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**foundation
investigation and
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CONT. 93-86

WP 140-87-08 DIST 6
HWY 407 STR SITE 37-1319

Proposed Crossing at
Black Creek Culvert and
Proposed Highway 407

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FOUNDATION INVESTIGATION REPORT

For

Proposed Crossing

at

Black Creek Culvert

and

Proposed Hwy. 407

W.P. 140-87-08, Site 37-1319

Highway 407, District 6, Toronto

INTRODUCTION

This report summarizes the results of a foundation investigation conducted at the aforementioned site. It is proposed to construct a reinforced box concrete culvert to transmit the waters of the Black Creek beneath the Hwy. 407 and associated ramps. The proposed profile grade of the Hwy. 407 and associated ramps varies from elevation 198.0 m to 200.6 m. Consequently, approach fills in the order of magnitude of 7 to 9.5 m will be required. Equivalently, depths of culvert roof cover ranges from 1.8 m to 4.4 m.

SITE DESCRIPTION AND GEOLOGY

The site is located colinear and adjacent to Black Creek in the valley area bounded by Jane Street to the west and Pellar Street to the north in the Town of Vaughan, Regional Municipality of York. Agricultural farmland and a three storey building bound the site to the east. Residential homes are located at the southern limits of the site.

The Black Creek which has a width ranging from approximately 2 to 4 m meanders in a river valley approximately 100 m in width. The depth of the creek ranges from approximately 0.5 m to 1.0 m. The water level at the time of the investigation was generally 0.3 to 0.6 m in depth.

Valley slopes are generally 4H:1V or flatter and are covered primarily with a combination of trees, shrubs and grasses. The valley floor is also populated with this vegetation.

A series of corrugated steel pipe culverts exist along the Black Creek alignment used to bridge existing unpaved and paved roadways that intersect the creek at the site. The most noticeable culvert exists approximately 75 m south of Pellar Street, constructed to access vehicular traffic to the 3 storey structure located east of the site. The roof of this culvert has been exposed as a result of the loss of the backfill cover. The cause of this soil loss may have been attributable to "piping" effects caused by high upstream water levels permeating through the joints of the existing timber headwall.

The area surrounding the site consists predominantly of industrial and commercial units.

Physiographically, the site lies in the geological domain known as the Bolton Area, an area that covers approximately 1200 square kilometers located at the northwestern border of the Municipality of Metropolitan Toronto. The Bolton Area has drumlins, till plains, moraines, meltwater channels and numerous other features associated with deglaciation. The area was covered with the Wisconsin glacier of the Pleistocene period that advanced into the region approximately 50,000 years ago and retreated approximately 15,000 years ago. The Black Creek, a tributary of the Humber River was formed by the advancement and retreat of the Ontario ice lobe.

The overburden deposits at the site consist of moraine tills of the Halton Till Formation underlain by glaciolacustrine sediments deposited by Lake Peel, a body of water impounded between lobes of projecting ice. The Halton Till is primarily a silt till composed of varying percentages of clay, silt, sand and gravel. The glaciolacustrine deposits generally consists of stratified silt, clayey silt and/or silty clay.

The surficial deposits of the Cenozoic era are underlain by bedrock of the Paleozoic era. Bedrock consists of grey, thinly bedded shales with interbedded limestone from the Dundas Meaford Formation. Bedrock topographical maps reveal that the bedrock exists at depths approximately 70-80 m below the natural ground surface at the site location.

INVESTIGATION PROCEDURE

Field Investigation

The fieldwork for the investigation was carried out between 90 02 12 to 90 02 21 and consisted of 9 sampled boreholes advanced to depths ranging from 15.7 to 36.9 m below the natural ground surface.

Track mounted CME 55 equipment employing hollow stem augering techniques was used to advance the boreholes in the overburden.

In general, subsoil samples were retrieved at 0.7 m intervals for the surficial 4.5 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). Relatively undisturbed samples were also randomly retrieved in the weaker cohesive clayey silt material underlying the surficial moraine till deposit at the site. These samples were retrieved via a Shelby tube sampler in accordance with standard practice (ASTM D1587) at 1.5 m intervals. 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 samples were identified in the field and then returned to the laboratory for applicable testing.

Groundwater levels were obtained by monitoring the levels in the open borehole throughout the duration of the field investigation. All open boreholes were backfilled at the completion of the fieldwork.

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) Consolidation Tests

Laboratory test results have been summarized in the subsequent section of this report entitled Subsurface 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 glacial till deposit consisting of a heterogeneous mixture of silt to clayey silt, sand and gravel. The main component of this till varies from a cohesionless silt to a cohesive clayey silt. The deposit is generally in a loose to compact or stiff to very stiff state. The thickness of this deposit ranges from 6.1 m to 14.2 m but is generally in the order of 10 m.

The till deposit is underlain by a clayey silt to silt deposit. The surface of this stratum varies from elevation 186.9 m to 178.6 m and its thickness is generally in the 3 to 9 m range. High natural moisture contents, generally in the 18-27% range characterize this stratum. The denseness/consistency of the stratum varies randomly and is generally loose to very loose or very soft to stiff.

The silt to clayey silt stratum is underlain by a cohesionless silt and/or sand with some silt stratum. The stratum extends for a thickness ranging from 4.6 m to 7.6 m or Elev. 166.8 to 172.2 m. This stratum is generally loose to compact.

A cohesive clayey silt to silty clay stratum with nodules and seams of interbedded silt underlies the cohesionless silt and sand stratum. This deposit is of a hard consistency and ranges in thickness from 7.6 m to 12.5 m. In general, the stratum is of thickness in the order of 12.2 to 12.5 m.

Underlying the cohesive clayey silt to silty clay, a very dense deposit of silt with a trace of sand exists. The surface of this deposit is at elevation of 159.2 to 159.5 m. The extent of this 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. 1408708-A.

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

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

The surficial deposit at the site consists of a heterogeneous mixture of silt to clayey silt, sand and gravel. The deposit extends from the ground surface at an elevation ranging from 192.5 to 193.0 for a thickness ranging from 6.1 m to 14.2 m. The deposit is generally oxidized and brown in colour for the surficial 1 to 1.5 m and unoxidized and grey below.

The main component of the till deposit varies from a silt to clayey silt across the site and also within the vertical extent of the deposit. Some black organics containing wood components also occur within the upper metre of the deposit at various locations.

Random layers of clayey silt of glaciolacustrine origin were also found interbedded within the till deposit. The interbeds are generally 0.5 to 2 m in thickness and of stiff consistency.

A grain size distribution envelope for the till deposit as determined by mechanical sieve and hydrometer analysis is given in Figure 1 in the Appendix. The envelope reveals a wide range of grain size characteristics of unstratified till deposits. The range in clay and silt percentages is approximately 10-18% and 39-45% which assists in explaining the varying behaviour of the deposit

across the site. Sand compositions present in the deposit range from 27-41% and gravel sizes amount to generally less than 10% of the deposit. Although not encountered during the field investigation, boulders and cobbles are also characteristic components of till deposits and hence can exist in this 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 2. A summary of the indices is provided in Table 1 below.

Table 1 - Het. Mix. of Clayey Silt-Silt, Sand
and Gravel (Glacial Till)

	<u>Range</u>	<u># of Tests</u>
Natural Moisture Content (w%)	8-21	11
Liquid Limit (w_L %)	14-22	11
Plasticity Index	3-10	11
Unit Weight (kN/m^3)	22.1-23.2	5

The test results reveal that the fine grained portion of the deposit ranges in behaviour from a plastic silt to a clayey silt of low plasticity. Natural moisture contents are generally less than plastic limit of soil or within the liquid limit - plastic limit range (w_L-w_p) indicating that the soil is in a plastic to semisolid state.

Standard Penetration tests carried out in this deposit revealed 'N' values ranging from 1 blow/0.3 m to 49 blows/0.3 m. Relatively lower 'N' values were encountered in the segment of the culvert bounded by BH's 4 to 6 inclusive which happens to correspond to the length of the culvert supporting the proposed Hwy. 407 eastbound/westbound lanes. The 'N' values improve north and south of this central segment. N-values determined by the Standard Penetration test are summarized in Table 2 below.

Table 2 - SPT 'N' Values

<u>Location*</u>	<u>BH's</u>	<u>'N' Values⁺</u>	
		<u>(blows/0.3 m)</u>	<u>Denseness/Consistency</u>
North	1-3	8-40	loose-compact/firm-stiff
Central	4-6	2-15	v. loose-compact/v. soft-stiff
South	7-9	6-49	firm-hard

*see Dwg. 1408708-A in Appendix

+excluding 'N' Values in surficial organic enriched material

Clayey Silt to Silt

Underlying the glacial till deposit exists a deposit that varies from a clayey silt to silt both in the vertical and horizontal plane. The surface of this stratum is generally at an elevation ranging from 182 to 186.9 m. At BH 3, however, the surface of this stratum is at elevation 178.6. The thickness of this stratum ranges from 3 to 9.1 m but is generally in the 4 to 7 m range.

A grain size distribution envelope for this deposit is illustrated in Figure 3 in the Appendix. The envelope identifies the high silt content of 74 to 92%. Clay percentages, however, are also present in the range of 5 to 25%. Hence the stratum can behave as a cohesive or cohesionless material.

Atterberg Limit tests were taken to define the behaviour of the soil and the results are plotted in Figure 4 in the Appendix and summarized in Table 3 below.

Table 3 - Clayey Silt to Silt

	<u>Range</u>	<u># of Tests</u>
Natural Moisture Content (w%)	24-27	8
Liquid Limit (w _L %)	20-28	8
Plastic Limit (I _p)	5-13	8
Unit Weight (kN/m ³)	19-20.2	2
Undrained Shear Strength (Cu) (kPa)		
- Field Vane	40->120	23
- Unconfined*	43-54	2
Sensitivity	2-4	23

*some of the samples were too dilated and hence the test was not conducted

The test results reveal that this stratum ranges in behaviour from a plastic silt to a clayey silt of low plasticity. Natural moisture contents generally exceed the liquid limit of the soil and hence the liquidity index generally exceeds unity.

In situ vane tests were conducted in the anisotropic, non-homogeneous soil, to determine the undrained shear strength (c_u) of the cohesive soil. Unconfined compression tests were also conducted in the laboratory to determine the undrained shear strength. Results of field and lab tests are plotted on the Record of Borehole sheets in the Appendix and summarized in Table 3 above. The results reveal that the undrained shear strength values of the soil range from 40-120 kPa. Consequently, the cohesive portion of the soil has a firm to very stiff consistency.

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 3 and identified on the Record of Borehole sheets. Sensitivity values range from 2 to 4 indicating that the soil has a low sensitivity.

The compressibility characteristics of the soil were determined by conducting consolidation tests on representative samples of the clayey silt material. Pertinent data is summarized in Table 4 below. The results reveal that the soil has relatively large preconsolidation pressures (p_c) indicating that the soil has been preconsolidated in the past in excess of the existing effective overburden pressure by a magnitude ranging from 236 to 239 kPa. In addition, compression indices of the soil range from .05 to .07, revealing that the material will not experience significant displacement under applied pressure.

The results (e-log p curves) of consolidation tests are illustrated in Figures 5 & 5a in the Appendix.

Table 4 - Compressibility Characteristics

<u>Sample</u>	<u>Depth</u> <u>(m)</u>	<u>El.</u> <u>(m)</u>	<u>Initial</u> <u>Void</u> <u>Ratio</u> <u>(e₀)</u>	<u>Compression</u> <u>Index</u> <u>(Cc)</u>	<u>Overconsolidation</u> <u>Pressure</u> <u>(pc-p'o)</u> <u>(kPa)</u>
BH 4, TW9	9.3	183.6	.67	.05	236
BH 5, TW12	13.9	179.1	.88	.05	237
BH 9, TW12	12.4	181.1	.67	.07	239

Standard Penetration tests carried out in this deposit revealed 'N' values ranging from 1 blow/0.3 m to 30 blows/0.3 m. In general, however, 'N' values are less than 10 blows/0.3 m, confirming the relatively weak nature of the soil.

Silt to Sand, some silt

The clayey silt to silt stratum is underlain by a cohesionless deposit consisting of a silt with interbedded silty sand or a sand with some silt. The surface of this deposit exists generally at an elevation ranging from 174.4 m to 179.3 m and extends for a thickness ranging from 4.6 m to 7.6 m. A grain size distribution envelope illustrating the gradation of this deposit is shown in Figure 6 in the Appendix. Some gravel zones also randomly exist in the deposit.

The fact that sloughing of the borehole occurred upon penetration into this deposit indicates that the deposit is under a 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 ranging from 2 blows/0.3 m to 54 blows/0.3 m. In view of the fact that the lower 'N' values may be the product of disturbance caused by unbalanced hydrostatic head and the higher 'N' values a result of gravel sizes randomly present in the deposit, 'N' values are generally in the 5 blows/0.3 m to 15 blows/0.3 m indicating a denseness of loose to compact.

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

The cohesionless silt/sand deposit is underlain by a cohesive stratum consisting of a clayey silt to silty clay with random nodules/seams of silt. The nodules and seams are generally 5 to 10 mm in thickness and are light grey in colour. The main deposit is of a dark grey hue. The surface of the stratum exists at an elevation ranging from 172.7 to 166.8 m or approximately 21.3 to 25.9 m below the natural ground surface. The thickness of the stratum is approximately 7.6 to 12.5 m.

A grain size distribution envelope for the material is illustrated in Figure 7 in the Appendix. The envelope illustrates that clay and silt percentages range from 22 to 65% and 29 to 78% respectively.

Atterberg Limit tests were carried out to define the behaviour and plasticity of the soil and the results are plotted in Figure 8 in the Appendix and summarized in Table 5 below.

Table 5 - Clayey Silt to Silty Clay

	<u>Range</u>	<u># of Tests</u>
Natural Moisture Content (w%)	22-28	4
Liquid Limit (w _L %)	31-50	4
Plasticity Index (I _p %)	15-30	4

The test results reveal that the stratum varies in plasticity from low (clayey silt) to intermediate (silty clay).

Standard Penetration tests carried out in this deposit revealed 'N' values ranging from 23 blows/0.3 m to 55 blows/0.3 m and consequently this stratum has a very stiff to hard consistency.

Silt, trace/some Sand

The cohesive clayey silt to silty clay stratum is underlain by a very dense cohesionless silt. This silt stratum also contains traces to some sand. The surface of the stratum exists at approximate elevation 159.2 m to 159.7 m. The extent of the deposit was not determined during the investigation.

A grain size distribution envelope illustrating the gradation of this material is provided in Figure 9 in the Appendix.

Standard Penetration tests carried out in this deposit revealed large 'N' values ranging from 120 blows/0.3 m to 180 blows/.15 m. These 'N' values indicate that the deposit is in a very dense state of condition.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water level in the open boreholes. Groundwater levels determined at the time of investigation ranged from 1 to 2.5 m below ground surface (Elevation 193.2 to 190.3 m). These water levels correlate approximately to the water level of the flowing Black Creek.

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

DISCUSSION AND RECOMMENDATIONS

A rigid frame concrete box culvert is proposed at the proposed Hwy. 407 - Black Creek crossing. The waters of the existing meandering Black Creek will be transmitted via the proposed culvert beneath the proposed Hwy. 407 and associated ramps. The culvert will support the Hwy. 407 Eastbound/Westbound lanes, the Jane-Hwy. 407 SE Ramp and the Hwy. 407-Jane N/S Ramp. Depths of cover to the roof of the culvert in conjunction with these proposed roadways are in the order of magnitude of 1.8 m to 4.4 m. The streambed elevation across the site is approximately at elevation 191 to 191.5 m across the site and hence the aforementioned depths of cover translate to approximately 7 to 9.5 m of approach embankment fills.

At the time of the foundation request, two proposals pertaining to the dimensions of the culvert were being considered.

- 1) 8 x 4 x 200 m
- 2) 6 x 4 x 275 m

The latter proposal extends further upstream to the existing Pellar Road.

Recommendations pertaining to the following foundation and geotechnical considerations are included in the scope of this report.

- 1) Structure Foundations
- 2) Approach Embankments
- 3) Construction Considerations

- 1) Structure Foundations

Structure Foundations can be founded on conventional spread footings within the surficial till deposit or deep foundations comprised of steel H-piles driven to the very dense silt stratum. Details of the foundation design are discussed below. The alternative or combination that proves to be most economical and technically feasible shall be selected for design.

a) Shallow Foundations - Spread Footings

The structure foundations can be supported on conventional spread footings at an elevation 191.5 m or lower within the surficial till deposit. In view of the varying nature and strength of the surficial till deposit, the length of the culvert has been subdivided into three subsections as identified on Dwg. 1408708-A. The bearing capacities for purposes of the O.H.B.D.C. are tabulated in Table 6 below.

Table 6 - Spread Footing Soil Capacities

<u>Section</u>	Bearing Capacities at S.L.S. Type II	Factored Capacity at U.L.S.
	<u>(kPa)</u>	<u>(kPa)</u>
1	125	300
2	75	150
3	200	375

The magnitude of total and differential settlement anticipated as a result of the applied loadings are expected to be within 25 mm for the foundations along section 1 and 3 and within 30 mm along section 2. Articulating the structure by using construction joints and integrated slab slope gradients is recommended to account for these differential settlements. The lower capacity and larger settlement along section 2 reflects the weaker subsoil conditions along this segment. The settlements should be limited to these magnitudes provided that the founding soil is not disturbed during construction or related activities. To preserve the competence of the founding soil, it is recommended that a working slab consisting of a 150 mm lean mix concrete be placed.

It is recommended that consideration may be given to the application of lightweight fill in conjunction with a pipe or pipe arch culvert at this site. Such an approach would reduce the magnitude of the load induced on the foundation soil, associated total and differential settlements and any resulting overstressing and/or cracking of the culvert. Should this option be selected, bedding and backfilling shall conform to current MTO Standards (OPSS 421 & OPSD 800 series).

All softened/loosened and/or organic material encountered at the founding elevation shall be removed and replaced with mass concrete or granular material such as MTO granular 'A'. Any granular material must be placed and compacted to achieve 100% of the Proctor maximum dry density as outlined in OPSS 501.08.02.

The footings must be protected against the scouring forces of the stream water. This can be obtained by constructing aprons and rip-rap at the culvert inlet and outlet. The design of the scour protection shall be made in conjunction with applicable hydrological parameters.

Adequate frost protection cover shall be provided for footings subject to frost protection as for instance during winter construction.

b) Deep Foundation Units - End Bearing Steel H-Piles

Alternatively, structure foundations can be founded on steel H-piles driven to the lower very dense silt deposit. For purposes of the O.H.B.D.C., the design axial capacity for vertical piles are summarized in Table 7 below.

Table 7 - Axial Capacities - Driven Steel H-Piles

<u>Pile Type</u>	<u>Bearing Capacities* at S.L.S. Type II (kN)</u>	<u>Factored Capacity at U.L.S. (kN)</u>	<u>Estimated Pile Type El. (m)</u>
HP 310 x 110	1150	1600	159.5±
HP 310 x 79	890	1150	159.5±

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.

The installation of the piles shall be controlled and monitored employing the Hiley Dynamic Pile Driving Formula driven in accordance with MTO Standards SS103-10 or SS103-11 assuming an ultimate capacity as tabulated in Table 8 below

Table 8 - Ultimate Capacity Employing
Hiley Dynamic Formula

<u>Pile Type</u>	<u>Ultimate Capacity</u>
HP 310 x 110	3450
HP 310 x 79	2670

To facilitate pile penetration, particularly through any boulders or cobbles that may exist in the surficial till deposit, it is recommended that steel H-piles be equipped with reinforced tips.

In view of the silty composition of the end bearing stratum, a temporary reduction in pore pressure and a corresponding increase in driving resistance will result because of soil dilation caused by driving. Where these factors are significant, a reduction in the bearing capacity may result with time. Consequently, it is essential that the piles be subject to a redriving test no earlier than seven days following initial installation to verify the pile capacity.

Pile spacing shall conform with Section 6.8.3.1.10 of the O.H.B.D.C. Adjacent piles should be checked for heaving during pile installation. 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.

Footing Construction

To facilitate construction of the footings, a temporary creek diversion and dewatering scheme will be required. Methods are discussed under "Construction Considerations" in subsequent sections of this report.

2. Approach Embankments

Materials

Approach fills in the order of magnitude of 7 to 9.5 m will be required immediately adjacent to the culvert walls. It is recommended that this material consist of a free draining material such as Granular 'A' or Granular 'B' to prevent hydrostatic pressure build-up on the culvert walls. Design parameters

of the soil are given in Table 9 below. Weep holes should also be designed in the walls to facilitate the drainage.

Table 9 - Backfill Properties

	<u>Granular 'A'</u>	<u>Granular 'B'</u>
Angle of Internal Friction (ϕ)	35°	30°
Unit Weight (kN/m^3) γ	22.8	21.2
Coefficient of Active Earth Pressure (K_a)*	0.27	0.33
Coefficient of Earth Pressure at Rest (K_0)*	0.43	0.5

*Horizontal surface backfill only

For a rigid and unyielding structure, the earth pressure coefficient at rest is to be used in computing lateral earth pressures.

The backfill beyond the granular wedge as illustrated on OPSD 803 series can consist of acceptable borrow material as defined in OPSS 212.05.

Embankment Construction

In the construction of the embankment fills, all softened and/or organic material should be excavated for their full depth within the plan limits prior to fill placement.

The backfill should be constructed in 300 mm lifts on alternating sides of the rigid box structure so that the maximum differential in backfill heights at no time exceeds 300 mm. The backfill shall be constructed in accordance with OPSS 902 series and applicable OPSD 803 series. The backfill shall be compacted to achieve the target maximum dry density as outlined in OPSS 501.07-08.

Stability

Stability computations were carried out to determine both the overall (global) stability and internal stability of the fills in the longitudinal direction of

the culvert. The analysis was carried out in terms of total stress or the undrained (short term) condition applying Bishop's Modified Method digitized on an in-house mainframe program. The analysis was conducted employing a factor of safety of 1.3 and circular slip surfaces. Properties of the fill material and subsoil parameters used in the analysis are illustrated in Figure 10 in the Appendix. Should the approach fill material differ significantly from the material properties indicated, this office should be contacted for further examination and evaluation.

The results of the analysis are summarized in Table 10 below. For fill heights up to and including 8 m, the embankment slopes can be constructed at 2H:1V. For fills exceeding 8 m, a nominal mid-height berm of 3.0 m width is required to ascertain internal and global stability of the embankment.

Table 10 - Slope Stability Analysis Results

<u>Height of Fill (m)</u>	<u>Proposed Geometry</u>
<8	2H:1V
>8-10	2H:1V, 3 m berm

The berm should be constructed with a nominal 20:1 gradient to promote surface runoff.

All slopes should be protected against surface erosion. This can be accomplished by conventional sodding application.

Settlement

It is anticipated that approximately 75-100 mm of total settlement can be realized as a result of elastic settlements induced within the fill itself and the elastic recompression of the native subsoil. It is predicted that the majority of the settlements will be realized during or immediately following construction.

The 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.

To minimize post construction maintenance, it is recommended that the embankment fills be placed as far in advance of the final surface paving as scheduling permits.

3) Construction Considerations

Temporary Diversion

To facilitate the construction of the culvert, a temporary diversion of the Black Creek will be required. This can be accomplished by temporarily realigning the creek either east or west of its existing location. Impervious earth dikes composed of suitable clay material (CH-see OPSS 1205) can be used upstream to prevent water inflow into the foundation excavation.

Dewatering

A dewatering scheme will be required to depress the water table below the footing founding elevation, particularly in the areas where large percentages of silt and sand in the surficial till are present. It is recommended that an oversized excavation composed of perimeter ditches and a sump pumping discharge system be used to drain accumulated water. An illustration of this scheme is provided in Figure 11 in the Appendix. 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.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and B. Chung, Engineering Trainee, 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.



A handwritten signature in cursive script, appearing to read "T. Sangiuliano".

T. Sangiuliano, P.Eng.
Foundation Engineer

A handwritten signature in cursive script, appearing to read "M.S. Devata".

M.S. 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/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

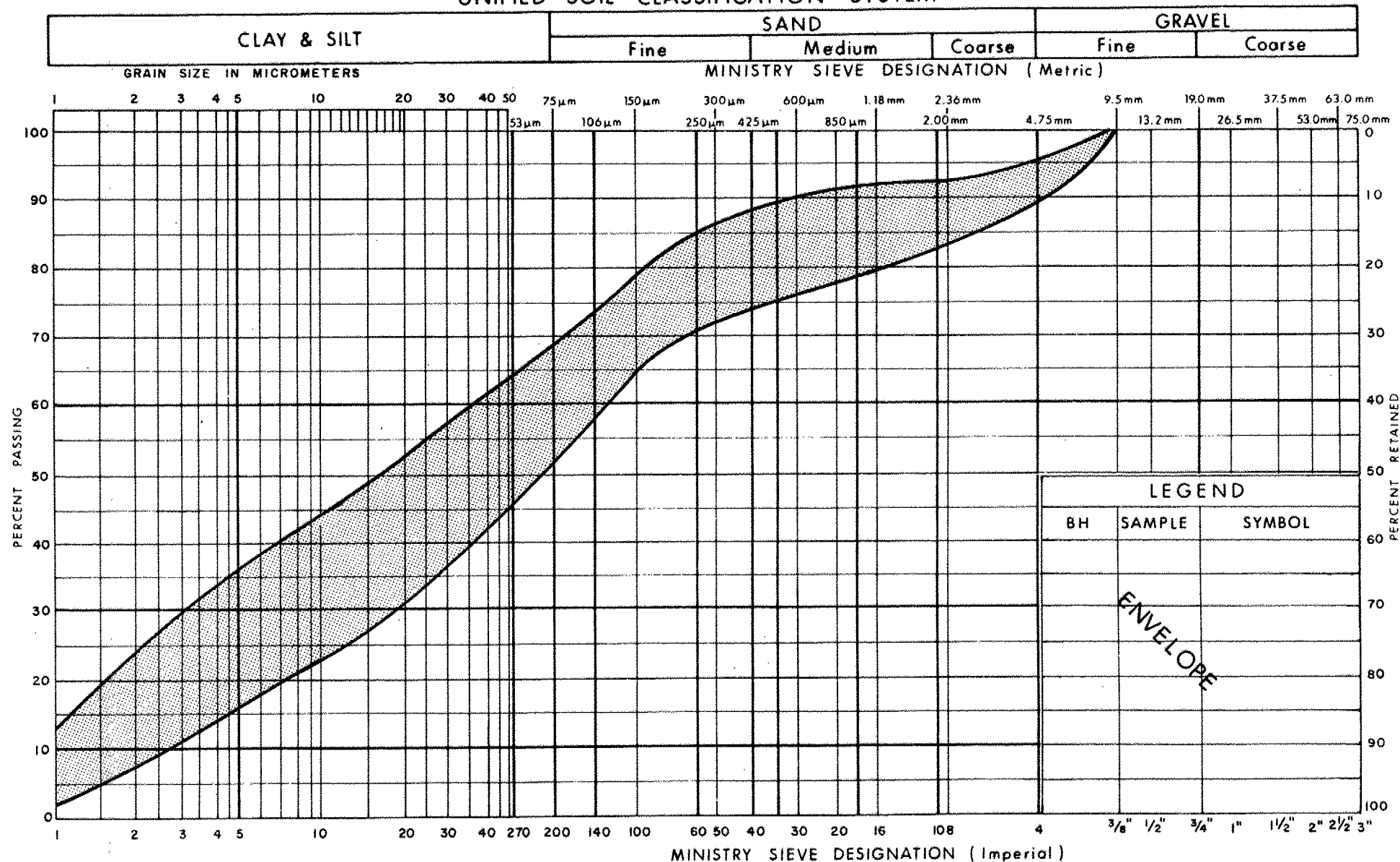
MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

UNIFIED SOIL CLASSIFICATION SYSTEM

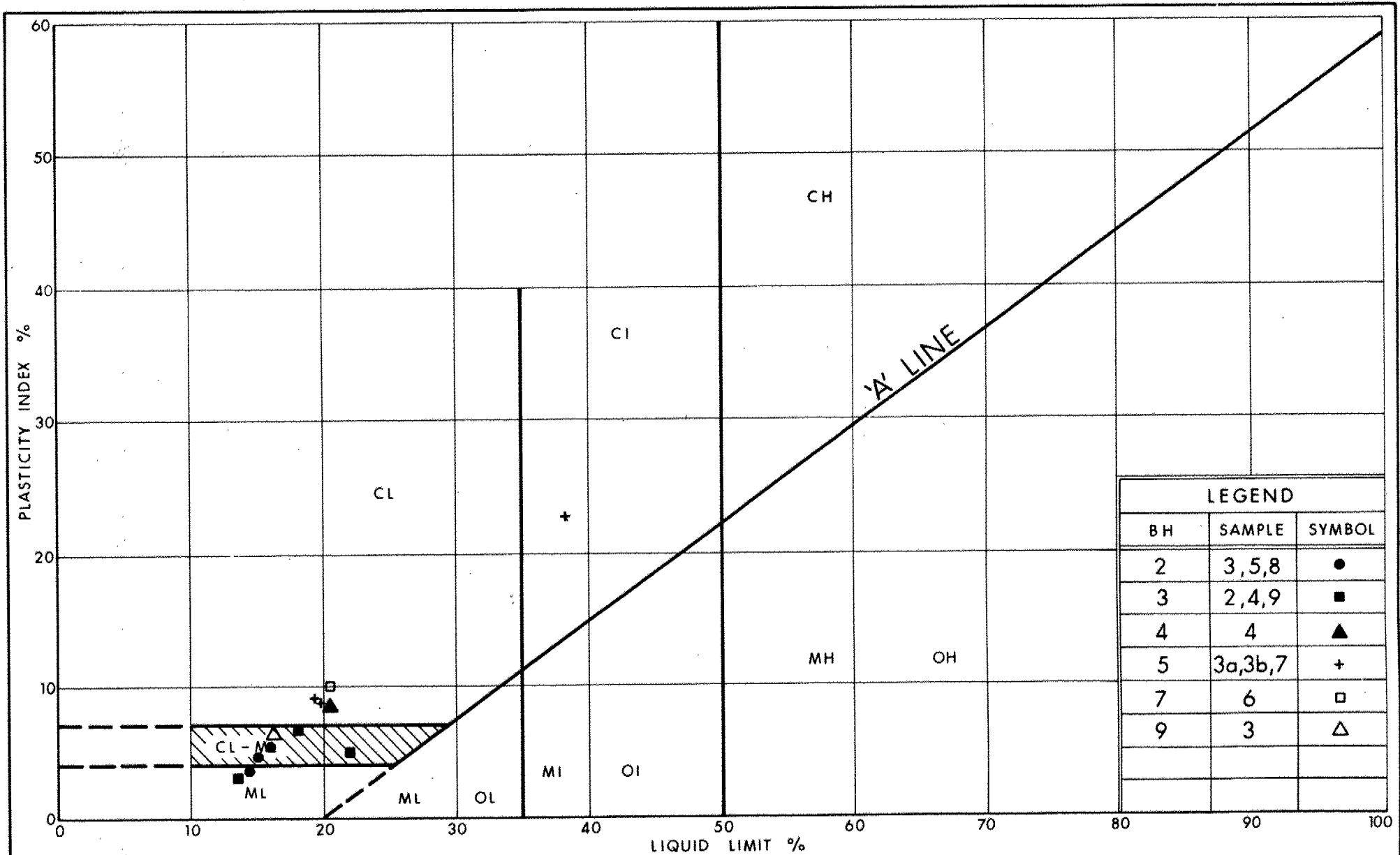


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Transportation

GRAIN SIZE DISTRIBUTION
HETEROGENEOUS MIXTURE OF SILT TO CLAYEY SILT,
SAND & GRAVEL (GLACIAL TILL)

FIG No 1

W P 140-87-08



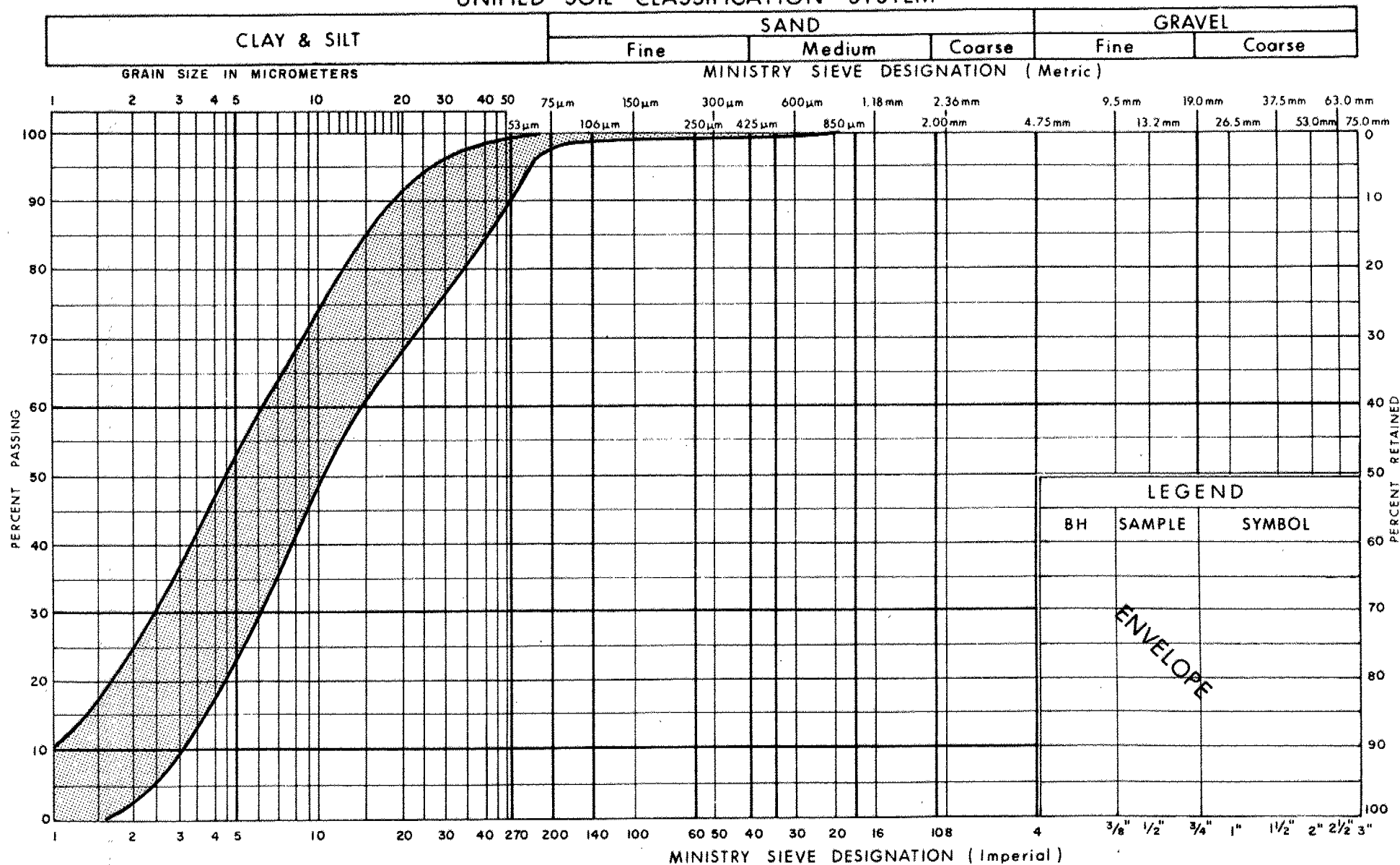
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PLASTICITY CHART
HETEROGENEOUS MIXTURE OF CLAYEY SILT,
SAND & GRAVEL (GLACIAL TILL)

FIG No 2

W P 140-87-08

UNIFIED SOIL CLASSIFICATION SYSTEM

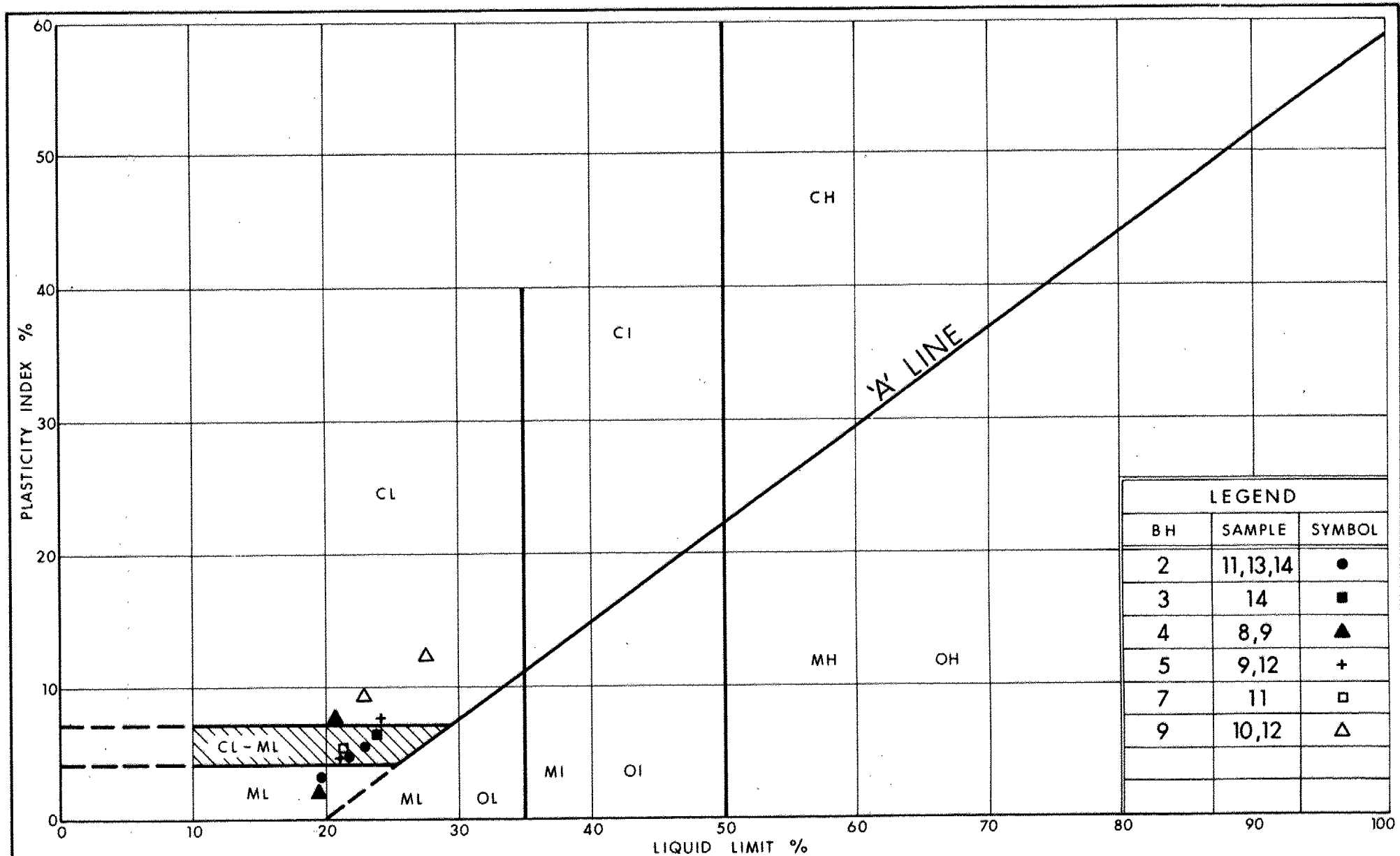


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GRAIN SIZE DISTRIBUTION CLAYEY SILT TO SILT

FIG No 3

W P 140-87-08



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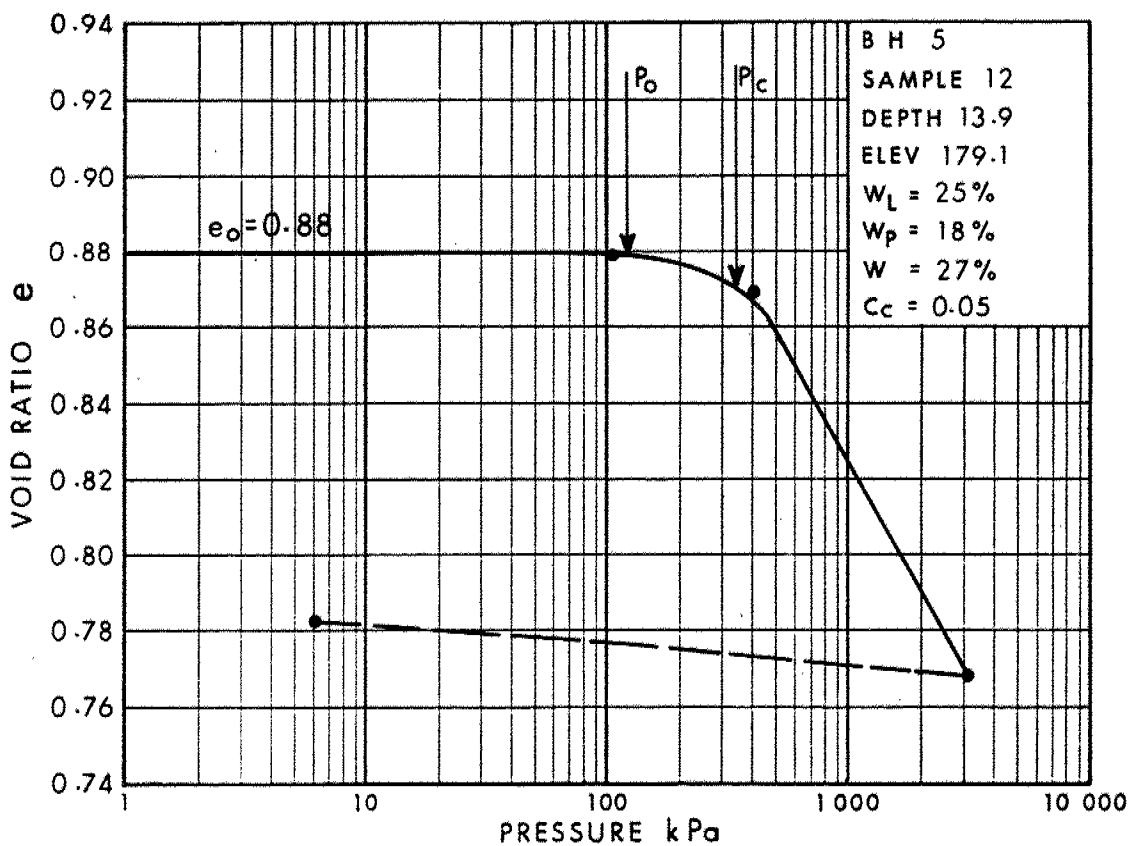
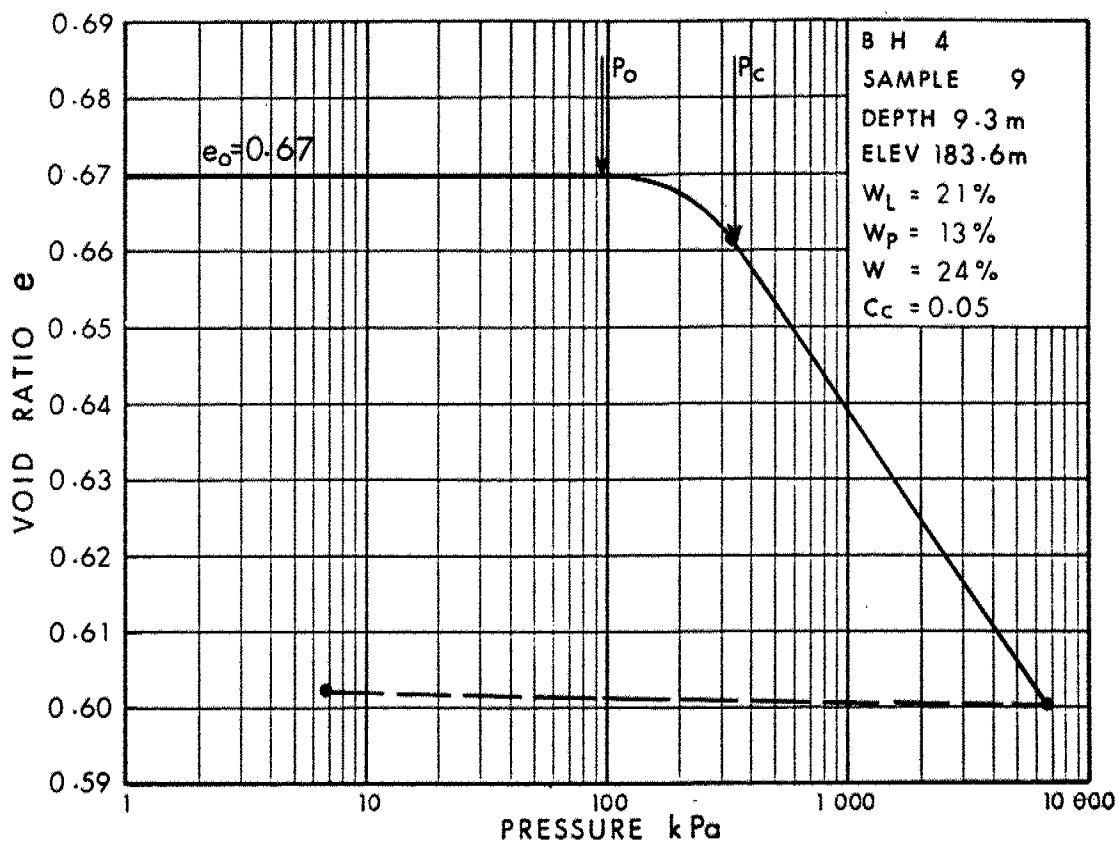
Ontario

PLASTICITY CHART CLAYEY SILT TO SILT

FIG No 4

W P 140-87-08

VOID RATIO - PRESSURE CURVES



VOID RATIO - PRESSURE CURVES

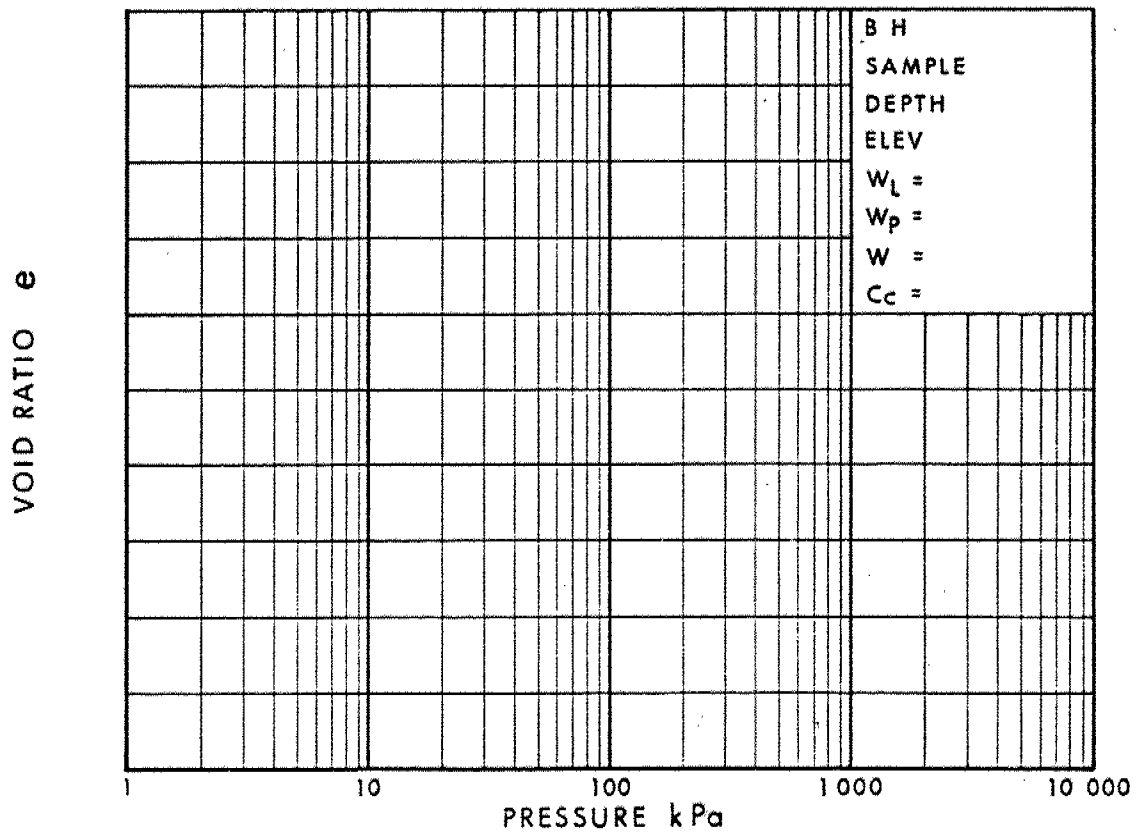
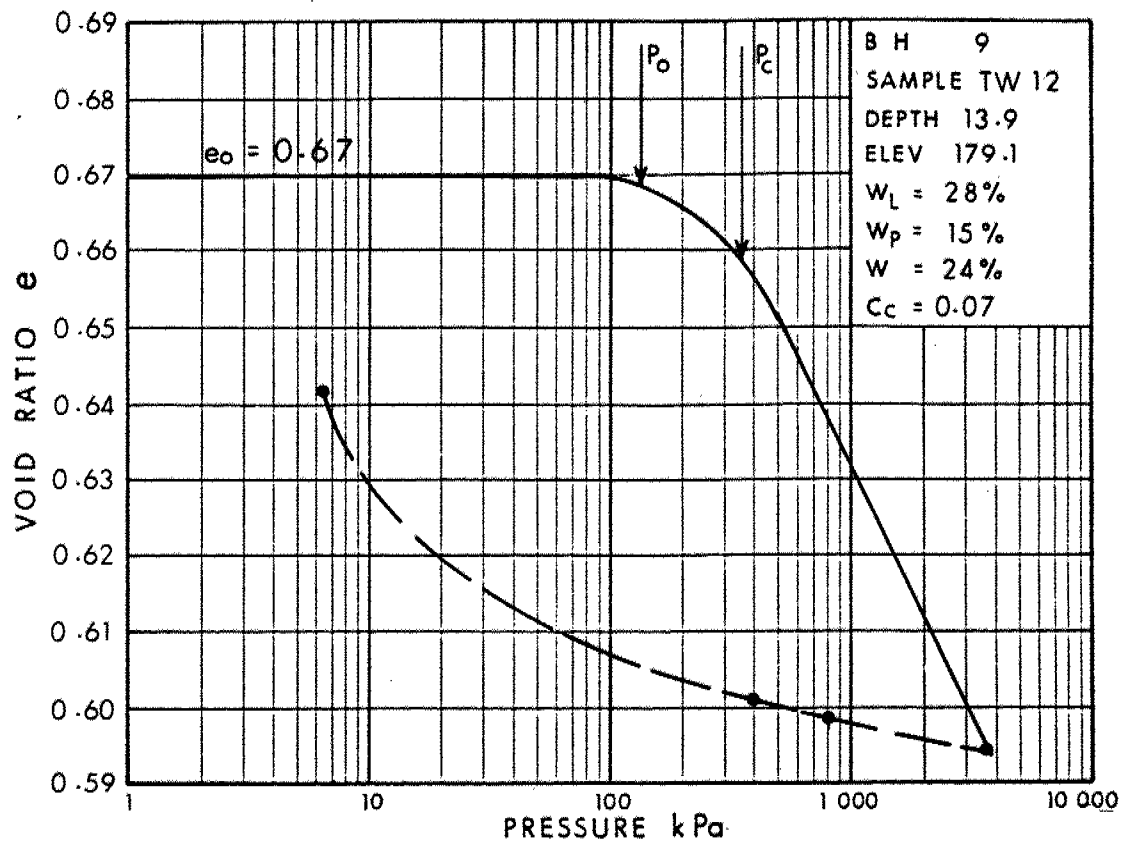
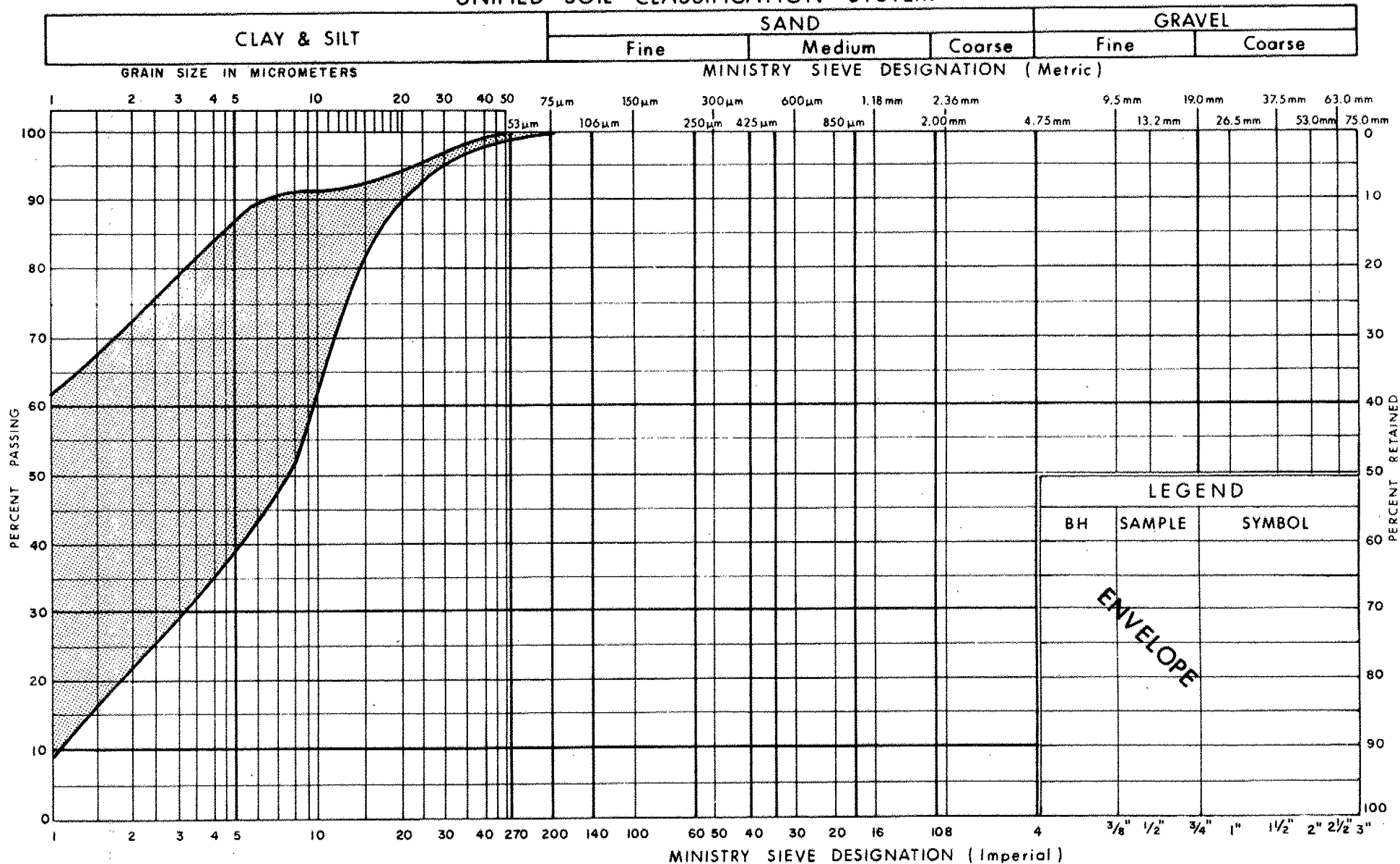


Fig 5a

W P 140-87-08

UNIFIED SOIL CLASSIFICATION SYSTEM



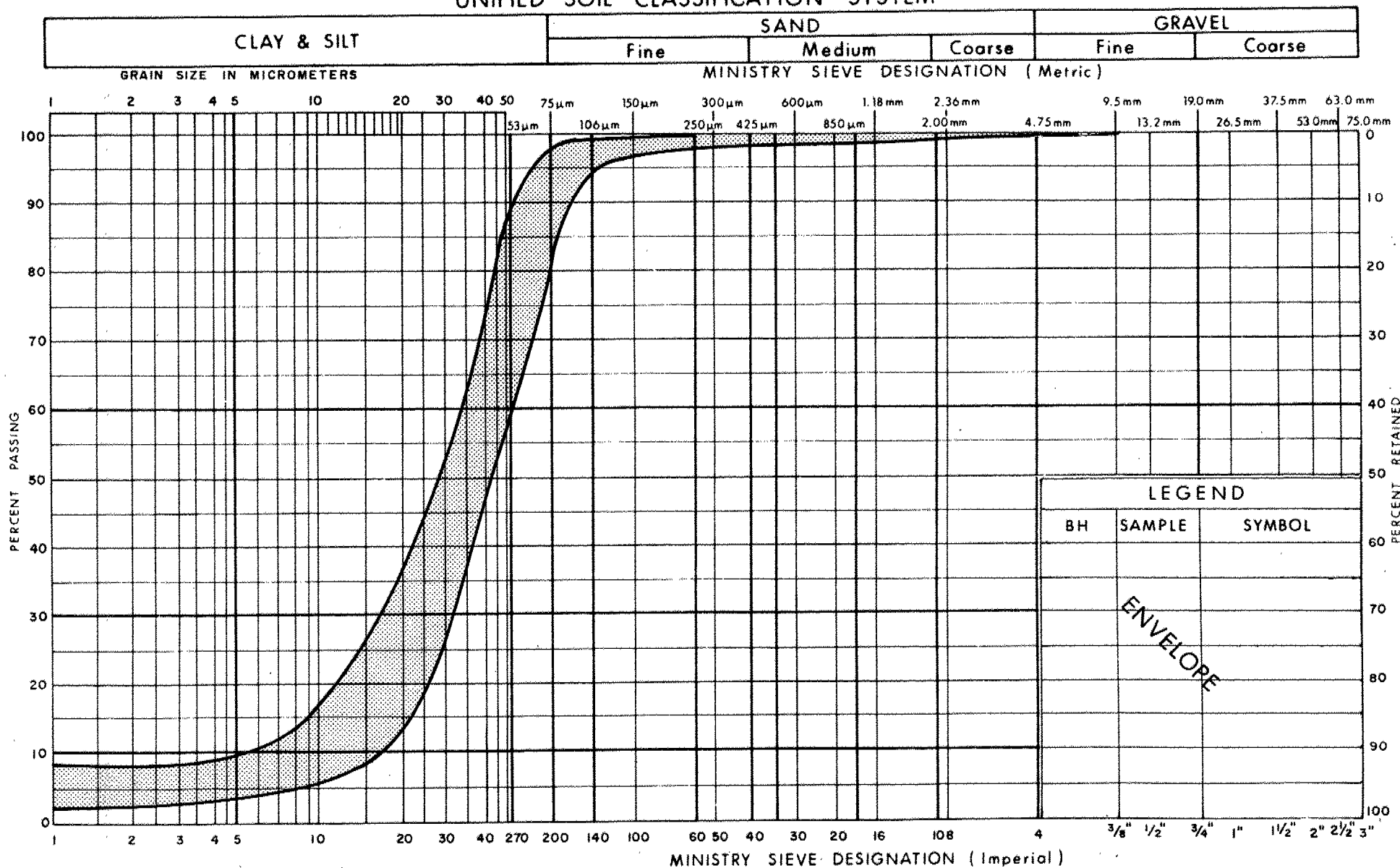
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GRAIN SIZE DISTRIBUTION
SILT, TRACE / SOME SAND

FIG No 6

W P 140-87-08

UNIFIED SOIL CLASSIFICATION SYSTEM



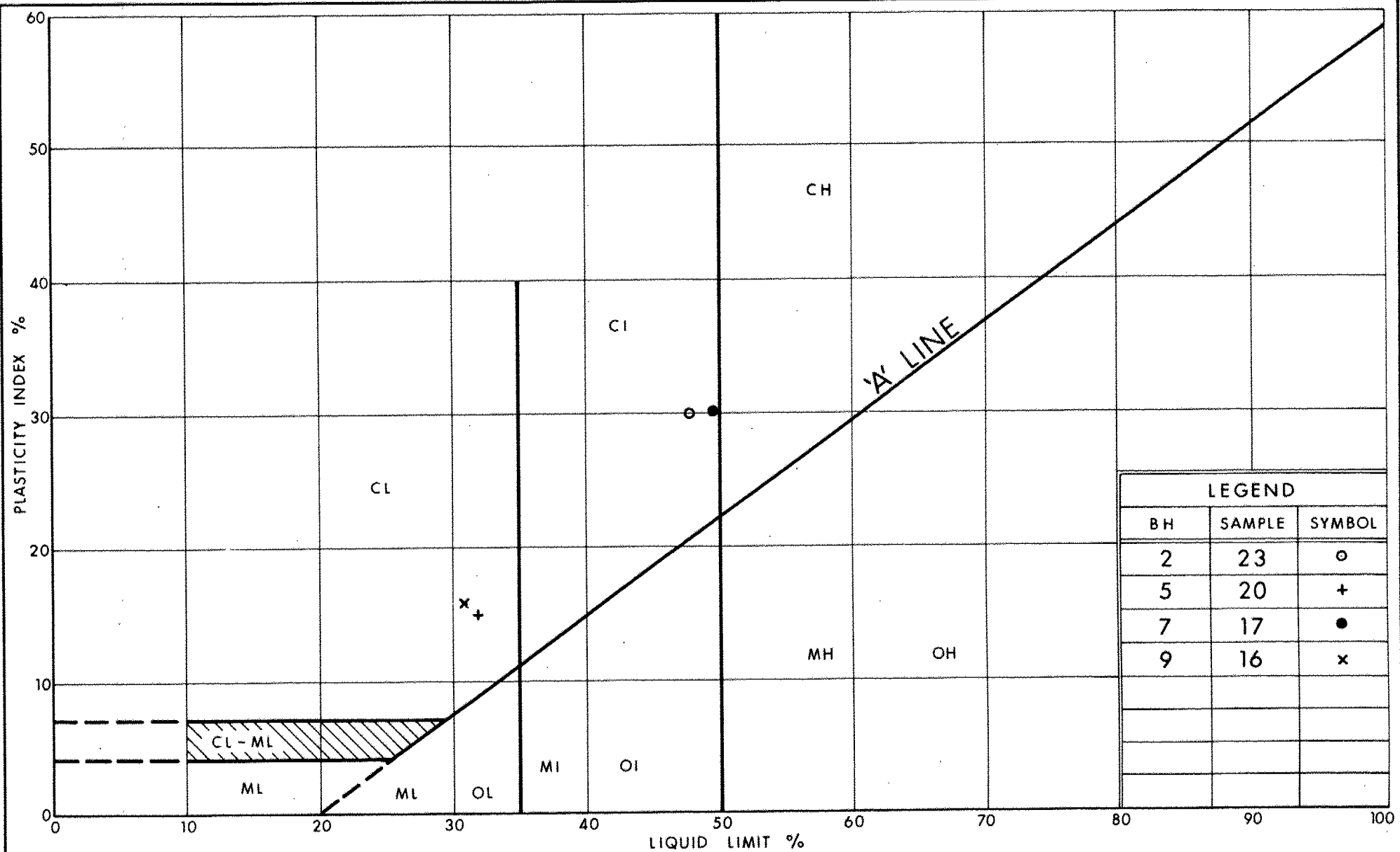
Ontario

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Transportation

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

FIG No 7

W P 140-87-08



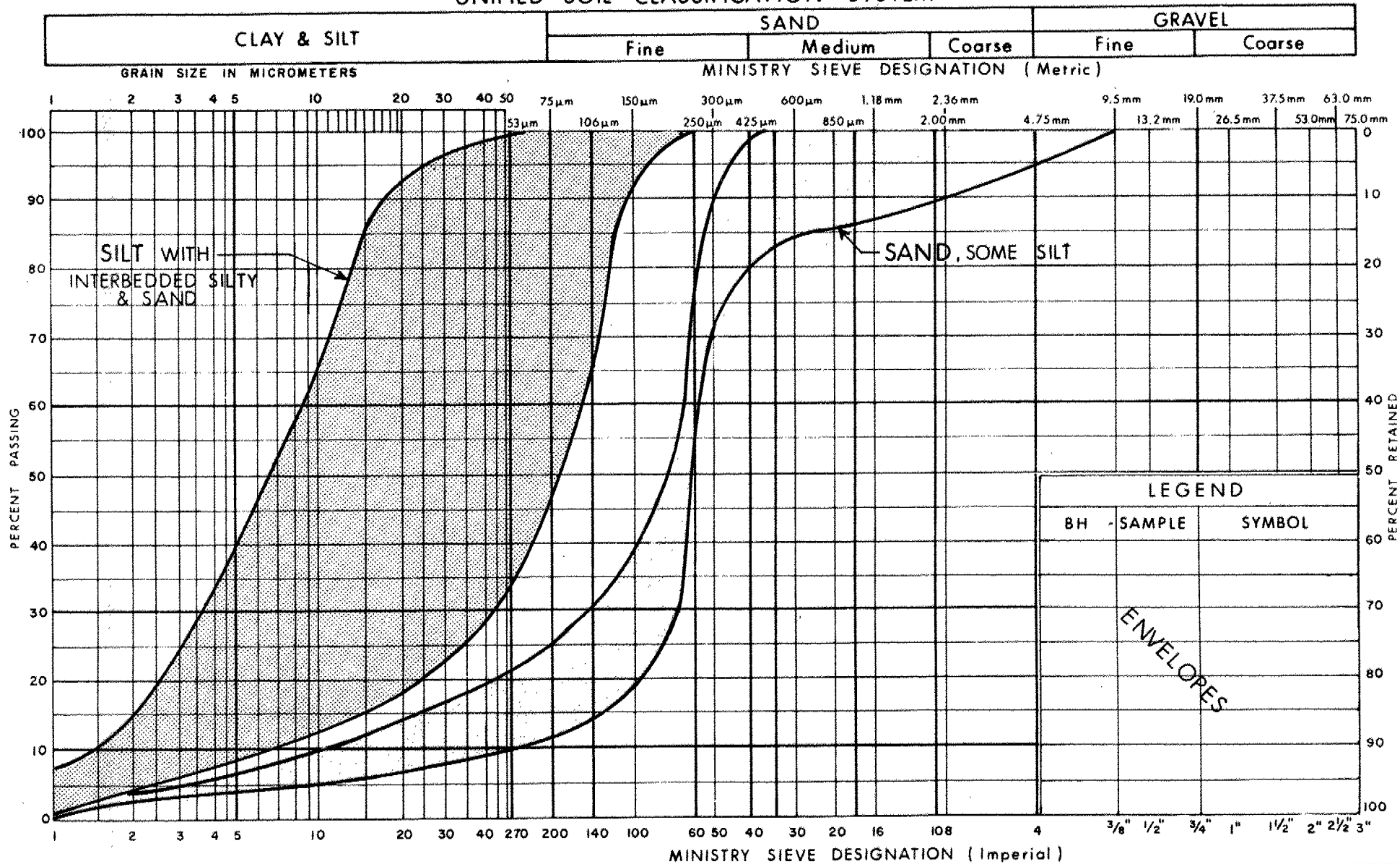
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PLASTICITY CHART CLAYEY SILT TO SILTY CLAY

FIG No 8

W P 140-87-08

UNIFIED SOIL CLASSIFICATION SYSTEM



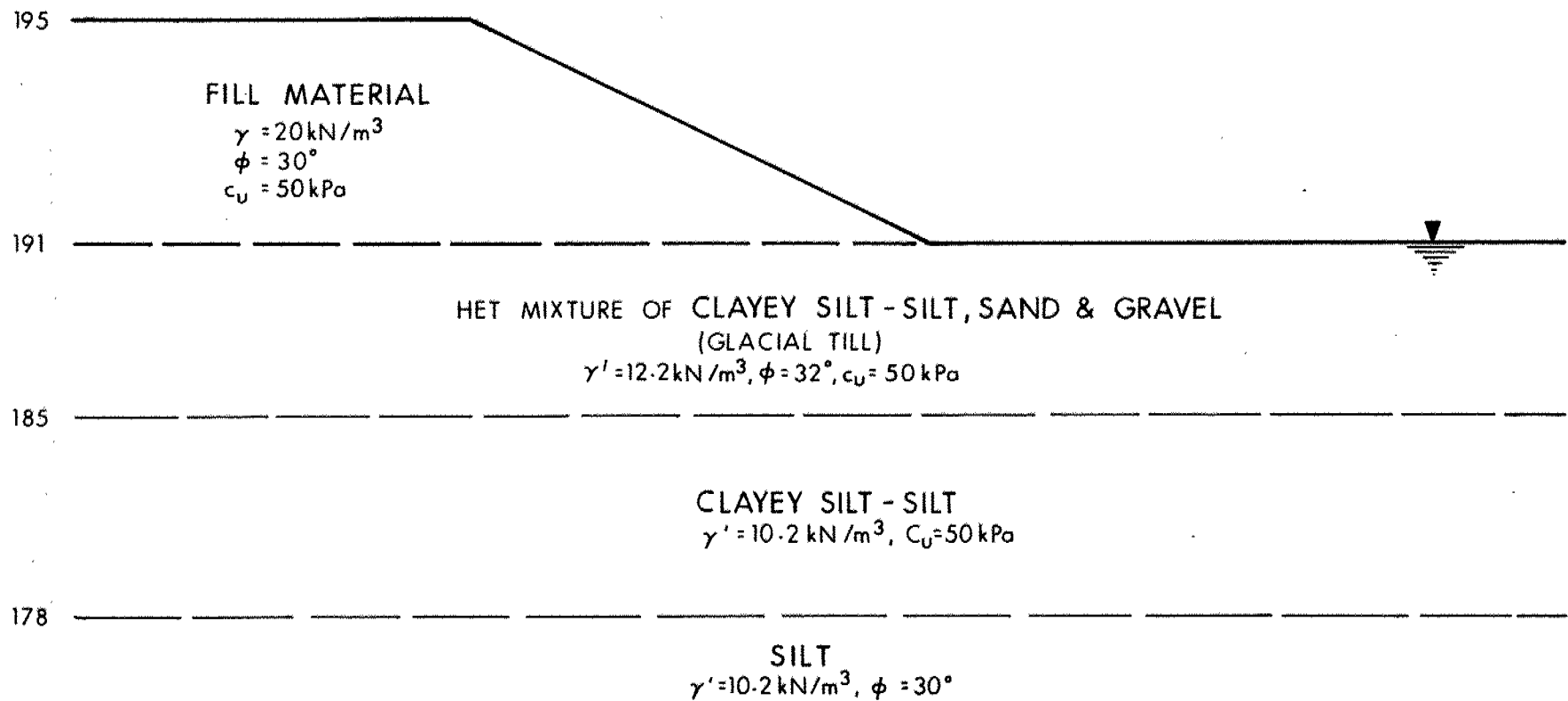
GRAIN SIZE DISTRIBUTION
SILT, TRACE / SOME SAND

FIG No 9

W P 140-87-09

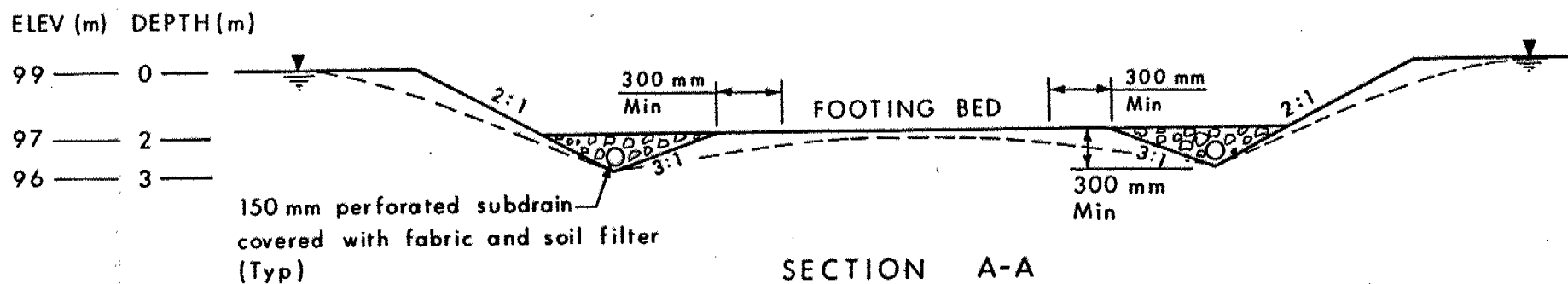
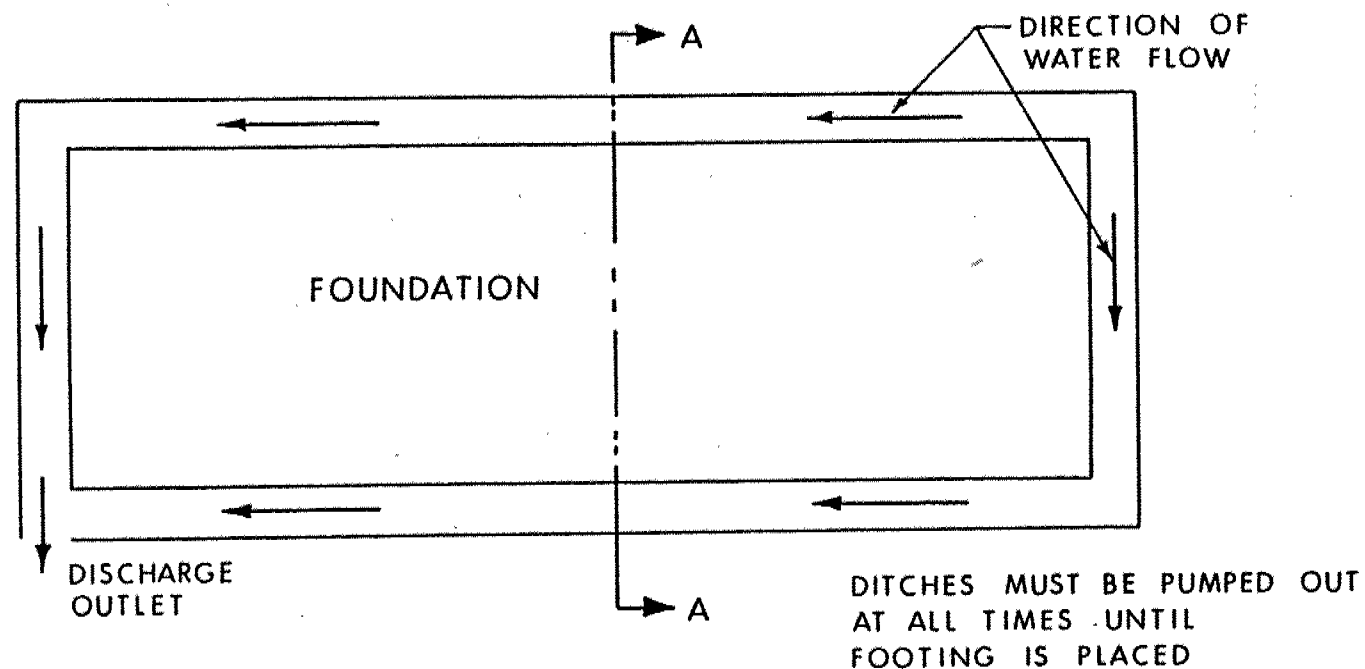


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APPROACH FILL STABILITY ANALYSIS

WP 140-87-08
FIG - 10



SECTION A-A
(NTS)

DEWATERING SCHEME - PERIMETER DITCHES

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT 7 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			w _p	w	w _L
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							WATER CONTENT (%)		
193.4	Ground Surface																
0.0																	
	Brown Grey		1	SS	14												
			2	SS	18												
			3	SS	13												
			4	SS	28												
	Clayey Silt (Lacustrine)		5	SS	25												
			6	SS	18												
	Het. mixture of Clayey Silt, Sand and Gravel (Glacial Till) Stiff to Hard		7	SS	13												
			8	SS	40												
			9	SS	18												
182.3			10	SS	29												
11.1			11	SS	30												
	Clayey Silt/Silt Grey Stiff to Hard/Compact to Dense		12	SS	10												
			13	TW	PH												
176.6			14	SS	6												
16.8	Silt, Some Sand Very Loose to Loose		15	SS	5												
174.7																	
18.7	End of Borehole																

20
15 \pm 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2

1 OF 2

METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 317 ; E 303 062 ORIGINATED BY TS
 DIST 6 HWY 407 BOREHOLE TYPE HS Auger, Washbore, Cone Test COMPILED BY TS
 DATUM Geodetic DATE 90 02 12-14 CHECKED BY BC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa		NATURAL MOISTURE CONTENT				WATER CONTENT (%)
								UNCONFINED • QUICK TRIAXIAL	+ FIELD VANE * LAB VANE	w _p	w			
192.7	Ground Surface							20 40 60 80 100						
0.0			1	SS	8							23.2	4 41 45 10	
			2	SS	10								7 33 45 15	
			3	SS	28									
			4	SS	8									
	Het. mixture of Silt, Sand and Gravel (Glacial Till) Loose to Compact		5	SS	21									
			6	SS	23									
			7	SS	24									
			8	SS	24							22.4		
			9	SS	25									
183.6			10	SS	13									
9.1			11	SS	13								0 0 89 11	
	Clayey Silt/Silt Grey Firm to Stiff/Loose to Compact		12	SS	2									
			13	SS	2								0 0 89 11	
			14	TW	PH								0 3 91 6	
			15	SS	2									
174.4			16	SS	9									
18.3			17	SS	8								0 52 42 6	
	Silt to Silty Sand Grey, Loose to Compact		18	SS	11								0 2 83 15	
			19	SS	16									
			20	SS	30								0 75 (25)	
166.8			21	SS	29									
25.9			22	SS	37									
	Silty Clay with Random Nodules/ Seams of Silt Grey, Layered, Hard		23	SS	40								0 0 35 65	
162.2														

Continued

+3, x5, Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 2

2 OF 2

METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 317 ; E 303 062 ORIGINATED BY TS
 DIST 5 HWY 407 BOREHOLE TYPE HS Auger, Washbore, Cone Test COMPILED BY TS
 DATUM Geodetic DATE 90 02 12-14 CHECKED BY BC

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	w _p	w			w _L
162.2	Continued		24	SS	30												
30.5																	
159.2																	
33.5	Silt, Some Sand Grey, Very Dense		25	SS	110	/8cm											
155.8			26	SS	120	/15cm											
			27	SS	120	/15cm											
36.9	End of Borehole																

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 140-87-08 LOCATION Co-ords: N4 849 343 : E 303 067 ORIGINATED BY TS
DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 90 02 15 CHECKED BY TS

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT 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	W _p	W		
192.8	Ground Surface															
0.0																
	Brown		1	SS	21											
	Grey		2	SS	12											
	Clayey Silt (Locustrine)		3	SS	10											
			4	SS	9											
			5	TW	PH											
			6	SS	16											
			7	SS	22											
	Het. mixture of Silt, Sand and Gravel (Glacial Till) Compact		8	SS	20											
			9	SS	17											
			10	SS	26											
			11	SS	25											
178.6			12	SS	20											
14.2			13	SS	4											
	Clayey Silt/Silt Grey, Stiff/Compact		14	SS	17											
174.1			15	SS	12											
18.7	End of Borehole															

METRIC

[illegible]

+3, x5: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 5

1 OF 2

METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 393 ; E 303 060 ORIGINATED BY TS
DIST 6 HWY 407 BOREHOLE TYPE HS Auger, Washbore COMPILED BY TS
DATUM Geodetic DATE 90 02 12-14 CHECKED BY BC

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 7 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					
193.0	Ground Surface													
0.0	Het. mixture of Clayey Silt, Sand and Gravel (Glacial Till) Firm to Stiff		1	SS	4		192							
			2	SS	4									
			3	SS	14									
			4	SS	13									
			5	SS	13									
			6	SS	8									
			7	SS	10									
186.9			8	SS	4									
6.1			9	SS	8									
			10	SS	7									
			11	SS	5									
			12	TW	PH									
179.3			13	SS	2									
13.7			14	TW	PH									
			15	SS	13									
			16	SS	15									
			17	SS	54									
171.7			18	SS	55									
21.3			19	SS	43									
			20	SS	46									
			21	SS	51									
			22	SS	50									
162.5														
30.5														

Continued

+3, x3: Numbers refer to
Sensitivity

20
15-0-5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 5

2 OF 2

METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 393 ; E 303 060 ORIGINATED BY TS
 DIST 6 HWY 407 BOREHOLE TYPE HS Auger, Washbore COMPILED BY TS
 DATUM Geodetic DATE 90 02 12-14 CHECKED BY BC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100					
162.5	Continued		23	SS	43											
30.5																
159.5			24	SS	105	/13cm										
33.5	Silt, Some Sand Grey, Very Dense		25	SS	180	/15cm										0 16 79 5
156.3			26	SS	200	/13cm										
36.7	End of Borehole															

RECORD OF BOREHOLE No 6

1 OF 1 METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 416 ; E 303 048 ORIGINATED BY TS
 DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
 DATUM Geodetic DATE 90 02 19 CHECKED BY BC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT 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	w _p	w	w _L		
193.0	Ground Surface															
0.0	Brown Grey Some Organics Very Soft		1	SS	2											
			2	SS	3											
	Clayey Silt (Locustrine) Stiff		3	SS	13											
			4	SS	15											
			5	SS	10											
			6	SS	8											
	Het. mixture of Clayey Silt to Silt, Sand and Gravel (Glacial Till) Firm to Stiff/ Loose to Compact		7	SS	6											
			8	SS	5											
183.9			9	SS	6											
9.1	Clayey Silt/Silt Grey Firm to Stiff/V. Loose to Loose		10	TW	PH											
			11	SS	7											
			12	SS	3											
177.8			13	SS	3											
15.2	Silt Grey, Very Loose to Loose		14	SS	3											
174.3			15	SS	8											
18.7	End of Borehole															

RECORD OF BOREHOLE No 7

1 OF 2 METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 455 ; E 303 046 ORIGINATED BY TS
DIST 5 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 90 02 19-21 CHECKED BY BC

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					
183.2	Ground Surface																
0.0			1	SS	1		192										
	Some Organics Very Soft		2	SS	4												
	Clayey Silt (Locustrine)		3	SS	19												
			4	SS	19		190										
			5	SS	21												
	Het. mixture of Clayey Silt, Sand and Gravel (Glacial Till) Firm to Hard		6	SS	13		188										9 29 44 18
			7	SS	6		186										
			8	SS	33		184										
			9	SS	32												
182.5			10	SS	21		182										
10.7			11	SS	8		180										0 0 84 16
	Clayey Silt/Silt Grey, Firm/Loose to Compact		12	SS	2		178										
			13	SS	1												
176.4							176										
16.8			14	SS	18		174										8 74 14 3
	Sand, Some Silt Grey, Compact						172										
171.9			15	SS	44		170										
21.3							168										
	Silty Clay Grey, Hard		16	SS	41		166										
			17	SS	50		164										
162.7																	
30.5																	

Continued

+3, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 7

2 OF 2

METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 455 ; E 303 046 ORIGINATED BY TS
DIST 5 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 90 02 19-21 CHECKED BY BC

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 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100					
162.7	Continued		18	SS	48											
30.5																
159.2			19	SS	120	/15cm										
34.0	Silt, Tr. Sand Grey, Very Dense		20	SS	120	/25cm										
156.2			21	SS	120	/23cm										
37.0	End of Borehole															

RECORD OF BOREHOLE No 9

1 OF 2 METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 510.7 : E 303 026.9 ORIGINATED BY TS
 DIST 5 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
 DATUM Geodetic DATE 90 02 19-20 CHECKED BY BC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W _p	W	W _L	
183.5	Ground Surface															
0.0	Some Organics		1	SS	10		192									
	Brown		2	SS	22											
	Grey		3	SS	15		190									
			4	SS	25											
			5	SS	15											
	Het. mixture of Clayey Silt, Sand and Gravel (Glacial Till) Stiff to Hard		6	SS	27		188									
			7	SS	20											
			8	SS	49		186									
			9	SS	48		184									
182.8			10	SS	8		182									
10.7	Clayey Silt Grey, Stiff to Hard		11	SS	9											
			12	TW	PH		180									
178.3			13	SS	5		178									
15.2	Sand, Some Silt Grey, Very Loose		14	SS	3		176									
							174									
172.2			15	SS	44		172									
21.3	Clayey Silt Grey, Very Stiff to Hard		16	SS	26		170									
			17	SS	23		168									
							166									
							164									
163.0																

30.5 Continued

+3, x 5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

Continued

RECORD OF BOREHOLE No 9

2 OF 2

METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 849 510.7 ; E 303 026.9 ORIGINATED BY TS
DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 90 02 19-20 CHECKED BY BC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			UNIT WEIGHT 7 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	w _p	w			w _L
163.0	Continued		18	SS	23												
30.5																	
159.7																	
33.8	Silt, Tr. Sand Grey, Very Dense		19	SS	120												
156.5			20	SS	120	/18cm											
			21	SS	120	/15cm											
37.0	End of Borehole																

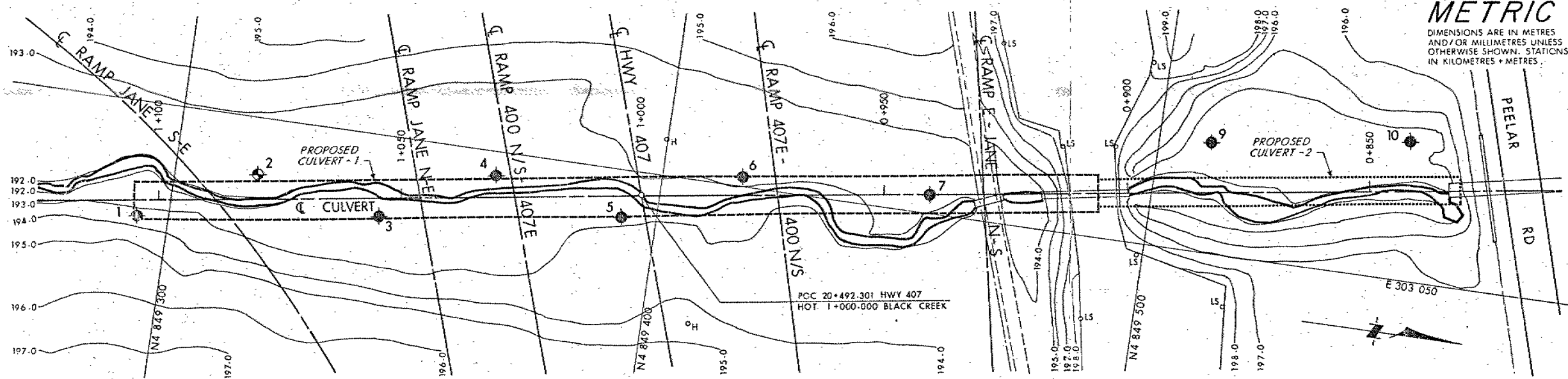
RECORD OF BOREHOLE No 10

1 OF 1

METRIC

W.P. 140-87-08 LOCATION Co-ords: N 4 848 551.2 ; E 303 020.9 ORIGINATED BY TS
 DIST 6 HWY 407 BOREHOLE TYPE HS Auger COMPILED BY TS
 DATUM Geodetic DATE 90 02 21 CHECKED BY BC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT 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	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	w _p	w	w _L		
194.2	Ground Surface																
0.0																	
	Some Organics		1	SS	4												
			2	SS	14												
	Brown		3	SS	21												
	Gray		4	SS	25												
			5	SS	35												
			6	SS	32												
			7	SS	39												
	Het. mixture of Clayey Silt, Sand and Gravel (Glacial Till) Very Stiff to Hard		8	SS	27												
			9	SS	27												
			10	SS	30												
182.0																	
12.2			11	SS	16												
	Clayey Silt Gray, Firm to Very Stiff		12	SS	8												
179.0																	
178.5	Sandy Silt, Grey, Compact		13	SS	13												
15.7	End of Borehole																

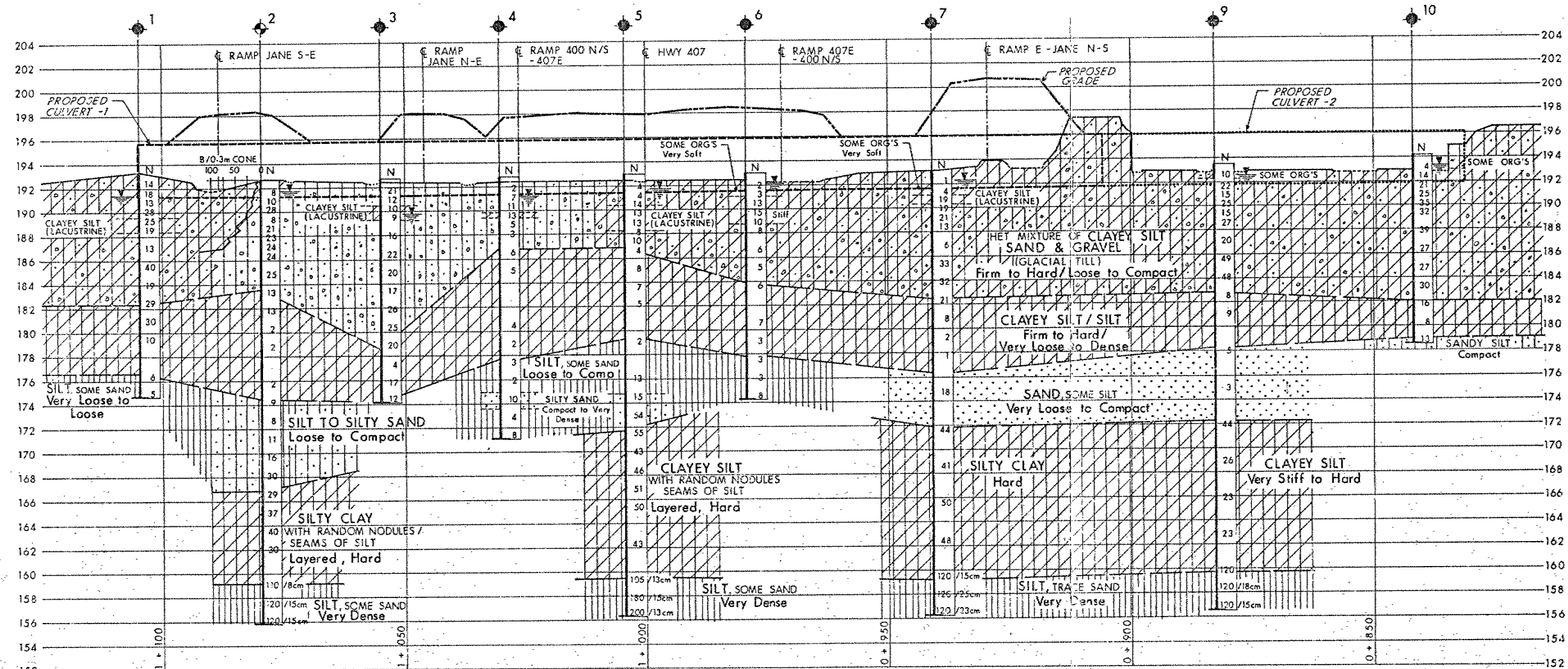
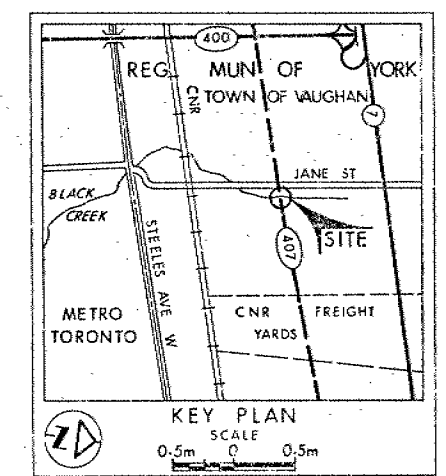


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES.

CONT No
WP No 140-87-08

BLACK CREEK CULVERT

BORE HOLE LOCATIONS & SOIL STRATA



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 90 02

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	193.4	4 849 293.5	303 074.0
2	192.7	4 849 317.0	303 062.0
3	192.8	4 849 343.0	303 067.0
4	192.9	4 849 366.0	303 055.0
5	193.0	4 849 393.0	303 060.0
6	193.0	4 849 416.0	303 048.0
7	193.2	4 849 455.0	303 046.0
9	193.5	4 849 510.7	303 026.9
10	194.2	4 849 551.2	303 020.9

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 CO.

REV	DATE	BY	DESCRIPTION

Geocres No 30M13-106

HWY No 407	DIST 6
SUBMITTAL CHECKED	DATE 90 06 13
DRAWN BY	APPROVED

37-1319
CWC 1408708-A

MEMORANDUM

(416) 235-3731

To: V.F. Boehnke,
Head, Structural Section
4th Floor, Atrium Tower
1201 Wilson Avenue, Downsview

Attn: L. Mikhailovsky, P. Eng.
Senior Structural Engineer

1991 07 23

From: Foundation Design Section
Room 315, Central Building, Downsview, Ontario
Central Region, MTO

Re: Final Design Review
Black Creek Structures
W.P. 140-87-08, Site: 37-1319
W.P. 140-87-09, Site: 37-1318
Highway 407, District 6, Toronto

Further to your request dated June 27, 1991 we have reviewed the drawings of final design for the above mentioned projects. The drawings were marked as preliminary but we understand that they are final drawings. The drawings DWG 1,2,3 (Sheets 72, 72, 76, 77, 78, 79, 80 and 81) produced by Fenco Engineers Inc. dated Oct. 1990 have been reviewed by this office and are found to be in conformance with our design requirements. However, it is expected that grading of approach slope will be maintained at 2H:1V and a special provision for dewatering will be incorporated in the contract package.

Should you have any further questions, please advise.


(KEN AHMAD)

for

D.H. Dundas, P. Eng.
Sr. Foundation Engineer

For

Murty Devata, P. Eng.
Chief Foundation Engineer

memorandum



To: V. Boehnke
Head, Structural Section
Central Region

Date: 1990 03 22

Atten: W. Garland
Inter. Structural Engineer

From: Foundation Design Section
Room 315, Central Building

Re: Proposed Crossing at Black Creek Culvert
and Proposed Highway 407
W.P. 140-87-08, Site 37-1319
Highway 407, District 6, Toronto

This memorandum summarizes the results of a foundation investigation conducted at the aforementioned site and provides preliminary comments pertaining to the structure foundations and related earthworks. These comments have been submitted in advance of the final report to assist in expediting the design so that conformance to project scheduling can be met. The final report will be submitted in the near future.

Proposed Structure

It is proposed to construct a reinforced box culvert to transmit the waters of the Black Creek beneath the Highway 407 and associated ramps. Approach fills in the order of magnitude of 7 to 9.5 metres will be required. Equivalently, depths of culvert roof cover ranges from 1.8 m to 4.4 metres.

Subsurface Conditions

The natural ground surface adjacent to the Black Creek is approximately 192.5 m to 193.0 m whilst the stream bed elevation is approximately 191 to 191.5 m.

The subsoil stratigraphy at the site consists of a surficial till deposit composed of a heterogeneous mixture of clayey silt to silt, sand and gravel. The thickness of this deposit ranges from 6.1 m to 14.2 m but is generally in the order of 10 metres. The deposit is generally in a loose to compact/firm to stiff condition. The till deposit is underlain by a clayey silt to silt deposit approximately 3 to 9 metres in thickness. A cohesionless silt and/or sand with some silt stratum approximately 4.6 m to 7.6 metres underlies the clayey silt to silt deposit. This stratum is in turn underlain by a hard clayey silt to silty clay stratum approximately 7.6 m to 12.3 m in thickness which is in turn underlain by a very dense silt deposit.

Groundwater levels obtained at the time of the investigation revealed that the groundwater table is generally at the elevation of the water in the creek. This corresponds to depths ranging from 1 to 2.5 metres below the natural ground surface.

Discussion and Recommendations

The following foundation/geotechnical items are hereby discussed.

- 1) Structure Foundations
- 2) Approach Embankments
- 3) Construction Considerations

Structure Foundations

The structure foundations can be founded on conventional spread footings or end bearing steel H-piles as discussed below:

a) Shallow Foundation - Spread Footings

The structure foundations can be supported on conventional spread footings at an elevation of 191.5 m or lower within the surficial till deposit. In view of the varying nature and strength of the surficial till deposit, the length of the culvert has been subdivided into three subsections as indicated in Table 1 and illustrated in Figure 1.

The corresponding soil capacities are summarized in Table 1 below.

Table 1

<u>Section</u>	<u>Bearing Capacity at S.L.S. Type II</u>	<u>Factored Capacity at U.L.S.</u>
1	125	300
2	75	150
3	200	375

The magnitude of total and differential settlement anticipated as a result of the applied loadings are expected to be within 25 mm for the foundations along section 1 and 3 and within 30 mm along section 2. Articulating the structure using construction joints and integrated slab slope gradients is recommended to accommodate differential settlements along the culvert pipe.

The footings must be protected against the scouring forces of the stream water. This can be obtained by constructing aprons and rip-rap at the culvert inlet and outlet. The design of the scour protection shall be made in conjunction with applicable hydrological parameters.

It is recommended that consideration may be given to the use of light weight fill together with pipe or pipe arch culverts at this site. Such an approach would reduce the load on the foundation soil, associated total and differential settlements and any resulting stressing and/or cracking of the

culvert. If this option is selected, bedding and backfilling shall conform to current MTO Standards.

b) Deep Foundation Units - End Bearing steel H-piles

Alternatively, structure foundations can be founded on steel H-piles driven to the lower very dense silt deposit. For purposes of the O.H.B.D.C., the design axial capacity for vertical piles are summarized in Table 2 below:

Table 2 - Axial Capacities - Driven Steel H-Piles

<u>Pile Type</u>	<u>Bearing Capacity at S.L.S. Type II (kN)</u>	<u>Factored Capacity at U.L.S. (kN)</u>	<u>Estimated Pile Tip El.(m)</u>
HP 310 x 110	1150	1600	159.5±
HP 310 x 79	890	1150	159.5±

Approach Embankments

The results of slope stability analyses of approach fills in the longitudinal direction have been conducted using total stress parameters applying Bishop's Modified Method. The results reveal that fill heights up to 8 metres can be constructed with 2H:1V slopes. For slopes exceeding 8 metres and up to 9.5 metres as required at the site, the slopes are to be constructed with a nominal 3 metre berm to ascertain internal and global stability.

It is anticipated that approximately 75-100 mm of total settlement can be realized as a result of elastic settlements induced within the fill itself and the elastic recompression of the native subsoil. It is recommended that the majority of these settlements will be realized during or immediately following construction.

Construction Considerations

Temporary Diversion

To facilitate the construction of the culvert, a temporary diversion of the Black Creek will be required. This can be accomplished by temporarily realigning the creek either east or west of its existing location. Impervious earth dikes composed of suitable clay material (CH-see OPSS 1205) can be used upstream to prevent water inflow into the foundation excavation.

Dewatering

A dewatering scheme will be required to depress the water table below the footing founding elevation, particularly in the areas where large percentages of silt and sand are present. It is recommended that an oversized excavation composed of perimeter ditches and a sump pumping discharge system be used to drain accumulated water.

If you have queries regarding the above comments or require additional information, please do not hesitate to contact this office.



T. Sangiuliano, P. Eng.
Foundation Engineer

for

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

TS/mmj



<==
Looking North

File: 371319 Stream : Black Creek
Date: 18 SEP 1989 Photos by: L. Mikhailovsky



<==
Looking West



<==
Looking East

File: 37-1319 Stream : Black Creek
Date: 18 SEP 1989 Photos by: L. Mikhailovsky



<==
Looking South