Cdn. Seabed Research Ltd.

SEDIMENT TRANSPORT AT ARTIFICIAL ISLAND SITES CANADIAN BEAUFORT SEA

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Submitted to:

Indian and Northern Affairs Canada
Les Terrases de la Chaudiere
Ottawa, Ontario
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and
Geological Survey Of Canada
Bedford Institute of Oceanography
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March, 1994

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CSR Project Number:	9226
Submission Date:	March, 1994

Table of Contents

Table of Contents

Table of Contents

Table of Contents
List of Tables in Text

List of Graphs in Text

List of Figures in Text

Section 1

Section 5.1

Section 5.2

Table of Contents

List of Figures in Text

Section 5.3

Section 5.4

Section 5.5

Section 5.6

Table of Contents

List of Figures in Text

Section 5.7

Section 5.8

Section 5.9

Section 5.10

Table of Contents

List of Figures in Text

Section 5.11

Section 5.12

Section 5.13

Table of Contents

List of Figures in Text

Section 6

Section 1
Introduction

Artificial islands were constructed in the Canadian Beaufort Sea between 1975 and 1986 in water depths ranging from 1m to 45m. A total of 37 island sites were constructed during this time interval. The islands provided temporary drilling platforms, typically built in an open water season, occupied during the subsequent winter months and then abandoned. Once abandoned, the islands were eroded by natural processes to the waterline within a few months to two years.

These islands are largely constructed of sand and gravel. The aggregate potential of the islands and the importance of this material to offshore development in the Canadian Beaufort Shelf has prompted Indian and Northern Affairs Canada as part of the Northern Oil and Gas Action Program (NOGAP) to commence a major island inventory and assessment project.

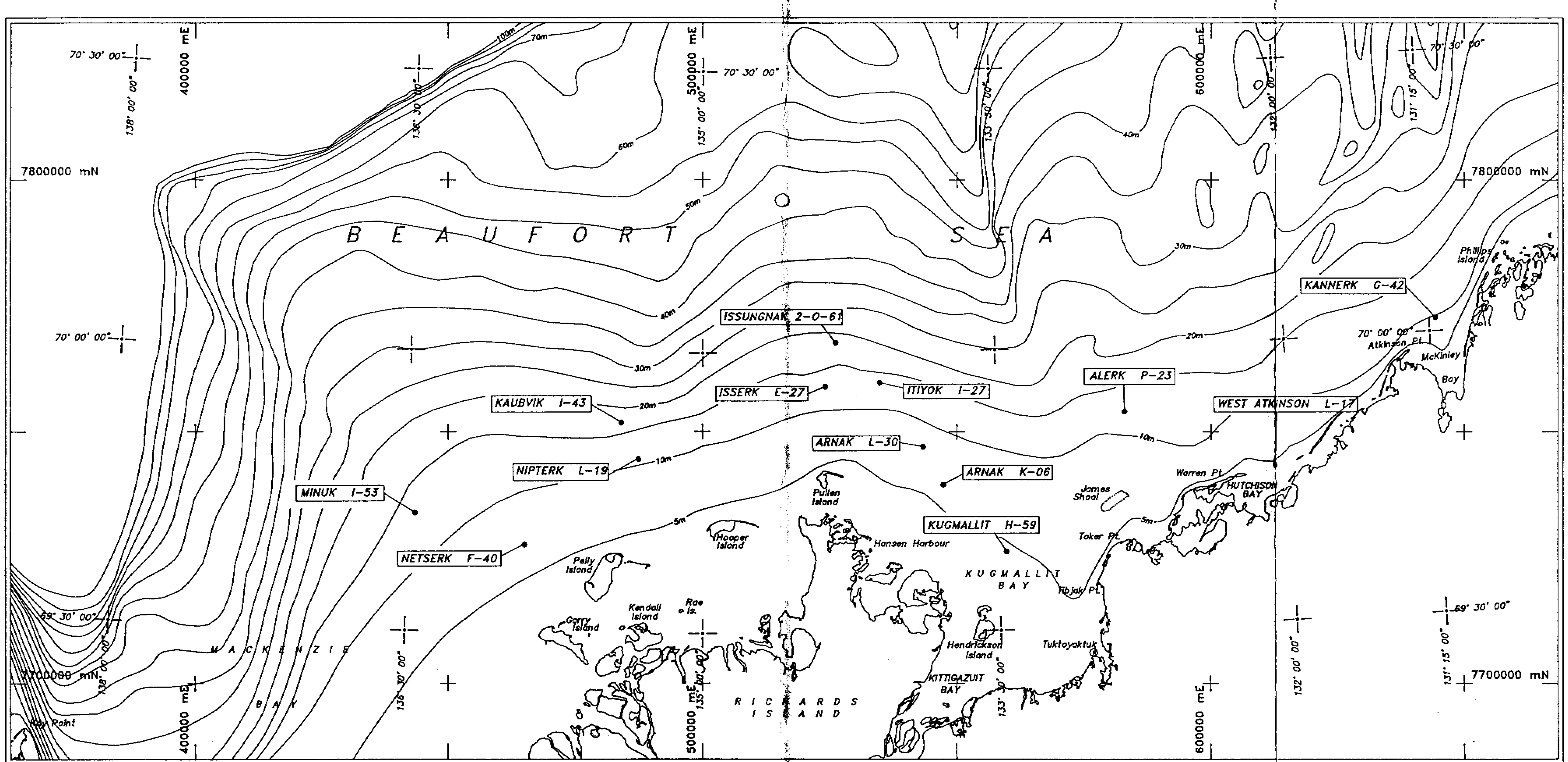
One of the main factors in the evaluation of the potential changes in the resource potential of the islands over time is information on the island dynamics. This topic is also of interest to the Geological Survey of Canada (GSC) from the perspective of using island erosion information for estimating regional sediment transport rates and directions. Therefore GSC provided partial funding, under the Program on the Energy Research and Development (PERD) Commitee 6.3.1 - Beaufort Offshore Geotechnics, for this particular study.

This project has several components including the development of a artificial island database (Klohn Crippen, 1993) as part of Supply and Services Canada Contract No. 038ST.A7134-2-0039. This database includes a compilation of existing hydrographic and geophysical data acquired at the island sites. The Scientific Authority for this contract was Mr. Robert J. Gowan. As a participant in this work Canadian Seabed Research Limited was contracted to analyze the hydrographic and geophysical survey data collected at 13 of the island sites. Figure 1.1 illustrates the locations of the 13 islands assessed in this study.

The objectives of this report were to address several key questions of relevance to the long term fate of the islands as an aggregate resource. These questions include:

1) In what ways are the islands changing with time after abandonment?
2) What seafloor processes are active at the island sites?
3) Does the location, water depth, construction material or design influence the behaviour of the islands after abandonment?
4) What are the direction and magnitude of sediment transport on the islands?
5) Which area of the islands are undergoing sediment erosion and where has this sediment accumulated?.
6) How do these processes impact the aggregate resource potential of the islands?

This report addresses these questions.



Regional Beaufort Sea Bathymetry and Coastline Map displaying the locations of the 13 islands investigated in this study.

FIGURE 1.1

Acknowledgements

The project manager and report authors wish to acknowledge the Energy, Mines and Resources Canada Program on Energy Research and Development Offshore Geotechnics Subprogram 6A4 (projects 6A4004: Sediment Properties and 6A4020: Beaufort Granular Resources Research) for funding this research (Supply and Services Canada contract: OSC93-01670-(009), Steve M. Blasco, Geological Survey of Canada, scientific authority).

Appreciation is extended to Imperial Oil, Gulf Canada Resources, Amoco Canada, Canadian Marine Drilling and the Geological Survey of Canada, for contributing the data required to meet the objectives of this study. Artificial island database compilations completed under the first phase of the INAC granular assessment project formed the basis of this second phase study. The first phase was completed under subcontract to Klohn Crippen Ltd. with Robert J. Gowan, Indian and Northern Affairs Canada, as the scientific authority. This initial study was funded by the Indian and Northern Affairs Canada Northern Oil and Gas Action Program A4: Granular Resources Inventory and Management Project and the Energy, Mines and Resources Canada Program on Energy Research and Development Offshore Geotechnics Subprogram 6A4 (project 6A4020: Beaufort Granular Resources Research: Supply and Services Canada contract 038ST.A7134-2-0039).

Contributions by Brian Rogers, Klohn Crippen and Dave Thompson, Challenger Surveys in providing high quality digital island morphology data and access to relevant video imagery were greatly appreciated. Brian Wright, B.D. Wright and Associates offered useful comments on environmental factors and on the review of the draft report.

Section 2
Previous Work

The hydrographic and geophysical data evaluated in this report ranges in vintage and type and were collected for a variety of purposes and clients. Table 2.1 summarizes the vintage and types of data collected at each of the island sites evaluated in this report. The earliest suite of data consists of hydrographic surveys completed by Canadian Engineering Surveys (CES) as part of the construction of the islands. These surveys range in vintage from 1981 to 1986.

In 1989 Canadian Seabed Research Limited conducted detailed hydrographic and geophysical surveys on four island sites: Arnak L-30, Issungnak O-61, Kaubvik I-43 and Itiyok I-27. These island surveys were conducted to determine the distribution of drilling debris and to evaluate the erosional history and fate of these islands for the Geological Survey of Canada.

In 1990 hydrographic and geophysical surveying was conducted on thirteen island sites by Challenger Surveys Ltd. and Geophysics GPR. The island sites surveyed were constructed by Esso, the client for that project. The objective of these surveys was to determine the extent and type of debris on the islands. The high quality of the geophysical data collected in the 1990 project has prompted the analysis presented in this report.

TABLE 2.1

Island	Physiographic Province	Water Depth (m)	Island Design	Date Constructed	Date Abandoned	Sidescan Surveys Following Abandonment	Bathymetric Surveys After Abandonment	Bathymetric Surveys at, or Prior to, Completion	Quality of 1990 Sidescan
Netserk F-40	Kringulik Plateau	7.0	SBR	1975	1976	1990	1981, 90		A
Kugmallit H-59	Kugmallit Channel	5.3	SBR	1976	1977	1990	1982, 90		A
Arnak L-30	Akpak Plateau	8.5	SB	1976	1977	1989/90	1982, 84, 89, 90		B
Kannerk G-42	Kaglulik Plain	8.5	SB	1976	1977	1990	1982, 90		A
Isserk E-27	Akpak Plateau	13.0	SB	1977	1978	1990	1982, 90		D
Issungak 2-O-61	Akpak Plateau	19.0	SB	1978/79	1981	1989/90	1981, 89, 90		D
Alerk P-23	Tingmiark Plain	11.6	SB	1980/81	1982	1990	1982	1981	A
West Atkinson L-17	Hutchison Bay	6.0	SB	1981/82	1982	1990	1990	1982	A
Itiyok I-27	Akpak Plateau	15.0	SB	1981/82	1983	1989/90	1984, 89, 90	1982	D
Nipterk L-19	Ikit Plateau	11.7	SB/S&G	1983/84	1985	1990	1990	1984	C
Minuk I-53	Kringulik Plateau	14.7	SB/S&G	1982-85	1986	1990	1987, 90	1985	A
Arnak K-06	Kugmallit Plateau	7.2	SB	1985	1986	1990	1990	1985	A
Kaubvik I-43	Ikit Trough	17.9	CRI	1983-86	1987	1989/90	1989, 90	1986	C

Island Design Classification

SBR	Sand Bag Retained
SB	Sacrificial Beach
S&G	Sand and Gravel
CRI	Caisson Retained Island

Quality of Sidescan Classification

A	Excellent
B	Very Good
C	Good
D	Poor

Section 3
Project Scope and Report Organisation

3.1 Project Scope

The original terms of reference of this project called for detailed mapping of four of the 13 abandoned island sites. Upon review of the existing data an alternate approach was proposed. This approach consisted of completing an assessment of each of the 13 island with emphasis on the quantifying the direction and magnitude of sediment transport. Section 4 -Interpretation Methods details the analysis procedures adopted for this study.

3.2 Report Organisation

The body of this report is organised into four main sections.

Section 4 - Interpretation Methods

This section details the procedures used to access the magnitudes and directions of sediment transport from the hydrographic and geophysical data for each island site.

Section 5 - Island Design, Morphology and Seafloor Features

In this section a summary is presented of each of the thirteen island sites. The general island description is presented for each site along with a detailed description of the island morphology and seafloor features. Bathymetry profiles are presented for each island and the areas of sediment depletion and sediment accretion are identified on these profiles. Diagrammatic seafloor features maps are presented for each island along with examples of sidescan data keyed to these diagrammatic.

A plan view of each island is presented with the areas of sediment depletion and accretion are identified. Where appropriate plan view residual bathymetry maps are presented. These contour maps display the magnitude and location of sediment erosion and accumulation.

In addition to the detailed site descriptions this section presents the results of the comparison of sidescan data collected in 1989 and 1990. This comparison was conducted to determine the continuity of seafloor processes and to aid in the assessment of the rate of seafloor change.

Section 6 - Sediment Transport Observation and Conceptual Models

In this section the sediment transport directions and magnitudes for each site are compiled and an presented along with the estimated sediment transport rates.

Conceptual model describing the sediment erosion patterns for each site are presented. The characteristics of each of these model island forms is discussed along with possible controlling factors. .

Section 7 - Environmental and Design Factors Impacting Island Erosion

The relationships between island erosion, island design and environmental factors is examined in this section.

Section 8 - Conclusions, Recommendations and Limitations

Section 4
Interpretation Methods

Each of the thirteen island sites were assessed using both the bathymetry data and sidescan data. The following sections 4.1 and 4.2 describe the procedures used in this assessment.

4.1 Bathymetry Analysis

The bathymetric data used in this study consists of; pre-existing contour maps of the islands, bathymetric field sheets, ASCII bathymetry data files and field records.

Each island bathymetry map provided a snapshot of the island form at a specific moment. These charts describe the result of sediment transport at the island. By understanding the island forms we hoped to better understand the sediment transport which produced these forms. The island form also provides a means of comparing and contrasting different islands.

4.1.1 Task 1 - Island Plan and Profile Descriptions

The first task in the bathymetry analysis was to described each island with respect to the two-dimension plan and profile form of the bathymetry charts . The plan view revealed variations in; island symmetry (elongation), the gradient of the island margins, the curvature of the island margins, and the regularity of the island crest.

4.1.2 Task 2 - Composite Profiles

The second task was to produce composite multi-year profiles from the contoured bathymetry charts for each site. These profiles were taken from the same location for each island and indicated the change in two-dimensional profile forms of the islands with time. The profiles were found to be a good guide to the sediment transport direction as the more steeply inclined margin corresponds to the direction of sediment accumulation.

The composite profiles indicate the areas of sediment depletion and accretion and the relationship between these components of sediment transport and the water depth. These profiles show vertical and horizontal components of accretion and the vertical components of depletion.

4.1.3 Task 3 - Contour Deviation

As a third task the base-line and follow-up survey maps where also overlain to determine the change in position of specific contours. The contour level used differed from island to island and generally was selected to correspond to the contour showing the maximum change. The availability of contiguous survey coverage was another criteria guiding the selection of the optimum contour level.

4.1.4 Task 4 - Sediment Depletion/Accretion Maps

The forth task in the bathymetry analysis included overlaying successive bathymetry charts to produce a sediment depletion/accretion map. This map identifies areas where the water depth has increased between the base-line and follow-up surveys as zones of sediment depletion. Areas where the water depth has decreased between the base-line and follow-up surveys are identified as zones of sediment accretion.

4.1.5 Task 5 - Residual Bathymetry

The fifth bathymetry analysis task consisted of conducting numerical bathymetry analysis to better define the sediment transport direction and magnitude. This method allowed the actual change in bathymetry between the base-line and follow-up surveys to be determined. This change, or residual bathymetry, was calculated by processing the base-line and follow-up survey to a common grid and performing grid-to-grid subtraction.

The selection of islands to use in the numerical bathymetry analysis depended upon two key factors including the timing of bathymetry surveys relative to island abandonment and submergence, and the extent of line coverage over the top and margins of the islands. The optimal case for bathymetry analysis included a base-line shortly after submergence and a follow-up survey long after submergence. In addition, the survey coverage on top and margins of the island must be complete.

Residual bathymetry analysis was completed at four islands sites: Netserk F-40, Arnak L-30, Isserk E-27 and Kannerk G-42.

Although the residual bathymetry allows both the bearing and magnitude of sediment transport to be estimated. The sediment transport "rate" requires consideration of the time between successive surveys and a knowledge of the timing of environmental conditions (eg. extreme storm events) which trigger sediment transport. The sediment transport rates determined in this study are averages based on lateral accretion at specific contours and do not consider environmental factors.

The residual bathymetry also provides a measure of the amount of sediment "loss" from the island system. This refers to the net decrease in island volume between successive years. This volume loss refers to sediment transported in suspension beyond the limits of the island and the sediment blanketing the seafloor around the island which is too thin to produce a measurable residual bathymetry. Both of these later components may be regarded as loss from the standpoint of resource evaluation as this sediment may be very difficult to recovery.

4.2 Sidescan Analysis

The sidescan analysis consists of two distinct components; seafloor characterisation, and repetitive mapping. The following sections describe these components.

4.2.1 Seafloor Characterisation

This component of the study was included for each of the 13 islands sites using the 1990 sidescan data.

The sidescan data from each these islands was viewed and used to characterize the seafloor geology. Particular emphasis was placed on recognising and delineating sediment transport features.

The sidescan data reviewed for each island site was used to construct diagrammatic seafloor features maps.

The sidescan data provides an acoustic image of the seafloor at the time of the survey. This image displays current seafloor processes and the footprints of historical processes. Evidence of sediment transport is ascertained from variations in seafloor acoustic texture, bedforms, variations in the degree of scour infill, and anomalous seafloor topography changes (eg. slump scars, pits). When evaluating the sidescan data for sediment transport features it was necessary to consider the spacial distribution of all these features. It was also necessary to distinguish between processes which are independent of the submerged island (eg. those processes which occur on the surrounding seafloor) such as ice scouring.

The spacial distribution of surficial sediment contacts have turned out to be a good indicator of the general transport direction. This is possible for those sites where the seafloor sediment beyond the island are of material of contrasting lithology and seafloor acoustic texture.

The method of using sidescan in the sediment transport analysis consists of establishing the acoustic facies on the island and beyond the island. The preferential extension of the island facies across the surrounding seafloor represents evidence of sediment transport. The direction of sediment transport should coincide with a change in the bathymetry (if the amount of sediment transported forms a measurable blanket).

Scour infilling provides a key to sediment transport direction. If scour infilling is distributed unevenly around the site than the area of greatest infilling corresponds to the preferred direction of sediment transport.

4.2.2 Comparison of 1989/1990 Sidescan Data

This analysis was limited to islands surveyed in 1989 and 1990 and includes 4 islands: Itiyok I-27, Arnak L-30, Issungnak O-61, and Kaubvik I-43. The purpose of this exercise was to evaluate short term changes in seafloor processes between two successive years.

The comparison of 1989 and 1990 sidescan and bathymetry data was undertaken in two parts: a) by determining which survey lines are coincident and parallel and comparing the field data at these areas, and b) by comparing all lines in the vicinity of anomalous seafloor geological and manmade features.

This comparison highlights changes, including variations in bedform scale and orientation, and in the degree of exposure or burial of island debris. It also presents examples which lack measurable change in between 1989 and 1990.

Section 5
Seafloor Features and Morphology

The following section presents the results of the detailed analysis of the sidescan and bathymetry data from each island. The islands are presented from oldest to youngest, as compiled by Klohn Crippen (1993).

The following text, sections 5.1 to 5.13, summarizes the island design and environment, details the changes in island morphology, documents the seafloor features, and describes the sediment transport direction and magnitude based on this analysis. For each of the thirteen island sites evaluated in this study a site summary diagrams is prepared. The design information and bathymetric charts are drawn from the island inventory of Klohn Crippen (1993).

The site summary diagrams include:

a) key bathymetry maps of the islands,

b) composite cross-section (parallel and perpendicular to the long axis of the islands),

c) diagrammatic seafloor features maps,

d) sediment depletion/accretion maps, and

f) residual bathymetry maps where appropriate.

The sidescan data examples are keyed to the diagrammatic seafloor features maps. The site summary diagrams and sidescan examples detail:

a) the acoustic texture of the islands and the acoustic texture of the surrounding seafloor;

b) the degree of scouring and variation in scour infill;

c) the distribution of scouring and the style of scour termination;

d) the location, orientation, and dimensions of bedforms on and off the island;

e) type and location of anomalous sediment contacts;

f) and, the location of possible seafloor slump or creep features.

The profiles and maps are prepared at the same horizontal scale. The scales are tailored to the island size and are listed on each island summary diagram. The sidescan examples are not slant range or aspect ratio corrected. The total slant range is 50m, horizontal scale lines are seperated by approximately 5m, and the off-line:along-line aspect exaggeration is approximately 2:1. The 1989 sidescan examples are presented at the same scale as the 1990 sidescan examples.

5.1 Netserk F-40

Esso constructed the Netserk F-40 island, a sandbag retained, sand filled island in 1975. The island is located on the Kringalik Plateau in 7.0m of water. The seafloor surrounding the island is composed of soft clay and loose silt. A total of 291,000 m^3 of sand was used to construct the island which is 100m in diameter and has 4.6m of freeboard. The island was abandoned in the summer of 1976 and had eroded to the waterline by 1978. The submerged island depth has increased from that time to -2.4m (1981), -3.0m (1983) and -4.6m (1990).

5.1.1 Morphology

Two post abandonment hydrographic surveys were conducted on the island. The 1981 survey acquired sparse and irregularly spaced coverage of the island top. The 1990 survey coverage consists of a regular rectangular survey grid over the top of the island.

Plan View

A comparison of the 1981 and 1990 bathymetry data indicate the island form has changed significantly in the intervening period.

The 1981 submerged island (Figure 5.1.1, top left) is strongly elongated in plan view with a north northwest-south southeast oriented long axis and a perpendicular short axis. The ratio of these axis is (1:1.6). The direction of elongation corresponds to a strong 2D asymmetric with a gentle (1:48) northwest inclined face and a much steeper (1:9) southeast inclined face. A distinct closed bathymetric high occurs in the southeast quadrant of the island.

By 1990 the F-40 island (Figure 5.1.1, top centre) is generally more symmetric in plan (1:1.3). The 2D asymmetry present in 1981 remains through 1990 when a steeper south inclines face (1:20) and a gentler north inclined face (1:70).

In contrast to the 1981 island top, the island top in 1990 is generally flat, with an indistinct bathymetric high.

Profile View

Figure 5.1.1 (lower left and centre) displays two composite 1981 and 1990 profiles, oriented north northwest - south southeast and west southwest - east northeast, crossing the middle of the Netserk island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1981 and 1990 west southwest - east northeast profiles appear symmetric with a consistent slope on the east and west inclined island faces. These composite 1981 and 1990 profiles indicate sediment depletion throughout the length of this profile except at the eastern limit where a zone of sediment accretion is identified.

The composite 1981 and 1990 north northwest - south southeast profiles displays a muted 2D asymmetry with a steeper sloping southern face and a gentler sloping north face. The composite 1981 and 1990 profiles indicate sediment depletion throughout the length of this profile. The greatest depletion occurs along the south inclined face of the island and decreases away from this area.

Contour Comparison

The area of deposition between 1981 and 1990 occurred in the east. The direction of sediment accumulation appears parallel to the short axis of the island. Based on the location of the 7m contour, the eastern face of the island has aggraded 52m east between 1981 and 1990. In contrast, the 7m contour has remained essentially stationary during this period at the north end of the site.

Residual Bathymetry

To further assess the areas of sediment erosion and deposition the residual bathymetry between the 1981 and 1990 hydrographic charts was calculated (Figure 5.1.1, lower right). This contour map displays the spatial distribution and magnitude of sediment loss.
This map indicates a very elliptical area of sediment depletion and a narrow zone of sediment accumulation. The area of greatest depletion occurs in the southeast. The maximum depletion is 4m while the maximum accretion is 2m. The volume of sediment loss from the vicinity of the island is (to follow) m^3 or (to follow) % of the original 1981 island volume.

5.1.2 Seafloor Features

The bathymetry data set of 1981 and 1990 is augmented by sidescan data collected in 1990. The quality of this data is excellent, with 100% coverage of the island achieved.

The sidescan data has been used to prepare a diagrammatic seafloor features map of the island (Figure 5.1.1, top right) which illustrates the location and type of seafloor features at the site.

The acoustic response of the Netserk F-40 island ranges from moderate to high reflectivity while the surrounding seafloor appears of low to moderate reflectivity. This contrasts other island sites where the islands are of lower reflectivity than the surrounding seafloor and may be attributed to the coarseness of sediment used in the construction of the F-40 island or the presence of a coarse sand or gravel lag on the island. The presence of coarse material is suggested by the presence of a lag deposit on the island (Figure 5.1.2, top) and higher relief long wavelength bedforms.

Large areas of the island seafloor appear, at the time of the 1990 sidescan survey, to be covered by well developed, probably recent, 2D bedforms. The high reflectivity of the bedforms suggests a coarse sand and gravel composition. The bedforms appear systematically distributed around the island and generally mimic the island shape described by the 6m contour. The bedforms indicate large areas of the island seafloor are actively undergoing sediment transport. The orientation of the bedform crests is consistently northeast-southwest indicating near-bottom current oriented perpendicularly. The uniformity of crest orientations around the site suggest cross-flow is not an important factor in sediment transport on the island. The lateral edges of the bedforms is sharp suggesting abrupt lateral changes ingrain size or bottom current velocity.

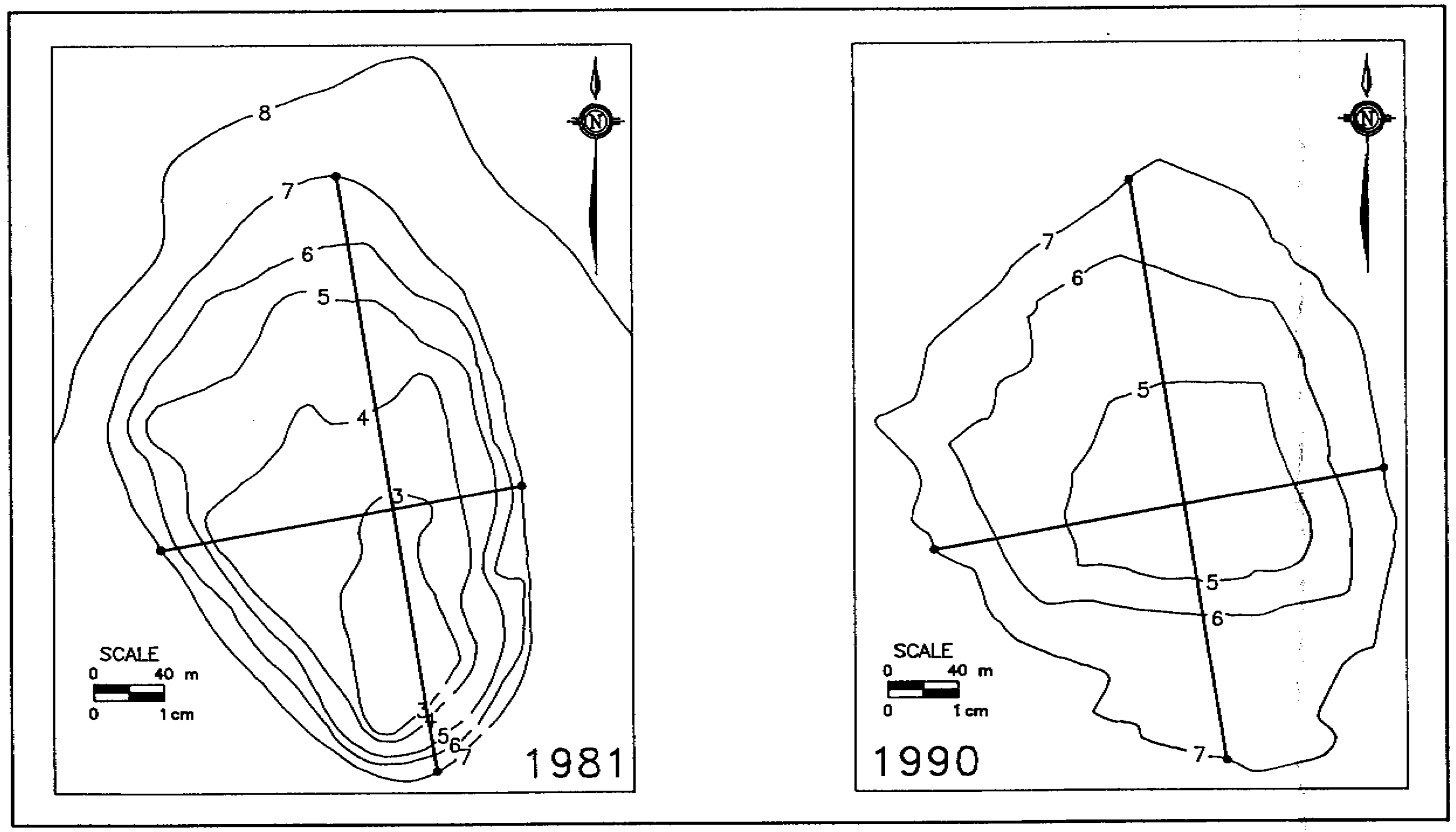
A lower reflectivity oriole occurs off the island's northeast and east margins (Figure 5.1.2, top and bottom). This is interpreted to represent a blanket or plume of finer grained sandy sediment rimming the eastern and northeast margins of the island. Ice scours in these areas (as shown on Figure 5.1.1, upper right) display differing degrees of sediment infill. The infilled scours are interpreted as indicators of deposition via suspended sediment transport.

Occasional ice scours affect the top and margins of the island and display various orientations.

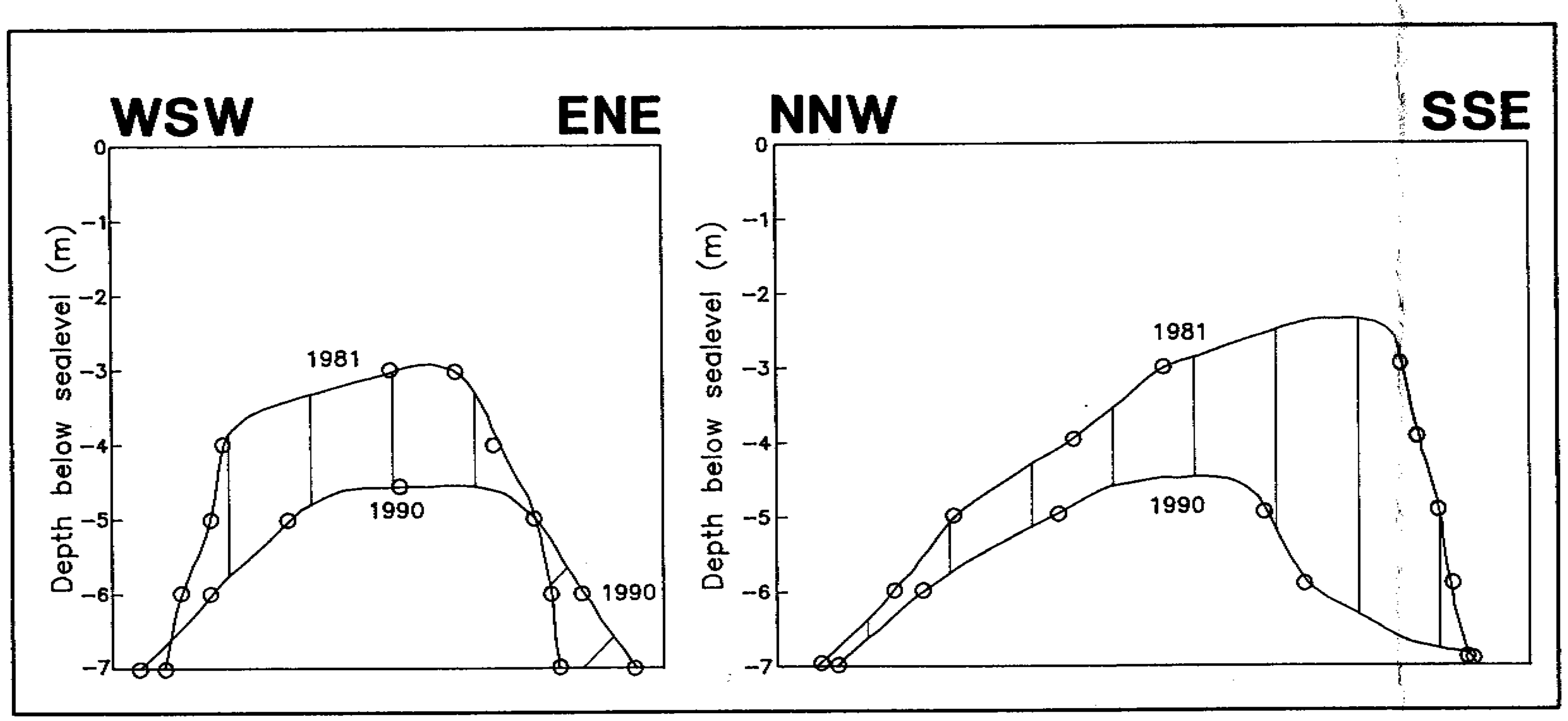
The comparison of 1981 and 1990 bathymetry suggest areas of the island which have been the sites of net sediment depletion and sediment accumulation. The rim of low reflectivity material observed beyond the northeast and east island margins corresponds to the zone of sediment accumulation identified on through the residual bathymetry analysis.

The sidescan data indicate that at the time of the 1990 survey large scale 2D bedforms occur in both the areas of net sediment accumulation and net sediment depletion. The orientations of the bedform sharply contrast with the direction of sediment transport determined through the residual bathymetry analysis. This bedform crests suggest a near-bottom current direction toward the southeast.

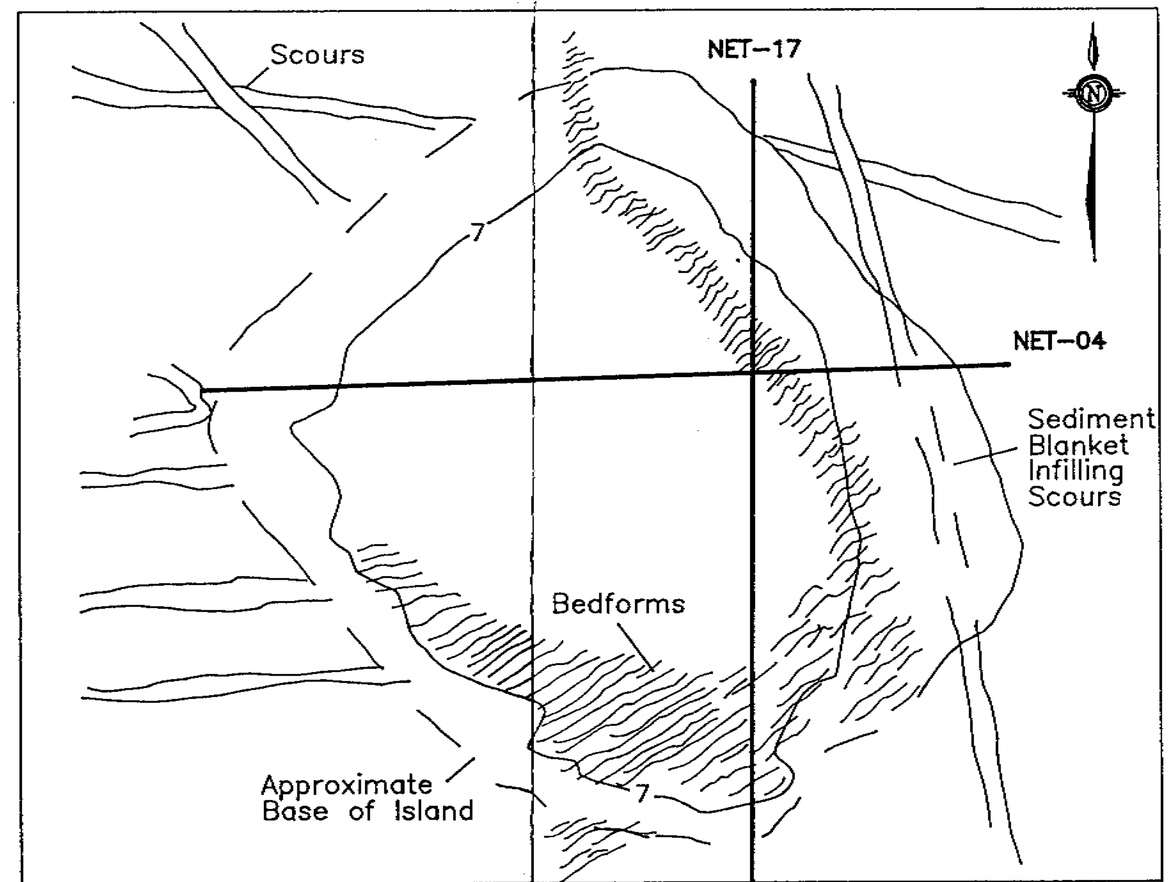
The long term changes in island topography determined from the 1981 and 1990 bathymetry analysis do not correspond to the shorter term seafloor processes evident on the sidescan data in 1990. This discrepancy is interpreted to indicate that two prominent sediment transport directions exist at the island namely toward the south and east.



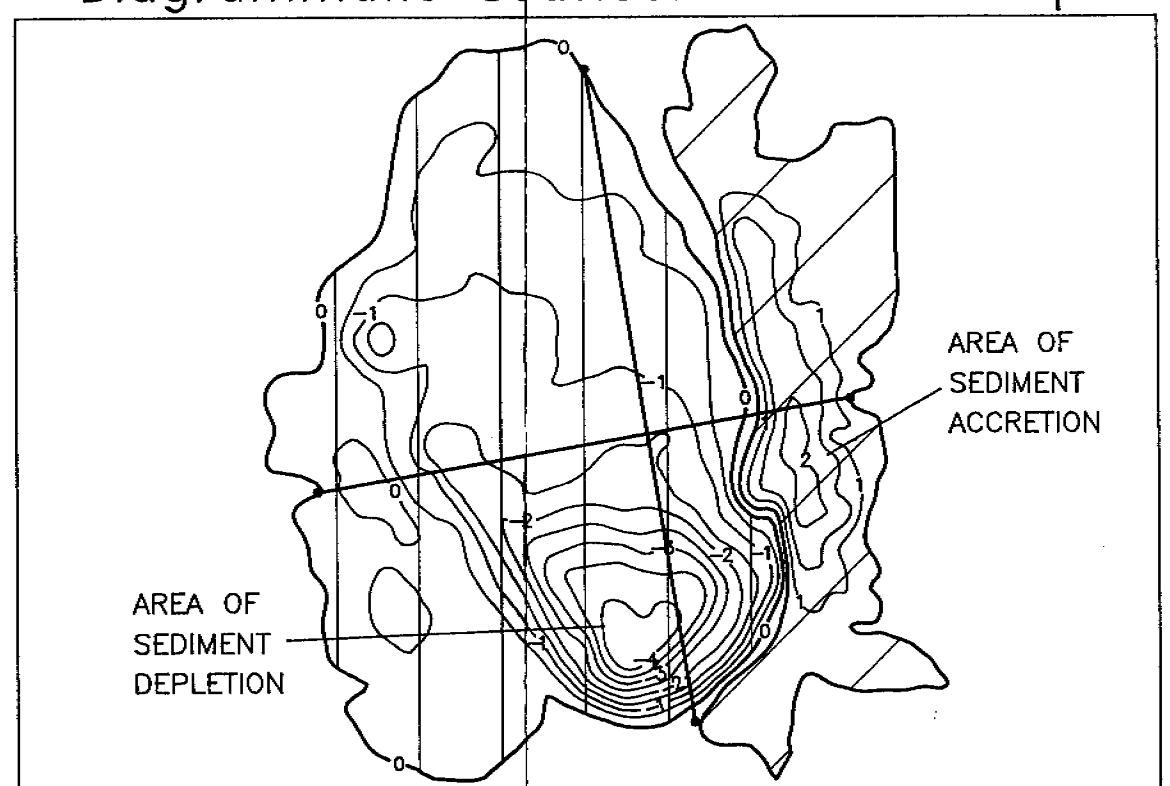
1981 and 1990 Bathymetric Contours



Composite 1981 and 1990 Cross Sections



Diagrammatic Seafloor Features Map



Sediment Depletion/Accretion Map

NETSERK F−40 ISLAND SUMMARY Scale 1:4000

FIGURE 5.1.1

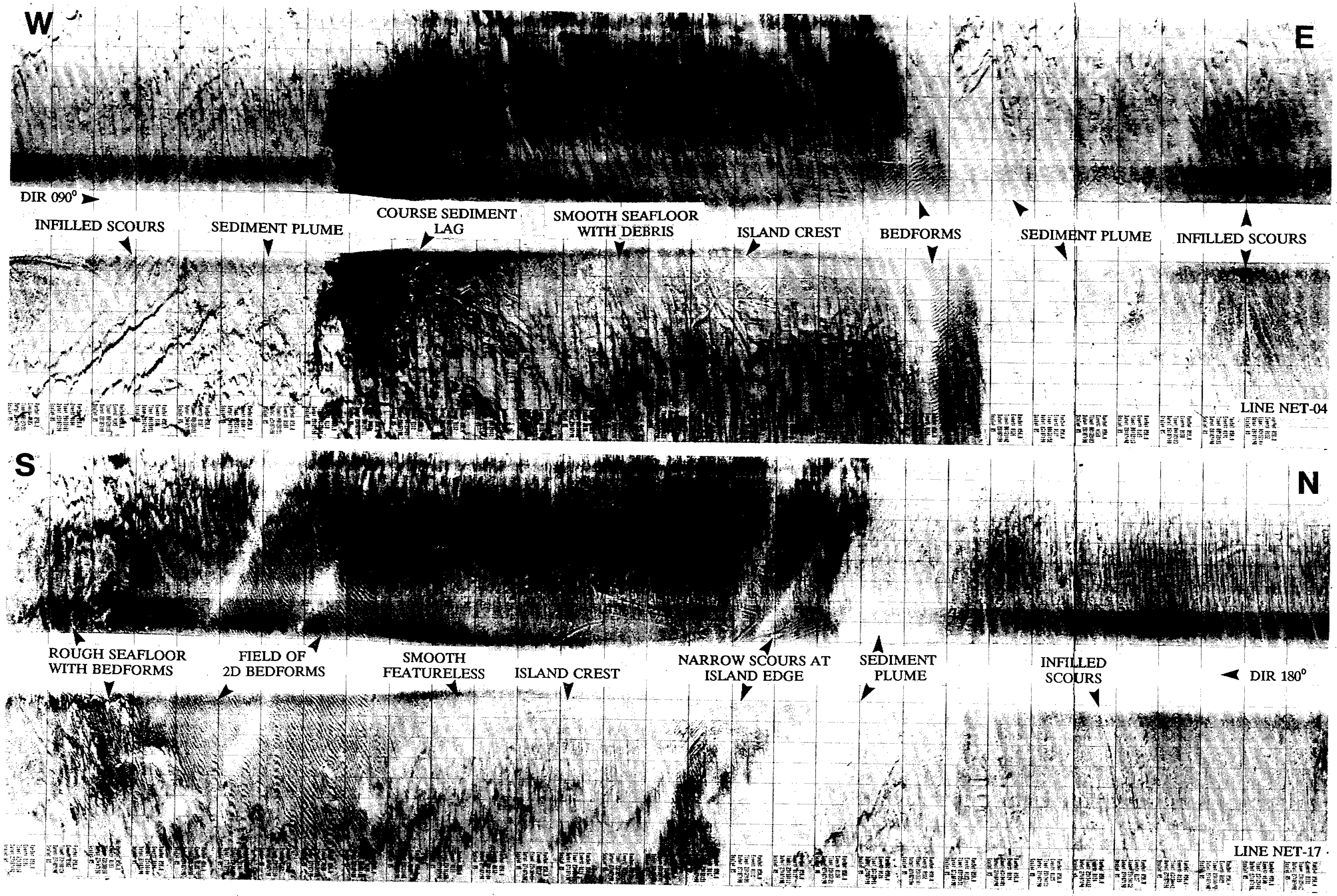


Figure 5.1.2 Sidescan data (Lines NET 04 and NET 17) displaying seafloor features characteristic of the F-40 island and surrounding Seafloor.

FIGURE 5.1.2

5.2 Kugmallit H-59

Kugmallit H-59 is a sandbag retained island constructed by Esso in 1976 in 5.3m of water on soft clay and silts in the Kugmallit Bay. The island required 236,000m^3 of sand fill to achieve a 4.6m freeboard. The island was abandoned in 1977 and by 1979 had eroded to the waterline. The submerged island depth has increased from that time to -2.0m (1982), -3.0m (1983) and -2.7m (1990).

5.2.1 Morphology

Two post abandonment hydrographic surveys were conducted on the island. The 1982 survey acquired a series of parallel lines over the top of the island and surrounding seafloor. The 1990 survey grid was largely limited to water depth greater than 4 metres except on the western side of the island where survey lines were run in water as shallow as 2.7m.

The Kugmallit 1990 chart provides spot values only on the top of the island. The ships track did not cross the island. However a reconnaissance survey was completed using a launch with approximate positioning only. Spot values from this survey are posted on the 1990 bathymetry chart. If grid-grid operation are to be completed on this island this data should be picked and posted and used in the griding.

<u>Plan View</u>

In contrast with the F-40 island the H-59 island does not display a dramatic change in form or relief between the 1982 and 1990 surveys. Based on the location of the 4m contour the island is elongated with a northeast-southwest oriented long axis and a northwest-southeast oriented short axis. The ratio of these axis is (1:1.4). The 2D island symmetric is difficult to evaluate given the paucity of relief and contours on this island on both the 1982 and 1990 charts (Figure 5.2.1, top left and centre). The southeastern face of the island appears on the 1982 chart to be slightly steeper than the northwestern face with gradients of 1:15 and 1:30, respectively.

The difference between the 1982 and 1990 charts indicates an area of sediment accumulation in the east and southeast. Based on the location of the 4m contour the island has aggraded up to 35m east between 1882 and 1990. The north and western margins of the island appear unchanged. The direction of sediment transport between 1981 and 1990 at the H-59 site appears to be parallel to the short axis of the island and is consistent with the transport direction observed at the F-40 site between 1981 and 1990.

<u>Profile View</u>

Figure 5.2.1 (lower right and centre) displays two composite 1982 and 1990 profiles, south southwest - north northeast and west northwest - east southeast, crossing the middle of the Kugmallit island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1982 and 1990, south southwest - north northeast profiles, appear symmetric with a consistent slope on both island faces. These composite 1981 and 1990 profiles indicate sediment depletion throughout the length of this profile except at the eastern limit where a narrow zone of sediment accretion is identified.

The composite 1982 and 1990 west northwest - east southeast profiles displays a muted 2D asymmetry with a steeper sloping southeast face and a gentler sloping northwest face. The composite 1982 and 1990 profiles indicate sediment depletion over the crest of the island and a major area of sediment accretion on the east southeast inclined island face.

Sediment Depletion/Accretion Map

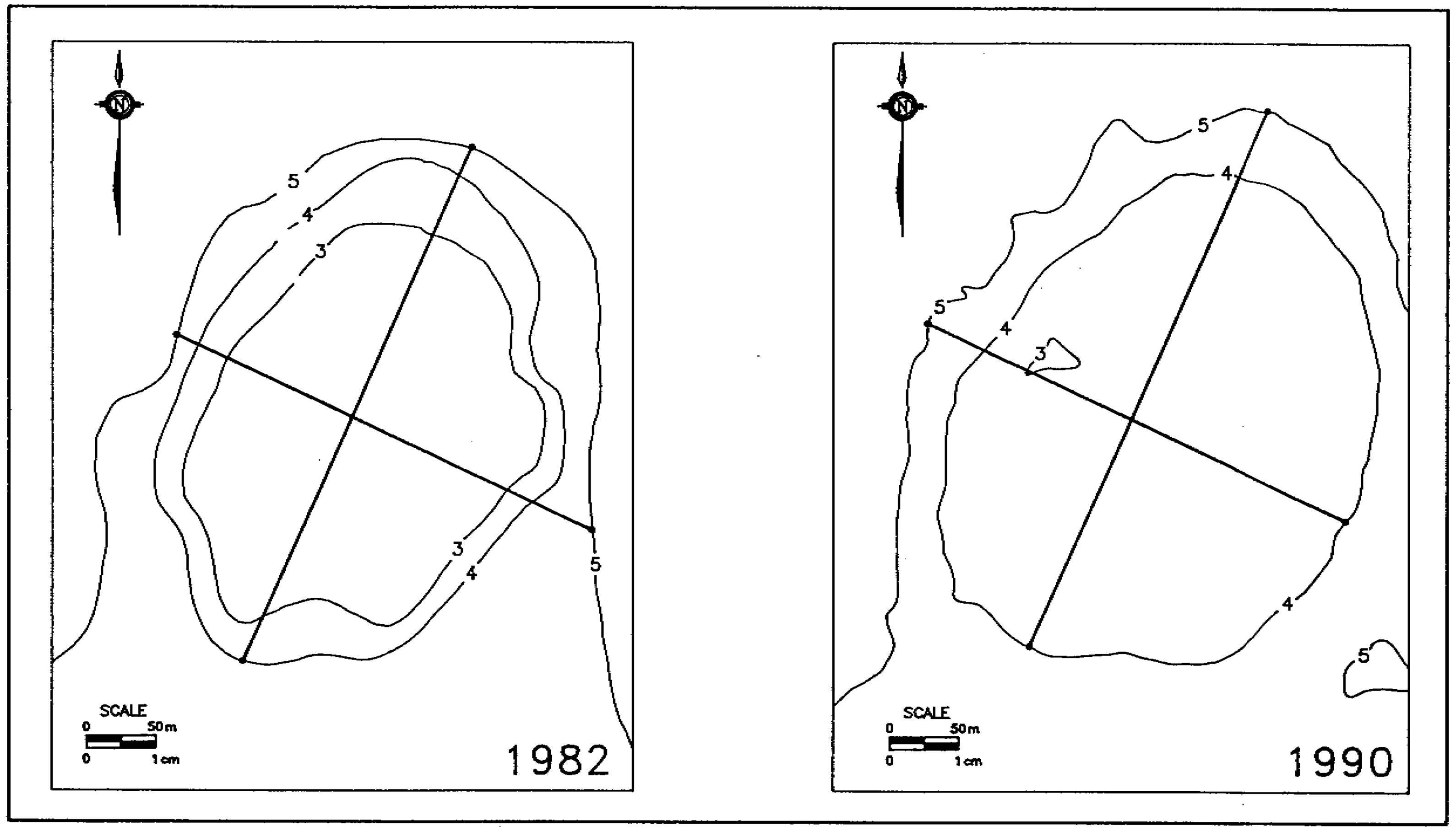
To further assess the sediment transport pattern the 1982 and 1990 bathymetry charts were overlain (Figure 5.2.1, lower right) and the approximate spatial distribution of sediment depletion and accretion was estimated. This figure suggests an area of erosion over the crest and an area of deposition throughout the south, east and western island periphery.

5.2.2 Seafloor Features

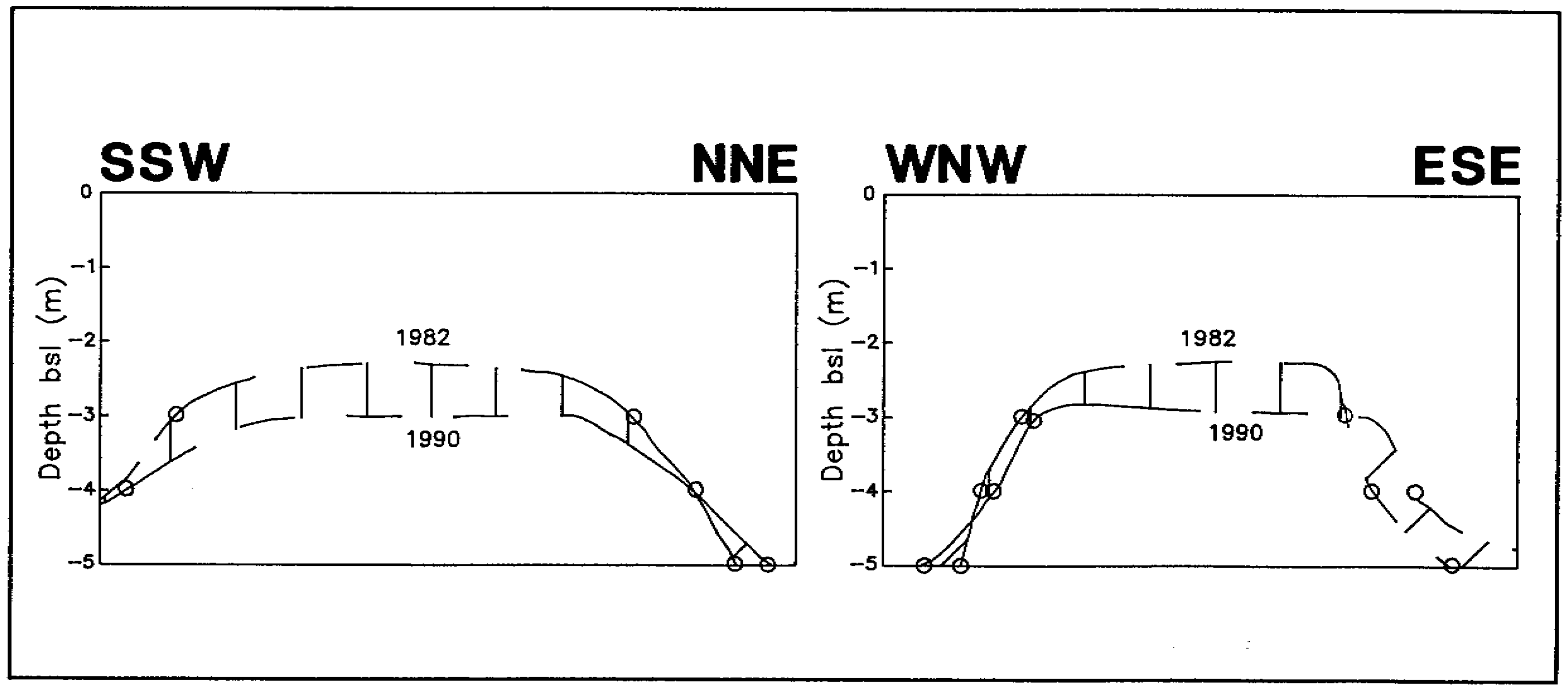
The sidescan data has been used to prepare a diagrammatic seafloor features map of the island (Figure 5.2.1, top right) which illustrates the location and type of seafloor features at the site.

The sidescan coverage of the island suggests a smooth, featureless, low reflectivity seafloor characterizes the island crest (Figure 5.2.2, bottom, KUG-25). This is contrast to the seafloor surrounding the island which is characterised by moderate reflectivity and scouring ranging in intensity from light to heavy (Figure 5.2.2, top, KUG-10). The scouring pattern at the site suggests the that scours postdate the island as scour patterns are influenced by the island.

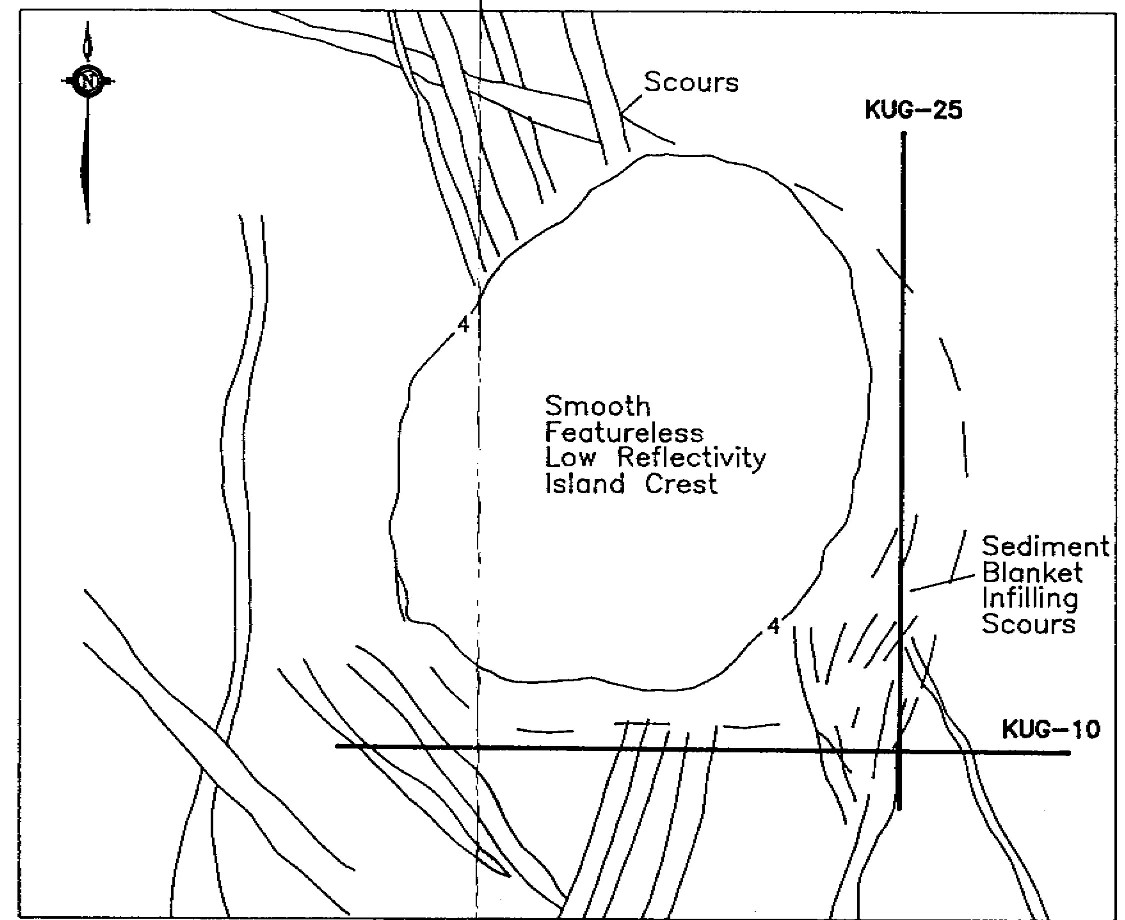
The prominent feature at the H-59 site is the presence of spatially variable scour infill. Scours on the north side of the site terminate abruptly against the island and do not appear to be influenced by infilling. To the southeast, scours are infilled by low reflectivity island sediment, suggesting transport in suspension in this direction.
The area of scour infill in the southeast corresponds with the area of sediment accumulation determined through the overlay of the 1982 and 1990 bathymetry data.



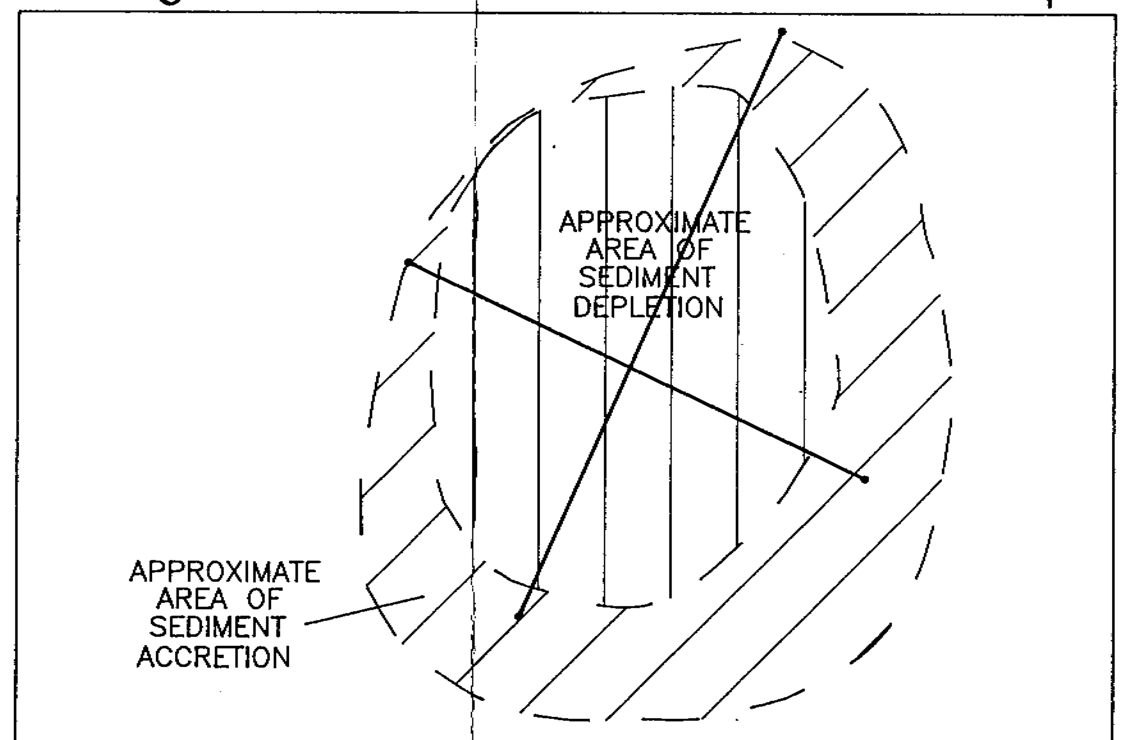
1982 and 1990 Bathymetric Contours



Composite 1982 and 1990 Cross Sections



Diagrammatic Seafloor Features Map



Sediment Depletion/Accretion Map

KUGMALLIT H-59 ISLAND SUMMARY Scale 1:5000

FIGURE 5.2.1

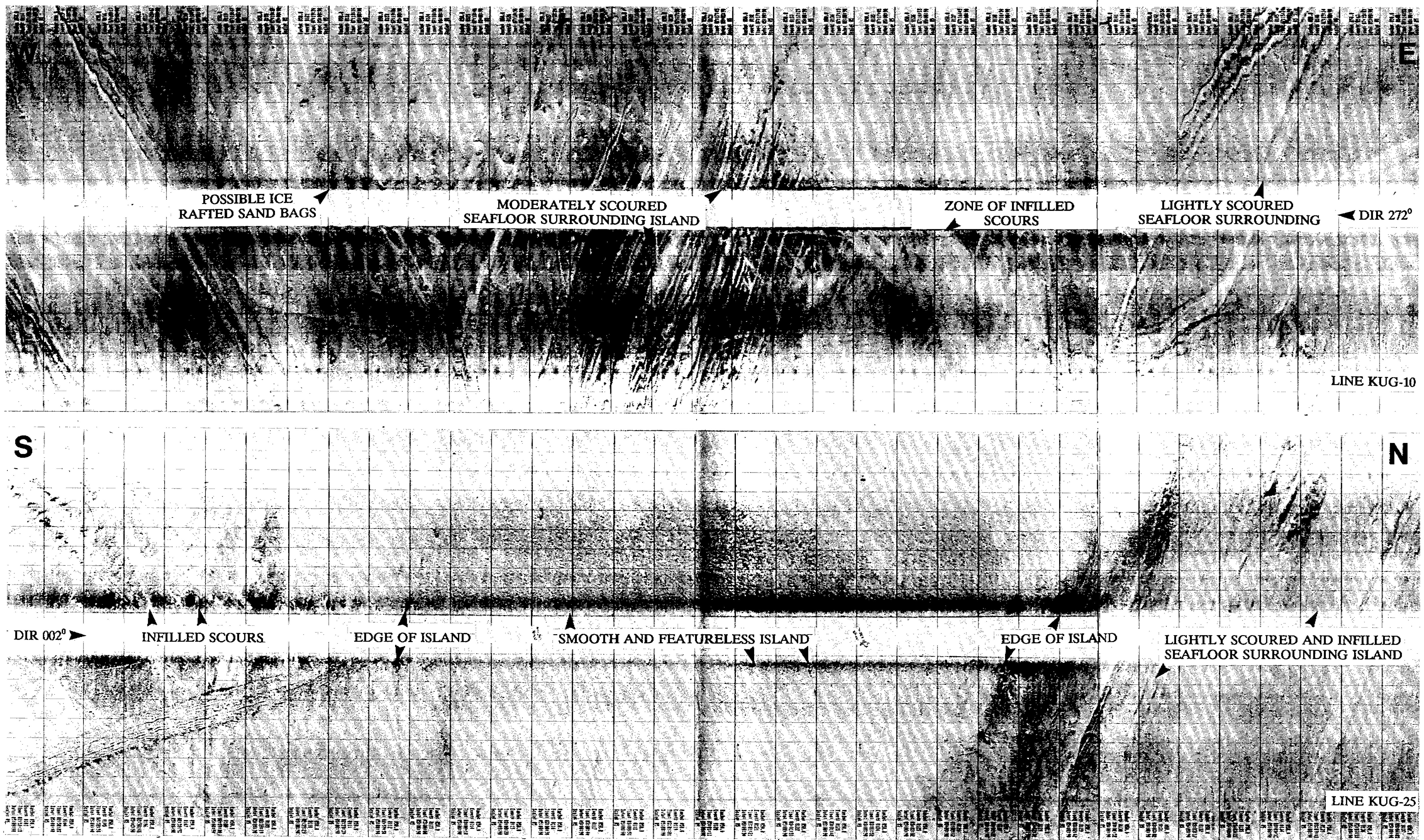


Figure 5.2.2 Sidescan data (Lines KUG 10 and KUG 25) displaying seafloor features characteristic of the H-59 island and surrounding seafloor.

FIGURE 5.2.2

5.3 Arnak L-30

Esso constructed the Arnak L-30 sacrificial beach island in 1976. The island is located in the Kugmallit Channel in 8.5m of water. The site was constructed with 1,150,000m^3 of sand extracted from an adjacent burrow pit. The island had a 122m x 111m working surface, 210m waterline diameter, and 5.2m of freeboard. Although the sacrificial beach was maintained at a slope of 20H:1V, the island experienced erosion at a rate of 3m/day. The island was eroded on the summer of 1977. By 1979 the island had eroded to the waterline. The submerged island depth has increased from that time to -2.7m (1984), -3.0m (1989) and -3.5m (1990).

5.3.1 Island Morphology

Four post-abandonment hydrographic surveys were conducted on the island in 1982, 1984, 1989 and 1990. The 1984 and 1989 survey island coverage is incomplete in water depths deeper than 4m. However the 1982 and 1990 data provide full coverage of the island and the surrounding seafloor. The 1982 survey was conducted as a series of parallel lines while the 1990 survey was completed as a grid. These two survey data sets are referred to in this description of island morphology (Figure 5.3.1, top left, top centre).

Plan View

The 1982 and 1990 bathymetry maps of the Arnak L-30 suggest the island is slightly elongated by a ratio of 1:1.3, with a northeast-southwest oriented long axis and a northwest-southeast oriented short axis.

The Arnak L-30 island margins differ in shape from north to south. This is best illustrated on the 1990 bathymetry (Figure 5.3.1, top centre). The edge of the island in the northern half of the site is characterised by a broad gentle curvature. In the south the island is more angular in shape with sharper planar faces. The change in island shape corresponds to a transition in the seafloor gradient. The gradient of the island's face gradually increases from 1:50 in the north to a maximum of 1:12 in the south.

The form of the island crest is described below. Survey coverage of the island top is provided through all four hydrographic data sets (1982, 1984, 1989 and 1990). Closed bathymetric highs occur on the top of the Arnak island at each of these maps. These highs differ is shape and location from year to year. Between the 1989 and 1990 surveys, the highs are strongly elongated northeast-southwest. These highs may be large scale sand ridges with a principal sediment transport direction perpendicular to their long axis. The distribution of targets observed on the island in 1990 appear to correspond to a bathymetric low at the southern base of one these highs. A zone of sediment scour may occur at the base of these highs exposing debris.

Profile View

Figure 5.3.1 (lower left and centre) displays two composite 1982 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Arnak island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1982 and 1990, southwest - northeast profile, appear symmetric with a consistent slope on both island faces. The form of the island crest has changed between these years. This is discussed further below. This composite profile indicates sediment depletion over the crest of the island and a minor accumulation along the southwest and northeast margins.

The composite 1982 and 1990 northwest - southeast profile displays depletion over the crest of the island and along the northwest margin of the island. A major area of sediment accretion is identified on the southeast inclined island face.
A minor area of accretion occurs at the base of the northwest inclined face.

Contour Comparison

The location of the 1982 and 1990 7m contour has been compared to determine the maximum measurable distance of sediment transport between these years. This comparison indicates sediment has been transported up to 60m southeast between 1982 and 1990. In contrast, the 7m contour has remained essentially stationary during this period in the northeast corner of the island.

Residual Bathymetry Map

A residual bathymetry map was prepared from the 1982 and 1990 hydrographic charts (Figure 5.3.1, lower right). This contour map displays the spatial distribution and magnitude of sediment loss (contours in metres, interval 0.5m). This figure indicates an circular area of erosion over the crest reaching up to 1.5m. The zone of accretion is crescent shaped and exceeds 3m in the height in the southeast. The zone of accretion thins to the east and southwest. The areas of sediment accumulation correspond to the margins of the island which are relatively steep and planar at the time of the 1990 survey.

The volume of sediment loss from the vicinity of the island is (to follow) m^3 or (to follow) % of the original 1982 island volume.

5.3.2 Seafloor Features

The 1990 sidescan data for this island ranges from excellent quality for the N-S oriented lines to poor quality for the E-W oriented lines. Complete coverage exists for the island and the lines extend beyond the island illustrating the surrounding seafloor and adjacent burrow pit. Numerous features are observed on the sidescan for this site including: short and long wavelength bedforms, surficial sediments contacts, and distinct target clustering. Each of these features are referenced in the discussion of the diagrammatic seafloor features map (Figure 5.3.2, top right).

Three distinct seafloor acoustic textures are recognised at the Arnak L-30 island site. These are identified on the diagrammatic seafloor features map as Facies A, B and C. These facies occur; on top of the island (facies a - lower reflectivity), south of the island in an area of sediment deposition (facies b - intermediate reflectivity) and on the north side of the site (facies c - higher reflectivity).

Figure 5.3.2, top, ARN-15) is an example of sidescan data keyed to this diagrammatic and displays facies A, B and C. The north side of this line, and the site, is characterised by a sharp contact between the island and the surrounding seafloor whereas the south margin appears more gradational. Scours are abruptly terminated on the north margin and are largely absent from the south margin. Where present, scours on the southeast margin, appear infilled.

The Arnak L-30 sidescan appears to display possible bedforms on the east, southeast and west margins of the island. This area corresponds to an area where the residual bathymetry is positive and sediment accretion is interpreted to occur. These features are tentatively identified as bedforms but may also be artifacts of a thermocline.

5.3.3 Comparison of 1989 and 1990 Sidescan Data at Arnak L-30

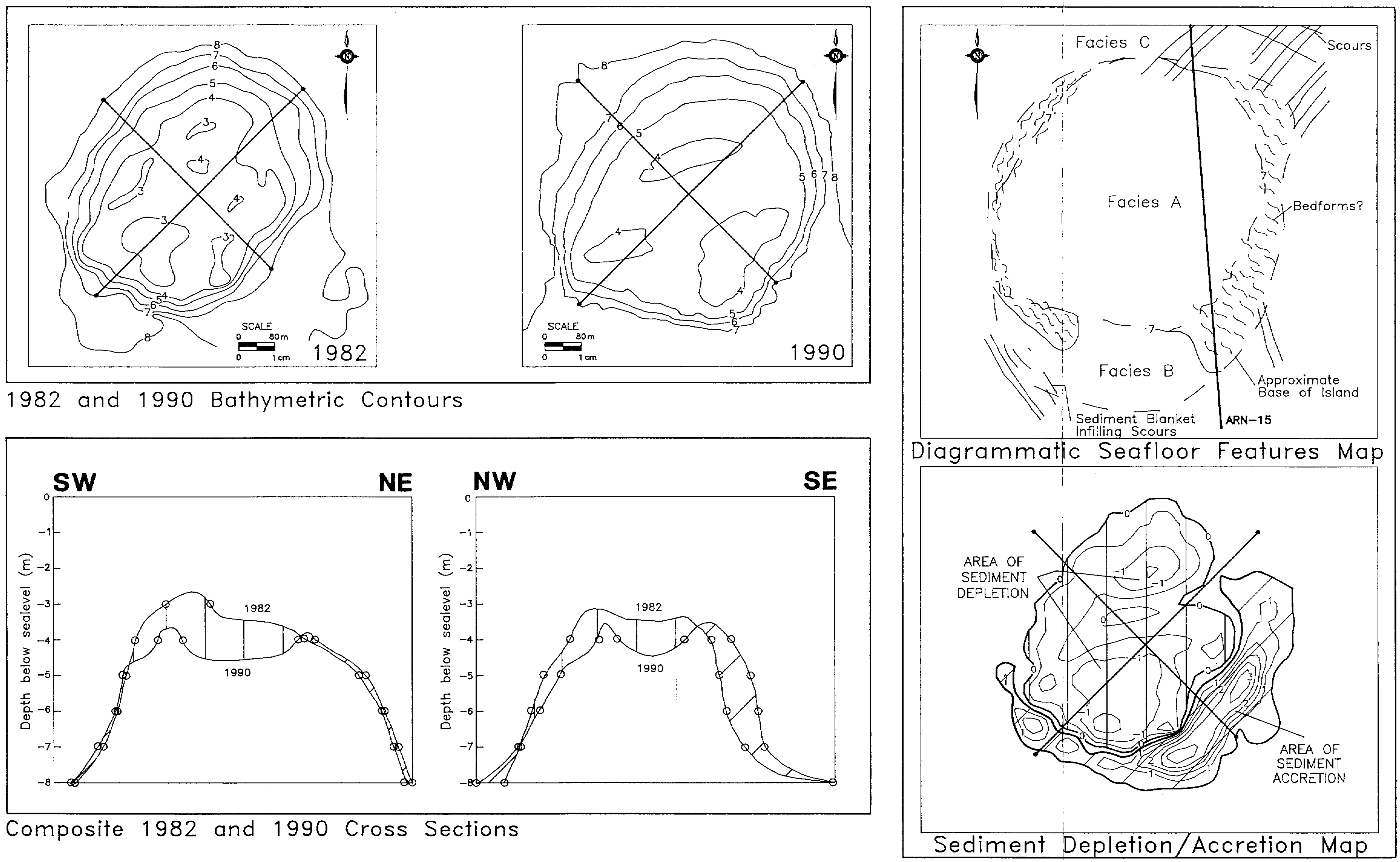
A comparison of 1989 and 1990 sidescan from one area of the Arnak L-30 island is presented here. The location and data for this comparison are presented as Figure 5.3.3. The prominent feature on the data is the presence of two pipes. The pipes display variations in length and acoustic shadowing, between 1989 and 1990. The shadowing is an indication of objects height.

The variations shown on this data suggest an increase in pipe burial between 1989 and 1990. The partially buried pipes are located between two major sand ridge features. This area is interpreted to be a zone of minor sediment deposition between 1989 and 1990.

In addition to the changes observed with respect to the pipes the seafloor sediment texture in varied between these years with a 90 degree change in sand ripple orientation.

In evaluating the pipe burial the effects of slant range, ship speed, target offset and towfish frequency were considered. In spite of these influencing factors we are reasonable confident that the changes in pipe length are real and attributable to sediment deposition in this area.

The 1989 and 1990 bathymetry charts indicate that this area is between 4.0m and 5.0m water depth in both 1989 and 1990.



ARNAK L-30 ISLAND SUMMARY Scale 1:8000

FIGURE 5.3.1

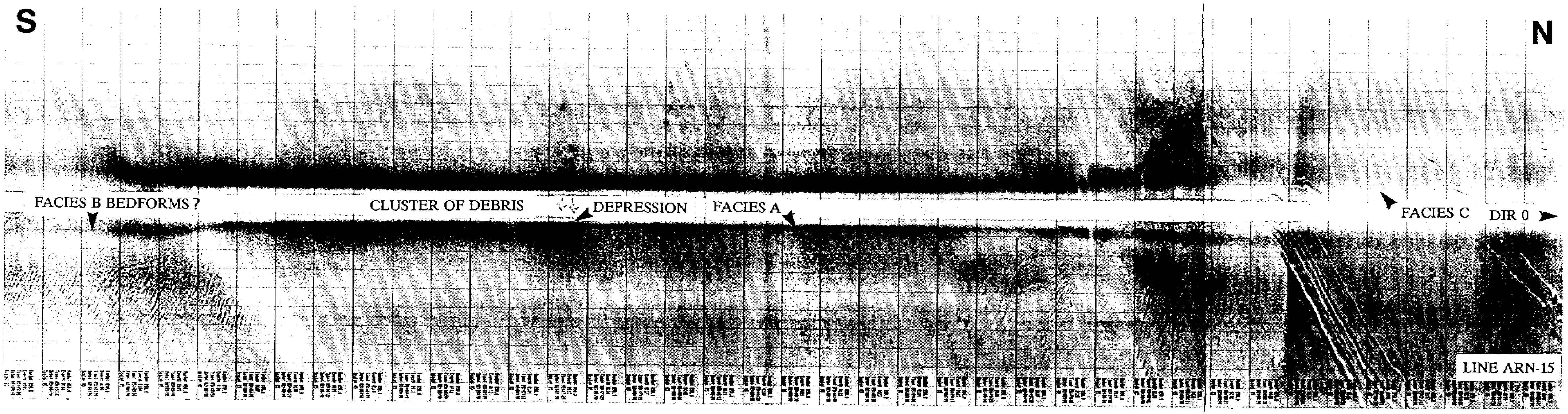


Figure 5.3.2 Sidescan data (Line ARN 15) displaying seafloor features characteristic of the L-30 island and surrounding seafloor.

FIGURE 5.3.2

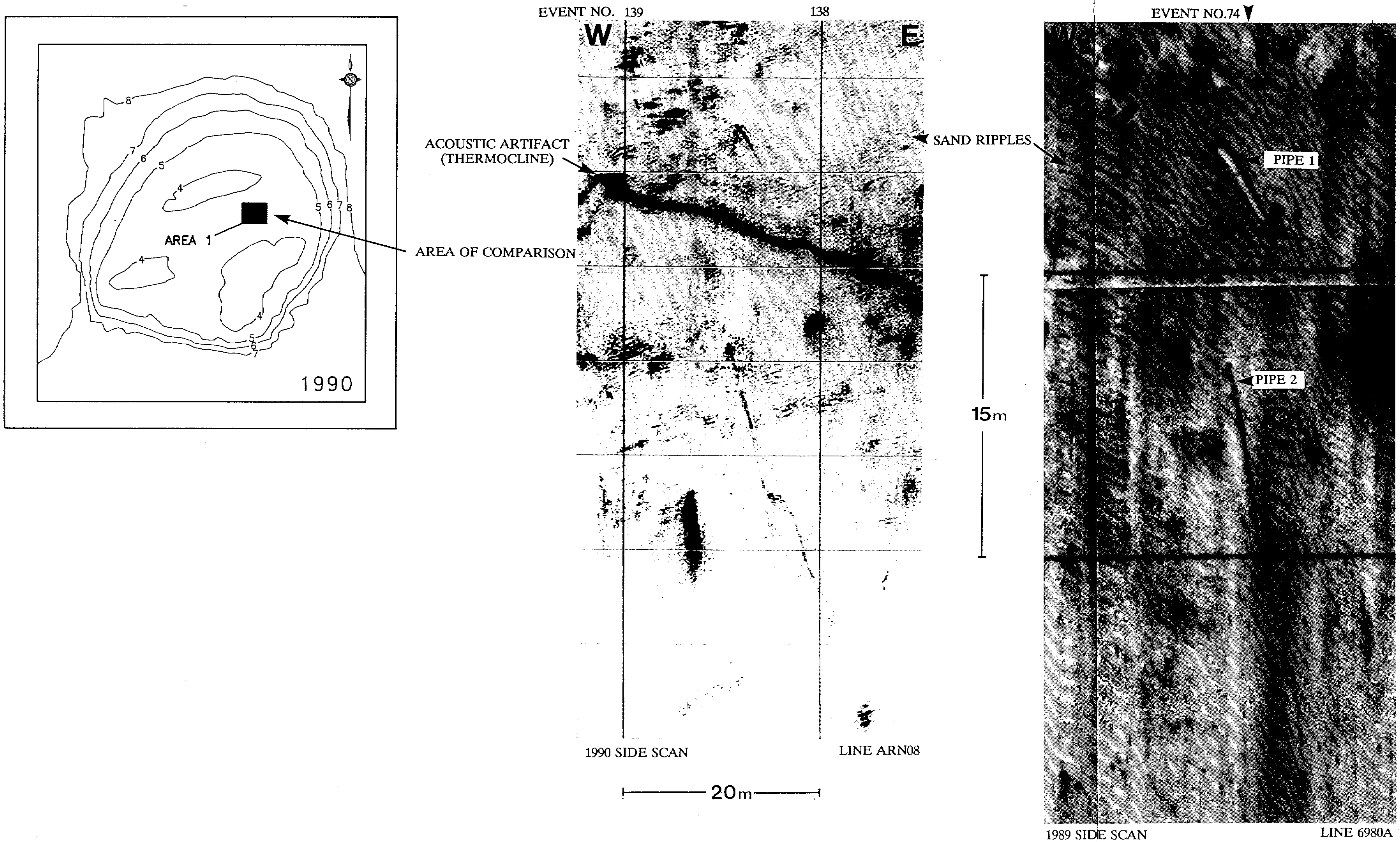


Figure 5.3.3 Comparison of 1989 and 1990 sidescan data collected over an area of pipe on L-30 island top.

FIGURE 5.3.3

5.4 Kannerk G-42

Kannerk was built as a sacrificial beach in 1976 in 8.5m of water on the Kaglulik Plain. Local sand (volume 1,150,000m^3) was used to create an island with a surface diameter of 100m and a freeboard of 5.2m. The island was subsequently abandoned in the summer of 1977 and had eroded to the waterline by 1978. The submerged island depth has increased from that time to -2.2m (1982), -4.0m (1983) and -3.2m (1990).

5.4.1 Island Morphology

Post abandonment hydrographic surveys were conducted on the island in 1982 and 1990. The 1982 and 1990 data provide full coverage of the island and the surrounding seafloor. The 1982 survey lines were acquired in a star through the 1976 site centre. The 1990 survey was completed as a grid.

Plan View

Both the 1982 and 1990 Kannerk island margins differ from northwest to southeast (Figure 5.4.1, top left and centre). The edge of the island in the west-northwestern half of the site is characterised by a broad gentle curvature. In the southeast the island is more angular in shape with a sharper planar face. This is best illustrated on the both the 1982 and 1990 bathymetry.

The change in island shape corresponds to a transition in the seafloor gradient. The gradient of the island's face gradually increases from 1:45 in the west-northwest to a maximum of 1:12 in the east-southeast.

Closed bathymetric highs occur on the top of the Kannerk G-42 island at both the 1982 and 1990 surveys. These highs differ is shape and location from year to year. In 1982 the high is horseshoe in shape with an elongation to the northwest-southeast. The 1990 high tends to mimic the general form of the island. The highs tend to be located toward the edge of the more steeply inclined margins.

Profile View

Figure 5.4.1 (lower right and centre) displays two composite 1982 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Kannerk island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

These composite profiles indicates sediment depletion over the crest of the island, and along the southwest and northeast faces. Sediment accumulation occurs along the more steeply dipping northeast and southeast faces.

Contour Comparison

The location of the 1982 and 1990 7m contour has been compared to determine the maximum measurable distance of sediment transport between these to years. This comparison indicates sediment has been transported up to 85m east-southeast between 1982 and 1990. In contrast the 7m contour has remained essentially stationary during this period in the west-northwest corner of the island.

Sediment Depletion/Accretion Map

To further assess the sediment transport pattern the 1982 and 1990 bathymetry charts were overlain to produce a sediment depletion/accretion map (Figure 5.4.1, upper right). This map indicates an area of sediment accumulation in the east, east-southeast and east-northeast. The west, southwest, and north margins have experienced various degrees of erosion. The west-northwest margins appear relatively unchanged. The areas of sediment accumulation correspond to the margins of the island which are relatively steep and planar.

Residual Bathymetry

In addition to the general sediment depletion/accretion map a residual bathymetry map was prepared from the 1982 and 1990 hydrographic charts (Figure 5.4.1, lower right). This contour map displays the spatial distribution and magnitude of sediment loss (contours in metres, interval 0.5m). This map indicates an elliptical area erosion has occurred over the crest of the island and a crescent shaped area of sediment deposition. The zone of accretion in elongated toward the east southeast where up to 4.5m of vertical accretion occurs. The maximum vertical depletion at the island crest is 1.5m.

The volume of sediment loss from the vicinity of the island is (to follow) m^3 or (to follow) % of the original 1982 island volume.

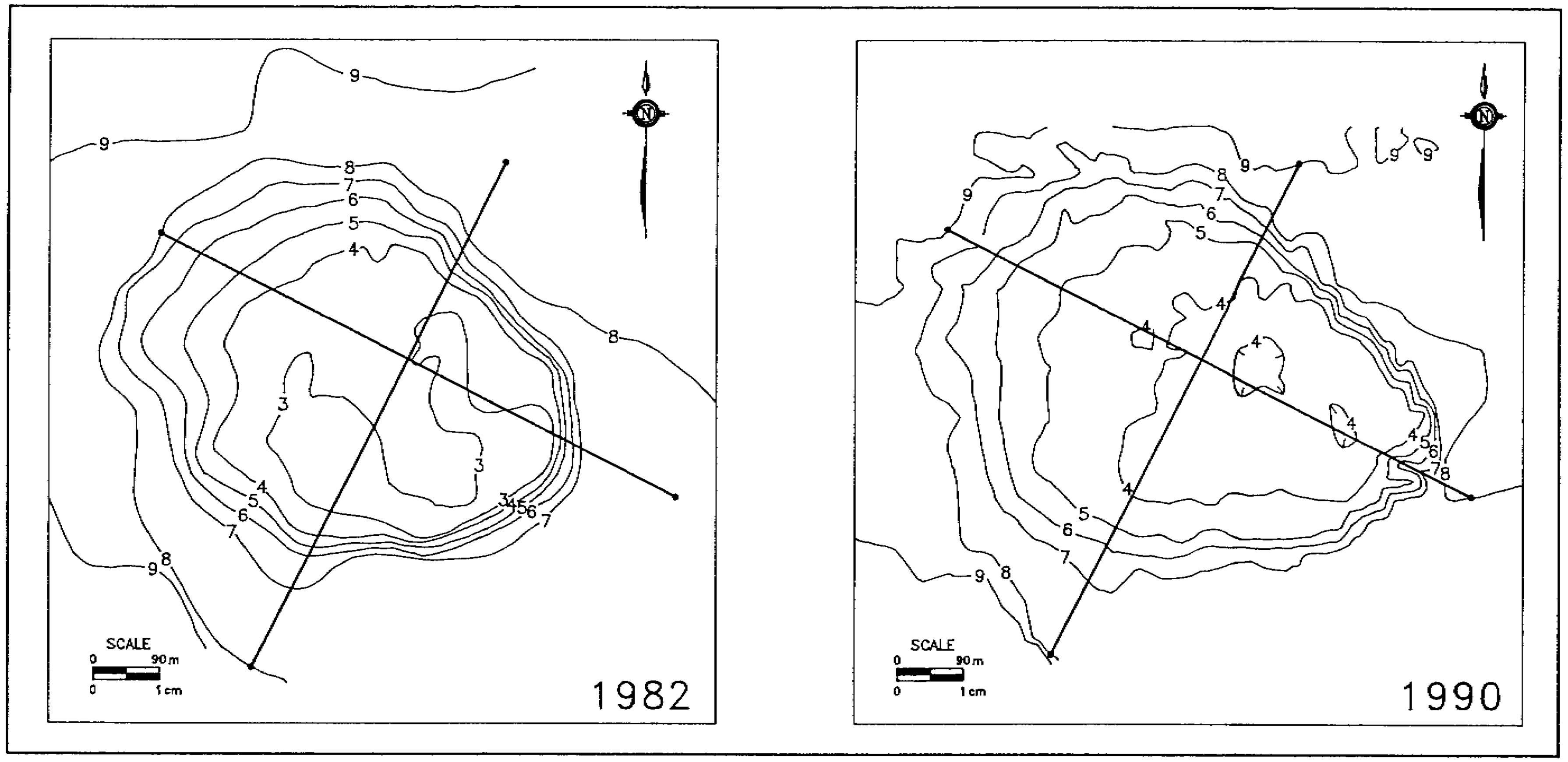
Technical Point

A technical point follows. The original 1982 Kannerk G-42 CES chart is in UTM zone 9 while the 1990 Challenger Chart is in UTM zone 8. For purposes of this report the 1982 map data was transformed to UTM zone 8.

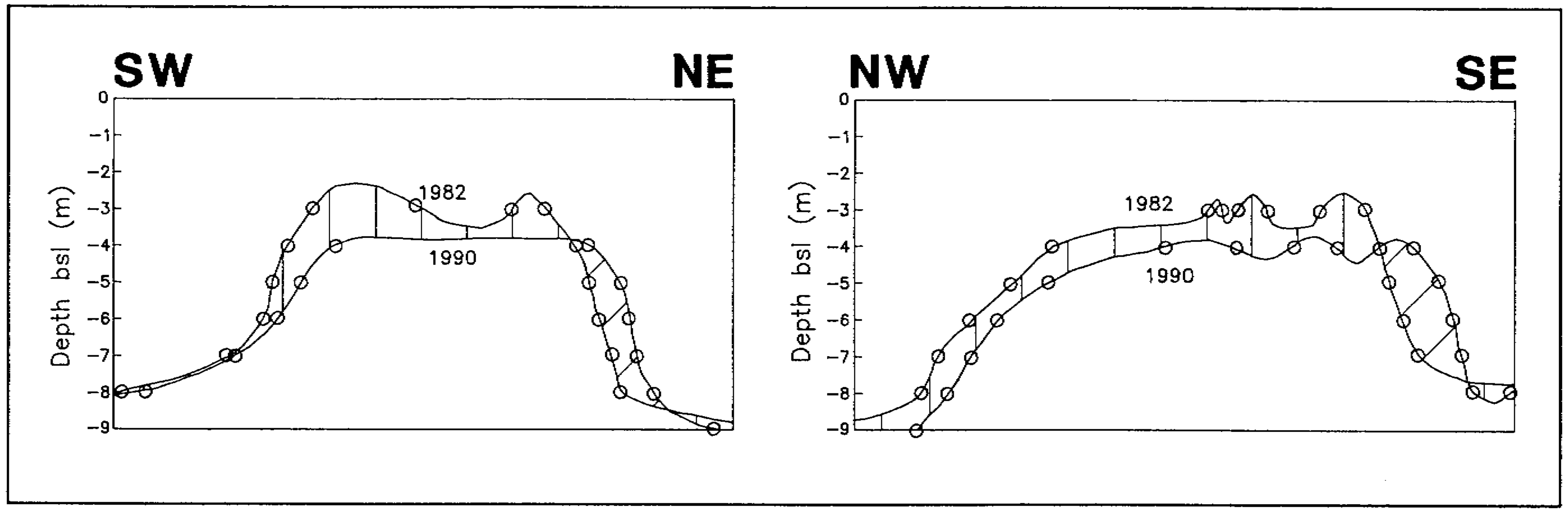
5.4.2 Seafloor Features

According to regional geological mapping the seafloor at the Kannerk site is mostly sand. The island is constructed from locally dredged sand and no lithological contrast exists between the surrounding seafloor sediment and the island sediment. The sidescan data is generally of low reflectivity and relatively featureless for both the island and the surrounding seafloor. Evidence of sediment transport is limited to small scale 2D bedforms (sand ripples) which occur on the west-northwest incline face of the island (Figure 5.4.2, bottom). These features are absent on the surrounding seafloor and at the island crest. The small scale bedforms appear to have an ordered distribution on the site and a preferred water depth.

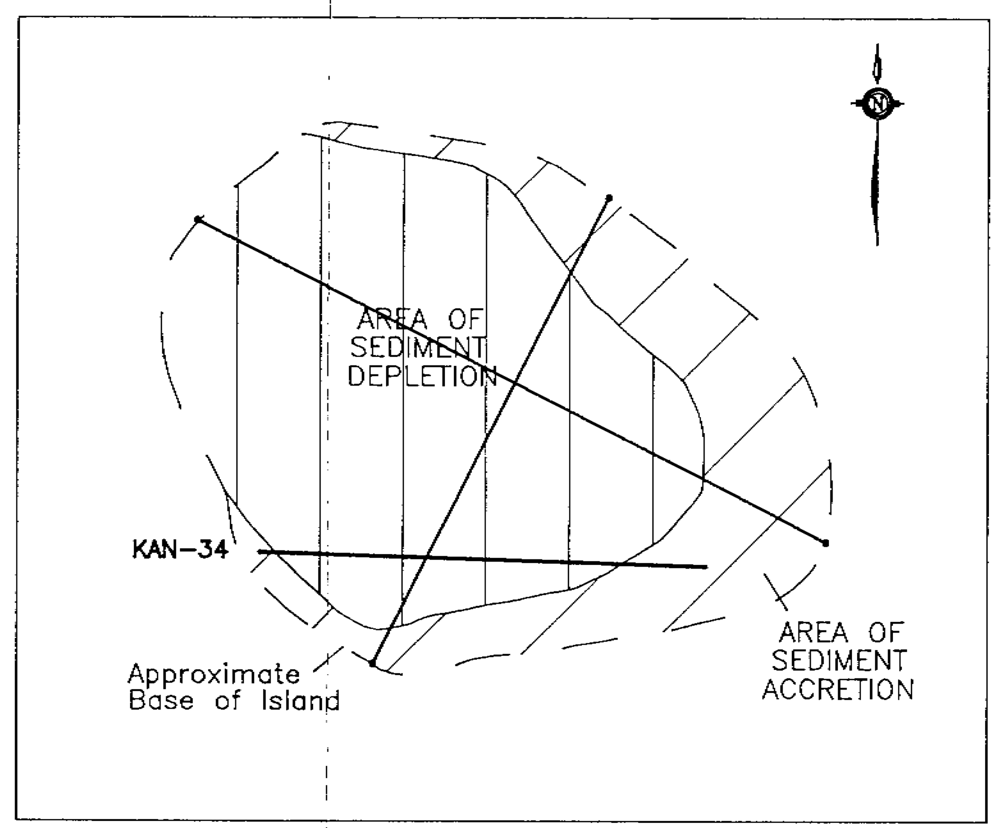
A possible slump or sediment creep feature is observed on the margin of the borrow pit. The site appears devoid of ice scours.



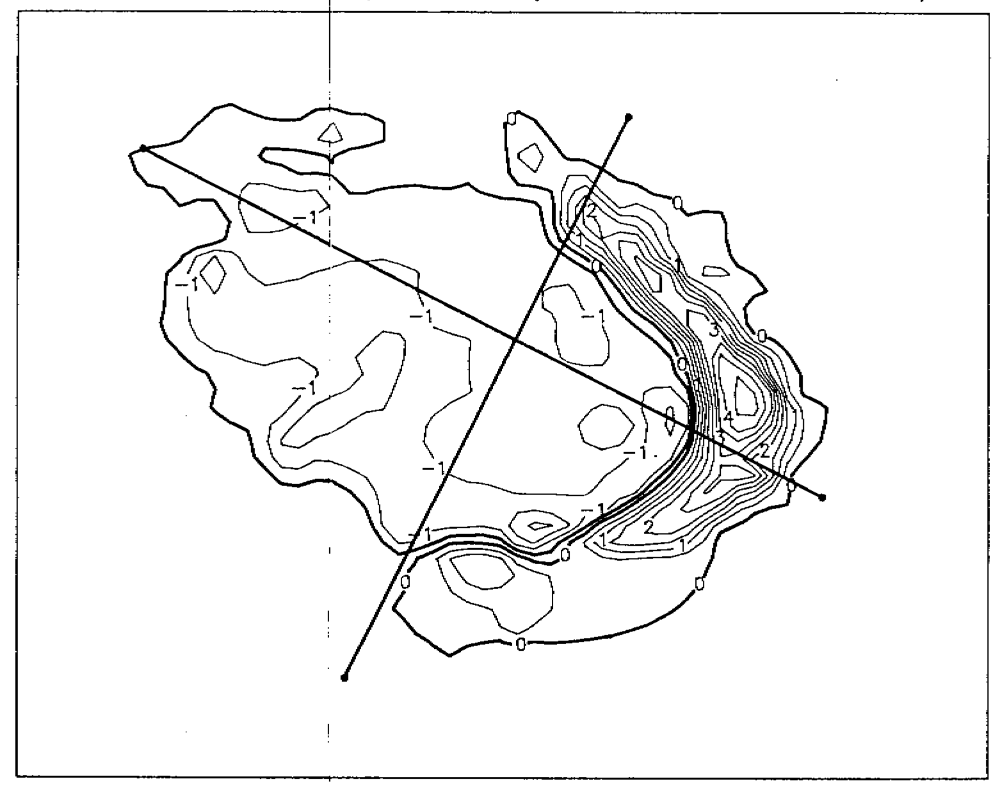
1982 and 1990 Bathymetric Contours



Composite 1982 and 1990 Cross Sections



Sediment Depletion/Accretion Maps



KANNERK G-42 ISLAND SUMMARY Scale 1:9000

FIGURE 5.4.1

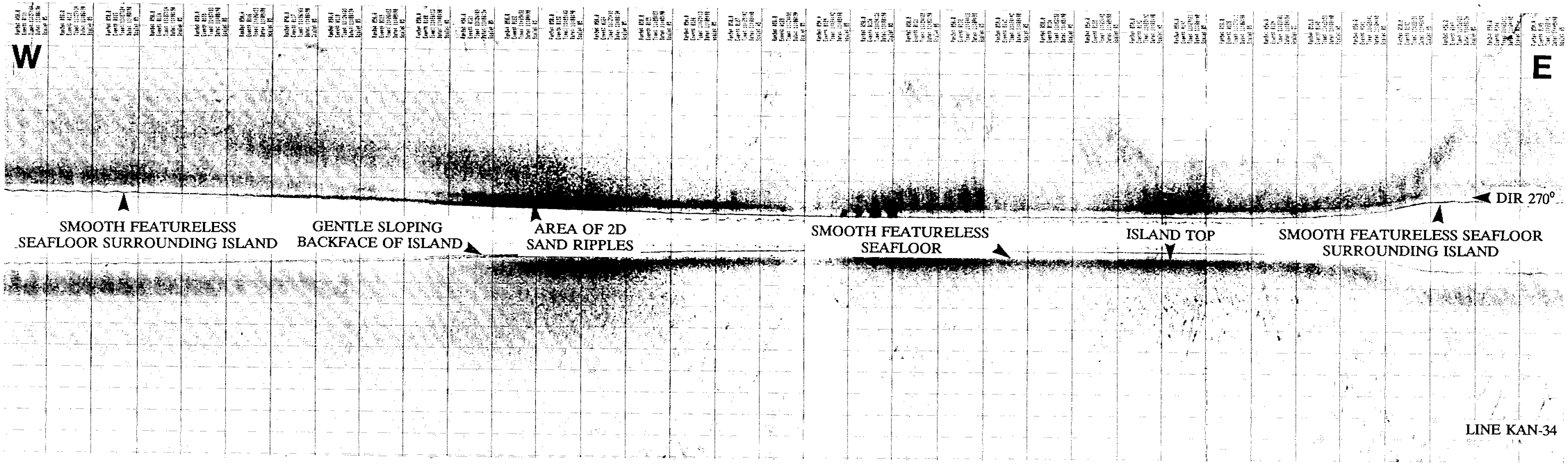


Figure 5.4.2 Sidescan data (Line KAN 34) displaying seafloor features characteristic of the G-42 island and surrounding seafloor.

FIGURE 5.4.2

5.5 Isserk E-27

Esso constructed Isserk E-27 as a sacrificial beach in 1977 in 13.0m of water on the Akpak Plateau. The island was constructed from a combination of sand dredged onsite and sand acquired at Tufts Point. The finished island consisted of 1,908,000m^3 of fill, had a working surface of 100m, a waterline dimension of 227m, and a 5.0m freeboard. The island was abandoned the summer of 1978 and eroded to the waterline in the same year. The submerged island depth has increased from that time to -4.5m (1982), -4.5m (1983) and -5.0m (1990).

5.5.1 Island Morphology

Post abandonment hydrographic surveys were conducted on the island in 1982 and 1990. The 1982 and 1990 data provide full coverage of the island and the surrounding seafloor. The 1982 survey lines were acquired as a series of parallel lines approximately 100m in spacing. Only one line crosses the top of the Isserk E-27 island in the 1982 CES survey chart. The sparse 1982 coverage may be responsible for the smoothed contour map for this data set.

The 1990 survey was completed as a grid of lines with a nominal spacing of 50m which results in a more detailed image of the island morphology. Because of this limitation with the 1982 data, the 1990 survey data set is referred to in this description of island morphology.

<u>Plan View</u>
The Isserk site may be described from the 1990 bathymetry maps as a smoothed triangular form (Figure 5.5.1, top centre). In contrast to the island sites described above, the Isserk island does not appear elongated, and the margins are similar in shape around the island.

The seafloor gradient of the island's face is generally uniform in the south, southeast, southwest, east and west at approximately 1:12. The gradient of the seafloor is least in the north and northwest at approximately 1:18.

A closed bathymetric high occurs on the top of the 1982 and 1990 maps on the western side of the site and mimics the general form of the island.

<u>Profile View</u>
Figure 5.5.1 (lower right and centre) displays two composite 1982 and 1990 profiles, south southwest - north northeast and west northwest - east southeast, crossing the middle of the Isserk island.
In contrast to other islands these profiles display only slight variations in the minimum depth of submergence of the island's crest.

The composite 1982 and 1990 profiles display sediment accumulation throughout the islands periphery with the greatest sediment accretion toward the east southeast.

Contour Comparison
The location of the 1982 and 1990 7m contour has been compared to determine the maximum measurable distance of sediment transport between these years. This comparison indicates sediment has been transported up to 85m east-southeast between 1982 and 1990. In contrast the 7m contour has remained essentially stationary during this period in the northwest corner of the island.

Sediment Depletion/Accretion Map
To further assess the sediment transport pattern the 1982 and 1990 bathymetry charts were overlain to produce a sediment depletion/accretion map (Figure 5.5.1, upper right).

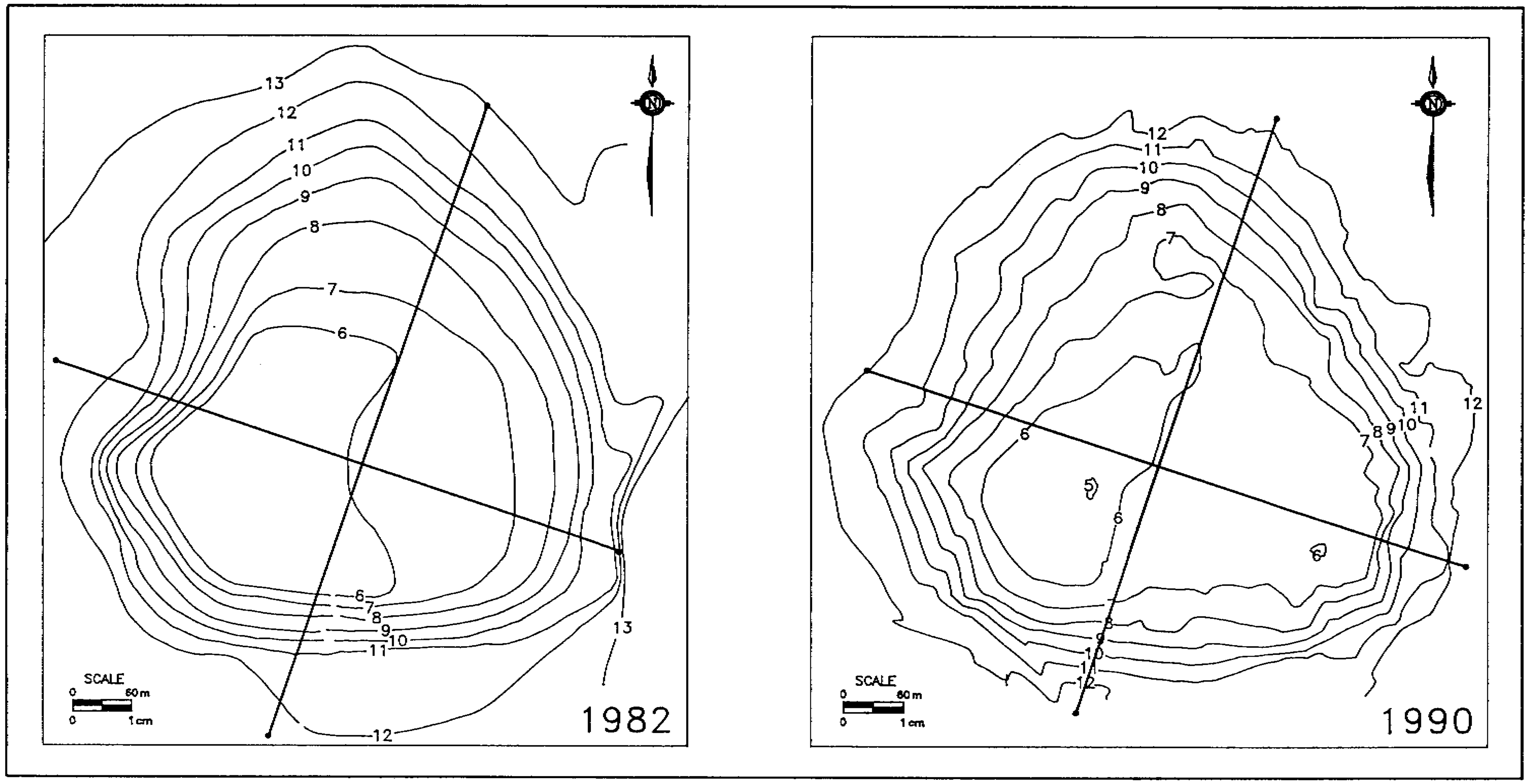
This map indicates the area of greatest sediment accumulation occurs in the east. The north margins appear relatively unchanged. The other margins display lesser degrees of erosion or deposition. The area of sediment accumulation corresponds to the direction of the Isserk borrow pit.

Residual Bathymetry Map
In addition to the general sediment depletion/accretion map a residual bathymetry map was prepared from the 1982 and 1990 hydrographic charts (Figure 5.5.1, lower right). This contour map displays the spatial distribution, and magnitude, of sediment loss (contours in metres, interval 0.5m). This map indicates a very irregular sediment erosion and deposition pattern overs over the crest of the island. The maximum vertical accretion occurs in the east southeast (up to 2.5m) with lesser amounts to the south (up to 1.5m). Sediment accretion in others areas of the islands periphery is irregular and is generally less than 0.5m in vertical extent.

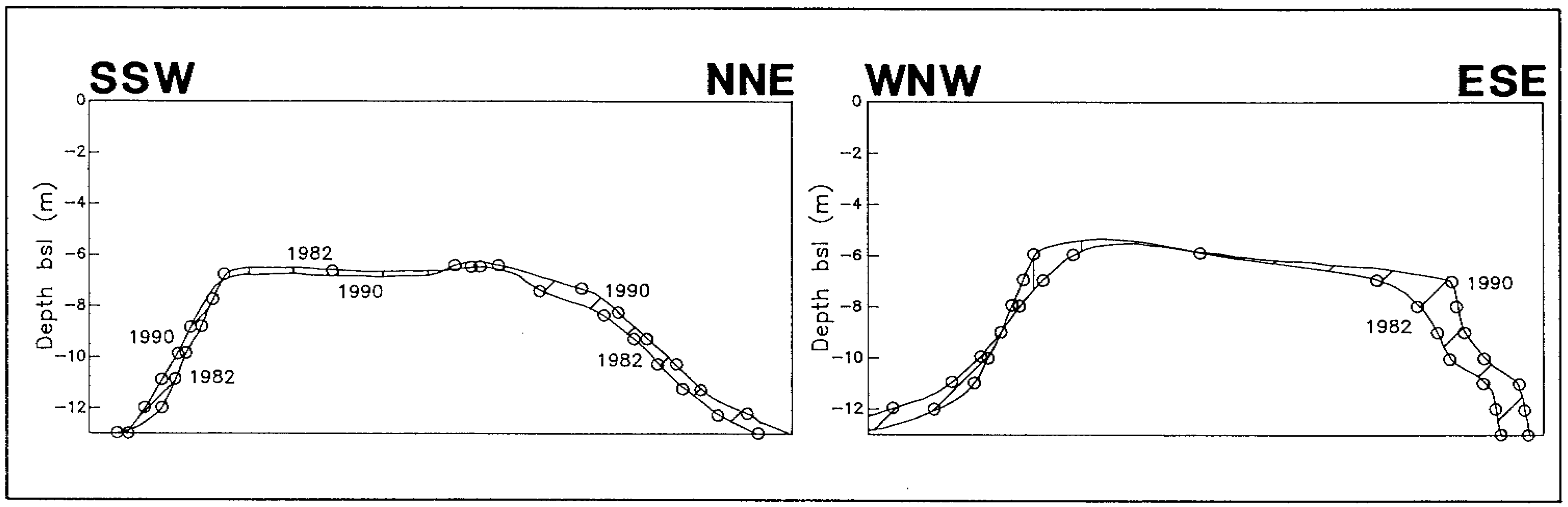
This sediment depletion/accretion pattern at the Isserk site is suggests that island this island is approaching an equilibrium condition.

5.5.2 Seafloor Features

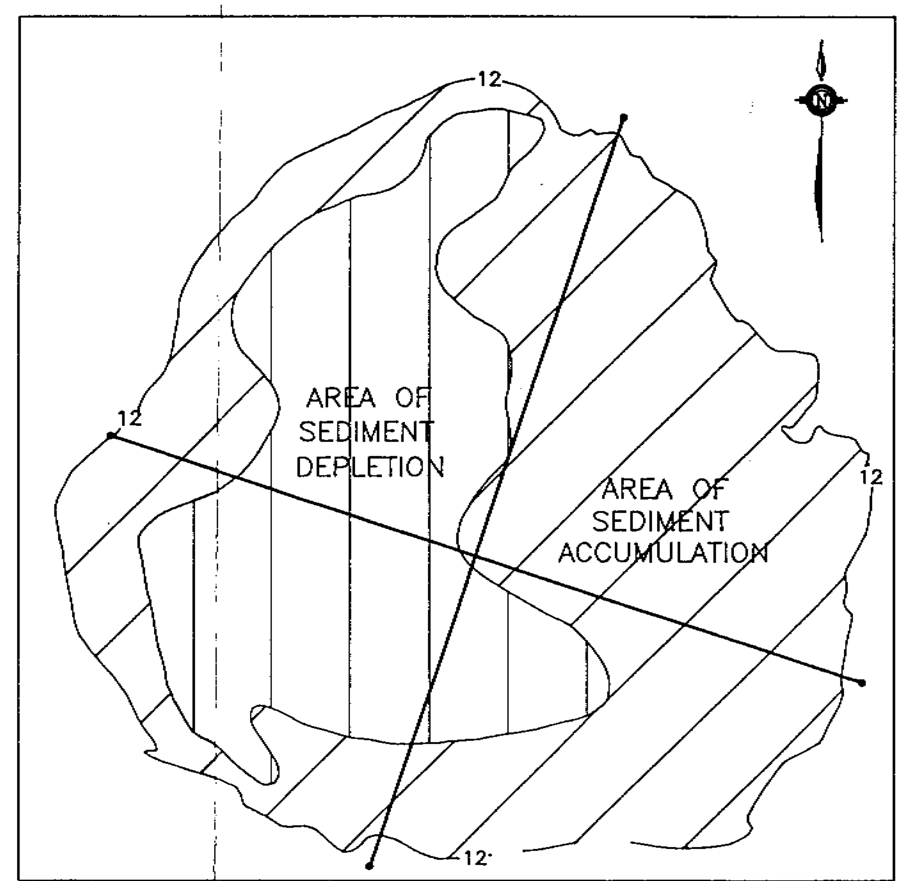
The sidescan data from the Isserk island is very noisy and difficult to interpret or map. In general the island appears of lower reflectivity than the surrounding seafloor. Abundant bedforms, or possibly wavenoise, dominates the data collected over the top of the island. The surrounding seafloor is heavily scoured in contrast to the island which appears lightly scoured.



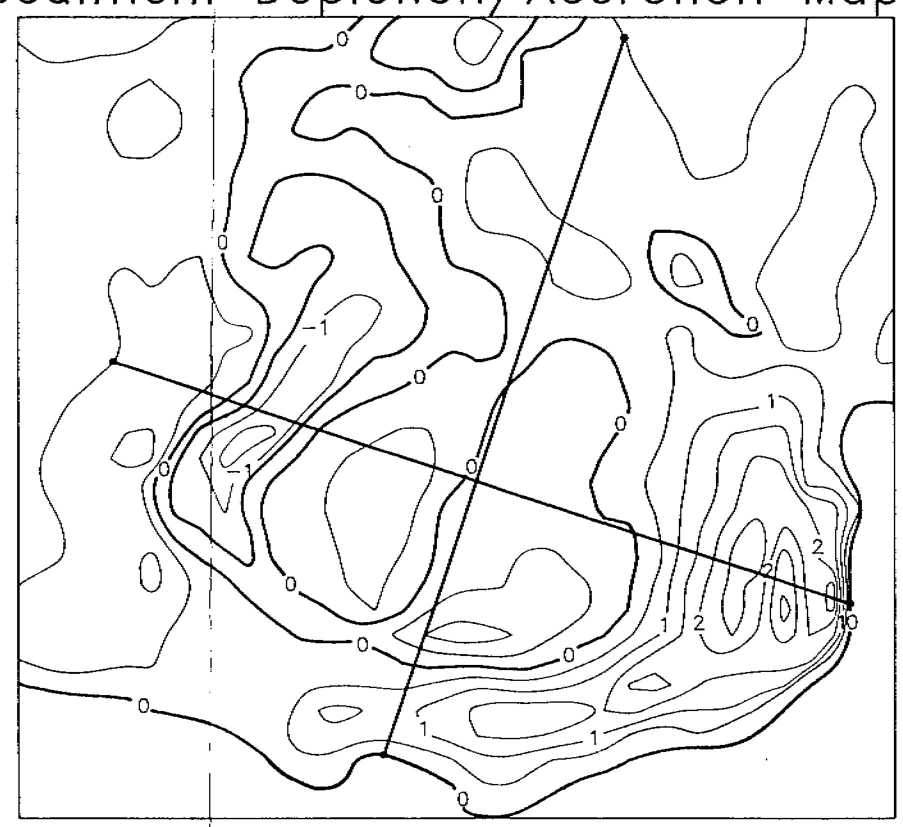
1982 and 1990 Bathymetric Contours



Composite 1982 and 1990 Cross Sections



Sediment Depletion/Accretion Maps



ISSERK E-27 ISLAND SUMMARY Scale 1:6000

FIGURE 5.5.1

5.6 Issungnak O-61

Issungnak O-61 was constructed in the 1978-79 open water season on stiff clay overlying sand on the Akpak Plateau. It was a sacrificial beach island requiring 4,100,000m^3 of sand acquired mostly from a local borrow pit. The portion of the island above the waterline was constructed of sand transported from Tufts Point. The islands working surface was 100m in diameter with a maximum freeboard of 5.0m. Sideslopes of 3H:1V were maintained above the waterline. Beach slopes of 20H:1V where constructed to the 800m diameter island base. In September 1979, as the island neared completion it was damaged by two storms which eroded the island to within 1.5m of sealevel and redistributed the sand in a 100m apron around the working surface. The following summer the island was rebuilt 40m to the west and renamed Issungnak 2-O-61. The island has undergone submergence since abandonment to reach tó minimum depths of -3.1m (1989) and -4.0m (1990).

5.6.1 Island Morphology

Hydrographic surveys have been conducted at the island site in 1981, 1989 and 1990. The 1981 survey was completed one month prior to island abandonment. The coverage of the island in the 1981 survey is an irregular star pattern with dense line spacing on the south and east margins, sparse spacing on the west and no coverage on the north. The survey is further limited to water depths greater than 2.2m. The 1989 survey lines were acquired as a series of north-south oriented subparallel lines approximately 50m in spacing and a single east-west tie line. The 1990 survey was completed as a grid of east-west lines which a nominal spacing of 50m and a series of north-south tie lines with a 200m line spacing.

Plan View

The 1981 bathymetry represents a snapshot of the island immediately prior to abandonment (Figure 5.6.1, top left). The island contour at that time describe a generally circular form with uniform face gradients throughout the island. The irregular 1981 coverage is responsible for the lack of contours in the north and the smoothed contours in the west.

The island morphology appears very similar between 1989 and 1990. Only the 1990 chart is presented on the summary diagram of Figure 5.6.1. Between 1989 and 1990 the elevation of the island crest has increased by up to 1m from 4m in 1989 to 5m in 1990 indicating ongoing island erosion.

By 1990 the island appears to have broadened toward the south (Figure 5.6.1, top centre). The edge of the island in the north and northwest quadrants of the site is characterised by a broad gentle curvature. In other quadrants the island is more angular in shape with sharper planar faces best developed in the south and east. The change in island shape corresponds to a transition in the seafloor gradient. The gradient of the island's face increasing from 1:22 in the northwest to 1:5 in the south.

Profile View

Figure 5.6.1 (lower left and centre) displays two composite 1981 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Issungnak island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1981 and 1990, southwest - northeast profile, appear symmetric with a consistent slope on both island faces. This composite profile indicates sediment depletion over the crest of the island and a very minor, to no, erosion or accumulation along the southwest and northeast margins.

The composite 1981 and 1990 northwest - southeast profile displays depletion over the crest of the island and along the northwest margin of the island. A major area of sediment accretion is identified on the southeast inclined island face.

Contour Comparison

The location of the 1981 and 1990 7m contour, has been compared to determine the maximum measurable distance of sediment transport between these years. This comparison indicates sediment has been transported up to 95m southeast between 1981 and 1990. In contrast the 7m contour has eroded approximately 70m in the northwest.

Sediment Depletion/Accretion Map

To further assess the sediment transport pattern the 1981 and 1990 bathymetry charts were overlain (Figure 5.6.1, lower right) and the approximate spatial distribution of sediment depletion and accretion was estimated. This map indicates the areas of sediment accumulation to the south and southeast. The northeast margin appear relatively unchanged. The island crest and north and northwest margins of the island have undergone sediment erosion between 1981 and 1990.

The areas of sediment accumulation correspond to the margins of the 1990 island which are relatively steep and planar (Figure 5.6.1, top center). The sediment accreting eastward is destined for the Issungnak borrow pit.

5.6.2 Seafloor Features

The 1990 sidescan data for this island is poor as rough sea states resulted in excessive towfish motion.

A diagrammatic seafloor features map (Figure 5.6.1, upper right) is based on the interpretation originally presented in the CSR (1990) report which used 1989 survey data. The 1989 data appear to have abundant 3-D megaripples on the top of the island. The corresponding 1990 data does not display these bedforms on the island crest (see Section 6.2.2). The predominate bedform crest orientations is northeast - southwest which is consistent with the southeast sediment transport interpreted for this island.

The 1989 seafloor displays a gradation in bedforms across the island transect. In summary the bedforms are present on the flat crest of the island and are absent along the margins and on the island slopes.

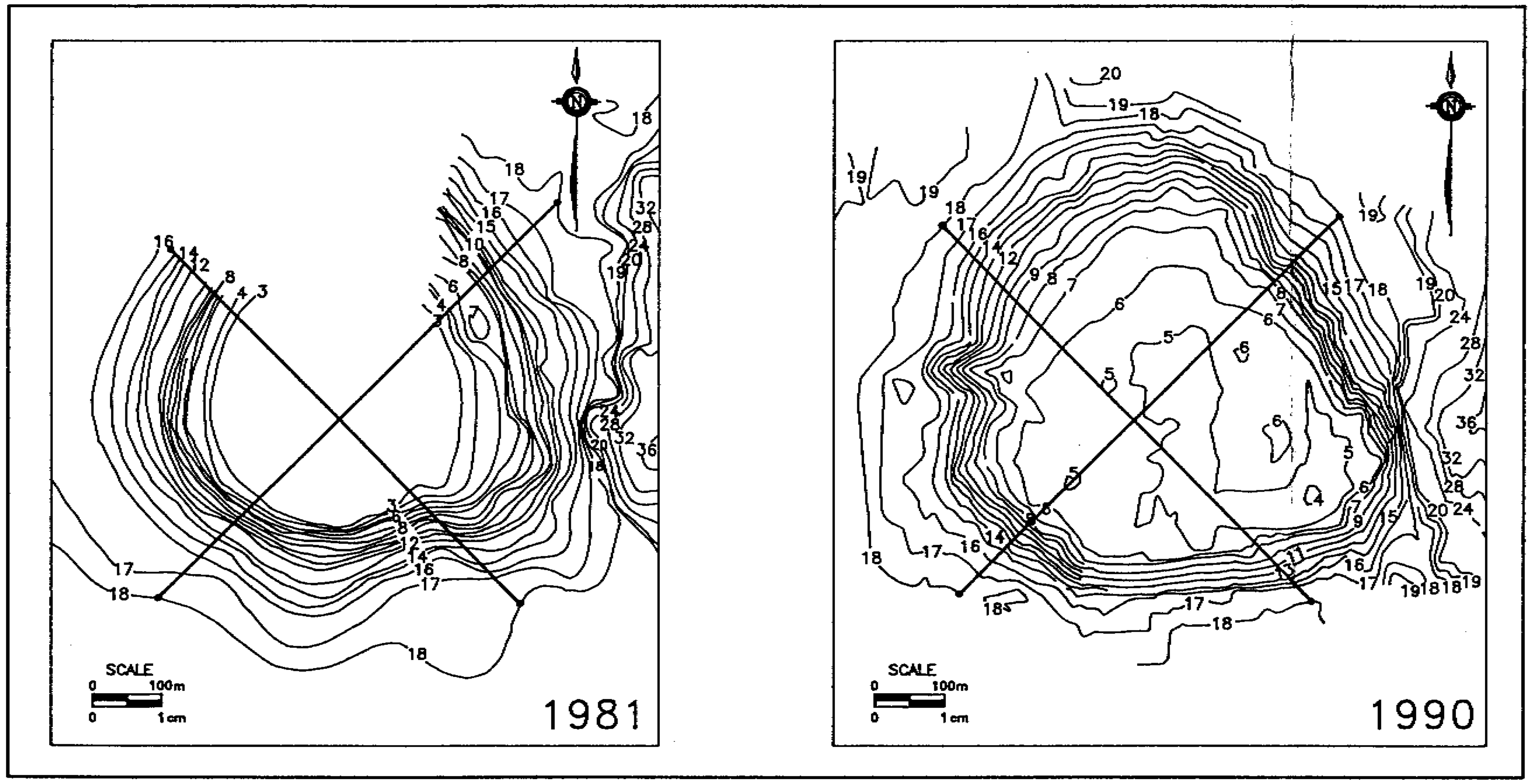
5.6.3 Comparison of 1989 and 1990 Sidescan at Issungnak O-61

The island morphology appears very similar between 1989 and 1990. However in this period the minimum elevation of the island crest has increased by up to 1m, from 3.1m in 1989, to 4.0m in 1990, indicating ongoing island erosion.

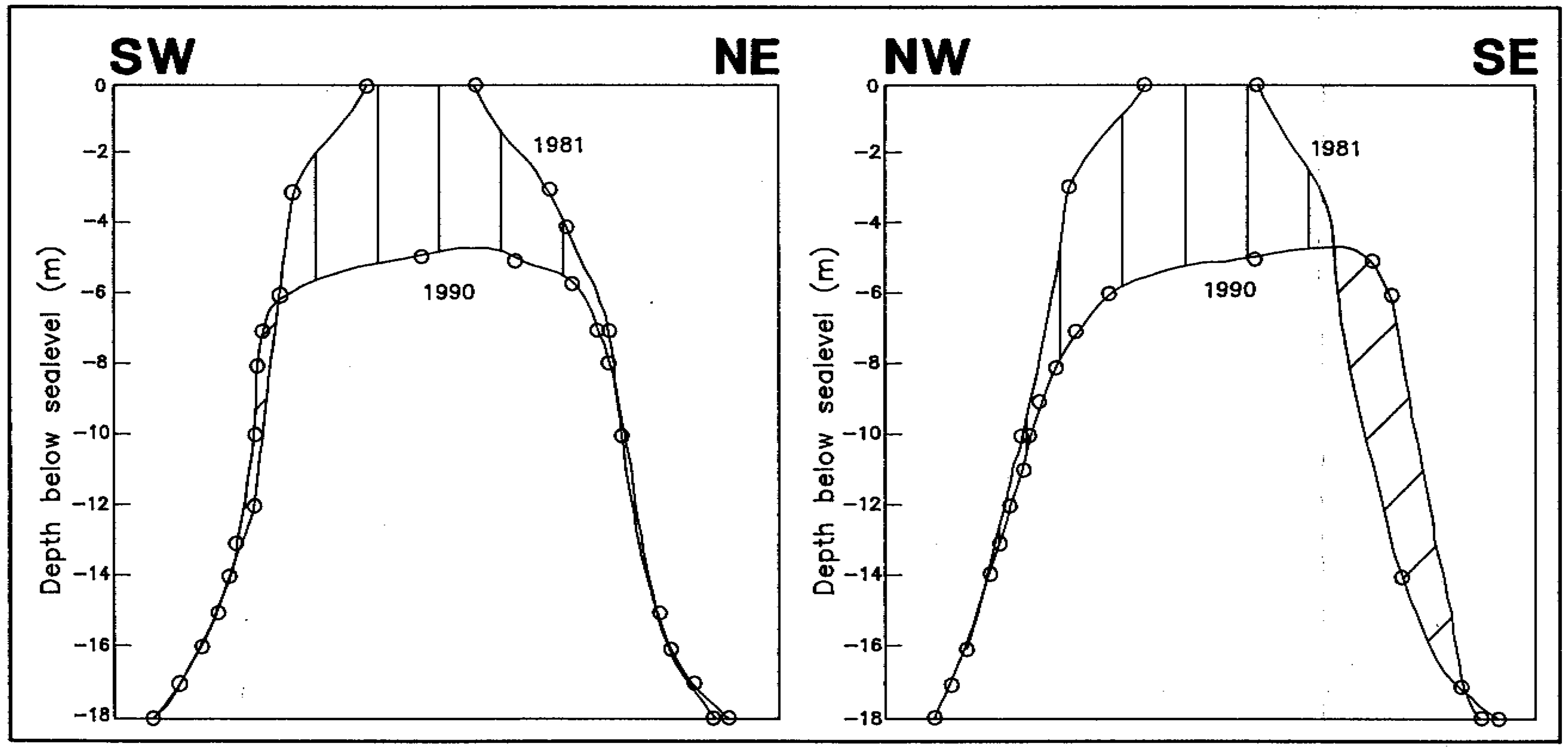
Two areas of contiguous sidescan coverage are contrasted at this island. Area 1 occurs along the northern margin of the island while Area 2 occurs along the south margin. Bathymetry analysis indicate that these area correspond to sites of long term sediment depletion and sediment accretion, respectively. Figures 5.6.2 and 5.6.3 present these comparisons which are described below.
The 1989 and 1990 sidescan data from Areas 1 indicate large areas of debris. Similar debris have been visually inspected at two locations on the Issungnak site and found to consist of sand bags, cable, fibre matting, and tied up junk. This debris remain through the 1989 and 1990 surveys in both areas.

In Area 2 an anomalous feature is detected in a field of bedforms. This represents an ideal candidate for measurement of the relative erosion and deposition. The 1989 and 1990 data are well positioned in this case based on two additional reference points; the island edge and a highly reflective area of debris. Both the 1989 and 1990 data display the island edge, debris and the isolated geometric object. This suggests that very little sediment has been eroded from or deposited in this area between 1989 and 1990.

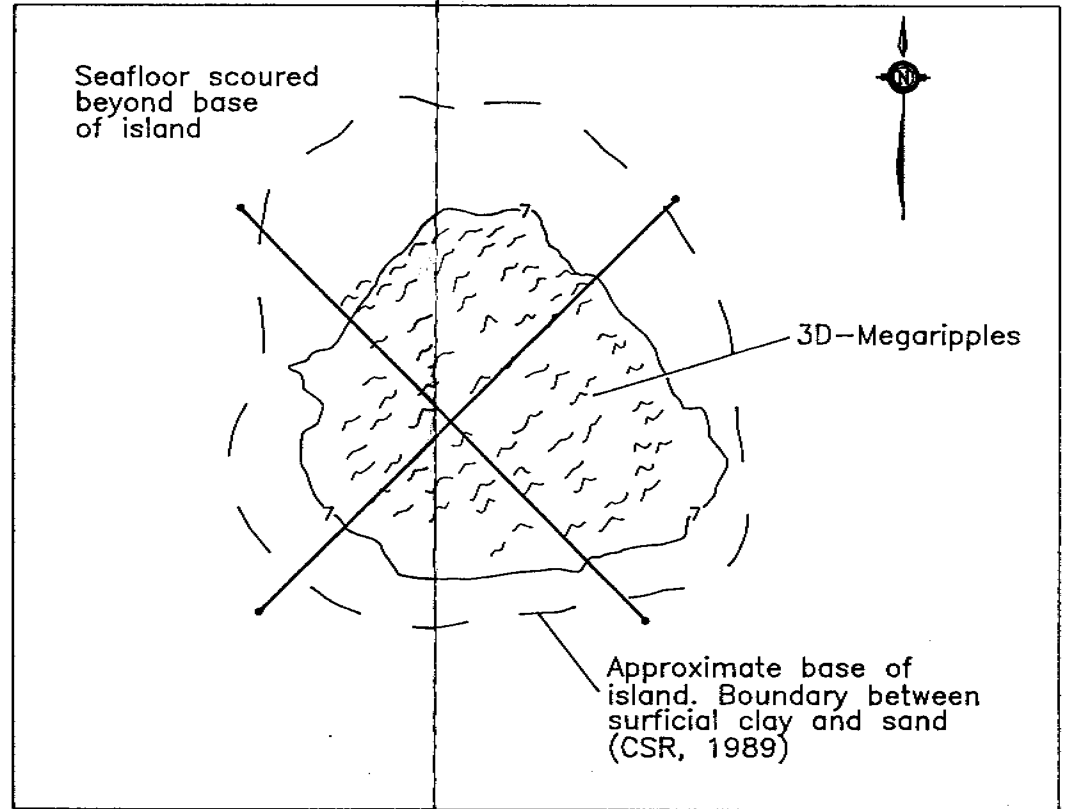
Some contrast does exist between the seafloor between the 1989 and 1990 surveys. The 1989 data appear to have abundant 3-D megaripples on the top of the island. The corresponding 1990 does not display these bedforms.



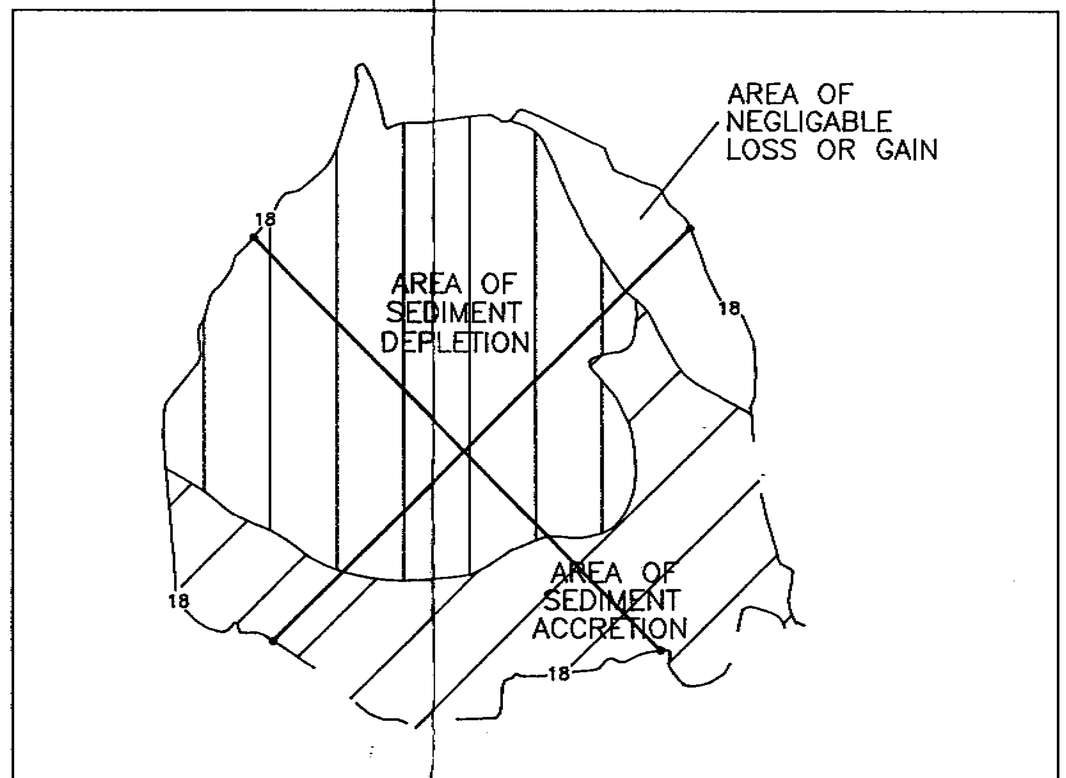
1981 and 1990 Bathymetric Contours



Composite 1981 and 1990 Cross Sections



Diagrammatic Seafloor Features Map



Sediment Depletion/Accretion Map

ISSUNGNAK O-61 ISLAND SUMMARY Scale 1:10 000

FIGURE 5.6.1

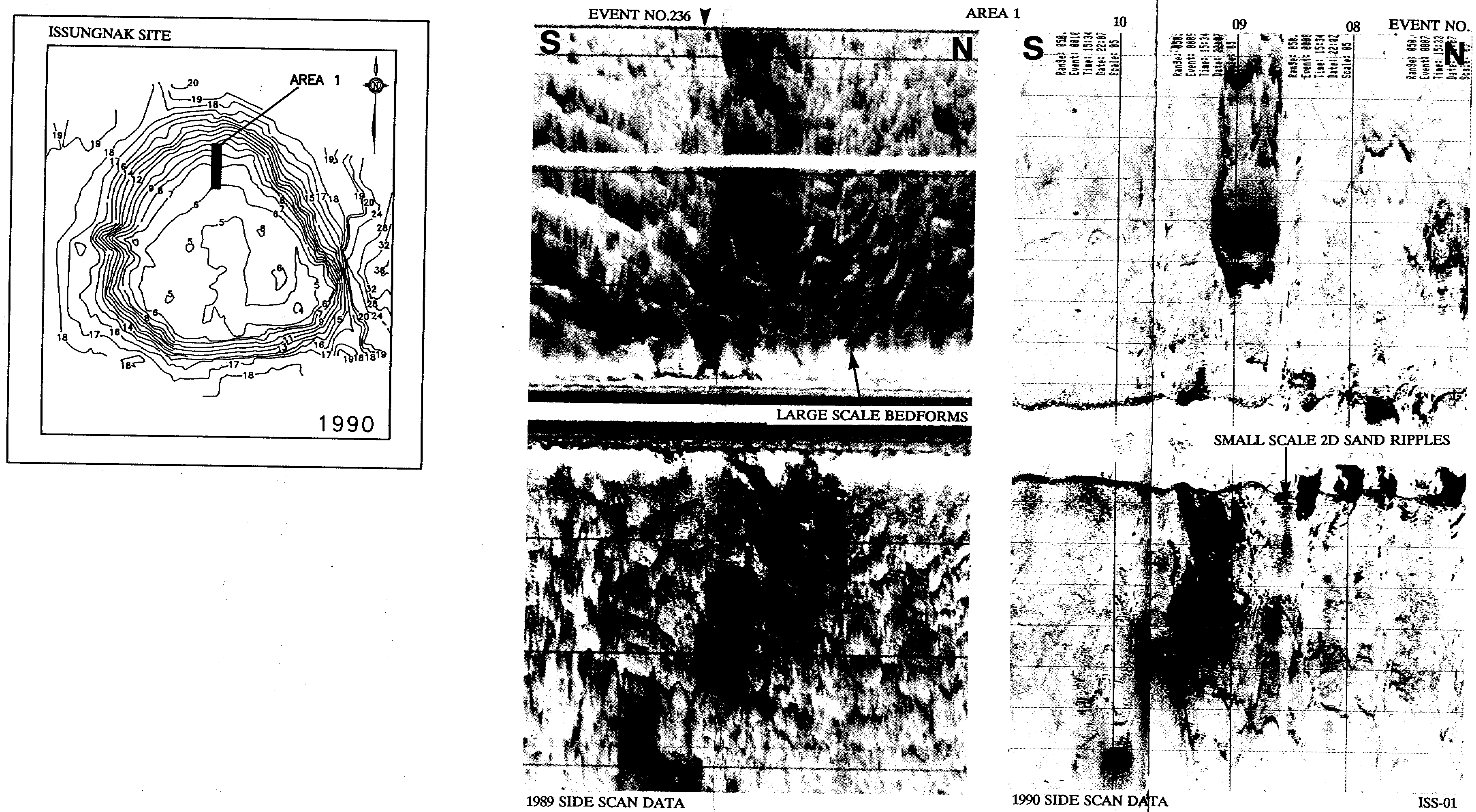


Figure 5.6.2 Comparison of 1989 and 1990 sidescan data collected over an area of debris on the north side of the Issungnak island top.

FIGURE 5.6.2

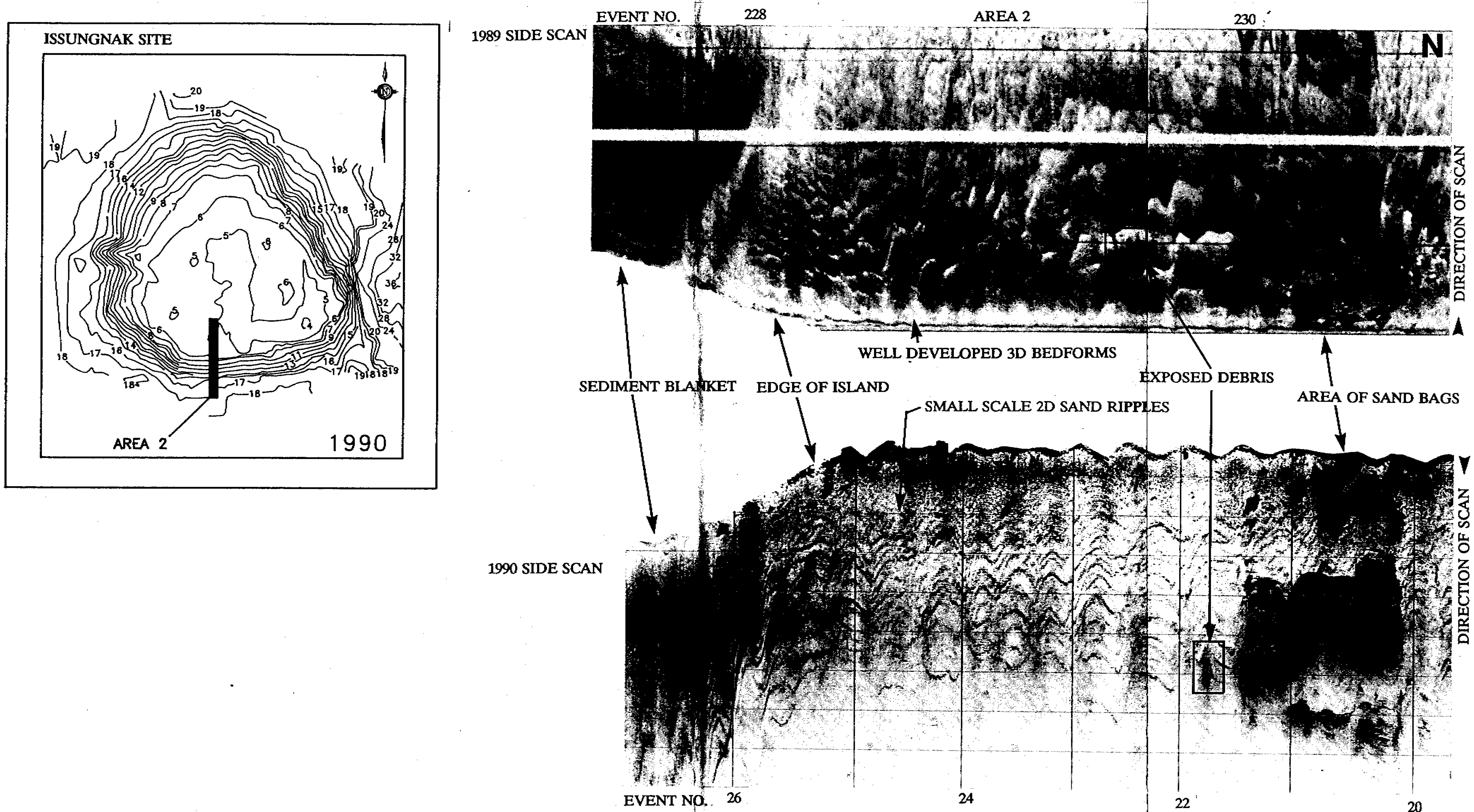


Figure 5.6.3 Comparison of 1989 and 1990 sidescan data collected over an area of south margin of the Issungnak island.

FIGURE 5.6.3

5.7 Alerk P-23

Esso constructed Alerk P-23, a sacrificial beach island, in 10.5m of water on a veneer of clay overlying sand on the Tingmiark Plain. The construction spanned the 1980-81 open water season to build the 100m working surface with a 4.5m freeboard. The island was constructed from 1,500,000m^3 of sand escalated from an onsite borrow pit. Drilling was conducted on the island in the winter of 1981. The island was abandoned in 1982. The island has undergone submergence since abandonment to reach to minimum depths of -2.3m (1982) and -3.1m (1990).

5.7.1 Island Morphology

Hydrographic surveys have been conducted at the island site in 1981, 1982 and 1990. The 1981 and 1982 surveys appears to have been completed upon completion of island construction, and at the time of island abandonment, respectively. The coverage of the island in both of these programs consists of a regular star pattern limited to water depths greater than 2.0m.

Plan View

The 1981 and 1982 hydrographic charts afford us a look at the changes in the submerged island form which occurred over an 11 month period between the fall of 1981 and the summer of 1982. In 1981 the as-constructed Alerk bathymetry map the island appears circular in plan view with steeper slopes on the south, southeast and east margins. By the time the island is abandoned (1982) the island is more angular in shape with sharper planar faces best developed in the south and east (Figure 5.7.1, top left). The edge of the island in the north and northwest quadrants of the site remains as broad gentle curvature.

The 1990 site bathymetry is based on detailed coverage of the surrounding seafloor, and variable coverage of the island margins. The orthogonal grid of lines surveyed at Alerk do not cross the island top. These lines are limited to water depths greater than 3m. At one location in the southwest portion of the site the lines do not extend into water depths of less than 10m.

The 1990 Alerk bathymetry which appears in earlier reports (Klohn Crippen (1993)) provides an incomplete or erroneous image of the islands morphology. Of particular concern to this study is the apparent valley-like depression on the 1990 bathymetry. This feature is outside the area of data coverage. This feature is a contouring artifact and probably results from an inappropriate contouring search radius. The 1990 bathymetry presented in Figure 5.7.1 (top center) has had this contouring artifact removed. For this reason it is critical that seafloor processes (eg. sediment slumps) are not interpreted directly from the contoured bathymetry maps without giving careful considerations to the extent of line coverage upon which these maps are based.

The island form developed by 1982 is enhanced by 1990.

Profiles View
Figure 5.7.1 (lower left and centre) displays two composite 1982 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Alerk island. These profiles display an increase in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1982 and 1990, southwest - northeast profile, indicates sediment depletion over the crest of the island and along the southwest and northeast margins. Minor accumulation occurs at the base of these island faces in water depths greater than 8m. The composite 1982 and 1990 northwest - southeast profile displays depletion over the crest of the island. The prominent feature is a zone of sediment accretion along the southeast inclined face. Sediment accumulation to a lesser extent also occurs along the northwest margin of the island.

To further assess the sediment transport pattern the 1982 and 1990 bathymetry charts were overlain (Figure 5.7.1, lower right) and the approximate spatial distribution of sediment depletion and accretion was estimated. Figure 5.7.1 suggests an area of erosion over the crest and a major area of deposition on the southeast. Minor accretion occurs on the northwest island faces and at the base of the southwest and northeast island slopes.

Contour Comparison
The location of the 1982 and 1990 7m contour has been compared to determine the maximum measurable distance of sediment transport between these to years. This comparison indicates sediment has been transported up to 105m southeast between 1982 and 1990. In contrast the 7m contour remained in approximately the same location in the north, northwest and west.

Sediment Depletion/Accretion Map
We have demonstrated for other islands that by overlying time sequential bathymetric charts the change in the seafloor topography in this period can be estimated and the area of sediment erosion and accumulation can be distinguished. Comparison of the 1984 and 1990 charts suggests the north, northwest and west margins of the island have undergone generally uniform erosion. The prominent area of sediment accumulation is identified in the south, southeast and east quadrants of the island. The island remains broad and concentric along the margins undergoing sediment erosion. In the areas of sediment accumulation the island faces become steeper and more planar. On the Alerk island (and on others) the sediment accumulation is clearly greatest in a specific direction where the residual bathymetry display a dendritic feature protruding over the surrounding seafloor.

The areas of sediment accumulation correspond to the margins of the island which are relatively steep and planar.

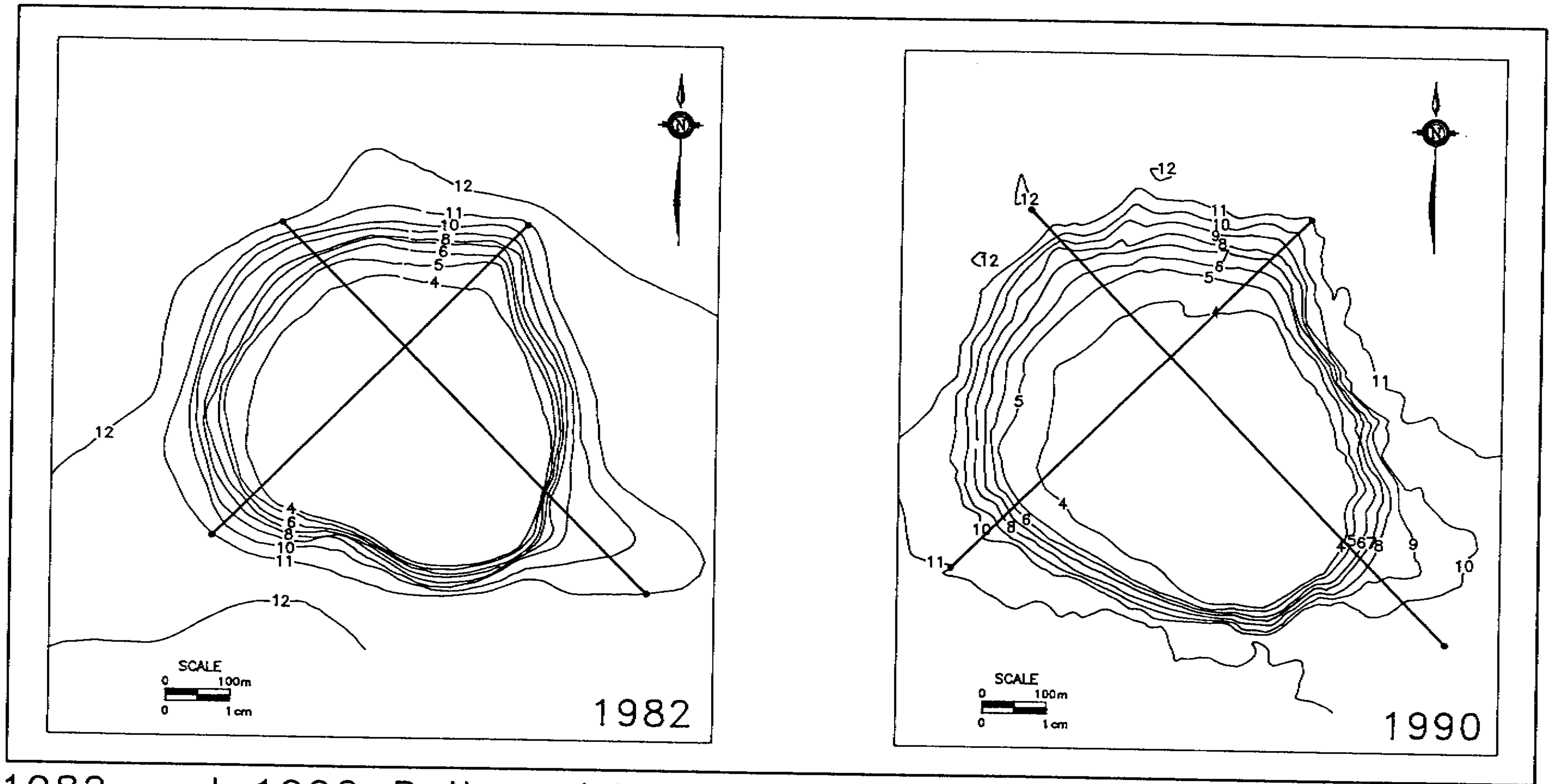
5.7.2 Seafloor Features

The bathymetry data are augmented by excellent quality sidescan data collected in 1990. The data coverage is limited to the surrounding seafloor and island margins with limited coverage of the island top in the north. The sidescan data has been used to prepare a diagrammatic seafloor features map (Figure 5.7.1, top right) which illustrate the location and type of seafloor features at the site. The diagrammatic illustrates a range of seafloor processes acting on different parts of the island.

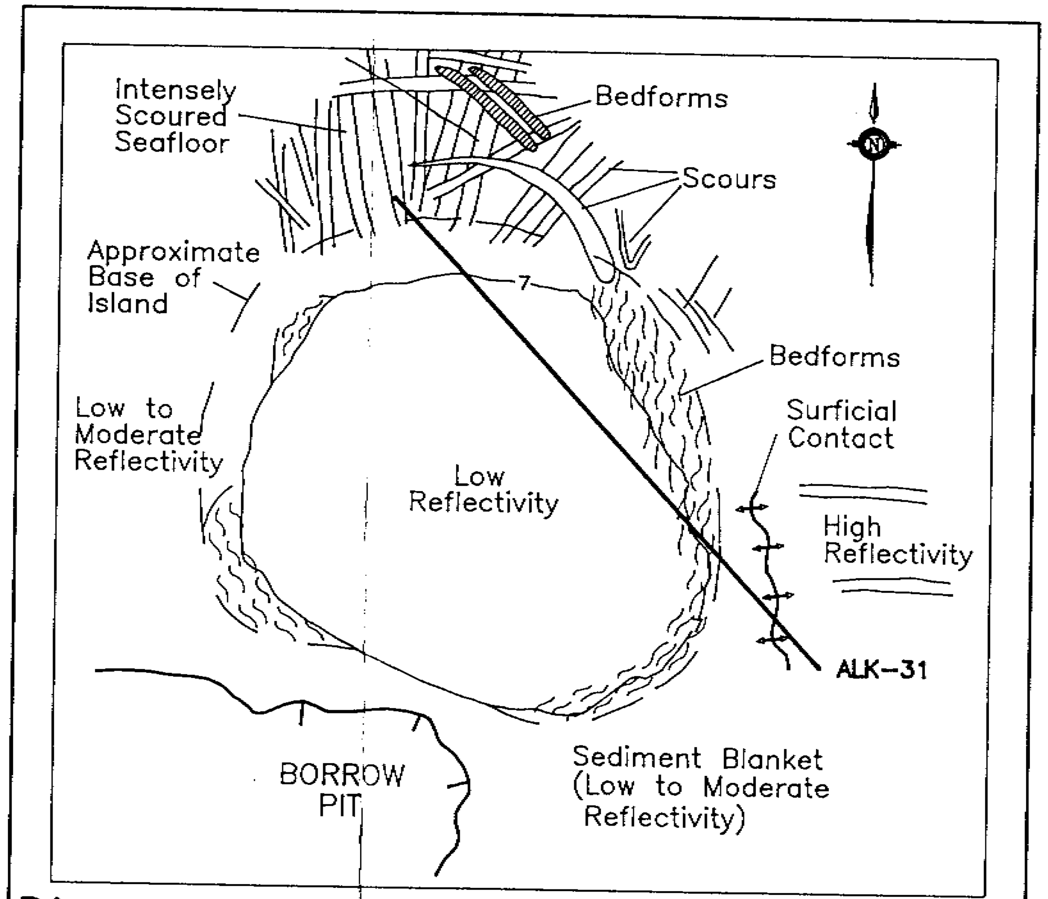
The sidescan data at the Alerk site (eg. Figure 5.7.2, ALK 31) displays a low reflectivity featureless island top. The north end of the site the surrounding seafloor is characterised by intense scours which abruptly terminate on the island margin. In contrast to the west, south and east of the islands margins scouring is absent or light. The island appears to have altered the scouring patterns. An expanded discussion of this process is provided in Section 7.

The south and southeast margins and face of the island are characterised by abundant bedforms (Figure 5.7.2, Sidescan Line, ALK 31). The seafloor surrounding the island varies from low reflectivity to moderate reflectivity seafloor. A sharp surficial sediment contact occurs southeast of the island. At this contact the seafloor reflectivity increases sharply away from the island. The bedforms and reflectivity contact observed on the sidescan indicate a sediment blanket occurs in this area. This sediment blanket is interpreted to have originated from the erosion of the Alerk island crest. This corresponds to the area of sediment accumulation as determined from the comparison of 1982 and 1990 bathymetry charts (see Section 5.7.2).

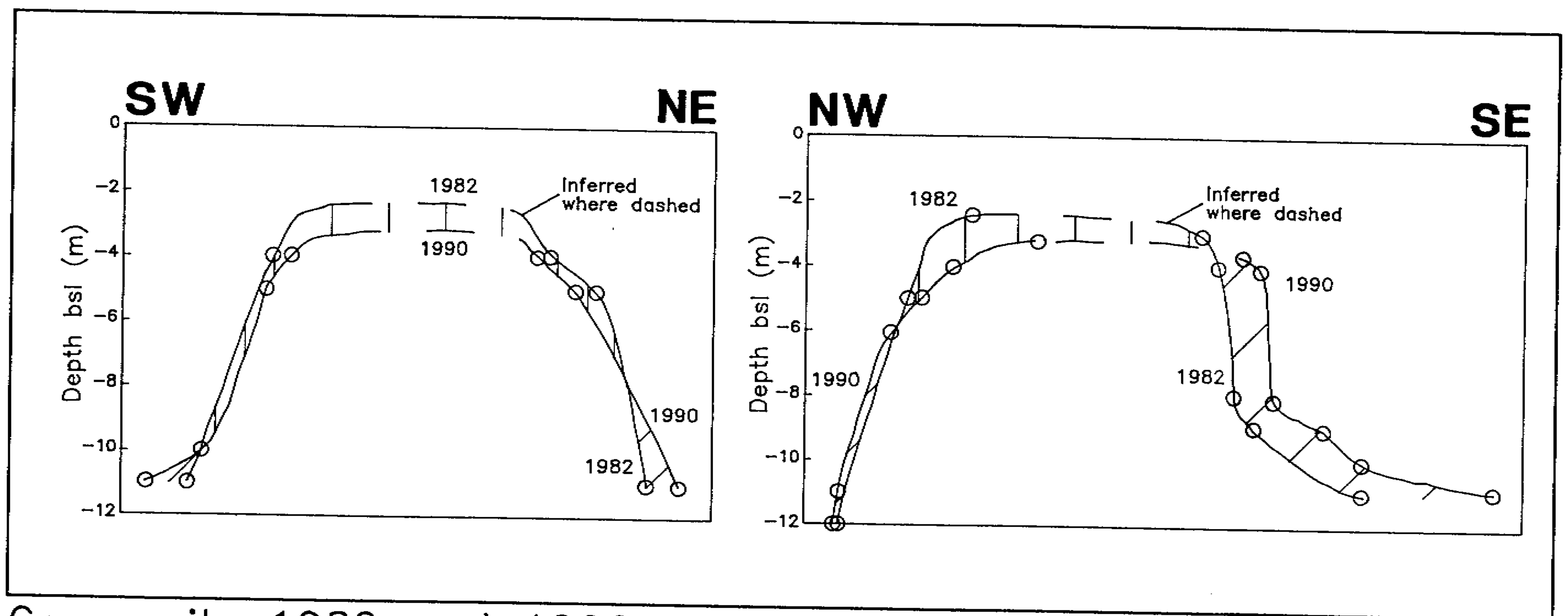
Bedforms and mounding occur on the southwest, northwest and east margins of the site (ALK 41 and ALK 14). A train of sand and gravel ripples are identified in a scour trough located beyond the north margin of the island indicating bedload transport is occurring on the seafloor surrounding the island (Figure 5.7.1, top right, Diagrammatic Seafloor Features Map).



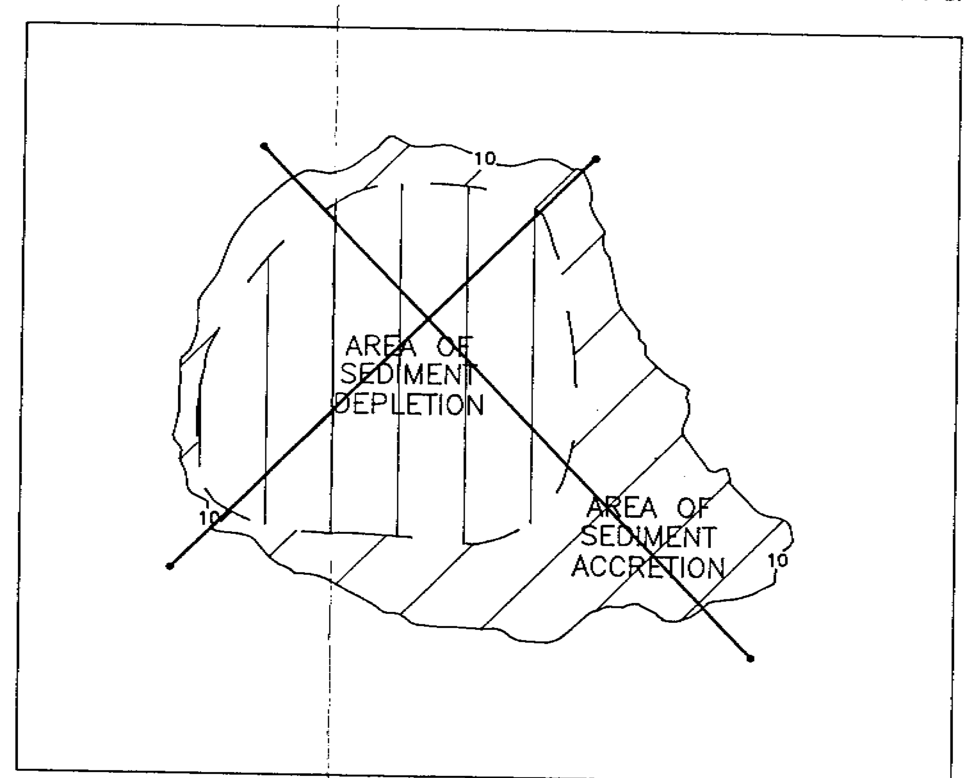
1982 and 1990 Bathymetric Contours



Diagrammatic Seafloor Features Map



Composite 1982 and 1990 Cross Sections



Sediment Depletion/Accretion Map

ALERK P-23 ISLAND SUMMARY Scale 1:10 000

FIGURE 5.7.1

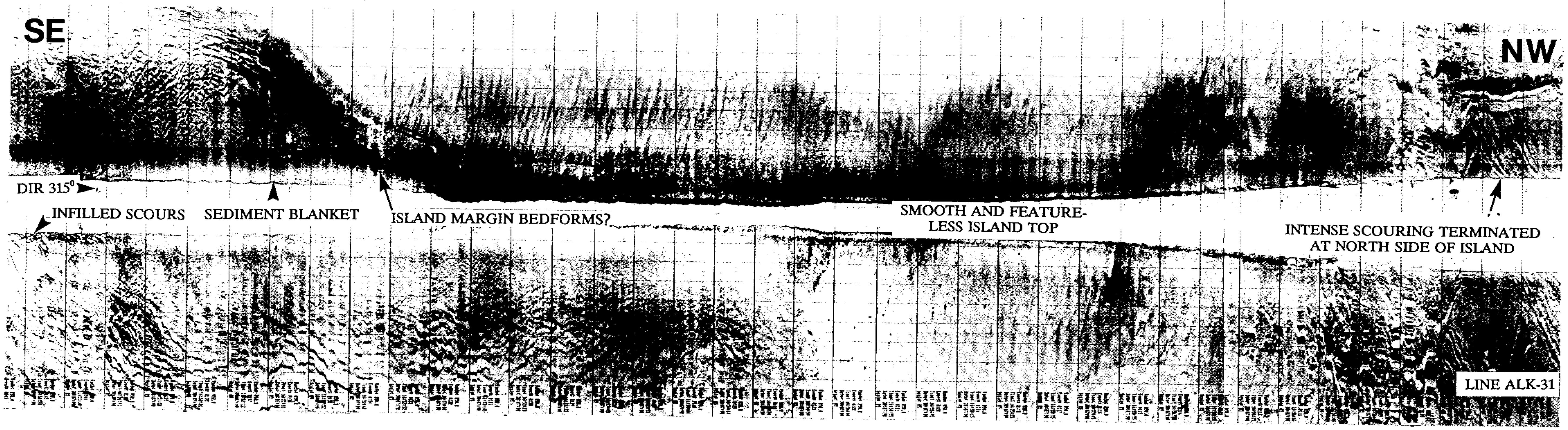


Figure 5.7.2 Sidescan data (Line ALK 31) displaying seafloor features characteristic of the P-23 island and surrounding seafloor.

FIGURE 5.7.2

5.8 West Atkinson L-17

West Atkinson was constructed in the 1981-82 open water season as a sacrificial beach island in 6-7m of water on a seabed of soft clay overlying sand (volume 1,000,000m^3). Sand fill was hydraulically placed from a local borrow pit to create a 100m diameter island with a 4.5m freeboard. Following the 1982 drilling activity the island was abandoned. The island has undergone submergence since abandonment to reach to minimum depths of -2.1m (1990).

5.8.1 Island Morphology

Hydrographic surveys have been conducted at the island site in 1982 and 1990. The 1982 survey appears to have been completed at the time of island abandonment. The coverage of the island in this programs consists of a regular star pattern limited to water depths greater than 2.0m and locally in the south to water depths greater than 4.0m.

Plan View

At the time the island abandonment (Figure 5.8.1, top left) the island is angular in shape with sharper planar faces best developed in the south and east. The edge of the island in the north and northwest quadrants of the site remains as broad gentle curvature.

The 1990 site bathymetry is based on detailed coverage of the surrounding seafloor, and variable coverage of the island margins. The orthogonal grid of lines surveyed at West Atkinson do not cross the island top. These lines are limited to water depths greater than 5.0m in all quadrants except in the northwest were coverage in obtained as shallow as 3.0m. Limited sounding were obtained in shallower water through a launch reconnaissance survey. The angularity of the 1990 bathymetric contours (Figure 5.8.1, top center) is attributed to the limited survey coverage on this island.

Profile View

Figure 5.8.2 (lower left and centre) displays two composite 1982 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the West Atkinson island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1982 and 1990, southwest - northeast profile, indicates sediment depletion over the crest of the island and along the southwest margin. Minor accumulation occurs at near the base of the island's northeast faces in water depths greater than 4m.

The composite 1982 and 1990, northwest - southeast, profile displays depletion over the crest of the island. The prominent feature is a zone of sediment accretion along the southeast inclined face. Minor accumulation occurs at near the base of the island's northeast faces in water depths greater than 5m.

Contour Comparison

The location of the 1982 and 1990 6m contour has been compared to determine the maximum measurable distance of sediment transport between these years. The 6m contour is the best level to evaluate at the West Atkinson Site as full coverage of this water depth is obtained in the 1982 and 1990 surveys. This comparison indicates sediment has been transported up to 200m southeast between 1982 and 1990. In contrast the 6m contour has remained essentially stationary during this period in the northwest corner of the island.

Sediment Depletion/Accretion Map

We have demonstrated for other islands that by overlying time sequential bathymetric charts the change in the seafloor topography in this period can be estimated and the area of sediment erosion and accumulation can be distinguished. Comparison of the 1982 and 1990 charts at West Atkinson is problematic due to the limited survey coverage and poor contouring of the 1990 data set. For this reason a sediment depletion/accretion map is not presented for West Atkinson.

In general we have found that islands remain broad and concentric along the margins which are stable or undergoing the least sediment erosion and the island faces become more steeper and planar in the areas of sediment accumulation. These general trends appear to hold true for the West Atkinson site were on the basis of the 1982 and 1990 6m contour the direction of greatest sediment accumulation is toward the southeast and the area which remains stable is toward the northwest. The 6m contour comparison also suggests the south and east and to a lesser extent northeast are areas of sediment accumulation.

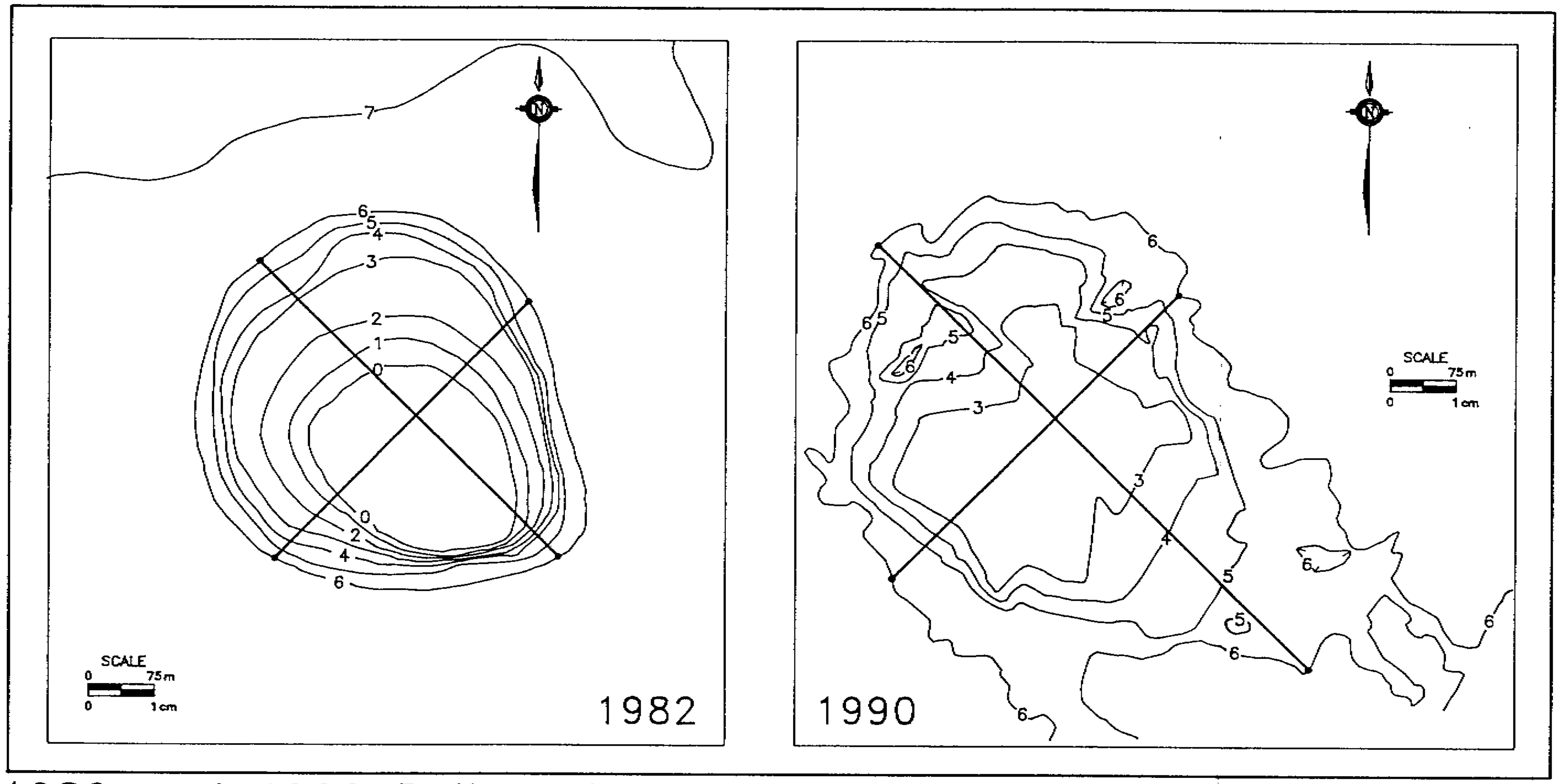
The direction of sediment accumulation inferred from the 1982 island geometry is consistent with the southeast sediment transport direction inferred from the comparison of the 6m contour on the 1982 and 1990 bathymetry charts. The island morphology characteristically evolved by in the first year of the islands life. The erosional pattern continues to the present day. The same early stage development of island morphology is observed at Alerk and may be characteristic of environmental factors (water depth etc.). This trend is explored further in Section 8.

5.8.2 Seafloor Features

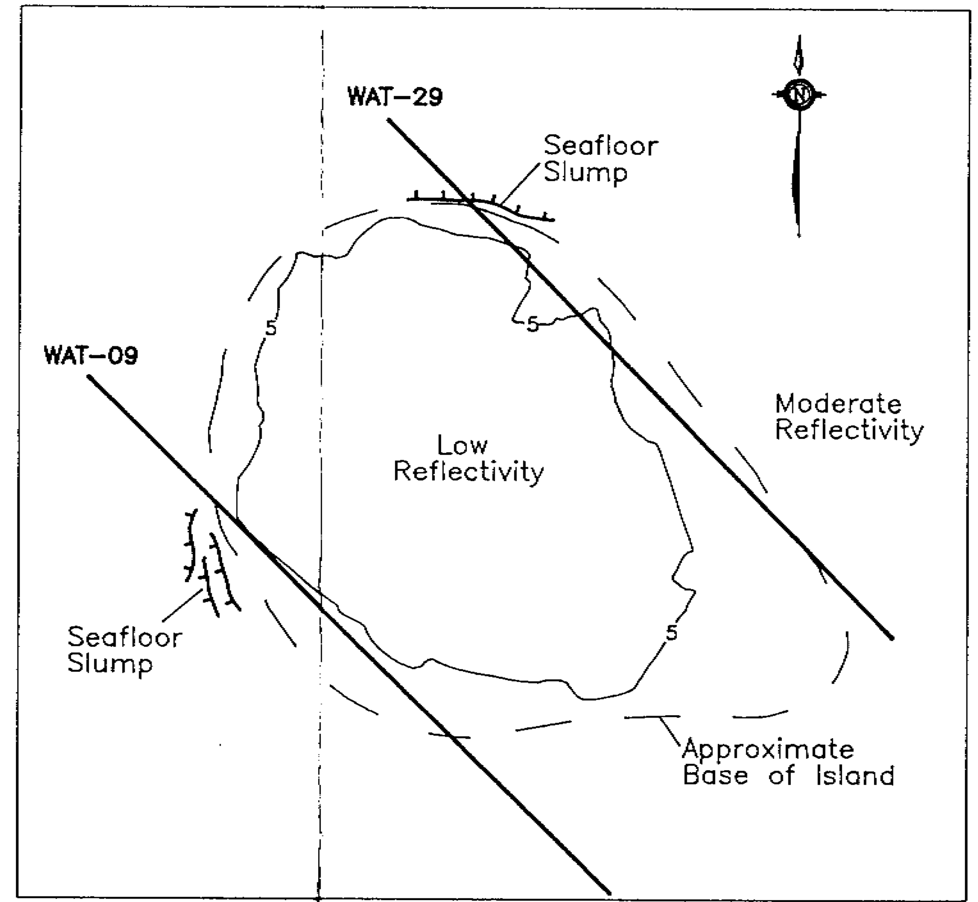
The bathymetry data are augmented by excellent quality sidescan data collected in 1990. The data coverage is limited to the surrounding seafloor and island margins with limited coverage of the island top in the north. The sidescan data has been used to prepare a diagrammatic seafloor features map (Figure 5.8.1, top right) which illustrates the location and type of seafloor features at the site.

The prominent feature of the island site is the slump scars on the western and northern site margins as shown on the diagrammatic seafloor features map of Figure 5.8.1 (top right). These features are displayed in Figure 5.8.2 which presents the sidescan data from lines WAT 09 and WAT 29. The slump feature on the western margin appears to be directed into the borrow pit. It is possible that the shallower water of the West Atkinson site contributes to slumping due to an increase in wave loading.

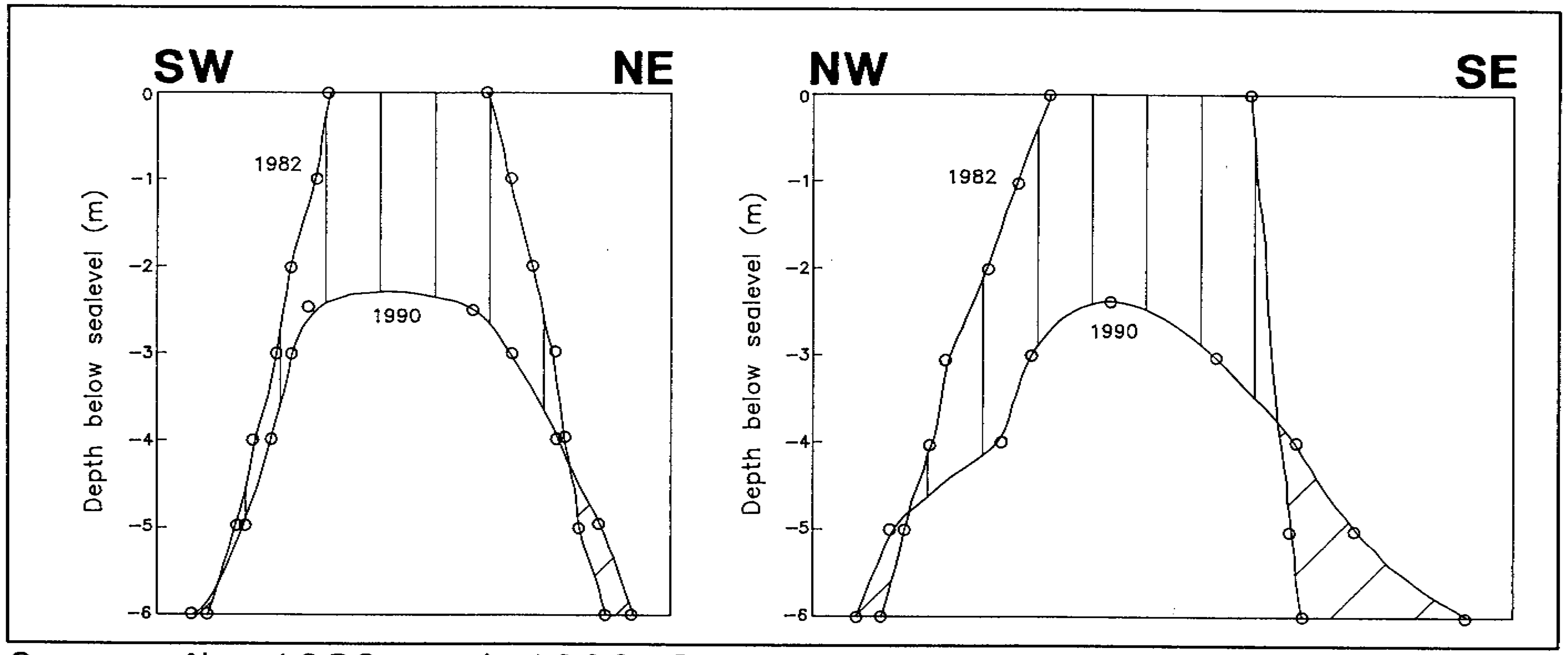
The sidescan data at the West Atkinson site (eg. Figure 5.8.2, bottom) displays a low reflectivity featureless island crest. The seafloor surrounding the island is also of low reflectivity characterised by a general absence of scours. Numerous point reflectors occur on the seafloor around the island. These features may be attributed to partially buried scour berms or coarser material loss from the suction dredge during borrow pit excavation.



1982 and 1990 Bathymetric Contours



Diagrammatic Seafloor Features Map



Composite 1982 and 1990 Cross Sections

WEST ATKINSON L-17 ISLAND SUMMARY Scale 1:7500

FIGURE 5.8.1

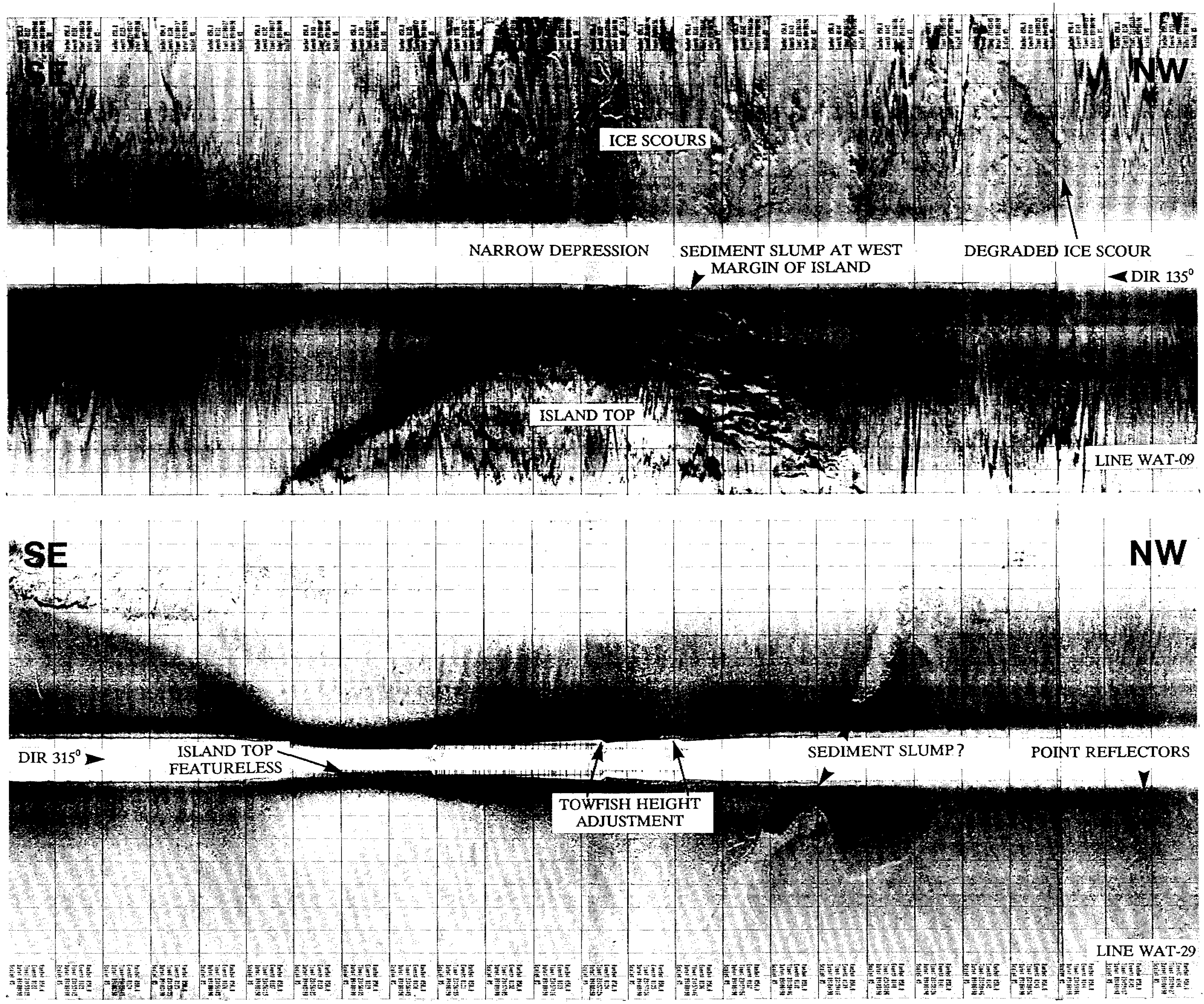


Figure 5.8.2 Sidescan data (Lines WAT 09 and WAT 29) displaying seafloor features characteristic of the L-17 island and surrounding seafloor.

FIGURE 5.8.2

5.9 Itiyok I-27

The Itiyok island was constructed was constructed by Esso in the 1982 open water season on a sandy seabed in 15.0m of water. The sacrificial beach required 1,943,000m^3 of sand fill dredged from an on onsite borrow pit. The island had a 108m diameter working surface, 4.5m of freeboard and 560m diameter base. The slopes were constructed at 9H:1V. The island was abandoned in 1983. The island has undergone submergence since abandonment to reach to minimum depths of -3.7m (1989) and -4.0m (1990).

5.9.1 Island Morphology

Hydrographic surveys have been conducted at the island site in 1982, 1984, 1989 and 1990. The 1982 and 1984 surveys appears to have been completed upon completion of island construction and one year after island abandonment, respectively. The coverage of the island in these programs consisted of a regular star pattern. The 1982 survey was limited to water depths greater than 2.0m and locally greater than 4.0m. The coverage in the 1984 programs was limited to water depths greater than 5.0m and locally in the south to water depths greater than 8.0m.

Both the 1989 and 1990 surveys provide full coverage on the island top, margins and surrounding seafloor. The 1989 survey lines were acquired as a series of north-south oriented subparallel lines approximately 50m in spacing and two east-west tie lines. The 1990 survey was completed as a grid of east-west lines which a nominal spacing of 50m and three north-south tie lines with a 120m line spacing.

<u>Plan View</u>
The submerged portion of the 1982 island appears generally concentric. This concentric form has not changed by the summer of 1984 approximately one year after abandonment. This contrasts other islands (Alerk and West Atkinson) were the island faces become sharp and planar shortly after abandonment.

Whereas the 1982 and 1984 island contours describe a concentric form by 1989 the island appears is non-concentric. The edge of the island in the north and northwest quadrants of the site is characterised by a broad gentle curvature. In other quadrants the island is more angular in shape with sharper planar faces best developed in the south and east. The change in island shape corresponds to a transition in the seafloor gradient. The gradient of the island's face increasing from 1:20 in the northwest to 1:6 in the south.

<u>1982/1984 Contour Comparison</u>
The 1982 and 1984 maps allow assessment of changes in the deeper water sections (greater than 8m) of the submerged island form which occurred over an 22 month period between the fall of 1982 and the summer of 1984. We are limited to assessing the deeper water as this is the only area in which contiguous coverage exists for both 1982 and 1984.

The location of the 1982 and 1984 10m contour has been compared to determine the maximum measurable distance of sediment transport between these to years. The 6m contour is the best level to evaluate at the Itiyok Site as full coverage of this water depth is obtained in the 1982 and 1984 surveys. This comparison suggests that sediment has begun being transported toward the southeast.

1989/1990 Bathymetry Comparison

The island morphology appears very similar between 1989 and 1990. However in this period the elevation of the island crest has increased locally from less than 4m to greater than 4m indicating ongoing island erosion. The change in elevation of the island top observed at Itiyok between 1989 and 1990 is also observed the Issungnak O-61 island.

By overlying the 1989 and 1990 charts the change in the seafloor topography in this 1 year period can be estimated and the area of sediment erosion and accumulation can be distinguished. This comparison suggests an area of minor sediment accumulation exists in the south. The west, northwest and north margins remain appear to be unchanged between the 1989 and 1990 surveys. The location of the 1989 and 1990 10m contour has been compared to determine the average measurable distance of sediment transport between these to years. This comparison indicates sediment has been transported approximately 12m south between 1989 and 1990.

The eastern margin of the Itiyok island differs locally from the 1989 and 1990 surveys. The difference occurs in the area of a prominent contoured spur displayed on the 1989 chart. This feature is located between survey lines and is very likely a contouring artifact on the 1989 data set.

Profile View

Figure 5.9.1 (lower left and centre) displays two composite 1982 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Itiyok island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1982 and 1990, southwest - northeast, profile (Figure 5.9.1, bottom left) appear symmetric with a consistent slope on both island faces. This composite profile indicates sediment depletion over the crest of the island. A significant, and uniform, accumulation of sediment exists along the southwest and northeast margins of the island. The anomalous depression, near the northeast edge of the 1990 island profile, is described in detail in Section 5.9.3, below.

The composite 1982 and 1990, northwest - southeast profile (Figure 5.9.1, bottom center), displays depletion over the crest of the island and along the northwest margin of the island. A major area of sediment accretion occurs on the southeast inclined island face. A very minor area of accretion occurs at the base of the northwest inclined face below 13m water depth.

Contour Comparison 1982/1990

The location of the 1982 and 1990 7m contour has been compared to determine the maximum measurable distance of sediment transport between these to years. This comparison indicates sediment has been transported up to approximately 100m southeast between 1982 and 1990. In contrast the 7m contour has eroded approximately 40m in the northwest. A comparison of the 1984 and 1990 7m contour yielded similar results as very little change was detected between 1982 and 1984.

Sediment Depletion/Accretion Map

The long term changes in island morphology are evaluated by overlaying the 1982 and 1990 bathymetry charts (Figures 5.9.1, upper left and center). The change in seafloor topography between these two periods allows the areas of sediment erosion and accumulation to be identified. Figure 5.9.1 (lower right) indicates a major zone of sediment depletion over the island crest and along the shallower section of the northwest margin. The area of greatest accretion is shown toward the southeast with significant accretionary zones on the southwest and northeast island faces. The deeper section of the northwest margin (water depths > 10m) is characterised as an area of immeasurable sediment loss or gain.

The areas of sediment accumulation correspond to the margins of the island which are relatively steep and planar best developed in the south and east. The change in island shape corresponds to a transition in the seafloor gradient.

5.9.2 Seafloor Features

A diagrammatic seafloor features map is produced for this site as Figure 5.9.1 (upper right). A zone of intense ice scouring exist on the east and north of the island side. Although these scours appear to abruptly terminated at the island margins of the island isolated scours are detected on the top of the Itiyok island. Sidescan data from an east-west cross section, Figure 5.9.2 (ITI-04), displays the scouring pattern characteristic of Itiyok. Few scours are present on the west and south sides of the island.

The south margin is anticipated to be the site of a major sediment accretion zone based on the bathymetry analysis. This margin is characterized by abundant high reflectivity bedforms visible on sidescan data and planar sloping surface on the bathymetry data.

An anomalous pit feature is observed on the 1990 Itiyok bathymetry data near the northeast edge of the island. This feature is discussed below.

5.9.3 Comparison of 1989/1990 Sidescan Data at Itiyok I-27

The Itiyok island morphology appears very similar in 1989 and 1990. However in this period the minimum elevation of the island crest has increased locally from less than 3.7m, to 4m, indicating ongoing island erosion. The change in elevation of the island top observed at Itiyok between 1989 and 1990 is also observed the Issungnak O-61 island.

All contiguous 1989 and 1990 sidescan lines in the vicinity of anomalous seafloor features, and geometric targets indicative of man-made objects, were checked. Three areas where identified to be of particular interest and are presented below.

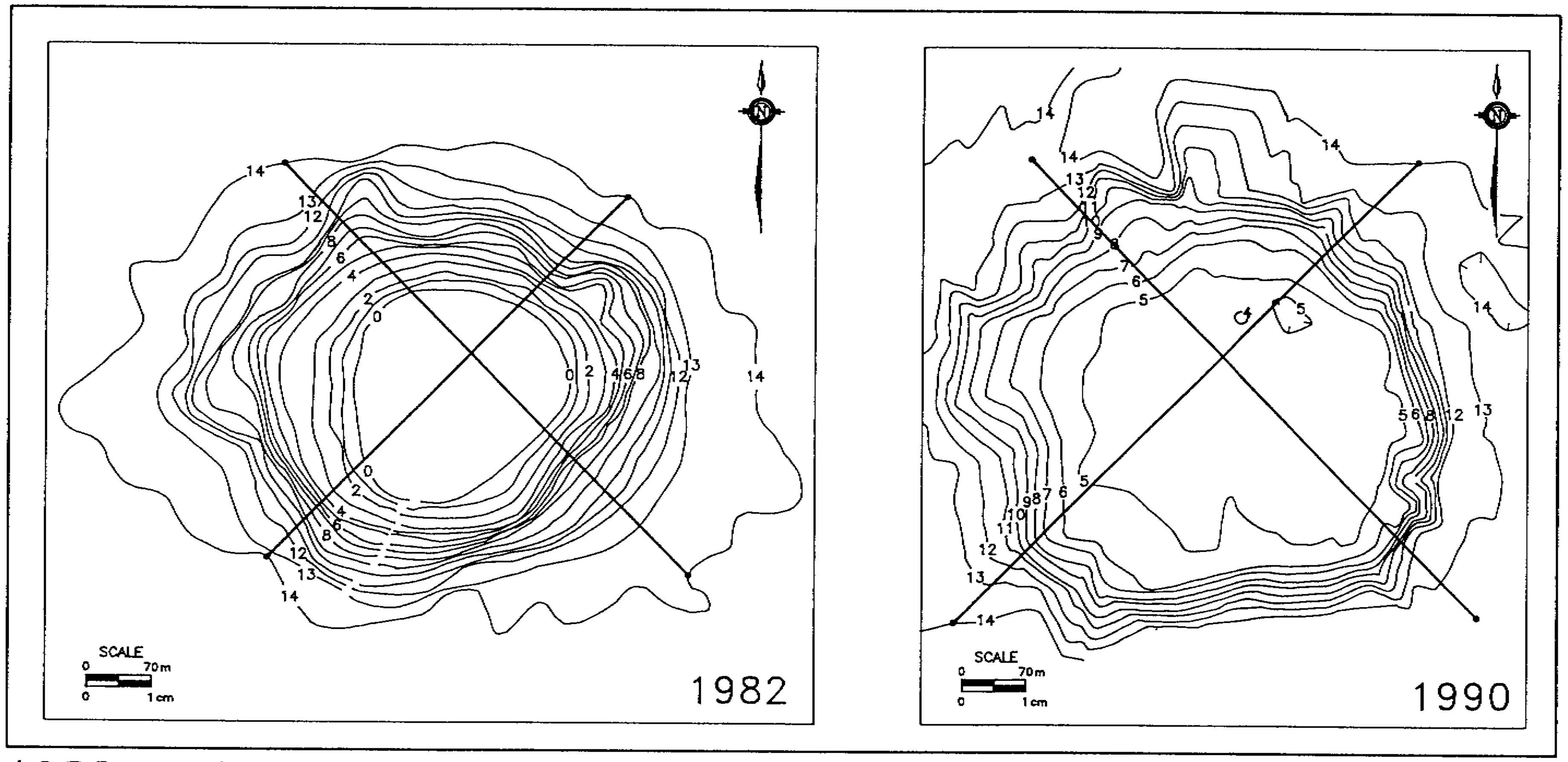
Areas 1 occurs on the northeast edge of the island. An anomalous seafloor depression occurs in this area and was intersected on three lines 1990 survey lines. These three line profiles are presented in Figure 5.9.3 and display a depression up to 2m in depth and approximately 30m in diameter. The corresponding 1989 bathymetry records do not display this feature suggesting it was formed in between 1989 and 1990.

This feature may be an ice grounding pit. Ice scours are observed on the top of the Itiyok island approximately 150m to the southwest of the pit feature. No ice scours are observed on the sidescan in association the pit.

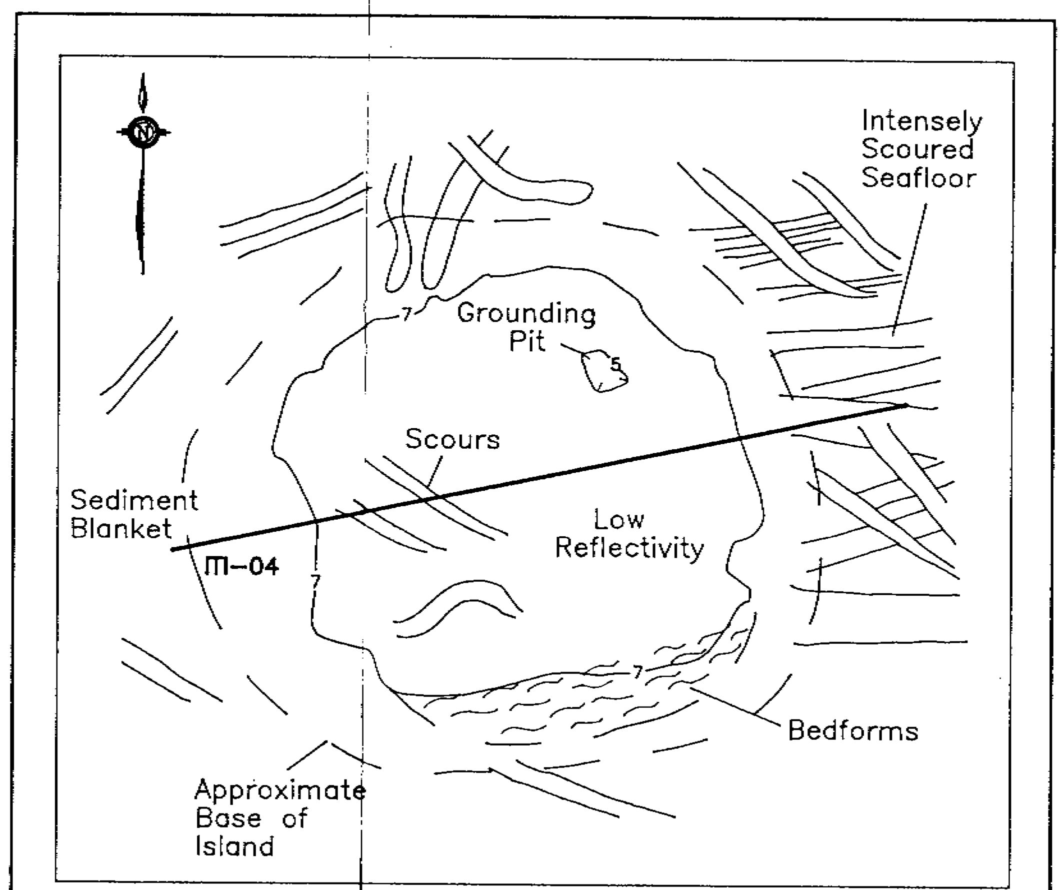
An alternate explanation is that this depression is the result of a sediment collapse or sediment boil. The proximity of this depression to the north margin of the island is consistent with this explanation. The north side of the island would be subjected to the greatest wave loading which may increase the pore pressure in the island and trigger sediment failure.

Area 2 occurs at the south edge of the Itiyok island top (Figure 5.9.4). The 1989 sidescan data in this area displays a small piece of debris which may be a cable. The 1990 sidescan from the corresponding area of debris. However in 1990 this piece of cable is surrounded by numerous other highly reflective geometric targets. This suggests that Area 2 represents a zone of erosion between 1989 and 1990.

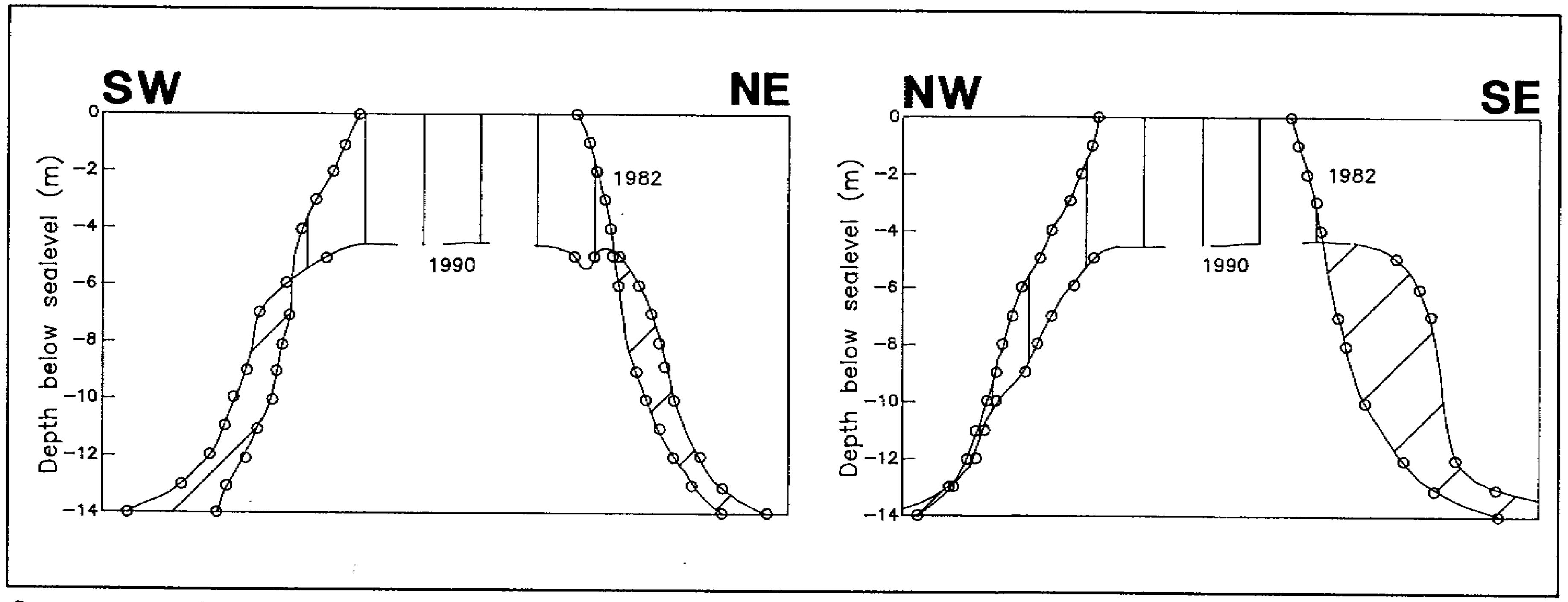
Area 3 occurs along the south inclined face of the Itiyok island (Figure 5.9.4). Bathymetry analysis indicates that this is the site of long term sediment accumulation. The 1989 and 1990 sidescan display two corresponding areas of debris. No measurable change in this debris could be seen between the 1989 and 1990 sidescan in this area.



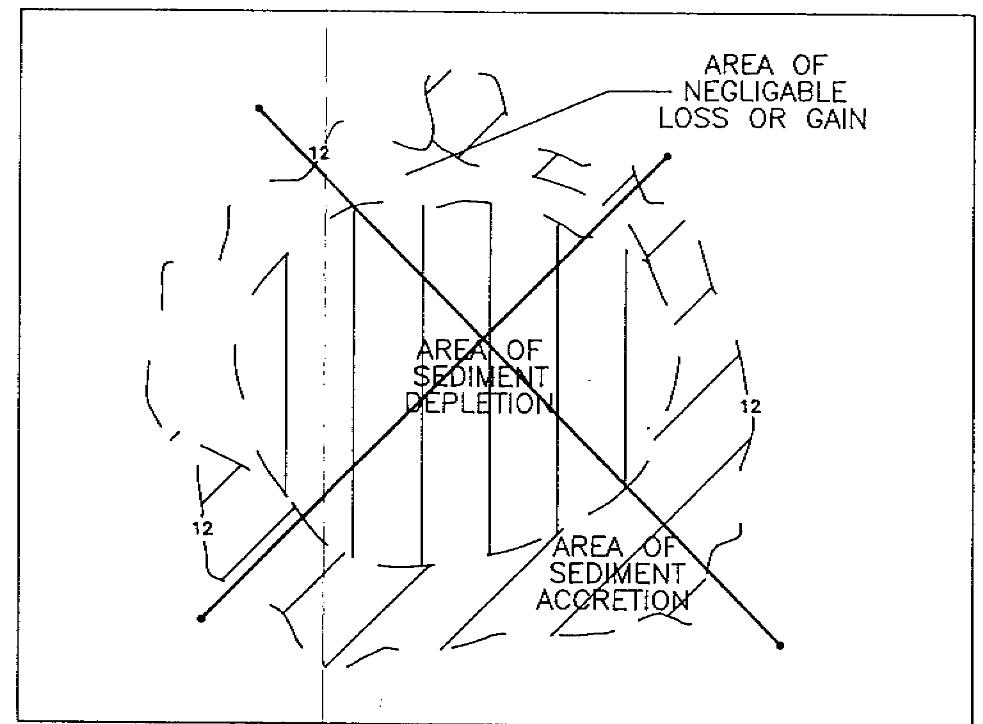
1982 and 1990 Bathymetric Contours



Diagrammatic Seafloor Features Map



Composite 1982 and 1990 Cross Sections



Sediment Depletion/Accretion Map

ITIYOK I-27 ISLAND SUMMARY Scale 1:7000

FIGURE 5.9.1

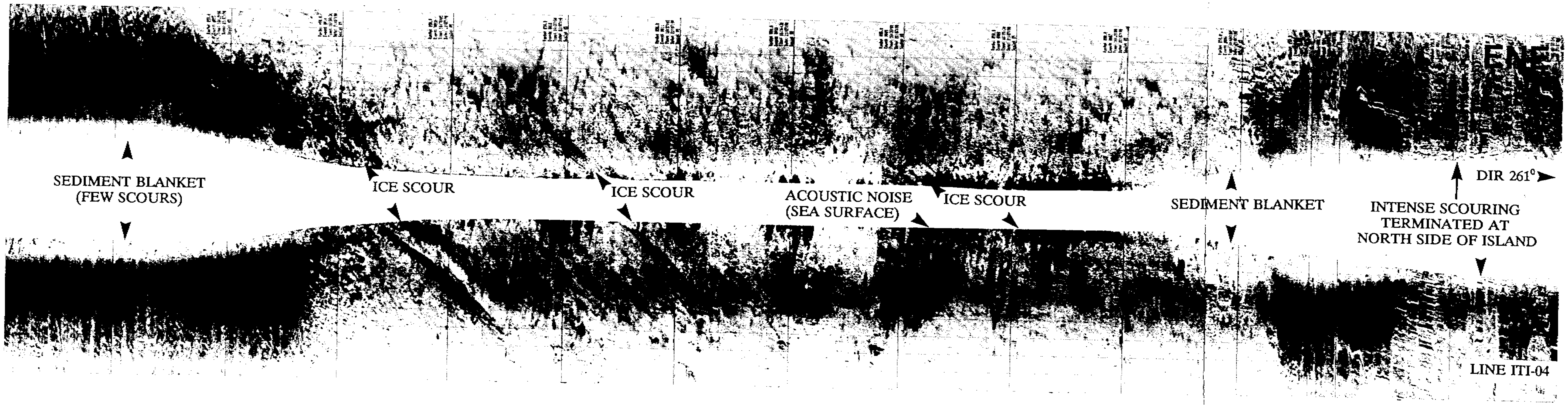


Figure 5.9.2 Sidescan data (Line ITI 04) Displaying Seafloor Features characteristic of the I-27 island and surrounding seafloor.

FIGURE 5.9.2

FIGURE 5.9.3

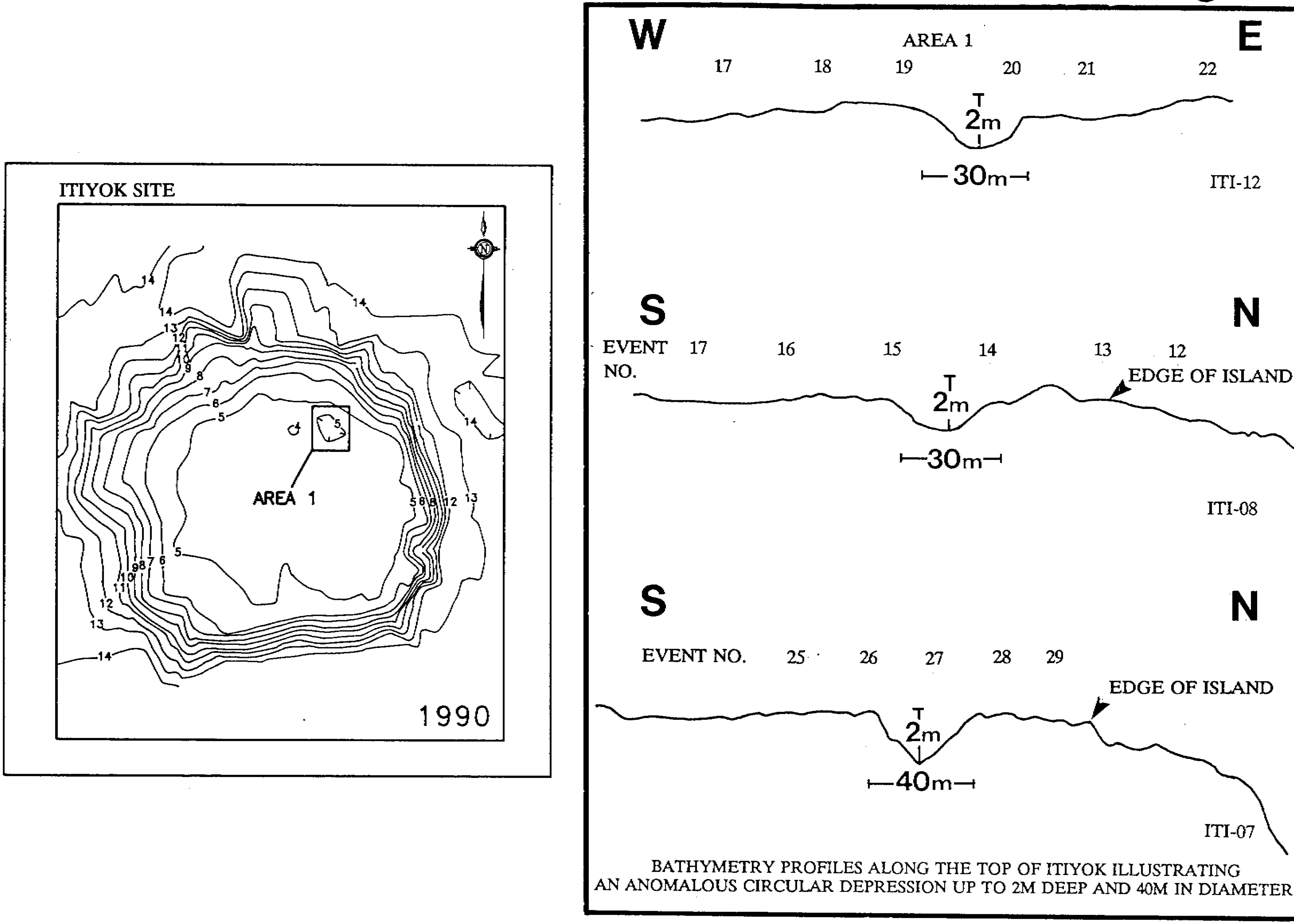
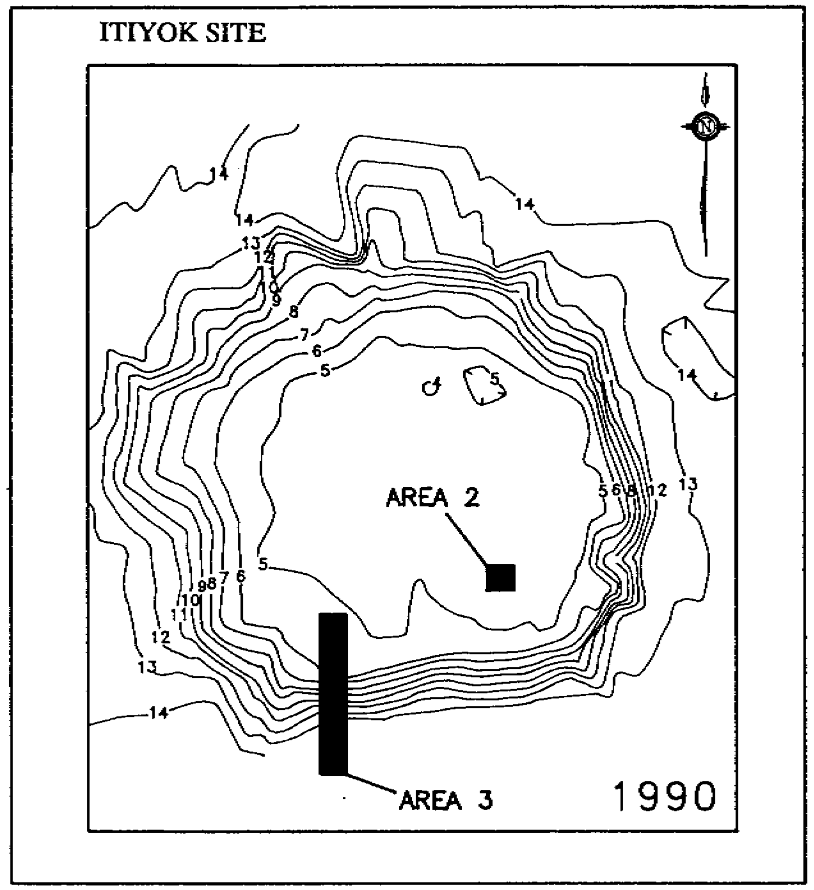


Figure 5.9.3 1990 site bathymetry map and 1990 echosounder records (Lines ITI 07, ITI 08 and ITI 12) displaying an anomalous depression on the northeast edge of the Itiyok island.



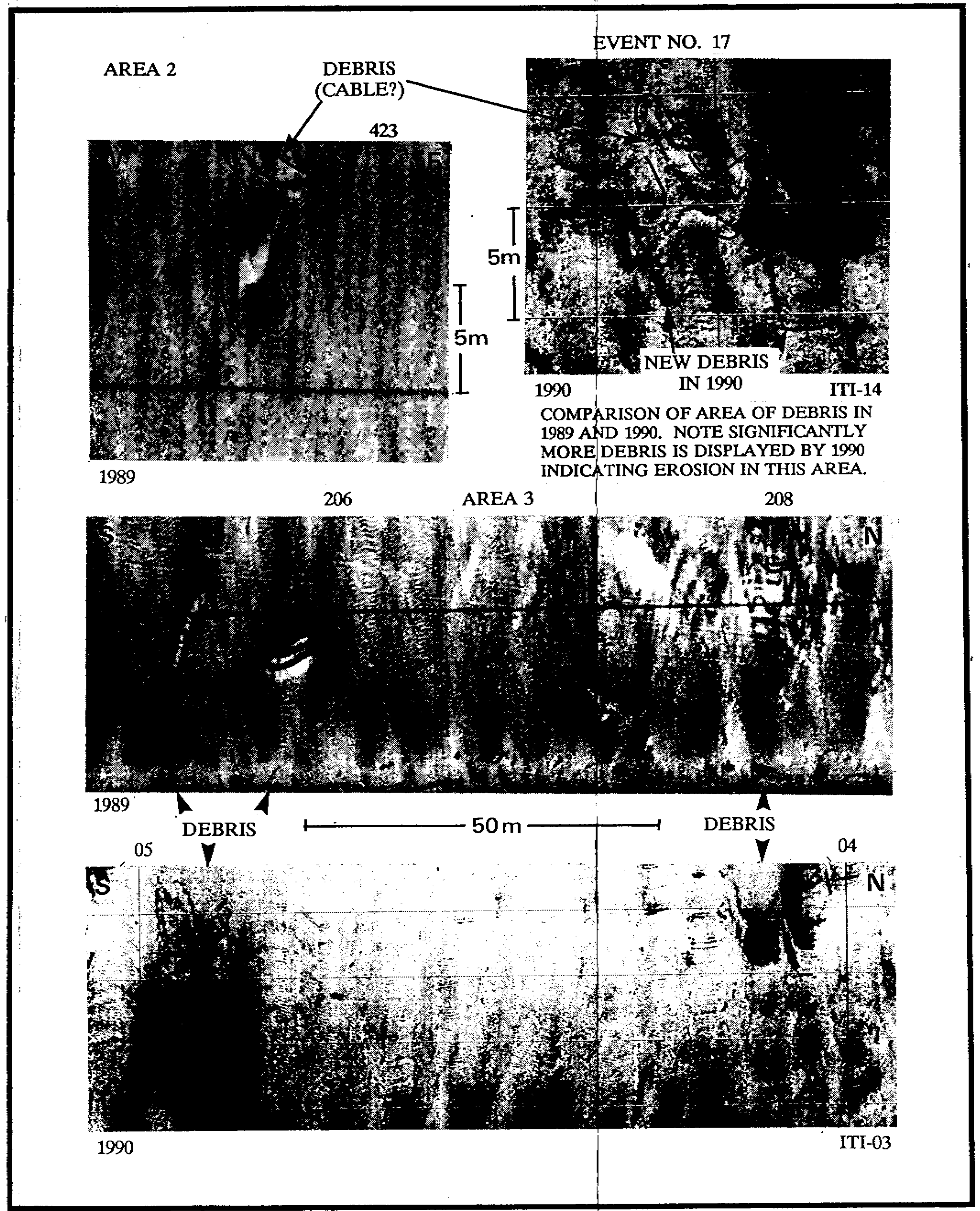


Figure 5.9.4 Comparison of 1989 and 1990 sidescan data collected over two area of the I-27 island. Area 1 and 2 are located on the south top of the island and along the south inclined face, respectively.

FIGURE 5.9.4

5.10 Nipterk L-19

Nipterk L-19 was a sacrificial beach (sand and gravel) island built by Esso in the 1983-84 open water seasons. Located in 13.0m of water in the Ikit Trough, the seabed consisted of soft clay overlying firm clay. Ukalerk sand and Issigak sand and gravel totalling 1,000,000m^3 was hopper placed to create an island with a 110m diameter working surface at a 5m freeboard, a 170m waterline diameter, and 370m diameter base area. Slopes were constructed at 3H:1V above the waterline, while the beach and base had 8H:1V and 4H:1V slopes, respectively. Two wells were drilled from this platform over the 1984-85 winter and spring seasons.
The island has undergone submergence since abandonment to reach to minimum depths of -2.0m (1990).

5.10.1 Island Morphology

Hydrographic surveys have been conducted at the island site in 1984 and 1990. The 1984 survey was conducted in the fall of 1984 and appears to represent the island at the conclusion of island construction. The coverage of the island in this programs consisted of a radial pattern. The 1984 survey provided thorough coverage to the island from the beach line to the surrounding seafloor using a combination of echosounding in water depths greater than 2m, lead line measurements in water depth between 0-2m and laser range measurements to calculate the beachline.

The 1990 survey lines were acquired as a series of northwest-southeast oriented, subparallel lines, approximately 50m in spacing, and four northeast-southwest tie lines. The coverage in the 1990 programs was largely limited to water depths greater than 3.0m. A reconnaissance survey of the island using a launch established the minimum water depth at the island top at approximately 2.0m.

<u>Plan View</u>
The 1984 island is roughly concentric with a gentler northeast, east and southeast margin and a steeper northwest, west and southwest margin (Figure 5.10.1, top left). This contrasts other islands were the island were the as constructed faces appear of uniform gradient.

A comparison of the 1984 and 1990 bathymetry data indicate the island form has changed significantly in the intervening period. The 1990 submerged island (Figure 5.10.1, top center) is strongly elongated in plan view with a northwest-southeast oriented long axis and a northeast-southwest oriented short axis. At the 5m contour the ratio of these axis is approximately 1:2. The direction of elongation corresponds to a strong 2D asymmetric with a gentle (1:23) northwest inclined face and a much steeper (1:4) southeast inclined face. A distinct closed bathymetric high occur in the southeast quadrant of the island. This plan and profile island form may be characteristic of island migration patterns in the early years of submergence. The elongation and southeastward shoal observed at the Nipterk L-19 site is also noted at the Netserk F-40 site.

Profile View

Figure 5.10.2 (lower left and centre) displays two composite 1984 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Nipterk island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1984 and 1990, southwest - northeast, profile (Figure 5.10.2, bottom left) appear symmetric with a consistent slope on both island faces. This composite profile indicates sediment depletion over the crest of the island. A minor accumulation of sediment exists along the northeast and southwest margins of the island. On some segments of these margin no detectable change exists between the 1984 and 1990 profiles.

The composite 1982 and 1990, northwest - southeast profile (Figure 5.10.2, bottom center), displays depletion over the crest of the island and along the northwest margin of the island. A major area of sediment accretion occurs on the southeast inclined island face. Along the deeper (>9m) segments of the northwest margin no detectable change exists between the 1984 and 1990 profiles.

Contour Comparison

The location of the 1984 and 1990 7m contour has been compared to determine the maximum measurable distance of sediment transport between these years. This comparison indicates sediment has been transported up to 230m southeast between 1984 and 1990. In contrast the 7m contour has remained relatively constant in the northwest recessing only 13m.

Sediment Depletion/Accretion Map

The sediment transport and long term changes in island morphology are evaluated by overlaying the 1984 and 1990 bathymetry charts. The comparison of the seafloor topography between these two periods allows the areas of sediment depletion and accretion to be distinguished (Figure 5.10.1, lower right). This figure indicates sediment accumulation exists in the south, southeast and east with the greatest accumulation occurring in the southeast. The major zone of sediment depletion occurs over the island crest and along the shallower section of the northwest and southeast margins. The deeper section of the northwest margin (water depths > 9m) is characterised as an area of immeasurable sediment loss or gain.

The edge of the island in the area of sediment accumulation form broad gentle curvatures. The areas of sediment accumulation occur where the island is more angular in shape with sharper planar faces best developed in the south and east. The change in island shape corresponds to a transition in the seafloor gradient.

5.10.2 Seafloor Features

A preliminary review of the sidescan data at the Nipterk L-19 island has been completed. A diagrammatic seafloor features map based on this review is presented as Figure 5.10.1 (upper right).

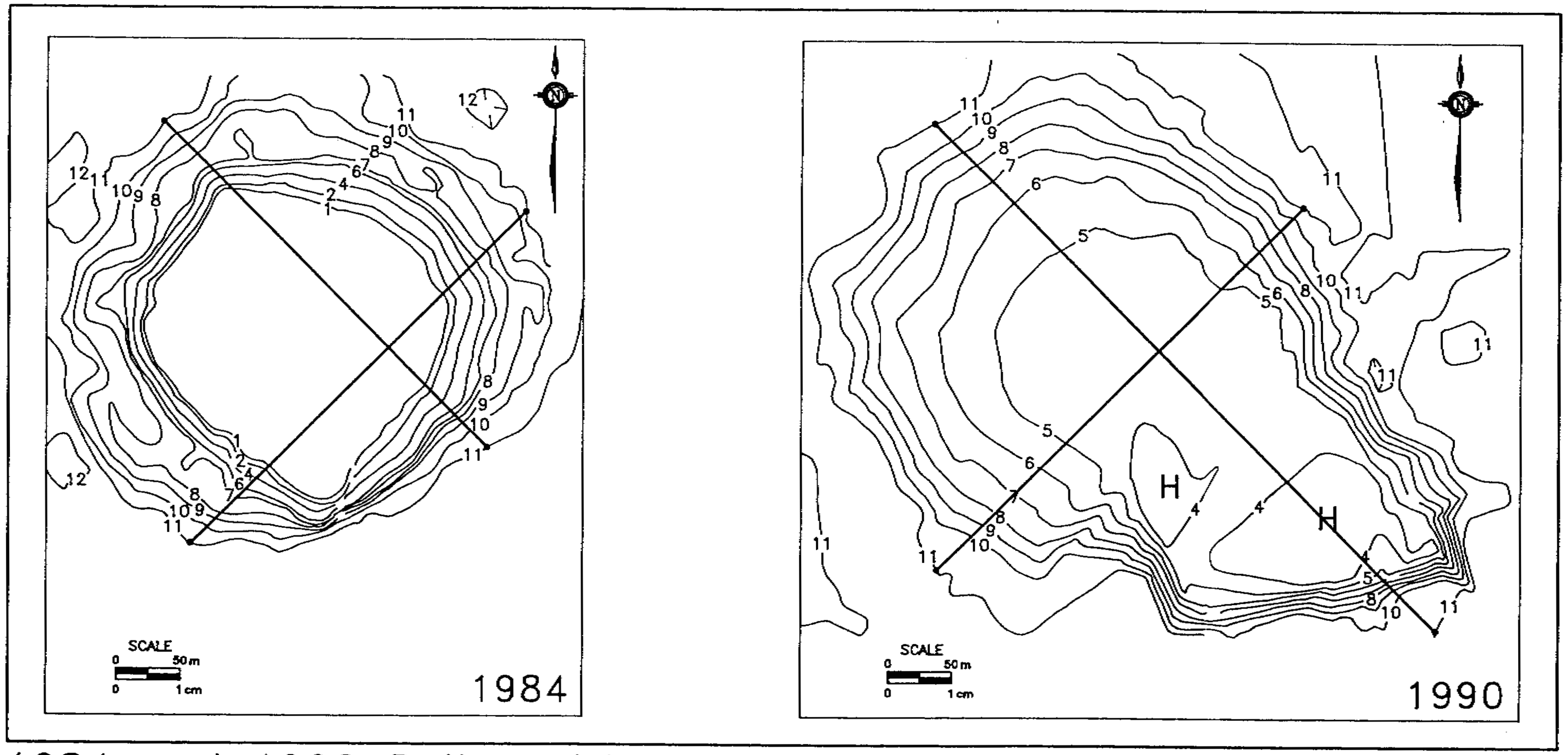
Bedforms occur on the seafloor surrounding the island particularly both in the northwest and northeast. Examples of these bedforms are shown on the sidescan data of lines NIP 8 (Figure 5.10.2, top) and NIP 9 (Figure 5.10.2, bottom) respectively. The high reflectivity of the bedforms and the long wavelength suggests that they are composed of coarse grained sediment probably sand and gravel. The sidescan data of these lines 8 displays an ice scours cutting the fields of bedforms. The timing of the survey, relative the timing of ice scouring activity, suggests these bedforms, vestiges of a major storm event, are at least one year old.

Scouring intensity on the surrounding seafloor is generally light however intense ice scouring is observed at the northeast margins of the island.

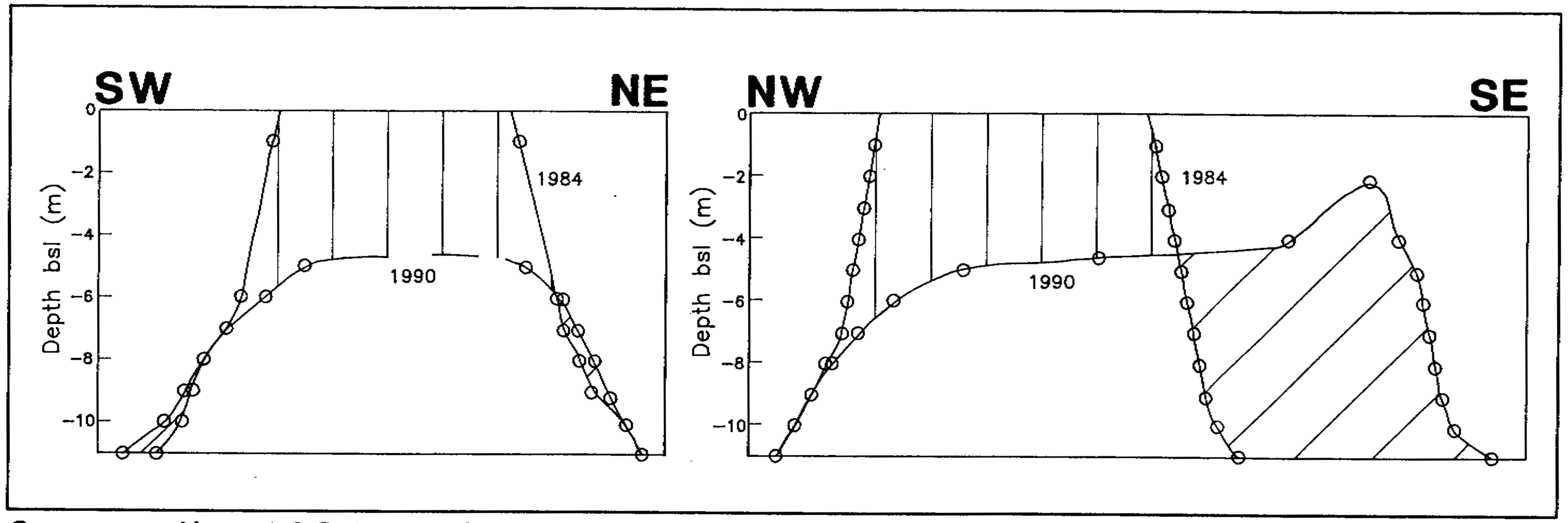
The seafloor appears to be of variable reflectivity with the island top displaying a mottled texture (Figure 5.10.2, bottom).

Areas of very high reflectivity are detected on the south margin of the island along NIP 10.

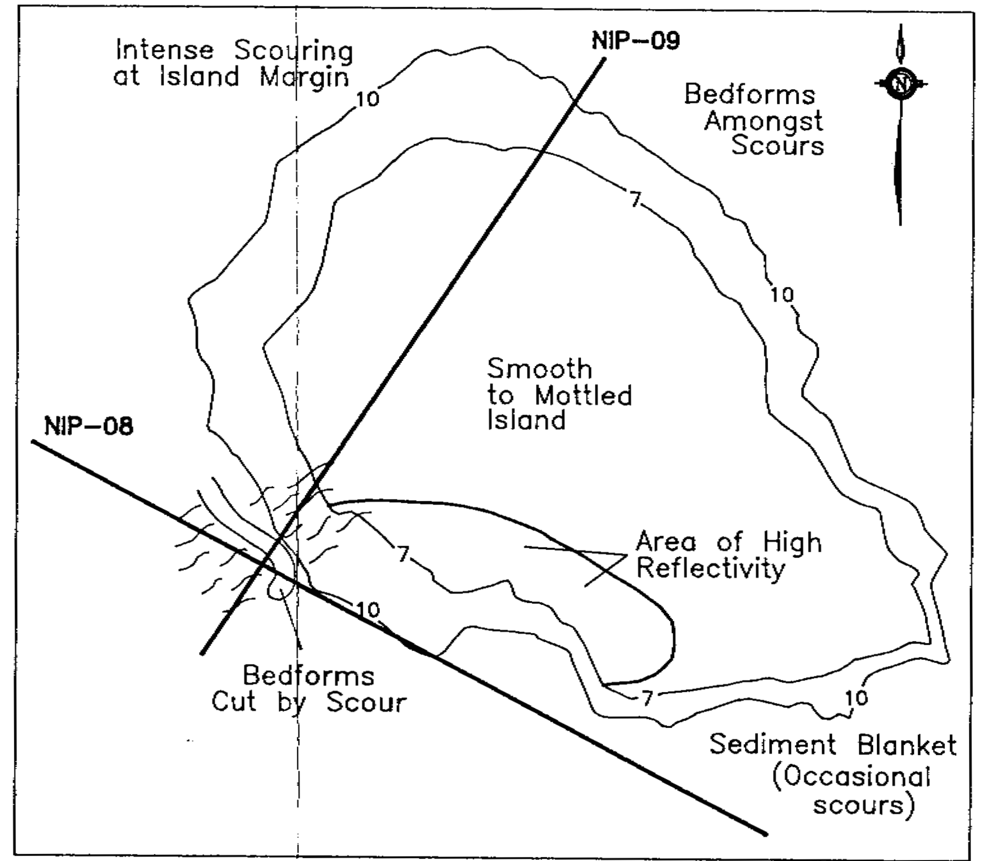
A possible sediment blanket occurs at the southeast end of the site infilling scours.



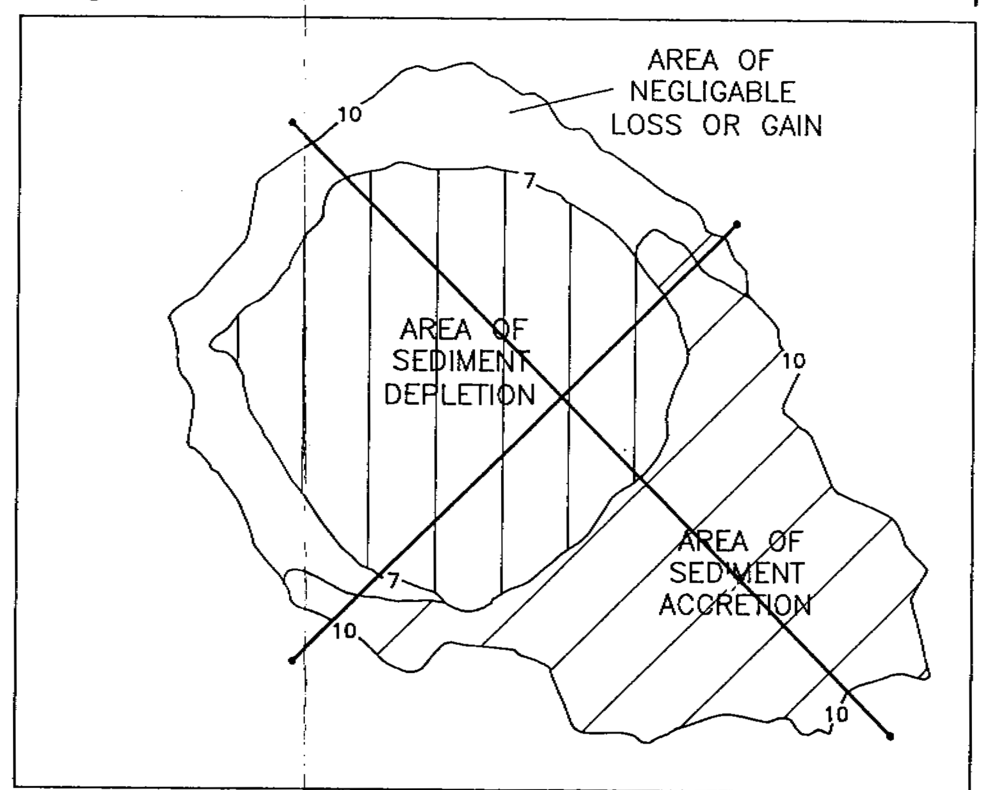
1984 and 1990 Bathymetric Contours



Composite 1984 and 1990 Cross Sections



Diagrammatic Seafloor Features Map



Sediment Depletion/Accretion Map

NIPTERK L-19 ISLAND SUMMARY Scale 1:5000

FIGURE 5.10.1

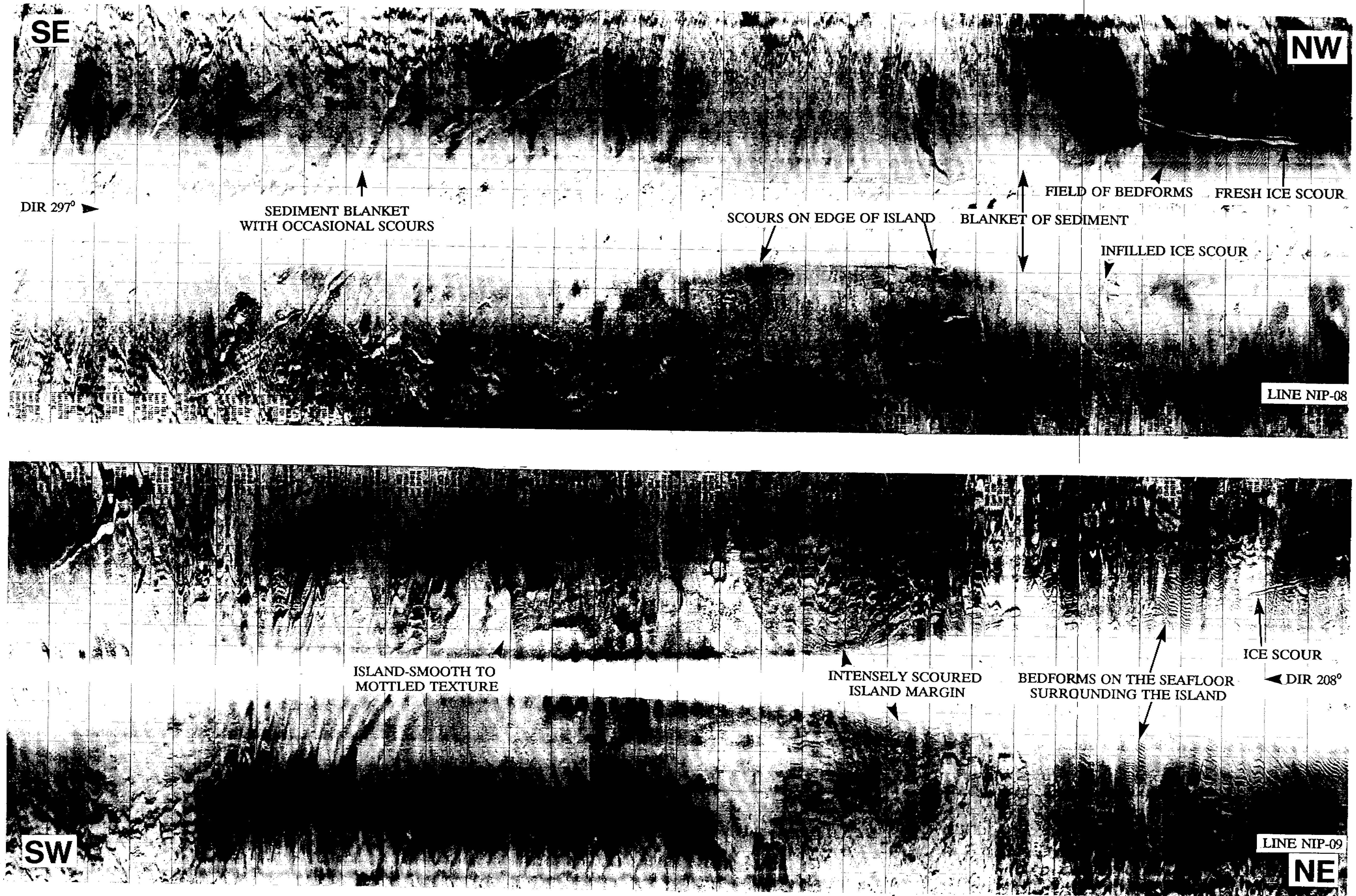


Figure 5.10.2 Sidescan data (Lines NIP 08 and NIP 09) displaying seafloor features characteristic of the L-19 island and surrounding seafloor.

FIGURE 5.10.2

5.11 Minuk I-53

Construction at Minuk started in September, 1982 and continued in the 1983 open water season. Esso built the sacrificial beach island in 14.7m of water on soft clay overlying firm clay on the Kringalik Plateau. Sand was dredged from the Ukalerk and Issigak borrow pits and hooper placed on the site. The island and drilling equipment were damaged in a severe storm in 1985. The island was repaired in the 1985 open water season and drilling was carried out in the 1985-86 winter. Requiring 2,000,000m^3 of sand and gravel, the island, when finished had a 110m diameter gravel capped working surface, a 5m freeboard and side slopes of 2H:1V. The beach sloped at 12H:1V and was protected by gravel. The island was subsequently abandoned in 1986. The island has undergone submergence since abandonment to reach to an indeterminate minimum depths.

5.11.1 Island Morphology

Hydrographic surveys have been conducted at the island site in October 1985, August 1987 and July 1990. The survey coverage for each of these years is incomplete and there is a general absence of contiguous multi-year coverage.

In summary the 1985 survey is confined to the eastern side of the island. In contrast the 1987 survey is confined to the western side of the island. The 1990 coverage is the most complete with coverage everywhere except the east central and southeast corner of the site. The lack of contiguous multi-year bathymetry coverage precludes evaluation of long term changes in island morphology.

Plan View
Figure 5.11.1 (top left) displays the 1990 Minuk island bathymetry. The dashed contours on the southeast corner of the island are inferred.

The northeast and east margins of the Minuk island are generally concentric, rounded and of gentler slope. In contrast the southwest, south, east and northeast margins are steeper and more planar.

Profile View
Figure 5.11.1 (lower left and centre) displays 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Minuk island. These profiles display the general profile form of the island.

The southwest - northeast profile (Figure 5.11.1, bottom left) appear symmetric with a consistent slope on both island faces.

The northwest - southeast profile (Figure 5.11.1, bottom center) displays a 2D asymmetry. The northwest margin appears very similar to the southwest and northeast margins with the exception of an anomalous closed bathymetric depression on the foot of this slope. The southeast inclined island face appears to be elongated at the base, suggesting an area of sediment deposition.

Contour Comparison

At other islands the location of the specific contour has been compared to determine the maximum measurable distance of sediment transport between successive years. This comparison is possible at the west side of the Minuk site where 1987 and 1990 survey data are coincident. The 7m contour has recessed a maximum of approximately 23m in the northwest corner of Minuk between 1987 and 1990. This is consistent with the sediment erosion pattern inferred from the island morphology.

Sediment Depletion/Accretion

Based on the analysis of the islands in this study a strong relationship exists between island morphology (plan and profile) and the dominant long direction of sediment transport. In general islands remain broad and concentric along the margins which are stable or undergoing the least sediment erosion and the island faces become more steeper and planar in the areas of sediment accumulation. By applying these concepts to Minuk the dominant sediment direction can be estimated. The Minuk island morphology suggests the direction of sediment transport is toward the south and east. This is based on the general steepening of the seafloor gradient, the elongation of the island in plan view and the presence of planar slopes along the south and east island margins. The area of sediment depletion is interpreted to occur in the west, northwest and north based on the concentric form and gentler slope of the seafloor in that area.

5.11.2 Seafloor Features

A review of the sidescan data at Minuk was conducted and a diagrammatic seafloor features map prepared (Figure 5.11.1, top right). This diagrammatic displays the location of two perpendicular sidescan lines crossing the Minuk island. This lines are presented as Figure 5.11.2 (top MIN 06 and bottom MIN 07).
The island crest is generally featureless and of low acoustic reflectivity. In slightly deeper water, toward the northwest inclined island face, the seafloor displays abundant small scale, 2D, sand ripples (Figure 5.11.2, bottom). The north side of the island is intensely soured with most scours terminating near the 14m contour but occasionally extending up the islands northeast inclined face (Figure 5.11.2, bottom). The site bathymetry indicates an anomalous closed depression at the northeast limit of the island. Sidescan and echosounder data indicate this depression is real and is due to a zone of severe scouring at the base of the island.
The seafloor displays a very high reflectivity at the south and north margins of the island (Figure 5.11.2 top and bottom).

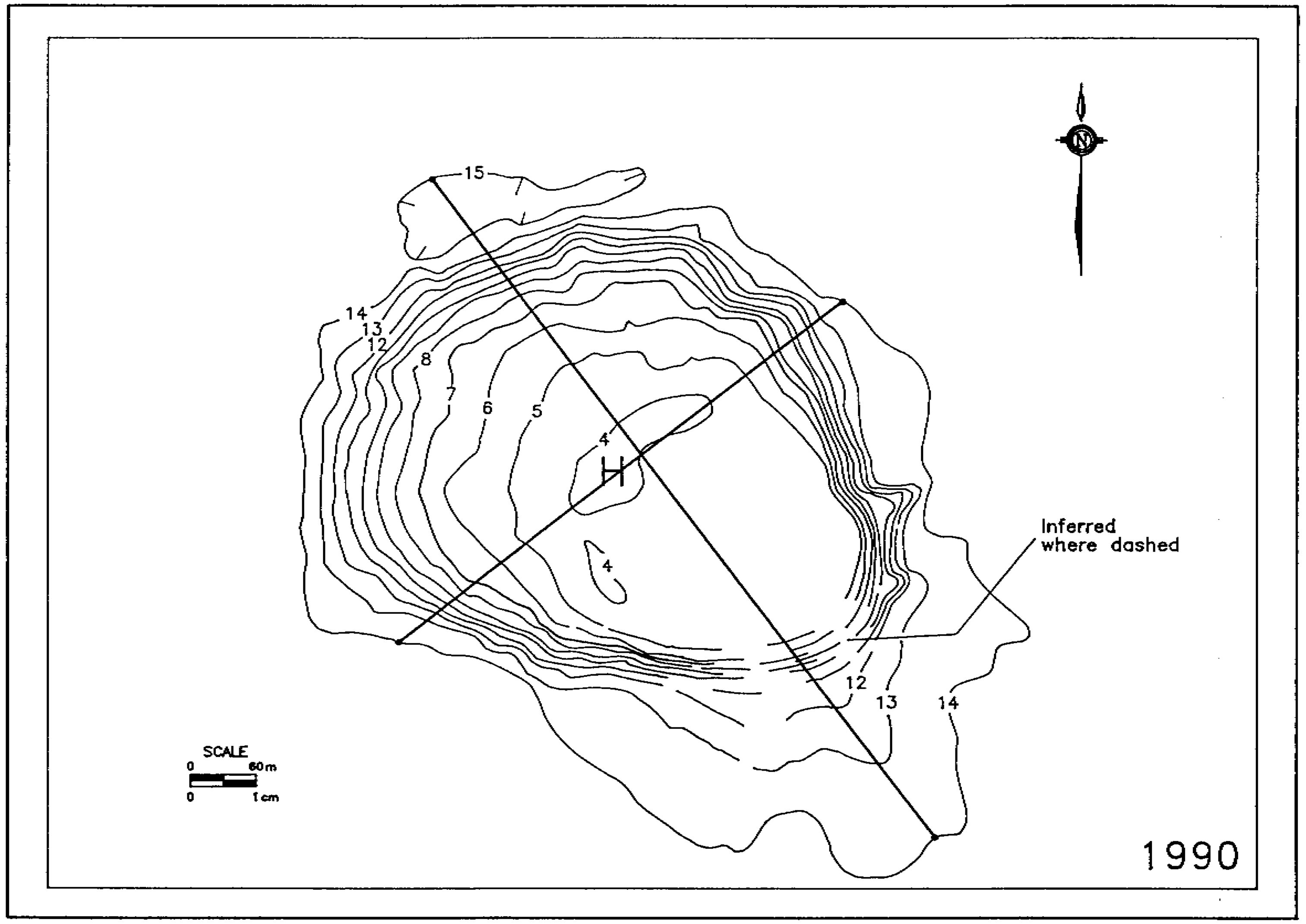
South of the island the seafloor is characterised by a low reflectivity sediment which appears to locally infill ice scours. The sharp contrast between the island sediment blanket and the intensely scoured surrounding seafloor is displayed in Figure 5.11.1 (top). This acoustic contact correlates directly to the 14m base of island contour.

Unlike the West Atkinson site no slump scars are observed on the island margin.

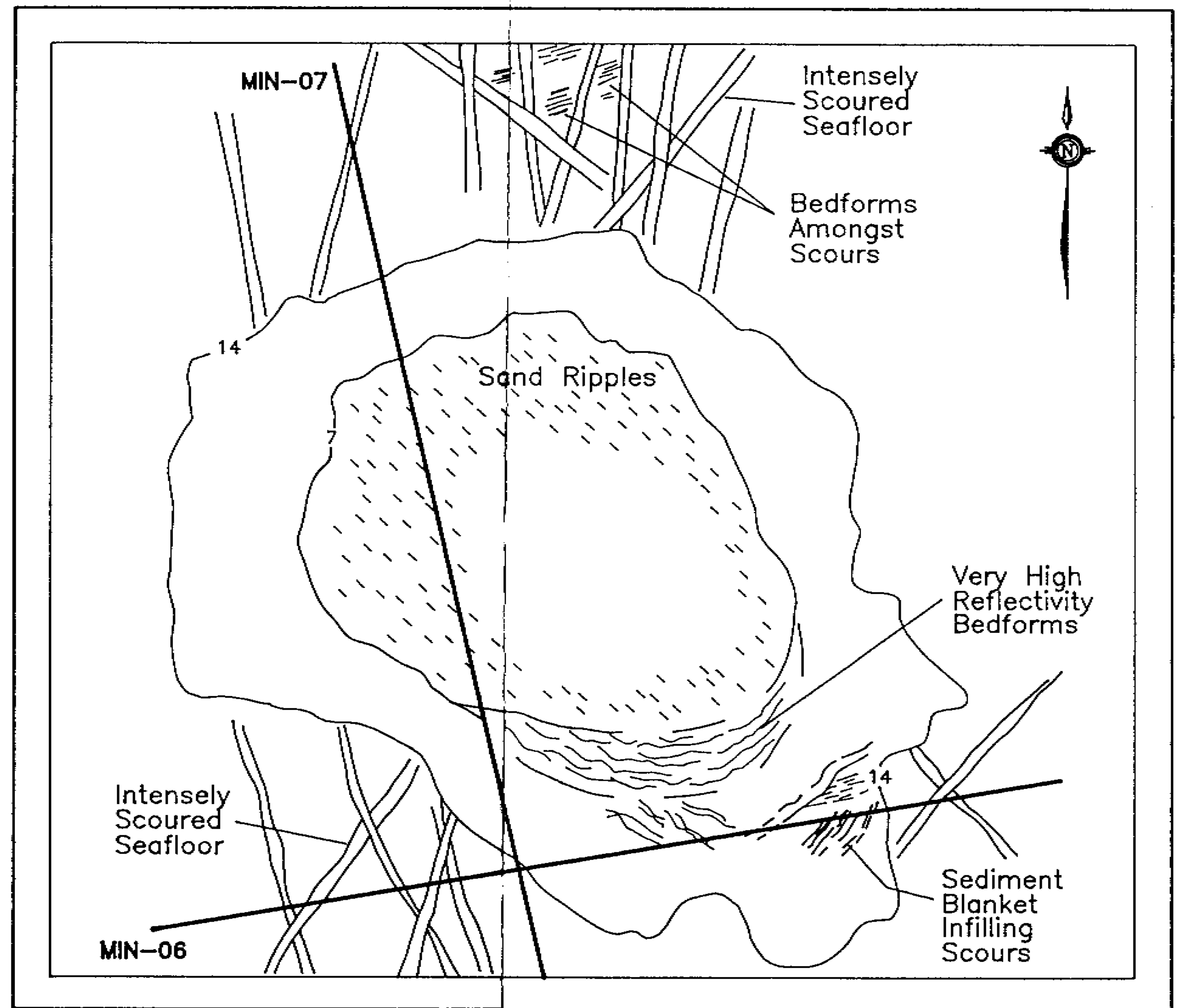
The 1990 bathymetry map indicates the island crest is awash at the southeast corner of the site. This suggests a shoal feature in this area. Early observations of the Itiyok site (ESRF, 1988) indicated the island top was awash when the water depth was approximately 2m.

The minimum water depth at the Minuk island remains uncertain due to the lack of coverage in the southeast corner of the site. Closed bathymetric occasionally occur at island margins experiencing the greatest sediment accumulation (eg. Netserk F-40 (1981), Kannerk G-42 (1990), Issungnak O-61 (1990).

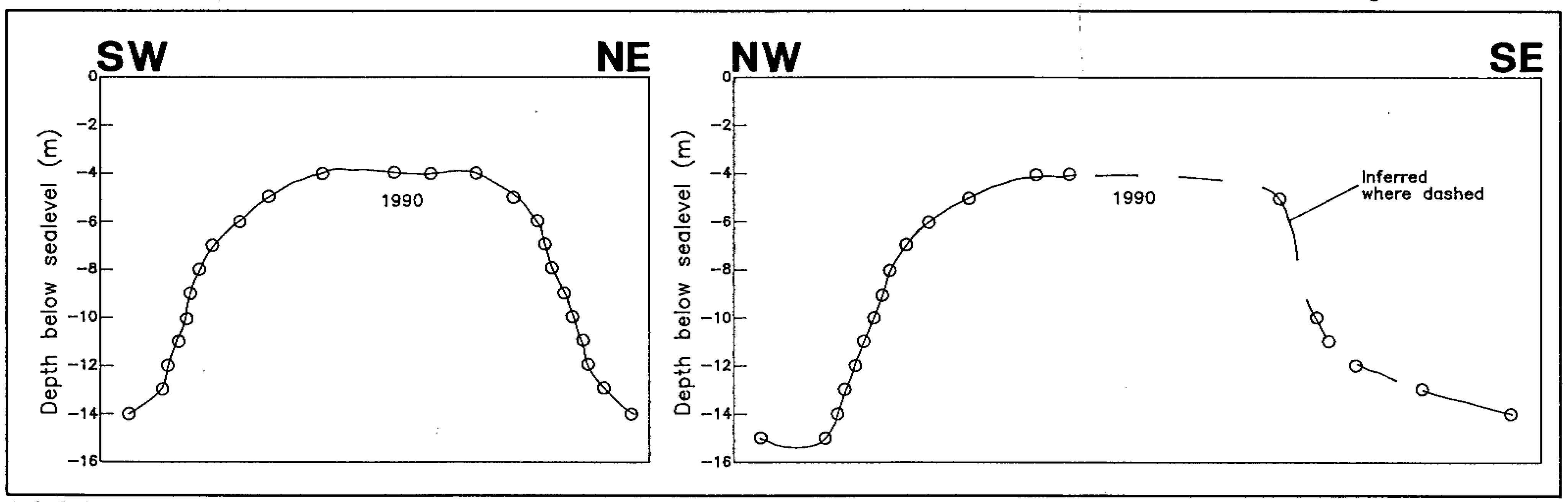
Abundant bedforms with wavelengths of approximately 0.5m occur along the base of the island amongst the ice scours on the north side of the site. The bedforms are most abundant near the north base of the island and diminish in abundance away from the island. The high reflectivity of these bedforms suggest they are composed of sand and gravel. Furthermore the presence of these bedforms on the north side of the site indicates that at least some sediment has been transported from the island and blanketed over the seafloor in this direction.



1990 Bathymetric Contours



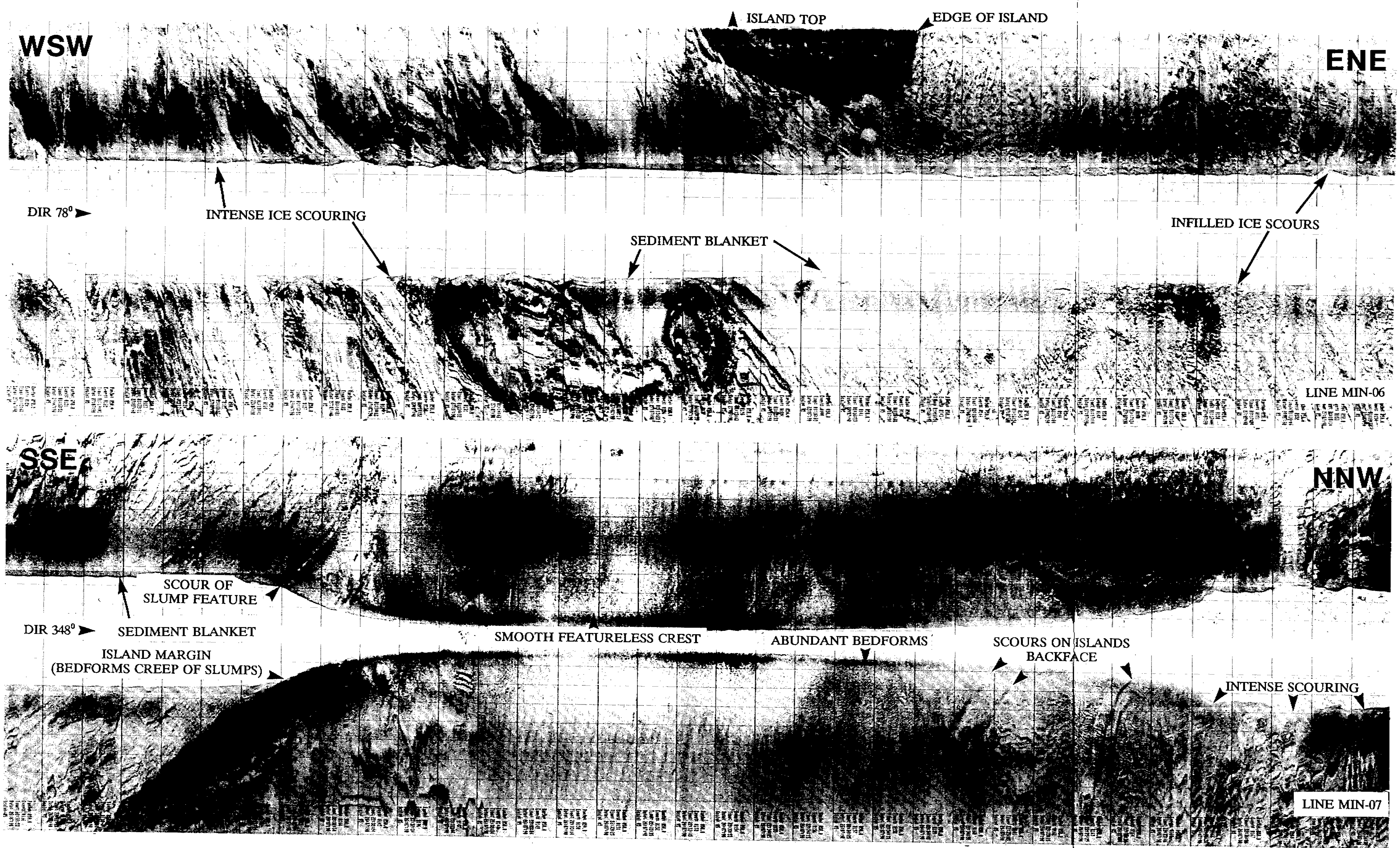
Diagrammatic Seafloor Features Map



1990 Cross Sections

MINUK I-53 ISLAND SUMMARY Scale 1:6000

FIGURE 5.11.1



WSW
ISLAND TOP
EDGE OF ISLAND
ENE
DIR 78°
INTENSE ICE SCOURING
INFILLED ICE SCOURS
SEDIMENT BLANKET
LINE MIN-06
SSE
NNW
SCOUR OF
SLUMP FEATURE
DIR 348°
SEDIMENT BLANKET
SMOOTH FEATURELESS CREST
ABUNDANT BEDFORMS
SCOURS ON ISLANDS
BACKFACE
ISLAND MARGIN
(BEDFORMS CREEP OF SLUMPS)
INTENSE SCOURING
LINE MIN-07

FIGURE 5.11.2

5.12 Arnak K-06

Arnak K-06 was constructed in 1985 as a sacrificial beach in 7.2m of water on the Akpak Plateau. The seabed consist of soft clay overlying compact sand and silty sand. The island was constructed from 700,000m^3 of sand fill dredged from an onsite burrow pit. The island, as constructed, had a working surface of 110m in diameter and with 5 metres of freeboard. The island slopes ranged from 6H:1V to 12H:1V or flatter. The island was used as a drilling program in 1986 and subsequently abandoned. The island has undergone submergence since abandonment to reach to minimum depths of -2.5m (1990).

5.12.1 Island Morphology

Hydrographic surveys have been conducted at the island site in August 1985 and 1990. The 1985 survey appears to represent the island at the conclusion of island construction. The island coverage in this programs consisted of a radial pattern which extends from the beach line to the surrounding seafloor.

The 1990 survey lines were acquired as a series of north-south oriented subparallel lines approximately 50m in spacing and a suite of eight east-west tie lines with a spacing of 100m. The coverage in the 1990 programs was largely limited to water depths greater than 3.0m with sparse coverage between the 3m and 6m isobaths. A reconnaissance survey of the island using a launch established the minimum water depth at the island top at approximately 2.5m.

<u>Plan View</u>
The 1985 island is irregular in shape (Figure 5.12.1, top left). The island is roughly concentric in the south. In contrast in the north bathymetric spurs occur particularly in the northwest and northeast. This contrasts other islands were the as constructed faces appear of uniform gradient and shape.

The 1990 bathymetry displays a larger and more uniform island (Figure 5.12.1, top centre).

<u>Profile View</u>
Figure 5.12.2 (lower right and centre) displays two composite 1985 and 1990 profiles, south southwest - north northeast and west northwest - east southeast, crossing the middle of the Arnak K-06 island.

The composite 1982 and 1990 profiles display sediment accumulation throughout the islands periphery with the greatest sediment accretion toward the southwest and southeast.

<u>Sediment Depletion/Accretion Maps</u>
The long term changes in island morphology are evaluated by overlaying the 1985 and 1990 bathymetry charts. The change in seafloor topography between these two periods allows the areas of sediment erosion and accumulation to be distinguished (Figure 5.12.1, bottom right, sediment depletion/accretion map).

A comparison of the 1985 and 1990 bathymetry data indicates the island form has changed significantly in this five year period. Specifically the island has been enlarged and flattened suggesting sediment has been eroded from the island top and deposited around the entire island periphery (Figure 5.12.1, bottom right). Although sediment has been deposited radially the area of greatest sediment accumulation have developed in the southwest, south and southeast toward the Arnak K-06 borrow pit.

Contour Comparison

The location of the 1985 and 1990 6m contour has been compared to determine the maximum measurable distance of sediment transport between these to years. This comparison indicates sediment has been transported up to 140m southeast between 1985 and 1990. In contrast the 6m contour has remained relatively constant in the northwest.

The gradient of the island margins appear to have decreased throughout the island periphery. This is in direct contrast to other island which display an increase in seafloor gradient in one orientation which corresponds to the direction of greatest sediment accumulation.

5.12.2 Seafloor Features

A diagrammatic seafloor features map is produced for this site as Figure 5.12.1 (top right). A prominent sediment depositional feature, identified on this figure is a lobe of sediment extending approximately 100m beyond the western island margin. This lobe thins downslope away from the island suggesting a sediment transport in this direction.

Figure 5.12.2 is a sidescan mosaic incorporating four lines crossing this feature. The acoustic texture of the sediment lobe sharply contrasts with the surrounding seafloor. Whereas the sediment lobe appears rubbly the surrounding seafloor appears flat and relatively featureless. Scours crossing the sediment lobe display distinct infilling patterns. The infilling begins at the surficial contact and increases in degree toward the axis of the lobe.

This lobe feature may have formed as a turbid sediment plume transported sediment downslope. The triggering mechanism for this slope failure may have been waveloading. The rubbly texture suggests that it has not been extensively reworked. Scours which cross this feature display infilling suggesting that this feature postdates the scours and was formed very recently.

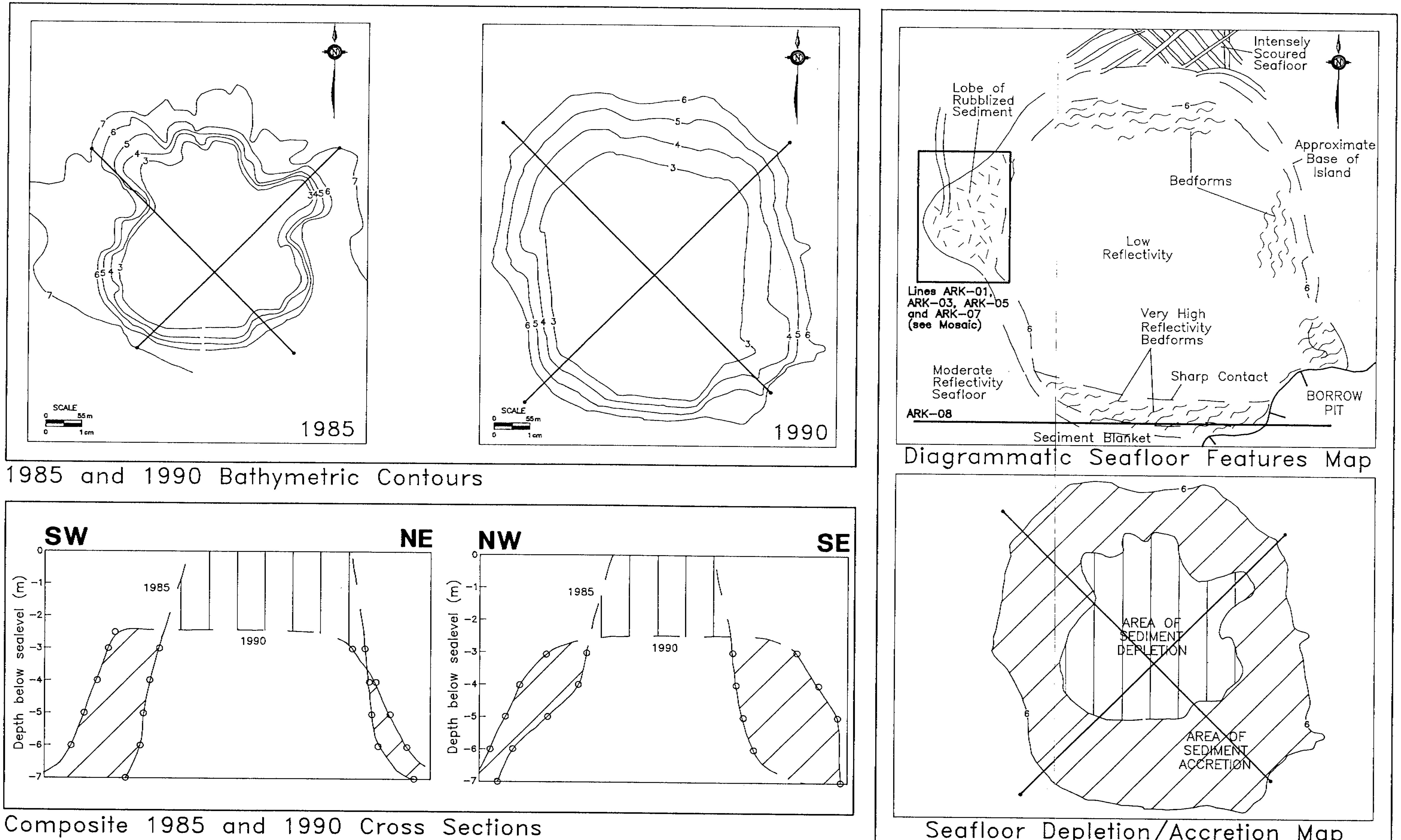
Another prominent feature of this island is the presence of very high reflectivity bedforms on the south and southeast margins of the island (Figures 5.12.3). These bedforms occur near the base of the island along the 6m contour. A very sharp contact exists on the shallow side of these features suggesting an abrupt change in bottom currents or other hydrodynamic conditions. The crest orientation of these bedforms appears to be northeast to southwest indicating a northwest to southeast current. The bedform orientation is consistent with the predominant southeast sediment transport accretion direction found from the comparison of the 1985 and 1990 bathymetry.

The north side of the site is intensely scoured. These scours abruptly terminated against the northern margin of the island.

The island top is characterised by 2D, short wavelength, bedforms which are evident on line ARK 21, ARK 27 and especially ARK 10.

An area of sediment mounding is identified on the southeast corner of the site and is probably a dump site.

Given the interpreted direction of sediment transport the Arnak K-06 island may be expected to infill the borrow pit created during the island construction.



ARNAK K-06 ISLAND SUMMARY Scale 1:5500

FIGURE 5.12.1

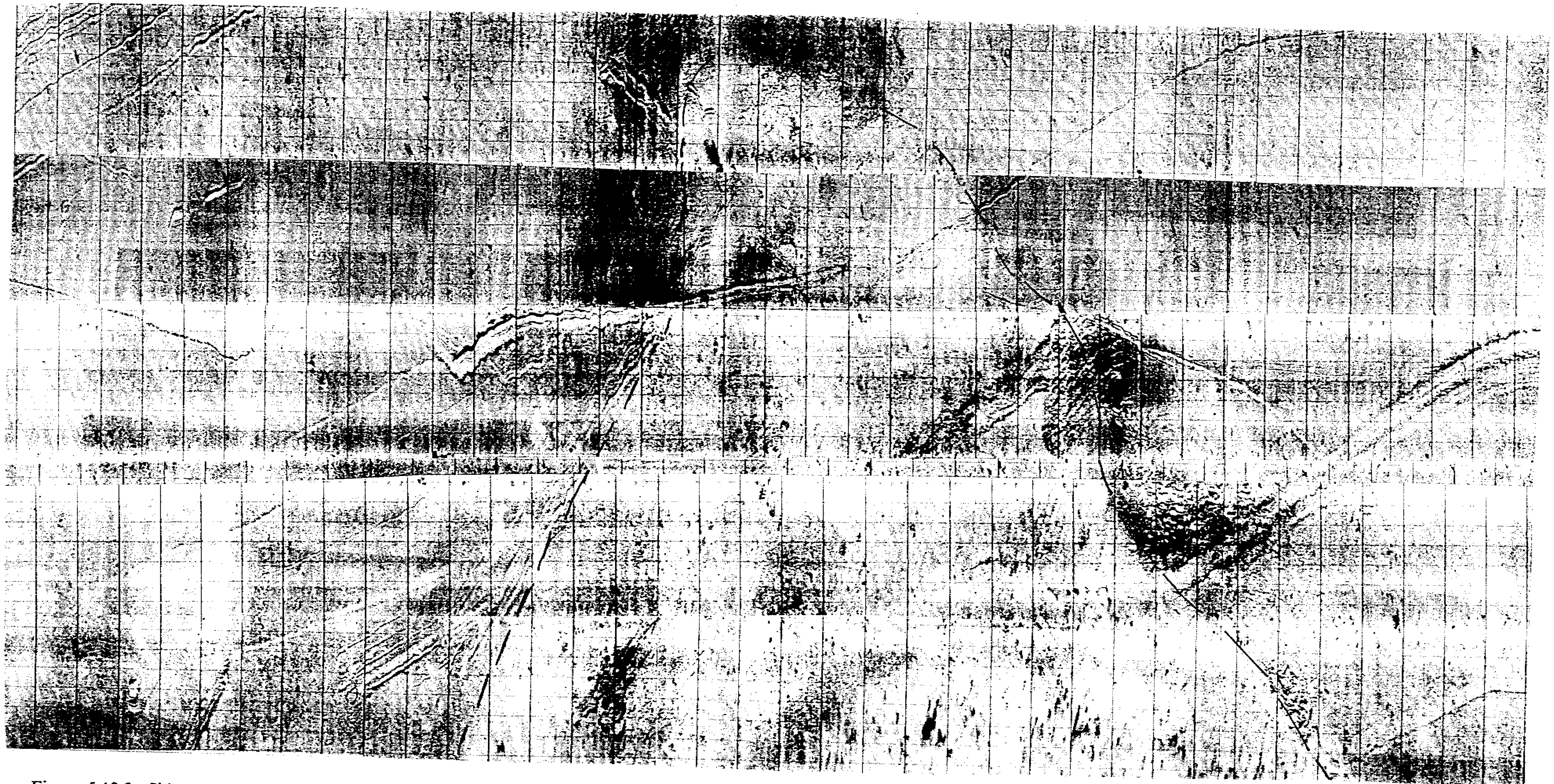


Figure 5.12.2 Sidescan mosaic (Lines ARK 01, 03, 05 and 07) displaying a sediment lobe on the west margin of the K-06 island.

FIGURE 5.12.2

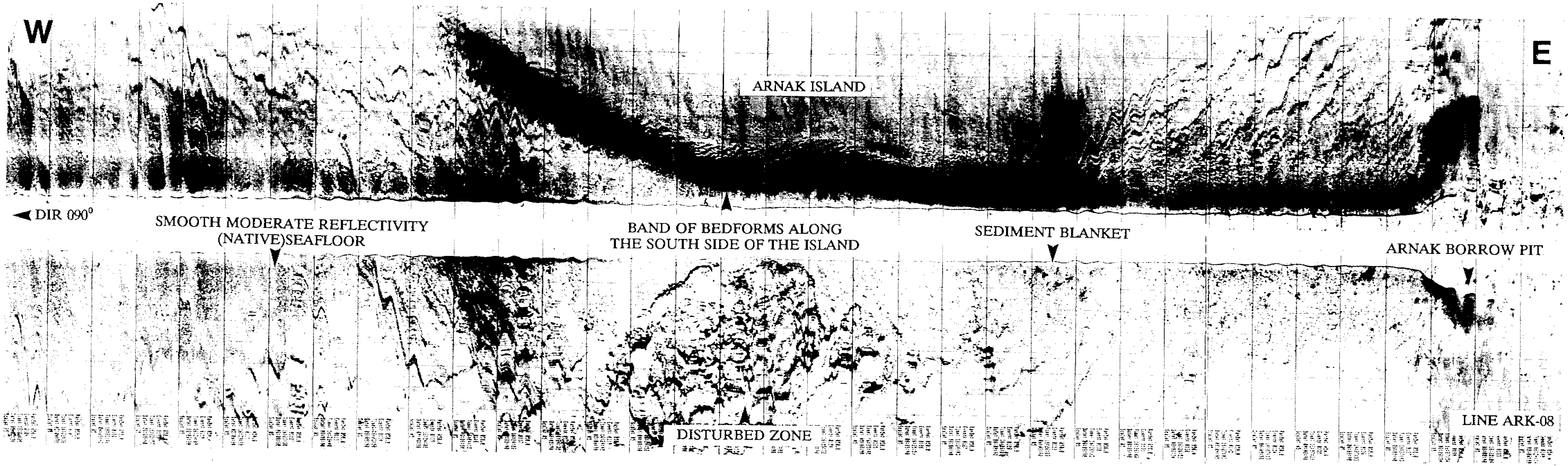


Figure 5.12.3 Sidescan data (Line ARK 08) displaying very high reflectivity bedforms on the south and southeast margins of the K-06 island.

FIGURE 5.12.3

5.13 Kaubvik I-43

Esso constructed Kaubvik I-43, a caisson retained island, during the 1983 to 1986 open water seasons in 17.9m of water. This island is the deepest site investigated in this project. The island is located in the Ikit Trough where the local seabed consists of soft silty clay overlying firm clay. A glory hole was excavated in the seabed prior to island construction. Sand and gravel totally 566,000m^3 was dredged from the Ukalerk, Issigak and Isserk borrow pits and dumped on the site. The berm was built within 9m of the waterline with a top surface diameter of 91m and slopes of 12H:1V. The caisson was ballasted to the berm and infilled with sand to 3m above the waterline. The island was used for drilling in the winter of 1986 and abandoned in 1987. During debalasting the sand core was partially removed leaving a berm 1m below the waterline.

The submerged island depth has increased from -1.0m at the time of abandonment (1987) to -3.6m (1989) and -4.5m (1990).

5.13.1 Island Morphology

Hydrographic surveys have been conducted at the island site in August 1986, September 1989, and July 1990. The 1986 survey appears to represent the island at the conclusion of island construction to the level of the 9m berm. This survey therefore does not include the sediment which was placed in the caisson and left on the island at the time of abandonment. The 1986 island coverage in this very detailed with a series of tightly spaced east-west survey lines.

The 1989 survey coverage consists of a series of subparallel east-west lines with an approximate spacing of 50m. The 1990 survey grid consists of more detailed grid of southwest-northeast lines, 50m in spacing, and northwest-southeast lines, 100m in spacing.

Plan View

The 1989 and 1990 bathymetry have been compared to evaluate short term changes in island morphology. This comparison suggests subtle difference between the 1989 and 1990 maps. However the 1989 survey coverage is adversely affected by navigation problems and the evaluation of subtle differences between the 1989 and 1990 maps is suspect. The bathymetric comparison presented here is based on the 1990, chart versus the 1989 chart, as the 1990 chart is based on more precise and detailed survey coverage.

A comparison of the 1986 and 1990 bathymetry data (Figure 5.13.1, top left and center) indicate the island form has changed significantly in the intervening four year period. The 1986 island appears concentric in form. In contrast the 1990 submerged island is strongly elongated in plan view with a northwest-southeast oriented long axis and a northeast-southwest oriented short axis. The degree of elongation is greatest in shallower water reaching a maximum of 1:2 at the 5m contour and diminishing to a negligible 1:1.1 at the 15m contour. The direction of elongation corresponds to a 2D asymmetric with a gentler (1:12) northwest inclined face and steeper (1:9) southeast inclined face. A distinct closed bathymetric high occur in the southeast quadrant of the island.

Profile View
Figure 5.13.1 (lower left and centre) displays two composite 1986 and 1990 profiles, southwest - northeast and northwest - southeast, crossing the middle of the Kaubvik island. These profiles display dramatic contrasts in the depth of submergence of the island and help identify the areas of sediment depletion and accretion.

The composite 1986 and 1990, southwest - northeast, profile (Figure 5.13.1, bottom left) appear symmetric with a consistent slope on both island faces. This composite profile indicates sediment depletion over the crest of the island. A significant, and uniform, accumulation of sediment exists along the southwest and northeast margins of the island.

The composite 1986 and 1990, northwest - southeast profile (Figure 5.13.1, bottom center), displays depletion over the crest of the island and along the northwest margin of the island. A major area of sediment accretion occurs on the southeast inclined island face. No measurable change occurs along the northwest margin in water depths greater than 12m.

Contour Comparison
The long term changes in island morphology are evaluated by overlaying the 1986 and 1990 bathymetry charts. A particular consideration at this site is that the comparison is limited to water depths greater than 9m. In water depths of less than 9m sediment has been dump from the caisson core at the time of island abandonment. No bathymetric control exists on the topography of the seafloor immediately following this dump event.

Due to this limitation the location of the 1986, and 1989, 15m contour has been compared to determine the approximate distance of measurable sediment transport between these years. This comparison indicates sediment has been transported up to 45m south between 1986 and 1990. In contrast the 15m contour has remained relatively constant in the north. Areas of sediment accumulation have developed in the south, west and east.

Sediment Depletion/Accretion Map
To further assess the sediment transport pattern the 1982 and 1990 bathymetry charts were overlain (Figure 5.13.1, lower right) and the approximate spatial distribution of sediment depletion and accretion was estimated. This figure indicates a major zone of sediment depletion over the island crest and along the shallower section of the northwest margin. The area of greatest accretion is shown toward the southeast with significant accretionary zones on the southwest and northeast island faces. The deeper section of the northwest margin (water depths > 12m) is characterised as an area of immeasurable sediment loss or gain.

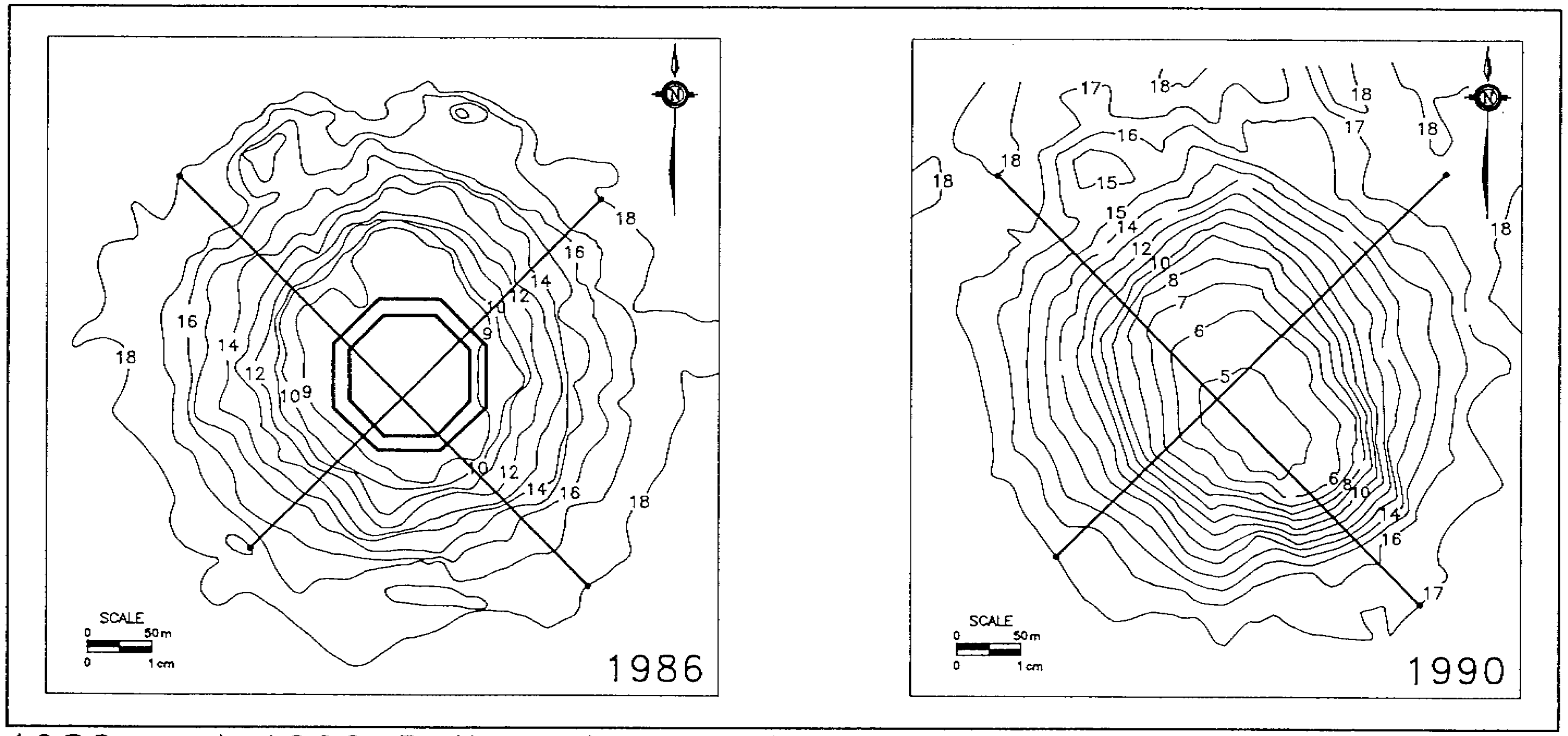
The 1990 Kaubvik island plan and profile island form may be characteristic of island migration patterns in the early years of submergence. This feature will be referred in Section 7 which contrasts different stages of island evolution. Similar characteristics are observed at the Netserk F-40 (1981) and Nipterk L-19 (1990) islands. These three islands, Kaubvik (1990), Netserk (1981) and Nipterk (1990) are 4, 5 and 6 years old, respectively, at the time of these surveys.

5.13.2 Seafloor Features

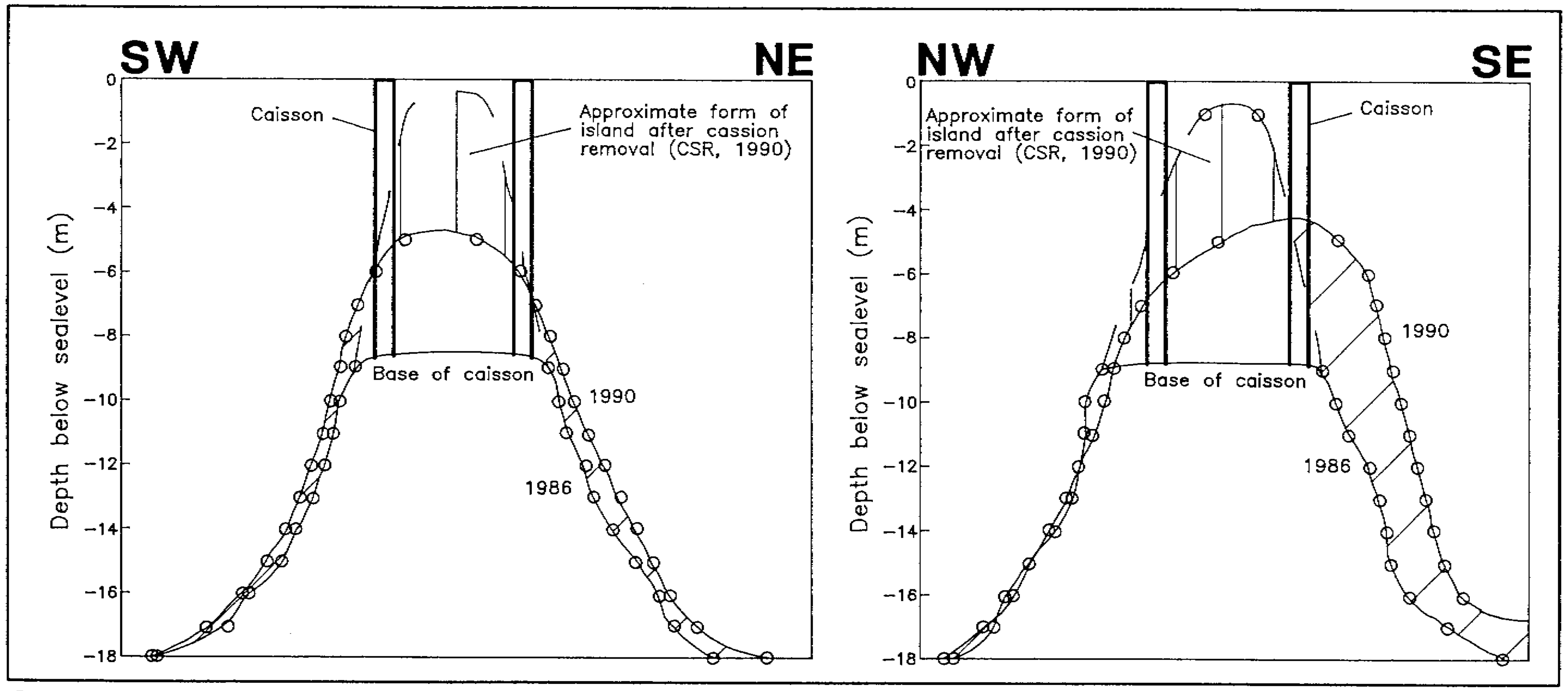
A diagrammatic seafloor features map of this island is presented as Figure 5.13.1, top right. Numerous features are noted including bedforms along the west and east margins of the site, featureless smooth seafloor on the crest of the island, interwoven low and high reflectivity zones to the southwest, distinct spatial variations in the scouring pattern on the island site. Essentially the seafloor beyond the edge of the island is intensely scoured to the north and east. A paucity of scours and a lower reflectivity seafloor characterize the seafloor to the south suggesting sediment transport in this direction.

Data examples which illustrates the variation in scouring and the sediment blanket transported beyond the island is presented as (Figure 5.13.2, top and bottom). The location of these lines is presented on the diagrammatic seafloor features map of Figure 5.13.1 (top right).

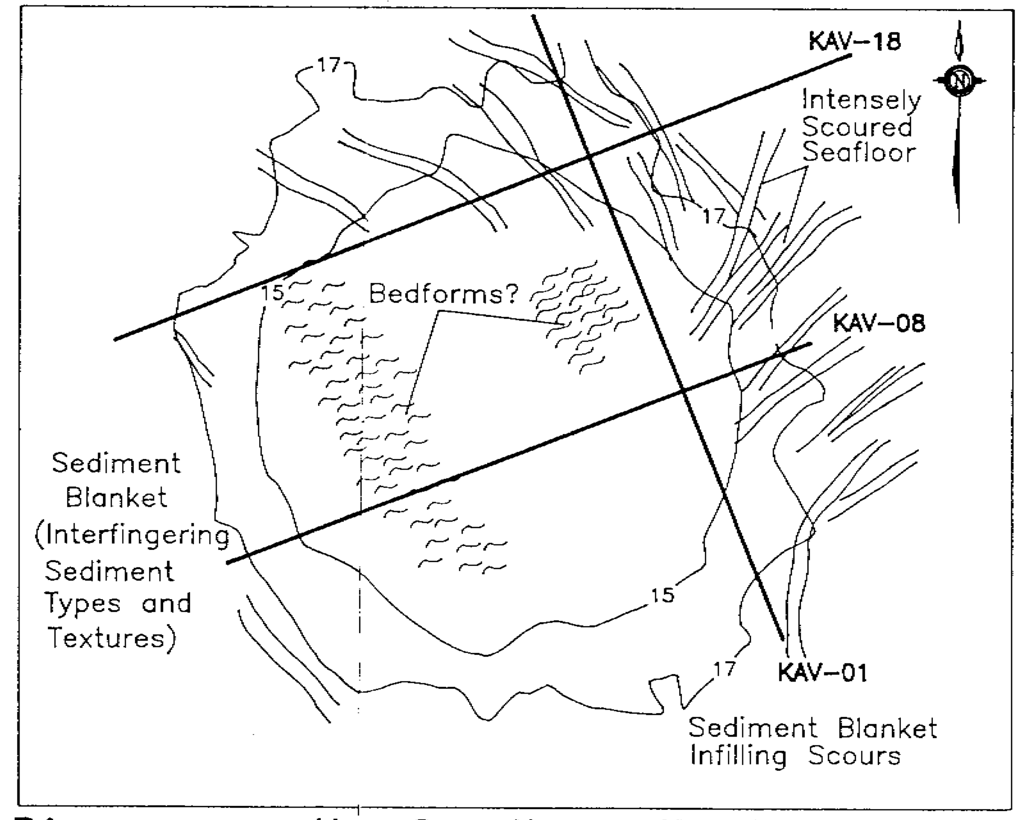
The sediment transport direction is inferred from the sidescan to be toward the southeast and corresponds to the direction of transport inferred from the bathymetry, island face slope and island symmetry.



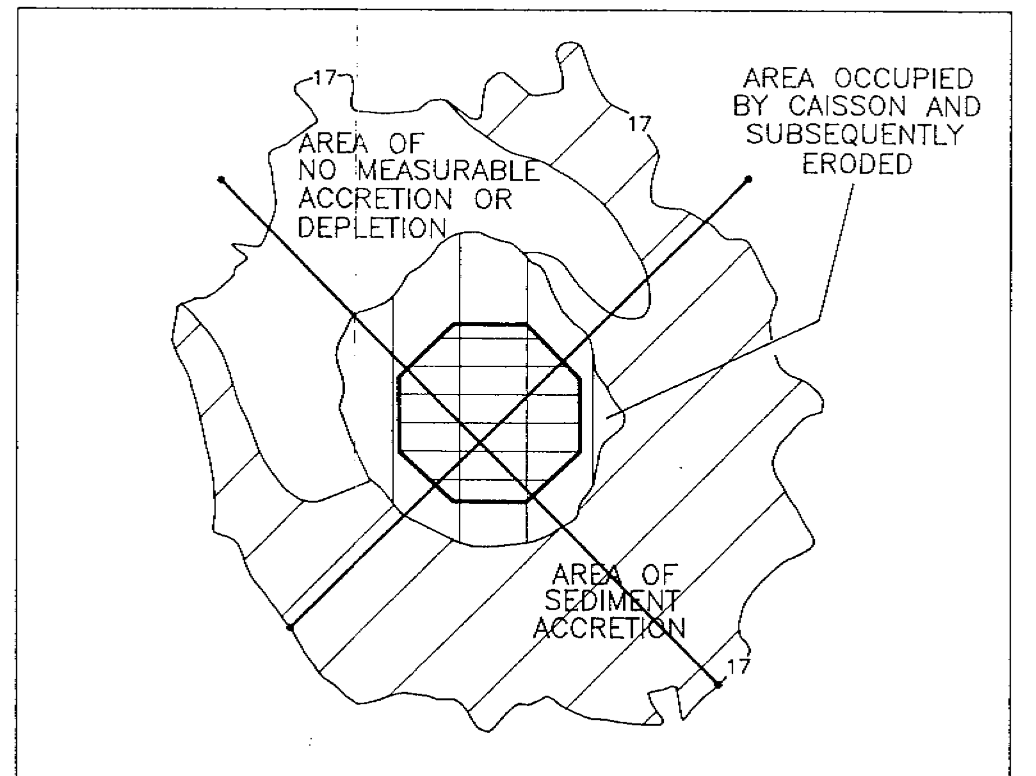
1986 and 1990 Bathymetric Contours



Composite 1986 and 1990 Cross Sections



Diagrammatic Seafloor Features Map



Sediment Depletion/Accretion Map

KAUBVIK I-43 ISLAND SUMMARY Scale 1:5000

FIGURE 5.13.1

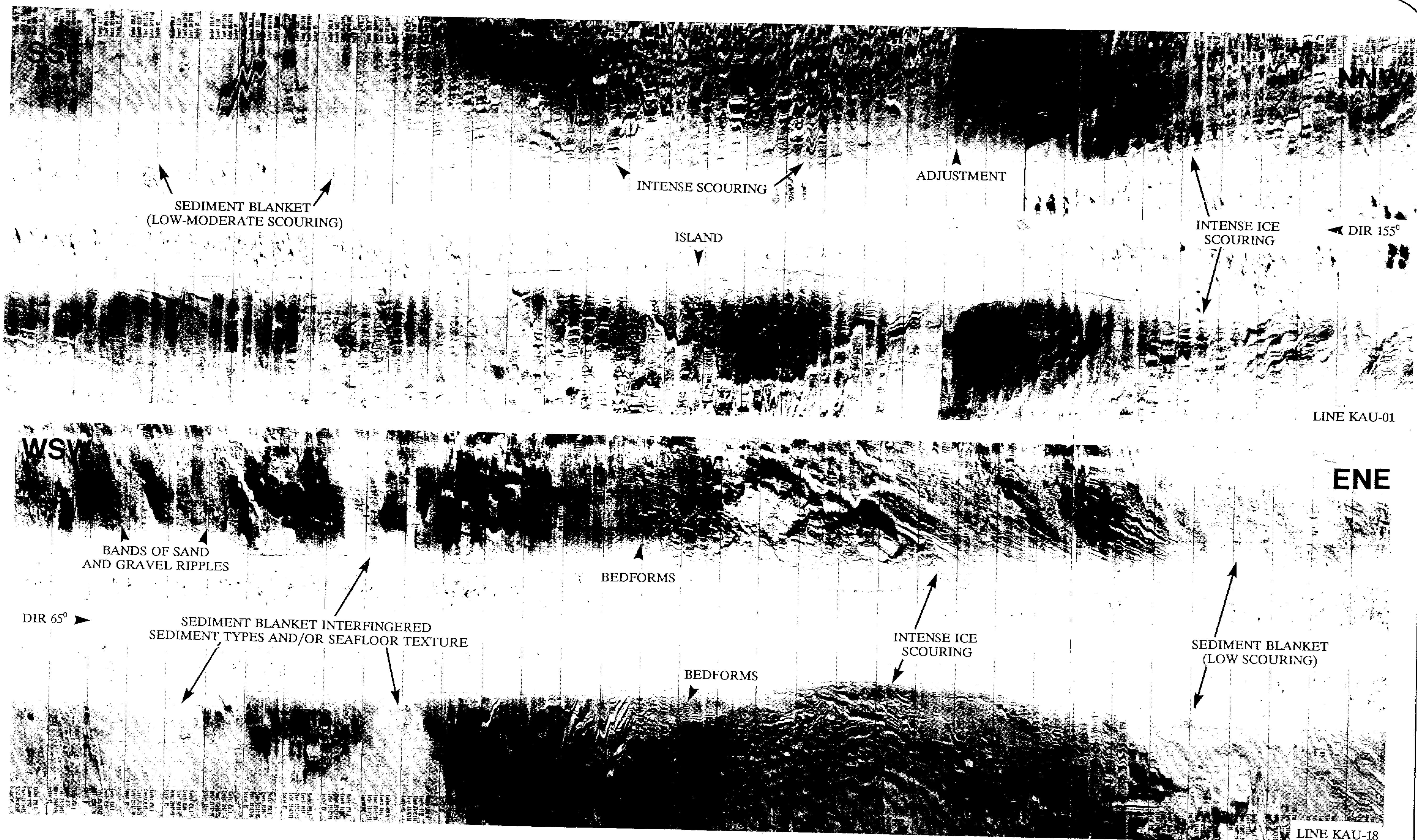


Figure 5.13.2 Sidescan data (Lines KAU 01 and KAU 34) displaying seafloor features characteristic of the I-43 island and surrounding seafloor.

FIGURE 5.13.2

Section 6
Sediment Transport - Observed and Conceptual Trends

6.1 Observed Regional Sediment Transport Trends

Figure 6.1 presents a summary of the bearing and magnitude of aggradation for islands assessed in this study.

The prominent direction of island migration is toward to southeast. Figure 6.1 suggests the direction of island sediment aggradation is related to island design. Only a small number of caisson retained and sand bag retained islands are present in the island population. The relationship between design and sediment transport is questionable.

The nine sacrificial islands evaluated are have aggraded toward the southeast and east-southeast. The two sand bag retained islands have aggraded toward the east. One caisson retained island was investigated and this island has aggraded toward the south.

The magnitude of island aggradation also appears to be related to island design. The magnitude of migration of the sacrificial beach islands varies widely from 60m to 230m. The sand bag retained islands studied appear to have migrated between 35m and 55m. The one caisson retained island investigated appears to have aggraded up to 45m.

The relationship between the date of island construction and the magnitude of island accretion is displayed in Graph 6.1. This graph suggests that recently abandoned islands have accreted further. However this does not factor in the timing of island abandonment, and the timing of the base-line and follow-up surveys. These are very important factors to evaluating the significance of the island accretion magnitudes.

The magnitude of island migration accretion relative to the timing of abandonment and the timing of the surveys is illustrated in Graph 6.2. This plot suggests that the magnitude of measured aggradation is very dependant on timing of the base-line and follow-up surveys. The magnitude of measured aggradation is significantly greater in cases where the base-line surveys were run shortly after abandonment (eg. within 5 years).

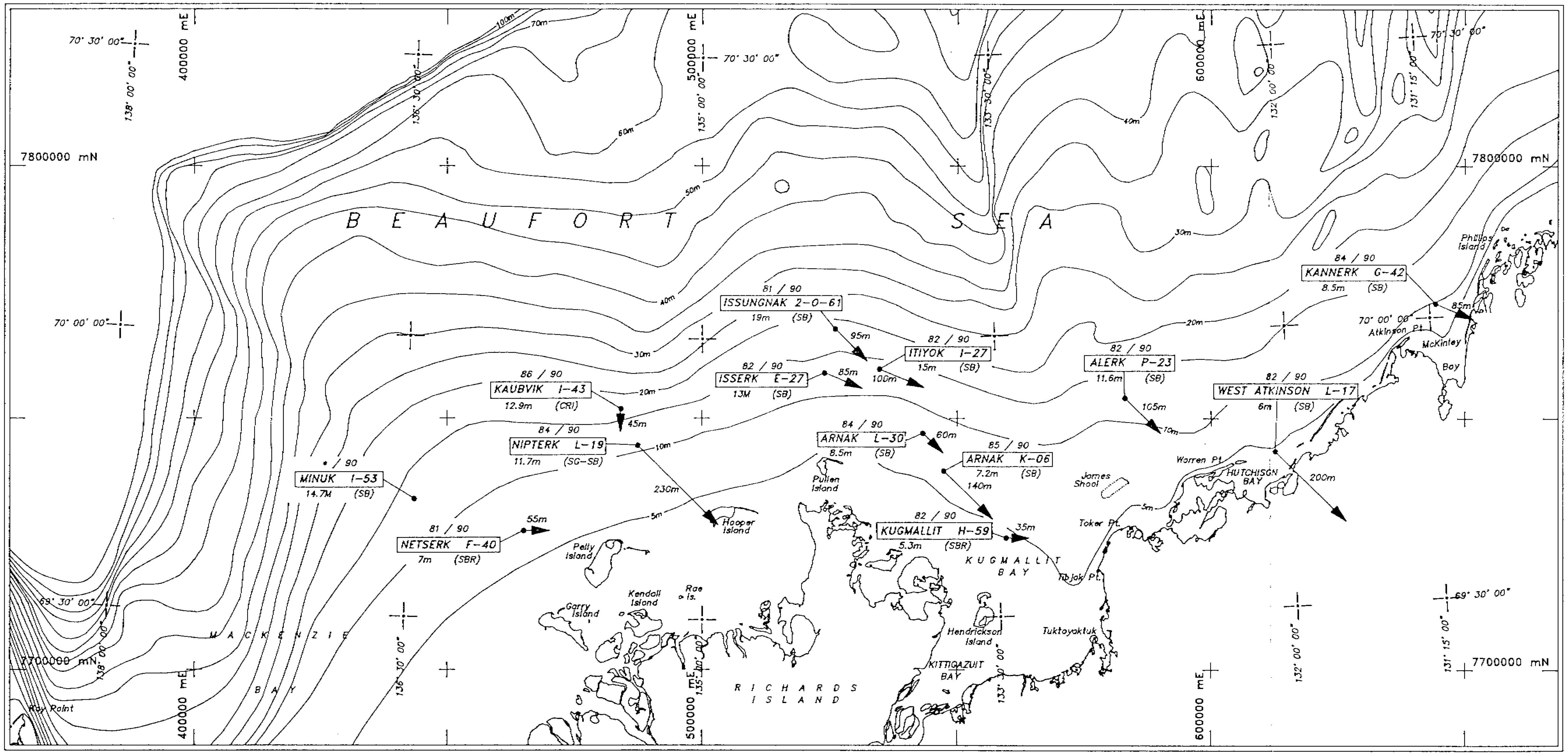
Lateral aggradation is probable more time dependant than island design dependant. Considering the timing of the base line survey (Graph 6.2) the average lateral aggradation rates are estimated for blocks of time following abandonment.

In summary the observed lateral accretion rates range from 230m/5 years to 95m/9 years in the first 5-10 years following abandonment for sacrificial beach islands. Lateral aggradation rates of 60m/6 years and 85m/8 years may be expected in the following 5 to 10 years. This translates to lateral migration rates of 10 to 45m/year in the first 5 to 10 years and 10m/year in the following 5 to 10 years. Due to survey timing lateral migration rates for sandbag retained islands can only be estimated for the period between 5 and 10 years following abandonment. In summary the maximum lateral aggradation rate for sandbag retained island is 55m/9 years (approximately 6m/year) in this period.

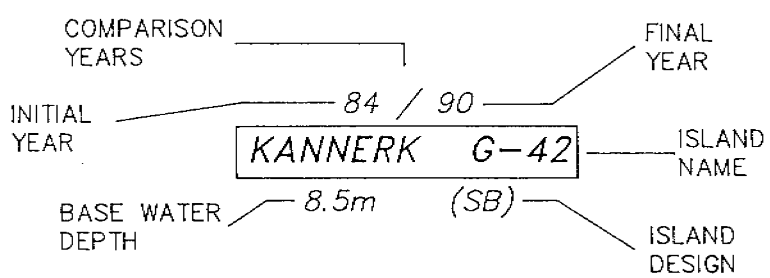
One caisson retained island aggradation rate is calculate for the first 5 year period. The caisson retained island displays a maximum accretion rate of 10 m/year in the first 4 years following island abandonment.

The rate of island accretion ranges from approximately 6m/year to 45m/year. This range probably reflects the timing of the surveys used to calculate the rates rather than island to island differences. The direction of island accretion remains an accurate and significant parameter.

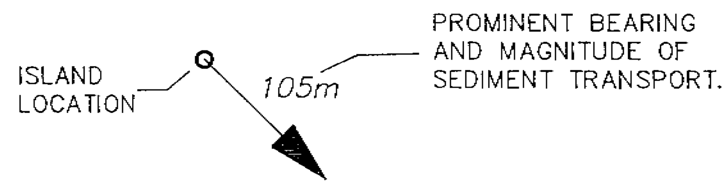
The minimum island depth versus the time after abandonment is displayed in Graph 6.3. Although this plot shows significant scatter a strong general trend is present. This trend indicates that the rate of island submergence is time dependant with the greatest rate of submergence occurring immediately following abandonment. Curve fitting to this data provides a means of estimating future island submergence depths.



ISLAND KEY



SEDIMENT TRANSPORT



ACTUAL MAGNITUDE : ARROW LENGTH
1 : 100

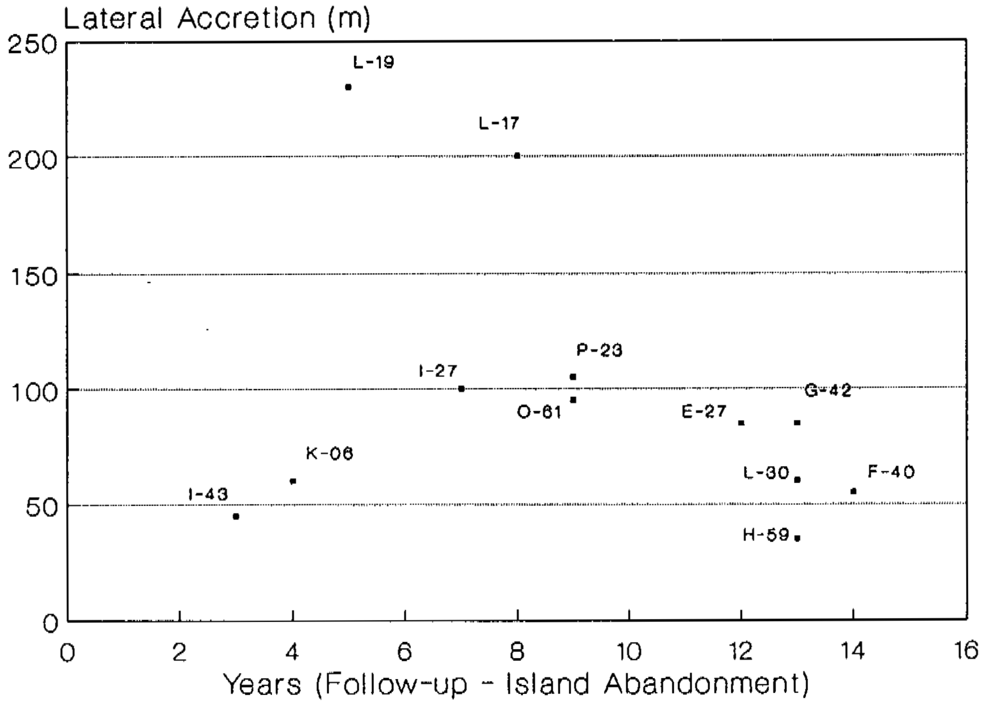
ISLAND DESIGN

SB	SACRIFICIAL BEACH
SG	SAND AND GRAVEL
SBR	SAND BAG RETAINED
CRI	CAISSON RETAINED ISLAND

ISLAND ACCRETION SUMMARY

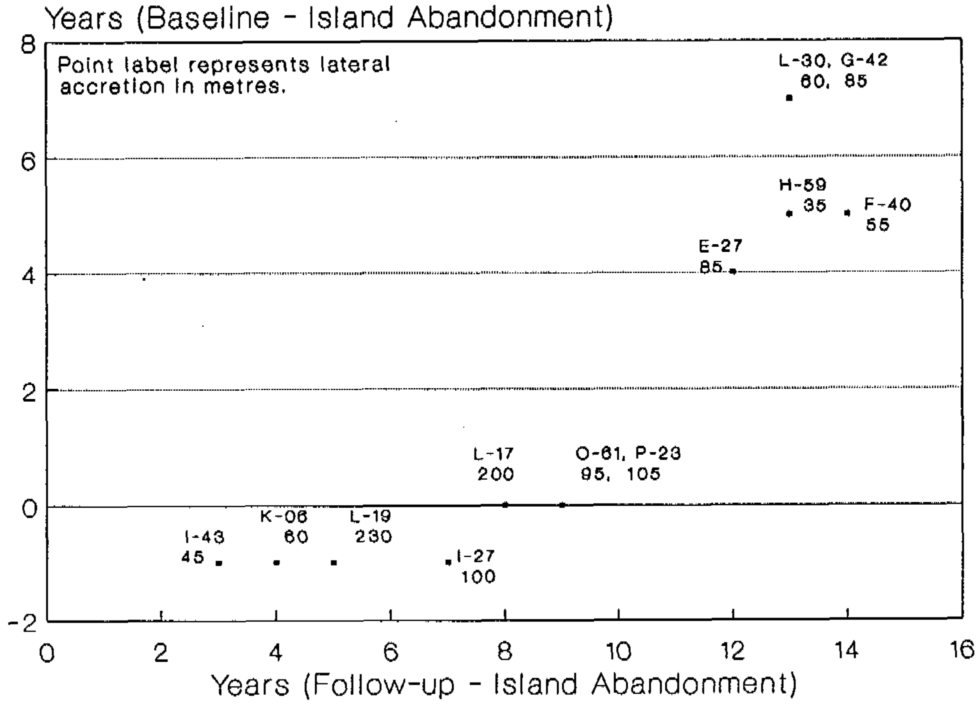
FIGURE 6.1

Graph 6.1

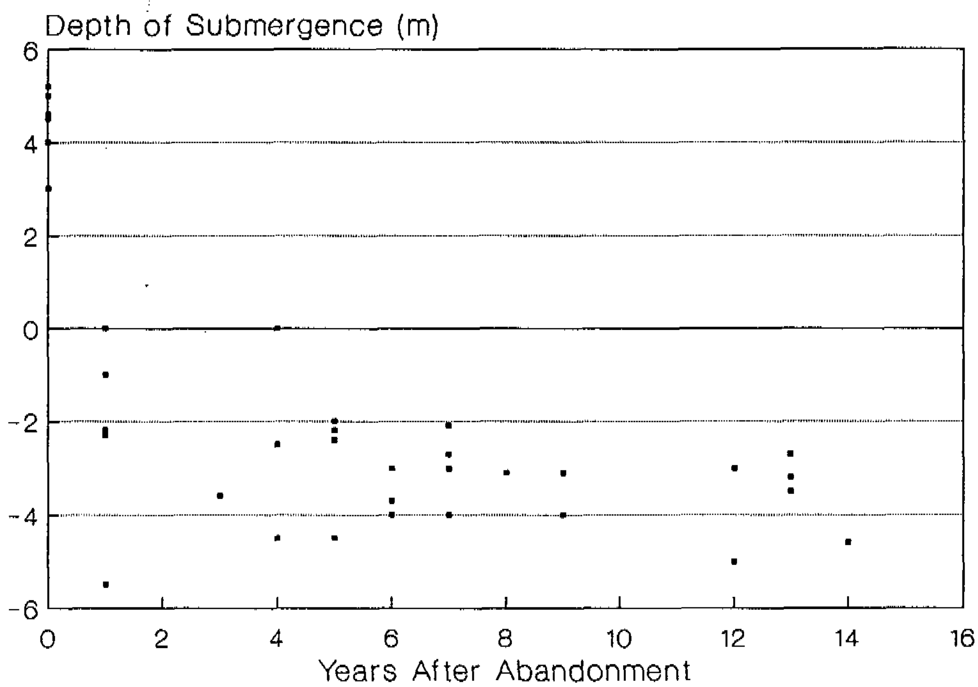


Lateral Accretion (m)
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
Years (Follow-up - Island Abandonment)
L-19
L-17
P-23
I-27
O-61
E-27
G-42
K-06
I-43
L-30
F-40
H-59

Graph 6.2


Years (Baseline - Island Abandonment)
Point label represents lateral accretion in metres.
L-30, G-42
60, 85
H-59
35
F-40
55
E-27
85
L-17
200
O-61, P-23
95, 105
K-06
60
L-19
230
I-43
45
I-27
100
8
6
4
2
0
-2
0
2
4
6
8
10
12
14
16
Years (Follow-up - Island Abandonment)

Graph 6.3



Depth of Submergence (m)
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12
14
16
Years After Abandonment

6.2 Conceptual Sediment Transport Trends

A series of conceptual models are presented in this section. These models examine the sediment depletion/accretion styles observed at the island sites. These styles appear to part of a spectrum of island erosion patterns. The islands erosion pattern have been classified into one of five island "sediment depletion/accretion types". These pattern are part of a spectrum which varies according to the degree of polarisation in sediment accumulation.

The type 1 erosion pattern is the least polarised with sediment accretion around the entire island periphery. The type 5 erosion pattern is the most polarised with sediment accumulation limited to one quadrant of the island.

By way of explaining these sediment transport patterns "Conceptual Island Plan and Profiles" have been prepared for each "type". These type 1 to type 5 diagrams are presented as Figures 6.2.1 to 6.2.5, respectively. Each model displays zones of sediment depletion and accretion on plan and in profile and is accompanied by one corresponding island example.

The conceptual plan view sediment depletion and accretion map is displayed as a contour map (eg. Figures 6.2.1 to 6.2.5, top left). The positive contours are shown in areas of sediment accretion and negative contours are shown in the areas of sediment depletion. These contour maps have been normalised so that the maximum sediment gain equals positive one and the maximum sediment loss equals negative one. This is done to make the conceptual plan views standard for each island. Underlying this contour map is one island example which is interpreted to fits each model.

Adjacent to these plan views are perpendicular profiles, oriented southwest to northeast and northwest to southeast. These profiles display the model sediment depletion/accretion patterns (top) and the corresponding multi-year profiles (below).

A summary of each island sediment transport type is given below along with a list of island sites which fit these models. These models provide a quantitative means of describing the island's erosional and depositional pattern and allow different island trend to be distinguished.

6.2.1 Sediment Depletion/Accretion - Type 1

The type 1 model is presented as Figure 6.2.1. The Arnak K-06 and Isserk E-27 islands fit this model. The type 1 erosion pattern is the least polarised with sediment accretion around the entire island periphery.

In summary the sediment depletion is located over the centre of the island while the area of sediment accumulation occurs around the islands periphery. Although sediment accumulation exists around the periphery the magnitude of this accumulation varies by quadrant with the area directly south of the island receiving the greatest sediment and the area to the north receiving the least. The east and west margins receive intermediate degrees of sediment.

Although both the Isserk E-27 and Arnak K-06 islands display the type 1 erosional pattern these islands very different in age - 9 years and water depth (Isserk is twice as deep as Arnak). There are only two attributes common to these island location - Akpak Plateau and island design - sacrificial beach. These are however not properties unique to these two islands.

The resultant island form from this erosion pattern displays appears concentric with a very low degree of elongation.

6.2.2 Sediment Depletion/Accretion - Type 2

The type 2 model is presented as Figure 6.2.2. The Itiyok I-27, Kaubvik I-43, Arnak L-30 fit this island erosion model.

In summary the sediment depletion is located over the centre of the island and in the northwest quadrant of the islands periphery. Sediment accumulation occurs in all other quadrants at the islands periphery. The magnitude of this accumulation varies with the area directly southeast of the island receiving the greatest sediment and the areas to the southwest and northeast receiving the least.

The key profiles across the model and example (Itiyok I-27) islands illustrate the relationship between bearing and magnitude of accretion.

Other than a common erosional pattern the Itiyok, Arnak and Kaubvik islands are very different. The island differ in water depth which ranges from 8.5m at Arnak to 17.9 at Kaubvik, island design (sacrificial beach - Itiyok I-27 and Arnak L-30; Caisson retained - Kaubvik I-43), location (Kugmallit Channel to the Ikit Trough), and construction material (sand to sand and gravel).

The resultant island form from this erosion pattern displays a low to moderate degree of elongation.

6.2.3 Sediment Depletion/Accretion - Type 3

The type 3 model is presented as Figure 6.2.3. This erosion model is a subtle hybrid of type 2 and 4. One island (Issungnak O-61) fits this model. The main difference between the type 2 and type model is the subtle skewing of the sediment accretion between the southwest and northeast island margins.

This erosional pattern is characterised by sediment depletion is located over the centre of the island and in the northwest quadrant of the islands periphery. Sediment accretion is strongly polarised in one quadrants (southeast). The other quadrants display a slight skewing in the degree depletion or accretion. At Issungnak minor accumulation occurs on the southwest margin while no change occurs along the northeast margin. This are of no change is identified as identified on the diagrammatic of Figure 6.2.3 as an area of immeasurable loss or gain.

The resultant island form from this erosion pattern displays a low to moderate degree of elongation.

6.2.4 Sediment Depletion/Accretion - Type 4

The type 4 model is presented as Figure 6.2.4. The Nipterk L-19, Kannerk G-42, Alerk P-23 and West Atkinson L-17 islands fit this model.

The type 4 erosion pattern is the most polarised with sediment accumulation strongly polarised to one quadrant of the island. In contrast to type 2 and 3 the resultant island form from this erosion pattern displays a moderate to high degree of elongation.

In summary the sediment depletion occurs over the centre of the island. The other margins are sites of minor sediment depletion and accretion. The direction of sediment accretion is strongly polarised toward the southeast in the case of the Nipterk L-19 example.

Figure 6.2.4 displays the plan and profile views across the model and the one example island (Nipterk L-19).

6.2.5 Sediment Depletion/Accretion - Type 5

The type 5 model is presented as Figure 6.2.5. The Netserk F-40 islands fit this model.

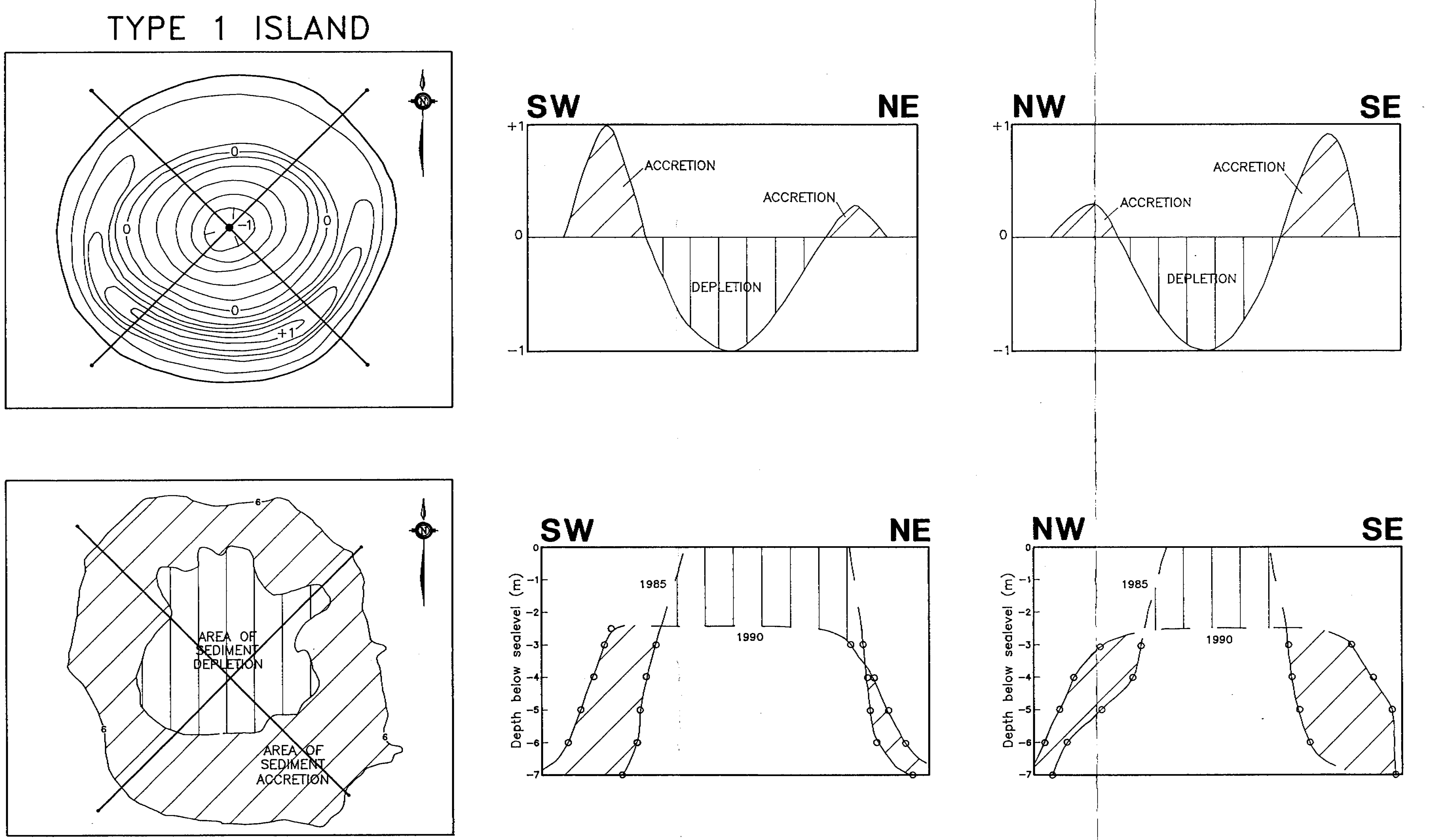
The type 5 erosion pattern is characterised by a large elliptical area of sediment depletion and narrow belt of sediment accretion along one margin. In contrast to other islands not direct spatial link exists between the area of greatest sediment depletion and the area of greatest accretion.

The erosional pattern determined from the 1981 and 1990 Netserk F-40 bathymetric charts is inconsistent with the other island sites.

6.3 Survey Timing and Island Conceptual Models

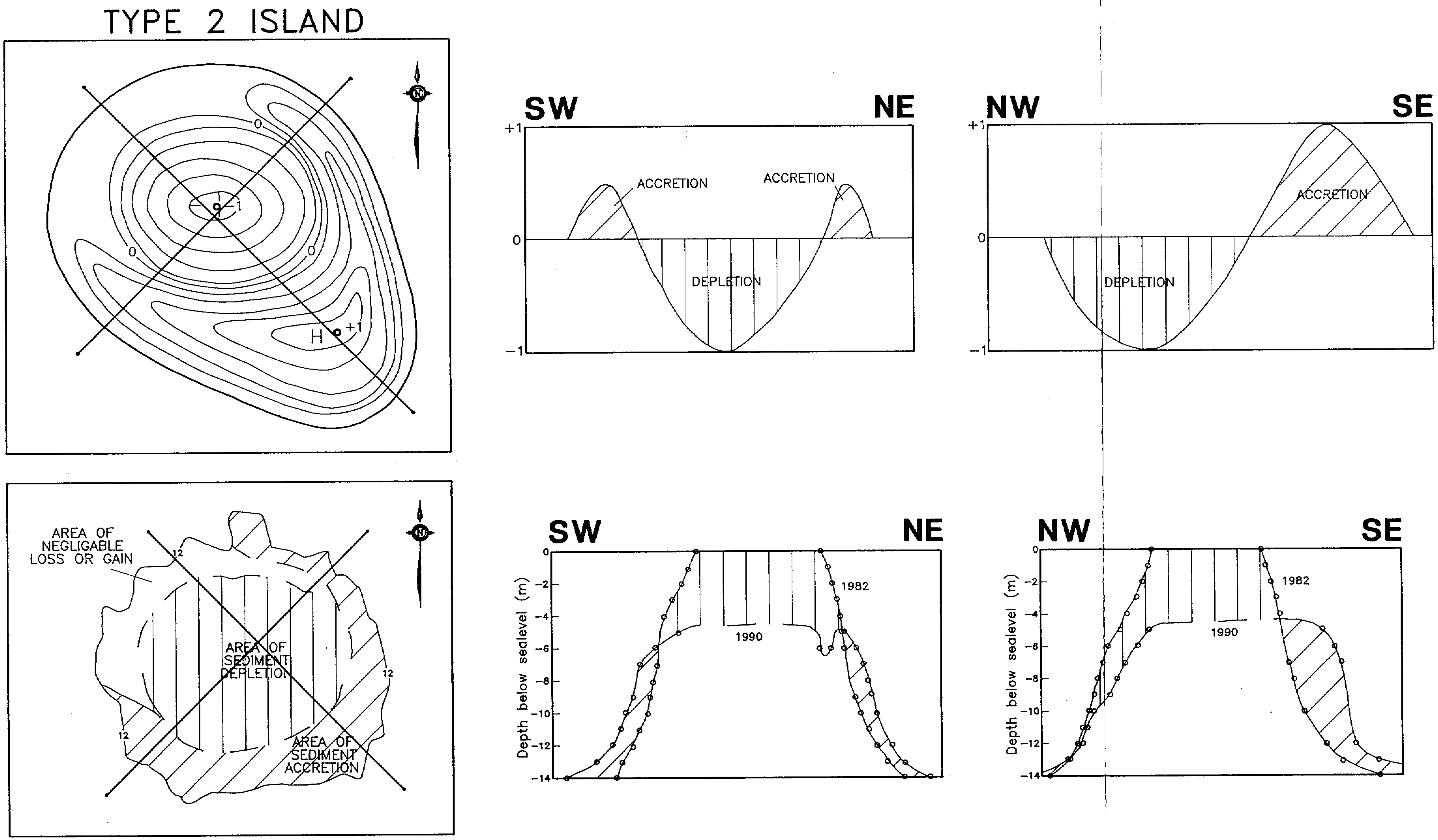
The conceptual models presented above classify erosion patterns of the islands and should ultimately be keyed to the number after abandonment and the environmental conditions affecting these islands. The timing of the base line and follow up surveys dictate the stages of the islands evolutionary history which area captured.

A comparison of the bathymetry data from the Netserk F-40 and Nipterk L-19 and Kaubvik I-43 sites indicate these islands develop similar forms approximately the same time after abandonment. The 1981 Netserk F-40, 1990 Nipterk L-19 and 1990 Kaubvik I-43 surveys were both conducted 4, 5 and 6 years after abandonment and represent similar stage in evolution. All three islands are strongly elongated in plan view with a northwest-southeast oriented long axis and a northeast-southwest oriented short axis. The direction of elongation corresponds to a strong 2D asymmetric with a gentle northwest inclined face and a much steeper southeast inclined face. A distinct closed bathymetric high occur in the southeast quadrant of both islands. This plan and profile island form may be characteristic of island migration patterns in the early years of submergence.



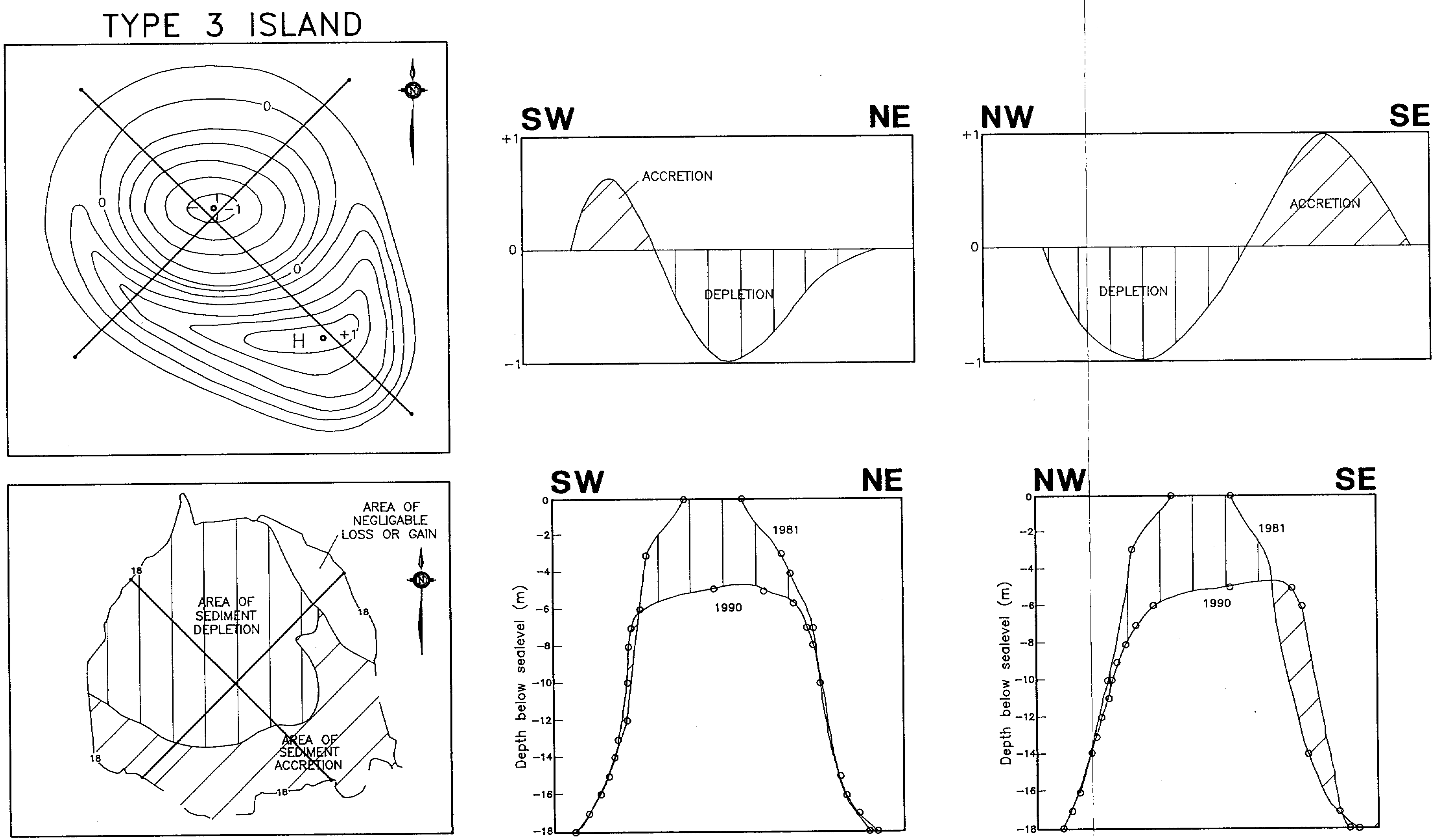
Conceptual Island Plan and Profiles Displaying Zones of Sediment Depletion and Accretion (top) and One Corresponding Island Example – Arnak K-06 (bottom)

FIGURE 6.2.1

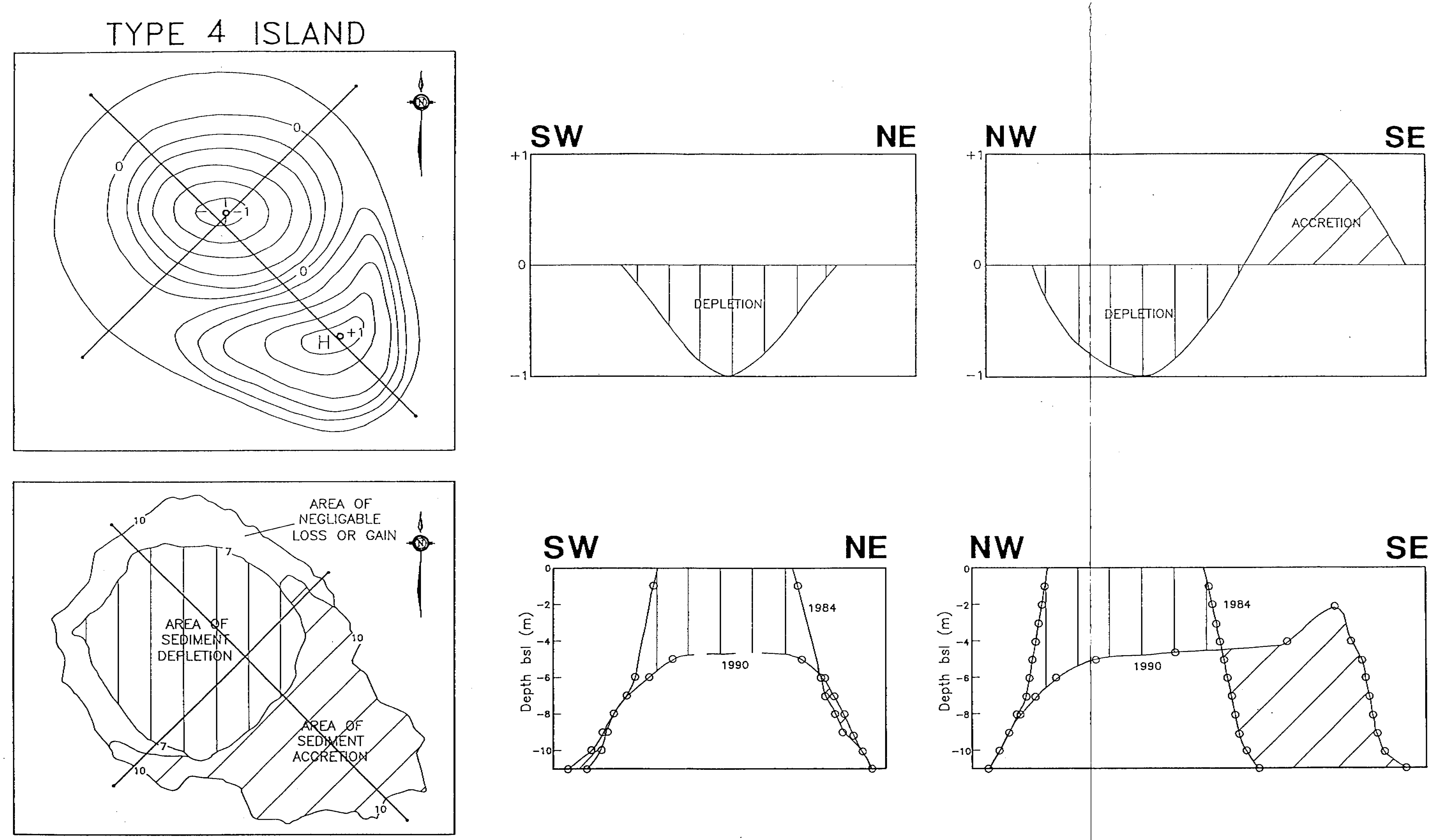


Conceptual Island Plan and Profiles Displaying Zones of Sediment Depletion and Accretion (top) and One Corresponding Island Example – Itiyok I-27 (bottom)

FIGURE 6.2.2

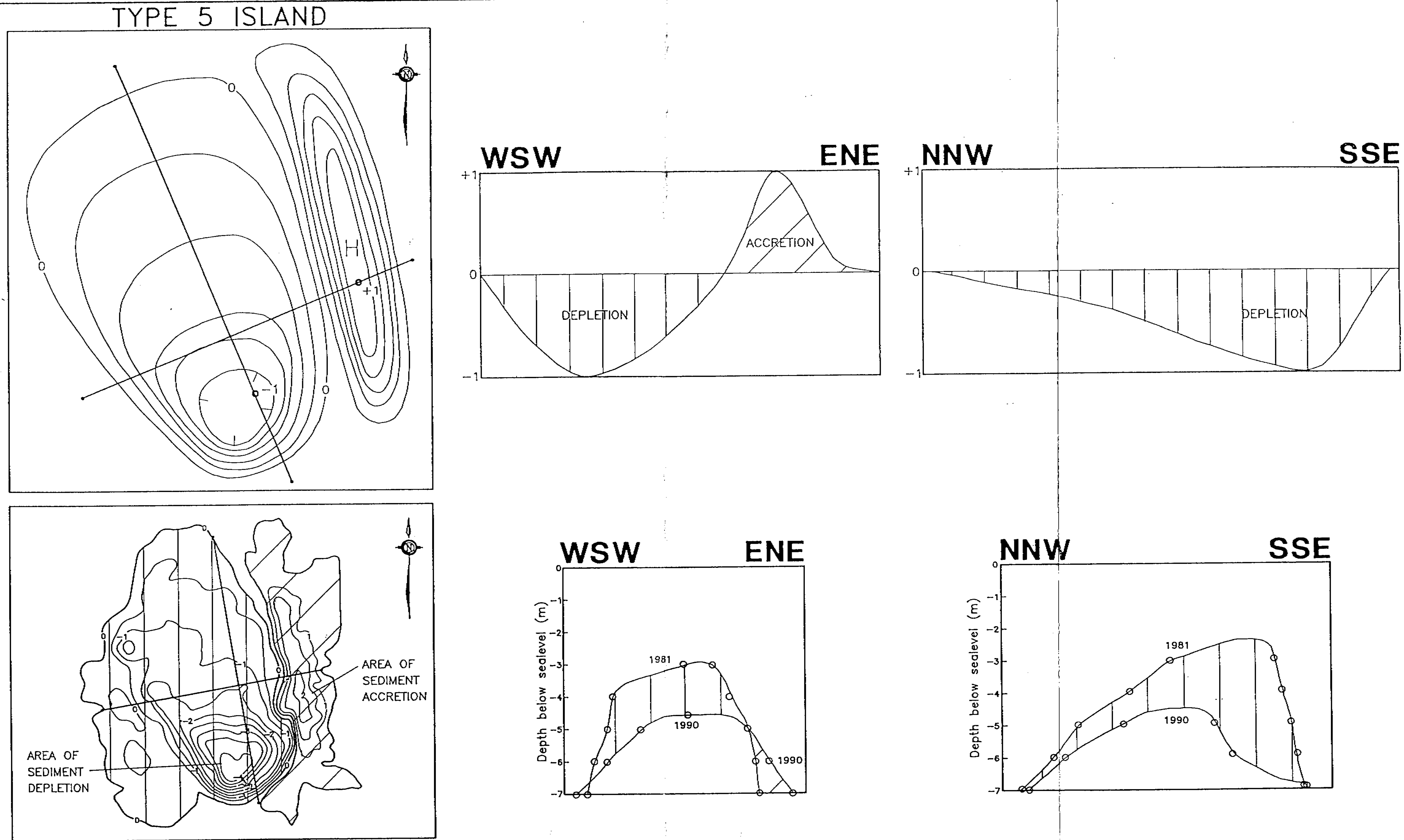


Conceptual Island Plan and Profiles Displaying Zones of Sediment Depletion and Accretion (top) and One Corresponding Island Example – Issungnak O–61 (bottom) FIGURE 6.2.3



Conceptual Island Plan and Profiles Displaying Zones of Sediment Depletion and Accretion (top) and One Corresponding Island Example – Nipterk L–19 (bottom)

FIGURE 6.2.4



Conceptual Island Plan and Profiles Displaying Zones of Sediment Depletion and Accetion (top) and One Corresponding Island Example — Netserk F-40 (bottom)

FIGURE 6.2.5

Section 7

Environmental Processes and Design Factors Impacting Islands Erosion

In the previous section sediment erosion models are proposed. The islands which fit these sediment erosion models span a range of environmental (eg. water depth, offshore location) and island design (eg. construction material, design type) conditions.

In this section the environmental processes and factors which impact upon island erosion are examined. The island design factors which appear to influence the erosional pattern of the islands are described in this section.

7.1 Environmental Processes

7.1.1 Winds and Near-bottom Current

Wave energy is well established as the environmental factors causing island erosion (Klohn Crippen, 1993). Wind is the driving force which causes both waves and near-bottom (non-tidal) currents.

Winds

In the Beaufort Sea, the dominant winds during the open water season are northwesterly and southeasterly to northeasterly (the cited wind direction refers to the direction the wind in coming from). The dominant direction of island accretion is toward the southeast (Figure 6.1). Sediment transport has been observed in other quadrants. The northwest however in always an area of sediment depletion.

The northwesterly dominant winds appear to be generating bottom currents which eroding sediment from the northwest inclined face of the island and the island top. This sediment is transported parallel to the southeast and depositing along the southeast inclined faces.

Wind induced near-bottom current result in sediment transport at the island sites and increased near bottom suspended solids concentration. In a study by Erickson et al. 1983 very high suspended solids concentration levels were found at the Issungnak. immediately (5 days) following a period of very large surface waves of up to 5m in height.

Obtaining the near-bottom current offshore at the island sites indirectly from the onshore wind data has been investigated (Fissel and Birch, 1984). The wind data in recorded continuously while offshore current data at the island sites is rare. Predicted bottom current data from onshore wind could be useful in assessing the magnitude of bottom currents and frequency of sediment transport. The Fissel and Birch (1984) study aimed to determine if statistically significant correlations exist between near-bottom current and the winds magnitude and direction as recorded at the coast. The correlation results suggested that the coupling between current and wind differ with the distance from the shore. The near-bottom current calculated from this regression method display significant deviation from the actual near bottom current measured at the island sites which limits the utility of this technique for our sediment transport study.

Near Bottom Currents

Near bottom current have been measured at numerous locations in the Beaufort Sea including nine artificial island sites. Three of these island sites are included in this study and include Isserk E-27, Issungnak O-61, and West Atkinson L-17. Near bottom current measured at these three islands are described in Fissel and Birch (1984).

The measurements at these island sited were obtained in the late summer of 1981 and 1982 specifically August 5 - September 14, 1982 (Isserk), August 6 - September 26, 1981 (Issungnak) and August 8 - September 26, 1981 (West Atkinson). The measured mean and maximum bottom current speed, vector average magnitude and direction is summarized in Table 7 of Fissel and Birch (1984).

A high degree of directional variability between all the site investigated on the continental shelf. They found that for most sites the directional distribution indicates a weak preference for flow in two approximately opposing directions. The dominant direction usually parallels the local bathymetry contours. Fissel and Birch found a degree of bimodal polarization in the directional distribution which was enhanced at the more inshore sites located North of Richards Island. These inshore sites correspond to the shallower water artificial island sites investigated in this study; Isserk E-27 and Issungnak O-61. At the nearshore West Atkinson L-17 island the bottom current were found to be highly polarized aligned parallel to the overall trend of the coastline.

7.1.2 Extreme Storm Events

This current study has revealed the magnitude and direction of sediment transport and documenting differences in the erosion styles of the island. Better understanding of the islands erosional history and forecasting future island erosion will require consideration of the storm history of the region. The timing of the extreme storm events is likely to be a very important factor. The rate of island submergence has been shown (Graph 6.3), in this study and in the earlier work (CSR, 1990), to decrease rapidly time beyond island abandonment. As the islands submerge the amount of sediment transport caused by the same extreme storm event will also decrease. Therefore an extreme storm in the early stages of island submergence will have a much greater impact on the fate of that island than an extreme storm event years latter.

The number of extreme storm events impacting on each island is provided in Table 7.1 along with the exposure rating. In general the number of extreme storm events impact on the island is directly related to time with the older islands being impacted by more extreme storms than the younger islands.

Additional extreme storm information, such as the timing of the extreme storms, the storm duration, direction and magnitude, are required if an improved understanding of the islands erosional history is to be gained and forecasting of the island fate is to be completed.

Klohn Crippen (1993) indicates that a recent Gulf Canada study entitled "Design Storm Characteristics, Amauligak Region, Beaufort Sea" provides a good representation of the storm wave and current parameters of importance for the island erosion assessment.

TABLE 7.1

Island	Water Depth (m)	Survey Year/ Minimum Depth (m)	Wave Conditions	
			Extreme Storm Events (1975 to 1988)	Exposure
Netserk F-40	7.0	75/+4.6, 81/-2.4, 83/-3.0, 90/-4.6	59 in 13 years	moderate
Kugmallit H-59	5.3	76/+4.6, 82/-2.0, 83/-3.0, 90/-2.7	56 in 12 years	low to moderate
Arnak L-30	8.5	76/+5.2, 84/-2.7, 89/-3.0, 90/-3.5	56 in 12 years	moderate
Kannerk G-42	8.5	76/+5.2, 82/-2.2, 83/-4.0, 90/-3.2	56 in 12 years	moderate
Isserk E-27	13.0	77/+5.0, 82/-4.5, 83/-4.5, 90/-5.0	46 in 11 years	high
Issungak 2-O-61	19.0	79/+5.0, 81/-2.2, 89/-3.1, 90/-4.0	31 in 8 years	high
Alerk P-23	11.6	81/+4.5, 82/-2.3, 90/-3.1	23 in 7 years	moderate to high
West Atkinson L-17	6.0	82/+4.5, 90/-2.1	23 in 7 years	moderate
Itiyok I-27	15.0	82/+4.0, 84/?, 89/-3.7, 90/-4.0	17 in 6 years	high
Nipterk L-19	11.7	84/+5.0, 90/-2.0	15 in 4 years	moderate to high
Minuk I-53	14.7	85/+5.0, 87/?, 90/?	15 in 4 years	high
Arnak K-06	7.2	85/+5.0, 90/-2.5	15 in 4 years	moderate
Kaubvik I-43	17.9	86/+3, 87/-1.0,89/-3.6, 90/-4.5	15 in 4 years	high

7.1.3 Ice-Scouring

The islands appear to create a local ice scour regime at a number of sites. The sidescan data at the Alerk P-23, Arnak L-30, Itiyok I-27, Arnak K-06 and Kaubvik I-43 displays intense ice scouring at the north side of these sites which abruptly terminate on the island margin. In contrast scouring is absent or light along the south margins. These islands appears to have altered the scouring patterns and produced a shadow zone relatively protected from scours. It is possible that this is the seafloor expression of a grounded rubble formation.

Ice-scouring appears to be only a minor factor affecting island degradation. Ice scours appear to tops and margins of a number of islands. It is possible that the relative importance of scouring in island degradation increases as islands become submerged and the erosion by bottom currents diminishes.

7.1.4 Sediment Slumping

Sediment slumping is interpreted to occur on two island sites -West Atkinson L-19 and Arnak K-06. In both of these cases the slumps occur on the margins of the island undergoing sediment depletion. These correspond to the north and northwest margins of the West Atkinson island and the northwest margin of the Arnak island. Slumps are not detected in the areas of sediment deposition.

These north margins of the islands are exposed to the greatest wave loading. The slumps observed slumps occur at the shallower water sites where wave loading may be expected to be greatest.

In the overall scheme of sediment transport at the island sites sediment slumping plays only a minor role.

7.1.5 Bedload Transport

Bedload transport of sediment is probably the most important mode of sediment transport. Bedforms occur on top of the islands, along the island margins and on the surrounding seafloor. Bedforms range in scale from centimetres to 2-3m in wavelength. Bedforms identified at the island sites include 2D small scale sand ripples which are prevalent at Kannerk G-42 , 2D coarse grained megaripples (Netserk F-40), 3D megaripples (Issungnak O-61 (1989)), and sand waves (eg. Arnak L-30). A number of sites display very high amplitude bedforms at the more steeply inclined and planar island margins.

The ROV dive tapes may help determine the scale and type of sediment in transport on this island.

7.2 Island Design Factor Impacting Island Erosion

7.2.1 Island Construction Sediment Type

Lateral accretion appears to be independent of island construction material.

Most of the islands investigated in this study were constructed of sand. These islands generally display a low reflectivity sediments on the island and on the surrounding seafloor. In contrast four islands (Netserk F-40, Nipterk L-19, Minuk I-53, Kaubvik I-43) were constructed using both sand and gravel. These islands display areas of higher reflectivity material and abundant lower wavelength bedforms on the island and/or on the surrounding seafloor.

The Netserk F-40 and Kaubvik I-43 islands display the least amount of lateral accretion of all the islands investigated in this study (Figure 6.1). The lateral accretion of the Minuk island was not calculated due to a lack both a base line and follow-up bathymetry charts.

In contrast the Nipterk L-19 island displays the greatest amount of lateral migration of all the islands investigated in this study (Figure 6.1)

7.2.2 Initial Island Shape

The initial island shape may impact upon the style of sediment transport on the island sites. Two islands (Arnak K-06 and Nipterk L-19) investigated in this study are less concentric at the time of construction completion and contrast other islands were the constructed faces appear uniform in plan shape.

The Arnak K-06 island is irregular in shape as surveyed in 1985. The island is roughly concentric in the south. In contrast in the north bathymetric spurs occur particularly in the northwest and northeast.

The Nipterk L-19 island appears in the 1984 as constructed survey to display a non-concentric form with a gentler northeast, east and southeast margin and a steeper northwest, west and southwest margin.

These contrasts in island form may impact the sediment transport at these sites.

7.2.3 Impact of Water Depth on Island Morphology

The rate of island erosion during the early stages of submergence appears to be related to water depth.
At shallow water islands migration begins immediately upon island construction and is well developed by the time the island is abandoned. The commencement of migration appears to be more retarded in deeper water sites at early stages of submergence.

The Alerk P-23 and Itiyok I-27 islands are sites are located in 10.5m and 15.0m of water respectively. These island display very contrasting degrees of change in the early stages of submergence.

At the Alerk P-23 island site the 1981 and 1982 surveys coincide with completion of island construction and island abandonment, respectively. These programs indicate the changes in the submerged island form which occurred over an 11 month period between the fall of 1981 and the summer of 1982. The 1981 as-constructed Alerk bathymetry map the island appears circular in plan view with steeper slopes on the south, southeast and east margins. By the time the island is abandoned the island is more angular in shape with sharper planar faces best developed in the south and east. In north and northwest margins of the island retain broad and gentle in curvature.

At the Itiyok I-27 island site the 1982 and 1984 surveys appears to have been completed upon completion of island construction and one year after island abandonment, respectively. These programs indicate the changes in the deeper water sections (greater than 8m) of the submerged island form which occurred over an 22 month period between the fall of 1982 and the summer of 1984. We are limited to assessing the deeper water as this is the only area in which complementary coverage exists for both 1982 and 1984. The submerged portion of the 1982 island appears generally concentric. This concentric form has not changed by the summer of 1984 approximately one year after abandonment.

In summary the submerged portion of the 1982 Itiyok island appears generally concentric. This concentric form has not changed by the summer of 1984 approximately one year after abandonment. This contrasts Alerk P-23 were the island faces become sharp and planar between the completion of construction (fall 1981) and the time of abandonment (summer 1982).

This comparison suggests that the shallower water islands respond more immediately to the erosional forces. The very shallow water (6.5m) West Atkinson L-19 island appears to reinforce this trend. In the first year of the islands life (1982) the morphology characteristic of a strong southeast oriented sediment transport pattern is well developed. This erosional pattern has continues up to the 1990 survey.

An additional factor to consider assessment is the timing of and severity of storm events. The severity of storm events between the fall of 1981 and the summer of 1984 should be evaluated to determine if the timing of these event could be contributing to these morphological differences.

Section 8
Conclusions, Recommendations and Limitations

This report addressed a number of questions.

1) In what ways are the islands changing with time after abandonment?

2) What seafloor processes are active at the island sites?

3) Does the location, water depth, construction material or design influence the behaviour of the islands after abandonment?

4) What are the direction and magnitude of sediment transport on the islands?

5) Which area of the islands are undergoing sediment erosion and where has this sediment accumulated?.

6) How do these processes impact the aggregate resource potential of the islands?

Each of these question are addressed below from the result of this analysis. Recommendations to resolve unanswered questions are also presented.

8.1 Conclusions

1) In what ways are the islands changing with time after abandonment?

1.1) Section 5 of this report details the observed changes in each island site. A consistent relationship between island form and sediment transport has been defined. In general the islands remain broad and concentric along the margins which are stable or undergoing the least sediment erosion and the island faces become more steeper and planar in the areas of sediment accumulation. These general trends appear to hold true for a number of sites. The fact that the areas of erosion retain the broad concentric form suggests that erosion is affecting the island uniformly. In areas of deposition the island faces are more planar and steeper. This suggests a strong directional component to the sediment transport and depositional processes. The development of longshore type current may be causing these distinctive depositional patterns.

This relationship between island morphology and the change in seafloor topography between successive periods is a key to understanding the mechanisms, rates and directions of sediment transport.

2) What seafloor processes are active at the island sites and what is the relationship between seafloor acoustic texture and sediment transport?

2.1) The seafloor acoustic texture has been used along with the bathymetry analysis to establish the direction and extent of sediment transport at the island sites.

2.2) The sidescan data have been used to produce diagrammatic seafloor features maps of each site. These maps display the acoustic texture of the islands and surrounding seafloor; the degree of scouring and scour infill; the distribution of scouring and the style of scour termination; the location, orientation, and type bedforms; the location of sediment contacts; and the location of sediment slumps.

2.3) Sediment slumps occur on two sites - West Atkinson L-19 and Arnak K-06. It is possible that the shallower water of these sites contributes to slumping due to an increase in wave loading.

2.4) The morphology of the island top varies from island to island with some islands displaying rounded crests while others display flat crests. Some islands are observed to have long wavelength topographic highs and lows interpreted to be migrating sand waves.

2.5) Ice scours and possibly an ice grounding pit are observed on some islands.

2.6) The areas of sediment depletion frequently correspond to low reflectivity featureless seafloor devoid of bedforms.

2.7) Abundant bedforms occur at the island sites. The type and scale of bedforms vary widely from site to site and with water depth at individual sites. The islands constructed of sand and gravel consistently have the best developed bedforms.

3) Does the location, water depth, construction material or design influence the behaviour of the islands after abandonment?

3.1) The rate of island erosion during the early stages of submergence appears to be related to water depth. At shallow water islands migration begins immediately upon island construction and is well developed by the time the island is abandoned. The commencement of migration appears to be more retarded in deeper water sites at early stages of submergence.

3.2) Lateral accretion appears to be independent of island construction material.

3.3) The island design appears to relate to migration direction. The 9 sacrificial islands evaluated are aggrading toward the southeast and east-southeast. The 2 sand bag retained islands are migrating toward the east. One caisson retained island was investigated and this island is migrating toward the south.

4) What are the direction, magnitude and rate of sediment transport on the islands?

4.1) The prominent direction of island migration is toward to southeast. Figure 6.1 displays the prominent transport direction and magnitude for each island.

4.1) The rate of island accretion ranges from approximately 6m/year to 45m/year. This range may reflect the timing of the surveys used to calculate the rates or island to island differences.

5) Which area of the islands are undergoing sediment erosion and where has this sediment accumulated?.

5.1) The change in seafloor topography has allowed the areas of sediment erosion and accumulation to be distinguished on several island sites. This comparison has shown a predictable evolution in island morphology distinguishes the areas of sediment accumulation and depletion.

5.2) A conceptual model is presented which classifies the erosion patterns of the islands. The timing of the base line and follow up surveys dictate the stages of the islands evolutionary history which are captured.

6) How do these processes impact the aggregate resource potential of the islands?

6.1) The submerged islands are, and will continue to be, a major aggregate resource. It appears that large areas of the islands undergo sediment depletion but the sediment is deposited in specific directions. This is resulting in a gradual migration and elongation of the islands. This strong erosional trend exists for all the island sites. Although these sites all differ to some degree they fit into a spectrum of island forms and the sediment transport directions are very similar. The islands are responding in an orderly manner which suggests a uniform driving force.

6.2) The areas of sediment accumulation on a number of islands corresponds to the direction of these islands borrow pit. This may have major implications for the resource potential of these islands as the sediment is not loss through becoming a thin layer over the surrounding clay seafloor. These islands include Isserk E-27, Issungnak O-61, and Arnak K-06. These island may be expected to infill the borrow pit created during the island construction.

6.3) Some sediment is lost from the island system in this process. The residual bathymetry provides a measure of the amount of sediment "loss" from the island system. This refers to the net decrease in island volume between successive years. This volume loss refers to sediment transported in suspension beyond the limits of the island and the sediment blanketing the seafloor around the island which is too thin to produce a measurable residual bathymetry. The later component is regarded as loss from the standpoint of resource recovery.

8.2 Recommendations

1) Microcomputer based Modelling of Island Erosion

The current study methodology is effective in assessing how the islands change form in profile and plan view. The study objective includes determining to what extent the island will continue to erode and be dispersed. Determining the relationship between the physical oceanographic processes which drive the sediment transport is an important key to unlocking the fate of the island.

We recommend that a microcomputer based numerical modelling program be used to evaluate artificial islands erosional fate. This numerical modelling could used to generate a two dimensional profile models which describe the changing island morphology with time. Whereas the existing hydrographic survey data provides a measure of the changes in island form, numerical modelling provides a means of predicted the continuity of this process. The existing hydrographic survey data provide an invaluable means of calibrating the numeric models.

The physical oceanographic input for the numerical modelling will depend on the available data and the model input requirements. Klohn Crippen (1993) indicates that a recent Gulf Canada study entitled "Design Storm Characteristics, Amauligak Region, Beaufort Sea" provides a good representation of the storm wave and current parameters of importance for the island erosion assessment. The initial modelling could be confined to these extreme events.

Numerical modelling of erosion at artificial island sites has been previously identified as a valuable tool for assessing sediment transport at artificial island sites (ESRF, 1986).

2) Sidescan Mosaic

Netserk F-40 has excellent quality 1990 sidescan data with 100% coverage over the island and surrounding seafloor. We recommend that sidescan mosaics for this island sites.

By overlaying the sidescan mosaics and bathymetry the seafloor processes can be accurately related to island morphology and area of sediment erosion and accumulation.

3) Remotely Operated Vehicle (ROV) Imagery

The 1990 island surveys included the acquisition of ROV Video at 10 island sites. This underwater imagery offer an excellent means to groundtruth the sidescan. Depending on the location of the ROV dive sites the sediment type, bedform geometry, and key seafloor features of relevance to island erosion could be visually inspected and measured. For example the video imagery could be used to determine the approximate sediment size (eg. sand or gravel) exposed on the island and the wavelength and height of bedforms. The presence of a gravel armour is likely to impede seafloor erosion rates on the islands. The wavelength and height of bedforms can be used to estimate the near-bottom current velocities responsible of island erosion.

8.3 Limitations

1) Seafloor features (eg. slumps) should not be interpreted from the site bathymetry contour map without prior consideration for the extent of survey line coverage.

2) The 1989/1990 comparison was limited by the poor overlap of 1989 and 1990 survey lines and the resolution limits of the sidescan. In summary there is some difficulty in matching features on both the 1989 and 1990 data. Features which are matched differ in shape. This may be due to differences in survey line location and orientation and the difference in scale between the 1989 and 1990 records.

3) The magnitude of the island accretion (Figure 6.1) is probably may be biased by the relative timing of the base-line and follow-up surveys.

4) Time did not permit the calculation of the volume of sediment loss from the island system.

5) The limits of the sediment depletion/accretion map and residual bathymetry plots are confined to the deepest closed contour on the island.

6) The small number of non-sacrificial beach island makes the link between design, sediment transport direction, magnitude and rate questionable.

7) The ice scouring patterns at the island sites has not been mapped in detail from the sidescan data. The diagrammatic seafloor features maps display the approximate location and orientation of the ice scours. A comprehensive documentation of the interaction of ice with the island structures is beyond the scope of this study.

Section 9
References

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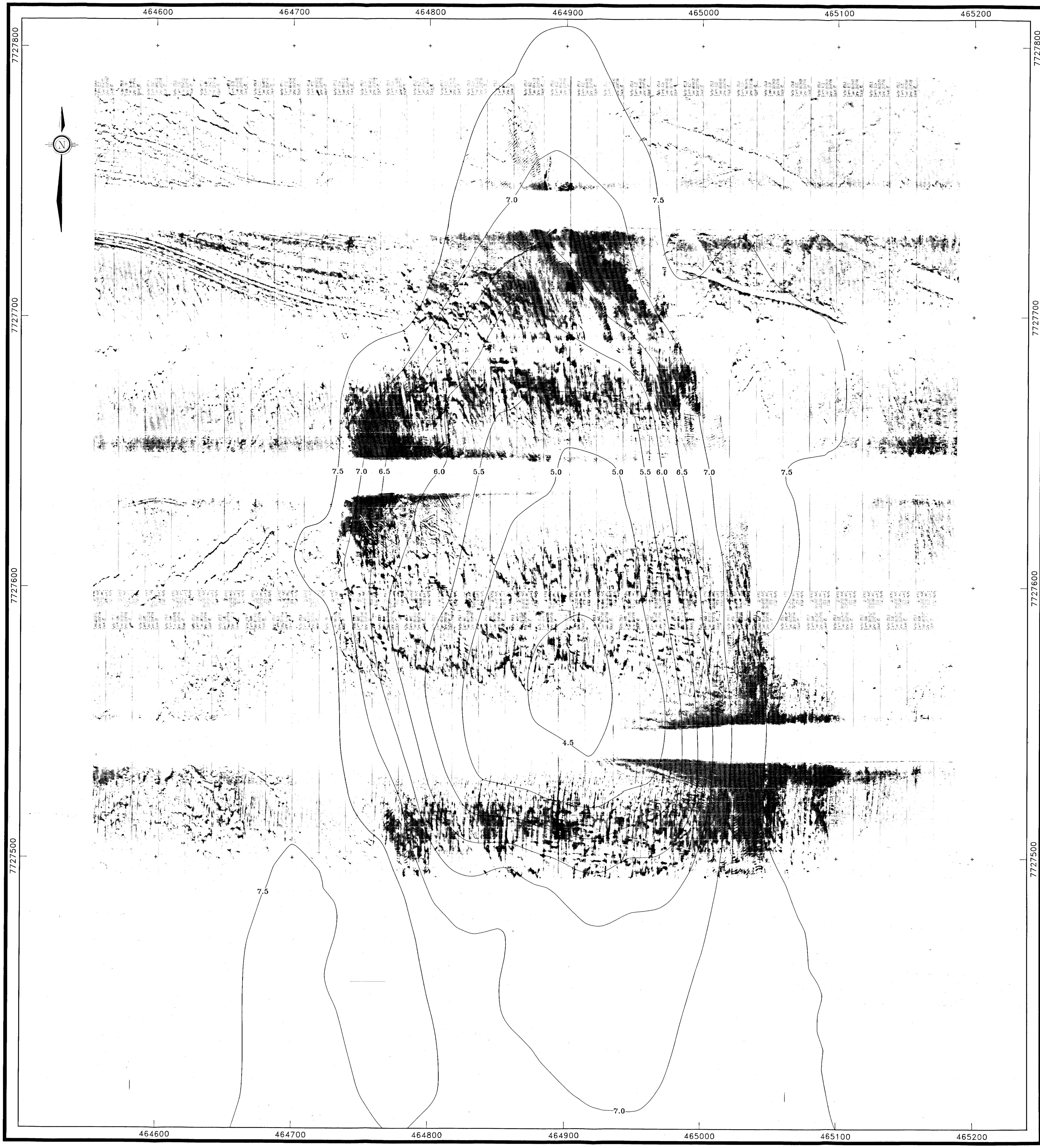
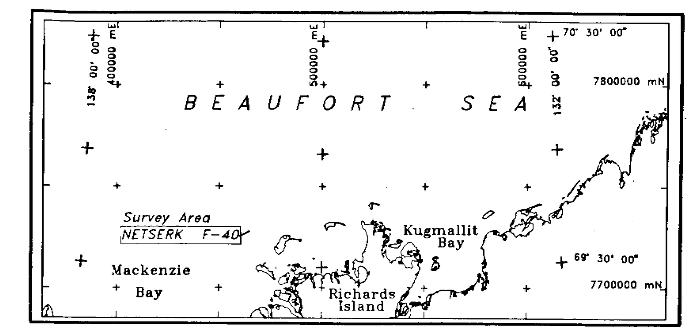


LOCATION MAP



LEGEND

7.0 — Bathymetric Contour (metres). Approximate where dashed

\+ UTM Grid Position

NOTES

MOSAIC

This mosaic displays 500kHz sidescan sonar data (Klein 595) which were recorded in the field with a constant ship speed correction. These data have not been slant range corrected. The along-track scale of individual records is approximately 1:1000 while the across-track scale is approximately 1:500. The mosaic was constructed from photographic reductions of original sidescan sonar records.

BATHYMETRY

Survey line spacing for bathymetric data was approximately 40m (N-S lines) and 100m (E-W lines). Contours were generated at 0.5m intervals using Surfer, a digital surface modelling package. Not to be used for navigation.

FIELD SURVEY

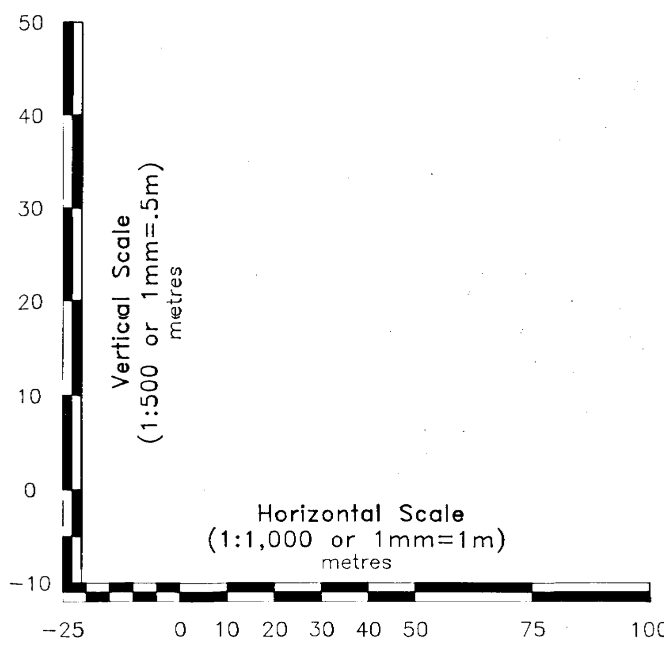
CHALLENGER SURVEYS and SERVICES (1990)

HORIZONTAL POSITIONS WERE DETERMINED USING THREE SYLEDIS MR3 RANGES WITH CHALLENGERS SURVEY NAVIGATION SYSTEM.

VESSEL: ATL ARCTIC SURVEYOR
SIDESCAN: KLEIN 595, 500kHz
SURVEY DATE: JULY 27 to JULY 28, 1990

BASEMAP

Projection: U.T.M. Zone 8, CM 135°W, Longitude
Spheroid: N.A.D. 27
Scale: X = 1:1000, Y = 1:500
Units: Metres



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Atlantic Geoscience Centre
&
Indian and Northern Affairs Canada

ENVIRONMENTAL GEOPHYSICS AND GEOLOGY

NETSERK F-40

SIDESCAN SONAR MOSAIC AND BATHYMETRY

GEOLOGIST : T. LaPierre	
DRN. BY : P. Campbell	DATE : October 1994
SCALE : X=1:1000 / Y=1:500	PROJECTION : UTM Zone 8
CSR PROJECT# : 9414	FILE : NS_SHELL.DWG

ENCLOSURE 1