

**FOUNDATION INVESTIGATION AND
DESIGN REPORT
PROPOSED CULVERT EXTENSIONS/
REPLACEMENTS
HWY 12 WIDENING
FROM SOUTH JUNCTION OF HWY 48 TO
NORTH JUNCTION OF HWY 48
W.P. 611-89-00
DISTRICT 7 - DURHAM
CENTRAL REGION
SITES 22-411C AND 22-412C**

Prepared for:

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Project: SPT 1024C
March 2003

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1.0 INTRODUCTION

As part of the proposed widening of Hwy 12 between the south and north junctions of Hwy 48, the extension or replacement of a total of seven (7) culverts is proposed. Details of the culvert extensions/replacements are shown below:

Location	Type	Extension/Replacement	Site No.
Hwy 48 N, 91m E of Hwy 12	Concrete Open 1.83x0.91m	11m Extension	-
Sta 21+066.0	Concrete Open 1.80x0.90m	New 41m	-
Sta 20+283.3	Concrete Open 1.22x0.61m	15m Extension	-
Sta 19+764.9	Concrete Box 3.65x1.85m	21m Extension	22-412C
Sta 18+233.0	Concrete Box 1.83x1.52m	16m Extension	-
Sta 13+573.8	Concrete Box 3.05x1.22m	15m Extension	22-411C
Sta 9+215.0	Concrete Box 2.44x1.20m	6m Extension	-

Shaheen & Peaker Limited (S&P) was retained by SNC-Lavalin Engineers and Constructors Inc. (SLE&C) to carry out a foundation investigation for the widening of two 3-span

structures to be located at Beaver River and White's Creek, and for the extensions/replacements of the seven (7) culverts listed above.

This report presents the factual foundation investigation results for the extension/replacement of the culverts. Details of the foundation investigation for the two bridge structure widenings are reported under separate cover. The work was performed in accordance with Consultant Assignment Agreement No. 2005-A-000341.

2.0 SITE DESCRIPTION AND PHYSIOGRAPHY

The culvert sites are located along Hwy 12 between Sta 9+205.0 and Sta 21+066.0. Exception to this is the northernmost culvert within the limits of this contract, which is located on the North Junction of Hwy 48, approximately 91 m east of Hwy 12.

The project extends from south to north, from the northern part of the Township of Brock to the northern part of the Township of Thorah. The area is underlain by the Trenton Limestone Formation comprising the Sherman Falls Bed at the south and the Cobourg Bed at the north. This formation emerged during the Middle Ordovician Period of the Paleozoic Era. It contains a high percentage of calcium carbonate and a low percentage of magnesium carbonate.

The soil deposits overlying the bedrock within the approximate southern half of the project consist of stoney, calcareous sand and silt tills with localized areas of stonefree calcareous clay. In the middle of the project site, areas of broadly graded, calcareous sand and gravel deposits are present. Within the northern reaches of the project, the dominant soil deposits are generally stonefree calcareous silt and clay.

3.0 METHOD OF INVESTIGATION

The scope of the investigation was to consist of drilling one (1) borehole at each of the 6 culvert extension sites and two (2) boreholes at the culvert replacement (new culvert) site. Due to the presence of overhead cables, the borehole scheduled at the east end of the new culvert site (Sta 21+066) had to be located at a distance of approximately 8 m west from the scheduled location. In view of this, a third borehole (C3) was drilled by means of a hand auger at the east end of the new culvert alignment. All other boreholes were drilled using a track-mounted power auger drill rig at the locations shown on Drawings 1 to 7 inclusive attached to this report in Appendix A. The boreholes were laid out in the field by S&P and were surveyed by SLE&C. The elevations and coordinates, shown on the Record of Borehole sheets, were provided to us by Vujeva Surveyors Ltd. on behalf of SLE&C.

A senior field technician from our office supervised the drilling of the boreholes and logged the soil profile. In the machine-drilled boreholes, soil samples were taken by the Standard Penetration Test (SPT) Method at 0.75 m intervals of depth in the upper 6.0 m, and at 1.5 m intervals below. Where the consistency of cohesive soils permitted (i.e. Boreholes C1 and

C2), in-situ field vane tests were performed to measure the undisturbed and remoulded undrained shear strength of these deposits. From Borehole C2, a relatively undisturbed soil sample was obtained by pressing a thin-walled soil sampler (TW) into the soil by hydraulic pressure for laboratory testing. Test results are plotted on the appropriate Record of Borehole sheets of Appendix A.

Borehole C8 encountered bedrock at relatively shallow depth (2.0 m). Drilling of this hole was then continued by rock coring using N size wireline diamond coring equipment, recovering 47.6 mm (NQ) diameter rock cores. The recovered cores were visually identified in the field and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and Fracture Index (FI) of the rock cores were recorded, as well as the degree of weathering of the rock materials.

From Borehole C3, which was advanced by hand augering to a depth of 1.8 m, only auger samples were recovered.

After completion of the drilling, standpipe type piezometers were installed in all boreholes, except Borehole C3.

The samples were visually identified in the field and transported to our laboratory, where they were re-examined by a senior engineer. Representative samples were selected for laboratory analyses, which included natural moisture contents, consistency (Atterberg limits)

(12) and particle size distribution (18). The results of the laboratory tests are summarized on the Record of Borehole sheets (Appendix A). The grading curves are plotted on Figures 1 to 6 and the results of the Atterberg limits tests are shown on Figures 7 and 8 attached to this report in Appendix B. On the TW sample obtained from Borehole C2, an unconsolidated undrained (quick) triaxial compression test was performed.

4.0 SUBSURFACE CONDITIONS

The boreholes encountered a variety of glacio-lacustrine, glacio-fluvial and glacial till deposits of variable texture and gradation.

Details of the subsurface conditions are presented on the individual Record of Borehole sheets. A brief description of the soil stratification and the relevant properties of the soil strata encountered at each culvert location are given in the following paragraphs.

4.1 Culvert at Hwy 48N, 91 m East of Hwy 12 (Borehole C2)

Below a 450 mm± thick **topsoil** layer, Borehole C2 encountered a deposit of firm to stiff **silty clay**, which extends to a depth of 10.8 m below the existing grade. This stratum is underlain by an approximately 4.4 m thick compact to dense **sand and silt**, followed by compact to dense **sand and silt till**. At a depth of 18.3 m, **another sand and silt deposit** was found, which was in a very dense state of compactness and in which the borehole was terminated at a depth of 20.0 m (El. 200.4 m).

The **silty clay** is a cohesive material which is typically composed of 0 to 6% sand, 52 to 68% silt and 26 to 48% clay size particles. Typical grading curves are shown on Figure 2. Atterberg limits tests gave liquid limits between 21 and 35%, plastic limits between 13 and 20% and plasticity indices ranging from 8 to 17% (see Figure 7). These test results indicate a clay deposit of low plasticity (CL) in the Unified Soil Classification System. The measured natural moisture contents of the silty clay range between 25 and 68% and generally are near to or greater than the measured liquid limit values.

A quick undrained triaxial compression test carried out on a relatively undisturbed thin-walled (TW) sample (Sample 5) gave an undrained shear strength of 64 kPa at a strain of 6% (Figure 9 in Appendix B), while a laboratory shear vane test performed on the same sample yielded an undrained shear strength of the order of 38 kPa. In-situ field vane tests performed in the silty clay deposit gave undrained peak shear strengths between 44 and 96 kPa. These values indicate a cohesive soil of firm to stiff consistency.

The sensitivity of the material, that is the ratio of the undisturbed to remolded shear strength, varies between 2.4 and 8, showing a material of low to high sensitivity and suggesting that when disturbed, the shear strength of the clay is only between 13 to 42% of its undisturbed shear strength.

SPT 'N' values recorded in this stratum gave between 0 and 5 blows/0.3 m penetration, but typically between 0 to 2 blows/0.3 m. Contrary to the measured shear strength values, the

'N' values suggest that the silty clay has a very soft to firm consistency. We are of the opinion that the 'N' values underestimate the actual shear strength of the soil.

The cohesionless **sand and silt** deposit, which was contacted from 10.8 m (El. 209.6 m) to 15.2 m (El. 205.2 m), i.e. the upper portion, and again from 18.3 m (El. 202.1 m) to 20.0 m (El. 200.4 m) or the bottom of the borehole, is generally narrowly graded mixture of sand, silt and clay size particles. Based on grading curves shown on Figure 4, this deposit is composed of 40 to 47% sand and 53 to 60% silt and clay size particles. The natural moisture content was found to be between 14 and 18%.

Based on the 'N' values obtained from the standard penetration tests, the upper sand and silt stratum is in a compact to dense condition, while the lower section is very dense.

A cohesionless to very low plasticity **sand and silt till** was contacted, which is sandwiched in-between the upper and lower zones of the sand and silt deposit described in the preceding paragraphs. A typical grading curve of a sample from the till is shown on Figure 4. This shows that the material is broadly graded and typically contains 7% gravel, 43% sand, 35% silt and 15% clay size particles. The natural moisture contents of the two samples taken from this unit were found to be 9 and 13%. SPT 'N' values of 14 and 34 blows per 0.3 m of penetration suggest a compact to dense condition.

The position of the **groundwater level** was observed in the uncased borehole during and shortly after drilling and in the piezometer installed to a depth of $16.8 \pm m$ below the ground surface. The water level on June 11, 2002, shortly after drilling, was found at a depth of 0.9 m below the ground surface. During the following two days after installation of the piezometer, the groundwater level was measured and found at depths of 11.5m (El. 208.9 m) and 8.5 m (El. 211.9 m). On June 22, 2001, the groundwater level was observed at a depth of 0.7 m below the ground surface or at El. 219.7 m, while on July 29, 2002 the piezometric groundwater level was found at a depth of 0.5 m below the ground surface (El. 219.9 m). These observations are shown on the Record of Borehole sheet. It should, however, be pointed out that the groundwater levels are subject to seasonal fluctuations and in response to major weather events.

4.2 New Culvert at Sta 21+066 (Boreholes C1, C3 and C4)

As shown on Drawing No. 2, three (3) boreholes (C1, C3 and C4) were put down at this location. Due to the presence of overhead cables at the east end of the proposed new culvert, Borehole C1 was drilled on the east (northbound) shoulder of Hwy 12. To obtain information on the subsurface conditions existing near the east end of the new culvert, a shallow, 1.8 m deep, borehole (Borehole C3) was advanced by a hand auger, yielding disturbed auger samples for identification.

Below 300 to 750 mm of topsoil (Boreholes C3 and C4) or a 1.8 m thick layer of fill (Borehole C1), the boreholes encountered a 2.4 to 2.8 m thick layer of firm silty clay. The

silty clay is underlain by glacial till of sandy clayey silt (hard), silty sand (very dense) or sand and silt (loose) texture. Refusal to augering on the presumed surface of the bedrock was met at between El. 225.5 and 225.4 m, or 5.3 and 3.7 m depths in Boreholes C1 and C4, respectively.

The **fill** consists of a heterogenous mixture of sand and clayey silt soils. A particle size analysis performed (Figure 1) shows that it is composed of 4% gravel, 51% sand and 45% soil fines (particles smaller than 75 microns). The natural moisture content was found to be between 13 and 15%. Standard penetration tests gave 'N' values of 8 blows/0.3 m penetration, suggesting that the fill is in a loose state of compactness.

The **cohesive silty clay** in Borehole C3 contains rootlets and is organic stained to a depth of 1.2 m. Elsewhere, this stratum is inorganic. A particle size analysis carried out on Sample 4 obtained from Borehole C1 shows that the silty clay is composed of 3% sand, 69% silt and 28% clay size particles. The results of this analysis are plotted on Figure 2, Appendix B. Atterberg limits tests gave liquid limits between 25 and 27%, plastic limits of 15 to 20% and plasticity indices of 7% to 10%. These indicate a silty clay of low plasticity (CL). The natural moisture content is generally greater than the liquid limit and was found to be between 25 and 51%. An in-situ field vane test, performed in Borehole C1 at a depth of approximately 3.7 m below the ground surface, gave an undrained shear strength of 110 kPa and sensitivity of 3.3, suggesting a very stiff consistency and low sensitivity. N-values of 4 to 7 blows/0.3 m penetration recorded in this stratum indicate only a firm

consistency.

The **sandy clayey silt till** in Borehole C1 is about 0.3 m thick. This is a cohesive material and has a hard consistency.

The **cohesionless silty sand** deposit, found in Borehole C1 at a depth of 4.9 m, extends to the termination depth (5.3 m) of the borehole and is in a very dense condition ($N > 100$). The natural moisture content was found to be of the order of 8%.

Sand and silt till was encountered in Borehole C4, between depths of 3.2 and 3.7 m (i.e. end of the borehole). A grain size analysis carried out on the sample recovered from this deposit shows that the material is composed of 18% gravel, 33% sand, 33% silt and 16% clay size particles. The grading curve is shown on Figure 3. Atterberg limits tests (liquid limit of 17%, a plastic limit of 11% and a plasticity index of 6%) indicate some plasticity and a slight cohesion. However, the general behaviour of this soil is expected to be that of a granular cohesionless material. An SPT 'N' value of 6 blows/0.3 m penetration suggests a loose state of compactness.

Refusal to augering was encountered in Boreholes C1 and C4, probably on the surface of bedrock, at depths of $5.3 \pm m$ and $3.7 \pm m$, or at El. $225.5 \pm m$ and $225.4 \pm m$, respectively.

The position of the **groundwater level** was observed in the uncased boreholes during drilling in all three boreholes and in the piezometers installed in boreholes C1 and C4 thereafter. The water levels shortly after drilling were found at El. between 226.8 m and 228.1 m. Two days after the installation of the piezometers, the groundwater level in the borehole located on the east side of the proposed culvert was found to be at 228.7 m. In the borehole located at the west side of the proposed culvert, the groundwater was recorded at El. 227.1 m one day after the installation of the piezometer. On June 22, 2001, i.e. 9 days later, the groundwater levels were observed at depths of 0.7 and 0.3 m below the ground surface or at El. 230.1 m and 228.8 m in Boreholes C1 and C4 respectively. On July 29, 2002, the piezometric groundwater level in Borehole C4 was recorded at El. 228.6 m or at a depth of 0.5 m below the ground surface. Groundwater level observations made in the piezometer installed in Borehole C1 lead us to believe that the relatively pervious soils (e.g. silty sand layer immediately above the bedrock in Borehole C1) underlying the silty clay deposit may be under excess hydrostatic pressure. These observations are shown on the Record of Borehole sheets. It should also be pointed out that the groundwater table would be subject to fluctuations.

4.3 Culvert at Sta 20+283.3 (Borehole C5)

Below a 400 mm thick veneer of **topsoil**, Borehole C5 encountered predominantly cohesionless granular deposits extending to the end of the borehole at a depth of 5.2 m below the ground surface or El. 226.8 m, where refusal to augering on presumed bedrock was noted.

Based on particle size analyses, together with visual and tactile examination, these cohesionless (i.e. granular) strata are classified as **gravelly silty sand till, silty sand, silty sand till, gravelly sand and sand and gravel**. With exception of the compact gravelly silty sand till near the ground surface, all other deposits were found to be in a dense to very dense state of compactness with SPT 'N' values ranging from 41 to greater than 100 blows/0.3 m penetration.

Particle size analyses were performed on four (4) samples obtained from this borehole. The results of these are plotted on Figures 5 and 6 and are summarized below:

Sample No.	Description of Material	% Gravel	% Sand	% Silt	% Clay	Grading Curve Shown on Figure No.
2	Gravelly silty sand till	29	26	32	13	6
3B	Silty sand till	12	57	26	5	5
5	Gravelly sand	31	56	13		6
6	Sand and gravel	47	42	11		6

The measured natural moisture contents of samples from these strata range from 8 to 17%, but are generally below 10%.

The **groundwater level** in the uncased borehole shortly after drilling was found at a depth of 1.5 m below the ground surface or at El. 230.5 m. For the long term observation of the fluctuation of the groundwater level, a piezometer was installed in the borehole, in which 1 and 10 days after its installation, the groundwater was found at El. 229.9 m and 230.5 m,

respectively. In the long term, seasonal fluctuations, including the rise of the groundwater level, are expected.

4.4 Culvert at Sta 19+764.9 (Borehole C6)

As shown on Drawing No. 4, Borehole C6 was put down at this culvert extension site. Borehole C6 encountered 300 mm **topsoil** underlain by cohesionless granular deposits of **silty sand, sandy silt, sand and sand and silt** to the termination depth of the borehole at 12.2 m. At the location of the borehole, the upper approximately 2.0 m of the silty sand material was found to be in a loose state of compactness (i.e. $N \leq 10$ blows/0.3 m), while the bulk of the soil profile deposits at greater depths are compact to dense with SPT 'N' values ranging from 14 to 44 blows/0.3 m penetration. Very dense conditions are indicated below El. 220.5 ±m from an N-value of 80. The presence of bedrock is inferred at a depth of 12.2m (El. 218.9 m) from the practical refusal on the split spoon sampler (no penetration for 100 blows).

Particle size analyses carried out on three representative samples obtained from Borehole C6 gave the following results:

Sample No.	Description of Material	% Gravel	% Sand	% Silt	% Clay	Grading Curve Shown on Figure No.
2	Silty sand	5	63	27	5	5
8	Sand and silt	0	43	57		4
10	Sand	19	69	11	1	5

The measured natural moisture contents throughout the soil profile range from 9 to 21%, but are mainly between 12 and 18%.

The **groundwater level** in the borehole after completion of the drilling was recorded at a depth of 1.6 m below grade (El. 229.5 m). A standpipe type piezometer was installed subsequently in the borehole to a depth of approximately 2.4 m below the existing ground surface.

One (1) and ten (10) days after the piezometer was installed, the groundwater level was found at depths of 2.3 m and 0.4 m (i.e. El. 228.8 m and 230.7 m) respectively, while on July 29, 2002 (i.e. more than 1 year later), the piezometric groundwater level was at El. 230.8 m (i.e. 0.3 m below the ground surface). The groundwater level at the site can be expected to be subject to seasonal fluctuations and in response to major weather events.

4.5 Culvert at Sta 18+233 (Borehole C7)

In Borehole C7 (Drawing 5), underlying a 500 mm thick layer of **topsoil**, an approximately 1.2 m thick **silty clay** deposit followed by 1.3 ±m thick **silty clay till** was encountered. Below these, **gravelly clayey silt till** is present grading into **gravelly silty sand till** at a depth of 4.0 m. Refusal to further augering (possibly on bedrock) was encountered at a depth of 4.4 m (El. 230.2 m) after penetrating this deposit by 0.4 m, where the borehole was terminated.

The deposits encountered below the topsoil to a depth of 4.0 m (El. 230.6 m) are **cohesive soils**. The natural moisture content in the silty clay near ground surface was found to be relatively high, of the order of 37%, while in the underlying cohesive tills, the measured natural moisture contents ranged from 11 to 12%. Atterberg limits tests performed on a sample obtained from the gravelly clayey silt (Sample No. 5) gave a liquid limit of 15%, a plastic limit of 10% and a plasticity index of 5%. Judging by the SPT 'N' values recorded ('N' = 5 to 10), these cohesive strata have firm to stiff consistency.

The **gravelly silty sand till** encountered at a depth of 4.0 m (El. 230.6 m) is a cohesionless soil composed of 24% gravel, 33% sand, 31% silt and 12% clay (Figure No. 6). The natural moisture content was found to be 6%. A single 'N' value greater than 100 blows/0.3 m penetration recorded in this stratum suggests a very dense state of compactness.

The position of the **groundwater level** was observed in the uncased borehole shortly after drilling and in the piezometer installed to a depth of 4.3 ±m below the ground surface. The water level shortly after drilling was found at a depth of 2.2 m below the ground surface (El. 232.4 m). The day following the installation of the piezometer, the groundwater level was measured at a depth of 3.5 m (El. 231.1 m). On June 22, 2001 (i.e. 10 days after the installation of the piezometer), the groundwater level was observed at a depth of 2.0 m below the ground surface or at El. 232.6 m while more than 1 year later, on July 29, 2002, the groundwater table was at El. 233.4 m (i.e. 1.2 m below the ground surface). These observations are shown on the Record of Borehole sheets. As mentioned before, the

groundwater table can be expected to be subject to seasonal fluctuations, as well as in response to major weather events.

4.6 Culvert at Sta 13+573.8 (Borehole C8)

Borehole C8 was drilled at the site of culvert extension at Sta 13+573.8 (Drawing 6). In this borehole, 460 mm thick **topsoil** is underlain by **silty clay till**, which extends to a depth of 1.7 m below the existing ground surface or to El. 247.2 m. It is followed by a thin (i.e. 0.3 m thick) layer of **silty sand till**, which overlies the **bedrock** at a depth of 2.0 m below ground surface or at El. 246.9 m.

The **silty clay till** is a cohesive material and Atterberg limits tests carried out on a sample recovered from the deposit gave a liquid limit of 52%, a plastic limit of 26% and a plasticity index of 26%. The plasticity chart shown on Figure 8 indicates a clay of high plasticity (CH). The natural moisture content of the same sample was 32%. A grain size distribution analysis carried out on the same sample showed 3% sand, 43% silt and 54% clay size particles (Figure 2). A single SPT 'N' value of 11 blows/0.3 m recorded in this stratum suggests a stiff consistency.

The **silty sand till** underlying the silty clay below a depth of 1.7 m (El. 247.2 m) was found to be essentially non-cohesive (i.e. basically granular) material. This deposit is 0.3 m thick and is very dense ($N > 100$ blows/0.3 m) with a natural moisture content of 9%.

The **bedrock**, encountered at the site below a depth of 2.0 m or El. 246.9 m, was identified as a light to medium grey crystalline limestone belonging to the Trenton Formation. The rock contains dark grey shaley partings and shale layers up to 100 mm in thickness. The bedrock was penetrated 1.5 m by coring.

The Total Core Recovery (TCR) of the rock, which represents the total length of rock core recovered and expressed as a percentage of the length of core run, was 90%. The Solid Core Recovery (SCR), which is the sum length of solid full diameter cores expressed as a percentage of the total length of the core run, was 60%.

The Rock Quality Designation (RQD) of the rock expresses the sum total of recovered rock cores which are equal or longer than 100 mm, as a percentage of the total length of the core run. The RQD value of the core was 42%, which indicates a "poor" quality rock.

The Fracture Index (FI) or the number of fractures per 0.3 m length of the core run varied from 2 to greater than 25, but was generally less than 5.

From a Point Load Test performed in the diametral direction on the limestone, the unconfined compressive strength (UCS) of the rock was estimated to be of the order of 105 MPa, indicating a "very strong" rock. Tactile examination of the shale partings indicate that the shale is "weak to medium" strong. With regard to its strength, the limestone can be classified as a Grade R3 to Grade R5 rock, while the shale is a Grade R2 to R3 rock.

The description of the rock in this report follows the International Society of Rock Mechanics (ISRM) conventions.

A piezometer was installed at the bottom of the borehole, at a depth of 3.5 m below existing grade, or at El. 245.4 m. In the piezometer, on June 22, 2001 and July 29, 2002 (i.e. 9 days and more than 1 year after its installation), the **groundwater level** was observed at El. 247.8 m (i.e. 1.1 m below the ground surface). It should be pointed out that these observations represent piezometric levels within the bedrock and a perched water condition may occur within the overburden. In addition, seasonal fluctuations and fluctuations in the groundwater due to weather events are likely to occur.

4.7 Culvert at Sta 9+215.0 (Borehole C9)

Borehole C9 encountered a 2.4 m thick deposit of **peat** followed by **firm sandy silty clay** and **stiff silty clay till** to a depth of 4.7 m below the ground surface or to El. 240.6 m. These cohesive soil strata are underlain by **compact silty sand till**, which is a granular (non-cohesive) material. The borehole was terminated at a depth of 5.5 m (El. 239.8 m) after penetrating this unit by 0.8 m, since at this depth refusal to augering, presumably on the surface of the bedrock was encountered.

The **peat** has a fibrous texture. The measured natural moisture content of this organic, cohesive material ranged from 65 to 313%. SPT 'N' values were 1 blow/0.3 m throughout the deposit, indicating a very soft consistency. The peat exhibits cohesive properties.

The **sandy silty clay**, which was contacted underlying the peat at a depth of 2.4 m below the ground surface or at El. 242.9 m, at the location of the borehole is about 0.7 m thick and contains occasional sand seams. A grain size distribution analysis performed on a sample obtained from this stratum indicates 35% sand, 28% silt and 37% clay size particles. This is a cohesive material and an Atterberg limits test gave a liquid limit of 30%, a plastic limit of 15% and a plasticity index of 15%. The natural moisture content was found to be 20%. A single 'N' value of 5 blows/0.3 m measured in the field suggests a firm consistency.


The **silty clay till**, which was contacted underlying sandy silty clay at 3.1 m depth (El. 242.2 m) is approximately 1.6 m thick and contains trace of sand and gravel. It exhibits cohesive properties and an Atterberg limits test performed on a representative sample gave a liquid limit of 30%, a plastic limit of 15% and a plasticity index of 15%. The measured natural moisture contents ranged from 21 to 28%. Recorded 'N' values in this stratum are between 11 and 14 blows/0.3 m, indicating a stiff consistency.


The **silty clay till** is underlain below El. 240.6 m, by **silty sand till**. This glacial deposit consists of a heterogeneous mixture of sand and silt with some clay and gravel. It is an essentially non-cohesive deposit. At the borehole location, it was found to be 0.8 m thick and based on a single SPT 'N' value of 20 blows/0.3 m, it is considered compact. The borehole was terminated within this deposit at El. 239.8 m upon encountering refusal to augering, possibly on bedrock.

cohesive deposit. At the borehole location, it was found to be 0.8 m thick and based on a single SPT 'N' value of 20 blows/0.3 m, it is considered compact. The borehole was terminated within this deposit at El. 239.8 m upon encountering refusal to augering, possibly on bedrock.

Shortly after completion of the borehole (June 13, 2001), the **groundwater level** was recorded at a depth of 4.3 m at El. 241.0 m in a piezometer installed near the bottom of the borehole. Subsequently, the position of the groundwater level was measured on June 22, 2001 and July 29, 2002 (i.e. 9 days and more than a year after installation). At these occasions, the water level was recorded 0.6 m and 0.1 m below the ground surface (El. 244.7 m and 245.2 m) respectively. In the long term seasonal fluctuations of the groundwater level are expected.

SHAHEEN & PEAKER LIMITED


Janos Garami, P.Eng.


Zuhtu Ozden, P.Eng.
MTO Designated Contact




Ivan P. Lieszkowszky, P.Eng.

Encl.

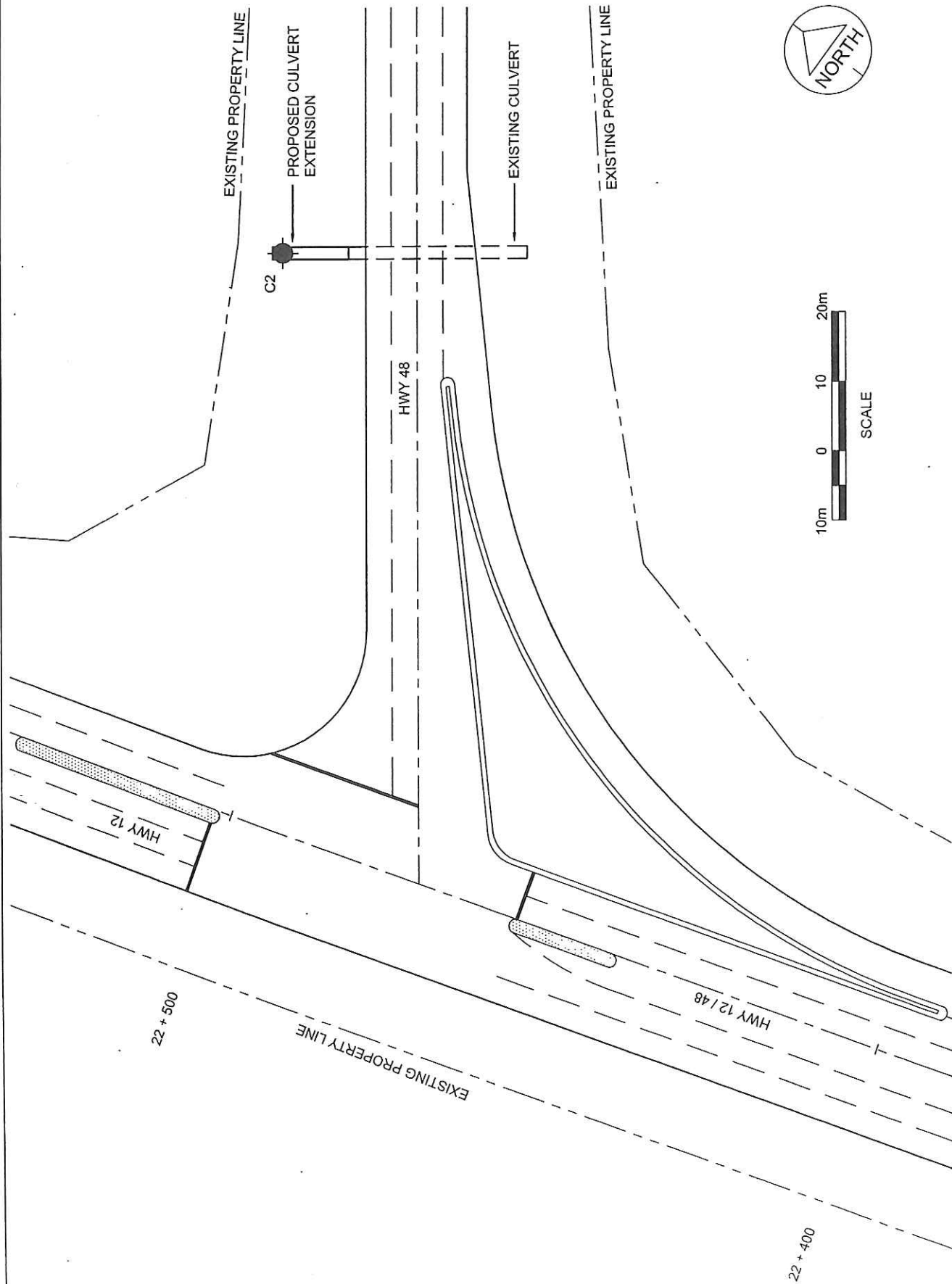
JG/SMP/ZO:sf

DR26/SPT 1024C JG



APPENDIX A

**BOREHOLE LOCATION PLANS - DRAWINGS 1 TO 7
RECORD OF BOREHOLES C1 TO C9**



HIGHWAY 12 WIDENING
PROPOSED CULVERT EXTENSION AT HWY 48, NORTH, 91m EAST OF HWY 12
BOREHOLE LOCATION PLAN

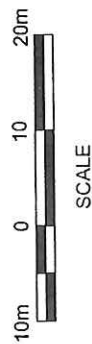
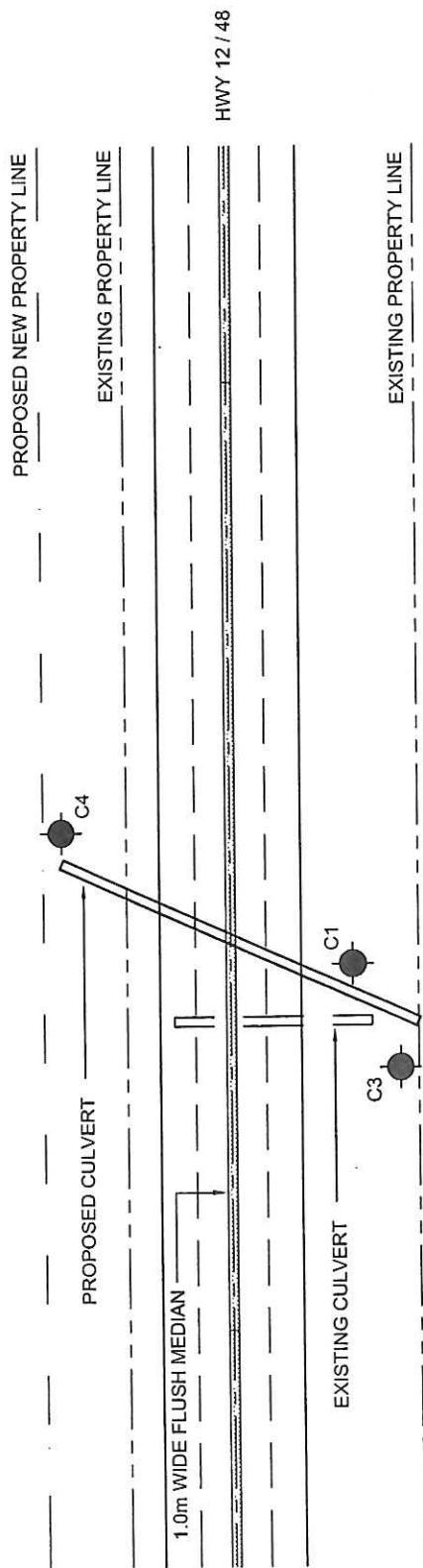
W.P. 611-89-00

Drawing No. 1

August, 2002

21 + 100

21 + 000



HIGHWAY 12 WIDENING
PROPOSED CULVERT EXTENSION AT STN 21+066.0
BOREHOLE LOCATION PLAN

W.P. 611-89-00
Drawing No. 2
August, 2002

20 + 300

C5

PROPOSED CULVERT
EXTENSION

EXISTING CULVERT

20 + 200

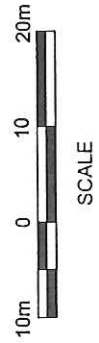
PROPOSED NEW PROPERTY LINE

EXISTING PROPERTY LINE

1.0m WIDE FLUSH MEDIAN

HWY 12 / 48

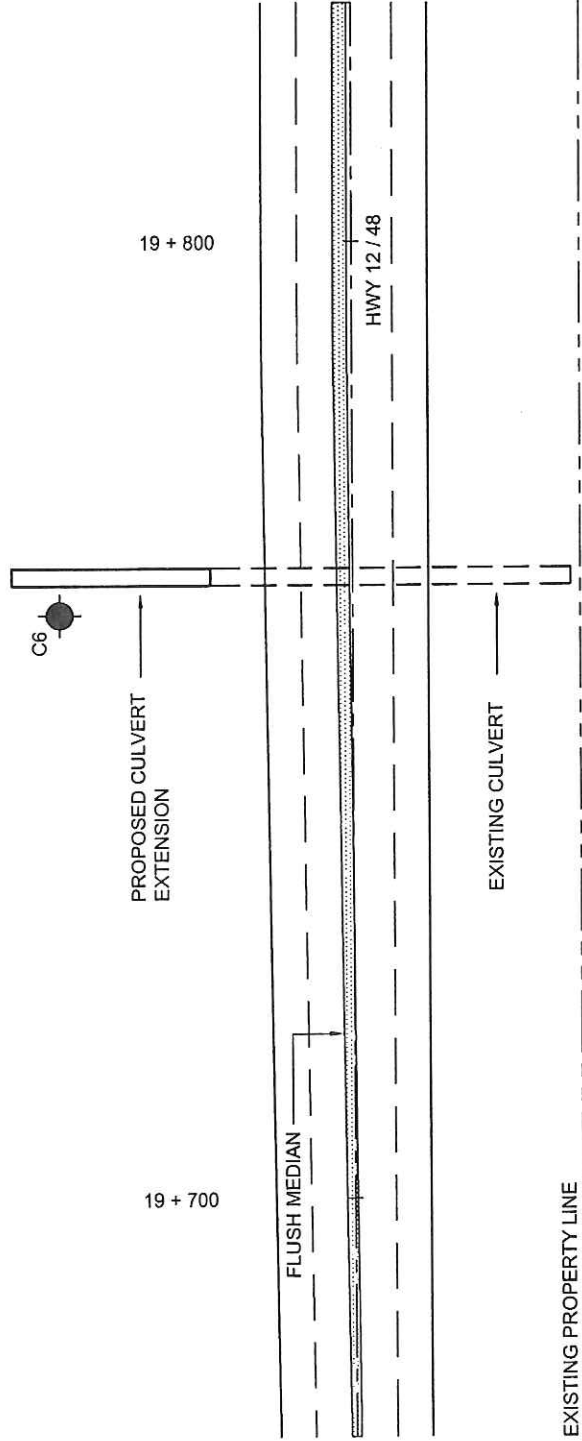
EXISTING PROPERTY LINE



HIGHWAY 12 WIDENING
PROPOSED CULVERT EXTENSION AT STN 20+283.3
BOREHOLE LOCATION PLAN

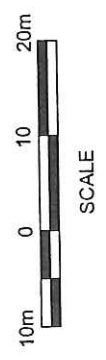
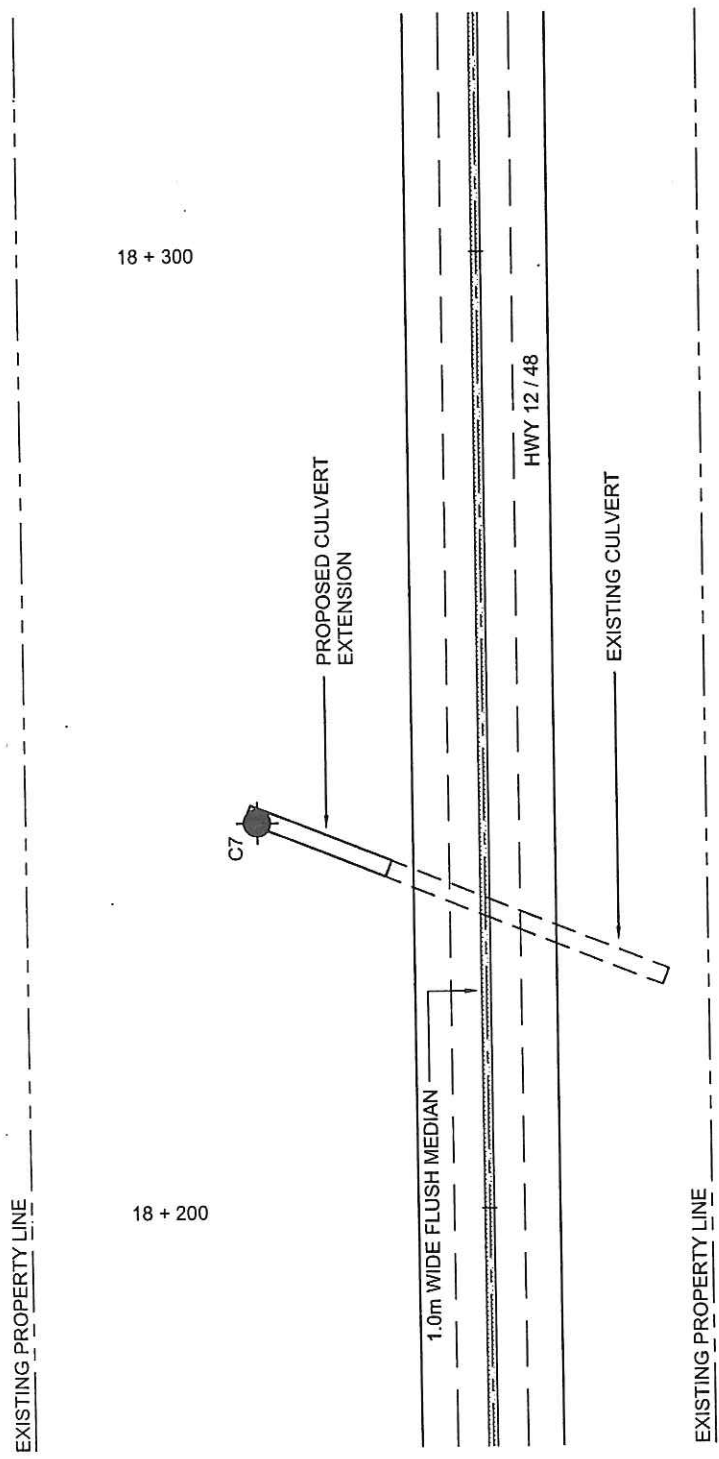
W.P. 611-89-00
Drawing No. 3
August, 2002

EXISTING PROPERTY LINE



HIGHWAY 12 WIDENING
PROPOSED CULVERT EXTENSION AT STN 19+764.9
BOREHOLE LOCATION PLAN

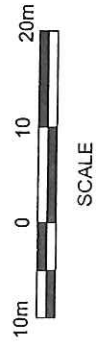
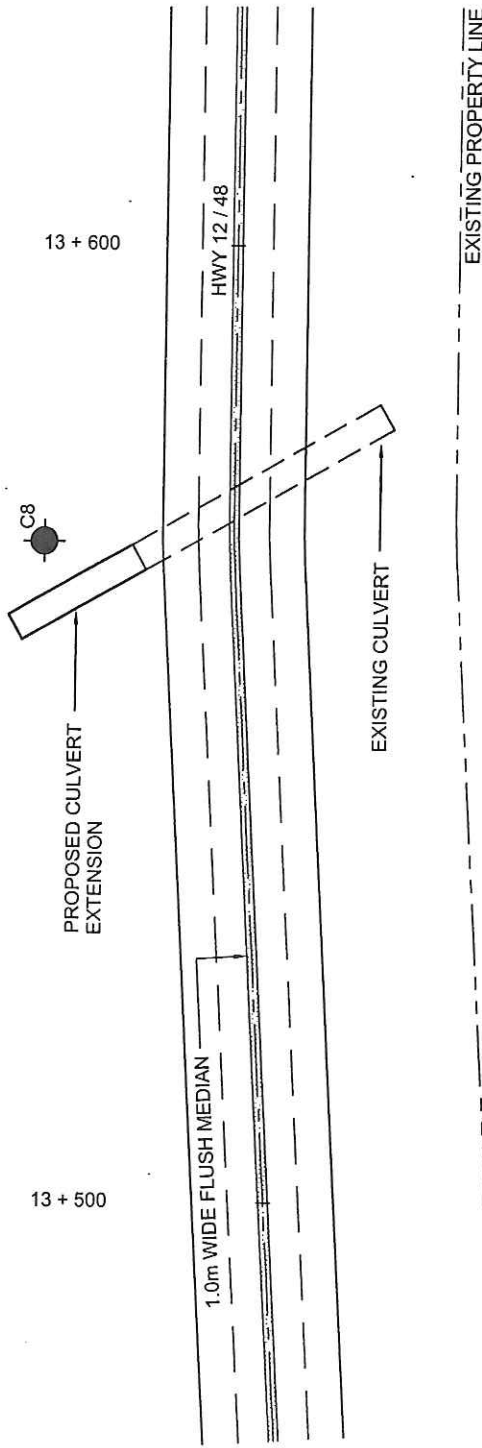
W.P. 611-89-00
Drawing No. 4
August, 2002



HIGHWAY 12 WIDENING
PROPOSED CULVERT EXTENSION AT STN 18+233.0
BORFHOLE LOCATION PLAN

W.P. 611-89-00
Drawing No. 5
August, 2002

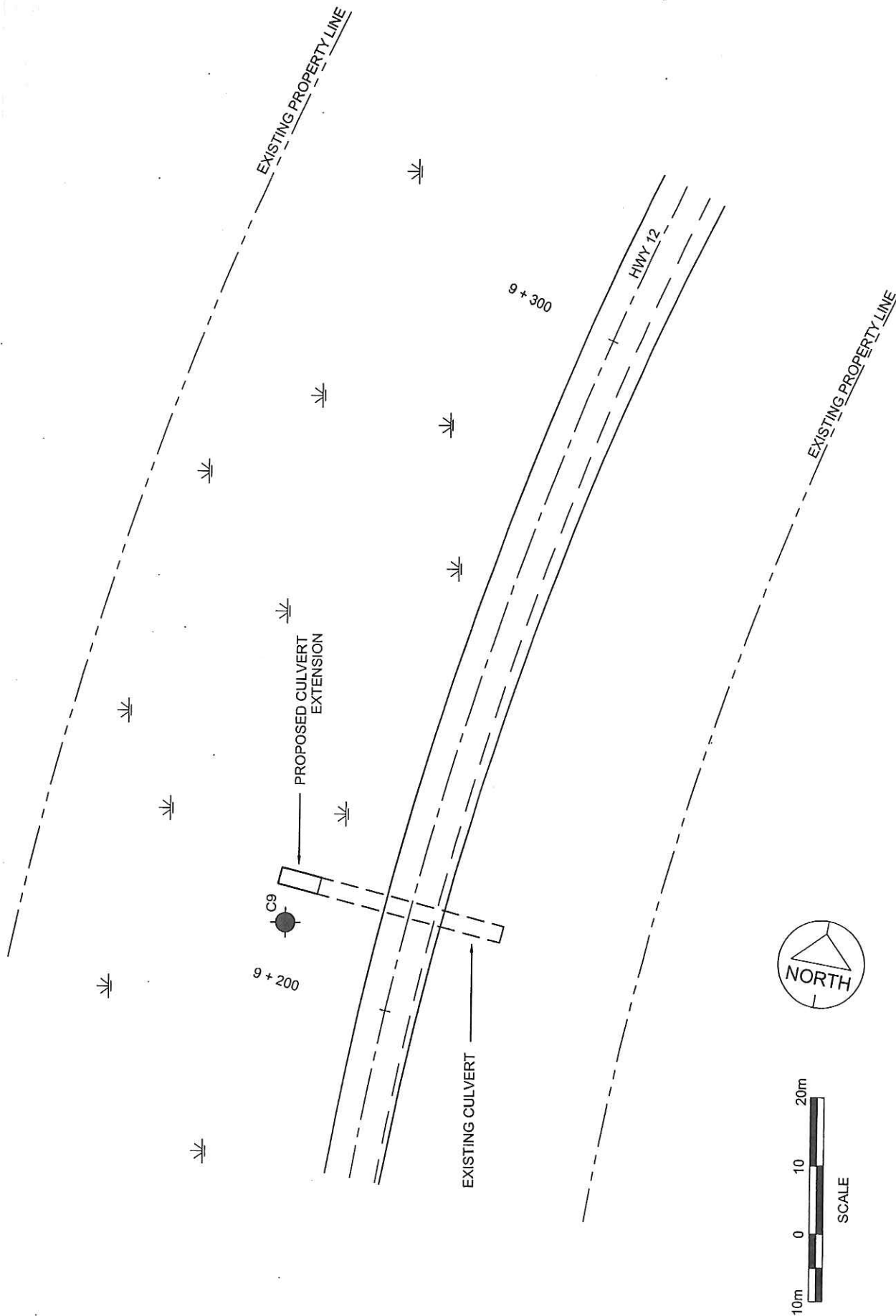
EXISTING PROPERTY LINE



HIGHWAY 12 WIDENING
PROPOSED CULVERT EXTENSION AT STN 13+573.8
BOREHOLE LOCATION PLAN

W.P. 611-89-00
Drawing No. 6
August, 2002

HIGHWAY 12 WIDENING
PROPOSED CULVERT EXTENSION AT STN 9+215.0
BOREHOLE LOCATION PLAN



RECORD OF BOREHOLE No C1

1 OF 1

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 925 663.5; E 333 233.1 ORIGINATED BY P.D.
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering COMPILED BY J.S.
DATUM Geodetic DATE 11.6.01 CHECKED BY J.G.

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			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								20	40	60	80						100	20

230.8	Ground Surface															
0.0	355 mm GRAVELLY SAND															
230.4																
0.4	FILL mixture of sand and clayey silt occ. clay lumps, trace of gravel brown, loose or firm		1	SS	10											
			2	SS	8											
			3	SS	8											
229.0																
1.8	SILTY CLAY brown to grey, firm to very stiff		4	SS	7											
			5	SS	4											
			6	AS	--											
226.2																
4.6	SANDY CLAYEY SILT (Glacial Till)															
225.9	some gravel, brown, hard		7	SS	98/ 150mm											
4.9	SILTY SAND															
225.5	some gravel, trace of clay grey, very dense															
5.3	END OF BOREHOLE Refusal to augering at 5.3m Presumed bedrock															
	* Water level at 4.0 m (not stabilized) upon completion															
	** Piezometer installed to 5.2 m															
	Water Level Record Date W.L. EL. (m) 12/06/01 228.8 13/06/01 228.7 22/06/01 230.1															

ON MOT SPT 1024C.GPJ ON MOT.GDT 22/11/02

3 X 3

Numbers refer to
Sensitivity

3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C2

1 OF 2

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 927 074 7' E 332 883.4
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering
DATUM Geodetic DATE 11.6.01

ORIGINATED BY P.D.

COMPILED BY J.S.

CHECKED BY J.G.

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					
220.4	Ground Surface													
0.0	450mm TOPSOIL		1	SS	5		220							
219.9														
0.5	SILTY CLAY trace of sand firm to stiff		2	SS	1		219							
			3	SS	2		218							
			4	SS	5		217							
			5	TW	PH		216							
			6	SS	2		215							
			7	SS	1		214							
			8	SS	1		213							
			9	SS	0		212							
			10	SS	0		211							
			11	SS	0		210							
			12	SS	19		209							
209.6			13	SS	21		208							
10.8	SAND and SILT some clay with silty clay seams grey compact to dense		14	SS	31		207							
							206							

SPT 1024C SPT 1024C GPJ ON MOT GDT 8/11/02

Continued Next Page

± 3 × 3

Numbers refer to
Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C2

2 OF 2

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 927 074.7; E 332 863.4
 DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering
 DATUM Geodetic DATE 11.6.01
 ORIGINATED BY P.D.
 COMPILED BY J.S.
 CHECKED BY J.G.

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 (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
205.2																	
15.2	SAND and SILT (Glacial Till) some clay, trace of gravel grey compact to dense		15	SS	14		205										7 43 35 15
							204										
			16	SS	34		203										
202.1							202										
18.3	SAND and SILT trace of clay grey very dense		17	SS	110		201										0 47 (53)
200.4																	
20.0	END OF BOREHOLE		18	SS	108/ 50mm												
	* Water level at 0.9 m (not stabilized) upon completion ** Piezometer installed to 16.8 m Water Level Record Date W.L. El.(m) 12/06/01 208.9 13/06/01 211.9 22/06/01 219.7 29/07/02 219.9																

+ 3 x 3

Numbers refer to
Sensitivity

○ 3%

STRAIN AT FAILURE

RECORD OF BOREHOLE No C3

1 OF 1

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 925 881.1 E 333 238.8 ORIGINATED BY P.D.
DIST 7 HWY 12 BOREHOLE TYPE Hand Augering COMPILED BY J.S.
DATUM Geodetic DATE 11.6.01 CHECKED BY J.G.

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					
228.5	Ground Surface																
0.0	300mm TOPSOIL		1	AS	-												
0.31	SILTY CLAY organic stained with rootlets to 1.2 m brown-black to grey inferred to be soft to firm		2	AS	-		228										
			3	AS	-												
			4	AS	-												
			5	AS	-												
226.7			6	AS	-		227										
1.8	END OF BOREHOLE																
	* Water level at 0.4 m (not stabilized) upon completion																

SPT 1024C SPT 1024C GPU ON MOT GDT 8/11/02

RECORD OF BOREHOLE No C4

1 OF 1

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 925 872.4; E 333 198.8 ORIGINATED BY P.D.
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering COMPILED BY J.S.
DATUM Geodetic DATE 12.6.01 CHECKED BY J.G.

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					
229.1	Ground Surface																
0.0	750mm TOPSOIL		1	SS	7		229										
228.3																	
0.8	SILTY CLAY brown firm		2	SS	7		228										
			3	SS	5		227										
			4	SS	6		226										
225.9																	
3.2	SAND and SILT (Glacial Till) some gravel and clay		5	SS	6												
225.4	grey loose																
3.7	END OF BOREHOLE Refusal to augering at 3.7m Presumed bedrock																
	* Water level at 1.3 m (not stabilized) upon completion																
	** Piezometer installed to 3.7 m																
	Water Level Record Date WL, El. (m) 13/06/01 227.1 22/06/01 228.8 29/07/02 228.6																

SPT 1024C SPT 1024C.GPJ ON MOT.GDT 8/11/02

RECORD OF BOREHOLE No C5

1 OF 1

METRIC

W.P. 611-69-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 924 913 2, E 333 443 7 ORIGINATED BY P.D.
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering COMPILED BY J.S.
DATUM Geodetic DATE 12.6.01 CHECKED BY J.G.

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					
232.01	Ground Surface															
0.0	TOPSOIL															
231.61			1	SS	8											
0.4	GRAVELLY SILTY SAND (Glacial Till) some clay grey to brown compact		2	SS	18											29 26 32 13
230.51																
1.9	SILTY SAND, trace of gravel brown, very dense		3	SS	64											12 57 26 5
230.2																
1.8	SILTY SAND (Glacial Till) trace of clay, some gravel brown, very dense															
229.7			4	SS	51											
2.3	GRAVELLY SAND some silt brown, very dense															
			5	SS	54											31 56 (13)
228.2																
3.8	SAND and GRAVEL some silt dense to very dense		6	SS	41											47 42 (11)
			7	SS	121/ 250mm											
226.8																
5.2	END OF BOREHOLE Refusal to augering at 5.2m Presumed bedrock * Water level at 1.5 m (not stabilized) upon completion ** Piezometer installed to 4.0 m Water Level Record Date WL, El. (m) 13/06/01 229.9 22/06/01 230.5															

SPT 1024C, SPT 1024C GPJ ON MOT GDT 8/11/02

RECORD OF BOREHOLE No C6

1 OF 1

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 924 410.5; E 333 593.3
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering
DATUM Geodetic DATE 12.6.01

ORIGINATED BY P.D.

COMPILED BY J.S.

CHECKED BY J.G.

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			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
							20	40	60	80	100	WATER CONTENT (%)					
							20	40	60	80	100	10	20	30	kN/m ³ GR SA SI CL		
231.1	Ground Surface																
0.0	300 mm TOPSOIL																
0.3	SILTY SAND trace of gravel and clay grey very loose to compact		1	SS	2												
			2	SS	10												
			3	SS	8												
			4	SS	19												
			5	SS	14												
227.1			6	SS	28												
4.0	SANDY SILT trace of clay grey, compact		7	SS	37												
226.5			8	SS	41												
4.6	SAND and SILT trace of clay grey compact to dense		9	SS	18												
223.4			10	SS	25												
7.6	SAND some gravel and silt, trace of clay grey compact to very dense		11	SS	44												
			12	SS	80												
218.9			13	SS	100/ 0mm												
12.2	END OF BOREHOLE Refusal probably on bedrock * Water level at 1.6 m (not stabilized) upon completion ** Piezometer installed to 2.4 m Water Level Record Date WL, El. (m) 13/06/01 228.8 22/06/01 230.7 29/07/02 230.8																

ON MOT SPT 1024C.GPJ ON MOT GDT 22/11/02

RECORD OF BOREHOLE No C7

1 OF 1

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 922 985.5, E 334 052.5 ORIGINATED BY P.D.
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering COMPILED BY J.S.
DATUM Geodetic DATE 6.6.01 CHECKED BY J.G.

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100					
234.6	Ground Surface															
0.0	500mm TOPSOIL		1	SS	5											
234.1			2	SS	5											
0.5	SILTY CLAY brown, firm															
232.9			3	SS	8											
1.7	SILTY CLAY (Glacial Till) some sand, trace of gravel grey, stiff		4	SS	10											
231.6																
3.0	GRAVELLY CLAYEY SILT (Glacial Till) grey, firm		5	SS	6											
230.6																
4.0	GRAVELLY SILTY SAND (Glacial Till) some clay, grey, very dense		6	SS	62/ 150mm											
230.2	END OF BOREHOLE															
4.4	Refusal to augering at 4.4m															
	* Water level at 2.2 m (not stabilized) upon completion															
	** Piezometer installed to 4.3 m															
	Water Level Record Date WL, El. (m) 13/06/01 231.1 22/06/01 232.6 29/07/02 233.4															

SPT 1024C SPT 1024C GPJ ON MOT GDT 8/11/02

RECORD OF BOREHOLE No C8

1 OF 1

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 918 520.4; E 335 484.2 ORIGINATED BY P.D.
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering & NQ Rock Core COMPILED BY J.S.
DATUM Geodetic DATE 13.6.01 CHECKED BY J.G.

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					
248.9	Ground Surface																
0.0	460mm TOPSOIL		1	SS	12												
248.4																	
0.5	SILTY CLAY (Glacial Till) trace of sand, high plasticity gray to brown stiff		2	SS	11		248									52	0 3 43 54
247.2																	
1.7	SILTY SAND (Glacial Till) some clay and gravel, grey/brown very dense		3	SS	100/ 25mm		247										FI = 2
246.9	LIMESTONE light to medium grey with dark grey shaley partings and shale layers up to 100 mm in thickness																FI = 3
2.0			4	RC	RQD 42%		246										FI = 3
	fresh with slight weathering along discontinuities and shaley partings																FI = >25
245.4																	FI = 7
3.5	medium strong to very strong, shaley partings are weak to medium strong END OF BOREHOLE																
	* Water level at 3.5 m (not stabilized) upon completion																
	** Piezometer installed to 3.5 m																
	Water Level Record Date WL, El. (m) 22/06/01 247.8 29/07/02 247.8																

ON MOT SPT 1024C.GPJ ON MOT.GDT 22/11/02

RECORD OF BOREHOLE No C9

1 OF 1

METRIC

W.P. 611-89-00 LOCATION From South Junction of Hwy 48 to North Junction of Hwy 48, ON - Coords: N 4 914 381 4; E 335 934 2
DIST 7 HWY 12 BOREHOLE TYPE Solid Stem Augering
DATUM Geodetic DATE 13.6.01

ORIGINATED BY P.D.

COMPILED BY J.S.

CHECKED BY J.G.

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			SHEAR STRENGTH kPa						
245.3	Ground Surface							20 40 60 80 100						
0.0	PEAT fibrous black very soft		1	SS	1		245						65	
			2	SS	1		244						280	
			3	SS	1		243						313	
242.9	SANDY SILTY CLAY occ sand seams grey, firm		4	SS	5		242						224	0 35 28 37
242.2	SILTY CLAY (Glacial Till) trace of sand and gravel grey, stiff		5	SS	14		241							
			6	SS	11		240							
240.6	SILTY SAND (Glacial Till) some clay grey, compact		7	SS	20									
239.8	END OF BOREHOLE Refusal to augering at 5.5m Possibly on bedrock													
5.5	* Water level at 4.3 m (not stabilized) upon completion ** Piezometer installed to 5.5 m Water Level Record Date WL, El. (m) 22/06/01 244.7 29/07/02 245.2													

SPT 1024C SPT 1024C GPJ ON MOT GDT 8/11/02

+ 3 × 3

Numbers refer to
Sensitivity

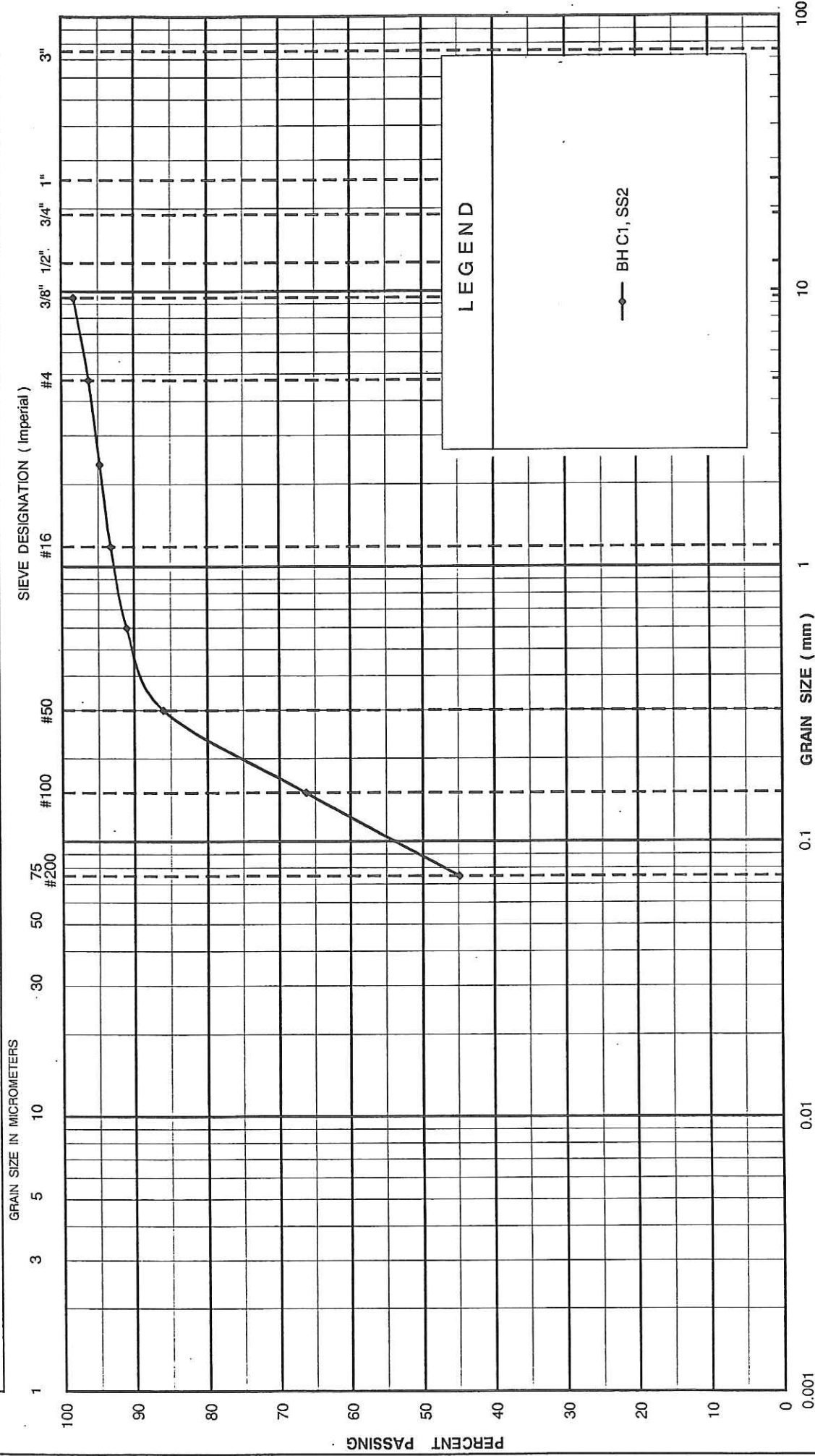
○ 3% STRAIN AT FAILURE

APPENDIX B

**LABORATORY TEST RESULTS
FIGURES 1 TO 9**

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT			SAND			GRAVEL		
GRAIN SIZE IN MICROMETERS			Fine	Medium	Coarse	Fine	Coarse	Coarse



GRAIN SIZE DISTRIBUTION
 FILL: SAND and CLAYEY SILT, trace of gravel

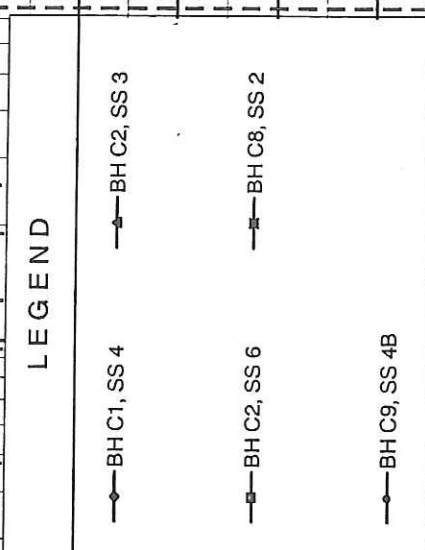
MINISTRY OF TRANSPORTATION

FIGURE No. 1

W.P. 611-89-00

DATE March, 2002

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



GRAIN SIZE DISTRIBUTION SILTY CLAY and SILTY CLAY TILL

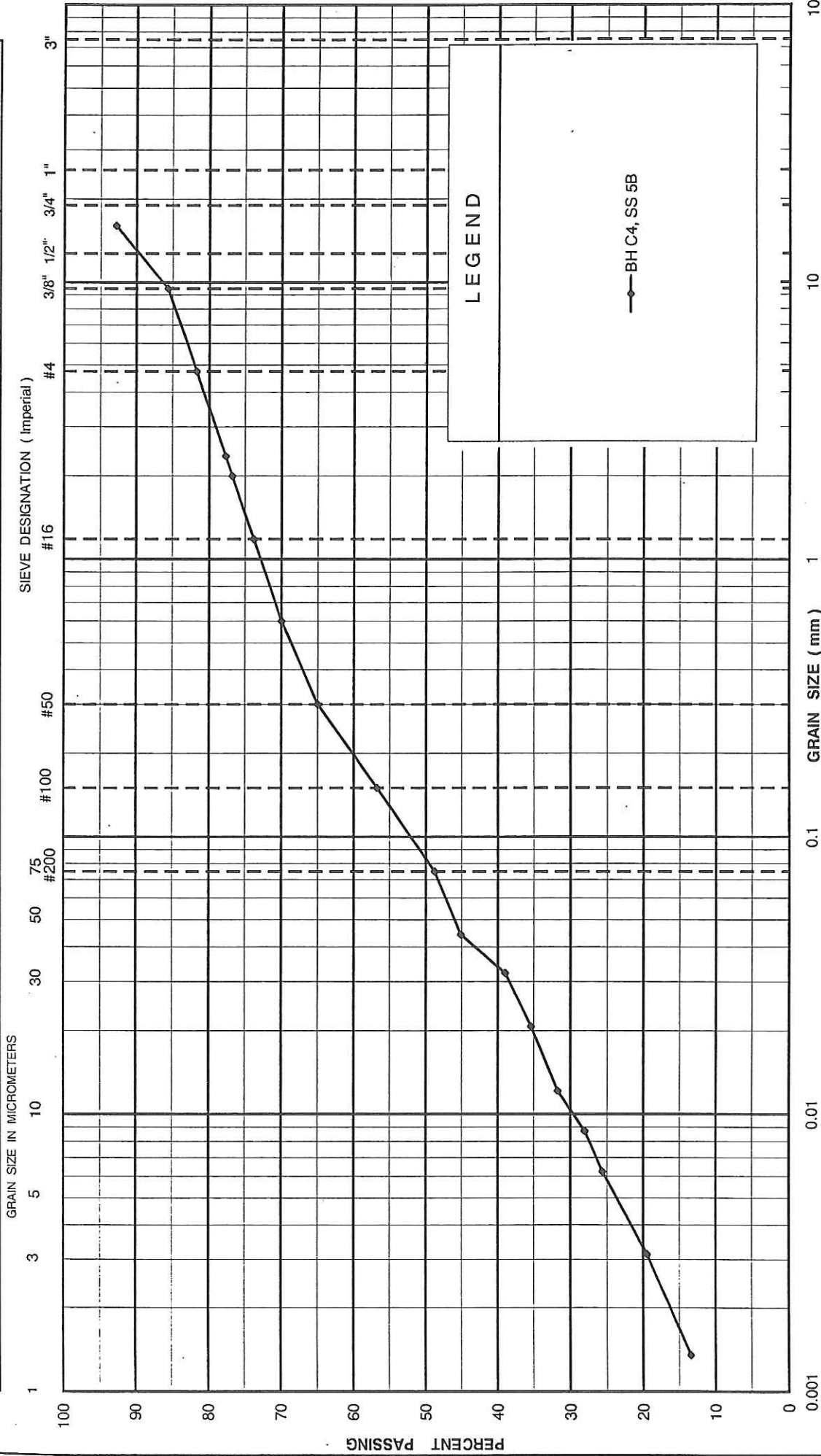
FIGURE No. 2

W.P. 611-89-00

DATE March, 2002

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



GRAIN SIZE DISTRIBUTION
SAND and SILT (TILL)

MINISTRY OF TRANSPORTATION

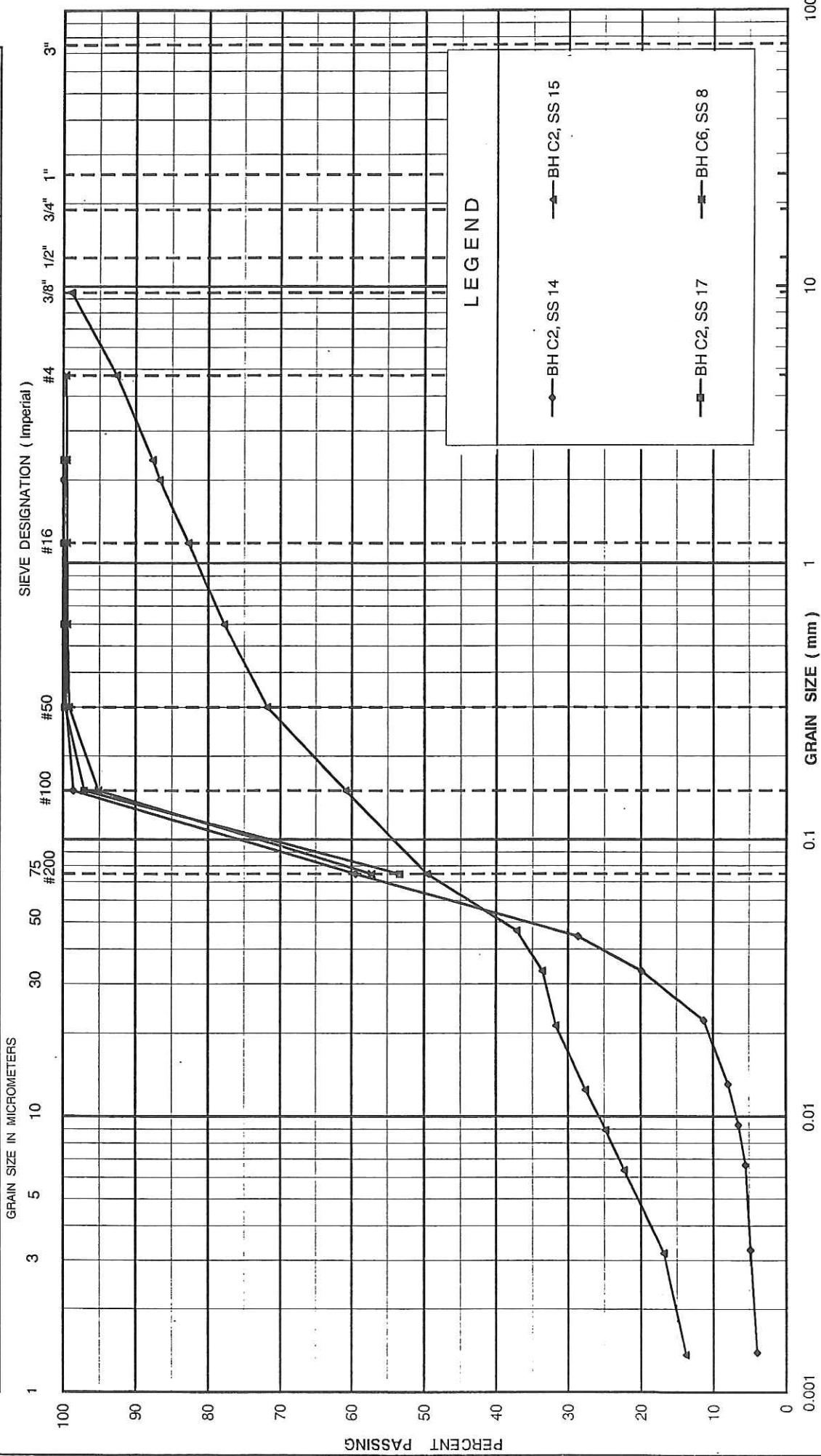
FIGURE No. 3

W.P. 611-89-00

DATE March, 2002

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT		SAND			GRAVEL		
GRAIN SIZE IN MICROMETERS		75	100	200	Fine	Coarse	Coarse



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT

GRAIN SIZE IN MICROMETERS

SAND

Fine

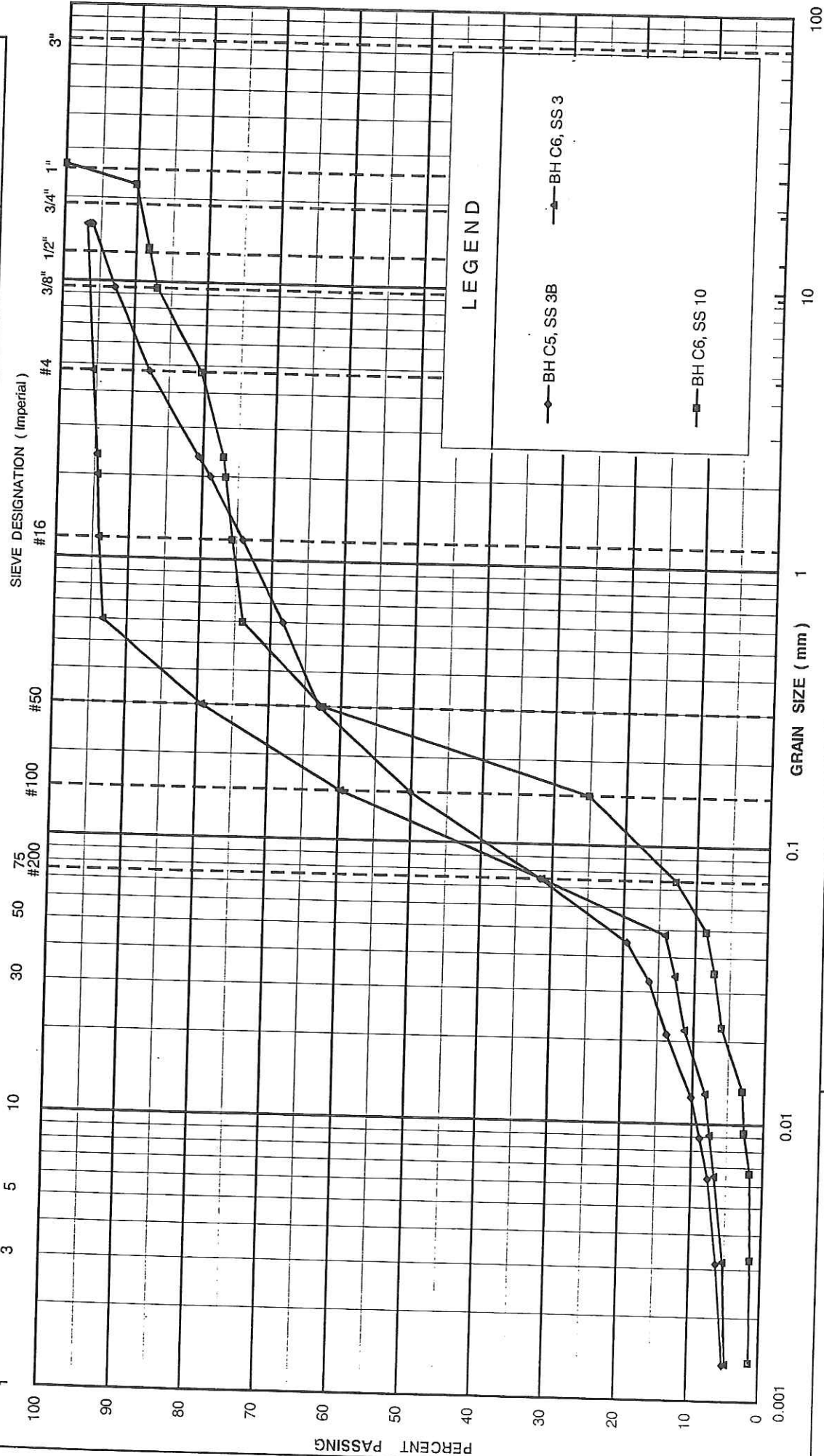
Medium

Coarse

Fine

GRAVEL

Coarse



MINISTRY OF TRANSPORTATION

GRAIN SIZE DISTRIBUTION
SAND, SILTY SAND (TILL), and GRAVELLY SILTY SAND (TILL)

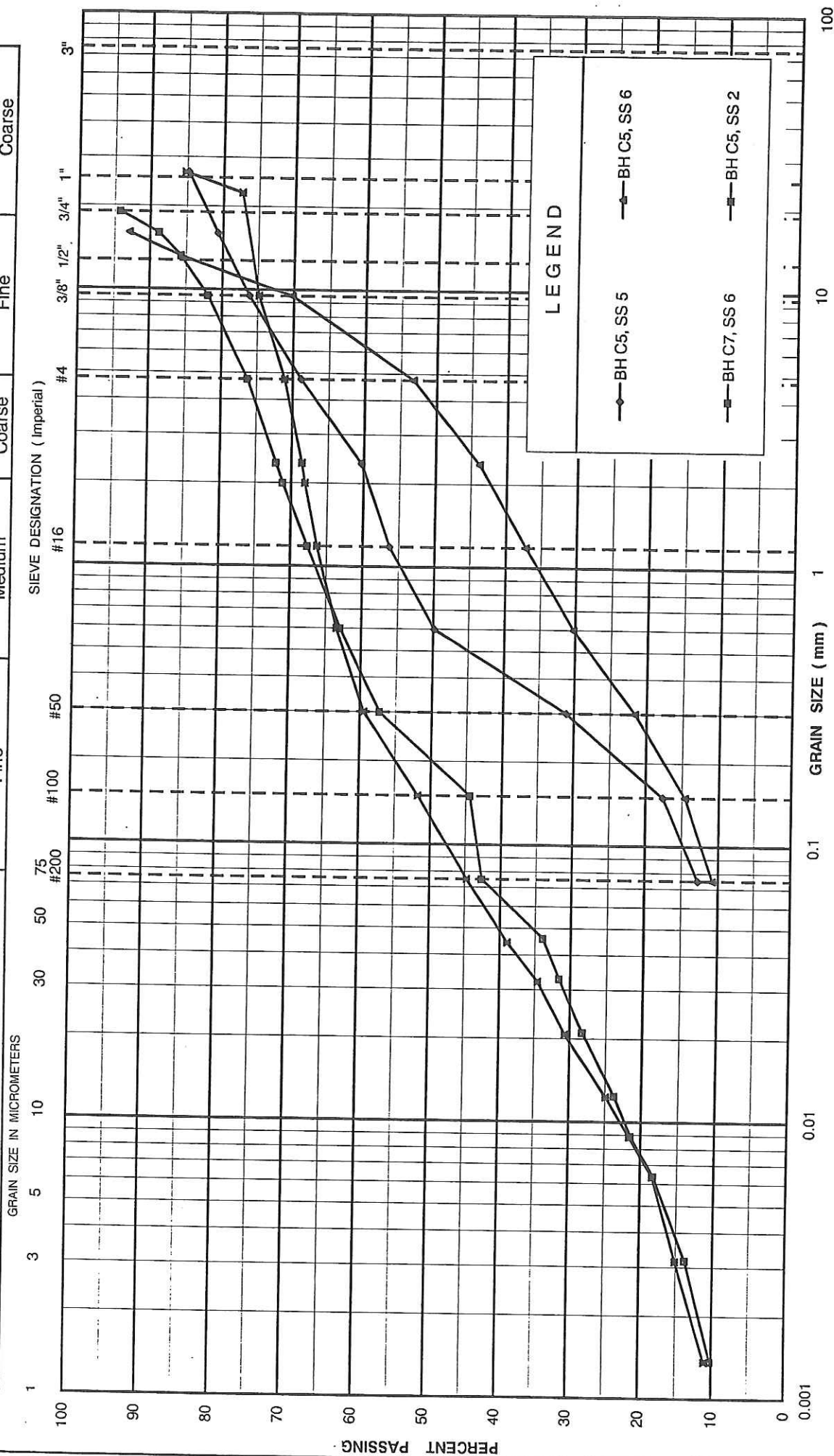
FIGURE No. 5

W.P. 611-89-00

DATE

March, 2002

CLAY AND SILT	SAND				GRAVEL	
	Fine		Medium	Coarse	Fine	
	GRAVEL					
GRAIN SIZE IN MICROMETERS						



GRAIN SIZE DISTRIBUTION

GRAVELLY SILTY SAND (TILL); GRAVELLY SAND; SAND and GRAVEL

FIGURE No. 6

W.P. 611-89-00

DATE March, 2002

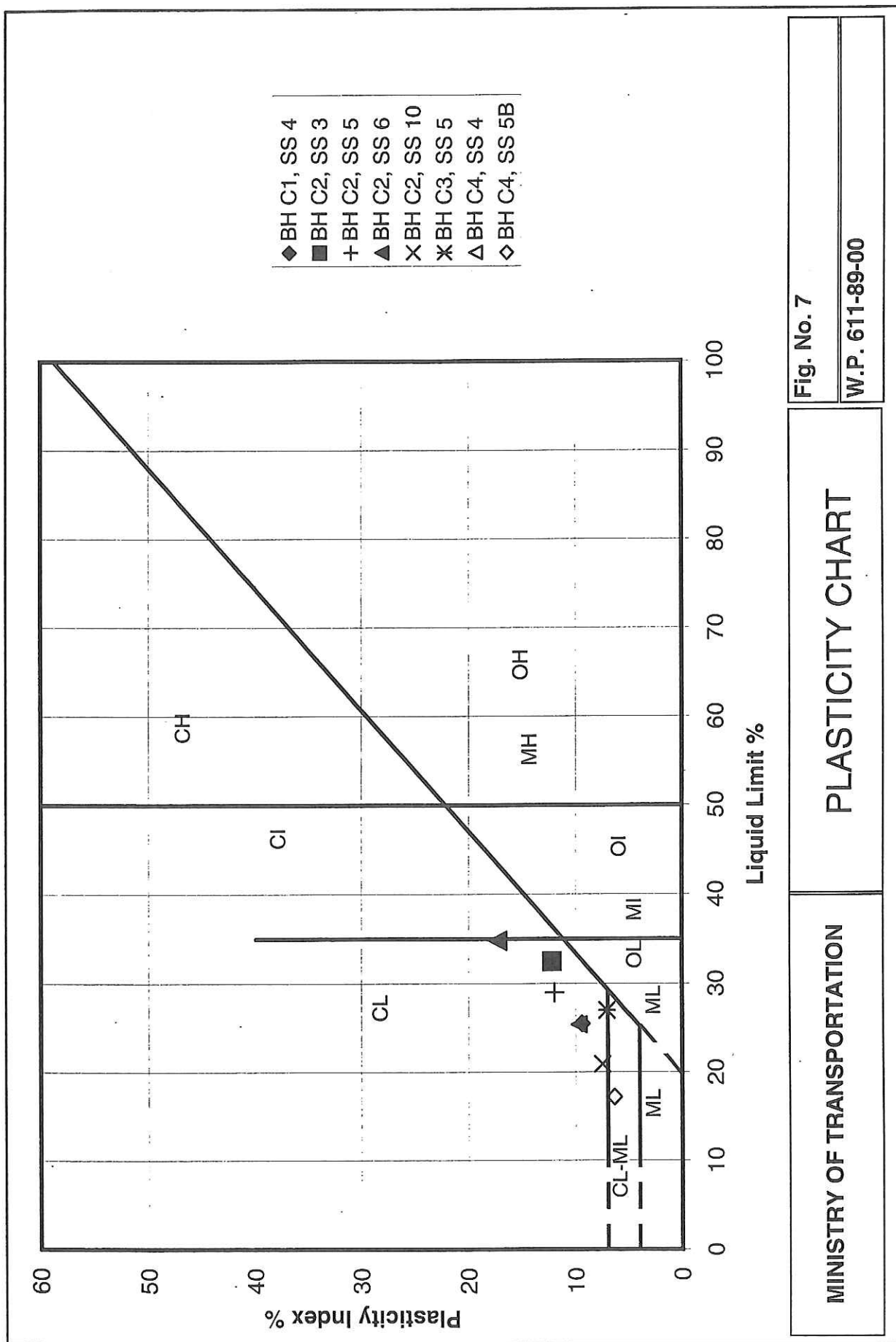


Fig. No. 7

PLASTICITY CHART

MINISTRY OF TRANSPORTATION

W.P. 611-89-00

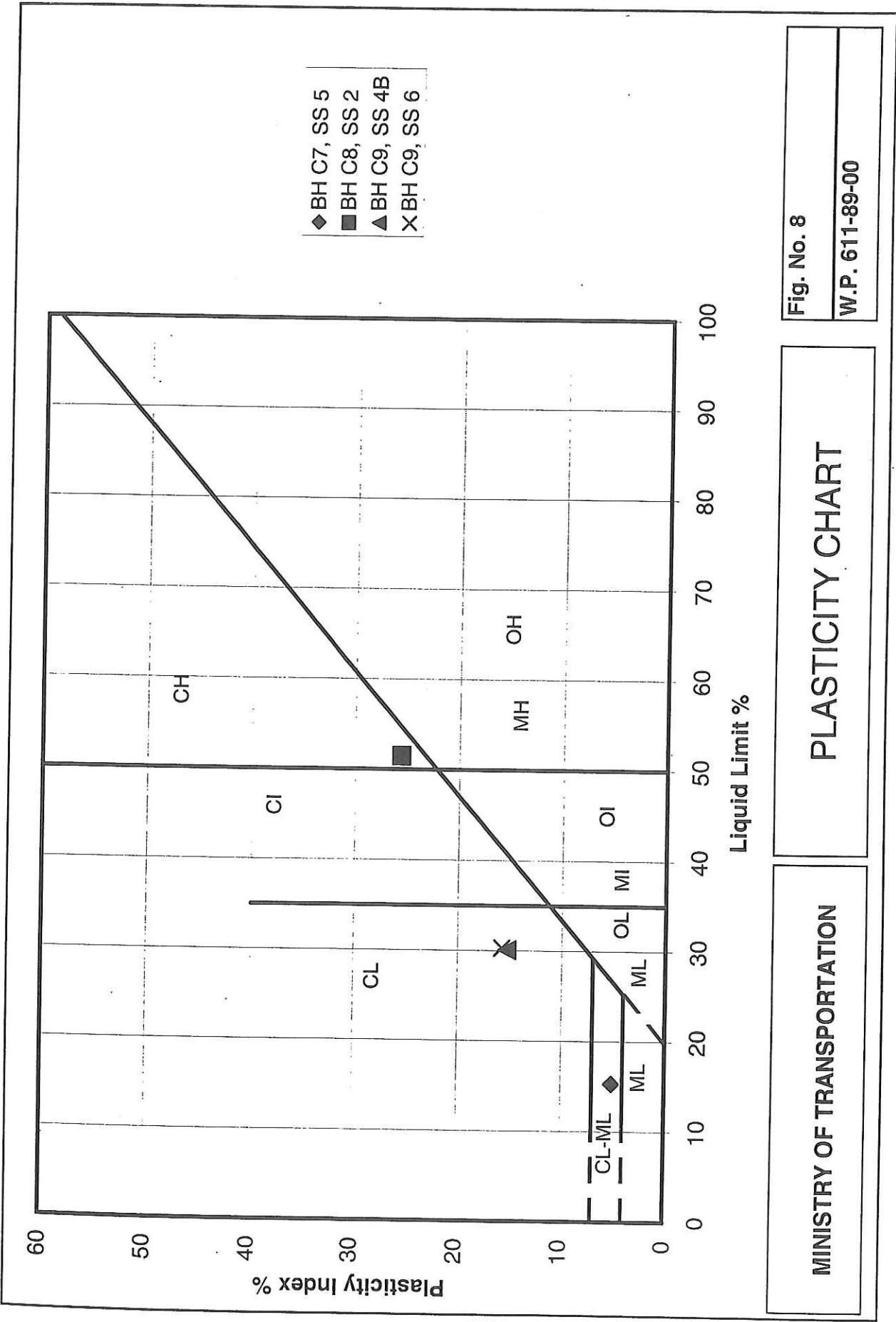
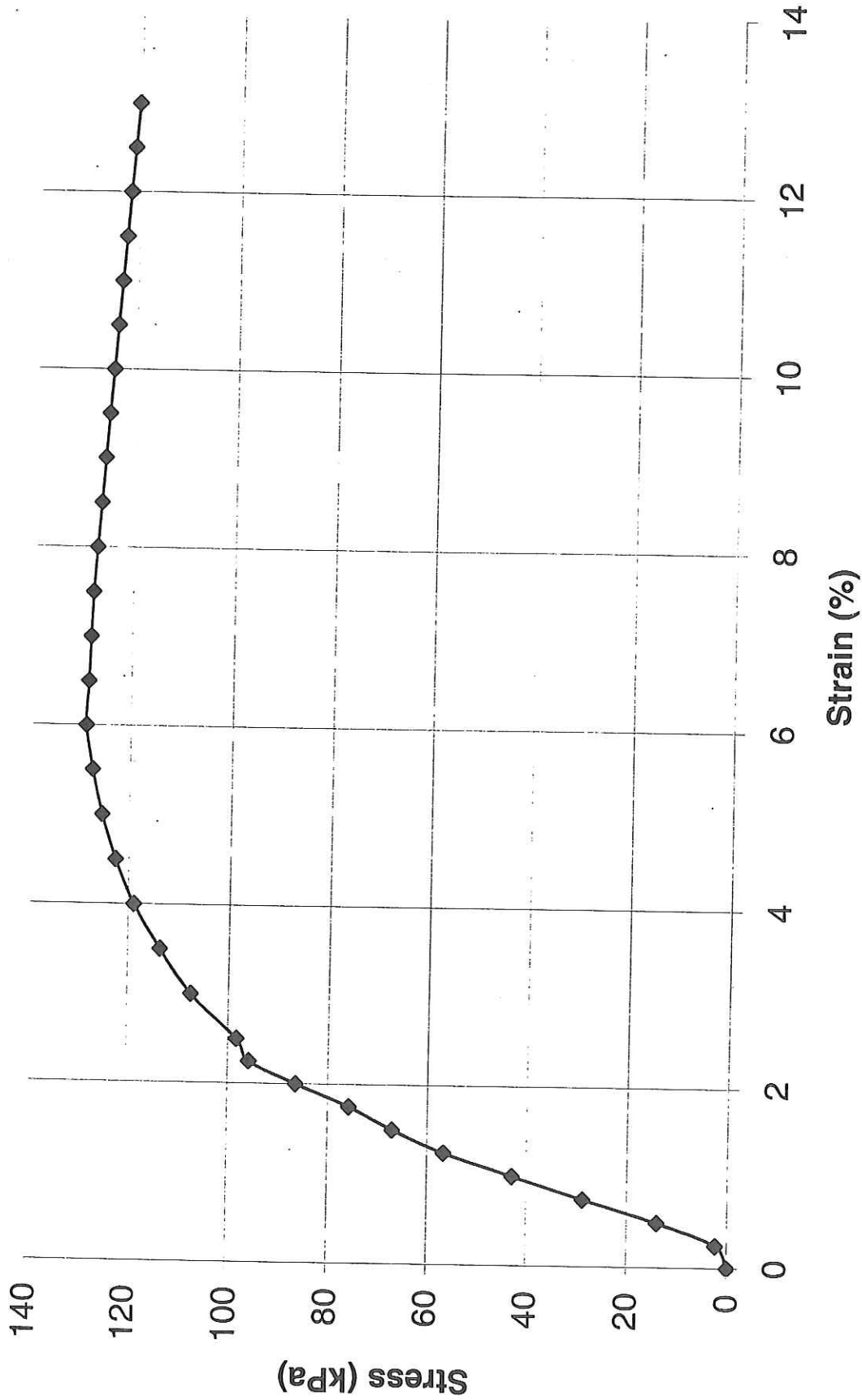


Fig. No. 8

W.P. 611-89-00

PLASTICITY CHART

MINISTRY OF TRANSPORTATION



CONFINED COMPRESSION TEST
BOREHOLE C2, SAMPLE 5

Figure No. 9
W.P. 611-89-00
July, 2001

Explanation of Terms Used in the Bedrock Core Log

Strength (ISRM)

Term	Grade	Description	Unconfined Compressive Strength	
			(MPa)	(psi)
Extremely weak rock	RO	Indented by thumbnail	0.25-1.0	36-145
Very weak	R1	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0-5.0	145-725
Weak rock	R2	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	5.0-25	725-3625
Medium Strong	R3	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	25-50	3625-7250
Strong rock	R4	Specimen require more than one blow of geological hammer to fracture it	50-100	7250-14500
Very strong rock	R5	Specimen requires many blows of geological hammer to fracture it	100-250	14500-36250
Extremely strong rock	R6	Specimen can only be chipped with geological hammer	>250	>36250

Bedding (Geological Society Eng. Group Working Party, 1970. Q.J. of Eng. Geol. Vol. 3)

Term	Bed Thickness	
Very thickly bedded	>2 m	>6.5 ft
Thickly bedded	600 mm-2 m	2.00-6.50 ft
Medium bedded	200 mm-600 mm	0.65-2.00 ft
Thinly bedded	60 mm-200 mm	0.20-0.65 ft
Very thinly bedded	20 mm-60 mm	0.06-0.20 ft
Laminated	6 mm-20 mm	0.02-0.06 ft
Thinly laminated	<6 mm	<0.02 ft

TCR (Total Core Recovery)

Sum of lengths of rock core recovered from a core run, divided by the length of the core run and expressed as a percentage.

SCR (Solid Core Recovery)

Sum length of solid, full diameter drill core recovered expressed as a percentage of the total length of the core run.

Weathering (ISRM)

Term	Grade	Description
Fresh	W1	No visible sign of rock material weathering
Slightly weathered	W2	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker than in its fresh condition
Moderately weathered	W3	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a corestone
Highly weathered	W4	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones
Completely weathered	W5	All rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact
Residual soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported

RQD (Rock Quality Designation, after Deere, 1968)

Sum of lengths of pieces of rock core measured along centreline of core equal to or greater than 100 mm from a core run, divided by the length of the core run and expressed as a percentage. Core fractured by drilling is considered intact. RQD normally quoted for N-size core.

RQD(%)	Rock Quality
90-100	Excellent
75-90	Good
50-75	Fair
25-50	Poor
0-25	Very poor

(FI) Fracture Index

Expressed as the number of discontinuities per 300mm (1 ft). Excludes drill-induced fractures and fragmented zones. Reported as ">25" if frequency exceeds 25 fractures/0.3m.

Broken Zone

Zone of full diameter core of very low RQD which may include some drill-induced fractures.

Fragmented Zone

Zone where core is less than full diameter and RQD = 0

APPENDIX C
EXPLANATION OF TERMS USED IN REPORT

Explanation of Terms Used in the Bedrock Core Log

Discontinuity Spacing (ISRM)

Term	Average Spacing	
Extremely widely spaced	>6 m	>20.00 ft
Very widely spaced	2 m-6 m	6.50-20.00 ft
Widely spaced	600 mm-2 m	2.00-6.50 ft
Moderately spaced	200 mm-600 mm	0.65-2.00 ft
Closely spaced	60 mm-200 mm	0.20-0.65 ft
Very closely spaced	20 mm-60 mm	0.06-0.20 ft
Extremely closely spaced	<20 mm	>0.06 ft

Note: Excludes drill-induced fractures and fragmented rock.

Discontinuity Orientation

Discontinuity, fracture and bedding plane orientations are cited as the acute angle measured with respect to the core axis. Fractures perpendicular to the core axis are at 90° and those parallel to the core axis are at 0°.

D33-work/Abbreviations

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 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

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_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1.0	VOID RATIO	e_{min}	1.0	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1.0	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER				D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	w	1.0	WATER CONTENT	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	S_r	%	DEGREE OF SATURATION	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_L	%	LIQUID LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_p	%	PLASTIC LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_p	%	PLASTICITY INDEX = $(w_L - w_p)$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	L	1	LIQUIDITY INDEX = $(w - w_p) / I_p$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	I_c	1	CONSISTENCY INDEX = $(w_L - w) / I_p$	j	kN/m ²	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1.0	VOID RATIO IN LOOSEST STATE			