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NOGAP Project D.1 Coastal Zone Geotechnics

A contribution to the Northern Oil and Gas Action Program

Steven M. Solomon

Atlantic Geoscience Centre
Bedford Institute of Oceanography
Box 1006
Dartmouth, Nova Scotia
Canada B2Y 4A2

Natural Resources Canada

Ressources naturelles Canada

Introduction and Objectives

A field program was undertaken in March-April, 1993 to collect cores, measure under-ice currents, and gather geophysical data from a variety of environments along the embayed east coast of Richards Island and along the modern Mackenzie Delta front in the Canadian Beaufort Sea. This activity was performed as a task under the Northern Oil and Gas Action Program (project D.1, Coastal Zone Geotechnics). The overall objective of this project is to improve our understanding of nearshore and coastal processes in areas of potential hydrocarbon development.

The objective of the coring operations in the vicinity of North Head was to characterize the shallow stratigraphy, and sediment properties within thermokarst lakes, drowned thermokarst basins, shallow embayments, inter-embayment channels, and along the exposed, barred outer coast. Along the Delta front, the objective of coring was to investigate sediment properties and shallow stratigraphy in the vicinity of a proposed hydrocarbon exploration site.

Electrical conductivity measurements were undertaken in order to ensure coring locations were chosen at proper locations and to help interpret changes in salinity and the presence of ice bonding. Current measurements were collected within interchannel embayments, between and outside of coastal barrier bars, and within distributary channels to investigate the presence or absence of currents, their magnitude and what, if any, tidal influence was present.

Background

The study area encompasses the nearshore/shoreface regions of the modern Mackenzie Delta and the older tundra surfaces of northern Richards Island **(FIGURE 1)**. The modern delta consists primarily of silts and fine sands which aggrade at distributary channel mouths to form islands. As the nearshore seabed aggrades it comes into contact with the winter ice and ultimately begins the process of permafrost formation (Hollingshead et al. 1978). Permafrost thickness beneath the modern delta surfaces reaches about 100 m (Dallimore et al. 1993). In contrast, the older tundra surfaces on Richards Island are underlain by more than 500 m of permafrost (Rampton, 1988). Thermokarst lakes dot the land surface and, as inundation by the sea takes place, they form a complex series of embayments and channels. Thaw takes place beneath the lakes when melting of massive ice bodies causes subsidence of the lakebed below the zone of winter ice contact. In the nearshore, drowning of the coastline by rising relative sea level brings the mean bottom temperature above the freezing point causing thawing of permafrost (Dyke, 1991). The Mackenzie River discharge plays a crucial role in thawing the coastal sediments. The summer temperatures in the river plume can exceed 10°C, whereas the Beaufort Sea marine water is much colder, especially below 5 m water depth.

Nearshore depth of thaw reaches 90 m within 5 km of the coast (Dallimore et al. 1991) and 20 m within 500 m of the coast on the northwest side of North Head (Dallimore et al. 1988). Taliks beneath recently inundated thermokarst lakes are about 40 to 60 m below the seabed (unpublished data, also compare with Hunter et al. 1981). Thus the nearshore and shoreface are zones of extremely rapid thermal change (cf. McDonald et al, 1973; Osterkamp and Harrison, 1977; 1982). The environments are also highly dynamic in an oceanographic sense (Solomon and Forbes, 1993). Waves, wave induced currents, tidal and storm surge currents contribute to the movement of sediments both on the shoreface and in the associated embayments. The interaction between the thermal and hydrodynamic environments is complex and provides the impetus for these investigations.

Methods

Coring

Coring was performed using three different systems depending upon whether sediments were ice-bonded and whether they contained appreciable inorganic matter. Unfrozen cores were laid horizontally in an insulated box with core tubes filled with sand and heated with a propane torch to maintain positive temperatures during the journey from the coring site to camp. At the camp, unfrozen cores were stored on the raised floor of a heated tent. Temperatures were variable but stayed below 10° C. Water samples were collected just below the ice at 8 locations using a weighted plastic bottle. Salinity and temperature measurements were made at the bottom of 5 borehole locations using a YSI conductivity meter. The field salinity results are suspect because it was difficult to prevent the formation of ice in the conductivity cell.

Livingston Coring System

A Livingston coring system was utilized in the cases where sediments were unbonded and it was anticipated that they were very soft and organic (e.g. the lake basins). The system consisted of a 1 m long, 3" (10 cm) diameter aluminum irrigation pipe as a core liner. A pointed piston was placed at the end of the tube and held in place by dogs so it could be pushed into the sediment with solid aluminum drill rod. The piston was connected to the surface by a wire, which, when pulled, would release the dogs allowing the pipe to be pushed forward into the sediment while the piston remained stationary. When the pipe was full, it was retrieved to the surface, the piston removed from the top of the pipe, capped at both ends and a new length of pipe was added. Plastic sewer pipe in 1.5 m lengths was used as casing which was advanced following each push of the irrigation pipe so as to keep the hole open without disturbing the sediment which had not yet been cored.

Problems with the Livingston system persisted throughout the field program. The dogs could not be kept free of ice, so that many attempts had to be made in order to collect each section of core and several holes had to be aborted. In addition, most of the coring locations appeared to be constituted primarily of inorganic material which limited the utility of the Livingston.

Vibracore

A portable vibracoring system was used in locations which were unbonded, sufficiently shallow, and firmer than could be penetrated by the Livingston system. In one location, where the ice bonded layer was penetrated, the upper section of the borehole was filled with water and vibracoring commenced at that point. The vibracoring system consists of 10 cm diameter irrigation pipe in 5 m lengths to which a portable cement vibrator is attached (using a specially built clamp). After augering through the ice, the irrigation pipe is vibrated into the sediment until the top of the pipe is just submerged or the until no more penetration is achieved. The pipe is filled with water, then stoppered to prevent the cored material from falling out the bottom and extracted from the sediment using a tripod and a "come-along". Upon retrieval, the top of the sediment inside the pipe is determined and the pipe is cut just above the sediment-water interface and capped at both ends. The use of this system depended upon being able to cap the top if the irrigation pipe; the maximum depth of penetration was therefore limited by the water depth.

CRREL Auger

Ice bonded material was collected using a CRREL auger system with a Stihl power head mounted on a Winke Unipress drill stand. Core was collected in lengths up to 35 cm within the hollow auger body and were extruded into plastic wrap, labelled and sealed in plastic bags. Auger samples of the overlying ice were also collected and handled in the same fashion. In most locations, core was retrieved as intact section, however, occasional samples appeared to be ground up in the coring process. This appeared to be related to poorly bonded material within the sedimentary sequence - possibly related to brine pockets. This system worked very well and cores of more than 3.5 m total length were retrieved. However, the auger did get stuck in the hole at one point and required considerable time and effort to recover.

Geophysics

Electrical conductivity was measured using Geonics EM-31 and EM-34 electromagnetic conductivity metres. These instruments induce a current in the ground by means of antennae and the apparent ground conductivity is measured using the in-phase and quadrature phase components of the secondary magnetic field. The EM-31 uses antennae at a fixed separation distance of about 3 m. By varying the height about the ground surface and the orientation of the of the instrument 4 quasi-independent measurements of conductivity are obtained with different investigation depths (up to a maximum of about 6 m depending upon the conductivity of the material). More readings allow investigation of ground conductivities using a multi-layered earth model.

The EM-34 uses independent coil antennae, the separation of which can be varied up to 40 m. Apparent ground conductivity was measured at spacings of 10, 20 and 40 m using both horizontal and vertical coil orientations. Thus six quasi-independent apparent conductivity measurements are made reflecting the resistivity at varying depths of penetration (maximum of about 20 m at 40 m spacing with vertical coils; again depending upon ground conditions).

Difficulties were encountered in calibrating the EM-31 because of a broken potentiometer. Repeat measurements at several sites suggest that the approximate calibrations performed at the beginning and the end of each day were probably reasonably good, but their suitability for detailed quantitative analysis is suspect.

Currents

Under-ice currents were measured at 5 sites (**TABLE 1, FIGURES 2, 3**) using an InterOcean™ S4 electromagnetic current meter. The current meter was deployed through holes augered and chiselled through ice up to 1.5 m thick. In all but one case the instruments were mounted on the end of a 2x4 and braced at the ice surface. Where the water depth exceeded the length of the 2x4, a clump weight consisting of sand and gravel packed in an aluminum core tube was used as an anchor. A line attached to one end of the tube allowed it to be pivoted to a vertical position for retrieval. The S4 was programmed to measure currents at hourly intervals for one minute with a 0.5 second sampling rate. It was deployed for 24 hours at 5 sites. Free water below the ice determined the position of the S4; it was deployed mid-depth between the base of the ice and the seabed or 1 m above the seabed (possible at only one location).

TABLE 1 S4 deployments

Location	Northing	Easting	Depth	Ice Thickness	Deployed@
Reindeer Ch. (@BH1,8)	530122	7727833	2.90m	1.55m	0.70m
Pipeline Ch. (@BH9)	527906	7731175	2.50	1.40	0.55
MR2 (in trough between inner and outer bars @BH13)	529202	7732901	2.46	1.63	0.40
Reindeer Bars (@BH25)	532378	7729681	2.80	1.77	0.40
Arvoknar Ch.	475073	7689441	7.21	1.63	1.0

Logistics

At North Head, on Richards Island, a camp was established using a chartered Twin Otter on skis. It consisted of 5 longhouse-style tents four of which were heated with diesel stoves. Four snowmobiles and two komatiks were used for transportation and to haul gear. The field crew at this site consisted of six people; four from the Geological Survey and two residents of Tuktoyaktuk. Two crews are established; one crew of three to perform geophysical measurements and one crew of three to drill and vibracore.

Twin Otters were used to transport crew and gear to Arvoknar Channel for the second phase of the program. Accommodations consisted of a well-site trailer with a generator which was provided by Shell Canada. Only the GSC personnel participated in this part of the program.

Positioning and Mapping

Positions were acquired using a Magellan hand-held GPS in non-differential mode using NAD83 at North Head and NAD27 at Arvoknar Channel. Accuracy of the positions was not particularly good based on several repeat measurements made at the same locations on different days. In one case, positions were different by over 200 m, on another occasion, positions were accurate to within 25 m. The relative positions of boreholes on survey lines was measured to within less than 0.5 m using a steel tape. Where necessary positions of survey lines and boreholes have been manually corrected to their true positions relative to the coastline.

The base map used for North Head was made from 1985 airphotos flown at 1:60,000. Aerial triangulation data was provided by Natural Resources Canada. The water line and the high water/base of cliff line were digitized from the air photos using a digital stereoplotter into the GIS CARIS. A .dxf file was extracted from CARIS and imported into the desktop mapping program MapInfo. The base map for the Modern Delta was extracted from a digital (CARIS) Canadian Hydrographic Survey Chart (7662) and imported into MapInfo.

Results

Observations

Rough ice conditions occurred within 100 m of the shoreline at the exposed outer coastal site at MR2 and a linear pile-up (trending 110°T) was present 1000 m from shore (**FIGURE 2**). Another small ice pile-up was found at the tip of a recurved spit on Reindeer Island. The rough ice and pile-ups consisted of plates and slabs of ice less than 1 m in diameter and several centimetres thick. In some cases, the ice contained obvious concentrations of sediment. The pile-ups were 1-2 m high. Blocks of multi-year ice several metres in diameter were stranded along the barrier beach at Wolfe Spit and along the exposed outer coast at the northern tip of North Head. A bar complex at the BH87 EM line (90-110 m from shore) is defined by a line of multi-year ice. Along the L39 EM line there is a low pile-up of thin, dirty ice plates and rare blocks of multi-year ice 800 m from the start of the line. The presence of these features can be explained by the occurrence of a storm or storms during the freeze-up process.

"Tidal" cracks ranging from about 20-100 cm wide were found in the embayments. A possible subtle bar system along the BH87 EM line (330-360 m) is defined by a slight buckling of the first year ice. These features are indicators of the effects of water level changes on ice morphology which probably reflect interaction with the seabed

Electrical Conductivity

EM31 and EM34 lines were run at 12 sites in the North Head area and 4 sites at Arvoknar Channel and Ellice Island. Lines varied from 300 m to more than 1000 m in length (**FIGURES 2** and **3**). The raw data were plotted in the field and used to assist in the choice of drilling locations (see **APPENDIX B** for a selection of plotted conductivity data).

In the saline environment of the drowned lakes and nearshore barred coastlines the conductivity data were difficult to interpret because of the nonlinear response of the instruments above about 100 mS/m (McNeill, 1980). However, in water depths which are shallow relative to the penetration depths and frozen (low conductivity) material is located close to the surface, useful information can be extracted. Within the zone of bottom-fast ice conductivity rises very rapidly with distance from the shoreline and the shallowest reading instruments exhibit subtle changes in amplitude which are consistent with the wavelengths and numbers of nearshore bars. Boreholes at several of these features failed to reveal a strong correlation between the water depth and conductivity (**FIGURE 4**). It is possible that subtle water depth variations can result in considerable differences in active layer thickness which are reflected in the ground conductivity. Conductivities within the ice contact zone at marine-influenced (i.e. saline) sites are nearly an order of magnitude more than those found in unfrozen, fresh water environment (140 to 300 mS/m versus 25 mS/m respectively).

Along the transect at MR2 (**FIGURE 5**), beyond the ice contact zone (water depths greater than about 1.5 m) there is an inverse relation between conductivity and water depth (i.e. higher conductivity at shallower depth). This suggests that the conductivity of the sea bottom (lower conductivity sediment plus high conductivity interstitial water) is greater than that of the overlying seawater plus sea ice. This result is counter-intuitive and could be an artifact of instrument non-linearity or may be related to brine concentrations in the seabed sediments. Monotonically increasing conductivity with distance form the shoreline in the 40 m reading of the EM34 suggests that it may be responding to the depth to the ice bonded permafrost table.

In thermokarst lakes which have been breached by the sea (Inner and Outer Lakes **FIGURE 2** and **FIGURE 6**), the zone of bottom-fast ice is characterized by very low conductivities. Higher conductivities are found at the basin-ward edge of this zone where there is likely a thin layer of unfrozen water overlying unfrozen ground. In the deeper basin centres where there is saline water greater than 3 m deep, conductivity declines (as a result of the previously mentioned non-linearity of the instrument response).

Where saline waters are virtually absent (i.e. along the coast of the modern delta and in fresh water lakes on Richards Island) ground conductivities are generally less than 25 mS/m (**FIGURES 7** and **8**). The conductivity profiles are more easily interpretable and hold a better potential for modelling depth to, and thickness, of shallow ice-bonded material. For instance, a narrow channel adjacent and parallel to the present modern delta shoreline is well defined by both conductivity instruments (**FIGURE 8**). Ice is frozen to the bottom at this location, but is thicker than ice further offshore, denoting deeper water. In general, conductivity increases dramatically across the channel, which is frozen at the seabed surface but is unbonded at depths greater than 2 m sub-seabed. The increase in unfrozen water content results in an increased conductivity, however, a decrease in conductivity at the 40 m spacing suggests that ice bonding may be present at depth. At the Ellice Island site (**FIGURE 3**), a relatively flat, low conductivity curve which increases dramatically beyond 450 m (**FIGURE 9**) suggests that near-surface ice bonding is restricted to the inshore zone. The much higher conductivity associated with the 40 m spacing of the EM34 suggests higher unfrozen water contents at depth.

Boreholes

Cores were attempted at 37 locations (**TABLE 2**) and cores were collected at 33 of them using one of the three techniques described above (**FIGURES 10, 11, 12, 13**). In the case of BH35, unfrozen material was encountered while drilling at BH32 with the CRREL auger and the hole was continued with a vibracorer after thawing the partially bonded material with hot water (**FIGURE 13**). At each of the CRREL auger sites the surface ice was kept for analysis of salinity and sediment content. Ice thickness ranged from 140 to 180 cm where ice was not bottom-fast. Ice formed from fresh water was usually clear while marine ice was opaque.

Sediment textures along the exposed outer coast of North Head range from medium sands to silty clays, whereas, in the embayments, silty clays predominate. Along the transect at Site Channel at the modern Mackenzie Delta front (**FIGURE 13**), sediments consisted of very fine sand to silty clay. Cores within basins recently breached by marine waters (cores 2, 3, 4, 4b, 10) are characterized by a more clay-rich upper unit probably corresponding to marine sedimentation.

Salinity, water, content, organic and inorganic carbon were measured in the laboratory. These data are reported in **APPENDIX C** Pore water salinities as high as 130 ppt illustrate the effects of freezing on brine concentration.

Currents

Currents were measured at 2 open coastal locations in the North Head area (**FIGURE 2**) and in the Arvoknar Channel in the modern delta (**FIGURE 3**). Currents were not detected at the two locations located within the embayments (**FIGURE 2**). Mean currents were about 3 cm/s at the exposed sites at the Reindeer Bars and MR2 sites and there was a pronounced tidal signal at the latter. Changes in velocity at the Reindeer Bar site may be related to tides. The flow directions were east-west at MR2 and northeastward at the Reindeer bars site. At Arvoknar Channel currents flowed consistently northward toward the mouth of the channel at 3-4 cm/s. The flow directions at both exposed coastal sites are roughly parallel with the trend of the bar system indicating that flow is confined to inter-bar troughs by bottom fast ice.

Conclusion

Analysis of the data is in progress. Cores have been subsampled for micropaleontological and palynological analysis, geochemical and cesium dating, and grain size. The information acquired during this field project from known sedimentary environments will provide a reasonable basis for the interpretation of deeper core and geophysical data.

Acknowledgements

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TABLE 2 - Boreholes

Borehole	E m	N m	Core type	Water depth(cm)	Ice thick(cm)	Temp °C	Salinity o/oo	Recovery cm	Range m
Datum:NAD 83									
BH1	530122	7727833	Liv	300	155	na	na	45	0+270
BH2	530149	7728861	Liv	237	150	-2	0.5	50	0+190
BH3	530151	7728939	Liv	791	163	-1	24	165	0+270
BH4	529629	7729448	Liv	644	160	+1	30	79	0+270
BH4a	529629	7729448	Liv	620	164	+1	39	99	0+270
BH4b	529629	7729448	Liv	615	163	na	na	176	0+270
BH5	529033	7729623	Liv	1210	na	+1	0.1	89	0+090?
BH6	525650	7730065	Liv	215	157	-0.1	18	50	0+250
BH7	525333	7730172	Liv	270	180	-1.5	17	78	0+580
BH8	530122	7727833	VC	290	155	+0.5	38	185	same as BH1
BH9	527906	7731175	VC	250	140	+3	9.5	49	0+350
BH10	530149	7728861	VC	238	159	-2?	25?	210	same as BH2
BH11	526748	7728406	CRREL	100	100	na	na	225	na
BH12	525810	7731671	CRREL	89	89	na	na	351	0+290
BH13	529202	7732961	VC	246	163	-1	24	309	0+365
BH14	529011	7732804	CRREL	133	133	na	na	170	0+100
BH15	528989	7732736	CRREL	145	145	na	na	200*	0+130
BH16	529360	7733206	VC	140	132	na	na	197	0+705
BH17	529346	7733199	VC	176	135	na	na	151	0+720
BH18	529311	7733146	VC	240	155	na	na	155	0+660
BH19	532147	7729371	CRREL	72	72	na	na	77	0+080
BH20	532147	7729371	CRREL	70	70	na	na	282	0+080
BH21	532206	7729433	CRREL	84	84	na	na	284*	0+130
BH22	532146	7729403	CRREL	82	82	na	na	276	0+110
BH23	532192	7729352	CRREL	71	71	na	na	244	0+050
BH24	532071	7729266	CRREL	0	0	na	na	175	0+000
BH25	532378	7729681	VC	280	177	na	na	177	0+450
BH26	527156	7732612	grab	137	137	na	na	na*	0+525
BH27	527131	7732585	VC	137	137	na	na	80	0+600
Datum: NAD27									
BH28	476894	7691076	CRREL	0	0	na	na	213	0+000
BH29	475073	7689441	S4	721	163	na	na	na	na
BH30	476855	7691209	VC	109	109	na	na	grab	0+150
BH31	476866	7641233	dry hole	67	67	na	na	grab	0+270
BH32	476882	7691188	CRREL	71	71	na	na	197	0+135**
BH33	476866	7641233	CRREL	64	64	na	na	197	0+270
BH34	476682	7691551	CRREL	91	91	na	na	309	0+540
BH35	476882	7691188	VC	continuation of BH32				497	0+135
BH36	476773	7691414	CRREL	100	100	na	na	225	0+400
BH37	476138	7690611	water	270	172	na	na	na	0+900

* seepage at base
**unfrozen (?) material at base

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Figure Captions

FIGURE 1 Index map of the southern Beaufort Sea coastal areas showing the two study sites.

FIGURE 2 Map of the North Head study site illustrating locations of EM geophysical profiles, boreholes and current meter deployments. Note the shallow slope of the shoreface as depicted by the 2 m isobath. Most of the embayments are less than 2 m deep.

FIGURE 3 Map of the Mackenzie Delta-front sites. With the exception of channels, water depths are uniformly less than 2 m.

FIGURE 4 EM31 and EM34 profiles (vertical dipoles) from the shoreline out to 700 m at the Reindeer Bars site. EM31_V1 refers to measurements taken at hip height; EM31_V2 refers to measurements taken with the instrument resting on the ice or ground surface. EM34_V10, EM34_V20, and EM34_V40 refers to EM34 measurements taken using 10, 20 and 40 m dipole spacings respectively. Bathymetry acquired in 1991 from a location close by has been projected onto the line. Borehole locations are denoted by BH#'s. Nearshore bar systems (within about 200 m of shore) are seen as relatively small changes in EM31 conductivity readings. The EM34_40 readings may be responding to the rapidly deepening permafrost table.

FIGURE 5 Symbols as described in FIGURE 4 along a line at MR2 Island (FIGURE 2). Note the inverse relation between EM and bathymetry within 400 m of the shoreline and the positive relation at 700 m. As at the Reindeer Bars site, the EM34_40 readings may be responding to the rapidly deepening permafrost table.

FIGURE 6 EM31 and EM34 lines at the Outer Thermokarst Lake site. This site is a breached and drowned thermokarst lake which has been inundated by saline Beaufort Sea waters. The shallow edges are well-defined by the very low conductivity values. Rapidly increasing conductivity at 150 m defines the edge of the ice contact zone; water depths increase rapidly towards the basin centre. Conductivities are very high, but difficult to interpret because of non-linear instrument response (McNeill, 1980).

FIGURE 7 EM31 and EM34 lines in a freshwater thermokarst lake. The maximum conductivity is an order of magnitude less than that found in the breached lake depicted in FIGURE 6. Note the rim of very low conductivity at the edge of the lake denoting the ice contact zone.

FIGURE 8 EM31 and EM34 lines from the modern Mackenzie Delta front at the Site Channel East (schane) location. This line is orthogonal to a rapidly retreating, very low (1 m) coastline. All of the EM spacings record a rapid increase in conductivity between 50 and 200 m of the shoreline. This corresponds to a zone of slightly deeper water in a moat-like channel which parallels the coastline. A 2 m thick seasonally ice-bonded layer was underlain by unfrozen very soft mud at BH32/35 (no care was taken at BH30). The much higher conductivity seen in the 40 m dipole spacing (EM34_40) suggests that ice bonding may decrease with depth along this line.

FIGURE 9 EM31 and EM34 lines from the modern Mackenzie Delta front at the Ellice Line1 site. The coastline is retreating very rapidly here (>6 m/a since the 1950s from air photos). Within about 300 m of the present shoreline relatively low shallow conductivity measurements suggest ice bonding in the near surface sediments. Higher conductivities farther offshore for all dipole spacings suggest that the water deepens below the ice contact zone and little ice forms at the sediment/water interface. The higher conductivity at the 20 and 40 m dipole spacings of the EM34 onshore and close to the present coastline indicates a relatively thin upper ice bonded unit.

FIGURE 10 Closeup of borehole and EM locations at North Head (note darker shading denotes lakes, lighter shading denotes land).

FIGURE 11 Closeup of borehole and EM locations at North Head (note darker shading denotes lakes, lighter shading denotes land).

FIGURE 12 Closeup of borehole and EM locations at North Head (note darker shading denotes lakes, lighter shading denotes land).

FIGURE 13 Closeup of borehole and EM locations at the Site Channel location. Note the present position of the coastline (approximate) compared to the 1958 charted position (CHS chart 7662).

Figure 1

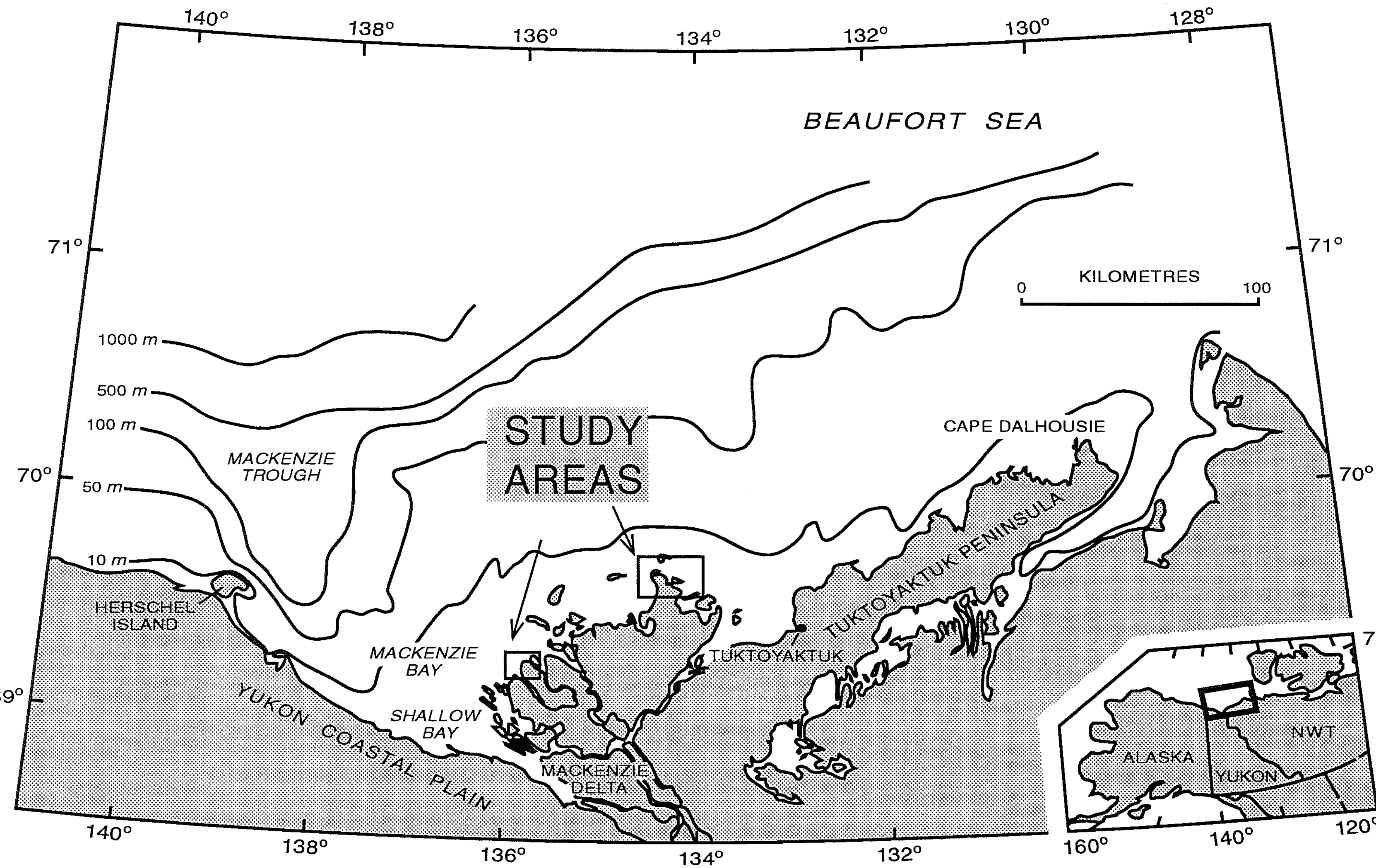

BEAUFORT SEA
STUDY AREAS
1000 m
500 m
100 m
50 m
10 m
MACKENZIE TROUGH
HERSCHEL ISLAND
MACKENZIE BAY
SHALLOW BAY
YUKON COASTAL PLAIN
MACKENZIE DELTA
TUKTOYAKTUK
TUKTOYAKTUK PENINSULA
CAPE DALHOUSIE
KILOMETRES
0
100
140°
138°
136°
134°
132°
130°
128°
71°
70°
69°
ALASKA
YUKON
NWT
160°
140°
120°
70°
60°

Figure 2

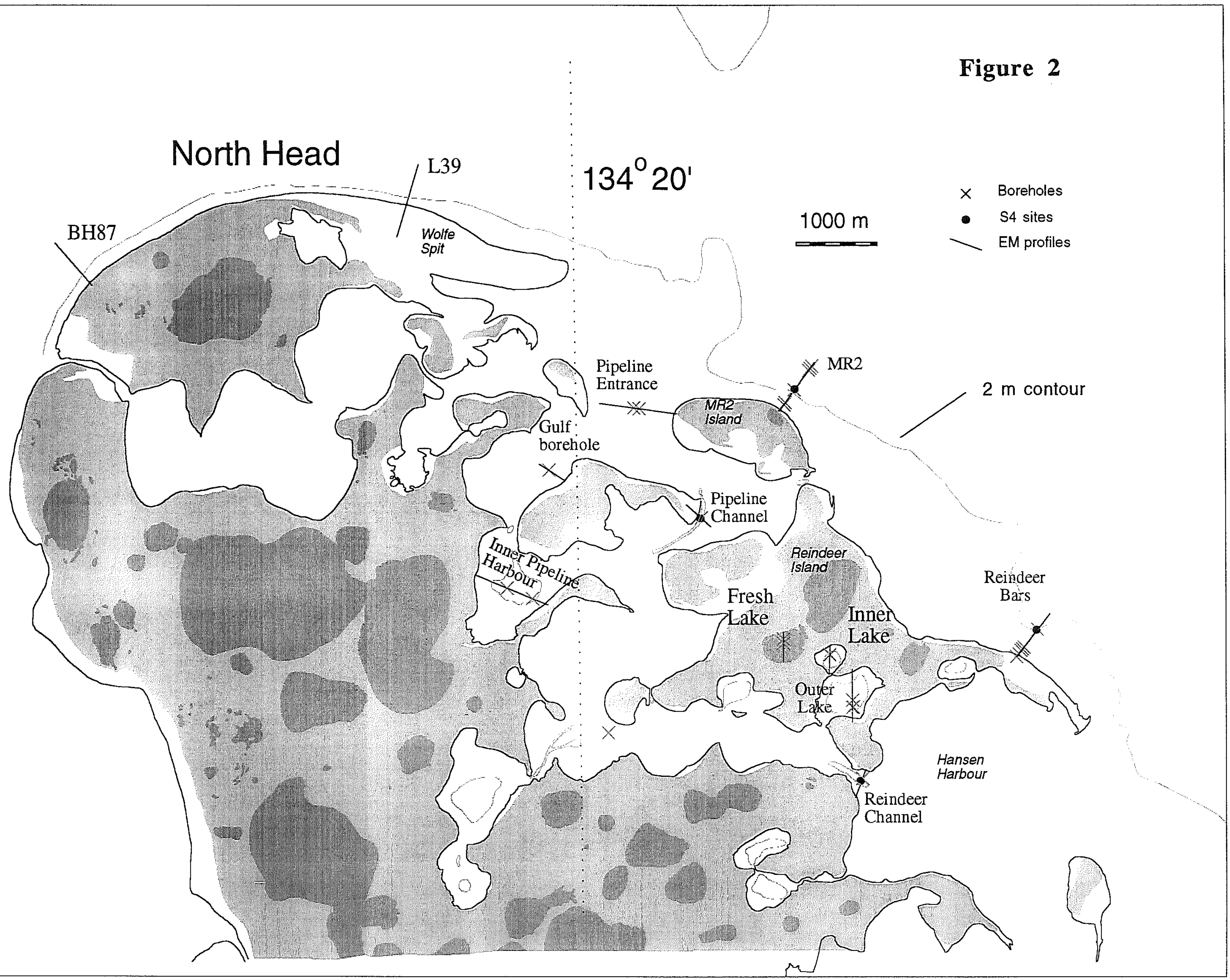
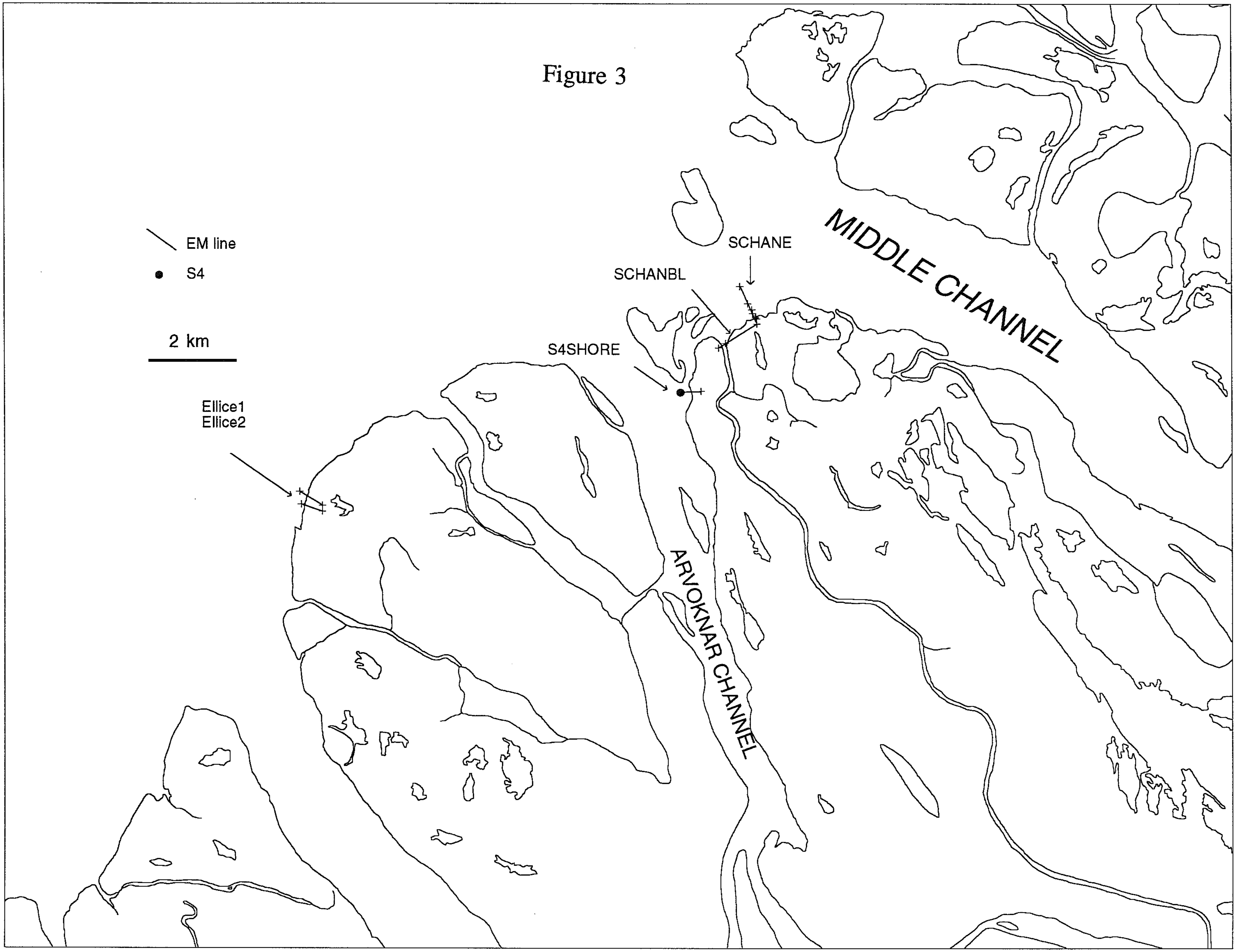
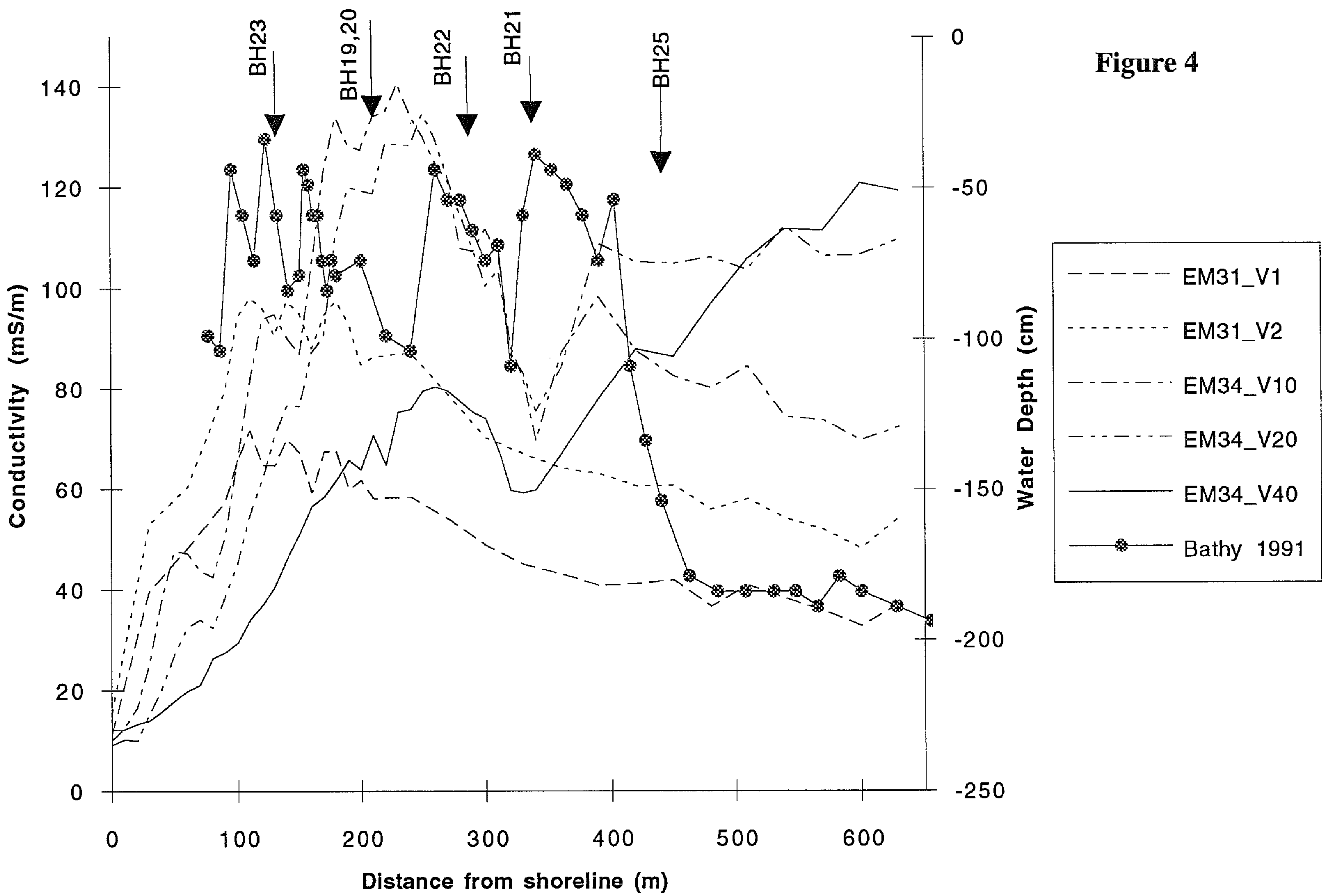

North Head
L39
134° 20'
BH87
Wolfe Spit
Boreholes
S4 sites
EM profiles
1000 m
Pipeline Entrance
MR2
2 m contour
MR2 Island
Gulf borehole
Pipeline Channel
Inner Pipeline Harbour
Reindeer Island
Reindeer Bars
Fresh Lake
Inner Lake
Outer Lake
Hansen Harbour
Reindeer Channel

Figure 3


EM line
S4
2 km
Ellice1
Ellice2
S4SHORE
SCHANBL
SCHANE
MIDDLE CHANNEL
ARVOKNAR CHANNEL



Conductivity (mS/m)
0
20
40
60
80
100
120
140
Distance from shoreline (m)
0
100
200
300
400
500
600
Water Depth (cm)
0
-50
-100
-150
-200
-250
BH23
BH19,20
BH22
BH21
BH25
EM31_V1
EM31_V2
EM34_V10
EM34_V20
EM34_V40
Bathy 1991

Figure 4

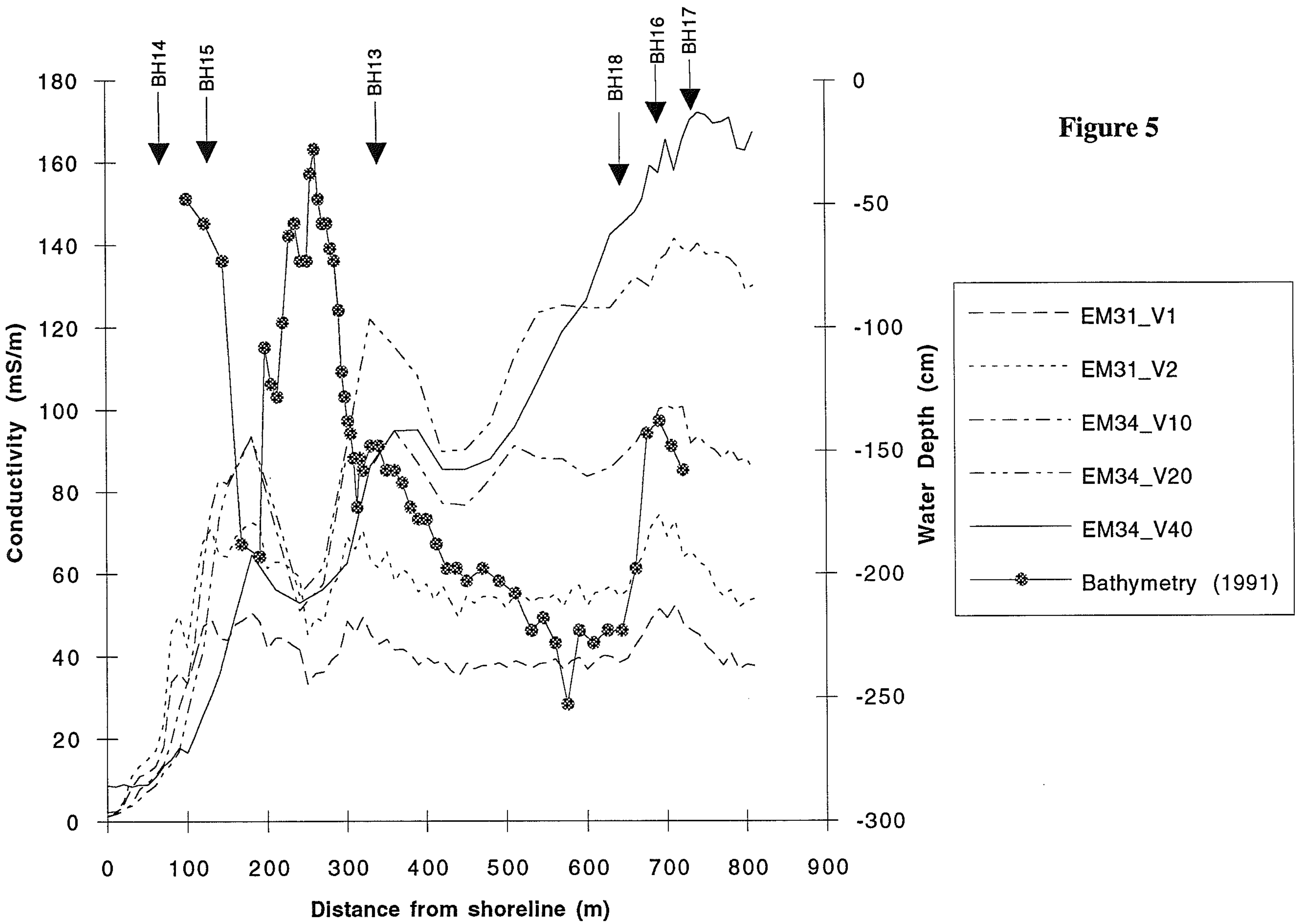

BH14
BH15
BH13
BH18
BH16
BH17
Conductivity (mS/m)
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
Distance from shoreline (m)
Water Depth (cm)
0
-50
-100
-150
-200
-250
-300
EM31_V1
EM31_V2
EM34_V10
EM34_V20
EM34_V40
Bathymetry (1991)

Figure 5

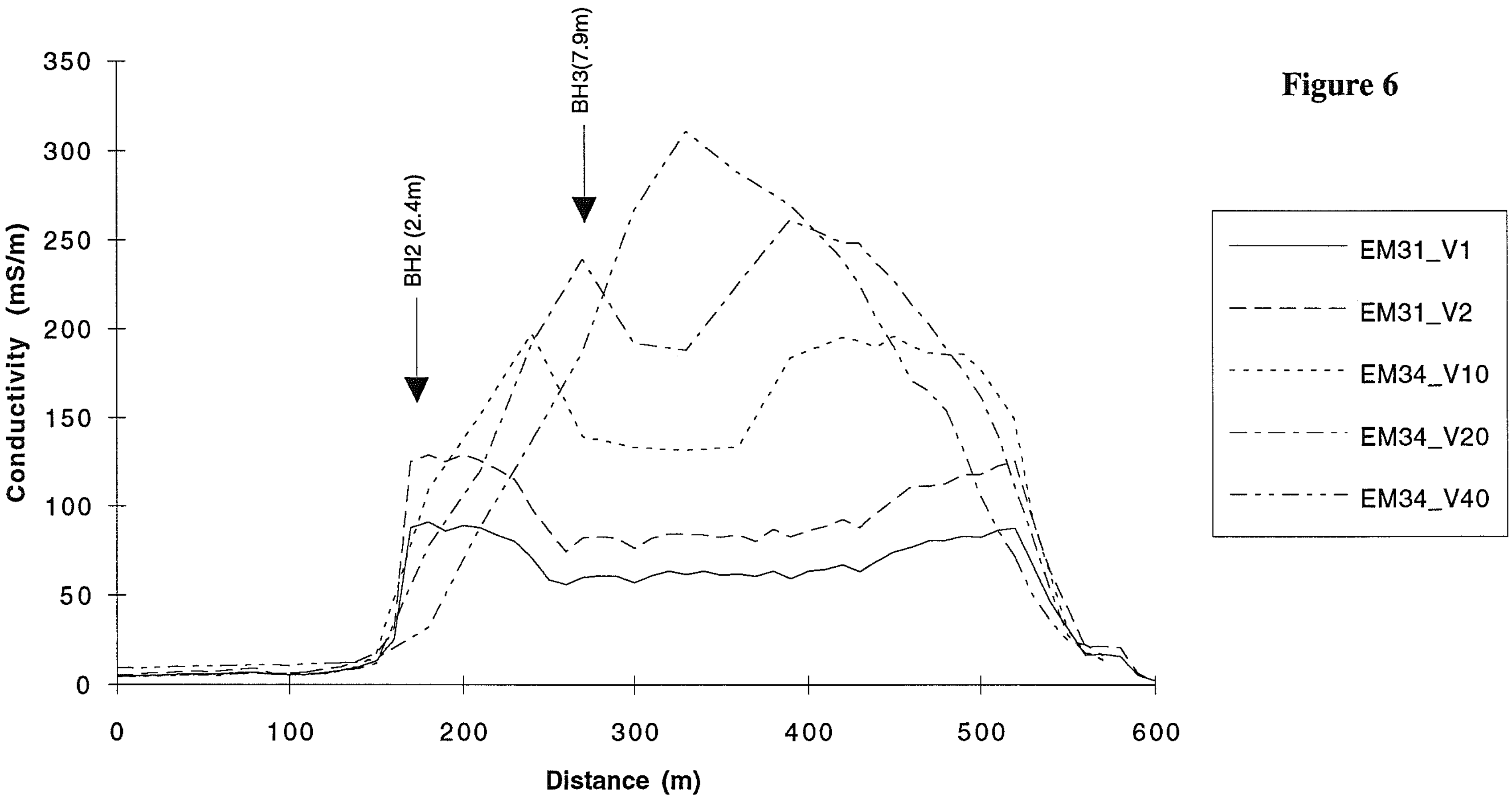

350
300
250
200
150
100
50
0
Conductivity (mS/m)
0
100
200
300
400
500
600
Distance (m)
BH2 (2.4m)
BH3(7.9m)
EM31_V1
EM31_V2
EM34_V10
EM34_V20
EM34_V40

Figure 6

Figure 7

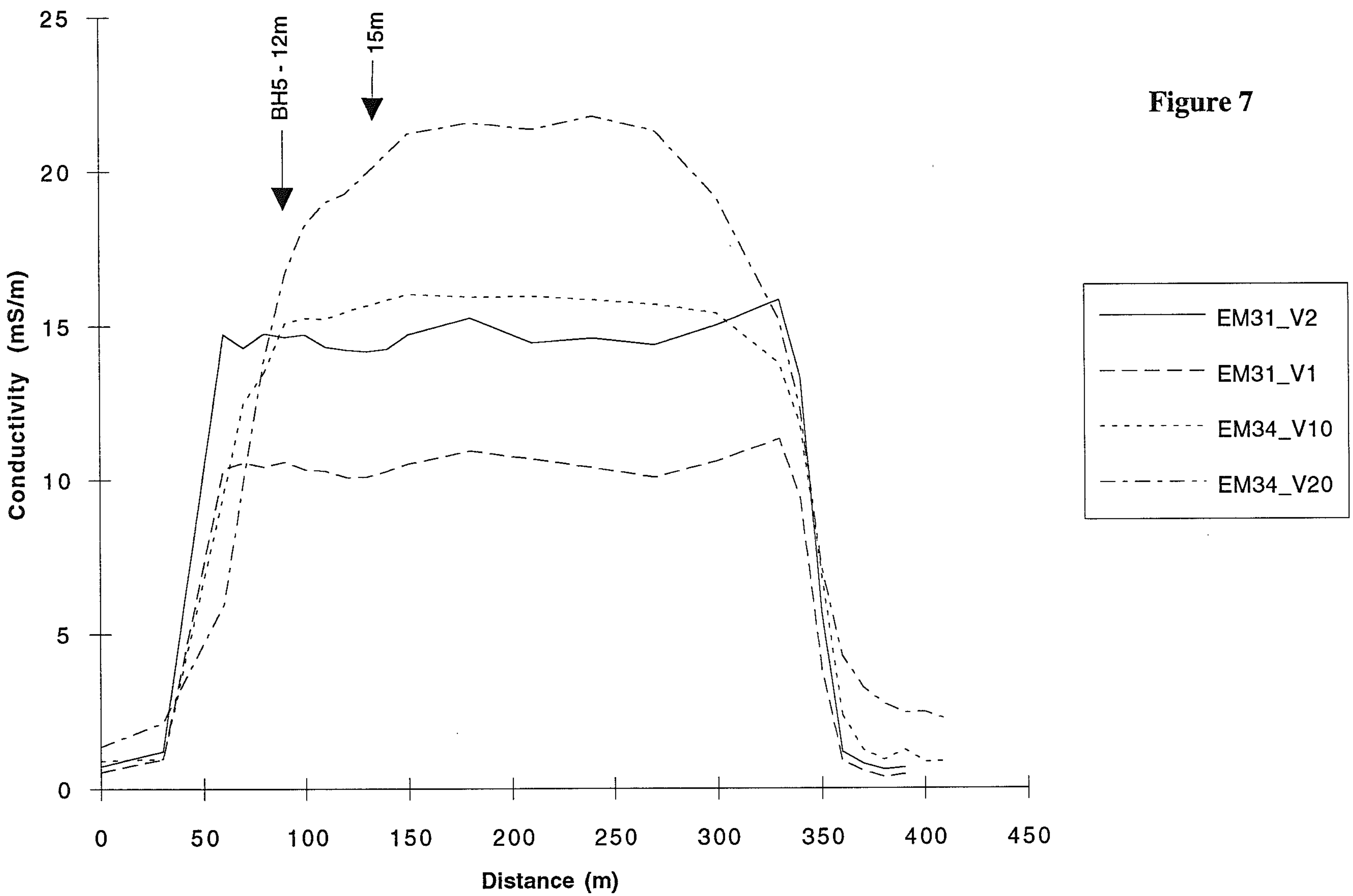

BH5 - 12m
15m
Conductivity (mS/m)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
Distance (m)
EM31_V2
EM31_V1
EM34_V10
EM34_V20

Figure 8

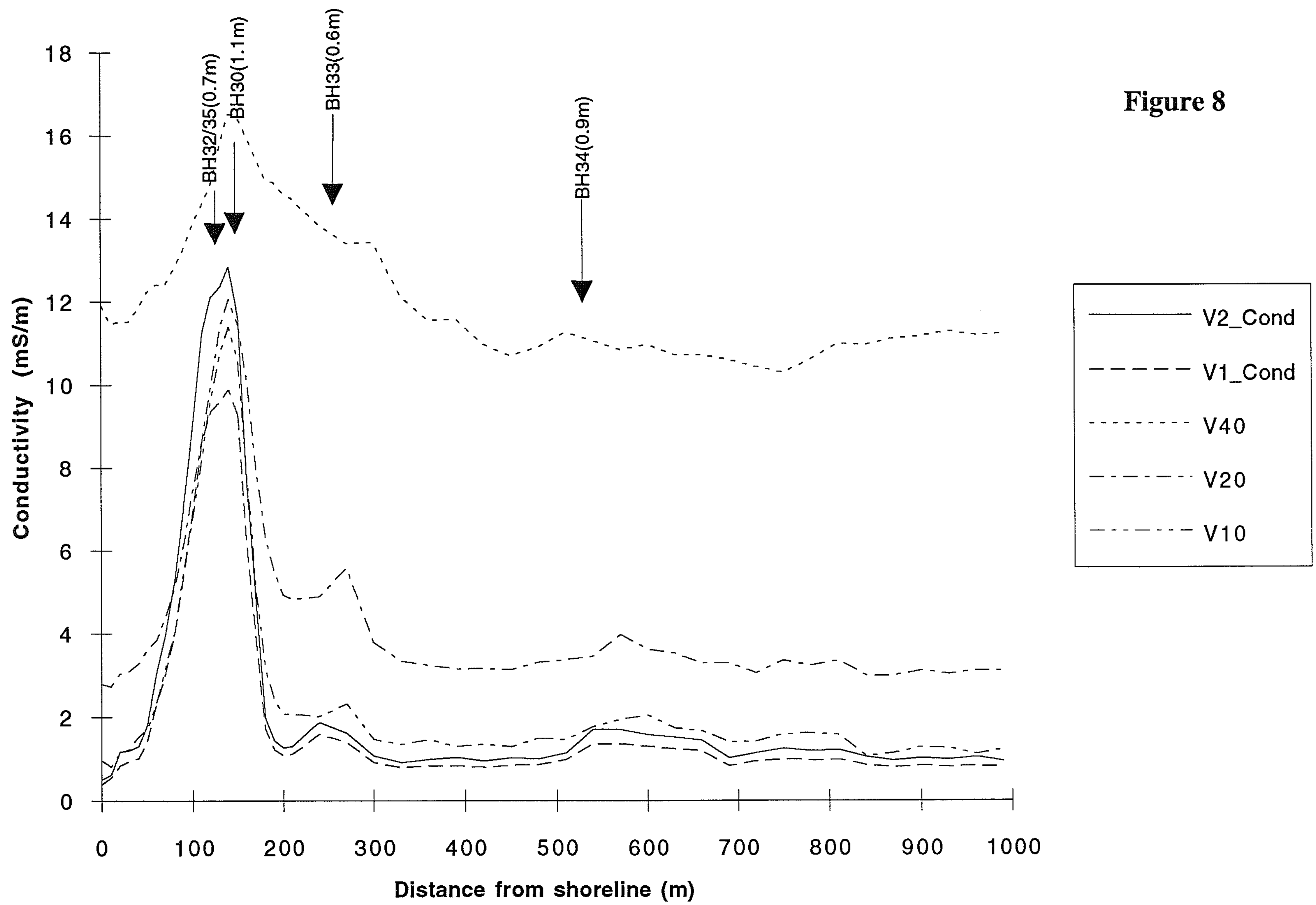

Conductivity (mS/m)
0
2
4
6
8
10
12
14
16
18
BH32/35(0.7m)
BH30(1.1m)
BH33(0.6m)
BH34(0.9m)
0
100
200
300
400
500
600
700
800
900
1000
Distance from shoreline (m)
V2_Cond
V1_Cond
V40
V20
V10

Figure 9

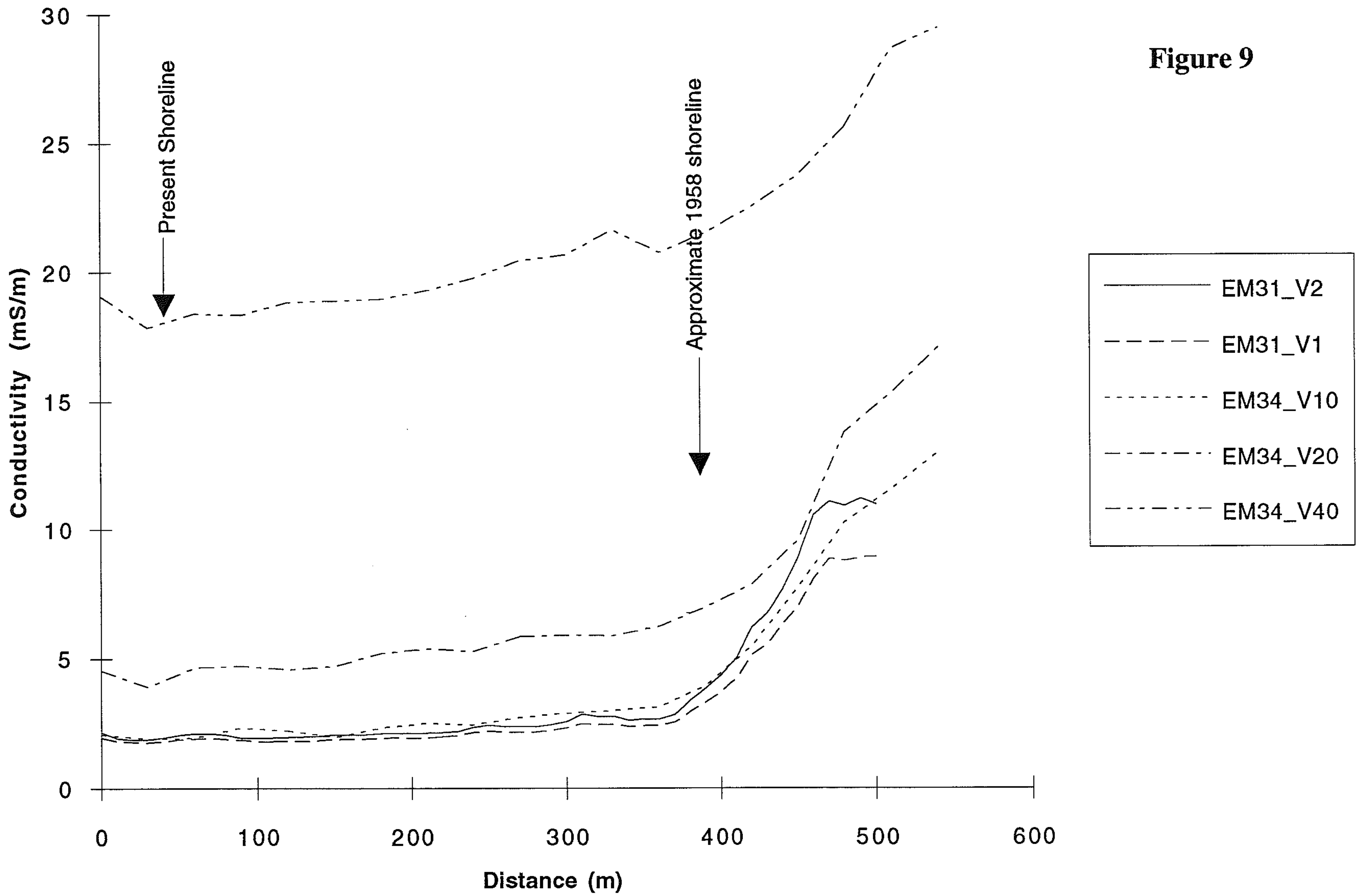

Conductivity (mS/m)
30
25
20
15
10
5
0
Present Shoreline
Approximate 1958 shoreline
0
100
200
300
400
500
600
Distance (m)
EM31_V2
EM31_V1
EM34_V10
EM34_V20
EM34_V40

Figure 10

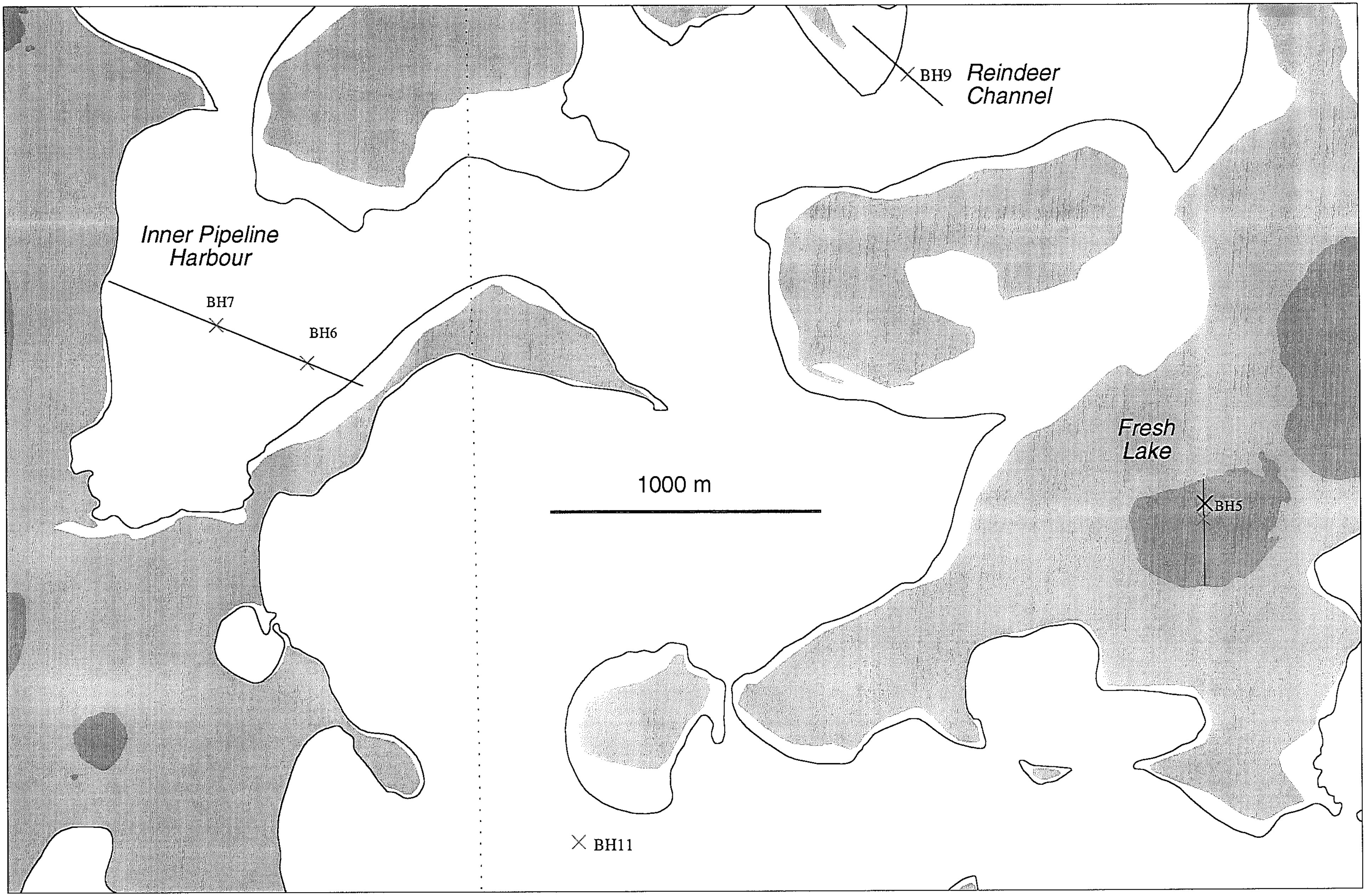

Inner Pipeline Harbour
BH7
BH6
Reindeer Channel
BH9
1000 m
Fresh Lake
BH5
BH11

Figure 11

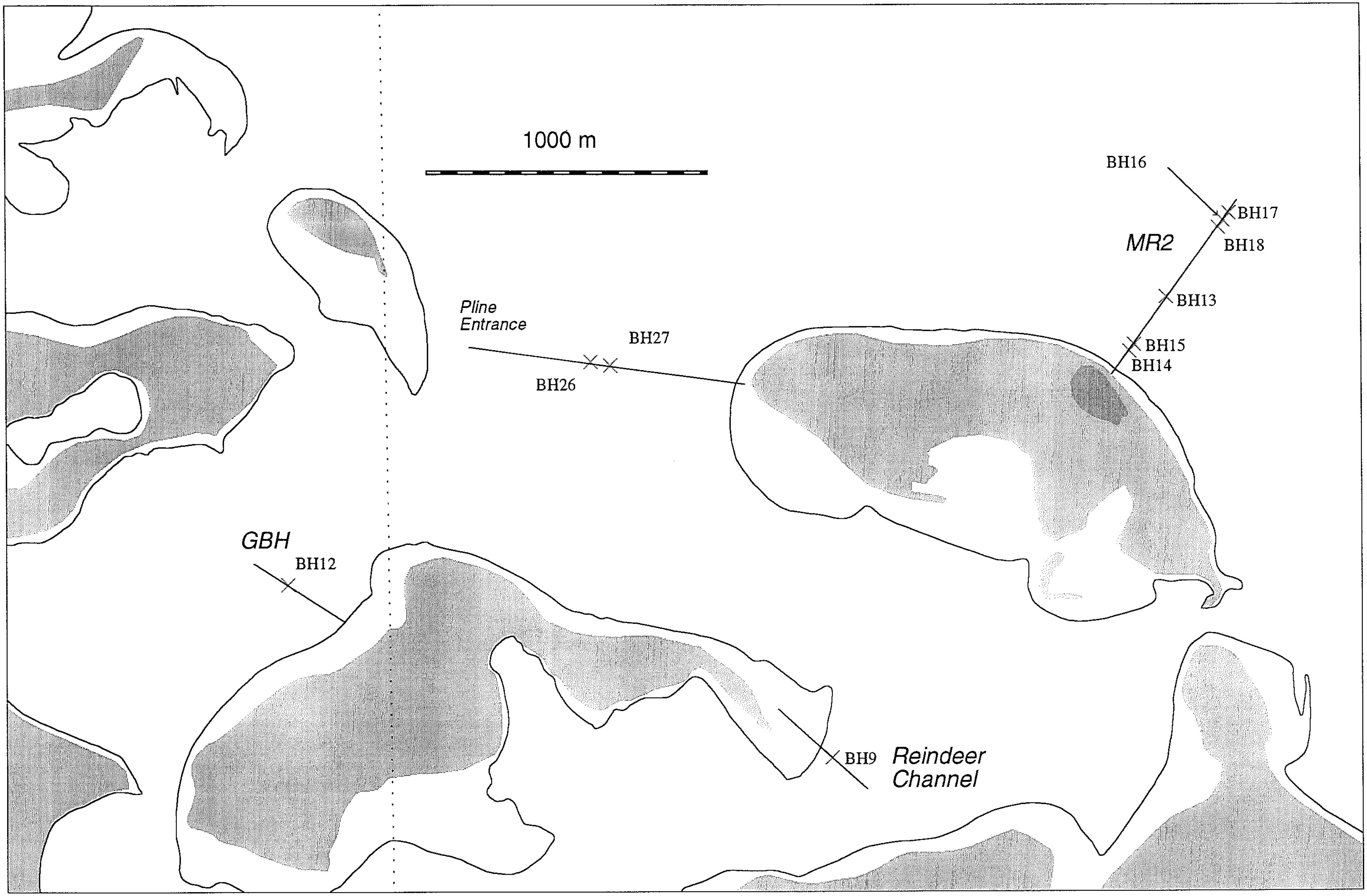
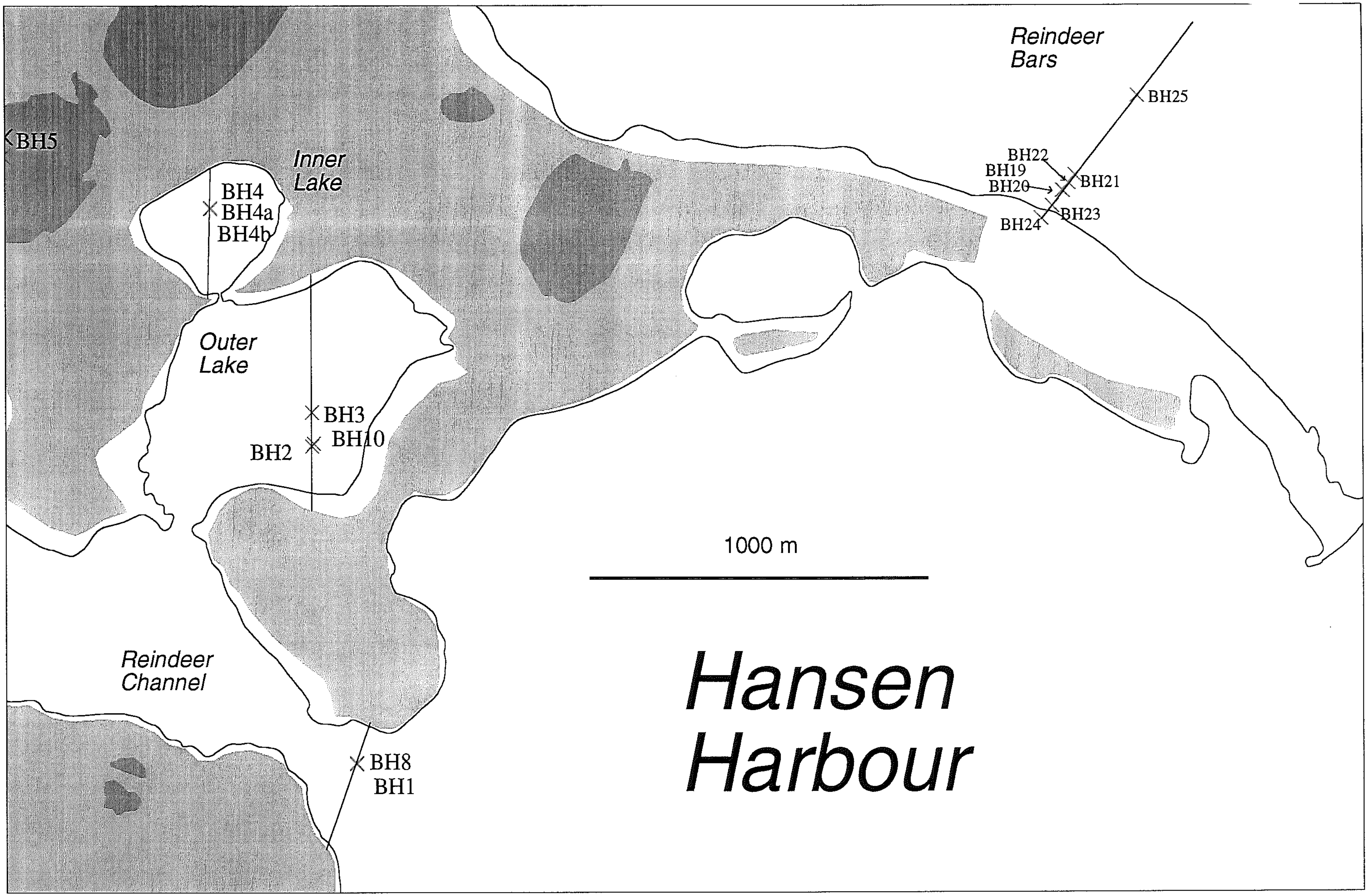
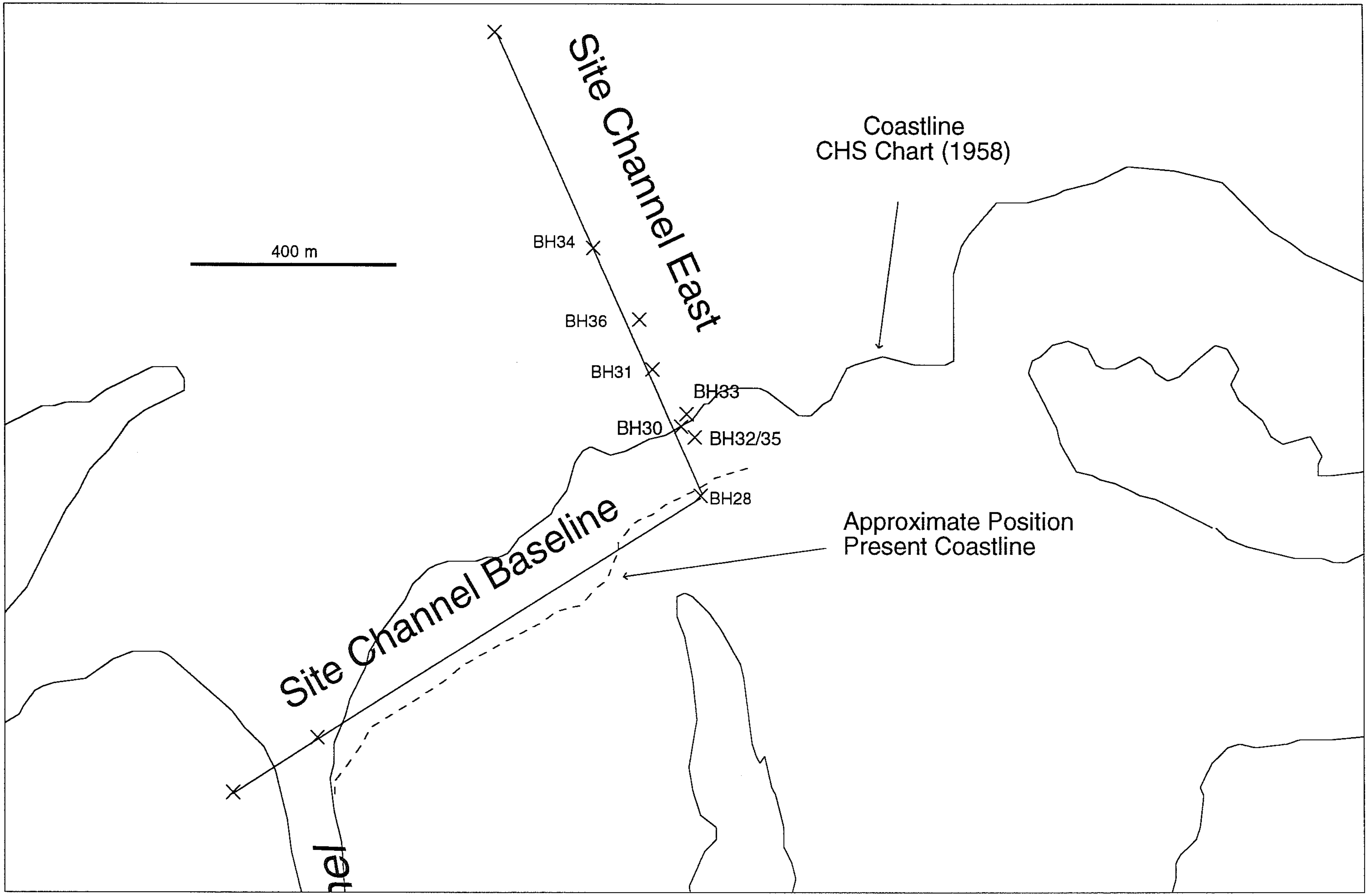

1000 m
BH16
BH17
BH18
MR2
BH13
BH15
BH14
Pline
Entrance
BH27
BH26
GBH
BH12
BH9
Reindeer
Channel

Figure 12



Reindeer Bars
BH25
BH22
BH19
BH20
BH21
BH23
BH24
BH5
Inner Lake
BH4
BH4a
BH4b
Outer Lake
BH3
BH10
BH2
1000 m
Reindeer Channel
BH8
BH1
Hansen Harbour

Figure 13


400 m
Site Channel East
BH34
BH36
BH31
BH33
BH30
BH32/35
BH28
Coastline
CHS Chart (1958)
Approximate Position
Present Coastline
Site Channel Baseline
nel

APPENDIX A

List of Geophysical Files, Calibration Data, S4 Deployments, Salinity

File List

Geophysics lines

Filename	Start Easting	Start Northing	End Easting	End Northing	Bearing
fresh*	529006	7729798	528989	7729306	000°T
Borehole @ 90m					
lake*	531161	7728734	530166	7729311	000°T
inlake*	529629	7729150	529632	7729471	000°T
r*inbdr*	532071	7729266	532517	7729821	050°T
Boreholes @ 0m,50m, 80m,110m,130m 220m, 450m					
rchan*	530011	7727497	530161	7727943	010°T
nplin(IP)	525912	7729908	524955	7730301	295T
Boreholes @ 285m, 645m					
MR2	528902	7732616	529372	7733247	040°T
Boreholes @ at 100m, 130m, 365m, 660m, 705m, 720m					
PLCH	527906	7731175	527756	7731323	140°T
Borehole @ 100m					
GBH	526041	7731599	525733	7731798	315°T
BH @ 290m					
PLE	527700	7732534	526660	7732660	090°T
Boreholes @ 525m, 600m					
L39	523875	7734855	524160	7735776	015°T
BH87	519740	7733984	519266	7734512	310°T
BH 006,025,050,082,300,150,227,600,525,35,064					
SCHANE	476894	7691076	476490	7691964	330°T
SCHANBL	476894	7691076	475971	7690507	240°T
S4SHORE	475542	7689467	475053	7689450	005°T
S4 SITE AND DRY HOLE@start					
ellice1	466296	7686612	465787	7686776	292°T
end fix at 0+500m					
ellice2	466289	7686751	465748	7687088	300°T

File Descriptions

EM34
fresh34 - freshwater lake on Reindeer Island EM34 VH 10, 20
lake1 - Outer drowned thermokarst across from camp EM34 V 10
lake40 - Outer drowned thermokarst across form camp EM34 V 40
lake20- - Outer drowned thermokarst across from camp EM34 V 20
inlake3 - Inner drowned thermokarst across from camp EM34 VH 10, 20
rchan34 - Reindeer channel EM34 VH 10, 20, 40
rainbr - Reindeer Barriers (1st half) EM34 VH 10, 20, 40
rainbar - Reindeer Barriers (1st 70 m) EM34 VH 10,20,40
raindr1 - Reindeer barriers (2nd half)EM34 10, 20, 40
IP - Inner pipline harbour (1st half) EM34 10, 20, 40
IP3,4 - Inner pipeline harbour 2nd half
PLCH - Pipeline channel
MR2 and MR2B - 1st 150 m of MR2 line (from shore)
MRMR2 - last 660m of MR2 line (total line length =810m)
GBH - Gulf Borehole line

PLE - Pipeline Harbour entrance line (1050 m)
OTL - rerun outer thermokarst lake
ITL - rerun inner thermokarst lake
L39 - Line 39 at Wolfe Spit
BH87 - TSD retreating site transect
SCHANE - Site channel east bank
SCHANBL - SITE CHANNEL BASELINE
S4SH34 - S4 SITE IN ARVOKNAR TO SHORELINE
ellice1 -at BMII 290T
ellice2 - 100m north of BMII

EM31
inlake - Inner drowned theromkarst across from camp
lake - outer drowned thermokarst across from camp
inplin1 - inner pipeline harbour 0-315 m[1]
npline2 - inner pipeline harbour 315-420 m[1]
npline3 - inner pipeline harbour 420-end[1]
reinbar - reindeer barriers
rchan31 - reindeer channel
freshlk - freshwater lake on Reindeer Island
MR2 - MR2 line from offshore
GBH - Gulf Borehole line
PLE - pipeline harbour entrance going west
PLE2 - pipeline harbour entrance going east (after recalibration)
L39 - Line 39 at Wolfe spit
BH87 - TSD borehole transect
REDOIP - rerun inner pipeline harbour
schane - Site channel east bank
SCHANBL - SITE CHANNEL BASELINE
S4SHORE - S4 SITE AND DRY HOLE
ellice1 -at BMII 290T
ellice2 - datalogger quit at about 330m
ellice2a - finished line by hand and added to .G31 file

[1] the EM31 was not working well on this line. When switching ranges the magnitude of the reading changed. This was especially apparent on npline3 on the ground, horizontal reading (April 6, 1993)

EM31 calibrations

April 1	0.62
April 5	0.7
April 6	0.8
April 7	0.72@X1 (after fiddle) 0.65@X3 0.5@X10
April 9	0.82
April 10	0.86 (24.5 in channel) (after batteries 0.89, 24.0)
April 11	0.72
April 12	0.61
April 13	0.46
April 22	2.1 at BMII hip start and end of ellice1
April 22	1.4 at BMII hip at end of ellice2

Sensitivity checks EM31

Start PLE (Ap12)

x1	0.61
x30	57 (offscale)
x100	62
x300	70
x1000	104

End PLE (Ap12)

x1	3.8
x3	11.6
x10	12.3
x30	8.3
x100	8.2
x300	7.6
x1000	5.4

StartGBH (Ap13)

x1	4.0
x3	7.4
x10	7.6
x30	8.1
x100	10.1
x300	16.1
x1000	36.6

End GBH (Ap13)

x1	3.9
x3	5.4
x10	6.0
x30	6.7
x100	8.8
x300	16.3
x1000	40.6

(whole survey done at x100)

Calibrations for 10 and 20 m spacing w/40m cable (April 10)

	10m	20m	40m	corr
10mV	.08		.2	-.12
10mH	.31		.46	-.15
20mV		.42	.56	-.14
20mH		.86	.83	+.03

Repeat fixes

BH13	529137	7732863	Ap10	528989	7732736	Ap7
BH14	528975	7732700	Ap10	529202	7732901	Ap7
BH15	528998	7732780	Ap10	529011	7732804	Ap7

Miscellaneous EM31 readings

Gravel Beach on Reindeer Spit

Easting:532960	Northing:7728510
Hip-horizontal	15 mS/m
Hip vertical	7 mS/m
Ground-horizontal	20 mS/m
Ground-vertical	12 mS/m

Pile up at Reindeer recurve - 2 m high plates of ice 3-4cm thick partly sediment laden

Easting:533382	Northing:7728562
Hip-horizontal	50 mS/m
Hip vertical	30 mS/m
Ground-horizontal	66 mS/m
Ground-vertical	48 mS/m

S4Shore - water depth = 7.2 m, ice thickness = 1.6 m

Easting:475073 Northing: 7689441

	field	model (1.6 m ice@0.1mS/m; fresh water@10mS/m)
Hip-horizontal	7 mS/m	6.8
Hip vertical	4 mS/m	3.8
Ground-horizontal	9 mS/m	8.5
Ground-vertical	5 mS/m	5.1

S4 deployments

93S4-1
Reindeer Channel at camp
530122 E 7727833 N
water depth=290cm
ice thickness=155cm
deployed 0.70cm above seabed (at BH1,8)

93S4-2
Pipeline Channel off spit
527906 E 7731175 N
water depth=250cm
ice thickness=140cm
deployed 0.55 m above seabed (at BH9)

93S4-3
MR2 in trough between inner and outer bars
529202 E 7732901 N
water depth=246cm
ice thickness 163cm
deployed 0.4 m above seabed (BH13) Ap8@1600-Ap9@1600

93S4-4
Reindeer Bars
532378 E 7729681 N
water depth=280cm
ice thickness=177cm
deployed 0.4 m above seabed (BH25)

93S4-5
Arvoknar Channel
475073 E 7689441N
water depth=721cm
ice thickness= 163cm
deployed 1 m above seabed Ap17@1700-Ap18@2000

YSI Profile cast at Arvoknar Channel S4 site

depth	temp (c)	salinity (0/00)	cond (micromhos/cm)
0	4.5	1.2	1050
1	3	1	910
2	2.9	1.1	990
3	3	1.1	1020
4	3	1.1	990
5	3	1	900
6	3	1	850
7	3	1	790

Salinity (ppt) at Borehole sites

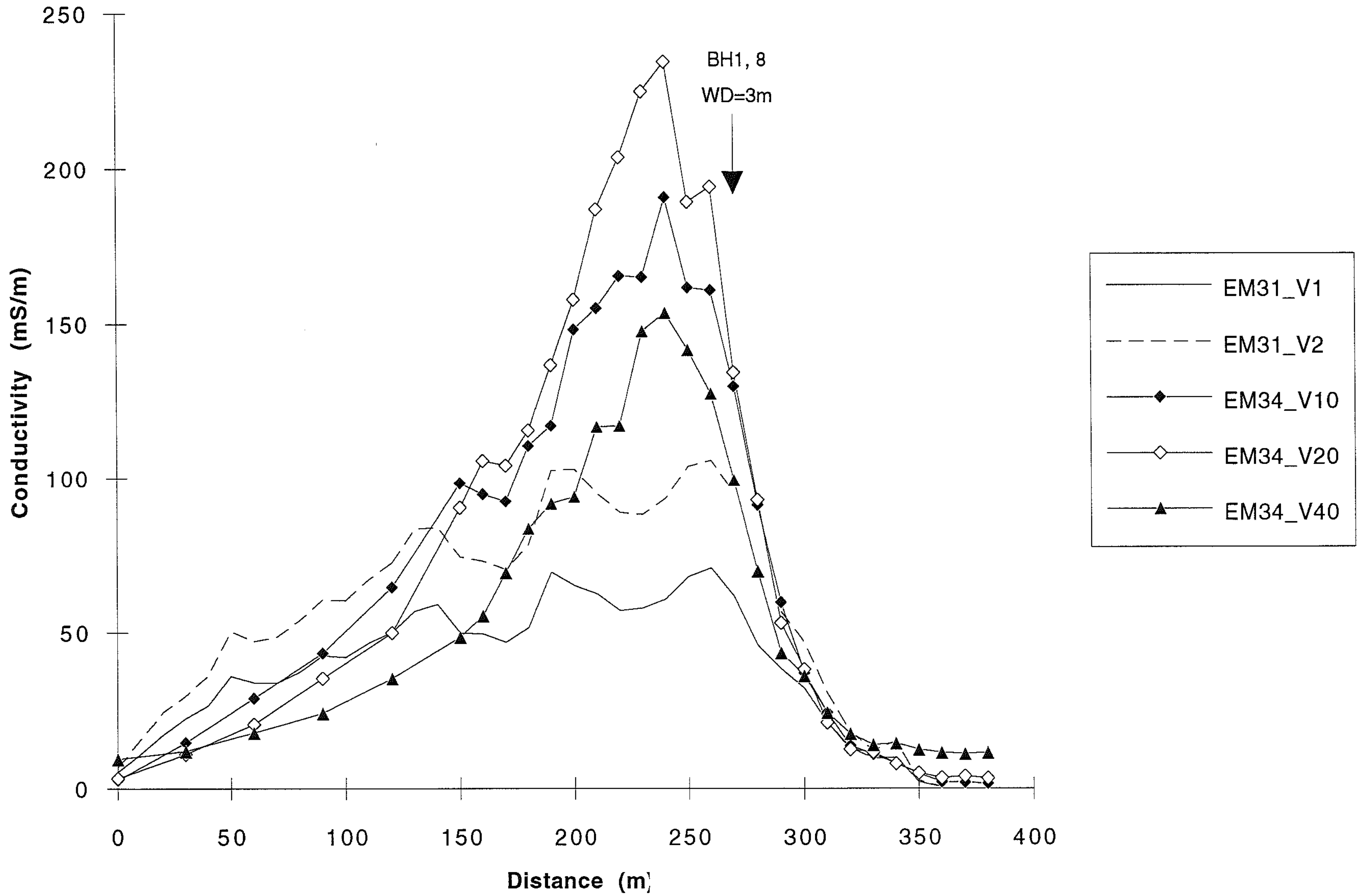
	Bottle (Lab)	YSI
BH2	16	0.5
BH3	15	24
BH4	34	30
BH10	17	25
BH13	0	24
BH17	0	na
BH18	0	na
BH25	0	na

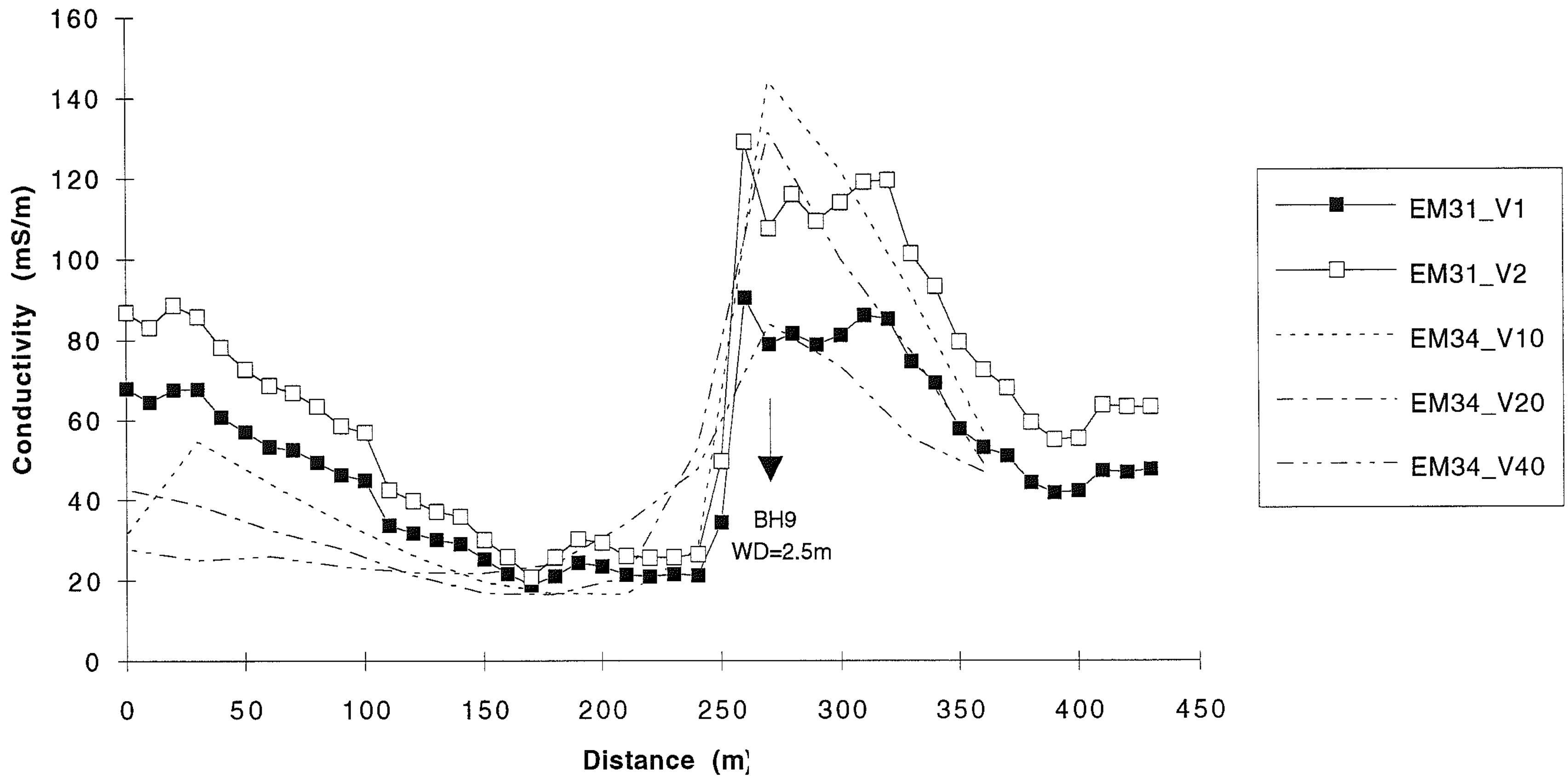
APPENDIX B: Selected EM profiles and Current Meter Data

EM profile and current meter deployment locations are plotted on FIGURE 2 and 3 of the text. For each EM profile, the distance from the start point is on the X-axis and the conductivity in millisiemens per metre (mS/m) is on the Y-axis. EM31_V1 and EM31_V2 represent hip and ground measurements using the EM31 with vertical dipoles. EM34_V10, EM34_V20, and EM34_V40 represent EM34 vertical dipole measurements at dipole spacings of 10m, 20m and 40 m respectively. Water depths (WD) at borehole (BH) locations are plotted where they are present.

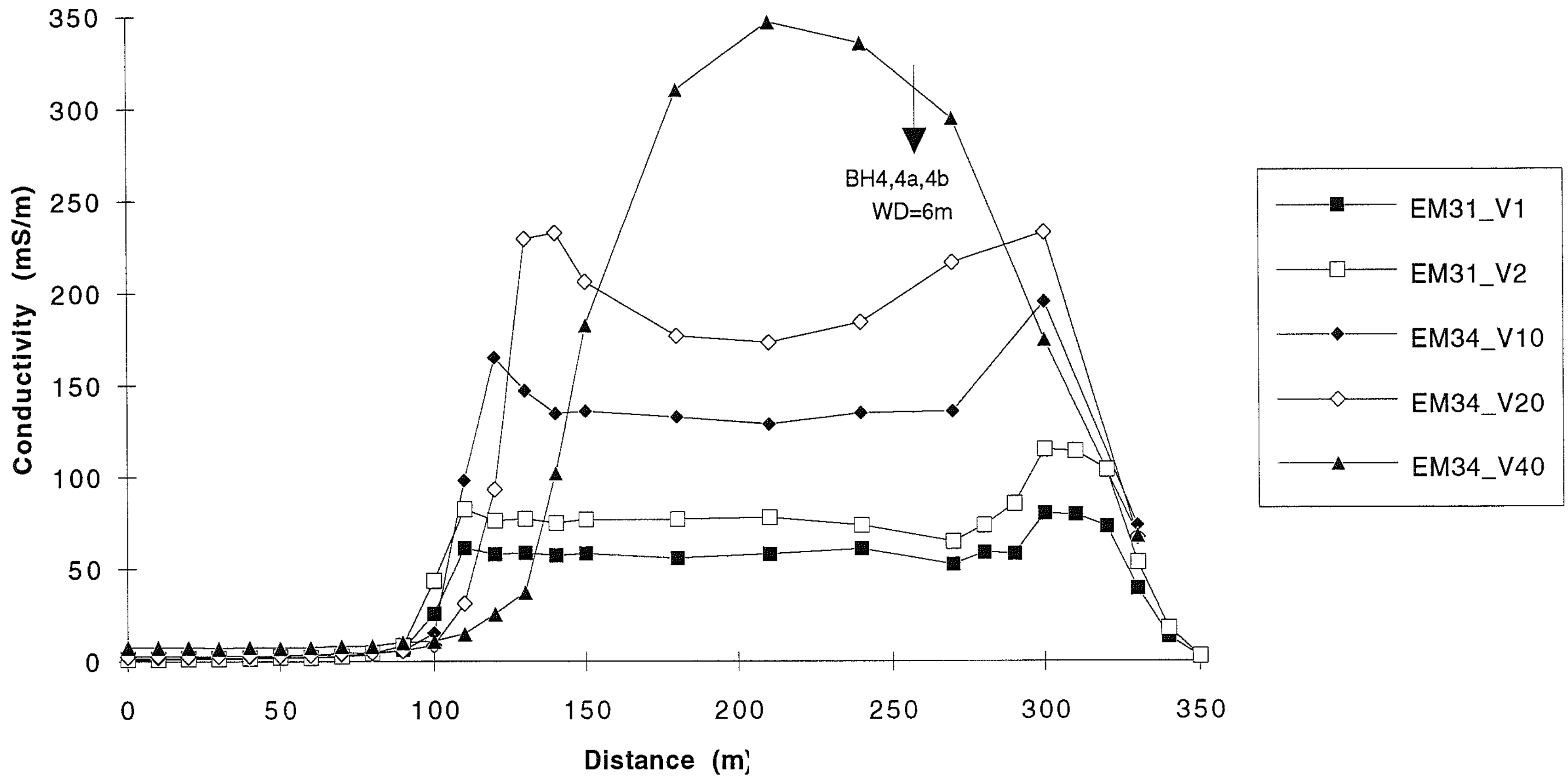
Current meter plats consist of a time series of direction and current speed for each of the five deployments. Disregard header information.

Reindeer Channel Chart 1

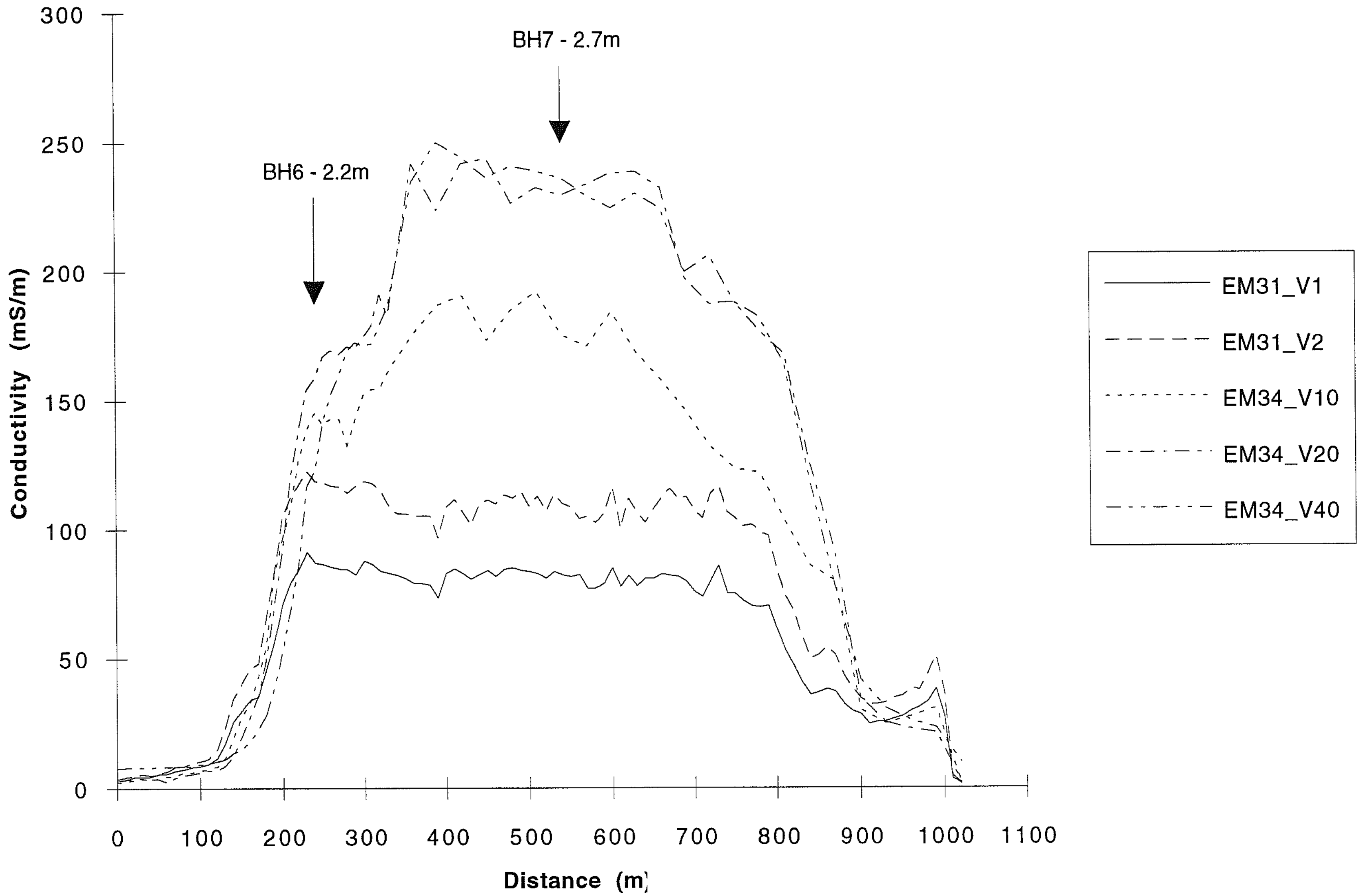



160
140
120
100
80
60
40
20
0
Conductivity (mS/m)
0
50
100
150
200
250
300
350
400
450
Distance (m)
BH9
WD=2.5m
EM31_V1
EM31_V2
EM34_V10
EM34_V20
EM34_V40

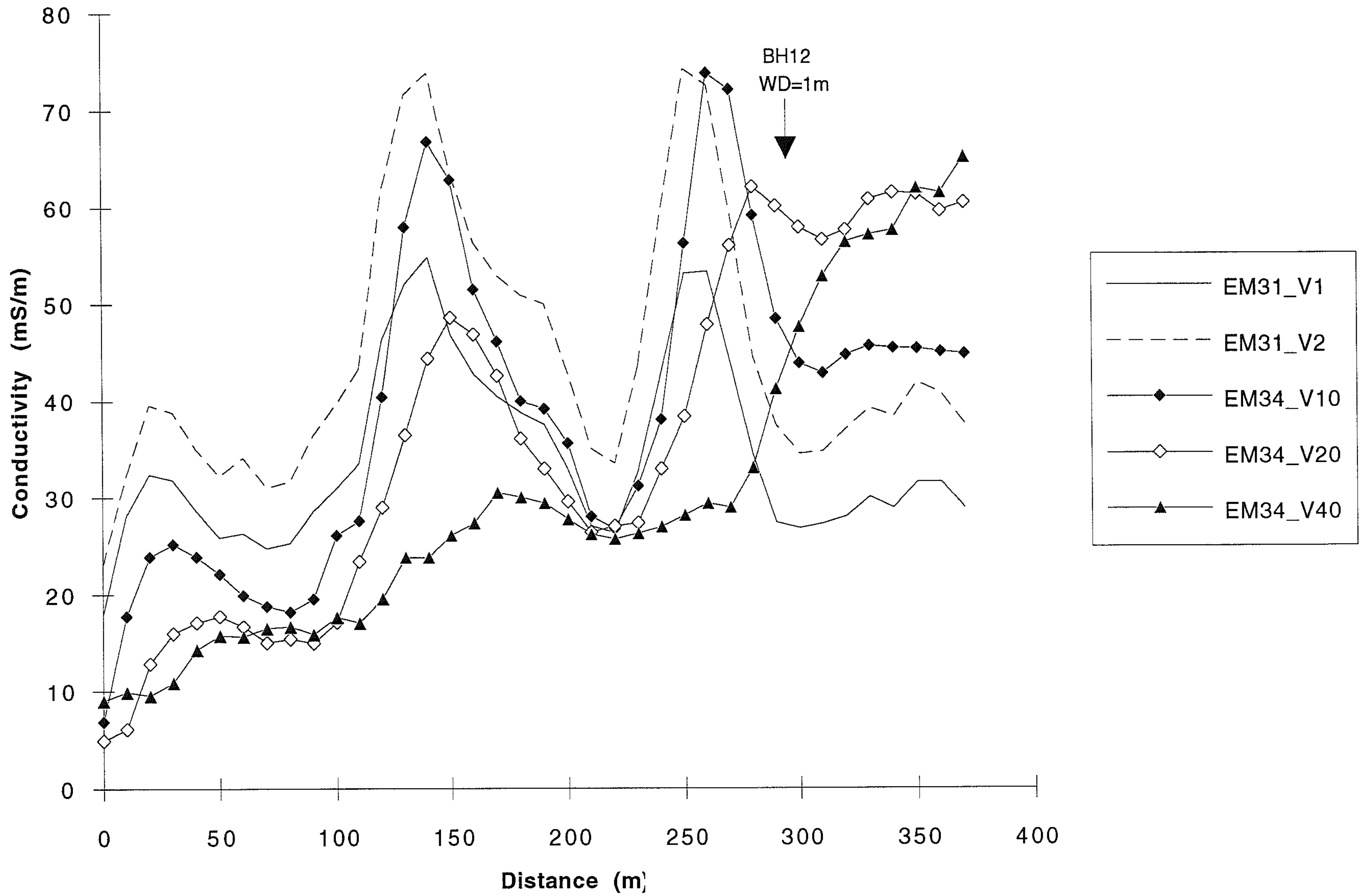
Inner Thermokarst Lake Chart 1



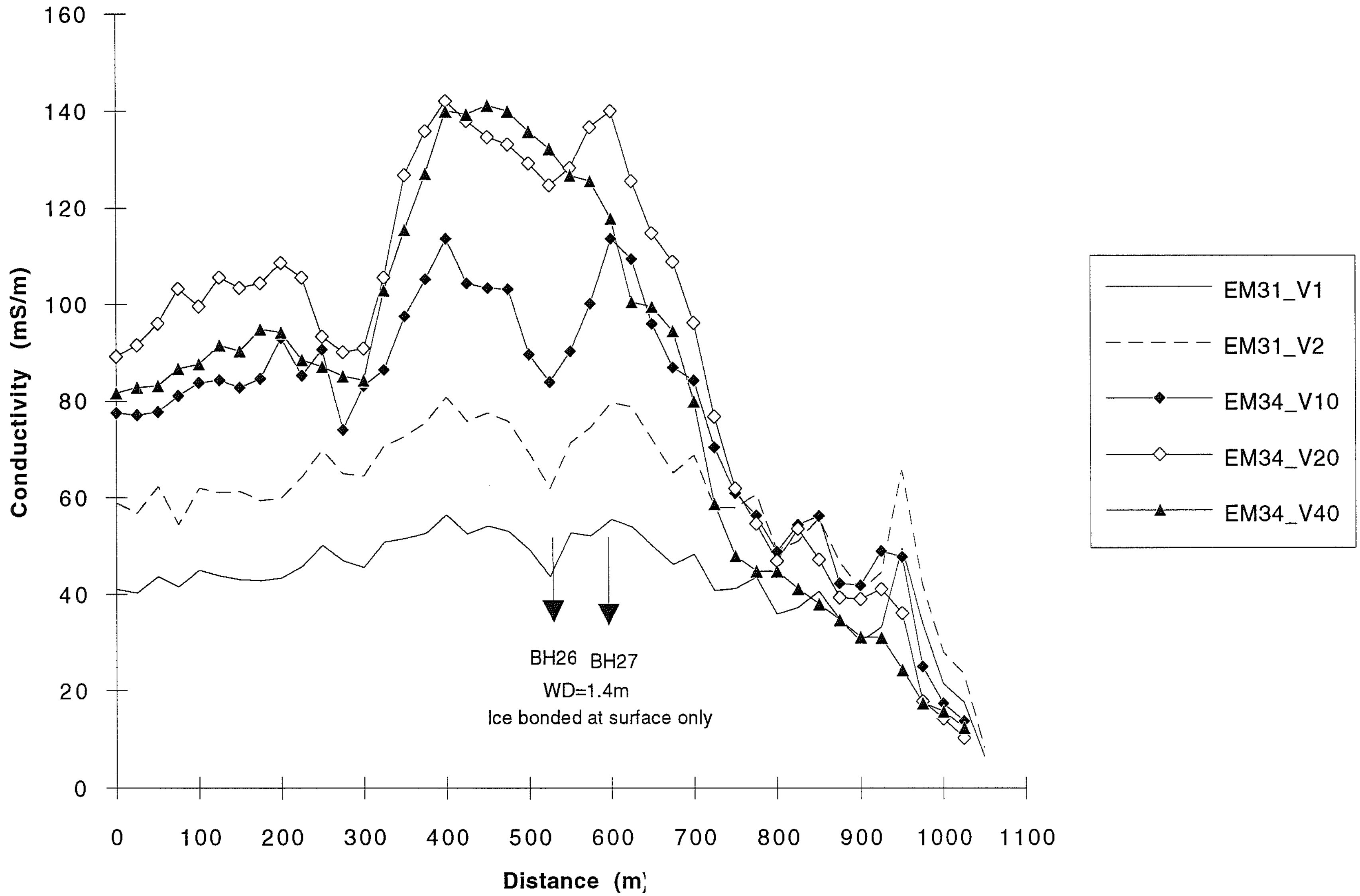
Inner Pipeline Hbr Chart 1



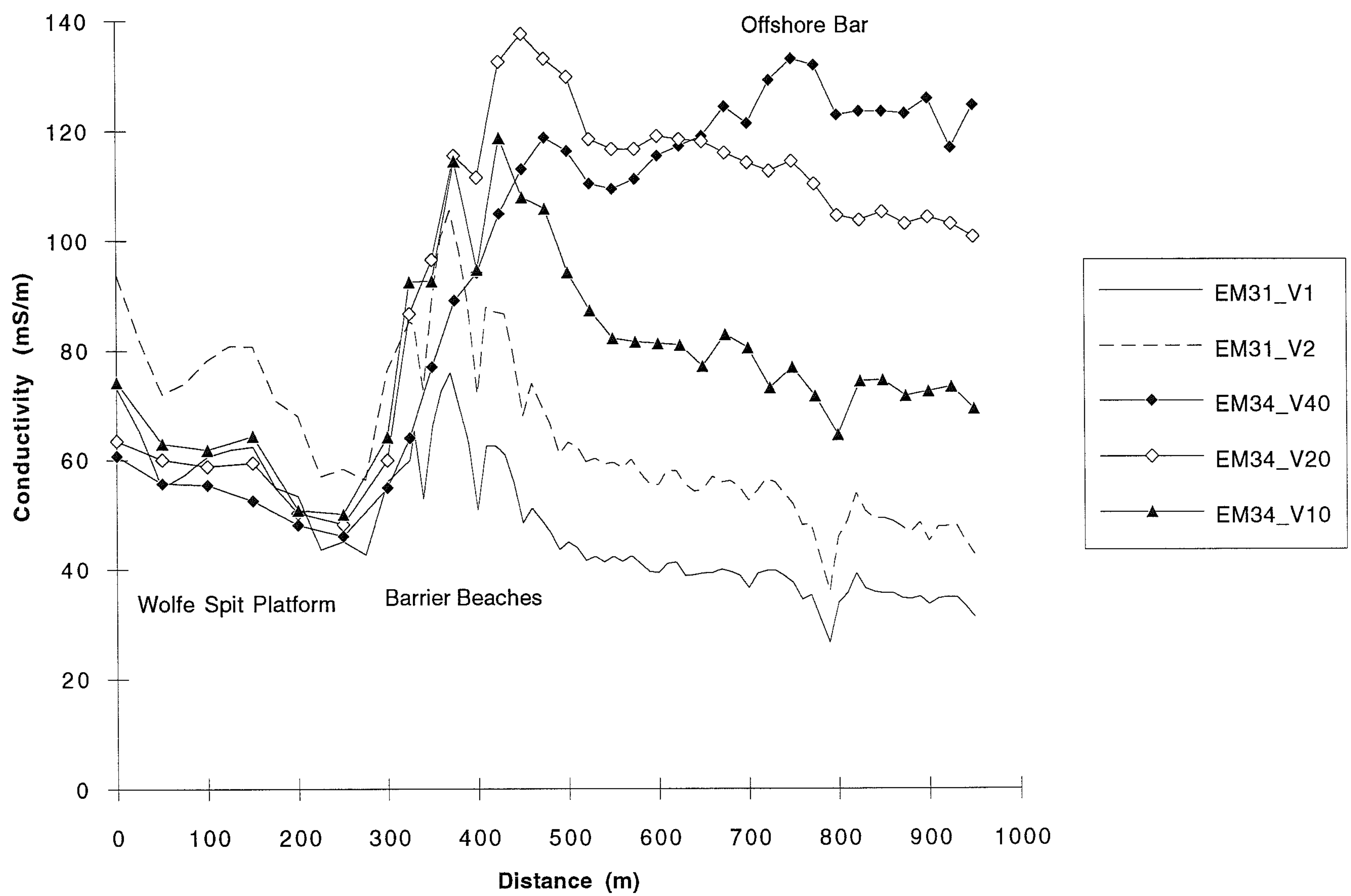
Gulf Borehole Chart 1



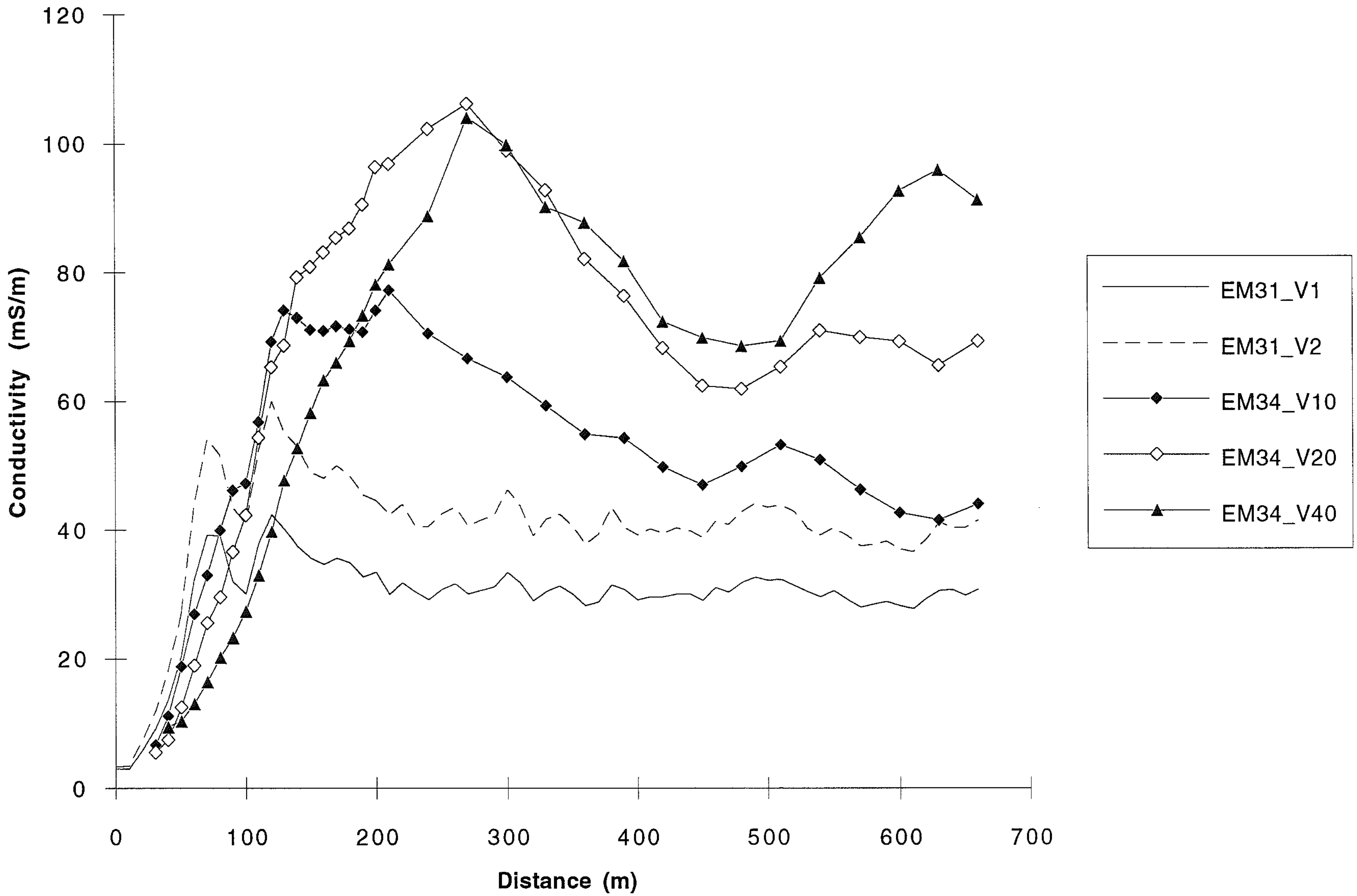
Pipeline Entrance Chart 2



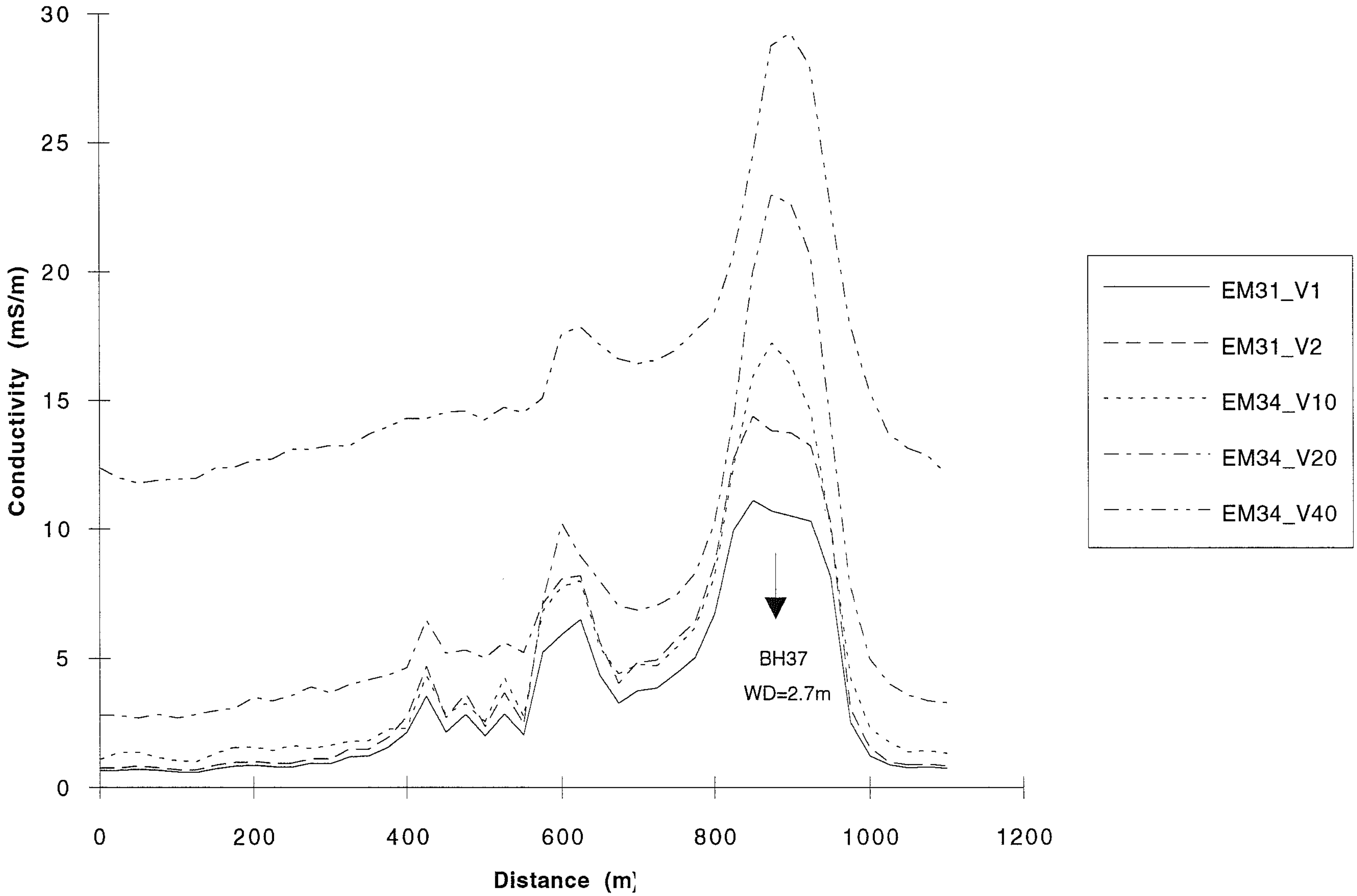
Line 39 (Wolfe Spit) Chart 2



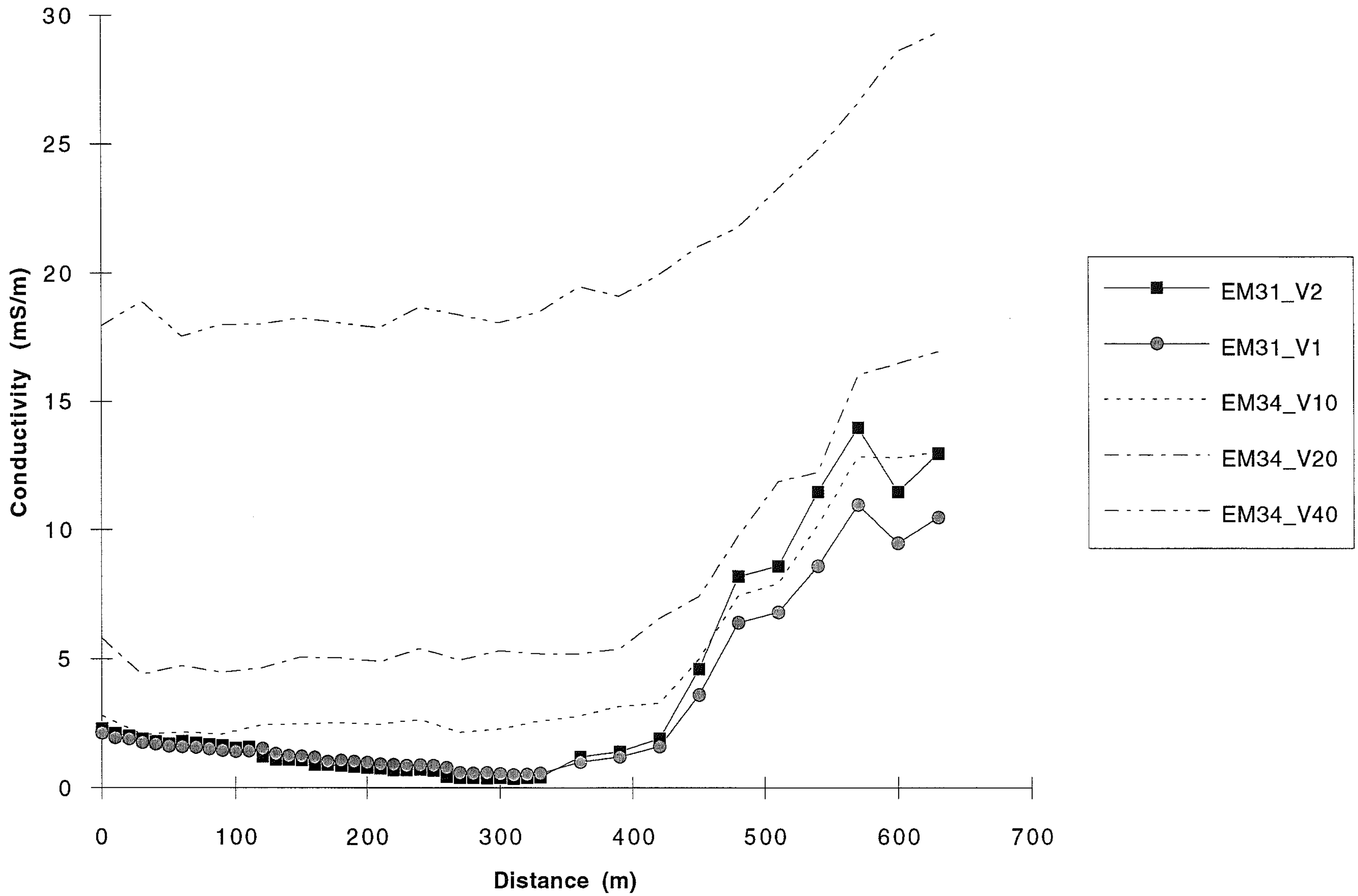
Retreating Site Chart 2

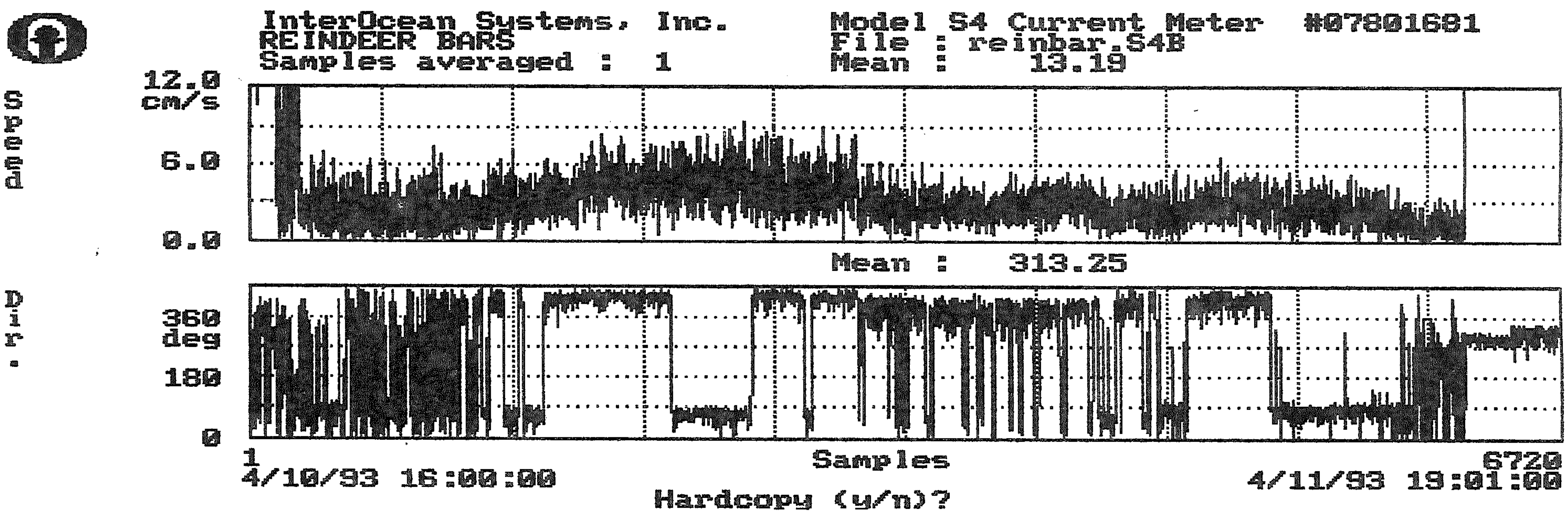


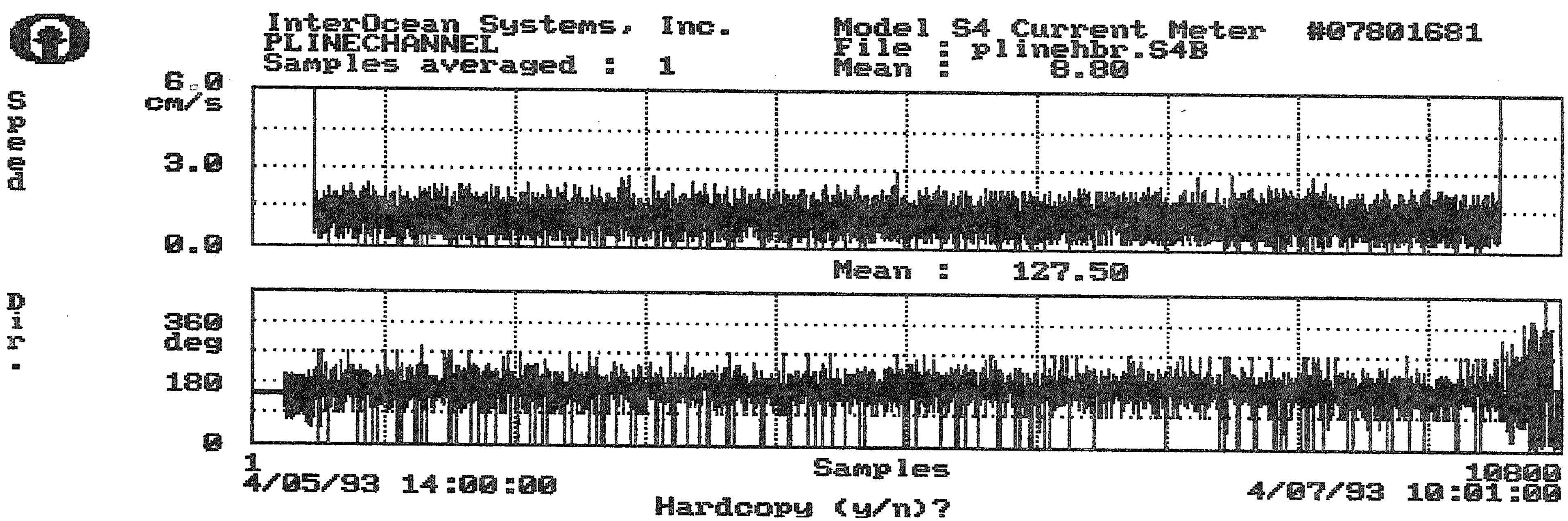
Site Channel (Baseline) Chart 3

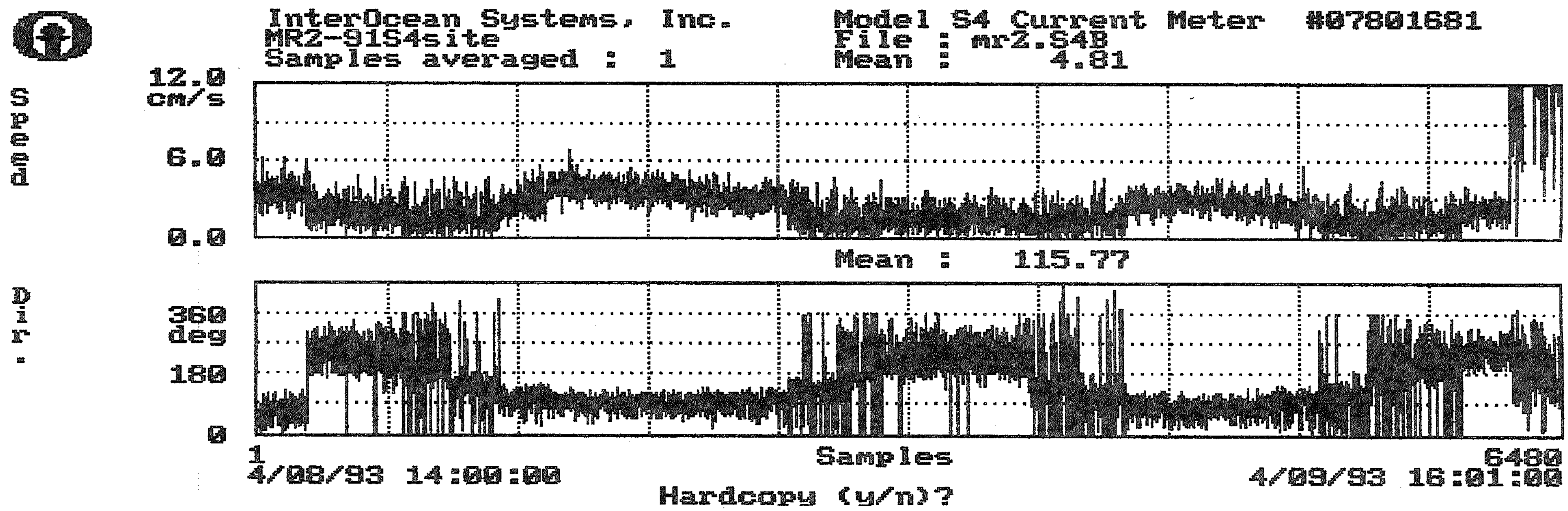


Ellice Line2 Chart 2

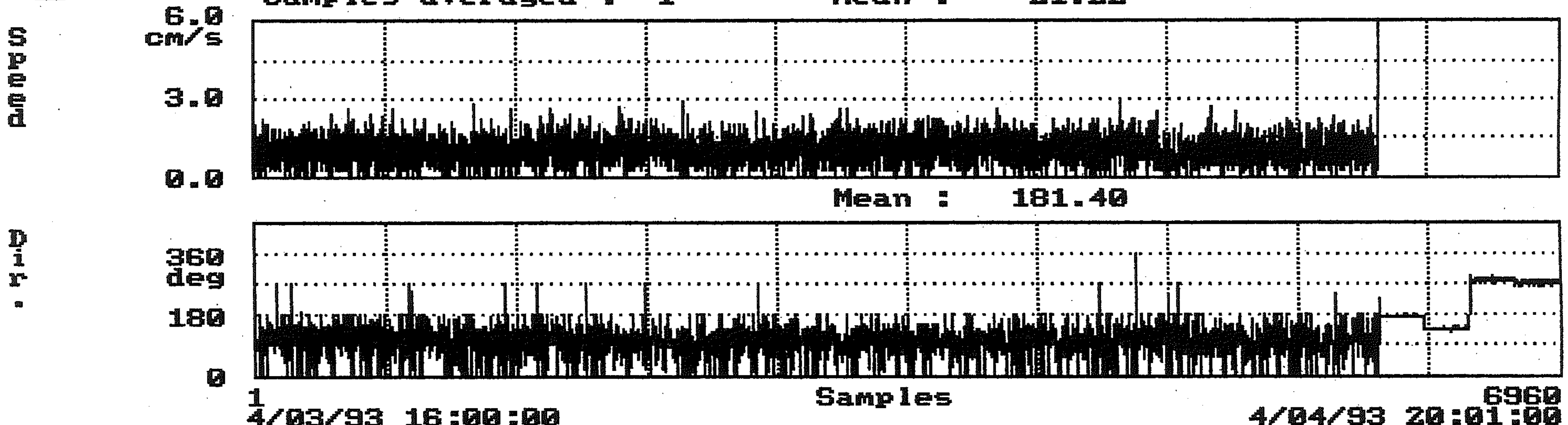



InterOcean Systems, Inc.
REINDEER BARS
Samples averaged : 1
Model S4 Current Meter #07801601
File : reinbar.S4B
Mean : 13.19
Speed
12.0 cm/s
6.0
0.0
Mean : 313.25
Dir.
360 deg
180
0
1
4/10/93 16:00:00
Samples
6720
4/11/93 19:01:00
Hardcopy (y/n)?

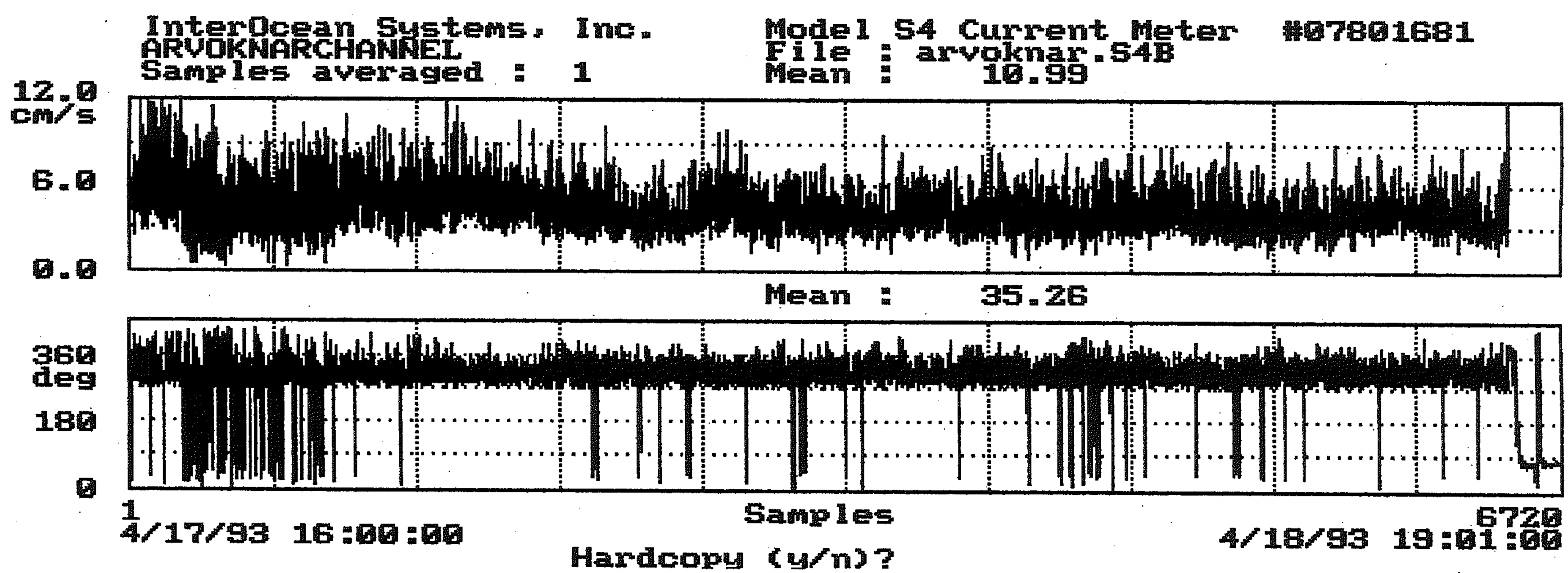

InterOcean Systems, Inc.
PLINECHANNEL
Samples averaged : 1
Model S4 Current Meter #07801681
File : plinehbr.S4B
Mean : 8.80
Speed
6.0
cm/s
3.0
0.0
Mean : 127.50
Dir.
360
deg
180
0
1
4/05/93 14:00:00
Samples
10800
4/07/93 10:01:00
Hardcopy (y/n)?


InterOcean Systems, Inc.
Model S4 Current Meter #07801681
MR2-91S4site
File : mr2.S4B
Samples averaged : 1
Mean : 4.81
Speed
12.0 cm/s
6.0
0.0
Mean : 115.77
Dir.
360 deg
180
0
1
4/08/93 14:00:00
Samples
6480
4/09/93 16:01:00
Hardcopy (y/n)?

InterOcean Systems, Inc. Model S4 Current Meter #07801681
CAMPCHANNEL File : reindeer.S4B
Samples averaged : 1 Mean : 21.22



Hardcopy (y/n)?


InterOcean Systems, Inc.
ARVOKNARCHANNEL
Samples averaged : 1
Model S4 Current Meter #07801681
File : arvoknar.S4B
Mean : 10.99
Speed
12.0
cm/s
6.0
0.0
Mean : 35.26
Dir.
360
deg
180
0
1
4/17/93 16:00:00
Samples
6720
4/18/93 19:01:00
Hardcopy (y/n)?

APPENDIX C: Core Salinity, Water Content, Carbon Content, and Grain Size Greater Than 250 Micrometres

Spreadsheet printouts for salinity, water content (moisture), total carbon (T.C.), organic carbon (O.C.), inorganic carbon (I.C.), the ration of organic to total carbon (OC/TC) and for some core, the percent of the sample which exceeds 250 micrometres are presented. For the frozen samples salinity was measured using a refractometer on pore water extracted by centrifuge. Salinity was measured for unfrozen samples using an electrical conductivity meter. Where insufficient water was presented the samples were diluted with distilled water. Organic and total carbon were measured using a Leco carbon analyzer (WR112). Textural information was acquired by dry sieving.

Core	Depth (cm)	Salinity(ppt)	Moisture	T.C.	O.C.	I.C.	OC/TC	% >250
11	78	22	30.9%	3.79%	1.47%	2.32%	0.39	0.28%
11	90	23	39.2%	3.54%	1.39%	2.15%	0.39	0.17%
11	115	25.9	26.8%	3.75%	1.30%	2.45%	0.35	0.25%
11	140	26.8	27.8%	4.31%	2.00%	2.31%	0.46	0.88%
11	170	24.1	24.7%	3.80%	1.53%	2.27%	0.40	0.80%
11	210	15.4	29.7%	3.45%	1.87%	1.58%	0.54	0.11%
11	240	7.5	29.5%	3.63%	1.27%	2.36%	0.35	0.10%
12	89	21	51.5%	3.02%	0.85%	2.17%	0.28	0.21%
12	117	26.4	24.9%	3.22%	0.89%	2.33%	0.28	0.11%
12	160	33.3	24.3%	3.52%	1.44%	2.08%	0.41	0.22%
12	185	24.6	21.8%	3.25%	1.17%	2.08%	0.36	0.04%
12	225	33.9	23.5%	2.96%	1.47%	1.49%	0.50	0.18%
12	270	31.4	24.8%	4.03%	2.49%	1.54%	0.62	0.41%
12	288	38.3	23.2%	3.18%	1.41%	1.77%	0.44	0.08%
12	350	37.8	22.4%	3.23%	1.81%	1.42%	0.56	0.15%
14	87	11	20.0%	1.71%	0.16%	1.55%	0.09	7.01%
14	175	16	20.3%	1.62%	0.18%	1.44%	0.11	0.78%
15	135	11	30.8%	2.29%	0.29%	2.00%	0.13	0.24%
15	185	7	26.4%	1.72%	0.26%	1.46%	0.15	1.83%
20	72	15	21.7%	1.30%	0.12%	1.18%	0.09	2.21%
20	110	62.5	14.3%	1.40%	0.12%	1.28%	0.09	7.67%
20	118	91.3	36.6%	3.85%	1.59%	2.26%	0.41	0.23%
20	128	55.2	14.2%	1.53%	0.22%	1.31%	0.14	0.71%
20	142	86.1	38.4%	5.67%	3.17%	2.50%	0.56	1.39%
20	170	60.1	18.1%	1.59%	0.17%	1.42%	0.11	0.51%
20	207	34.9	12.2%	1.36%	0.13%	1.23%	0.10	1.82%
20	210	96.8	33.3%	2.88%	1.66%	1.22%	0.58	0.12%
20	288	66.1	23.0%	3.22%	1.48%	1.74%	0.46	0.18%
21	82	12	20.5%	1.46%	0.11%	1.35%	0.08	5.23%
21	197	111.3	30.4%	2.79%	1.16%	1.63%	0.42	0.78%
21	265	80.9	25.0%	3.15%	1.46%	1.69%	0.46	0.07%
22	82	31.5	19.2%	1.42%	0.12%	1.30%	0.08	3.96%
22	150	78.8	18.4%	1.11%	0.12%	0.99%	0.11	9.96%
22	205	78.7	15.1%	1.34%	0.13%	1.21%	0.10	7.62%
22	218	130.8	35.6%	2.94%	1.82%	1.12%	0.62	0.30%
22	270	101.2	24.9%	3.13%	1.54%	1.59%	0.49	0.37%
23	72	18	19.8%	1.48%	0.11%	1.37%	0.07	10.07%
23	150	105.0	31.1%	4.25%	2.49%	1.76%	0.59	0.75%

Core	Depth (cm)	Salinity(ppt)	Moisture	T.C.	O.C.	I.C.	OC/TC	% >250
23	180	67.4	15.9%	2.16%	0.66%	1.50%	0.31	0.14%
23	235	65.9	22.5%	3.30%	1.47%	1.83%	0.45	0.00%
24	2	12.9	16.4%	0.81%	0.13%	0.68%	0.16	21.28%
24	50	8.3	17.2%	1.18%	0.13%	1.05%	0.11	12.91%
24	100	7.8	16.9%	1.52%	0.12%	1.40%	0.08	3.46%
24	125	18.3	26.8%	2.81%	1.39%	1.42%	0.49	3.81%
24	160	33.2	23.8%	3.30%	1.45%	1.85%	0.44	0.59%
24	175	33.7	24.6%	3.86%	1.78%	2.08%	0.46	0.13%
28	0	3	56.7%	7.32%	5.07%	2.25%	0.69	7.77%
28	28	1.7	33.8%	4.70%	2.08%	2.62%	0.44	2.14%
28	92	1	50.8%	3.71%	1.52%	2.19%	0.41	0.90%
28	145	3	49.1%	3.68%	0.99%	2.69%	0.27	1.00%
28	165	1	56.6%	3.47%	0.78%	2.69%	0.22	0.61%
28	225	4	26.6%	3.17%	0.36%	2.81%	0.11	0.06%
30	197	0	27.7%	3.43%	0.54%	2.89%	0.16	0.00%
32	102	0	55.5%	3.65%	0.93%	2.72%	0.25	0.11%
32	128	0	32.6%	3.18%	0.59%	2.59%	0.19	0.10%
32	190	0	38.8%	3.27%	0.42%	2.85%	0.13	0.20%
33	65	0.0	23.5%	3.26%	0.37%	2.89%	0.11	0.00%
33	147	0	28.6%	3.04%	0.28%	2.76%	0.09	0.12%
33	179	0.0	27.9%	3.96%	1.36%	2.60%	0.34	0.10%
34	82	0	31.7%	3.38%	0.28%	3.10%	0.08	0.00%
34	91	0	32.5%	3.30%	0.30%	3.00%	0.09	0.00%
34	125	0.0	23.9%	3.31%	0.33%	2.98%	0.10	0.16%
34	140	0	26.0%	3.34%	0.38%	2.96%	0.11	0.00%
34	170	0.0	22.9%	3.37%	0.27%	3.10%	0.08	0.14%
34	175	0.0	23.2%	3.39%	0.25%	3.14%	0.07	0.00%
34	188	0.0	24.2%	3.22%	0.46%	2.76%	0.14	0.11%
34	220	1.8	26.1%	3.43%	0.79%	2.64%	0.23	0.28%
34	220	0	52.1%	3.51%	0.72%	2.79%	0.21	0.37%
34	270	0.0	25.3%	3.13%	0.31%	2.82%	0.10	0.00%

CORE #	Depth(cm)	Salinity	Moisture	TC (%)	OC (%)	IC (%)	OC/TC
1	1	18.37					
1	5		23.03	2.3	1.18	1.12	0.51
1	12	21.25					
1	18		34.44	3.93	2.53	1.4	0.64
1	23	24.40					
1	34	25.72					
1	36		29.34	3.77	1.89	1.88	0.50
2	1	14.17					
2	2		42.21	3.31	1.9	1.41	0.57
2	10		34.86	4.07	2.34	1.73	0.57
2	12	13.38					
2	23	11.02					
2	30		31.26	3.87	2.42	1.45	0.63
2	34	9.71					
2	43	5.77	28.10	2.75	1.72	1.03	0.63
	0		48.43	3.04	1.78	1.26	0.59
3	1	34.64					
3	9	35.69	51.59	2.76	1.87	0.89	0.68
3	19	35.42					
3	29	34.64	48.34	2.86	1.71	1.15	0.60
3	39	35.42					
3	49	34.64	44.80	3.02	1.73	1.29	0.57
3	59	35.16					
3	69	34.64	42.54	3.62	2.36	1.26	0.65
3	89	32.80	45.53	3.53	2.73	0.8	0.77
3	99	32.28					
3	109	32.80	46.58	3.65	3.16	0.49	0.87
3	119	32.54					
3	129	32.01	53.33	5.6	4.78	0.82	0.85
3	139	31.49					
3	149	31.23	41.19	3.01	2.37	0.64	0.79
4	0	39.10					
4	9	38.05	60.34	2.7	1.84	0.86	0.68
4	20	37.00					
4	24		57.82	3.22	2.61	0.61	0.81
4	40	35.69	66.17	6.57	5.85	0.72	0.89
4	49		66.24	8.2	7.95	0.25	0.97
4	50	34.90					
4	60	34.38					
4	69		69.54	8.82	8.82	0	1.00
4	70	33.59					

4b	0	37.79	55.50	2.63	1.91	0.72	0.73
4b	10	38.31	56.38	2.67	1.86	0.81	0.70
4b	20	37.26	51.36	2.85	1.9	0.95	0.67
4b	30	36.74	56.82	3.82	3.12	0.7	0.82
4b	40		72.49	5.39	4.83	0.56	0.90
4b	42	35.69					
4b	50		67.41	7.66	6.92	0.74	0.90
4b	52	34.90					
4b	60		71.21	9.1	8.63	0.47	0.95
4b	62	34.64					
4b	70		72.43	10.1	10.1	0	1.00
4b	72	27.37					
4b	80		70.00	9.47	9.05	0.42	0.96
4b	87		73.54	9.93	9.11	0.82	0.92
4b	90	31.23					
4b	96		73.34	9.87	9.1	0.77	0.92
4b	105	30.44	68.26	8.5	8.4	0.1	0.99
4b	113		66.21	8.46	8.25	0.21	0.98
4b	121						
4b	125	29.39	69.28	9.68	9.41	0.27	0.97
4b	132		72.13	10.4	9.82	0.58	0.94
4b	140	27.82	57.94	3.91	3.4	0.51	0.87
4b	142						
4b	150	27.03					
4b	152		56.59	5.64	5.17	0.47	0.92
4b	160	26.24					
4b	162		63.45	7.75	7.42	0.33	0.96
4b	169		59.22	6.29	5.99	0.3	0.95
4b							
5	6	2.36					
5	8		45.66	2.34	1.71	0.63	0.73
5	16	0.26					
5	18		48.77	2.88	2.36	0.52	0.82
5	28	0.26	58.00	4.39	3.82	0.57	0.87
5	38	0.26	50.19	3.54	2.97	0.57	0.84
5	48	0.26	53.81	3.18	2.62	0.56	0.82
5	58	0.26	47.87	3	2.37	0.63	0.79
5	68	0.26	48.71	3.35	3.07	0.28	0.92
5	78	0.26	48.00	3.68	3.33	0.35	0.90
5	88		50.00	4.03	3.62	0.41	0.90
6	4	26.50	37.81	3.21	1.82	1.39	0.57
6	14		36.47	3.09	1.76	1.33	0.57
6	24	32.28	33.74	3.26	1.7	1.56	0.52
6	38	28.00	28.04	3.39	1.75	1.64	0.52

7	2	28.60	43.15	3.22	1.94	1.28	0.60
7	12	25.19	37.68	3.17	1.81	1.36	0.57
7	22	26.24	38.84	2.92	1.85	1.07	0.63
7	32	27.29	33.97	3.55	1.99	1.56	0.56
7	42	27.11	34.17	3.24	1.87	1.37	0.58
7	52	25.98	30.56	3.76	2.29	1.47	0.61
7	62	25.98	35.34	3.27	1.84	1.43	0.56
7	72	25.19	35.58	3.55	2.17	1.38	0.61
9	0		27.46	3.21	1.37	1.84	0.43
9	10		21.53	2.86	0.86	2	0.30
9	20		19.95	3.37	1.21	2.16	0.36
9	30		16.98	2.88	0.87	2.01	0.30
9	40		19.02	3.24	0.99	2.25	0.31
10	0	20.47					
10	1		38.26	3.58	1.82	1.76	0.51
10	10	18.11					
10	11		35.23	3.13	1.76	1.37	0.56
10	20	15.22					
10	21		34.13	3.13	1.87	1.26	0.60
10	30	9.26					
10	31		34.04	3.31	2.06	1.25	0.62
10	40	5.89					
10	41		28.66	3.24	2.26	0.98	0.70
10	50						
10	51		25.10	1.18	0.75	0.43	0.64
10	60						
10	61		22.14	0.46	0.27	0.19	0.59
10	70						
10	71		14.86	1.43	0.26	1.17	0.18
10	80		18.48	1.62	0.25	1.37	0.15
10	90						
10	100		19.80	1.66	0.47	1.19	0.28
10	120		19.31	1.68	0.21	1.47	0.13
10	130						
10	140		19.96	1.1	0.16	0.94	0.15
10	160		18.81	1.47	0.16	1.31	0.11
10	180		18.96	1.48	0.19	1.29	0.13
13	33	12.38					
13	53	14.30					
13	80	21.20					
13	170	19.12					
13	270	16.29					

16	15	17.77					
16	140	21.73					
16	162	20.08					
27	28		24.77	3.29	0.96	2.33	0.29
27	38		24.54	3.38	1.06	2.32	0.31
27	48		62.44	3.49	1.29	2.2	0.37
27	68		23.91	3.36	1.14	2.22	0.34
35	310		33.06	4.99	2.76	2.23	0.55
35	356		25.06	3.25	0.4	2.85	0.12
35	420		26.43	3.42	0.79	2.63	0.23
35	450		26.92	3.23	0.49	2.74	0.15
35	505		23.49	3.08	0.37	2.71	0.12