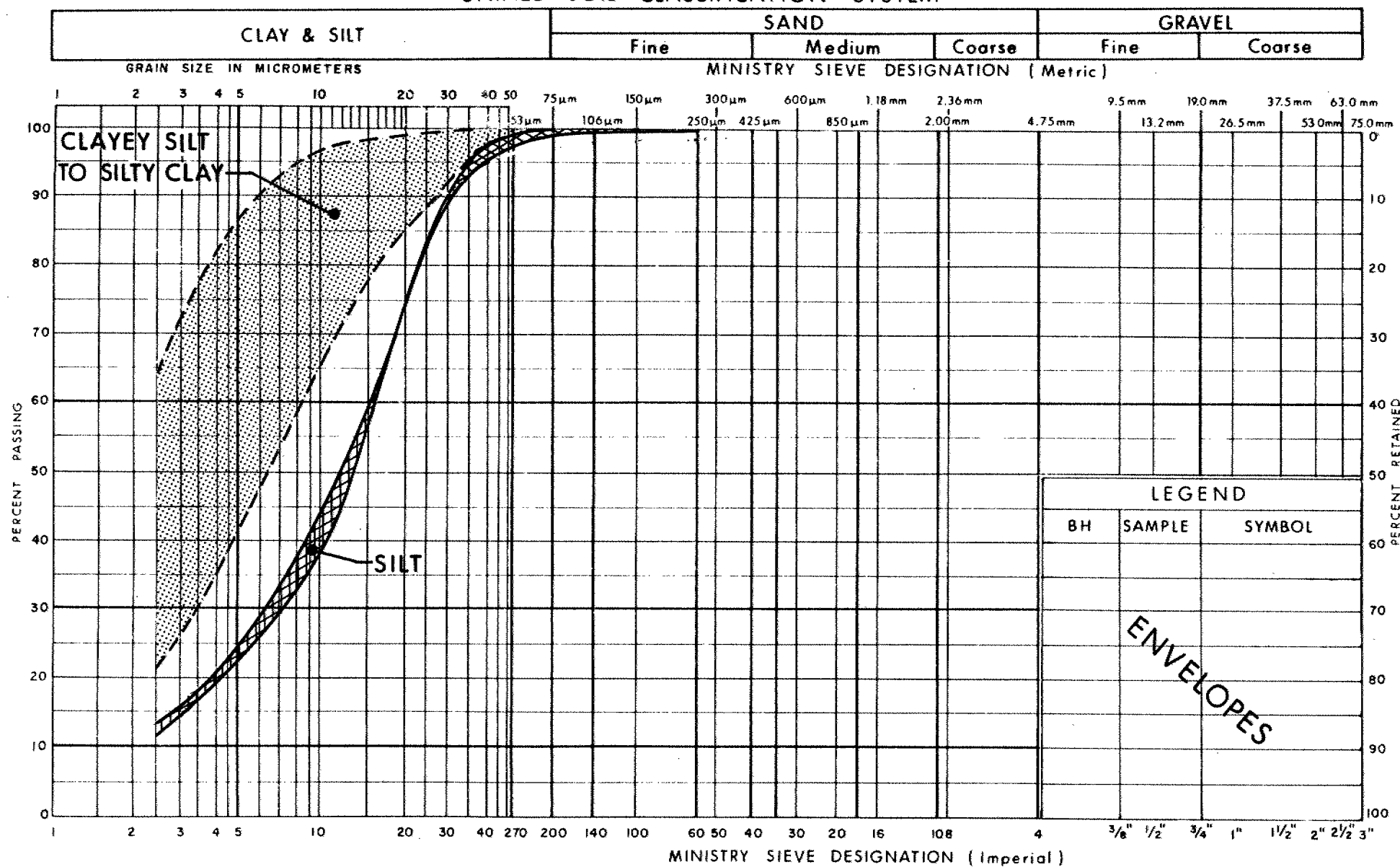
PLASTICITY CHART SILT

WITH INTERBEDDED SEAMS/LAYERS OF CLAYEY SILT

FIG No 5

W P 114-87-00(D)

UNIFIED SOIL CLASSIFICATION SYSTEM

Ministry of
Transportation

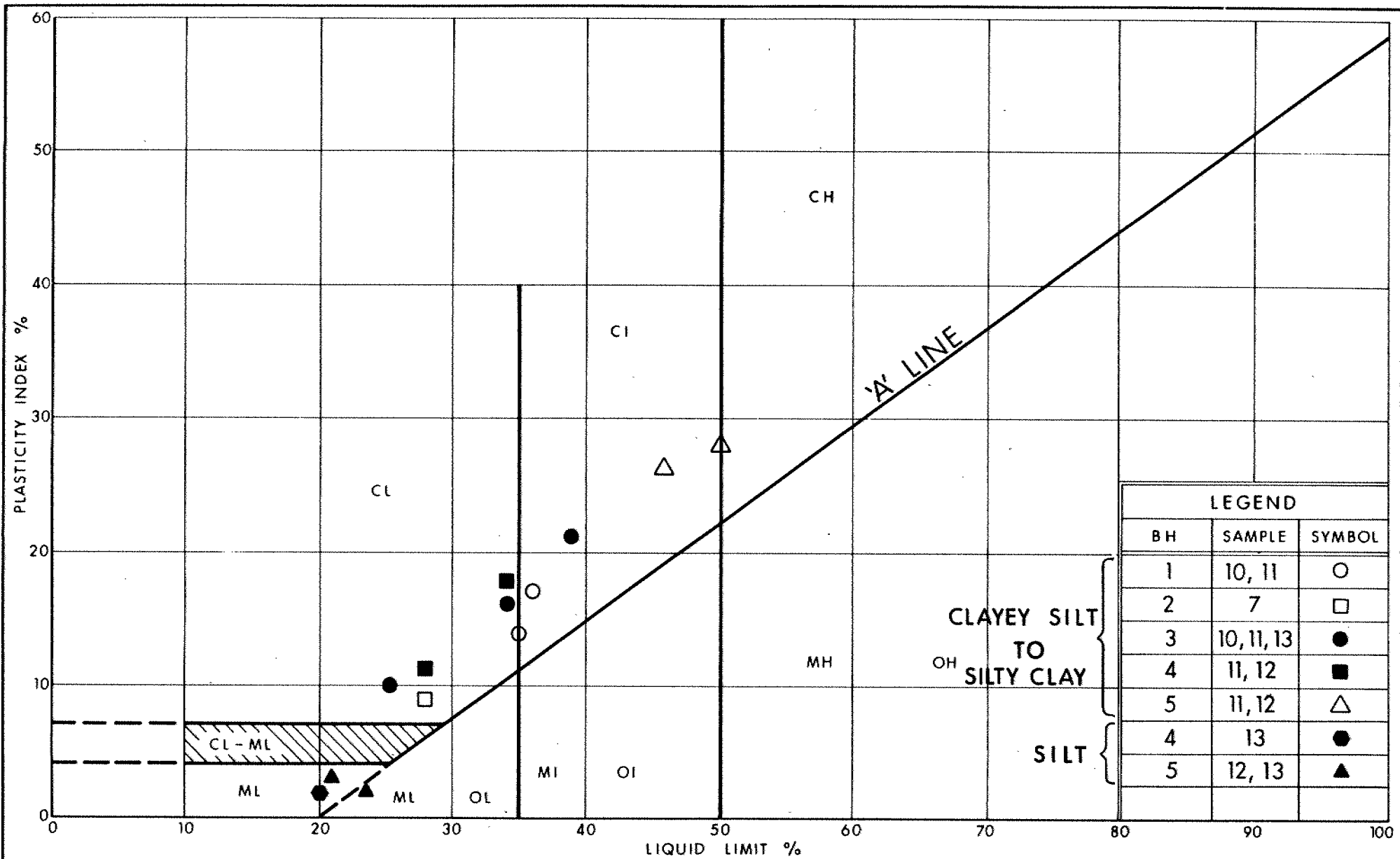
Ontario

GRAIN SIZE DISTRIBUTION

LAYERED SILT & CLAYEY SILT TO SILTY CLAY

FIG No 6

W P 114 - 87 - 00 (D)



Ontario

Ministry of
Transportation

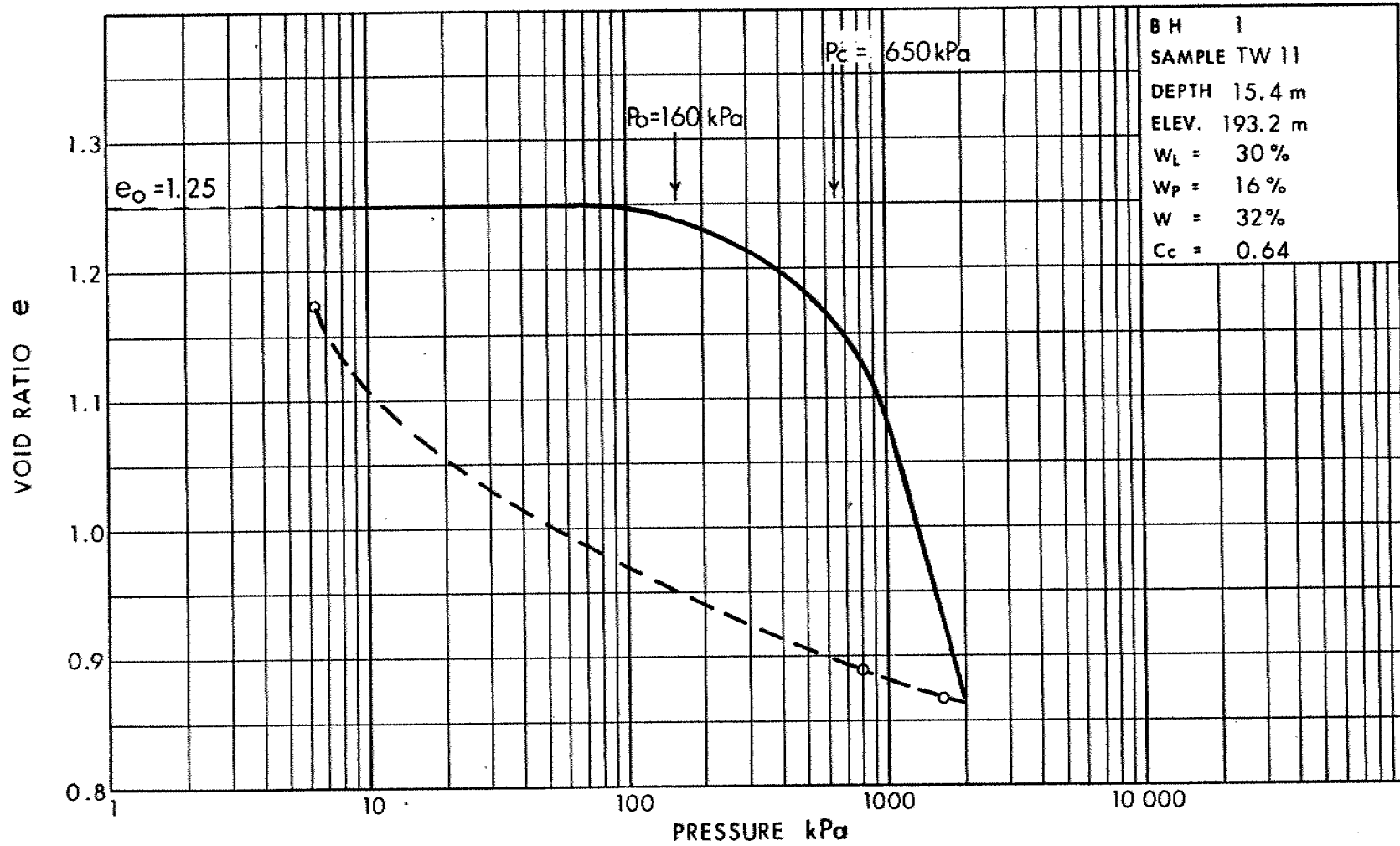
PLASTICITY CHART

LAYERED SILT & CLAYEY SILT TO SILTY CLAY

FIG No 7

W P 114-87-00(D)

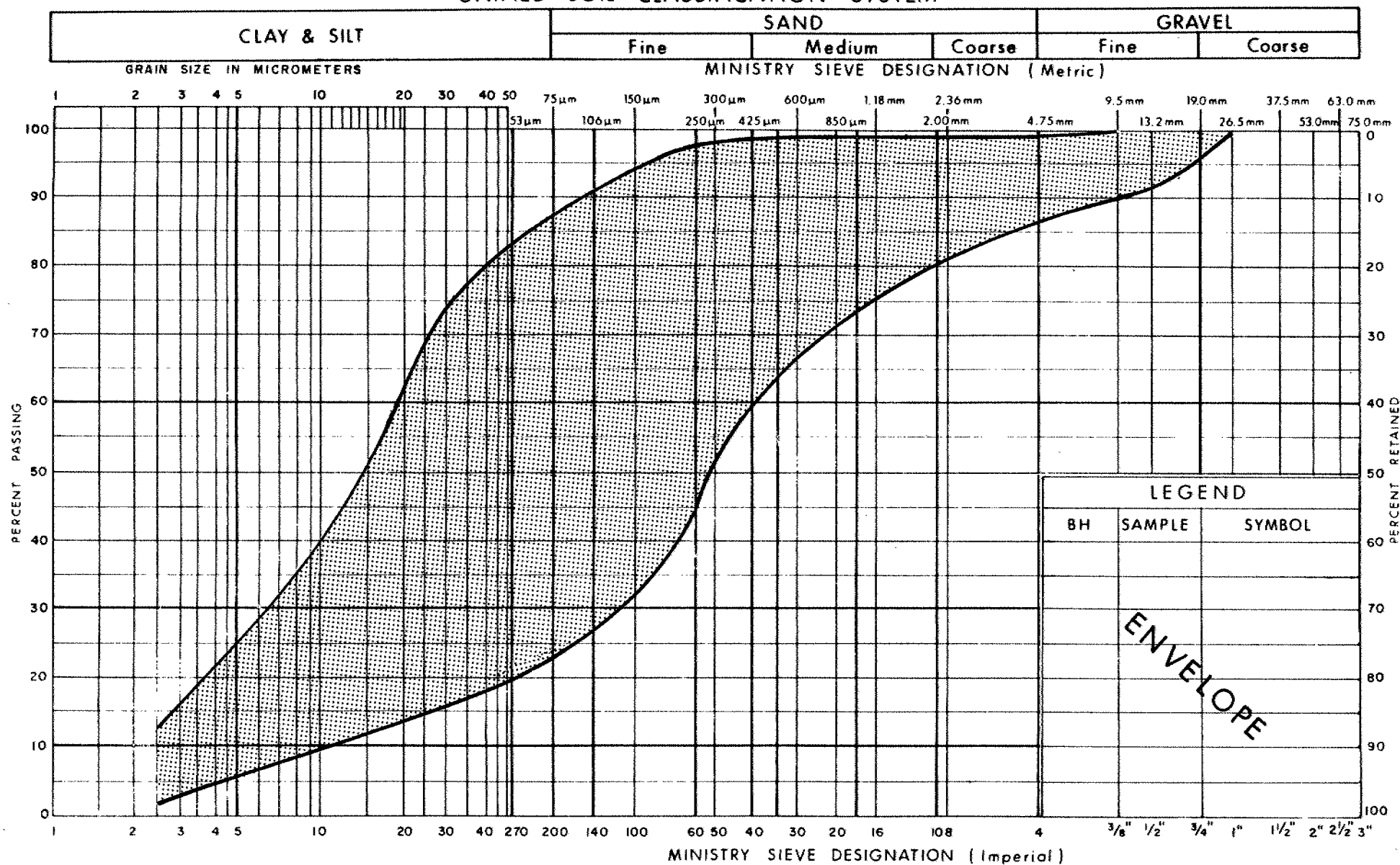
VOID RATIO - PRESSURE CURVE



WP 114 - 87 - 00 (D)

FIG No 8

UNIFIED SOIL CLASSIFICATION SYSTEM

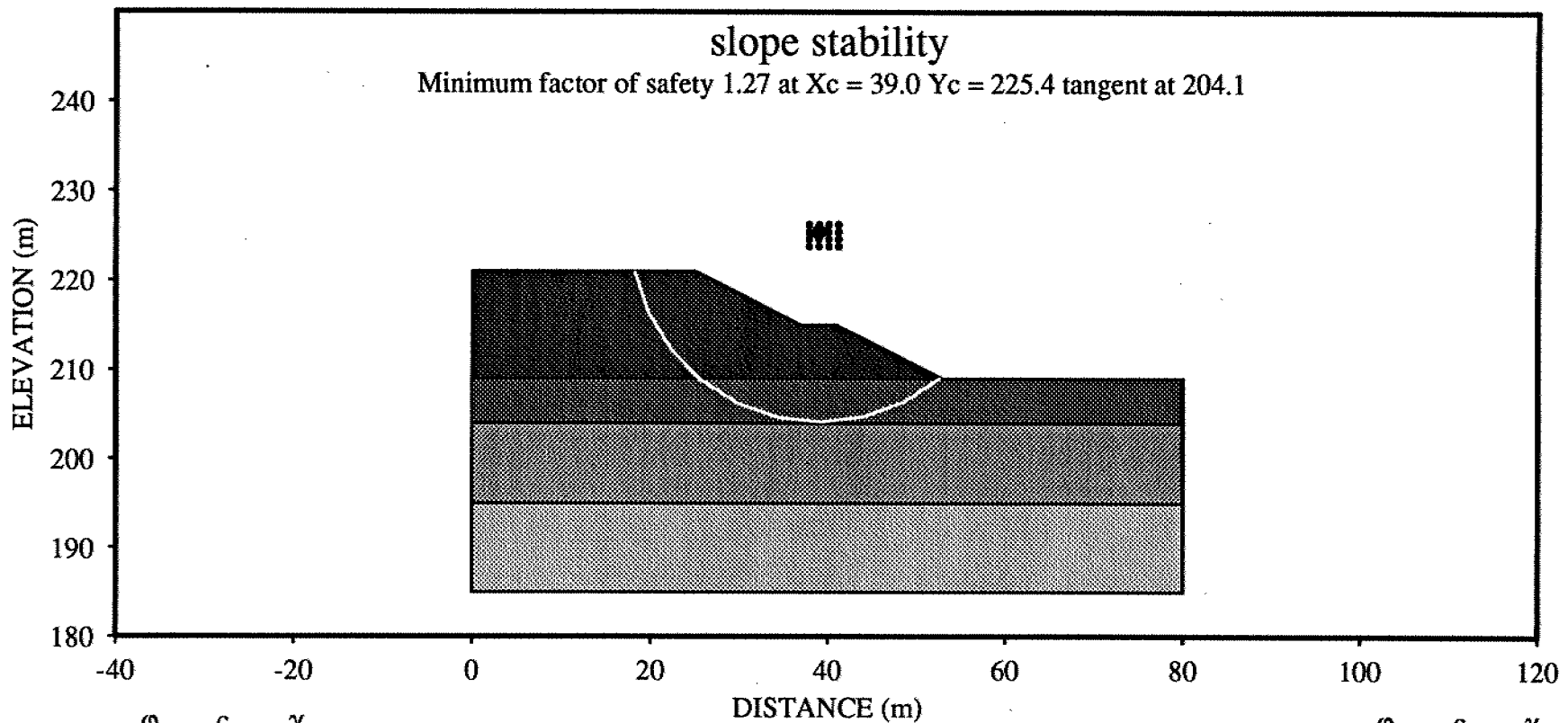


Ministry of
Transportation

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

FIG No 9

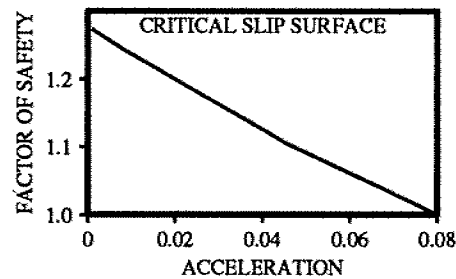
W P 114-87-00(D)



ϕ	c	γ	
30.0	0.0	20.0	FILL
0.0	50.0	19.0	CLAYEY SILT

CRITICAL ACCELERATIONS

0.078	0.080	0.084	0.090
0.079	0.080	0.084	0.090
0.080	0.081	0.085	0.091
0.082	0.083	0.086	0.093



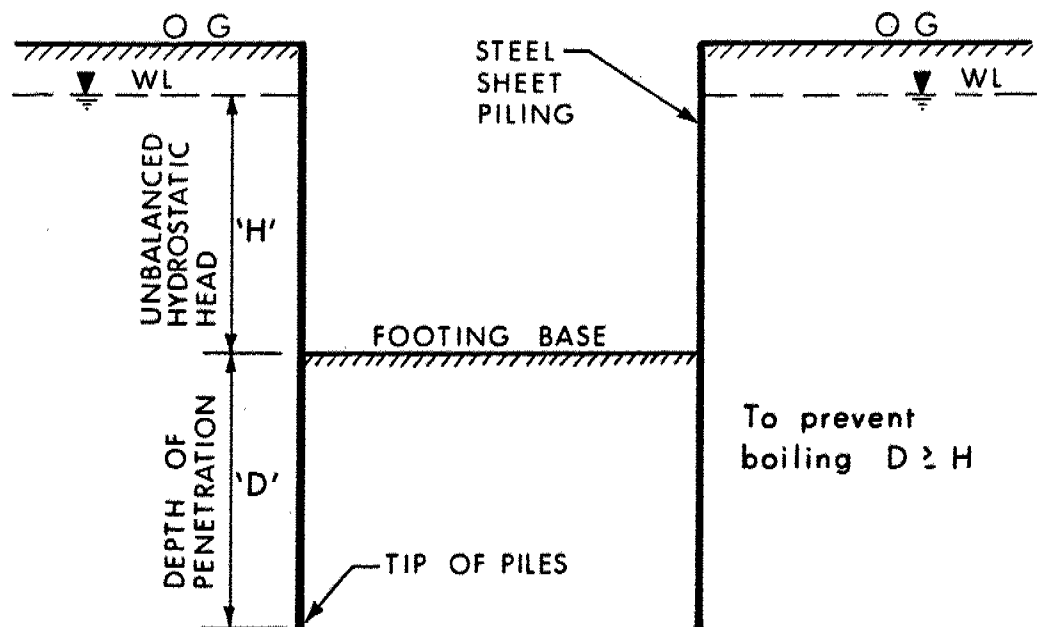
	ϕ	c	γ
SILT	0.0	70.0	20.0
LAYERED SILT	0.0	90.0	19.0

FACTORS OF SAFETY

1.284	1.274	1.277	1.291
1.284	1.273	1.276	1.290
1.286	1.274	1.276	1.290
1.291	1.278	1.279	1.293

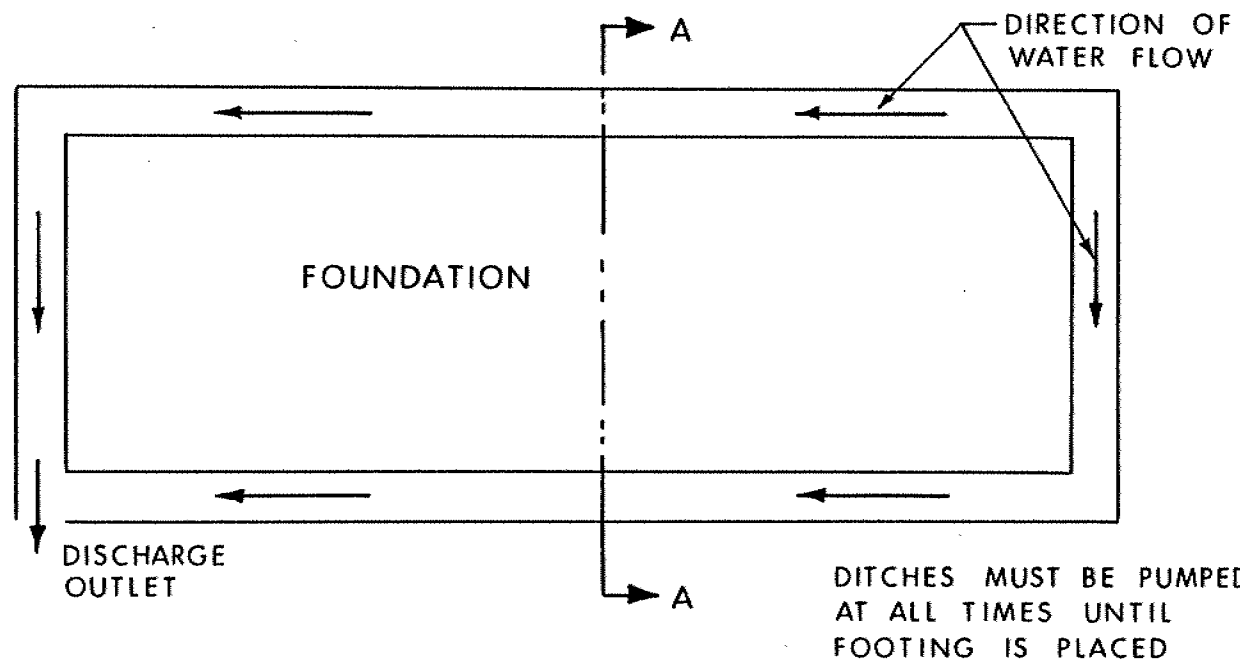
WP 114 - 87 - 00 (D)

FIG 10



COFFERDAM CONSTRUCTION

W P 114-87-00(D)
FIG 11



SECTION A-A
(NTS)

DEWATERING SCHEME - PERIMETER DITCHES

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 650.6 E 257 227.6 ORIGINATED BY TS
DIST 4 HWY 403 BOREHOLE TYPE HS Auger, BW Casing, BXL Core COMPILED BY TS
DATUM Geodetic DATE 92 07 06-07 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
208.6	Ground Surface													
0.0	Clayey Silt to Silty Clay with random layers of Silt Brown ----- Grey Stiff		1	SS	7		208							
			2	SS	6		206						18.9	0 0 62 38
204.0	Silt with interbedded seams/layers of Clayey Silt Grey, Loose to Compact / Stiff to Very Stiff		3	TW	PH		204							0 82 8 10
4.6			4	SS	10									0 2 83 15
			5	TW	PH		202							
			6	SS	8		200							
			7	SS	5		198							0 0 88 12
			8	SS	6		196							0 0 39 61
			9	SS	6		194							0 0 50 50
194.9			10	SS	7		192							0 0 45 55
13.7	Layered Silt and Clayey Silt to Silty Clay Grey, Loose/Stiff to Very Stiff		11	TW	PH		190							
			12	TW	PH		188							
			13	SS	9		186							0 2 57 41
			14	SS	9		184							0 2 71 27
184.5	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till), Dense		15	SS	36		182							1 16 74 9
24.1			16	RC	REC 97%									RQD = 84%
183.3	Bedrock - Dolostone Light Grey, Unweathered Medium Strong		17	RC	REC 97%									RQD = 87%
25.3														
180.3	End of Borehole • 92 07 07													
28.3														

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 891.6 E 257 277.1 ORIGINATED BY MK
DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY MK
DATUM Geodetic DATE 76 03 23-24 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								20 40 60 80 100	20 40 60 80 100						
208.7	Ground Surface														
0.0	Clayey Silt with random layers of Silt		1	SS	5		208								
205.7	Brown, Stiff						206								
3.0	Silt with interbedded seams/layers of Clayey Silt Grey, Loose/Stiff to Very Stiff		2	SS	7										
			3	TW	PH										
			4	SS	6										
			5	TW	PH										
			6	SS	7										
			7	TW	PH										
		8	SS	8											
185.0	Layered Silt and Clayey Silt to Silty Clay Grey, Loose to Compact/ Stiff to Very Stiff	9	SS	10											
13.7		10	TW	PH											
		11	SS	9											
		12	TW	PH											
		13	SS	64	/15cm										
184.3															
183.9															
24.8	End of Borehole (Auger Refusal - Probable Bedrock) • Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till) Very Dense														

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 740.0 E 257 281.0 ORIGINATED BY LD
DIST 4 HWY 403 BOREHOLE TYPE HS Auger, NW Casing, MXL Core and Cone Test COMPILED BY TS
DATUM Geodetic DATE 92 07 06-07 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W _P W W _L	WATER CONTENT (%) 10 20 30		
208.6	Ground Surface												
0.0	Cloyey Silt with random layers of Silt Brown Grey Firm to Stiff		1	SS	3	*	208					20.0	0 2 81 17
			2	SS	1		206						
203.6			3	SS	5		204					0 0 85 15	
5.0	Silt with interbedded seams/layers of Cloyey Silt Grey, Very Loose to Loose/ Stiff to Very Stiff		4	SS	3		202						
			5	TW	PH		200					0 0 87 13	
			6	SS	3		198					0 0 87 13	
			7	SS	4		196					0 0 63 37	
			8	SS	4		194						
			9	TW	PH		192					0 0 78 22	
196.4			10	SS	7		190						
12.2	Layered Silt and Cloyey Silt to Silty Clay Grey, Loose to Compact/ Stiff to Very Stiff		11	SS	9		188						
			12	SS	7		186						
			13	SS	16		184					5 9 76 10	
			14	TW	PH		182					RQD = 98%	
			15	SS	6							RQD = 83%	
184.2			16	SS	62								
24.4	Heterogenous Mixture of Silt, Sand and Gravel (Glacial Till), Very Dense		17	SS	**								
183.0			18	RC	REC 100%								
25.6	Bedrock - Dolostone Light Grey, Unweathered Medium Strong		19	RC	REC 100%								
180.3													
28.3	End of Borehole * GWL not established ** Sampler Bouncing												

+3, x5: Numbers refer to
Sensitivity 20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 681.0 E 257 167.2 ORIGINATED BY LD
DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 92 07 07 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	w _p w w _L	WATER CONTENT (%)		
208.5	Ground Surface												
0.0	Clayey Silt with random layers of Silt Brown, Firm to Stiff		1	SS	7		208					20.0	0 10 74 16
			2	TW	PH		206					18.8	0 2 80 18
204.7			3	SS	6		204						
3.8	Silt with interbedded seams/layers of Clayey Silt Grey, Very Loose to Compact/ Stiff to Very Stiff		4	SS	4		202						0 1 83 16
			5	SS	10		200						
			6	SS	6		198						0 0 89 11
			7	SS	6		196						
			8	SS	8		194						0 0 50 50
195.1			9	SS	8		192						
13.4	Layered Silt and Clayey Silt to Silty Clay Grey, Very Loose to Compact/ Stiff to Very Stiff		10	TW	PH		190						0 0 53 47
			11	TW	PH		188						
			12	SS	9		186						0 0 42 58
184.7			13	SS	4		184						0 1 90 9
23.8 183.8	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till)												
24.7	End of Borehole * 92 07 09 ** Sampler Bouncing (Probable Bedrock)												

RECORD OF BOREHOLE No 5

1 OF 1 METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 719.1 E 257 221.0 ORIGINATED BY TS
 DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS
 DATUM Geodetic DATE 92 07 07-08 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	w _p	w	w _L	WATER CONTENT (%)	7 kN/m ³	GR SA SI CL
208.6	Ground Surface														
0.0	Clayey Silt		1	SS	5		208								0 3 76 21
	Brown, Very Stiff		2	TW	PH		206								0 2 76 22
204.3			3	SS	5		204								0 0 78 22
4.3	Silt with interbedded seams/layers of Clayey Silt		4	SS	4		202								0 0 88 12
	Grey, Very Loose to Loose/ Stiff to Very Stiff		5	SS	7		200								0 0 53 47
			6	SS	6		198								
			7	SS	5		196								
			8	SS	4		194								
194.9			9	SS	10		192								
13.7	Layered Silt and Clayey Silt to Silty Clay		10	TW	PH		190								
	Grey, Loose to Compact/ Stiff to Very Stiff		11	SS	5		188								
			12	TW	PH		186								
			13	SS	5		184								
184.2			14	SS	9		182								
24.4	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till), Loose						180								15 62 22 1
183.1							178								
25.5	End of Borehole (Auger Refusal - Probable Bedrock)						176								
	* 92 07 09						174								

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 708.2 E 257 119.3 ORIGINATED BY LD
DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 92 07 08 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
208.5	Ground Surface																
0.0	Clayey Silt with random layers of Silt		1	SS	8		208										
205.8	Very Stiff Brown Grey		2	SS	4		206										
2.7	Silt with interbedded seams/layers of Clayey Silt		3	SS	5		204										
			4	SS	5		202										
			5	SS	6		200										
	Grey, Loose/Stiff to Very Stiff		6	SS	9		198										
			7	SS	6		196										
			8	SS	5		194										
196.3			9	SS	8		192										
12.2	Layered Silt and Clayey Silt to Silty Clay		10	TW	PH		190										
	Grey, Loose to Compact/ Stiff to Very Stiff		11	SS	6		188										
			12	SS	14		186										
187.2			13	SS	15												
21.3	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till)																
184.4	Compact																
24.1	End of Borehole (Auger Refusal - Probable Bedrock)																
	* 92 07 09																

+3, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

ROCK CORE DESCRIPTION
WP 114-87-00D

Page 1 of 1

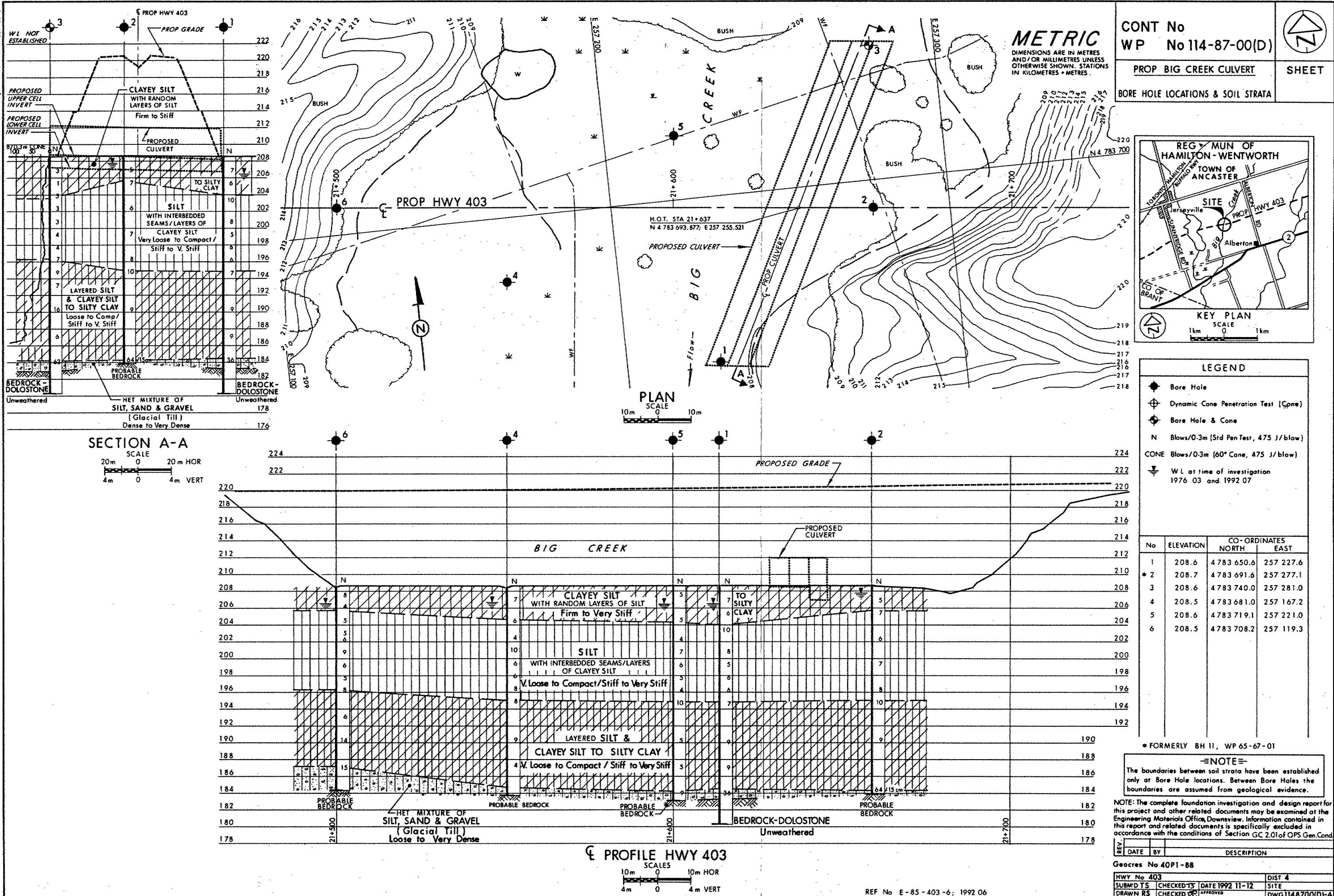
CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
1	16	25.30-26.82	97	84	25.30-28.35	DOLOSTONE with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, flat to near vertical, undulating to planar, smooth to rough.
	17	26.82-28.35	97	87		
3	18	25.60-27.13	100	98	25.60-28.35	DOLOSTONE with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, flat to near vertical, undulating to planar, smooth to rough.
	19	27.13-28.35	100	83		

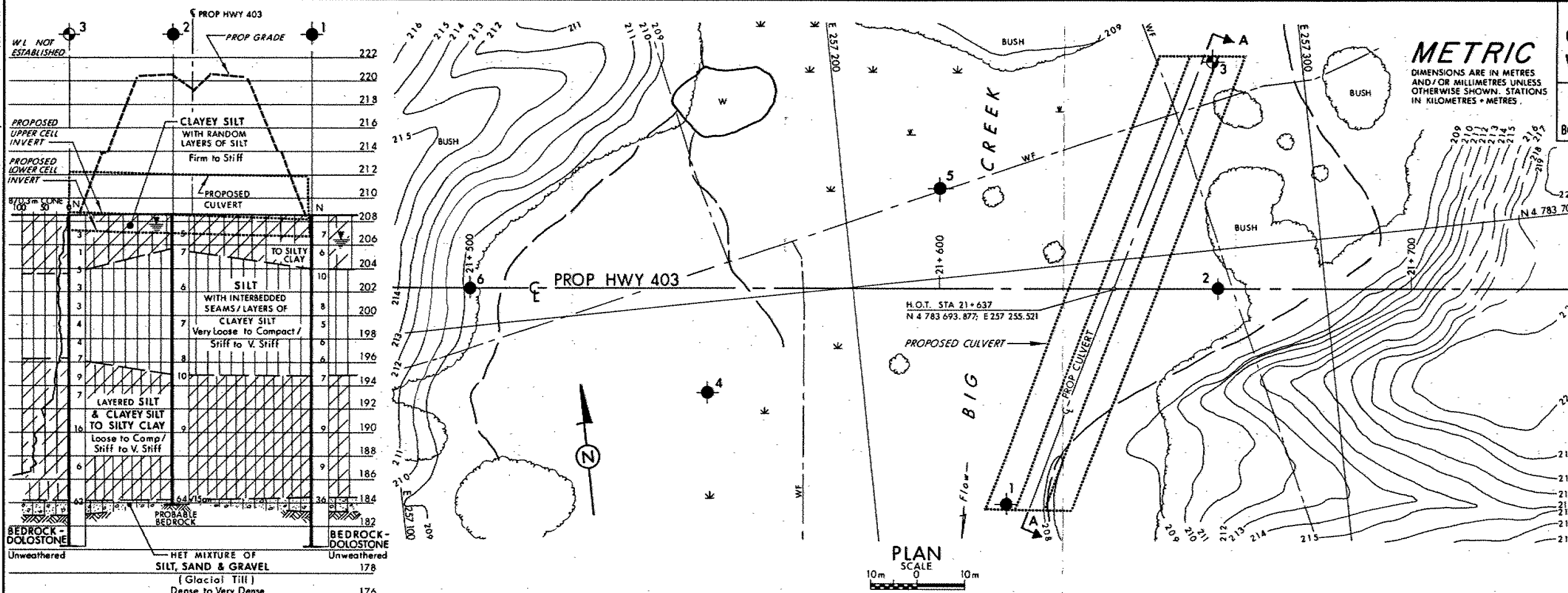
*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

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

Logged by: DAW, Soils and Aggregates Section



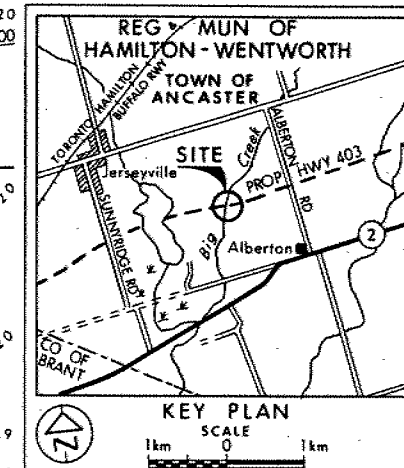


CONT No
WP No 114-87-00(D)

PROP BIG CREEK CULVERT

BORE HOLE LOCATIONS & SOIL STRATA

SHEET



- LEGEND**
- Bore Hole
 - Dynamic Cone Penetration Test (Cone)
 - Bore Hole & Cone
 - N Blows/0.3m (Std Pen Test, 475 J/blow)
 - CONE Blows/0.3m (60° Cone, 475 J/blow)
 - W.L. at time of investigation 1976 03 and 1992 07

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	208.6	4 783 650.6	257 227.6
* 2	208.7	4 783 691.6	257 277.1
3	208.6	4 783 740.0	257 281.0
4	208.5	4 783 681.0	257 167.2
5	208.6	4 783 719.1	257 221.0
6	208.5	4 783 708.2	257 119.3

* FORMERLY BH 11, WP 65-67-01

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 GC 2.01 of OPS Gen. Cond.

REV	DATE	BY	DESCRIPTION
1			

Geacres No 40P1-88

HWY No 403	CHECKED TS	DATE 1992 11-12	DIST 4
SUBWD T5	CHECKED RS	APPROVED	SITE
DRAWN RS	CHECKED		DWG 1148700(D)-A

SECTION A-A

