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WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION REPORT

A0 2984.03.510

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TO: Devon Canada Corporation Home Oil Tower 1600, 324 – 8th Avenue SW Calgary, AB T2P 2Z5	DATE: May 30, 2003
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ATTENTION: Mr. Bill Scott	PAGE 1 OF 1

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KLOHN CRIPPEN

May 30, 2003

Devon Canada Corporation
Home Oil Tower
1600, 324 – 8th Avenue SW
Calgary, Alberta
T2P 2Z5

Mr. Bill Scott
Drilling Engineer, Offshore Projects

Dear Mr. Scott

Winter 2003 On-Ice Geotechnical Investigation Report

We are pleased to submit our report on the Winter 2003 On-Ice Geotechnical Investigation in the Canadian Beaufort Sea. We have enjoyed the opportunity to work with Devon Canada on this very interesting assignment.

Please call if you have any questions.

Sincerely,

KLOHN CRIPPEN CONSULTANTS LTD.

Brian T. Rogers, M.Sc., P.Eng.
Project Manager

030530report - onice geotechnical data report.doc
A02984.03.500

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WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION REPORT

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May 2003

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APPENDICES

1. INTRODUCTION

1.1 Background

Klohn Crippen Consultants Ltd. was retained by Devon Canada Corporation to conduct a geotechnical investigation of the shallow seabed soils at selected sites in the Mackenzie Delta area of the Beaufort Sea. The investigation locations were selected by Devon Canada to provide geotechnical data to support the Exploration Drilling Program under Exploration License EL420 (Devon Canada, 2002). The geotechnical investigation comprised a total of 8 locations within the following areas:

- Paktoa (3 sites)
- Nipterk (2 sites)
- Kekertak (1 site)
- Tuwak (1 site)

The primary means used to obtain shallow seabed data was the Cone Penetration Test (CPT). The CPT is a steel rod that is instrumented with load cells and pressure transducers to measure the tip stress, side friction and pore water pressure as the rod is pushed into the soil at a constant rate. The data are recorded electronically at 50 mm depth intervals, providing a near-continuous log of the soil response. The soil stratigraphy and a number of geotechnical parameters can be inferred from the data obtained from the CPT. The investigations also included sampling using a thick-walled tube sampler, and in-situ vane tests to provide alternative measurements of the seabed shear strength.

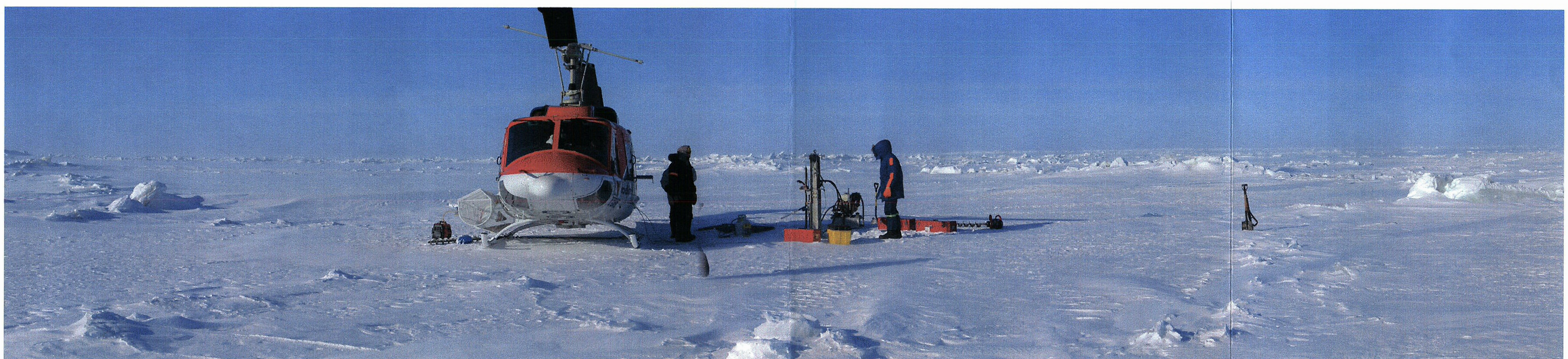
The base for the investigations was Inuvik. All equipment and the field crew were transported daily to each site by a Bell 212 helicopter. Panoramic photographs showing the geotechnical investigation set up at both Nipterk and Tuwak are shown on the next page.

1.2 Authorization

This work was undertaken under a Consulting Technical Services Agreement with Devon Canada Corporation. The Devon Canada representative was Mr. Bill Scott. Regulatory approvals were arranged by Mr. Bill Livingstone of Devon Canada.

A Geotechnical Operation Authorization (Operation Identifier No. 9438-D31-1E) was received from the National Energy Board on March 25, 2003. Approval for the geotechnical investigation (Submission # 02/03-01) was received from the Environmental Impact Screening Committee on March 21, 2003.

2003 April 11 – CPT03-06 – Nipterk
Nipterk panorama



2003 April 13 – CPT03-09 – Tuwak
Tuwak panorama

2. GEOTECHNICAL INVESTIGATIONS

2.1 Objectives

The objective of this investigation was to obtain soil strength information using the CPT from the mudline to a depth of 8 m or to an undrained shear strength (Su) of 50 kPa, whichever was reached first. The practical depth of investigation by pushing the CPT rods without a supporting casing was limited by the potential to buckle and break the rods. The actual depth of the soundings ranged between 2.4 m and 5.6 m below mudline. The target undrained shear strength of 50 kPa was exceeded in every sounding except CPT03-03, where the sounding depth was limited due to very high side friction on the rods and concern that the hydraulic ram would not be able to pull the rods back out of the soil. Several of the soundings exceeded 100 kPa undrained strength.

2.2 Locations and Site Conditions

A total of 9 CPT soundings were conducted at 8 sites. CPT03-01 and CPT03-02 were conducted at the same location in the Paktoa area. The tip channel on the CPT was not functional for CPT03-01, and a second sounding, CPT03-02, was done immediately adjacent to obtain the required data. The locations of the investigations are shown on Figure 1. Plots of the CPT soundings are included in Appendix I.

The CPT sounding locations[1] are summarized in Table 2.1. The water depths and ice thicknesses are summarized in Table 2.2. Additional holes were drilled through the ice approximately 50 m to 60 m from the CPT holes at the Nipterk sites to obtain additional ice thickness data. These measurements are also reported in Table 2.2.

[1] Although borehole coordinates are reported to the nearest metre, this is not intended to imply a degree of accuracy. The coordinates were obtained using a handheld GPS and verified by the helicopter GPS. The horizontal accuracy of the 12 channel GPS used is reported to be approximately 15 m.

With the exception of one test hole near CPT03-07 in the Nipterk area where the ice thickness was 2.20 m, the ice thickness ranged between 1.40 m and 1.65 m thick. The median ice thickness was 1.50 m. The distance from the ice surface to the water surface ranged from 50 mm to 160 mm with a median value of 80 mm.

2.3 Site Access and Equipment

Access to the drill sites was by Bell 212 helicopter operated by Canadian Helicopters from Inuvik. The field crew included Scott Martens from Klohn Crippen who led the investigation program, Jamie Sharp and Aaron Muir from ConeTec Investigations who operated the CPT, vane shear and sampling equipment, and two local assistants from Kavik Axys who were responsible for wildlife monitoring and general support to the program.

The time at each work site was limited by the maximum duty day for the helicopter pilot of 14 hours, which included preparation and shutdown time. The return flight from Inuvik to the well sites was approximately 3 hours, including the time for a fuel stop each way.

Table 2.1 Borehole Locations

Borehole	Site	Date	Sample Hole	Borehole Coordinates						Depth Below Mudline	
				NAD27		UTM NAD27		UTM NAD83		CPT	Sample Hole
				latitude (N)	longitude (W)	N (m)	E (m)	N (m)	E (m)	(m)	(m)
CPT03-01/02	Paktoa	8-Apr-03	yes	69° 39' 01"	136° 27' 43"	7727371	443261	7727540	443151	5.51/4.93	3.05
CPT03-03	Paktoa	12-Apr-03	yes	69° 37' 35"	136° 28' 32"	7724731	442659	7724900	442549	4.64	2.89
CPT03-04	Paktoa	12-Apr-03	no	69° 34' 25"	136° 25' 18"	7718791	444619	7718960	444509	4.30	-
CPT03-05	Paktoa	7-Apr-03	yes	69° 35' 19"	136° 11' 21"	7720270	453715	7720439	453605	5.60	2.43
CPT03-06	Nipterk	11-Apr-03	yes	69° 45' 23"	135° 29' 40"	7738625	480897	7738794	480787	3.32	1.22
CPT03-07	Nipterk	11-Apr-03	yes	69° 45' 03"	135° 30' 00"	7737989	480677	7738158	480567	3.53	2.13
CPT03-08	Kekertak	13-Apr-03	yes	69° 51' 58"	133° 46' 08"	7751271	547286	7751440	547176	2.36	2.74
CPT03-09	Tuwak	13-Apr-03	yes	69° 44' 03"	133° 33' 41"	7736736	555606	7736905	555496	5.50	2.74

Table 2.2 Water Depth and Ice Thickness

Borehole	Site	Date	Location Relative to CPT Hole	Water Depth (m)	Ice Thickness (m)	Ice Surface to Water Line (m)
CPT03-01/02	Paktoa	8-Apr-03	-	12.46	1.65	0.08
CPT03-03	Paktoa	12-Apr-03	-	11.94	1.50	0.07
CPT03-04	Paktoa	12-Apr-03	-	9.67	1.45	0.08
CPT03-05	Paktoa	7-Apr-03	-	7.57	1.63	0.08
CPT03-06	Nipterk	11-Apr-03	-	9.92	1.43	0.08
CPT03-06	Nipterk	11-Apr-03	north 50 m	9.81	1.46	0.09
CPT03-06	Nipterk	11-Apr-03	east 50 m	9.95	1.45	0.09
CPT03-06	Nipterk	11-Apr-03	south 50 m	9.87	1.42	0.05
CPT03-06	Nipterk	11-Apr-03	west 50 m	10.14	1.44	0.08
CPT03-07	Nipterk	11-Apr-03	-	9.69	1.50	0.08
CPT03-07	Nipterk	11-Apr-03	south 60 m	9.54	2.20	0.16
CPT03-08	Kekertak	13-Apr-03	-	11.09	1.59	0.10
CPT03-09	Tuwak	13-Apr-03	-	7.53	1.59	0.12

The work included 5 field days, in addition to one standby day due to the helicopter being required by others due to an emergency, and a second due to poor visibility which prevented the helicopter from flying. The work schedule is summarized in Table 2.3.

Table 2.3 Work Schedule Summary

Date	Helicopter Time (hours)[2]	Site Time (hours)[3]
April 7	2.4	7.0
April 8	2.5	8.3
April 9	No site work – helicopter required on long-term contract	
April 10	No site work – insufficient visibility for helicopter flight	
April 11	2.4	8.0
April 12	2.6	7.0
April 13	2.3	7.7

[2] Only includes time when helicopter engine was running. Does not include refueling time.
[3] Only includes time on the ice. Does not include loading/unloading time in Inuvik and flight time.

The still-air temperatures ranged between approximately -15C and -25C during the work. Strong winds up approximately 70 km/h were present on some days during the work.

The CPT equipment was provided and operated by ConeTec Investigations Ltd. from Vancouver B.C. The CPT probe had a conical tip with an area of 15 cm^2, and a friction sleeve with an area of 225 cm^2. Porewater pressure was measured at a piezometer element immediately above the cone tip. Data were recorded at 50 mm depth intervals. The rod diameter for approximately 3 m above the cone tip was 38 mm; 54 mm diameter rods were used above this to provide greater resistance to buckling during pushing.

The primary equipment required to operate the CPT included the following:

- hydraulic ram in an aluminum frame (the "ramset");
- hydraulic power pack (gasoline engine) and hydraulic reservoir;
- data acquisition computer, and;

- gasoline generator.

In addition to the CPT equipment, ConeTec provided apparatus for in-situ vane shear testing and tube sampling.

A 150 mm diameter, gasoline powered solid-stem auger was used to drill through the ice to allow access to the seabed.

Photographs of the equipment in operation are included in Appendix II. A detailed description of the CPT apparatus and a complete list of equipment are contained in the ConeTec report in Appendix III.

The total weight of the drilling equipment was approximately 1500 lbs. The total helicopter payload including the field crew but not including the helicopter pilot and fuel was approximately 2500 lbs. The heavy load required that the helicopter make a fuel stop at a fuel cache enroute to the investigation sites and on the return flight.

2.4 Investigation Procedures

A 150 mm diameter hole was drilled through the ice using the ice auger. The hydraulic ramset was set over the ice hole and bolted to the ice using four to six ice screws. The CPT probe was temperature equalized for 10 minutes at 2.5 m below the water surface. The CPT sounding was started approximately 1 m above the seabed to ensure so that tip stress and pore pressure data were obtained prior to entering the soil. These data were compared to the calculated water pressure at the mudline and used to temperature-correct the data. This temperature correction was likely necessary due to temperature changes between the upper and lower seawater.

Separate holes were drilled through the ice for collecting soil samples and performing vane shear tests. Where two sample tubes were pushed at one site, both tubes were pushed through the same hole. The sampler was then lowered through the hole in the seabed remaining from the first sample run.

Samples were obtained using a thick-walled tube sampler adjacent to the CPT holes, with the exception of CPT03-04, where time constraints did not permit soil sampling. The sampler was pushed into the soil using the hydraulic ram. Depending on the available time at the site, either one or two sample runs were performed. Samples were obtained in 1.2 m long plastic tubes with a 38 mm inner diameter, which were sealed on-site. The samples were extruded and logged in the Klohn Crippen laboratory in Calgary.

The samples recovered from the thick-walled tube sampler were subject to some disturbance during sampling and shipping, and the strengths interpreted from the lab vane are likely less than the in-situ strength of the soils. The lab vane values are plotted on the data summary figures in Appendix I to show the general trend of strength but should not be considered a reliable estimate of the actual strength of the soil deposit.

3. SUBSURFACE CONDITIONS

3.1 General

The soil within the depth of investigation typically comprised medium to high plastic, silty clay. The clay was very soft near the seabed but rapidly increased in stiffness with depth. The clay was dark olive grey, with occasional thin, very dark grey organic layers. Individual shells were occasionally found within the soil matrix.

The clays recovered in the sample tubes were typically massive. Portions of the samples from CPT03-07 and CPT03-08 were fissile with beds dipping up to 15° from the horizontal. Because it was not possible to monitor the verticality of the drill string at the mudline, the dip noted in the samples may not reflect the true dip of the sediments.

Descriptions of the soil samples recovered are provided on the logs on the CPT summary sheets in Appendix I.

3.2 CPT Data Interpretation

The CPT data, including an interpretation of the undrained shear strength, are provided on Figures I-01 to I-09 in Appendix I. The CPT data plotted on these Figures are:

- q_c – recorded tip stress
- q_t – tip stress corrected for unequal end area
- f_s – sleeve friction
- Rf – friction ratio
- U – dynamic porewater pressure
- Su – undrained shear strength (interpreted)
- SBT – soil behaviour type (interpreted)

Plots of the CPT data are also provided in the ConeTec Investigations report, which is included in Appendix III. These plots show the raw data and interpreted parameters. The Klohn Crippen plots in Appendix I show similar results, but include corrections for temperature effects on the pressure transducers, which were not included in the ConeTec plots.

The undrained shear strength is estimated from the CPT data using Equation (1):

$$S_u = \frac{q_t - \sigma_v}{N_{kt}} \qquad (1)$$

In order to apply Equation (1) to estimate the undrained shear strength from the CPT data, the total vertical stress and the N_{kt} factor must be estimated.

An average soil unit weight of 18.5 kN/m^3 was assumed to calculate the total vertical stress. Weaver and Poplin (1997) note that the water column is dominated by a wedge of fresh water from the Mackenzie River with an average salinity in the range of 5 ppt to 2 ppt and an average temperature near 0°C. A thin layer of saline water is present near the seabed with a salinity in the range of 25 ppt to 30 ppt. Based on these data, an average unit weight of 9.94 kN/m^3 for the water above the seabed was calculated.

Previous investigators have recommended N_{kt} values in the range of 10 to 14 (Jefferies et al, 1985) or 15 (Weaver and Poplin, 1997). A N_{kt} factor of 14 was selected for the interpretation of the CPT data presented in this report.

The Soil Behaviour Type (SBT) is not an accurate prediction of the soil type based on grain size distribution, but is a guide to the behaviour of the soil in the immediate vicinity of the probe. The SBT is interpreted on the basis of the of tip stress (qt) and the friction ratio (Rf) from relationships proposed by Robertson (1990). The simplified (non-normalized) correlation was found to be more reliable for these shallow seabed sediments that the normalized correlation also proposed by Robertson (1990), and the SBT shown on the Figures in Appendix I is based on the simplified correlation.

3.3 Vane Shear Testing

In-situ vane tests were performed at the Paktoa (CPT03-01/02) and Nipterk (CPT03-07) sites using a large (100 diameter x 240 mm length) vane. This large vane size was chosen due to the anticipated low strength of the shallow clays and to reduce the relative effects of system friction in the results. The field vane results are plotted on the CPT data summary sheets in Appendix I. At the Nipterk site (CPT03-07), the soil strength at the test depth was too high to shear with the vane, and the undrained strength from the vane test plotted on Figure I-07 is a lower bound estimate of the actual strength. The in-situ vane test results correlate well with the CPT results.

3.4 Laboratory Testing

The laboratory testing program comprised 14 Atterberg limits tests and 25 water content tests. The Atterberg limits results are summarized on Figure 2. The test results are plotted together with the CPT data on Figures I-01 to I-09 in Appendix I. The samples were all medium to high plastic clay (CI-CH), with liquid limits ranging from 40% to 55%. Water contents ranged from 26% to 56% with a median of 38%. The liquidity indices ranged from 0.4 to 1.5 with a median of 0.68, indicating that the samples were normally to lightly overconsolidated. The water content data and liquidity indices should be treated with caution as the samples froze in the liner tubes and some migration of moisture within the soil likely occurred.

Where multiple Atterberg Limits were performed at one location, the typical pattern was for the soil below approximately 2 m below mudline to be less plastic than the surficial soil layer. The exception to this trend was at Tuwak (CPT03-09) where the sample taken from 0.9 m depth was less plastic than the two deeper samples.

4. REGIONAL SETTING

The surficial geology in the Canadian Beaufort Shelf regions is generally well described as a result of the seismic and geotechnical programs conducted for previous exploration drilling. The near-surface seabed soils have been influenced by the sediment outflow from the Mackenzie River delta system, and have been reworked by wave and current action and by ice scouring.

The shelf has been subdivided into a number of physiographic regions, based on the physical properties of the surficial sediments. These regions are highlighted in Figure 1, and consist of a series of submerged plateaus and troughs, with a trend to more finer grained sediments to the west (O'Connor 1980, 1982). In general terms, the plateaus have coarser grained sediments and high strength silts and clays and thus provide better foundation conditions for drilling platforms. In the trough regions, greater depths of soft silts and clays are evident near surface, particularly in the Mackenzie trough to the west.

Generalized conditions for the relevant physiographic regions are summarized as follows:

Mackenzie Trough

The Mackenzie Trough underlies most of the southwestern portion of the Devon block including the Paktoa site. The surficial sediments within this depression consist of up to 30 m of soft to firm silts and clays, which have probably been deposited within the last 25,000 years and are geologically very young.

Kringalik Plateau

The Kringalik Plateau appears to have been subjected to different geologic processes during deposition. The upper sediments consist of soft to stiff silty clays that vary in thickness from 0 m to 14 m. These soft clays are underlain by a sequence of stiff to very stiff silts and clays. The Nipterk site is located on the boundary between the Kringalik Plateau and the Ikit Trough.

Ikit Trough

The Ikit Trough is a bathymetric depression between the Akpak and Kringalik plateaus. The surficial geology is made up of a sequence of inter-layered clayey silt and silty clay strata. The sediments, which are very-soft to soft at the surface, become stiff to hard below about 16 m.

Akpak Plateau

The Akpak Plateau is geologically complex. The western part of the Plateau comprises a sequence of sands, silts and clays over a thick sand unit, which the central area contains up to 14 m of surficial clayey silt. Along the eastern edge, sands and gravel up to 5 m in thickness have been encountered at the seabed. Where sands are encountered, they are compact to very dense.

Kugmallit Channel

The Kugmallit Channel is a relatively narrow depression that extends northward from Kugmallit Bay to the edge of the continental shelf and underlies most of Devon eastern block. Both the Kekertak and Tuwak sites are located within the Kugmallit Channel. The stratigraphy is relatively uniform consisting mainly of silty clays overlying fine to medium sands. The sediments deposited in the channel range from very soft to firm clays.

The undrained strength profiles obtained from the CPT data during the Winter 2003 On-Ice investigations have been plotted on Figure 3 for the Paktoa sites in the Mackenzie Trough, on Figure 4 for the Nipterk sites on the edge of the Kringalik Plateau, and on Figure 5 for the Kekertak and Tuwak sites in the Kugmallit Channel.

Generally the data is consistent with the regional settings, showing low strength zones in the upper ice scoured marine silts and clays, and increasing undrained shear strengths with depth below mudline. The profile from the Kekertak site shows a more rapid increase in shear strength with depth, which is not so typical of regional conditions in the Kugmallit Channel. Additional site data will be required to confirm that the inferred undrained shear strength profile is representative of the seabed in this area.

5. CLOSURE

This report is an instrument of service of Klohn Crippen Consultants Ltd. The report has been prepared for the exclusive use of Devon Canada Corporation. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen. In this report, Klohn Crippen has endeavoured to comply with generally accepted geotechnical practice common to the local area. Klohn Crippen makes no other warranty, expressed or implied.

The conclusions contained in this report are based on data derived from a limited number of test holes obtained from widely spaced subsurface explorations. The methods used indicate subsurface conditions only at the specific locations where samples were obtained or where in-situ tests would infer, and only to the depths penetrated. The samples and tests cannot be relied on to accurately reflect the nature and extent of strata variations that usually exist between sampling or testing locations.

Respectfully submitted,

KLOHN CRIPPEN CONSULTANTS LTD.

Scott N. Martens, M.Eng., P.Eng.
Geotechnical Engineer

Brian T. Rogers, M.Sc., P.Eng.
Project Manager

APPEGA Permit #433

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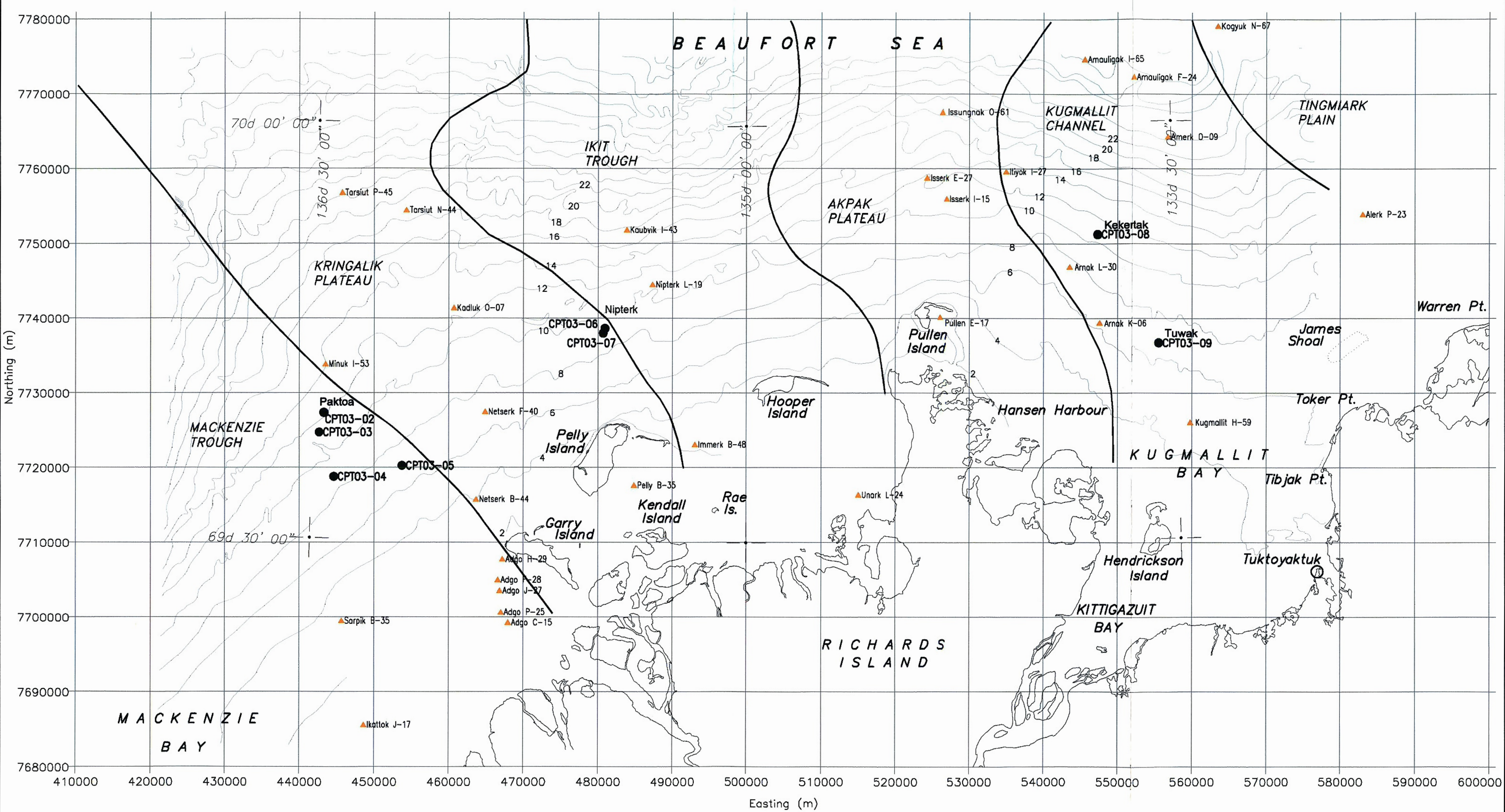
FIGURES



NOTES:

1. COORDINATES ARE UTM NAD27 ZONE 8
2. BATHYMETRY FROM DEVON NOVEMBER 2001.

LEGEND

● DEVON CANADA CPT SITES

▲ ABANDONED ISLAND SITES

SCALE 1:500 000 0 10 000 20 000

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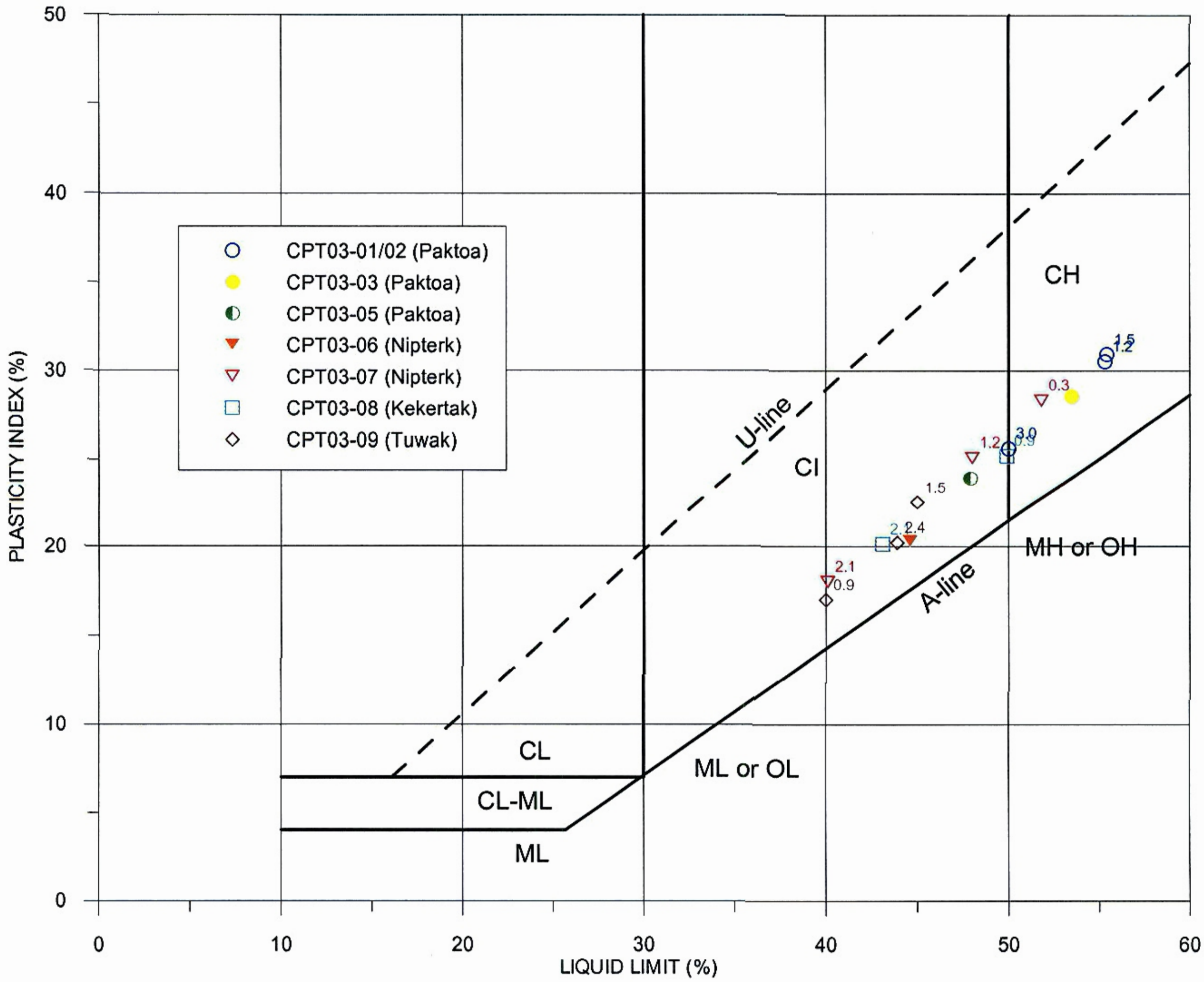
PROJECT	WINTER 2003 ON- ICE GEOTECHNICAL INVESTIGATION
TITLE	2003 CPT LOCATION PLAN
PROJECT No.	PA 2984.03
FIG. No.	Figure 1

2984.03 FIG-01.dwg

KCC-F-B-M



NOTES:
Depths below mudline are noted where multiple tests were done at one well location.

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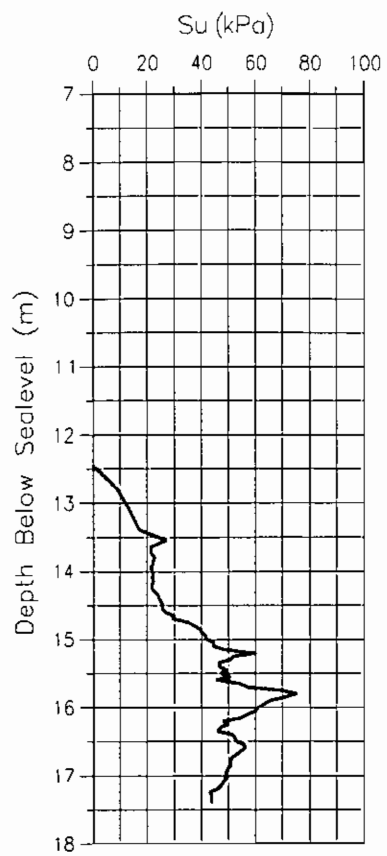
CLIENT	PROJECT
devon	WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION
KLOHN CRIPPEN	TITLE: ATTERBERG LIMITS SUMMARY

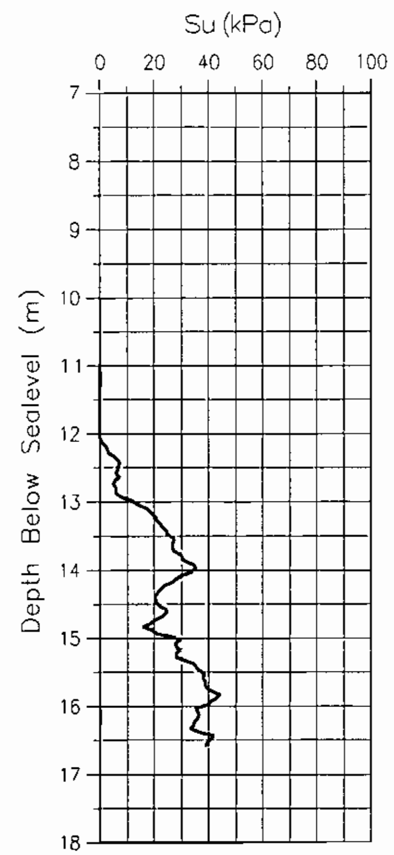
DATE	PROJECT No.	FIG. No.
MAY 2003	A02984.03	Figure 2

FIGURE 2 ATTERBERG LIMITS SUMMARY.GRF

A SIZE PORTRAIT.GRF



CPT03-02



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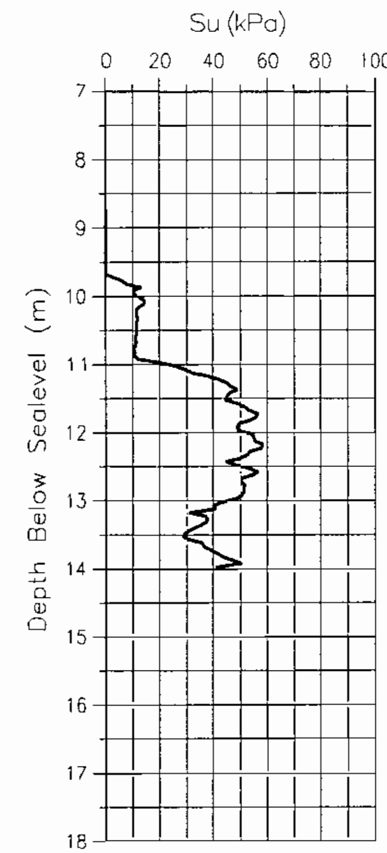

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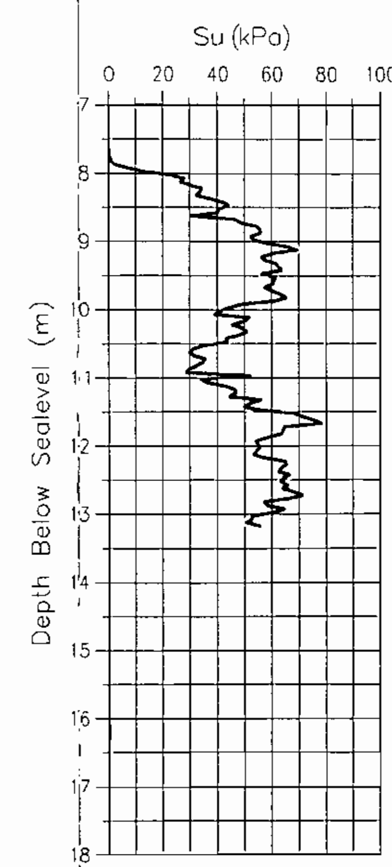

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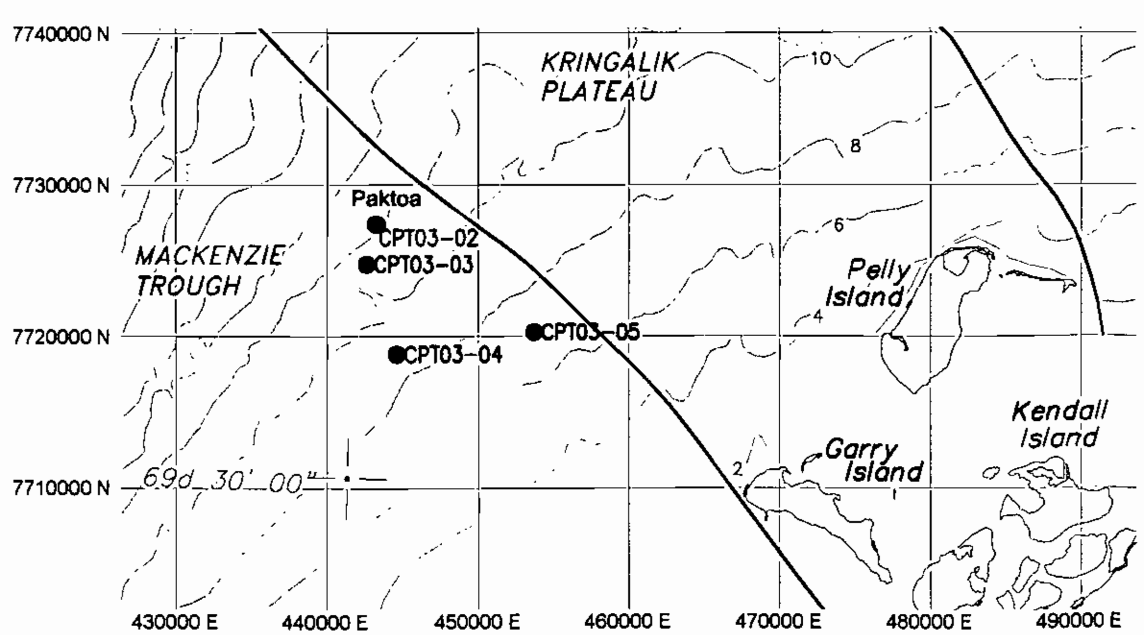


PLAN

NOTES:

1. THE UNDRAINED SHEAR STRENGTH (Su) IS AN INTERPRETED PARAMETER, ASSUMING $N_{KT}=14$, $\gamma_w=9.94$ kN/m³ AND $\gamma_{SAT}=18.5$ kN/m .
2. COORDINATES ARE UTM NAD27 ZONE 8
3. BATHYMETRY FROM DEVON NOVEMBER 2001.

TO BE READ WITH KLOHN CRIPPEN REPORT DATED MAY 2003

CLIENT: devon

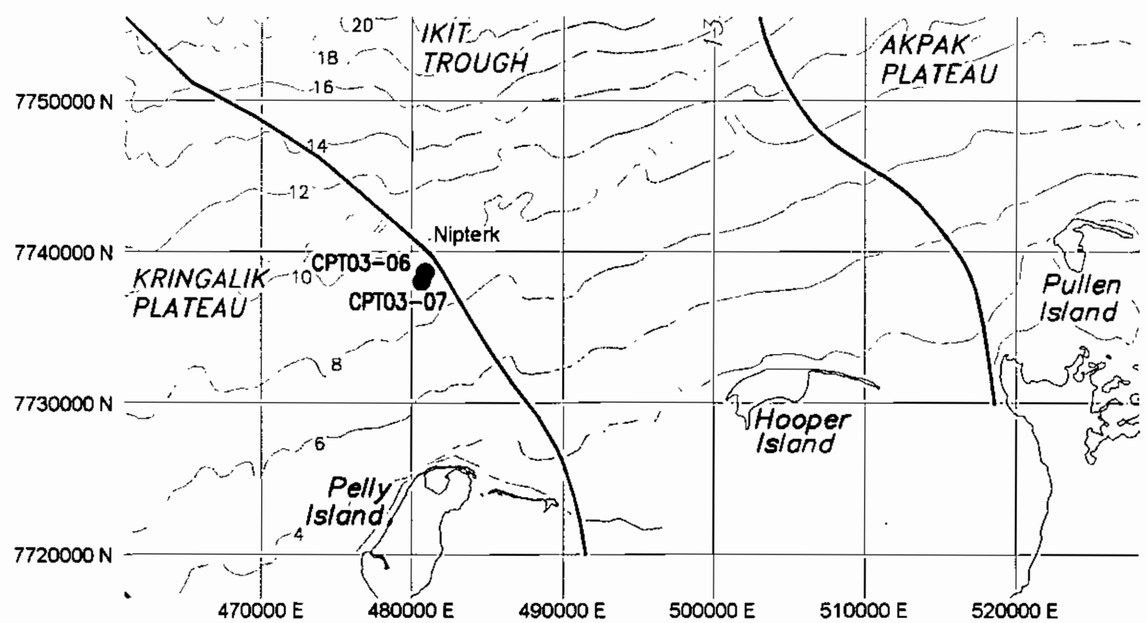
KLOHN CRIPPEN

PROJECT: WINTER 2003 ON - ICE GEOTECHNICAL INVESTIGATION

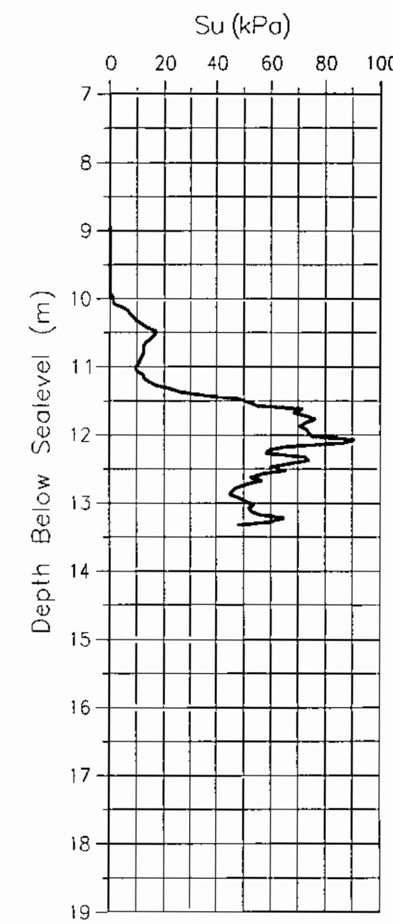
TITLE: SITE INVESTIGATION CPT DATA PAKTOA SITE

PROJECT No.: PA 2984.03

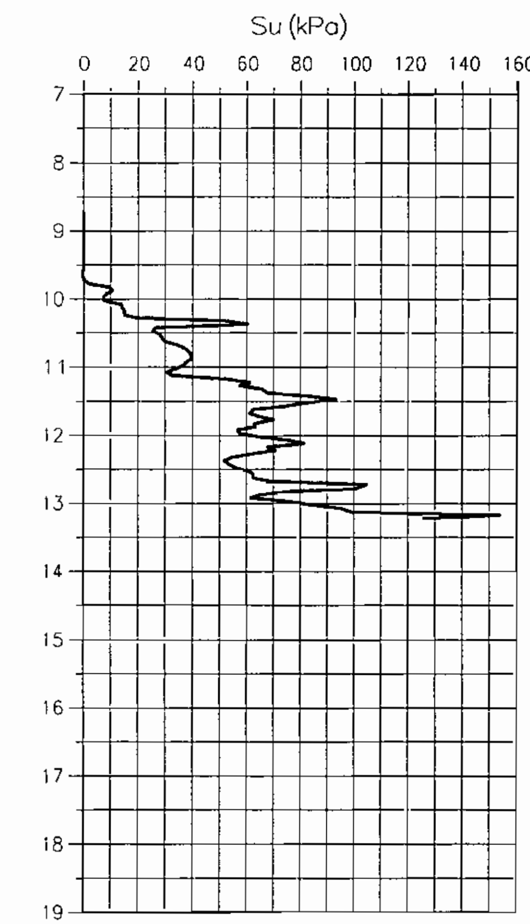
FIG. No.: Figure 3



PLAN



CPT03-06



CPT03-07

NOTES:

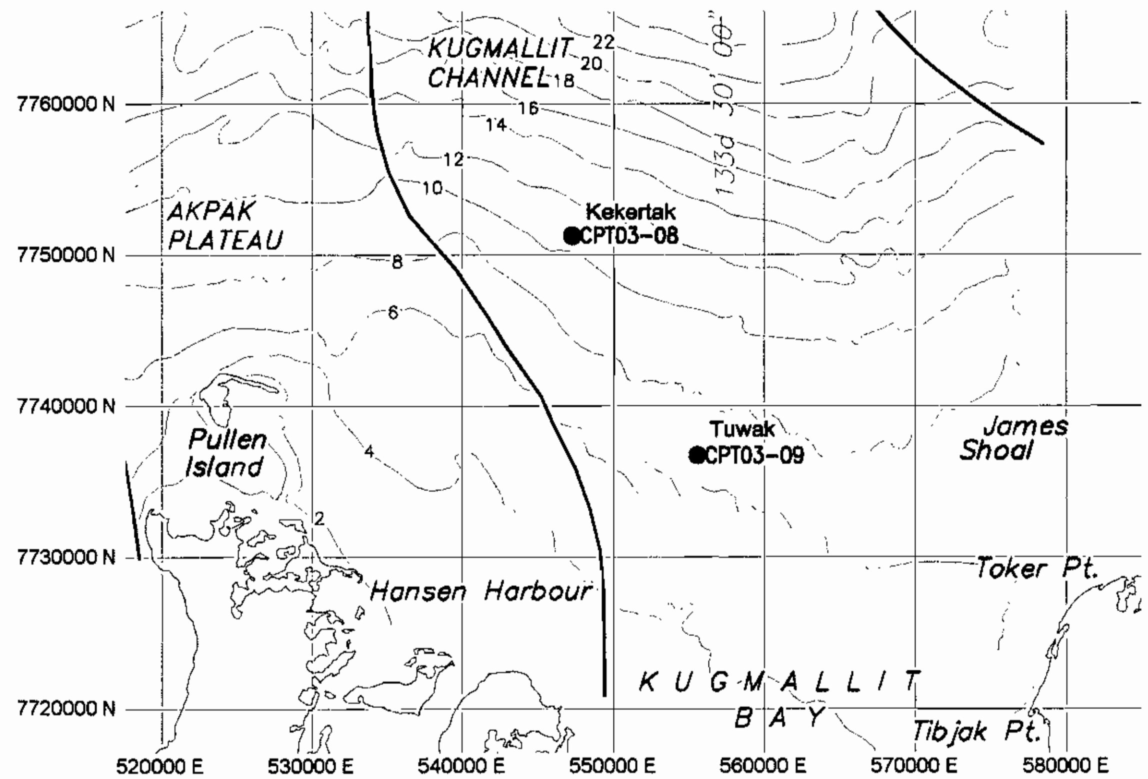
1. THE UNDRAINED SHEAR STRENGTH (Su) IS AN INTERPRETED PARAMETER, ASSUMING $N_{KT}=14$, $\gamma_w=9.94$ kN/m³ AND $\gamma_{SAT}=18.5$ kN/m .
2. COORDINATES ARE UTM NAD27 ZONE 8
3. BATHYMETRY FROM DEVON NOVEMBER 2001.

TO BE READ WITH KLOHN CRIPPEN REPORT DATED MAY 2003

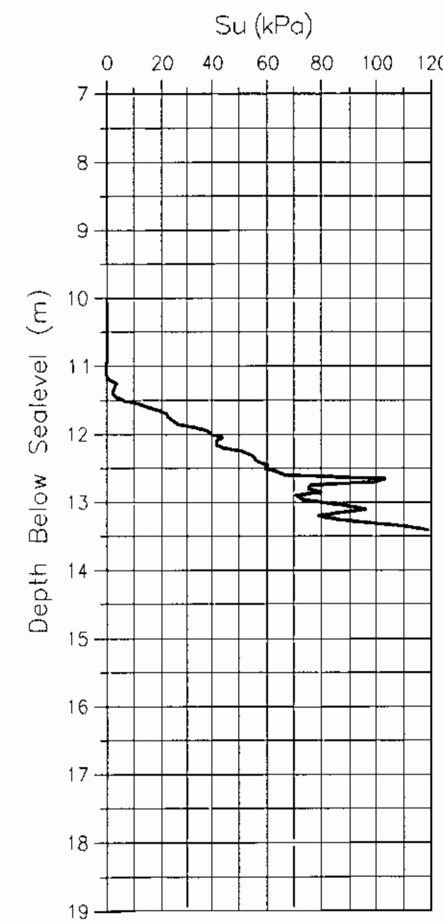
CLIENT: devon / KLOHN CRIPPEN	PROJECT	WINTER 2003 ON - ICE GEOTECHNICAL INVESTIGATION
	TITLE	SITE INVESTIGATION CPT DATA NIPTERK SITE
	PROJECT No. PA 2984.03	FIG. No. Figure 4

2984.03.FIG-04.dwg

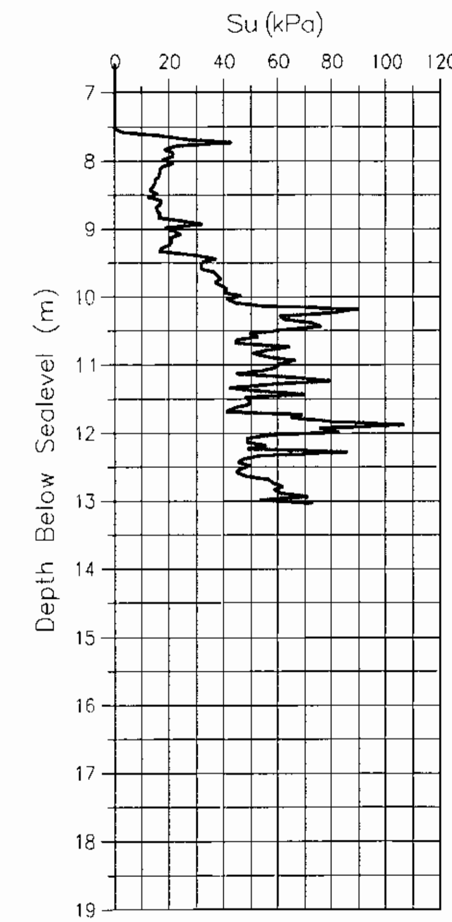
KCC-F-B-M



PLAN



CPT03-08
KEKERTAK



CPT03-09
TUWAK

NOTES:

1. THE UNDRAINED SHEAR STRENGTH (Su) IS AN INTERPRETED PARAMETER, ASSUMING $N_{KT}=14$, $\gamma_W=9.94$ kN/m³ AND $\gamma_{SAT}=18.5$ kN/m .
2. COORDINATES ARE UTM NAD27 ZONE 8
3. BATHYMETRY FROM DEVON NOVEMBER 2001.

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CLIENT: devon

KLOHN CRIPPEN

PROJECT: WINTER 2003 ON - ICE GEOTECHNICAL INVESTIGATION

TITLE: SITE INVESTIGATION CPT DATA KEKERTAK AND TUWAK SITES

PROJECT No. PA 2984.03

FIG. No. Figure 5

2984.03.FIG-05.dwg

APPENDIX I

CPT Data And Borehole Logs

MODIFIED UNIFIED SOIL CLASSIFICATION SYSTEM

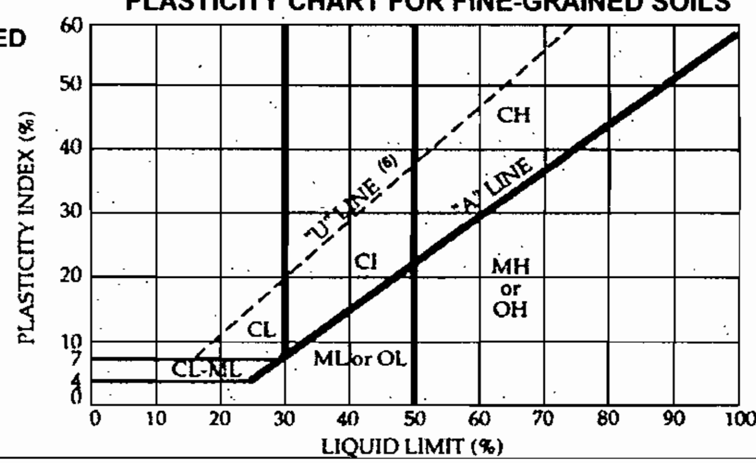
MAJOR DIVISION		GROUP SYMBOL	LOG SYMBOL	TYPICAL DESCRIPTION	LABORATORY CRITERIA: FINES (%)	GRADING	PLASTICITY	NOTES
COARSE-GRAINED SOILS (>50% BY WEIGHT RETAINED ON #200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN 4.75mm	GW		WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	0-5	$C_U > 4$ (1) $1 < C_C < 3$ (2)		DUAL SYMBOLS REQUIRED IF 5-12% FINES DUAL SYMBOLS REQUIRED IF ABOVE "A" LINE AND $4 < I_P < 7$
		GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	0-5	NOT SATISFYING REGUIREMENTS FOR GW (ABOVE)		
		GM		SILTY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	>12		BELOW "A" LINE or $I_P < 4$ (3)	
		GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	>12		ABOVE "A" LINE and $I_P > 7$	
	SANDS MORE THAN HALF COARSE GRAINS SMALLER THAN 4.75mm	SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	0-5	$C_U > 6$ $1 < C_C < 3$		
		SP		POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	0-5	NOT SATISFYING REGUIREMENTS FOR SW (ABOVE)		
		SM		SILTY SANDS, SAND-SILT MIXTURES	>12		BELOW "A" LINE or $I_P < 4$	
		SP		CLAYEY SANDS, SAND-CLAY MIXTURES	>12		ABOVE "A" LINE and $I_P > 7$	
FINE-GRAINED SOILS (>50% BY WEIGHT PASSING #200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY	$W_L < 50\%$ (4) and BELOW "A" LINE			SEE PLASTICITY CHART
		MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS	$W_L > 50\%$ and BELOW "A" LINE			
	CLAYS ABOVE "A" LINE NEGLIGIBLE ORGANIC CONTENT	CL		INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS	$W_L < 30\%$ and ABOVE "A" LINE			
		CI		INORGANIC CLAYS OF MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS	$30\% < W_L < 50\%$ and ABOVE "A" LINE			
		CH		INORGANIC CLAYS OF HIGH PLASTICITY	$W_L > 50\%$ and ABOVE "A" LINE			
	ORGANIC SILTS & CLAYS BELOW "A" LINE	OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW AND MEDIUM PLASTICITY	$W_L < 50\%$ and BELOW "A" LINE			
		OH		ORGANIC SILTS AND ORGANIC CLAYS OF HIGH PLASTICITY	$W_L > 50\%$ and BELOW "A" LINE			
HIGHLY ORGANIC SOILS		Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR AND ODOUR, AND OFTEN FIBROUS TEXTURE			

OTHER COMMON SOIL SYMBOLS

TOPSOIL

UNDIFFERENTIATED FILL

PLASTICITY CHART FOR FINE-GRAINED SOILS (5)



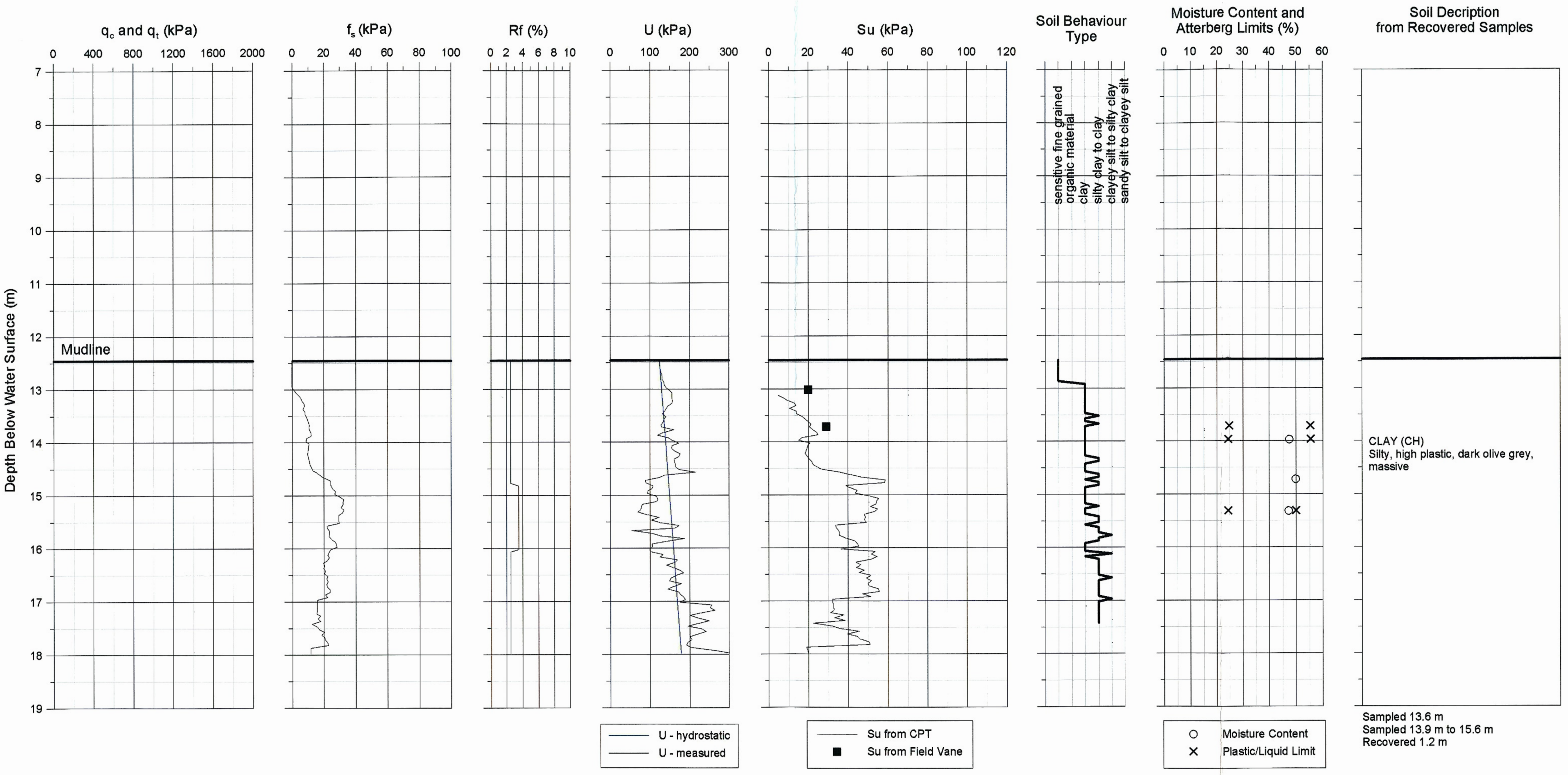
NOTES:

(1) $C_U = D_{60} / D_{10}$
(2) $C_C = (D_{30})^2 / (D_{60}D_{10})$
(3) I_P = Plasticity Index (%)
(4) W_L = Liquid Limit (%)
(5) This plasticity classification conforms to the Unified Soil Classification System (USCS)and the ASTM D-2487 plasticity chart, except for the addition of an intermediate catergory for clay where the liquid limit is between 30% and 50% (CI). Under ASTM and USCS, all clays with a liquid limit less than 50% are classified as low plasticity (CL).
(6) "U" Line marks typical upper limit
"A" Line divides clays from silts and organic soils

KLOHN CRIPPEN

SYMBOLS AND TERMS

FOR SOIL DESCRIPTIONS AND TEST HOLE LOGS



NOTES:

1. Tip channel not functional. Undrained strength estimated from sleeve friction and assumed friction ratio. SBT shown from adjacent CPT03-02.
2. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m³ and γ_{sat}=18.5 kN/m³.
3. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).

TO BE READ WITH KLOHN CRIPPEN REPORT DATED MAY 2003

CLIENT: devon

KLOHN CRIPPEN

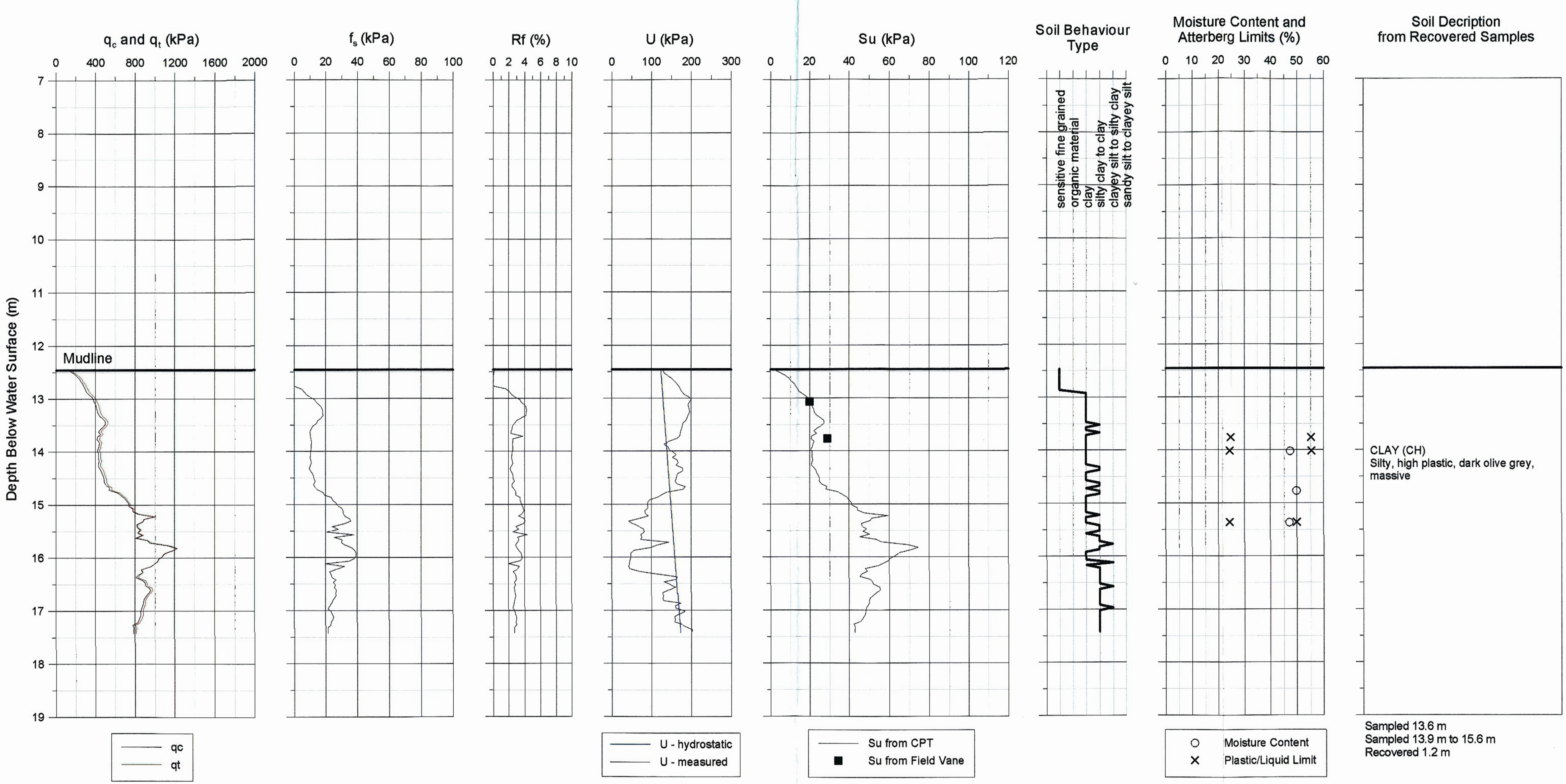
PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-01 DATA SUMMARY PAKTOA SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-01

CPT03-01 B size.grf



NOTES:

1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m³ and γ_{sat}=18.5 kN/m³.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).
3. The soil samples used for lab vane tests were likely disturbed. The lab vane strengths should be used only to indicate a general trend in soil strength.

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KLOHN CRIPPEN

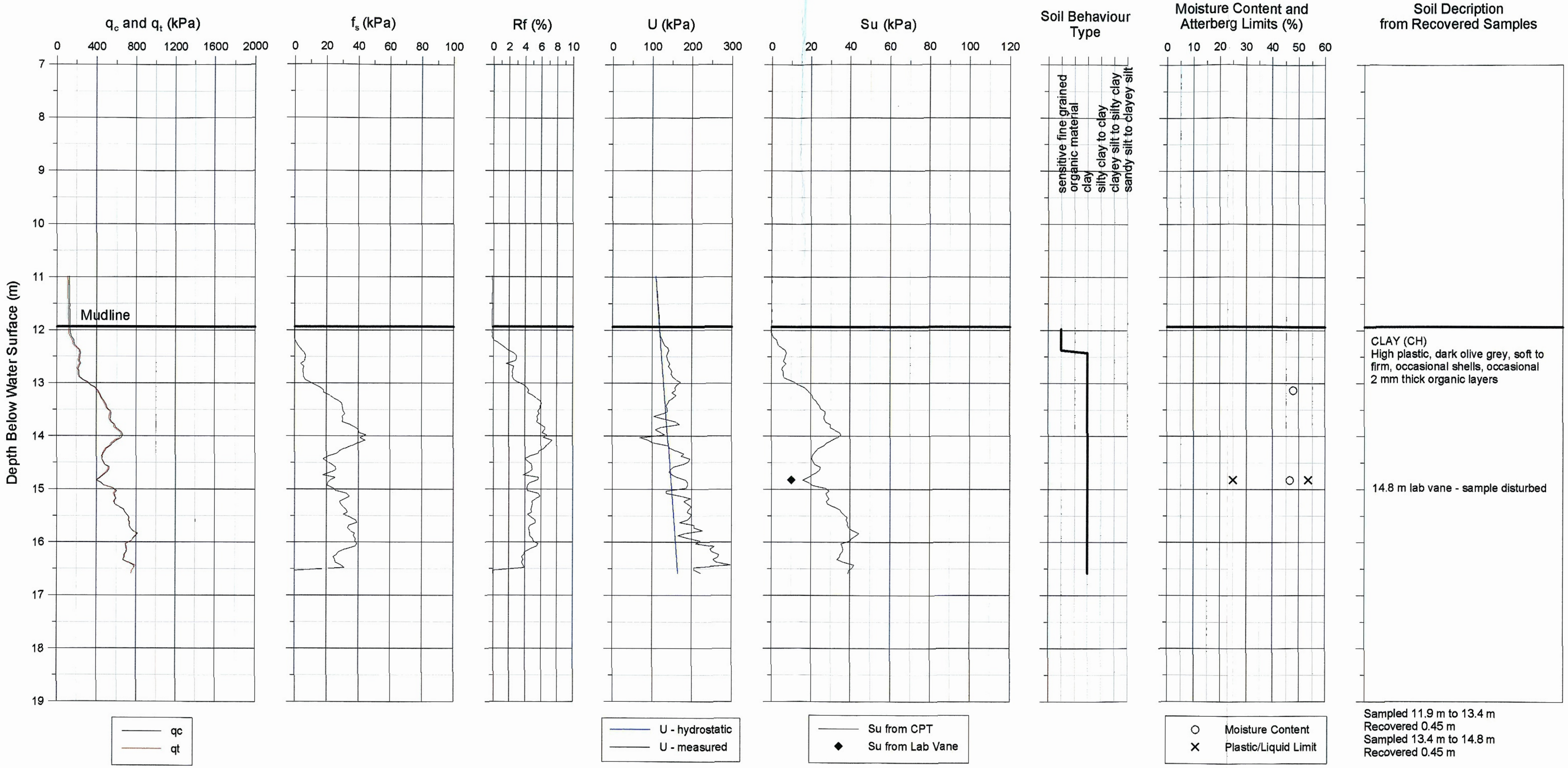
PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-02 DATA SUMMARY PAKTOA SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-02

CPT03-02 B size.grf



NOTES:

1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m³ and γ_{sat}=18.5 kN/m³.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).
3. The soil samples used for lab vane tests were likely disturbed. The lab vane strengths should be used only to indicate a general trend in soil strength.

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KLOHN CRIPPEN

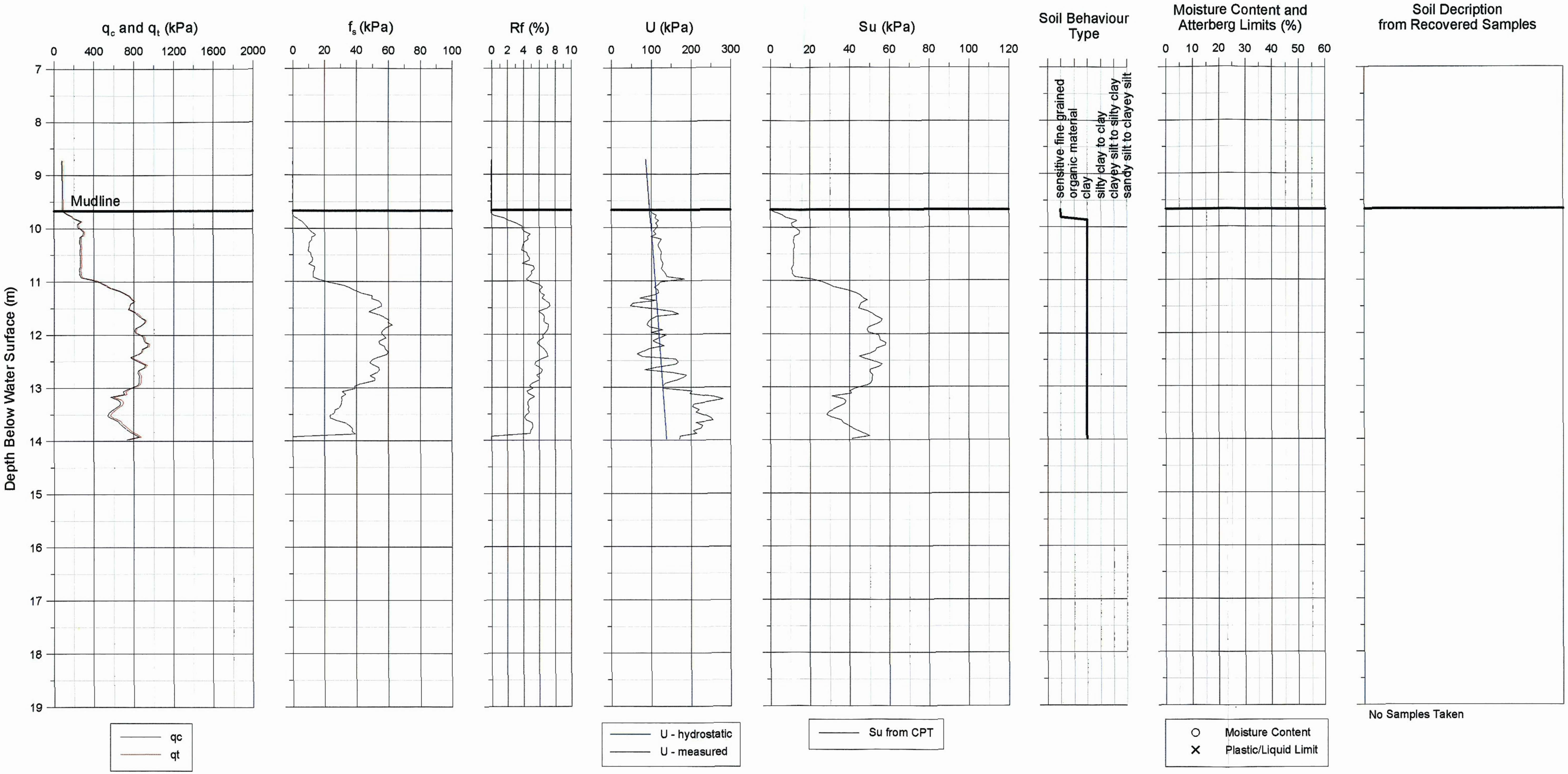
PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-03 DATA SUMMARY PAKTOA SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-03

CPT03-03 B size.grf



NOTES:

1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m^3 and γ_{sat}=18.5 kN/m^3.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).

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CLIENT: devon

KLOHN CRIPPEN

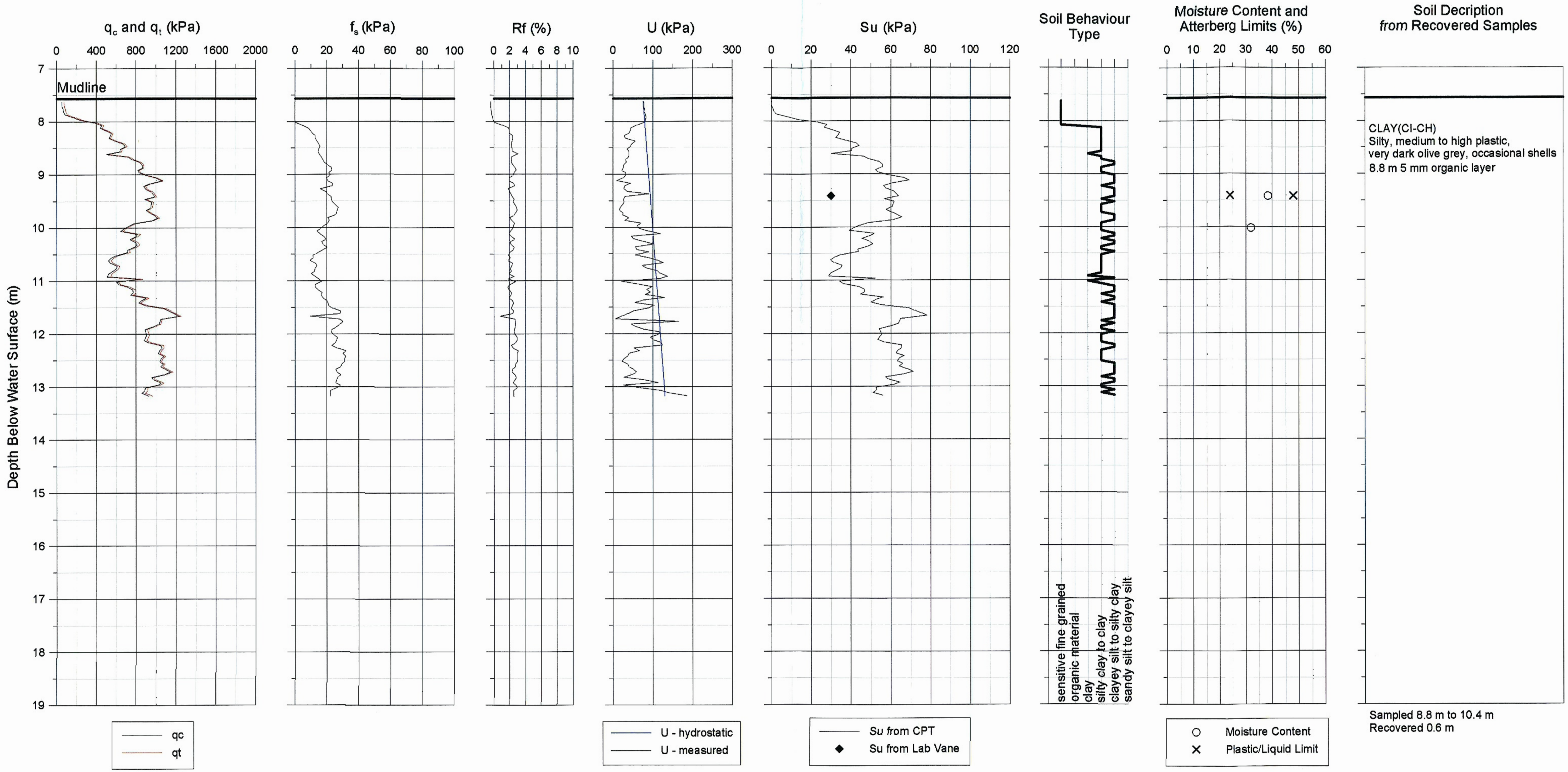
PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-04 DATA SUMMARY PAKTOA SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-04

CPT03-04 B size.grf



NOTES:

1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m³ and γ_{sat}=18.5 kN/m³.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).
3. The soil samples used for lab vane tests were likely disturbed. The lab vane strengths should be used only to indicate a general trend in soil strength.

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CLIENT: devon

KLOHN CRIPPEN

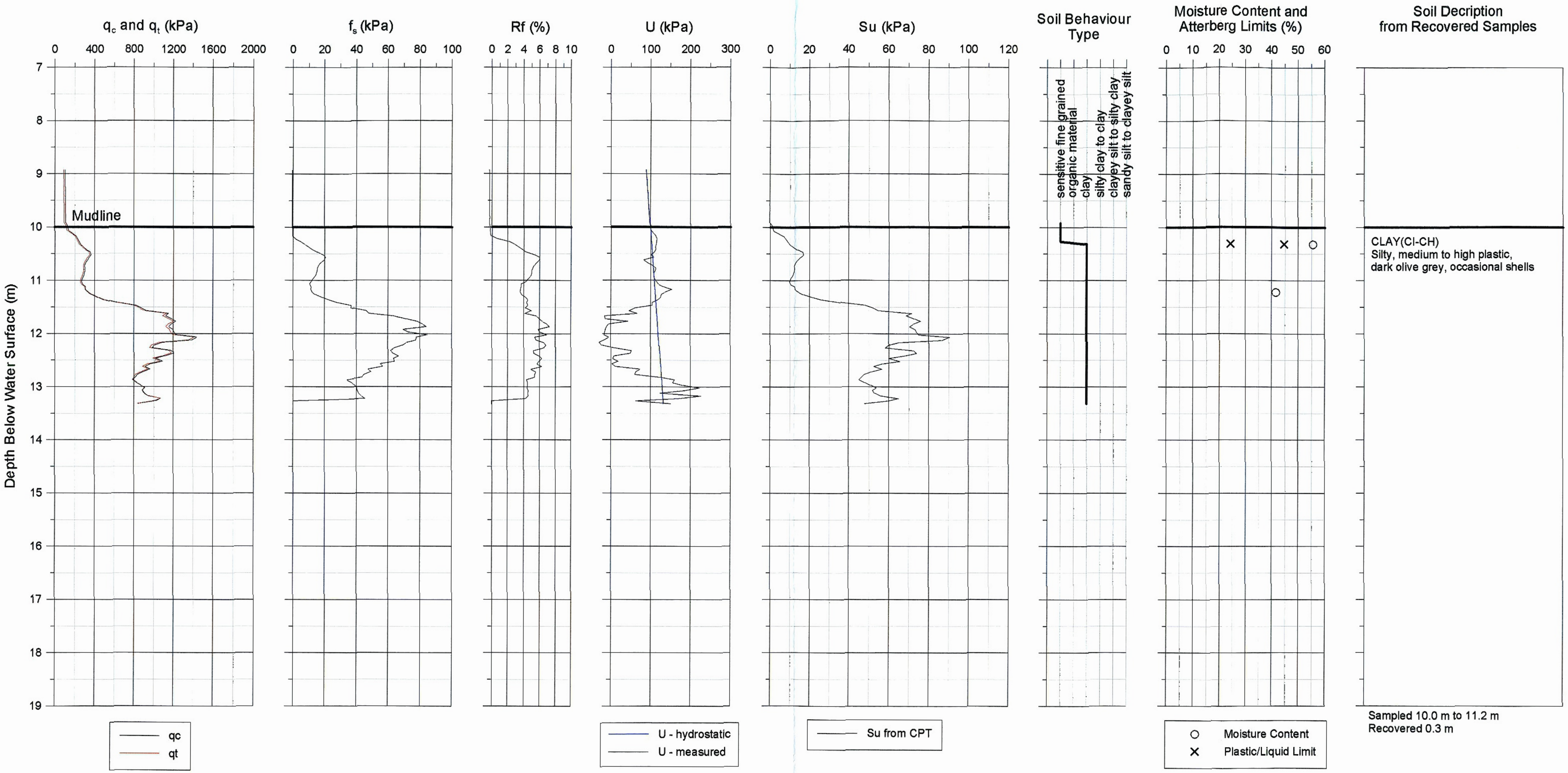
PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-05 DATA SUMMARY PAKTOA SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-05

CPT03-05 B size.grf



NOTES:
1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m³ and γ_{sat}=18.5 kN/m³.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).
3. The soil samples used for lab vane tests were likely disturbed. The lab vane strengths should be used only to indicate a general trend in soil strength.

CPT03-06 B size.grf

TO BE READ WITH KLOHN CRIPPEN REPORT DATED MAY 2003

CLIENT: devon

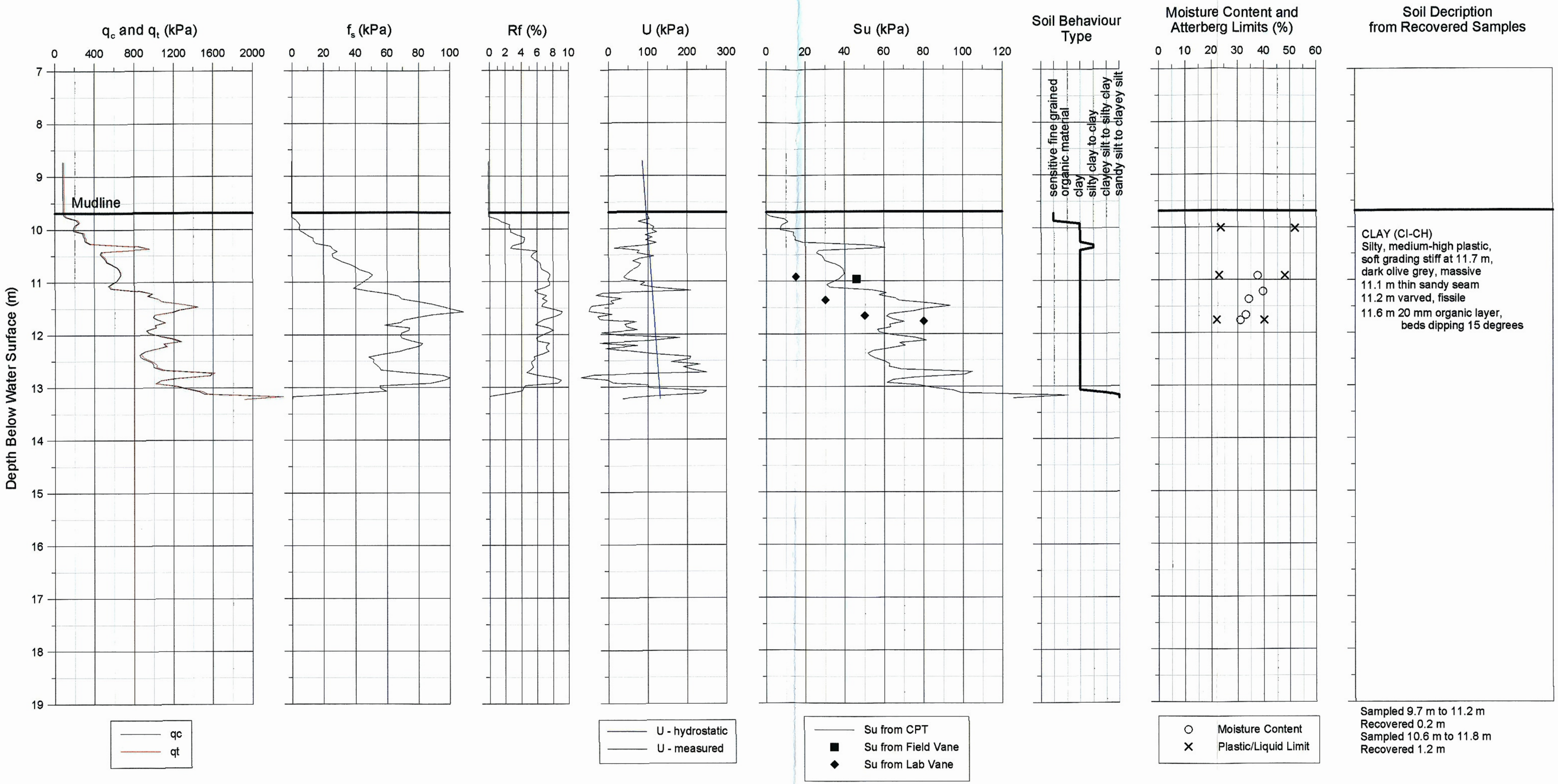
KLOHN CRIPPEN

PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-06 DATA SUMMARY NIPTERK SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-06



NOTES:

1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m^3 and γ_{sat}=18.5 kN/m^3.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).
3. The soil samples used for lab vane tests were likely disturbed. The lab vane strengths should be used only to indicate a general trend in soil strength.

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CLIENT: devon

KLOHN CRIPPEN

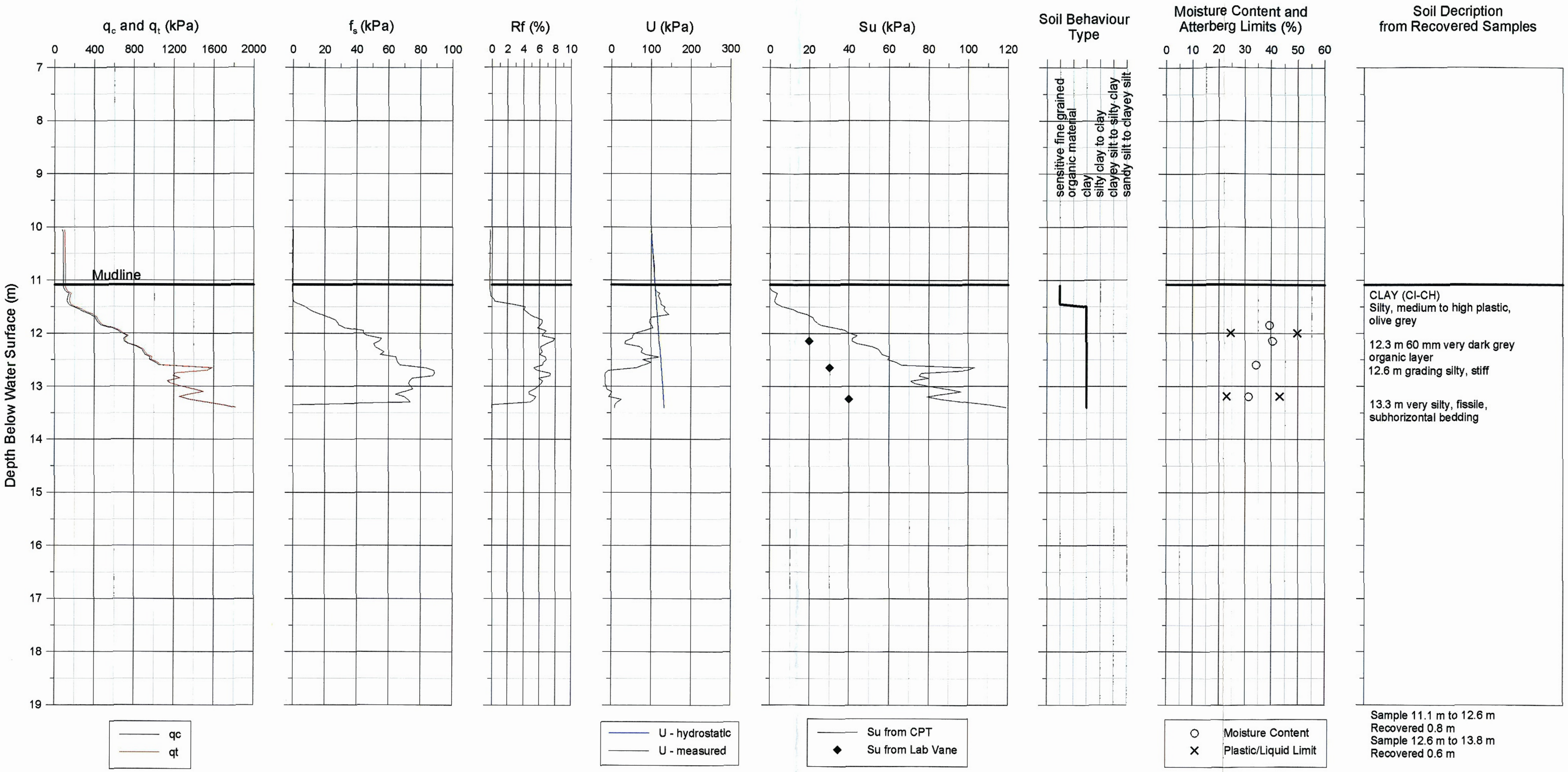
PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-07 DATA SUMMARY NIPTERK SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-07

CPT03-07 B size.grf



NOTES:

1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m³ and γ_{sat}=18.5 kN/m³.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).
3. The soil samples used for lab vane tests were likely disturbed. The lab vane strengths should be used only to indicate a general trend in soil strength.

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CLIENT: devon

KLOHN CRIPPEN

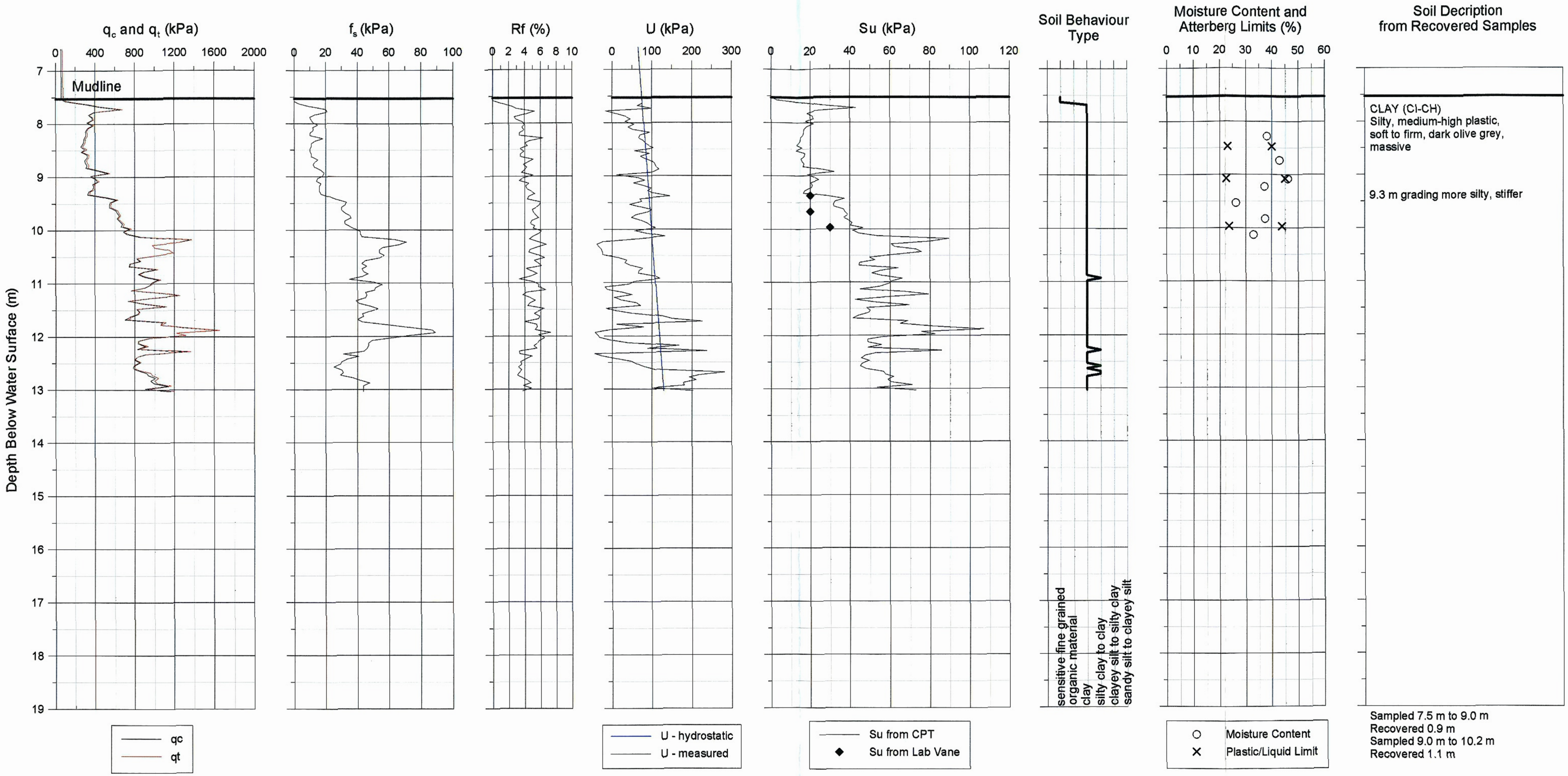
PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-08 DATA SUMMARY KEKERTAK SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-08

CPT03-08 B size.grf



NOTES:

1. The undrained shear strength (Su) was interpreted from the CPT data assuming N_{KT}=14, γ_w=9.94 kN/m³ and γ_{sat}=18.5 kN/m³.
2. The Soil Behaviour Type (SBT) interpreted from the CPT data is based on the relationships proposed by Robertson (1990).
3. The soil samples used for lab vane tests were likely disturbed. The lab vane strengths should be used only to indicate a general trend in soil strength.

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CLIENT: devon

KLOHN CRIPPEN

PROJECT: WINTER 2003 ON-ICE GEOTECHNICAL INVESTIGATION

TITLE: CPT03-09 DATA SUMMARY TUWAK SITE

PROJECT No. PA 2984.03

FIG. No. FIGURE I-09

CPT03-09 B size.grf

APPENDIX II

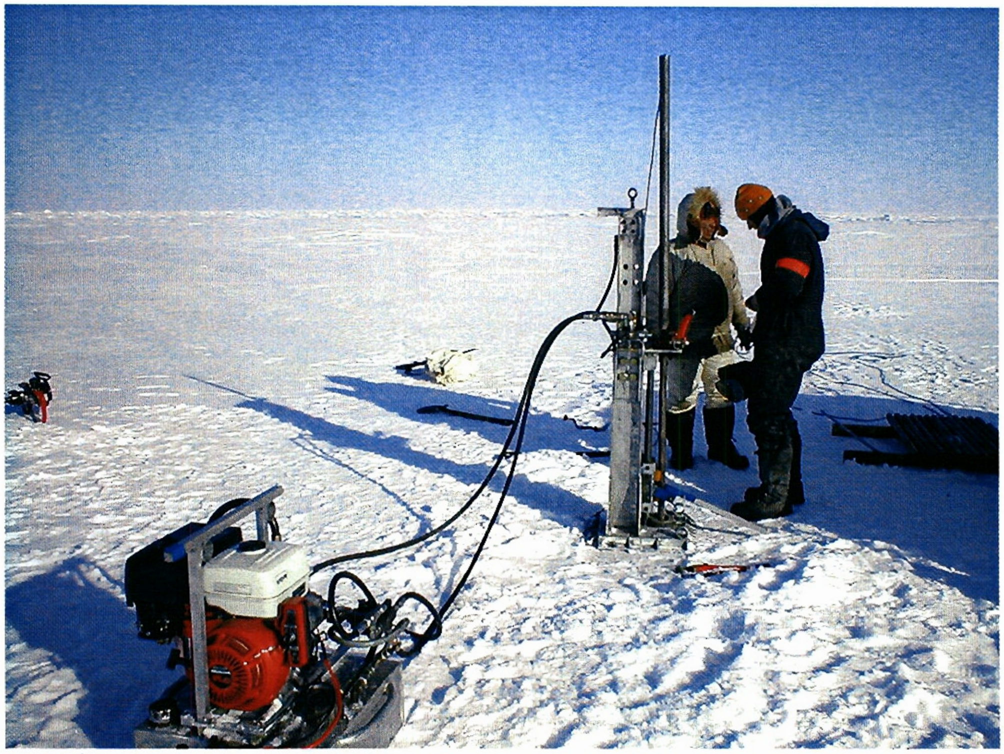
Site Photographs

2003 April 08 – CPT03-01/02 - Paktoa
CPT testing

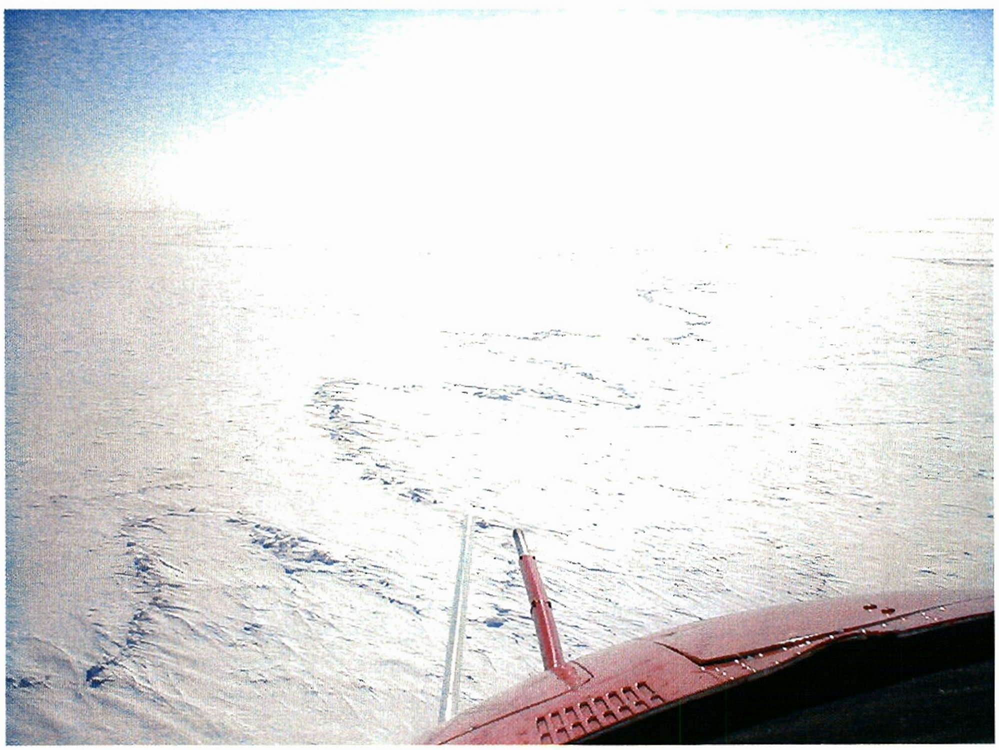
2003 April 08 – CPT03-01/02 - Paktoa
Wildlife monitor and ice ridges at Paktoa

2003 April 08 – CPT03-01/02 - Paktoa
Wildlife monitor and ice buoy near drill site

2003 April 12 – CPT03-03 - Paktoa
Ice conditions near drill site



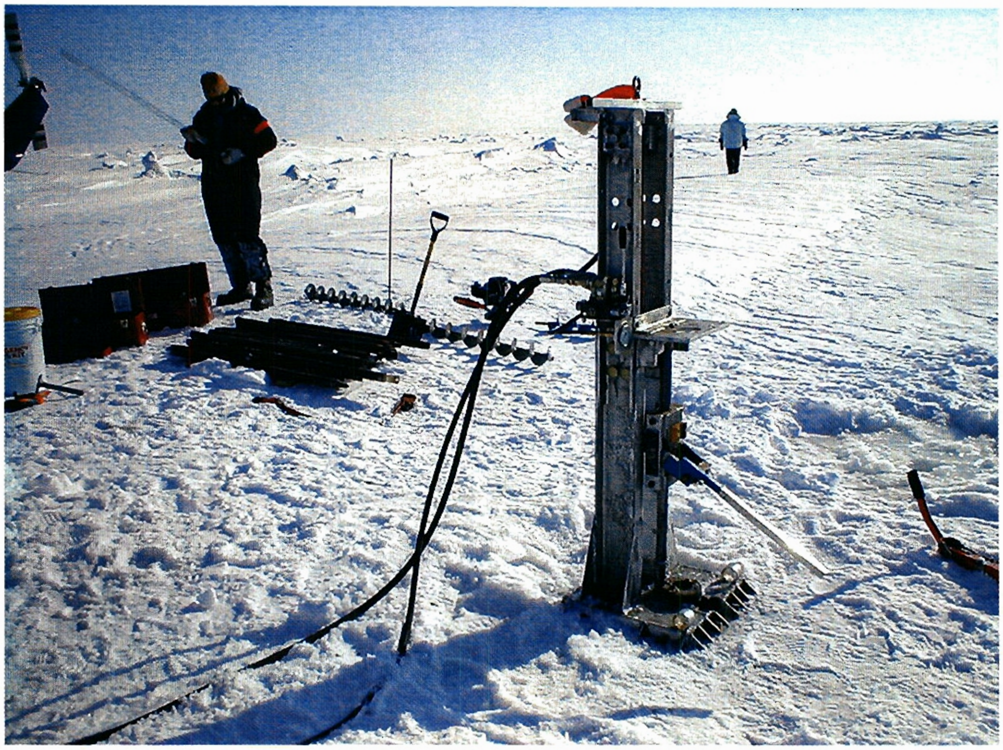
2003 April 12 – CPT03-03 - Paktoa
CPT setup



2003 April 12 – CPT03-04 - Paktoa
Ice conditions near drill site

2003 April 12 – CPT03-04 - Paktoa
Ice ridges near helicopter

2003 April 07 – CPT03-05 - Paktoa
Ramset and hydraulic power pack

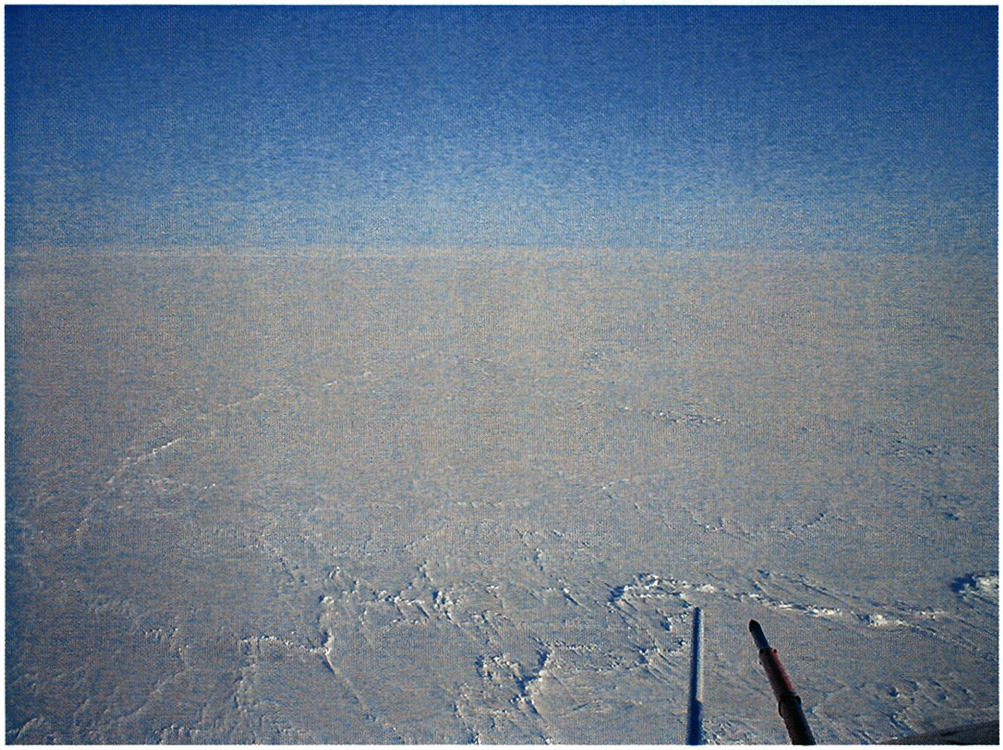


2003 April 07 – CPT03-05 - Paktoa
Ramset

2003 April 07 – CPT03-05 - Paktoa
Ice ridges

2003 April 07 – CPT03-05 - Paktoa
Data acquisition setup in tent with propane heater

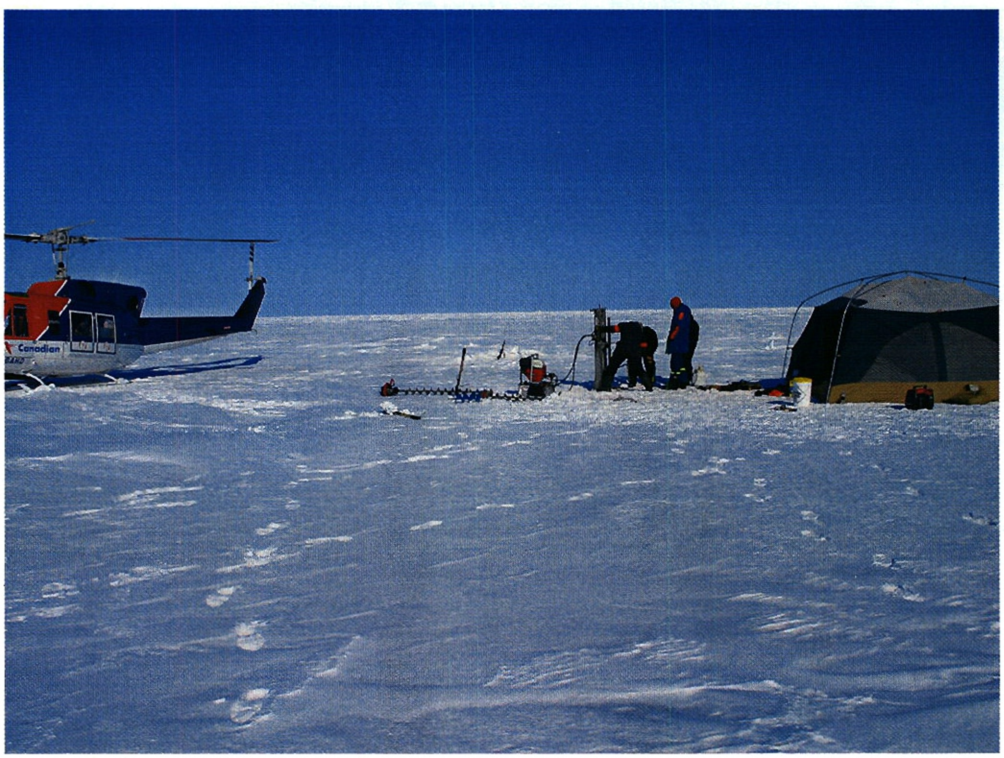
2003 April 07 – CPT03-05 - Paktoa
Work site with tent to shelter computer equipment



2003 April 11 – CPT03-06 - Nipterk
Ice conditions near drill site

2003 April 11 – CPT03-06 – Nipterk
Wildlife monitor and ice buoy near drill site

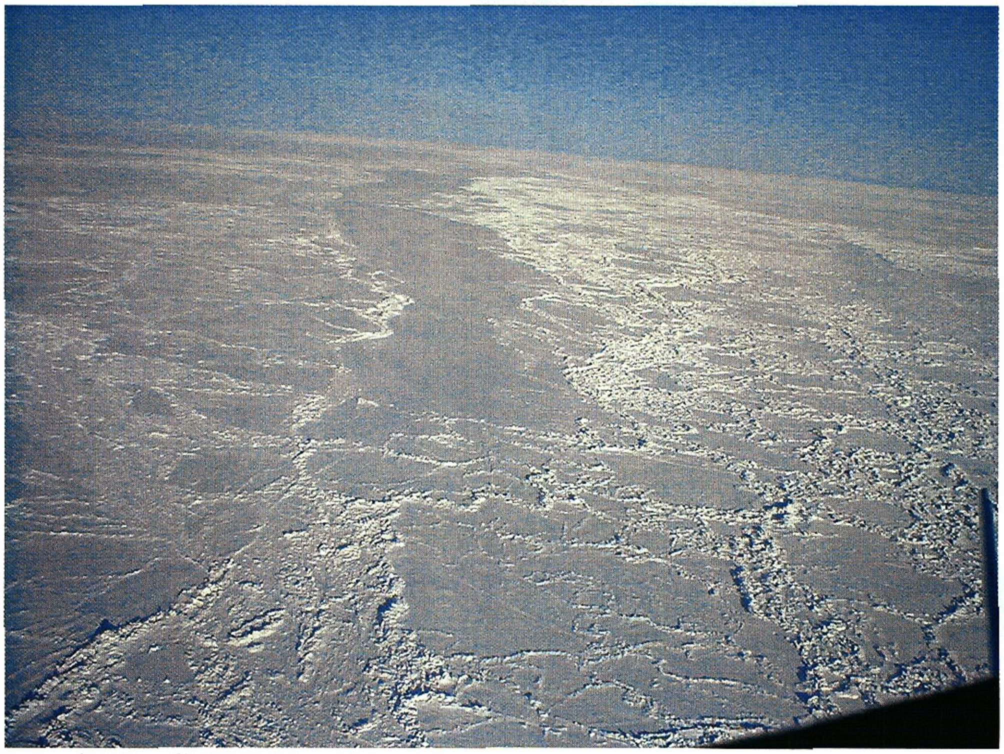
2003 April 11 – CPT03-06 – Nipterk
Ice auger location for additional ice thickness measurement



2003 April 11 – CPT03-06 – Nipterk
CPT setup

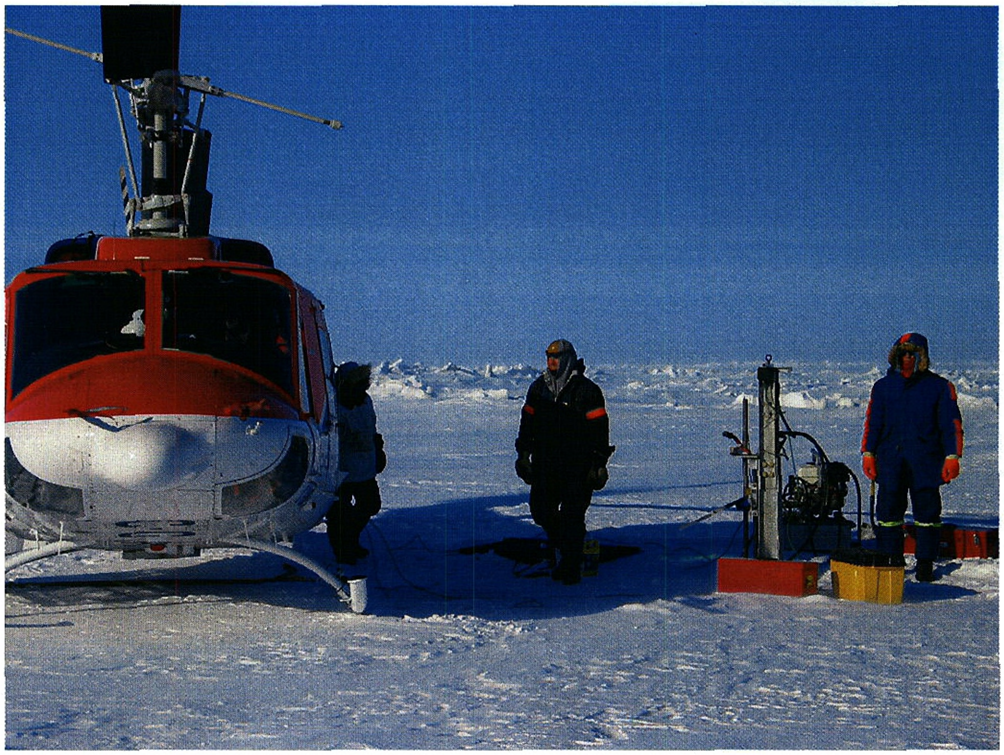
2003 April 11 – CPT03-07 – Nipterk
CPT setup

2003 April 11 – CPT03-07 – Nipterk
Augering additional ice holes

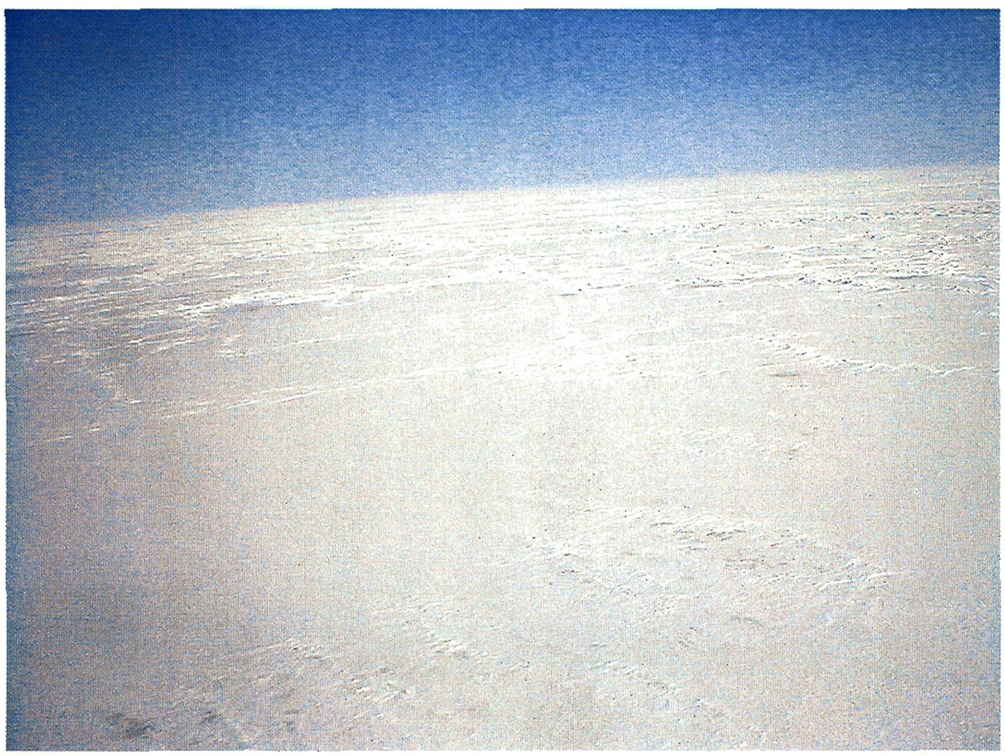


2003 April 13 – CPT03-08 – Kekertak
Ice conditions near drill site

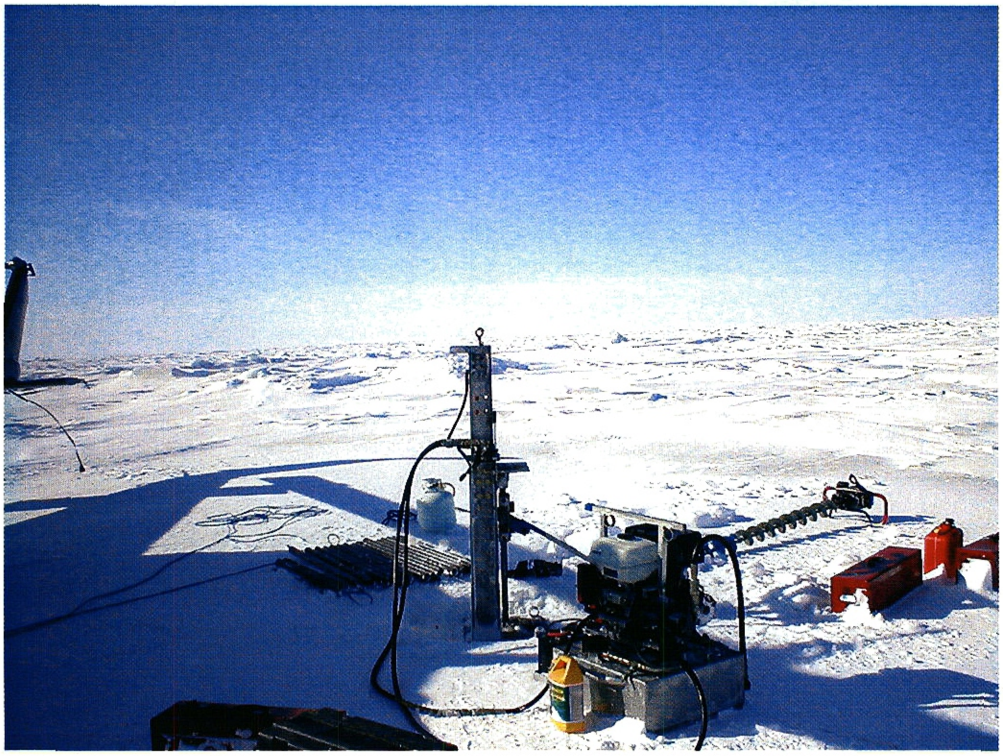
2003 April 13 – CPT03-08 – Kekertak
Ice ridges at drill site



2003 April 13 – CPT03-08 – Kekertak
Drill site with ice ridges in background



2003 April 13 – CPT03-09 – Tuwak
Ice conditions near drill site



2003 April 13 – CPT03-09 – Tuwak
Drill site

APPENDIX III

ConeTec Investigations Report

Beaufort Sea On-Ice Geotechnical Investigation

Presentation of Cone Penetration Testing Results

April 7th through April 13th, 2003

Prepared for:
Klohn Crippen Consultants Ltd.
Calgary, Alberta

Prepared by:
CONETEC

April 26, 2003

TABLE OF CONTENTS

1.0 INTRODUCTION

This report presents the results of a piezocone penetration testing (CPTU) program conducted off Beaufort Sea landfast ice. CPTU soundings were carries out at various locations offshore of Richards Island, Northwest Territories. The sites were pre-determined by Klohn Crippen Consultants and located by GPS. A Bell 212 helicopter was used for transport of equipment and crew. The work was conducted between April 7th and April 13th, 2003. There were two standby days for weather and helicopter priority during this time.

A new lightweight CPT deployment system was designed and constructed for this project and is discussed in the following section.

2.0 FIELD EQUIPMENT AND PROCEDURES

2.1 Electric Piezocone Testing

ConeTec Investigations Ltd. carried out the CPTUs using an integrated electronic cone system. For this project a low capacity compression type cone with a maximum tip range of 40 bar was used for better resolution in the soft seabed sediments. One of the soundings (CPT03-02) used a full capacity cone. Figure 1 shows a schematic of a ConeTec piezocone penetrometer.

The cone has a tip area of 15 cm^2 and a friction sleeve area of 225 cm^2. A piezometer element 6 mm thick is located immediately behind the cone tip in the U_2 position. The compression cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.85. The cone system used during the program was capable of recording the following parameters at 5 cm depth intervals:

- Tip Resistance (qc)
- Sleeve Friction (fs)
- Dynamic Pore Pressure (Ud)

The above parameters were stored on digital media for future analysis and reference.

The porous plastic pore pressure element was located directly behind the cone tip. Each element was saturated in glycerin under vacuum pressure prior to penetration. Pore pressure dissipations were not recorded during this project.

Complete sets of baseline readings were taken prior to and after each sounding to determine temperature shifts and any zero load offsets. Establishing temperature shifts and load offsets enables corrections to be made to the cone data where necessary. These corrections can be important, especially where the load conditions are relatively low, and generally represent the single largest source of error with respect to the accuracy of cone data. Since the probes are temperature compensated, load shifts due to changes in probe temperature are only a problem when extreme temperature changes occur during the test. For this project extreme cold temperatures were present. However, the cone was placed 2.5 metres below the ice surface for a minimum of 10 minutes prior to recording initial baselines. Therefore the baselines used for each sounding represented baselines at sea water temperature and no data shifts were necessary.

ConeTec cones are calibrated above and beyond the stated ASTM standards (ASTM D5778-95).

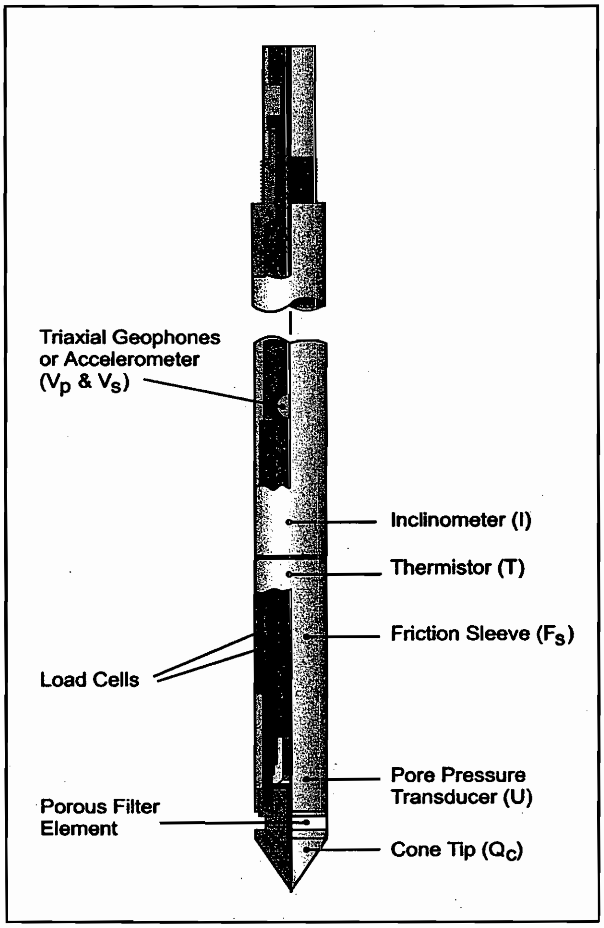


Figure 1:Compression Cone

Two kinds of data acquisition systems were used on this project. For the first two sites (Paktoa and P4) an iCPT system was used. This employs a cableless memory cone that is initialized at surface, deployed, and then downloaded at surface. The iCPT cones have the same design as analog cones, however the data is stored within the cone, and the thermistor, inclinometers, and geophones are not installed. Depth events are recorded at surface and integrated into the downloaded data via time stamps. This system was initially chosen to eliminate bulk and weight, and to save time on the ice involved with stringing and unstringing the cable through the deployment rods. However this system was abandoned due to problems with internal electronics due to the extreme cold temperatures. For the remaining 6 locations a traditional analog cable cone and DAS was used and proved to be the more robust system.

The testing equipment and crew were mobilized each day from Inuvik by a Bell 212 helicopter operated by Canadian Helicopters Inuvik. The helicopter had a payload of approximately 2500 lbs after fuel. The crew comprised of approximately 1000 lbs and therefore all testing equipment could not weigh more than 1500 lbs. The equipment consisted of:

- light weight ramset
- powerpack and hydraulic resevoir
- 2.125 inch direct push drill rods (18 metres)
- 1.5 inch CPT rods (5 metres)
- 2-3 cone penetrometers
- 2 Data acquisition systems
- Honda Generator, 900 W
- 2 Soil Samplers (Macro-core) and associated equipment
- 3 Shear Vanes and associated equipment
- Ice Auger Equipment
- Safety Equipment and Spill Response Kit
- 4 Tool Boxes
- 2 propane bottles, tiger torch and sunflower heater
- 8 man tent for shelter
- Satellite Phone
- Gun
- Misc. Personal Gear

The Ramset and Power Pack were designed and fabricated specifically for this project by ConeTec. Each piece of equipment had to be transported manually. The equipment was capable of penetrating 8 m below mudline or penetrating soils with shear strengths in the order of 50 kPa. Operations were carried in up to 12.5 metres of water. The ramset was anchored to the ice using 22 cm mountaineering ice screws. Four screws properly placed proved to be more than enough reaction to anchor the ramset to the ice surface. A backup anchoring method was fabricated but never used.

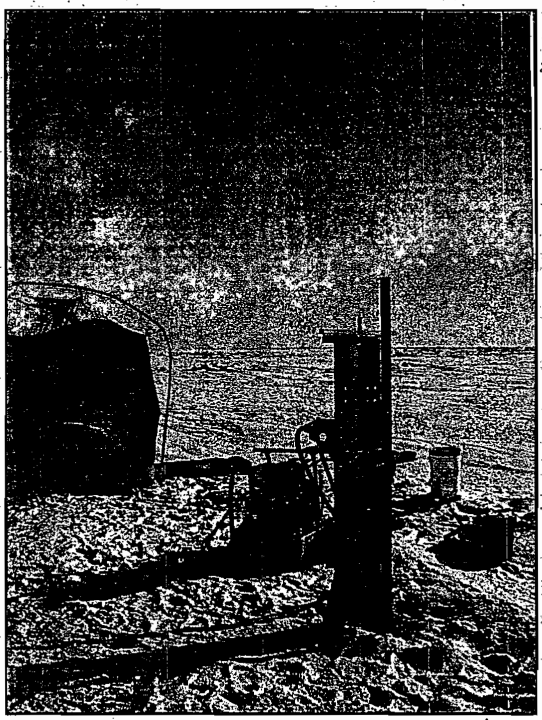


Photo 1: Deployment System

Photo 2: Data Acquisition System

3.0 CONE PENETRATION TEST DATA AND INTERPRETATION

3.1 CPTU Data

The cone penetration test data is presented in graphical form in Appendix. Appendix A contains CPTU plots of Tip Resistance (q_t), Sleeve Friction (f_s), Friction Ratio (R_f, %) and Dynamic Pore Pressure (Ud) plotted versus depth. Appendix B contains advanced plots with undrained shear strength, Su, and equivalent standard penetration test blow counts, N1(60). The plots have mudline indicated. This line is based on measurements made from ice surface immediately prior to the sounding. The soundings CPT03-03, 04, 06, 07, 08, 09 were initiated one metre above mudline in order to delineate and characterize the soil – water interface at mudline. CPT03-02 was started four feet below mudline. This hole was carried out using the iCPT memory cone, and therefore data was recovered for the upper 4 feet. This time-domain data has been inferred and presented in Appendix A and B, and in tabular form on the data CD in Appendix E.

Soil Behaviour Types included on all of the plots are based on charts developed by Robertson et al. (1990), see Figure 2. The charts relate cone tip resistance and friction ratio to determine the respective soil behaviour type (SBT). It should be noted that it is not always possible to clearly identify a soil type based on q_t and R_f. Occasionally soils will fall within different soil categories on the classification charts. In these situations, experience and judgment and an assessment of the pore pressure data should be used to infer the soil type.

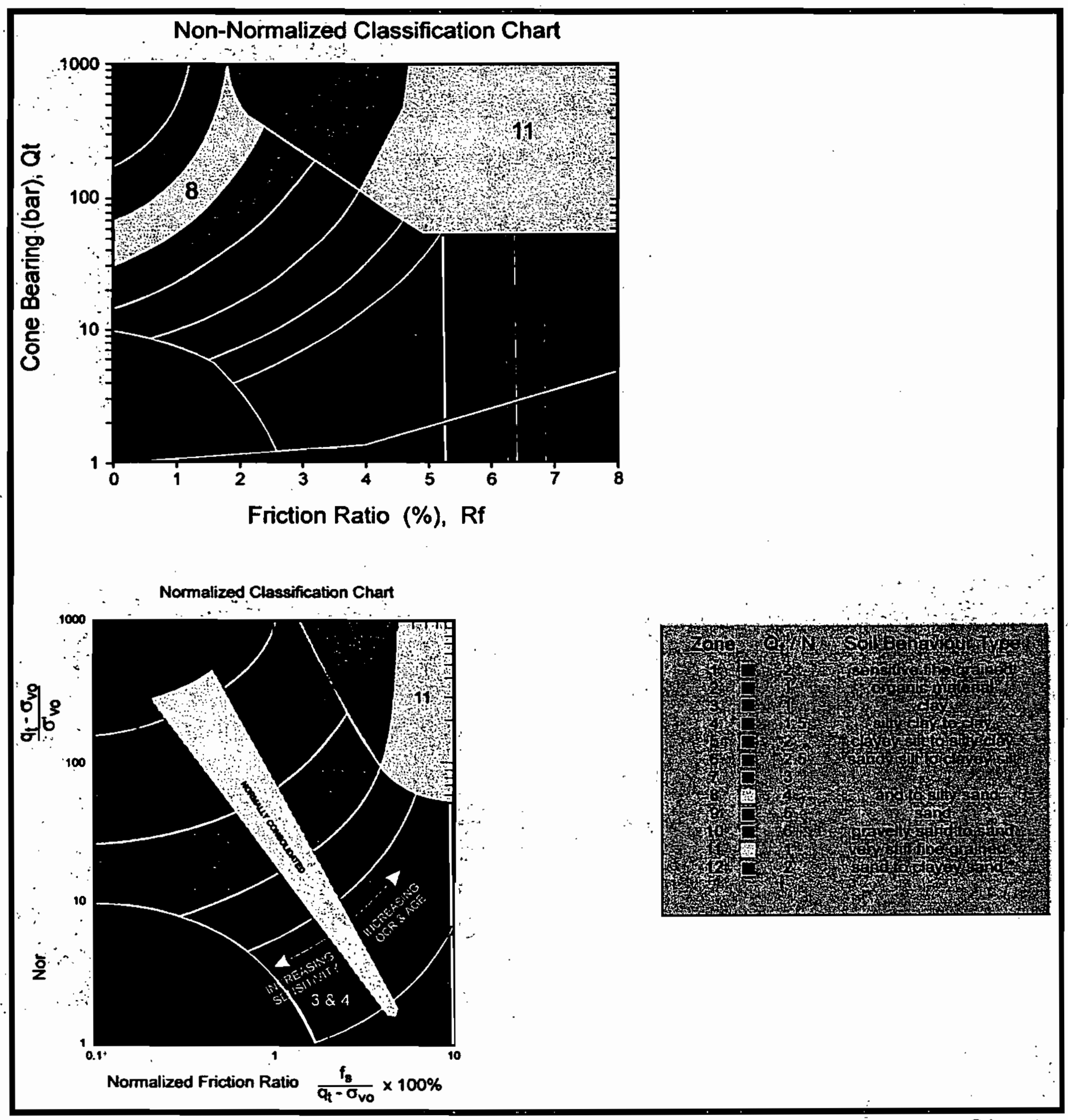


Figure 2: Robertson et al. 1990 Soil Behaviour Type Interpretation Chart

The cone tip (q_c) reading is the total force acting on the cone tip divided by the projected area of the tip. It indicates the relative density, or stiffness, of the soil. The sleeve friction (f_s) is the frictional force the soil is imposing on the friction sleeve divided by the surface area of the friction sleeve. The friction ratio (R_f), expressed as a percentage, is a ratio of the sleeve friction readings divided by the cone tip readings. The friction ratio gives an indication of the grain size characteristics of the material. Generally, cohesive soils have high friction ratios, low cone bearing and generate large excess pore water pressures. Cohesionless soils have lower friction ratios, high cone bearing and generate little or no excess pore water pressures. The dynamic pore pressure (U_d) readings record the pore pressures generated around the cone tip during cone penetration. To record equilibrium or static water pressures (U_t) the penetration must be stopped to allow the dynamic pore pressures to come into equilibrium. Alternatively, to calculate consolidation and permeability parameters, the dissipation is run to 50% dissipation (t_{50}).

Due to the complex stress conditions around the cone, pore pressures will be different at various locations on the cone. For this project, all pore pressures were recorded behind the tip, in the U_2 position.

Due to the inner geometry of a cone penetrometer, the ambient pore water pressure will act on the shoulder area behind the cone and on the ends of the friction sleeve. This results in an imbalance of stresses and is known as the "unequal area effect". This effect influences the total stress determined from the cone and friction sleeve. For the cone resistance, the unequal area is represented by the cone area ratio 'a', which is approximately equal to the ratio of the cross-sectional area of the load cell or shaft divided by the projected area of the cone. The corrected total cone resistance, q_t, is given by the equation:

$$q_t = q_c + U_2\,(1-a)$$

For ConeTec cones, the net end area ratio is 0.85. All the calculations and plots included in this report are in terms of q_t; however, the raw data files contain the recorded data, q_c.

A similar effect occurs for friction sleeves that have different cross-sectional areas at each end. This condition will result in an imbalance of forces on the friction sleeve leading to incorrect friction values. ConeTec Investigations Ltd. cones are designed with equal end area friction sleeves to eliminate this problem.

3.2 CPTU Interpretations

The data disk in Appendix E contains the results of the interpretation program CPTSUMM.

A number of interpreted geotechnical soil parameters are presented in these tables. In addition, a guide for the use of the interpreted results can be found in Appendix C. For interpretations based on effective stresses, it is necessary to input unit weights for the soils and a groundwater table or hydraulic gradient. The unit weight of water used was 9.94 kN/m^3, and for the soil a unit weight of 18.5 kN/m^3. These were provided by the client.

For the undrained shear strength relationship, one must assume or determine a Nkt factor. For this project, Klohn Crippen Consultants provided an Nkt of 14.

For all locations, the water surface is assumed to be 10 cm below ice surface.

Undrained shear strength (Su) and normalized standard penetration test equivalents (N1(60)) are plotted versus depth in Appendix B.

The CPTU data and the interpretation files are stored in ASCII text files on the accompanying data CD. The contents of the CD are detailed in Appendix E.

4.0 VANE SHEAR TESTS

Vane shear tests were completed successfully at one site (PAKTOA), vane shears were conducted using a large vane. No slip coupling is present and shear strength was calculated from vane dimensions and recorded torque. Frictional losses were estimated by slowly rotating the vane in the water above mudline and recording the torque. Residual shear strength was recorded approximately 270 degrees rotation after peak strength. Remolded strength was recorded by rotating the rods 360 degrees 20 times, then recording the torque to turn the vane. All dimensions, calculations and results are presented in Appendix D.

5.0 DIRECT PUSH SOIL SAMPLING

Soil samples were obtained at all locations to a maximum depth of 3 metres below mudline. A 4 foot by 1.5 inch ID macro-core sampler was used to collect the samples. This sampler is equipped with 3 different kinds of soil catchers and a clear plastic liner and caps for sample storage. The sampler was directly pushed into the soils, with no hammering or rotation involved. In order to collect samples from below the first sample interval, a piston rod and tip are utilized. The sampler is pushed to the desired depth interval, and messenger rods are used to release the tip, then the sampler is driven again. For this project the holes stayed open and the piston rod and tip were not necessary.

We trust that the information presented in this report is sufficient for your purposes. If you have any questions regarding the contents of this report or the field program please do not hesitate to contact our office.

Sincerely,

James Sharp
ConeTec Investigations Ltd.

Appendix A

Standard CPTU Plots

ConeTec Investigations Ltd.

CONETEC

Job No: 03-126
Client: Klohn Crippen Consultants Ltd.
Project: Beaufort Sea, NWT
Date: April 7th to 13th, 2003

TABLE CPTU - CPT SUMMARY

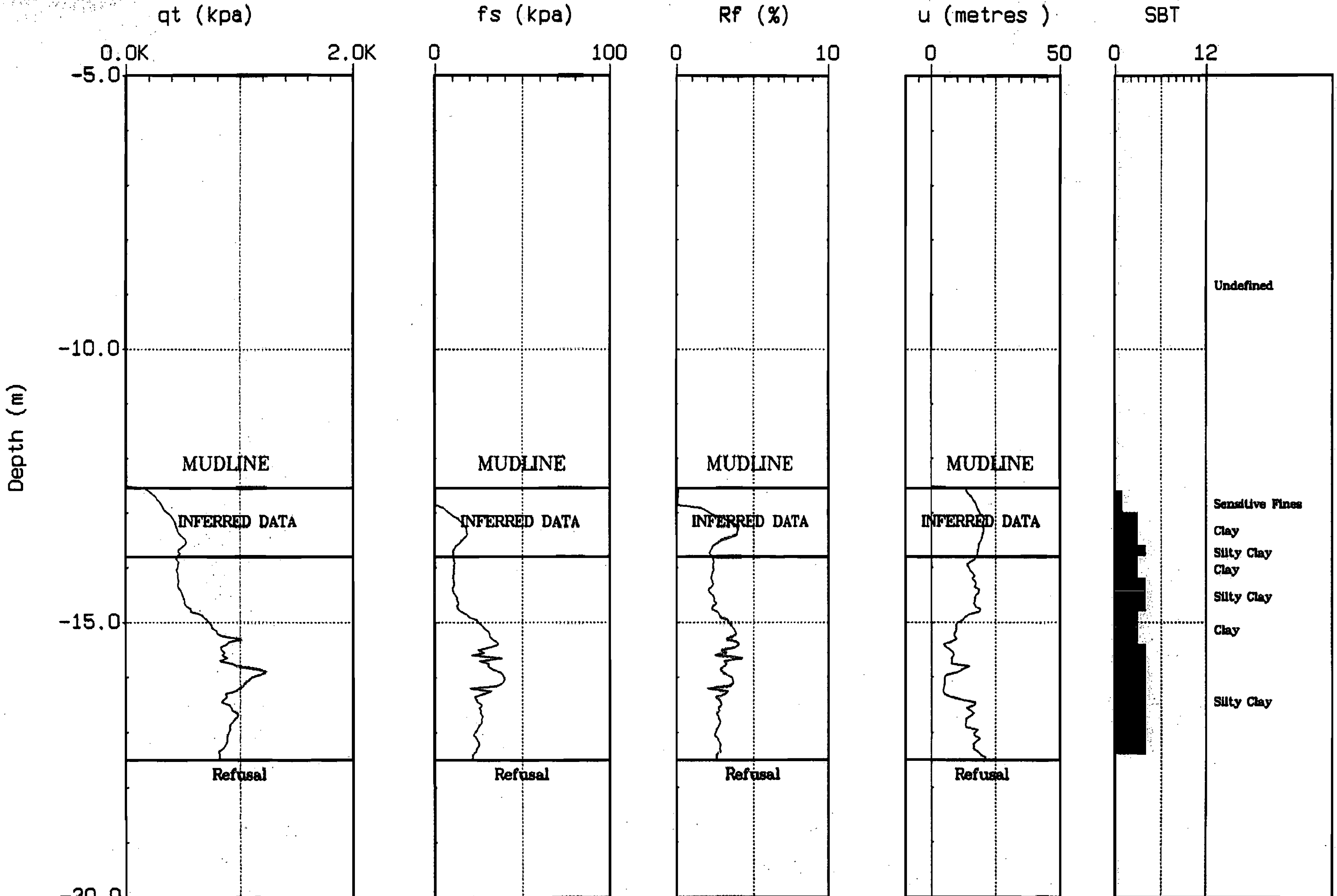
CPT Sounding	File Name	Site Number	Date	Depth to Mudline from Ice Level (m)	Refusal Depth (m)	Cone Type
CPT03-02	126CPPAB.DRF	PAKTOA PA	03/08/03	12.54	17.50	2nd iCPT attempt, standard capacity cone**
CPT03-03	126CPP1.DAT	PAKTOA P1	03/12/03	12.00	16.65	Analog Slimes Cone
CPT03-04	126CPP2.DAT	PAKTOA P2	03/12/03	9.75	14.05	Analog Slimes Cone
CPT03-05	126CPP4B.DRF	PAKTOA P4	03/07/03	7.65	13.25	Slimes iCPT
CPT03-06	126CPNI.DAT	NIPTERK NI	03/11/03	9.96	13.40	Analog Slimes Cone
CPT03-07	126CPN2.DAT	NIPTERK N2	03/11/03	9.77	13.30	Analog Slimes Cone
CPT03-08	126CPKE.DAT	KEKERTAK KE	03/13/03	11.18	13.50	Analog Slimes Cone
CPT03-09	126CPTU.DAT	TUWAK TU	03/13/03	7.65	13.15	Analog Slimes Cone

CONETEC

Klohn Crippen

Site: CPT03-02
Location: BEAUFORT GEOTECH

Cone: 20 ton iCPT 138
Date: 04:08:03 15:30



Max. Depth: 17.50 (m)

Depth Inc.: 0.050 (m)

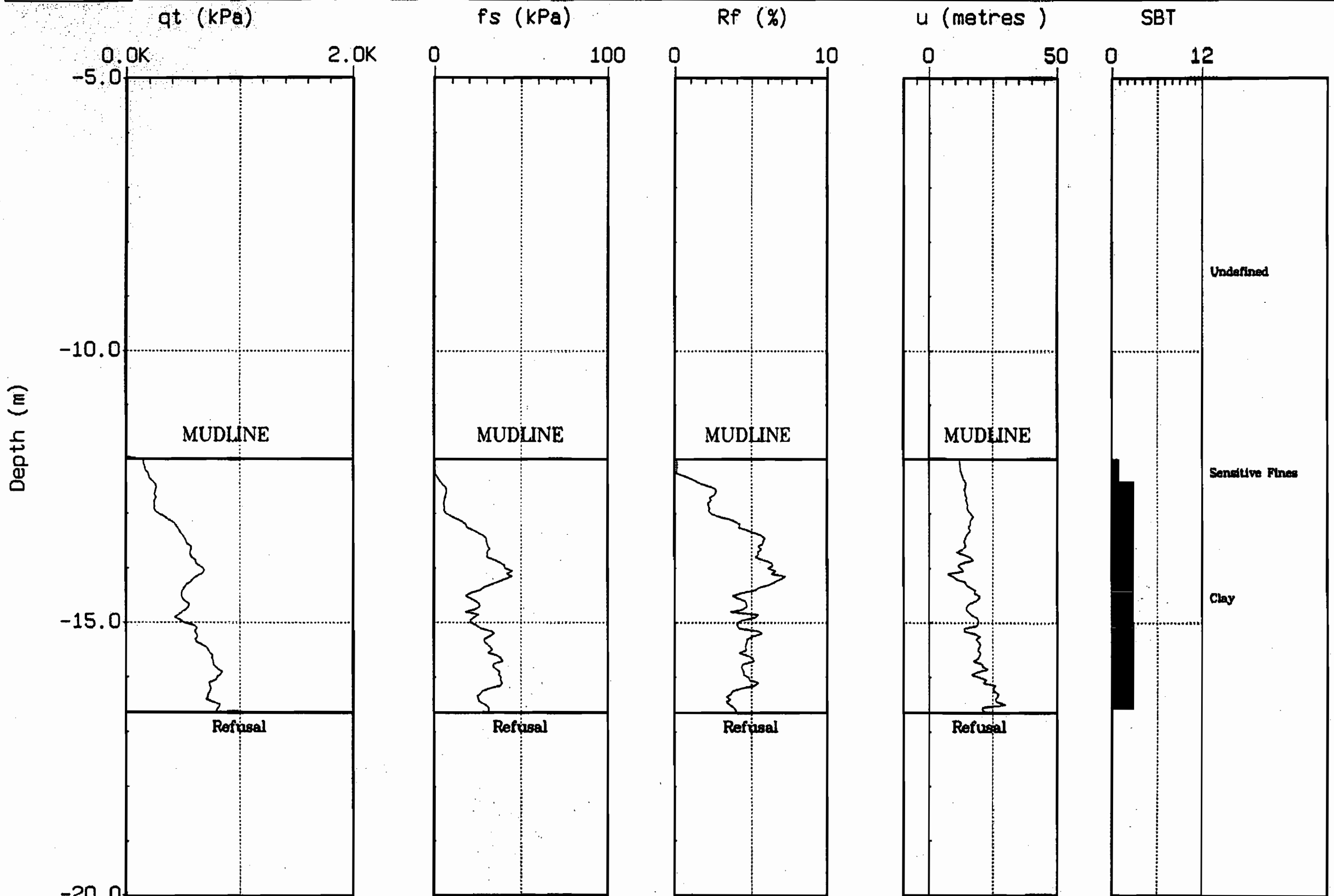
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

Klohn Crippen

Site: CPT03-03
Location: BEAUFORT GEOTECH

Cone: Lou Capac 064
Date: 04:12:03 11:55



Max. Depth: 16.65 (m)

Depth Inc.: 0.050 (m)

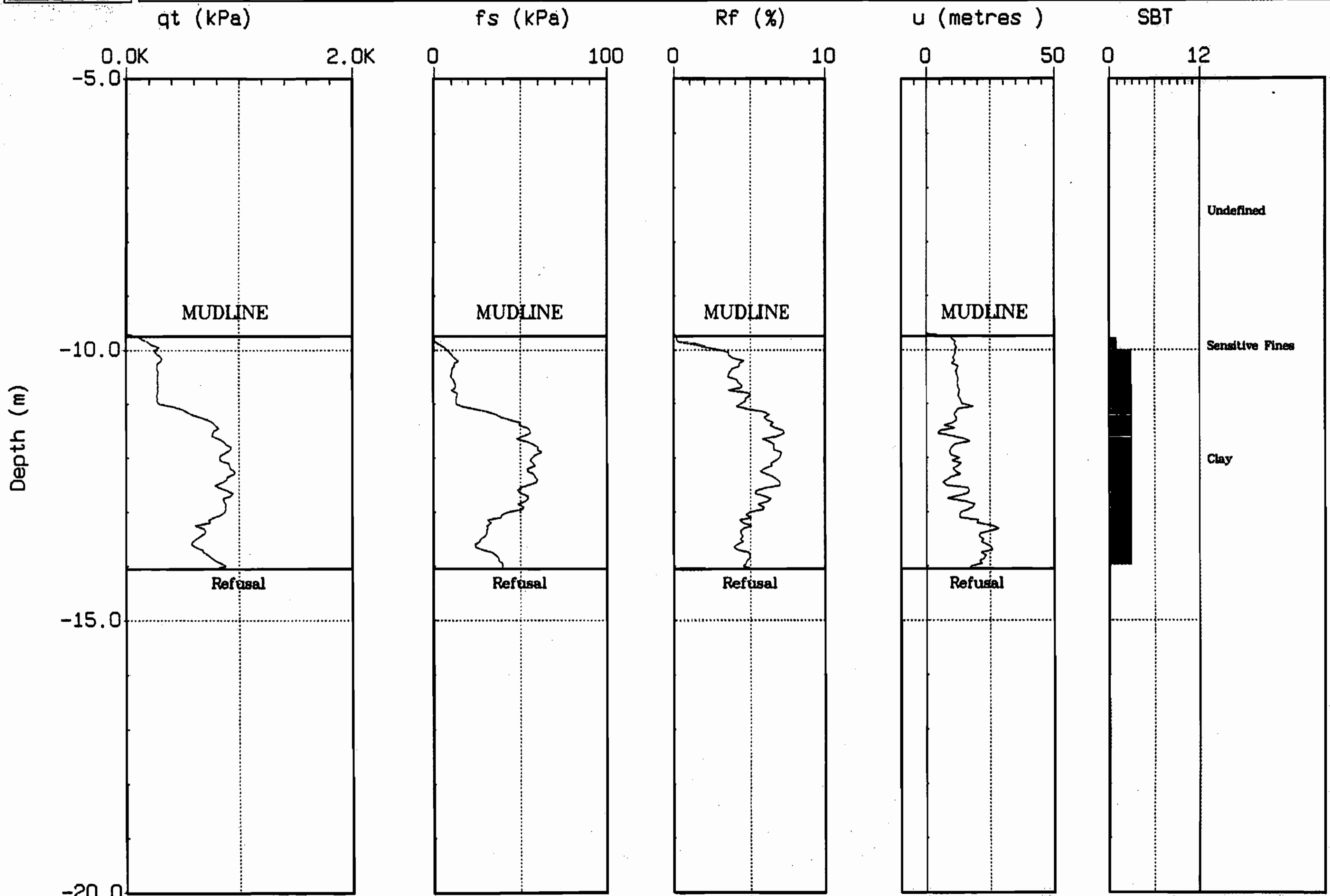
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

Klohn Crippen

Site: CPT03-04
Location: BEAUFORT GEOTECH

Cone: Low Capac 064
Date: 04:12:03 16:20



Max. Depth: 14.05 (m)

Depth Inc.: 0.050 (m)

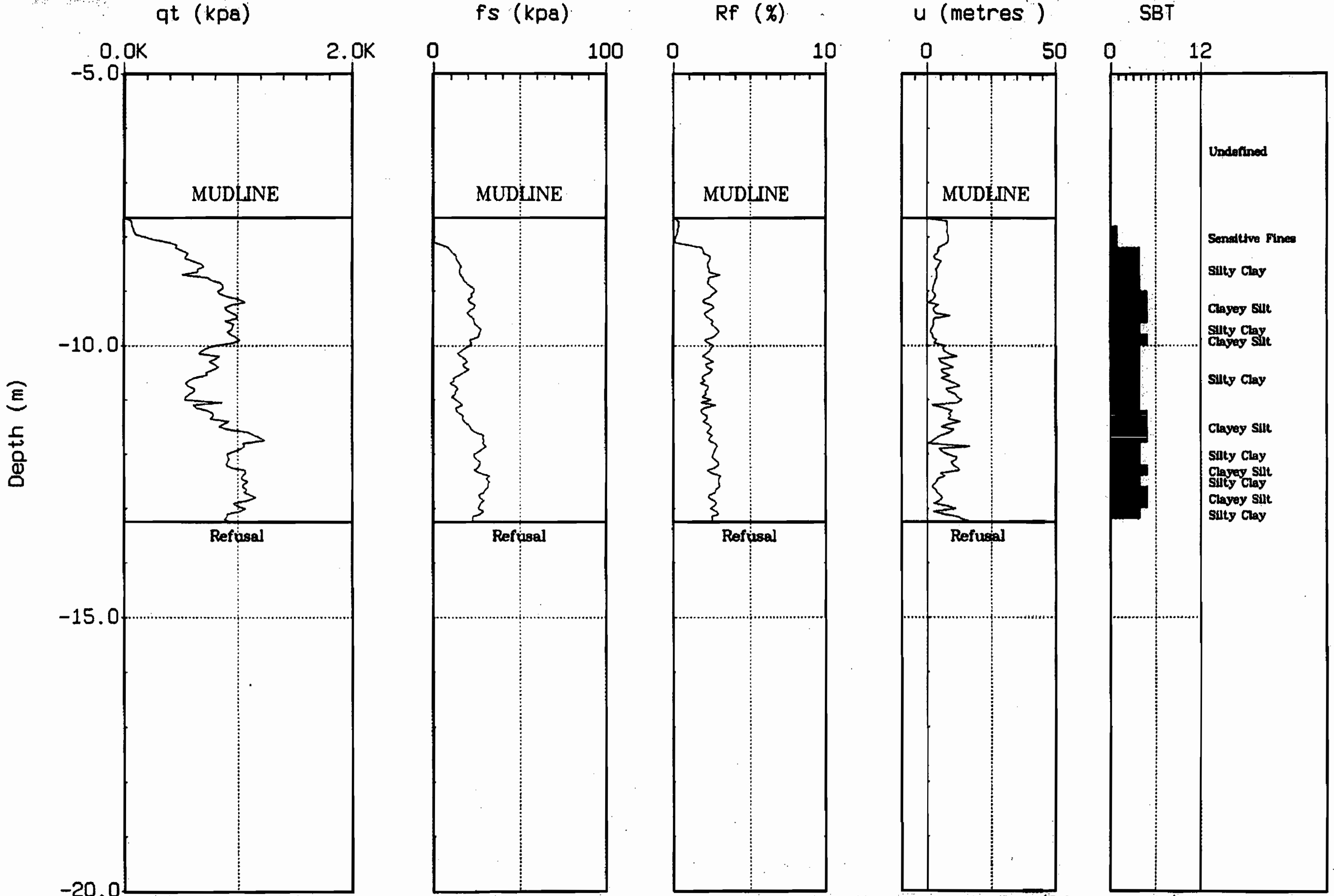
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

Klohn Crippen

Site: CPT03-05
Location: BEAUFORT GEOTECH

Cone: Slime iCPT 065
Date: 04:07:03 15:15



Max. Depth: 13.25 (m)

Depth Inc.: 0.050 (m)

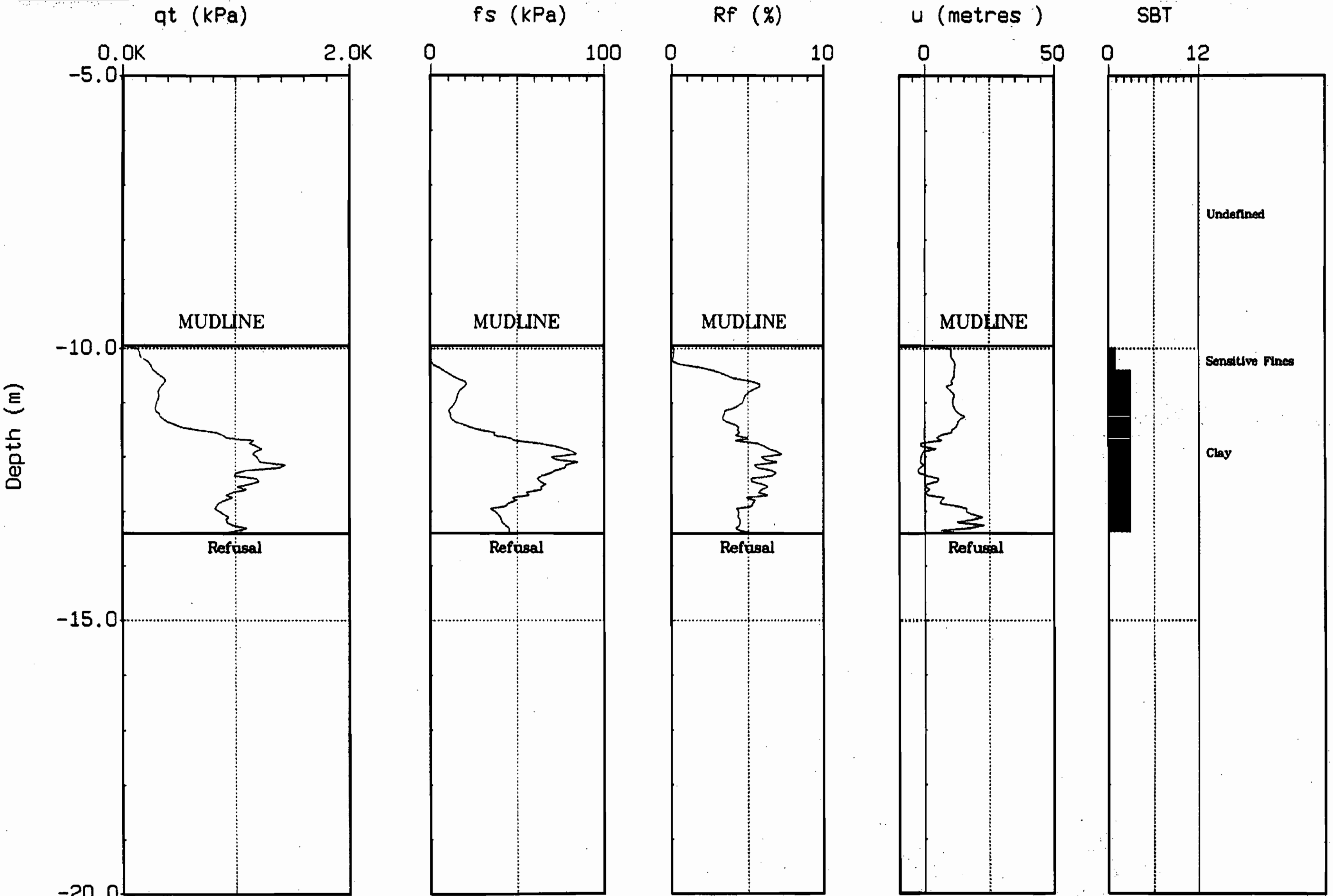
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

Klohn Crippen

Site: CPT03-06
Location: BEAUFORT GEOTECH

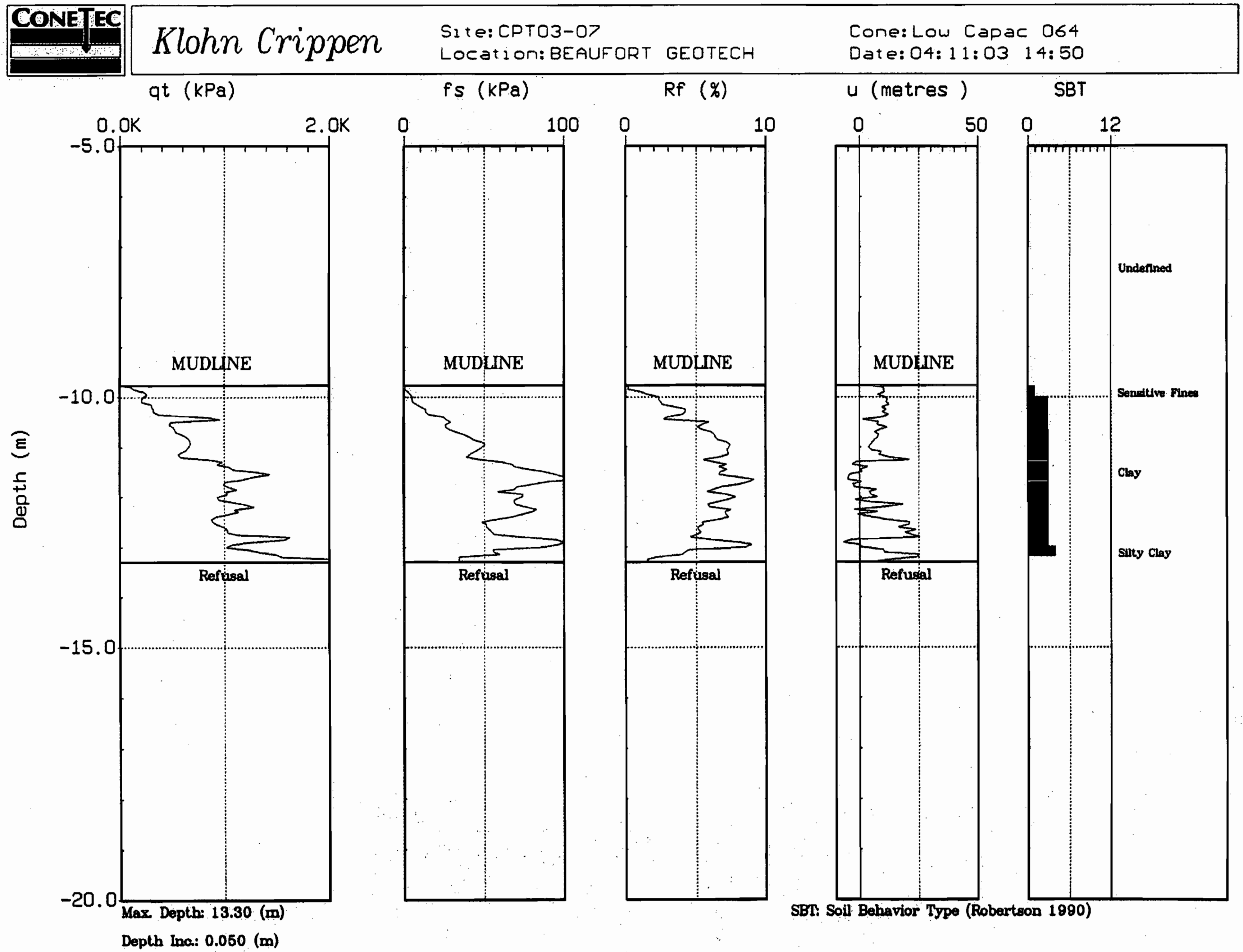
Cone: Low Capac AD064
Date: 04:11:03 11:40



Max. Depth: 13.40 (m)

Depth Inc.: 0.050 (m)

SBT: Soil Behavior Type (Robertson 1990)



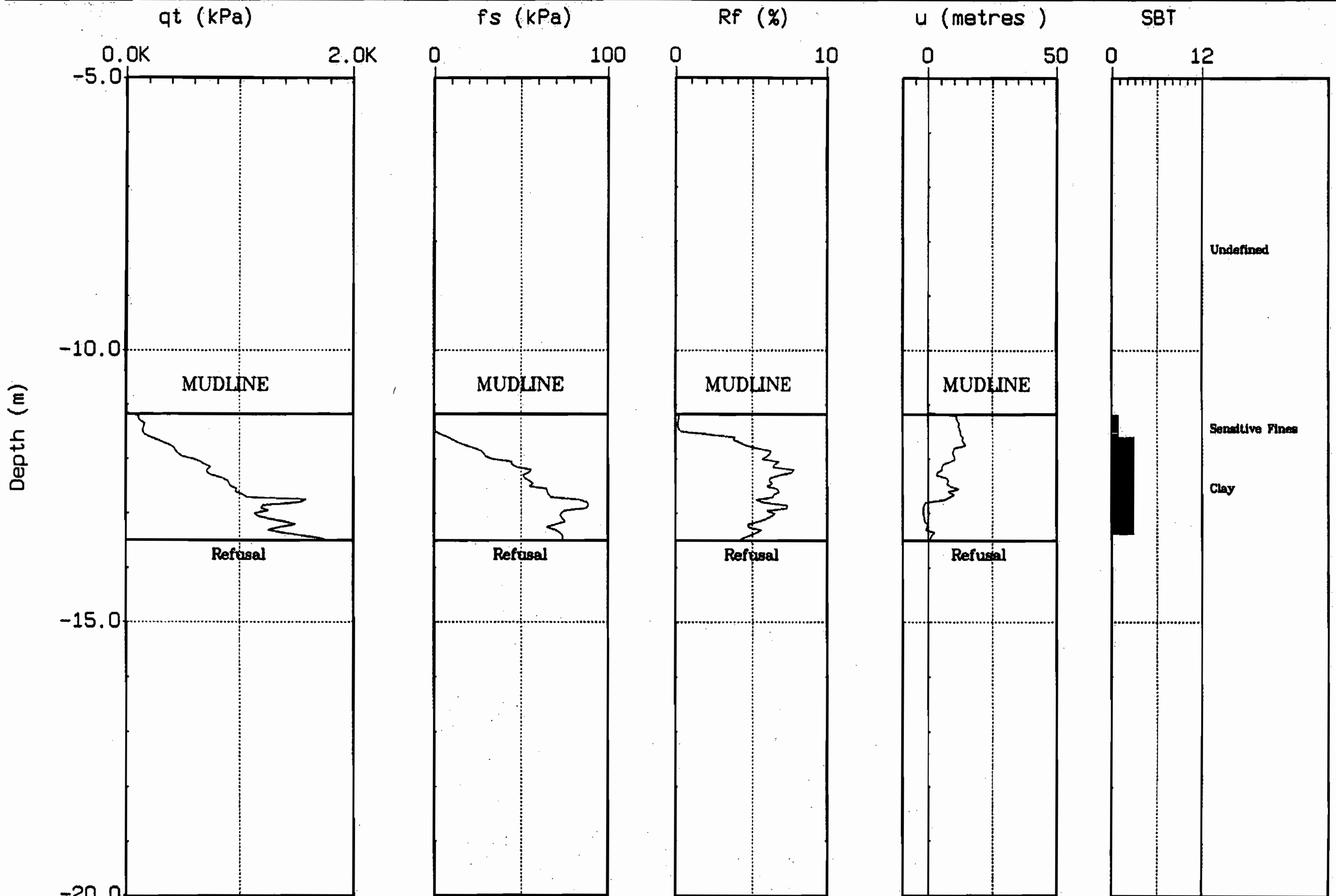
CONETEC
Klohn Crippen
Site:CPT03-07
Location:BEAUFORT GEOTECH
Cone:Low Capac 064
Date:04:11:03 14:50
qt (kPa)
fs (kPa)
Rf (%)
u (metres)
SBT
0.0K
2.0K
0
100
0
10
0
50
0
12
-5.0
-10.0
-15.0
-20.0
Depth (m)
MUDLINE
Refusal
Undefined
Sensitive Fines
Clay
Silty Clay
Max. Depth: 13.30 (m)
Depth Inc.: 0.050 (m)
SBT: Soil Behavior Type (Robertson 1990)

CONETEC

Klohn Crippen

Site: CPT03-08
Location: BEAUFORT GEOTECH

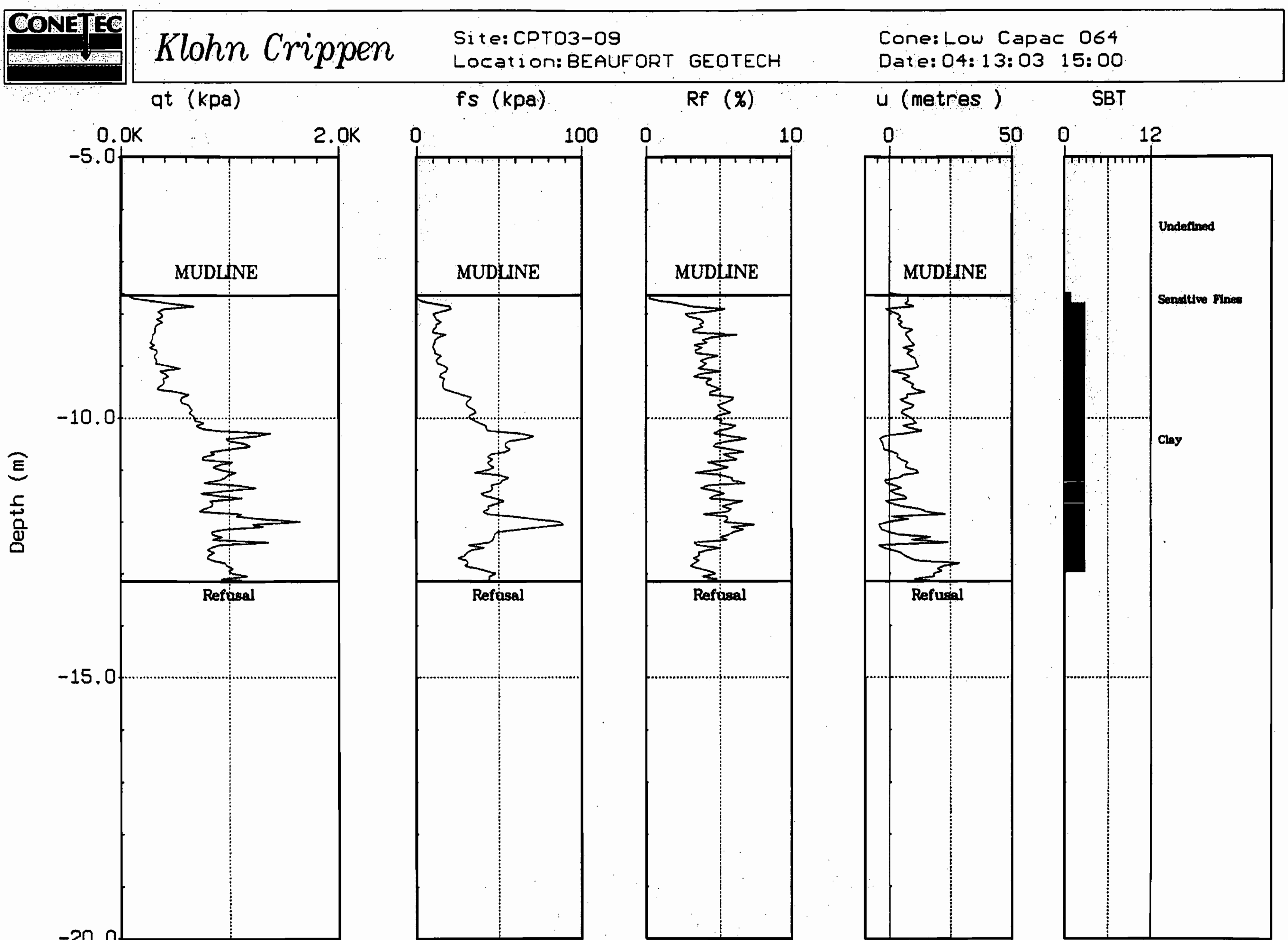
Cone: Low Capac 064
Date: 04:13:03 10:30



Max. Depth: 13.50 (m)

Depth Inc.: 0.050 (m)

SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 13.15 (m)
Depth Inc.: 0.050 (m)
SBT: Soil Behavior Type (Robertson 1990)

Appendix B

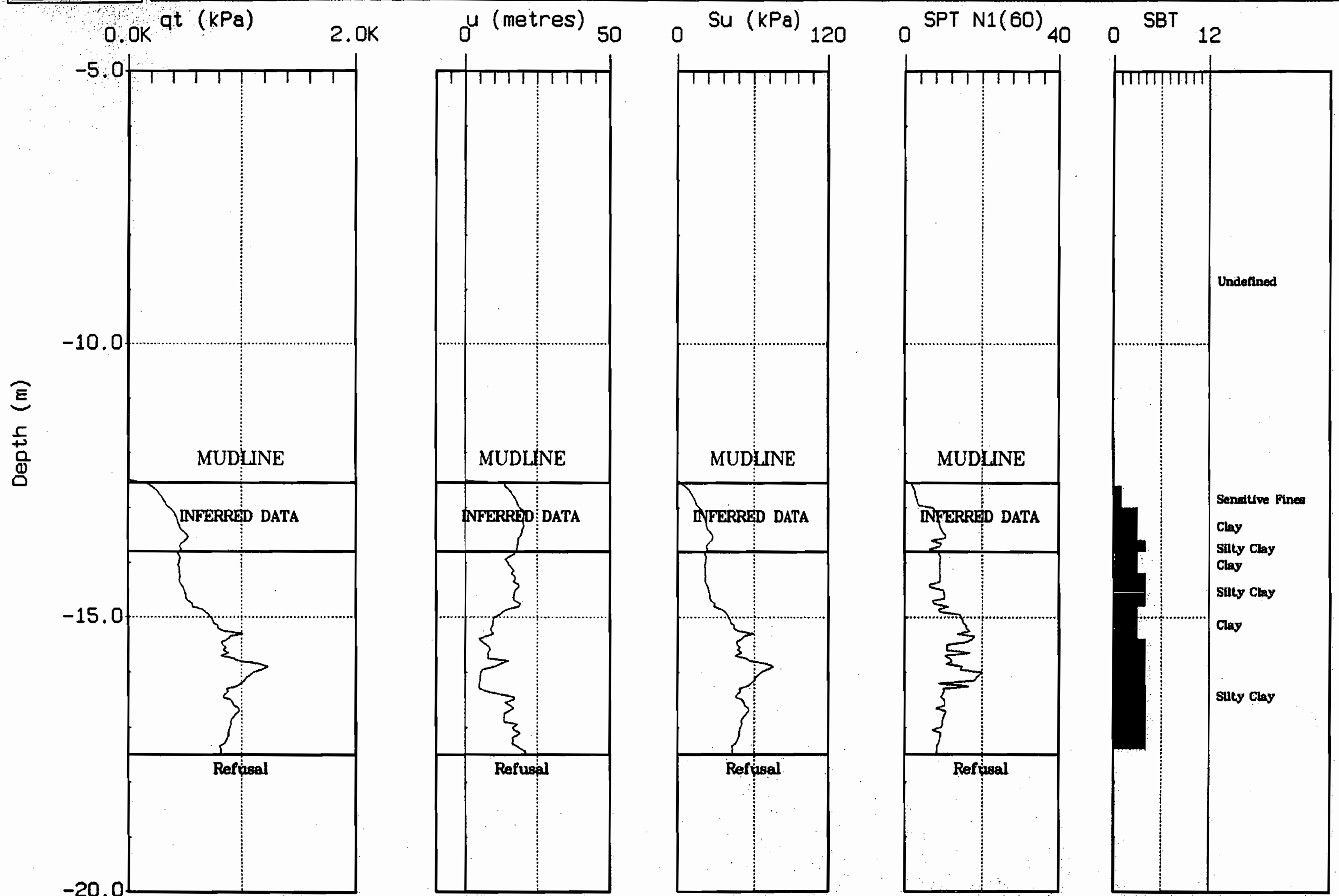
Advanced CPTU Plots

ConeTec Investigations Ltd.

Klohn Crippen

Site: CPT03-02
Location: BEAUFORT GEOTECH

Cone: 20 ton ICPT 138
Date: 04:08:03 15:30



Max. Depth: 17.50 (m)

Depth Inc.: 0.05 (m)

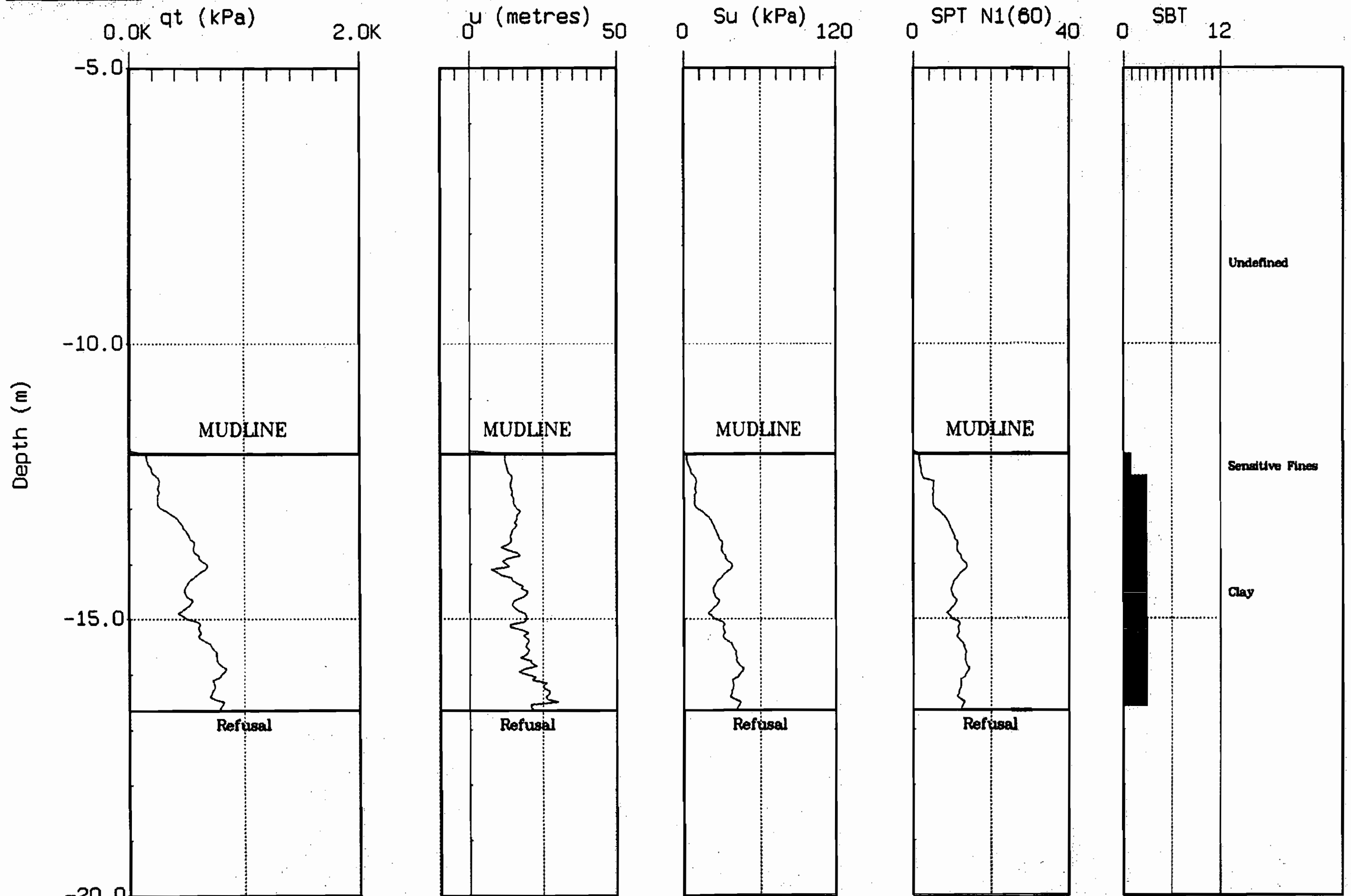
SBT: Soil Behavior Type (Robertson and Campanella 1990)

CONETEC

Klohn Crippen

Site: CPT03-03
Location: BEAUFORT GEOTECH

Cone: Low Capac 064
Date: 04:12:03 11:55



Max. Depth: 16.65 (m)

Depth Inc.: 0.05 (m)

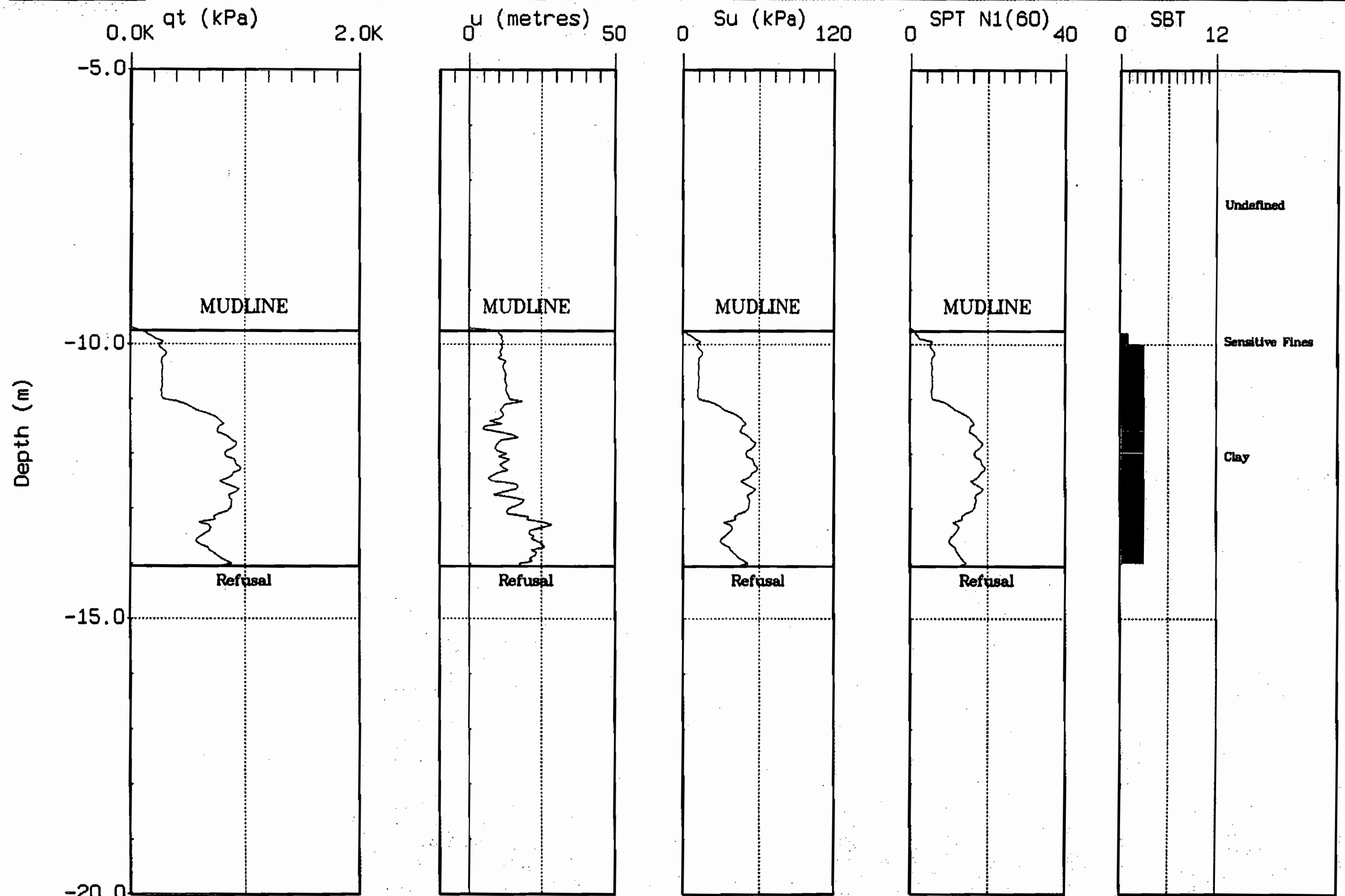
SBT: Soil Behavior Type (Robertson and Campanella 1990)

ConeTec

Klohn Crippen

Site: CPT03-04
Location: BEAUFORT GEOTECH

Cone: Low Capac 064
Date: 04:12:03 16:20



Max. Depth: 14.05 (m)

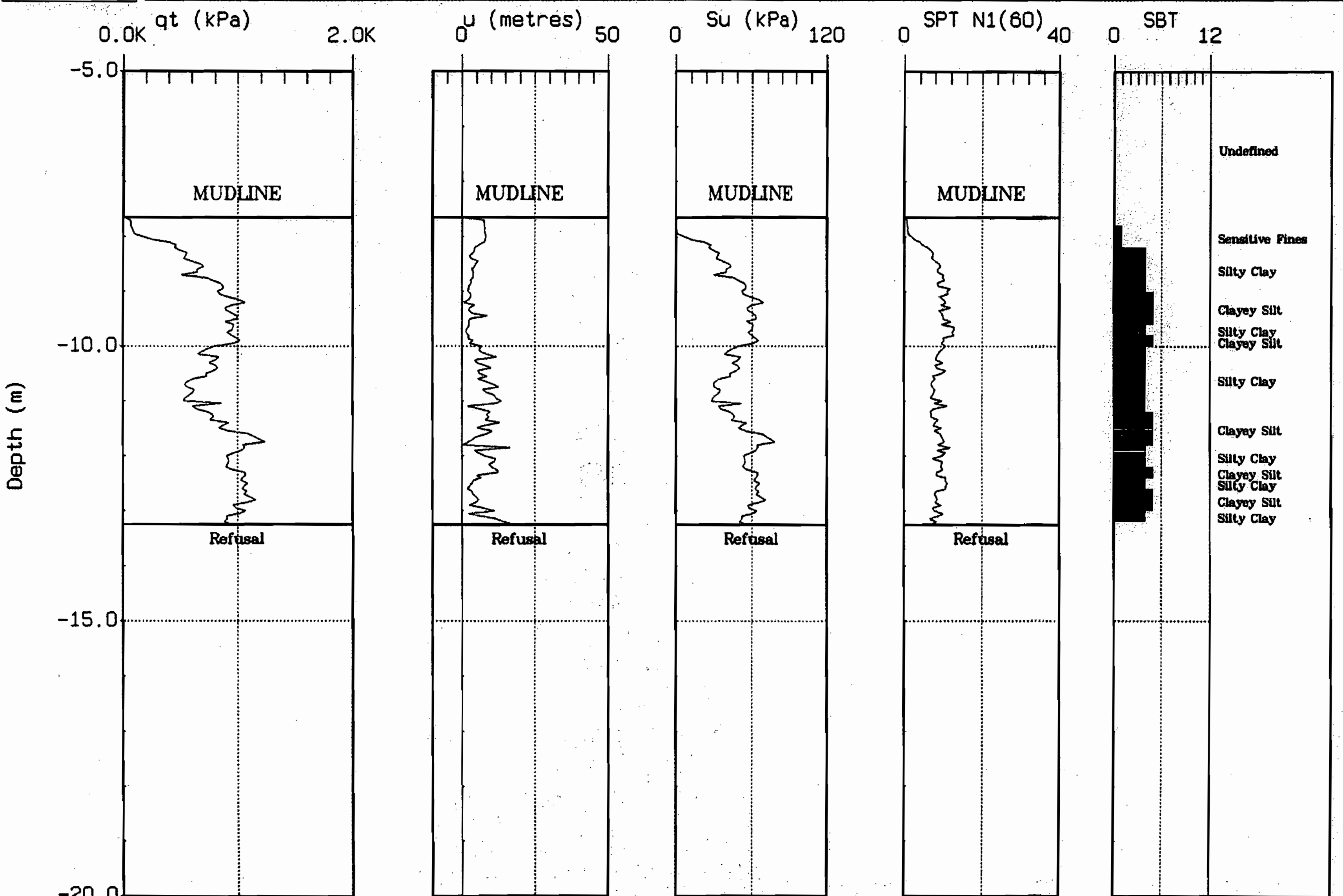
Depth Inc.: 0.05 (m)

SBT: Soil Behavior Type (Robertson and Campanella 1990)

Klohn Crippen

Site: CPT03-05
Location: BEAUFORT GEOTECH

Cone: Sime CPT 065
Date: 04:07:03 15:15

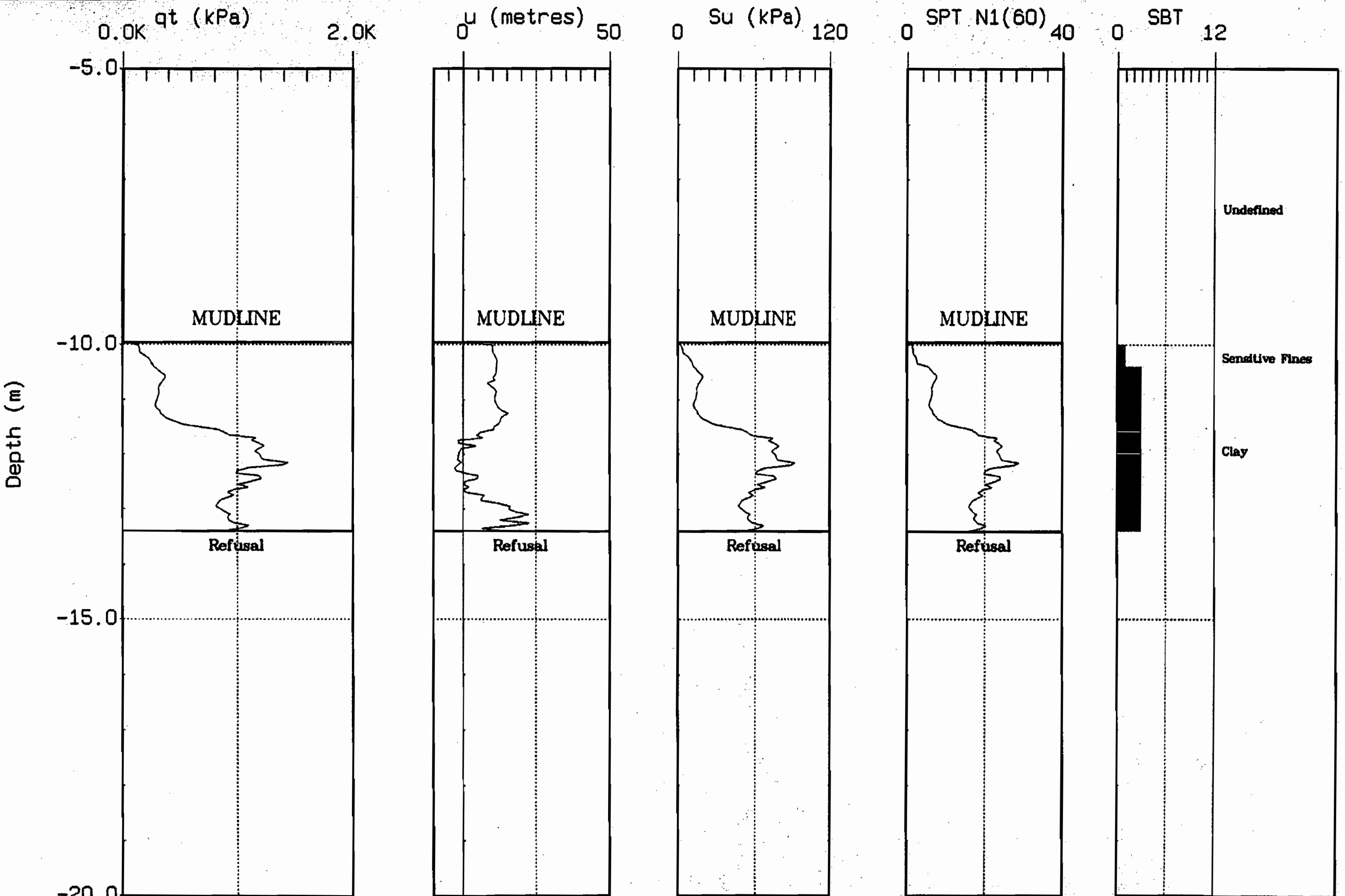


Max. Depth: 13.25 (m)

Depth Inc.: 0.05 (m)

SBT: Soil Behavior Type (Robertson and Campanella 1990)

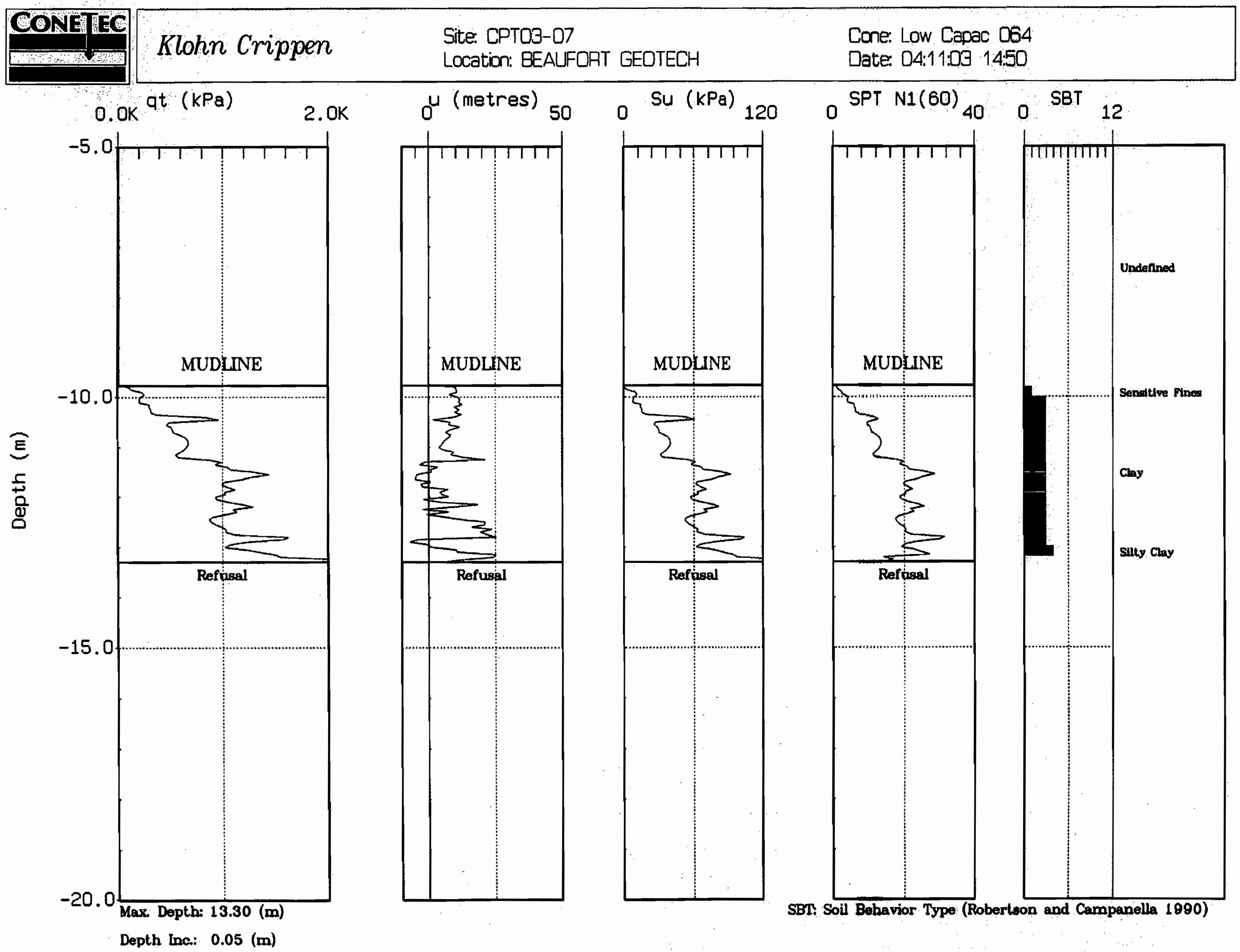
CONETEC | *Klohn Crippen* | Site: CPT03-06 | Location: BEAUFORT GEOTECH | Cone: Low Capac AD064 | Date: 04:11:03 11:40

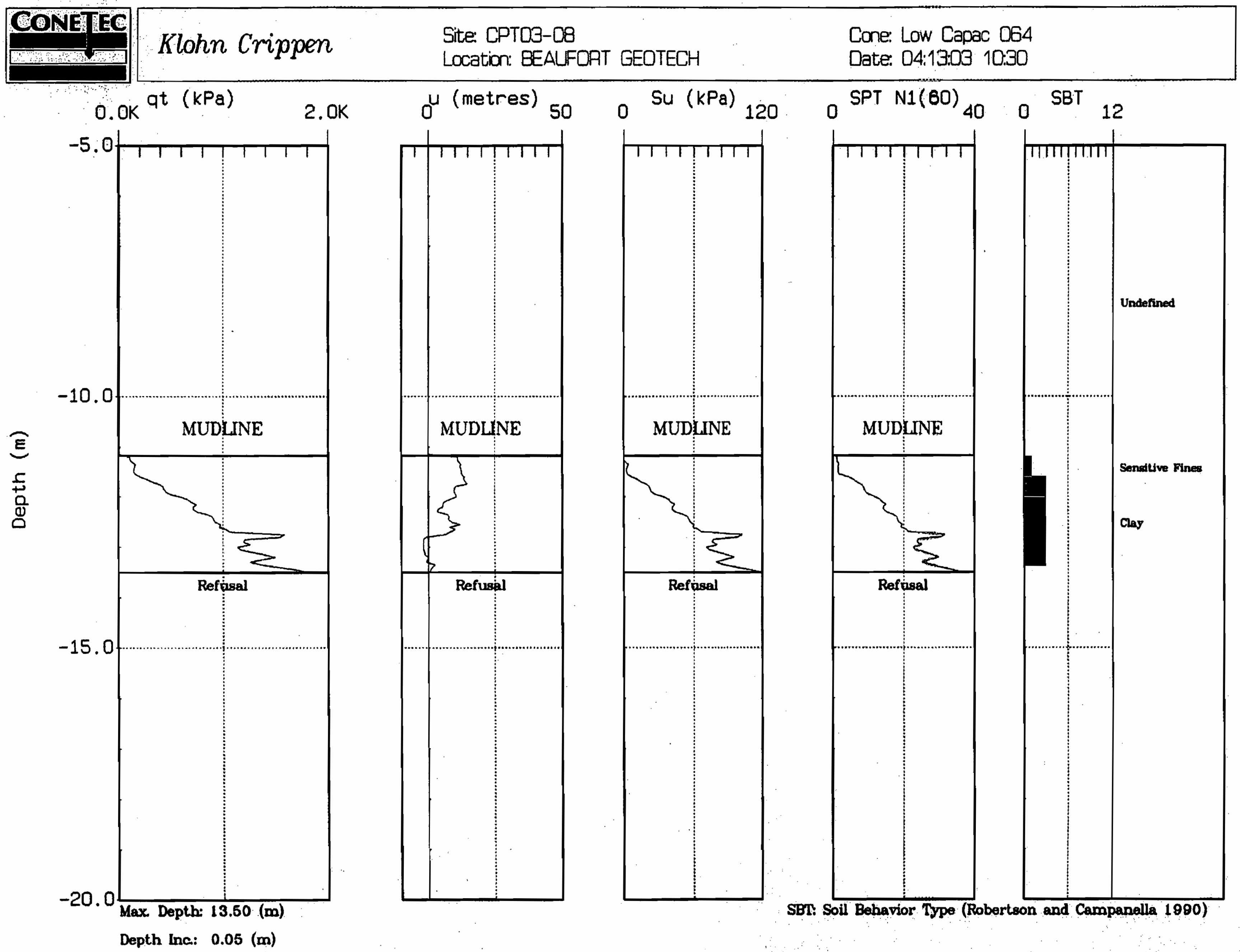


Max. Depth: 13.40 (m)

Depth Inc.: 0.05 (m)

SBT: Soil Behavior Type (Robertson and Campanella 1990)


CONETEC
Klohn Crippen
Site: CPT03-07
Location: BEAUFORT GEOTECH
Cone: Low Capac 064
Date: 04:11:03 14:50
qt (kPa)
0.0K
2.0K
u (metres)
0
50
Su (kPa)
0
120
SPT N1(60)
0
40
SBT
0
12
-5.0
-10.0
-15.0
-20.0
Depth (m)
MUDLINE
Refusal
Undefined
Sensitive Fines
Clay
Silty Clay
Max. Depth: 13.30 (m)
Depth Inc.: 0.05 (m)
SBT: Soil Behavior Type (Robertson and Campanella 1990)



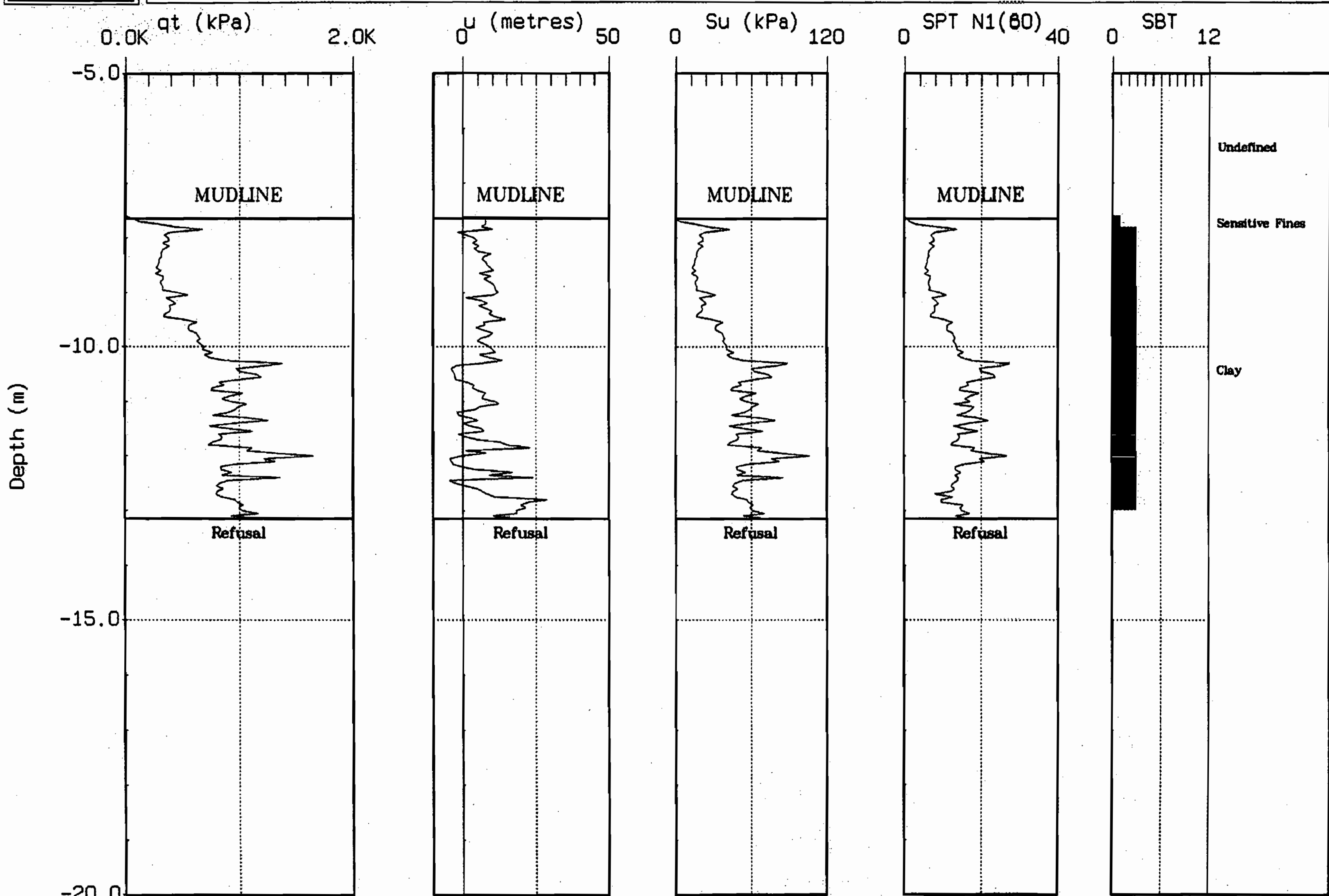
CONETEC
Klohn Crippen
Site: CPT03-08
Location: BEAUFORT GEOTECH
Cone: Low Capac 064
Date: 04:13:03 10:30
qt (kPa)
0.0K
2.0K
u (metres)
0
50
Su (kPa)
0
120
SPT N1(60)
0
40
SBT
0
12
Depth (m)
-5.0
-10.0
-15.0
-20.0
MUDLINE
Refusal
Undefined
Sensitive Fines
Clay
Max. Depth: 13.50 (m)
Depth Inc.: 0.05 (m)
SBT: Soil Behavior Type (Robertson and Campanella 1990)

ConeTec

Klohn Crippen

Site: CPT03-09
Location: BEAUFORT GEOTECH

Cone: Low Capac 064
Date: 04:13:03 15:00



Max. Depth: 13.15 (m)

Depth Inc.: 0.05 (m)

SBT: Soil Behavior Type (Robertson and Campanella 1990)

Appendix C

CPTU Interpretations Guide

ConeTec Investigations Ltd.

ConeTec CPT Interpretations as of January 7, 1999 (Release 1.00.19)

ConeTec's interpretation routine should be considered a calculator of current published CPT correlations and is subject to change to reflect the current state of practice. The interpreted values are not considered valid for all soil types. The interpretations are presented only as a guide for geotechnical use and should be carefully scrutinized for consideration in any geotechnical design. Reference to current literature is strongly recommended.

The CPT interpretations are based on values of tip, sleeve friction and pore pressure averaged over a user specified interval (typically 0.25m). Note that Qc is the recorded tip value, Qt, corrected for pore pressure effects. Since all ConeTec cones have equal end area friction sleeves, pore pressure corrections to sleeve friction, Fs, are not required.

The tip correction is: $Qt = Qc + (1-a) \bullet Ud$

where: *Qt* is the corrected tip load
Qc is the recorded tip load
Ud is the recorded dynamic pore pressure in the U_2 position
a is the Net Area Ratio for the cone (typically 0.85 for ConeTec cones)

Effective vertical overburden stresses are calculated based on a hydrostatic distribution of equilibrium pore pressures below the water table or from a user defined equilibrium pore pressure profile (this can be obtained from CPT dissipation tests). The stress calculations use unit weights assigned to the Soil Behaviour Type zones or from a user defined unit weight profile.

Details regarding the interpretation methods for all of the interpreted parameters are given in table 1. The appropriate references referred to in table 1 are listed in table 2.

The estimated Soil Behaviour Type is based on the charts developed by Robertson and Campanella shown in figure 1.

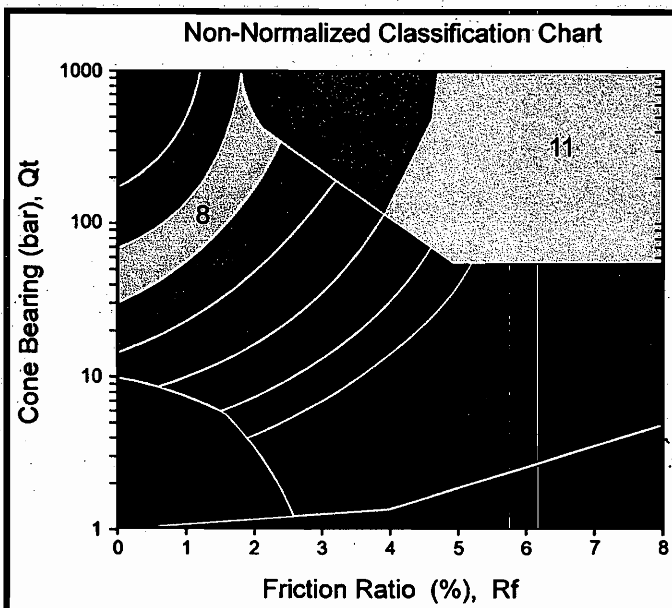
Table 1 CPT Interpretation Methods

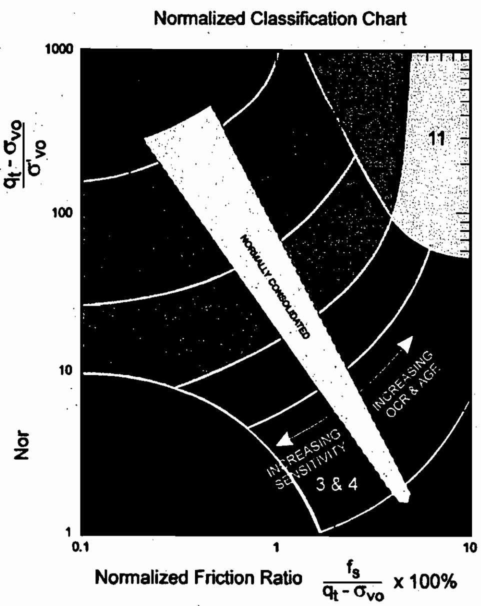
Interpreted Parameter	Description	Equation	Ref
Depth	mid layer depth		
AvgQt	Averaged corrected tip (Qt)	$AvgQt = \frac{1}{n}\sum_{i=1}^{n} Qt_i$	
AvgFs	Averaged sleeve friction (Fs)	$AvgFs = \frac{1}{n}\sum_{i=1}^{n} Fs_i$	
AvgRf	Averaged friction ratio (Rf)	$AvgRf = 100\% \bullet \frac{AvgFs}{AvgQt}$	
AvgUd	Averaged dynamic pore pressure (Ud)	$AvgUd = \frac{1}{n}\sum_{i=1}^{n} Ud_i$	
SBT	Soil Behavior Type as defined by Robertson and Campanella		1

CPT Interpretations

U.Wt.	Unit Weight of soil determined from: 1) uniform value or 2) value assigned to each SBT zone 3) user supplied unit weight profile		
TStress	Total vertical overburden stress at mid layer depth	$TStress = \sum_{i=1}^{n} \gamma_i h_i$ where γ_i is layer unit weight h_i is layer thickness	
EStress	Effective vertical overburden stress at mid layer depth	$EStress = TStress - Ueq$	
Ueq	Equilibrium pore pressure determined from: 1) hydrostatic from water table depth 2) user supplied profile		
Cn	SPT N_{60} overburden correction factor	$Cn=(\sigma_v')^{-0.5}$ where σ_v' is in tsf $0.5 < C_n < 2.0$	
N_{60}	SPT N value at 60% energy calculated from Qt/N ratios assigned to each SBT zone		3
$(N1)_{60}$	SPT N_{60} value corrected for overburden pressure	$N1_{60} = Cn \bullet N_{60}$	3
$\Delta(N1)_{60}$	Equivalent Clean Sand Correction to $(N1)_{60}$	$\Delta(N1)_{60} = \frac{K_{SPT}}{1-K_{SPT}} \bullet (N1)_{60}$ Where: K_{SPT} is defined as: 0.0 for FC < 5% 0.0167 • (FC - 5) for 5% < FC < 35% 0.5 for FC > 35% FC - Fines Content in %	7
$(N1)_{60cs}$	Equivalent Clean Sand $(N1)_{60}$	$(N1)_{60cs} = (N1)_{60} + \Delta(N1)_{60}$	7
Su	Undrained shear strength - Nkt is use selectable	$Su = \frac{Qt - \sigma_v}{N_{kt}}$	2
k	Coefficient of permeability (assigned to each SBT zone)		6
Bq	Pore pressure parameter	$Bq = \frac{\Delta u}{Qt - \sigma_v}$	2
Qtn	Normalized Qt for Soil Behavior Type classification as defined by Robertson, 1990	$Qtn = \frac{Qt - \sigma_v}{\sigma'_v}$	4
Rfn	Normalized Rf for Soil Behavior Type classification as defined by Robertson, 1990	$Rfn = 100\% \bullet \frac{f_s}{Qt - \sigma_v}$	4
SBTn	Normalized Soil Behavior Type (slightly modified from that published by Robertson, 1990. This version includes all the soil zones of the original non-normalized SBT chart - see figure 1)		4
Qc1	Normalized Qt for seismic analysis	$qc1 = qc \bullet (Pa/\sigma_v')^{0.5}$ where: Pa = atm. pressure	5
Qc1N	Dimensionless Normalized Qt1	qc1N = qc1 / Pa where: Pa = atm. pressure	

ΔQc1N1	Equivalent clean sand correction	$\Delta qc1N = \frac{K_{CPT}}{1 - K_{CPT}} \bullet qc1N$ Where: K_{CPT} is defined as: 0.0 for FC < 5% 0.0267 • (FC - 5) for 5% < FC < 35% 0.5 for FC > 35% FC - Fines Content in %	5
Qc1Ncs	Clean Sand equivalent Qc1N	*qc1Ncs = qc1N + Δqc1N*	5
Ic	Soil index for estimating grain characteristics	$Ic = [(3.47 - \log Q)^2 + (\log F + 1.22)^2]^{0.5}$	5
FC	Fines content (%)	$FC = 1.75(Ic^{3.25}) - 3.7$ *FC=100 for Ic > 3.5* *FC=0 for Ic < 1.26* *FC = 5% if 1.64 < Ic < 2.6 AND Rfn<0.5*	8
PHI	Friction Angle	Campanella and Robertson Durunoglu and Mitchel Janbu	1
Dr	Relative Density	Ticino Sand Hokksund Sand Schmertmann 1976 Jamiolkowski - All Sands	1
OCR	Over Consolidation Ratio		1
State Parameter			9
CRR	Cyclic Resistance Ratio		7





Zone	Q_t / N	Soil Behaviour Type
1	2	sensitive fine grained
2	1	organic material
3	1	clay
4	1.5	silty clay to clay
5	2	clayey silt to silty clay
6	2.5	sandy silt to clayey silt
7	3	
8	4	and to silty sand
9	5	sand
10	6	gravelly sand to sand
11	1	very stiff fine grained
12	2	sand to clayey sand

Figure 1 Non-Normalized and Normalized Soil Behaviour Type Classification Charts

Table 2 References

No.	Reference
1	Robertson, P.K. and Campanella, R.G., 1986, "Guidelines for Use, Interpretation and Application of the CPT and CPTU", UBC, Soil Mechanics Series No. 105, Civil Eng. Dept., Vancouver, B.C., Canada
2	Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.
3	Robertson, P.K. and Campanella, R.G., 1989, "Guidelines for Geotechnical Design Using CPT and CPTU", UBC, Soil Mechanics Series No. 120, Civil Eng. Dept., Vancouver, B.C., Canada
4	Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27.
5	Robertson, P.K. and Fear, C.E., 1995, "Liquefaction of Sands and its Evaluation", Keynote Lecture, First International Conference on Earthquake Geotechnical Enginnering, Tokyo, Japan.
6	ConeTec Internal Report
7	Robertson, P.K. and Wride, C.E., 1997, "Cyclic Liquefaction and its Evaluation Based on SPT and CPT", NCEER Workshop Paper, January 22, 1997
8	Wride, C.E. and Robertson, P.K., 1997, "Phase II Data Review Report (Massey and Kidd Sites, Fraser River Delta)", Volume 1 - Data Report (June 1997), University of Alberta.
9	Plewes, H.D., Davies, M.P. and Jefferies, M.G., 1992, "CPT Based Screening Procedure for Evaluating Liquefaction Susceptibility", 45th Canadian Geotechnical Conference, Toronto, Ontario, October 1992.

Appendix D

Vane Shear Data

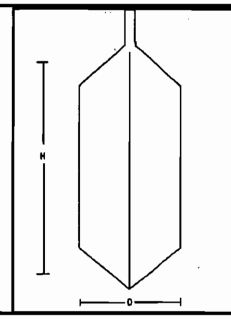
ConeTec Investigations Ltd.

ConeTec Investigations Ltd.

Project No: 03-126
Client: Klohn Crippen
Site: Beaufort Geotech Project
Date: April, 2003

[illegible]

Vane Constants - C		
Small Vane		**517**
D=	5	
H=	11.5	
Medium Vane		**1811**
D=	7.5	
H=	18	
Large Vane		**4294**
D=	10	
H=	24	



$C = pi*[(D^2H/2) + (D^3/6)]$

Where: D=Diameter of Vane, H= Height of Vane, T= Torque Reading

Su (kPa)=98.1 * T/C

When T is in kg-cm and C is in cm^3
Note: These calculations are for a square vane.

Adjacent Sounding	Test Depth (m, below mudline)	Test Date	Vane Used	Vane Constant	Friction T (cm-kg)	Peak T (cm-kg)	Residual T (cm-kg)	Remolded T (cm-kg)	Su (kPa) Peak	Su (kPa) Residual	Su (kPa) Remolded
CPT03-02	0.60	4/8/03	Large	**4294**	**12**	866.15	489.12	25.00	19.5	10.9	0.3
(PAKTOA)	1.27	4/8/03	Large	**4294**	**12**	1263.56	815.20	560.45	28.6	18.4	12.5

**Depths are to center of vane*
**1 N-m = 10.19 kg-cm*

Appendix E

Data CD

File Type	Contains
*.cor	All CPTU data- D, Qc, Fs, Ud
*.ifi	Importable Interpretation output
03-126CPTSumm.xls	CPT Summary
03-126VaneSumm.xls	Vane Data
126cp??.*	Files of hole # CPT03-??