THERMAL OBSERVATIONS CONDUCTED AS PART OF BEAUFORT DEITA OIL PROJECT LIMITED'S SAMPLING CRUISE ON THE M.S. NORWETA. BEAUFORT SEA, SEPTERMBER 1976

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1. INTRODUCTION

In September 1976 the Geothermal Studies section of the Earth Physics Branch participated in a survey conducted by Beaufort Delta Oil Project Limited (B.D.O.P.L.) in the Southern Beaufort Sea. This report presents and comments on the thermal measurements recorded during this field programme on board the M.S. Norweta.

2. B.D.O.P.L. AND EPB's INVOLVEMENT IN THE CRUISE

Beaufort Delta Oil Project Limited was formed in 1974, by a consortium of five companies (Gulf Oil Canada Ltd., Imperial Oil Ltd., Shell Canada Ltd., Interprovincial Pipe Line Ltd., and Trans Mountain Pipe Line Co. Ltd.), with the intent to file an application to build a crude oil pipeline from the Beaufort Sea - Mackenzie Delta Region, through the Mackenzie Valley to connect with existing pipeline systems. B.D.O.P.L. thus set up a study group to examine the engineering, financial, social, environmental and related aspects of the pipeline.

As part of this study, during the summer of 1976, B.D.O.P.L. conducted a field programme in the southern Beaufort Sea, surveying potential pipeline corridors. The survey was divided into two phases: 1) seismic and bathymetric operations; and 2) sampling operations.

Through B.D.O.P.L.'s desire to exchange information with government, to provide as comprehensive as possible a coverage of the survey and to relate results to previous work carried out by industry and government, the GSC and EPB were invited to observe and/or participate in the survey. The invitation, extended to the Geothermal Studies section, to conduct temperature measurements during the sampling phase, provided the opportunity to record further sub sea-bottom temperatures. These results would be helpful in understanding the permafrost character and environment in the Beaufort Sea.

3. SUMMARIZED ITINERARY

The sampling phase of the survey brought together personnel from B.D.O.P.L., EBA Engineering Consultants Ltd., Kenting Exploration Services Limited, all from Calgary, and the Geothermal Studies section of the Earth Physics Branch, Ottawa. Equipment was set up on board the Norweta and tested on September 1 and sampling was begun the following day. From September 2 through September 7, 43 sampling stations were visited in the Kugmallit Bay region of the southern Beaufort Sea, (Fig. 1). Sampling followed "Corridors" roughly perpendicular to shore and "Laterals" roughly parallel to shore, e.g. KC for Kugmallit Corridor and TL for Tuktoyaktuk Lateral. After completing the sampling operations, the Norweta proceeded up the Mackenzie River to Inuvik, where the survey disbanded on September 8.

4. EQUIPMENT FOR TEMPERATURE MEASUREMENT

Equipment used consisted of a single thermistor probe on an electrical cable to measure incremental water temperature profiles, a thermal gradiometer probe to measure temperature at the sediment-water interface and at a depth of 3 m in the sediments, and a Wheatstone bridge used in conjunction with both probes for surface recording of sensor resistances.

The single thermistor probe portable temperature logging system was similar to that described by Judge (1973). The sea-bottom probe, assembled for the Norweta cruise, operated on the same principles as the single probe, but consists of two thermistor probes mounted on a simple frame (Fig. 2). A lead weight (about 41 kg) mounted on top of the probe provided the momentum required to drive the three metre long pipe (standard water pipe, 2.5 cm inside diameter) into the bottom mud. About 20 cm below the weight, a 35 cm diameter aluminium disc mounted perpendicular to the length of the pipe prevented the sea-bottom probe from penetrating more than 3 m. One thermistor probe was positioned at the bottom end of the pipe, the other was attached to the disc, with a spacing of 3 m between the two.

The two thermistor probes of the sea-bottom probe, each on electrical cable, were connected to the bridge at the surface via 150 m of seven conductor double armoured winch cable and 15 m of deck cable. Unfortunately the winch used had a fixed fall rate and therefore the sea-bottom probe could not free fall and probe penetration was consequently reduced somewhat.

At each station the sea-bottom probe was lowered over the bow and the water depth recorded using the Norweta's sounder. The single thermistor probe was lowered in increments to the bottom by means of a portable hand winch. Depth was recorded by running the cable through a meter block.

Incremental water temperatures (as well as salinity and conductivity) were also recorded with a Yellow Springs Instrument SCT Meter Model 33 by B.D.O.P.L.'s environmental coordinator. These measurements were limited by the cable length to a maximum depth of 13 m.

5. DATA REDUCTION AND ACCURACY

5.1. EPB Temperature Measurements

Temperature sensors used in both EPB probes were Fenwall glass bead thermistors. The variation of thermistor resistance with temperature was determined in the laboratory by calibration at 5K intervals, over the range $-20^{o}C$ to $+20^{o}C$, in a constant temperature bath against a platinum resistance thermometer. Calibration tables were prepared by interpolation between calibration points (Judge, 1973). The accuracy of field temperature measurements was 0.01K . The accuracy of the calculated sediment temperature gradients was 0.01 km^{-1}. However, some of the measured temperatures and hence gradients, were less accurate due to difficulties in balancing the bridge in rough seas.

5.2 SCT Meter Measurements

Salinities determined with the SCT Meter were of unknown reliability since the meter was not checked against known solutions; the meter had a stated accuracy of 2 parts per thousand. SCT Meter temperatures (accuracy of 0.1 K) were suspect for all but the final eleven sampling stations due to malfunction of the equipment. B.D.O.P.L.'s temperatures recorded at these final stations, despite minor corrections determined by a post-field calibration, were always greater by roughly 2 K from EPB temperatures and were not included in the discussion of the results. The source of this discrepancy was not determined.

5.3 Total Water Depth

Total water depth was recorded by three different techniques: 1) the Norweta's sounder, accurate to 0.3 m, 2) the line on the SCT Meter, which could be 0 m to 1 m from the bottom when no drift occurred , but had a maximum length of 13 m, and 3) the meter registering the length of the single thermistor probe cable, accurate to 15 cm when no slippage over the pulley clamp and no drift occurred. Knowing these sources of error and given the possible existence of differences in bottom topography (due, for example, to scouring), helped to resolve conflicting water depths recorded at many stations by the separate instruments. Once this 'average' water depth was determined no adjustment was made to correct measured depths of individual temperature observations, as these adjustments would not be evenly distributed throughout a profile (e.g. in the case of slippage or drift of the line part way through descent).

5.4 Penetration of Thermal Gradiometer Probe

For the first 9 stations, penetration of the sea-bottom probe was assumed to be complete. However, this was probably not always true, particularly for the last half of these stations where the bottom was more compact. For later stations, penetration was determined by visually estimating the height of the mud line on the pipe. This visual estimation was subject to error since the mud was not cleaned off between stations. Also, by trying to maintain the winch cable and therefore the probe in the vertical position while compensating for the ship's drift, the probe might have fallen or leaned over.

6. DATA

Temperatures recorded by EPB are listed in Appendix A, Table 1, in order of station visited. Gradients in the sediments, calculated from the sediment-water interface temperature and the sub-bottom temperature, are listed in Table 2, Appendix A, in chronological order. Salinities recorded by B.D.O.P.L.'s SCT Meter are given in Table 3. Measurements either were not made or were curtailed at several stations principally due to equipment failure, but also due to rough seas, hard sea-bottom and lack of time.

Contour maps of bathymetry, bottom temperatures, surface salinities and bottom salinities are shown in figures 3, 4, 7 and 8, respectively. Sub-bottom temperatures and sediment temperature gradients are mapped in figures 5 and 6 respectively. Graphs of bottom temperatures versus water depth and sub-bottom temperatures versus water depth are plotted in figures 9 and 10. Contoured cross sections of salinities and temperatures for the main sampling lines, KC, SC, PC and TL are shown in Figures 11 to 18.

7. RESULTS AND DISCUSSION:

7.1 Bottom and Sub-Bottom Temperatures

The spatial map of bottom temperatures (Fig. 4) reveals an expected decrease in bottom temperatures going away from shore into deeper waters. Sub-bottom temperatures are plotted regardless of penetration in Figure 5, and show a similar, but less well defined trend reflecting variable and imprecise measurement of probe penetration.

Comparing Figures 9 and 10, lateral variations in temperatures are greater at the sediment-water interface than in the sediments. The sediments rapidly attenuate short-term fluctuations in water temperature. Variations appear to have been greater, as might be expected, in shallower waters.

7.2 Gradients

Gradients in bottom sediments show no general trend throughout the study area (Fig. 6). The wide spacing of sampling stations, the problems and inaccuracies in measuring, and the limited and uncertain depth of probe penetration, constitute too many unknowns to draw constructive conclusions from derived gradients.

Variations in sediment gradients are controlled by the annual variation of bottom water temperature, the mean annual sea-bottom temperature, the depth to relic permafrost and the thermal properties of the sediments. In general there is a trend of decrease in annual wave variation (temperature range) and mean annual bottom temperature with increase in water depth. This was especially apparent along the Kugmallit Corridor where the gradient became less negative away from shore.

Negative near-surface temperature gradients occur in the summer months because of the slow rate of penetration of the annual wave due to the low thermal diffusivity of the sediments. The warmer the summer temperatures and the closer the permafrost table to the surface, the more negative the gradient. In deeper colder waters, the gradient is close to zero where bottom temperatures are zero and where relic permafrost is close to bottom, or will be positive if either no relic permafrost exists or if new ice -bonding or -lensing is forming close to the surface.

Temperature gradients, measured during B.D.O.P.L.'s survey, which were very close to zero, such as those at the northern stations along the Pullen Corridor, probably were the result of lack of probe penetration rather than relic permafrost close to bottom.

7.3 Oceanographic Implications

The following are general comments on water salinity and temperature cross-sections along the main sampling lines (Figs. 11 to 18). In late summer 1976:

i) Mackenzie River water flowing into Kugmallit Bay along KC and SC remained fairly uniform and warmed the sea bottom out to depths of 8 m. At greater depths, and further offshore, mixing with cold sea water was more marked and resulted in a rapid decrease in bottom water temperatures to reach $0^{\circ}C$ in depths of ~18 m.

ii) The cross section along the Pullen Corridor indicated that Mackenzie River water flowing eastwards from Mackenzie Bay remained warm and fresh near the surface. Below this warm layer, gradual mixing with sea water occurred resulting in colder and more saline bottom waters in the vicinity of Pullen Island. Thus along the Pullen Corridor bottom temperatures decreased gradually with water depth rather than only below 8 m water depth; $0^{\circ}C$ bottom temperatures were reached in water depths of 13 m.

iii) Mackenzie River water flowing eastwards along the Tuktoyaktuk Peninsula (line TL) had slightly cooled and increased in salinity, but remained a uniform body of water. Bottom temperatures were warm — $6^{\circ}C$ at 12 m depth.

8. RELATION TO BEAUFORT SEA DATA BASE

8.1 Statistics

The bottom temperatures and salinities measured during the Norweta cruise, supplement the existing summer Beaufort Sea data base listed in the Beaufort Sea Project Technical Report No. 22 (Hunter et al. 1976). Observations correspond to three of the depth zones delineated by Hunter et al. (1976): 0-10m, 10-20 m and 20 - 40m.

Temperature and salinity statistics from the Norweta cruise are listed in Appendix B. An updated version of statistics on all Beaufort Sea summer bottom temperatures and salinites including 1976 Norweta data is also listed in Appendix B.

The range of temperatures and salinities of the Norweta data, for each depth zone, was much smaller than for the complete Beaufort Sea data base. This may be because Norweta data covered a span of a week, versus a span of over four months for the whole data base. The Norweta data, warm summer temperatures, were recorded late in the summer season (the optimum time in the season for maximum water temperature) and therefore the mean of temperatures for the 0-10 m depth zone and for the 10-20m depth zone were much higher, and the salinities slightly lower than in the data base.

The major change from or difference to the previous Beaufort Sea summer statistics occurred in the 0-10 m depth zone for summer temperatures. Warm temperatures recorded on the Norweta cruise increased the arithmetic mean summer temperature from 3.1^{o}C to 4.8^{o}C.

8.2 Winter Data and Previous Summer Data

Seasonal variation in bottom temperature was difficult to determine since nearly all available winter data (Hunter et al. 1976) are from outside the Norweta survey area (most of it from the area further south in Kugmallit Bay near Tuktoyaktuk). However, two holes jet-drilled in April 1976, through the ice in the Beaufort Sea (Judge et al., 1976), were close to stations GL6 and GL5 (Fig. 1). Bottom temperatures recorded during this drilling programme were on the order of -1.5^{o}C; those in September were 1.0^{o}C (2m above bottom). Seasonal range in this location was at least 2.5K.

August and September bottom temperatures prior to 1976 in the present study area are mapped in Fig. 19 and except for two observations, date from 1952. Their distribution, being somewhat clustered, allowed no cross sections comparable to those drawn from Norweta data. The distribution of previous July bottom temperatures (again mostly 1952 data) is shown in figure 20. July temperatures are colder than late summer temperatures and probably too early in the summer to make meaningful comparisons.

Comparing the spatial distribution of these August and September temperatures (span of 2 months) to that of the Norweta temperatures (span of 6 days) revealed the following similarities, despite a time lapse of 24 years:

i) Warm bottom temperatures, around 7°C, in Kugmallit Bay northeast of Hendrickson Island.

ii) Warm, 2° to 4°C, temperatures north of Pullen Island.

iii) Negative temperatures along the northern end of the Kugmallit Corridor.

From the sparse data prior to 1976, no obvious yearly change or trend in bottom water temperatures was apparent, and in fact 1976 data did not seem markedly different. No major conclusion could be drawn however, since only two separate years of surveying were represented by the data.

9. SUMMARY OF MAIN FINDINGS

1. Seabottom probe penetration was the source of many problems and inaccuracies. A free falling probe, a more sturdy pipe and more accurate measurement of penetration would enable the determination of more precise gradients.

2. Bottom temperatures (and sub-bottom) were warmest and showed the greatest lateral variations near shore, close to fresh water input. Lateral variations in sediment temperatures were less than those of bottom water temperatures; sediments rapidly attenuate short-term water temperature fluctuations.

3. Sediment temperature gradients were negative due to a variety of factors including the annual variation of bottom water temperature, the mean annual sea-bottom temperature, the depth to the permafrost table and the thermal diffusivity of the sediments. The trend along the Kugmallit Corridor of less negative gradients away from shore, reflected the general decrease in the annual temperature variation and mean annual bottom temperatures with increasing water depth and distance from shore.

4. The meaning of the variations in sediment temperature gradients could not be easily unravelled due to the wide spacing of sampling stations as well as problems with the penetration of the sea-bottom probe. A more detailed study would be able to relate the gradients to the presence of relic permafrost, depth of permafrost table, formation of permafrost, etc.

5. Little winter data was available to document the seasonal variation of bottom temperatures prior to 1976. Data was only representative of two separate sampling years and was thus insufficient to draw any major conclusions.

10. ACKNOWLEDGMENTS

We wish to first thank Vic Allen and John Collyer of the Earth Physics Branch for their hard work in designing and constructing the thermal gradiometer probe at very short notice. For the encouragement and cooperation received on board the Norweta while setting up, operating and repairing equipment, a collective thank you is extended to all; the crew, EBA Engineering, B.D.O.P.L. and Kenting. To those who gave not only manual, but moral support as well, to Mike O'Connor, John Kunz and Frank, a special thank you.

The data from this report is included in Beaufort Delta Oil Project Limited (1976).

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APPENDIX A

DATA LISTINGS

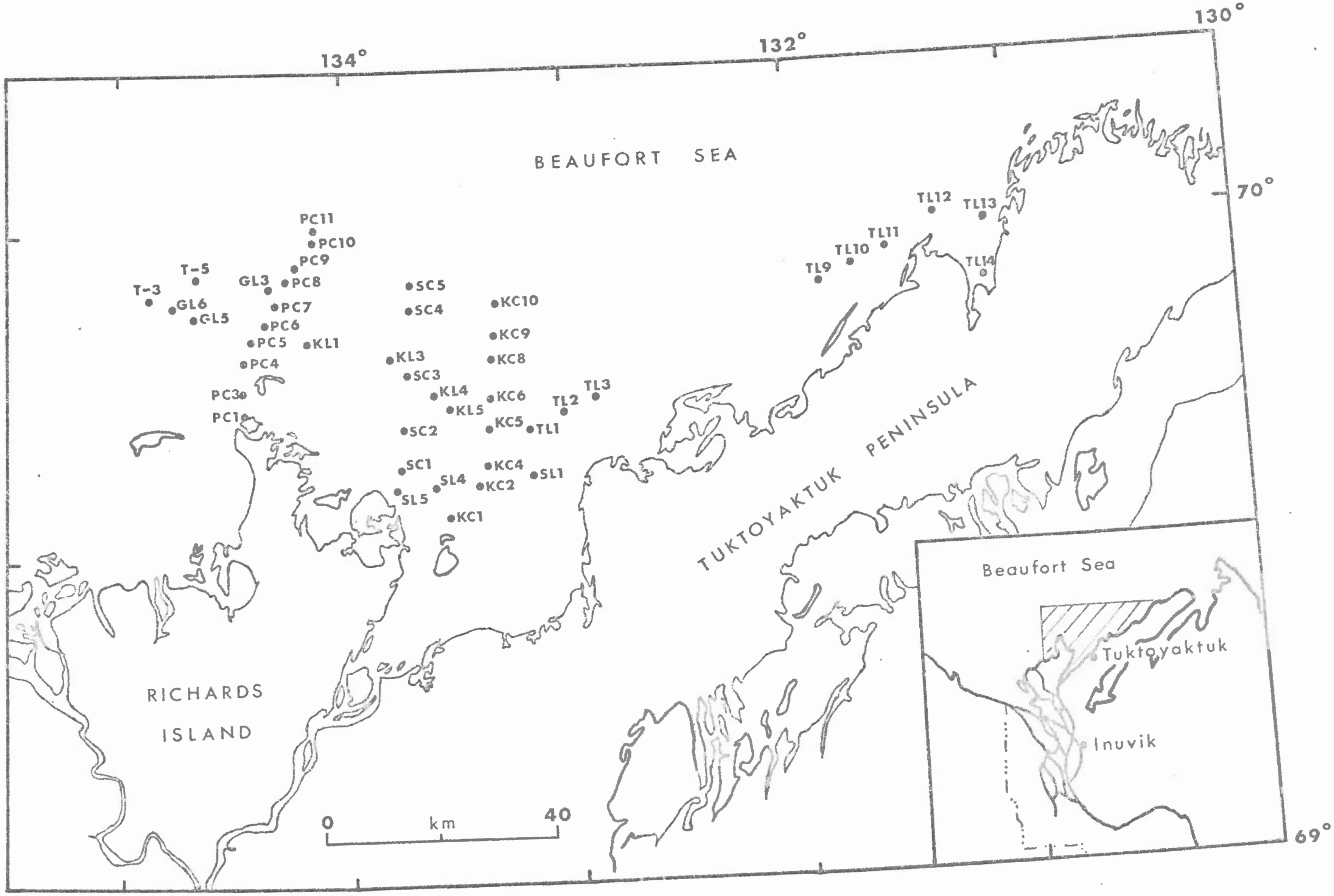

FIGURE 1 LOCATION MAP

(T-3 and T-5, jet drilled holes, April 1976)

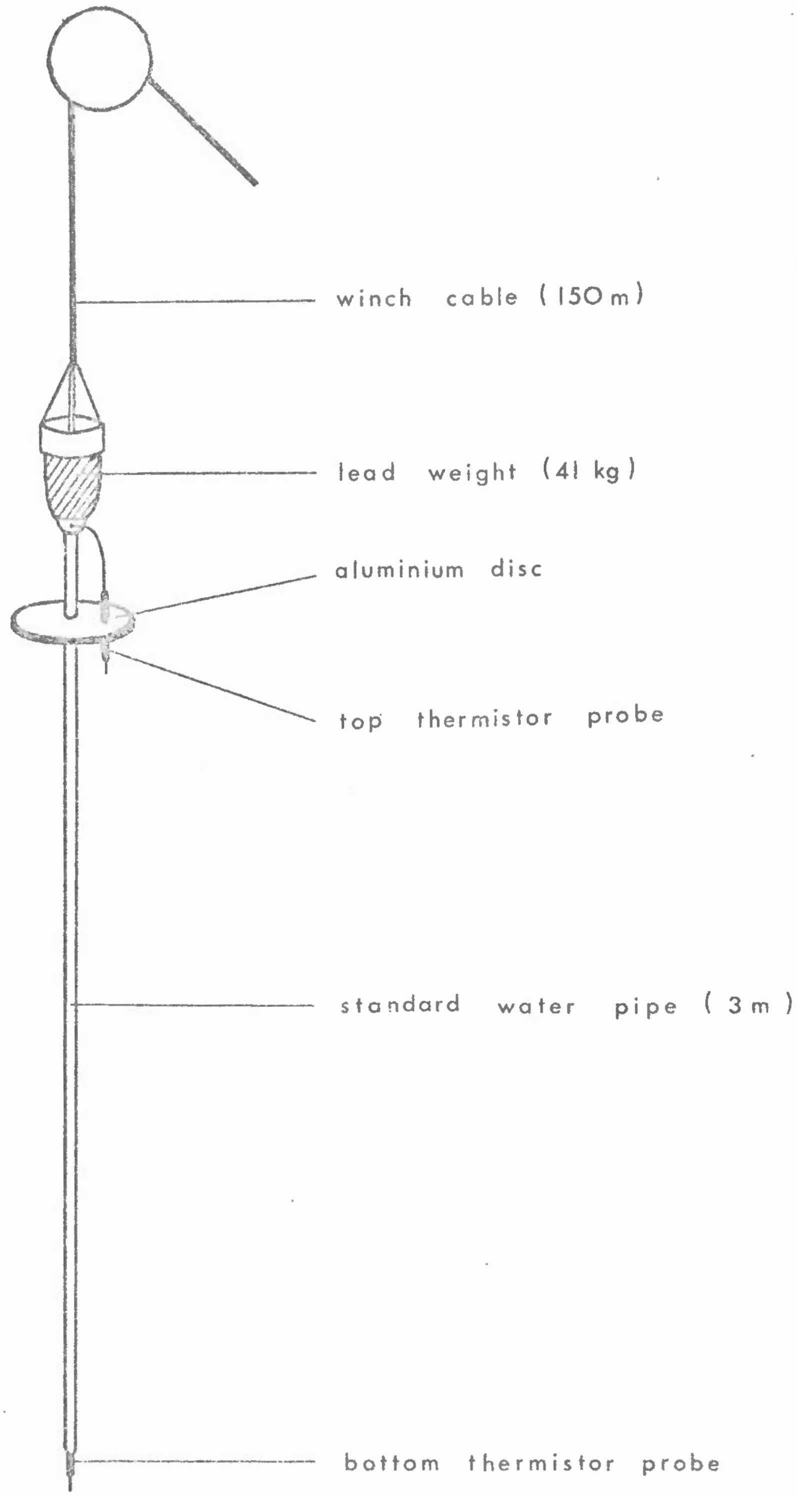

FIGURE 2 DIAGRAM OF THERMAL GRADIOMETER PROBE

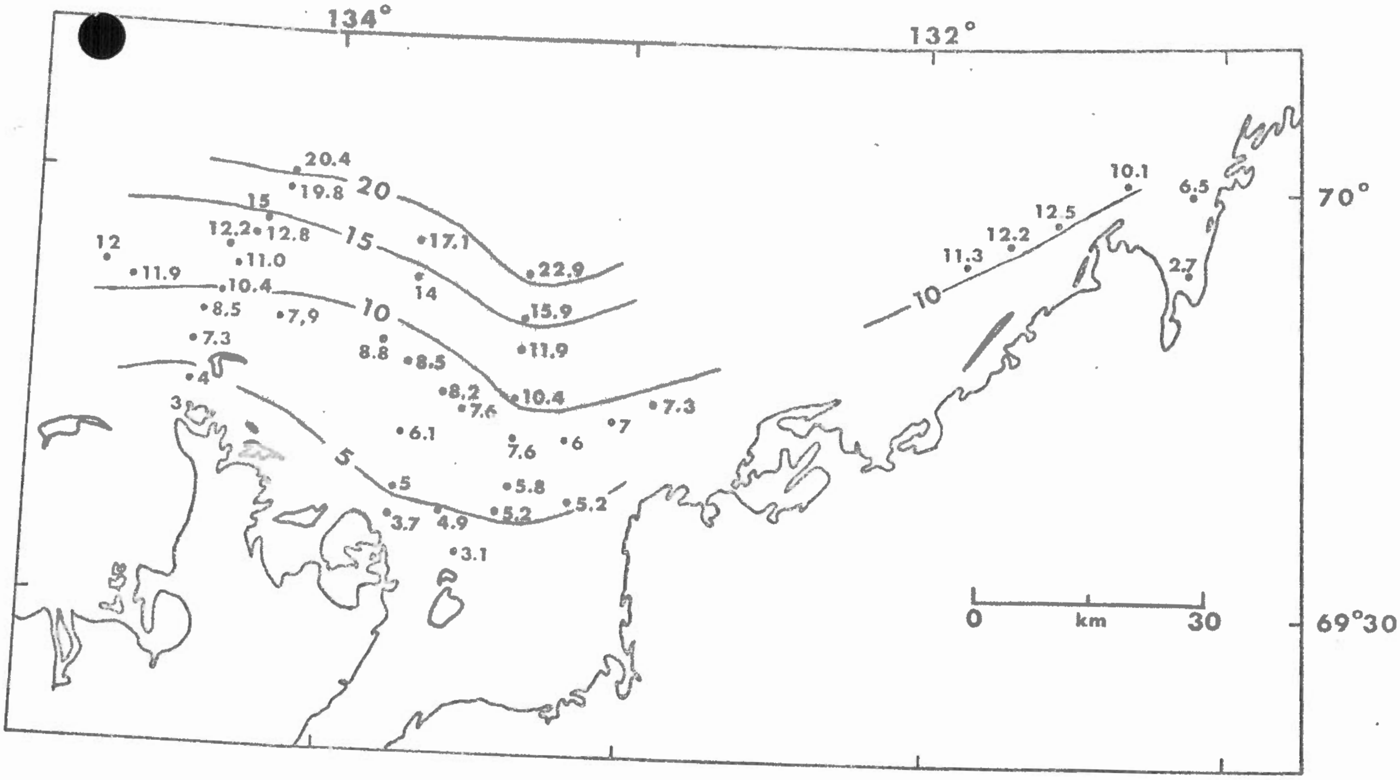

FIGURE 3 BATHYMETRY (m)

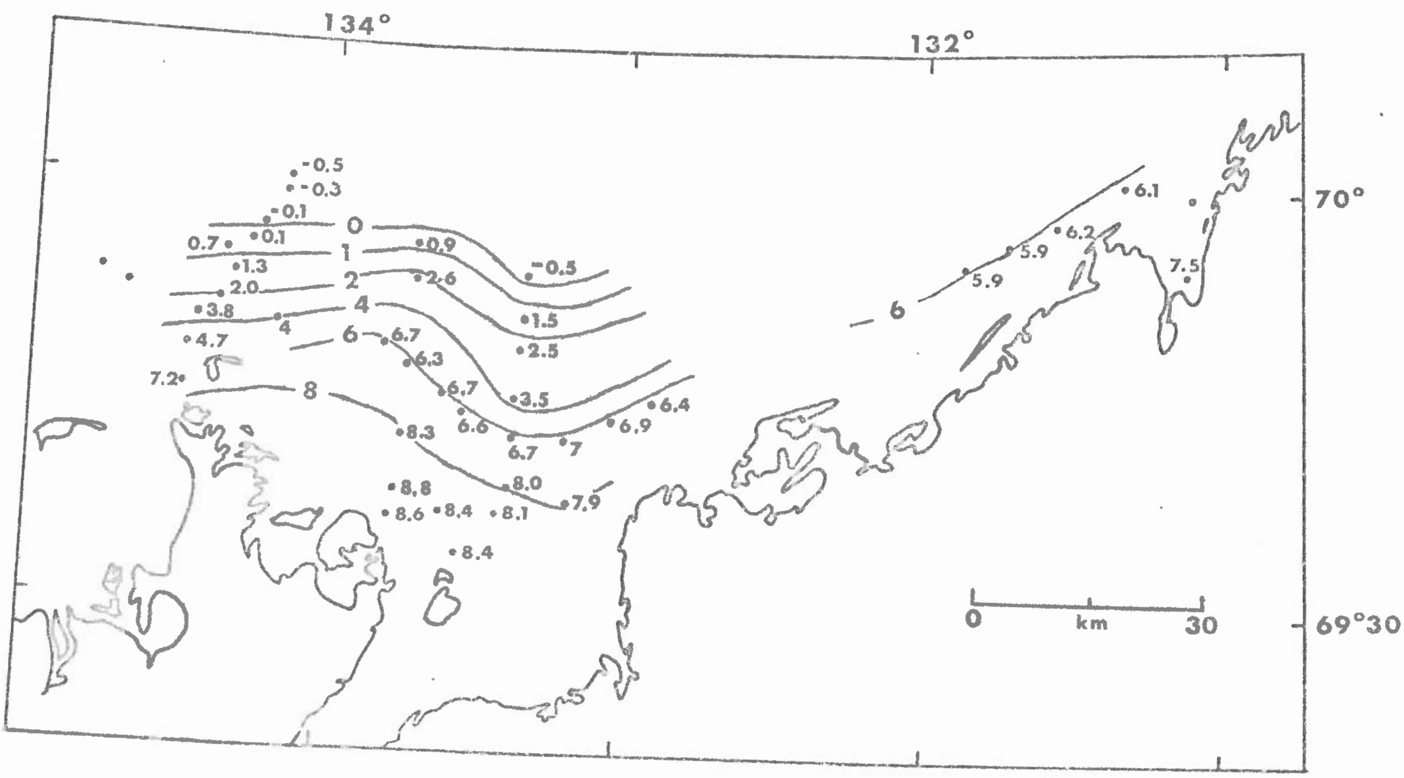

FIGURE 4 BOTTOM TEMPERATURE (°C)

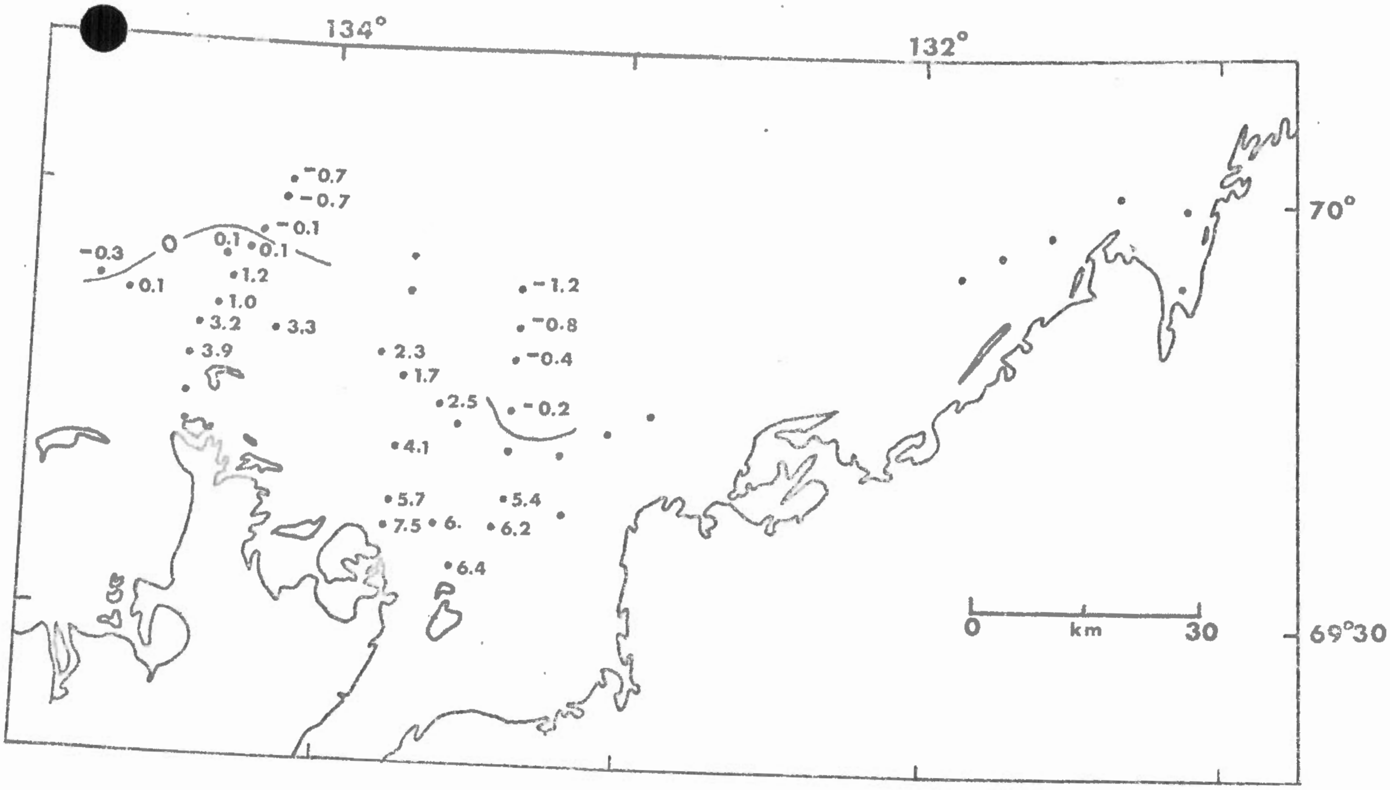

FIGURE 5 SUB-BOTTOM TEMPERATURE (°C)
(regardless of penetration)

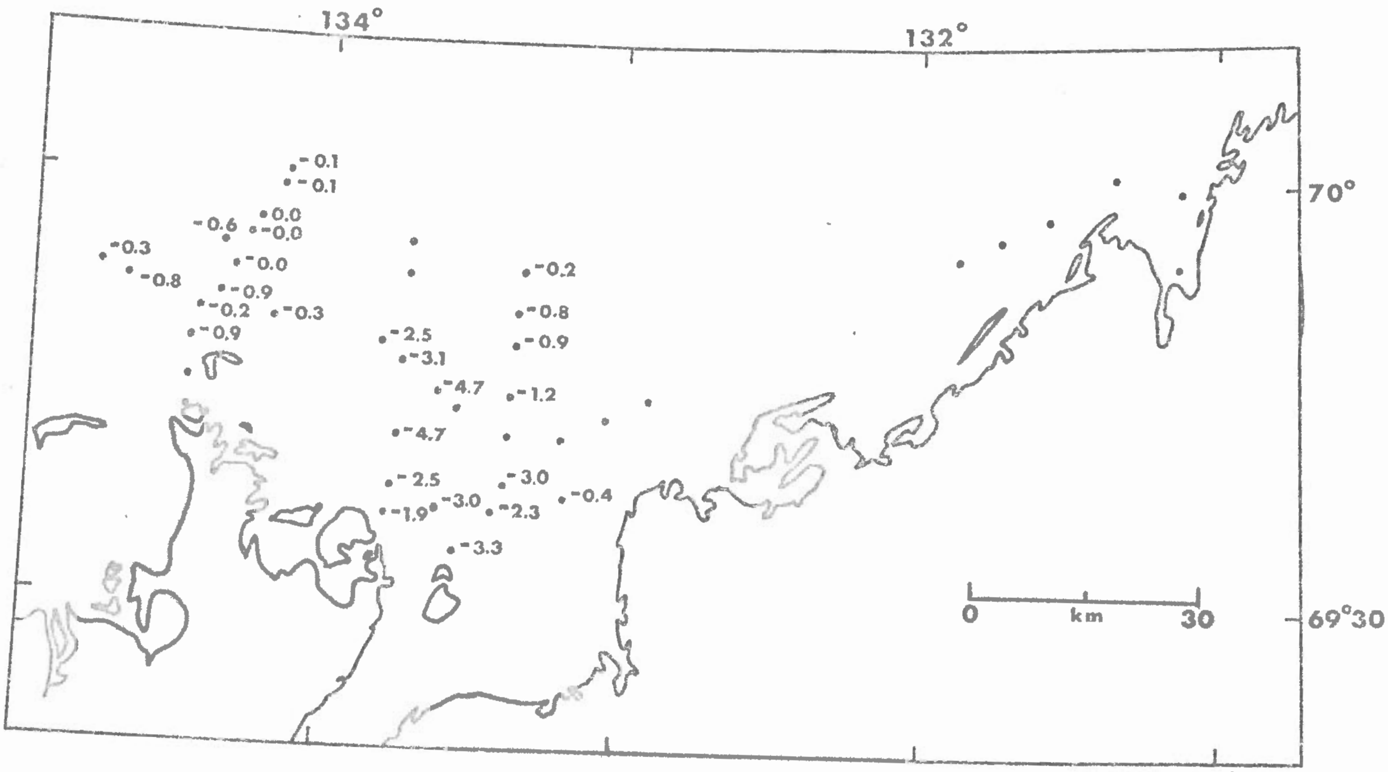

FIGURE 6 SEDIMENT TEMPERATURE
GRADIENT (K/M)

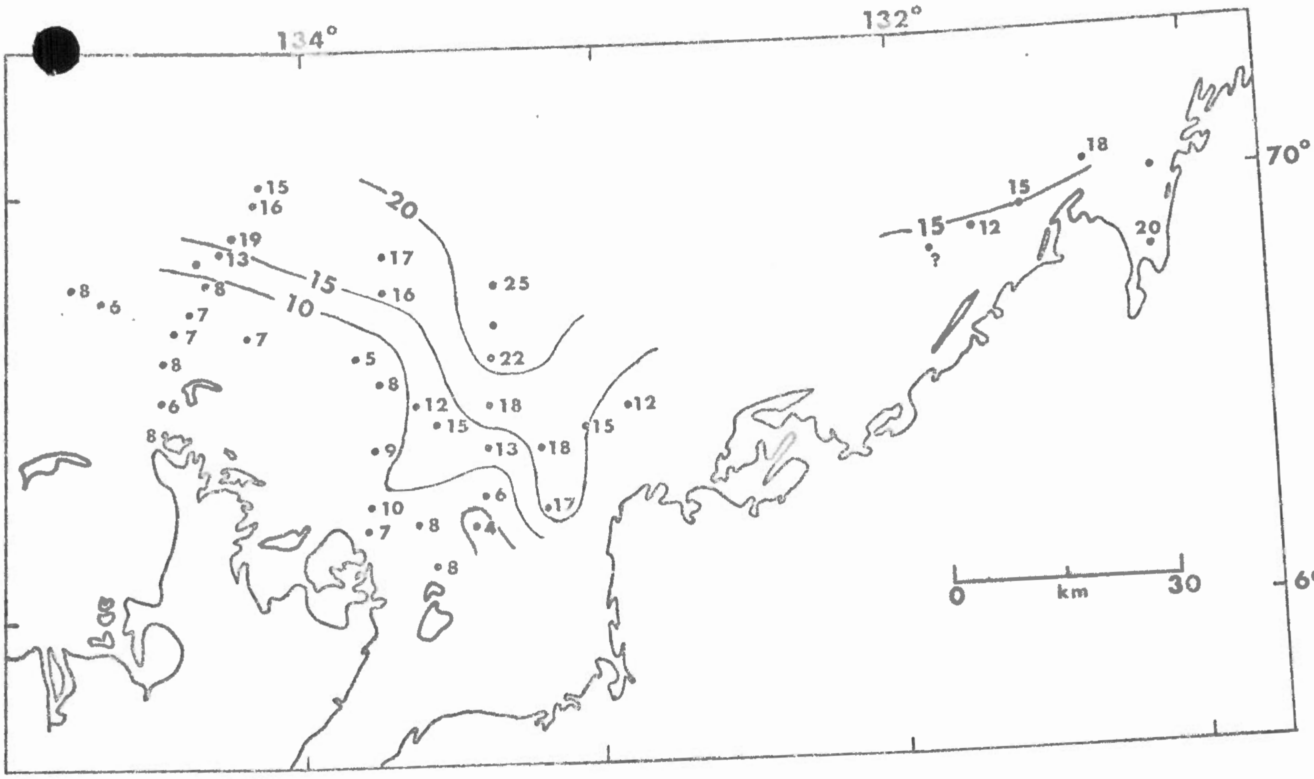

FIGURE 7 SURFACE SALINITIES (‰)
at 1 m water depth

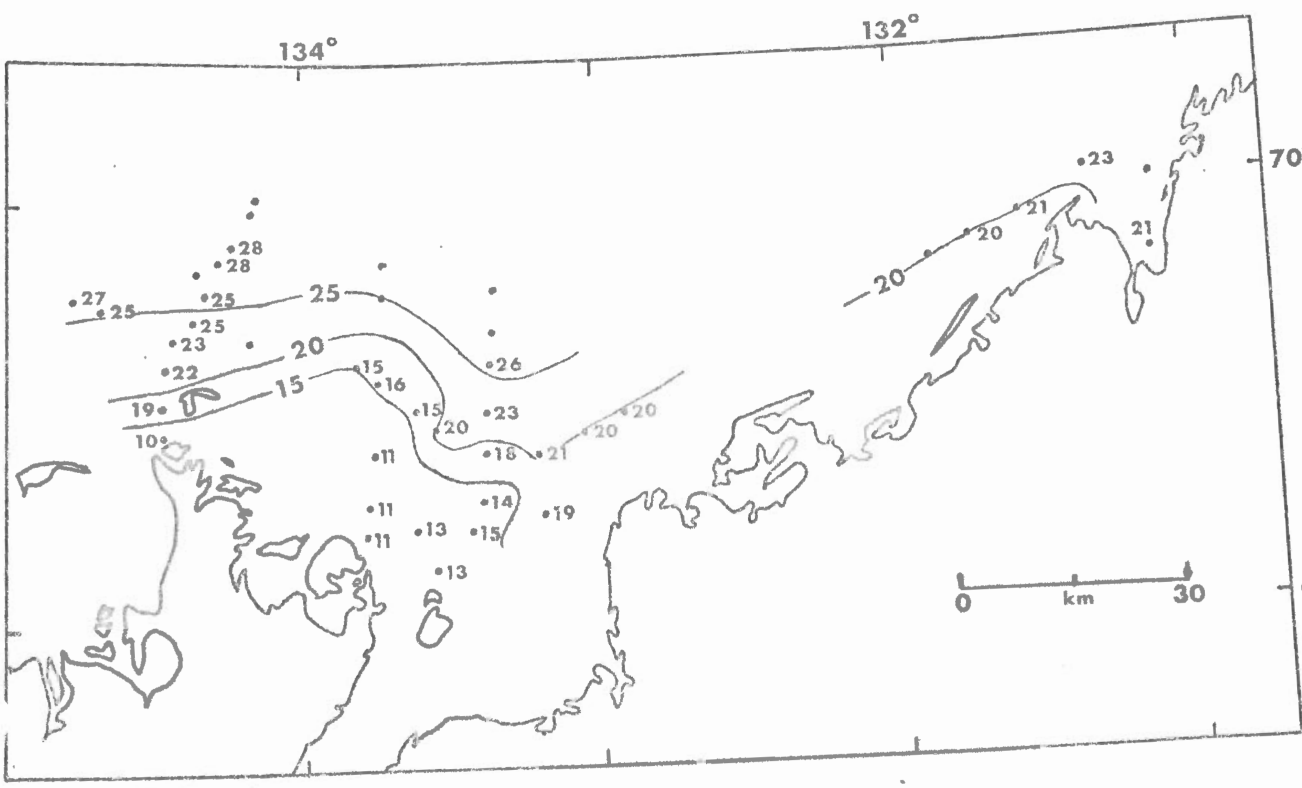

FIGURE 8 BOTTOM SALINITIES (‰)
0 to 2 m from bottom

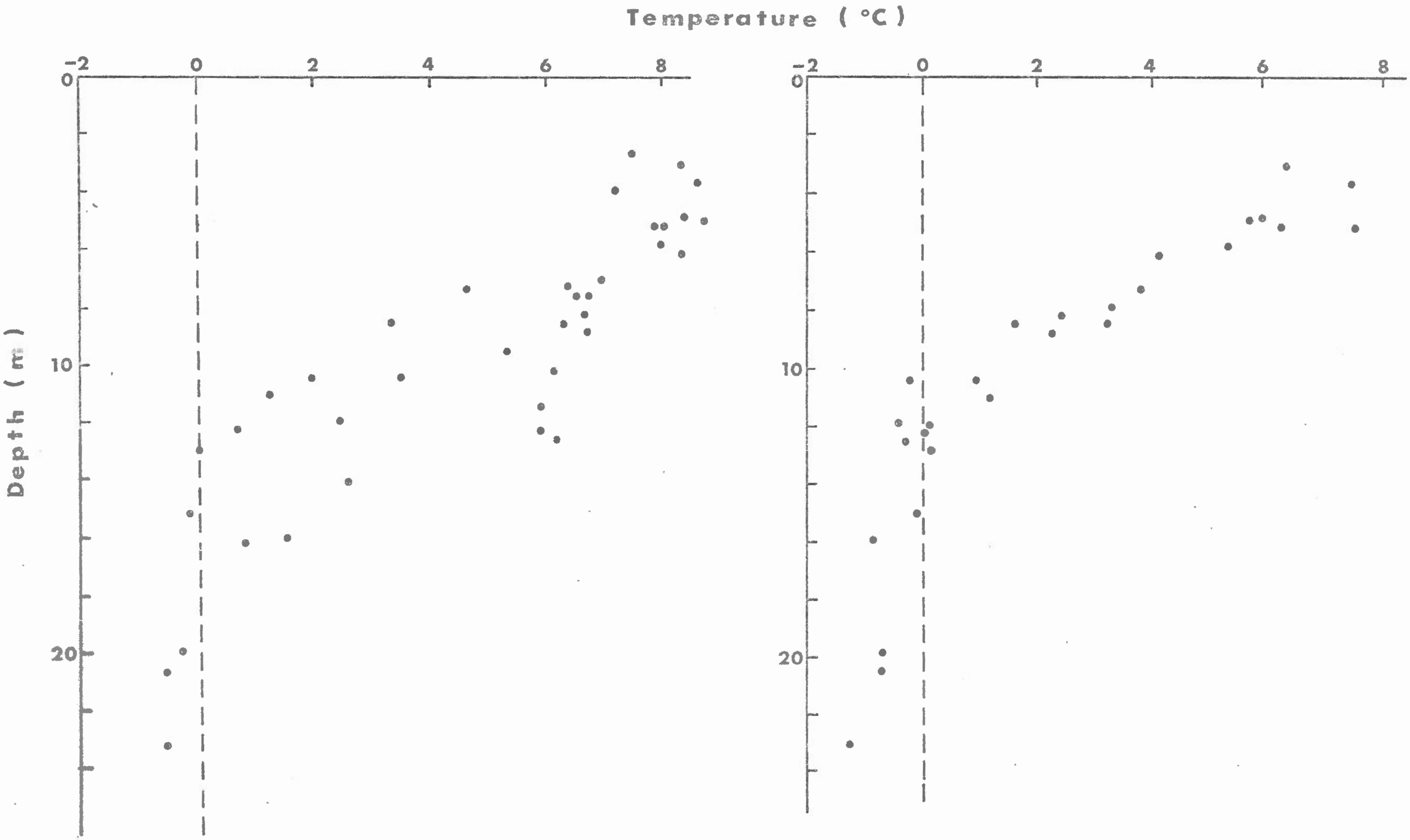

FIGURE 9 Bottom temperature vs total water depth

FIGURE 10 Sub-bottom temperature vs total water depth

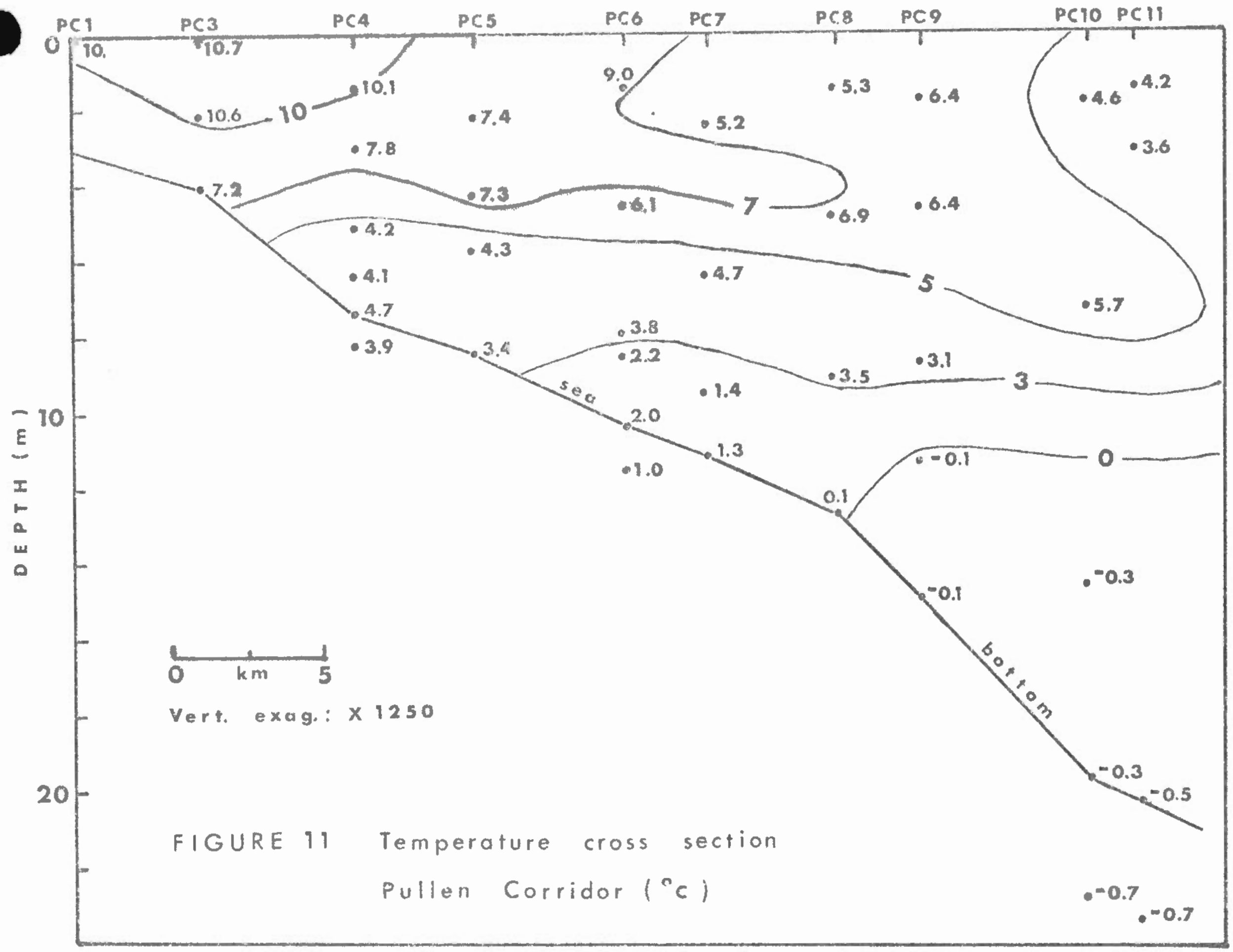

FIGURE 11 Temperature cross section
Pullen Corridor (°c)

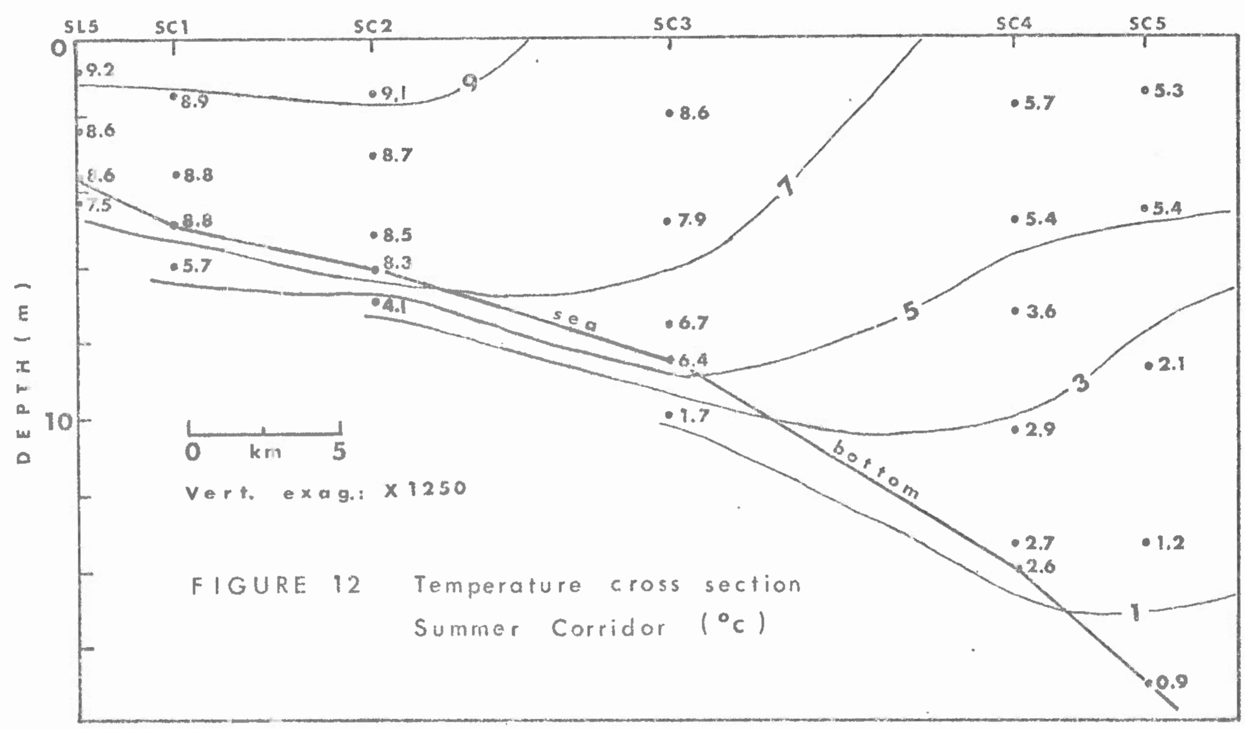

FIGURE 12 Temperature cross section
Summer Corridor (°c)

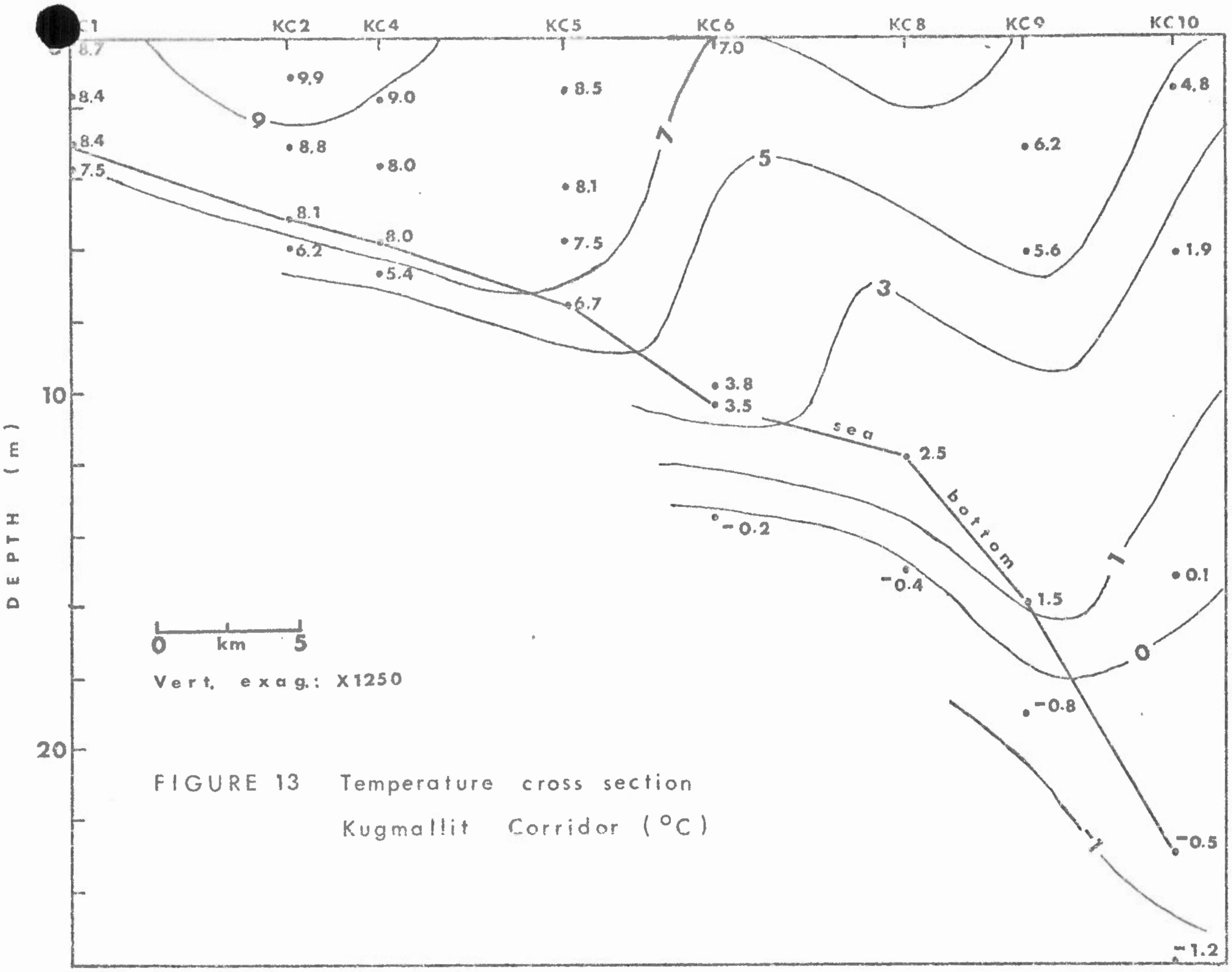

FIGURE 13 Temperature cross section
Kugmallit Corridor (°C)

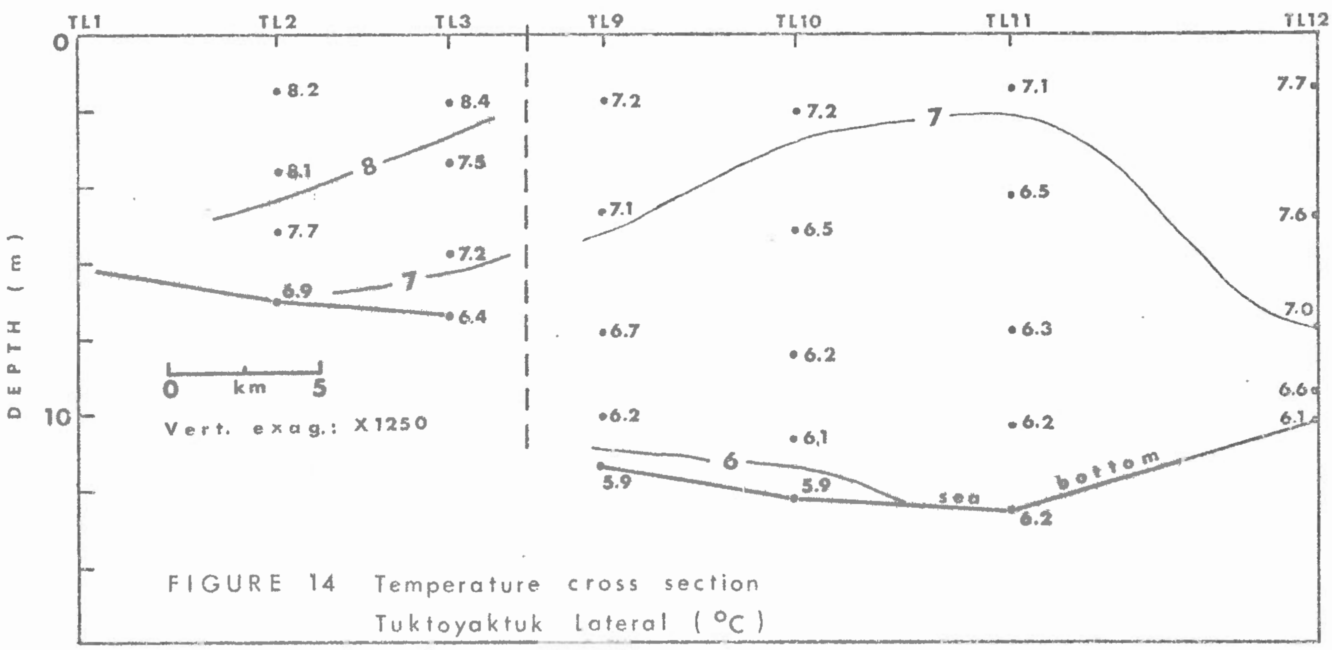

FIGURE 14 Temperature cross section
Tuktoyaktuk Lateral (°C)

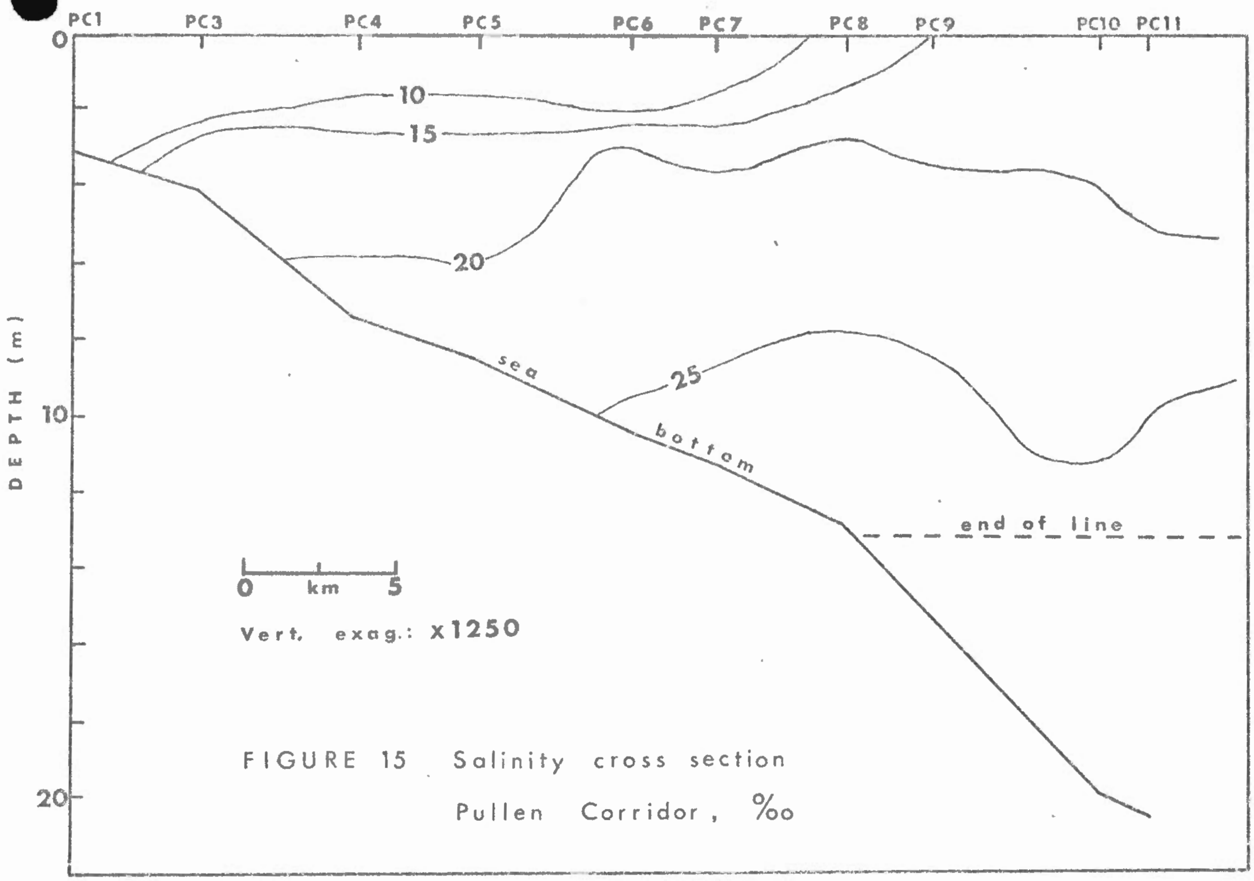

FIGURE 15 Salinity cross section
Pullen Corridor, ‰

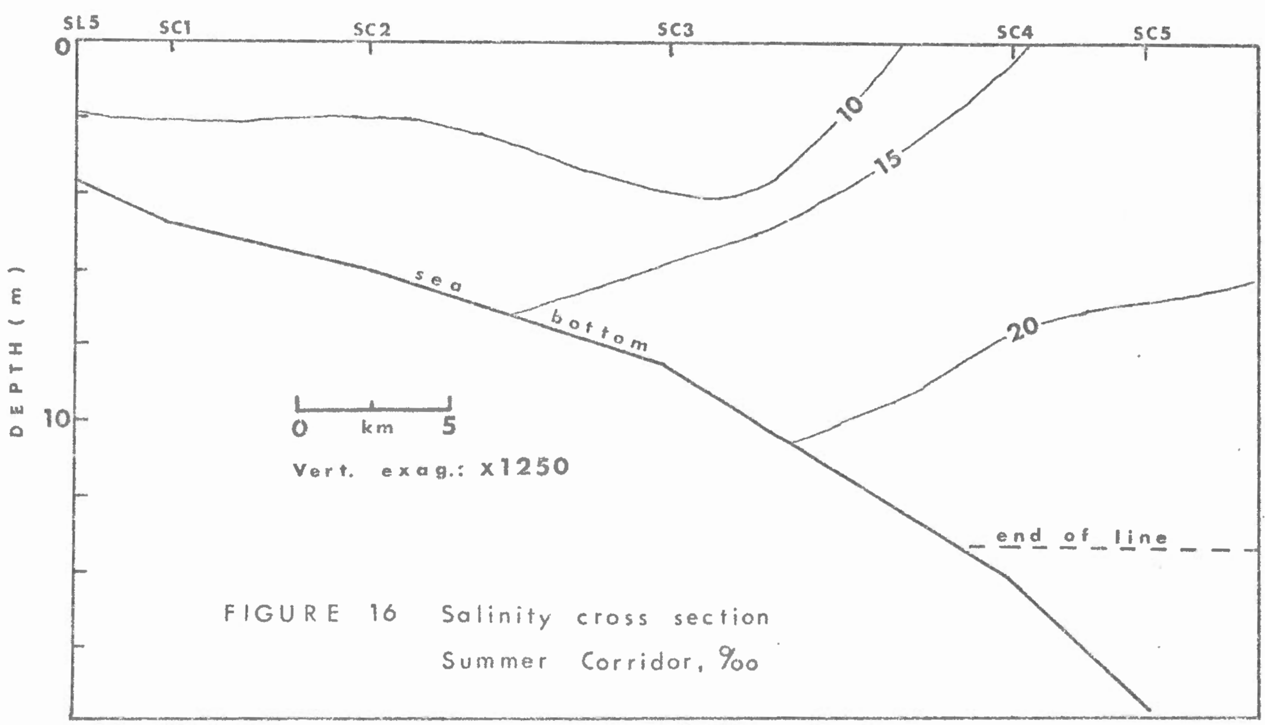

FIGURE 16 Salinity cross section
Summer Corridor, ‰

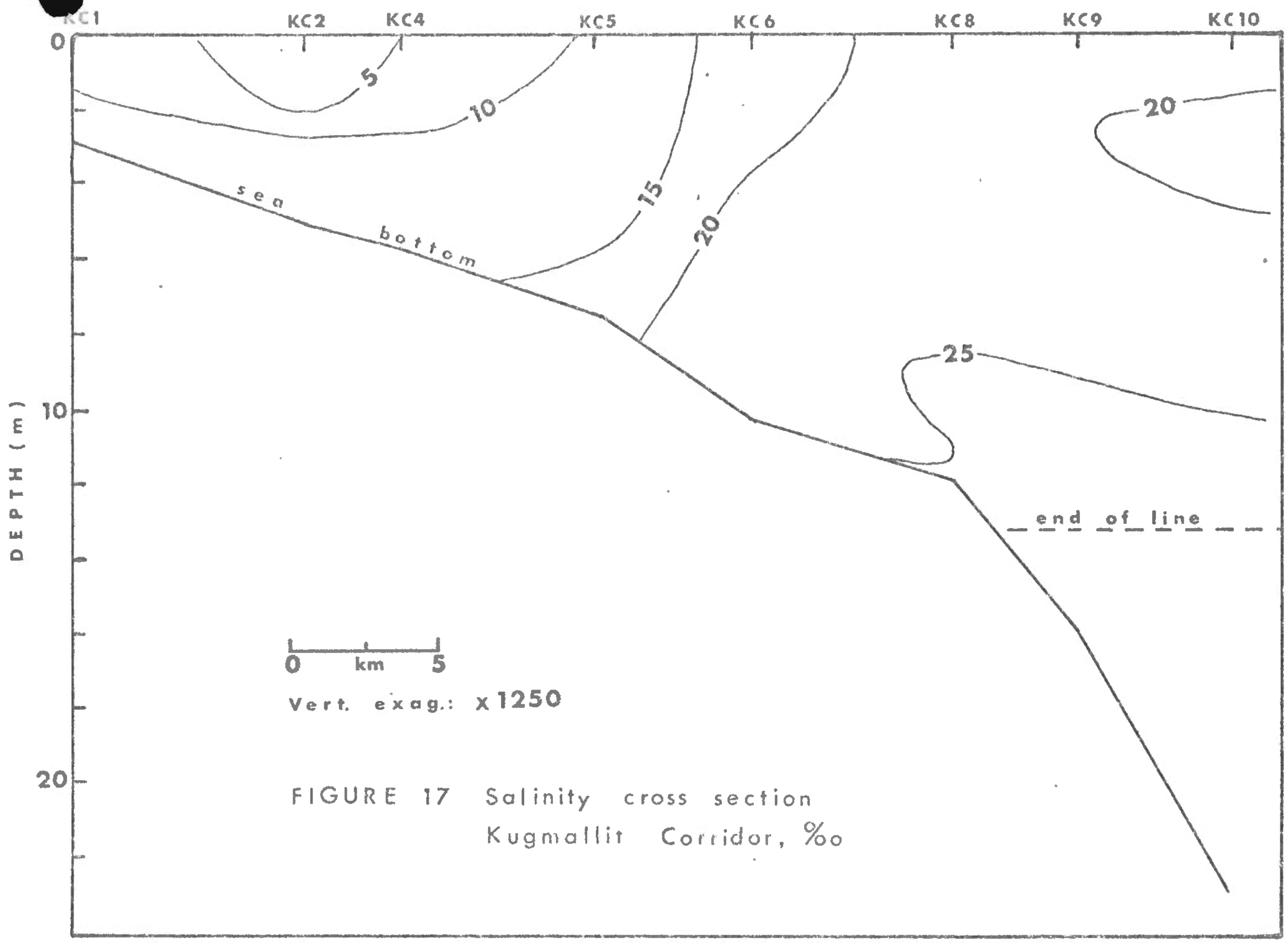

FIGURE 17 Salinity cross section
Kugmallit Corridor, ‰

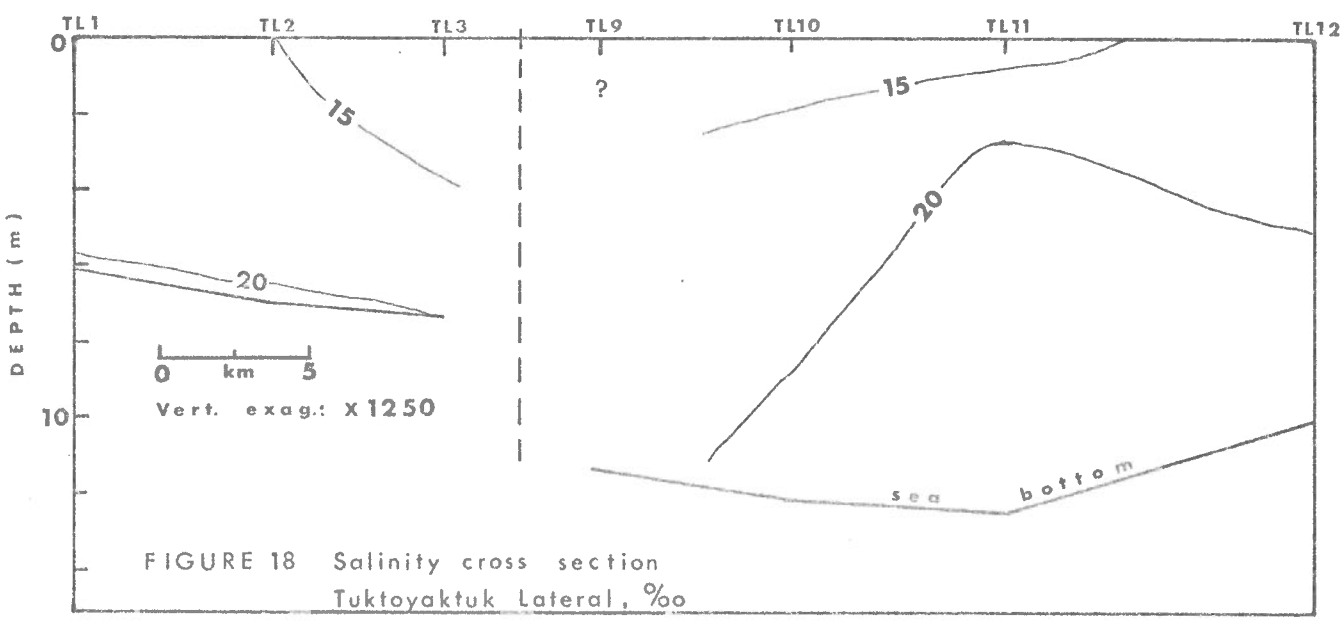

FIGURE 18 Salinity cross section
Tuktoyaktuk Lateral, ‰

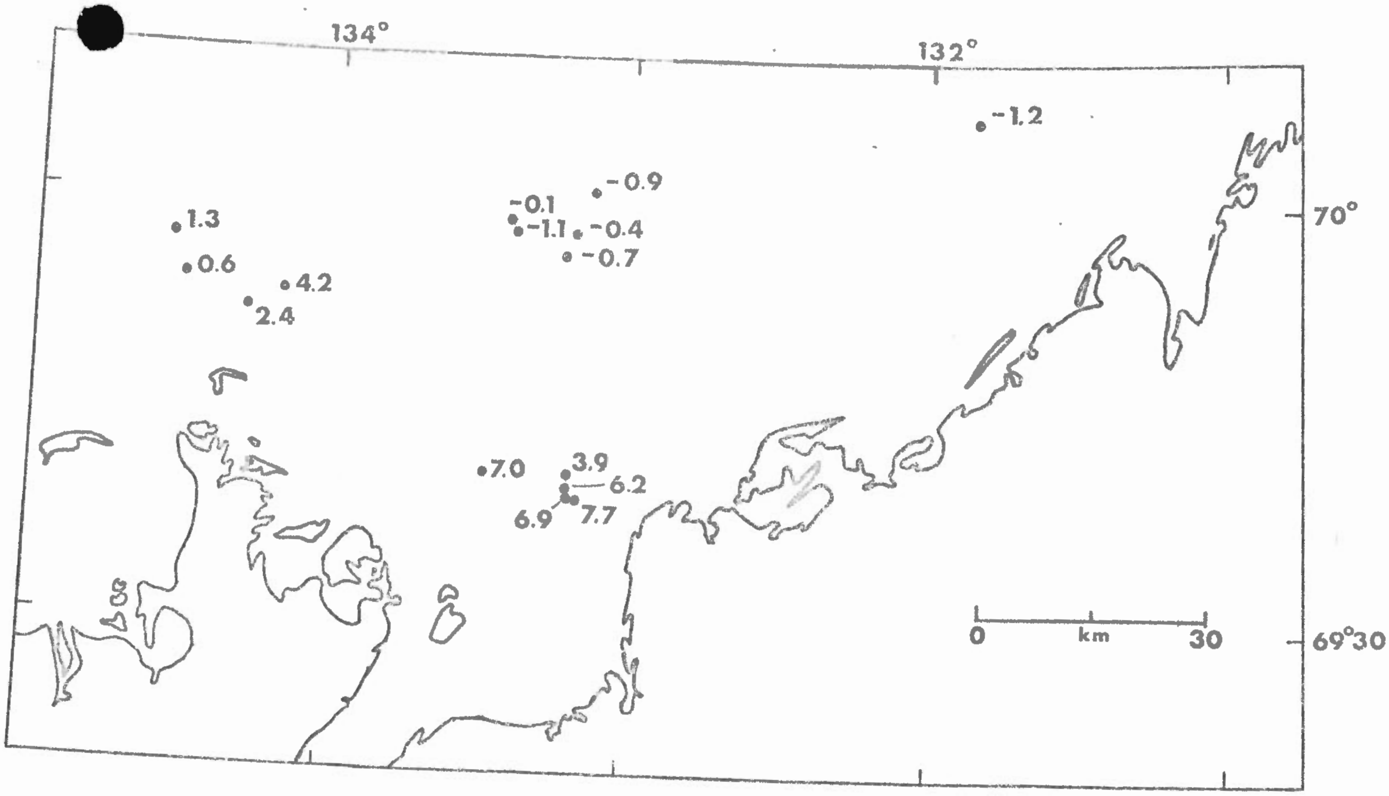

FIGURE 19 August and September bottom temperatures prior to 1976

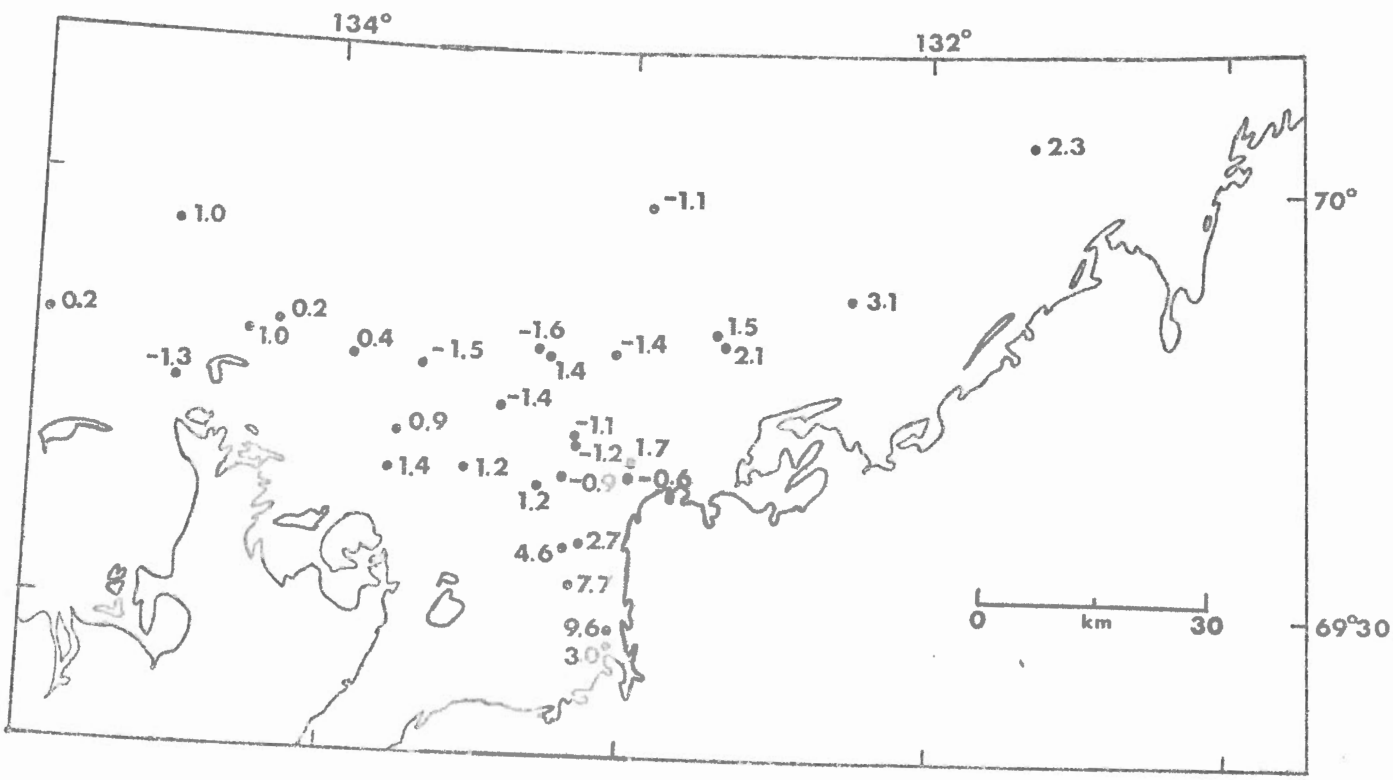

FIGURE 20 July bottom temperatures prior to 1976

TABLE 1 EPB TEMPERATURE DATA

Station	Date	Total Water Depth (M)	Thermal Gradiometer Probe: Pene-tration (M)	Thermal Gradiometer Probe: Top Temp. (°C)	Thermal Gradiometer Probe: Bottom Temp. (°C)	Single Probe: Reading Depth (from surface) (M) B= Bottom	Single Probe: Temp. (°C)
KC6	2/9/76	10.4	3.1	3.59	-0.23	0	6.98
						9.9	3.76
						10.4(B)	3.54
KC8	2/9/76	11.9	3.1	2.48	-0.42	-	-
KC9	2/9/76	15.9	3.1	1.53	-0.84	3.1	6.16
						6.1	5.60
KC10	2/9/76	22.9	3.1	-0.50	-1.24	1.5	4.80
						6.1	1.93
						15.2	0.05
						20.7(B)	-0.50
PC11	3/9/76	20.4	3.1	-0.51	-0.69	1.5	4.20
						3.1	3.57
PC10	3/9/76	19.8	3.1	-0.33	-0.67	1.8	4.57
						7.3	5.68
						14.6	-0.34
						18.0(B)	-0.25
PC9	3/9/76	15.0	3.1	-0.08	-0.08	1.8	6.35
						4.6	6.36
						8.8	3.14
						11.3	-0.09
						15.5(B)	-0.09
PC8	3/9/76	12.8	3.1	0.05	0.14	1.5	5.34
						4.9	6.93
						9.1	3.53
						13.4(B)	0.06
PC7	3/9/76	11.0	3.1	1.33	1.23	2.4	5.23
						6.4	4.68
						9.5	1.38
						B	1.26
PC6	3/9/76	10.4	1.2	2.24±.21	0.95±.18	1.5	9.00±.15
						4.6	6.05
						7.9	3.83
						10.7(B)	1.99
PC5	3/9/76	8.5	3.1	3.83±.33	3.22	2.1	7.43
						4.3	7.30
						5.8	4.32
						8.5(B)	3.35
PC4	3/9/76	7.3	0.9	4.18	3.86±.08	1.5	10.11
						3.1	7.79
						6.4	4.14
						7.3(B)	4.65
PC3	3/9/76	4.0	-	-	-	0	10.73
						2.1	10.63
						4.0(B)	7.23
PC1	3/9/76	3.0	-	-	-	0	9.99
GL6	4/9/76	12.5	1.1	1.04±.10	-0.28±.10	-	-
GL5	4/9/76	11.9	1.1	1.30±.14	0.13±.11	-	1
GL3	4/9/76	12.2	2.4	1.30±.06	0.06	1.8	9.09
						4.3	5.11
						9.1	1.12
						12.2(B)	0.72

TABLE 1 EPB TEMPERATURE DATA

Station	Date		Thermal Gradiometer Probe			Single Probe	
		Total Water Depth (M)	Penetration (M)	Top Temp. (°C)	Bottom Temp. (°C)	Reading Depth (from surface) (M) B= Bottom	Temp. (°C)
KL1	4/9/76	7.9	2.4	4.41±.24	3.32	–	–
SC1	5/9/76	5.0	1.2	8.78	5.73±.05	1.5	8.93
						3.6	8.80
						4.9 (B)	8.75
SC2	5/9/76	6.1	0.9	8.62±.03	4.12	1.5	9.10
						3.1	8.66
						5.2	8.48
						6.1 (B)	8.33
KL4	5/9/76	8.2	0.9	7.22±.03	2.45	2.1	7.45
						4.9	7.20
						7.0	6.79
						8.2 (B)	6.68
SC3	5/9/76	8.5	1.5	6.68	1.66	2.1	8.55
						4.9	7.87
						7.6	6.68
						8.5 (B)	6.32
KL3	5/9/76	8.8	1.8	6.88	2.29	1.8	9.08
						4.6	8.61
						7.6	6.86
						8.8 (B)	6.73
SC4	5/9/76	14.0	–	–	–	1.8	3.73
						4.9	5.36
						7.3	3.63
						10.4	2.92
						13.4	2.66
						14.0 (B)	2.62
SC5	5/9/76	17.1	–	–	–	1.5	5.34
						4.6	5.36
						8.8	2.11
						13.4	1.15
						17.1	0.87
						17.7 (B)	0.85
TL14	6/9/76	2.7	–	–	–	1.5	7.81
						2.7 (B)	7.51
TL13	6/9/76	6.5	–	–	–	–	–
TL12	6/9/76	10.1	–	–	–	1.5	7.67
						4.9	7.60
						7.3	7.01
						9.5	6.57
						14.6 (B)	6.14
TL11	6/9/76	12.5	–	–	–	1.5	7.10
						4.3	6.54
						7.9	6.28
						10.4	6.21
						13.4 (B)	6.20
TL10	6/9/76	12.2	–	–	–	2.1	7.15
						5.2	6.46
						8.5	6.20
						10.7	6.08
						13.7 (B)	5.93

TABLE 1 EPB TEMPERATURE DATA

Station	Date	Total Water Depth (M)	Thermal Gradiometer Probe: Pene-tration (M)	Thermal Gradiometer Probe: Top Temp. (°C)	Thermal Gradiometer Probe: Bottom Temp. (°C)	Single Probe: Reading Depth (from surface) (M) B= Bottom	Single Probe: Temp. (°C)
TL9	6/9/76	11.3	–	–	–	1.8	7.15
						4.7	7.13
						7.9	6.66
						10.1	6.16
						11.3(B)	5.92
TL3	6/9/76	7.3	–	–	–	1.8	8.44
						3.4	7.52
						5.8	7.24
						7.3(B)	6.40
TL2	6/9/76	7.0	–	–	–	1.5	8.18
						3.6	8.14
						5.2	7.71
						7.0(B)	6.93
TL1	6/9/76	–	–	–	–	–	–
KL5	6/9/76	7.6	–	–	–	1.5	8.50
						4.6	6.89
						7.6(B)	6.55
KC5	6/9/76	7.6	–	–	–	1.5	8.47
						4.3	8.13
						5.8	7.51
						8.2(B)	6.74
SL1	6/9/76	5.2	0.9	–	7.54±.05	1.8	8.87
						4.0	7.94
						5.2(B)	7.92
KC1	7/9/76	0.6	0.6	–	6.38±.05	0	8.73
						1.8	8.39
						3.1(B)	8.36
SL5	7/9/76	3.7	0.6	–	7.49±.19	0.9	9.21
						2.4	8.63
						3.7(B)	8.61
SL4	7/9/76	4.9	0.8	–	6. ± 1.	1.2	8.47
						2.7	8.41
						4.9(B)	8.40
KC2	7/9/76	5.2	0.8	–	6.24±.28	1.2	9.90
						3.1	8.84
						5.2(B)	8.07
KC4	7/9/76	5.8	0.9	–	6.35±.19	1.8	8.98
						3.7	8.04
						5.8(B)	8.01

TABLE 2 SEDIMENT TEMPERATURE GRADIENTS

Station	Gradient (K /M)
KC6	-1.23
KC8	-0.94
KC9	-0.75
KC10	-0.24
PC11	-0.06
PC10	-0.14
PC9	0
PC8	0.03
PC7	-0.03
PC6	-0.87±0.16
PC5	-0.17±0.13
PC4	-0.88±0.09
GL6	-0.25 approx.
GL5	-0.79 approx.
GL3	-0.64
KL1	-0.28 approx.
SC1	-2.52± .04
SC2	-4.68
KL4	-4.70
SC3	-3.11
KL3	-2.47
SL1	-0.42± .05
KC1	-3.30± .08
SL5	-1.87± .32
SL4	-3.01 ± 1.27
KC2	-2.29± .35
KC4	-2.96± .22

TABLE 3 BEAUFORT DELTA OIL PROJECT LIMITED

Salinity Data (S-C-T Meter)

Salinity (^{o}/oo)

Depth/Station (M)	KC-6	KC-8	KC-10	PC-11	PC-10	PC-9	PC-8	PC-7	PC-6	PC-5	PC-4	PC-3	PC-1	GL-6	GL-5
1	18.2	21.5	24.5	15.5	16.1	19.3	13.4	8.2	6.5	6.5	8.2	6.0	8.0	7.5	6.0
2	17.2	22.2	18.0	17.2	17.2	19.5	16.8	10.6	6.9	11.0	11.5	6.0	10.0	11.4	8.5
3	16.5	22.2	18.5	17.2	17.5	19.5	21.1	17.1	20.5	18.0	16.5	18.3	9.5	17.5	15.2
4	21.0	22.3	18.8	18.2	20.5	20.4	21.0	22.1	21.4	18.2	17.2	18.6		19.5	16.5
5	22.5	22.2	20.7	19.2	21.3	21.0	22.5	22.0	21.5	18.2	19.5			19.5	19.2
6	23.0	23.7	21.5	21.5	22.0	21.5	23.1	22.5	22.0	20.0	21.8			20.8	21.0
7	23.0	24.0	23.2	22.7	22.0	22.0	24.0	22.5	22.2	22.0	21.8			22.0	21.5
8	23.0	24.2	24.0	22.3	22.1	24.5	25.5	23.0	23.0	23.0				22.5	22.2
9	23.0	25.5	23.5	22.3	22.8	25.5	26.5	25.0	24.8	23.0				24.5	22.3
10		25.5	24.0	26.5	22.5	27.1	27.0	25.2						25.5	24.5
11		24.2	27.2	27.2	24.5	27.5	27.0							26.3	25.1
12		26.0	27.2		26.5	27.6	27.5							26.5	
13			27.5		26.5	27.7									

	KL-1	KL-3	SC-1	SC-2	KL-4	SC-3	SC-5	SC-4	TL-14	TL-12	TL-11	TL-10	TL-9	TL-3	TL-2	TL-1	KL-5
1	7.0	5.0	9.8	9.2	12.0	8.0	17.2	16.4	19.8	17.6	15.0	12.2	31.2	12.2	15.1	18.0	14.8
2	7.0	7.0	10.0	10.1	12.3	9.2	17.3	16.5	21.0	16.7	18.0	14.9	37.2	12.4	15.1	18.1	14.9
3	8.5	8.0	10.1	10.4	13.0	9.0	17.2	16.9		19.2	20.5	16.0	34.0	13.5	15.1	18.1	14.5
4	18.0	8.2	10.7	10.5	13.7	10.0	17.2	17.1		18.3	21.0	16.6	33.8	16.0	15.7	18.1	15.3
5	21.0	9.0	11.0	10.5	14.2	12.5	17.2	17.1		20.0	21.0	17.2	33.0	17.5	17.9	18.1	20.2
6	21.0	10.4			14.5	15.5	17.4	17.2		22.2	21.0	18.5		18.8	19.5	20.5	20.2
7	22.2	14.5			14.8	15.5	21.0	19.8		22.5	21.3	19.2		19.5			
8	22.2	14.5			15.0	15.5	21.0	21.1		23.0	20.5	19.5					
9		14.7				15.5	22.1	22.2		23.0	20.5	19.9					
10						15.7	22.8	22.4		23.0	21.0	20.0					
11							24.2				21.5	20.0					
12							24.8				21.0	20.1					
13											21.0						

	KC-5	SL-1	KC-1	SL-5	SL-4	KC-2	KC-4
1	12.5	17.3	7.5	6.5	7.5	4.0	5.6
2	12.5	14.0	12.5	10.7	8.6	4.3	6.0
3	12.0	16.0	13.0	10.5	12.5	14.3	11.5
4	12.0	17.5			12.5	14.5	13.5
5	14.5	19.0				14.5	13.5
6	15.0						
7	17.8						

APPENDIX B

STATISTICS

STATISTICS OF NORWETA CRUISE

1. SUMMER BOTTOM TEMPERATURES

Depth Zone (M)	Number of Observations	Arithmethic Mean °C	Range K	Standard Deviation K	Source of Data
0 - 10	20	7.00	5.40	1.48	EPB DATA ONLY
0 - 10	31	7.8	7.7	1.8	EPB + B.D.O.P. non suspect data
0 - 20	17	2.43	6.45	2.29	EPB
0 - 40	2	-0.51	-	-	EPB

2. SUMMER BOTTOM SALINITIES (B.D.O.P.L. DATA)

Depth Zone (M)	Number of Observations	Arithmetic Mean ‰	Range ‰	Standard Deviation ‰
0 - 10	22	16.5	13.5	4.2
10 - 20	11	24.5	7.6	2.5

STATISTICS OF TOTAL BEAUFORT SEA DATA BASE

(INCLUDING NORWETA DATA)

1. SUMMER BOTTOM TEMPERATURES

Depth Zone (M)	Number of Observations	Arithmetic Mean °C	Range K	Standard Deviation K
0 - 10	84	4.8	15.5	4.2
10 - 20	69	1.6	12.9	2.8
20 - 40	59	1.1	12.6	3.3
40 - 60	45	0.1	11.4	2.9
60 - 80	20	0.0	10.4	3.1
80 - 100	3	-1.1	1.0	-
100 - 200	19	-1.2	1.1	0.3
200 - 1000	50	0.1	2.0	0.5

2. SUMMER BOTTOM SALINITIES

Depth Zone (M)	Number of Observations	Arithmetic Mean ‰	Range ‰	Standard Deviation ‰
0 - 10	74	19	31	8
10 - 20	59	28	21	5
20 - 40	47	27	21	8
40 - 60	28	20	20	7
60 - 80	15	30	20	7
80 - 100	3	32	0.4	-
100 - 200	19	33	2	0.6
200 - 1000	50	35	2	0.4