Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Report to
GULF CANADA RESOURCES INC.
on
BEAUFORT SEA GEOTECHNICAL INVESTIGATION - 1981

KRINGALIK

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812-2102

November, 1982

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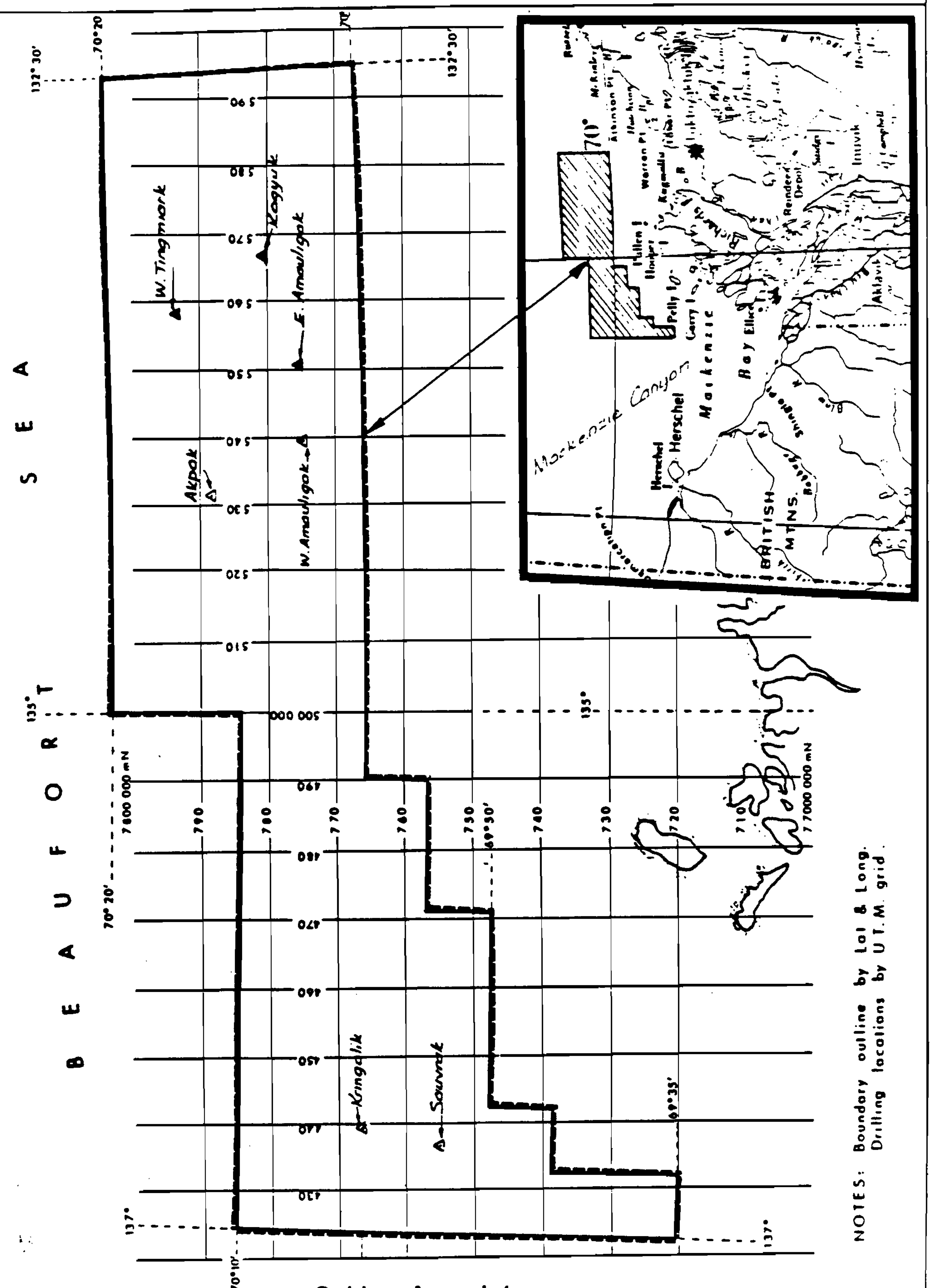
SITE LOCATION PLAN

Figure 1



NOTES: Boundary outline by Lat & Long.
Drilling locations by U.T.M. grid.

Project No. 812-2102 Drawn G.B. Reviewed 1 Date Oct '81

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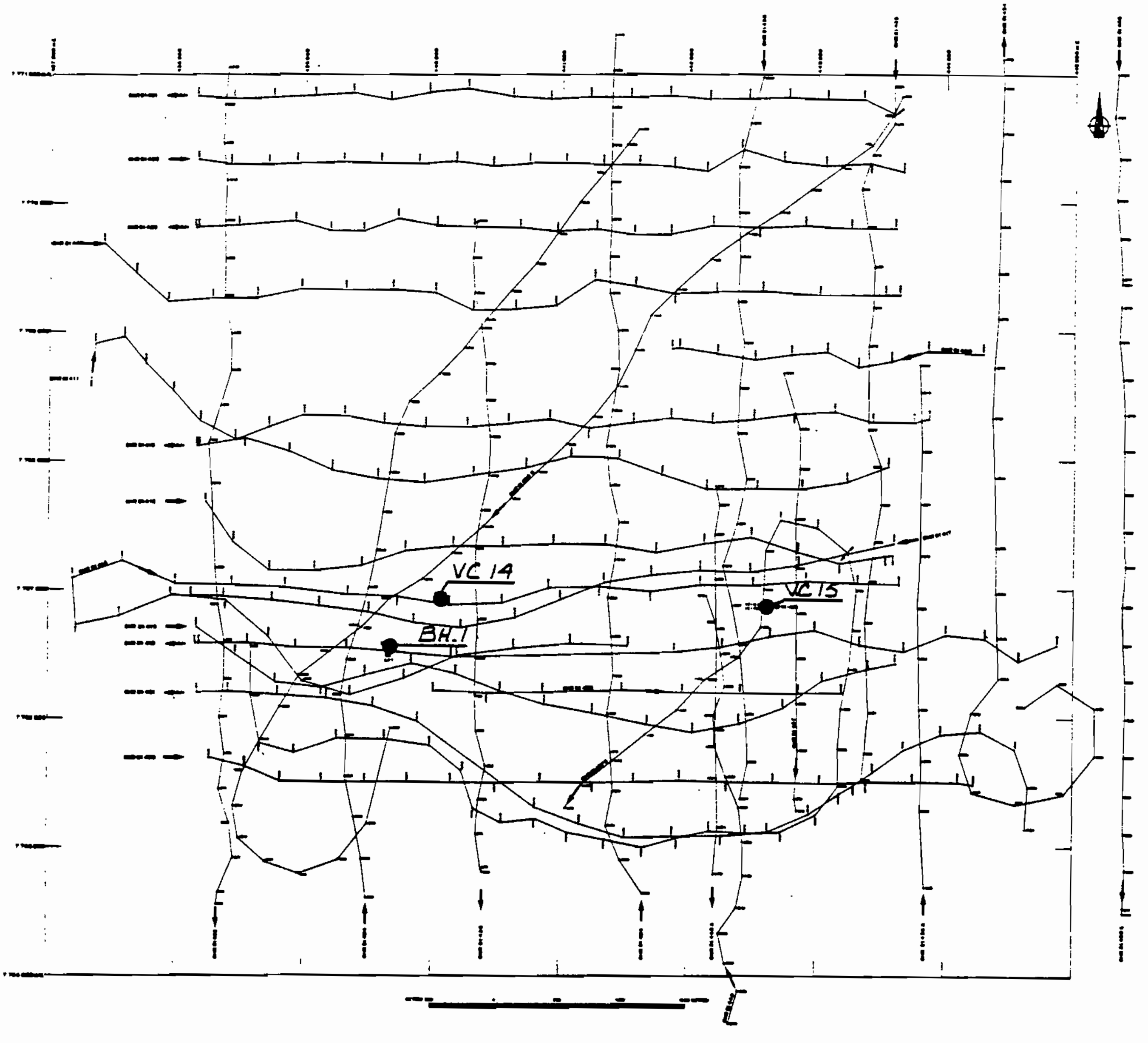
GEOPHYSICAL SURVEY LINES AND BOREHOLE LOCATIONS

Figure 2



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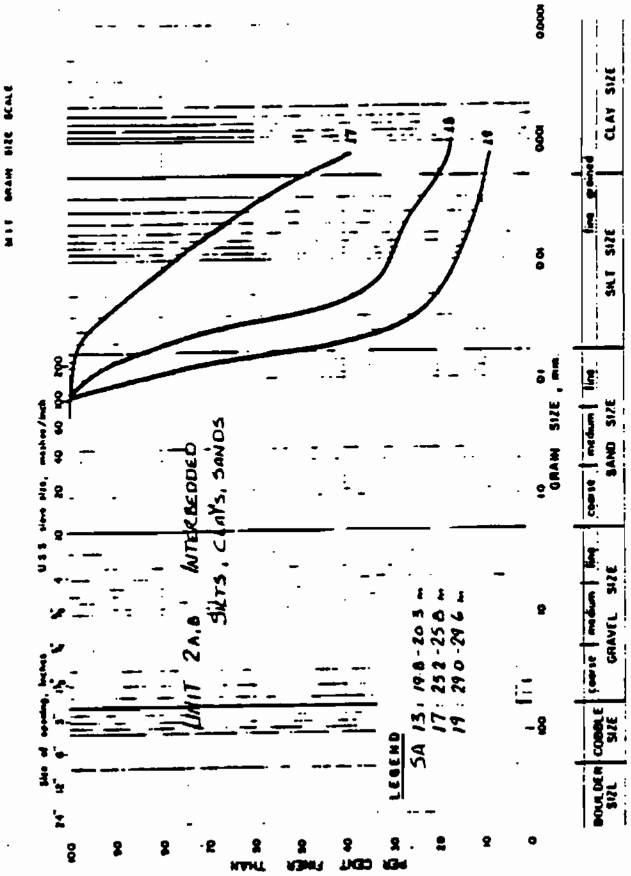
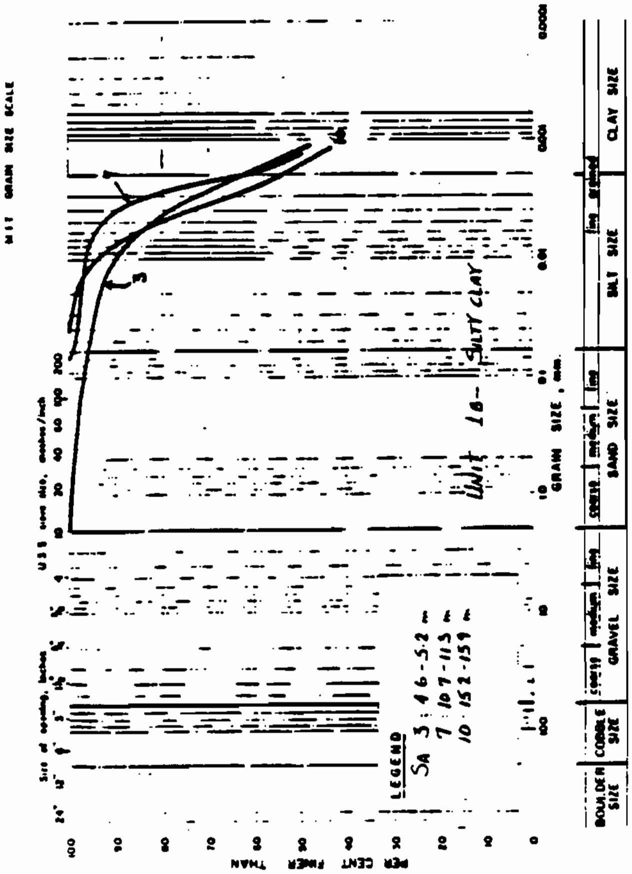
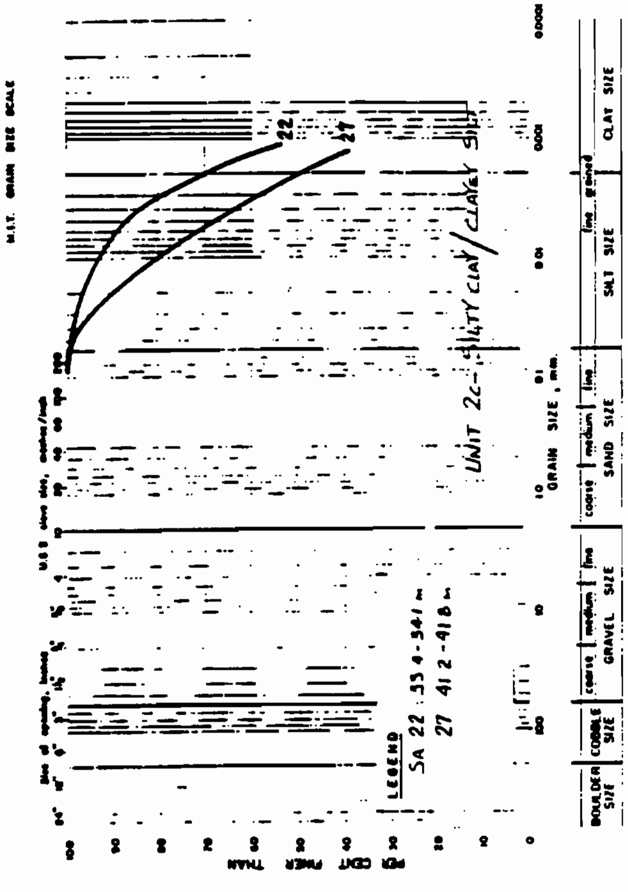
GRAIN SIZE DISTRIBUTION

Figure 3







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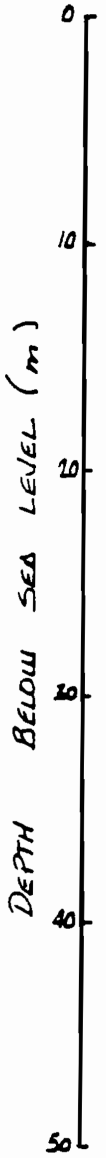
SUMMARIZED STRATIGRAPHY AND ENGINEERING PROPERTIES FOR PRELIMINARY DESIGN KRINGALUK SITE

Figure 6



	SIMPLIFIED STRATIGRAPHY	SOIL PROPERTIES	
0.0	WATER DEPTH 33 m		
	SOFT SILTY CLAY (1A)	$W_n \sim 47\%$ $I_p \sim 35\%$	$S_u \sim 20$ kPa
4.3			
	FIRM - HARD SILTY CLAY (1B)	$W_n \sim 33\%$ $I_p \sim 26\%$ $\gamma \sim 19.1$ kN/m³ $T \sim 0°$ to $-1.1°C$	$S_u \sim 150$ kPa $c' \sim 0$, $\phi' \sim 28\frac{1}{2}°$ $A_f \sim 0.3$ $P_c - P_o' \sim 400$ kPa $C_r \sim 0.04$ (est'm)
16.5			
17.8	(SEE 2A BELOW)	(SEE 2A BELOW)	
	DENSE SILT (2B)	$W_n \sim 28\%$ $T \sim -0.6°$ to $-1.1°C$	$N \sim 40.50$ Blows/300 mm
21.0			
	INTERBEDDED SAND, CLAYEY SILT, AND SILTY CLAY (2A)	$W_n \sim 29\%$ $I_p \sim NP$ (20% clayey layer) $\gamma \sim 18.8$ kN/m³ $T \sim -1.1$ to $-2.2°C$	$N \sim 62.34.29$ Blows/300 mm $S_u \sim 150$ kPa in clayey layers $c' \sim 0$, $\phi \sim 28\frac{1}{2}°$, $A_f \sim 0.3$ $P_c - P_o' \sim 500$ kPa $C_c \sim 0.30$ $C_r \sim 0.06$
34.4			
	VERY STIFF TO HARD CLAYEY SILT TO SILTY CLAY (2C)	$W_n \sim 29\%$ $I_p \sim 25\%$ $\gamma \sim 19.6$ kN/m³ $T \sim -1.7°$ to $-3.3°C$	$S_u \sim 100$ kPa $c' \sim 0$, $\phi' \sim 28\frac{1}{2}°$, $A_f \sim 0.3$ (est'm) $P_c - P_o' \sim 100$ kPa $C_c \sim 0.34$, $C_r \sim 0.04$ (est'm)
46.5	(END OF BH)		

NOTE: STRATIGRAPHY AND ENGINEERING PROPERTIES GIVEN ON THIS FIGURE ARE FOR PRELIMINARY DESIGN PURPOSES ONLY.

Project No. 812-2102 Drawn DB Reviewed ff Date Nov-82

APPENDIX 1

BOREHOLE LOGS

PROJECT No 812-2102 DRAWN D.S. REVIEWED VB DATE NOV-82

RECORD OF BOREHOLE BH1

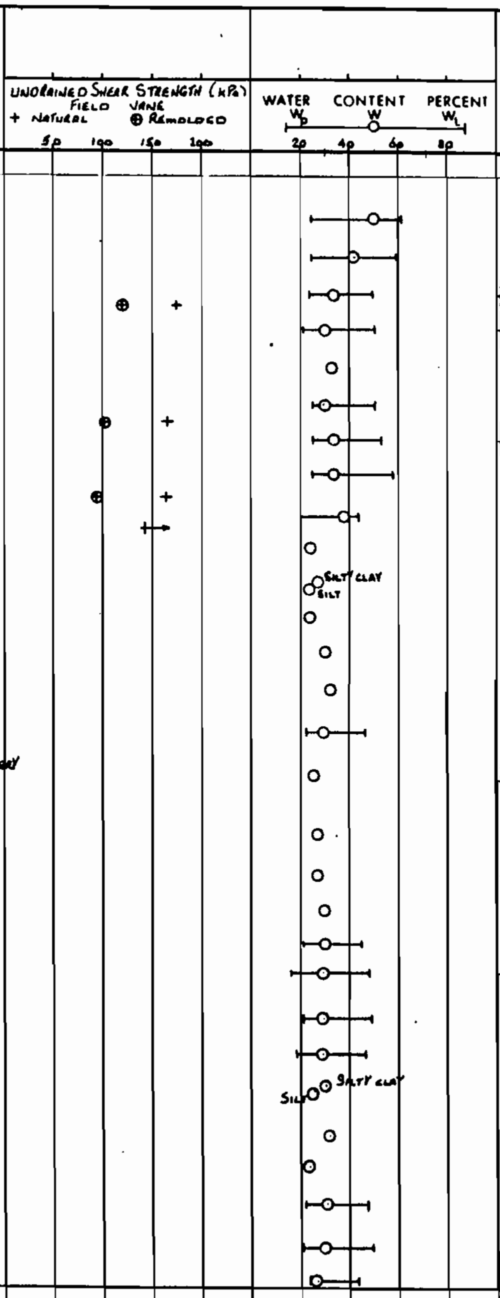
LOCATION (See Figure 2.2) N 7 766 548 E 459 691
KRINGALIK SITE
SAMPLE HAMMER WEIGHT 63.5 kg

BORING DATE SEPTEMBER 25.26 1981
DROP 0.76 METERS

BOREHOLE DIAMETER 10.2 cm
DATUM SEA FLOOR

Boring Method:
AW RODS FOR IN SITU VANE TEST
BQ SAMPLING RODS
MUD SUPPORTED HOLE **
4 7/8 in. OD (117.5mm) DRILL PIPE WITH CASING SHOE DRILL BIT

SOIL PROFILE		SAMPLES					
Elev. Depth (m)	DESCRIPTION	Strat. Plot	Number	Type	Blows/300mm	TEMPERATURE °C	ADDITIONAL LAB. TESTING
	SEA FLOOR (WATER DEPTH 33 m)						
0.0	(1A) VERY SOFT GREY SILTY CLAY TRACE OF FINE GRAVEL AND SHELL FRAGMENTS						
1			1	TO.			
4			2	TO.			
4.5	(1B) FIRM TO STIFF, BECOMING VERY STIFF TO HARD GREY SILTY CLAY, SOME LAMINATION AND ORGANICS OCCASIONAL SHELLS, EVIDENCE OF MINOR SHEARS CROSS-CUTTING BEDDING		3	TO.		-1.1	MH, R̄ $\gamma = 19.0$ KN/m³
6			4	TO.		-1.1	R̄ $\gamma = 19.1$ KN/m³
8			5	DO.	33	-0.6	
10			6	TO.		-1.1	
12			7	TO.		-1.1	H,C $\gamma = 19.2$ KN/m³
			8	TO.		0	
14			9	TO.		-0.6	
16			10	TO.		-0.6	H
16.5	(2A) INTERBEDDED GREY SILTY FINE SAND CLAYEY SILT AND SILTY CLAY LAMINATED, ORGANIC HORIZONS		11	DO.	62	0	
17.8	(2B) DENSE TO VERY DENSE, GREY SILT, WITH SOME FINE SAND AND CLAY		12	DO.	50	-1.1	
20			13	DO.	40	-0.6	MH
21.0	(2A) INTERBEDDED DENSE GREY SILTY SAND, STIFF GREY CLAYEY SILT, AND SILTY CLAY, LAMINATED, ORGANIC HORIZONS, VISIBLE ICE CRYSTALS (Vx) IN SOME SAMPLES		14	TO.		-2.2	
24			15	DO.	39	-1.1	
			16	TO.		No Recovery	
26			17	TO.		-1.1	H,C,R̄ $\gamma = 18.9$ KN/m³
28			18	TO.		-1.1	
30			19	TO.		-2.2	MH
			20	DO.	29	-1.7	
31.4	(2C) VERY STIFF TO HARD, GREY CLAYEY SILT/SILTY CLAY, LAMINATED, OCCASIONAL SILTY FINE SAND LAYERS/LENSES, SOME THIN ICE LENSES (Vr) ICE CRYSTALS (Vx) SOME ORGANICS. ICE LENSES ARE HARD CLEAR, RANDOMLY ORIENTED, UP TO 3 mm THICK AND 200mm LONG. ICE BONDING (Nb) ALSO FOUND IN MOST SAMPLES.		21	TO.		-2.2	
34			22	TO.		-2.2	H,C $\gamma = 19.6$ KN/m³
36			23	TO.		-2.8	
			24	TO.		-2.8	
38			25	TA.		-2.8	
40			26	DO.	35	-1.7	
41			27	TO.		-2.8	H
44			28	TO.		-2.8	
			29	TO.		-3.3	
46			30	TO.		-3.3	
46.5	END OF BOREHOLE						
48							
50							



NOTE: ALL T.O. SAMPLES WERE 75 mm dia.
ALL D.O. SAMPLES WERE 50 mm dia.

** CONDUCTOR STRING
a) 6 5/8 in. (168 mm) O.D. INNER CASING FROM 1 m BELOW SEA FLOOR TO MOON POOL
b) 8 5/8 in. (219 mm) O.D OUTER CASING TO 17.7 m BELOW MOONPOOL DECK
c) DRILLING MUD DISCHARGE ONTO SEABED THROUGH SLOTS IN 6 5/8 in. CASING

SCALE 1:200

Golder Associates

BOREHOLE No BH1

PROJECT No 812-2102 DRAWN D.S. REVIEWED VB DATE NOV-82

RECORD OF BOREHOLE BH1

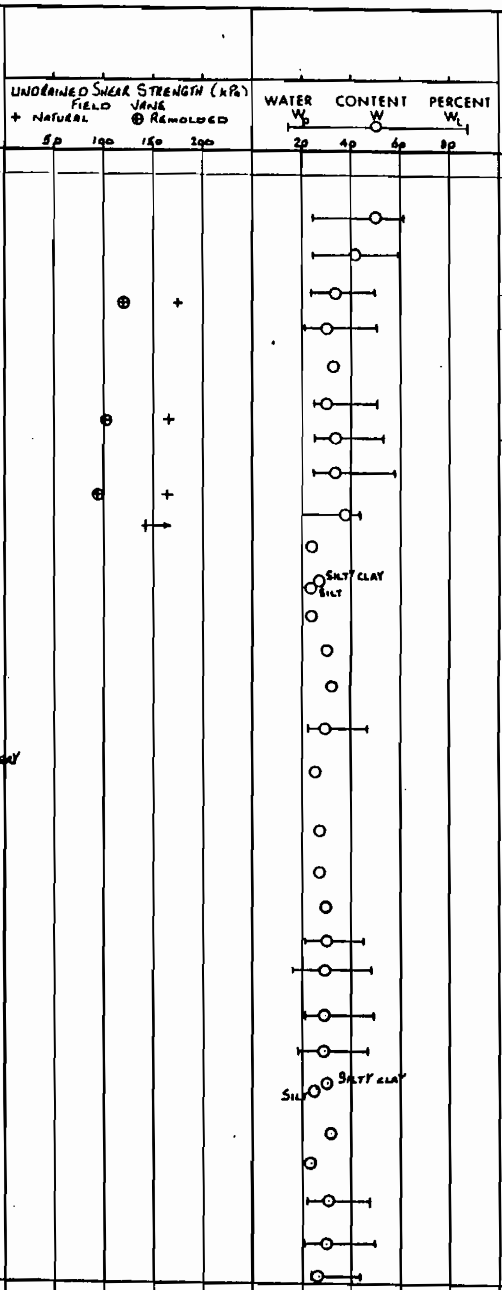
LOCATION (See Figure 1.2) N 7 766 548 E 439 691
KRINGALIK SITE
SAMPLE HAMMER WEIGHT 63.5 kg

BORING DATE SEPTEMBER 25, 26 1981
DROP 0.76 METERS

BOREHOLE DIAMETER 10.2 cm
DATUM SEA FLOOR

Boring Method: SQ SAMPLING RODS AW RODS FOR IN SITU VANE TEST
4 3/4 in. OD (117.5 mm) DRILL PIPE WITH CASING SHOE DRILL BIT MUD SUPPORTED HOLE **

Elev. Depth (m)	DESCRIPTION	Number	Type	Blows/300mm	TEMPERATURE °C	ADDITIONAL LAB. TESTING
00	SEA FLOOR (WATER DEPTH 33 m)					
1	(1A) VERY SOFT GREY SILTY CLAY TRACE OF FINE GRAVEL AND SHELL FRAGMENTS	1	To.			
		2	To.			
4 4.5	(1B) FIRM TO STIFF, BECOMING VERY STIFF TO HARD GREY SILTY CLAY, SOME LAMINATION AND ORGANICS OCCASIONAL SHELLS, EVIDENCE OF MINOR SHEARS CROSS-CUTTING BEDDING	3	To		-1.1	MH, R̄ γ = 19.0 KN/m³
6		4	To.		-1.1	R̄ γ = 19.1 KN/m³
8		5	Do.	33	-0.6	
10		6	To.		-1.1	
		7	To.		-1.1	H, C γ = 19.2 KN/m³
12		8	To.		0	
14		9	To.		-0.6	
16		10	To.		-0.6	H
16.5	(2A) INTERBEDDED GREY SILTY FINE SAND CLAYEY SILT AND SILTY CLAY LAMINATED ORGANIC HORIZONS	11	Do.	62	0	
17.8	(1B) DENSE TO VERY DENSE, GREY SILT, WITH SOME FINE SAND AND CLAY	12	Do.	50	-1.1	
20		13	Do.	40	-0.6	MH
21.0	(2A) INTERBEDDED DENSE GREY SILTY SAND, STIFF GREY CLAYEY SILT, AND SILTY CLAY, LAMINATED, ORGANIC HORIZONS, VISIBLE ICE CRYSTALS (Vx) IN SOME SAMPLES	14	To.		-2.2	
24		15	Do.	39	-1.1	
		16	To.		No Recovery	
26		17	To.		-1.1	H, C, R̄ γ = 18.9 KN/m³
28		18	To.		-1.1	
30		19	To.		-2.2	MH
		20	Do.	29	-1.7	
31.4	(2C) VERY STIFF TO HARD, GREY CLAYEY SILT/SILTY CLAY, LAMINATED, OCCASIONAL SILTY FINE SAND LAYERS/LENSES, SOME THIN ICE LENSES (Vs) ICE CRYSTALS (Vx) SOME ORGANICS. ICE LENSES ARE HARD CLEAR, RANDOMLY ORIENTED, UP TO 3 mm THICK AND 100 mm LONG. ICE BONDING (Nb) ALSO FOUND IN MOST SAMPLES.	21	To.		-2.2	
34		22	To.		-2.2	H, C γ = 19.6 KN/m³
36		23	To.		-2.8	
		24	To.		-2.8	
38		25	To.		-2.8	
40		26	Do.	35	-1.7	
41		27	To.		-2.8	H
44		28	To.		-2.8	
		29	To.		-3.3	
46		30	To.		-3.3	
46.5	END OF BOREHOLE					
48						
50						



NOTE: ALL T.O. SAMPLES WERE 75 mm dia.
ALL O.O. SAMPLES WERE 50 mm dia.

** CONDUCTOR STRING
a) 6 5/8 in. (168 mm) O.D. LINER CASING FROM 1 m BELOW SEA FLOOR TO MOON POOL
b) 8 5/8 in. (219 mm) O.D OUTER CASING TO 17.7 m BELOW MOONPOOL DECK
c) DRILLING MUD DISCHARGE ONTO SEABED THROUGH SLOTS IN 6 5/8 in. CASING

PIEZOMETER OR STANDPIPE INSTALLATION

SCALE 1:200

Golder Associates

BOREHOLE No. BH1

APPENDIX 2

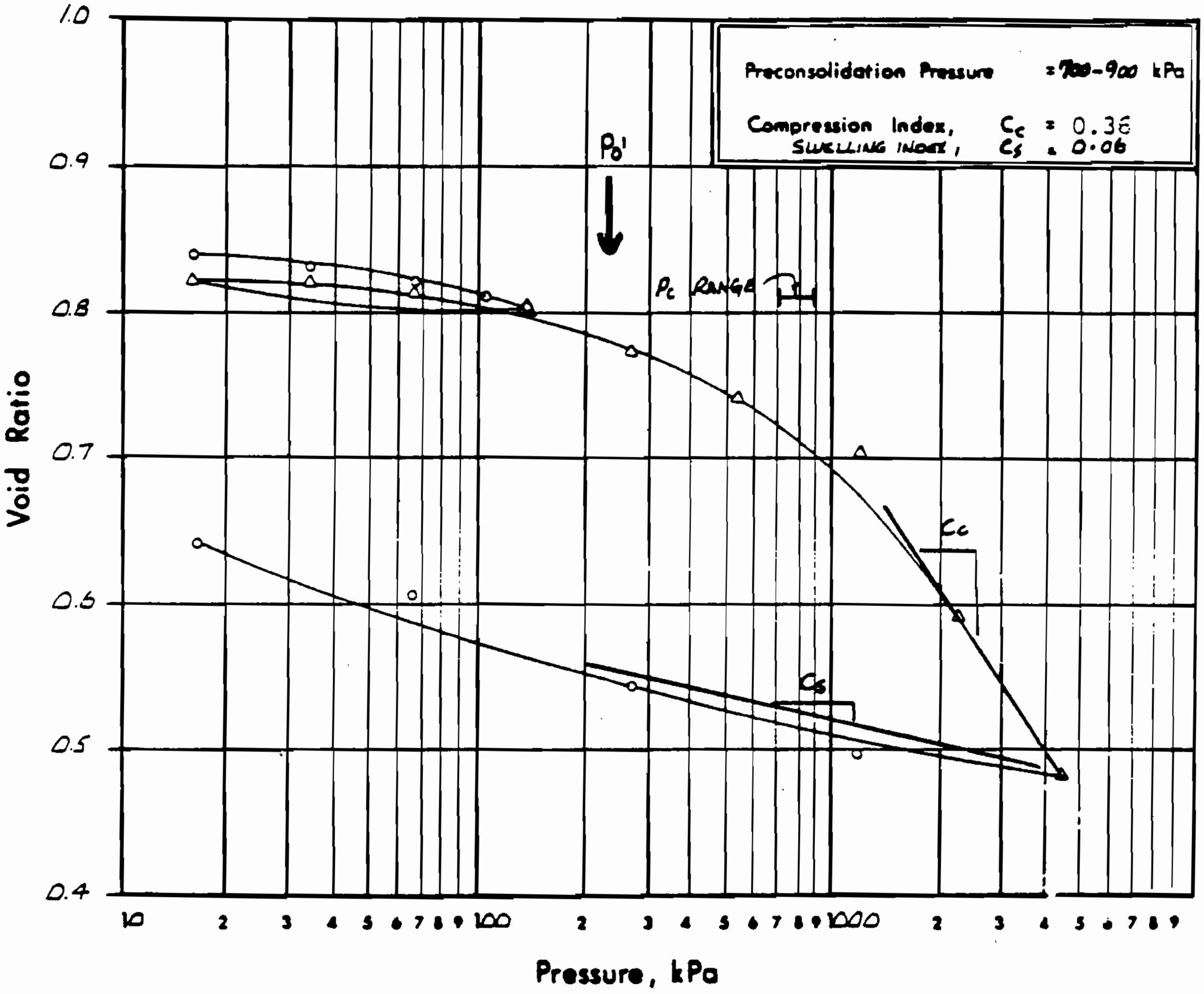
CONSOLIDATION TEST RESULTS

CONSOLIDATION TEST

Figure. 6

Site. Kringalik **Borehole No.** 1

Sample No. 17 **Depth.** 25.2 - 25.8 m ($P_0' \sim 235$ kPa)



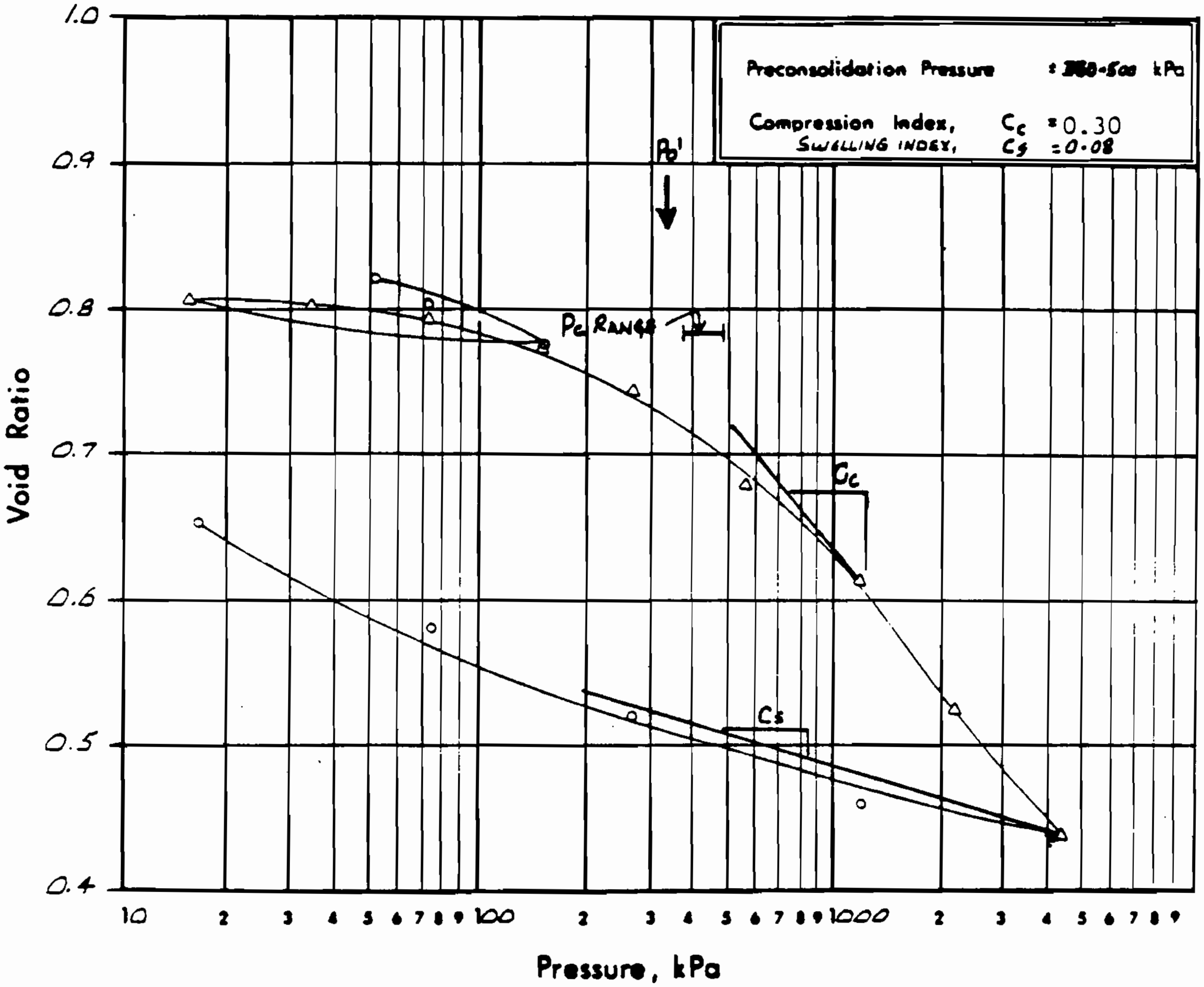
PRESSURE kPa	VOID RATIO	m_v kPa^{-1}	c_v cm^2/sec	k cm/sec
17.1	0.823			
34.2	0.821	7.18×10^{-5}	1.5×10^{-1}	1.1×10^{-6}
68.6	0.814	1.15×10^{-4}	4.4×10^{-2}	5.0×10^{-7}
137.3	0.802	9.35×10^{-5}	8.6×10^{-2}	7.9×10^{-7}
274.7	0.778	9.82×10^{-5}	7.6×10^{-2}	7.4×10^{-7}
549.4	0.744	6.97×10^{-5}	3.6×10^{-2}	2.5×10^{-7}
1098.8	0.702	4.38×10^{-5}	3.6×10^{-2}	1.5×10^{-7}
2197.6	0.568	6.08×10^{-5}	7.5×10^{-2}	4.5×10^{-7}
4395.5	0.481	3.06×10^{-5}	[illegible].9x10^-2	1.0×10^{-7}

CONSOLIDATION TEST

Figure. 7

Site. KRINGALIK **Borehole No.** 1

Sample No. 22 **Depth.** 33.5 - 34.1 m ($P_o' \sim 330$ kPa)



PRESSURE kPa	VOID RATIO	m_v kPa^{-1}	c_v cm^2/sec	k cm/sec
17.7	0.806	-	-	-
35.4	0.805	9.09×10^{-5}	4.9×10^{-3}	1.4×10^{-8}
71.0	0.794	1.81×10^{-4}	1.4×10^{-3}	2.4×10^{-8}
141.9	0.777	1.29×10^{-4}	2.0×10^{-3}	3.6×10^{-8}
283.9	0.746	1.23×10^{-4}	1.6×10^{-3}	1.4×10^{-8}
567.8	0.683	1.26×10^{-4}	1.9×10^{-3}	2.4×10^{-8}
1135.5	0.619	6.74×10^{-5}	1.8×10^{-3}	1.2×10^{-8}
2197.1	0.527	5.37×10^{-5}	1.3×10^{-3}	6.7×10^{-9}
4542.2	0.434	2.59×10^{-5}	1.4×10^{-3}	3.5×10^{-9}

APPENDIX 3

VIBRACORE HOLE LOCATIONS AND LOGS

Locations and Depths of Kringalik Vibracore Holes

(Locations in UTM Zone 8, WAD 72)

Hole #		VC14	VC15
Location	N	7 776 934	7 766 866
	E	440 079	442 624
Depth (m)		7.3	21.9

supervision of McElhanney on September 11 and 13, 1981. The locations and depths below seabed of the vibracore holes are as follows:

Locations and Depths of Kringalik Vibracore Holes
(Locations in UTM Zone 8, WAD 72)

Hole #	VC14	VC15
Location N	7 776 934	7 766 866
E	440 079	442 624
Depth (m)	7.3	21.9

2.2 Laboratory Testing

A detailed description of test techniques is given in Appendix II. In summary, detailed laboratory tests were carried out to determine the index properties and engineering properties of the samples obtained from Borehole 1. These test results are summarized on the Record of Borehole Sheet for Borehole 1 and Table 1, and are given in detail on Figures 3 - 8. Index testing and grain size analyses were also carried out on samples from the vibracore holes. The results of these tests are given on the Record of Borehole sheets for VC14 and 15, and on Table 2.

Visual classification, temperature measurements, sieve analyses and shear strength measurements (using a pocket penetrometer, laboratory vane and fall cone apparatus together with two consolidated undrained triaxial tests) were made on samples from Borehole 1 on board the Frank Broderick. A total of 3 oedometer consolidation tests were also performed in our Calgary laboratory (Figures 5 to 7, Table 3).

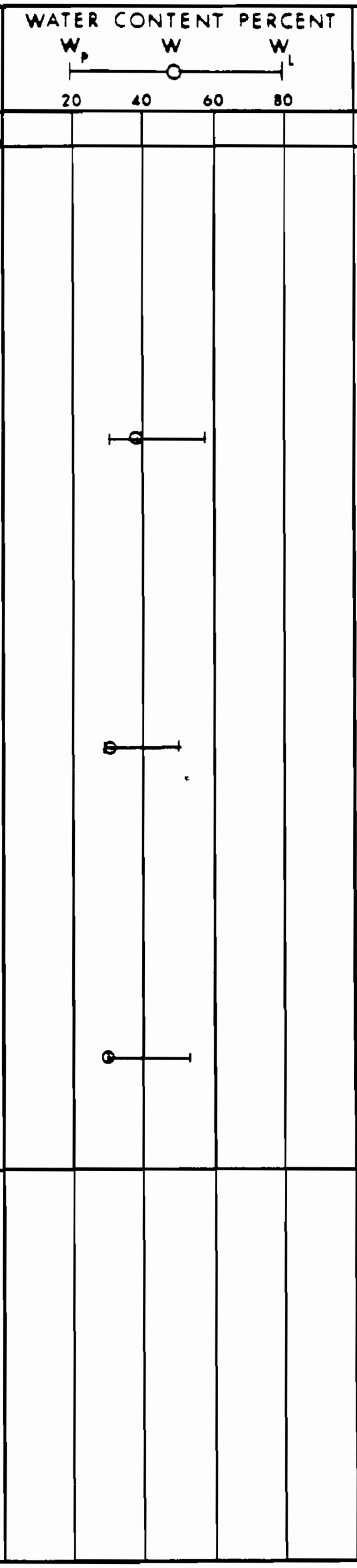
RECORD OF BOREHOLE VC 14

UTM GRID ZONE 8 WAD 72

SITE NAME: Kringalik LOCATION CO-ORDS: N 7 766 934 E 440 079 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: September 11, 1981 WATER DEPTH: 33.2 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	ADDITIONAL LAB. TESTING
	Sea Floor			
0.0	Very soft greenish grey silty CLAY, occasional sub-angular stones			
1.8 2.0	Soft greenish grey, silty CLAY occasional stones some small shell fragments			
3.8 4.0	Firm greenish grey and dark grey laminated / mottled silty CLAY, some small shell fragments			
5.2 6.0	Stiff to very stiff greenish grey and dark grey laminated silty CLAY			
7.3	End of Borehole			



PROJECT No. 812-2102

Golder Associates

BORE HOLE No. VC 14

SHEET 1 OF 1

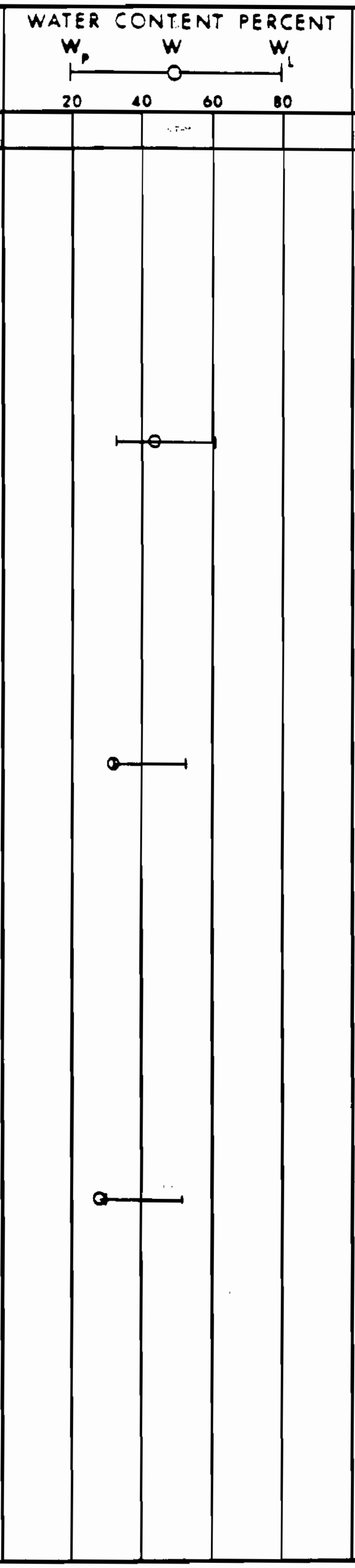
RECORD OF BOREHOLE VC 15

UTM GRID ZONE 8 NAD 72

SITE NAME: Kringalik LOCATION CO-ORDS: N 7 766 866 E 442 624 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: September 13,1981 WATER DEPTH: 34.4 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_P W W_L 20 40 60 80	ADDITIONAL LAB TESTING
	Sea Floor				
0.0	Very soft greenish grey silty CLAY some shell fragments, occasional pebbles				
1.8 2.0	Soft greenish grey silty CLAY, some small shell fragments, occasional pebbles				
3.8 4.0	Firm, greenish grey and dark grey mottled silty CLAY, some small shell fragments and occasional pebbles				
5.8 6.0	Stiff, greenish grey and dark grey mottled silty CLAY				
6.7	Very, stiff greenish grey and dark grey mottled, silty CLAY				
8.0					
10.0					



PROJECT No. 812-2102 **Golder Associates** BORE HOLE No. VC 15 SHEET 1 OF 3

RECORD OF BOREHOLE VC 15

UTM GRID ZON. 8 WAD 72

SITE NAME: Kringalik

LOCATION CO-ORDS: N 7 766 866 E 442 624

DATUM: Seo floor

BOREHOLE TYPE: Sonic.

DIAMETER: 10·16cm

BORING DATE: September 13,1981

WATER DEPTH: 34.4 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_P W W_L 20 40 60 80	ADDITIONAL LAB. TESTING
10.0 12.0	as above				
12.8 14.0	Compact grey medium to fine grained SAND, some coarse sand, trace of gravel, some small shell fragments		5		M
14.9 16.0 18.0 20.0	Soft to firm, greenish-grey, SILT, and fine grained SAND		6 7		M M

PROJECT No. 812-2102

Golder Associates

BOREHOLE No. VC 15

SHEET 2 OF 3

RECORD OF BOREHOLE VC 15

UTM GRID ZONE 8 WAD 72

SITE NAME: Kringalik

LOCATION CO-ORDS: N 7 766 866 E 442 624

DATUM: Sea floor

BOREHOLE TYPE: Sonic.

DIAMETER: 10·16cm

BORING DATE: September 13,1981

WATER DEPTH: 34.4 m.

DEPTH. 1:50(m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_p W W_L 20 40 60 80	ADDITIONAL LAB. TESTING
20.0	Soft to firm, greenish grey, SILT, and fine grained SAND		8		M
21.9	End of Borehole				

PROJECT No. 812-2102

Golder Associates

BORE HOLE No. VC 15

SHEET 3 OF 3

APPENDIX 4

FIELD INVESTIGATION PROCEDURES

812-2102 November, 1982

The initial phase of the 1981 Field Program was to undertake geophysical traverses (by the Arctic Sounder) at the proposed site areas to determine, on a preliminary basis, the general stratigraphy at the sites. For calibration of the geophysical results and for the preliminary borrow search, a number of vibro-cored boreholes (VC series) were carried out from the same vessel. The vibra-coring carried out from the Arctic Sounder was not performed under the direction of Golder Associates, and details of these operations are therefore not included in this report. The geophysical and vibracore data was reviewed on site for selection of a potential MAC (Mobile Arctic Caisson) site within each site area. Potential MAC sites were selected based on water depth, thickness and consistency of surficial deposits, uniformity of stratigraphy and absence of permafrost.

Each selected MAC site was investigated by means of sampling and in situ testing from the Frank Broderick to verify the suitability of the chosen location from a geotechnical standpoint. Detailed sampled borings were put down from the Frank Broderick. This vessel was equipped with a diesel powered all hydraulic combined sonic/rotary top drive drillrig (modified Simco 5000 WS). The rig was mounted on rails to allow moving the rig and thereby to facilitate handling of casings and conductor pipes.

The casing system consisted of a conductor pipe and two different size casings. The conductor pipe, 203 mm (8") in diameter, was suspended from the moonpool cover to a maximum depth of approximately 27 m, to give additional lateral support to, and allow free vertical movement of, a 152 mm (6") casing, supported on the seafloor by means of a casing footing. The casing footing was equipped with longitudinal slots to allow discharge of the drilling mud onto the sea floor.

Inside the 152 mm (6") casing, 102 mm (4") casing was used for drilling and advanced by means of a wireline casing advancer. Sampling was carried out below the 102 mm (4") casing using split spoon sampling equipment and/or 76 mm (3") Shelby tubes attached to BQ drillrods.

In addition to conventional split spoon and Shelby tube sampling, the rig was also equipped for wireline Shelby tube sampling and down hole standard penetration testing. However, these options were not used due to time and weather constraints.

For the foundation investigation borehole, the sampling intervals were generally 1.5 m down to approximately 30 m below sea floor, 3.0 m between 30 m and 60 m and 4.6 m below 60 m. These sampling intervals applied to both split spoon and Shelby tube sampling.

Despite occasional difficulties in performing the standard penetration test in rough weather conditions, the 'N' values obtained are considered to be reliable. This is supported by the comparison between SPT 'N' value profiles where profiles were drilled within 300 m of one another. All tests were performed using a rope and cathead system for raising the drop-hammer, with BQ drill rod used for sampling.

In situ vane tests were performed with a Nilcon vane borer at selected depths in cohesive soils. This instrument has a limited twist slip coupling between the vane and rods, which allows the vane shear resistance to be distinguished from rod friction. In addition a continuous mechanical trace of torque against rotation is obtained. All tests were carried out using a 100 mm vane, with a rated capacity of 220 kPa. Remoulded tests were generally performed after measurement of peak (undisturbed) strengths. To ensure that the vane remained stationary in the soil, the vane and vane rods were suspended from the 152 mm casing resting on the sea bed. Field vane strengths measured during this investigation have not been modified to account for effects such as strain rate or anisotropy.

In addition to the above techniques Static Cone Penetration Testing was attempted, but no results were obtained due to difficulties in handling the equipment on the ship. The equipment was however tried in shallow water and under ideal weather conditions.

APPENDIX 5

LABORATORY TESTING PROCEDURES

The geotechnical laboratory on the Frank Broderick was equipped for routine testing of all samples and for preliminary shear strength determination on cohesive soils. The laboratory equipment included the following.

- Hydraulic sample extruder for extrusion of Shelby tube samples.
- Sieves, hydrometers and balances for determination of grain size distribution.
- Oven for water content determination
- Casagrande liquid limit device for determination of liquid limit.
- Pilcon shear vane, pocket penetrometer and Geonor fall cone for determination of undrained shear strength.
- Triaxial apparatus for determination of shear strength by unconfined compression tests, UU (unconsolidated undrained) or CU (consolidated undrained) triaxial tests.
- Thermometers for temperature measurement of samples.
- Microscope for classification of ice bonded soils.

Split spoon samples were classified and a portion of each sample was placed in a sealed container for shipment to Calgary. For most samples, a sieve analysis was carried out on the ship. Hydrometer tests were attempted but were found to give incorrect results due to vibrations and the movements of the ship.

Following extrusion and classification of Shelby tube samples, one portion of each sample was sealed and prepared for shipment to Calgary and another was used for on board testing. On board, laboratory shear strength measurements were made using the fall cone, Pilcon vane and pocket penetrometer. The portions of samples retained onboard were used for determination of moisture content, Atterberg limits and for triaxial testing.

Where temperature measurements indicated the possibility of ice bonding, without visual evidence of ice, the samples were examined under the microscope.

Sample temperatures were taken as soon as the samples arrived in the laboratory by inserting a 1.5 mm diameter probe into the sample. Initially a mechanical dial gauge type reading to the nearest degree Fahrenheit was used. Towards the end of the investigation, an electronic thermometer, accurate to 0.1°C. was used.

Temperatures measured on Shelby tube samples are probably close to the in situ temperature, as ambient temperatures during most of the operation were close to 0°C. Temperatures of split spoon samples should be considered as approximate only as the temperature could be significantly altered when the sampler is driven, particularly as the blowcounts were frequently high.

In general, it appeared that ice or ice bonding was present in samples where the measured temperature was lower than approximately -1.6°C. However, some thawing during the sampling process occurs and this figure may not be representative for the material in situ.

All consolidation tests were performed using a conventional oedometer cell and gravity loading frame. The loading procedure was, however, modified slightly to improve the assessment and interpretation of test results. The vertical stress on the sample was applied in increments up to an effective stress level slightly less than the in situ effective overburden pressure. This load was then removed, allowing the sample to swell back under a nominal load. The purpose of this loading and unloading is to reduce the effects of sample disturbance on the consolidation curve obtained from the subsequent load increments. After the initial loading and rebound, the consolidation tests were performed in the usual manner. Samples were unloaded in increments after the final load increment. Each load was allowed to remain on the sample until primary consolidation was completed, based on Taylor's "square root of time" interpretation. Therefore the void ratio - log stress curves have not been corrected for secondary compression effects.

The undrained shear strength of samples was measured using a number of methods. It should be appreciated that rapid methods (i.e. laboratory vane, fall cone and pocket penetrometer tests) provide only approximate values of undrained shear strength since considerable scatter in test results is frequently evident from these various tests on the same sample. This variation is caused by a combination of varying boundary conditions and effective stress paths associated with the various tests. Other factors are also important, such as varying strain rate, and effect of intrinsic anisotropy of the soils being tested together with the small volume of test sample in relation to natural heterogeneity of the soil.

Effective stress strength parameters (c' and Ø') were determined in consolidated undrained triaxial tests with porewater pressure measurement (R tests). The triaxial test specimens were 50 or 72 mm in diameter and between 101 and 158 mm high. The tests were carried out on "undisturbed" specimens obtained from the Shelby tube samples. To ensure saturation of the test specimens (B>99%), back pressures were applied. The specimens were consolidated under cell pressures approximately equal to the in situ vertical effective stress. When consolidation was completed, drainage from the test specimen was shut off and undrained shearing carried out at a constant rate of strain. The strain rate of 1 to 3.5%/hr. adopted in these tests allows for equalization of porewater pressure throughout the samples. Water contents, unit weights and Atterberg limits were determined for the majority of triaxial test specimens.