



**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
for**

**WELLAND RIVER/OLD WELLAND CANAL NORTHBOUND BRIDGE
SITE NO. 34-304N
HIGHWAY 406
WELLAND, ONTARIO
GWP 280-99-00**

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PML Ref.: 08TF005E
Index No.: 072FIDR
Geocres No.: 30M03-232
October 30, 2008



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PART A
PRELIMINARY FOUNDATION INVESTIGATION REPORT
for
Welland River/Old Welland Canal Northbound Bridge
Site No. 34-304N
Highway 406
Welland, Ontario
G.W.P. 280-99-00

1. INTRODUCTION

This report summarises the results of a preliminary foundation investigation carried out for construction of a bridge over both the Welland River and Old Welland Canal in Welland, Ontario. The investigation was conducted for McCormick Rankin Corporation on behalf of the Ministry of Transportation of Ontario (MTO).

The current plans call for the bridge to carry the two-lane Highway 406 northbound traffic over the Welland River and Old Welland Canal between approximate Sta. 14+615 and 14+920, Highway 406 chainage.

A subsurface investigation was not included in the Terms of Reference (TOR) for this project. The TOR indicated that the data obtained by MTO for the existing bridge should be used for this preliminary report. The centreline of the existing bridge is located about 25 m west of the proposed bridge centreline.

The report provides preliminary subsurface information pertaining to the proposed structure foundations and approaches within about 20 m of the abutments.

2. SITE DESCRIPTION

The site is located on the Highway 406 alignment at the crossing of the Welland River and Old Welland Canal south of Merritt Road (Thorold) in Welland, Ontario. The bridge to be erected will carry northbound traffic on the twinned section of Highway 406 across the Welland River and Old Welland Canal located immediately to the north of the river and separated by land known as Merritt Island. The alignment of the existing and proposed structures is considered to be south-north. A preliminary plan to the proposed bridge location is attached as Figure A.



The area near both the canal and river is generally covered by predominantly deciduous forest, bush and grass. The typical topography is gently flat and undulating with scattered man-made high ground areas likely resulting from excavations for canal construction.

The new twin bridge will be located about 100 m west of the existing Trillium Railway bridge. The man-made Old Welland Canal runs parallel to the Welland River and the water level in the canal is typically higher than in the river, about 2.5 m at the time of the field investigations in 1987 and 1988. The existing canal in this section is one of previously dug canals. Part of the spoil from each of the replacement canals was cast in the old canals. It appears from aerial photographs of the area that one such filled-in canal may have been present along Towpath Road about 350 m north of the existing canal. The presence of the filled-in old canals may indicate the presence of poorly compacted soils.

Stockpiles of the spoil from the canal excavations were also placed at various locations along the right-of-way of Highway 406. As interpreted from the highway profile available at this time, a 4 m high fill stockpile appears to exist on the north bank of Old Welland Canal near the alignment of the proposed northbound lanes (approximately from Sta. 14+920 to 15+150).

The site is located in the Haldimand Clay Plain physiographic region. The native soils are typically represented by lacustrine silts and clays. The rock type in the project area is dolostone of the Salina Formation. The bedrock is anticipated at depths of 20 to 25 m.

3. PREVIOUS INVESTIGATIONS

Subsurface information contained in previous reports prepared by MTO for the existing bridge was used in preparation of this report.



The reports prepared by MTO are as follows:

LOCATION	GEOCRES No.	REPORT NAME	DATE DRILLED
Welland River	30M3-187	Welland River Crossing	October and November 1987
Old Welland Canal	30M3-188	Old Welland Canal Overpass	October and November 1987
Welland River and Welland Canal	30M3-192	Welland River and Welland Canal Bridge	October and November 1987, November 1988

The boreholes and dynamic cone penetration tests (cone tests) from GEOCRES Nos. 30M3-187 and 30M3-188 were reused for 30M3-192 except for 3 cone tests from 30M3-188 on the north margin of the canal. The re-used test holes were renumbered in 101 to 105 and 201 to 204 for GEOCRES No. 30M3-187 and 30M3-188 respectively. Three additional boreholes 205 to 207 were also drilled in November 1988.

Copies of the previous foundation investigation reports prepared by MTO are enclosed in Appendices A, B and C. This report primarily references to the record of boreholes included in the Welland River and Welland Canal Bridge report, GEOCRES No. 33M3-192 (Appendix A).

4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets 101 to 106 and 201 to 207 for details of the subsurface conditions including soil classification, inferred stratigraphy, boundary elevations, standard and dynamic cone penetration test data, in situ vane undrained shear strength values and groundwater observations. Boreholes were not drilled for the proposed locations of either the proposed northbound bridge foundations or approach embankments some 20 m from the bridge abutments. The data obtained from the previous boreholes at the existing bridge location is considered to be representative for preliminary design of the new bridge.



The results of laboratory Atterberg limits testing, grain size distribution analyses are shown on the following Figures:

- Figures 1 and 2 (Appendix A) – Plasticity Charts
- Figure 3 (Appendix A) – Grain Size Distribution Charts
- Figures 2 and 3 (Appendix B) – Grain Size Distribution Charts
- Figures 2 and 3 (Appendix C) – Grain Size Distribution Charts

These results and the moisture content determinations are also shown on the Record of Borehole sheets. The locations of the boreholes and cone tests used for this report are indicated on Drawing 2 (Appendix A).

The stratigraphic profile along the centreline of the existing bridge is presented on Drawing 2 (Appendix A). The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

Localized fill about 5 m thick was encountered on the north margin of the Welland River. Elsewhere on land, a local 1 m thick topsoil unit was encountered on the south margin of the canal. Within the canal, organic silt was found below 9 to 10 m of water. The subsurface stratigraphy revealed in the boreholes below the surficial units generally comprised a stratified deposit of clayey silt to silty clay with variable thickness of 7 to 20 m (this soil was excavated by over 10 m for the construction of the canal). The clayey soil units are interbedded and underlain by 2 to 5 m thick sandy/silty soils mantling dolostone bedrock. The bedrock surface was contacted/inferred at depths of 21.3 to 26.9 m in five boreholes. The strata encountered are summarised below.



4.1 Fill

Surficial fill was present in borehole 102 drilled on the north margin of the Welland River. Composed of gravel/sandy gravel, the fill was compact to very dense and had a moisture content of 11 to 16%. The fill contained a surficial layer of boulders and extended to 5.2 m depth (elevation 166.5).

As indicated previously in this report, there is a possibility that areas near the existing canal were filled in the past with spoil from the excavation of the existing as well as previously dug and filled-in canals.

4.2 Topsoil

Topsoil was present surficially in borehole 204 drilled on the south margin of the canal and north of the Merritt Island Service Road. This unit was 1.0 m thick and penetrated at elevation 175.9.

4.3 Organic Silt

A layer of organic silt was encountered on the canal bed in boreholes 205 to 207 below 9.3 to 10.4 m of water (as measured in 1987). The organic silt had a thickness of 400 to 700 mm and was penetrated at elevation 162.3 to 163.6.

4.4 Clayey Silt to Silty Clay

A continuous cohesive deposit of clayey silt to silty clay was present surficially in boreholes 101, 103 to 105, 201 to 203 and underlay the fill, topsoil or organic silt in the remaining boreholes. This deposit was firm to hard in consistency. The results of in situ vane testing yielded an undrained shear strength of 46 to 116 kPa.



Two layers of these soils were encountered in boreholes 101 to 103 drilled on both margins of the Welland River and a single layer was encountered in the remaining boreholes. The upper layer of the deposit was about 7.0 to 20.1 m thick and penetrated at depths of 13.1 to 20.1 m (elevation 155.8 to 157.8).

The lower clayey silt to silty clay which was encountered beneath sandy/silty soils in boreholes 101 to 103 was 1.6 to 3.7 m thick and penetrated at depths of 21.3 to 26.9 m (elevation 150.3 to 150.5).

Boreholes 206 and 207 and cone tests 105 and 203 were terminated within the cohesive deposit at depths of 9.4 to 18.7 m (elevation 154.6 to 161.9).

The results of Atterberg limits testing conducted on selected cohesive samples are presented in Figures 1 and 2 (Appendix C). The moisture content of the clayey silt to silty clay ranged from 11 to 30%, with an average value of 21%. The grain size distribution charts of the cohesive samples tested are included in the reports attached in Appendices B and C.

4.5 Sandy Silt/Sand and Silt

Interbedded in the silty clay/clay silt deposit in boreholes 101 to 103 (and possibly 104) and overlain by the clayey silt to silty clay in the remaining boreholes were cohesionless sandy/silty soils of various granulometric composition. These deposits were compact to very dense (SPT-'N' values of 10 to 100), locally loose, and had a moisture content of 10 to 20%. The sandy/silty soils were 2.1 to 5.0 m in thickness and penetrated at depths of 19.5 to 24.0 m (elevation 151.9 to 154.2) in boreholes 101 to 103, 201 and 205. Drilling was terminated within the strata at depths of 15.5 to 23.0 m (elevation 153.9 to 156.0) in boreholes 104, 202 and 204.

The envelope of grain size distribution curves for the sandy silt is shown in Figure 3 (Appendix A), Figure 3 (Appendix B) and Figure 2 (Appendix C).



4.6 Bedrock

Bedrock/probable bedrock was contacted below the native soils at depths of 21.3 to 26.9 m (elevation 150.3 to 153.1) in boreholes 101 to 103, 201 and 205. The bedrock was at elevation 150.3 to 150.5 in boreholes 101 to 103 drilled north and south of the Welland River and at elevation 153.1 and 151.9 in boreholes 201 and 205 drilled near the north bank and within the Old Welland Canal. The rock surface slopes up from south to north at a rate of 0.9% between the most distant boreholes 103 and 201.

The bedrock predominantly comprises a grey to light tan brown dolostone interbedded with a black to dark grey shale. A detailed description of the rock cores retrieved is given in the Tables attached in Appendix A.

The measured core recovery was in a range of 50 to 100%, locally 28%. The RQD determined from the rock cores varied between 0 and 39%, thus indicating a very poor to poor quality rock.

4.7 Groundwater

The groundwater level in most boreholes was reported to be at or near the water levels in the Welland River (elevation 170.9) or Old Welland Canal (elevation 173.3 to 173.4). The water levels were measured in October and November 1987 and in November 1988. The current water levels may differ and should be established during the field investigation for detail design.



The groundwater conditions observed at each borehole location are tabulated below:

BOREHOLE	ELEVATION (m)	REMARKS
101	–	Artesian condition encountered at elevation 149.6, water level rose to 0.5 m above ground, elevation 172.4
102	171.1	–
103	172.0	–
104	170.9	Artesian condition encountered at elevation 155.4, water level rose to 1.4 m above ground, elevation 172.3
105	170.9	–
201	173.0	–
202	173.4	Artesian condition encountered at elevation 156.0, water level rose to 0.3 m above ground, elevation 173.7
203	173.4	–
204	161.3	–
205	173.3	–
206	173.3	–
207	173.3	–

The artesian condition was observed within the sandy/silty soils encountered in the boreholes. The artesian water level rose above the ground surface 0.3 to 1.4 m (elevation 172.3 to 173.7) in boreholes 101, 104 and 202.

5. MISCELLANEOUS

A site investigation including subsurface explorations was not required under the Terms of Reference of this study. The data utilized in this report was obtained from the MTO GEOCREST library of completed reports for the existing bridge.

PART B
PRELIMINARY FOUNDATION DESIGN REPORT

for
Welland River/Old Welland Canal Northbound Bridge
Site No. 34-304N
Highway 406
Welland, Ontario
G.W.P. 280-99-00

6. ENGINEERING RECOMMENDATIONS

6.1 General

This report provides preliminary foundation engineering comments and recommendations regarding design and construction of foundations, abutments and approaches for a new northbound bridge over both the Welland River and Old Welland Canal in Welland, Ontario. The investigation was conducted for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

The current plans call for the bridge to be a two-lane 11-span structure carrying the Highway 406 northbound traffic over the Welland River and Old Welland Canal between approximate Sta. 14+615 and 14+920, Highway 406 chainage. The new bridge will twin the existing two-lane bridge about 25 m to the east, centreline to centreline as illustrated in Figure A. [NOTE: A general arrangement drawing for the structure was not provided for this preliminary study.]

Based on the August 11, 2008 proposed profile for the northbound lanes, the deck will be at approximate elevations 181.3 and 180.8 at the south and north ends of the bridge, respectively. Fill up to 4.5 and 6.2 m high will be required behind the south and north abutments respectively. We note that the original ground appears to have been previously filled with a 1.5 to 3.0 m high stockpile at the north end of the new bridge.



The existing bridge foundations were designed with HP 310 x 110 steel piles driven to bedrock as shown on Drawings 3 and 5 of Contract No. 93-76, WP No. 171-90-01, dated August 1991. The installation of new foundations should be designed and carried out to avoid affecting the existing piled foundations.

In summary, the subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised a stratified stiff to hard cohesive deposit of clayey silt to silty clay underlain or interbedded by compact to very dense sandy/silty soils mantling a relatively level and flat dolostone bedrock formation of very poor to poor quality.

The foundation frost penetration depth at this site is 1.2 m. The seismic site coefficient is 1.0 - Type I soil profile as per clause 4.4.6 of the Canadian Highway Bridge Design Code (CHBDC) 2006 Edition – for the anticipated foundation conditions.

The design and construction of foundations for the northbound bridge should consider the presence of artesian groundwater conditions which could potentially affect the performance of shallow foundations and the installation of drilled deep foundations such as caissons. Installation of steel H-piles driven to bedrock through the relatively impervious clayey soil units will mitigate the need for control of artesian groundwater. The H-piles driven to the bedrock alternative is considered to be the preferred method of construction from a foundation engineering perspective.

The need to pre-auger the hard clayey soils for the pile installations should be carefully assessed for detail design based on the conditions at the northbound bridge location, because of difficulties experienced in other MTO projects with pre-augering, in particular for the installation of battered piles. If required, pre-augering should not be carried below a level at least 5 m above the upper boundary of the cohesionless soils to avoid potential problems related to artesian conditions encountered in the boreholes.

From the MTO past experience, the soil types in the area are problematic regarding surficial slope stability and erosion control. Preliminary recommendations are provided in the report.



The discussions and recommendations provided in this report are based on subsurface data from the existing bridge and should be used for preliminary design purposes only. Additional subsurface investigations should be carried out for the detail design of the new bridge. All depths are referenced to the ground surface and water levels in the river and canal at the time of the investigation (October and November 1987, November 1988) and may vary from the current levels.

All elevations in this report are expressed in metres. The standard specifications referenced in the report are listed in Table 1.

6.2 Foundations

6.2.1 General

Based on the available data, design and construction of foundations to support the new bridge is considered to be feasible at the site. Due to the artesian groundwater conditions encountered in the boreholes, the foundations of the structure should not bear on the native soils. Consequently, spread footings or deep foundations founded on the native soils should not be considered for this site and the bridge should be founded on piles driven to the bedrock underlying the site.

To prevent the installation of new foundations from affecting the steel H-pile foundations of the existing bridge, steel H-piles which have a lower soil displacement effect than alternative piles, such as steel tube piles should be used.

In conclusion, supporting the anticipated foundation loads on end-bearing steel H-piles founded on bedrock is considered to be the most suitable method in view of potential problems with artesian conditions within the cohesionless deposits encountered in the boreholes and to avoid affecting the existing foundations.



6.2.2 Piles

Taking into account the approximately 300 m length of the proposed structure, construction of integral abutments is not feasible at this site. The H-piles should be driven to refusal on bedrock contacted at depths of 21.3 to 26.9 m (elevation 150.3 to 153.1). Penetration of the piles a short distance (0.5 to 1.0 m) into the rock before refusal should be expected. The preliminary founding levels for the driven piles are provided in the following table.

LOCATION	DEPTH TO BEDROCK, m	ELEVATION
South Abutment	26.9	150.5
Pier No. 1	± 18.0	150.5
Pier No. 2	± 16.6	150.5
Pier No. 3	21.3	150.4
Pier No. 4	21.6	150.3
Pier No. 5	± 26.6	150.3
Pier No. 6	± 12.6	150.3
Pier No. 7	± 12.3	151.0
Pier No. 8	± 11.4	151.9
Pier No. 9	12.1	151.9
Pier No. 10	± 18.9	152.5
North Abutment	24.0	153.1

The piles should be designed using the following preliminary factored axial resistances at ultimate limit states (ULS):

<u>H-Pile Section</u>	<u>Factored Axial Resistance at ULS, kN</u>
HP 310 x 110	1600
HP 310 x 132	1900



The resistance at ULS has been reduced by 20% in view of the very poor to poor quality rock identified in the retrieved rock cores. The rock quality and above values of the geotechnical resistances should be confirmed at the new bridge foundations during the detail design.

The resistance at serviceability limit states (SLS) normally allows for 25 mm compression of the pile and founding medium. Considering the bedrock to be non-yielding and the pile length required, the design is not expected to be governed by settlement criteria since the loading needed to produce 25 mm axial deformation of the pile is larger than the factored resistance at ULS.

The approach fill embankment as well as any fill placed below grade to deal with unsuitable/compressible soils within the limits of the pile foundation should comprise Granular A or Granular B Type II or Type III with a maximum size of 75 mm to enable driving of the piles and minimise the potential for damage during pile installation.

The approach embankment fill should be placed at least 3 months ahead of the pile driving to minimise potential negative skin friction which may occur along the piles driven at the abutments due to consolidation settlement of the native soils.

The type of equipment required to drive the piles will be somewhat dictated by the design capacity. In general, the piles at this site should be driven to practical refusal using a hammer that transfers at least 50 kJ of energy to the pile to ensure the pile penetration through the very stiff to hard native soils. Since the piles will be set on rock, a specific set for this project is not provided.

The piles should be installed and monitored in accordance with the requirements of SP 903S01. This should involve confirmation of the founding elevation, alignment, plumbness, uniformity of set, quality of splices and be performed on a full-time basis by experienced geotechnical personnel.



Oslo driving shoes according to OPSD-3000.100 or Titus H-bearing shoes according to SP 903S01 should be provided to minimise the potential for damage when driving through dense or hard zones and setting on bedrock.

Pile caps should be provided with at least 1.2 m of earth cover or equivalent thermal insulation as protection against frost action. A 25 mm thick layer of polystyrene insulation is thermally equivalent to 600 mm of soil cover.

The clayey deposits at the site have typically medium to high susceptibility to erosion. Consequently, the need for erosion control due to fluctuations of the water levels in the Welland River and Old Welland Canal should be considered during detail design.

Resistance to lateral loads may be provided in part by mobilization of passive resistance along the pile. The following lateral resistances for the HP 310 x 110 or HP 310 x 132 sections are recommended:

	<u>Stiff Clayey Soil</u>	<u>Hard Clayey Soil</u>
Factored Lateral Resistance at ULS, kN	160	260
Lateral Resistance at SLS, kN	65	200

If greater resistance is required, batter piles should be installed.

6.2.3 Caissons

Installation of caissons through the clayey material and sandy/silty soils will be problematic due to the groundwater and artesian conditions present at the site. Measures would have to be taken by the Contractor to ensure the prevention of cave and caisson base upheaval. Loss of ground could also affect the piled foundations of the existing bridge. Therefore, supporting the structure on caissons bearing on bedrock is not recommended at this site.



6.3 Lateral Earth Pressures

The abutment walls should be designed to resist the unbalanced horizontal earth pressure imposed by the backfill adjacent to the wall. The lateral earth pressure, p (kPa), may be computed using the equivalent fluid pressure diagrams presented in Section 6.9 of the CHBDC or employing the following equation, assuming a triangular pressure distribution.

$$p = K (\gamma h + q) + C_p + C_s$$

where K = coefficient of lateral earth pressure (dimensionless)
 γ = unit weight of free-draining granular material, kN/m^3
 h = depth below final grade, m
 q = surcharge load, kPa, if present
 C_p = compaction pressure, kPa (refer to clause 6.9.3 of CHBDC)
 C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)
where \emptyset = angle of internal friction of retained soil (35° for Granular A or Granular B Type II or Type III)
 δ = angle of friction between the soil and wall (23.5° for Granular A or Granular B Type II or Type III)

Free-draining granular material should be used as backfill behind the wall. The following parameters are recommended for design:

PARAMETERS	GRANULAR A OR GRANULAR B TYPE II OR TYPE III
Angle of Internal Friction (degrees)	35
Unit Weight (kN/m^3)	22.8
Active Earth Pressure Coefficient (K_a)	0.27
At Rest Earth Pressure Coefficient (K_o)	0.43
Passive Earth Pressure Coefficient (K_p)	3.69

The coefficient of earth pressure at rest should be used for design of rigid and unyielding walls, the active earth pressure coefficient for unrestrained structures. The magnitude of the passive resistance is dependent on the actual lateral movement of the structure toward the retained soil. We refer to Figure C6.16 of the CHBDC for this computation.



A subdrain system (SP 405F03) or weep holes (OPSD-3190.100) should be installed to minimise the build-up of hydrostatic pressure behind the wall. Where there is a possibility for flooding behind the wall, a subdrain should be installed. The subdrain tiles should be surrounded by a properly designed granular filter or geotextile to prevent migration of fines into the system. The drainage pipe should be placed on a positive grade and lead to a frost-free outlet. A geotextile specification should be prepared for detail design.

A retained soil system (RSS) could also be employed. The founding material is expected to comprise granular engineered fill or clayey silt/silty clay. The following parameters should be employed for design of the RSS wall foundation:

	<u>Granular A or Granular B Type II or Type III</u>	<u>Native Clayey Silt/Silty Clay</u>
Friction Angle (degrees)	35	0
Cohesion (kPa)	0	50
Unit Weight (kN/m ³)	22.8	19.0

The supplier of the retained soil system should be responsible for design of the structure (backfill, reinforcement, internal and external stability) and provide drawings at the detail design stage to show pertinent information such as location, length, height, elevations, performance level, appearance, etc.

6.4 Approach Embankments

It is anticipated that the approach embankments will be up to 4.5 and 6.2 m in height behind the south and north abutments, respectively, and constructed with earth borrow or granular material. The subgrade revealed in boreholes 103 and 201 drilled near the abutments consists of typically stiff to very stiff clayey silt/silty clay.

The existing fill, topsoil and other deleterious material at the abutment locations and along the alignment within 20 m of the abutments should be stripped prior to placement of the approach fill on the inorganic native soils.



In general, the embankments should be constructed following conventional MTO procedures (OPSD-200.010, 201.010, 202.010 and SP 206S03). Embankment slopes inclined no steeper than 2 horizontal to 1 vertical should be stable. A 2 m wide mid-height berm should be provided for slopes greater than 6 m high for erosion control and slope maintenance purposes. Erosion control measures should be included where the soil in earth cuts on embankment fills is susceptible to erosion. Such measures as rip-rap, vegetation cover, slope flattening, intercepting ditches may be considered.

Based on plasticity characteristics of the clayey silt/silty clay, maximum settlements of the approach fill as a result of consolidation of the underlying cohesive deposit induced by the embankment loads are estimated to be 30 to 40 mm. The approach fill should be placed at least 3 months prior to pile driving to minimise potential negative skin friction along the piles due to consolidation settlement of the clayey soils. No bearing capacity problems are anticipated.

The backfill to the abutments should comprise granular material placed in conformance to the requirements of SP 206S03 and OPSS 501 to minimise post-construction settlements.

The need for erosion control due to fluctuations of the water levels in the Welland River and Old Welland Canal should be considered at the detail design stage. Since the soils in the area are susceptible to surficial slope instability and erosion, local protection measures such as rip-rap, should be implemented during detail design on the margins of the Welland River and Old Welland Canal.

6.5 Excavation and Groundwater Control

Excavation for construction of the abutments and pier pile caps is expected to be carried out primarily within the native clayey silt/silty clay. Excavation of these soils should be relatively straightforward.

The fill and firm to stiff clayey silt/silty clay are classified as Type 3 soils according to Occupational Health and Safety Act (Ontario Regulation 213/91) criteria. Therefore, temporary cut slopes



inclined at 45° to the horizontal should generally be stable. Flatter side slopes may be required if excessively soft/wet materials or concentrated seepage zones are encountered locally.

During the investigation in October and November 1987 and November 1988, the groundwater level was reported to be at or near the river or canal water level (elevation 170.9 to 173.4). Artesian conditions were encountered in three boreholes. Groundwater control for the local excavations required for on-land abutments and pier footings will likely be straightforward using sump pumps installed in the excavations.

The need for shoring or construction of cofferdams will be dependent on the locations selected during detail design for the abutments and pier foundations placed near the water edge. Cofferdams seated on the bottom of the canal or river will be required for piers in the water. These temporary structures will need to be driven into the cohesive soils encountered under water and at least partially unwatered for construction of the pier caps. The contractor should provide the detail design of these temporary shoring systems.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

7. ADDITIONAL STUDIES

The investigations for this report are considered adequate for preliminary design purposes. The recommendations provided are preliminary only and are based on our interpretation of the factual information obtained by MTO for the existing bridge. A detail foundation investigation will be required at the selected location of the northbound bridge during the detail design stage of the project. Further consideration during detail design should be given to issues such as:

- Artesian conditions
- Surficial and deep seated slope stability
- Erosion control
- Navigation in the canal and river related to the presence of temporary shoring/cofferdams



8. CLOSURE

The report was prepared by Mr. G. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C. Nascimento, P.Eng., Project Manager. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Principal Contact, carried out an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

NOTE: Hard copies signed and stamped

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer

NOTE: Hard copies signed and stamped

Carlos M.P. Nascimento, P.Eng.
Project Manager

NOTE: Hard copies signed and stamped

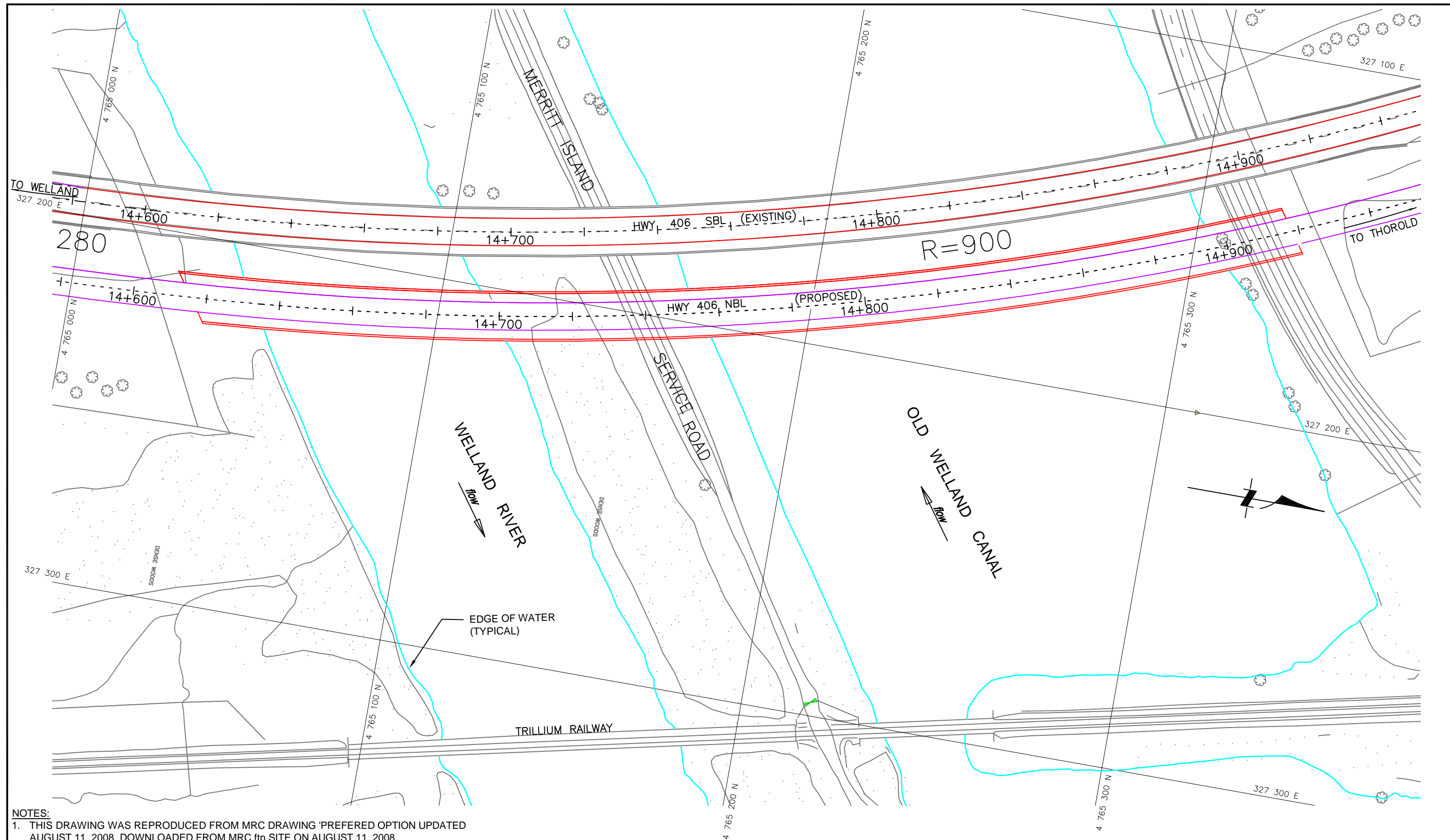
Brian R. Gray, MEng, P.Eng.
MTO Designated Principal Contact
GD/CN/BRG:mi-nk



TABLE 1
STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
OPSS 501	Construction Specification for Compacting
SP 206S03	Construction Specification for Grading
SP 405F03	Construction Specification for Pipe Subdrains
SP 903S01	Construction Specification for Piling
OPSD-200.010	Earth/Shale Grading – Undivided Rural
OPSD-201.010	Rock Grading-Undivided Rural
OPSD-202.010	Slope Flattening Using Excess Material on Earth or Rock Embankment
OPSD-3000.100	Foundation Piles – Steel H-Pile Driving Shoe
OPSD-3190.100	Retaining Wall and Abutment Wall Drain Detail

Note: This table is preliminary and will be finalised for detail design.



PROPOSED WELLAND RIVER AND OLD WELLAND CANAL NORTH BOUND BRIDGE
SITE PLAN

METRIC

SCALE
0 10 20m



Peto MacCallum Ltd.
CONSULTING ENGINEERS

GWP No 280-99-00

HIGHWAY 406
PRELIMINARY DESIGN STUDY



FIGURE
A



APPENDIX A

Copy of Foundation Investigation Report
For
Welland River and Welland Canal Bridge (Existing)
Structure Site No. 34-304N
Highway 406
GEOCRES No. 30M3-192

- Notes:**
1. Boreholes 101 to 105 were reused and renumbered from report with GEOCRES No. 30M3-187 attached in Appendix B.
 2. Boreholes 201 to 204 were reused and renumbered from report with GEOCRES No. 30M3-188 attached in Appendix C.

FOUNDATION INVESTIGATION REPORT

CONTRACT NO. 93-76



**Ministry of
Transportation**

INDEX

<u>Page No:</u>	<u>DESCRIPTION</u>
1	Index
2	Abbreviations & Symbols
3-25	Foundation Investigation Report for Welland River and Welland Canal Bridge W.P. 171-90-01, Site 34-304 Hwy. 406, District 4, Burlington

Note: For purposes of the contract, this report supersedes all other Foundation Reports prepared by, or for the Ministry in connection with the above mentioned project.

FOUNDATION INVESTIGATION REPORT
For
Welland River and Welland Canal Bridge
W.P. 171-90-01, Site 34-304
Hwy 406, District 4, Burlington

INTRODUCTION

This report contains the results of a soil investigation carried out at the above mentioned site.

The field work for this project was carried out between 87 10 14 and 88 11 24, and comprised of ten sampled boreholes and Dynamic cone Penetration Test adjacent to these holes. In addition, Cone Penetration Tests were carried out at two locations.

Boreholes were advanced to a maximum depth of 30.5 m (elevation 146.9 m) below the existing ground level using a continuous flight hollow stem auger and BW casing. Rock cores were obtained in four of the boreholes using BX size core barrel.

SITE DESCRIPTION

The site is located between the shores of the Old Welland Canal and the Welland River in the north end of Welland. The Merritt Island which is a narrow strip of parkland separates the Old Welland Canal from the Welland River. The vegetation on the island is predominantly deciduous forest and bush groomed grass. A roadway and pedestrian walkway runs the length of the Island.

The topography of the site with the exception of the South Shore of the river (4 m to 5 m high embankment) is generally flat to rolling. The Welland River flows slowly through the area with a gradient of less than 200 mm per kilometre.

Physiographically, the area is located in the region known as the "Haldimand Clay Plain". The Haldimand Clay Plain which lies between the

Niagara Escarpment and Lake Erie can be described as falling in to a series of parallel belts. The high grounds are of moraines and the intervening troughs are floored with lacustrine silt or clay. The underlying rocks consist of a succession of Palaeozoic limestones and overlying these is a series of softer rocks which include shale members.

SUBSURFACE CONDITIONS

The underlying subsoil at this site consists of stratified deposits composed of clayey silt to silty clay with occasional silt seams, and sandy silt with varying proportions of silt and sand content. In the Old Welland Canal area, the sandy silt deposit is sandwiched between the clayey layer and the bedrock, whereas in the Welland River area, it is sandwiched between clayey deposits. For classification purposes, the soils encountered at this site can be divided into three different zones.

- a) Clayey Silt to Silty Clay, trace of Sand
- b) Sandy Silt, trace/some Gravel
- c) Dolostone Bedrock

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the Record of Borehole sheets contained in the Appendix of this report. A stratigraphical section is shown on Dwg. No. 2. This drawing also shows the locations and elevations of the borings. Description of the strata encountered are given below.

Clayey Silt to Silty Clay, trace of Sand

This clayey deposit was encountered in all the boreholes immediately below the floor of the canal and river, and in other areas, it was encountered at the ground level. This deposit was intercepted twice in boreholes located in the Welland River area. Occasional silt seams varying in thickness from a few millimeters to a maximum of 3 m were also encountered in this deposit. The thickness of this layer varies from 7.2 m to a maximum of 20

m and extends to elevation 157.8 m to 155.8 m. However, thickness of the clayey layer underlying the sandy silt deposit varies from 1.6 m to a maximum of 3.7 m. The natural moisture content was observed to vary from 11% to 30% with an average value of 21%. The Atterberg Limits Test determined for the representative soil samples of this deposit are shown on Figure 1 & 2. The in-situ Vane Shear Test results were observed to vary from 46 kPa to a maximum of 116 kPa indicating firm to very stiff consistency. However, in the depth range of elevation 164 m to 158 m, it was observed to be hard (N-values 34 blows/0.3 m to over 100 blows/0.3 m).

Sandy Silt, trace/some Gravel

The clayey silt to silty clay layer is underlain by this deposit. The thickness of this deposit varies from 2.1 m to 5.0 m and extends to elevation 154.2 m to 151.6 m. The Grain Size Distribution Test results are shown on Figure 3 in an envelope form. These results indicated 3% to 20% gravel, 16% to 46% sand and 40% to 81% silt. The Standard Penetration Test results of this deposit varies over a wide range (9 blows/0.3 m to 91 blows/0.3 m) indicating loose to very dense state of compaction. The lower 'N' values were observed in boreholes located in the Welland River area.

Bedrock

The rock cores were examined by Mr. S.A. Senior, Geological Engineer and his description is included in the Appendix of this report.

The project area is underlain by dolostone bedrock interbedded with shale. The unweathered bedrock is expected to be in the depth range of elevation 153.0 m to 150.3 m. The bedrock up to the depth of drilling may be classified as very poor quality rock.

Groundwater Conditions

The groundwater level was observed at or near the canal or river water level (elevation 173.4 m to 171.2 m). In three boreholes artesian

condition was encountered in the bedrock. Seasonal fluctuation of the groundwater level may be expected. The groundwater level at each borehole location is as follows:

<u>Borehole No.</u>	<u>Elevation</u>	<u>Remarks</u>
101	-	Artesian Condition encountered at El. 149.6 m, rose to El. 172.4 m
102	171.2	
103	172.0	
104	-	Artesian Condition encountered at El. 155.4 m, rose to El. 172.3 m
201	172.9	
202	-	Artesian Condition encountered at El. 156.0 m, rose to El. 173.7 m
204	161.4	Water Level not stabilized
205	173.3	
206	173.3	
207	173.3	

MISCELLANEOUS

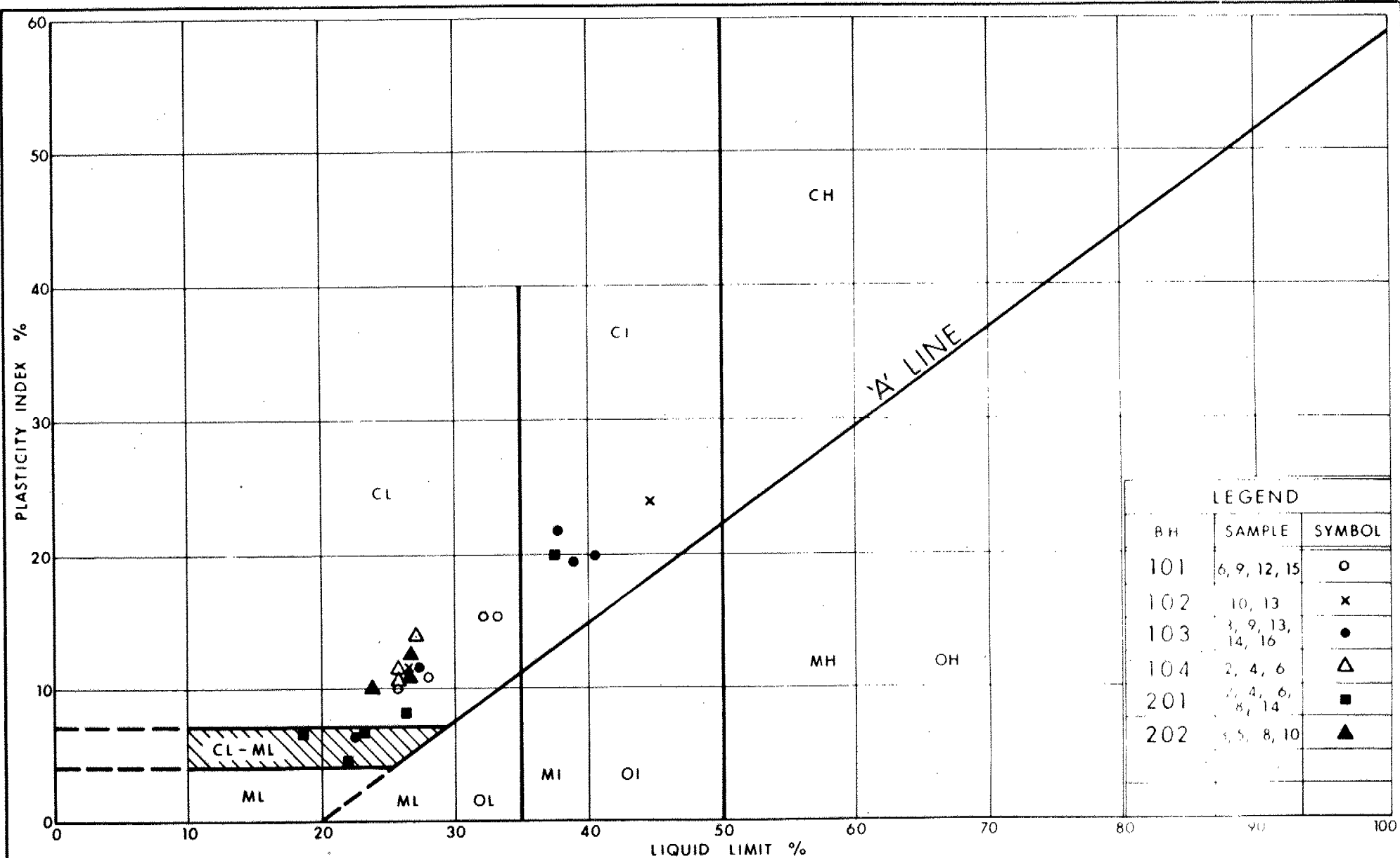
The field work for this investigation was carried out under the supervision of Mrs. P. Marks, Foundation Engineer and Mr. J. Robertson, Student Specialist. The equipment was owned and operated by F.E. Johnston Drilling Co. Ltd. This report was prepared by Mr. M. Vasavithasan, reviewed by P. Payer, Senior Foundation Engineer and approved by Mr. M. Devata, Chief Foundation Engineer.



P. Payer
P. Payer, P. Eng.
Senior Foundation Engineer

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

APPENDIX



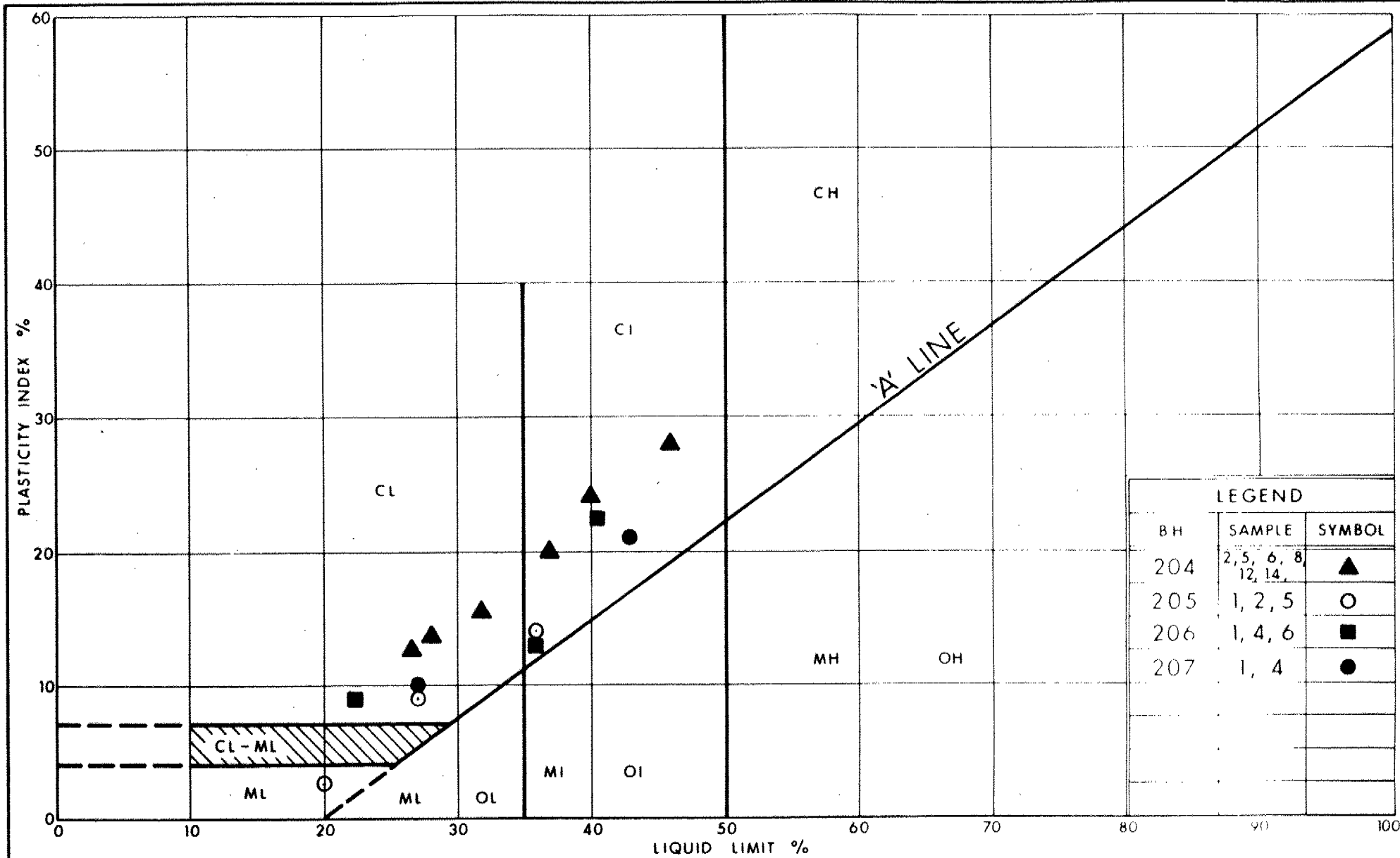
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PLASTICITY CHART CLAYEY SILT TO SILTY CLAY

FIG No 1

W P 171-90-01

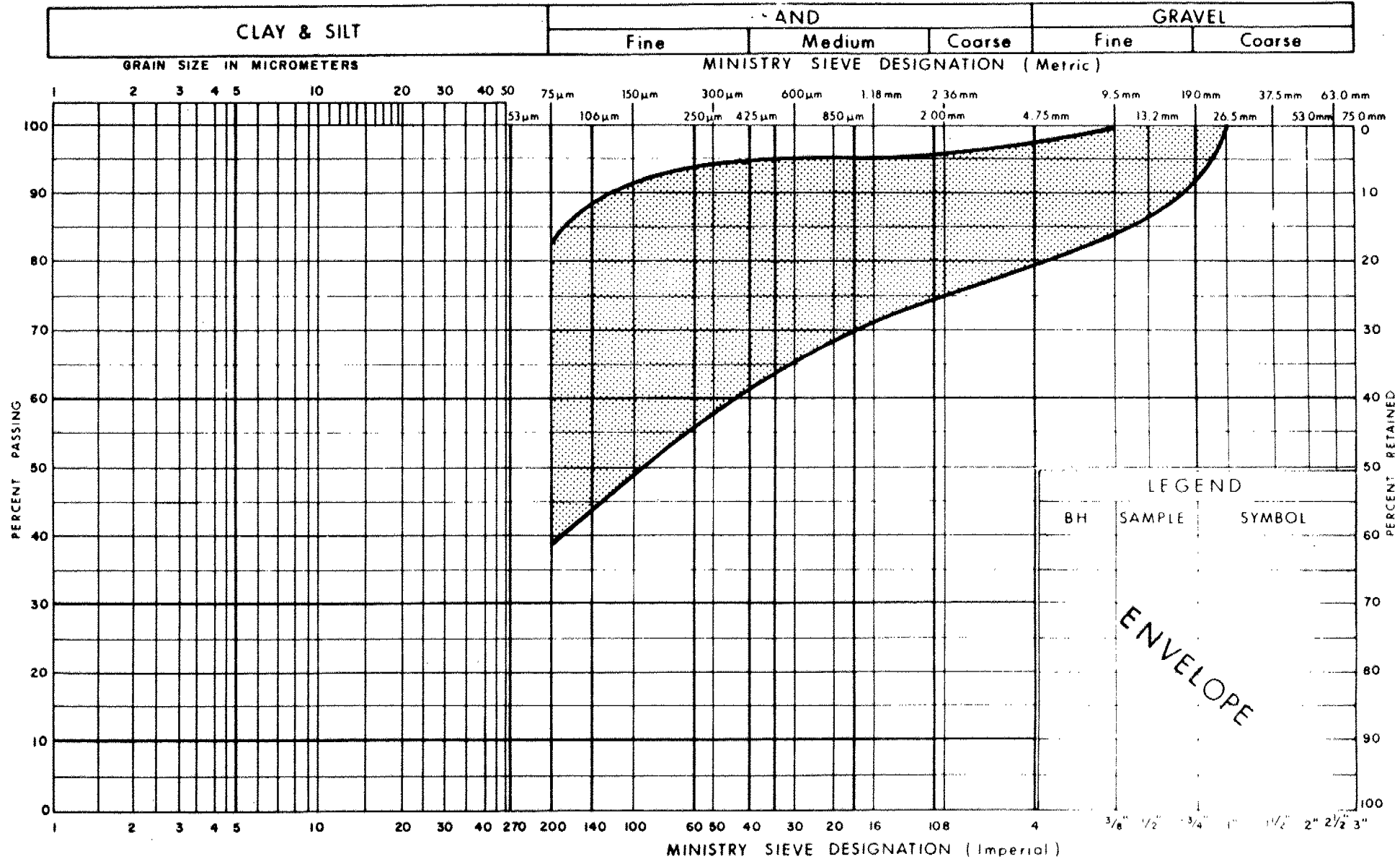


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PLASTICITY CHART CLAYEY SILT TO SILTY CLAY

FIG No 2
W P 171-90-01

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION
SANDY SILT, TRACE / SOME GRAVEL

FIG No 3

W P 171 - 90 - 01

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 kg, 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, 10mm DIA., INTO THE GROUND BY AN IMPACT ENERGY ON 1" SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED IN TONS PER SQUARE INCH PER INCH 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 CONSISTENCY AS INDICATED BY THE FOLLOWING:

CU (kPa)	1-2	2-5	5-15	15-30	30-50	50-100
	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)	0-10	10-30	30-50	>50
	VERY LOOSE	LOOSE	COMPACT	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 MIN 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	50-100mm	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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_a	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_f	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
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

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^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No 101

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - ORDS. N 4 764 905.4, E 327 177.5 ORIGINATED BY P.M.
 DIST 4 HWY 406 BOREHOLE TYPE CONTINUOUS FLIGHT AUGER (H.S.) & CONE TEST COMPILED BY M.T.
 DATUM GEODETTIC DATE 87.10.19 to 87.10.21 CHECKED BY J.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		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			
171.8	Ground Level											
0.0	CLAYEY SILT to SILTY CLAY. With Occasional Silt Seams, Trace of Sand, Stiff to Firm		1	SS	12							
			2	SS	17							0 4 (96)
			3	SS	13							
			4	SS	15							
			5	SS	12							
			6	SS	14							0 3 (97)
			7	SS	6							
			8	SS	5							
			9	TW	PH							
			10	SS	38							
			11	SS	37							
			12	SS	47							
155.8	SANDY SILT, Trace of Gravel, Loose to Compact		13	SS	6							
16.1			14	SS	9							3 16 (81)
151.9	CLAYEY SILT to SILTY CLAY, Trace of Sand, Very Stiff		15	SS	29							
20.0												0 1 (99)
150.3	DOLOSTONE BEDROCK Sound		16	RC BX	REC 50%							
21.6			17	RC BX	REC 97%							
147.8	End of Borehole											
24.0												
<p>• Note: Artesian Condition Water Level Rose to 0.5m Above Ground Level El: 172.4</p>												

+3, x5: Numbers refer to
Sensitivity

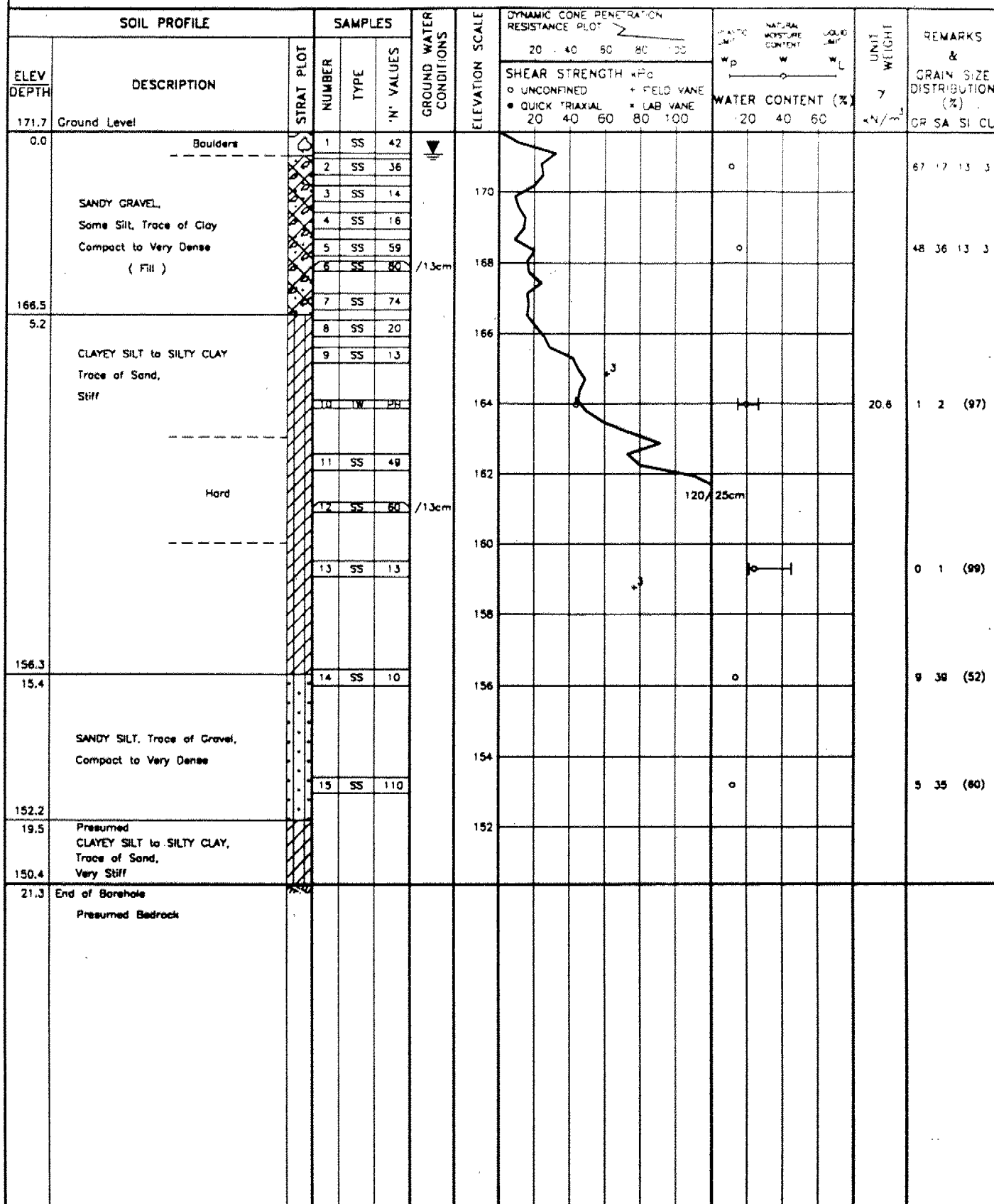
20
15-25 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 102

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - ORDS. N 4 764 893.6; E 327 185.0 ORIGINATED BY P. V.
DIST 4 HWY 406 BOREHOLE TYPE CONTINUOUS FLIGHT AUGER (H.S.) & CONE TEST COMPILED BY V. V.
DATUM GEODETIC DATE 87 10 22 to 87 10 23 CHECKED BY P. V.



RECORD OF BOREHOLE No 104

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - ORDS. N 4 764 830.8; E 327 186.4 ORIGINATED BY H.W.
DIST 4 HWY 406 BOREHOLE TYPE CONTINUOUS FLIGHT AUGER (H.S.) & CONE TEST COMPILED BY V.V.
DATUM GEODETTIC DATE 87 10 30 to 87 11 05 CHECKED BY J.P.

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					
170.9	Water Level												
0.0													
168.5	Ground Level												
2.4	CLAYEY SILT to SILTY CLAY. Trace of Sand. Stiff to Very Stiff ----- Hard -----		1	SS	10								
			2	SS	10								
			3	SS	9								
			4	SS	34								
			5	SS	45								
			6	SS	56								
			7	SS	22								
157.8	SANDY SILT, Some Gravel, Very Dense		8	SS	53								
13.1			9	SS	74								
155.4													
15.5	End of Borehole • Note: Artesian Condition Water Level Rose to 1.4m Above Ground Level El: 172.3												

RECORD OF BOREHOLE No 105

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - ORDS. N 4 764 844.0; E 327 185.0 ORIGINATED BY _____
 DIST 4 HWY 406 BOREHOLE TYPE CONE TEST COMPILED BY M
 DATUM GEODETIC DATE 87 11 05 CHECKED BY D D

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					
170.9	Water Level													
0.0														
167.1	Ground Level													
3.8														
	Presumed CLAYEY SILT to SILTY CLAY, Trace of Sand, Stiff													
161.5														
9.4	End of Cone Test													

RECORD OF BOREHOLE No 201

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - QROS. N 4 765 090.2; E 327 121.8 ORIGINATED BY P.M.
DIST 4 HWY 406 BOREHOLE TYPE CONTINUOUS FLIGHT AUGER (H.S.) & CONE TEST COMPILED BY M.Y.
DATUM GEODETTIC DATE 87 10 14 to 87 10 16 CHECKED BY J.P.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100		
177.1	Ground Level													
0.0			1	SS	27		176							0 2 (98)
			2	SS	16		174							0 1 92 7
	Silt, Trace of Sand and Clay		3	SS	12		172							0 3 77 20
			4	SS	37		170							1 2 (97)
			5	SS	28		168							
			6	SS	10		166							
			7	SS	12		164							
			8	TW	PH		162							
			9	SS	12		160							
	CLAYEY SILT to SILTY CLAY, With Occasional Silt Seams, Trace of Sand, Very Stiff to Stiff		10	SS	14		158							
			11	SS	12		156							
			12	SS	16		154							
			13	SS	80	/15cm	152							
	Trace of Gravel, Hard		14	SS	57		150							
			15	SS	75									
157.1			16	RC	85%									
20.0			17	RC	100%									
	SAND and SILT, Some Gravel, Trace of Clay Very Dense		18	RC	REC 65%									
153.1			19	RC	REC 93%									
24.0	Weathered													
	DOLOSTONE BEDROCK Sound													
149.8														
27.3	End of Borehole													

RECORD OF BOREHOLE No 202

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - ORDS. N 4 765 073.8, E 327 128.3 ORIGINATED BY P
DIST 4 HWY 406 BOREHOLE TYPE BX CASING & CONE TEST COMPILED BY M
DATUM GEODETIC DATE 87 11 07 to 87 11 10 CHECKED BY P.P.P.

SOIL PROFILE			SAMPLES			GROUND WATER • CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
173.4	Water Level															
0.0																
171.4	Ground Level															
2.0																
			1	SS	10											
			2	SS	10											
			3	SS	10											
			4	SS	11											
			5	SS	11											
			6	SS	11											
			7	SS	11											
			8	SS	67											
			9	SS	94											
			10	SS	61											
			11	SS	63											
157.4																
16.0	SAND and SILT, Some Gravel, Trace of Clay, Dense		12	SS	33											
156.0			13	SS	48											
17.4	End of Borehole															
154.8																
18.8	End of Cone Test															
	• Note: Artesian Condition Water Level Rises to 0.3m Above Ground Level El: 173.7															

+3, x3: Numbers refer to
Sensitivity

20
15-25 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 203

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - ORDS. N 4 764 844.0; E 327 168.0 ORIGINATED BY R
DIST 4 HWY 406 BOREHOLE TYPE CONE TEST COMPILED BY V
DATUM GEODETC DATE 87 11 12 CHECKED BY J.P.

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL * LAB VANE	WATER CONTENT (%) 20 40 60					
173.4	Water Level													
0.0														
170.7	Ground Level													
2.7														
	Presumed CLAYEY SILT to SILTY CLAY, Trace of Sand and Gravel, Stiff to Hard													
161.9														
11.5	End of Cone Test													

METRIC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIMIT MOISTURE CONTENT		UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20 40 60 80 100	W _p W _L	20 40 60		
175.0	Ground Level						SHEAR STRENGTH kPa • UNCONFINED + FIELD VANE • QUICK TRIAXIAL * LAB VANE 20 40 60 80 100	WATER CONTENT (%)	20 40 60	7	GR SA SI	

+3, x3: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 205

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - QROD. N 4 785 038.5; E 327 121.0 ORIGINATED BY S.M.H.
DIST 4 HWY 406 BOREHOLE TYPE WASH BORE NX CASING, BXL ROCK CORE & CONE TEST COMPILED BY M.V.
DATUM GEODETTIC DATE 88 11 16 to 88 11 23 CHECKED BY P.P.

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		
173.3	Water Level													
0.0														
164.0	Canal Bed													
9.3	Organic Silt		1	SS										0 14 60 28
			2	SS	97									28 14 41 16
			3	SS	71									
	CLAYEY SILT to SILTY CLAY, With Occasional Silt Seams, Some Sand and Gravel, Hard to Very Stiff		4	SS	28									
			5	SS	22									15 52 26 7
156.8			6	SS	38									
16.5			7	SS	89									
	SAND and SILT, Some Gravel, Trace of Clay, Very Dense													
151.9			8	SS	91									60 26 11 3
21.4			9	RC	100%									RQD 0%
			10	RC	REC									RQD 14%
	DOLOSTONE BEDROCK		11	RC	REC									RQD 0%
			12	RC	REC									RQD 22%
149.8														
23.5	End of Borehole													

+3, x5, Numbers refer to
Sensitivity

20
15-5 (X) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 206

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - QRS. N 4 764 998.0; E 327 139.5 ORIGINATED BY S.M.
 DIST 4 HWY 406 BOREHOLE TYPE WASH BORE NX CASING & CONE TEST COMPILED BY M.V.
 DATUM GEODETIC DATE 88 11 23 CHECKED BY J.P.B.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		WATER 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		
173.3	Water Level													
0.0														
163.3	Canal Bed													
10.0	Organic Silt		1	SS										
	CLAYEY SILT to SILTY CLAY, Some Sand and Gravel, Hard		2	SS	56									
			3	SS	48									
	Firm to Very Stiff		4	SS	6									
			5	SS	23									
154.8			6	SS	44									
18.7	End of Borehole													14 20 45 21

RECORD OF BOREHOLE No 207

1 OF 1

METRIC

W.P. 171 - 90 - 01 LOCATION CO - ORDS. N 4 784 989.5, E 327 147.5 ORIGINATED BY S.M.T.
 DIST 4 HWY 406 BOREHOLE TYPE WASH BORE NX CASING & CONE TEST COMPILED BY M.V.
 DATUM GEODETTIC DATE 88 11 24 CHECKED BY J.P.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIMIT 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			
173.3	Water Level												
0.0													
162.9	Conol Bed												
10.4	Organic Silt		1	SS	38								0 12 65 23
	CLAYEY SILT to SILTY CLAY, Some Sand and Gravel, Hard		2	SS	47								
			3	SS	47								
	Firm		4	SS	7								0 20 60 20 0 38 52 10
155.8			5	SS									
17.5	End of Borehole												

DESCRIPTION OF ROCK CORE - WP 171-90-01

HOLE #	CORE RECOVERY			CORE DESCRIPTION	
	DEPTH (m)	%CR*	%RQD*	DEPTH (m)	DESCRIPTION
101	21.62-22.48	50	0	21.62-23.72	DOLOSTONE , medium grey; very fine grained, very closely laminated; medium to strong rock; slightly weathered; very close spaced fractures, extremely close spaced fracture zone at 21.87 m. DOLOSTONE , light tan brown; fine grained; medium strong to strong rock; slightly weathered; very close to extremely close spaced fractures.
	22.48-24.00	97	7		
103	26.92-27.43	28	0	26.92-27.56	DOLOSTONE , medium grey; fine grained; medium strong rock; slightly weathered; very close spaced fractures.
	27.43-29.03	79	0	27.56-28.17	SHALE , black to very dark grey; very fine grained; medium strong to weak rock; slightly weathered; very close spaced fractures.
	29.03-30.63	100	39		
				28.17-29.26	DOLOSTONE/SHALE (interbedded), medium to dark grey; fine to medium grained, very closely laminated, very thinly bedded; medium strong rock; slightly weathered; very close spaced fractures.
				29.26-30.48	DOLOSTONE , medium grey; very fine grained, very closely laminated; medium to strong rock; slightly weathered; very close spaced fractures.
				30.48-30.63	DOLOSTONE , light tan brown; fine grained; medium strong to strong rock; slightly weathered; very close to extremely close spaced fractures.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

DESCRIPTION OF ROCK CORE - WP 171-90-01

CORE RECOVERY				CORE DESCRIPTION	
HOLE #	DEPTH (m)	%CR*	%RQD*	DEPTH (m)	DESCRIPTION
201	23.98-24.31	85	33	23.98-27.25	DOLOSTONE, light to medium grey; very finely crystalline, thinly laminated; medium strong to strong rock; slightly weathered; very close spaced fractures, extremely close spaced fracture zones at 24.31-24.38 m and 25.20-25.63 m.
	24.31-24.61	100	0		
	24.64-26.24	65	0		
	26.24-27.25	93	12		

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

2 of 3

ROCK CORE DESCRIPTION

WP 171-90-01

CORE RECOVERY					CORE DESCRIPTION	
BH #	RC #	DEPTH (m)	CR* (%)	RQD (%)	DEPTH (m)	DESCRIPTION
205	9	21.36-21.51	83	0	21.36-23.47	DOLOSTONE, medium grey to brownish grey; fine to very fine grained, argillaceous, thinly laminated; medium strong rock; unweathered to slightly weathered; very closely spaced fractures: flat, undulating, rough.
	10	21.51-22.25	59	14		
	11	22.25-23.01	50	0		
	12	23.01-23.47	78	22		

Logged by: S. A. Senior, Soils and Aggregates Section

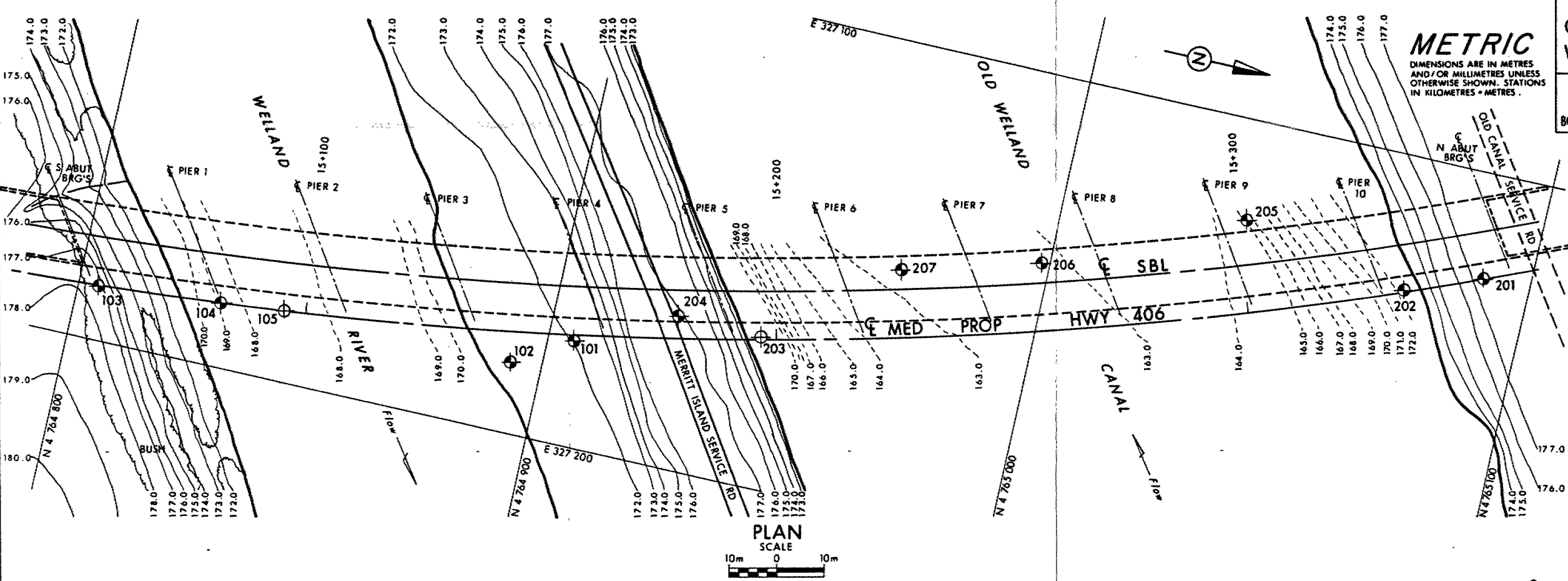
3 of 3

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

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

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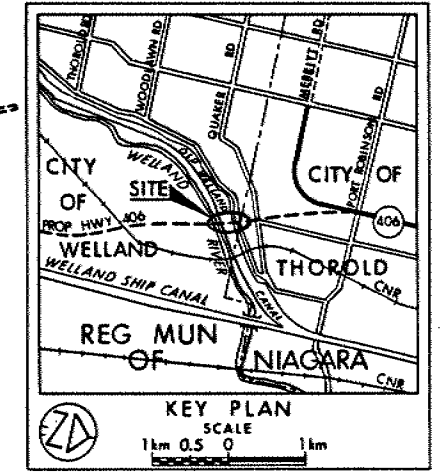


CONT No
WP No 171-90-01

WELLAND RIVER &
OLD WELLAND CANAL
BORE HOLE LOCATIONS & SOIL STRATA



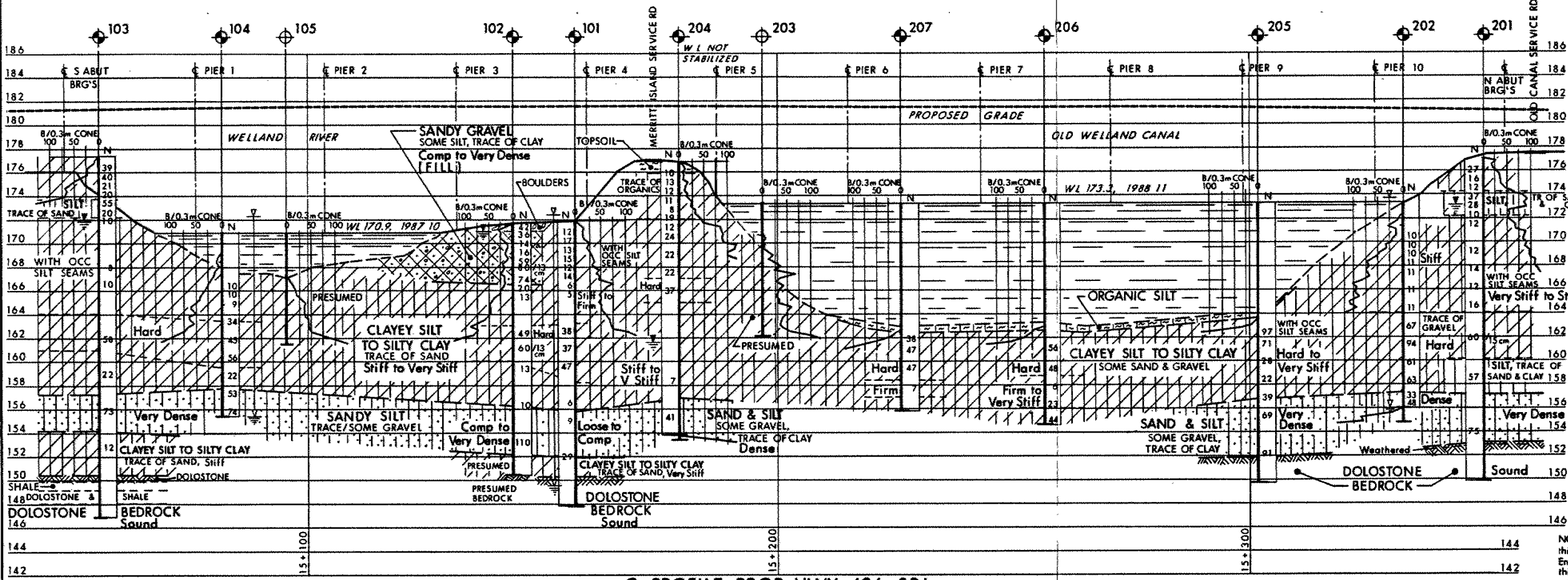
SHEET



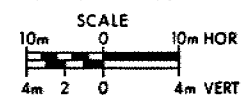
LEGEND

- 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
- 87 10, 11 and 88 11
- Head
- ARTESIAN CONDITION
- Encountered

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
101	171.9	4 764 905.4	327 177.5
102	171.7	4 764 893.6	327 185.0
103	177.4	4 764 804.1	327 188.6
104	170.9	4 764 830.6	327 186.4
105	170.9	4 764 844.0	327 185.0
201	177.1	4 765 090.2	327 121.8
202	173.4	4 765 073.8	327 128.3
203	173.4	4 764 944.0	327 168.0
204	176.9	4 764 925.5	327 167.5
205	173.3	4 765 038.5	327 121.0
206	173.3	4 764 998.0	327 139.5
207	173.3	4 764 969.5	327 147.5



PROFILE PROP HWY 406 SBL



NOTE

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

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

REV	DATE	BY	DESCRIPTION
1			
2			
3			
4			

Geocres No 30M3-192

HWY No 406 SBL	DIST 4
SUBMID MV CHECKED 4/ DATE 1991 03 06	SITE 34-304
DRAWN RS CHECKED 0/ APPROVED	DWG 2



APPENDIX B

Copy of Foundation Investigation Report
For
Welland River Crossing
Structure Site No. 34-305S
Highway 406
GEOCRES No. 30M3-187

Note: 1. Boreholes 1 to 5 in this report were reused as boreholes 101 to 105 for report with GEOCRES No. 30M3-192 attached in Appendix A.

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WP 11-68-15

DIST 4

HWY 406

STR SITE 34-305S

WELLAND RIVER

DISTRIBUTION

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FOUNDATION INVESTIGATION REPORT

For

Welland River Crossing

WP 11-68-15; Site No. 34-305S

Hwy. 406, District #4, Welland

INTRODUCTION

This report contains the results of a Foundation Investigation carried out for the proposed alignment of Hwy. 406 through the north end of Welland, during the period from 87-10-19 to 87-11-05. The fieldwork consisted of four sampled boreholes and 7 dynamic cone penetration tests (two of which were from the bottom of the borehole). The borings in holes 1, 2 & 3 were advanced by hollow stem auger (8.3 cm I.D.) using a machine mounted on a muskeg vehicle. Borehole 4 was advanced using a skid mounted diamond drill on a raft on the Welland River.

Sampling was performed to a maximum depth of 30.6 m to an approximate elevation of 146.8 m. The cone tests were from ground level to a maximum depth of 10 m to elevation 161.7 m and from the bottom of Borehole 4 to elevation 155.1 m.

SITE DESCRIPTION

The site is located at the Welland River in the north end of Welland. The river is bounded on the north by Merritt Island, a narrow strip of parkland separating the Old Welland Canal from the river. The vegetation on the island is predominantly deciduous forest and brush. A roadway and pedestrian walkway run the length of the island. The south shore has a 4 to 5 m high bank beyond which is a level field with virtually no trees.

The area is part of the clay plain typical of the Niagara Peninsula south of the escarpment. The terrain is flat to rolling. The Welland River flows slowly through the area with a gradient of less than 200 mm per kilometer.

SUBSURFACE CONDITIONS

General

A thick layer of silty clay, trace sand, gravel and organics, was evident in each borehole. Above this layer, in borehole 2 was 5.2 m of sandy gravel fill. Above the silty clay, in borehole 3, was 3.7 m of hard silty clay overlying 1.5 m of dense silt.

A 3 m to 4 m deposit of loose to very dense sand silt, trace gravel was encountered below the silty clay and finally a deposit of stiff silty clay above bedrock. Sound Dolostone and Shale bedrock was proven in boreholes 1 and 3 at elevations 150.3 and 150.5 m respectively.

The plan and location of borings and the stratigraphical profile are shown on Dwg. 116815-A in the attached appendix. The field results and laboratory tests are plotted on the Record of Borehole sheets also included in the appendix. A brief description of the different soil types is given below.

Silty Clay, Trace of Sand

A 3.7 m deposit of hard to very stiff silty clay of medium plasticity, trace sand, was present at the surface of borehole 3 to elevation 173.7 m. The silt content increased with depth to the adjacent deposit.

The natural moisture content was 21.5%, liquid limit 38.5% and plastic limit 19%. The results from a grain size distribution test showed 1% sand and 99% fines.

The plasticity of the deposit was medium. The consistency ranged from hard to very stiff.

Silt, Trace of Sand

Under the silty clay deposit described below in borehole 3 a 1.5 thick deposit of silt, trace of sand to elevation 172.2 m was found. The natural moisture content was 18.5%. The grain size distribution test indicated that the deposit consisted of 1% sand and 99% fines. The denseness of the deposit ranged from very dense to dense.

Sandy Gravel, Fill

At the surface to elevation 166.5 m in borehole 2, 5.2 m of fill material was found. The material consisted of a sandy gravel, some silt, trace of clay. The natural moisture content ranged from 11% to 15.5%. The results from the grain size distribution test, indicated 48.5 to 66.5% gravel, 17.5 to 36.5% sand, 12.5 to 13% silt and 2.5 to 3 % clay. The denseness of the fill deposit ranged from compact to very dense.

Silty Clay, Trace of Sand, Gravel and Organics

Below the fill in borehole 2, the silt in borehole 3 and at the ground surface in boreholes 1 and 4 was a deep deposit of silty clay with varying amounts of sand and gravel. It was the thickest deposit ranging in thickness from 10.2 to 16.1 m to elevation 155.8 m in borehole 1 and to 157.3 m in borehole 3.

The physical properties of the material as determined by field and laboratory tests are listed below:

	<u>Mean</u>
Unit Weight (γ)	20.8 kN/m ³
Natural Moisture Content (w)	20.5%
Liquid Limit (w_L)	29%
Plastic Limit (w_p)	16%

	<u>Mean</u>
Field Vane Undrained Shear Strength	61.3 kPa
Unconfined Shear Strength	54.8 kPa

The consistency of the deposit ranged in the top portion from firm to hard while a lower portion ranged from stiff to very stiff. Figure 1 indicates the material plotted mainly as a silty clay of low plasticity (CL). The results from the grain size distribution are included in Figure 2 in envelope form.

Sandy Silt, Trace/Some Gravel

Below the silty clay deposit described above, was a sandy silt, trace to some gravel, encountered at elevation 155.8 m to 157.3 m, 3.1 m to 3.9 m in thickness. It was found in all boreholes and had a denseness ranging from loose (BH #2) to very dense (BH #3 & BH #4). The natural moisture content was found in laboratory tests to be an average of 13.7%. The results of the grain size distribution test are shown in Figure 3 in envelope form.

Silty Clay, Trace of Sand

Another silty clay layer was encountered below the sandy silt at elevation 151.9 m to 154.2 m and overlying bedrock at elevation 150.3 m to 150.5 m. The layer ranged in thickness from 1.6 to 3.7 m. Although it was not established in borehole 2, it has been presumed to exist.

The consistency was found to be stiff to very stiff. Laboratory results indicated a natural moisture content (w) of 25.5%, a plastic limit (w_p) of 16.5% and a liquid limit (w_L) of 33%. The limits indicate that the material is a silty clay of low plasticity. The results of the grain size distribution test show a sand content between 1% to 8% and a fine content of 92% to 99%.

Bedrock

Bedrock was encountered below the overburden material at the following elevations:

	<u>Unweathered Bedrock</u>	<u>Presumed Bedrock</u>
BH #1	150.3 m	
BH #2		150.4 m
BH #3	150.5 m	

At all borehole locations, the bedrock was found to be sound dolostone and shale of the Salina Formation. The rock core samples were examined by Mr. S.A. Senior, MTC Geological Engineer and his descriptions are included in Figure 4 of the appendix of this report.

GROUNDWATER CONDITIONS

The following groundwater conditions were observed during the field investigation:

<u>Borehole</u>	<u>Elevation</u>
BH #1	Artesian condition in bedrock at elevation 149.6 m, Head 0.53 m to elevation 172.4 m
BH #2	171.2 m
BH #3	172.0 m
BH #4	Artesian conditions encountered at elevation 155.4 m, Head 1.3 m to elevation 172.2 m

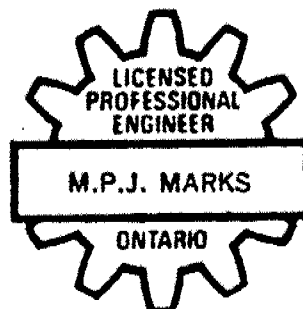
The boreholes indicate the groundwater level at approximate elevation 172 m. This level will most likely vary seasonally and with fluctuations in the canal and river level.

Rip rap to prevent scour should be placed to a height of 0.3 m above the high water level in accordance with hydrological requirements.

Settlements will occur due to consolidation of the cohesive soil in the original ground due to the weight of the new approach embankments. This settlement is not anticipated to be significant.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of Mrs. Pamela Marks, Foundation Engineer and Mr. I. Robertson, Student Specialist. The equipment was owned and operated by F. E. Johnston Drilling Co. Ltd. This report was prepared by Mr. I. Robertson and Mrs. P. Marks and reviewed by Mr. K. Selby.



I. Robertson

I. Robertson
Student Specialist

Pamela Marks

P. Marks, P.Eng.
Foundation Engineer

K. G. Selby

K. G. Selby, P.Eng.
Chief Foundations Engineer
(West)

APPENDIX

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

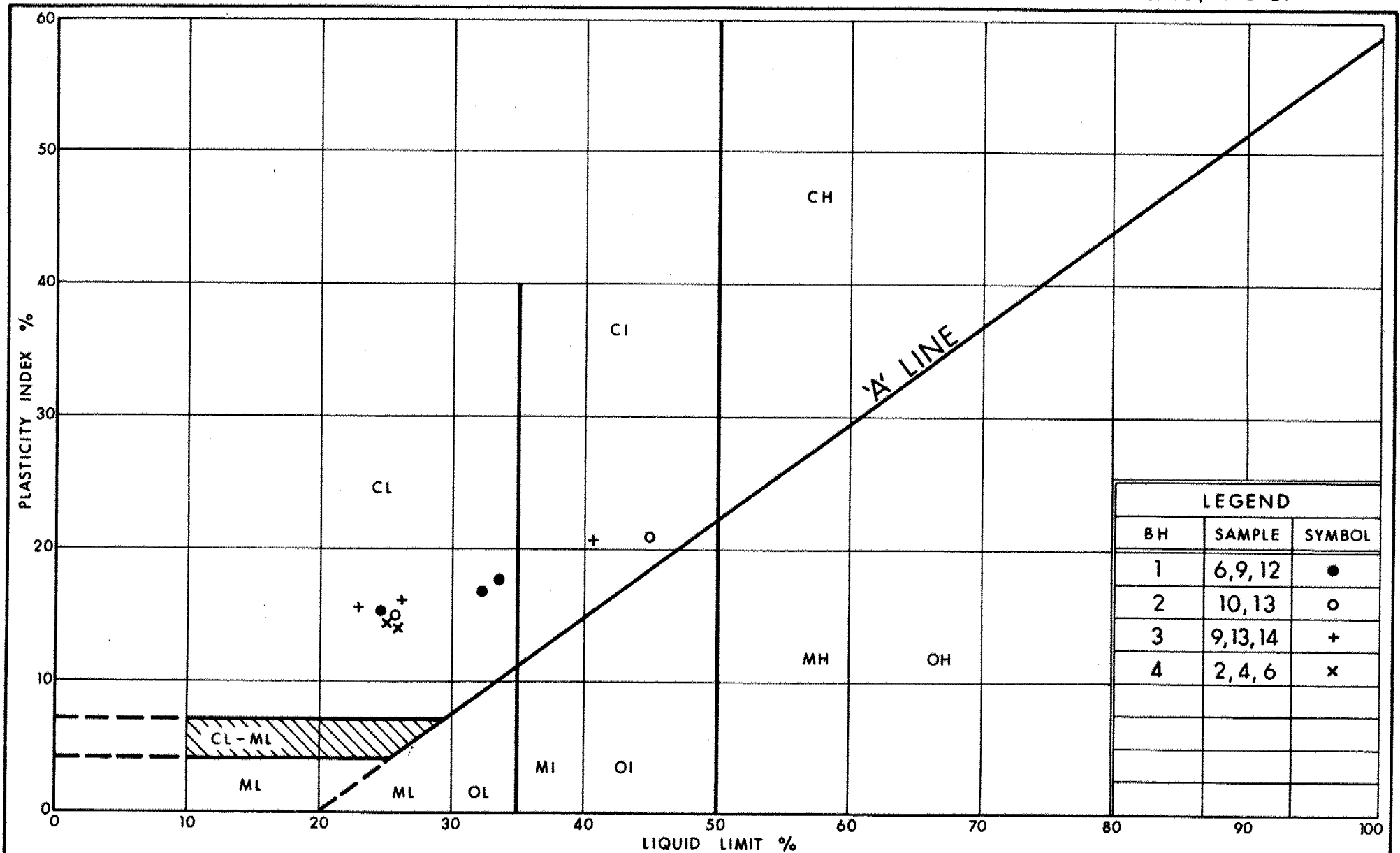
u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
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'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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



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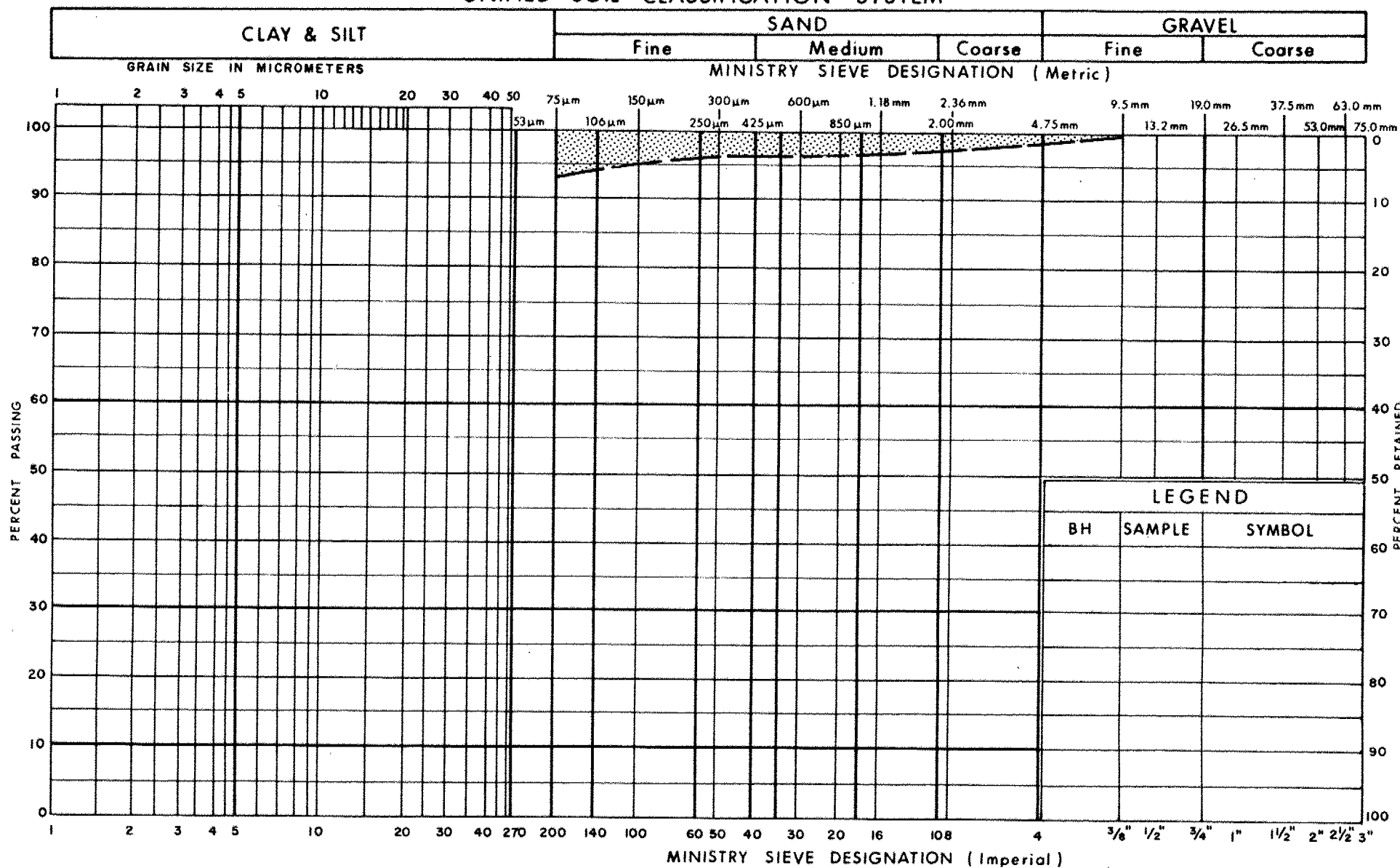
Ontario

PLASTICITY CHART
SILTY CLAY
TRACE OF SAND, GRAVEL AND ORGANICS

FIG No 1

W P 11-68-15

UNIFIED SOIL CLASSIFICATION SYSTEM

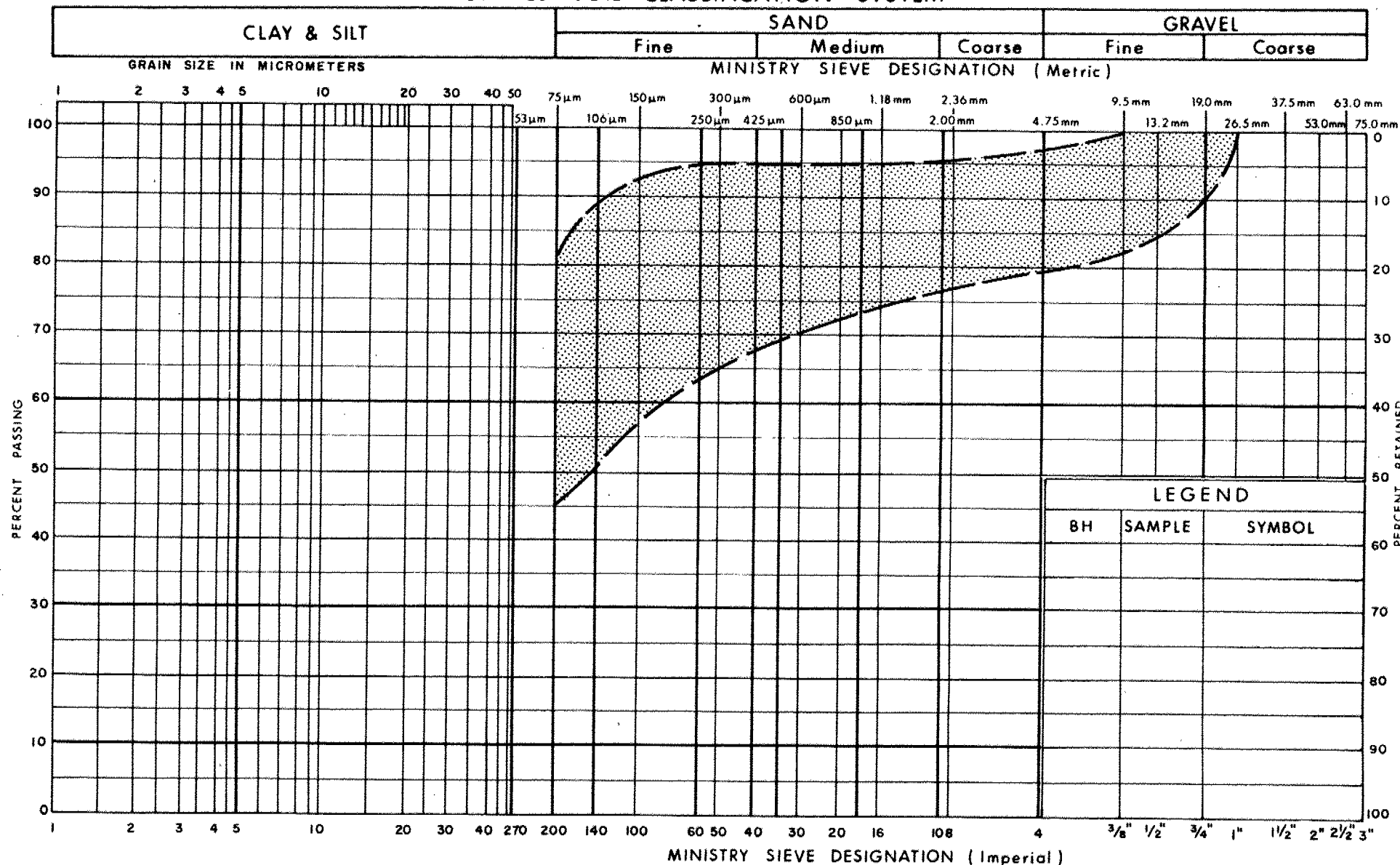
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Transportation

GRAIN SIZE DISTRIBUTION
SILTY CLAY
TRACE OF SAND, GRAVEL & ORGANICS

FIG No 2

W P 11-68-15

UNIFIED SOIL CLASSIFICATION SYSTEM

Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
SANDY SILT
TRACE TO SOME GRAVEL

FIG No 3

W P 11-68-15

DESCRIPTION OF ROCK CORE - WP 68-11-15

CORE RECOVERY				CORE DESCRIPTION	
HOLE #	DEPTH (m)	%CR*	%RQD*	DEPTH (m)	DESCRIPTION
1	21.62-22.48	50	0	21.62-23.72	DOLOSTONE , medium grey; very fine grained, very closely laminated; medium to strong rock; slightly weathered; very close spaced fractures, extremely close spaced fracture zone at 21.87 m. DOLOSTONE , light tan brown; fine grained; medium strong to strong rock; slightly weathered; very close to extremely close spaced fractures.
	22.48-24.00	97	7		
3	26.92-27.43	28	0	26.92-27.56	DOLOSTONE , medium grey; fine grained; medium strong rock; slightly weathered; very close spaced fractures.
	27.43-29.03	79	0	27.56-28.17	SHALE , black to very dark grey; very fine grained; medium strong to weak rock; slightly weathered; very close spaced fractures.
	29.03-30.63	100	39		
				28.17-29.26	DOLOSTONE/SHALE (interbedded), medium to dark grey; fine to medium grained, very closely laminated, very thinly bedded; medium strong rock; slightly weathered; very close spaced fractures.
				29.26-30.48	DOLOSTONE , medium grey; very fine grained, very closely laminated; medium to strong rock; slightly weathered; very close spaced fractures.
				30.48-30.63	DOLOSTONE , light tan brown; fine grained; medium strong to strong rock; slightly weathered; very close to extremely close spaced fractures.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

1../1

FIG 4



RECORD OF BOREHOLE No 1

METRIC

W P 11-68-15 LOCATION Co-ords. N 4 764 905.4; E 327 177.5 ORIGINATED BY PM
DIST 4 HWY 406 BOREHOLE TYPE Continuous Flight Auger (H.S.) COMPILED BY PM
DATUM Geodetic DATE 87 10 19 to 87 10 21 CHECKED BY _____

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					
171.9	Ground Level						172.4							
0.0														
	Occ. Pockets of Silt		1	SS	12									0 4 96
			2	SS	17									
	Thin Layers of Silt		3	SS	13									
			4	SS	15									
			5	SS	12									
			6	SS	14									0 3 (97)
	Firm		7	SS	6									
			8	SS	5									
	Silty Clay													
	Trace of Sand		9	TW	PH								20.76	0 2 (98)
			10	SS	38									
			11	SS	37									
	Occ. Pockets of Silt		12	SS	47									0 0 (100)
	Stiff		13	SS	6									
155.8														
16.1	Sandy Silt		14	SS	9									3 16 (81)
	Trace of Gravel													
	Compact													
151.9			15	SS	29									0 1 (99)
20.0	Silty Clay													
	Trace of Sand													
	Very Stiff													
150.3														
21.6	Sound Dolostone Bedrock		16	RC	50%									
			17	RC	97%									
147.9														
24.0	End of Borehole													

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2

METRIC

W P 11-68-15 LOCATION Co-ords. N 4 764 893.6; E 327 185.0 ORIGINATED BY PM
DIST 4 HWY 406 BOREHOLE TYPE Continuous Flight Auger COMPILED BY PM
DATUM Geodetic DATE 87 10 22 - 87 10 23 CHECKED BY

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 Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N' VALUES			20 40 60 80 100	20 40 60 80 100					
171.7	Ground Level													
0.0	Boulders Sandy Gravel		1	SS	42									67 17 13 3
			2	SS	36									
	Some Silt		3	SS	14									
	Trace of Clay		4	SS	16									
	Compact/Very Dense (Fill)		5	SS	59									
			6	SS	80/13 cm									48 36 13 3
166.5			7	SS	74									
5.2			8	SS	20									
			9	SS	13									
	Silty Clay		10	TW	PH								20.76	1 2 (97)
	Traces of Sand		11	SS	49									
	to Traces of Gravel		12	SS	60/13 cm									
			13	SS	13									
	Stiff													0 1 (99)
	To With Sand													
156.3			14	SS	10									9 39 (52)
15.4	Sandy Silt													
	Traces of Gravel													
	Loose to													
	Very Dense		15	SS	110									5 35 (60)
152.2														
19.5	Presumed Silty Sand													
	Trace of Sand													
150.4	Very Stiff													
21.3	Presumed Bedrock													
	End of Borehole													

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

RECORD OF BOREHOLE No 3

METRIC

W P 11-68-15 LOCATION Co-ords. N 4 764 804.1; E 327 188.6
DIST 4 HWY 406 BOREHOLE TYPE Continuous Flight Auger (H.S.)
DATUM Geodetic DATE 87 10 24 to 87 10 27
ORIGINATED BY IR
COMPILED BY PM
CHECKED BY

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 Y 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										
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE											
177.4	Ground Level																	
0.0	Silty Clay		1	SS	39		176							0 1 (99)				
	Trace to Sand		2	SS	40													
	Hard to		3	SS	21													
	Very Stiff		4	SS	20		174							0 1 (99)				
173.7	Silt		5	SS	55													
3.7	Trace of Sand		6	SS	20													
172.2	Very Dense/ Comp		7	SS	10		172											
5.2	Silty Clay		8	TW	PH			+2										
	Trace of Sand							+2										
	Trace of Gravel		9	TW	PH		170	8					20.84	1 2 (97)				
			10	SS	8			+2										
							168	2										
	Stiff		11	SS	10		166	2										
			12	TW	PH													
	Hard		13	SS	58		162							0 0 (100)				
							160											
	Very Stiff		14	SS	22									0 1 (99)				
157.3							158											
20.1	Sandy Silt		15	SS	73		156							20 36 (44)				
	Some Gravel																	
	Very Dense																	
154.2	Silty Clay		16	SS	12		154							0 8 (92)				
23.2	Trace of Sand																	
	Stiff						152											
150.5			17	RC	28%		150											
26.9	Sound Dolostone		18	RC	79%													
	Bedrock Dolostone						148											
	Shale		19	RC	100%													
146.8	Dolostone																	

+3, x5: Numbers refer to
Sensitivity

15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 4

METRIC

W P 11-68-15 LOCATION Co-ords. N 4 764 830.6; E 327 186.4 ORIGINATED BY PM
DIST 4 HWY 406 BOREHOLE TYPE Continuous Flight Auger (H.S.) COMPILED BY PM
DATUM Geodetic DATE 87 10 30 to 87 11 05 CHECKED BY

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	20 40 60 80 100					
170.9	Water Level													GR SA SI CL
0.0														
168.5	Ground Level													
2.4														
	Silty Clay													
	Trace of Sand		1	SS	10									0 3 (97)
			2	SS	10									
			3	SS	9									
	Stiff													
	Trace of Gravel		4	SS	34									1 5 (94)
	Hard		5	SS	45									
			6	SS	56									0 1 (99)
	Very Stiff		7	SS	22									
157.8														
13.1	Sandy Silt		8	SS	53									12 29 (59)
156.6	Trace to Some Gravel													
	Very Dense													
14.3	Presumed Sandy Silt													
	Trace of Gravel													
155.4	Very Dense		9	SS	74									
15.5	End of Borehole													
154.7														
16.2	End of Cone Test													

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

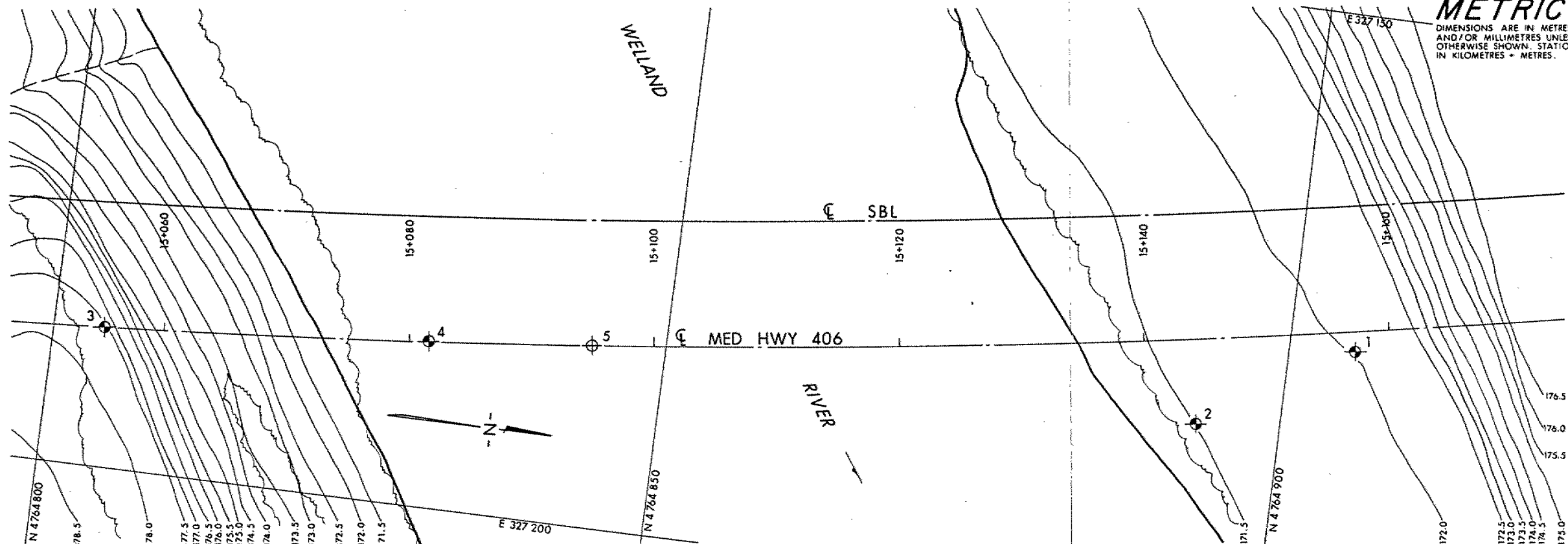
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 5

METRIC

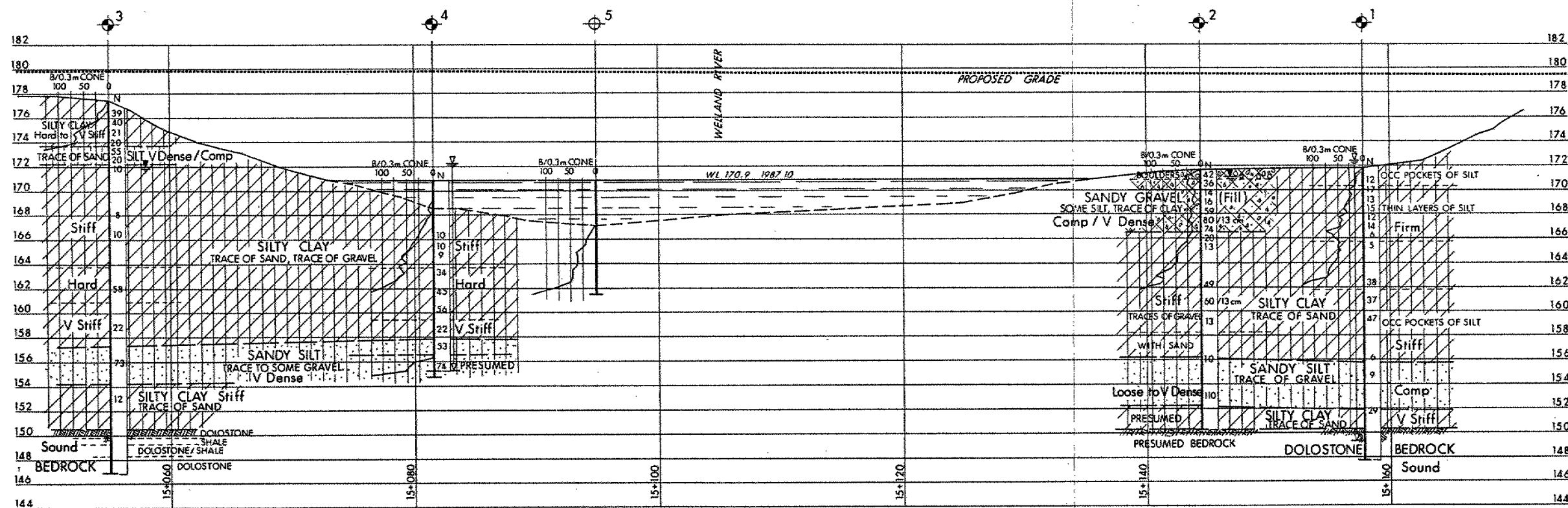
W P 11-68-15 LOCATION Co-ords. N 4 764 844.0; E 327 185.0 ORIGINATED BY IR
 DIST 4 HWY 406 BOREHOLE TYPE Cone Test COMPILED BY PM
 DATUM Geodetic DATE 87 11 05 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
170.9	Water Level												
167.1	Ground Level												
3.8	Presumed Silty Clay Trace of Sand Trace of Gravel Stiff												
161.5	End of Cone Test												
9.4													



PLAN

SCALE
4m 2 0 4m



PROFILE MED HWY 406

SCALE
4m 2 0 4m

METRIC

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

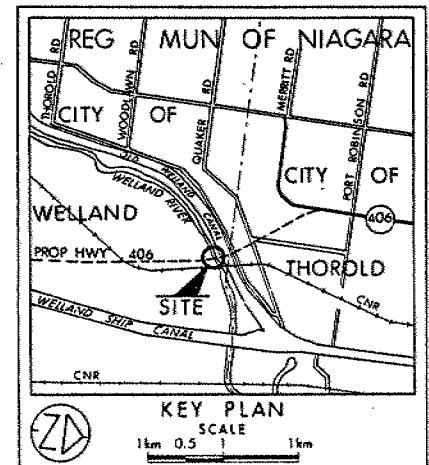
CONT No
WP No 11-68-15

WELLAND RIVER

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 1/blow)
- CONE Blows/0.3m (60° Cone, 475 1/blow)
- Wt at time of investigation 87 10
- Head
- Encountered
- ARTESIAN CONDITION

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	171.9	4764 905.4	327 177.5
2	171.7	4764 893.6	327 185.0
3	177.4	4764 804.1	327 188.6
4	170.9	4764 830.6	327 186.4
5	170.9	4764 844.0	327 185.0

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

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

REV.	DATE	BY	DESCRIPTION

Geocres No 30M3-187

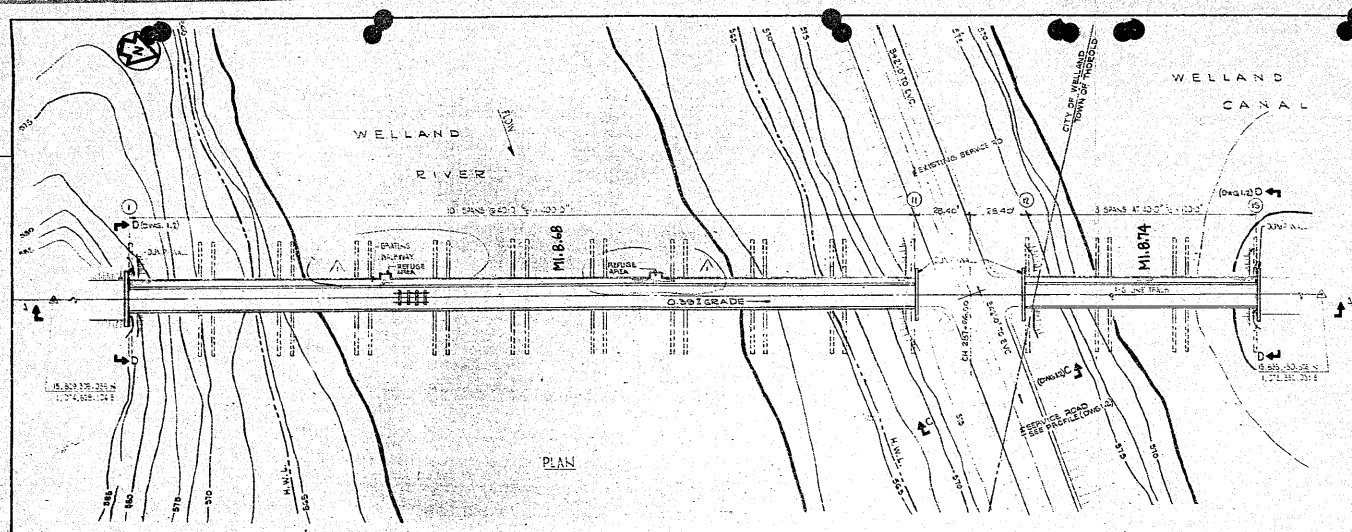
HWY No 406	DIST 4
SUBWD PM CHECKED	DATE 1988 01 14
DRAWN SO CHECKED	APPROVED
	OWG 116815-A



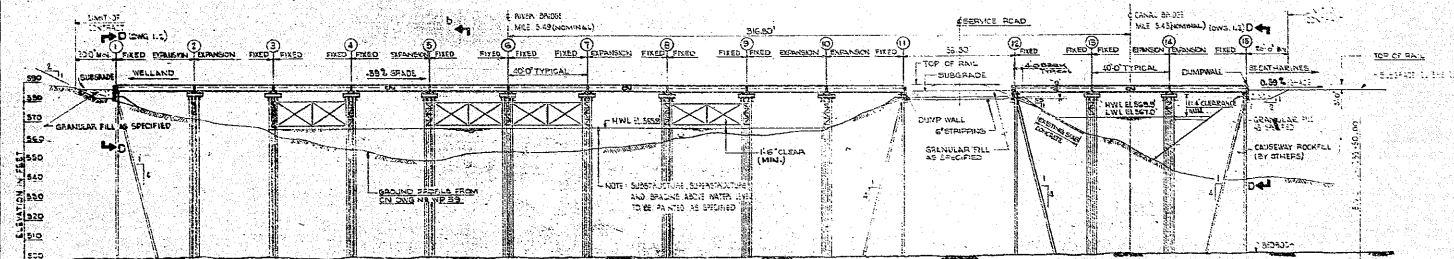
APPENDIX C

Copy of Foundation Investigation Report
For
Old Welland Canal Overpass and Causeway
Structure Site No. 34-304S
Highway 406
GEOCRES No. 30M3-188

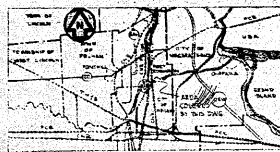
Note: 1. Boreholes 1 to 4 in this report were reused as boreholes 201 to 204 for report with GEOCRES No. 30M3-192 attached in Appendix A.



PLAN



ELEVATION A-A



KEY PLAN

SCALE 1:250

ACRES CONSULTING SERVICES LIMITED	
PROJECT NO.	10010
PROJECT NAME	WELLAND RIVER AND CANAL CROSSING
PROJECT LOCATION	WELLAND RIVER AND CANAL CROSSING
PROJECT DATE	1980
PROJECT DRAWN BY	10010
PROJECT CHECKED BY	10010
PROJECT APPROVED BY	10010

CONTRACT NO. BW903-FD-08

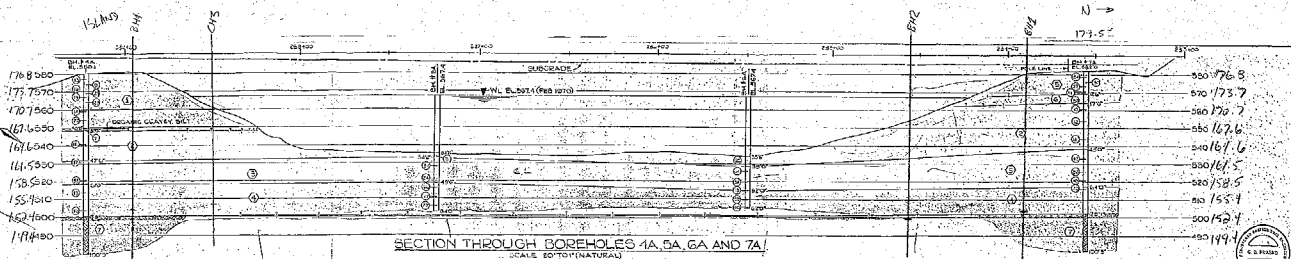
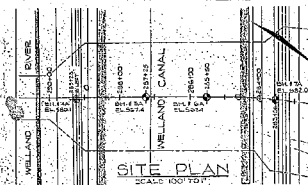
DESIGN NO. BW903-FD-08	
DESIGNER: ACRES CONSULTING SERVICES LIMITED	
CLIENT: GREAT LAKES SW. ONTARIO	
PROJECT NO. 10010	
PROJECT NAME: WELLAND RIVER AND CANAL CROSSING	
PROJECT LOCATION: WELLAND RIVER AND CANAL CROSSING	
PROJECT DATE: 1980	
PROJECT DRAWN BY: 10010	
PROJECT CHECKED BY: 10010	
PROJECT APPROVED BY: 10010	
Office of Chief Engineer Bureau de l'ingénieur en chef	
AA-903-545-11	

NOTES

1. CONTRACT AND COPIES OF THIS DRAWING MUST BE KEPT TOGETHER WITH THE PROJECT RECORDS AND NOT BE SEPARATED FROM THE RECORDS.
2. FOR GENERAL NOTES, SEE DRAWING NO. BW903-FD-08-1.
3. FOR SPECIAL NOTES, SEE DRAWING NO. BW903-FD-08-2.

REVISION LIST

1. WELLAND RIVER AND CANAL CROSSING
P.L. LINE, STRUCTURE AND GRADES
GENERAL, STRUCTURE AND GRADES
10-903-545-1-1
2. WELLAND RIVER AND CANAL CROSSING
P.L. LINE, STRUCTURE AND GRADES
10-903-545-1-2
3. WELLAND RIVER AND CANAL CROSSING
P.L. LINE, STRUCTURE AND GRADES
10-903-545-1-3
4. WELLAND RIVER AND CANAL CROSSING
P.L. LINE, STRUCTURE AND GRADES
10-903-545-1-4
5. WELLAND RIVER AND CANAL CROSSING
P.L. LINE, STRUCTURE AND GRADES
10-903-545-1-5
6. WELLAND RIVER AND CANAL CROSSING
P.L. LINE, STRUCTURE AND GRADES
10-903-545-1-6



COLOUR KEY

- | | |
|--|---------------------------------|
| ① MIXED FILL | ⑤ GREY BROWN CLAYEY SILT TILL |
| ② REDDISH BROWN CLAYEY SILT/CLAY | ⑥ REDDISH BROWN FINE SANDY SILT |
| ③ REDDISH BROWN SANDY CLAYEY SILT TILL | ⑦ DOLOMITE BEDROCK |
| ④ REDDISH GREY BROWN SILTY SAND TILL | |

LEGEND

- ✦ BOREHOLE (JOB NO. 70NS)
- ✦ BOREHOLE (JOB NO. 70NQ)
- ⊙ BLOWS/FOOT

NOTE

SEE BOREHOLE LOGS FOR COMPLETE SOIL DETAILS

NOTE: The soil profile has been verified from data obtained at the borehole locations only. The indicated contents shown are based on equivalent weights and there may vary from those shown between borings.

CANADIAN NATIONAL RAILWAYS
WELLAND CANAL PROJECT

WELLAND CANAL RELOCATION PROJECT
LINE F-G WELLAND CANAL CROSSING

PREPARED BY:
PETO ASSOCIATES LTD.

DRAWN UY, PL	CHECKED UY, PL	SCALE AS SHOWN	DATE NOVEMBER, 1971	JOB NO. 70 NS
-----------------	-------------------	-------------------	------------------------	------------------

DOCUMENT MICROFILMING IDENTIFICATION

G.I.-30 SEPT. 1976

GEOCRES No. 30M3-188

DIST. 4 REGION

W.P. No. 11-86-16

CONT. No.

W. O. No.

STR. SITE No. 34-304S

HWY. No. 406

LOCATION Hwy 406 &

OLD WELLAND CANAL

No. of PAGES -

=====

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WP 11-68-16

DIST 4

HWY 406

STR SITE 34-304S

Old Welland Canal Overpass
and Causeway

DISTRIBUTION

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FOUNDATION INVESTIGATION REPORT

For

Old Welland Canal Overpass and Causeway

WP 11-68-16; Site No. 34-304S

Hwy. 406, District #4, Burlington

INTRODUCTION

This report contains the results obtained from a Foundation Investigation carried out at the above mentioned site for the proposed structure and causeway. The fieldwork was performed during the period from 87-10-14 to 87-11-20 utilizing a skid mounted diamond drill on a raft and a machine mounted on a muskeg vehicle. Borings were advanced using hollow stem augers (82 mm I.D.) and BX casing (60 mm I.D.). Sampling was performed to a maximum depth of 27.3 m to elevation 149.8 m and the cone tests to a maximum depth of 9.8 m to elevation 160.8 m from ground surface.

It should be noted that due to weather conditions we have been unable to complete our planned boring program in the Old Welland Canal. We have however obtained some soils information from along the C.N. railway line, and are of the opinion that the soils conditions at the site are the same as those indicated at the C.N. structure and causeway. Further investigation is to be carried out at a later date. It is believed that this additional fieldwork will confirm the information we have to date regarding the soils conditions at the proposed causeway.

SITE DESCRIPTION

The site is located at the Old Welland Canal in the north end of Welland. The Old Canal is bounded to the south by Merritt Island, a narrow strip of parkland separating the Old Welland Canal from the Welland River. The vegetation on the island is predominantly deciduous forest, bush groomed grass, and a small roadway. The north shore of the Old Canal is groomed grass, roadway and short wild brush on the slopes.

The area is part of the clay plain typical of the Niagara Peninsula south of the Escarpment. The terrain is flat to rolling.

SUBSURFACE CONDITIONS

General

The material encountered consisted mainly of a stiff to hard silty clay, traces of sand, gravel. In borehole 1 two layers of compact/very dense silt, trace of clay, sand, gravel were encountered within the silty clay. At elevation 156.9 m to 157.4 m beneath the above deposits overlying the bedrock was approximately 3 m of a dense to very dense sand and silt, some gravel trace of clay. Bedrock was encountered at elevation 153.1 m.

The plan and location of borings and the stratigraphical profile are shown on drawing number 116816-A in the attached Appendix. The obtained field and laboratory tests are plotted on the Record of Borehole sheets also in the Appendix of this report. A brief description of the different soil types is given below.

Silty Clay of Medium Plasticity

A 2.9 to 3.9 m deposit of stiff silty clay of medium plasticity, traces of sand, organics was encountered at the surface of borehole 1 and below a 1 m deposit of topsoil in borehole 4.

The natural moisture content was 21 to 24%, liquid limit 37 to 46% and the plastic limit 16 to 18%. The results from grain size distribution tests showed 2 to 8% sand and 92 to 98% fines.

The plasticity of the deposit as shown in Figure 1 indicates the material plotted as a silty clay of medium plasticity (CI). The consistency was mainly stiff.

Silt, Traces of Sand, Trace to Some Clay

Under the silty clay deposit described above in borehole 1 a 2.2 m thick deposit of silt, trace of clay, sand to elevation 171.9 m was found. The natural moisture content was 19-21%, liquid limit 22-23% and plastic limit 16-18%. The deposit is therefore a silt of low plasticity.

The results from the grain size distribution tests are shown on Figure 2. The denseness of the deposit ranged from dense decreasing with depth to compact.

Silty Clay of Low Plasticity, Traces of Sand, Gravel

At the floor of the old canal in borehole 2 (at elevation 171.4 m) under the above deposits in boreholes 1 and 4 at elevation 172 m was a deposit of silty clay of low plasticity, trace of sand, gravel. It was the thickest deposit (above bedrock) ranging in thickness from 11.9 to 15.1 m to elevation 160.1 m in borehole 1 to 156.9 m in borehole 4.

The physical properties of the material as determined by field and laboratory tests are listed below:

	<u>Mean</u>
Unit Weight (γ)	20.8 kN/m ³
Unconfined Shear Strength	87.1 kPa
Field Vane Undrained Shear Strength	70.4 kPa
Natural Moisture Content (w)	18.7%
Liquid Limit (w_L)	27.6%
Plastic Limit (w_p)	15.0%
Initial Voids Ratio (e_0)	0.59
Compression Index (C_c)	(0.06 - 0.2)

The consistency of the deposit ranged from stiff to hard at elevation 164 m and in borehole 4 back to stiff at elevation 160 m. The deposit is a glacial till. Figure 3 indicates the material plotted as a silty clay of low plasticity (CL). The results from the grain size distribution tests are included in Figure 4 in envelope form.

Silt, Traces of Clay, Sand, Gravel

In borehole 1 at elevation 160.1 under the deposit described above a 3 m + thick strata of silt, traces of clay, sand, gravel was encountered. The natural moisture content found in a laboratory test was 17%, liquid limit 18.5% and plastic limit 12%, indicating a silt of low plasticity. The grain size distribution test indicated 3% gravel, 6% sand, 86% silt and 5% clay. The denseness of the layer was very dense.

Sand and Silt, Some Gravel, Trace of Clay

In all boreholes this deposit of sand and silt some gravel, trace of clay was found from elevation 156.9 to 157.4 m to the bottom of the boreholes or to bedrock in borehole 1. The deposit was 4 m to 1.4 m + thick.

The natural moisture content ranged from 10 to 13%. The results from the grain size distribution tests indicate 14% gravel, 39 to 46% sand, 34 to 39% silt and 6 to 8% clay. The denseness ranged from dense to very dense.

Bedrock

Bedrock was encountered below the overburden material at the following elevation:

<u>Borehole</u>	<u>Sound Bedrock</u>	<u>Weathered Bedrock</u>
1	152.97 m	153.12 m

Bedrock is Dolostone of the Salina Formation.

The rock core samples were examined by Mr. S. A. Senior, M.T.C. Geological Engineer and his description is included in Figure 5 of the Appendix of this report.

GROUNDWATER CONDITIONS

The following groundwater conditions were observed during the field investigation:

<u>Borehole</u>	<u>Elevation</u>
1	172.9 m
2	173.4 m
4	161.4 m

The boreholes indicate the groundwater level at approximate elevation 172.9 m. This level will most likely vary seasonally and with fluctuations in the canal and river level.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of Mrs. Pamela Marks, Foundation Engineer and Mr. Ian Robertson, Student Specialist. The equipment was owned and operated by F.E. Johnston Drilling Co. Ltd. This report was prepared by Mrs. P. Marks and reviewed by Mr. K. Selby.



P.J. Marks, P.Eng.
Foundation Engineer

K.G. Selby, P.Eng.
Chief Foundations Engineer
(West)

APPENDIX

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

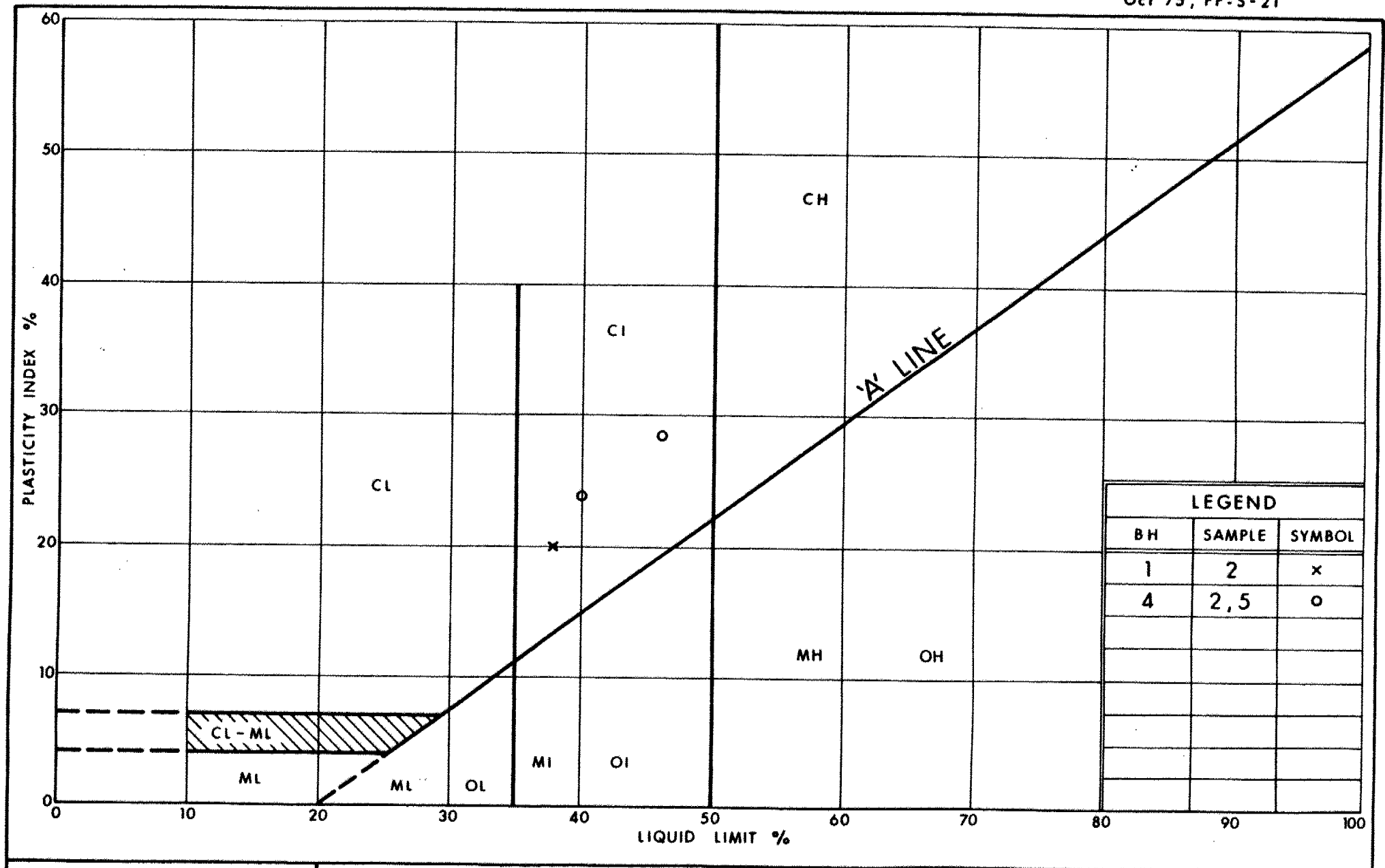
u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	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_r	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{\min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

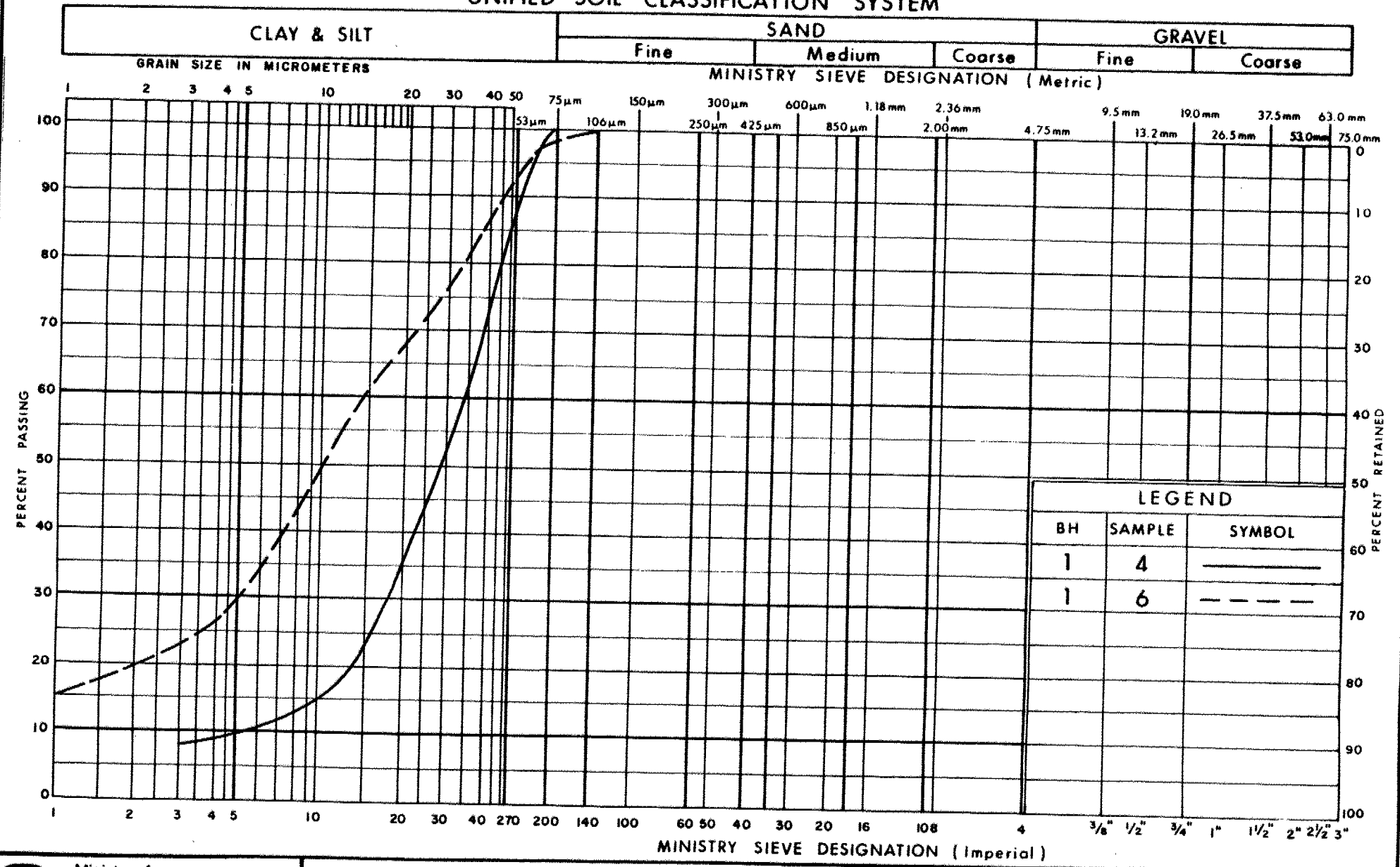
Ministry of
Transportation

PLASTICITY CHART SILTY CLAY OF MEDIUM PLASTICITY

FIG No 1

W P 11-68-16

UNIFIED SOIL CLASSIFICATION SYSTEM

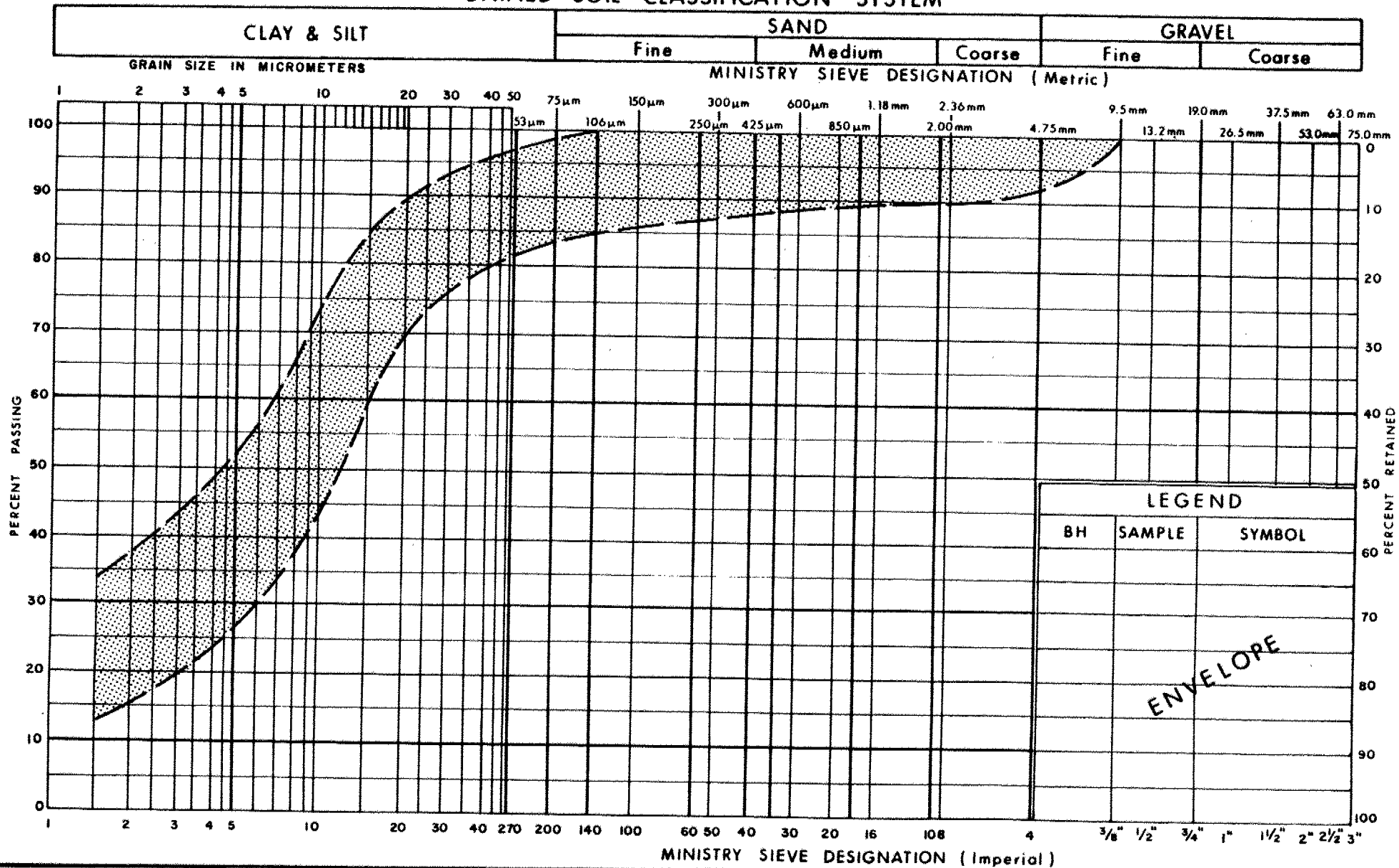


Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
SILT
 TRACES OF SAND, TRACE TO SOME CLAY

FIG No 2
 W P 11-68-16

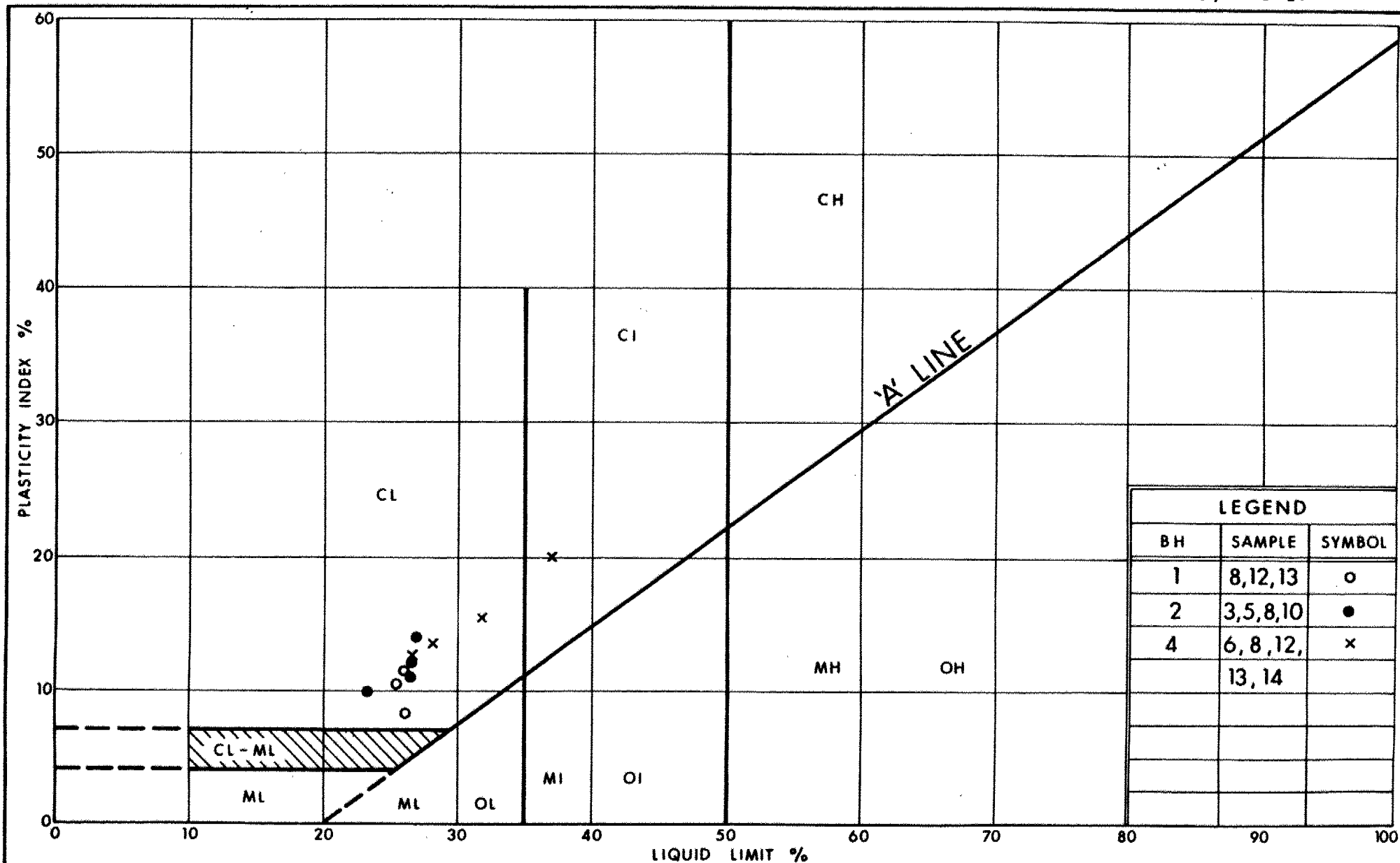
UNIFIED SOIL CLASSIFICATION SYSTEM

Ministry of
Transportation

GRAIN SIZE DISTRIBUTION SILTY CLAY OF LOW PLASTICITY, TRACES OF SAND & GRAVEL

FIG No 3

W P 11-68-16



Ontario

Ministry of
Transportation

PLASTICITY CHART
SILTY CLAY
OF LOW PLASTICITY, TRACES OF SAND & GRAVEL

FIG No 4

W P 11-68-16

DESCRIPTION OF ROCK CORE - WP 11-68-16

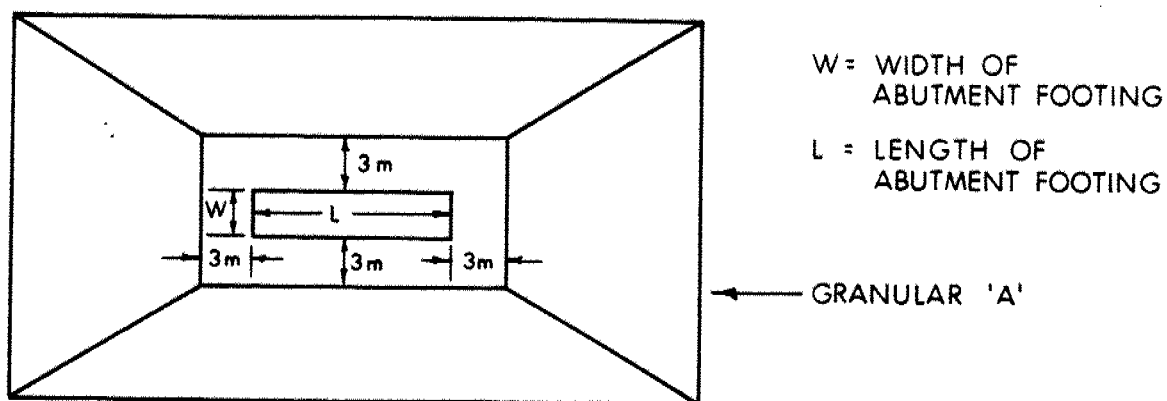
CORE RECOVERY				CORE DESCRIPTION	
HOLE #	DEPTH (m)	%CR*	%RQD*	DEPTH (m)	DESCRIPTION
1	23.98-24.31	85	33	23.98-27.25	DOLOSTONE, light to medium grey; very finely crystalline, thinly laminated; medium strong to strong rock; slightly weathered; very close spaced fractures, extremely close spaced fracture zones at 24.31-24.38 m and 25.20-25.63 m.
	24.31-24.61	100	0		
	24.64-26.24	65	0		
	26.24-27.25	93	12		

*CR = CORE RECOVERY

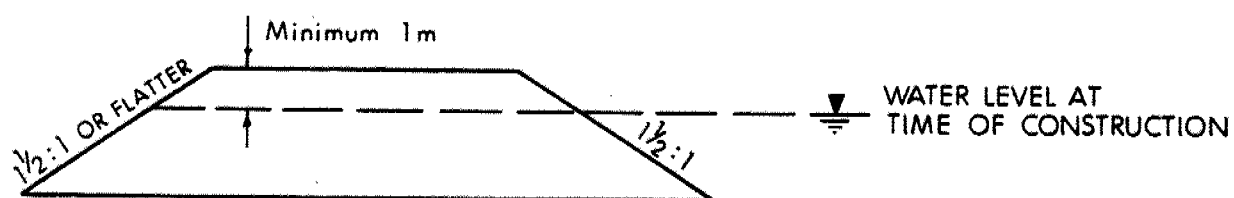
*RQD = ROCK QUALITY DESIGNATION

1/..1

FIG 5



PLAN VIEW OF 'PRISM'



TYPICAL SIDE (& FORWARD,
 BACK) SLOPE

- NOTE : 1 Drawing not to scale
 2 All dimensions shown as minimums

FIG 6 - MINIMUM DIMENSIONS AND DETAILS

RECORD OF BOREHOLE No 1

METRIC

W P 11-68-16 LOCATION Sta. 15 + 350.6 E Med. Hwy. 406 ORIGINATED BY PM
 DIST 4 HWY 406 BOREHOLE TYPE Continuous Flight Auger (H.S.) COMPILED BY PM
 DATUM Geodetic DATE 87 10 14 to 87 10 16 CHECKED BY PM

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 Y 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 (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL							x LAB VANE	
177.1	Ground Level							20 40 60 80 100										
0.0	Silty Clay Traces of Sand Stiff		1	SS	27		176								0 2 (98)			
			2	SS	16													
174.2			3	SS	12		174								0 1 92 7			
2.9	Silt Trace of Sand Trace to Some Clay Dense to Compact		4	SS	37													
			5	SS	28													
172.0			6	SS	10		172								0 3 77 20			
5.1			7	SS	12													
	Silty Clay Traces of Sand (Glacial Till) Stiff		8	TW	PH		170						20.9	1 2 (97)				
			9	SS	12													
			10	SS	14		168											
			11	SS	12													
			12	SS	16		166											
	Traces of Gravel Hard		13	SS	60/	15 cm	164								0 2 (98)			
160.1							162								4 4 (92)			
17.0	Silt Traces of Clay Sand, Gravel Very Dense		14	SS	57		160								3 6 86 5			
157.1							158											
20.0	Sand and Silt Some Gravel Trace of Clay Very Dense						156											
			15	SS	75		154								14 46 34 6			
153.1			17	RC	85													
24.0	Weathered Sound Dolostone Bedrock		18	RC	100		152											
			19	RC	REC 65													
149.8			20	RC	REC 93		150											
27.3	End of Borehole																	

+3, x5 : Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 2

METRIC

W P 11-68-16 LOCATION Sta. 15 + 333.0 Med. Hwy. 406 ORIGINATED BY IR
DIST 4 HWY 406 BOREHOLE TYPE Casing BX COMPILED BY PM
DATUM Geodetic DATE 87 11 07 to 87 11 10 CHECKED BY /

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
173.4	Water Level												
0.0													
171.4	Ground Level												
2.0													
	Silty Clay		1	SS	10								
	Traces of Sand, Gravel		2	SS	10								
	(Glacial Till)		3	SS	10								1 3 (96)
			4	SS	11								2 3 (95)
			5	SS	11								
			6	SS	11								
	Stiff Hard		7	SS	11								
			8	SS	67								9 12 (79)
			9	SS	94								
			10	SS	61								6 6 51 37
			11	SS	63								
157.4													
16.0	Sand and Silt Some Gravel		12	SS	33								14 39 39 8
156.0	Trace of Clay Dense		13	SS	48								
17.4	End of Borehole												
154.8													
18.6	End of Cone												

+³, x⁵: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 3

METRIC

W P 11-68-16 LOCATION Sta. 15 + 197.0 E Med. Hwy. 406 ORIGINATED BY IR
DIST 4 HWY 406 BOREHOLE TYPE Cone Test COMPILED BY PM
DATUM Geodetic DATE 87 11 12 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES								
173.4 0.0	Water Level												
170.7 2.7	Ground Level												
	Presumed Silty Clay Traces of Sand, Gravel Stiff to Hard												
162.5 10.9	End of Cone Test												



RECORD OF BOREHOLE No 4

METRIC

W P 11-68-16 LOCATION Sta. 15 + 179.0 5.2 m Left of E Med. Hwy. 406 ORIGINATED BY PM
DIST 4 HWY 406 BOREHOLE TYPE Continuous Flight H.S. Auger COMPILED BY IR
DATUM Geodetic DATE 87 11 17 to 87 11 18 CHECKED BY

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					
176.9	Ground Level													
0.0	Topsoil													
175.9			1	SS	10		176							
1.0	Silty Clay		2	SS	13									0 8 (92)
	Trace of Organics, Sand		3	SS	12									
	Stiff		4	SS	11		174							
			5	SS	8									0 3 (97)
172.0			6	SS	19		172							0 3 71 26
4.9			7	SS	12									
	Silty Clay		8	SS	24									5 5 (90)
	Traces of Sand, Gravel		9	SS	22		170							
	(Glacial Till)		10	SS	22									1 1 83 15
			11	SS	37		166							
	Stiff to Very Stiff		12	TW	PH		164						20.7	0 3 67 30
	Hard		13	TW	PH		162						20.8	8 9 62 21
							160							
	Stiff		14	SS	7		158							0 1 (99)
156.9														
20.0	Sand and Silt Some Gravel Trace of Clay Dense		15	SS	41		156							
153.9							154							
23.0	End of Borehole													
23.9	End of Cone													

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 5

METRIC

W P 11-68-16 LOCATION Sta. 15 + 346.8; Offset 9.4 m Lt. of E Med. Hwy. 406 ORIGINATED BY IR
 DIST 4 HWY 406 BOREHOLE TYPE Cone Test COMPILED BY PM
 DATUM Geodetic DATE 87 11 18 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
176.6	Ground Level												
0.0	Presumed Silty Clay Traces of Sand Stiff						176						
	Presumed Silt, Trace of Sand, Trace to Some Clay, Dense						174						
173.2													
3.4	End of Cone												

METRIC

W P 11-68-16 LOCATION Sta. 15 + 366.2; Offset 8.4 m Lt. of C Med. Hwy. 406 ORIGINATED BY IR
DIST 4 HWY 406 BOREHOLE TYPE Cone Test COMPILED BY PM
DATUM Geodetic DATE 87 11 19 CHECKED BY _____

[illegible]

+3, x5 : Numbers refer to Sensitivity

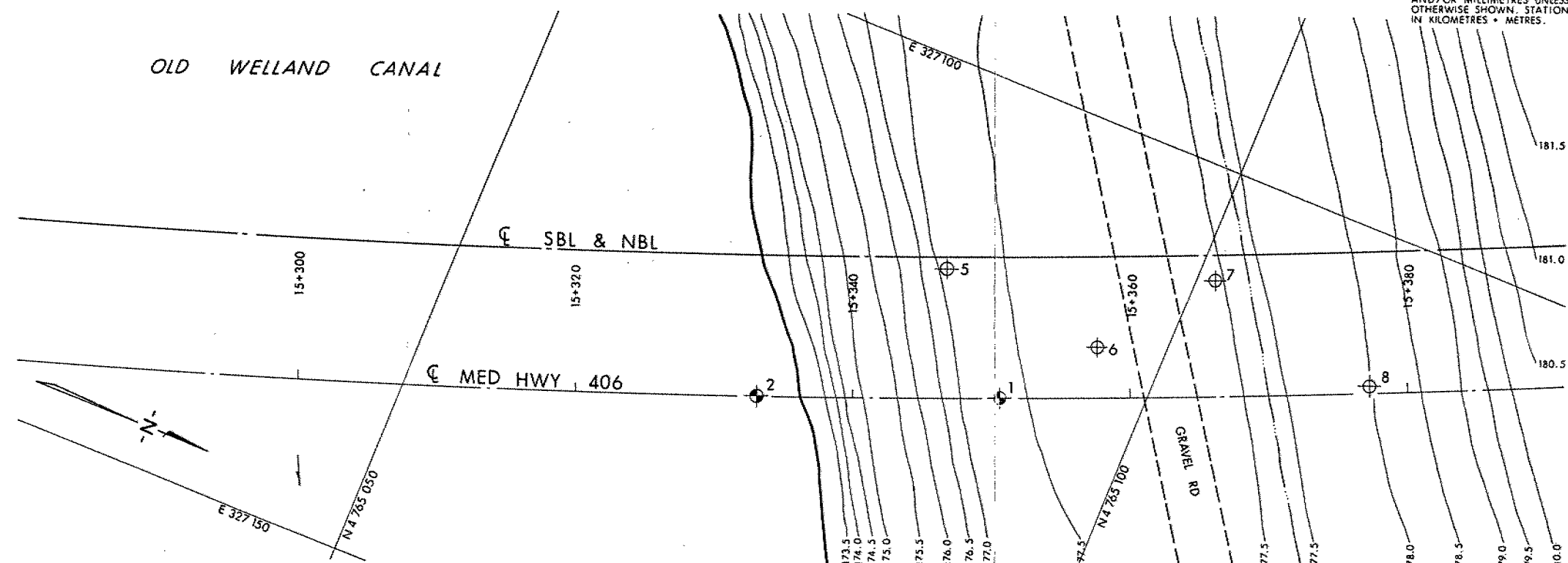
20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 8

METRIC

W P 11-68-16 LOCATION Sta. 15 + 377.4; Offset 0.5 m Lt. of C Med. Hwy. 406 ORIGINATED BY IR
 DIST 4 HWY 406 BOREHOLE TYPE Cone Test COMPILED BY PM
 DATUM Geodetic DATE 87 11 19 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
178.0 0.0	Ground Level												
	Boulders												
	Presumed Silty Clay												
	Traces of Sand												
	Stiff												
174.6 3.4	End of Cone												



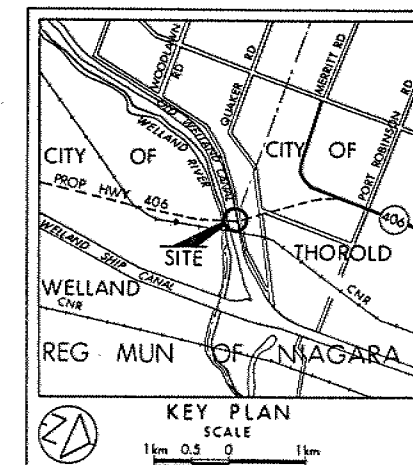
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES - METRES.

CONT No
WP No 11-68-16

OLD WELLAND CANAL
BORE HOLE LOCATIONS & SOIL STRATA



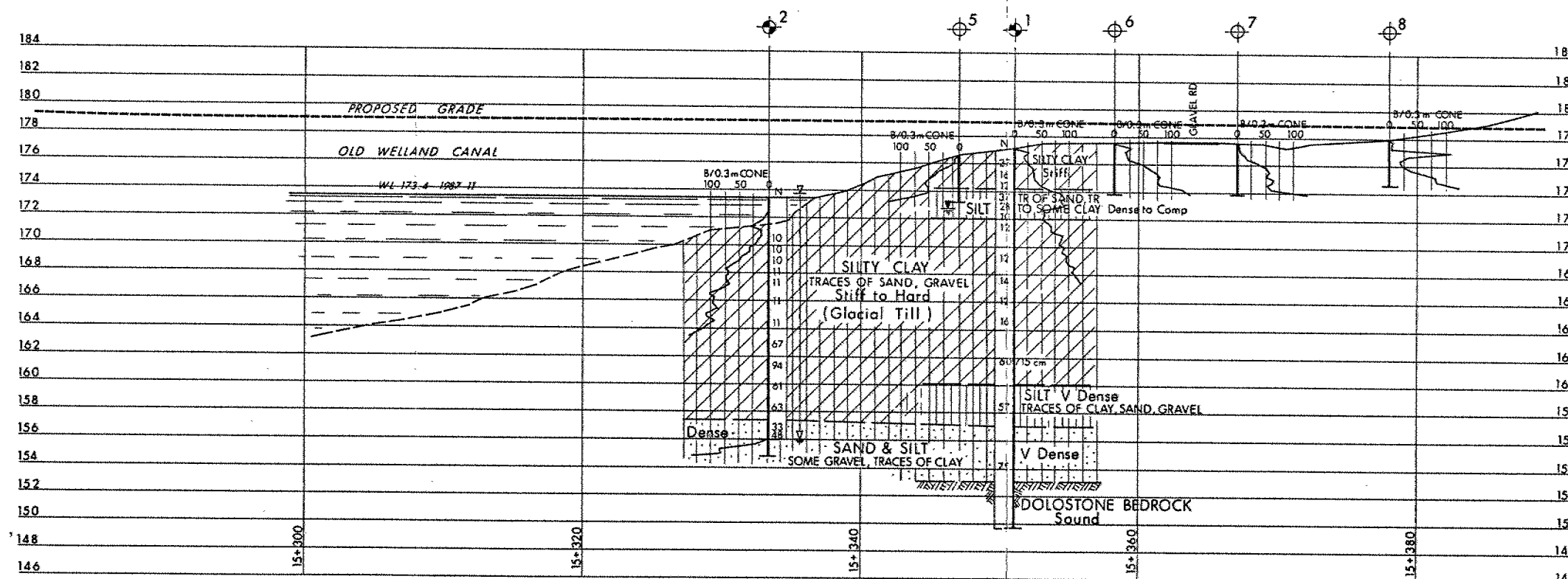
SHEET



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 87.10 & 11
- Head
- Encountered
- ARTESIAN CONDITION

No	ELEVATION	STATION	OFFSET
1	177.1	15+350.6	⊕
2	173.4	15+333.0	⊕
3	173.4	15+197.0	⊕
4	176.9	15+179.0	5.2 m LT
5	176.6	15+346.8	9.4 m LT
6	177.6	15+357.6	3.6 m LT
7	177.5	15+366.2	8.4 m LT
8	178.0	15+377.4	0.5 m LT



PROFILE MED HWY 406

SCALE
4m 2 0 4m

NOTE: REFER TO RECORD OF BORE HOLE FOR
SUBSOIL INFORMATION FOR BH'S 3 & 4

NOTE

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

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

REV.	DATE	BY	DESCRIPTION

Geocres No 30M3-188

HWY No 406	DIST 4
SUBM'D PM CHECKED	DATE 1988.01.21
DRAWN SO CHECKED	APPROVED
SITE 34-3045	DWG 116816-A