



**LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE**

Northern Engineering Services Company Limited

CALGARY ALBERTA



**ENGINEERS FOR
Arctic Gas**

17A
710.4
• A68
AGAS L33
286 1977

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

Received

JUN 8 1977

ALASKAN ARCTIC GAS
ANCHORAGE

NORTHERN ENGINEERING SERVICES COMPANY LIMITED
Calgary, Alberta



Prepared For:
Canadian Arctic Gas Study Limited

May 1977

Project 12071

ARLIS
Alaska Resources
Library & Information Services
Anchorage, Alaska

Northern Engineering Services Company Limited

635 - 6TH AVENUE S.W., CALGARY, ALBERTA T2P 0S5 — TELEPHONE (403) 265-8500—TELEX 038-24868—TWX 821-2283

31 May 1977

Canadian Arctic Gas Study Ltd.
2170 Calgary House,
550 - 6th Avenue S.W.
Calgary, Alberta
T2P 0S5

Attention: Mr. A.W. Wirth
Vice President
Engineering and Construction

REFERENCE: Laboratory Testing for Thaw-Slope Stability:
Continuous Permafrost Zone.

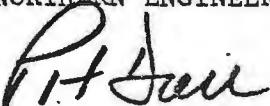
Gentlemen:

We are pleased to submit this report which summarizes the results of laboratory tests undertaken for Projects 12071 and 12093, on frozen soils from the Continuous Permafrost Zone of the Northwest Territories, Yukon Territory and Alaska.

The report presents laboratory data pertaining to the analysis of Thaw-Slope Stability from a series of sites located along the proposed pipeline route between the Katakturuk River in Alaska and Travallant Lake, N.W.T.

Yours very truly,

NORTHERN ENGINEERING SERVICES COMPANY LIMITED



P.H. Dau, P. Eng.
President

SCM/dmw

Encl.

PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE MAY 1977

CONTENTS

	Page
1. SUMMARY	1
2. INTRODUCTION	3
3. TEST HOLE SITES	5
4. DETERMINATION OF SOIL PROPERTIES	7
4.1 Tests Employed and Parameters Studied	7
5. TEST RESULTS	13
5.1 Explanation of Terminology Used in the Test Data Presentation	13
5.2 Parameters	14
5.3 Presentation of Test Results	18
5.4 Discussion	183
6. CONCLUSION	195
REFERENCES	197
APPENDIX A Explanation of Terms and Symbols on Test Hole Logs	

PROJECT 12071

<u>CANADIAN ARCTIC GAS STUDY LIMITED</u>
<u>CALGARY</u>
<u>ALBERTA</u>

<u>LABORATORY TESTING PROGRAM</u>
<u>FOR THAW-SLOPE STABILITY</u>
<u>CONTINUOUS PERMAFROST ZONE</u>

DATE

MAY 1977

LIST OF FIGURES

	Page
FIGURE 2.1 Key Map	2
FIGURE 4.2.1 Relationship between Frozen Bulk Density and Water Content	11
FIGURE 5.2.1 Strain vs Normal Stress for a Consolidation Permeability Test	16
FIGURE 5.4.1 Plasticity Chart for Fine-Grained Soils	184
FIGURE 5.4.2 Plasticity Index vs Per Cent Clay Sives	185
FIGURE 5.4.3 Frozen Bulk Density vs Thaw-Settlement Parameters	188
FIGURE 5.4.4 Frozen Bulk Density vs Average Coefficient of Compressibility	189
FIGURE 5.4.5 Frozen Bulk Density vs Thaw-Strain at 1000 psf	190
FIGURE 5.4.6 Plasticity Index vs Residual Strength Coefficient	193

PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY

ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE

MAY 1977

LIST OF TABLES

	Page
TABLE 5.4.1 Mineralogical Analysis of Clay Content	183
TABLE 5.4.2 Thaw-Settlement Parameters derived from Consolidation-Permeability Tests	187
TABLE 5.4.3 Summary of Average Shear Strength Parameters	191

PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY
ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE

MAY 1977

1. SUMMARY

This report presents the results of the laboratory test program for frozen soils from the North Slope in the Continuous Permafrost Zone of Alaska, the Yukon Territory and the Northwest Territories. Consolidation-permeability tests, direct shear, and triaxial tests were performed on representative frozen mineral soil samples obtained during the 1975 drilling programs.

The relationships between the thaw-settlement parameter, which is related to the thaw-settlement potential of the soil, and bulk density of the soil are found to be in good agreement with those published (Watson et al, and Speer et al) for the soils from several sites along the Mackenzie Valley, and for those results previously published by Northern Engineering Services Company Limited (NESCL).

The work is a continuation of the studies of thaw-settlement and slope stability being carried out by NESCL.

CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY
1975
AREA OF OPERATIONS

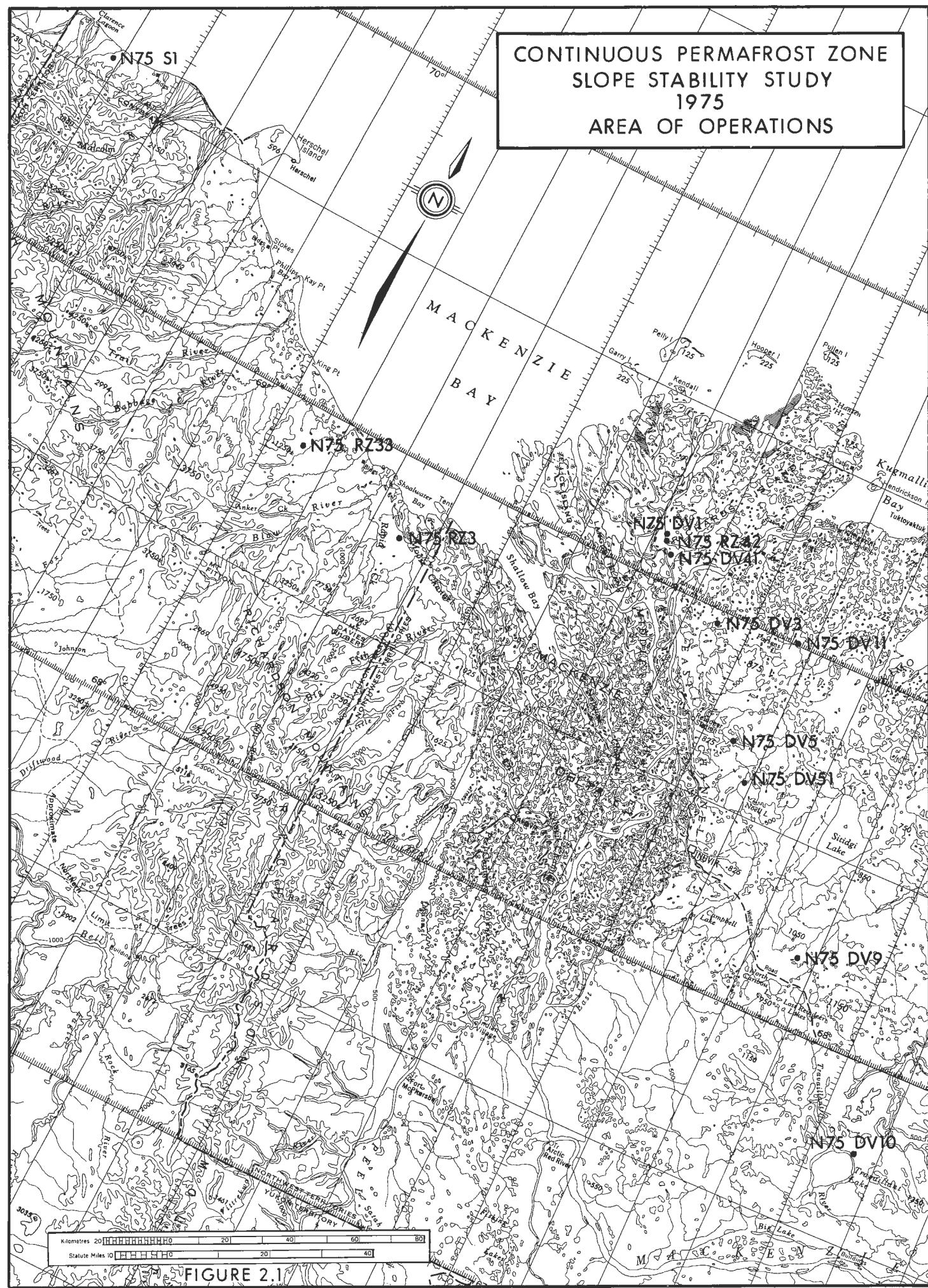


FIGURE 2.1

PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY

ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE

MAY 1977

2. INTRODUCTION

The objective of this report is to present data that may be used to assess the thaw-settlement potential of ice-rich permafrost in the vicinity of the proposed Arctic Gas pipeline in the North Slope region of the Northwest Territories, Yukon Territory, and Alaska. It is recognized that the potential for thaw-settlement will not pose as great a problem as in the Discontinuous Permafrost Zone because in this region the gas will be chilled to below the freezing point of water. The locations of the Canadian sites considered in this report are shown on Figure 2.1. The location of the Katakuk River site, in Alaska, is identified in Section 5.3. The information collected in the field in July, and October to November, 1975 and the drilling and sampling program, is described in the NESCL Geotechnical Data Report, cited as Reference 1. Subsequent laboratory tests, presented in this report, were conducted in Calgary by R.M. Hardy and Associates Limited, the test program being under the supervision of NESCL.

The major part of the laboratory testing program was directed towards obtaining thaw-settlement parameters of the samples obtained. The frozen initial water content and bulk density were determined for each consolidation-permeability test, together with a range of tests to verify the soil classification for each sample. Where values of specific gravity of the soil were not available, a value of 2.67 was assumed. Data for the coefficients of consolidation and permeability are presented.

The thaw-settlement test data presented in this report were derived from consolidation-permeability tests and analyzed by the method discussed by Watson et al (Reference 2) which expresses thaw-settlement in terms of two thaw-settlement parameters, A_o and a_o .

PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY
ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE

MAY 1977

3. TEST HOLE SITES

The test hole log information presented in this report is drawn from the previously mentioned NESCL Geotechnical Data Report (Reference 1). The test hole logs were revised subsequent to completion of laboratory tests and are presented at the front of the information pertaining to each site. Detailed profiles of water content (frozen) and bulk density versus depth are presented on the logs.

Site descriptions, detailed maps of site locations, and air-photos can be found in the referenced Geotechnical Data Report.

PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE

MAY 1977

4. DETERMINATION OF SOIL PROPERTIES

4.1 Tests Employed and Parameters Studied

The following tests were employed along with the parameters directly measured. Listed also are parameters derived from the test data.

4.1.1 Consolidation-Permeability Test

The purposes of the consolidation-permeability test were:

1. to determine directly, in the laboratory, the coefficient of permeability (K_m) of the soil samples,
 2. to determine the consolidation coefficients, C_v and M_v , under incremental pressures, and derive the coefficients of permeability (K_c) by calculation,
 3. to determine the values of the thaw-settlement parameter (A_o), and the average coefficient of compressibility (a_o).

The strain (ϵ_p) at a given effective normal stress also may be used to express the potential for thaw-settlement. During this series of tests, an effective normal stress of 1000 psf was chosen.

4.1.2 Direct Shear Test

The objectives of the direct shear test were:

1. to determine the peak shear strength, the angle of internal friction (ϕ'), and the cohesion intercept in terms of effective stress.
2. to evaluate the residual shear strength (ϕ_r') and cohesion (c_r').
3. to verify the difference in the values of shear strength, with and without a horizontal plane cut through the sample by means of a thin piano wire.

The soil index tests were correlated with results of the direct shear test to ascertain any relationships between soil type and shear strength.

4.1.3 Triaxial Test

The objective of the triaxial test was to determine shear strength parameters, ϕ' and c' , in terms of effective stress.

4.1.4 Other Tests

Mineralogical analyses of the clay content of selected samples were carried out to investigate the average composition for the area studied.

4.2 Test Procedures

The apparatus and procedures employed for sample preparation and laboratory tests for consolidation-permeability, direct shear, and triaxial test are discussed in detail in Section 4

of the NESCL report cited as Reference 3. With the exception of the reference to the Thaw-Settlement Test, which was not done during the program, the methods of test for the series of frozen samples from the Continuous Permafrost Zone were the same, and carried out concurrently with those for the Discontinuous Permafrost Zone.

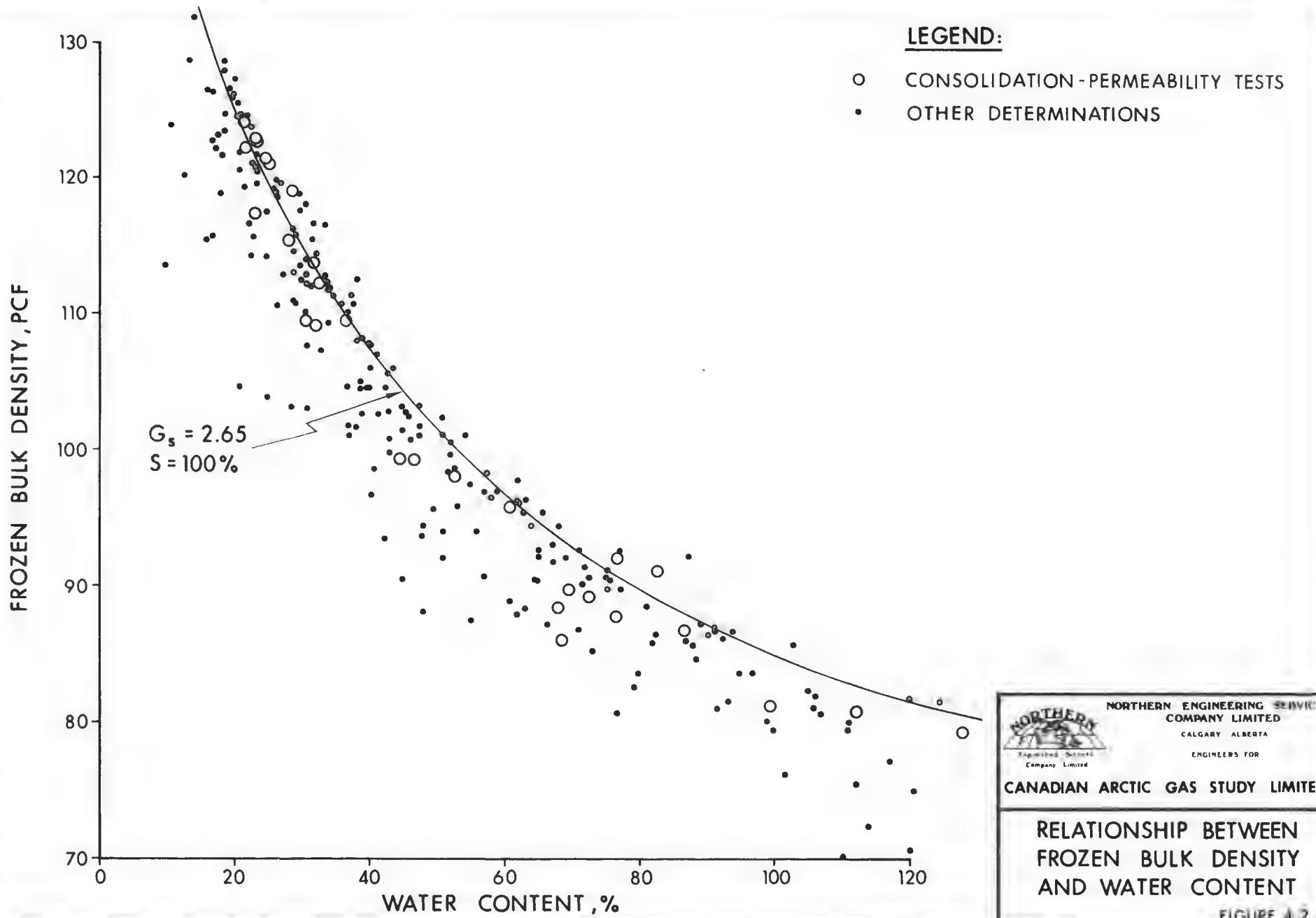
The procedures used in determining soil index properties were carried out according to the Standards described by the American Society for Testing and Materials, Annual Book of ASTM Standards (latest designations), (Reference 4):

ASTM D 422 Particle-size Analysis of Soils
ASTM D 423 Liquid Limit of Soils
ASTM D 424 Plastic Limit and Plasticity Index of Soils
ASTM D 2216 Laboratory Determination of Moisture Content
of Soil

The general principles used in the direct shear test are described by ASTM D 3080-72, but slight modifications were employed because initially the samples were frozen (see Section 4.3 of the report cited as Reference 3).

Bulk density of the frozen samples was determined by two methods, differing only in the method of obtaining of the volume of the sample. Samples for consolidation-permeability, direct shear, and triaxial tests were measured directly; samples not required for the special tests were weighed in air, then submerged in a calibrated cylinder containing FAXAM-40 oil. The volume was derived by reading the oil levels before and after total submergence of the sample. The volume, and therefore, bulk density of representative large pieces of otherwise disturbed samples may be determined by this method of displacement.

The frozen bulk density volumes thus obtained have been plotted with respect to their corresponding natural water contents, as shown on Figure 4.2.1. It can be seen that these results compare favourably with the theoretical relationship shown by NESCL to exist between these two parameters (Reference 5).



PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE

MAY 1977

5. TEST RESULTS

5.1 Explanation of Terminology Used in the Test Data Presentation

The explanation of terminology used in the test data presentation is as described in Section 4.1 of the NESCL report, cited as Reference 3. For convenience it is repeated here and should be referred to when using the summaries of test data appearing in Section 5.3.

- Pressure or Consolidation Pressure: effective stress applied to the sample and maintained until primary consolidation is completed.
 - Average Pressure: mean of two applied effective stresses for which the average values of C_v , M_v and K_c are calculated.
 - Water Head: difference in head between the water level on the top of sample and water level in the burette. It was maintained at 1 foot (30.5 cm).
 - Cut Plane: a cut failure plane introduced by pulling a thin piano wire through the sample in the direct shear box.
 - Consolidated Undrained Triaxial Test: the soil specimen is consolidated (drainage allowed) under an all-round pressure, but no drainage is allowed during the application of deviator stress.

- Consolidated Drained Triaxial Test: the soil specimen is consolidated under an all-round pressure, and then the deviator stress is applied, drainage being permitted during both stages.
- Residual Shear Strength Coefficient, μ_r : ratio of residual shear stress (τ_r) to effective normal stress (σ_N').

5.2 Parameters

5.2.1 Consolidation-Permeability Test

The permeability of soil directly measured in the laboratory is expressed as:

$$K_m = \frac{Q}{A} \times \frac{L}{h}$$

where K_m = coefficient of permeability, cm/sec
 Q = rate of flow, cm^3/sec
 A = cross-sectional area of the sample container
 L = length of sample, cm
 h = head of water, cm, acting on the sample.

The coefficient of consolidation, C_v , is given by:

$$C_v = \frac{T_v H^2}{t_{50}}$$

where C_v is given in cm^2/sec
 T_v = time factor for 50 per cent consolidation.
 H = one half of the soil specimen length, cm.
 t_{50} = time for 50 per cent compression, secs.

The coefficient of compressibility or of volume change, M_v , is defined as:

$$M_v = \frac{\Delta V/V}{\Delta \sigma}$$

where M_v is given in cm^2/g
 ΔV = change in volume of the sample, cm^3
 V = initial volume of the sample, cm^3
 $\Delta \sigma$ = change in effective stress causing the volume change ΔV , g/cm^2 .

The permeability of soil calculated from the above parameters is given as:

$$K_c = \gamma_w \times C_v \times M_v$$

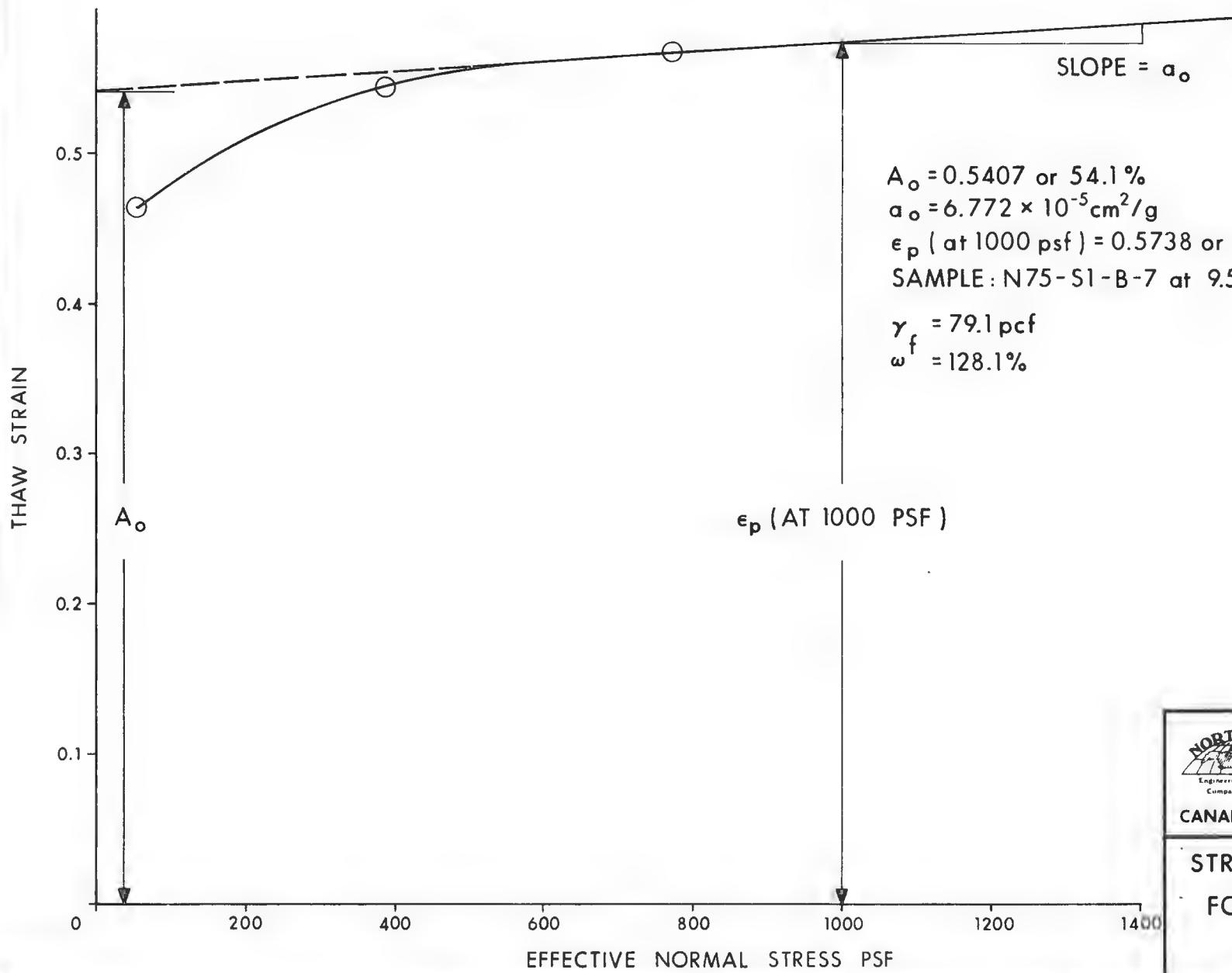
where K_c is given in cm/sec.
 γ_w unit weight of water, g/cm^3

Thaw strain, as obtained by consolidation permeability tests, is defined as:

$$\text{Volumetric Strain} = \frac{\Delta H}{H}$$

where ΔH = cumulative change in height of the soil sample
 H = initial height of the soil sample

The physical meanings of the parameters, A_o and a_o , are illustrated graphically in Figure 5.2.1.



NORTHERN
Engineering Services
Company Limited
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

STRAIN Vs NORMAL STRESS
FOR A CONSOLIDATION-
PERMEABILITY TEST

FIGURE 5.2.1

Thaw-settlement Parameter, A_o , is defined as the thaw strain at zero pressure, and is obtained by extending back the straight portion of the curve to intercept the thaw strain axis at the zero pressure ordinate.

Average Coefficient of Compressibility, a_o , is defined as the slope of the linear portion of the curve.

Strain at any applied pressure, P , is given by:

$$\epsilon_p = A_o + P \times a_o$$

5.2.2 Direct Shear Test

The drained peak shear strength value obtained from a direct shear test is given in terms of effective stress parameters, by:

$$\tau = c' + \sigma' \tan \phi'$$

where τ = drained shear strength in psi
 c' = cohesion intercept of the Mohr-Coulomb relationship, psi
 σ' = normal stress on the failure plane, psi
 ϕ' = angle of shearing resistance or the slope of the Mohr-Coulomb relationship, degrees

The residual shear strength for effective stresses is given by:

$$\tau_r = c_r' + \sigma' \tan \phi_r$$

where τ_r , and c_r' and ϕ_r' are defined same as above but for residual shear stresses.

5.3

Presentation of Test Results

The test results obtained from the laboratory program are presented in this section. Subsections 5.3.1 to 5.3.13 present the data from the sites listed below:

SUBSECTION NO.	SITE NO.	LOCATIONS	
		LATITUDE	LONGITUDE
5.3.1	Katakturuk R.	69°50' N	145°21' W
5.3.2	N75-S1	69°34'26"N	140°32'15"W
5.3.3	N75-RZ 33	68°53'58"N	137°45'00"W
5.3.4	N75-RZ 3	68°46'53"N	136°41'46"W
5.3.5	N75-RZ 42	69°06'54"N	134°53'35"W
5.3.6	N75-DV 1	69°07'58"N	134°58'58"W
5.3.7	N75-DV 41	69°04'03"N	134°46'25"W
5.3.8	N75-DV 11	68°59'59"N	133°39'45"W
5.3.9	N75-DV 3	68°57'42"N	134°16'14"W
5.3.10	N75-DV 5	68°41'58"N	133°45'28"W
5.3.11	N75-DV 51	68°36'36"N	133°32'59"W
5.3.12	N75-DV 9	68°11'37"N	132°36'56"W
5.3.13	N75-DV 10	67°44'20"N	131°39'41"W

Where available, the order of data presentation under each subsection is as follows:

1. Test Hole Logs - Logs for all test holes previously published in a preliminary form in Reference 1 have now been finalized. A plot of the frozen bulk density and material water content against depth has been added to the Laboratory Test Data column. Appendix A contains an explanation of the terms and symbols presented on these test hole logs.

2. Summary of Test Data for Soil Classification - This table summarizes the Particle Size Analysis and Atterberg Limits Test results used for soil classification purposes.

3. Summary of Consolidation - Permeability Test Data
4. A plot of the Log of the Measured Permeability (K_m) versus the Log of the Effective Stress (P) for the Consolidation-Permeability Tests. Superimposed on the same drawing is a plot of the Log of the Calculated Permeability (K_c) versus the Log of the Effective Stress (P).
5. A plot of the Void ratio (e) versus the Log of the Effective Stress (P) for the Consolidation-Permeability tests.
6. A plot of the Log of the Coefficient of Consolidation (C_v) versus Log of the Effective Stress (P) for the Consolidation-Permeability Tests.
7. Summary of the direct Shear Test Data.
8. A plot of the Effective Normal Stress (σ'_N) versus Shear Stress (τ) for the Direct Shear Tests for each soil group from a site.
9. Summary of Triaxial Test Data
10. A plot of the Effective Normal Stress (σ'_N) versus Shear Stress (τ) for the Triaxial Tests.

5.3.1 Katakturuk River Site

A limited series of tests was done on a disturbed bulk soil sample obtained from this location during a 1974 reconnaissance of the Alaska segment of the proposed pipeline route. These consisted of a series of reversible Direct Shear Tests on a remoulded unfrozen sample of the soil, Particle Size Analysis and Atterberg Limits Tests for soil identification purposes and the Mineralogical Analysis presented in Table 5.4.1.

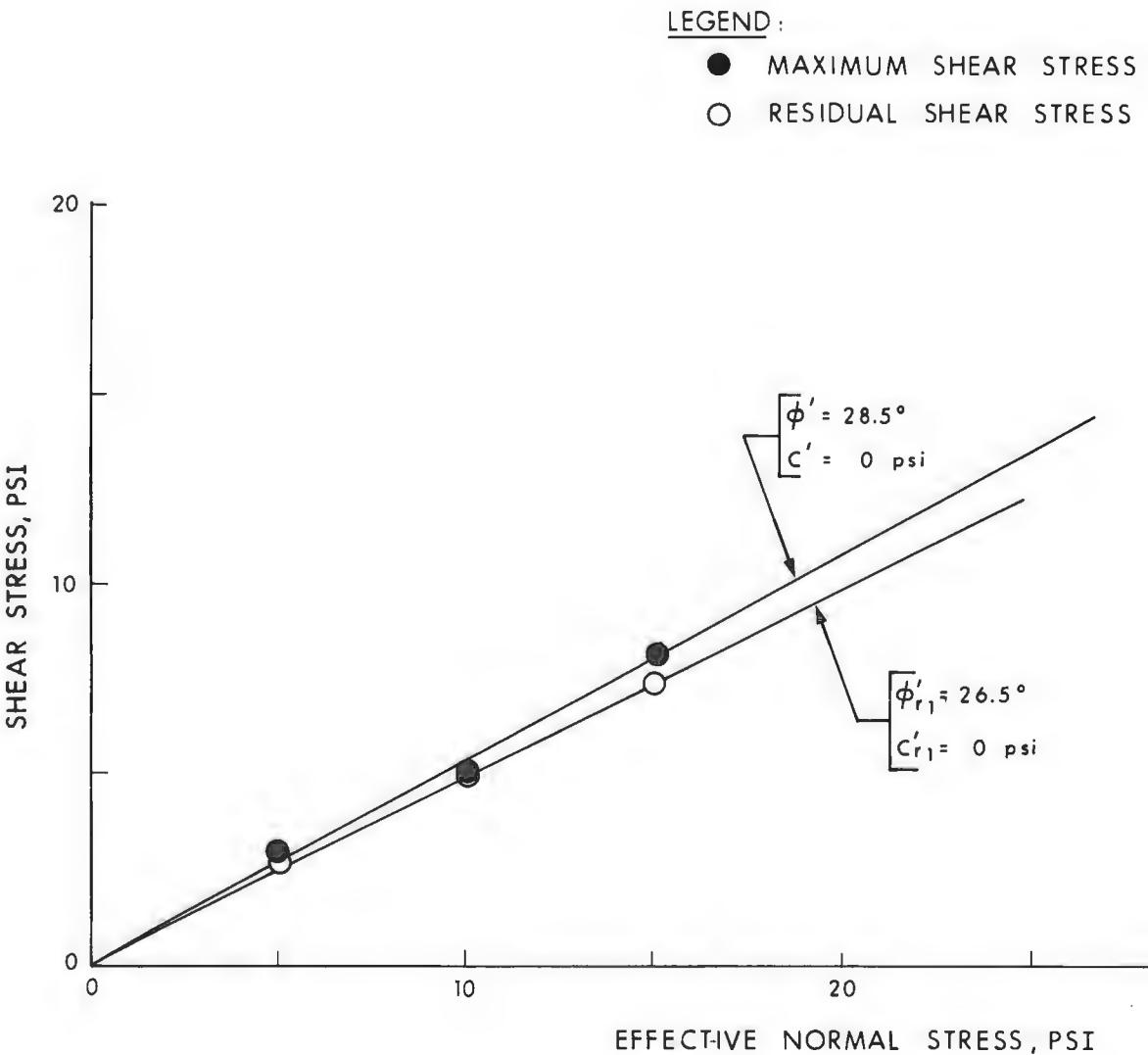
SUMMARY OF DIRECT SHEAR TEST DATA

** Unfrozen bulk density

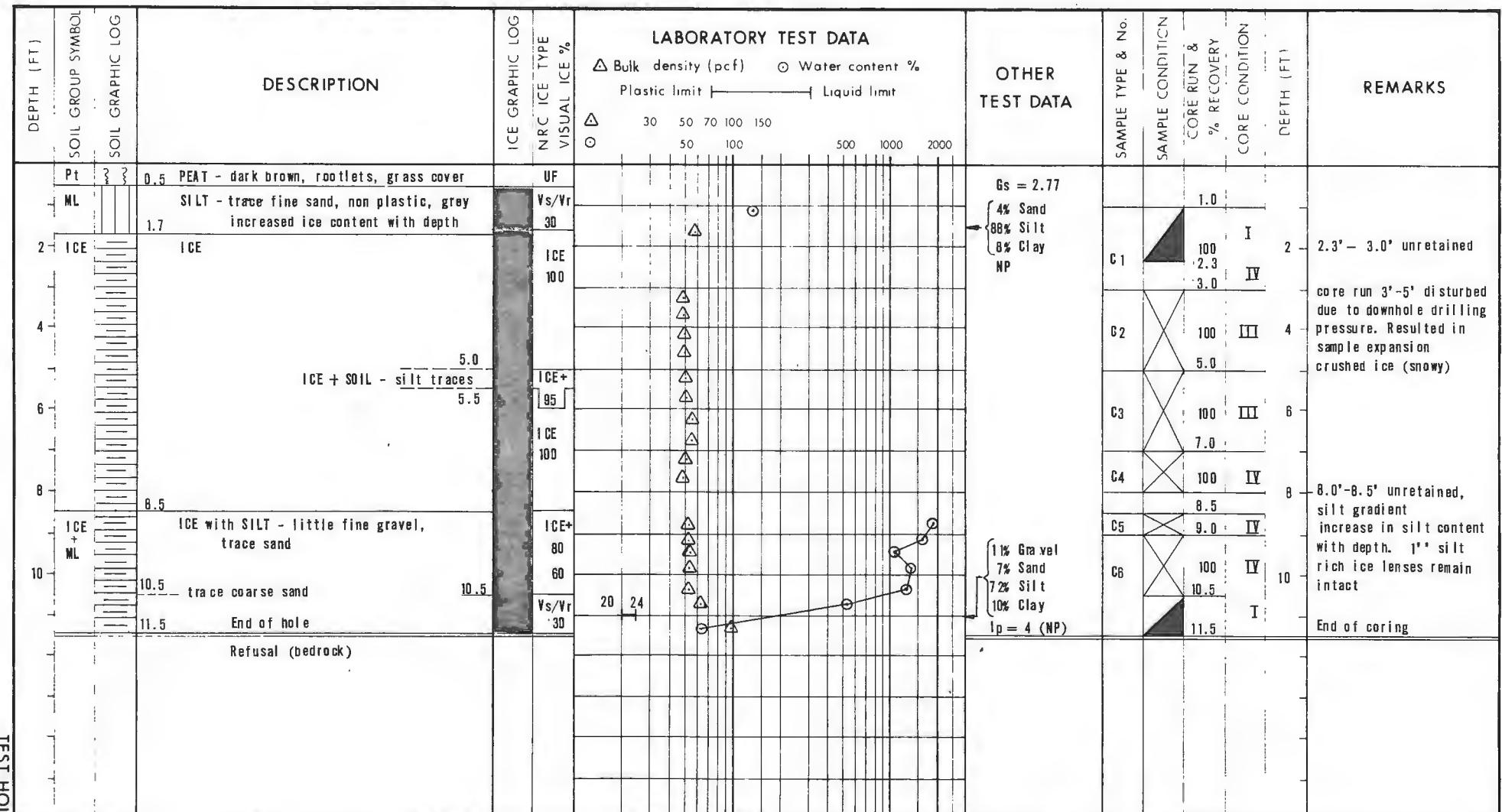
+ Water content after preparing slurry & consolidating at 1 psi

Natural water content = 24.2%

FOR SOIL GROUP : CI

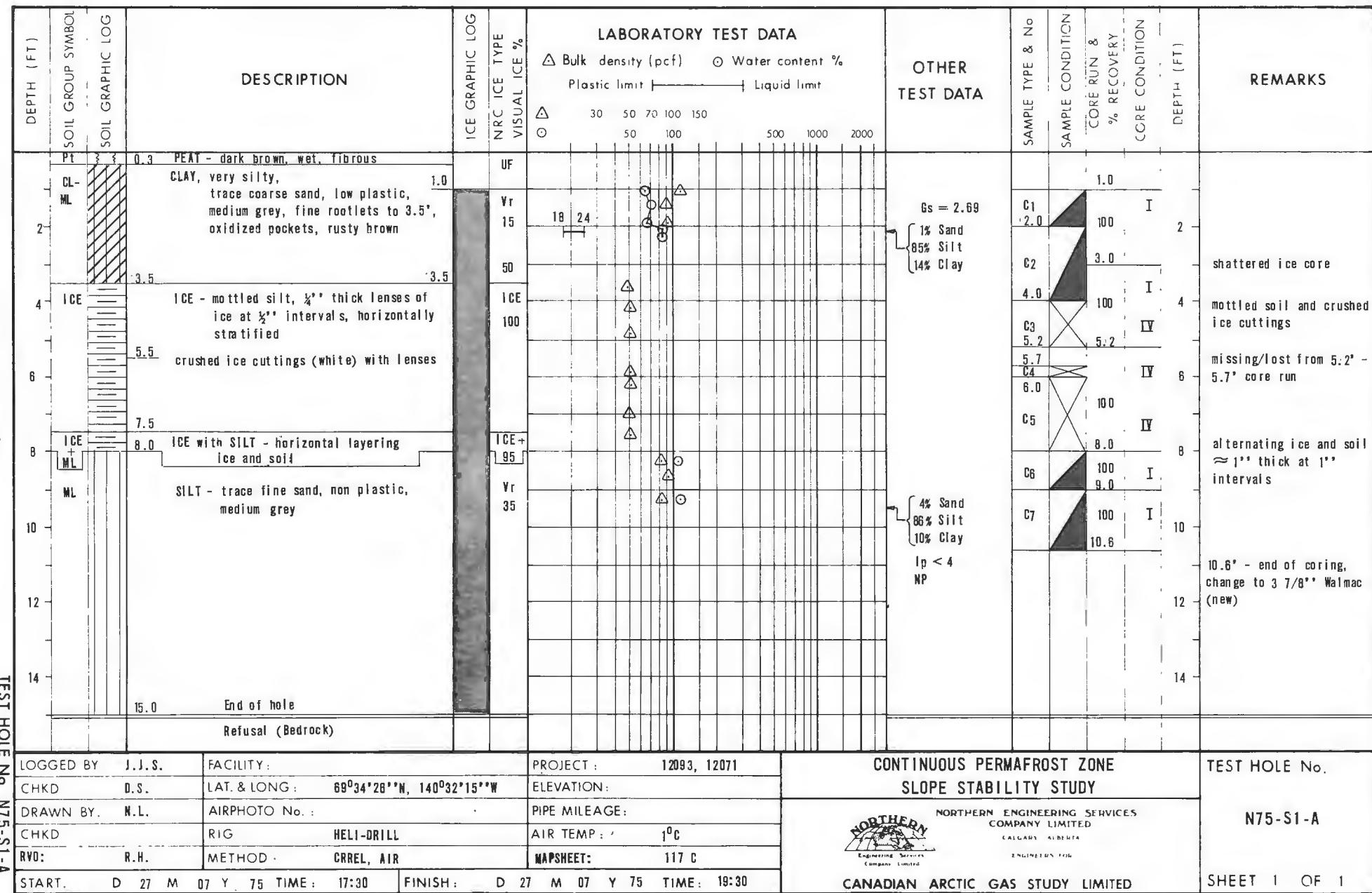


TEST HOLE LOG

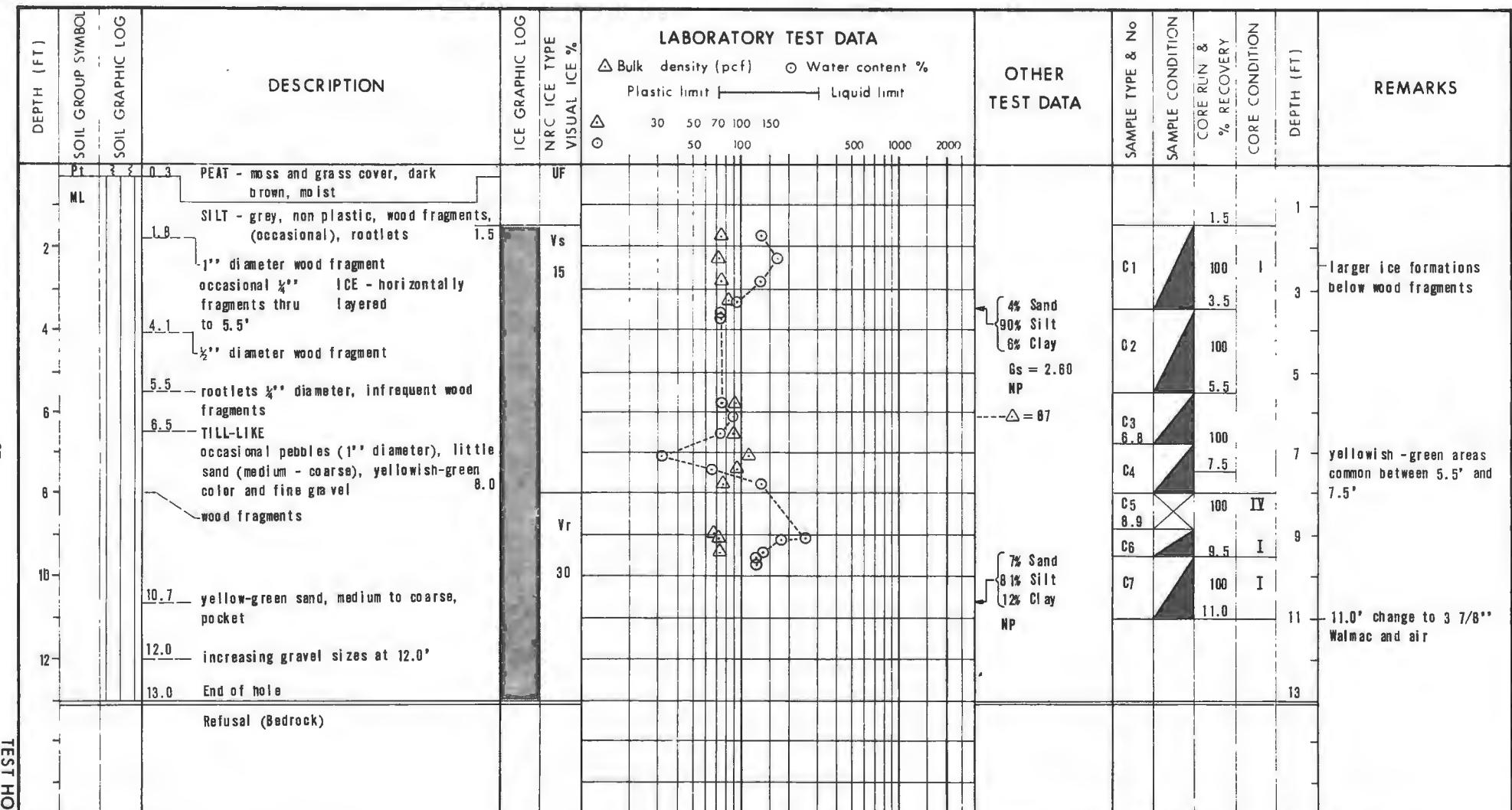


LOGGED BY	O.O.	FACILITY	PROJECT	12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY	NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS LTD	TEST HOLE No.
CHKD	O.S.	LAT. & LONG :	69°34'26"N, 140°32'15"W	ELEVATION:			N75-S1-1
DRAWN BY	N.L.	AIRPHOTO No. :		PIPE MILEAGE:			
CHKD	RIG.	HELI-ORILL		AIR TEMP:			
RVD:	R.H.	METHOD	CRREL (4")	MAPSHEET:			
START.	D 27 M 07 Y 75 TIME:	15:30	FINISH:	D 27 M 07 Y 75 TIME:	17:00	CANADIAN ARCTIC GAS STUDY LIMITED	SHEET 1 OF 1

TEST HOLE LOG



TEST HOLE LOG



LOGGED BY:	D.O.	FACILITY:	PROJECT :	12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY				TEST HOLE No.	
CHKD:	D.S.	LAT. & LONG :	69°34'28"N, 140°32'15"W	ELEVATION:					N75-S1-B	
DRAWN BY:	N.L.	AIRPHOTO No.:		PIPE MILEAGE:						
CHKD	RIG.	HELI-DRILL		AIR TEMP :	10°C					
RVD:	R.H.	METHOD: CRREL (4") and 3 7/8" Walmac & Air		MAPSHEET:	117 C					
START.	D 27 M 07 Y 75	TIME: 20:00	FINISH:	D 27 M 07 Y 75	TIME: 21:30					SHEET 1 OF 1



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution				Soil Group	Remarks
		W _L %	W _P %	> 0.074 mm Gravel %	Sand %	Silt %	< 0.074 mm Clay* %		
N75-S1-1-1	1.0-3.0	NP	NP	0	4	88	8	ML	
N75-S1-1-6	10.5-11.5	24	20	11	7	72	10	ML	
N75-S1-A-2	2.0-4.0	24	18	0	1	85	14	CL-ML	
N75-S1-A-7	9.0-10.6	NP	NP	0	4	86	10	ML	
N75-S1-B-2	3.5-5.5	NP	NP	0	4	90	6	ML	
N75-S1-B-7	9.5-11.0	NP	NP	0	7	81	12	ML	

* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

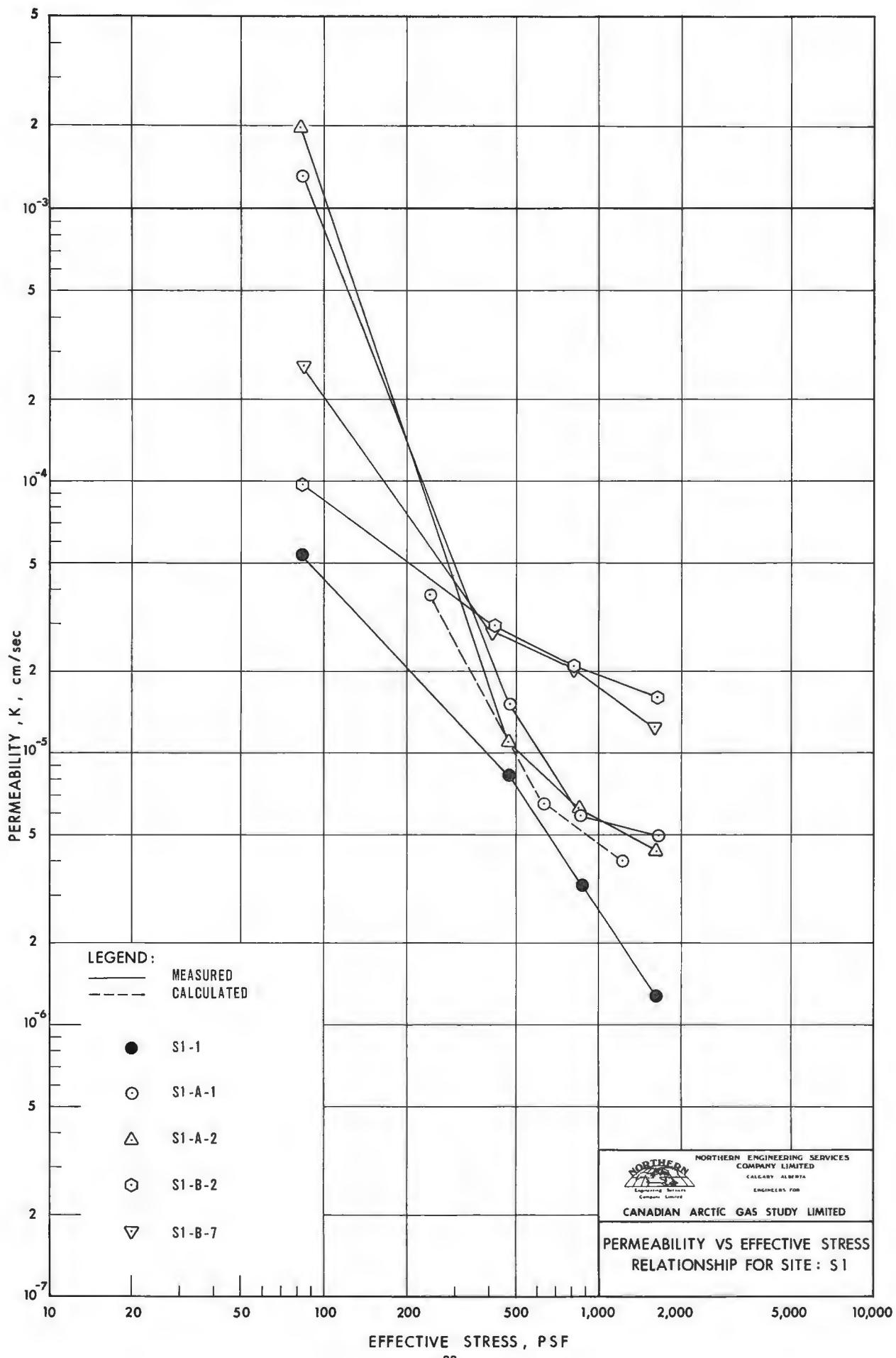
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

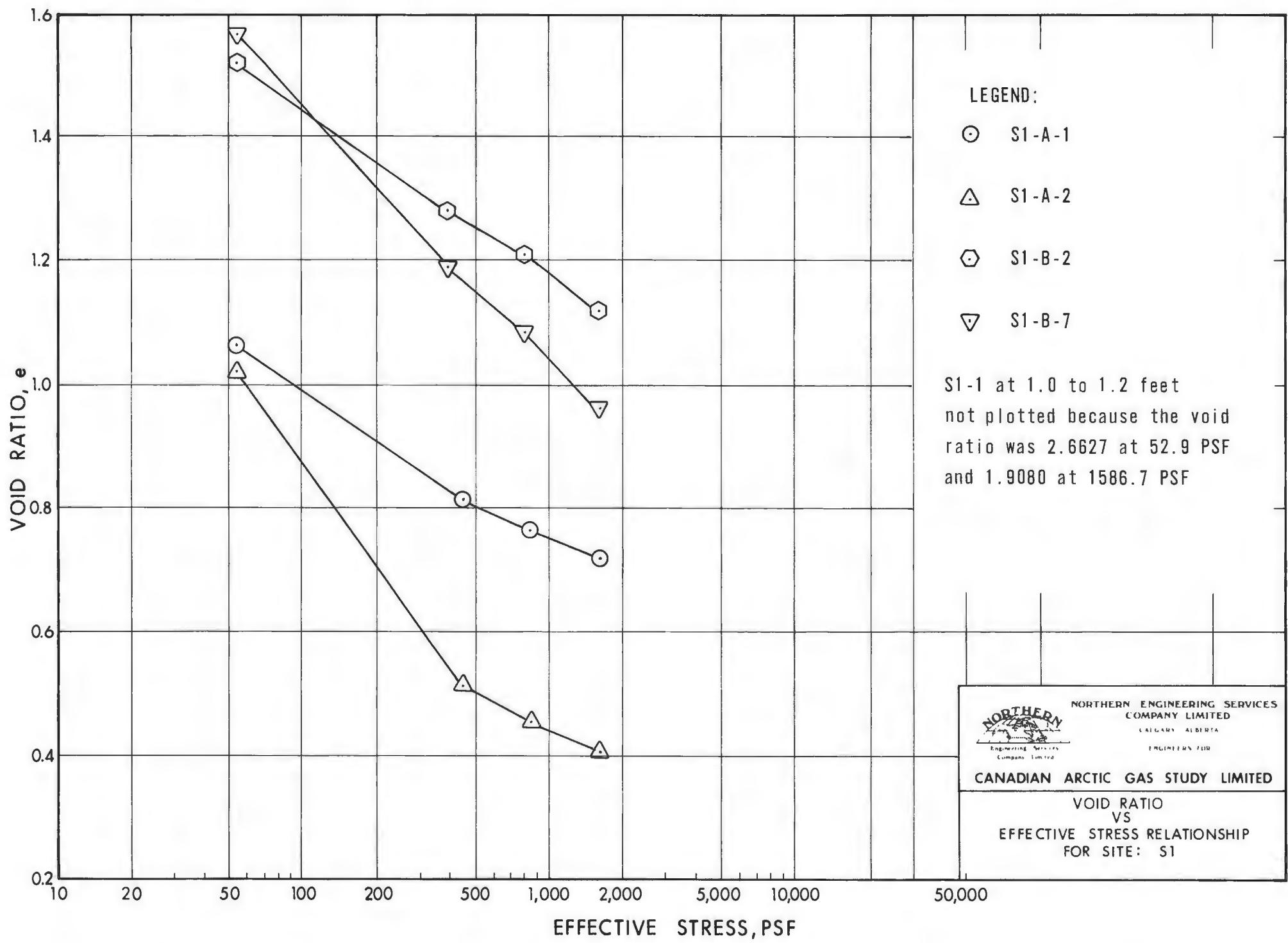
SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
S1-1-1	1.0-1.2	77.5	138.1	NP	NP	88	8	0.0		4.312					
								52.9		2.663					
								445.0		2.668	1.0	5.35			
									248.9	2.223					
										2.205	1.0	0.83			
								836.9		2.100					
									640.9						
								1586.7		2.098	1.0	0.33			
									1211.8	1.934					
										1.908	1.0	0.13			
S1-A-1	1.0-1.2	92.0	76.8	-	-	-	-	0.0		2.226					
								52.1		1.065					
								436.6		1.012	1.0	129.6			
									244.3						
										0.814					
								824.1		0.800	1.0	1.50			
										0.766					
								1598.4		0.762	1.0	0.59			
										0.720					
								1211.2		0.718	1.0	0.50			

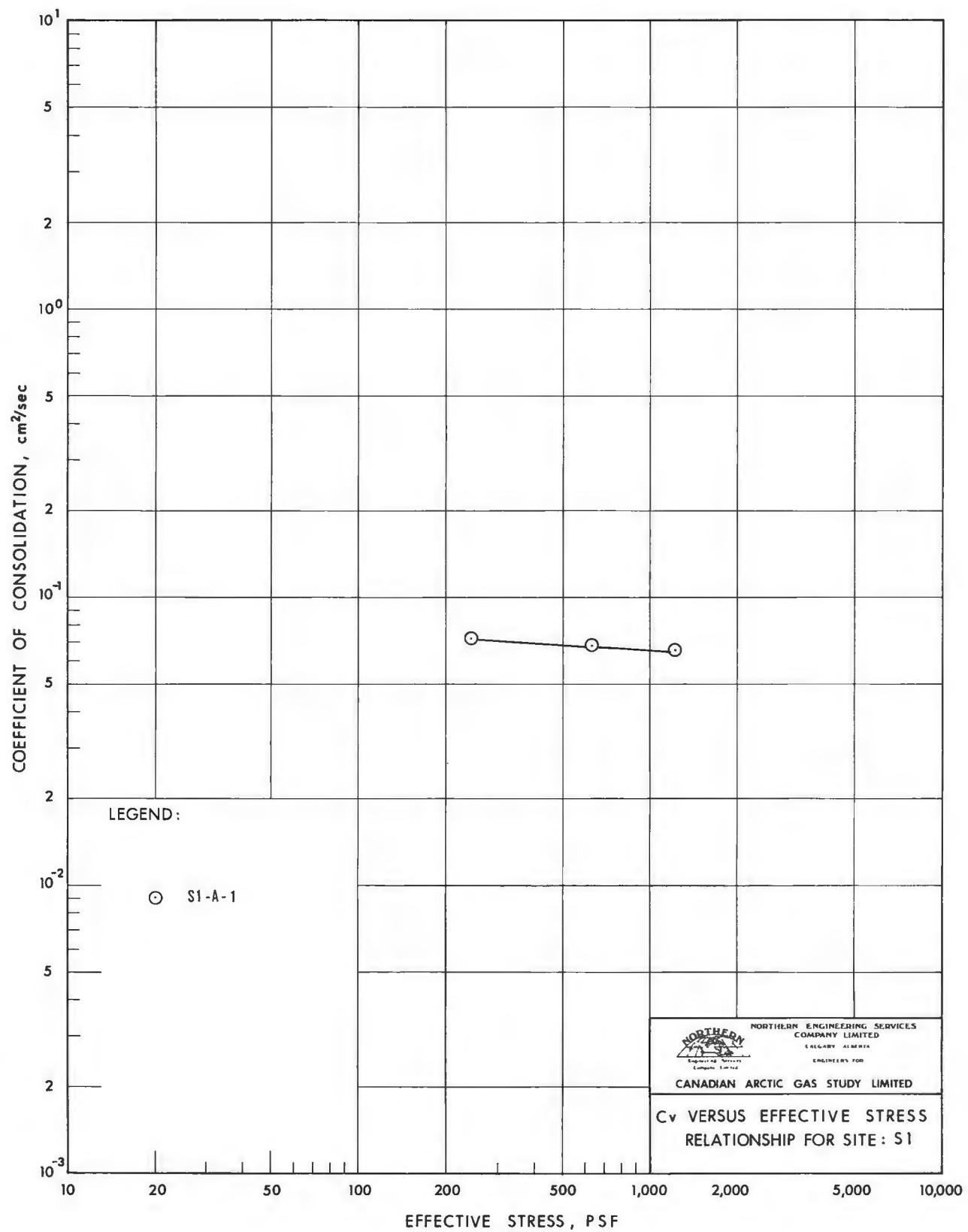
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
S1-A-2	2.0-2.3	91.1	82.7	24	18	85	14	0.0	2.366						
								51.7		1.022					
									0.984	1.0	197.80				
								437.2		0.516					
									244.4			3.04	73.46	2.23	
										0.501	1.0	1.18			
								826.8		0.457					
									632.0			-	=	-	
										0.453	1.0	0.61			
								1607.6		0.405					
									1217.2			-	-	-	
										0.402	1.0	0.44			
S1-B-2	3.5-3.8	87.6	77.1	NP	NP	90	6	0.0	2.281						
								53.3		1.538					
									1.433	1.0	9.72				
								390.9		1.279					
									222.1			-	-	-	
										1.272	1.0	2.89			
								792.7		1.208					
									591.8			-	-	-	
										1.191	1.0	2.08			
								1597.2		1.119					
									1194.9			-	-	-	
										1.110	1.0	1.60			

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA





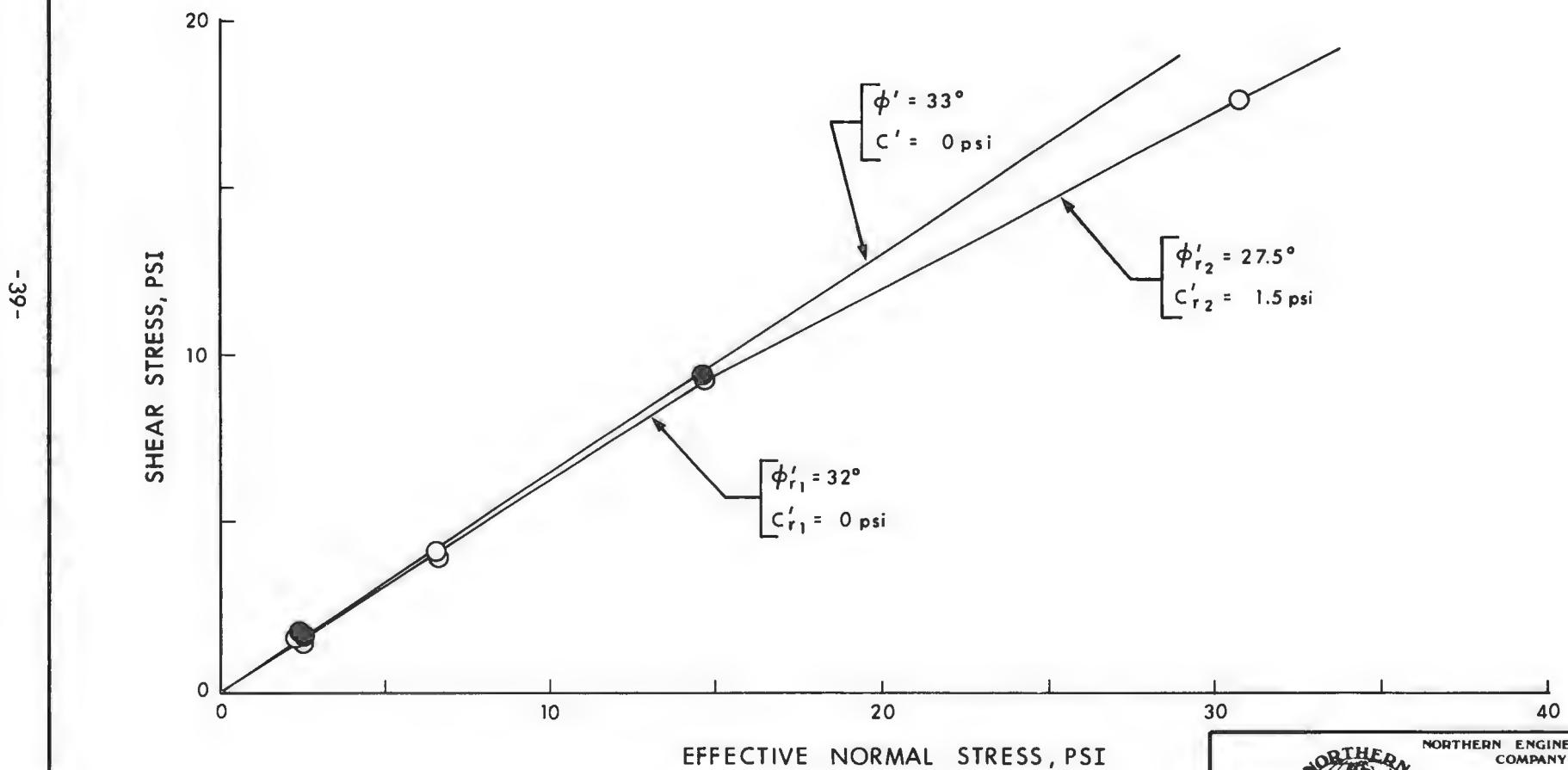


SUMMARY OF DIRECT SHEAR TEST DATA

FOR SOIL GROUP : CL - ML

LEGEND:

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

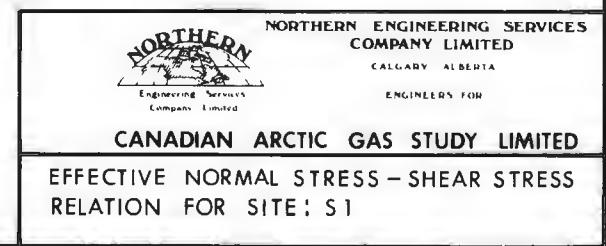
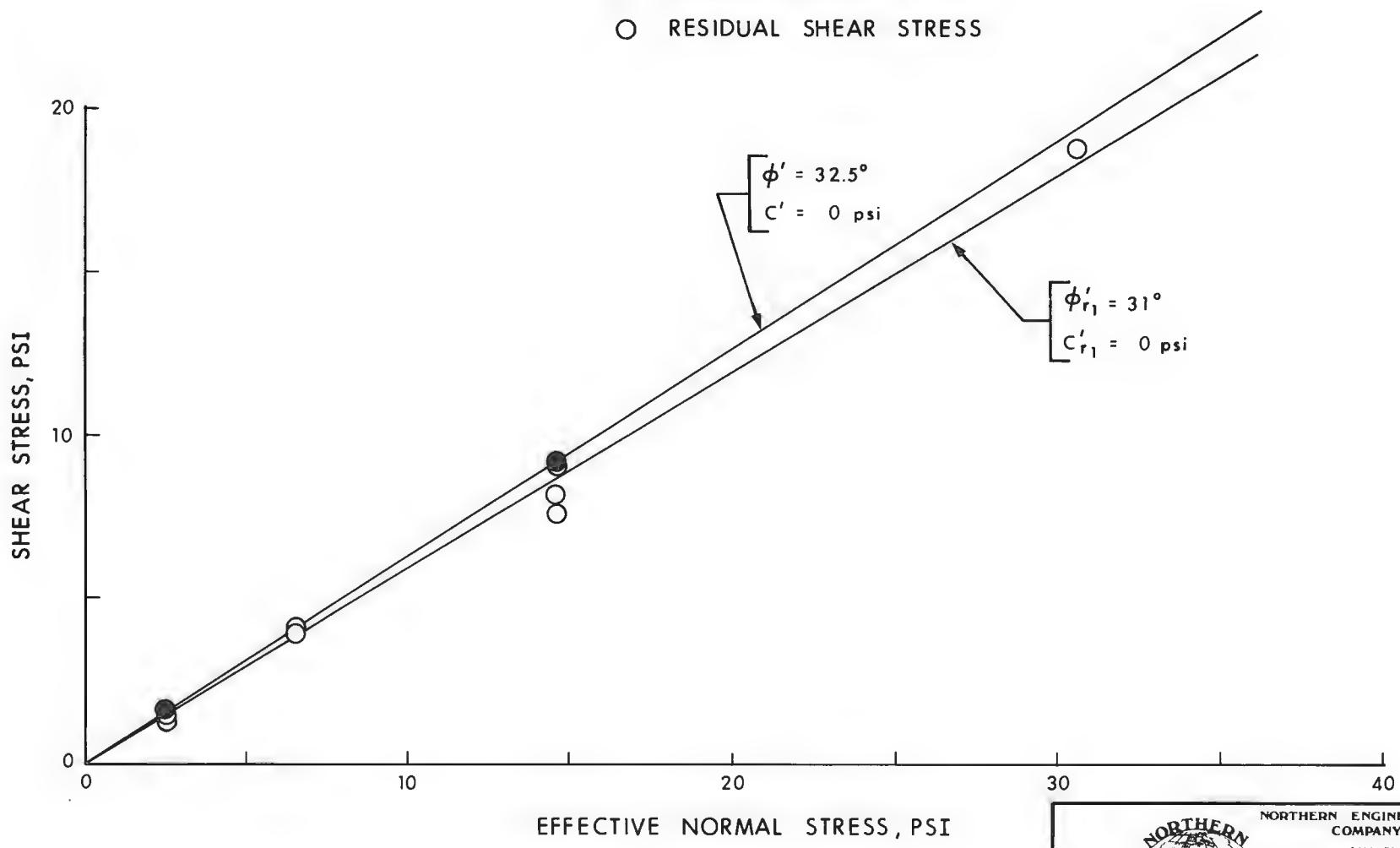
CANADIAN ARCTIC GAS STUDY LIMITED

EFFECTIVE NORMAL STRESS - SHEAR STRESS
RELATION FOR SITE: S1

FOR SOIL GROUP : ML

LEGEND :

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



TEST HOLE LOG

TEST HOLE NO. N75-RZ33-1	DEPTH (FT)	SOIL GROUP SYMBOL CL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE UF	LABORATORY TEST DATA						OTHER TEST DATA	SAMPLE TYPE & NO.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT)	REMARKS	
							Dry density (pcf)	Water content %	Plastic limit	Liquid limit	30	50	70	100	150	500	1000	2000		
	0.2			0.2 PEAT - dark brown, moist, willow and sedge roots, moss cover.																- Peat blanket, 3' - 4' willows, sedges.
	2	CL		CLAY - silty, dark grey, mottling light browns, low plastic, rootlets to depth 3', (till-like)																- no coring attempted
	3.0					F														- start drilling with 4 1/2" Walmac (used).
	4																			
	6																			
	8																			
	10																			
	12																			
	14			14.0 occasional fine gravel																8.0' change to new 3 7/8"
	16																			Walmac.
LOGGED BY:	J.J.S.	FACILITY:		PROJECT:	12093, 12071		CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY						NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY, ALBERTA ENGINEERS LTD						TEST HOLE NO.	
CHKD	D.S.	LAT. & LONG :	88°53'58"N, 137°45'00"W	ELEVATION:															N75-RZ33-L	
DRAWN BY:	J.J.S.	AIRPHOTO No.:	A 23838-68, 88	PIPE MILEAGE:			NORTHERN Engineering Services Company Limited	CANADIAN ARCTIC GAS STUDY LIMITED						SHEET 1 OF 3						
CHKD	R.H.	RIG:	HELI-DRILL	AIR TEMP:	0°C - 8°C															
RVD:		METHOD:	Walmac bit w/AIR (4 1/2" & 3 7/8")	MAPSHEET:	117 D															
START:	D 01 M 08 Y 75	TIME:	13:00	FINISH:	D 01 M 08 Y 75	TIME:	13:50													



NORTHERN
Engineering Services
Company Limited
CALGARY, ALBERTA
ENGINEERS LTD

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE LOG

DEPTH (FT)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE	VISUAL ICE %	LABORATORY TEST DATA										OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT)	REMARKS		
							▲ Dry density (pcf)	○ Water content %	Plastic limit					Liquid limit											
16	CL		CLAY (cont'd.)		F				30	50	70	100	150	500	1000	2000					16				
18																					18				
20																					20				
22																					22				
24																					24				
26	CL																				26				
28			23.0 - increase in fine gravel sizes.																		28				
30			25.0 -																		30				
32			CLAY - trace fine to coarse gravel, dark grey, medium plastic. (till-like)																		32				
LOGGED BY	J.J.S.	FACILITY			PROJECT :	12083, 12071																			
CHKD	D.S.	LAT. & LONG :	88°53'58"N, 137°45'00"W		ELEVATION :																				
DRAWN BY	J.J.S.	AIRPHOTO No. .	A 23838-88, 69		PIPE MILEAGE:																				
CHKD.	RIG.	HELI-DRILL			AIR TEMP :	00°C																			
RVD:	R.H.	METHOD :	Walmac bit (4 1/2" & 3 7/8") & AIR		MAPSHEET:	117 D																			
START.	D 01	M 08	Y 75	TIME : 13:00	FINISH:	D 01	M 08	Y 75	TIME : 13:50																



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.
N75-RZ33-L
SHEET 2 OF 3

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE	VISUAL ICE %	LABORATORY TEST DATA										OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS
							▲ Dry density (pcf)	○ Water content %	Plastic limit		Liquid limit		30	50	70	100	150	500	1000	2000			
32	C1		CLAY - (cont'd.)		F																	32	
			33.0																			33.0	downhole progress still possible at same rate as through clay.
34			CLAYSTONE? weathered?																			34	
			35.0																			35.0	difficulty in progressing further.
36			intact?																			36	36.0
			REFUSAL: (BEDROCK)																				

LOGGED BY	J.J.S.	FACILITY:	PROJECT :	12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY	NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED	TEST HOLE No.													
CHKD	D.S.	LAT. & LONG :	88°53'58" N, 137°45'00" W	ELEVATION:																
DRAWN BY	J.J.S.	AIRPHOTO No. :	A 23838-88, 88	PIPE MILEAGE:																
CHKD		RIG:	HELI-DRILL	AIR TEMP : 0°C																
RVD:	R.H.	METHOD :	Walmac bits w/AIR.	MAPSHEET: 117 D																
START.	D 01	M 08	Y 75	TIME: 13:00	FINISH:	D 01	M 08	Y 75	TIME: 13:50											SHEET 3 OF 3



TEST HOLE LOG

TEST HOLE NO.	LOGGED BY D.H.D.	FACILITY LAI & LONG	PROJECT: 12093, 12071	LABORATORY TEST DATA		OTHER TEST DATA	REMARKS
				DESCRIPTION	Bulk density (pcf) Plastic limit	Water content % + liquid limit	
1	P.I.	0.3	PEAT - dark brown, fibrous, moist, willow roots.	UF			
2	DL	0.5	SILT - (organic) mottled dark medium browns. 1.0 oxidized pockets, roots & fibres.	VR 10 VS 15			
2	ML	1.7	SILT - little fine gravel, dark brown, oxidized pockets	3.0			
4			- trace medium - coarse sand, light brown	VR/VS 5			
4			- infrequent 1/2" black, hard, surrounded pebbles.	NON occa. Vx(%)			
6	OL	6.4	SILT - (organic) dark brown/black	VT 10			
8	ICE	ICE	occasional lenses, stratified, 1/2" - 1 1/2" thick, 2" - 3" long, with < 1% silt suspended.	ICE 100			shattered ice core (snowy) core run 7.0'-9.0' shattered, expanded volume.
10							unrecovered core run 9.0' - 11.0'
12							11.0' change to 3 7/8" Walmac.
14							snowy cuttings.
16							

LOGGED BY D.H.D.	J.J.S. D.S.	FACILITY LAI & LONG	PROJECT: 12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY	TEST HOLE No. N75-RZ33-U
DRAWN BY D.H.D.	N.L.	AIRPHOTO No A 23838-88, 69	ELEVATION:		
RVD: R.H.		RIG HELI-DRILL	PIPE MILEAGE:		
		METHOD CRREL (4") & 3 7/8" Walmac	AIR TEMP: 7°C		
START	D 31	M 07	Y 75	MAPSHEET: 117 D	SHEET 1 OF 4
				CANADIAN ARCTIC GAS STUDY LIMITED	

TEST HOLE LOG

TEST HOLE LOG

TEST HOLE NO. N75-RZ33-U	DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	NOT VERIFIED BY LABORATORY TESTS		ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA										OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS	
				DESCRIPTION				▲ Dry density (pcf)	○ Water content %	Plastic limit	Liquid limit	30	50	70	100	150	500	1000	2000						
	32	ICE +		frequent coarse sand and fine gravel		ICE +																		32	3 7/8" Walmac bit
	34																							34	
-46	36																							36	"dirty", sleet-like cuttings
	38																							38	
	40																							40	
	42																							42	
	44																							44	
	46																							46	
	48																							48	

LOGGED BY:	J. J. S.	FACILITY:	PROJECT:	12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY	NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED	TEST HOLE No.
CHKD:	O.S.	LAT. & LONG:	88°53'58"N, 137°45'00"W	ELEVATION:			
DRAWN BY:	K.M.	AIRPHOTO No.:	A 23838-68, 69	PIPE MILEAGE:			
CHKD:		RIG:	HELI-DRILL	AIR TEMP.: 7°C			
RVD:	R.H.	METHOD:	AIR	MAPSHEET: 117 D			
START.	D 31 M 07 Y 75 TIME: 20:15	FINISH:	D 31 M 07 Y 75 TIME: 21:30				SHEET 3 OF 4



TEST HOLE LOG

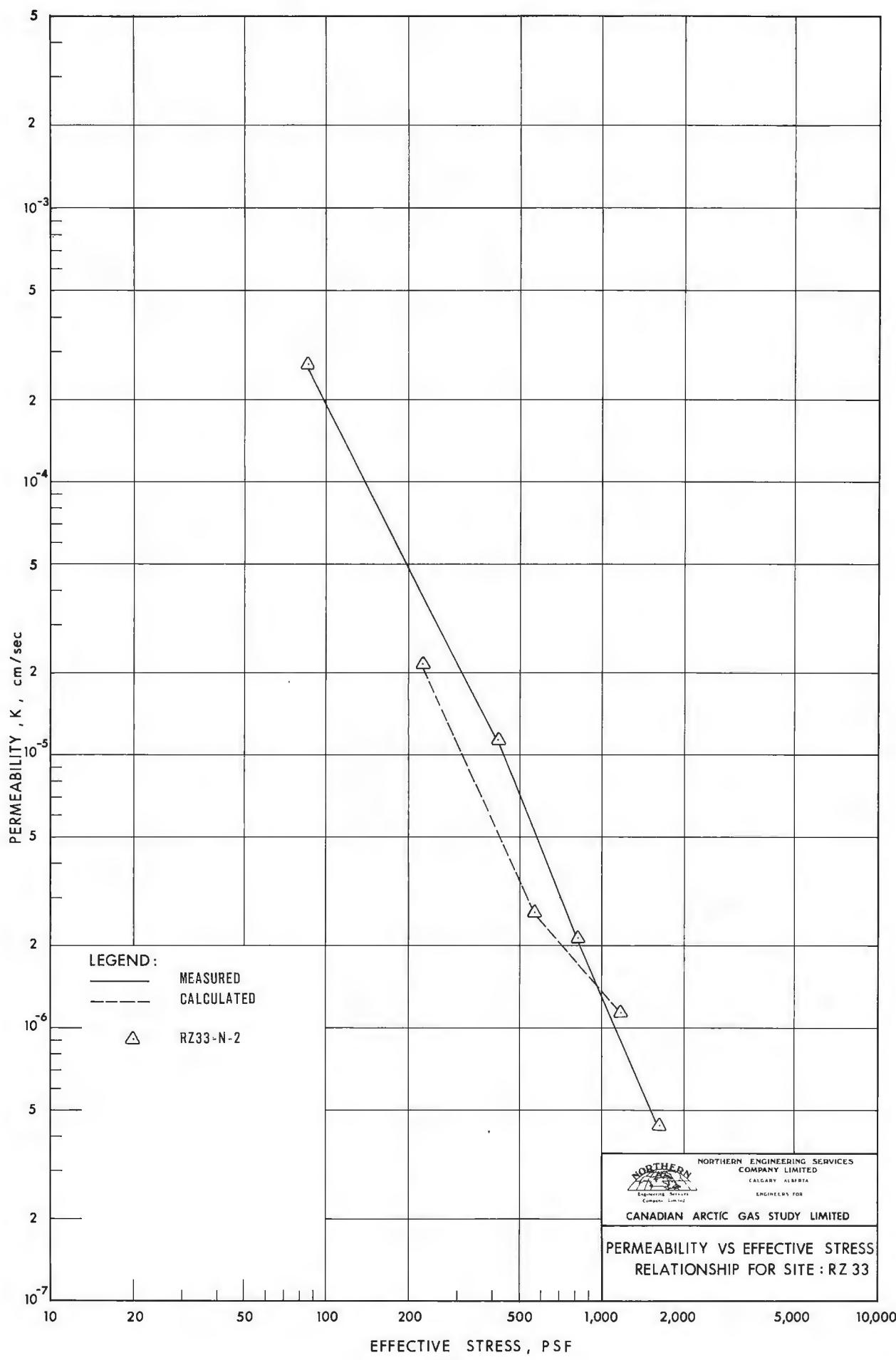
TEST HOLE LOG

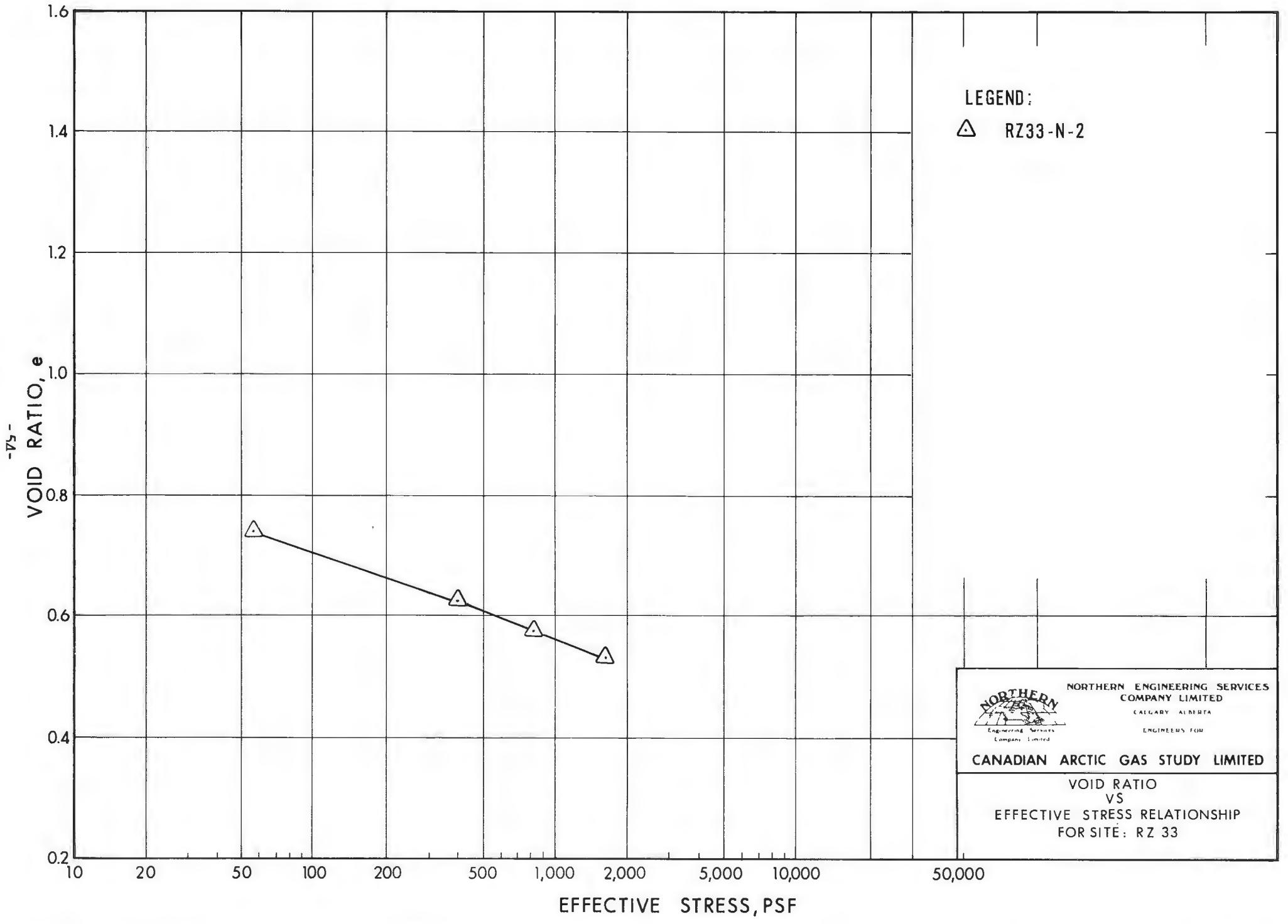
SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

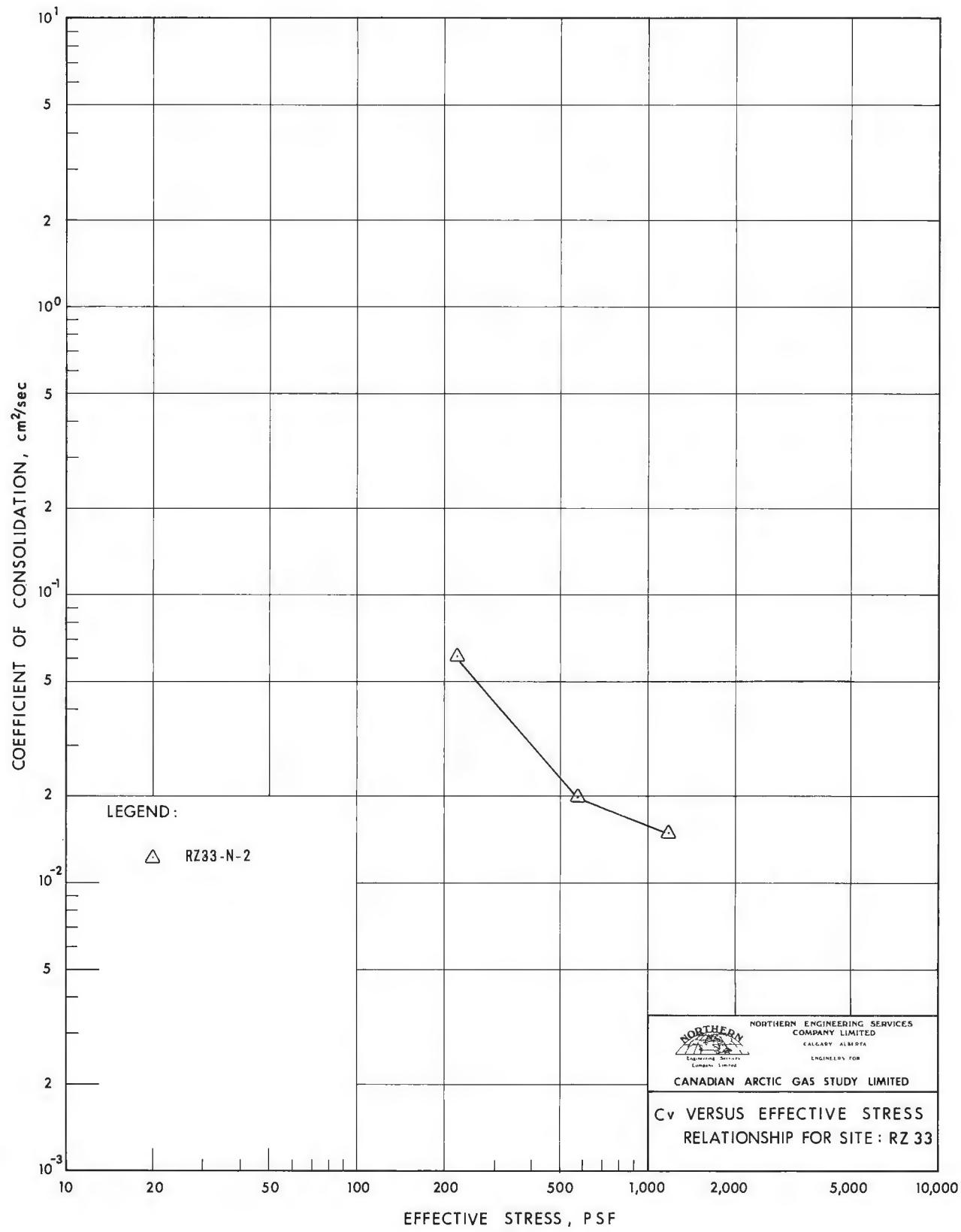
Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution				Soil Group	Remarks
		W _L %	W _P %	> 0.074 mm Gravel %	Sand %	Silt %	< 0.074 mm Clay * %		
N75-RZ33-N-2	4.0-5.0	30	18	9	23	46	22	CI	

* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA





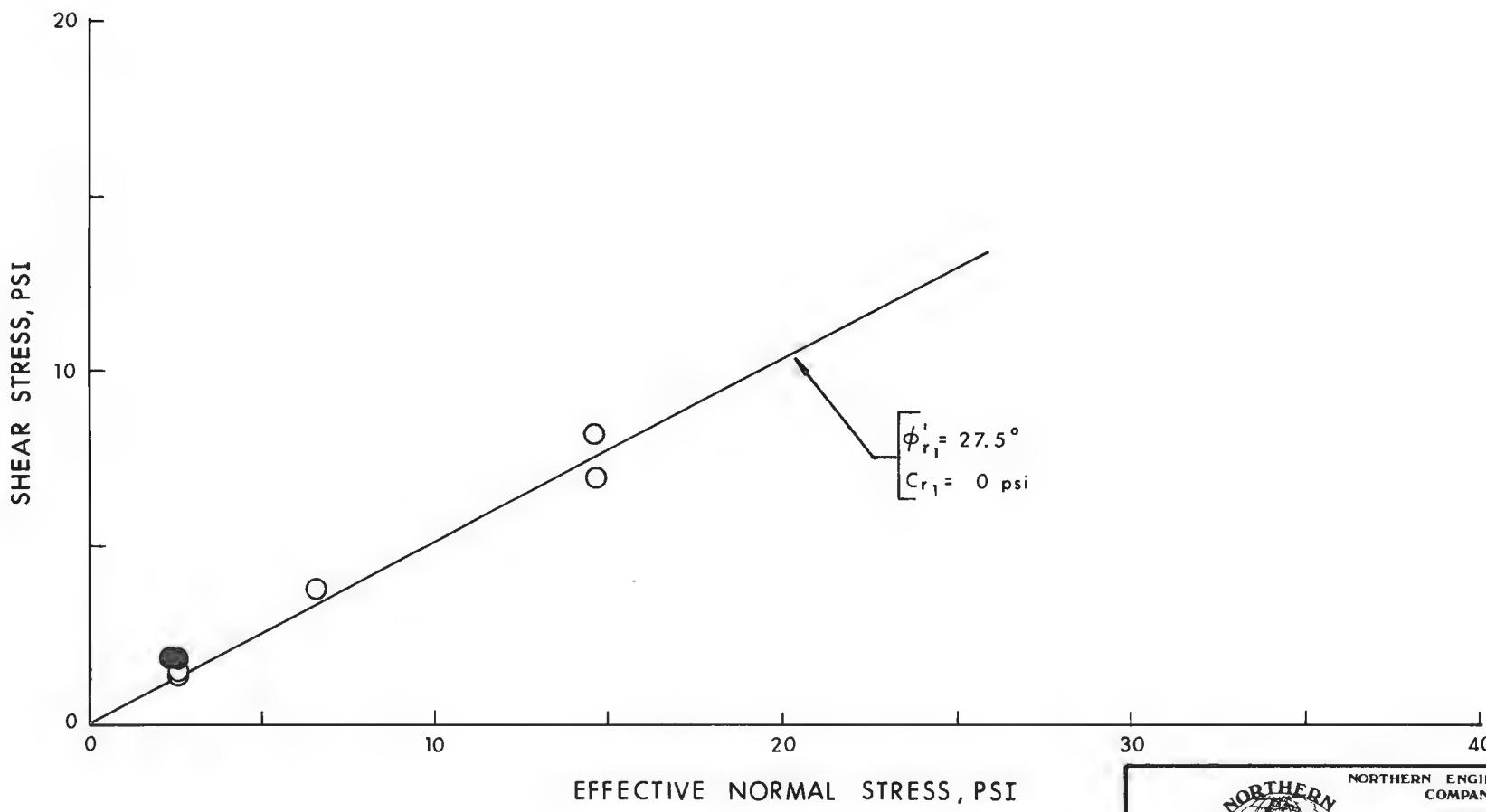


SUMMARY OF DIRECT SHEAR TEST DATA

FOR SOIL GROUP : CI

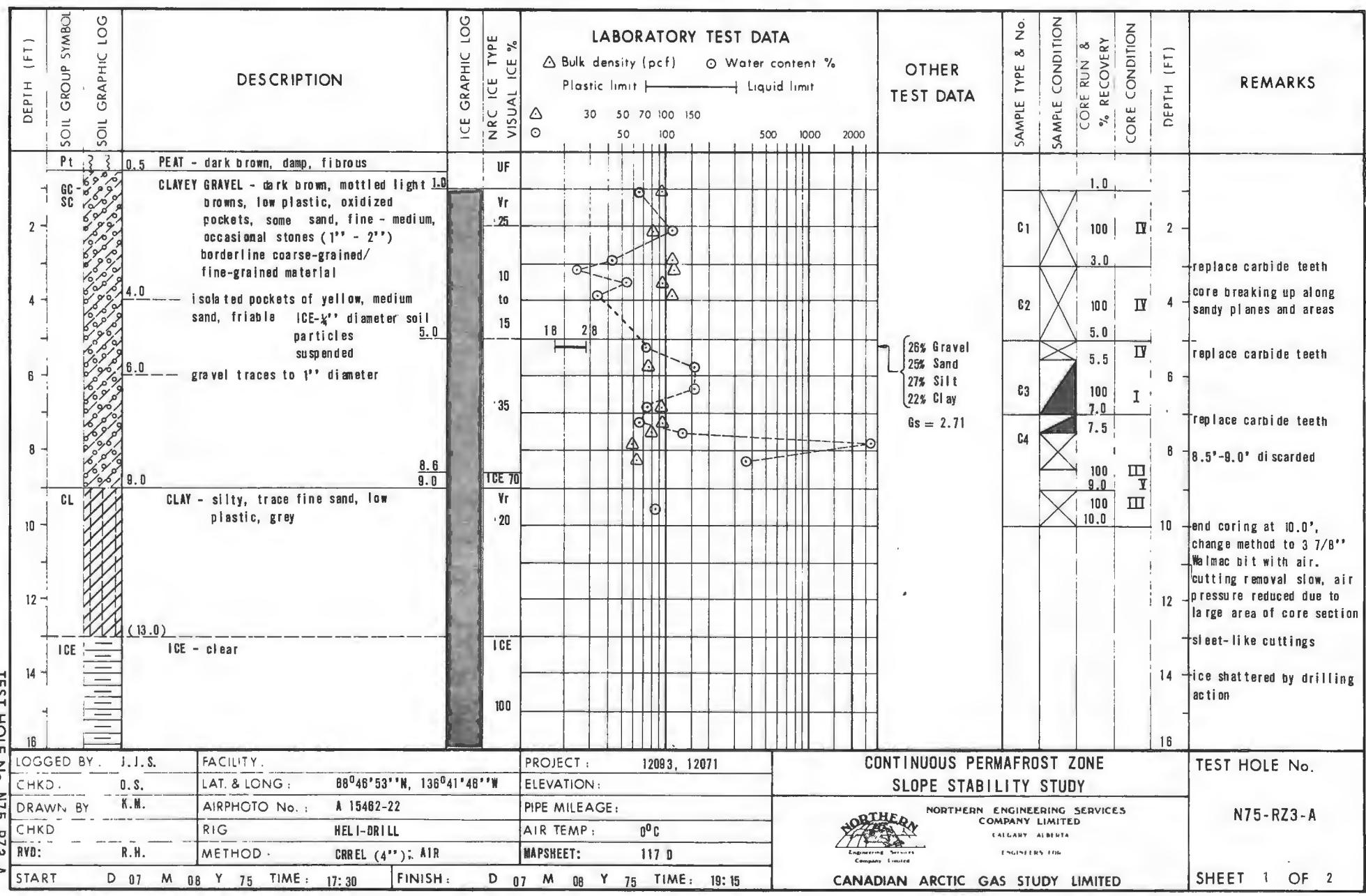
LEGEND :

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LIMITED
Engineering Services
Company Limited
EFFECTIVE NORMAL STRESS - SHEAR STRESS
RELATION FOR SITE: RZ-33

TEST HOLE LOG



TEST HOLE LOG

DEPTH (FT)	SOIL GROUP SYMBOL — SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA										OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT)	REMARKS
					△ Bulk density (pcf)	○ Water content %	Plastic limit		Liquid limit		30	50	70	100	150						
16	ICE	ICE (cont'd)	ICE	100																16	sleet-like cuttings
		17.0																			
CH		CLAY - dark grey, high plastic	F	15																	
18																					
19		19.0 End of hole																		19	cease exploration as cuttings plugging down-hole - high risk of jamming bit.

LOGGED BY:	J.J.S.	FACILITY:	
CHKD:	D.S.	LAT. & LONG:	68°48'53" N, 138°41'48" W
DRAWN BY:	K.M.	AIRPHOTO No.:	A 15482-22
CHKD:	R.H.	RIG:	HELI-DRILL
RVD:		METHOD:	CRREL (4"); AIR
START.	D 07 M 08 Y 75	TIME:	17:30
	FINISH:	D 07 M 08 Y 75	TIME: 10:15

PROJECT: 12093, 12071

ELEVATION:

PIPE MILEAGE:

AIR TEMP: 0°C

MAPSHEET: 117 D

CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

N75-RZ3-A

SHEET 2 OF 2

TEST HOLE LOG

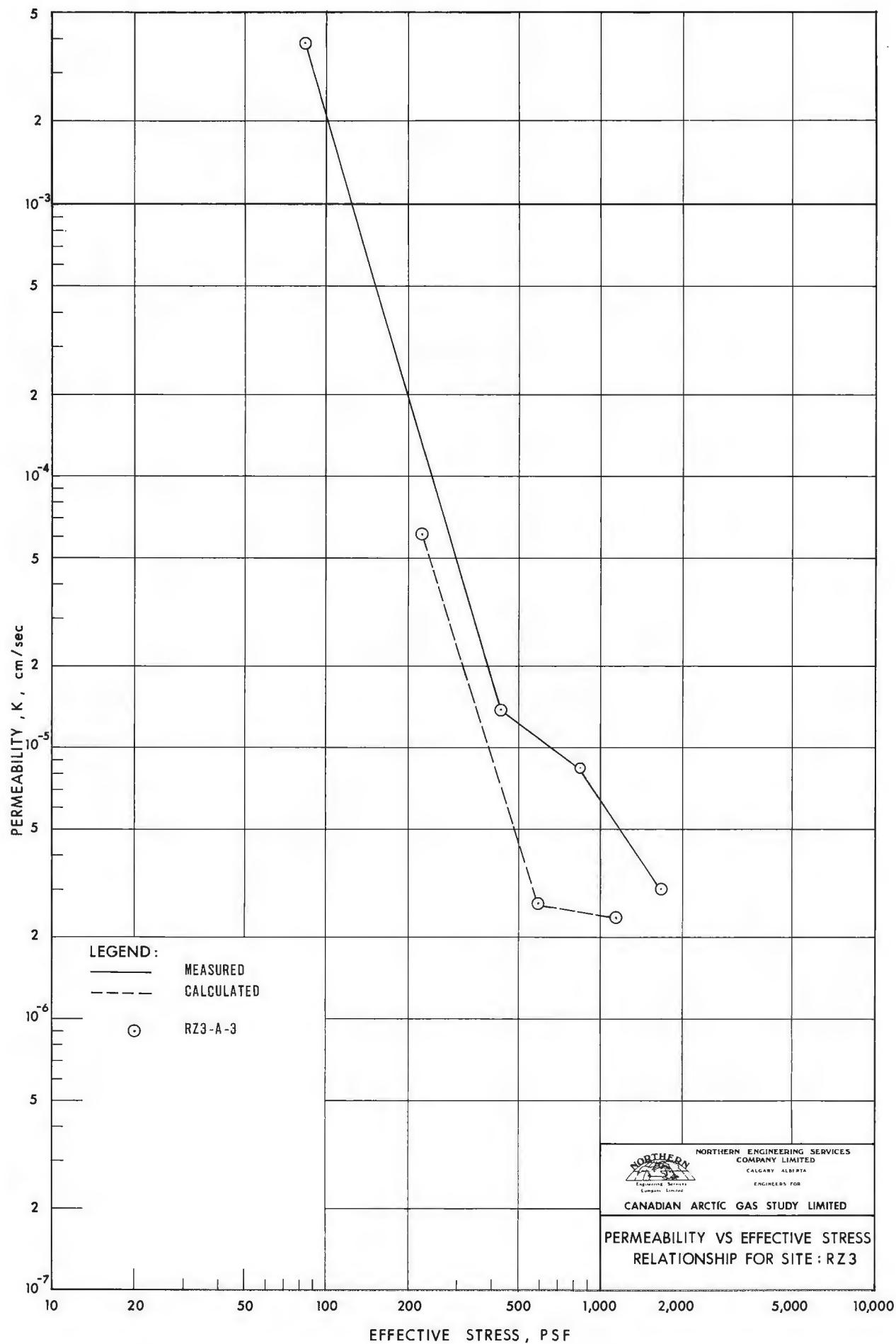
TEST HOLE No.	DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA						OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS										
							△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit	30	50	70	100	150	500	1000	2000											
		Pt	?	0.4 PEAT - dark brown, moist, fibrous		UF																							
		ML		SILT - trace sand, fine to coarse, low plastic, light brown with mottling																									
2				dark brown, occasional gravel particles to 3"	2.3																								
		Pt	?	2.6 PEAT - dark brown, fibrous		Vr 35																							
		ML		SILT - trace sand, fine to coarse, low plastic, light brown, occasional	3.5																								
4		ICE	+	gravel particles to 3", isolated fine sand conglomerate (yellow) to 1/2"	4.0	ICE + 70																							
		ML		soil color changes to medium grey, some fine sand, no gravel	5.2	Vr 20																							
6					7.4	Vs 10																							
				stratified 1/16" thick, 1/2" long lenses	8.9																								
				9.3	9.3	ICE																							
10		SM		SAND - fine to medium and silt, trace fine gravel, non plastic, grey, fine to medium, little clayey silt, trace fine gravel	10.0	Vr 20																							
				occasional coarse sand particles fine, little silt, trace fine gravel	10.0	Nan																							
12					11.7	F																							
					12.0																								
20																													
21		ICE			21.0																								
		36		ICE	36.0	ICE																							
				End of hole		100																							
LOGGED BY: J.J.S.			FACILITY.			PROJECT : 12093 , 12071			CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY						NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS INC						TEST HOLE No.								
CHKD:	D.S.		LAT. & LONG :	88°46'53" N, 136°41'48" W		ELEVATION:																							
DRAWN BY: K.M.			AIRPHOTO No. :	A 15482-22		PIPE MILEAGE:																							
CHKD:	RIG.		HELI-DRILL			AIR TEMP.:	42°C																						
RDY:	R.H.		METHOD :	4" I.D. CRREL BARREL; AIR		MAPSHEET:	117 D		CANADIAN ARCTIC GAS STUDY LIMITED																				
START:	D 07	M 08	Y 75	TIME : 20:20	FINISH: D 07	M 08	Y 75	TIME : 22:30																					
									CANADIAN ARCTIC GAS STUDY LIMITED																				

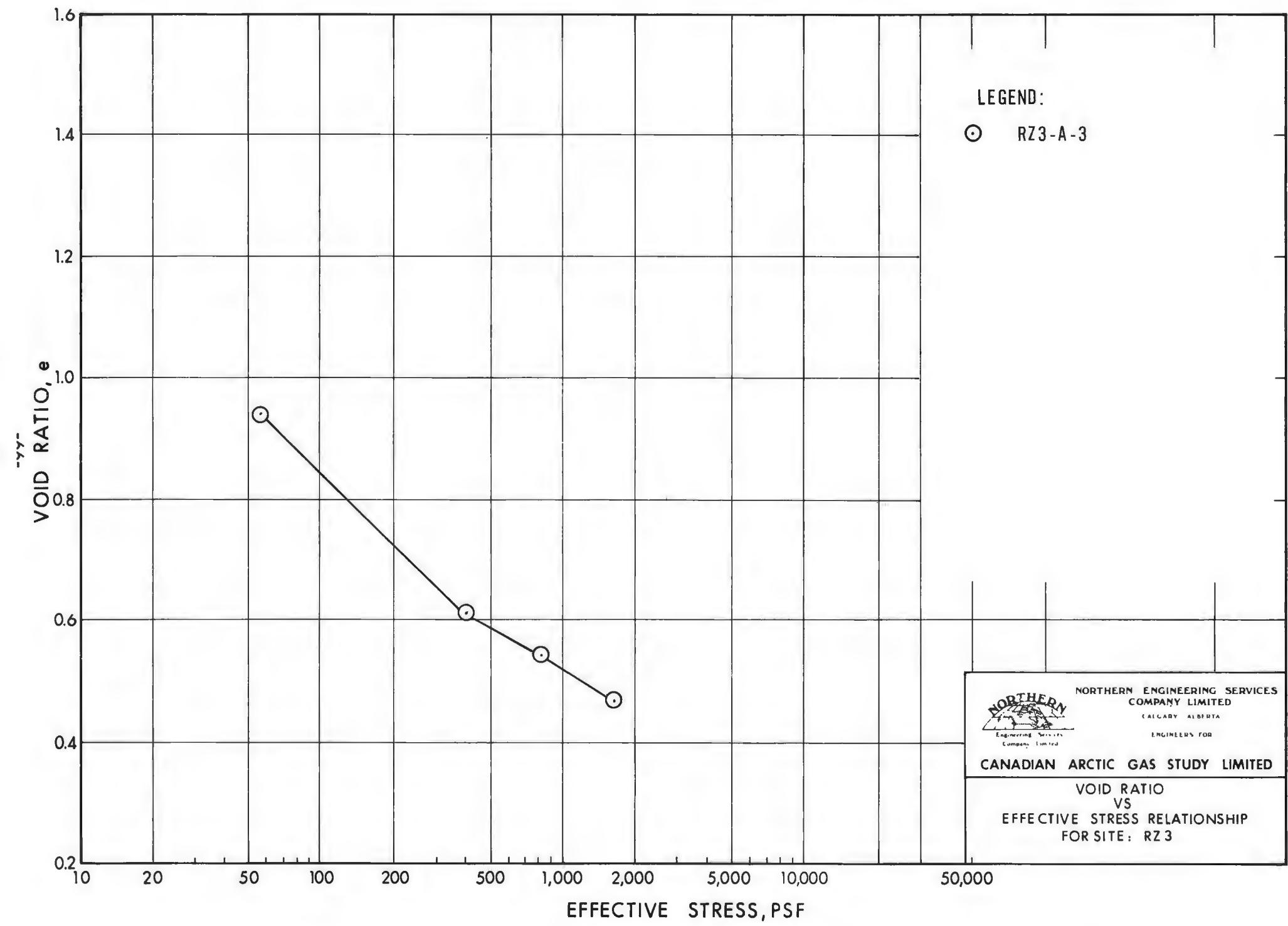
SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution				Soil Group	Remarks
		W _L %	W _P %	> 0.074 mm Gravel %	Sand %	Silt %	< 0.074 mm Clay* %		
N75-RZ3-A-3	5.0-7.0	28	18	26	25	27	22	GC-SC	
N75-RZ3-D-4	8.0-9.0	29	25	0	25	69	6	ML	
N75-RZ3-D-5	9.0-10.0	NP	NP	2	55	38	5	SM	
N75-RZ3-D-6	10.0-11.2	NP	NP	2	83	11	4	SM	
N75-RZ3-D-7	11.2-12.2	NP	NP	3	79	16	2	SM	

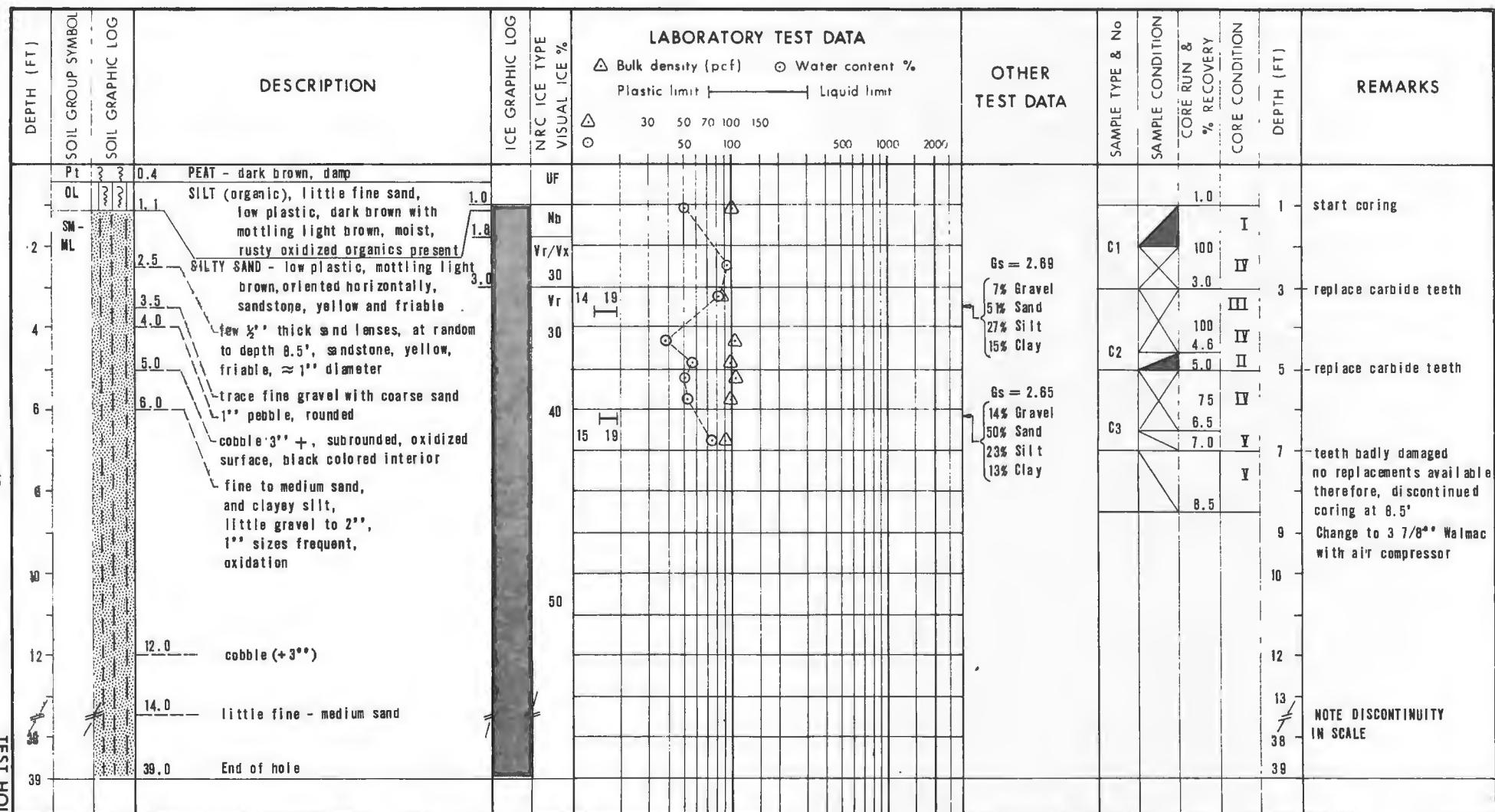
* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA





TEST HOLE LOG



LOGGED BY . J.J.S.

FACILITY:

PROJECT #: 12093, 12071

CHKD D. S.

LAT. & LONG :

ELEVATION:

DRAWN BY: K.M.

AIRPHOTO No. :

PIPE MILEAGE:

CHKD

RIG

HELI-DRILL

AIR TEMP : $7^{\circ}\text{C} - 10^{\circ}\text{C}$

RYD: R.H.

METH

OD : CRREL (4") & 3 7/8" Walmar

C MAPSHEET: 107 C

START: D 09 M

Y

75 TIME : 13:00 FINISH : D

09 M 08 Y 75 TIME: 14:50

Journal of Health Politics, Policy and Law, Vol. 29, No. 4, December 2004
DOI 10.1215/03616878-29-4 © 2004 by The University of Chicago

1

Digitized by srujanika@gmail.com

Digitized by srujanika@gmail.com

CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY



**NORTHERN ENGINEERING SERVICE
COMPANY LIMITED**

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

N75-RZ42-B

SHEET 1 OF 1

SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution > 0.074 mm				Soil Group	Remarks
		W _L %	W _P %	Gravel %	Sand %	Silt %	Clay * %		
N75-RZ42-B-2	3.0-4.6	19	14	7	51	27	15	SM-ML	
N75-RZ42-B-3	5.0-6.5	19	15	14	50	23	13	SM-ML	

* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

TEST HOLE LOG

TEST HOLE LOG

LOGGED BY : G.H.

FACILITY:

PROJECT : 12093, 12071

CHKD : R.H.

LAT. & LON.

ELEVATION:

DRAWN BY: N.L.

AIRPHOTO No. : BR 74405-282

PIPE MILEAGE:

CHKD.

RIG:

AIR TEMP.: -15°C

14

METHOD : CBBEL CORE BARREL

10. The following table summarizes the results of the study.

CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY



**NORTHERN ENGINEERING SERVICES
COMPANY LIMITED**

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

N75-DV1-A

SHEET 2 OF 2

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA						OTHER TEST DATA	REMARKS	
						△ Bulk density (pcf)	○ Water content %	Plastic limit	—	Liquid limit				
1	Pt		Moss, roots, grass (2") PEAT, fibrous, coarse texture, occasional woody chunks, brown		Vr UF	40 0	60 20	80 40	100 60	120 80	140 100	△	W = 118%	4" i.d. CRREL core barrel
2			Vs, approx. 1" spacing crumbly		Vs 5		△					△	W = 164%	core shattered
3			2.5 - silty layers to 1/2", vertical bubble trains in 1" of clear ice		Vs 2.8	2.5	2.8					△	W = 139%	
4			Vs hairline to 1/16"		Vs 20							△	W = 163%	
5	ICE + Pt		ICE with peat, cloudy; at 4.8" woody inclusions to 1/2"		ICE + 5.3	5.3						△	W = 243%	
6	Pt		PEAT, amorphous, grey, fewer woody inclusions, hairline Vs		Vs 10	6.2	6.2					△	W = 237%	
7	ICE + ML		ICE with occasional silt layers, 7.0 - silty		ICE + 90							△	W = 220%	
8	ML		7.6 silty layers to 1/2", 1/2"-1" apart		Vs 7.6							△	(W = 575%)	shattered, expanded

LOGGED BY: G.H.

CHKD: R.H.

DRWN. BY: N.L.

CHKD: RA

START: D 23 M 10 Y 75 TIME: 10:30

FACILITY:

LAT. & LONG :

AIRPHOTO No. :

RIG:

METHOD:

PROJECT: 12083, 12071

ELEVATION:

PIPE MILEAGE:

AIR TEMP.: -10°C

TIME: 12:30

CONTINUOUS PERMAFROST ZONE

SLOPE STABILITY STUDY

NORTHERN ENGINEERING SERVICES

COMPANY LIMITED

CALGARY ALBERTA

ENGINEERS FOR



CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE NO.

N75-DV1-B

SHEET 1 OF 3

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA						OTHER TEST DATA	DEPTH (FT.)	REMARKS								
						△ Bulk density (pcf)	○ Water content %	Plastic limit		Liquid limit												
8	ML		(SILT) little fine to coarse sand, brown, Vs to $\frac{1}{2}''$, $\frac{1}{2}''$ to $1''$ apart	VS				40	60	80	100	120	140	△	8							
Pt			PEAT, fibrous, woody, silty, brown, organic odour					0	20	40	60	80	100	○								
9			SAND, fine to coarse, trace gravel, clean (SP)	1/8"																		
Pt.			PEAT, with occasional silty sand layers	occ.																		
10	CI		CLAY, some sand, trace gravel, till-like	Vc																		
10.3																						
10.3	ICE + CI		ICE with clay inclusions	ICE +																		
10.9				80																		
11.6	CI ?		CLAY, inferred	Vs																		
11.6																						
12.0	ICE + CI		ICE with (clay) inclusions	ICE +																		
12.0	CI		TILL Vs to $1/8''$ CLAY, little fine to medium sand, trace gravel, dark grey-brown	Vs																		
			scattered Vx to $1/8''$																			
13			blocky fissured occasional cobbles																			
14.2			black (organic?) specks woody inclusions to $\frac{1}{4}''$																			
15.5			frequent pebbles to $1\frac{1}{2}''$																			
16																						
LOGGED BY: G.H.		FACILITY:				PROJECT: 12093, 12071		CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY						TEST HOLE No.								
CHKD: R.H.		LAT. & LONG : $69^{\circ}08'50''N$, $134^{\circ}53'40''W$				ELEVATION:		 NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED						N75-DV1-B								
DRWN. BY: A.M.		AIRPHOTO No.: 8R 74405-282				PIPE MILEAGE:																
CHKD: T.H.		RIG: RANGER III				AIR TEMP.: $-10^{\circ}C$																
		METHOD: CRREL CORE BARREL																				
START: D 23 M 10 Y 75 TIME: 10:30		FINISH: D 23 M 10 Y 75 TIME: 12:30												SHEET 2 OF 3								

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUALICE %	LABORATORY TEST DATA							OTHER TEST DATA	REMARKS	
						△ Bulk density (pcf)	○ Water content %	Plastic limit ————— Liquid limit							
16	CI		TILL, continued CLAY, little coarse sand, trace fine gravel, 16.8 - infrequent cobbles, pebble layers every 2" 17.0 cobble at depth 17"	Vs 1-2" apart	Vs 1/2" 15										
17			End of hole Refusal on cobble												17

-75-

TEST HOLE No. N75-DV1-B

LOGGED BY: G.H. FACILITY:

PROJECT: 12093, 12071

CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY

TEST HOLE No.

CHKD: R.H. LAT. & LONG: 69°08'50"N, 134°53'40"W

ELEVATION:

NORTHERN ENGINEERING SERVICES

COMPANY LIMITED

CALGARY ALBERTA

ENGINEERS FOR

DRWN. BY: A.M. AIRPHOTO No.: BR 74405-282

PIPE MILEAGE:

CHKD: R.H. RIG: RANGER III

AIR TEMP.: -10°C

METHOD: CRREL CORE BARREL



CANADIAN ARCTIC GAS STUDY LIMITED

N75-DV1-B

SHEET 3 OF 3

PC-9,SK373

SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

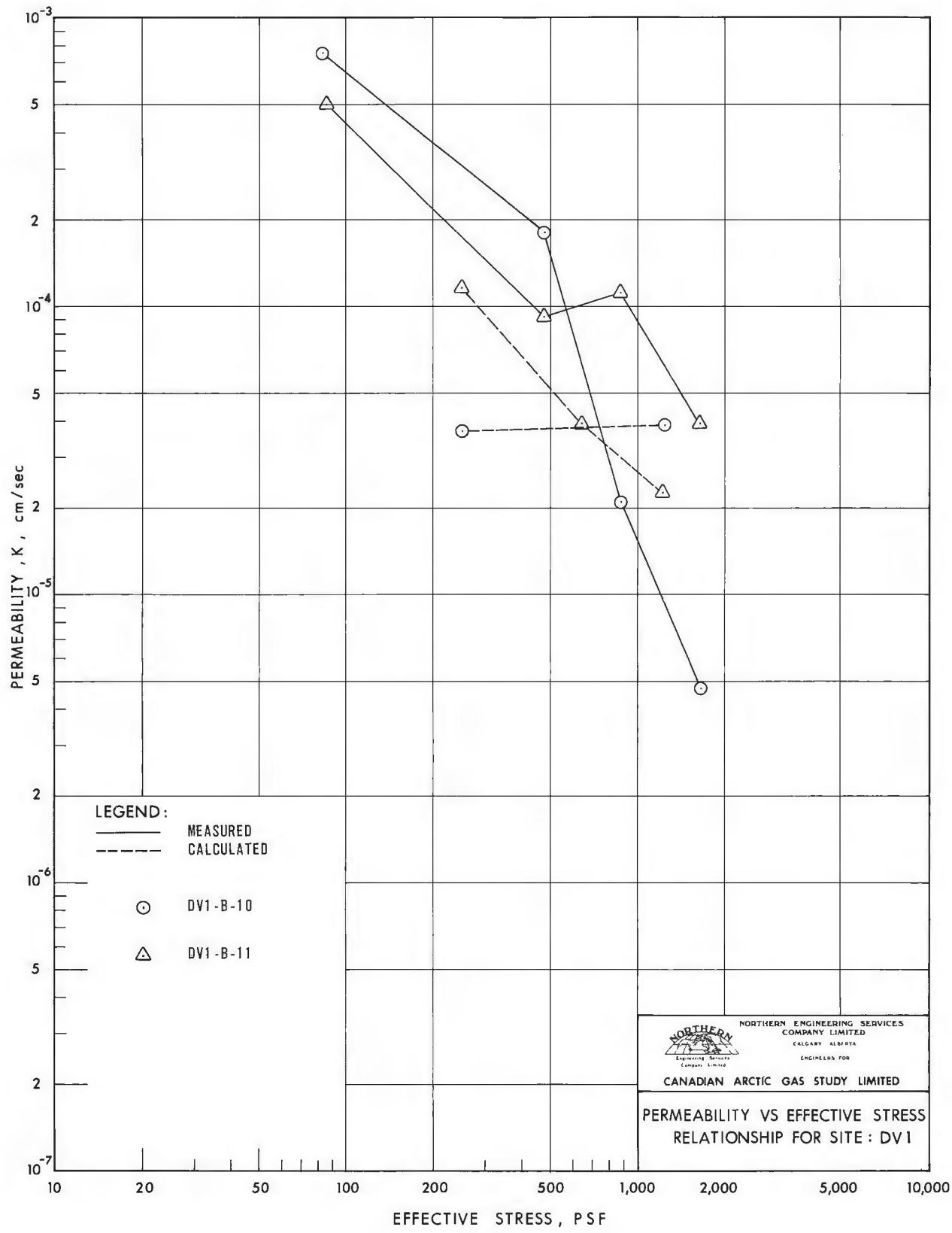
Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution				Soil Group	Remarks
		W _L %	W _P %	> 0.074 mm Gravel %	Sand %	Silt %	Clay* %		
DV1-A-20	11.1-11.8	34	19	3	19	45	33	CI	
DV1-B-9	10.0-10.8	34	19	5	23	46	26	CI	ICE + CI
DV1-B-10	12.0-12.7	38	20	2	17	45	36	CI	
DV1-B-11	12.7-13.9	41	19	2	16	45	37	CI	

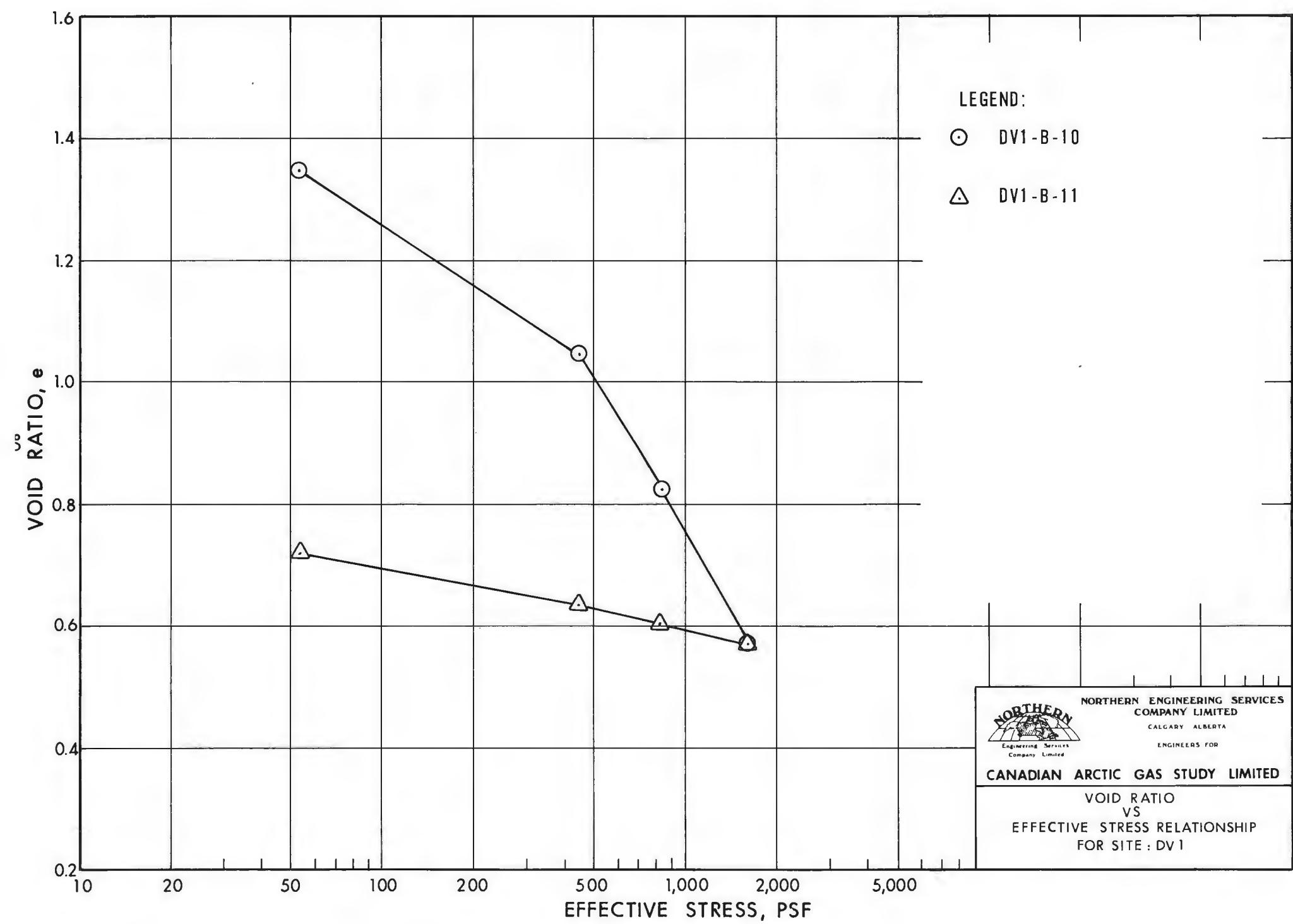
* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

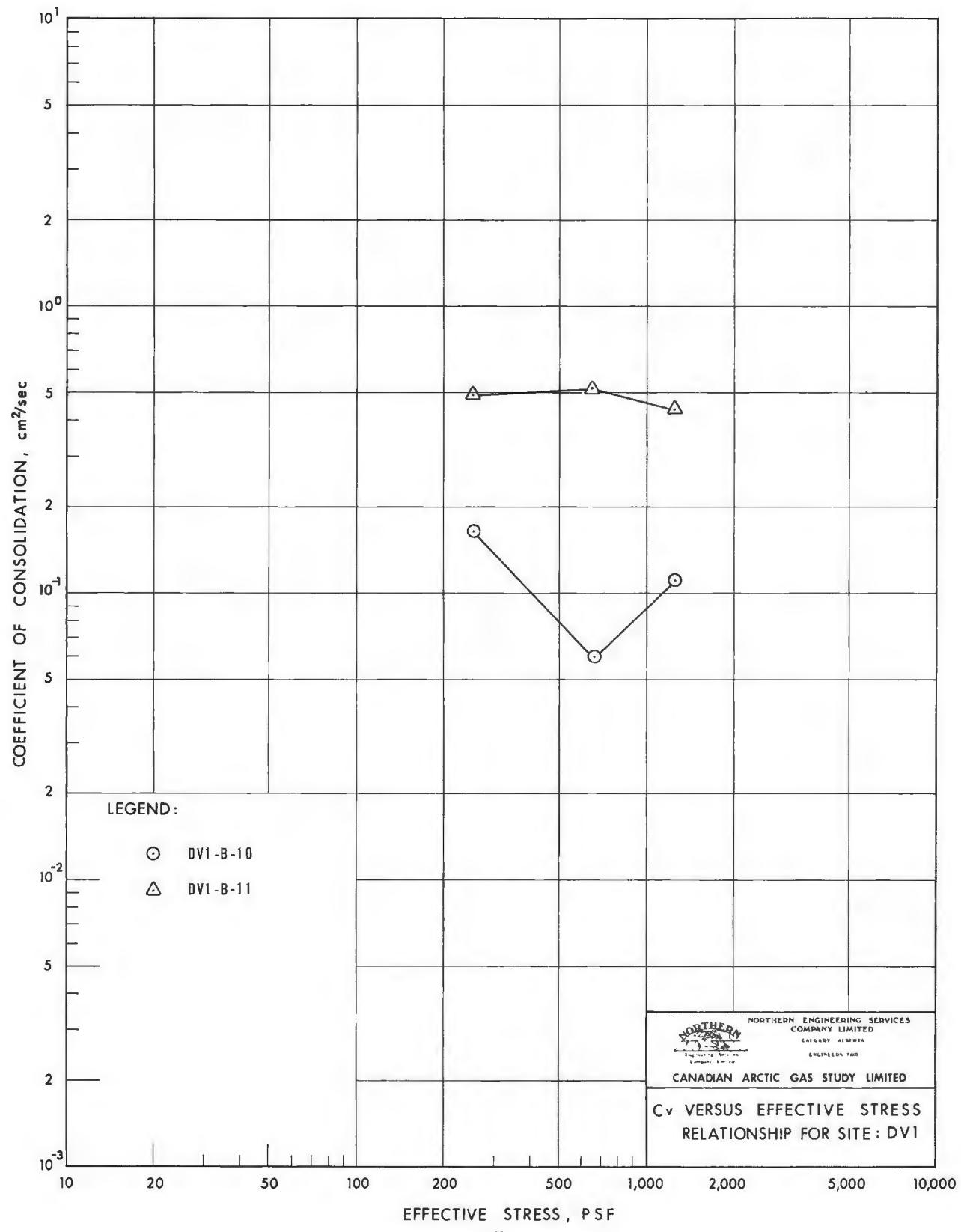
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV1-B-10	12.0-12.2	96.2	60.8	38	20	45	36	0.0	1.784						
								52.9	1.353						
									1.290	1.0	76.23				
								445.0	1.045						
									0.879	1.0	18.45				
								248.9					16.12	23.05	3.72
								837.0	0.821						
									0.816	1.0	2.13				
								641.0							
								1616.0	0.571						
									0.414	1.0	0.47				
								1226.5					10.91	35.28*	3.85
DV1-B-11	13.0-13.2	121.3	25.3	41	19	45	37	0.0	0.721						
								53.6	0.722						
									0.712	1.0	49.79				
								443.5	0.636						
									0.629	1.0	9.09				
								248.5					47.85	23.94	11.46
								836.1	0.604						
									0.603	1.0	11.12				
								639.8					49.95	7.78	3.88
								1620.1	0.569						
									0.568	1.0	3.89				
								1228.1					42.87	5.33	2.29

*Accuracy of this datum point in doubt





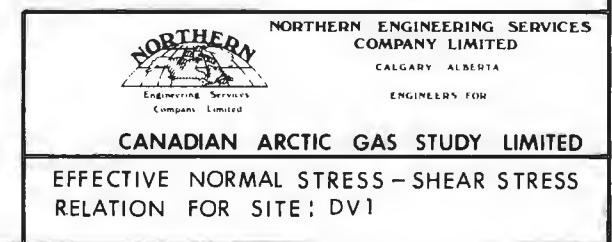
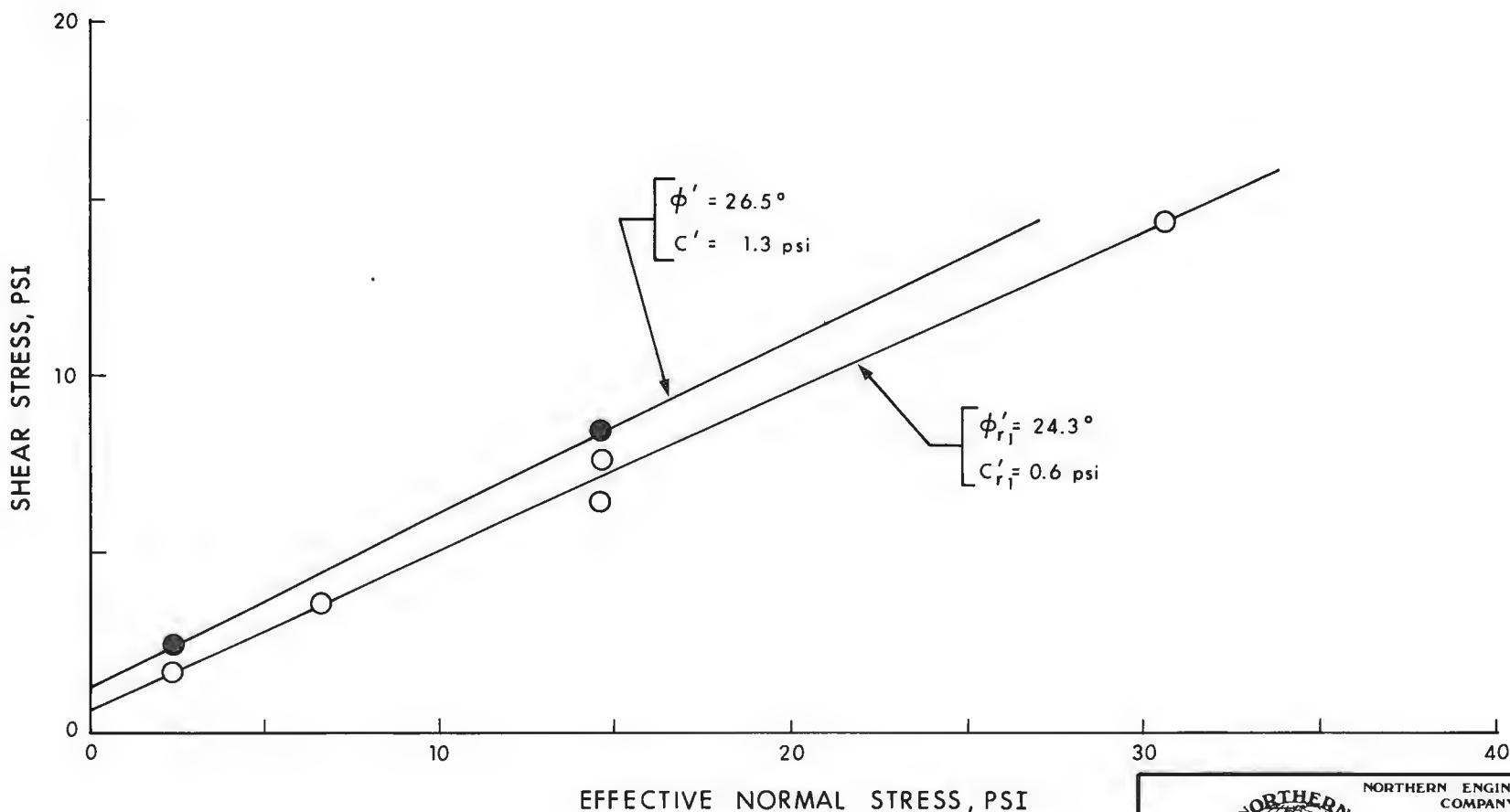


SUMMARY OF DIRECT SHEAR TEST DATA

FOR SOIL GROUP : CI

LEGEND :

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



TEST HOLE LOG

ST HOLE No. N75-DV41-A

LOGGED BY: G.H.

ACILITY:

PROJECT: 12093, 1207

CHKD · R.H.

AT. & LON

ELEVATION :

DRWN BY: A.M.

AIRPHOTO No. :

PIPE MILEAGE :

CHKD: ✓ 24

IG:

AIR TEMP : -12°C

— 1 —

METHOD : CANNED CURE BARREL

Digitized by srujanika@gmail.com

CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY



**NORTHERN ENGINEERING SERVICES
COMPANY LIMITED**

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

N75-DV41-A

SHEET 1 OF 1

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA						OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN &% RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS	
Pt			PEAT, moss, fibrous, woody, 0.5 green to brown	0.5	Nb	△	40	60	80	100	120	140	△	○	Water content %	Plastic limit	Liquid limit		
ML			SILT, and gravel		F? Nb?	△								w = 182%			IV	4" i.d. CRREL core barrel	
1			SILT, and gravel	1.0		○											II		
GM			GRAVEL, silty, some fine to coarse sand, brown, pebbles subangular to rounded, no peat from 1.5"	2.0		○											IV		
2			End of hole Refusal - gravel														2.0		

-98-

TEST HOLE NO. N75-DV41-B

LOGGED BY:	G.H.	FACILITY:	PROJECT:	12093, 12071	CONTINUOUS PERMAFROST ZONE	TEST HOLE No.	
CHKD:	R.H.	LAT. & LONG :	69°04'11"N, 135°48'53"W	ELEVATION:	SLOPE STABILITY STUDY	N75-DV41-B	
DRWN. BY:	A.M.	AIRPHOTO No.:		PIPE MILEAGE:			
CHKD:		RIG:	RANGER III	AIR TEMP.:	-12°C		
		METHOD:	CRREL CORE BARREL				
START:	D 20 M 10 Y 75	TIME:	14:15	FINISH:	D 20 M 10 Y 75 TIME: 14:40	CANADIAN ARCTIC GAS STUDY LIMITED	SHEET 1 OF 1

PC-9SK373



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	NOT VERIFIED BY LABORATORY TESTS		ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA						OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS
			DESCRIPTION				△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit									
	Pt	7 7	PEAT, moss, twigs, (2") brown, fibrous, woody	D.6		Nb	40	60	80	100	120	140		w = 159%					4" i.d. CRREL core barrel
1	OL	7 7	SILT, (organic), brown 1.0 pebbles to 2"				0	20	40	60	80	100	○						
	GM	7 7	GRAVEL, silty, some fine to coarse sand, pebbles subangular to rounded, occasional cobbles	1.2															1.2
			End of hole, 1.2"																
			Refusal - gravel																

-87-

TEST HOLE No. N75-DV41-C

LOGGED BY: G.H. FACILITY:

CHKD: R.H. LAT. & LONG : 69°04'11"N, 135°46'53"W

DRWN BY: N.L. AIRPHOTO No. :

CHKD: RH RIG: RANGER III

START: D 20 M 10 Y 75 TIME: 15:00

PROJECT: 12093, 12071

ELEVATION:

PIPE MILEAGE:

AIR TEMP : -12°C

FINISH: D 20 M 10 Y 75 TIME: 15:20

CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.
N75-DV41-C

SHEET 1 OF 1

TEST HOLE LOG

TEST HOLE No. N75-DV11-A	DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA						OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (Ft.)	REMARKS		
							40	60	80	100	120	140		△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit				
				PEAT, fibrous, rootlets, brown	+ +	Vx															
	0.1	ICE + OL		ICE with organic silt, approx. 75% ice, peaty layers in clear ice	ICE +	70															
1	1.2	CL-ML		CLAY, silty, and sand, trace gravel, trace fibrous peat, brown, (till-like)	Vs 10																
				trace sand, dark brown	hairline Vs to 1/16"	approx. 1/8" spacing															
	3	SM		3.4	3.4		Nf														
	4			SAND, fine to medium, and silt strongly bonded	Nbe																
	5																				
	6			fine sand, light brown, infrequent pebbles to 1", subangular to subrounded	Nb?																
	6.3																				
	6.9	GP	o o o	GRAVEL, fine to coarse, some sand, clean, brown	Nb?																
	7	SP		SAND, fine, clean, light brown, trace gravel to 1"	Nb																
	8																				
LOGGED BY: G.H.	FACILITY			PROJECT: 12093, 12071																	
CHKD: R.H.	LAT. & LONG :			68°59'59"N, 133°40'30"W	ELEVATION:																
DRWN BY: A.M.	AIRPHOTO No.:			A 12854-303	PIPE MILEAGE:																
CHKD: R.H.	RIG:			RANGER III	AIR TEMP :	-10°C															
	METHOD:			CRREL CORE BARREL																	
START: D 19 M 10 Y 75 TIME: 12:15	FINISH: D 19 M 10 Y 75 TIME: 15:00																				

**CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY**



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.
N75-DV11-A

SHEET 1 OF 2

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA						OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN &% RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS		
						△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit	40	60	80	100	120	140△					
8	SP		8.1 SAND, fine to coarse, and gravel, (to 3") clean, brown, skip-graded End of hole, 8.5' Refusal - gravel		Nb ?										P200 = 2	C9	8.1 8.5	IV	8.5	borderline sand/gravel

TEST HOLE NO. N/5-DV11-A

LOGGED BY: G.H. FACILITY:

CHKD: R.H. LAT. & LONG : 68°59'59" N, 133°40'30" W

DRWN.BY: A.M. AIRPHOTO No. : A 12854-303

CHKD: *R.H.* RIG: RANGER III

METHOD: CORER CORE BARREL

PROJECT: 12093, 12071

ELEVATION:

PIPE MILEAGE:

AIR TEMP: -10°C

START: D 19 M 10 Y 75 TIME: 12:15 FINISH: D 19 M 10 Y 75 TIME: 15:10

CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

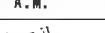
TEST HOLE NO.

N75-DV11-A

SHEET 2 OF 2

PC-9,SK373

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC VISUAL ICE %	LABORATORY TEST DATA							OTHER TEST DATA	REMARKS		
						40	60	80	100	120	140	△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit	
Pt	Pt		PEAT, fibrous, brown, rootlets		Vr 5											
0.5																
(ML)			SILT, clayey, trace fine sand, trace coarse sand, pebbles, damp when thawed		UF											
1																
(1.6)			(1.6) TILL													
2	CL		CLAY, some fine sand layers, trace fine gravel, trace coarse sand, medium plastic		Vs 40											
3																
4																
4.0																
4.5																
5																
5.1																
5.3																
5.8																
6																
(6.4)																
SM-			TILL		Vs 25											
ML-			SAND, silty with SILT, sandy		occ.											
?																
7																
7.2			7.2 frequent pebbles and cobbles,													
7.6			7.6 subangular to subrounded thin silt layers													
8																
LOGGED BY: G.H.	FACILITY:		PROJECT: 12071, 12093													
CHKD: R.H.	LAT. & LONG .	68°59'59" N, 133°40'30" W	ELEVATION:													
DRWN. BY: A.M.	AIRPHOTO No. :	A 12854-303	PIPE MILEAGE:													
CHKD: 	RIG:	RANGER III	AIR TEMP:	-10°C												
	METHOD:	CRREL CORE BARREL														
START: D 19 M 10 Y 75 TIME: 15:30	FINISH: D 19 M 10 Y 75 TIME: 18:45															

**CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY**

**NORTHERN ENGINEERING SERVICES
COMPANY LIMITED**
CALGARY ALBERTA
ENGINEERS FOR

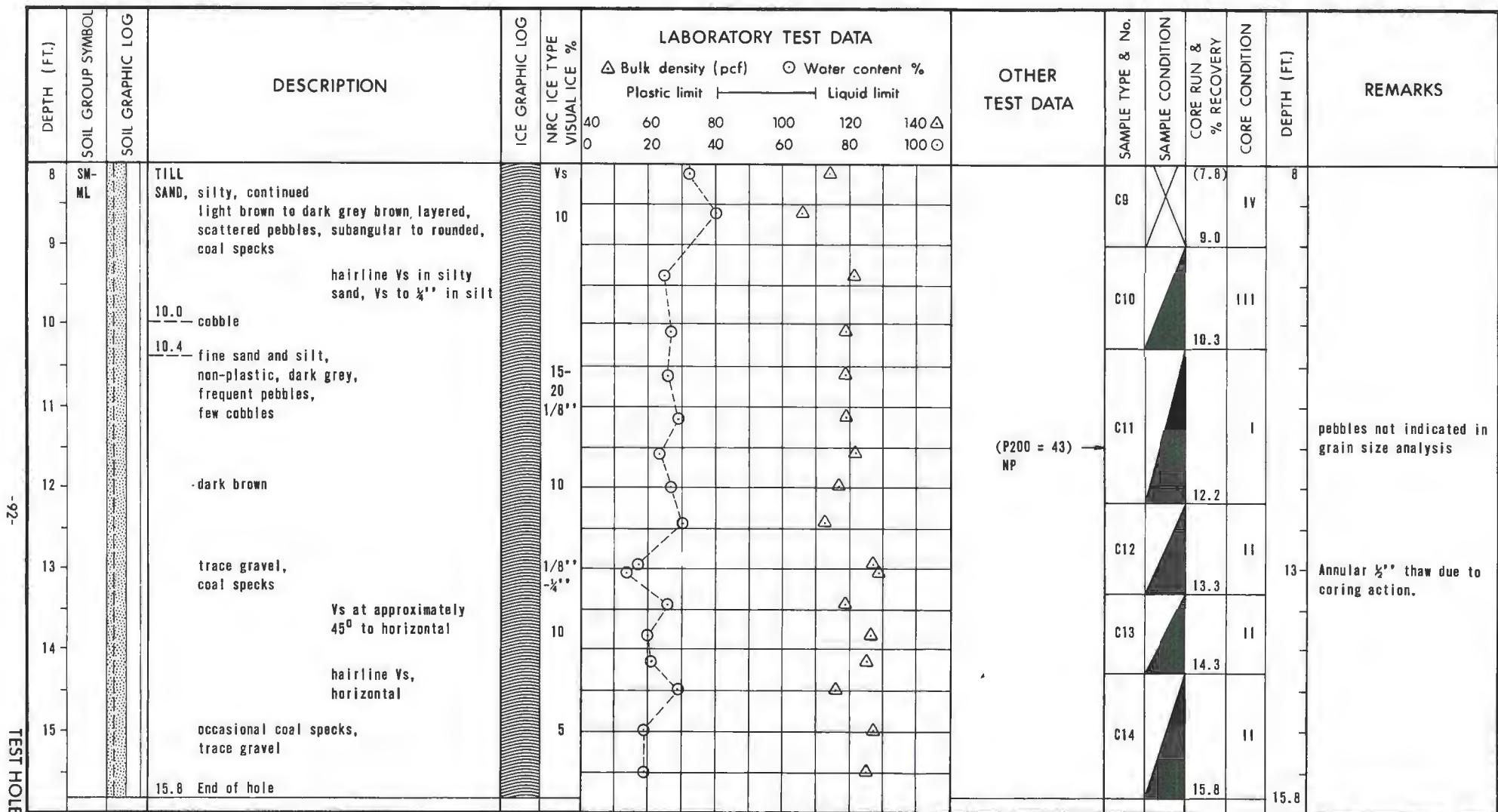
CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE NO.

N75-DV11-B

SHEET 1 OF 2

TEST HOLE LOG



LOGGED BY:	G.H.	FACILITY:	PROJECT:	12071, 12093	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED	TEST HOLE No.
CHKD:	R.H.	LAT. & LONG :	68°59'59" N, 133°40'30" W	ELEVATION:		N75-DV11-B
DRWN. BY:	A.M.	AIRPHOTO No. :	A 12854-303	PIPE MILEAGE:		
CHKD:		RIG:	RANGER III	AIR TEMP.:		
		METHOD:	CRREL CORE BARREL			
START:	D 19 M 10 Y 75	TIME:	15:30	FINISH:		SHEET 2 OF 2

PC-9,SK373

SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution > 0.074 mm				Soil Group	Remarks
		W _L %	W _P %	Gravel %	Sand %	Silt %	Clay* %		
DV11-A-4	2.2-3.4	20	13	2	42	39	17	CL-ML	
DV11-A-5	5.1-5.3			0	62	P200 =	38	SM	No hydrometer analysis
DV11-A-9	8.1-8.5			46	52	P200 =	2	SP	Borderline sand/gravel
DV11-B-5	3.5-5.0	22	14	9	35	41	15	(CL)	Sandy layer
DV11-B-6	5.0-5.8	38	19	5	18	42	35	CI	
DV11-B-7	5.8-5.9	20	15					CL-ML	Sandy silty layer
DV11-B-11	10.3-12.2	NP	NP	0	57	32	11	SM-ML	

* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

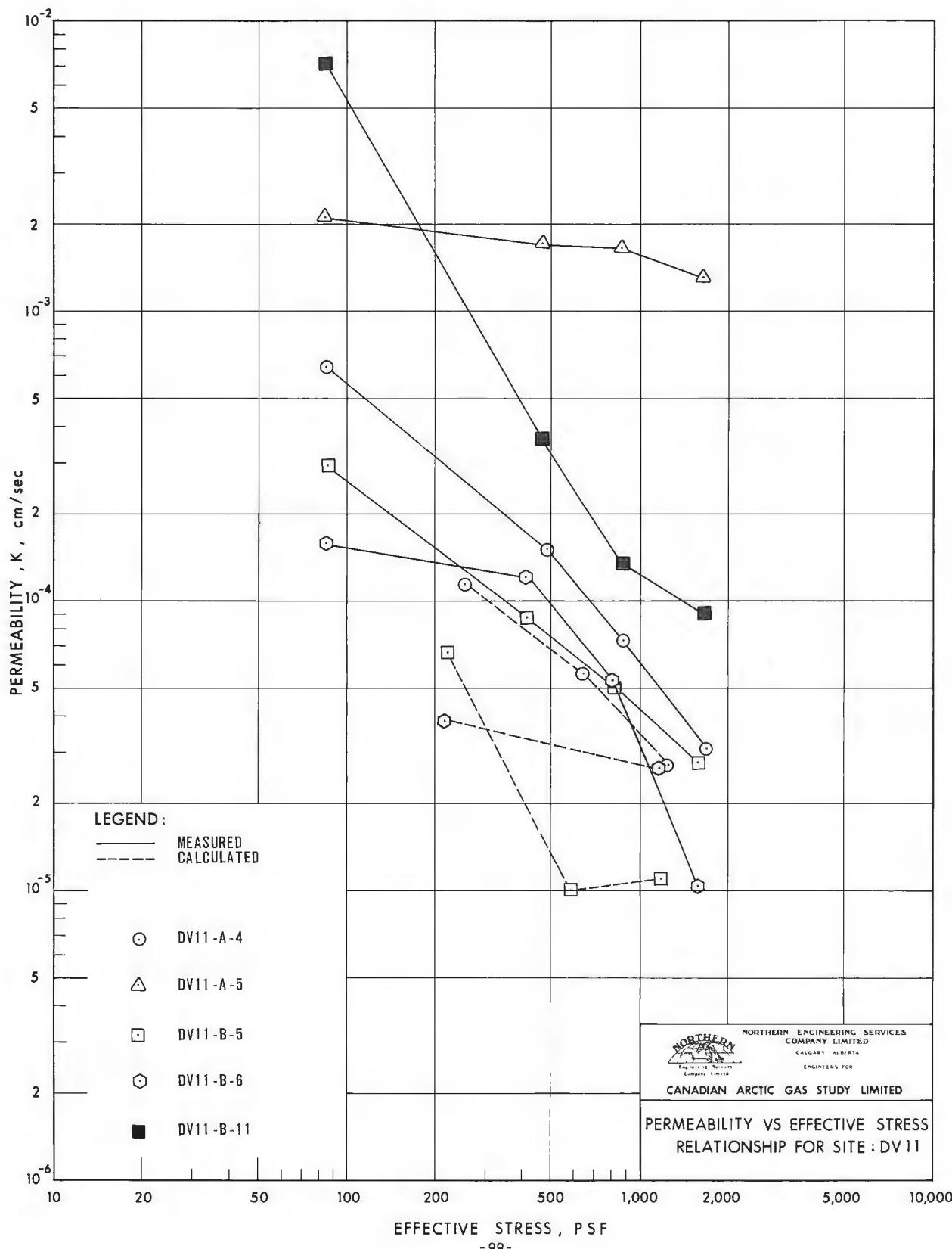
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

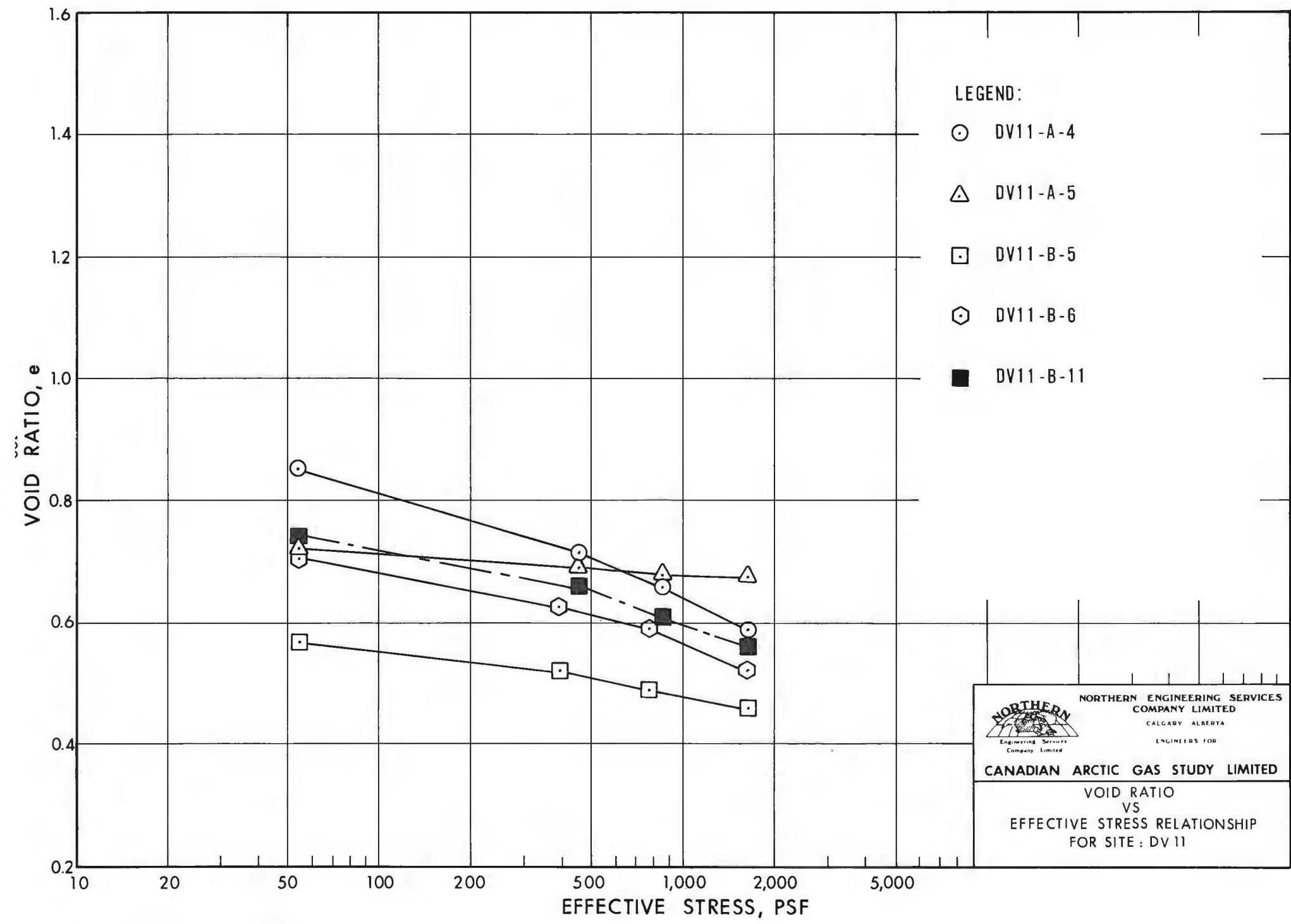
SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV11-A-4	2.6-2.9	112.2	32.8	20	13	39	17	0.0	0.972						
								53.7	0.854						
								444.3	0.715						
									0.713	1.0	61.74				
								249.0							
								837.7	0.657						
									0.655	1.0	7.24				
								641.0							
								1623.8	0.586						
									0.585	1.0	3.07				
								1230.7							
DV11-A-5	4.9-5.1	117.3	23.5	NP	NP	(P200 = 38%)	0.0		0.755						
								51.7	0.722						
								438.9	0.719	1.0	205.90				
									0.690						
								245.3	0.689	1.0	172.20				
								828.5	0.678						
									0.677	1.0	166.70				
								633.7							
								1609.0	0.665						
									0.663	1.0	129.30				
								1218.7							

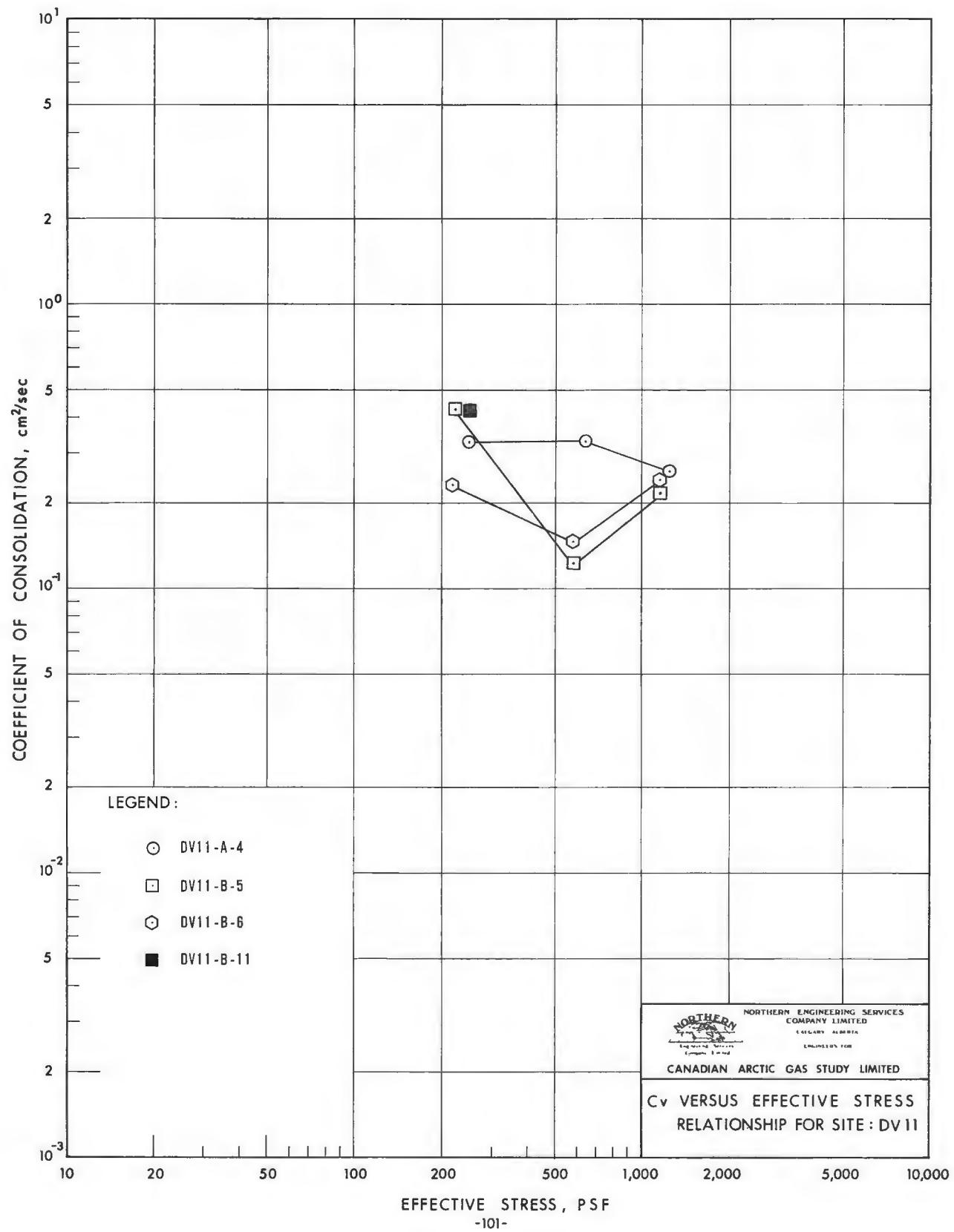
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	$K_{CALC.} \times 10^{-5}$ CM./SEC.
DV11-B-5	4.0-4.2	124.0	21.8	22	14	41	15	0.0		0.636					
								54.2		0.567					
									0.555	1.0	28.70				
								380.7		0.517					
									0.514	1.0	8.49				
								217.4				41.62	15.53	6.46	
								771.4		0.490					
									0.488	1.0	5.04				
								576.0				11.93	8.45	1.01	
								1540.0		0.460					
									0.458	1.0	2.73				
								1155.7				21.29	5.10	1.09	
DV11-B-6	4.9-5.2	121.0	25.5	38	19	42	35	0.0		0.728					
								53.7		0.706					
									0.673	1.0	15.56				
								378.2		0.630					
									0.627	1.0	12.15				
								215.9				23.16	16.70	3.87	
								771.6		0.591					
									0.589	1.0	5.35				
								574.9				-	-	-	
								1557.7		0.519					
									0.519	1.0	1.04				
								1164.6				23.63	11.26	2.66	

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA





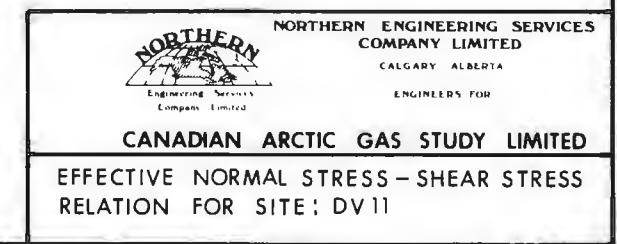
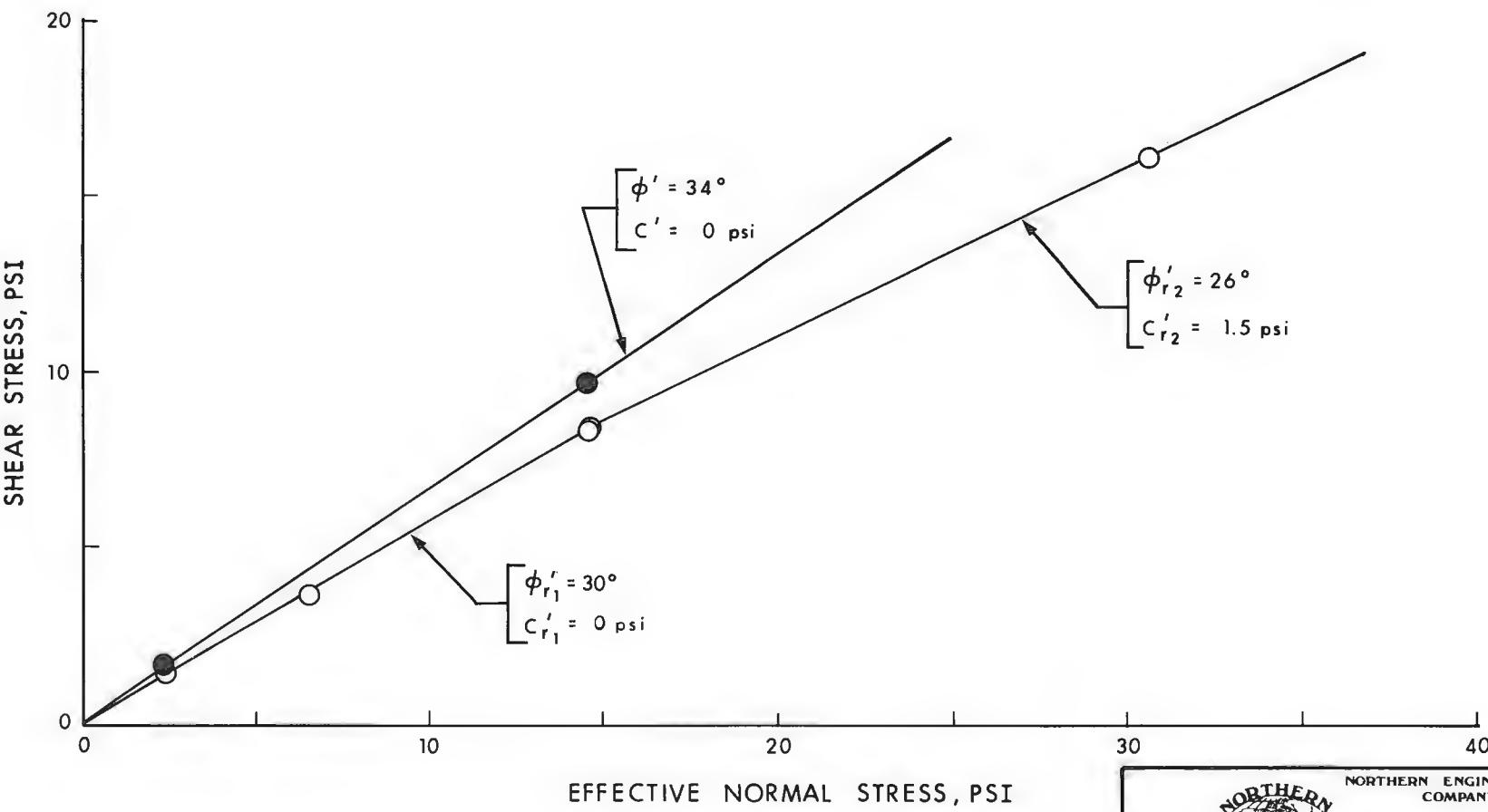


SUMMARY OF DIRECT SHEAR TEST DATA

FOR SOIL GROUP : SM

LEGEND :

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



TEST HOLE LOG

DEPTH (FT)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	LABORATORY TEST DATA										OTHER TEST DATA	REMARKS			
					NRC VISUAL ICE %	ICE TYPE	Bulk density (pcf)	Water content %	Plastic limit	Liquid limit	30	50	70	100	150	500	1000	2000	
0	Pt		Moss, grass, 2"			Nb													
1	ML		PEAT, fibrous, rootlets, dark brown	0.7		Vr													4" i.d. CRREL core barrel
2			0.5			5													
3			SILT, trace fine to coarse sand, frequent subrounded pebbles to 1", dark grey, till-like, ice layers to 1/2"	(1.5)		Vt/Vs													
4				2.2		35													
5				2.7		Vs													
6	(SP)		2" layer of fine to coarse sand, little fine gravel	3.1		1/2"													Vs 1/2" - 1/4" at sand/clay interfaces
7	SC-CL		SAND, fine to coarse, clayey, thin layers of silty sand and fine gravel, thin peaty layers to 1/8" at 3.3° and 3.7°, dark brown,	4.0		10													
8			5.0 (till)	5.0		1/2"													
9				5.2		1/4"													
10			ICE with clay, little sand, cloudy, trace gravel to 1", breaks easily	5.2		5												Vs about 30° to horizontal	
11						1/16"												core badly shattered	
12						-1/8"													
13						80													
14						ICE													
15						ICE +													
16						+													
17						80													
18																			
19																			
20																			
21																			
22																			
23																			
24																			
25																			
26																			
27																			
28																			
29																			
30																			
31																			
32																			
33																			
34																			
35																			
36																			
37																			
38																			
39																			
40																			
41																			
42																			
43																			
44																			
45																			
46																			
47																			
48																			
49																			
50																			
51																			
52																			
53																			
54																			
55																			
56																			
57																			
58																			
59																			
60																			
61																			
62																			
63																			
64																			
65																			
66																			
67																			
68																			
69																			
70																			
71																			
72																			
73																			
74																			
75																			
76																			
77																			
78																			
79																			
80																			
81																			
82																			
83																			
84																			
85																			
86																			
87																			
88																			
89																			
90																			
91																			
92																			
93																			
94																			
95																			
96																			
97																			
98																			
99																			
100																			
101																			
102																			
103																			
104																			
105																			

LOGGED BY: G.H. FACILITY: PROJECT: 12093, 12071
 CHKD: R.H. LAT. & LONG: 68°57'40"N, 134°15'40"W ELEVATION:
 DRAWN BY: N.L. AIRPHOTO No.: BR 74405-263 PIPE MILEAGE:
 RIG: RANGER III AIR TEMP.: -12°C
 METHOD: CRREL CORE BARREL TIME: 17:20
 START: D 21 M 10 Y 75 FINISH: D 21 M 10 Y 75 TIME: 14:35

CONTINUOUS PERMAFROST ZONE
 SLOPE STABILITY STUDY
 NORTHERN ENGINEERING SERVICES
 COMPANY LIMITED
 CALGARY ALBERTA
 ENGINEERS FOR
 CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.
 N75-DV3-A
 SHEET 1 OF 2

TEST HOLE LOG

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE	VISUAL ICE %	LABORATORY TEST DATA							OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS	
							40	60	80	100	120	140	△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit					
Pt			PEAT, fibrous, 2" moss 0.5 woody, twigs		F																4" i.d. CRREL core barrel
OL			SILT, (organic), peaty, trace fine to coarse sand, gravel to 1", rootlets 1.4 well-bonded		Nb																
1																					
Pt			PEAT, fibrous, brown, Vs hairline to 2"		Vs 20																
2																					
OL			SILT, (organic), peaty, well-bonded, 2.4 occasional pebbles																		
3																					
Pt			PEAT, fibrous, brown, well-bonded layer of ice with silt inclusions		35																
3.2																					
OL			SILT, (organic), little fine gravel, 3.7 trace sand		Vx 5-10																
4			TILL, CLAY, some fine to coarse sand, trace fine gravel, 4.6		Vs																
SP			4.8 sand layer, clean peat layer 1/8" thick																		
5																					
CL-CI																					
5.4																					
SC			SAND, clayey, some gravel		Vs 25																
6																					
ICE +			5.8 ICE with clayey, silty sand, cobble at 6.5'		ICE +																
SC			6.7																		
7																					
SC-CI			TILL, SAND, clayey, some gravel, occasional peat inclusions, ice to approx. 1/16"		Vs 40																
(B.O.)																					
8																					
LOGGED BY: G.H.	FACILITY			PROJECT: 12093, 12071																	
CHKD: R.H.	LAT. & LONG:	68° 57' 40" N, 134° 15' 40" W	ELEVATION:																		
DRWN BY: N.L.	AIRPHOTO No.:	BR 74405-263	PIPE MILEAGE:																		
CHKD: <u>R.H.</u>	RIG:	RANGER III	AIR TEMP:	-15°C																	
	METHOD:	CRREL CORE BARREL																			
START: D 22 M 10 Y 75 TIME: 11:10	FINISH: D 22 M 10 Y 75 TIME: 16:45																				



CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY

NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

N75-DV3-B

SHEET 1 OF 2

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE % VISUAL ICE %	LABORATORY TEST DATA							OTHER TEST DATA	DEPTH (FT.)	REMARKS			
						△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit	40	60	80	100	120	140 △			
0										0	20	40	60	80	100			
8	CI		TILL, CLAY, sandy, 8.5 occasional woody inclusions, 9.0 frequent fibres, cobble cobble, pebbles		8.7	Vs										C11	(7.8) 8.4	IV
9					Vr to 1/8"	Vr 10										C12	9.8	I
10			little sand, (trace gravel)		9.7	Vs to 1/4"	Vs 50									P200 = 66		III
10.5			10.5		10.5		ICE +									C13	10.5	I
11	ICE + CI		ICE with soil, layers of ICE, with ICE + soil to 1/2", approx. 80% ice by volume		11.4											C14	11.3	IV
11.7			11.7		11.5	Vs?										C15	11.9	IV
12	CI		CLAY, some fine gravel, brown, cobble at 12.0'													C16	12.5	III
12.3			12.3															
ML			12.5 SILT, dark brown			Vs 10												
			End of hole															
-80-																		
LOGGED BY: G.H.	FACILITY:		PROJECT: 12093, 12071															
CHKD: R.H.	LAT. & LONG :	68°57'40" N, 134°15'40" W	ELEVATION:															
DRWN BY: H.L.	AIRPHOTO No. :	BR 74405-263	PIPE MILEAGE:															
CHKD: R.H.	RIG:	RANGER III	AIR TEMP:	-15°C														
	METHOD:	CRREL CORE BARREL																
START: D 22 M 10 Y 75 TIME: 11:10	FINISH: D 22 M 10 Y 75 TIME: 18:45																	

CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

N75-DV3-B

SHEET 2 OF 2

SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution > 0.074 mm				Soil Group	Remarks
		W _L %	W _P %	Gravel %	Sand %	Silt %	Clay * %		
DV3-A-7	4.0-5.0	20	13	10	44	29	17	SC-CL	
DV3-B-6	3.8-4.6	30	18	9	28	38	25	CL-CI	
DV3-B-8	5.3-6.2	31	16	25	36	25	14	SC	
DV3-B-9	6.2-7.5			22	34	25	19	SC-CI	
DV3-B-12	8.9-9.1			10	24	38	28	CI	
DV3-B-13	9.8-10.5	40	18	2	19	44	35	CI	

* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM. ² /SEC.	$M_v \times 10^{-5}$ CM. ² /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV3-A-7	4.3-4.5	109.4	31.1	20	13	29	17	0.0		0.997					
								51.0		0.782					
										0.758	1.0	35.29			
								432.9		0.646					
										0.637	1.0	7.15			
								241.9					33.34	35.47	11.82
								817.2		0.592					
										0.591	1.0	4.94			
								625.0					29.13	14.40	4.19
								1587.1		0.534					
										0.532	1.0	0.81			
								1202.1					6.10	9.38	0.57
DV3-A-13	8.7-9.0	68.1	283.5	-	-	-	-	0.0		8.388					
								53.3		1.357					
										1.325	1.0	13.55			
								390.9		1.196					
										1.191	1.0	2.10			
								222.1					3.08	33.64	1.04
								792.7		1.130					
										1.125	1.0	1.12			
								591.8					-	-	-
								1597.2		1.027					
										1.018	1.0	0.82			
								1194.9					1.48	11.74	0.17

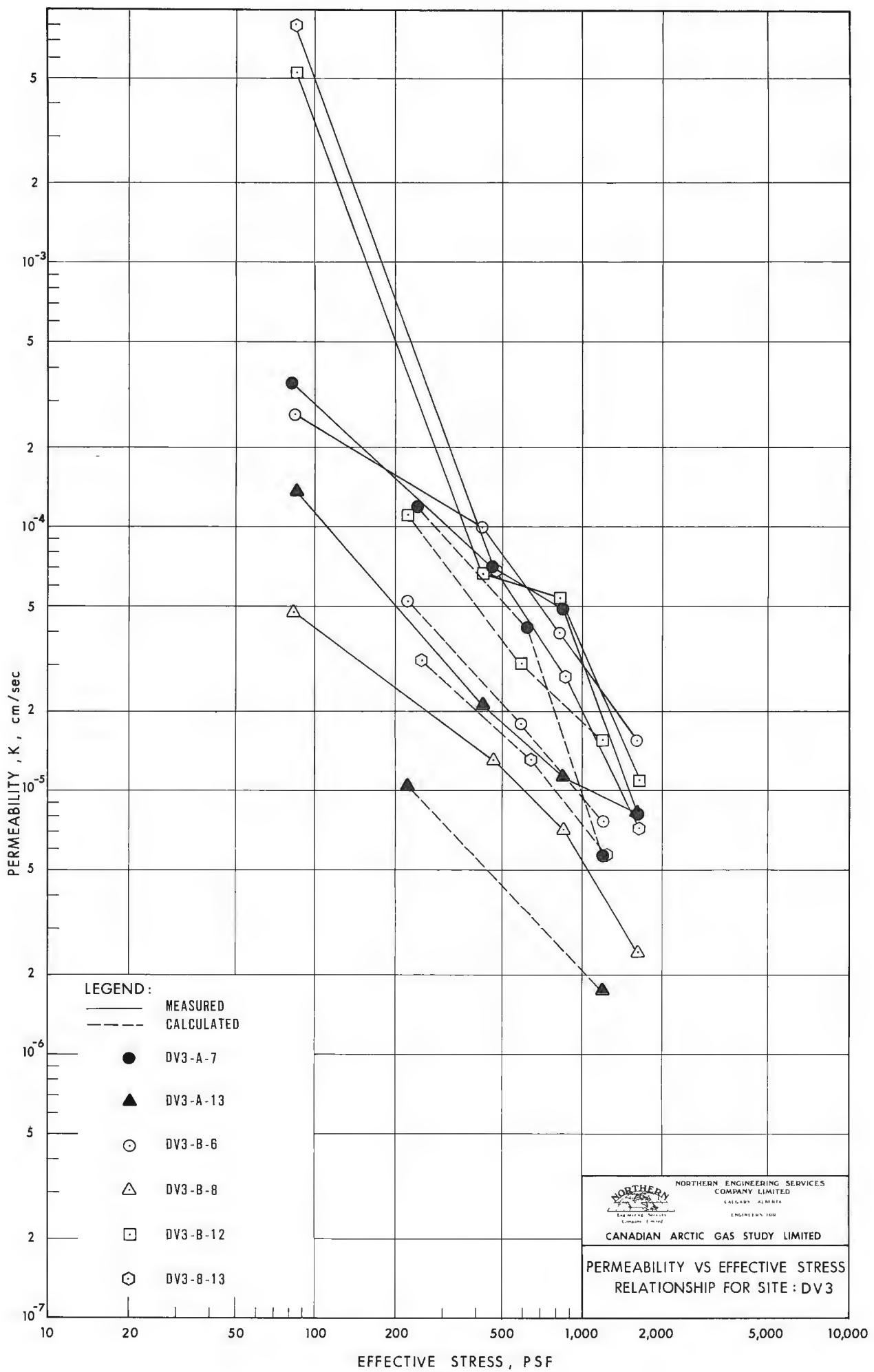
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

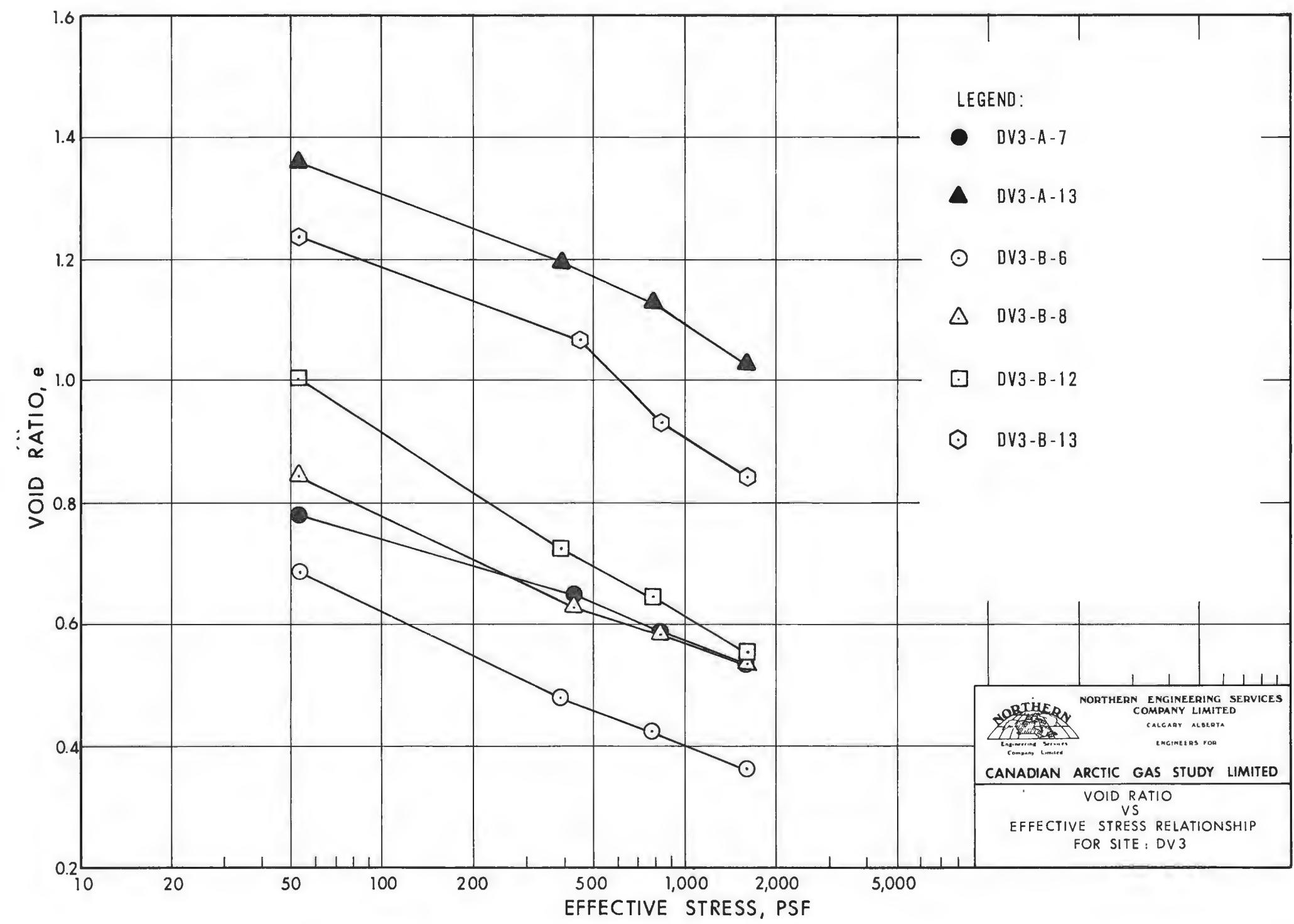
SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV3-B-6	3.8-4.0	99.4	45.4	30	18	38	25	0.0		1.438					
								53.1		0.678					
								389.4		0.597	1.0	26.61			
								789.6		0.475					
								221.2		0.463	1.0	9.89			
								589.5		0.420			11.19	46.51	5.21
								1597.7		0.415	1.0	3.95			
								1193.6		0.363			11.84	15.14	1.79
								817.2		0.363	1.0	1.56			
								432.9		0.620					
								241.9		0.618	1.0	1.29			
								625.0		2.157			8.16	9.36	0.76
DV3-B-8	5.4-5.6	89.6	69.7	31	16	25	14	0.0		0.839					
								51.0		0.770	1.0	4.72			
								1587.4		0.620					
								1202.3		0.618	1.0	1.29			
								817.2		0.580			13.53	45.80	6.20
								625.0		0.580	1.0	0.70			
								1202.3		-	-	-			
								817.2		0.534					
								625.0		0.532	1.0	0.24			
								1587.4		-	-	-			

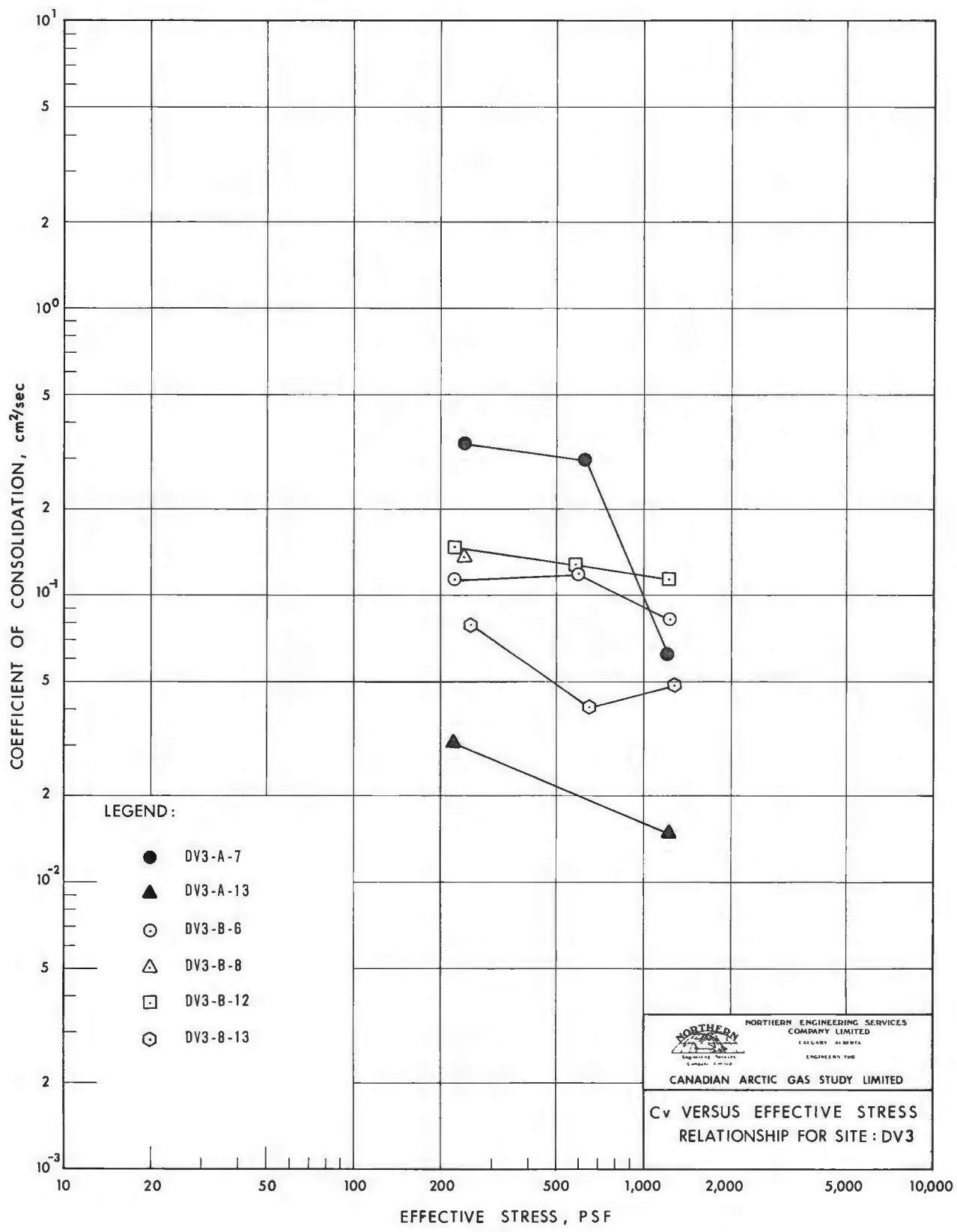
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH F.T.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.	
DV3-B-12	8.7-8.9	109.7	36.8		38	28	0.0		1.078							
							53.3		0.988							
							390.9		0.982	1.0	520.2*					
								0.723								
								0.723	1.0	6.62						
								222.1				14.46	78.25	11.31		
								792.7		0.643						
									0.639	1.0	5.37					
									591.8			12.59	23.95	3.02		
									1597.2		0.550					
										0.548	1.0	1.09				
									1194.9			11.30	13.81	1.56		
DV3-B-13	10.0-10.2	80.6	112.7	40	18	44	35	0.0		3.398						
								54.2		1.231*						
									1.226	1.0	787.4*					
								448.4		1.063						
									1.062	1.0	68.04					
									251.3			7.95	39.03	3.10		
									839.3		0.934					
										0.930	1.0	2.73				
										643.8			4.12	31.28	1.29	
										1618.2		0.844				
											0.841	1.0	0.72			
										1228.7			4.86	11.64	0.57	

*Accuracy of this datum point in doubt.







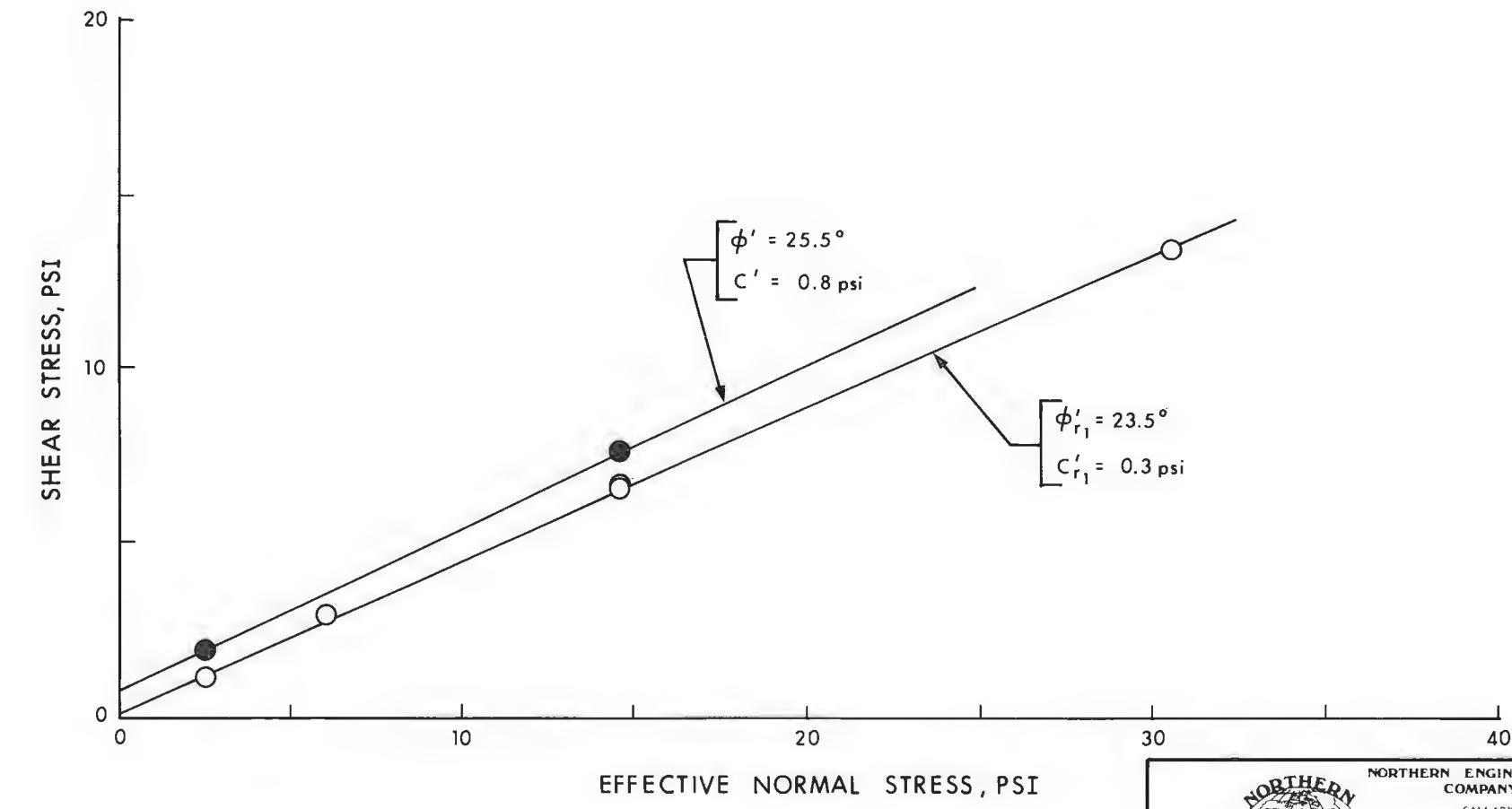
SUMMARY OF DIRECT SHEAR TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	NORMAL STRESS PSI	MAX. SHEAR STRESS PSI	RESIDUAL SHEAR STRESS PSI	ϕ' DEG.	C' PSI	ϕ'_r DEG.	C_r' PSI	REMARKS
DV3-A-7	4.0-5.0	104.8	39.0	20	13	29	17	2.5	1.8	1.2	25.5	0.8	23.5	0.3	Cut plane
								5.9		3.0					
								14.5		6.6					
DV3-A-7	4.6-4.9	105.6	38.5	20	13	29	17	14.5	7.7	6.8	25.5	0.8	23.5	0.3	Cut plane
								30.6		13.6					
DV3-B-6	3.8-4.6	88.9	68.9	30	18	38	25	2.4	1.6	1.2	31.5	0.3	30.5	0.0	Cut plane
								6.5		3.8					
								14.5		8.3					
DV3-B-6	3.8-4.6	85.6	76.6	30	18	38	25	14.5	8.7	8.1*	31.5	0.3	25.5	0.9	Cut plane
								30.7		16.4					
* Accuracy of this datum point in doubt															

FOR SOIL GROUP : SC - CL

LEGEND :

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

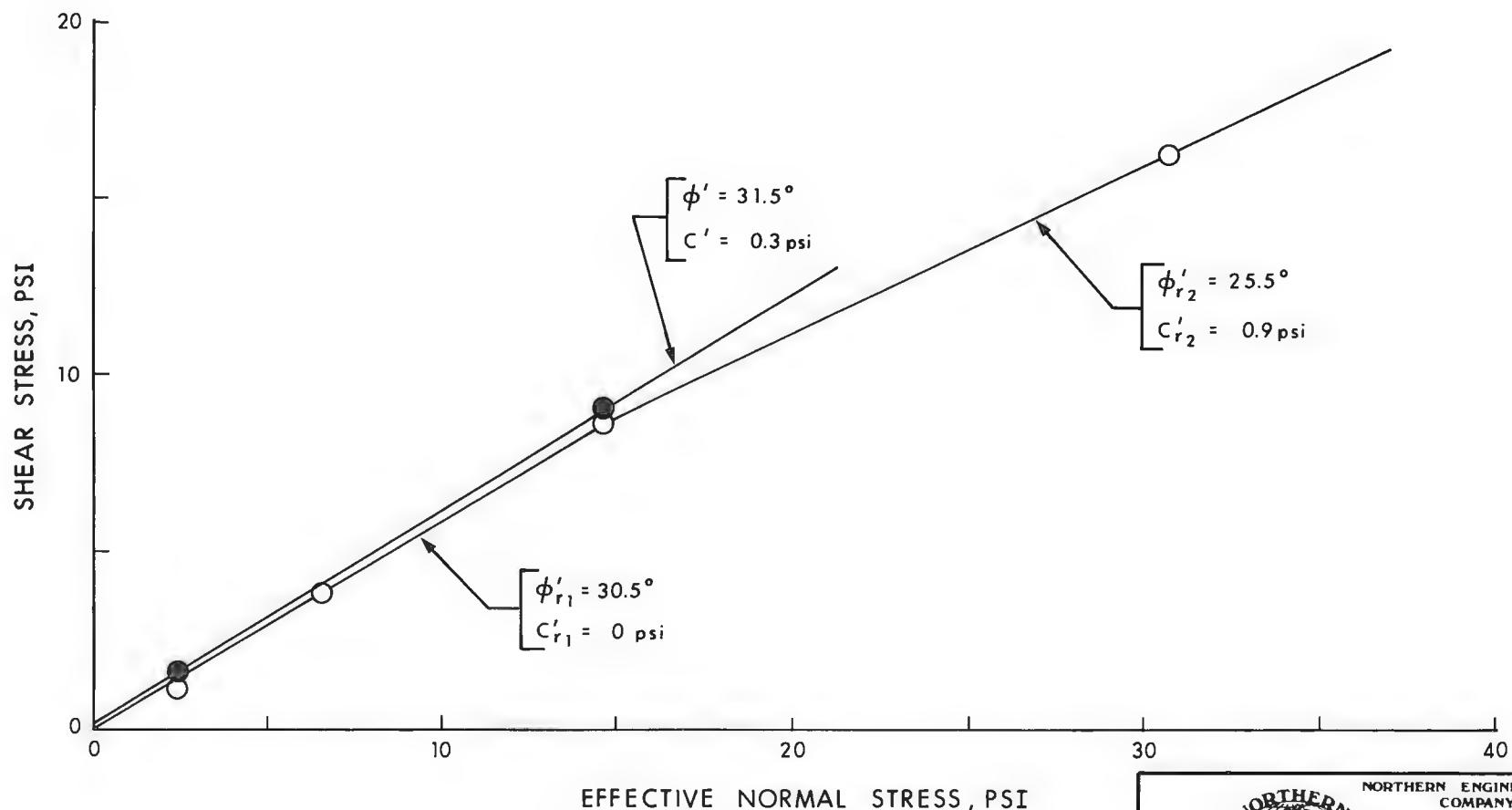
CANADIAN ARCTIC GAS STUDY LIMITED

EFFECTIVE NORMAL STRESS - SHEAR STRESS
RELATION FOR SITE: DV3

FOR SOIL GROUP : CL - CI

LEGEND :

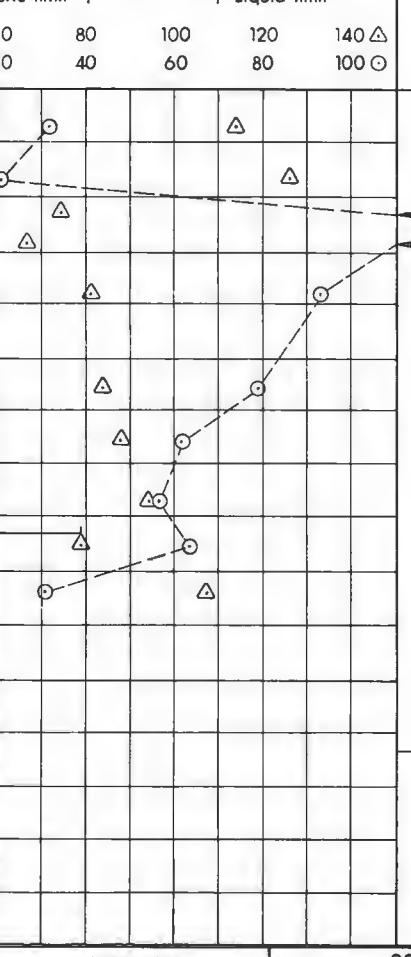
- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



EFFECTIVE NORMAL STRESS , PSI

	NORTHERN ENGINEERING SERVICES COMPANY LIMITED
	CALGARY ALBERTA ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LIMITED	
EFFECTIVE NORMAL STRESS - SHEAR STRESS RELATION FOR SITE : DV3	

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	LABORATORY TEST DATA	OTHER TEST DATA	DEPTH (FT.)	REMARKS
Pt.			PEAT, fibrous, moss					
OL			0.2 SILT, (organic), black					
1	CL		0.9 well-bonded by ice TILL CLAY, silty trace sand, trace fine gravel, dark brown, coal inclusions					4" i.d. CRREL core barrel
2			scattered Vx to 1/8"					
3			layers of soil and ice with soil - easily breaks					
4			Vs 1-2" apart					
5			dark brown					
5.0			layers of soil and ice with soil					
5			layer of pebbles to 2"					
5.5			Vs 1/2" apart					
6			pebble layer					
6.0			cobble, 4"					
6.2			End of hole Refusal - cobble				6.2	
LOGGED BY: G.H. FACILITY:				PROJECT: 12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY			TEST HOLE No.
CHKD: R.H.	LAT. & LONG :	68°12'00"N, 133°45'00"W		ELEVATION:				N75-DV5-A
DRWN BY: A.M.	AIRPHOTO No. :	BR 74404-95		PIPE MILEAGE:				
CHKD: <u>R.H.</u>	RIG:	RANGER III		AIR TEMP : -10°C				
	METHOD:	CRREL CORE BARREL			NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR			
START: D 24 M 10 Y 75 TIME: 11:20	FINISH: D 24 M 10 Y 75 TIME: 12:00	CANADIAN ARCTIC GAS STUDY LIMITED						SHEET 1 OF 1

TEST HOLE No. N75-DV5-1

LOGGED BY: G.H.

CHKD · R.H.

DRWN BY: A.M.

CHKD: ✓

5

CILITY:

T. & LONG : $68^{\circ}12'00''$ N. $133^{\circ}45'00''$ E.

IRPHOTO No. : BR 74404-95

G: RANGER III

METHOD : CRREL CORE BARREL

PROJECT: 12093, 12071

ELEVATION :

PIPE MILEAGE :

AIR TEMP : -10°C

1000-10000 mg/m³

**CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY**



**NORTHERN ENGINEERING SERVICES
COMPANY LIMITED**

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

N75-DV5-A

SHEET 1 OF 1

TEST HOLE LOG

TEST HOLE No. N75-DV5-A-2	DEPTH (FT)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	LABORATORY TEST DATA												OTHER TEST DATA	SAMPLE TYPE & NO.	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT)	REMARKS
					ICE GRAPHIC LOG	NRC ICE TYPE	VISUALICE %	△ Bulk density. (pcf)	○ Water content %	Plastic limit	Liquid limit											
Pt	0	Pt	Moss, grass, rootlets, peat	+ + + +	Vx																	
	0.3	C1	TILL	0.5	UF																	
	1		CLAY, silty, trace fine sand, pebbles, subangular to rounded	1.1	Vs	40																
	2			1.8	Vs	40																
	2.8			1.8	Vs	40																
	3		occasional cobbles to approx. 3" pebble layer at 3.2"	2.8	Vs	40																
	4			4.3	Vs	40																
	5				Vs	40																
	6		6.0 - subrounded pebble, 3"	6.0	ice $\frac{1}{2}''$ crumbly	Vs approx. $\frac{1}{4}''$ spacing	8.0															
	7		some fine sand, trace gravel to $1\frac{1}{2}''$, grey	7																		
	8			8																		
LOGGED BY:	G.H.	FACILITY:		PROJECT:	12093, 12071																	
CHKD:	R.H.	LAT. & LONG:	68°12'00"E, 133°45'00"W	ELEVATION:																		
DRWN BY:	A.M.	AIRPHOTO No.:	BR 74404-95	PIPE MILEAGE:																		
CHKD:	RIG:	METHOD:	RANGER III	AIR TEMP.:	-10°C																	
START:	D 24 M 10 Y 75	TIME:	12:40	FINISH:	D 24 M 10 Y 75	TIME:	14:15															



CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY
NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.
N75-DV5-A-2

SHEET 1 OF 2

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA							OTHER TEST DATA	REMARKS			
						△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit	40	60	80	100	120	140		
8	C1		TILL CLAY, continued 8.3 pebble layer, ice layer to $\frac{1}{2}$ "		Vr					40	60	80	100	120	140		
										0	20	40	60	80	100		
9			9.3 layer of pebbles to 2"														9
			9.6 pebbles to 1 $\frac{1}{2}$ ", ice layers to $\frac{1}{2}$ "														10
10			10.2 pebbles to 1"														11
			10.5 occasional black organic														
			10.8 inclusions to $\frac{1}{2}$ "														
			little sand, little gravel														
11			11.0 End of hole Refusal - boulder														
-125-																	

TEST HOLE No. N75-DV5-A-2

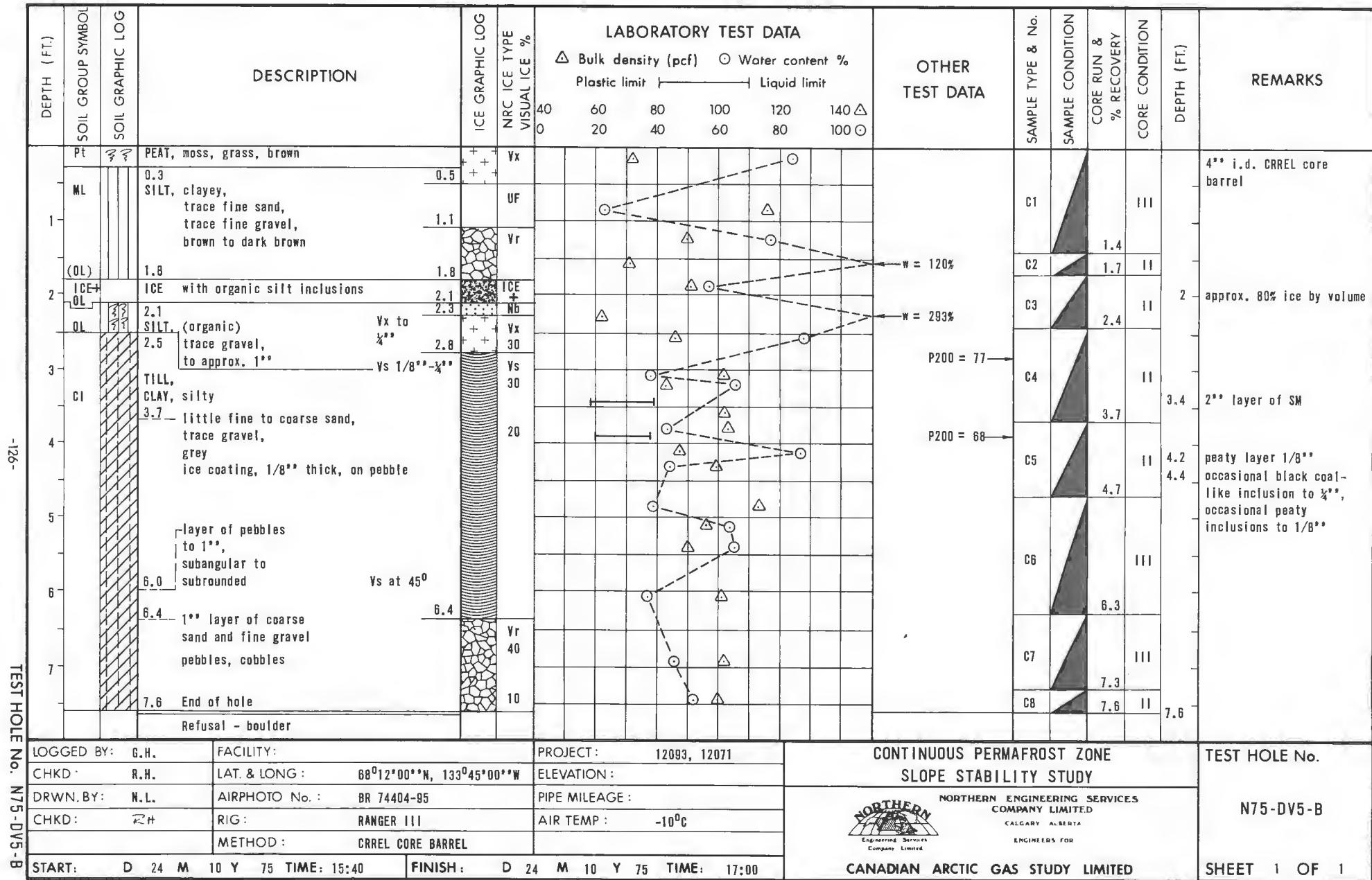
LOGGED BY:	G.H.	FACILITY:	PROJECT:	12093, 12071
CHKD:	R.H.	LAT. & LONG :	68°12'00"E, 133°45'00"W	ELEVATION :
DRWN. BY:	A.M.	AIRPHOTO No. :	BR 74404-95	PIPE MILEAGE :
CHKD:	<i>R.H.</i>	RIG:	RANGER III	AIR TEMP : -10°C
		METHOD:	CRREL CORE BARREL	
START:	D 24 M 10 Y 75	TIME:	12:40	FINISH: D 24 M 10 Y 75 TIME: 14:15

PROJECT: 12093, 12071
ELEVATION:
PIPE MILEAGE:
AIR TEMP : -10°C

CONTINUOUS PERMAFROST ZONE
SLOPE STABILITY STUDY
NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.
N75-DV5-A-2
SHEET 2 OF 2
PC-9SK373

TEST HOLE LOG



SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

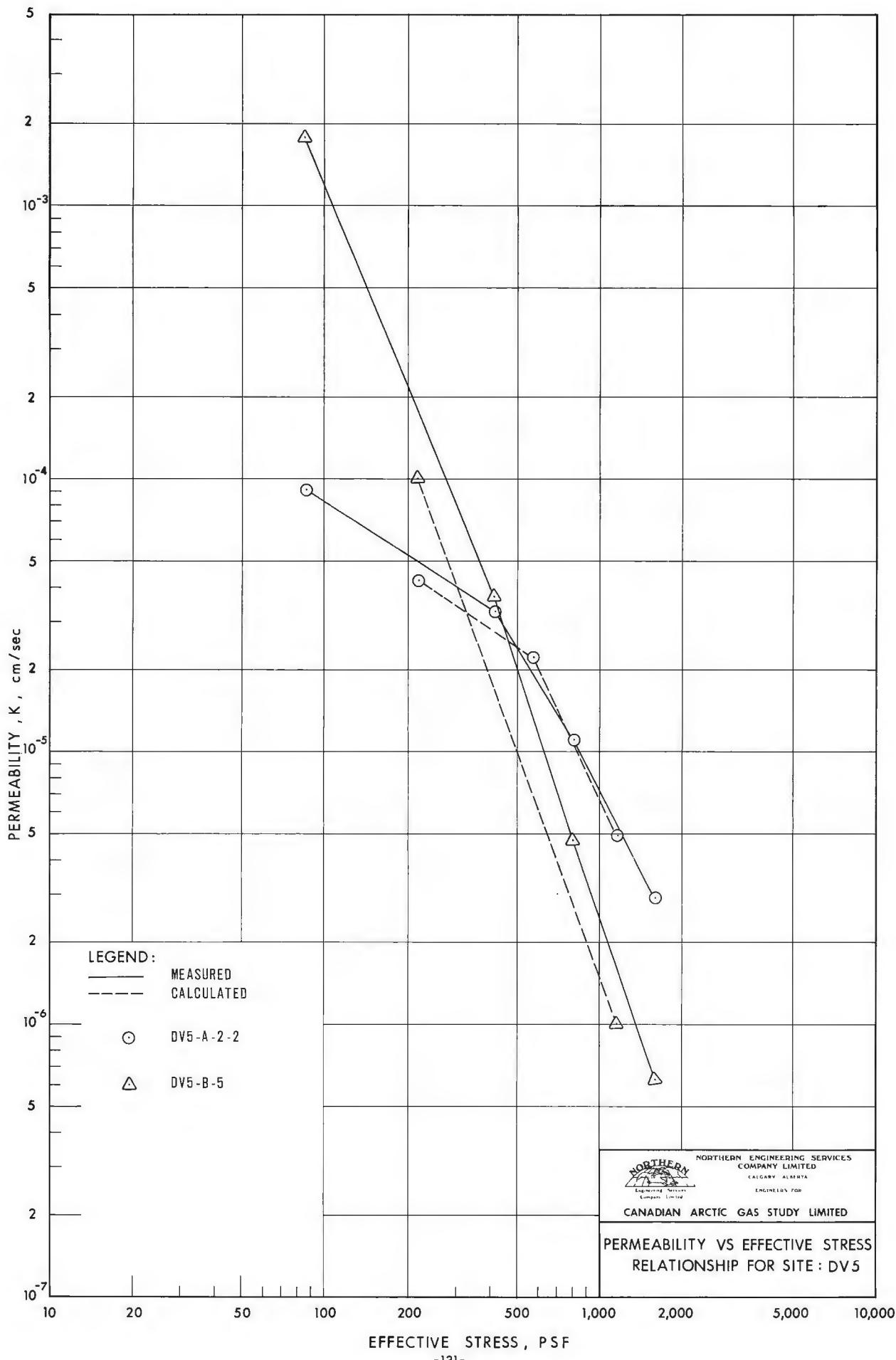
Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution > 0.074 mm				Soil Group	Remarks
		W _L %	W _P %	Gravel %	Sand %	Silt %	Clay* %		
DV5-A-3	3.7-5.0	39	17					CI	
DV5-A-2-1	6.2-7.5	40	18	3	19	42	36	CI	
DV5-A-2-2	7.5-8.5	36	18	7	20	40	33	CI	
DV5-A-2-4	10.2-11.0	39	18	10	18	34	38	CI	
DV5-B-4	2.4-3.7	39	18	7	16	40	37	CI	
DV5-B-5	3.7-4.7	38	20	19	13	35	33	CI	

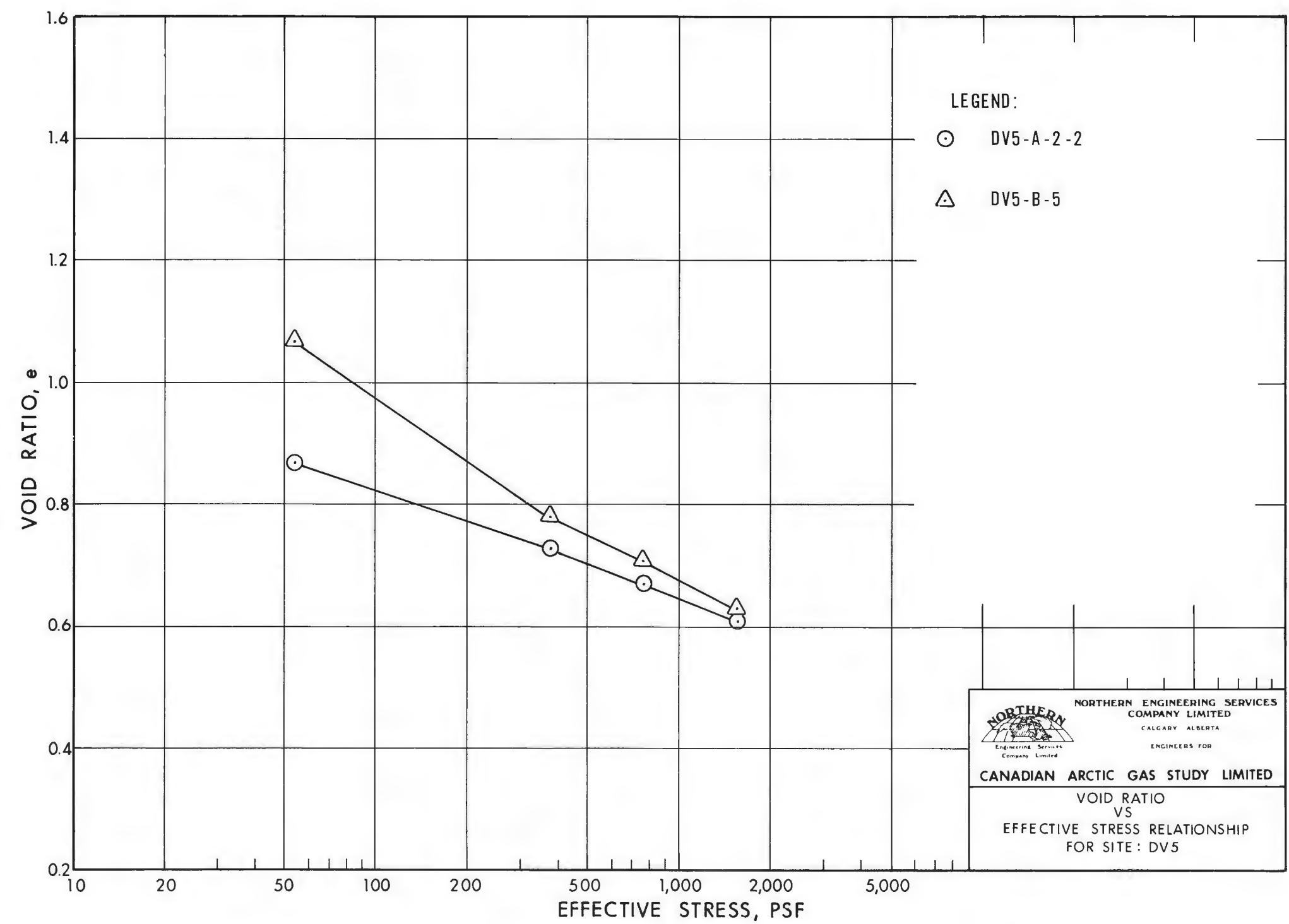
* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

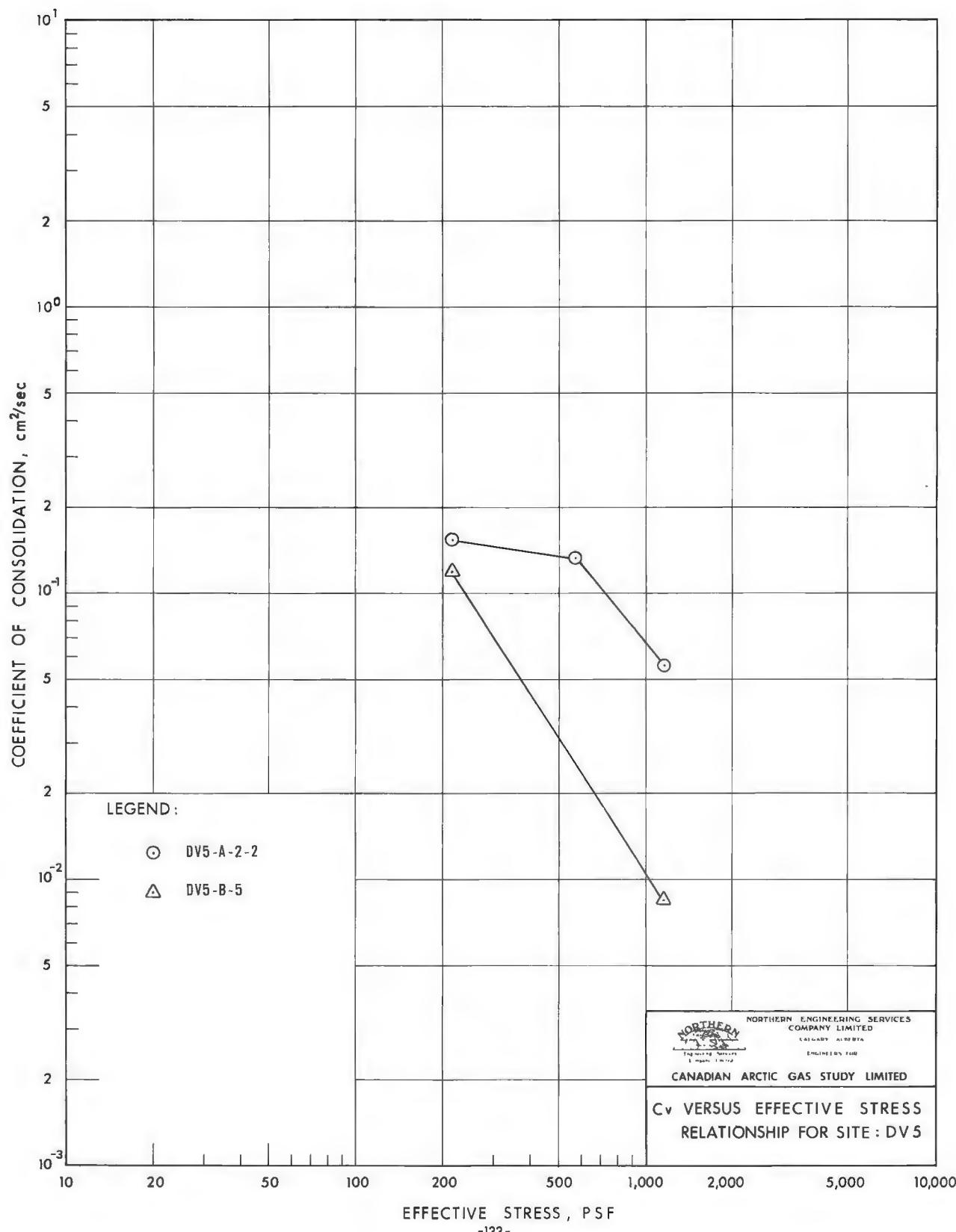
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM. 2 /SEC.	$M_v \times 10^{-5}$ CM. 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV5-A-2-2	7.5-8.5	113.8	32.1	36	18	40	33	0.0		0.933					
								53.7		0.870					
										0.806	1.0	9.02			
								378.2		0.729					
										0.721	1.0	3.26			
								215.9					15.13	27.16	4.11
								771.6		0.665					
										0.665	1.0	1.09			
								574.9					12.91	17.25	2.23
								1557.7		0.607					
										0.607	1.0	0.29			
								1164.6					5.54	8.92	0.49
DV5-B-5	4.0-4.25	86.5	86.9	38	20	35	33	0.0		2.599					
								54.2		1.074					
										1.048	1.0	179.40			
								380.7		0.775					
										0.759	1.0	3.70			
								217.4					11.81	83.82	9.90
								771.4		0.703					
										0.704	1.0	0.47			
								576.0					-	-	-
								1554.0		0.625					
										0.623	1.0	0.06			
								1162.7					0.86	11.76	0.10

*Accuracy of this datum point in doubt







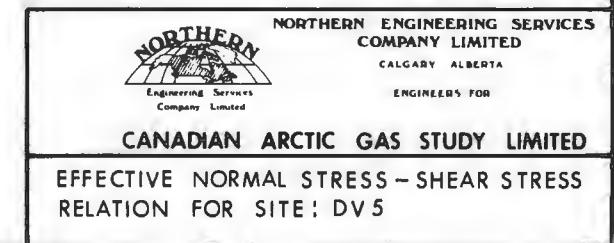
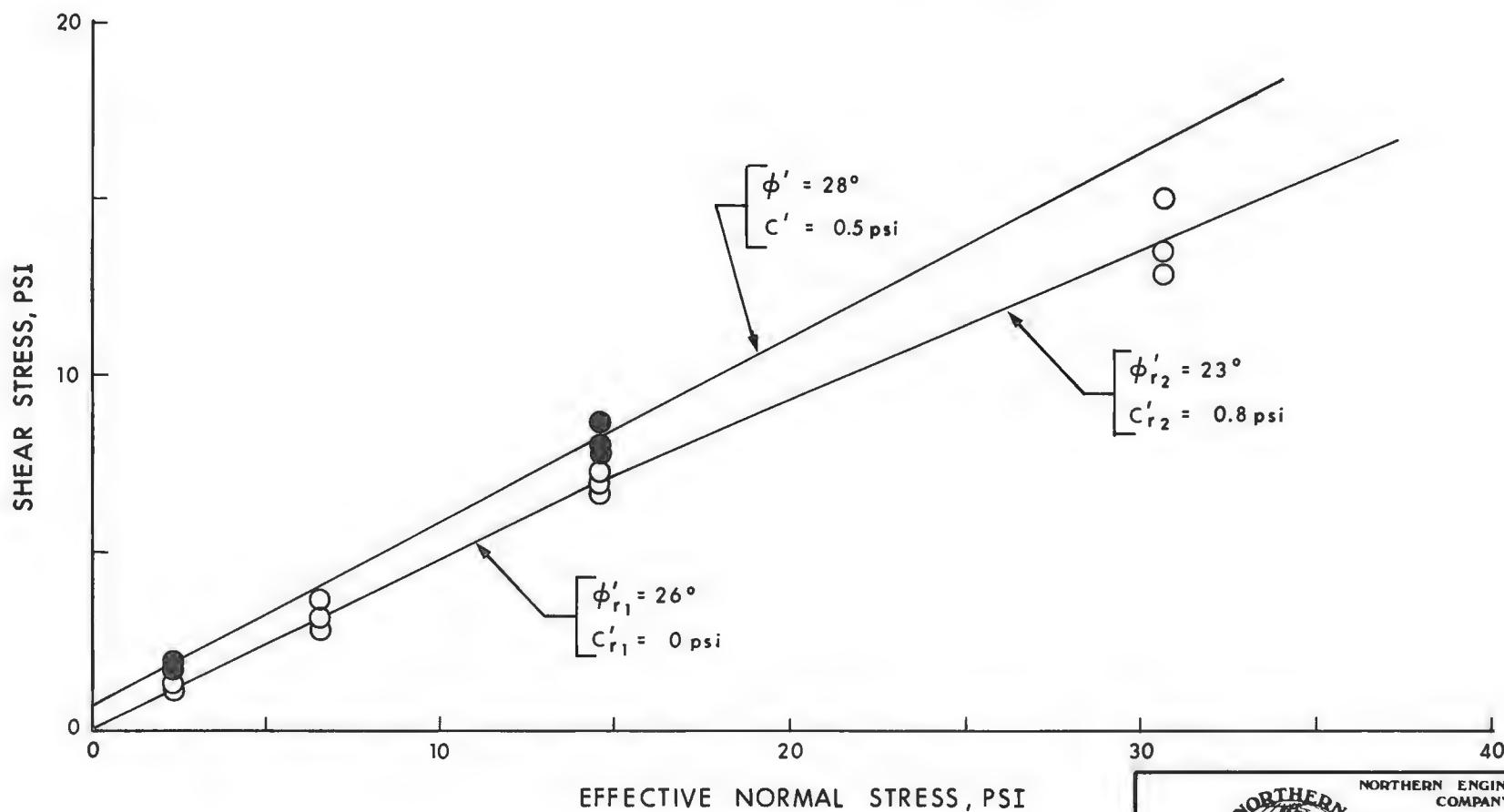
SUMMARY OF DIRECT SHEAR TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	NORMAL STRESS PSI	MAX. SHEAR STRESS PSI	RESIDUAL SHEAR STRESS PSI	ϕ' DEG.	C' PSI	ϕ'_r DEG.	C'_r PSI	REMARKS
DV5-A-2-2	7.5-8.5	119.6	20.8	36	18	40	33	2.4	1.9	1.3	30.0	0.5	26.0	0.3	Cut plane
								6.5		3.3					
								14.5		7.1					
DV5-A-2-2	7.5-8.5	117.1	22.0	36	18	40	33	14.5	8.9	7.4	30.0	0.5	26.0	0.3	Cut plane
								30.7		15.2					
DV5-B-4	3.1-3.3	83.2	66.4	39	18	40	37	2.4	1.7	1.4	26.0	0.8	24.0	0.5	
								6.5		3.7					
								14.6		7.1					
DV5-B-4	3.3-3.5	76.6	70.0*	39	18	40	37	14.5	7.7	7.0	26.0	0.8	20.5	1.6	
								30.7		13.0					
DV5-B-5	3.7-4.7	97.7	43.8	38	20	35	33	2.4	1.5	1.2	28.0	0.3	25.5	0.0	
								6.5		3.2					
								14.6		6.9					
DV5-B-5	3.7-4.7	99.3	44.4	38	20	35	33	14.5	8.1	6.8	28.0	0.3	23.0	0.9	
								30.7		13.6					
* Accuracy of this datum point in doubt															

FOR SOIL GROUP : CI

LEGEND:

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	NOT VERIFIED BY LABORATORY TESTS	DESCRIPTION	ICE GRAPHIC LOG	LABORATORY TEST DATA							OTHER TEST DATA	SAMPLE TYPE & NO.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS
					NRC ICE TYPE VISUAL ICE %	40 0	60 20	80 40	100 60	120 80	140 100							
Pt	Ys	PEAT, moss, grass, roots (3") 0.4 brown, fibrous, brown, green																
GM	Nf occ. Vx	GRAVEL, some fine to coarse sand, little silt, brown, pebbles angular to subrounded, Vx to 1/8", poorly bonded, friable some Vc around pebbles																
1.8		End of hole Refusal - cobble																

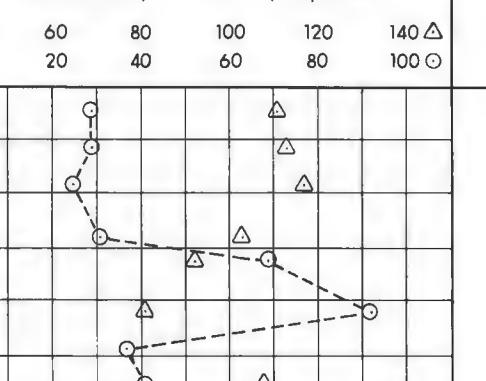
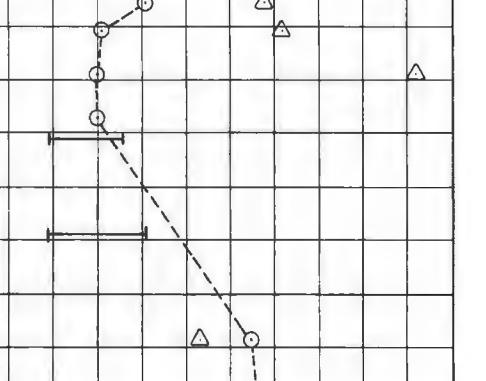
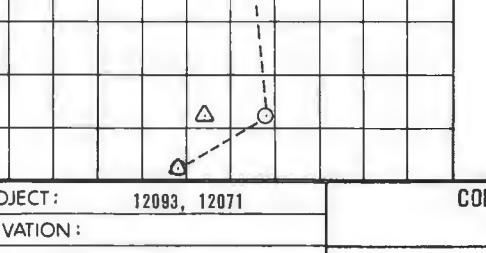
-137-

TEST HOLE No. N75-DV51-A

LOGGED BY:	G.H.	FACILITY:	PROJECT:	12083, 12071
CHKD:	R.H.	LAT. & LONG :	68°33'40"N, 133°33'20"W	ELEVATION:
DRWN BY:	N.L.	AIRPHOTO No. :	BR 74404-89	PIPE MILEAGE:
CHKD:	R.H.	RIG:	RANGER III	AIR TEMP : -15°C
		METHOD:	CRREL CORE BARREL	
START:	D 26	M 10	Y 75	TIME: 14:15
				FINISH: D 26 M 10 Y 75 TIME: 14:40

CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY  NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED		TEST HOLE No.
N75-DV51-A		SHEET 1 OF 1

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUALICE %	LABORATORY TEST DATA	OTHER TEST DATA	SAMPLE TYPE & NO.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS	
Pt			Moss, grass, roots, fibres											
DL	33	33	SILT, (organic) trace gravel to 2", trace fine to coarse sand, brown, Vs to 1/8", well-bonded	++	Vx 10			C1			II		4" i.d. CRREL core barrel	
1	33	33	1.3											
CI			TILL CLAY, silty, trace sand, grey-brown, frequent cobbles, frequent layers of pebbles to 1 1/2", Vs to 1/8", 1/8"-1/2" spacing	VS	50			C2		2.0	IV			
2								C3		2.5	IV			
3			3.3 - 1/2" layer of silty sand 3.5 - pebbles to 1 1/2"					C4		3.7	II			
4			- some gravel, little sand, Vx to 1/8"					C5		4.3	II			
5			- white inclusions to 1/2"					C6			I			
6			- little gravel, little sand					C7		8.2	II			
			- isolated cobbles, infrequent pebbles							7.0	IV			
6.0			6.0 Vs to 1/4"							(8.4)	II			
ICE +			ICE, with silt inclusions, clear ice with vertical bubble trains,	ICE +										
ML			6.7 vertical silt bands to 1/2"											
7			Layers to 1/2", of silt 7.2 in cloudy ice											
7.2														
SC			SAND, and silty clay, grey (till)	Vr	40									
8			Vr to 1/2"											
LOGGED BY: G.H.			FACILITY:			PROJECT: 12093, 12071			CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY				TEST HOLE No.	
CHKD:	R.H.	LAT. & LONG :	68°36'40"N, 133°33'20"W			ELEVATION:			NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR  CANADIAN ARCTIC GAS STUDY LIMITED				N75-DV51-B	
DRWN BY:	N.L.	AIRPHOTO No. :	BR 74404-89			PIPE MILEAGE:								
CHKD:	RIG:	RANGER III			AIR TEMP : -18°C									
	METHOD :	CRREL CORE BARREL												
START:	D 26 M 10 Y 75	TIME:	15:00		FINISH:	D 26 M 10 Y 75	TIME:	17:00						

1

TEST HOLE No. N75-DV51-B

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA							OTHER TEST DATA	REMARKS		
						40	60	80	100	120	140	△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit	
8	SC		SAND, and silty clay, continued trace gravel to $\frac{3}{4}''$, subangular to rounded, (till), grey, occasional cobbles		Vr											
9						40	60	80	100	120	140	△	○			
10						0	20	40	60	80	100					
11																
12	CI		(11.3) CLAY, little fine to coarse sand, trace fine gravel, (till)													
13																
14			coarse sand ($\frac{1}{4}''$) particles													
14.9			End of hole													
			Refusal - cobble													
TEST HOLE NO. N75-DV51-B																
LOGGED BY:	G.H.	FACILITY			PROJECT:	12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY							TEST HOLE No. N75-DV51-B		
CHKD	R.H.	LAT. & LONG :	68°36'40" N, 133°33'20" W		ELEVATION:											
DRWN BY:	N.L.	AIRPHOTO No.:	8R 74404-89		PIPE MILEAGE:											
CHKD:	R.H.	RIG:	RANGER III		AIR TEMP:	-18°C										
		METHOD:	CRREL CORE BARREL													
START:	D 26	M 10	Y 75	TIME: 15:00	FINISH:	D 26	M 10	Y 75	TIME: 17:00						SHEET 2 OF 2	



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE % VISUAL ICE	LABORATORY TEST DATA						OTHER TEST DATA	SAMPLE TYPE & No. SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS	
					40	60	80	100	120	140							
Pt	??	Moss, grass, roots for 2 inches															
	??	PEAT, fibrous, roots, twigs, brown															
1	??	well-bonded															
	??	1.4															
1.4	Cl	TILL, CLAY, silty, brown, occasional layers of silty sand, to approx. 1 inch thickness, infrequent pebbles to 1.5 inches	VR 40	20													
2																	
3																	
4																	
4.0		little fine to medium sand, trace fine to coarse gravel, dark brown	VS 20														
5																	
5.8		End of hole															
TEST HOLE NO. N75-DV5-C	LOGGED BY: G.H.	FACILITY:		PROJECT: 12083, 12071		CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY						TEST HOLE No.					
CHKD: R.H.		LAT. & LONG :	68°36'40"E, 133°33'20"W	ELEVATION:		NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED						N75-DV51-C					
DRWN. BY: N.L.		AIRPHOTO No. :	BR 74404-89	PIPE MILEAGE:													
CHKD: RA		RIG:	RANGER III	AIR TEMP.:	-20°C												
		METHOD:	CRREL CORE BARREL														
START: D 27 M 10 Y 75 TIME: 11:40	FINISH: D 27 M 10 Y 75 TIME: 12:10					CANADIAN ARCTIC GAS STUDY LIMITED						SHEET 1 OF 1					

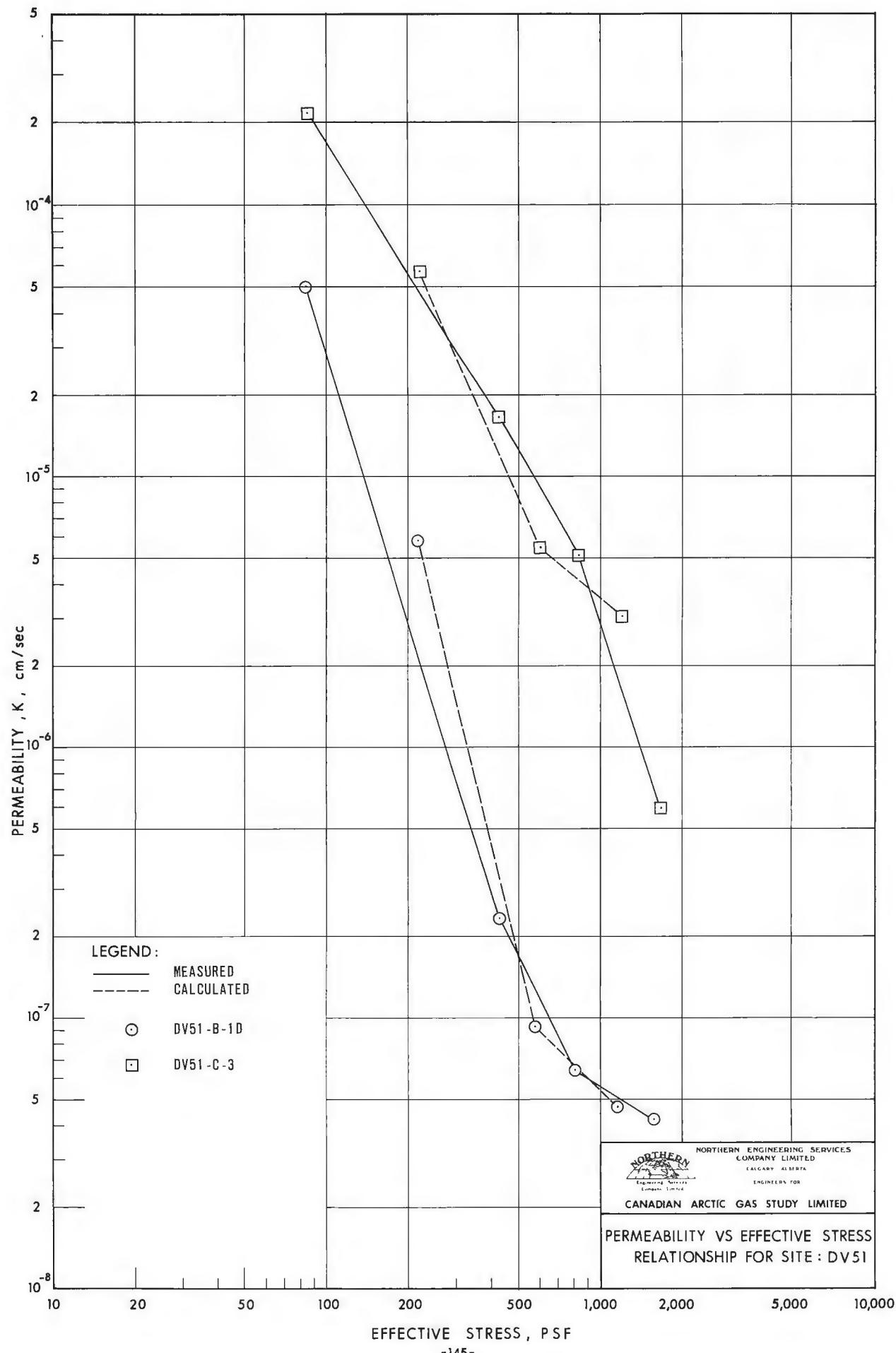
SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

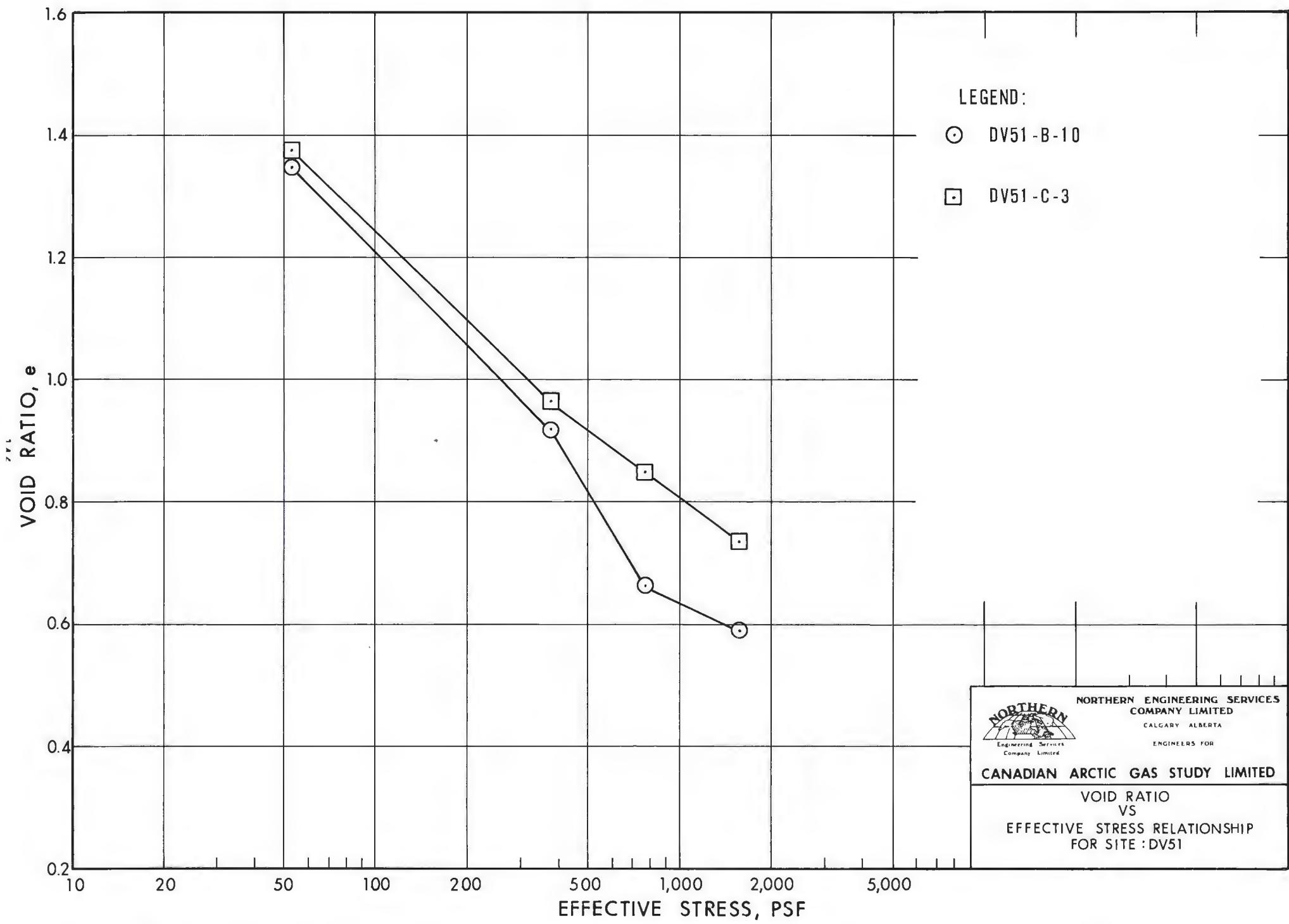
Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution > 0.074 mm				Soil Group	Remarks
		W _L %	W _P %	Gravel %	Sand %	Silt %	Clay* %		
DV51-B-5	3.9-4.3	36	19	27	14	32	27	CI	
DV51-B-6	4.3-6.1	41	19	15	13	39	33	CI	
DV51-B-8	8.4-9.7	37	17	8	55	27	10	SC	
DV51-B-10	10.8-13.2	41	18	2	16	47	35	CI	
DV51-B-11	13.2-14.0	45	21	2	13	51	34	CI	
DV51-C-3	3.5-4.7	39	20	5	12	44	39	CI	

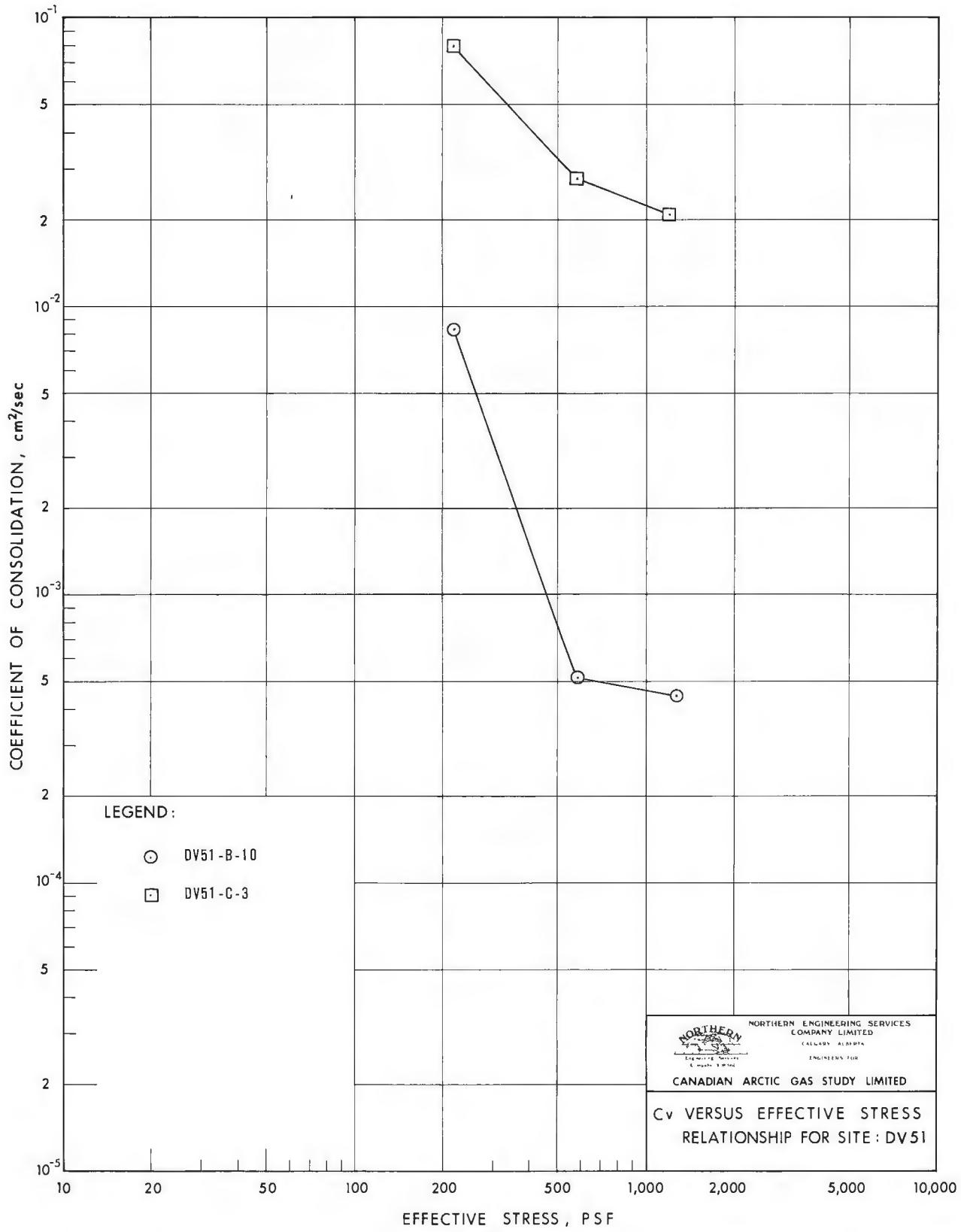
* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM. ² /SEC.	$M_v \times 10^{-5}$ CM. ² /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV51-B-10	10.8-11.0	98.1	52.9	41	18	47	35	0.0		1.598					
								54.2		1.348					
									0.934	1.0	4.91				
								380.7		0.717					
									0.714	1.0	0.02				
									217.4			0.82	72.55	0.59	
								771.4		0.655					
									0.653	1.0	0.01				
								576.0				0.05	18.21	0.01	
								1554.0		0.586					
									0.585	1.0	0.004				
								1162.7				0.05	10.21	0.005	
DV51-C-3	4.0-4.3	81.3	99.7	39	20	44	39	0.0		3.091					
								53.3		1.379					
									1.238	1.0	21.54				
								391.6		0.974					
									0.952	1.0	1.64				
									222.4			7.91	71.31	5.64	
								793.4		0.852					
									0.846	1.0	0.51				
								592.5				2.75	19.90	0.55	
								1604.6		0.736					
									0.733	1.0	0.06				
								1199.0				2.06	14.88	0.31	





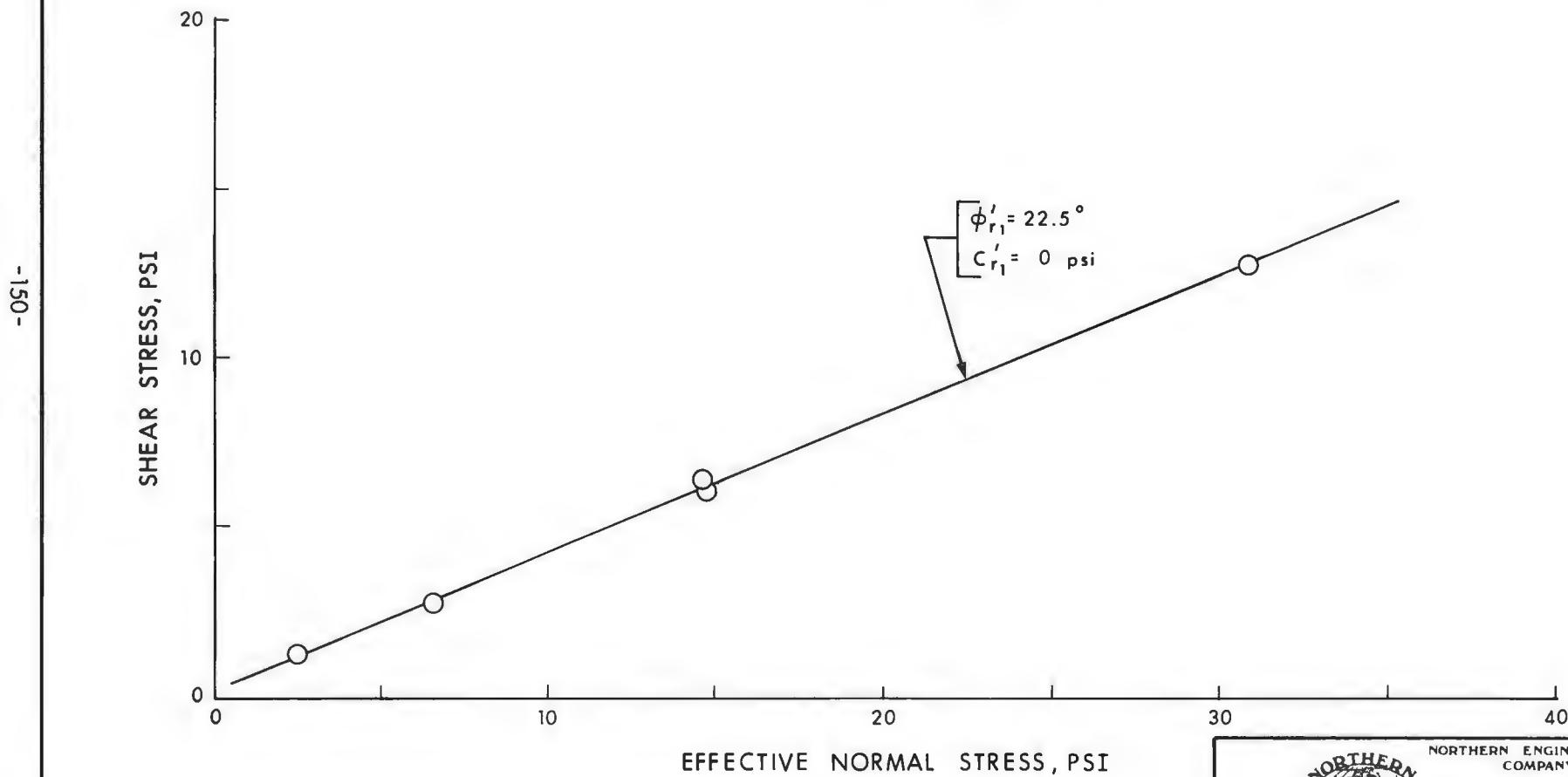


SUMMARY OF DIRECT SHEAR TEST DATA

FOR SOIL GROUP : CI

LEGEND :

- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED

CALGARY ALBERTA

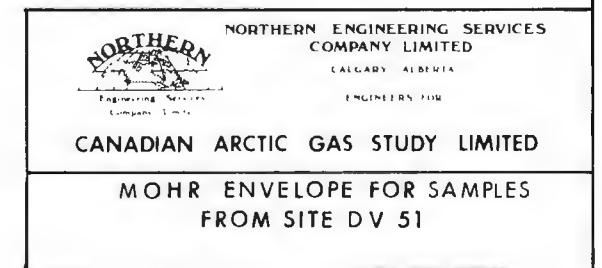
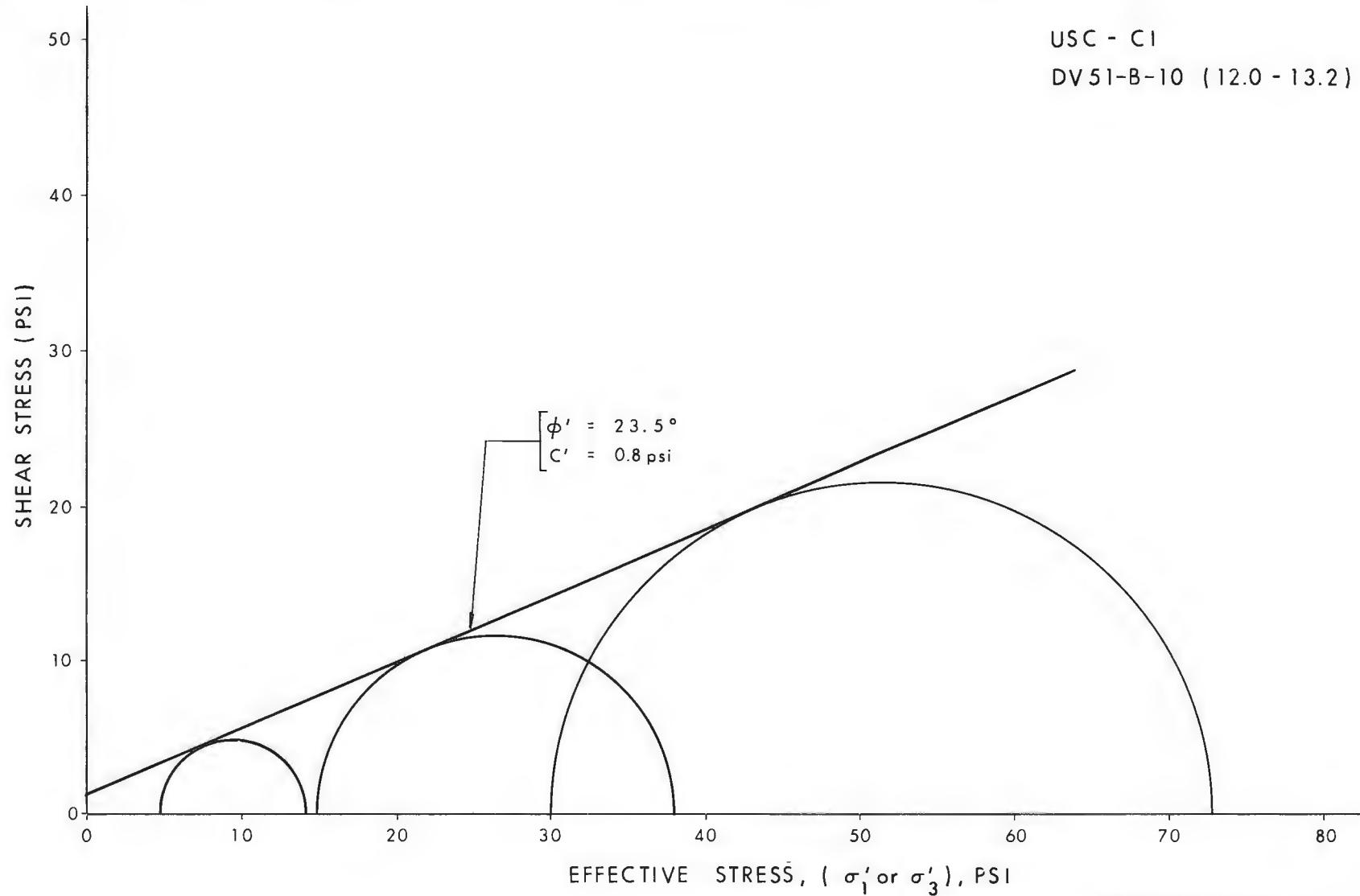
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

EFFECTIVE NORMAL STRESS - SHEAR STRESS
RELATION FOR SITE: DV51

SUMMARY OF TRIAXIAL TEST DATA

Sample Number & Depth, ft	Sample Details		Atterberg Limits		Grain Size Distribution	Strain Rate in/hr	σ_3 psi	$(\sigma_1 - \sigma_3)_{max}$ psi	Pore Pressure at $(\sigma_1 - \sigma_3)_{max}$ psi	c' psi	ϕ' deg	Remarks
	γ_f	W %	W_L %	W_P %								
	pcf	%	%	%								
DV51-B-10 (12.0-13.2)	111	37.4	41	18	Gravel = 3 Sand = 14 Silt = 49 Clay = 34 Gravel = 3 Sand = 14 Silt = 49 Clay = 34 Gravel = 3 Sand = 14 Silt = 49 Clay = 34	0.036	5	9.2	-			Consolidated - Drained
DV51-B-10 (12.0-13.2)	109	39.8	41	18		0.036	15	23.5	-	0.8	23.5	
DV51-B-10 (12.0-13.2)	104	43.1	41	18		0.036	30	42.7	-			



TEST HOLE LOG

三

IE31 HOLE No. N/3-D

LOGGED BY G.H.

ACILITY:

PROJECT: 12093- 12071

CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY



**NORTHERN ENGINEERING SERVICES
COMPANY LIMITED**

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No

N75-DV9-A

SHEET 1 OF 2

TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA							OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS	
						40	60	80	100	120	140	△ Bulk density (pcf)	○ Water content %	Plastic limit	Liquid limit					
8	CI		TILL, continued CLAY, trace gravel, subangular to rounded, trace sand, grey, occasional peaty inclusions, hairline Vs		Vs ≤ 5														8	
9																				
9.4			- trace coarse sand (as white inclusions), trace gravel to 1", dark grey																	
10																				
10.5																				
10.7																				
11.0																				
11			occasional pebble layers																	
11.5																				
12			white inclusions hairline Vs																	
12.5																				
13			little fine to medium sand, trace gravel to ½", dark brown, Vs to ½", approx. 2" spacing clear ice																	
14.0			End of hole																	
-154																				
TEST HOLE No. N75-DV9-A	LOGGED BY: G.H.	FACILITY:		PROJECT: 12093, 12071		CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY		TEST HOLE No.												
CHKD: R.H.		LAT. & LONG:	68°11'40"E, 132°33'20"W	ELEVATION:		NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED		N75-DV9-A												
DRWN. BY: N.L.		AIRPHOTO No.:	BR 74404-26	PIPE MILEAGE:																
CHKD: 14		RIG:	RANGER III	AIR TEMP:	-26°C to -37°C															
		METHOD:	CRREL CORE BARREL																	
START: D 28 M 10 Y 75 TIME: 15:00	FINISH: D 04 M 11 Y 75 TIME: 16:15																			

PC-9SK373

TEST HOLE LOG

TEST HOLE No. N75-DV9-B

TEST HOLE LOG

-156- TEST HOLE NoN75-0W9-B-2

LOGGED BY: G.H.

FACILITY:

CHKD: R.H.

LAT. & LONG : $68^{\circ}11'40''N$, $132^{\circ}33'20''E$

DRWN BY: N.L.

AIRPHOTO No. : BR 74404-2B

CHKD: 五行

RIG: RANGER III

•

METHOD

PROJECT: 12093, 12071

ELEVATION:

PIPE MILEAGE :

AIR TEMP : -33°C

CONTINUOUS PERMAFROST ZONE

SLOPE STABILITY STUDY



**NORTHERN ENGINEERING SERVICES
COMPANY LIMITED**
CALGARY ALBERTA

CANADIAN ARCTIC GAS STUDY LIMITED

TEST HOLE No.

NZE DWG B-2

SHEET 1 OF 1

SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

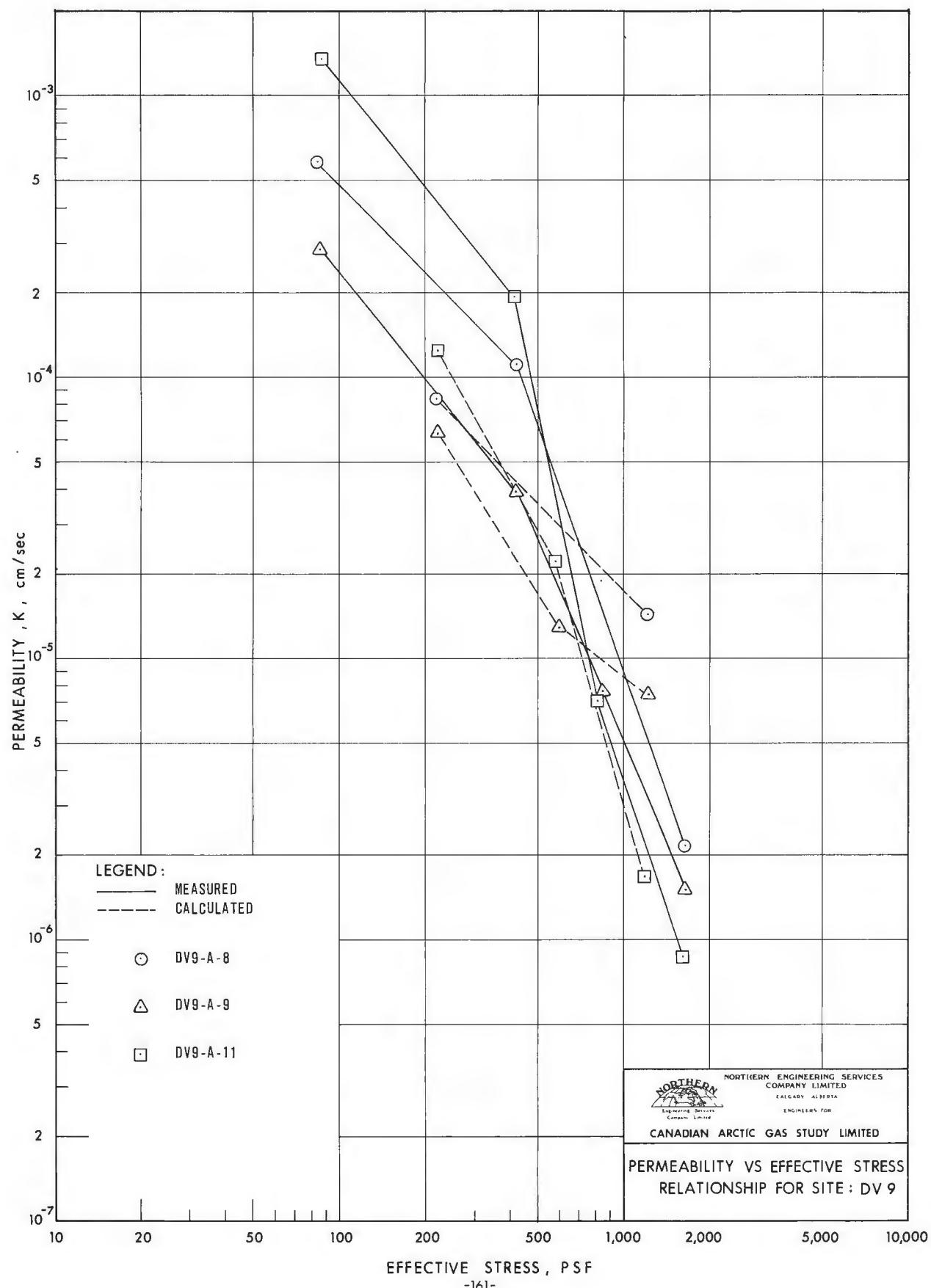
Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution > 0.074 mm				Soil Group	Remarks
		W _L %	W _P %	Gravel %	Sand %	Silt %	Clay* %		
DV9-A-8	9.2-10.1	40	20	5	17	35	43	CI	
DV9-A-9	10.1-11.0	40	19	5	9	49	37	CI	
DV9-A-11	12.2-13.2	42	18	2	12	44	42	CI	

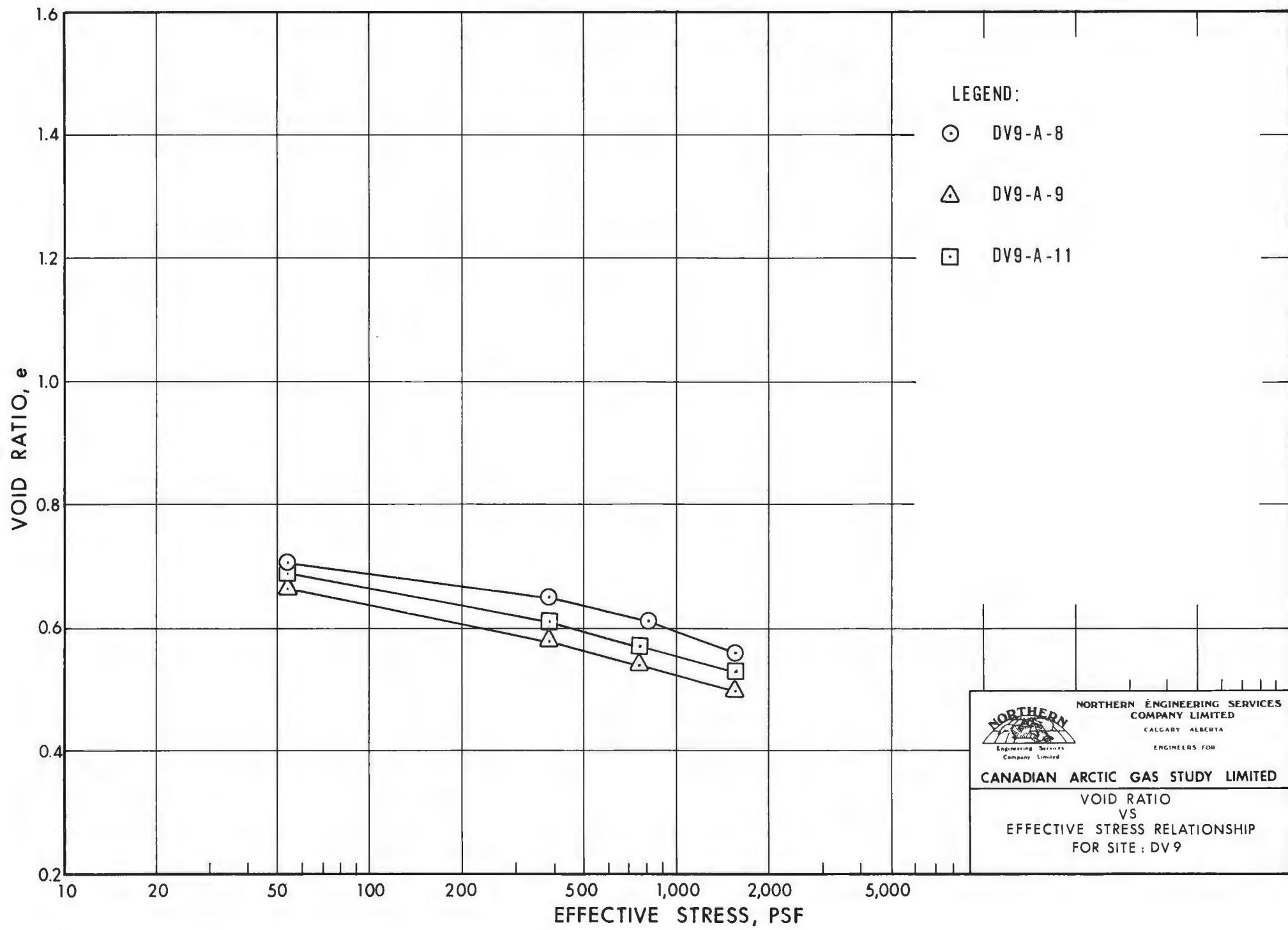
* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

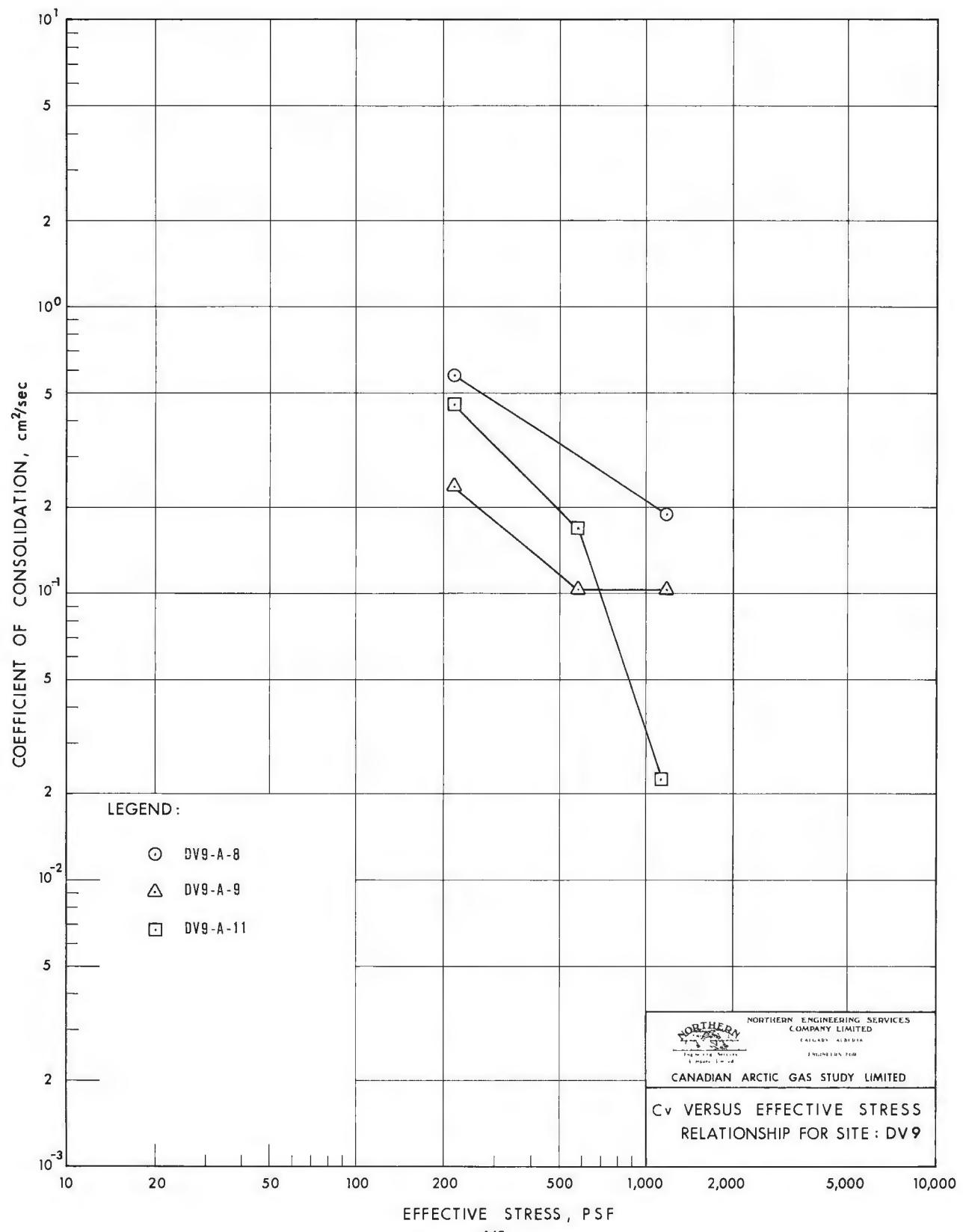
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.	
DV9-A-8	9.2-9.4	122.5	23.9	40	20	35	43	0.0		0.685						
								53.6		0.697						
										0.690	1.0	58.43				
								387.2		0.649						
										0.645	1.0	10.82				
								220.4					56.47	14.90	8.42	
								815.6		0.608						
										0.607	1.0					
								601.4					-	-	-	
								1604.9		0.558						
										0.555	1.0	0.22				
								1210.2					18.99	7.66	1.45	
DV9-A-9	10.7-11.0	122.2	22.2	40	19	49	37	0.0		0.666						
								53.4		0.664						
										0.658	1.0	28.52				
								391.6		0.585						
										0.582	1.0	3.85				
								222.5					23.65	27.11	6.41	
								794.1		0.543						
										0.540	1.0	0.77				
								592.9					10.34	12.36	1.28	
								1607.1		0.497						
										0.495	1.0	0.15				
								1200.6					10.43	7.05	0.74	

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

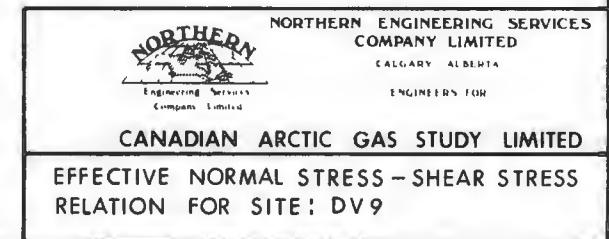
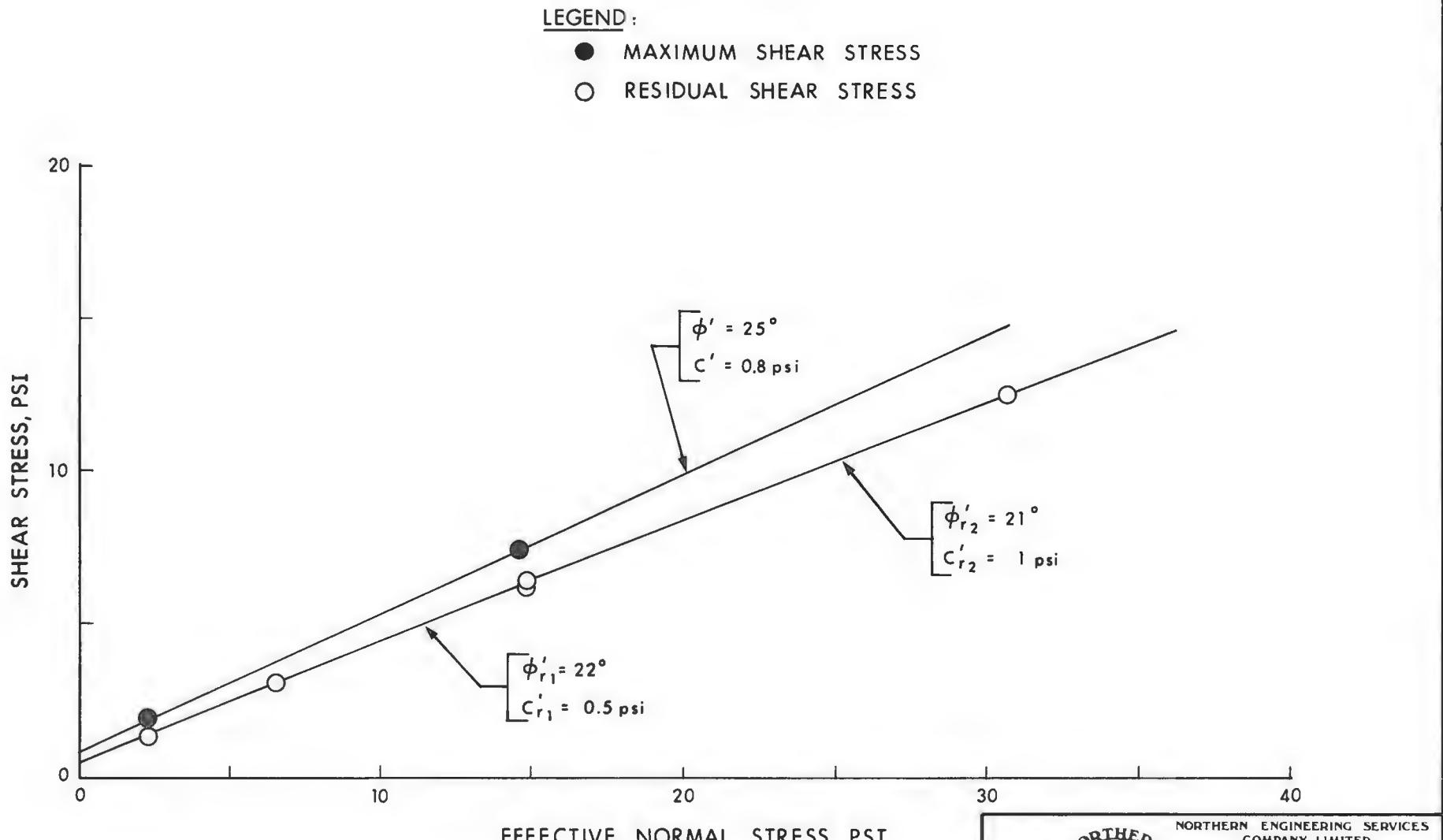




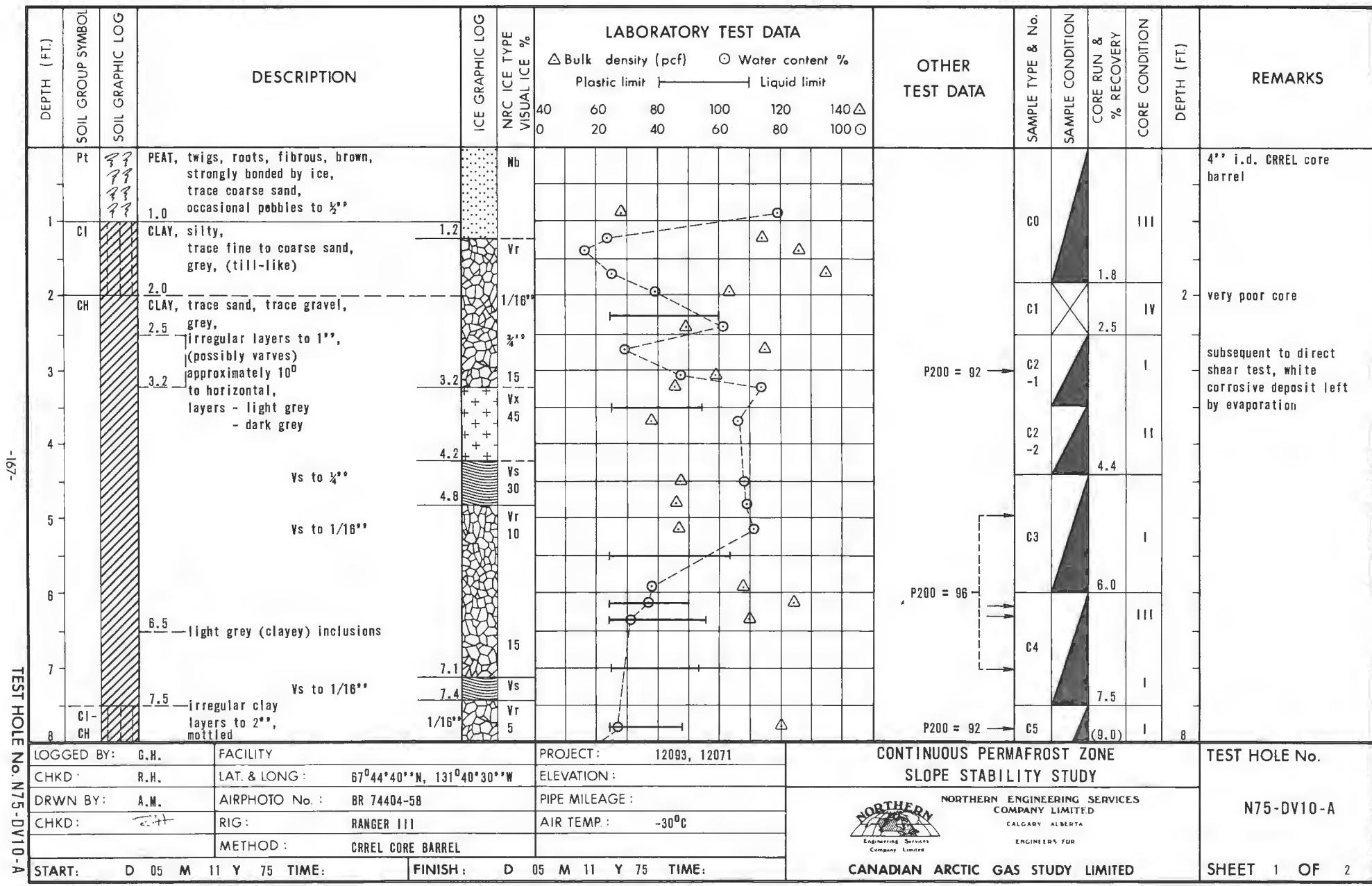


SUMMARY OF DIRECT SHEAR TEST DATA

FOR SOIL GROUP : CI



TEST HOLE LOG



TEST HOLE LOG

DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUAL ICE %	LABORATORY TEST DATA							OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS
8 (CI)			CLAY, little to some fine sand, highly variable plasticity, laminated - light grey - dark grey Vr to 1/8", infrequently to 1/2"	Vr 5	40 60 80 100 120 140 △ 0 20 40 60 80 100 ○	△ Bulk density (pcf) ○ Water content % Plastic limit ————— Liquid limit													
9			CLAY, trace fine sand, high plastic, grey	Vr 15									P200 = 87 → (7.5)				8		
10	CH			Vr 15									P200 = 85 → 9.0						
11	(CL)		11.0 silty, grey, possibly lower plasticity at 11.5", pebble rounded to 1"	Vr to 1/2"	30								P200 = 77 →						
11.3	CH			Vr to 1/2"	50								C6						
12				Vr to 1"									C7	11.0	I				
13													C8	11.3	I				
13.0																			
13.7																			
13.9																			
14			1" clear ice clear ice with soil inclusions at 14.5" clear ice with soil inclusions	Vr															
14.3																			
14.5			End of hole																
			at 14.5" clear ice with soil inclusions																
TEST HOLE No. N75-DV10-A	LOGGED BY: G.H.	FACILITY:	PROJECT: 12093, 12071	CONTINUOUS PERMAFROST ZONE SLOPE STABILITY STUDY	TEST HOLE No.														
CHKD: R.H.	LAT. & LONG : 67°44'40"N, 131°40'30"W	ELEVATION:	 <p>NORTHERN ENGINEERING SERVICES COMPANY LIMITED CALGARY ALBERTA ENGINEERS FOR CANADIAN ARCTIC GAS STUDY LIMITED</p>	<p>N75-DV10-A</p>															
DRWN. BY: A.M.	AIRPHOTO No.: 8R 74404-58	PIPE MILEAGE :																	
CHKD: R.H.	RIG: RANGER III	AIR TEMP : -30°C																	
	METHOD: CRREL CORE BARREL																		
START: D 05 M 11 Y 75 TIME:	FINISH: D 05 M 11 Y 75 TIME:																		

SUMMARY OF TEST DATA FOR SOIL CLASSIFICATION

Sample Identification	Sample Depth Ft	Atterberg Limits		Grain Size Distribution > 0.074 mm				Soil Group	Remarks
		W _L %	W _P %	Gravel %	Sand %	Silt %	Clay * %		
DV10-A-1	2.1-2.2	60	24					CH	
DV10-A-2	2.5-4.4	54	25	2	6	40	52	CH	
DV10-A-3	5.3-5.6	63	24	0	4	34	62	CH	
DV10-A-4	6.0-6.3	50	24	0	4	41	55	CH	
DV10-A-4	6.3-6.6	56	24					CH	
DV10-A-4	6.8-7.2	53	25	0	4	33	63	CH	
DV10-A-5	7.5-80	48	24	0	8	37	55	CI-CH	
DV10-A-5	8.0-8.3	28	16	0	13	44	43	CI	
DV10-A-5	8.3-8.6	32	18	0	15	40	45	CI	
DV10-A-5	8.6-9.0	31	16	0	23	48	29	CI	
DV10-A-6	9.5-10.0	62	22	0	5	33	62	CH	
DV10-A-8	12.0-12.7	58	23					CH	

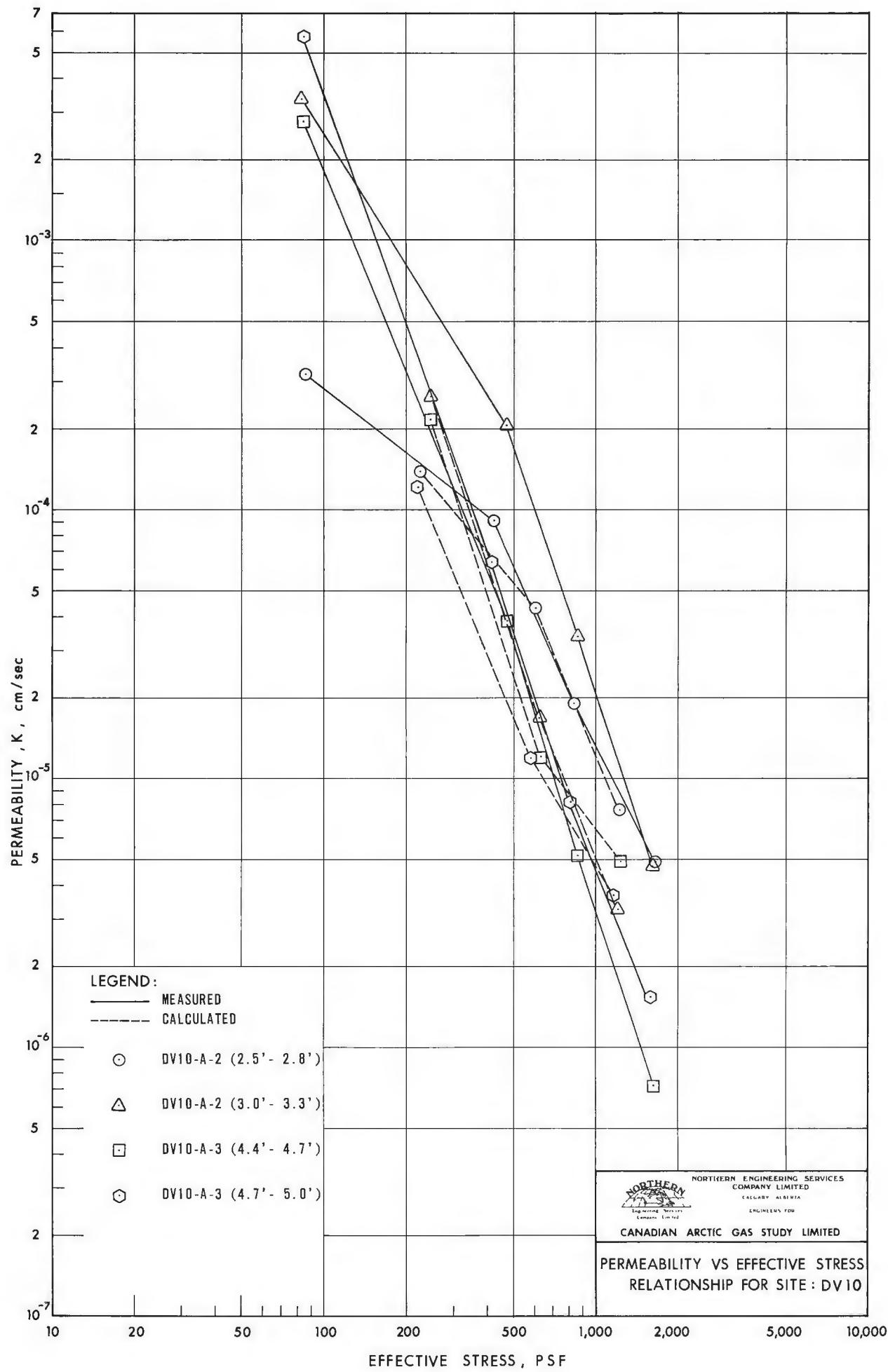
* Clay sizes assumed to be less than 0.002 mm average soil particle diameter

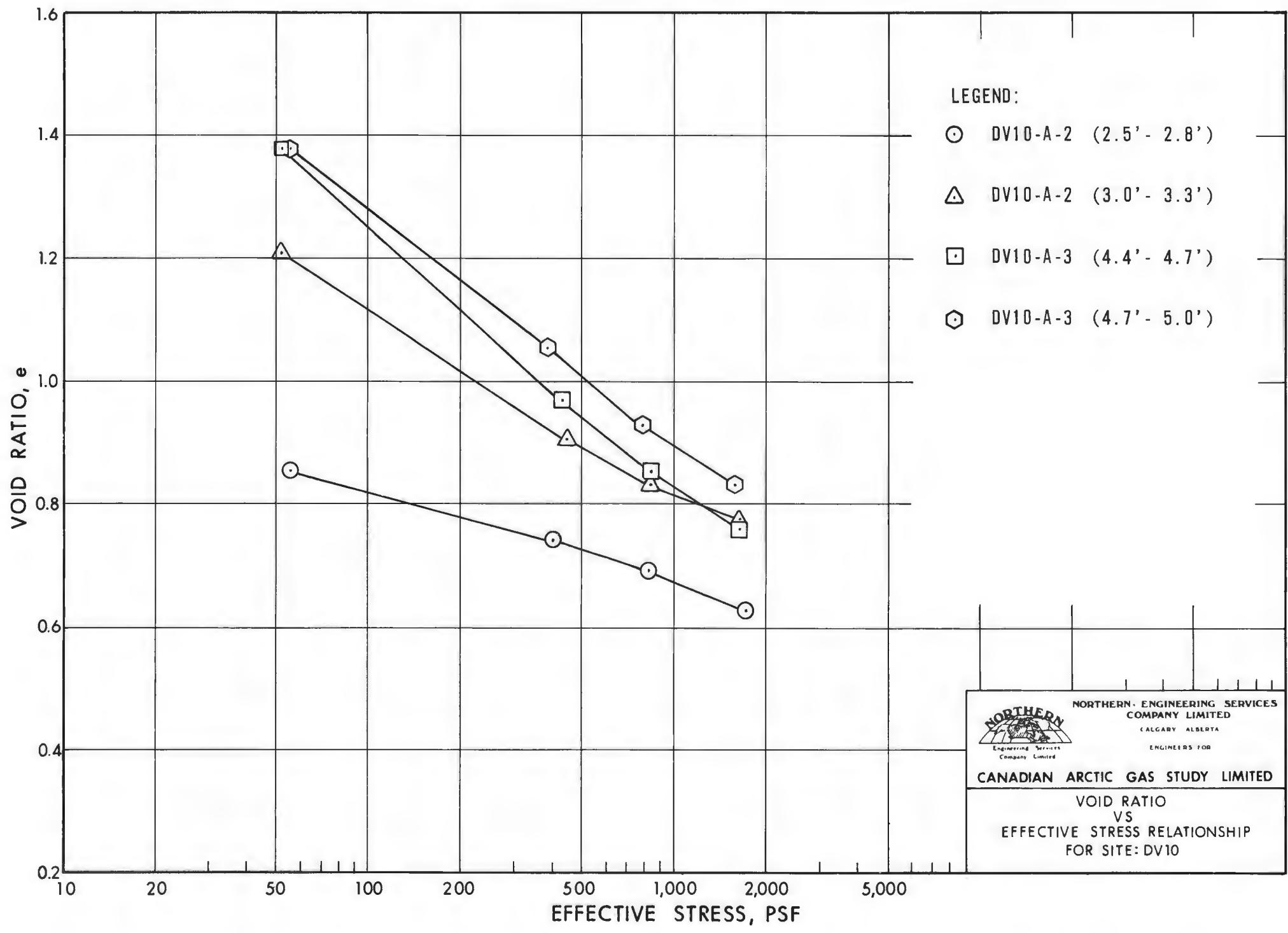
SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

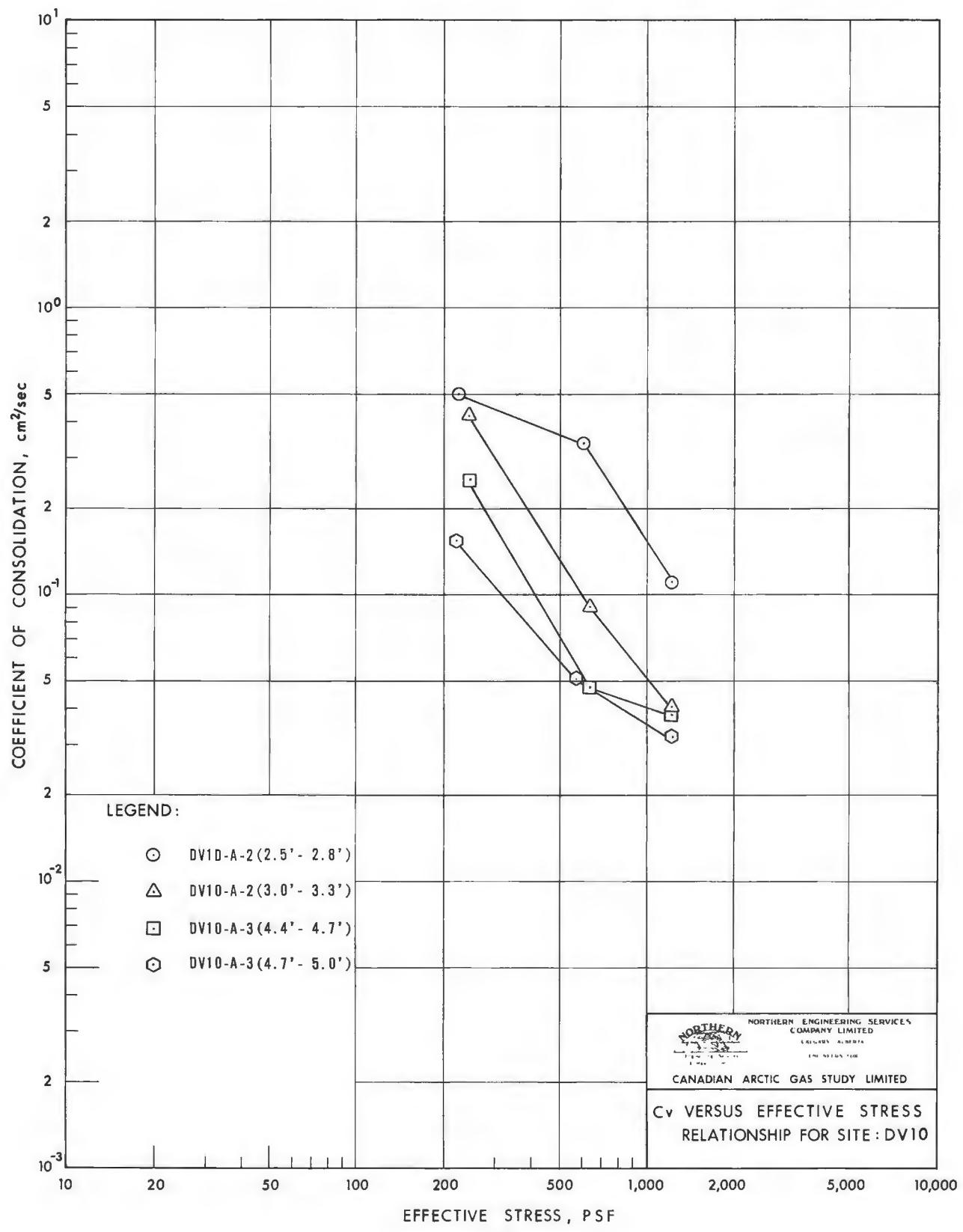
SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV10-A-2	2.5-2.8	115.3	28.6	54	25	40	52	0.0		0.859					
								54.2		0.853					
										0.831	1.0	32.57			
								396.2		0.744					
										0.739	1.0	9.03			
								225.2					47.62	29.03	13.82
								804.8		0.691					
										0.681	1.0	1.97			
								600.5					32.83	13.24	4.35
								1633.0		0.633					
										0.632	1.0	0.49			
								1218.9					10.91	7.03	0.77
DV10-A-2	3.0-3.3	99.4	47.1	54	25	40	52	0.0		1.467					
								51.0		1.210					
										1.175	1.0	336.20			
								432.9		0.907					
										0.895	1.0	20.76			
								241.9					40.69	65.52	26.67
								817.2		0.826					
										0.821	1.0	3.42			
								625.0					8.96	19.36	1.73
								1589.1		0.765					
										0.763	1.0	0.44			
								1203.1					4.03	8.07	0.33

SUMMARY OF CONSOLIDATION - PERMEABILITY TEST DATA

SAMPLE NUMBER	DEPTH FT.	FROZEN BULK DENSITY PCF	INITIAL WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SILT %	CLAY %	CONSOLIDATION PRESSURE PSF	AVERAGE PRESSURE PSF	VOID RATIO	WATER HEAD FT.	K MEAS. $\times 10^{-5}$ CM./SEC.	$C_v \times 10^{-2}$ CM 2 /SEC.	$M_v \times 10^{-5}$ CM 2 /G.	K CALC. $\times 10^{-5}$ CM./SEC.
DV10-A-3	4.4-4.7	88.3	68.4	63	24	34	62	0.0		2.179					
								51.7		1.376					
								438.9		1.371	1.0	274.10			
										0.973					
										0.951	1.0	3.85			
								245.3					24.09	88.78	21.39
								828.5		0.853					
										0.852	1.0	0.51			
								633.7					4.65	25.93	1.21
								1609.7		0.761					
										0.759	1.0	0.07			
								1219.1					3.82	12.86	0.49
DV10-A-3	4.7-5.0	85.9	69.0	63	24	34	62	0.0		2.280					
								54.6		1.382					
										1.380	1.0	571.70			
								383.8		1.059					
										1.016	1.0	6.37			
								219.2					15.02	82.15	12.34
								772.9		0.926					
										0.915	1.0	0.81			
								578.3					5.01	23.65	1.19
								1570.7		0.828					
										0.825	1.0	0.15			
								1171.8					3.16	11.62	0.37





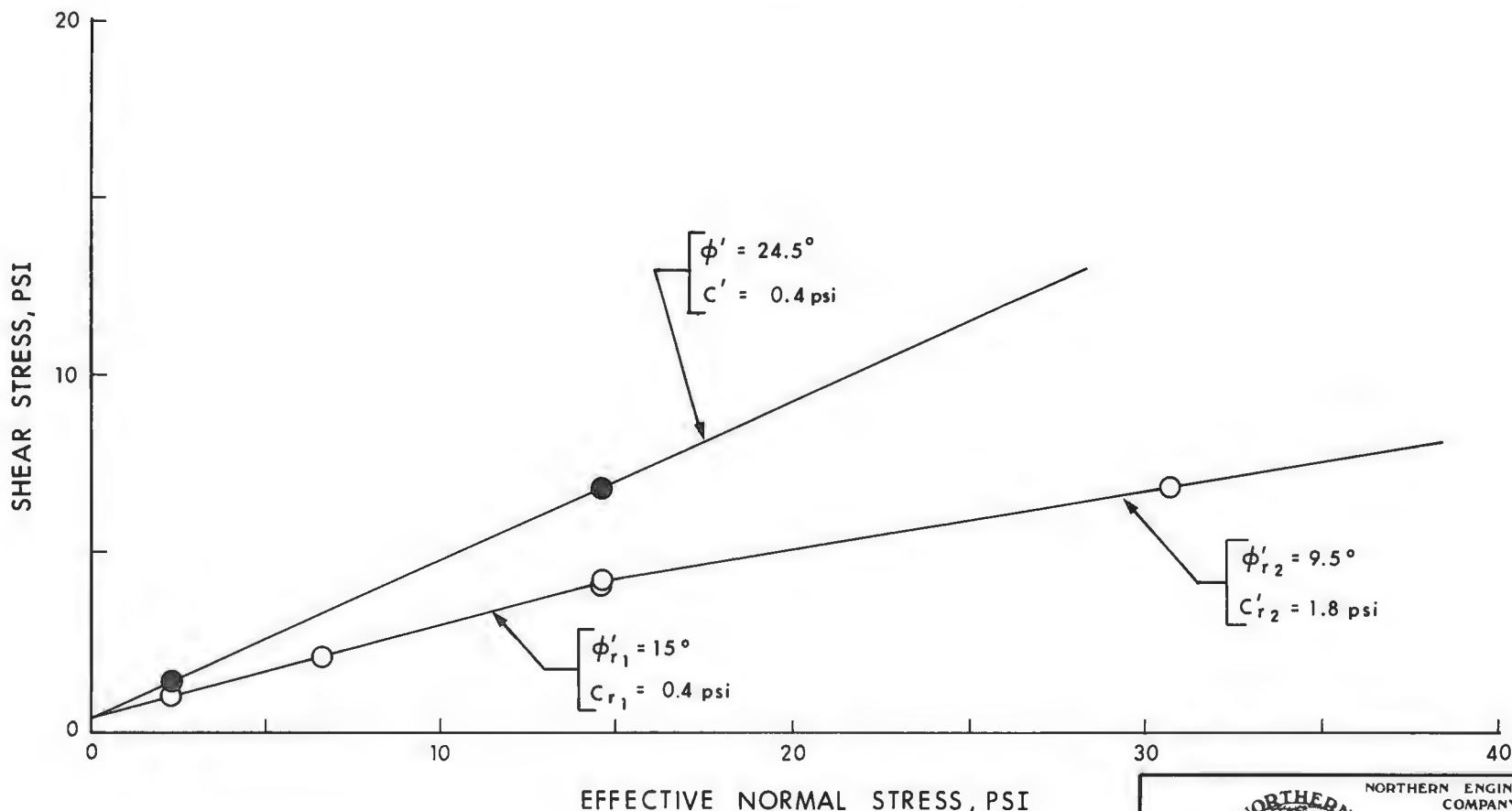


SUMMARY OF DIRECT SHEAR TEST DATA

FOR SOIL GROUP : CH

LEGEND :

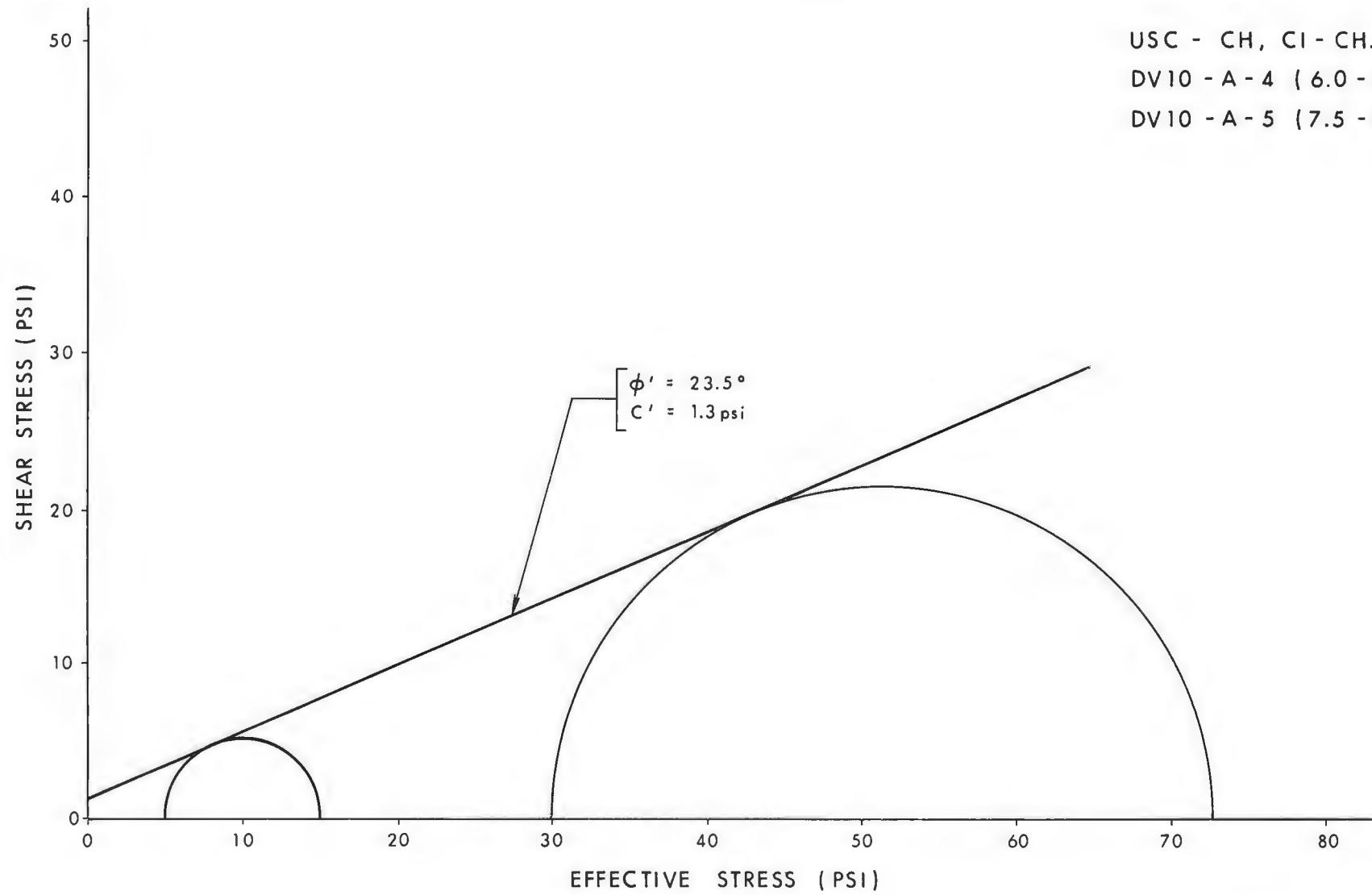
- MAXIMUM SHEAR STRESS
- RESIDUAL SHEAR STRESS



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LIMITED
EFFECTIVE NORMAL STRESS - SHEAR STRESS RELATION FOR SITE: DV10

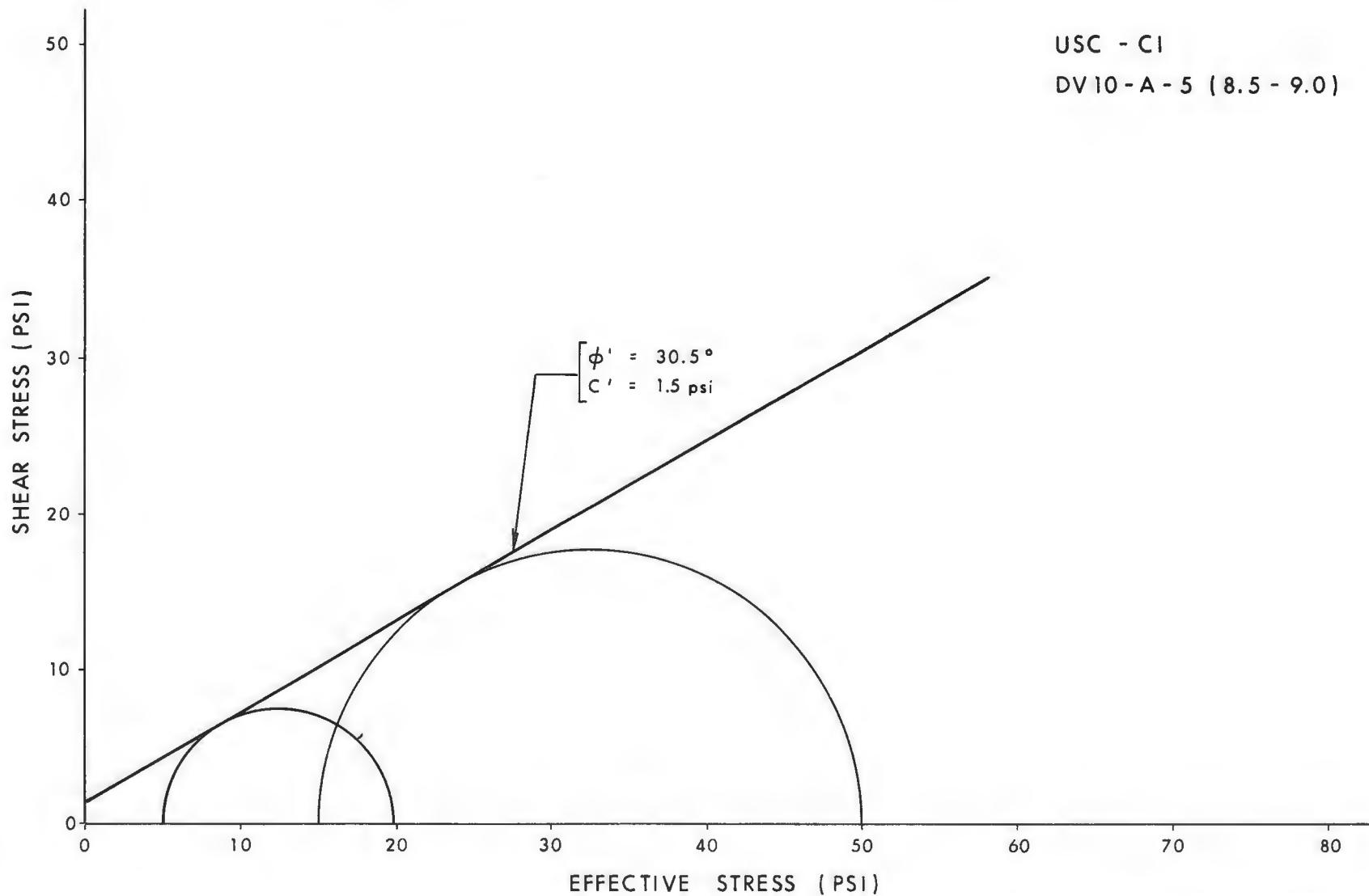
SUMMARY OF TRIAXIAL TEST DATA

Sample Number & Depth, ft	Sample Details		Atterberg Limits		Grain Size Distribution	Strain Rate in/hr	σ_3 psi	$(\sigma'_1 - \sigma'_3)_{max}$ psi	Pore Pressure at $(\sigma'_1 - \sigma'_3)_{max}$ psi	c' psi	ϕ' deg	Remarks
	γ_f pcf	W %	w_L %	w_P %								
DV10-A-4 (6.0-6.2)	123.6	37	50	24	Sand = 4 Silt = 41 Clay = 55	0.036	5	10.4	-	1.3	23.5	Consolidated - Drained
DV10-A-5 (7.5-8.0)	120.0	27	48	24	Sand = 8 Silt = 37 Clay = 55	0.036	30	42.9	-			
DV10-A-5 (8.0-9.0)	118.4	24	32	18	Sand = 15 Silt = 40 Clay = 45	0.036	5	14.8	-	1.5	30.5	Consolidated - Drained
DV10-A-5 (8.0-9.0)	118.7	29	31	16	Sand = 23 Silt = 49	0.036	15	35.0	-			
DV10-A-5 (8.0-9.0)	127.3	21	28	16	Sand = 13 Silt = 44 Clay = 43	0.036	15	35.6	-			
DV10-A-6 (9.2-9.7)	111.4	34	62	22	Sand = 5 Silt = 34 Clay = 61	0.036	30	40.0	-	-	-	Consolidated - Drained (Data Not Plotted)



USC - CH, CI - CH.
 DV10 - A - 4 (6.0 - 6.2)
 DV10 - A - 5 (7.5 - 8.0)

NORTHERN ENGINEERING SERVICES
 COMPANY LIMITED
 CALGARY ALBERTA
Engineering Services
 Company Limited
 ENGINEERS FOR
 CANADIAN ARCTIC GAS STUDY LIMITED
 MOHR ENVELOPE FOR SAMPLES
 FROM SITE DV 10



 NORTHERN ENGINEERING SERVICES COMPANY LIMITED <small>CALGARY ALBERTA</small>	<small>ENGINEERS FOR</small> CANADIAN ARCTIC GAS STUDY LIMITED
	MOHR ENVELOPE FOR SAMPLES FROM SITE DV 10

5.4 Discussion5.4.1 General

All the test results have been presented and grouped on site-by-site basis.

As can be seen from the combined liquid limit versus plasticity index standard plot (see Figure 5.4.1), also known as plasticity chart, almost all the points plot above the A-line and fall mainly in the CI category of the modified Unified Soil Classification System.

The combined plot of single average values of clay sizes by weight (less than 0.002 mm) in per cent and plasticity index (Figure 5.4.2), for all sites shows that most of the points lie within the boundaries established for illitic and kaolinitic soils.

This observation is further verified by the mineralogical composition analysis performed on certain samples (Reference 6). Table 5.4.1 summarizes the values obtained. It can be seen from this table that for CI soils, illite content ranges from 60 to 70 per cent and that of kaolinite from 10 to 25 per cent, while for CL soil sample illite content is 55 per cent and kaolinite is 25 per cent.

TABLE 5.4.1
MINERALOGICAL ANALYSIS OF CLAY CONTENT
Sample Nos.

Clay Mineral	Katakturuk Sample "A"	Katakturuk Sample "B"	DV 51-B-2	DV 3-A-7*
1. Montmorillonite %	5	15	-	10
2. Chlorite %	5	15	10	5
3. Illite %	70	60	65	55
4. Kaolinite %	20	10	25	25
Soil Type (USC)	CI	CI	CI	CL

* Note: 5 per cent of this sample consisted of quartz

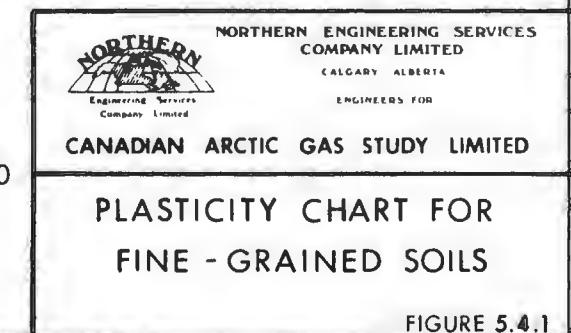
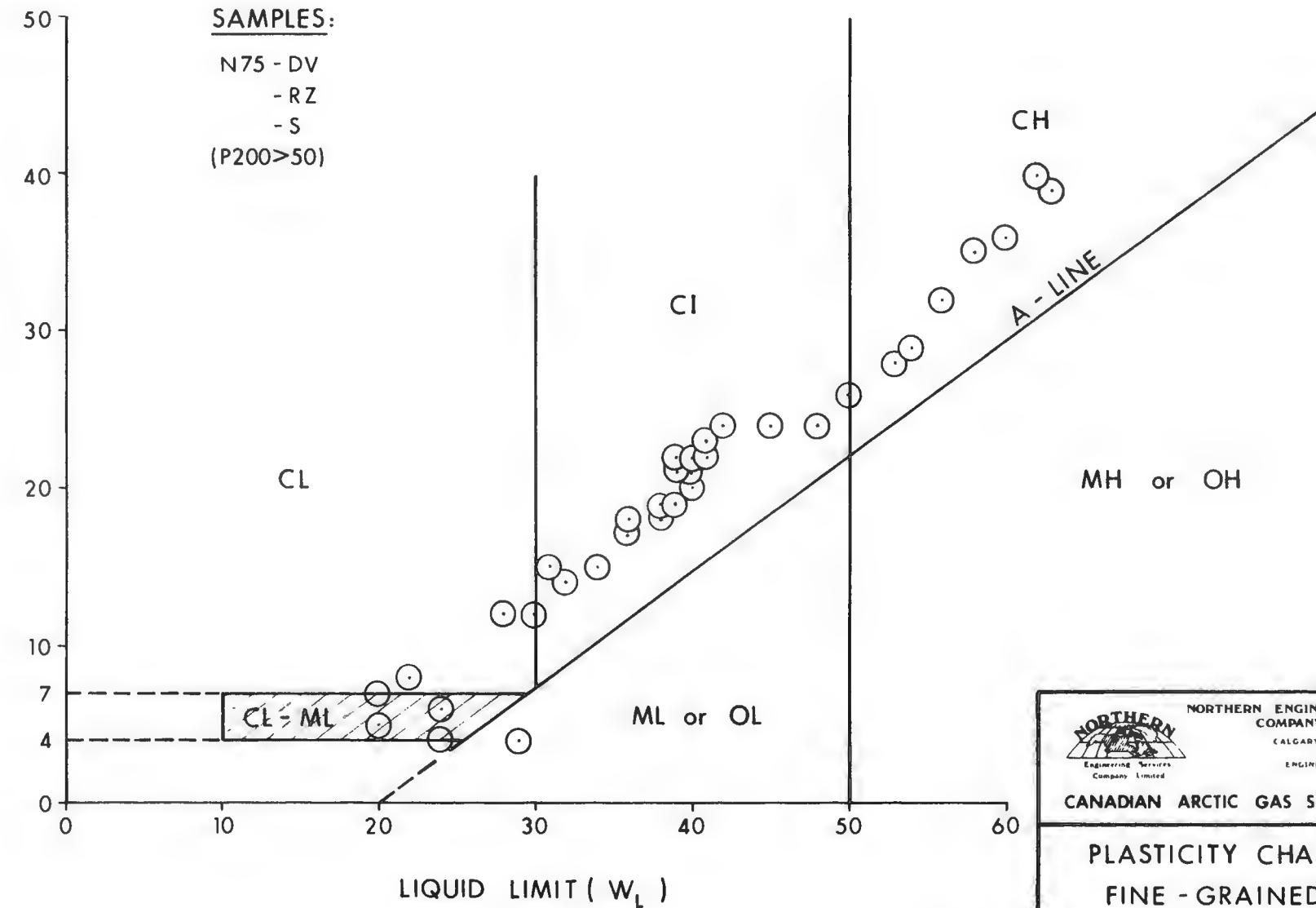
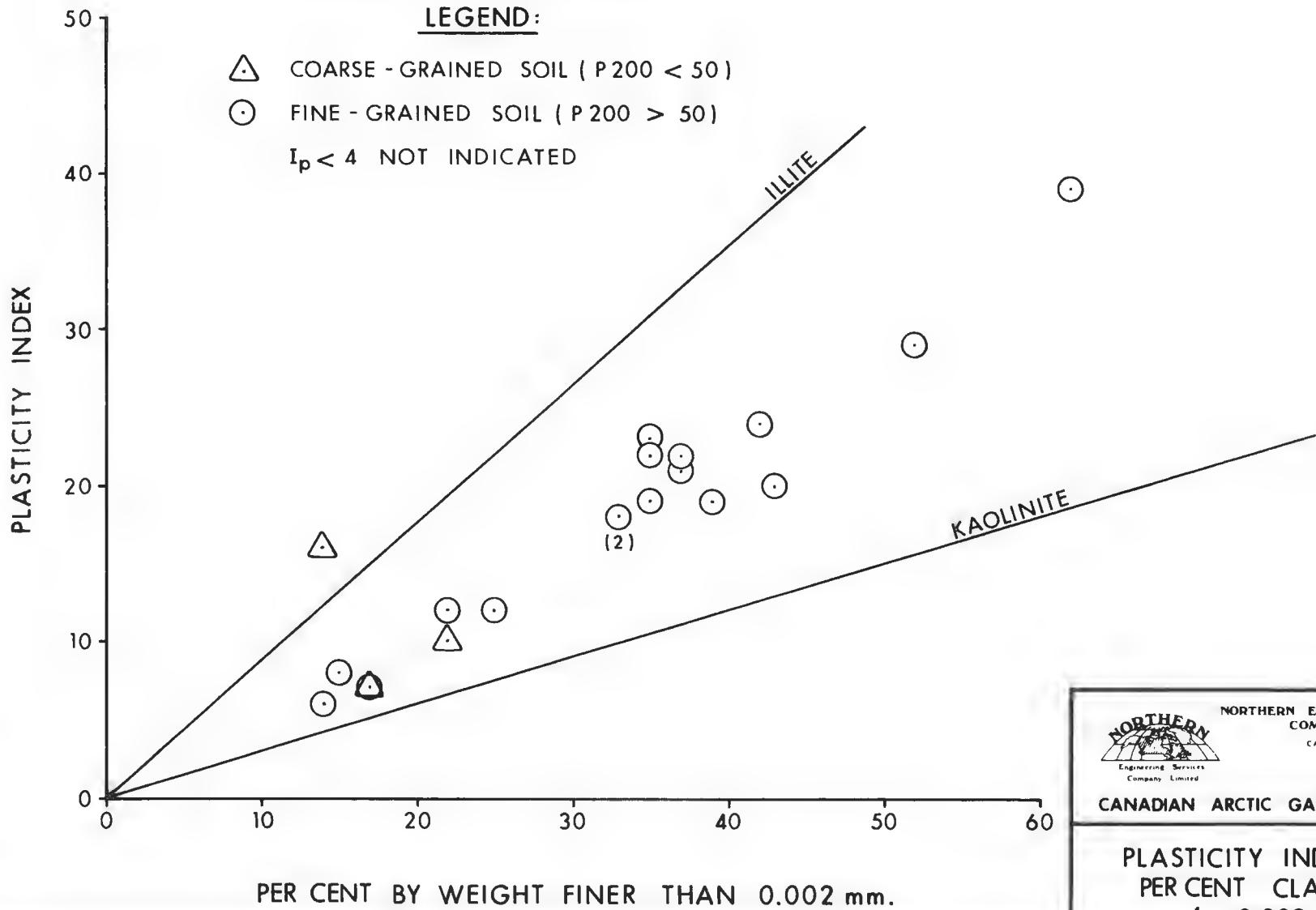


FIGURE 5.4.1

N 75 - DV, - S, AND - RZ SAMPLES

LEGEND:

- △ COARSE - GRAINED SOIL ($P_{200} < 50$)
- FINE - GRAINED SOIL ($P_{200} > 50$)
- $I_p < 4$ NOT INDICATED



NORTHERN ENGINEERING SERVICES
COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR

CANADIAN ARCTIC GAS STUDY LIMITED

PLASTICITY INDEX VERSUS
PER CENT CLAY SIZES
(< 0.002 mm.)

FIGURE 5.4.2

5.4.2 Consolidation - Permeability Tests

A plot of the log of K_m , the measured Coefficient of Permeability, versus the log of the Effective Stress, along with the log of K_c , the calculated Coefficient of Permeability versus the lot of the Effective Stress is presented where Consolidation-Permeability Tests have been carried out on samples from a given site.

It can be said that the measured permeability coefficient values fall within a certain broad range and that, as a general rule, the calculated permeability coefficient values fall within the same range as for the measured ones.

Graphical presentations of the log of the Effective Stress versus Void Ratio and the log of the Effective Stress versus the log of the Coefficient of Consolidation also have been presented.

The Thaw Settlement Parameter, A_o , the average coefficient of compressibility a_o , and the strain (ϵ_p) at an Effective Normal Stress of 1000 psf as derived from the Consolidation-Permeability Tests are summarized on Table 5.4.2. The corresponding Frozen Bulk Density (γ_f) and Natural Water Content values have been included. The plots of A_o versus γ_f , a_o versus γ_f and ϵ_p versus γ_f appear in Figures 5.4.3, 5.4.4, and 5.4.5 respectively.

5.4.3 Direct Shear Tests

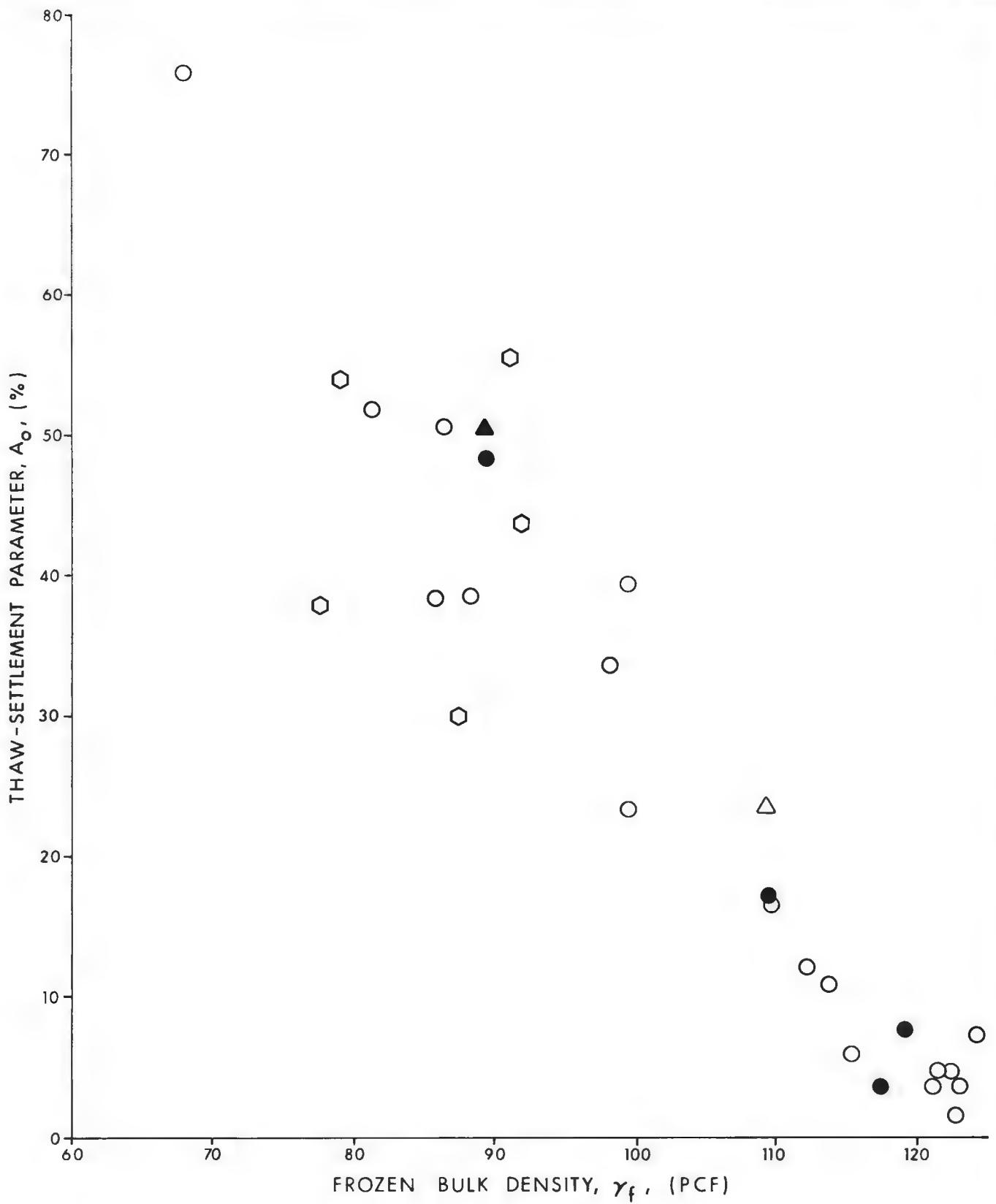
Direct Shear Test data have been graphically presented in the form of Effective Normal Stress versus Shear Stress plots on the basis of individual site location and Unified Soil Classification soil type. The results are summarized in Table 5.4.3.

TABLE 5.4.2

THAW-SETTLEMENT PARAMETERS DERIVED
FROM CONSOLIDATION-PERMEABILITY TESTS

SAMPLE NO.	DEPTH ft.	FROZEN BULK DENSITY	NATURAL WATER CONTENT %	THAW-SETTLEMENT PARAMETER A _o	AV. COEFF. OF COMPRESSIBILITY a _o x 10 ⁻⁵ cm ² /gm	STRAIN AT 1000 psf ε _p
		pcf	%			
S-1-1-1	1.0 - 1.2	77.5	138.1	0.381	8.55	0.423
S 1-A-1	1.0 - 1.2	92.0	76.8	0.438	3.72	0.456
S 1-A-2	2.0 - 2.3	91.1	82.7	0.551	4.03	0.571
S 1-B-2	3.5 - 3.8	87.6	77.1	0.300	6.94	0.334
S 1-B-7	9.5 - 9.7	79.1	128.1	0.541	6.77	0.574
RZ 33-N-2	4.3 - 4.5	109.1	32.6	0.234	5.96	0.263
RZ 3-A-3	5.0 - 5.4	89.2	72.8	0.506	6.02	0.535
DV 1-B-10*	12.0 - 12.2	96.2	60.8	0.249	23.60	0.365
DV 1-B-11	13.0 - 13.2	121.3	25.3	0.046	5.31	0.072
DV 11-A-4	2.6 - 2.9	112.2	32.8	0.122	9.29	0.167
DV 11-A-5	4.9 - 5.1	117.3	23.5	0.036	1.96	0.045
DV 11-B-5	4.0 - 4.2	124.0	21.8	0.072	4.84	0.095
DV 11-B-6	4.9 - 5.2	121.0	25.5	0.038	10.87	0.091
DV 11-B-11	10.9 - 11.3	119.0	28.8	0.078	7.25	0.113
DV 3-A-7	4.3 - 4.5	109.4	31.1	0.172	7.78	0.210
DV 3-A-13	8.7 - 9.0	68.1	283.5	0.762	2.80	0.776
DV 3-B-6	3.8 - 4.0	99.4	45.4	0.394	5.99	0.424
DV 3-B-8	5.4 - 5.6	89.6	69.7	0.484	3.83	0.503
DV 3-B-12	8.7 - 8.9	109.7	36.8	0.166	11.36	0.221
DV 3-B-13*	10.0 - 10.2	80.6	112.7	0.538	5.36	0.565
DV 5-A2-2	7.5 - 8.5	113.8	32.1	0.110	7.78	0.148
DV 5-B-5	4.0 - 4.3	86.5	86.9	0.506	5.61	0.533
DV 51-B-10	10.8 - 11.1	98.1	52.9	0.377	6.93	0.371
DV 51-C-3	4.0 - 4.3	81.3	99.7	0.520	7.13	0.555
DV 9-A-8	9.2 - 9.4	122.5	23.9	0.014	7.83	0.052
DV 9-A-9	10.7 - 11.0	122.2	22.2	0.046	7.09	0.081
DV 9-A-11	12.8 - 13.2	122.9	23.6	0.035	7.01	0.069
DV 10-A-2	2.5 - 2.8	115.3	28.6	0.060	7.71	0.098
DV 10-A-2	3.0 - 3.3	99.4	47.1	0.234	6.53	0.266
DV 10-A-3	4.4 - 4.7	88.3	68.4	0.386	7.64	0.423
DV 10-A-3	4.7 - 5.0	85.9	69.0	0.384	7.64	0.421

* Data not reliable

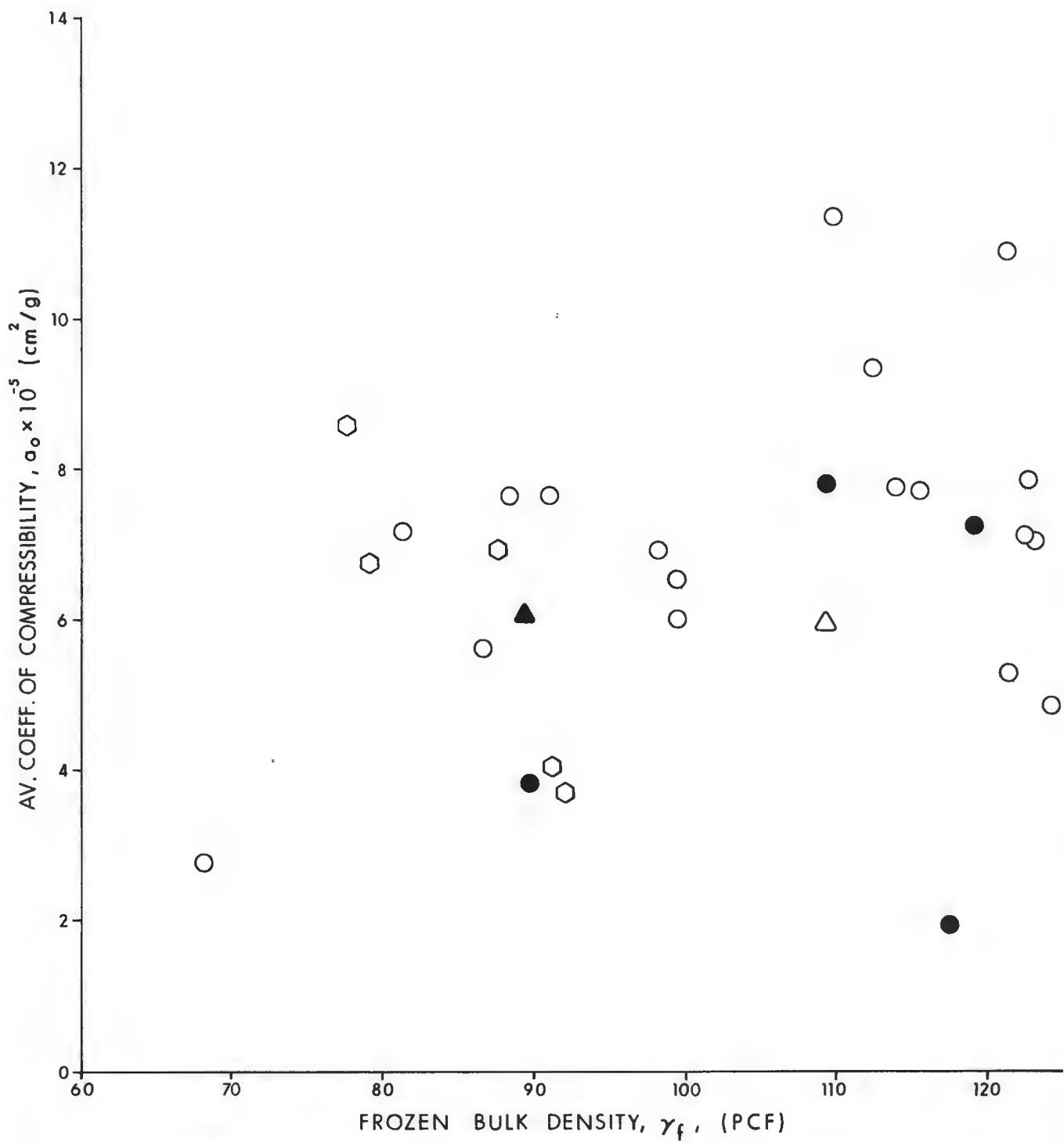


LEGEND

- N75 - S SAMPLES
- △ N75 - RZ SAMPLES
- N75 - DV SAMPLES
- COARSE-GRAINED SOIL
} ($P_{200} < 50$)
- ▲ COARSE-GRAINED SOIL
} ($P_{200} < 50$)

FROZEN BULK DENSITY
VERSUS
THAW-SETTLEMENT PARAMETER

FIGURE 5.4.3

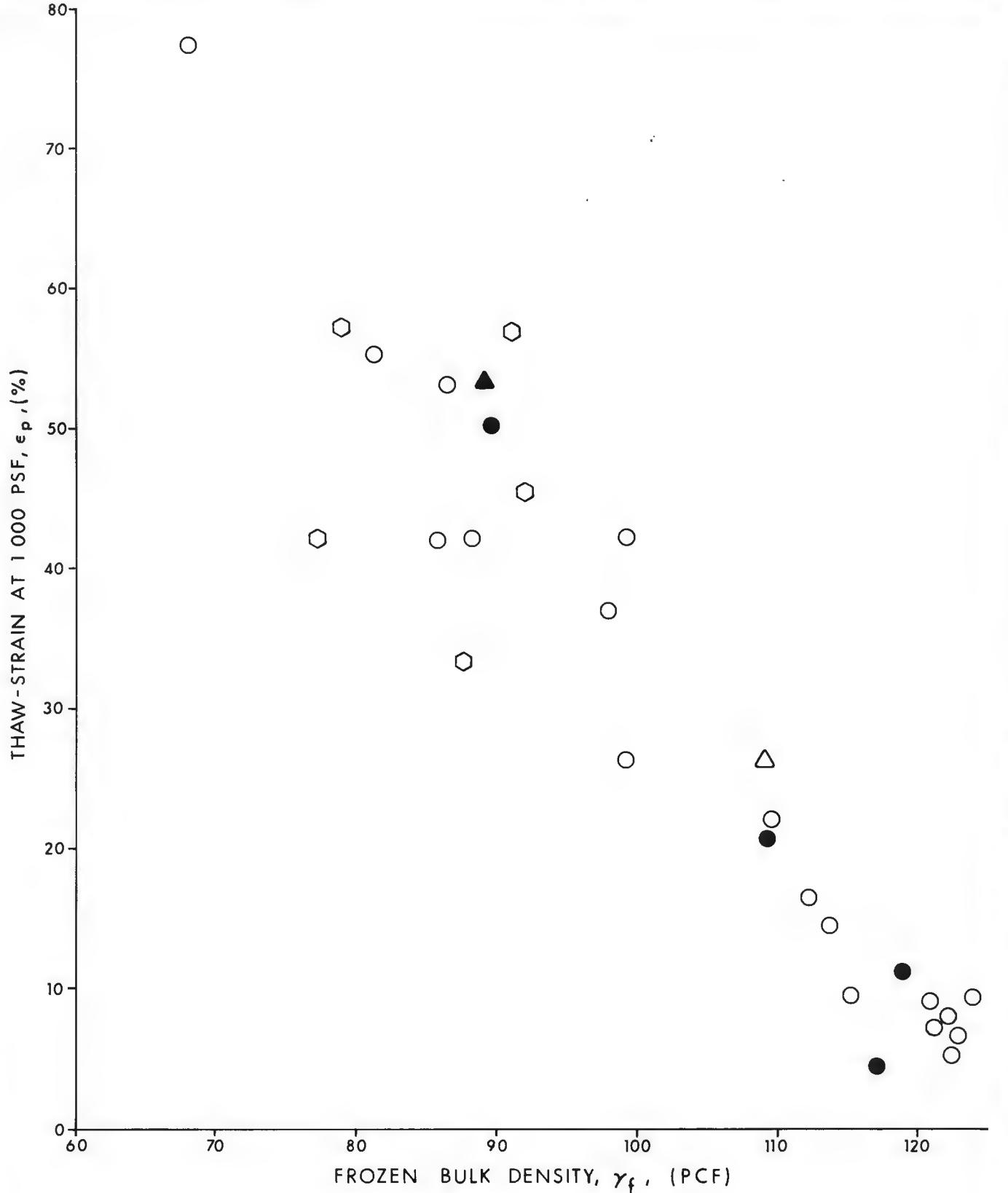


LEGEND

- N75 - S SAMPLES
- △ N75 - RZ SAMPLES
- N75 - DV SAMPLES
- COARSE-GRAINED SOIL
▲ (P₂₀₀ < 50)

FROZEN BULK DENSITY
VERSUS AVERAGE COEFFICIENT
OF COMPRESSIBILITY

FIGURE 5.4.4



LEGEND

- N75 - S SAMPLES
- △ N75 - RZ SAMPLES
- N75 - DV SAMPLES
- COARSE-GRAINED SOIL
- ▲ COARSE-GRAINED SOIL

FROZEN BULK DENSITY
VERSUS
THAW - STRAIN AT 1000 PSF

FIGURE 5.4.5

TABLE 5.4.3
SUMMARY OF AVERAGE SHEAR STRENGTH PARAMETERS

Site No.	ϕ' deg.	c' psi	ϕ'_{r1} deg.	c'_{r1} psi	ϕ'_{r2} deg.	c'_{r2} psi	USC
1. Katakturuk	28.5	0.0	26.5	0.0	26.5	0.0	
2. S1	33.0	0.0	32.0	0.0	27.5	1.5	CL-ML
	32.5	0.0	31.0	0.0	31.0	0.0	ML
3. RZ 33	-	-	27.5	0.0	-	-	CI
4. RZ 3	-	-	-	-	-	-	
5. DV 1	26.5	1.3	24.5	1.3	24.5	1.3	CI
6. DV 11	34.0	0.0	30.0	0.0	26.0	0.0	SM
7. DV 3	25.5	0.8	23.5	0.3	23.5	0.3	SC-CL
	31.5	0.3	30.5	0.0	25.5	0.9	CL-CI
8. DV 5	28.0	0.5	26.0	0.0	23.0	0.8	CI
9. DV 51	-	-	22.5	0.0	22.5	0.0	CI
10. DV 9	25.0	0.8	22.0	0.5	21.0	1.0	CI
11. DV 10	24.5	0.4	15.0	0.4	9.5	1.8	CH

ϕ' and c' are peak shear strength parameters

ϕ'_{r1} and c'_{r1} are residual shear strength parameters for normal effective stresses less than 14.5 psi.

ϕ'_{r2} and c'_{r2} are residual shear strength parameters for normal effective stresses greater than 14.5 psi.

The plots for individual tests have not been shown in this report, but only the values of parameters ϕ' , c', ϕ'_{r} , and c'_{r} are given in the test data summary tables.

It should be mentioned that a linear relationship between effective normal stress and shear stress is assumed, even at low stresses. No attempt is made to draw a smooth curvilinear Mohr-Coulomb envelope, but rather, where there is a change in slope, two distinct intersecting lines are drawn through average values of σ_N' and τ for each particular site.

By artificially introducing a cut plane in the direct shear test specimen, no appreciable change in the values of the shear strength parameters is observed for the soils tested when these values are compared to those obtained without a cut plane.

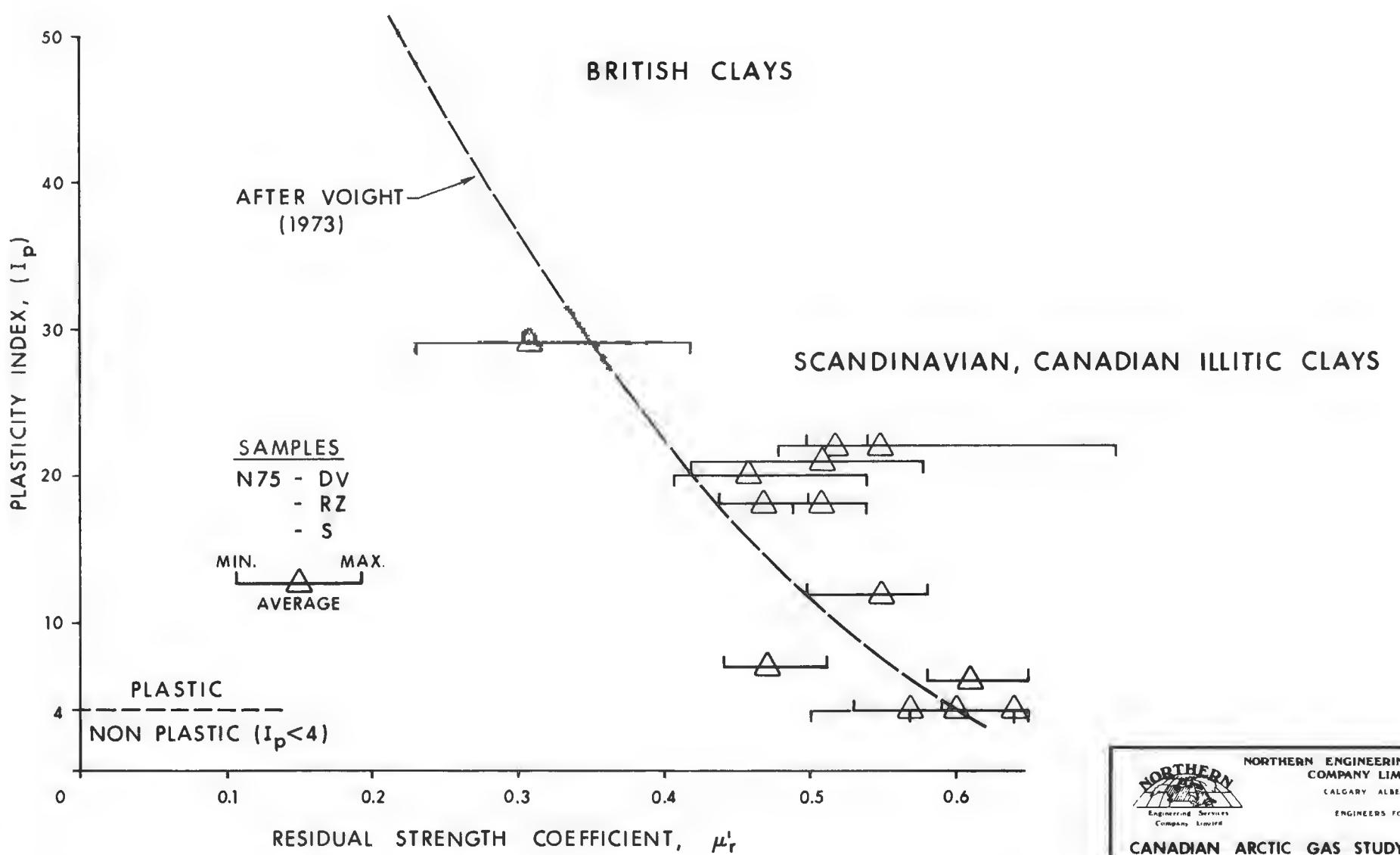
A plot of the Residual Shear Strength Coefficient (μ_r) versus the Plasticity Index, (I_p) for individual tests has been presented on Figure 5.4.6. A relationship developed by Voight (1973) (see reference 7) has also been superimposed.

5.4.4 Triaxial Tests

Where available, data from triaxial tests have been compiled in summary tables and presented by individual site locations.

Mohr stress circles for Effective Normal Stresses have been presented. The Mohr-Coulomb shear strength envelope was assumed to be linear.

The results have been grouped so that only data obtained from similar soil type appear on one plot.



NORTHERN ENGINEERING SERVICES COMPANY LIMITED
Engineering Services Company Limited
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS STUDY LIMITED

PLASTICITY INDEX VS
RESIDUAL STRENGTH
COEFFICIENT

FIG. 5.4.6

PROJECT 12071

CANADIAN ARCTIC GAS STUDY LIMITED
CALGARY
ALBERTA

LABORATORY TESTING PROGRAM
FOR THAW-SLOPE STABILITY
CONTINUOUS PERMAFROST ZONE

DATE

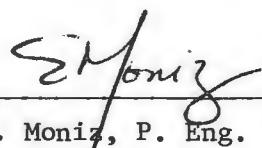
MAY 1977

6. CONCLUSION

Laboratory test data for soil samples from the Continuous Permafrost Zone have been presented in this report.

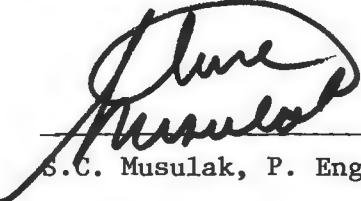
Satisfactory agreements have been obtained with data available in the published literature.

Prepared by:



E. Moniz, P. Eng.

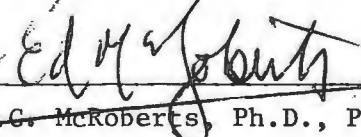
R. Hunt, C.E.T.



S.C. Musulak, P. Eng.

S. Law, Ph.D., P. Eng.

Approved by:



E.G. McRoberts, Ph.D., P. Eng.
Manager, Geotechnical Design

REFERENCES

1. Northern Engineering Services Company Limited, Geotechnical Data Report, Slope Stability Study, 1975 Drilling and Sampling Program, Continuous Permafrost Zone, March 1976.
2. Speer, T.L., Watson, G.H. and Rowlay, R.K., "Effects of Ground-Ice Variability and Resulting Thaw-Settlements on Buried Warm-Oil Pipelines", Proc. 2nd Int. Permafrost Conf., Yakutsk, U.S.S.R., 1973, p 746-752.
3. Northern Engineering Services Company Limited, Laboratory Testing for Thaw Slope Stability, Discontinuous Permafrost Zone, February, 1977.
4. American Society for Testing and Materials, Annual Book of ASTM Standards. (Part 19 or latest designations).
5. Northern Engineering Services Company Limited, Thaw Settlement Studies, Proposed Arctic Gas Pipeline Route, February 1977.
6. Scafe, D., Clay Mineralogic Studies of some Mackenzie River Valley Soils, for Northern Engineering Services Company Limited, Alberta Research Council, 1976
7. Voight, B., "Correlation Between Atterberg Plasticity Units and Residual Shear Strength of Natural Soils", Geo. Vol. XXIII, 265-267, 1973
8. Northern Engineering Services Company Limited, Thaw-Settlement Test Data, Fort Simpson Area. November 1976.
9. Watson, G.H., Slusarchuk, W.A. and Rowlay, R.K. "Determination of some Frozen and Thawed Properties of Permafrost Soils", Canadian Geotechnical Journal, Vol. 10, No. 4, November 1973, p 592-606.

APPENDIX A

Explanation of Terms and Symbols on the Test

Hole Logs Found in Section 5.3

APPENDIX A - EXPLANATION OF TERMS AND SYMBOLS

1. General

The terms and symbols used on the test hole logs to summarize the results of the field investigation and of subsequent laboratory testing are described in detail below and are illustrated in the appended exhibit test hole log (Plate 1).

General information, such as test hole number, test hole location, and rig type is noted in the lower portion of the test hole log. Detailed sub-surface information observed at each test hole location and laboratory test data, are presented in columnar form on the test hole log. Each column used is described in detail below using the reference numbers shown on the appended blank test hole log (Plate 2).

It should be noted that the soil type, stratigraphic boundaries, and in situ conditions have been established only at the test hole location and that they are not necessarily representative of subsurface conditions elsewhere across the site.

Columns 1 and 13: Depth: The depth of test hole below existing ground surface is shown in these columns.

Column 2: Soil Group Symbol: A soil classification symbol in accordance with a modification of the Unified Soil Classification System¹ is noted in this column. A definition of each Group Symbol is given in Table 1 "Soil Classification System".

Column 3: Soil Graphic Log: Soil strata are depicted graphically in accordance with the "Graphic Symbol" column of Table 1 "Soil Classification System".

(1) References are listed on page A-16.

- Column 4: Description: A detailed engineering description of each soil stratum encountered is noted in this column. This description is given in accordance with the criteria outlined in Section 2.3 "Soil Description". A description of the ground ice is included in this column according to the NRC procedures² which are explained in Section 2.4 "NRC Ice Type". The depths to ground water level, seepage, and the interface between different soil strata are indicated in this column. The interface between soil strata is shown as a single continuous line. A broken line indicates a change in soil type where the location of the interface between the strata is uncertain or inferred. A double line at the bottom of the test hole log indicates "Refusal" which may be defined as "further penetration was not possible with the equipment used".
- Column 5: Ice Graphic Log: The various types of ground ice are depicted graphically according to Table 2 "Ground Ice Classification".
- Column 6: NRC Ice Type: (Visual Ice %): Abbreviated symbols for the forms of ground ice are noted in this column. A description of the NRC classification² is contained in Section 2.4 "NRC Ice Type", and in Table 2 "Ground Ice Classification". The volume of ground ice is estimated visually and expressed as a percentage of the total volume of soil and ice.
- Column 7: Laboratory Test Data: The results of laboratory determinations of water content, Atterberg limits and density are plotted against depth. These are described in Section 2.5 "Test Data Summary".

Column 8: Other Test Data: Test data additional to those represented in Column 7 are noted in this column at the appropriate depth. The symbols used to represent the more common engineering laboratory tests are given in Section 2.5 "Test Data Summary". The results of specialized testing are also indicated in this column using an abbreviated written form.

Column 9: Sample Type and Number: The type and reference number of each sample attempted, whether it was recovered or lost, are recorded at the appropriate depth. The system used is described in Section 2.1 "Soil Sample Data".

Column 10: Sample Condition: The condition of each sample whether it was recovered or lost, is recorded against depth. A description of the graphic representation and abbreviations used is given in Section 2.1 "Soil Sample Data".

Column 11: Core Run and % Recovery: The length of core recovered is expressed as a percentage of the total length attempted. The depths to the top and bottom of the core run are recorded as described in Section 2.2 "Core Data".

Column 12: Core Condition: The condition of the core, or segments of the core, is assessed visually and assigned a rating of I to V. The ratings and nomenclature used are given in Section 2.2 "Core Data".

Column 14: Remarks: Additional pertinent information and comments such as in situ drilling conditions, sampling criteria, and instruments installed are noted in this column.

2. Description Details

The various terms, symbols, and abbreviations are discussed in detail to facilitate interpretation and understanding of the data presented on the test hole logs.

2.1 Soil Sample Data

(a) Sample Type and Number (Column 9)

Each sample attempted, whether it is recovered or lost, is assigned a reference number. The series of soil samples from each test hole is numbered in a sequentially increasing numerical order with increasing depth below ground surface.

The type of sample attempted is indicated using one of the following letters:

- A Auger sample
- B Bulk sample
- C Core sample
- D Drive sample (thick-walled tube, unless otherwise noted)
- P Pitcher tube sample
- R Block sample
- S Split spoon standard penetrometer sample
- U Tube sample (thin-walled unless otherwise noted)
- W Wash or Air Return sample
- X Other samples

The sample type and number are recorded at the appropriate depth on the test hole log.

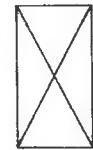
Example: Sample A2: - designates the second sample attempted in the test hole. This sample was taken off an auger.

(b) Sample Condition (Column 10)

The condition of each sample attempted is designated by one of the following symbols at the appropriate depth interval:



undisturbed



disturbed



not recovered

2.2

Core Data

The details relating to length of core attempted and the percentage of core recovered are presented as follows:

(a) Core Run and % Recovery (Column 11)

The length of core attempted is shown by recording the top and bottom depth measurements for each core run. The recovered core length is expressed as a percentage of the total core run attempted.

(b) Core Condition (Column 12)

The condition of each core, or segments of core recovered, together with any unrecovered portions of the core, is recorded. The nomenclature in the following table is used to describe the conditions of the core:

<u>Condition of Soil Cores</u>			
<u>Rating</u>	<u>Recovered Condition</u>	<u>Disturbance or Remolding</u>	<u>Suitability for Testing</u>
I	Excellent	Negligible	Representative
II	Good	Slight	Representative
III	Fair	Considerable	Use Judgment
IV	Poor	Complete	Equivalent to Disturbed Samples
V	No recovery	-	-

2.3 Soil Description (Column 4)

Soils are classified and described according to their engineering properties and behaviour.

2.3.1 Soil Description System

The following properties are described for a comprehensive soil classification system:

Grain size distribution or plasticity, colour, moisture, sensitivity, structure, foreign materials, and consistency or strength.

The soil in each stratum is described on the test hole logs using the Unified Soil Classification System¹ modified slightly so that an inorganic clay of "medium plasticity" is recognized. Selected adjectives are used to define the actual or estimated percentage range by weight of the various components. The use of the modifying adjectives is similar to a system developed by D.M. Burmister³.

The identification of soil components and fractions is defined by the Modified Unified Soil Classification System which classifies soils into three major divisions:

Coarse-grained soils - gravel and sand

Fine-grained soils - silt and clay

Highly organic soils - peat

Classification of soils is based on the grain size distribution of that portion of the soil smaller than the 3-inch U.S. Standard sieve size.

Soils with more than half by weight of the components coarser than the No. 200 U.S. Standard sieve size (0.074 mm) are described as COARSE-GRAINED (or granular) soils. Coarse-

grained soils (gravel and sand) are classified by grain size distribution and are subdivided into coarse and fine gravel, and coarse, medium, and fine sand.

Soils with more than half by weight of the components finer than the No. 200 sieve size are described as FINE-GRAINED soils. These may be cohesive or non-cohesive. Note that for visual classification the No. 200 sieve size is about the smallest size of particle that can be distinguished individually by the unaided eye.

Fine-grained soils (silt and clay) are classified by behaviour on the basis of the liquid limit and plasticity index of the fraction finer than the No. 40 U.S. Standard sieve size. The boundaries defining the fine-grained soil groups are shown in the Plasticity Chart in Table 1 "Soil Classification System". The Plasticity Chart is also used to determine the behaviour of the fines content of coarse-grained soils.

Particle size and shape are usually described for coarse-grained soils, and plasticity is usually described for fine-grained soils. An exception to this rule applies when describing glacial till; then plasticity, particle size, and shape are all included in the description.

The principal component of the fraction of the soil passing the 3-inch U.S. Standard sieve size is shown capitalized on the test hole logs.

The proportions by weight of the minor components are defined according to the following descriptors:

<u>Descriptor</u>	<u>Proportion</u>
"and"	50 to 35 per cent
"some"	35 to 20 per cent
"little"	20 to 10 per cent
"trace"	10 to 1 per cent

The descriptors used must not contradict the classification by the Modified Unified Soil Classification System.

The terms given above are used to define proportions by weight of granular components, but they may also be used to define the proportion of minor components of fine-grained material, according to the subdivisions of the Plasticity Chart, Table 1 "Soil Classification System". The adjectives are not used to subdivide a principal fine-grained component. The modifier "y" or "ey" (e.g., SILT, clayey) is used when the liquid limit and plasticity index plot close to the "A-line" on the Plasticity Chart.

Peat and other highly organic soils are classified under the Group Symbol "Pt". Peat may be categorized and described using the Radforth Classification System⁴.

The soil is described first by identifying the principal component, followed by the minor components in order of decreasing proportion by weight. This is followed by other significant identifying features such as plasticity, colour, moisture, structure, and strength.

2.3.2 Typical Example of a Complete Soil Description

"CLAY, silty, little medium sand, trace coarse gravel, medium plasticity, yellow-brown", describes a yellow-brown, fine-grained, silty clay soil containing 50 per cent or more of components finer than the No. 200 U.S. Standard sieve size with minor components of sand and gravel. The fraction passing the No. 40 U.S. Standard sieve size plots above, and close to the "A-line" on the Plasticity Chart. The soil contains between 10 per cent and 20 per cent of sand particles generally in the size range No. 10 to No. 40 (i.e. finer than the No. 10 Standard sieve size and larger than the No. 40 Standard sieve size) and between 1 per cent and 10 per cent of gravel in the size range 3/4-inch to 3-inch. The identifying

feature "medium plasticity" indicates that the liquid limit plots between 30 and 50 on the Plasticity Chart. Such a soil is classified as CI by the Modified Unified Soil Classification System.

2.3.3 Typical Examples of the Use of Modifiers and Descriptors

(a) Fine-grained soil with a minor coarse-grained component:

"CLAY, silty, some fine sand", describes a fine-grained soil having a fines content in excess of 50 per cent (i.e., 50% of material finer than the No. 200 U.S. Standard sieve size), which plots above the "A-line", on the Plasticity Chart, with a liquid limit less than 50 on the Plasticity Chart, and has a minor component of fine sand.

"CLAY, some silt, some fine sand", would not be used as the fines are classified by behaviour (plasticity) and not by particle size. Such a soil would be classified as CI or CL according to the Unified Soil Classification System.

(b) Coarse-grained soil with minor fine-grained component:

"GRAVEL, fine, some silty clay", describes a coarse-grained soil with a minor component of fines, which has a liquid limit and plasticity index that plot above and close to the "A-line" on the Plasticity Chart. Such a soil is classified as GC by the Unified Soil Classification System.

"SAND, some silt", is correct in that "silt" in this case is a minor component of non-plastic fines which plot below the A-line on the Plasticity Chart.

2.3.4 Glacial Till

The term "glacial till" is in widespread use in present engineering practice, however, because it is a mode of deposition, there is no provision in the Unified Soil Classification System for this term.

The term "till" is used on the test hole logs in its most general form, which has been defined by ASTM Designation D 653 as:

"A material deposited by glaciation, usually composed of a wide range of particle sizes, which has not been subjected to the sorting action of water."⁵

Glacial till is described on the test hole logs as "TILL", followed by the principal soil component also capitalized.

Example: "TILL, CLAY, silty, little fine gravel, low plastic, rust-brown--".

A loose, soft, or slightly stratified deposit believed to be transported or reworked material of glacial deposition, or of uncertain glacial origin, is described as "till-like" at the end of the soil description.

Example: "CLAY, silty, little fine gravel, low plastic, rust-brown, till-like."

2.3.5 Fill

"Fill" is material placed by artificial means, whether or not its placement was controlled.

It is described on the test hole logs as "FILL", followed by the principal soil component also capitalized.

Example: "FILL, SILT, clayey, some fine gravel".

Well-compacted fill, placed some considerable time before the test hole investigation, may be difficult to distinguish from natural material unless the history of the site is known. Such material is indicated as "FILL?" on the test hole logs.

2.4

NRC Ice Type and Estimated Visual Ice (Column 6)

Ground ice is divided by the NRC system on the basis of examination by the unaided eye into the three major categories shown below. A complete description of this system is contained in the NRC "Guide to a Field Description of Permafrost for Engineering Purposes".²

2.4.1

Ground Ice Classification Categories

Non-visible ice	N
Visible ice less than one inch thick	V
Visible ice greater than one inch thick	ICE or ICE + soil type

Table 2, "Ground Ice Classification", shows the various types of ground ice recognized by the NRC Classification System. Graphic symbols for ground ice have been devised to complement the graphic soil log.

Frozen soils in the N group may, on close examination, indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. The impression received by the unaided eye, however, is that the ice does not occupy space in excess of the original voids in the soil. Excess ice in the N group can be identified by use of a hand magnifying lens, or by placing some frozen soil in a small jar, allowing it to melt and observing the supernatant water. To the unaided eye, ice in frozen soils in the V group appears to occupy space in excess of the original voids in the soils.

The volume of ground ice can be described quantitatively in two ways. "Excess ice" is the volume of supernatant water expressed as a percentage of the total volume of the thawed soil and water. This quantity is often referred to as "excess moisture". "Visual ice" is the estimated volume of segregated ice discernible by eye in the frozen sample and is expressed as a percentage of the total volume of the frozen soil. By these definitions the quantity "excess ice" and "visual ice" are not necessarily the same for a given frozen soil. Care is taken when estimating the volume of ice coatings on granular material (V_c). The ice is usually obvious, giving the impression of "excess ice", which may not necessarily be the case.

2.4.2 Ice Description Terminology

The following terminology used in Column 4 "Description" has been generally taken from Table II of the NRC Guide².

"Ice Coatings on Particles" are discernible layers of ice found on or below the larger soil particles in a frozen soil mass. They are associated sometimes with hoarfrost crystals that have grown into voids produced by the freezing action.

"Ice Crystal" is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in combination with other ice formations.

"Clear Ice" is transparent and contains only a moderate number of air bubbles.

"Cloudy Ice" is relatively opaque due to entrained air bubbles or other reasons, but is essentially sound and non-pervious.

"Porous Ice" contains numerous voids, usually interconnected, and generally results from melting at air bubbles or along crystal interfaces, from presence of salt or other materials in the water, or from the freezing of saturated snow; though porous, the mass retains its structural unity.

"Candled Ice" is ice that has rotted or otherwise formed into long columnar crystals very loosely bonded together.

"Granular Ice" is composed of coarse, more or less equidimensional ice crystals weakly bonded together.

"Ice Lenses" are lenticular ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss and commonly in repeated layers.

"Ice Segregation" is the growth of ice as distinct lenses, layers, veins, and masses in soils, commonly but not always oriented normally to direction of heat loss.

"Well-bonded" signifies that the soil particles are strongly held together by the ice and that the frozen soil possesses relatively high resistance to chipping or breaking.

"Poorly-bonded" signifies that the soil particles are weakly held together by the ice that the frozen soil possesses poor resistance to chipping or breaking.

"Friable" denotes extremely weak bonds between soil particles. The material is easily broken up.

The symbols "UF" or "F" may be used in Column 6. "UF" is added to indicate unfrozen zones in areas of generally frozen ground and also to avoid possible errors of omission. "F" is used in certain cases along with the corresponding graphic representation for "Undifferentiated" permafrost or frozen active layer soils. It may be used:

- (1) Where temperature sensors (thermistors) have been installed which indicate that the formation temperature is below 0°C, but the material in the field has the texture of unfrozen material.

- (2) Where temperature sensors have not been installed, but the soil temperature is suspected to be below 0°C. The soil is deformable because of the high unfrozen water content, but is neither " friable" nor " bonded".
- (3) Where the soil is known to be frozen, but due to circumstances beyond field control, the ice type cannot be determined because of grinding or temporary thawing of the material by the drilling operation.
- (4) Where, for reasons of economy or expediency, the hole was neither logged nor sampled, e.g., where instrumentation is installed adjacent to a previous test hole and soil stratigraphy is known to an acceptable degree.

2.5

Test Data Summary

(a) Test Data (Column 7)

The results of laboratory determinations of water content, together with Atterberg limits, and density (unit weight) are plotted symbolically against depth in this column.

Water content is determined in accordance with ASTM Designation D 2216, "Standard Method of Laboratory Determination of Moisture Content of Soil"⁵. The water content of highly organic material is determined by similar procedure, except that the material is oven-dried to constant weight at 85°C instead of 105°C⁶.

Liquid limit and plastic limit are determined in accordance with ASTM Designations D 423 and D 424, respectively⁵.

In situ density is determined from the weights and volumes of intact samples and is reported as either "dry density" which is the weight of soil solids per unit volume, or as "bulk density" which is the total weight per unit volume.

(b) Other Test Data (Column 8)

Tests and test data other than, or additional to, those shown in Column 7 are indicated in Column 8.

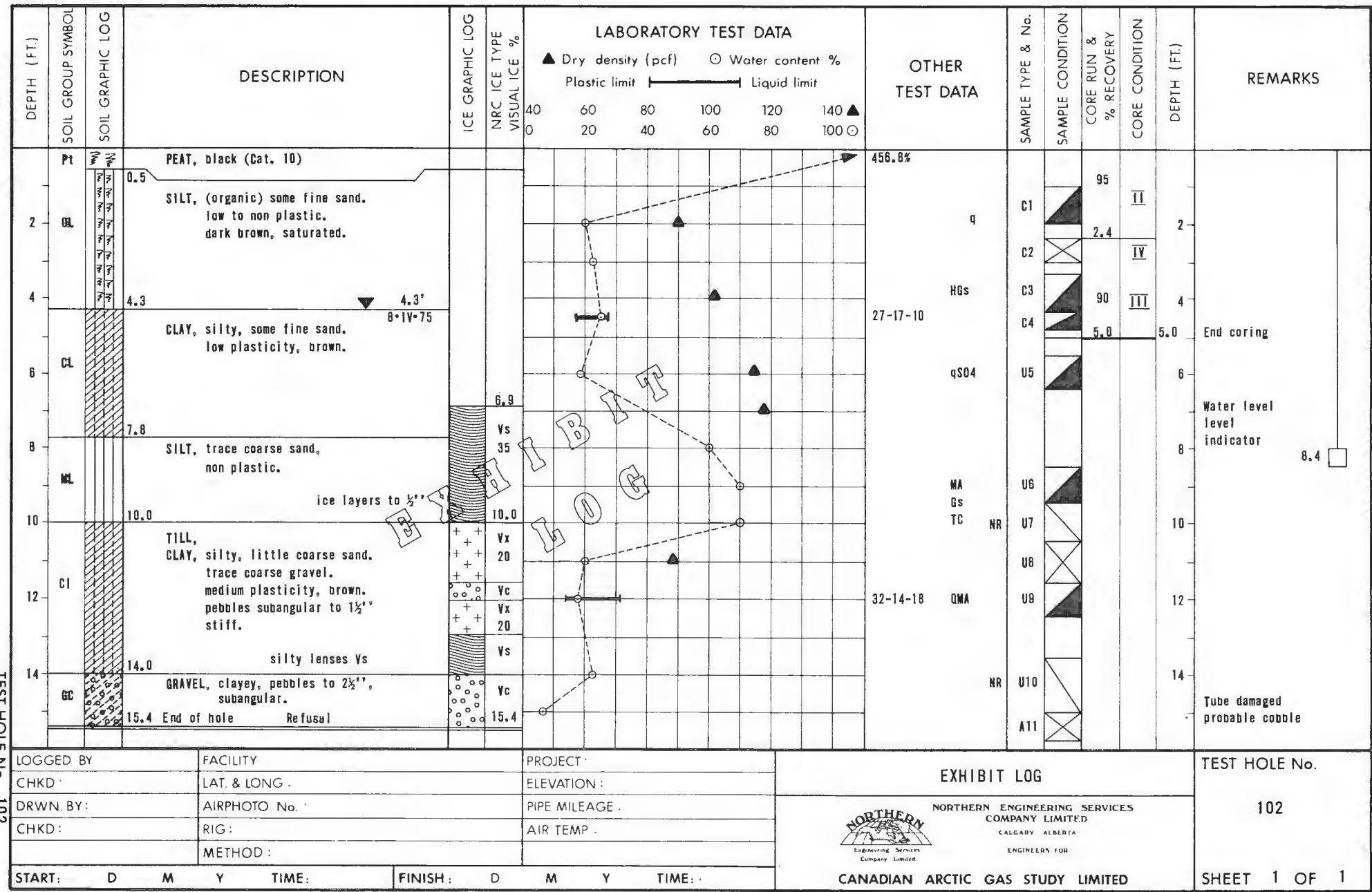
The more common engineering tests are denoted using the following symbols:

D_{10}	grain size at 10% passing
D_{30}	grain size at 30% passing
D_{60}	grain size at 60% passing
C	consolidation
C_c	coefficient of curvature $(D_{30})^2 / D_{10} \times D_{60}$
C_u	coefficient of uniformity D_{60} / D_{10}
G_s	specific gravity of soil solids
H	hydrometer analysis
k	permeability
MA	mechanical analysis (sieve analysis)
N	the penetration resistance, i.e., the number of blows required for the second and third 6-inches of penetration during a Standard Penetration Test (SPT) in accordance with ASTM Designation D 1586 (see also SPT)
NP	non-plastic
OC	organic content
PP	pocket penetrometer
P200	per cent passing the No. 200 sieve size
Q	triaxial test
q	unconfined compressive strength
S	shear test
SO_4	water soluble sulphate
SPT	standard penetration test (blow counts for 6-inches, 12-inches, 18-inches penetration are shown sequentially)
TC	thaw consolidation
w	water content
W_L, W_P, I_P	liquid limit, plastic limit, and plasticity index, respectively

REFERENCES:

1. "Unified Soil Classification System" Technical Memorandum 3-357 prepared for Office, Chief of Engineering, by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S. Army. Volume I, March 1953.
2. National Research Council, Canada, "Guide to a Field Description of Permafrost for Engineering Purposes", prepared by Pihlainen, J.A. and Johnston, G.H., Technical Memorandum 79, NRC 7576, Ottawa, 1963.
3. American Society for Testing and Materials, Procedures for Testing Soils, "Suggested Methods of Testing for Identification of Soils", Fourth Ed. pp 221-233, December 1964.
4. National Research Council, Canada, "Guide to a Field Description of Muskeg", (Based on the Radforth Classification System) compiled by MacFarlane, I.C. Technical Memorandum 44 (Revised Edition) NRC 4214, Ottawa, 1958.
5. American Society for Testing and Materials, "Annual Book of Standards", (Part 19, 1974 or latest Standard) Philadelphia, Pa., U.S.A.
6. Goodman, L.J. and Lee, C.N., 1962, "Laboratory and Field Data on Engineering Characteristics of Some Peat Soils", Proc. 8th Muskeg Res. Cong. NRC ACSSM Tech. Memo 74 pp 107-129.

TEST HOLE LOG



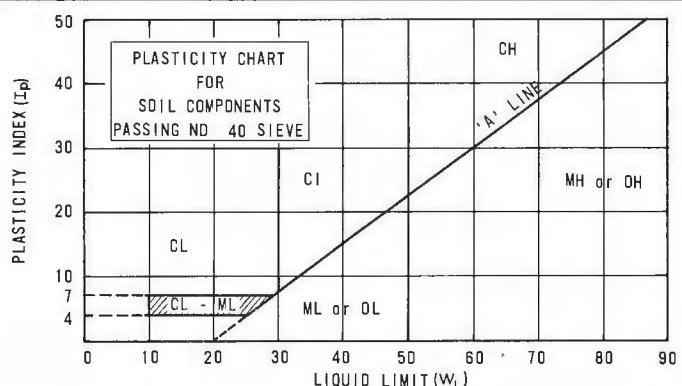
TEST HOLE LOG

TEST HOLE NO.	DEPTH (FT.)	SOIL GROUP SYMBOL	SOIL GRAPHIC LOG	DESCRIPTION	ICE GRAPHIC LOG	NRC ICE TYPE VISUALICE %	LABORATORY TEST DATA							OTHER TEST DATA	SAMPLE TYPE & No.	SAMPLE CONDITION	CORE RUN & % RECOVERY	CORE CONDITION	DEPTH (FT.)	REMARKS		
							▲ Dry density (pcf)			○ Water content %												
Plastic limit			Liquid limit																			
40	60	80	100	120	140	▲	0	20	40	60	80	100	○									
1	2	3		4	5	6								7	8	9	10	11	12	13	14	
LOGGED BY:		FACILITY:		PROJECT:														TEST HOLE No.				
CHKD:		LAT. & LONG :		ELEVATION :														NORTHERN		NORTHERN ENGINEERING SERVICES COMPANY LIMITED		
DRWN. BY:		AIRPHOTO No. :		PIPE MILEAGE :														Engineering Services Company Limited		CALGARY ALBERTA		
CHKD:		RIG :		AIR TEMP. :														ENGINEERS FOR				
		METHOD :																				
START: D M Y TIME:		FINISH: D M Y TIME:		CANADIAN ARCTIC GAS STUDY LIMITED												SHEET OF						

SOIL CLASSIFICATION SYSTEM

MAJOR DIVISION		GROUP SYMBOL	GRAPHIC SYMBOL	TYPICAL MATERIALS		LABORATORY CLASSIFICATION CRITERIA			
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN NO. 200 SIEVE)	GRAVELS MORE THAN HALF OF COARSE FRACTION LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (NO APPRECIABLE FINES)	GW	WELL GRADED GRAVELS, AND GRAVEL - SAND MIXTURES LITTLE OR NO FINES		D_{60}	$C_u = \frac{D_{30}}{D_{10}} > 4$ $C_c = \frac{(D_{30})^2}{C_{10} \times D_{60}}$ 1 to 3		
		DIRTY GRAVELS (WITH FINES)	GP	POORLY GRADED GRAVELS, AND GRAVEL - SAND MIXTURES, LITTLE OR NO FINES		NOT MEETING ABOVE REQUIREMENTS			
	GRAVELS MORE THAN HALF OF COARSE FRACTION SMALLER THAN NO. 4 SIEVE	DIRTY GRAVELS (WITH FINES)	GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES		CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW 'A' LINE AND P.I. LESS THAN 4		
		CLEAN SANDS (NO APPRECIABLE FINES)	GC	CLAYEY GRAVELS, GRAVEL - SAND - (SILT) CLAY MIXTURES			ATTERBERG LIMITS ABOVE 'A' LINE OR P.I. MORE THAN 7		
	SANDS MORE THAN HALF OF COARSE FRACTION SMALLER THAN NO. 4 SIEVE	DIRTY SANDS (WITH FINES)	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		D_{60}	$C_u = \frac{(D_{30})^2}{D_{10}} > 6$ $C_c = \frac{C_{10} \times D_{60}}{D_{30}}$ 1 to 3		
		DIRTY SANDS (WITH FINES)	SP	POORLY GRADED SANDS, LITTLE OR NO FINES		NOT MEETING ABOVE REQUIREMENTS			
	SANDS MORE THAN HALF OF COARSE FRACTION SMALLER THAN NO. 4 SIEVE	DIRTY SANDS (WITH FINES)	SM	SILTY SANDS, SAND - SILT MIXTURES		CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW 'A' LINE AND P.I. LESS THAN 4		
		DIRTY SANDS (WITH FINES)	SC	CLAYEY SANDS, SAND - (SILT) CLAY MIXTURES			ATTERBERG LIMITS ABOVE 'A' LINE OR P.I. MORE THAN 7		
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES NO. 200 SIEVE)	SILTS BELOW 'A' LINE NEGLIGIBLE ORGANIC CONTENT	$w_L < 50$	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY		CLASSIFICATION IS ACCORDING TO PLASTICITY CHART (SEE BELOW)			
		$w_L > 50$	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY, OR SILTY SOILS					
	CLAYS ABOVE 'A' LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$w_L < 30$	CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY SANDY, OR SILTY CLAYS, LEAN CLAYS					
		$30 < w_L < 50$	CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS					
	ORGANIC SILTS & CLAYS BELOW 'A' LINE ON CHART	$w_L > 50$	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS					
		$w_L < 50$	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY					
	$w_L > 50$	OH		ORGANIC CLAYS OF HIGH PLASTICITY					
HIGHLY ORGANIC SOILS		Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS		STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE			

SOIL COMPONENTS					
FRACTION	U.S. STANDARD SIEVE SIZE	DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS			
GRAVEL	PASSED RETAINED	PERCENT	DESCRIPTOR		
coarse	3 inch	3/4 inch			
SAND	No. 4	No. 10	and some	CL	CH
medium	No. 10	No. 40			
SILT (non plastic) or CLAY (plastic)	No. 40	No. 200	little trace	CL - ML	MH or OH
fine	No. 200				



- ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD A.S.T.M. E 11.
- BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, e.g. GW-GC IS A WELL-GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12%.
- TOUGHNESS AND DRY STRENGTH INCREASE WITH INCREASING PLASTICITY INDEX WHEN COMPARING SOILS AT EQUAL LIQUID LIMIT

OVERSIZE MATERIAL	
Rounded or subrounded COBBLES 3 inch to 8 inch BOULDERS > 8 inch	Not rounded ROCK FRAGMENTS > 3 inch ROCKS > 1 cubic yard in volume

TABLE 2
GROUND ICE CLASSIFICATION

Category	Group Symbol	Subgroup Symbol	Graphic Symbol	Description
		F		Undifferentiated
Non-visible Ice	N	Nf	[diagonal hatching]	Poorly bonded or friable frozen soil
		Nbn	[dotted pattern]	Well bonded frozen soil with no excess ice
		Nbe	[dotted pattern with diagonal lines]	Well bonded frozen soil with excess ice. Free water present when sample thawed
Visible Ice less than one inch thick	V	Vx	[plus signs]	Individual ice crystals or inclusions
		Vc	[circles]	Ice coatings on particles
		Vr	[irregular shapes]	Random or irregularly oriented ice formations
		Vs	[wavy lines]	Stratified or distinctly oriented ice formations
Visible Ice greater than one inch thick	ICE	ICE + soil type	[diagonal hatching]	Ice greater than one inch thick with soil inclusions
		ICE	[solid black]	Ice greater than one inch thick without soil inclusions

Adapted from NRC 7576

