HALIFAX REGIONAL MUNICIPALITY

GEOTECHNICAL INVESTIGATION
FOR
HALIFAX HARBOUR SOLUTIONS PROJECT

PROJECT NO. 14417

PROJECT NO. 14417

FINAL REPORT TO

HALIFAX REGIONAL MUNICIPALITY

ON

HALIFAX HARBOUR SOLUTIONS PROJECT

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1.0 GENERAL

1.1 Introduction

Jacques, Whitford and Associates Limited, acting at the request of the Halifax Regional Municipality, Halifax Harbour Solutions Project Group, has carried out a geotechnical investigation for proposed outfalls at the Halifax North and Dartmouth (Coast Guard) sites. The purpose of the investigation was to obtain information on the stratigraphy at the two sites. This report has been prepared specifically and solely for the project which is described above. It contains all of the findings of the investigation.

1.2 General Location

The proposed locations of the outfalls are shown on Drawing No. 14417-1 in **Appendix 1** and Drawing No. 14417-2 in **Appendix 2**. The locations are described as follows:

- Halifax North Outfall - this outfall is located in the downtown Halifax area immediately to the south of the Purdy's Wharf/Casino Complex on the Halifax waterfront. The outfall would extend eastward from Upper Water Street into the basin between the south property limit of the Karlsen Shipping Wharf and the north property line of the Casino Complex.

- Dartmouth Outfall - the Dartmouth outfall is located on the east shore of the Halifax Harbour in the vicinity of the Coast Guard, on the Dartmouth Waterfront. The outfall would extend south from the infill of the Coast Guard complex approximately parallel to the shoreline, for a distance of approximately 900 metres.

1.3 Report Format

This report is divided into three main sections as follows: a general section which addresses activities common to both locations and sections detailing the specific findings at each location.

Section 1	-	General
Section 2	-	Halifax North Outfall
Section 3	-	Dartmouth Outfall

1.4 Geotechnical Field Investigation

Field work for the geotechnical investigation was carried out between August 21st and September 1st, 1999 and consisted of putting down 7 boreholes, BH HN1 to BH HN3 inclusive on Halifax North and BH D1 to BH D4 inclusive at the Dartmouth site. The boreholes were performed to determine subsurface stratigraphy at selected locations. Boreholes were carried out using an auger drill mounted on a centre-well barge.

The boreholes were put down to depths of 2.5 to 12.8 m below the seafloor in B-sized casing. Diamond drilling procedures were frequently required to advance the casing through cobbles and boulders in the overburden. In the boreholes, soil samples were taken using a 50 mm OD split spoon sampler in conjunction with Standard Penetration Test (SPT) N-values. Bedrock was cored in BQ size.

All soil samples and rock core were taken to our Dartmouth laboratory for final classification and testing. Geotechnical laboratory testing included moisture content determinations, Atterberg limit tests, and grain size analyses.

Elevations at the borehole and cone penetration test locations were determined with respect to Lowest Normal Tide (LNT) Datum.

Detailed logs of the soils and bedrock encountered and the sampling and testing carried out are given on the Borehole Records in **Appendix 1**; the results of laboratory testing are shown on the Borehole Records or on separate figures in **Appendix 2**.

1.5 Borehole Locations

Borehole locations were surveyed and referenced to control monuments established by Wallace, MacDonald & Lively Ltd. (WML). The initial location of the boreholes were established by WML with buoys placed at defined locations. The final locations were surveyed by our personnel from shore-based survey moments established by WML. Locations were referenced to the Nova Scotia grid (3E MTM Projection, ATS 77 Datum). Location co-ordinates are tabulated on the drawings and on the borehole records for each borehole.

1.6 Samples - Environmental Testing

Samples were collected as part of the geotechnical program for environmental testing. Where depths of water were not excessive, grab samples were obtained at the surface at the locations of boreholes. Samples from the split spoon sampler were also obtained and were catalogued relative to depth of sediment for additional testing. Testing was carried out at Philip Environmental to conform to Canadian Environmental Protection Act (CEPA) requirements. Total petroleum hydrocarbon tests for the selected samples were also carried out. The results of the testing are detailed in the applicable section for each geographic area.

2.0 HALIFAX NORTH OUTFALL

2.1 Location

The location of the proposed Halifax North outfall is bounded by Karlsen Shipping Company Limited property to the north, the Casino to the south and the west limits of Lot "R" of the Halifax Regional Municipality adjacent to Upper Water Street. Lot "R" extends approximately 140 m (458.2 feet) east of the sewer easement and has a width of approximately 27.5 m (90 feet). The proposed outfall extends beyond the east limits of Lot "R". The general layout of Lot "R" is shown on Drawing No. 14417-3; however, the detailed legal plan for the area should be obtained before finalizing space restrictions.

2.2 Review of Existing Data

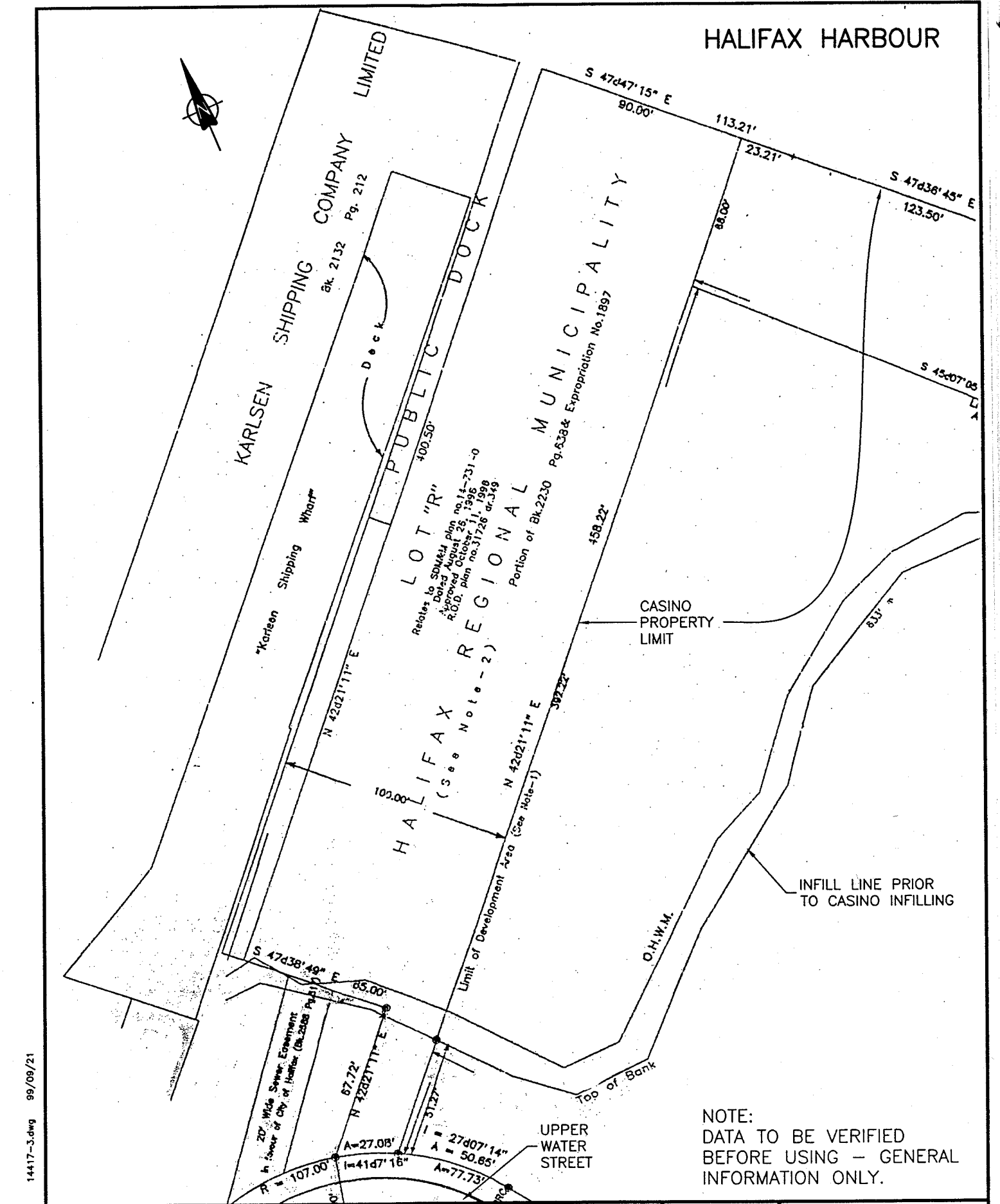
The review of existing data included the in-house files (confidential), hydrographic surveys, the general geological data within the Harbour, and overview of existing facilities relative to considerations for the outfall.

- The review of existing data on hydrographic information implies that the elevations from the Hydrographic Chart are consistent with the elevations obtained at the boreholes. Generally from a review of other data, elevations in the basin between Karlsen Shipping and the Casino vary from -3 m at 20 metres from the east bank to in excess of -15 metres at the west end of Lot "R".

- Surficial geological information was compiled by Atlantic Geoscience Centre - Enclosure 7 dated March 22, 1990. In the area of the proposed outfall where mapping has occurred, the surface is indicated to be holocene mud and transgressive gravel. The data has been scanned and information from the survey relative to the approximate location of the borehole locations are shown on Drawing No. 14417-4.

- Isopach map of holocene mud was also developed. Drawing No. 14417-5 indicates the thickness along the alignment, where mapping has occurred. Generally the thickness is shown to vary from 0.1 to 3 m.

- Various boreholes have been placed along the adjacent shoreline and infill area. Along the shoreline various thicknesses of organic silt can be anticipated. The thicknesses at the toe of infill slopes includes the softer deposits that have been displaced during infilling of water lots. The fills/organic silts are underlain by a thin veneer of till, in turn underlain by slate bedrock. Higher ridges of bedrock slope into the harbour, running east/west with the valleys infilled with silts/tills. Bedrock surface based on other adjacent sites slopes into the harbour at approximately 6 percent. Bedrock surface was encountered at adjacent sites at elevation (-) 8 m near the shoreline, while at the east limits of the water lot bedrock was at (-) 16.8 m.



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HALIFAX NORTH

APPROX. AREA OF BASIN AT OUTFALL

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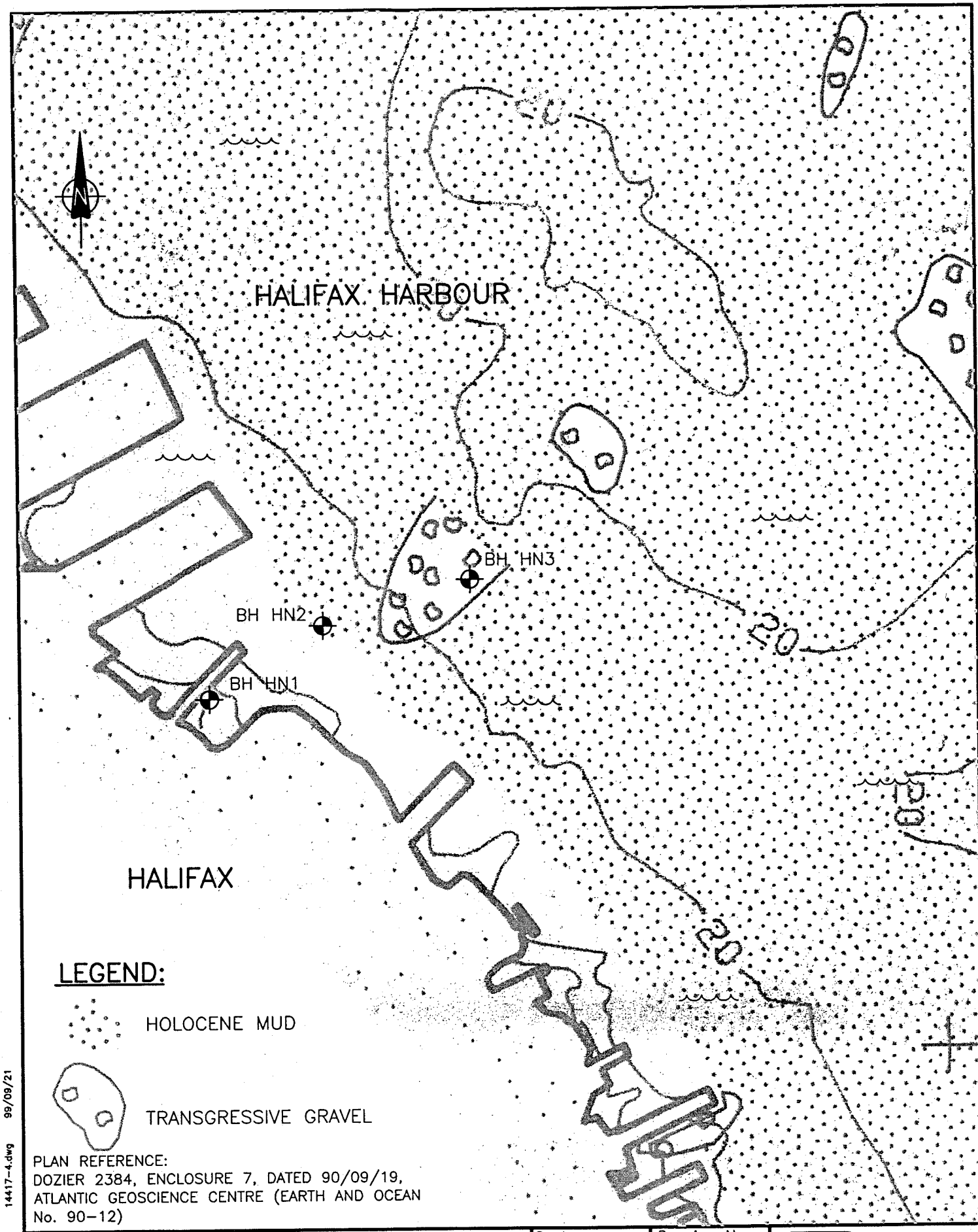

PLAN REFERENCE:
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ATLANTIC GEOSCIENCE CENTRE (EARTH AND OCEAN
No. 90-12)

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HALIFAX NORTH
SURFICIAL GEOLOGY

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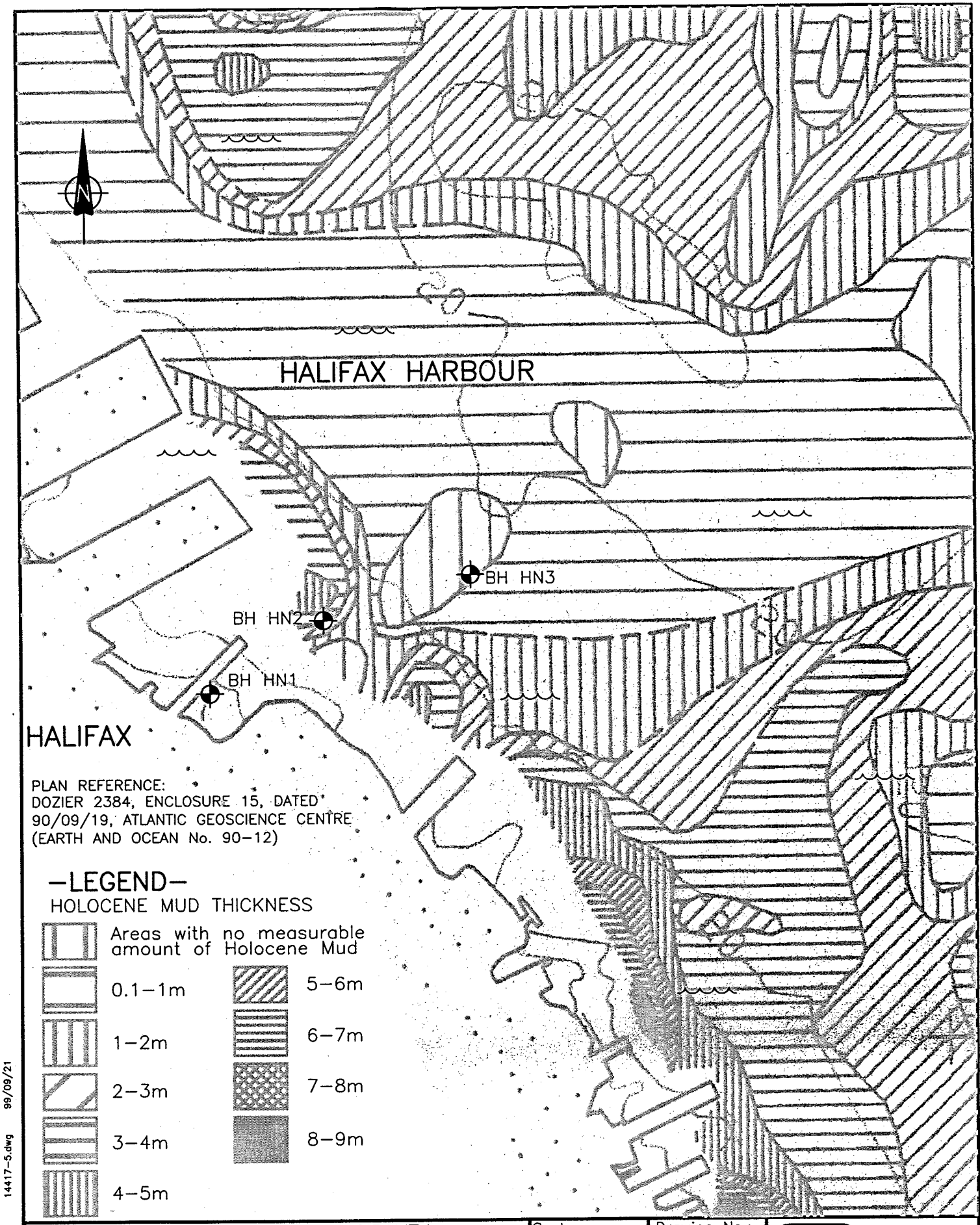

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DOZIER 2384, ENCLOSURE 15, DATED 90/09/19, ATLANTIC GEOSCIENCE CENTRE (EARTH AND OCEAN No. 90–12)

–LEGEND–

HOLOCENE MUD THICKNESS

- Areas with no measurable amount of Holocene Mud
- 0.1–1m
- 1–2m
- 2–3m
- 3–4m
- 4–5m
- 5–6m
- 6–7m
- 7–8m
- 8–9m

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HALIFAX HARBOUR SOLUTIONS

HALIFAX NORTH

ISOPACH MAP

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- Within the basin between the Karlsen Wharf and the Casino, the north face of the Casino infill consist of a rockfill, with associated scour protection. Soft deposits were displaced during the infill program and not dredged. In the inner area of the basin, the toe of the fill extends to the property limits. Piles have been advanced through the slope to carry the structure. Generally, the slope is established at 2H:1V. Excavations would have to address impacts on the slope and lateral loads on piles if instability of the slope were to occur.

2.3 Geotechnical Conditions

The strata encountered in Boreholes HN 1 to HN 3 inclusive are described on the Borehole Records in **Appendix 1** and in further detail below.

2.3.1 Organic Silt

A surficial layer of marine sediments comprised of very loose (or very soft) organic silt and organic sandy silt was encountered in all of the boreholes. The total thickness of the organic silt ranges from 0.4 m (HN 3) to 3.5 m (HN 1). The thicker silt deposits occur in the nearshore borehole within the basin adjacent to the Sheraton Casino.

Grain size analysis carried out on samples of the organic silt gave an average of 25 percent sand sizes and 78 percent silt and clay sizes. Moisture contents ranged from 84 to 117 percent and averaged 95 percent. Atterberg limit tests showed the material to vary from non-plastic to having a PI of 7.4 to 23.6 with liquid limits of 27.4 to 49. Classification of the material would vary from a medium compressible organic silt to a highly compressible silt. Standard Penetration Test N-values were 0 (penetration under the weight of rods) to 1 blow per foot indicating the organic silt is in a very loose (very soft) condition. Based on the field and laboratory testing carried out during the present and previous investigations, the following design parameters are assigned to the organic silt:

Submerged Unit Weight	2.2 kN/m^3
Effective Angle of Internal Friction	25E
Effective Cohesion	0
Undrained Shear Strength	10 kPa
Compression Ratio	0.33

2.3.2 Glacial Till/Sandy Silt and Silty Sand

Glacial till was encountered below the organic silt at BH HN1 and BH HN2 borehole locations. The thickness of the till ranged from 1.7 m in Borehole HN 1 to 3.3 m in Borehole HN 2. In Borehole HN 3, a compact to dense grey brown sandy silt/silty sand was encountered, having a thickness of 0.6 m.

The till is grey in colour and is comprised predominantly of silty gravel with sand; cobbles and boulders are frequently present. Standard penetration test N-values ranged from 26 to refusal. Although the higher blow counts are partly attributed to the presence of cobbles and boulders, the tests indicate that the till is generally dense to very dense. Extensive cobbles and boulders were encountered in Borehole HN 2 as evidenced by the requirement to core. The following properties are assigned to the sand and gravel till:

Submerged Unit Weight	13 kN/m^3
Effective Angle of Internal Friction	38E
Effective Cohesion	0

2.3.3 Bedrock

Bedrock was proven by core drilling in all the boreholes. Bedrock was encountered below the till at depths ranging from 1.8 m to 8.5 m. The bedrock consists of grey slate of the Halifax Formation. Rock Quality Designations (RQDs) ranged from 9 to 67 percent. Overall, the rock is classified as fractured to very severely fractured.

2.4 Summary of Borehole Data

The borehole data is summarized as follows relative to thickness of layers and pertinent elevations.

Table 2.1 Summary of Borehole Data

Borehole No.	Surface Elevation (m)	Thickness of Organic Silt (m)	Thickness Till (m)	Depth to Bedrock (m)	Elevation of Top of Bedrock (m)
HN 1	- 4.63	3.5	1.7	5.2	-9.8
HN 2	- 15.94	5.2	3.3	8.5	- 24.4
HN 3	- 23.62	0.6	0.6*[1]	1.2	- 24.8
Note: Elevations to Chart Datum *1 - Sandy Silt/Silty Sand Layer					

2.5 Sediment Chemistry

The results of the sediment chemistry are shown on Table 2.2 for the samples tested. The table also shows the Ocean Disposal Environment Canada Guidelines and Land Disposal without containment guidelines as per the Nova Scotia Department of Environment. The exceedance numbers for each sample are shown in **"bold"** relative to Environment Canada Guidelines. The surface samples and samples at depth in the organic silt generally exceed the Ocean Dumping guidelines relative to copper, lead, zinc and mercury; while the concentration of PCBs in the nearshore sample, to the south of the Karlsen Shipping and closer to the existing outfall (HN 1-1A) is high. One sample in the till HN1 SS3, shows slight exceedance on copper and zinc. The concentrations of PAHs in the organic silt are also above the guideline.

Table 2.2 Sediment Chemistry Halifax

Parameter	Units	EQL	HN1-1A Organic Silt	HN1-2 Organic Silt	HN1-3 Till	HN2-1B Organic Silt	HN2-2 Organic Silt	HN3-1 Organic Silt	Ocean Disposal Env. Canada Guidelines	Land Disposal Without Containment NSDOE
Cadmium	mg/kg	0.3	4.7	1.1	nd	0.6	0.5	0.6	0.6	5
Copper	mg/kg	2.0	**290**	**110**	**160**	**87**	24	81	81	150
Lead	mg/kg	0.5	**1000**	**830**	18	**310**	21	**280**	66	150
Zinc	mg/kg	2.0	**1100**	**380**	**170**	**260**	90	**210**	160	1000
Mercury	mg/kg	0.01	**5.3**	**3.4**	0.02	**0.91**	0.04	**1.5**	0.75	2
Gravel	%	0.1	nd	12.3	58.1	nd	nd	nd		
Sand	%	0.1	27.7	13.4	22.2	6.8	10.2	25		
Silt	%	0.1	45.6	47.3	14.8	68.3	53	47.9		
Clay	%	0.1	26.8	27	4.8	24.9	36.9	27		
Benzene	mg/kg	0.025	nd	0.113	nd	nd	nd	0.255		
Toluene	mg/kg	0.025	nd	nd	nd	nd	nd	0.634		
Ethylbenzene	mg/kg	0.025	nd	0.074	nd	nd	nd	0.168		
Xylenes	mg/kg	0.05	nd	0.306	nd	nd	nd	1.39		
Total Petroleum Hydrocarbons	mg/kg	32.5	8230	nd	nd	1290	nd	nd		100
Total PAHs	mg/kg	0.5	**270.1**	**110.19**	0.05	**82.11**	0.1	**1044.3**	2.5	100
PCBs	µg/kg	10.0	**3870**	nd	nd	98	nd	nd	100	50000
DDE	µg/kg	10.0	nd	nd	nd	nd	nd	nd	100	
DDT	µg/kg	10.0	nd	nd	nd	nd	nd	nd	100	
DDD	µg/kg	10.0	nd	nd	nd	nd	nd	nd	100	

* PCB is Aroclor 1260; TPH is possible weathered fuel oil fraction and lube oil fraction

2.6 Discussion

The soils can be summarized as fairly deep deposits of organic silts and sands in the inner basin, underlain by till and bedrock. In the outer area (HN3) the thickness of organic silt is thinner (0.6 m).

Based on the interpretation of the data obtained, it is recommended that in the assessment of the construction and long term considerations the following issues will have to be addressed:

- the founding level for the pipe system will have to be evaluated. The inner harbour has deep deposits of organic silt which is highly compressible. If settlement is a major concern then removal and replacement of the organic silt would be required. For removal, consideration would have to be given to disposal of the sediments. As outlined in Table 2.2, the material exceeds Environment Canada Guidelines in reference to heavy metals, with the inner harbour surface deposit being exceeded on PCBs.

- trench excavation of the organic silt will result in inflow of the very soft "fluffy" upper layer. Trench excavations of the organic silt for short term stability should be undertaken with suitable side slopes.

- dredging or trench excavations will have to be assessed relative to the stability of the slope of the existing infill at the Casino site. The infill projects to the property line at the intersect of the slope with the existing surface. As noted previously, socketed pipe piles project through the slope and carry the upper structure. The effect, if any, will be influenced by the proximity of any excavation to the north property limit of the Casino.

- the stability of the silt deposit can be evaluated based on the parameters previously outlined. Where infill is placed below the low water mark, the submerged weight for material such as Type C4 or Type C5 Clear Stone as per NSDOT&PW should be assumed to be 9.5 kN/m^3 Gradations for clear stone are included in **Appendix 1**.

- within the existing shoreline, pieces of concrete and large boulders can be anticipated based on previous experience on the infills on the shoreline. The excavation for the pipe system should extend at least 300 mm below the invert of the pipe and replaced by clear stone bedding. Should soft deposits be encountered, overexcavating and replacement with rock surge and bedding as levelling course would be recommended. It is recommended that the slope along the excavation on the shoreline be protected with a double armour layer. A sub-armour, should underlie the armour.

- bedrock encountered is Halifax Series slate, which is known to be potentially acid producing and any excavations into the slate must consider disposal requirements as per the Nova Scotia Department of Environmental guidelines.

3.0 DARTMOUTH (COAST GUARD)

3.1 Location

The location of the proposed Dartmouth outfall is at the south end of the Canadian Coast Guard and extends southward along the west side of the Halifax Harbour to the Nova Scotia Hospital. The general layout is shown on Drawing No. 14417-2 in **Appendix 2**.

3.2 Review of Existing Data

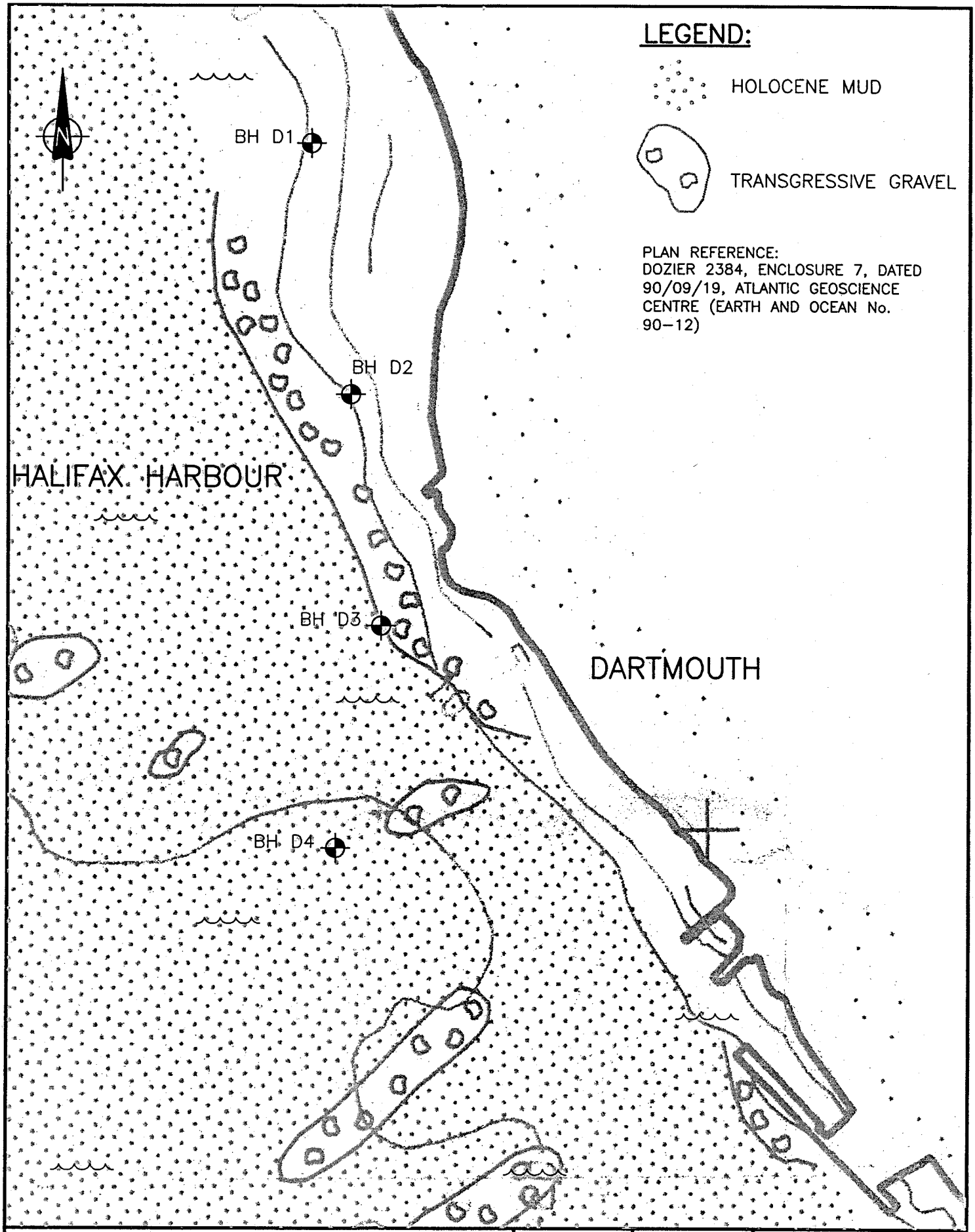
The review of the existing data included our in-house files; hydrographic and geophysical data and the borehole data from adjacent sites. Particulars are noted below:

- Surficial geology information has been compiled on mapping by Atlantic Geoscience Centre - Enclosure 7 dated March 22, 1990. In the area of the proposed outfall, where mapping has occurred, the surface is indicated to be holocene mud and transgressive gravel. A portion of the mapping is shown on Drawing No. 14417-6. The holocene mud is identified as sandy to clayey silt ranging to clayey to sandy silt; gas charged over large areas. The trangressive gravel is described as muddy-sandy poorly sorted gravel; occurs as thin veneer over till or bedrock.

- Isopach map of holocene mud was also developed. Drawing No. 14417-7 outlines the information available in the vicinity of the proposed outfall. A large portion of the area of this study was not covered by the mapping (in the area adjacent to the shoreline). The borehole locations for this project are placed on the map and show that the thickness of holocene mud increases towards the west, with deep deposits at the southwest end of the proposed outfall.

- A series of boreholes was carried out for Public Works Canada (in 1991) in the infill area at the Coast Guard facility. Other boreholes were advanced in 1975 for a section of the shoreline adjacent to the north end of the proposed outfall.

  The approximate location of some boreholes undertaken in the areas are shown on Drawing No. 14417-8. Approximate locations only are shown. Pertinent data is summarized below. From this data the silt thickness is seen to increase towards the west. Where the thickness of sand/gravel is indicated as (>) the borehole was not advanced to bedrock.



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DARTMOUTH

SURFICIAL GEOLOGY

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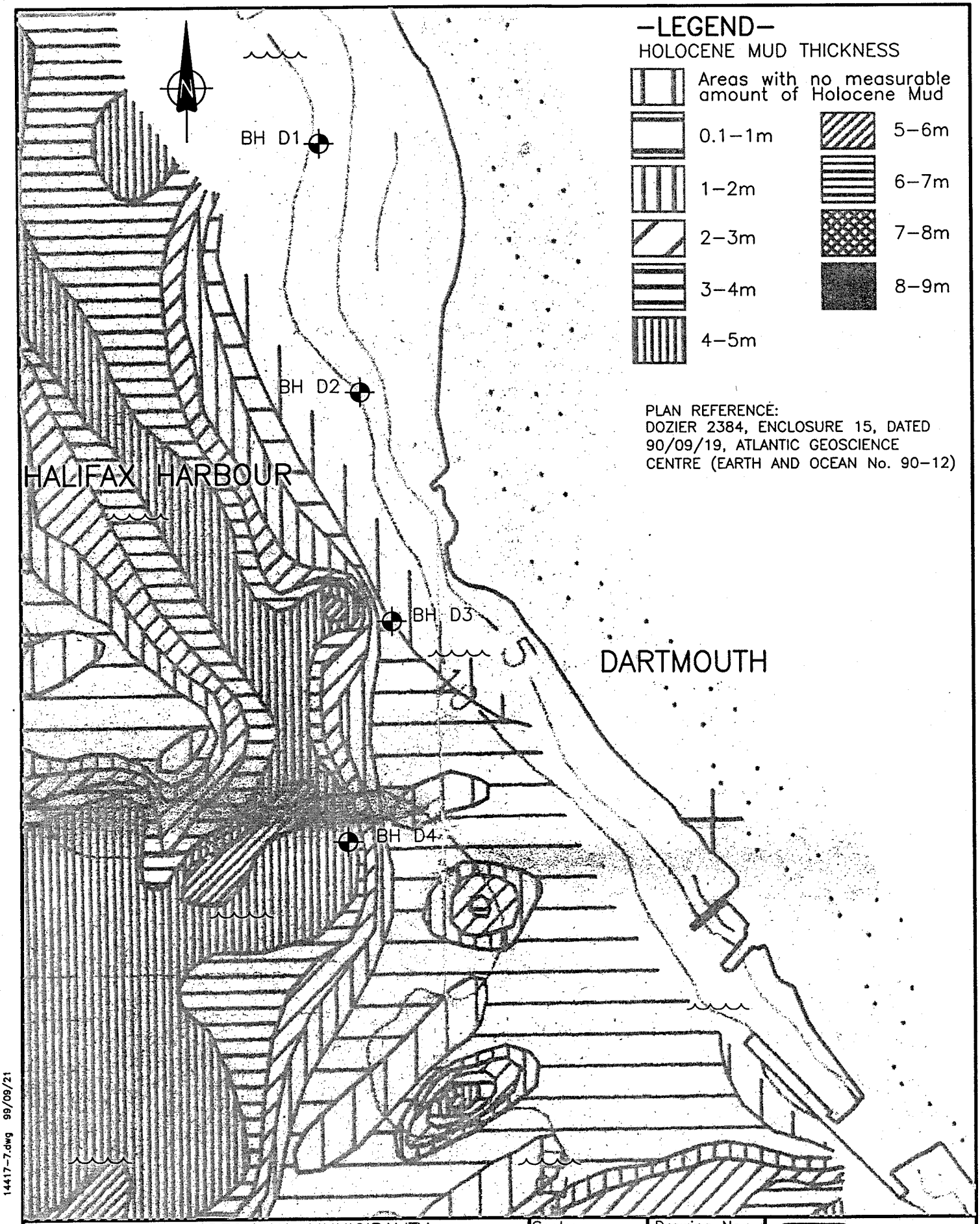

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DARTMOUTH

ISOPACH MAP

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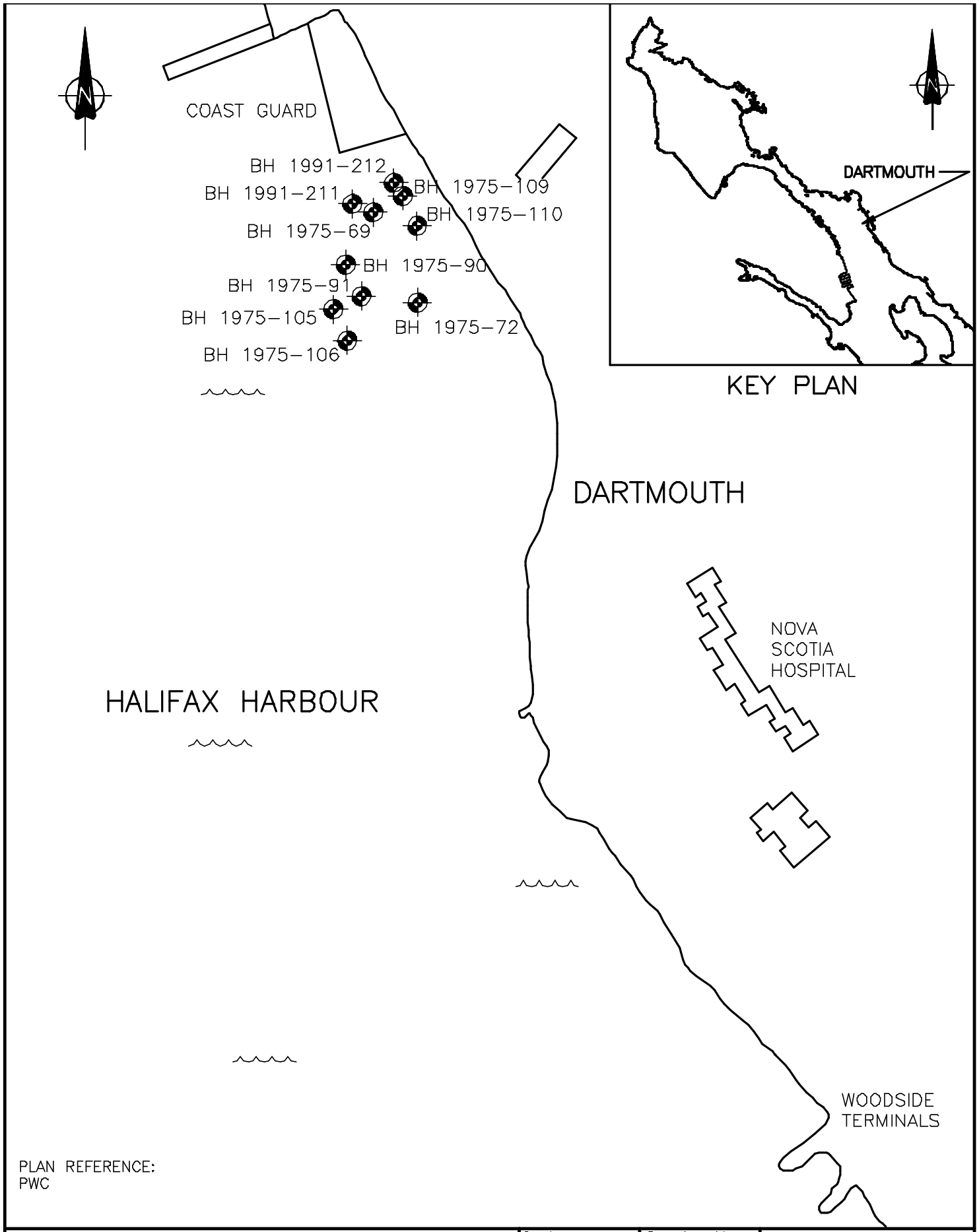

PLAN REFERENCE:
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HALIFAX HARBOUR SOLUTIONS
DARTMOUTH
PREVIOUS BOREHOLE LOCATIONS

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Summary Adjacent Boreholes*[1]			
Borehole No.	**Surface Elevation (m)**	**Thickness of Silt (m)**	**Thickness Sand/Gravel**
1975 - 110	- 5.88	3.11	1.07
1991 - 212	- 4.12	0.61	3.96
1975 - 109	- 6.0	1.92	3.04
1975 - 69	- 8.84	7.31	0.37
1991 - 211	- 9.46	7.32	> 2.74
1998 - 72	- 8.14	2.01	1.03
1975 - 91	- 11.07	1.37	> 0.45
1975 - 90	- 11.04	5.12	1.46
1975 - 106	- 13.41	2.44	> 1.83
1975 - 105	- 13.26	2.44	> 0.90
*1 Source: Public Works Canada			

3.3 Goetechnical Conditions

The strata encountered in Boreholes D1 to D4 inclusive are described in detail on the Borehole Records in **Appendix 2** and in further detail below.

3.3.1 Organic Silt

A surficial layer of marine sediments comprised of very loose (very soft) organic silt was encountered in all boreholes. The total thickness of the organic silt ranges from 0.61 m (D 2) to 4.5 m (D 4). The thicker silt deposits were encountered to the south and southwest areas of the proposed outfall.

Grain size analyses carried out on samples of the organic silt indicated silt/clay fraction to be 57 percent, with the sand size particles (shells, sand) representing 41 percent. Moisture contents varied from 71.5 to 197 percent, with an average of 142 percent. Atterberg limit results vary from non-plastic to a liquid limit varying from 58 to 104, with a plasticity index of 18 to 26, indicating a material of high compressibility. Standard penetration points (N values) were 0 (penetration under the weight of the rods).

Based on the classification testing carried out on this project and field testing carried out in the immediate area the following design parameters are recommended:

Submerged Unit Weight	1.8 kN/m^3
Effective Friction Angle	20 degrees
Effective Cohesion	0
Undrained Shear Strength	9 kPa (average)
Compression Ratio	0.35

3.3.2 Sand and Gravel

Below the surficial layer in Boreholes D 2, D 3, and D 4, a compact fine to coarse sand with silt was encountered. In Borehole D 1 and below the sand deposits in Boreholes D 2 and D 3 a dense to very dense greyish brown silty sand with some gravel and occasional to some cobbles and boulders was encountered. The thickness of the sand and silty sand layer varied from 3.9 m (D1) to 5.0 m (D3).

Grain size analysis on the minus 35 mm fraction of the material show it to contain 16 to 21 percent gravel, 42 to 62 percent sand, and 16 to 42 percent silt/clay size particles. Moisture contents vary from 12 to 15 percent.

Standard penetration tests performed frequently gave values varying from 18 to 44 in the sand deposits, to in excess of 50 in the silty sand and gravel. Due to the presence of cobbles/boulders the split spoon often met refusal.

For analysis and design the following parameters are recommended:

Upper Sand

Submerged Unit Weight	9.6 kN/m^3
Effective Friction Angle	30 degrees
Effective Cohesion	0

Silty Sand and Gravel

Submerged Unit Weight	12.0 kN/m^3
Effective Friction Angle	38 degrees
Effective Cohesion	0

3.3.3 Sand With Clayey Silt/Silty Clay Laminations

Underlaying the silty sand in Borehole D4, a brown fine sand with numerous laminations of clayey silt and silt were encountered. Moisture contents in the material varied from 19 to 25 percent. Atterberg limits carried out on three samples indicated inorganic silts and clays of low compressibility. Liquid limits of 21 to 26 percent with a plasticity index of 3.6 to 6.8 were obtained.

For design purposes the following parameters are recommended:

Submerged Unit Weight	10.8 kN/m^3
Effective Angle of Friction	30E
Effective Cohesion	0
Undrained Shear Strength	200 kPa

3.3.4 Summary of Borehole Data

The borehole data is summarized as follows relative to thickness of layers and pertinent information.

Borehole No.	Surface Elevation	Thickness of Silt (m)	Thickness of Sand (m)	Thickness of Silty Sand (m)
D1	- 8.53	1.2	-	> 3.9
D2	- 9.05	0.7	0.9	> 3.2
D3	- 8.53	4.3	1.3	3.7*[1]
D4	-19.75	4.4	2.6	4.7*[2]

*1 Slate pieces, split spoon refusal elev. (-) 17.8.
*2 Sand with area of silt/clay laminations; slate pieces; split spoon refusal at elev. (-) 31.5.

3.4 Sediment Chemistry

The results of the sediment chemistry are shown on Table 2. The table outlines the Environment Canada (EC) Guidelines for Ocean Dumping as well as the NSDOE guidelines for land disposal without containment. The exceedance values relative to EC are noted in **bold**. The following is noted:

- the top zones of organic silt have values exceeding the EC guidelines;
- high values are associated with heavy metals primarily lead, zinc and mercury as well as PAHs;
- the sediment chemistry of the organic silts at depth are generally below the values of the EC guidelines;
- the sediment chemistry for the silty sands/sands below the organic silt were all below the EC guidelines; and
- TPH values in the upper silt zones were above the NSDOE values for disposal without containment.

Table 3.1 Sediment Chemistry Dartmouth

Parameter	Units	EQL	D1-A Organic Silt	D1-3 Silty Sand	D2-1A Organic Silt	D2-2 Silty Sand	D3-1A Organic Silt	D3-1B Organic Silt	D3-4 Sand	D4-1A Organic Silt	D4-1B Organic Silt	D4-2 Silty Sand	Env. Canada Guidelines	Land Disposal Without Containment NSDOE
Cadmium	mg/kg	0.3	0.5	nd	0.3	nd	**0.7**	**0.8**	0.5	0.4	**0.6**	nd	0.6	5
Copper	mg/kg	2.0	72	19	40	24	68	22	11	58	24	9	81	150
Lead	mg/kg	0.5	**140**	16	**95**	17	**160**	19	9.6	**150**	20	12	66	150
Zinc	mg/kg	2.0	**150**	59	120	61	**180**	80	57	**160**	85	62	160	1000
Mercury	mg/kg	0.01	**1.1**	0.04	0.38	0.02	**0.97**	0.03	0.01	**0.85**	0.04	0.02	0.75	2
Gravel	%	0.1	nd	60.5	6.4	46.7	nd	nd	12.5	nd	nd	34.7	-	-
Sand	%	0.1	23.5	17.6	65.4	2.9	8.3	6.3	56.1	6.3	10.9	35.9	-	-
Silt	%	0.1	50.2	15.3	16.5	30	61.6	50.7	20.8	61.5	69.5	26.8	-	-
Clay	%	0.1	26.3	6.6	11.7	20.4	30.1	43.1	10.6	32.2	19.6	2.6	-	-
Benzene	mg/kg	0.025	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-
Toluene	mg/kg	0.025	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-
Ethylbenzene	mg/kg	0.025	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-
Xylenes	mg/kg	0.05	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	-
Total Petroleum Hydrocarbons	mg/kg	32.5	nd	nd	1830	nd	2440	nd	nd	1950	63.3	nd	-	100
Total PAHs	mg/kg	0.5	**17.19**	nd	**18.82**	nd	14.2	0.18	nd	**9.19**	nd	nd	2.5	100
PCBs	µg/kg	10.0	nd	nd	63.3	nd	95.3	nd	nd	164	nd	nd	100	50,000
DDE	µg/kg	10.0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	100	-
DDT	µg/kg	10.0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	100	-
DDD	µg/kg	10.0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	100	-

* PCB is Aroclor 1260; TPH is lube oil fraction

3.5 Discussions

The soils can be summarized as thin deposits of organic silt on the north end (BH D1, D2), with deeper deposits of organic silt (BH D3/D4) on the south southwest end of the outfall. These deposits in turn were underlain by silty sands, and in BH D4 by silty sands, sands and laminated clayey silt and silt.

In the assessment of the construction and long term considerations the following is noted:

- where the silt deposit is small, less than 1.5 m (BH D1/D2) displacement of the layer could occur if embankment fills are used to form the founding level. Alternatively the pipe could be founded on a prepared surface by excavating silts and displacing laterally (subject to environmental approval);

- consideration will have to be given to settlement in the areas of the deeper deposits of organic silt (BH D3/D4). The settlements can be approximated based on the loads to be applied and the design parameters outlined in the previous section for the organic silt; and

- if short term excavations are required in the organic silt, the upper “fluffy” material will run into the excavation; the slopes for short term stability should be established with geotechnical input.

4.0 CLOSING

The comments and recommendations presented in this report are based on our present understanding of the project. It is recommended that geotechnical engineering involvement be maintained during planning and design so that alternatives are selected with the full appreciation of subsurface conditions.

The present geotechnical investigation consisted of a series of widely-spaced boreholes and cone penetration tests, while the geophysical survey consisted of data recorded on lines at variable spacing. The results and recommendations presented are based on interpolation between the test locations. Conditions different from those at the test locations may occur and this should be considered in planning and design for the project.

This report was written by W.R. Sutherland, P.Eng., and reviewed by S.G. MacNeill, P.Eng. We trust that the report contains the information required at this time. We are available at your convenience to discuss the contents of the report or any other geotechnical aspects of the project.

Respectfully submitted,

JACQUES, WHITFORD AND ASSOCIATES LIMITED

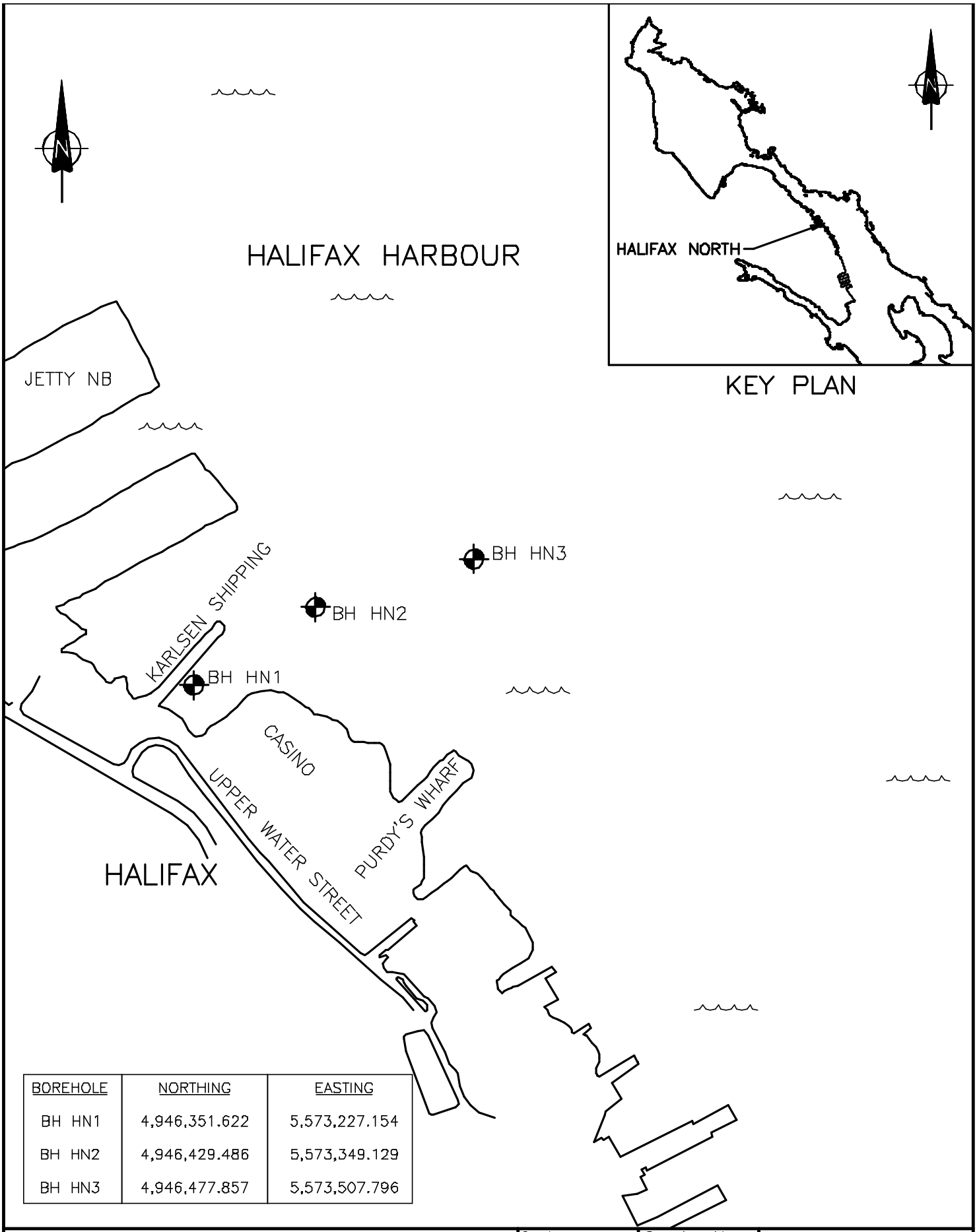
William R. Sutherland, M.Eng., P.Eng.

S. Gregory MacNeill, P.Eng.

APPENDIX 1

HALIFAX NORTH

Drawing No. 14417-1 - Borehole Locations
Symbols and Terms Used on Borehole Records
Borehole Records
Grain Size Analysis
Plasticity Chart
Clear Stone Specification (NSDOT&PW)



BOREHOLE	NORTHING	EASTING
BH HN1	4,946,351.622	5,573,227.154
BH HN2	4,946,429.486	5,573,349.129
BH HN3	4,946,477.857	5,573,507.796

HALIFAX REGIONAL MUNICIPALITY

HALIFAX HARBOUR SOLUTIONS

HALIFAX NORTH

BOREHOLE LOCATIONS

Scale:	Drawing No.:
1 : 5 000	14417–1

Date:	Dwn. By:	App'd:
99/09/21	V.A.H.	

Jacques Whitford

14417-1-2.dwg 99/09/21

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil	-	mixture of soil and humus capable of supporting good vegetative growth
Peat	-	fibrous aggregate of visible and invisible fragments of decayed organic matter
Till	-	unstratified glacial deposit which may range from clay to boulders
Fill	-	any materials below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

Desiccated	-	having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	-	having cracks, and hence a blocky structure
Varved	-	composed of regular alternating layers of silt and clay
Stratified	-	composed of alternating successions of different soil types, e.g. silt and sand
Layer	-	>75 mm
Seam	-	2 mm to 75 mm
Parting	-	< 2 mm
Well Graded	-	having wide range in grain sizes and substantial amounts of all intermediate particle sizes
Uniformly Graded	-	predominantly of one grain size

Terminology describing soils on the basis of grain size and plasticity is based on the Unified Soil Classification System (USCS) (ASTM D-2488). The classification excludes particles larger than 76 mm (3 inches). This system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%

The standard terminology to describe cohesionless soils includes the compactness (formerly "relative density"), as determined by laboratory test or by the Standard Penetration Test 'N' - value.

Relative Density	'N' Value	Compactness %
Very Loose	<4	<15
Loose	4-10	15-35
Compact	10-30	35-65
Dense	30-50	65-85
Very Dense	>50	>85

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests, or occasionally by standard penetration tests.

Consistency	Undrained Shear Strength		'N' Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25-0.5	12.5-25	2-4
Firm	0.5-1.0	25-50	4-8
Stiff	1.0-2.0	50-100	8-15
Very Stiff	2.0-4.0	100-200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Rock Quality Designation (RQD)

The classification is based on a modified core recovery percentage in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. RQD was originally intended to be done on NW core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from *in situ* fractures.

RQD	ROCK QUALITY
90-100	Excellent, intact, very sound
75-90	Good, massive, moderately jointed or sound
50-75	Fair, blocky and seamy, fractured
25-50	Poor, shattered and very seamy or blocky, severely fractured
0-25	Very poor, crushed, very severely fractured

Terminology describing rock mass:

Spacing (mm)	Bedding, Laminations, Bands	Discontinuities
2000-6000	*Very Thick*	*Very Wide*
600-2000	*Thick*	*Wide*
200-600	*Medium*	*Moderate*
60-200	*Thin*	*Close*
20-60	*Very Thin*	*Very Close*
<20	*Laminated*	*Extremely Close*
<6	*Thinly Laminated*	

Strength Classification	Uniaxial Compressive Strength (MPa)
Very Low	1-25
Low	25-50
Medium	50-100
High	100-200
Very High	>200

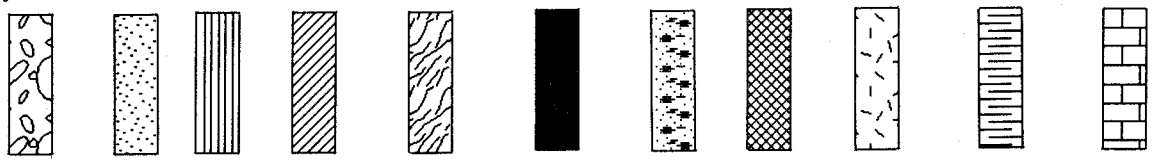
Terminology describing weathering:

Slight - Weathering limited to the surface of major discontinuities. Typically iron stained.

Moderate	-	Weathering extends throughout rock mass. Rock is not friable.
High	-	Weathering extends throughout rock mass. Rock is friable.

STRATA PLOT

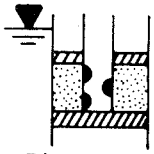
Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



Boulders, Cobbles, Gravel | Sand | Silt | Clay | Organics | Asphalt | Concrete | Fill | Igneous Bedrock | Metamorphic Bedrock | Sedimentary Bedrock

WATER LEVEL MEASUREMENT

Borehole or Standpipe



Piezometer

SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits.

N - VALUE

Numbers in this column are the results of the Standard Penetration Test: the number of blows of a 140 pound (64 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (305 mm) into the soil. For split spoon samples where insufficient penetration was achieved and 'N' values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75).

OTHER TESTS

S	Sieve analysis
G_s	Specific gravity of soil particles
k	Permeability (cm/sec)
	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer
H	Hydrometer analysis
γ	Unit weight
C	Consolidation
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct shear
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$; the index corrected to a reference diameter of 50 mm)

BOREHOLE RECORD

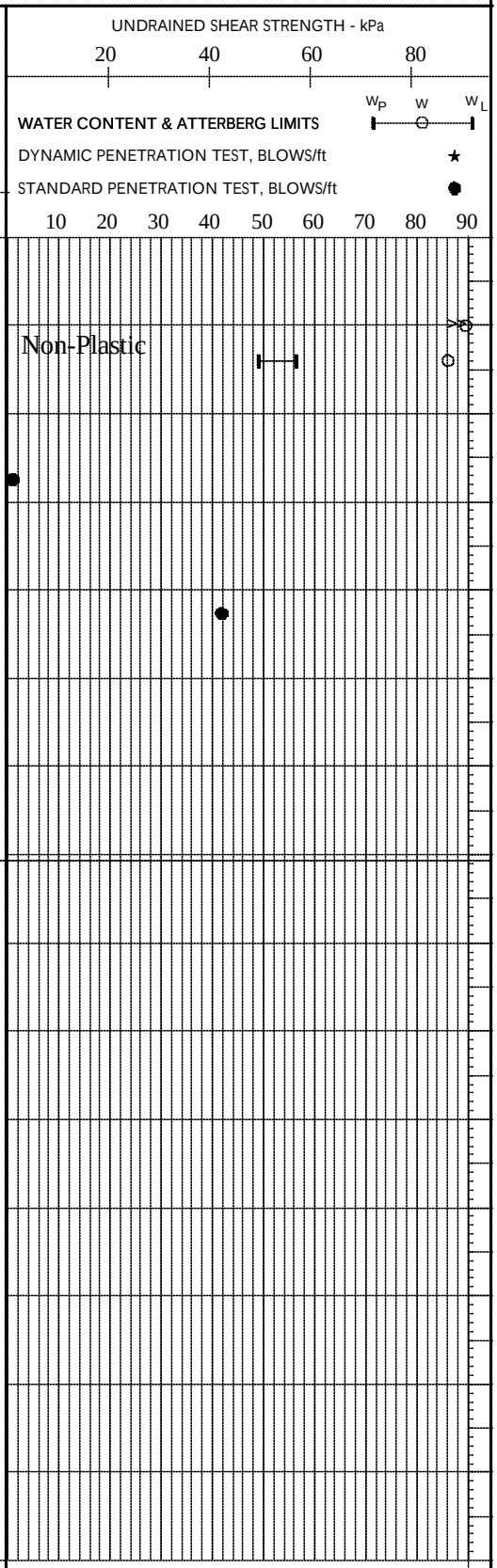
NORTHING: **4946351.622**
EASTING: **5573227.154**
HN 1

CLIENT **HALIFAX REGIONAL MUNICIPALITY** PROJECT No. **14417**

LOCATION **HALIFAX NORTH** BH SIZE **B**

DATES: BORING **99/08/21** WATER LEVEL **-** DATUM **CHART**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR-RQD %	OTHER TESTS
0	-4.6	Very soft black ORGANIC SANDY SILT			GRAB				S
1					SS	1	600	Wt. of Rods	
2									
3	-8.14				SS	2	450	1	
4		Dense to very dense olive grey silty sand with some gravel: TILL			SS	3	150	42	
5	-9.78								
6		Grey moderately weathered to fractured SLATE			BQ	4	66%	RQD 53%	
7	-11.70				BQ	5	94%	67%	
8		End of Borehole							
9									
10									
11									
12									
13									
14									
15									



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BOREHOLE RECORD

NORTHING: **4946429.486**
EASTING: **5573349.129**
HN 2

CLIENT **HALIFAX REGIONAL MUNICIPALITY** PROJECT No. **14417**

LOCATION **HALIFAX NORTH** BH SIZE **B**

DATES: BORING **99/08/26** WATER LEVEL **-** DATUM **CHART**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY	SAMPLES N-VALUE OR-RQD %	OTHER TESTS
							mm		
0	-15.9	Very soft black ORGANIC SILT			GRAB				
1									
2					SS	1A		Wt. of Rods	
3									
4		Grey brown organic silt with wood pieces and seashells			SS	1B	500	1/1200	
5	-21.12				SS	2	50	Refusal	
6		Dense to very dense olive green silty SAND with quartzite cobbles and boulders (150mm to 200mm size)			SS	3	75	Refusal	
7					SS	4	0	Refusal	
					BQ	5	150	-	
8	-24.44				BQ	6	500		
9		Very severely fractured SLATE			BQ	7	50%	RQD 0%	
	-25.66				BQ	8	100%	0%	
					BQ	9	100%	0%	
10		End of Borehole			BQ	10	50%	0%	
11									
12									
13									
14									
15									

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80
WATER CONTENT & ATTERBERG LIMITS w_P w w_L
DYNAMIC PENETRATION TEST, BLOWS/ft ★
STANDARD PENETRATION TEST, BLOWS/ft ●
10 20 30 40 50 60 70 80 90

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BOREHOLE RECORD

NORTHING: **4946477.857**
EASTING: **5573507.796**
HN 3

CLIENT **HALIFAX REGIONAL MUNICIPALITY** PROJECT No. **14417**

LOCATION **HALIFAX NORTH** BH SIZE **B**

DATES: BORING **99/08/25** WATER LEVEL **-** DATUM **CHART**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY	SAMPLES N-VALUE OR-RQD %	OTHER TESTS
							mm		
0	-23.6								
	-24.23	Very soft black ORGANIC SILT			SS	1A	300	Wt. of Rods	
1	-24.84	Compact to dense grey brown sandy silt/silty sand			SS	1B	200	26	S
		Very severely fractured grey SLATE			BQ	2	50%	RQD 0%	
2	-26.15				BQ	3	100%	0%	
		End of Borehole							
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80
WATER CONTENT & ATTERBERG LIMITS w_P w w_L
DYNAMIC PENETRATION TEST, BLOWS/ft ★
STANDARD PENETRATION TEST, BLOWS/ft ●
10 20 30 40 50 60 70 80 90

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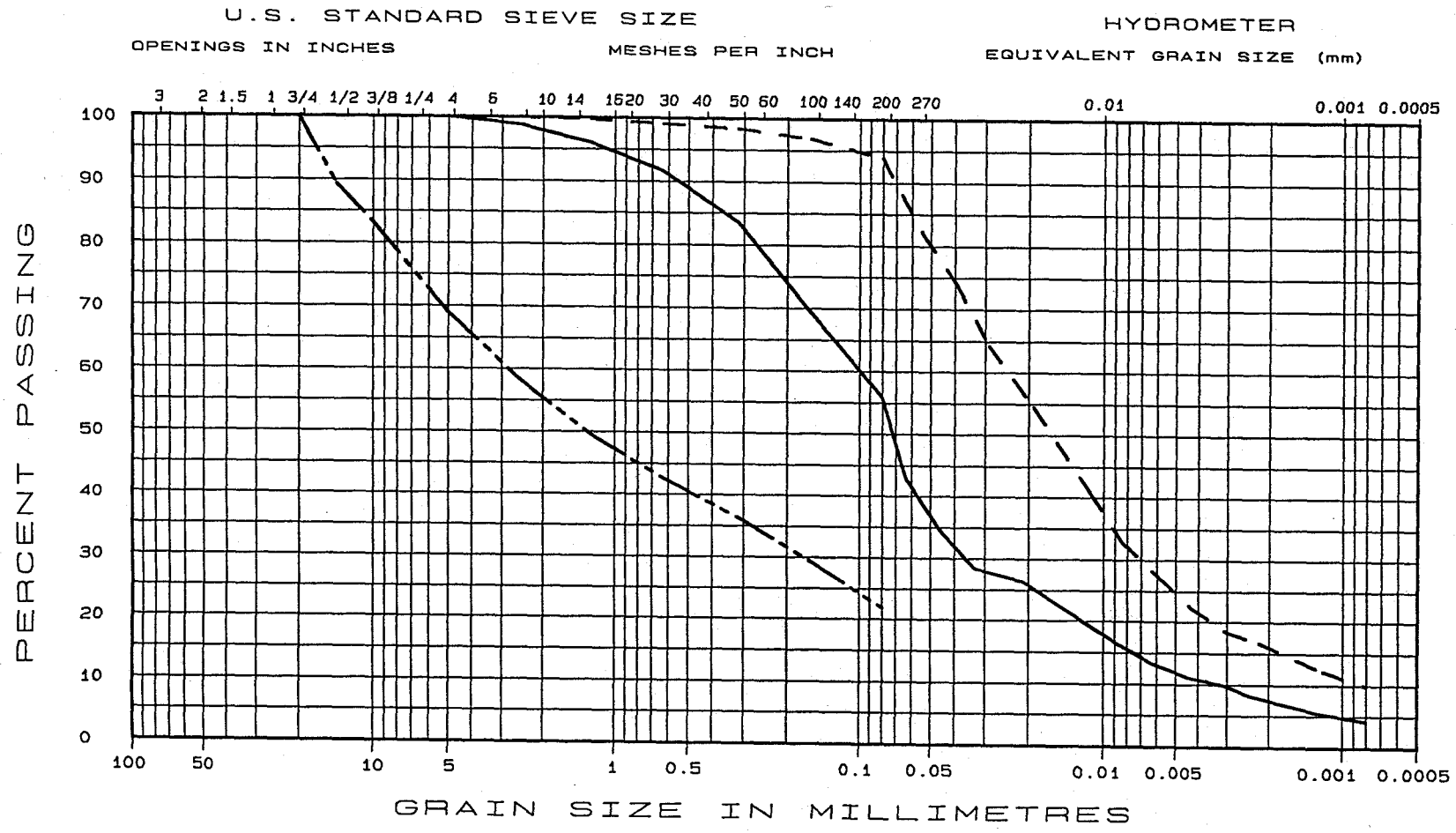
14417



GRAVEL		SAND			SILT & CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification

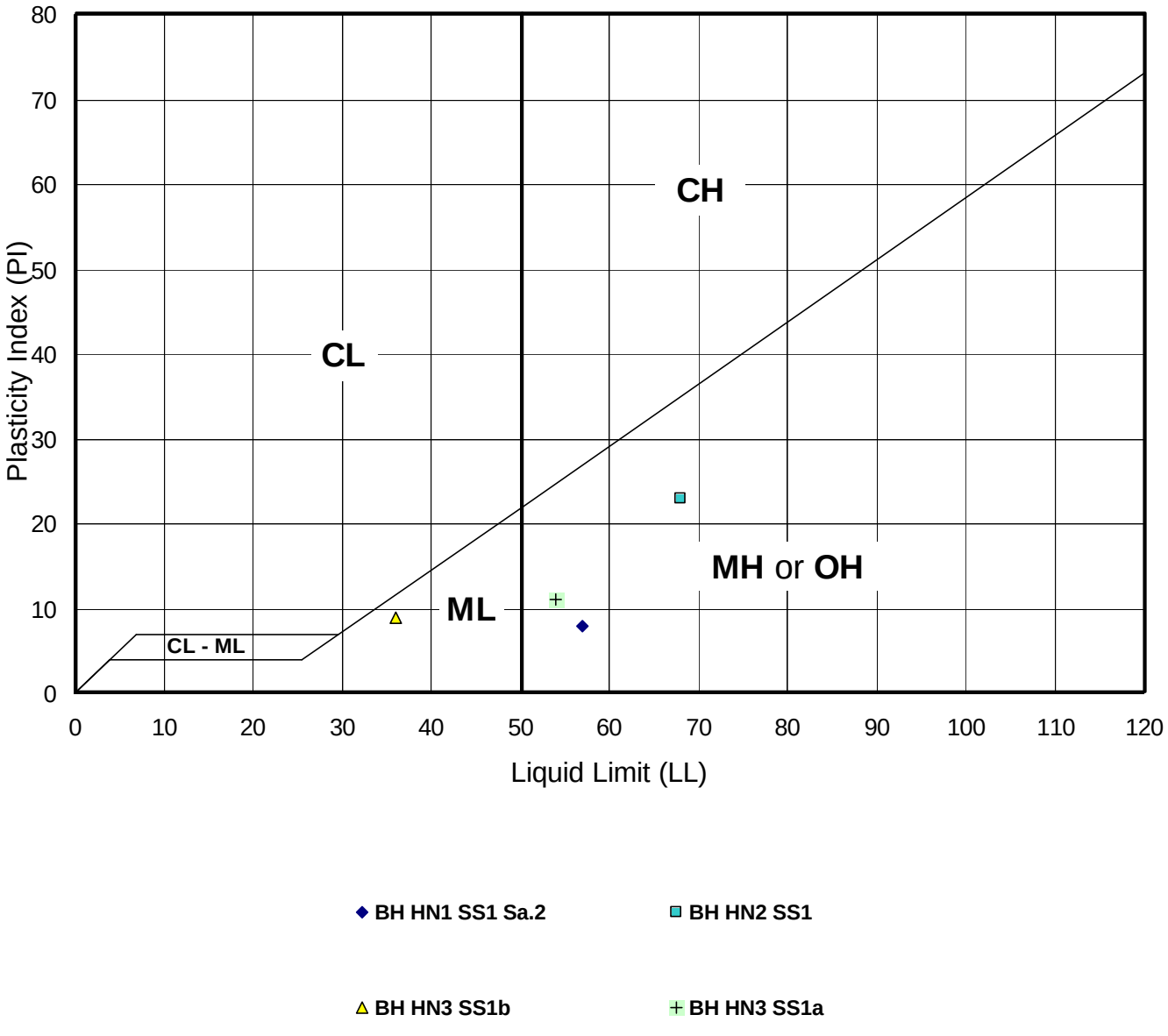
	LOCATION	SAMPLE	DEPTH	SAMPLE DESCRIPTION
———	HN1	SS1-1	0.0-2.0m	Sandy silt (OH)
— — —	HN2	SA1	3.0-4.0m	Silt (OH)
———	HN3	SS1B	0.6-1.2m	Silty sand with gravel (SM)

FIGURE

Halifax Harbour Solutions

Halifax North

Plasticity Chart



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14417

FIGURE 1

SECTION 4 - CLEAR STONE

1.0 DESCRIPTION

Clear Stone C1 to C5 shall be composed of crushed or uncrushed, screened rock. Clear Stone is normally specified for use as drainage enhancement, flow checks or slope protection.

2.0 REFERENCES

All reference standards shall be current issue or latest revision at the first date of tender advertisement. This specification refers to the following standards, specifications or publications:

- ASTM C 117, Test Method for Material Finer Than 75 µm Sieve in Mineral Aggregate by Washing
- ASTM C 127, Test Method for Specific Gravity and Absorption of Coarse Aggregate
- ASTM C 136, Test Method for Sieve Analysis of Fine and Coarse Aggregates
- ASTM D 4318, Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils
- DOT&PW TM-1, Test Method for the Resistance of Coarse Aggregate to Degradation in the Micro-Deval Apparatus
- Division 3 Section 5, Compaction of Gravels
- Division 1 Section 4, General Provisions

3.0 SUBMISSIONS AND DESIGN REQUIREMENTS

4.0 MATERIALS

Materials for Clear Stone shall consist of hard, durable stone particles, in conformance with this specification.

4.1 Gradation Requirements. The stone shall be free from flat, elongated or other objectionable pieces and shall be approved by the Engineer prior to utilization. The gravels shall be tested in accordance with ASTM C 117 and C 136 and shall fulfil the gradation requirements listed in Table 3.4.1.

4.2 Physical Properties. Clear Stone aggregates shall conform to the properties listed in Table 3.4.2.

5.0 CONSTRUCTION METHODS

Crushing, if required, screening and transporting of materials shall be performed by such methods that a uniform grade of material will be placed on the roadbed. If directed by the Engineer Clear Stone shall be compacted as detailed in Division 3 Section 5 except the Control Strip may have to be modified as directed by the Engineer.

Table 3.4.1 - Gradation

Sieve Size, mm	Percent Passing				
	C1	C2	C3	C4	C5
250	100				
200		100	100		
150	20-35	90-100	90-100		
112		0-10	20-35	100	
80			0-20	90-100	
56	0-10				
40					
28				0-10	100
20			0-10		90-100
14					
10					0-40
5					0-10

Table 3.4.2 - Physical Properties

Property	Test Method	Class C1 to C5
Absorption, % max.	ASTM C 127	1.75
Plasticity Index	ASTM D 4318	0
Micro-Deval, % max.	DOT&PW TM-1	25

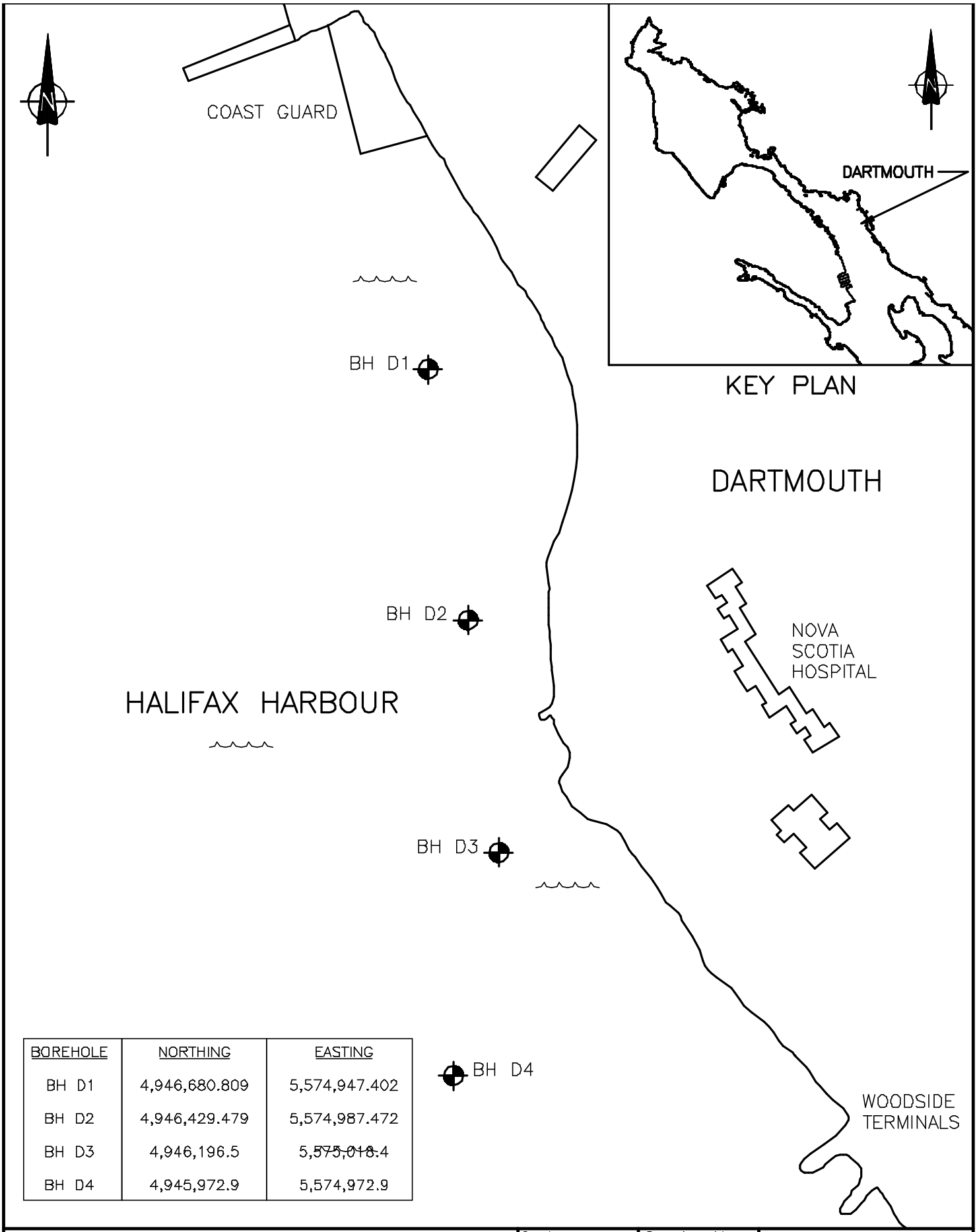
Stockpiles shall be built in layers not to exceed 1 m in depth. Each layer shall be completed before beginning the next layer. Materials delivered to the stockpile in trucks shall be uniformly spot-dumped and the stockpile built as specified above. Coning of stockpiles shall not be permitted..

6.0 QUALITY CONTROL / QUALITY ASSURANCE

APPENDIX 2

DARTMOUTH (COAST GUARD)

Drawing No. 14417-2
Borehole Records
Grain Size Analysis
Plasticity Chart



BOREHOLE	NORTHING	EASTING
BH D1	4,946,680.809	5,574,947.402
BH D2	4,946,429.479	5,574,987.472
BH D3	4,946,196.5	5,575,018.4
BH D4	4,945,972.9	5,574,972.9

14417-1-2.dwg 99/09/21

HALIFAX REGIONAL MUNICIPALITY

HALIFAX HARBOUR SOLUTIONS

DARTMOUTH

BOREHOLE LOCATIONS

Scale:	Drawing No.:
1 : 5 000	14417-2

Date:	Dwn. By:	App'd:
99/09/21	V.A.H.	

Jacques Whitford

BOREHOLE RECORD

NORTHING: **4946680.809**
EASTING: **5574947.402**
D 1

CLIENT **HALIFAX REGIONAL MUNICIPALITY** PROJECT No. **14417**

LOCATION **DARTMOUTH** BH SIZE **B**

DATES: BORING **99/08/27** WATER LEVEL **-** DATUM **CHART**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY	SAMPLES N-VALUE OR-RQD %	OTHER TESTS
	-8.5						mm		
0		Very soft grey/brown ORGANIC SILT			SS	1	300	Wt. of Rods	
1	-9.66	Compact to very dense brown silty sand, with some gravel; occasional cobbles and boulder: TILL			BQ	2	150	-	
2					SS	3	250	33	
3					BQ	4	525	-	
					SS	5	125	93/250	
4					SS	6	50	-	
					SS	7	200	100/225	S
5	-13.62	End of Borehole							
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/ft ★
STANDARD PENETRATION TEST, BLOWS/ft ●
10 20 30 40 50 60 70 80 90

Non-Plastic

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BOREHOLE RECORD

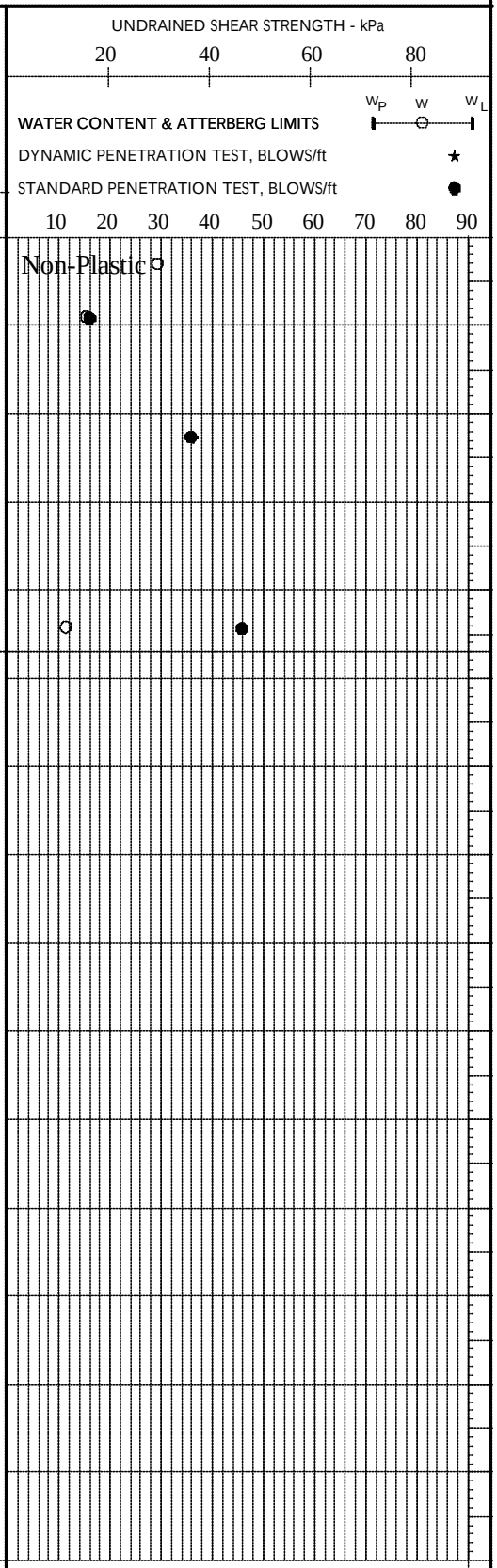
NORTHING: **4946429.479**
EASTING: **5574987.472**
D 2

CLIENT **HALIFAX REGIONAL MUNICIPALITY** PROJECT No. **14417**

LOCATION **DARTMOUTH** BH SIZE **BW**

DATES: BORING **99/08/28** WATER LEVEL **-** DATUM **CHART**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY	SAMPLES N-VALUE OR-RQD %	OTHER TESTS
							mm		
0	-9.1								
	-9.66	Very soft black ORGANIC SILT			SS	1A	-	Grab	
1		Compact grey fine and coarse silty SAND			SS	1B	150	16	S
	-10.58								
2		Dense to very dense brown silty SAND with gravel; occasional to some cobbles and boulders			SS	2	300	36	S
3					SS	3	50	Refusal	
					BQ	4	550	-	
4		-boulder 300mm in size			SS	5	200	46	S
	-13.75								
5		End of Borehole							
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									



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BOREHOLE RECORD

NORTHING: **4946196.5**
EASTING: **5575018.4**
D 3

CLIENT **HALIFAX REGIONAL MUNICIPALITY** PROJECT No. **14417**

LOCATION **DARTMOUTH** BH SIZE **BW**

DATES: BORING **99/08/31** WATER LEVEL **-** DATUM **CHART**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR-RQD %	OTHER TESTS
0	-8.5	Very soft black to brownish grey ORGANIC SILT; some wood pieces, trace of shells			SS	1	600	Wt. of Rods	S
4	-12.83	Compact to dense grey SAND with gravel, some cobbles and boulders			SS	2	600	Wt. of Rods	S
5					BQ	3	300	-	
	-14.14				SS	4	350	18	
6		Dense to very dense greyish brown silty SAND with gravel; numerous cobbles and boulders (75 to 150mm size)			SS	5	0	Refusal	
8					SS	6	100	50/100	
					SS	7	0	50/50	
9	-17.82								
	-18.07	Grey SLATE particles			SS	8	75	50/100	
10		End of Borehole							

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80
WATER CONTENT & ATTERBERG LIMITS w_P w w_L
DYNAMIC PENETRATION TEST, BLOWS/ft ★
STANDARD PENETRATION TEST, BLOWS/ft ●
10 20 30 40 50 60 70 80 90

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BOREHOLE RECORD

NORTHING: **4945972.9**
EASTING: **5574972.9**
D 4

CLIENT **HALIFAX REGIONAL MUNICIPALITY** PROJECT No. **14417**

LOCATION **DARTMOUTH** BH SIZE **BW**

DATES: BORING **99/09/01** WATER LEVEL **-** DATUM **CHART**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY	SAMPLES N-VALUE OR-RQD %	OTHER TESTS
	-19.8						mm		
0		Very soft black to grey brown ORGANIC SILT with trace of shells			SS	1	450	Wt.of Rods	
4	-24.23								
5		Compact to dense grey silty SAND with gravel			SS	2	150	14	
					SS	3	275	44	S
6									
7	-26.76				SS	4	125	34	
		Dense brown fine SAND, clay and silt laminations			SS	5	600	42	S
8									
9		- thin clay laminations			SS	6	600	54	S
10		- silt with sand and clay laminations			SS	7	600	36	
11									
	-31.49				SS	8	200	46	S
12		Grey SLATE pieces with interbedded silt and sand			SS	9	125	100/175	
	-32.55								
13		End of Borehole							
14									
15									

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80
WATER CONTENT & ATTERBERG LIMITS w_P w w_L
DYNAMIC PENETRATION TEST, BLOWS/ft
STANDARD PENETRATION TEST, BLOWS/ft
10 20 30 40 50 60 70 80 90

Non-Plastic

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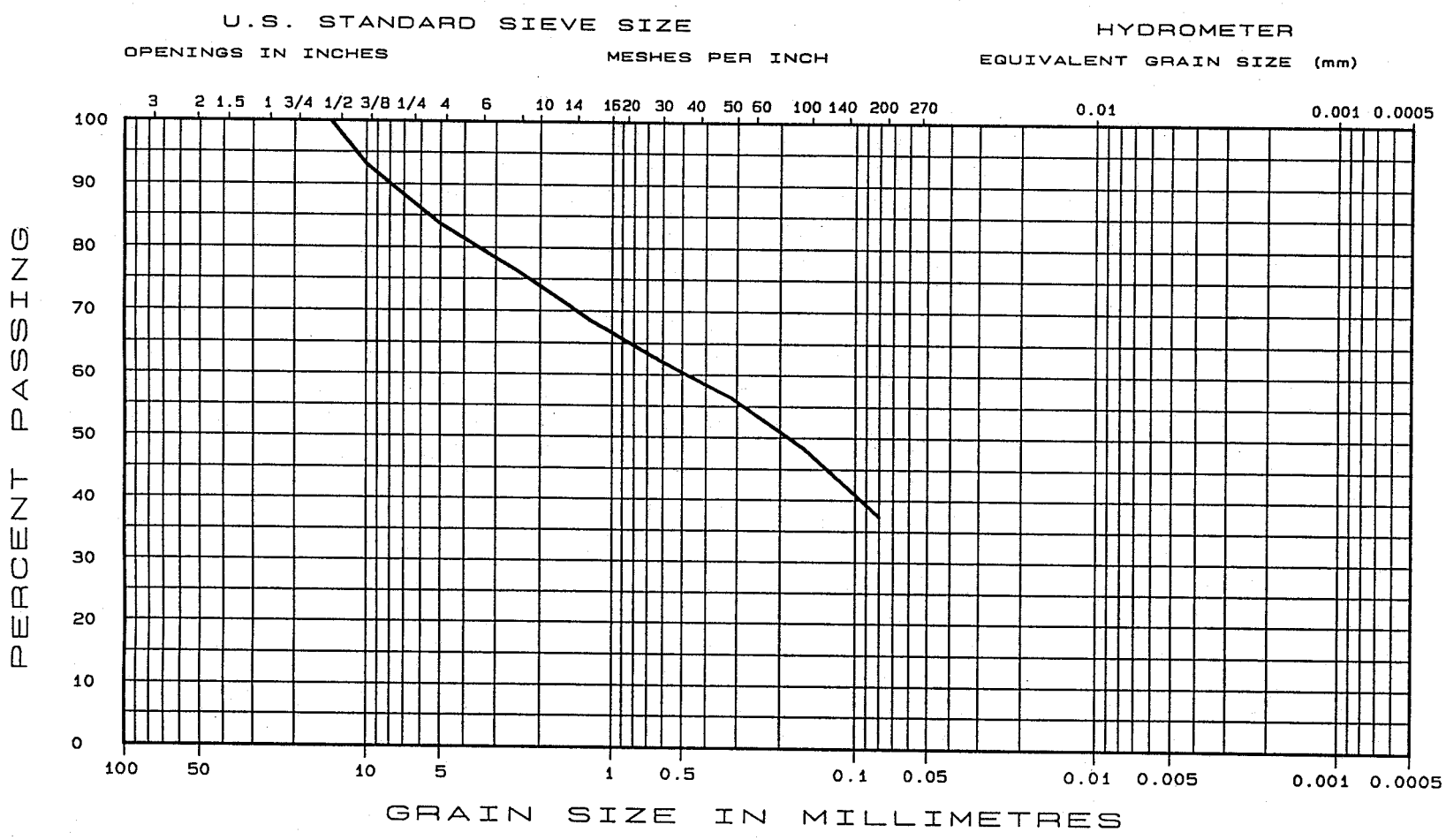
14417



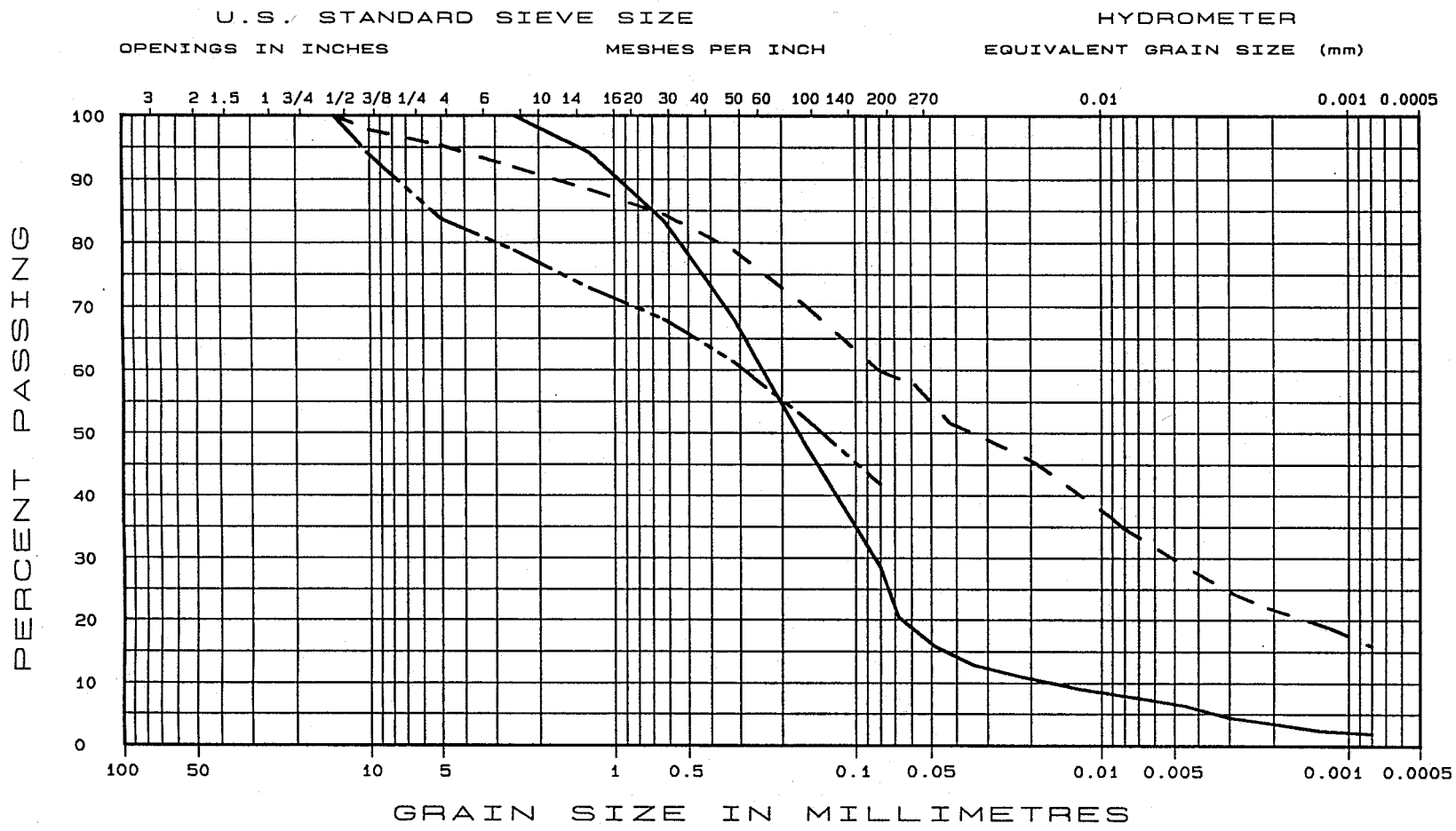
GRAVEL		SAND			SILT & CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification

	LOCATION	SAMPLE	DEPTH	SAMPLE DESCRIPTION
———	D1	SS7	4.3-4.65m	Silty sand with gravel (SM)

FIGURE

14417



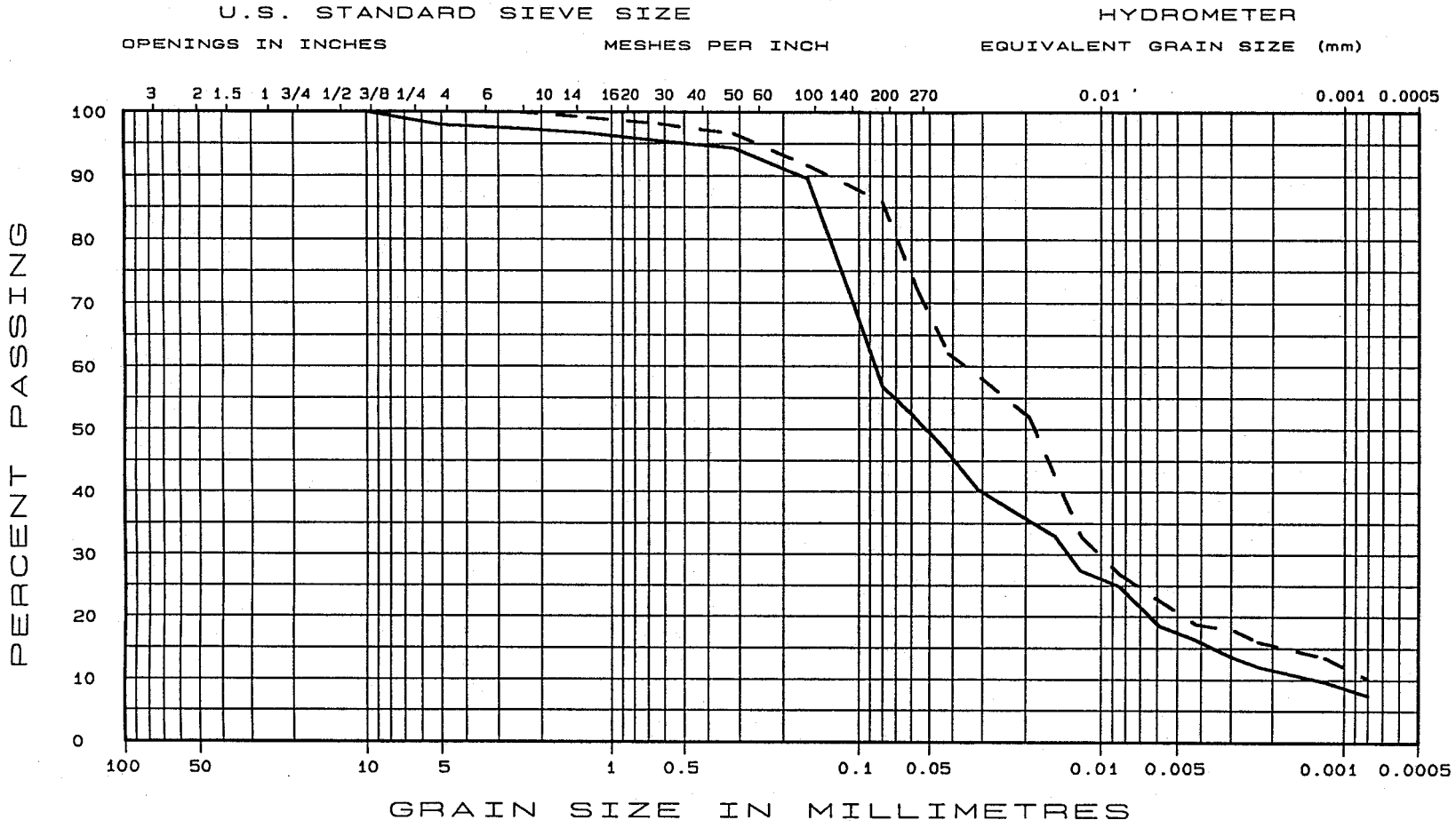
GRAVEL		SAND			SILT & CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification

	LOCATION	SAMPLE	DEPTH	SAMPLE DESCRIPTION
———	D2	SS1	0.90-1.22m	Silty sand (SM)
— — —	D2	SS2	1.96-2.57m	Sandy Silt (MH)
—·—	D2	SS5	4.17-4.78m	Silty sand with gravel (SM)

FIGURE

14417



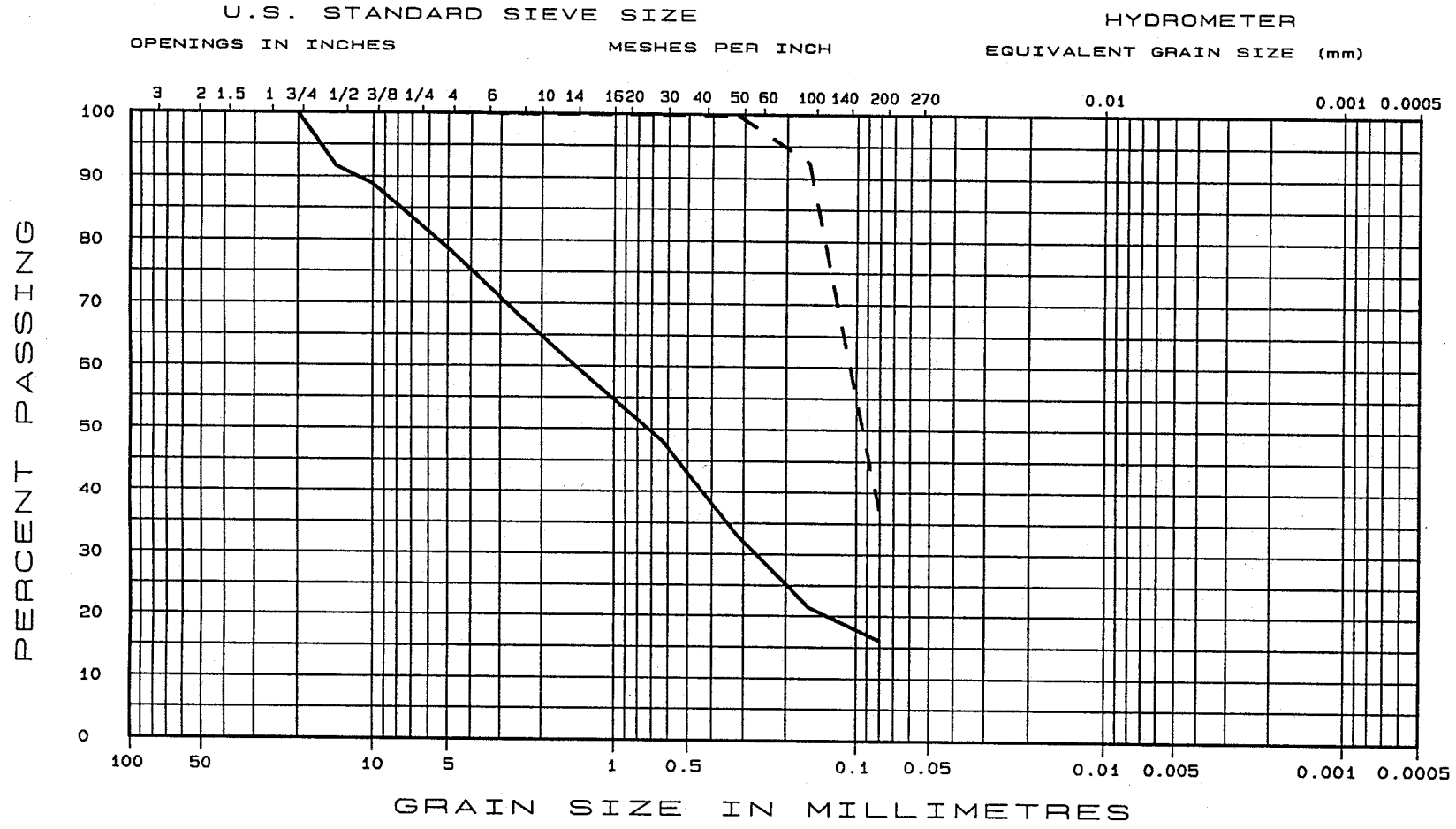
GRAVEL		SAND			SILT & CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification

	LOCATION	SAMPLE	DEPTH	SAMPLE DESCRIPTION
———	D3	SS1	0.0-3.68m	Organic silt (OH)
— — —	D3	SS2	3.68-4.29m	Organic silt (OH)

FIGURE

14417



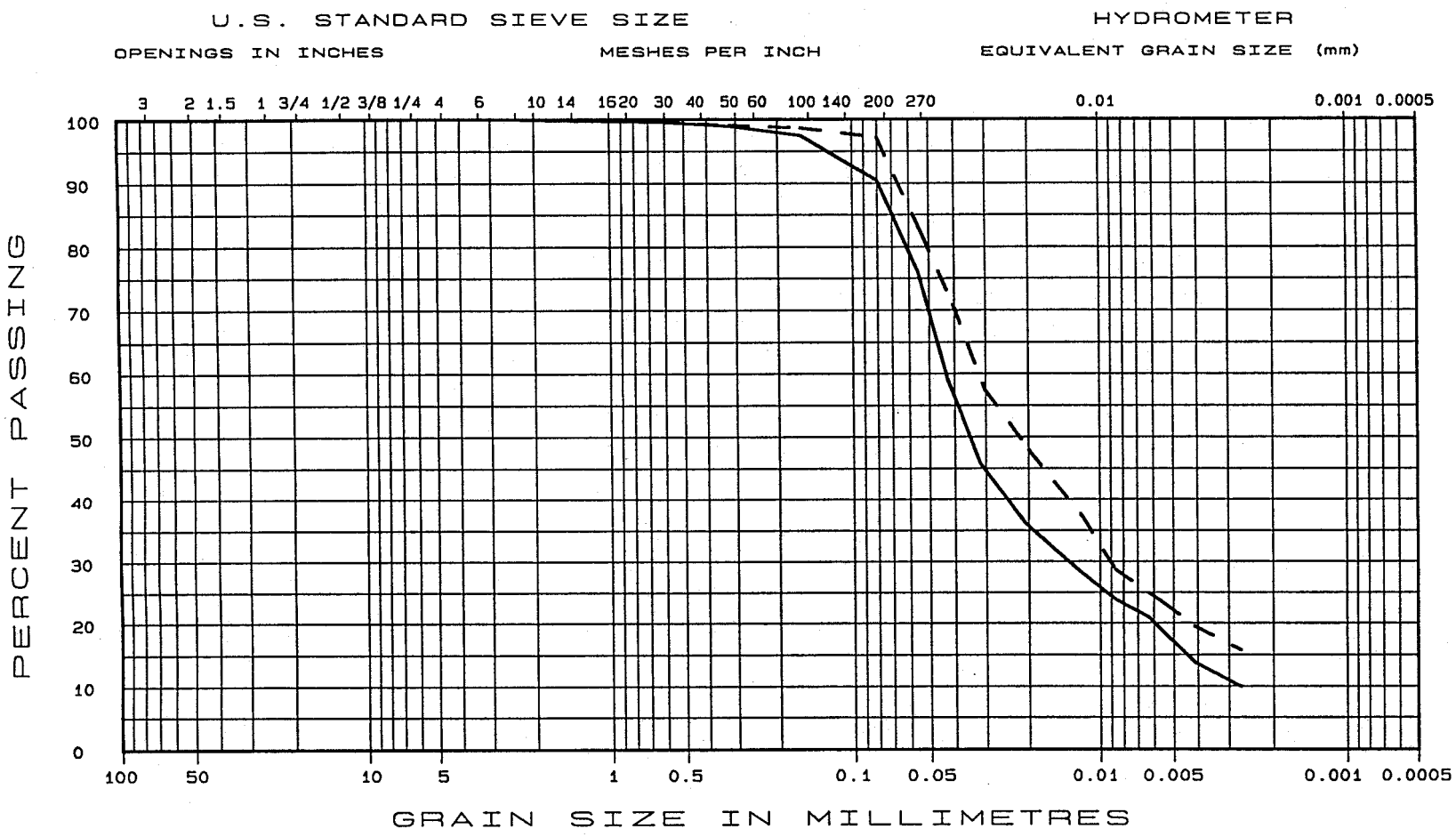
GRAVEL		SAND			SILT & CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification

	LOCATION	SAMPLE	DEPTH	SAMPLE DESCRIPTION
———	D4	SS3	5.18-5.79m	Silty sand with gravel (SM)
— — —	D4	SS5	7.01-7.62m	Silty, clayey sand (SM-SC)

FIGURE

14417



GRAVEL		SAND			SILT & CLAY
Coarse	Fine	Coarse	Medium	Fine	

Unified Soil Classification

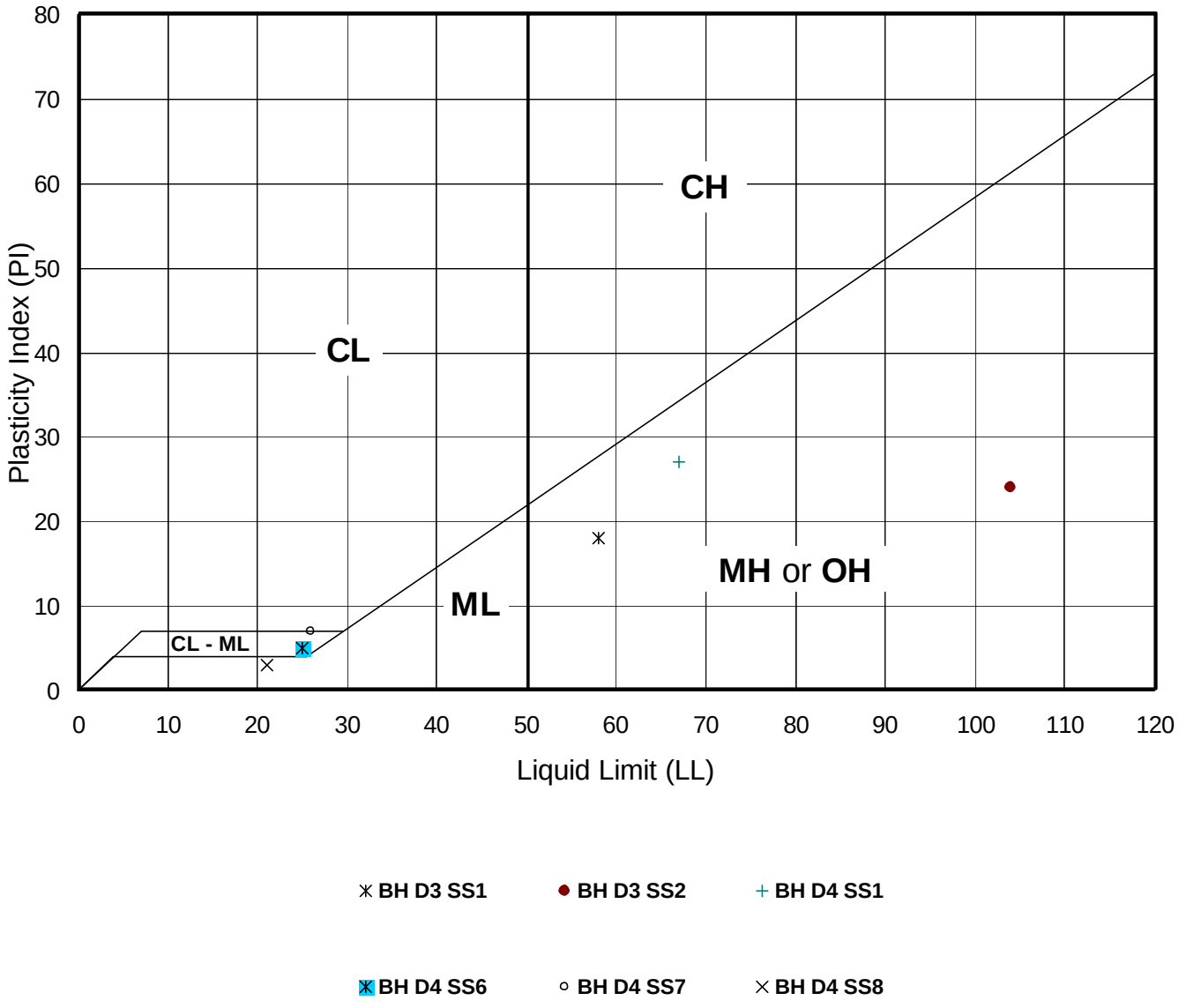
	LOCATION	SAMPLE	DEPTH	SAMPLE DESCRIPTION
———	D4	SS6	8.53-9.14m	Clayey silt (CL-ML)
— — —	D4	SS8	11.20-11.81m	Silt (ML)

FIGURE

Halifax Harbour Solutions

Dartmouth Site

Plasticity Chart



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