ABANDONMENT OF OFFSHORE ARTIFICIAL ISLANDS IN THE BEAUFORT SEA

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EXECUTIVE SUMMARY

Numerous artificial islands have been constructed in the southern portion of the Canadian Beaufort Sea. These structures are required to support year-round oil and gas exploration in a region with severe environmental design loads. They are temporary in nature, typically occupied for less than one year. Construction water depths have ranged from 1.3 to 45 metres. Following completion of exploration activities, drilling equipment and slope protection are removed, permitting the granular fill to be dispersed by waves. The purpose of this study was to summarize current knowledge on the impacts associated with the abandonment of these islands.

Pertinent information concerning the potential impact of abandoned islands on the physical, chemical, and biological environment has been reviewed and summarized. The possibility of interference with traditional summer navigation and over-ice hunting practice has also been considered. The physical environment includes ice, currents, sediment transport and dynamics, island morphology, chemical oceanography, and sediment chemistry. Biological components consist of benthos, fish, birds, and marine mammals.

Current island abandonment practices are considered to have had no direct significant effect on the physical, chemical, or biological environment in the Beaufort Sea. Possible indirect effects on the biological component are related to the timing of the breakup of the landfast ice sheet and alteration of the yearly seaward extent of the landfast ice sheet. It has been suggested in some literature reviewed that the presence of islands could cause a delay in ice breakup, or that an increase in the seaward extent of the ice could effect both the population and distribution of marine mammals and birds. However, these effects have not yet been observed in the Beaufort Sea.

Effects on hunting and trapping are also related to the extent of the landfast ice sheet. It is thought by some individuals that the presence of islands will increase the seaward extent of the landfast ice, resulting in

a similar increase in the distances travelled by hunters. There appears to be no evidence in support of this.

Government regulations and responsibilities regarding island abandonment are not clear. This is due to the involvement of many agencies, with no one agency being responsible for all aspects of island abandonment. COGLA, INAC, MOT, and Environment Canada are the primary agencies involved. Regulation through various Acts (Territorial Lands Act, Public Lands Grants Act, Navigable Waters Protection Act, Ocean Dumping Control Act, Arctic Waters Pollution Prevention Act, Fisheries Act, Canada Oil and Gas Act) further serves to confuse the issue since these Acts are used in an ad hoc manner.

The impact of abandoned islands on navigation has been identified as the primary concern. It is believed that this impact could be mitigated through the charting of the locations of the abandoned islands as well as through the installation of permanent aids to navigation at the sites of abandoned islands. Recent policy guidelines proposed under the Navigable Waters Protection Act place major restrictions upon exploration activities in certain portions of the Beaufort Sea. These guidelines propose that islands constructed in a certain zone be "scalped" either to an elevation of -12 metres, or to the seabed as part of the approved abandonment program. This zone is designated a "navigational corridor", set aside for future tanker traffic. This proposal is considered to be premature, because a production and transportation scenario for Beaufort Sea oil has not been developed. Industry has suggested that it discriminates against exploration companies that already hold leases within the proposed corridor.

The available information is considered to be satisfactory, with deficiencies identified only in the area of sediment dynamics following island abandonment. Data pertaining to the rate and extent of island deterioration following abandonment is sparse at present. A formal monitoring program to quantify island deterioration and resultant sediment dispersal patterns and relate these to construction material types and environmental conditions would benefit future planning.

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1.0 INTRODUCTION

1.1 Project Description

Numerous artificial islands have been constructed in the southern portion of the Canadian Beaufort Sea. These structures are required to support year-round oil and gas exploration in a region with severe environmental design loads. They are temporary in nature and often are occupied for less than one year. Construction water depths have ranged from 1.3 to 45 metres. Following completion of exploration activities, drilling equipment and slope protection are removed, permitting the granular fill to be dispersed by waves and currents.

Government and industry have monitored the abandonment of some islands by conducting oceanographic, geotechnical, and biological research. Some of this information has been published, some of it is proprietary.

In an effort to summarize available information in one report, the Environmental Protection Service (EPS) of Environment Canada, through the Department of Supply and Services (DSS), retained EBA Engineering Consultants Ltd. (EBA), to summarize available information into one report. EBA was assisted in this task by subconsultants Arctic Laboratories Limited (ALL), ESL Environmental Services Limited (ESL) and Stanley Associates Engineering Ltd. (SAEL).

The contract was initiated in February, 1984 as DSS contract number OSG 83-00171. Mr. Warren Fenton (EPS, Yellowknife) was the designated project Scientific Authority.

Funding for this project was provided through the interdepartmental Panel on Energy Research and Development (PERD). The report outlines findings of the contractors and does not necessarily represent the views and/or policies of the Environmental Protection Service, Environment Canada.

1.2 Project Scope

The scope of the project described in this report included the following:

a) a review of island design and construction techniques, including identification of factors affecting island deterioration and a review of industry practice and government regulations regarding island abandonment;

b) a summary of the physical and chemical effects of island abandonment; considering physical oceanography, sediment transport, island morphology changes, island integrity, chemical oceanography, and sediment chemistry;

c) a review and summary of the biological aspects of island abandonment, including effects on benthos, fish, birds, and marine mammals; and

d) a description of the potential land use conflicts that have been raised including vessel navigation and effects on hunting and trapping.

The following three sections of this report (Sections 2.0 through 4.0) provide a review of island design and construction practice, present the environmental effects of island abandonment, and summarize potential land use conflicts associated with island abandonment. Conclusions are presented in Section 5.0.

2.0 REVIEW OF ISLAND DESIGN AND CONSTRUCTION PRACTICE

2.1 History of Island Development

2.1.1 Introduction

Thirty artificial islands have been constructed or are under construction in the Canadian Beaufort Sea (Figure 1, Table 1). These temporary structures are used to support exploratory drilling for oil and gas. Conventional "southern" exploration platforms such as drillships, semi-submersibles, submersibles, and jack-ups are generally not feasible for year-round use in arctic waters, due to the severe design loads imposed by both winter and summer sea ice. Lateral loads generated through the movement of ice can be several orders of magnitude greater than those from other environmental forces such as wind, waves, and earthquakes (Vivatrat and Kreider, 1982).

These structures consisted of surface piercing islands (islands) and sub-sea berms (berms) that supported gravity structures. Island types are presented in Figure 2. Islands commonly consisted of granular soil (usually sand) that was placed on the seabed until the surface of the island extended 3 to 4 metres above the waterline. Some early islands were constructed from clammed local seabed soil (Riley, 1975), some from trucked onshore gravel (Agerton, 1983; Galloway et al., 1982; Riley, 1975); the majority were built from dredged seabed sand (Figure 3). Common practice was to place the sand hydraulically, with a floating pipeline, dump barge, or hopper dredge. Sand placed by hopper dredge (usually a trailing suction hopper dredge) was commonly bottom-dumped at the delivery point, however, the sand could also have been discharged by pumping through a pipeline. Details of the 1983 Beaufort Sea dredging plant are presented in the Canadian Data Report of Hydrography and Ocean Sciences No. 5, (Taylor et al., 1984). Sand was

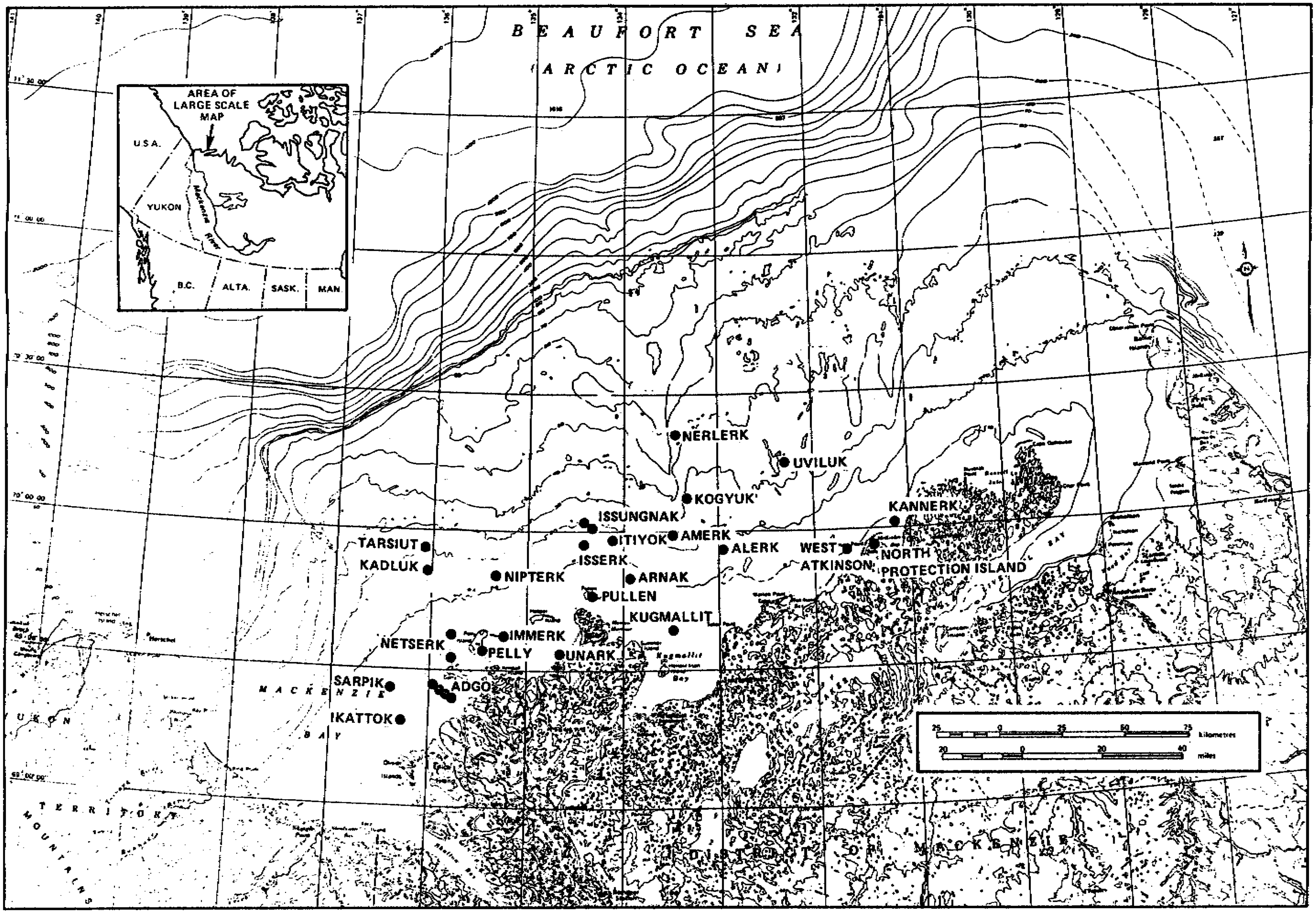

FIGURE 1 LOCATION OF ARTIFICIAL ISLANDS IN THE BEAUFORT SEA

TABLE 1 ISLANDS CONSTRUCTED IN THE BEAUFORT SEA

			ESTABLISHED	WATER DEPTH (m)	ISLAND TYPE	CONSTRUCTION METHOD[1]	FOUNDATION CONDITIONS	SURFACE DIMENSIONS (m)	FILL QUANTITY (m^3)	WATERLINE DIMENSIONS (m)	FREEBOARD (m)
...merk B-48	Esso	1972/73	July, 1973	3.0	Sacrificial beach, sand and gravel (1)	Cutter suction dredge floating pipeline (A)	Sand and silt	90 Dia.	180,000	145 Dia.	4.3
Adgo F-28	Esso	1973	Sept., 1973	2.1	Sandbag retained silt, gravel cap (2)	Clamshell placed local silt within sandbag retaining dike (A)	Soft clays and loose silts	45x180	46,000	45x180	1.0
Pullen E-17[2]	Esso	1973/74	March, 1974	1.5	Gravel (3)	Truck hauled gravel from onshore site in winter (C)	Sand and silt	70x115	65,000	70x115	3.0
Unark L-24[2,4]	Sun	1973/74	Winter, 1973 1974, 1975	1.3	Gravel (3)	Truck hauled gravel from onshore site in winter (C)	Soft clay and loose silts	60x120	44,000	60x120	3.7
Pelly B-35[2,4]	Sun	1974	Summer, 1975	2.0	Grounded barge with protective berm (4)	Berm built of sand bag filled gabion baskets surrounding clamshell placed local silt (A)	Soft clays and loose silts	85x155	35,000	85x155	2.4
Netserk B-44[2]	Esso	1974	Sept., 1974	4.6	Sandbag retained sand (2)	Clamshell placed sand fill hauled by barge (B)	Soft clays and loose silts	100 Dia.	306,000	100 Dia.	4.6
Adgo P-25[2,4]	Esso	1974	Sept., 1974	1.5	Sandbag retained silt, gravel cap (2)	Clamshell placed local silt within sandbag retaining dyke (A)	Soft clays and loose silts	70x145	27,000	70x145	1.0
Adgo C-15[2,4]	Esso	1975	March, 1975	1.5	Gravel (3)	Truck hauled gravel from onshore site in winter (C)	Soft clays and loose silts	55x155	70,000	55x155	3.0
Netserk F-40[2]	Esso	1975	Sept., 1975	7.0	Sand bag retained sand (2)	Clamshell placed sand fill hauled by barge (B)	Soft clays and loose silts	100 Dia.	291,000	100 Dia.	4.6

NOTE:
1. The number in parentheses for Island Type corresponds to one of the six types shown on Figure 2. Similarly, the letter after Construction Method corresponds to one of the five methods shown in Figure 3. Acronyms are defined within the text of the report.
2. Island constructed under Territorial Lands Act.
3. Island constructed under Public Lands Grants Act.
4. Island is officially abandoned.

TABLE 1 ISLANDS CONSTRUCTED IN THE BEAUFORT SEA (continued)

ISLAND NAME	COMPANY	YEAR CONSTRUCTED	DATE ESTABLISHED	WATER DEPTH (m)	ISLAND TYPE[1]	CONSTRUCTION METHOD[1]	FOUNDATION CONDITIONS	SURFACE DIMENSIONS (m)	FILL QUANTITY (m^3)	WATERLINE DIMENSIONS (m)	FREEBOARD (m)
Sarpik B-35[2]	Esso	1975/76	March, 1976	4.3	Gravel (3)	Truck hauled gravel from onshore site in winter (C)	Soft clays and loose silts	100 Dia.	118,000	100 Dia.	3.0
Ikattok J-17[2,4]	Esso	1975	July, 1975	1.5	Sandbag retained sand (2)	Clamshell placed local silt within sandbag retaining dyke (A)	Soft clays and loose silts	45x130	38,000	45x130	2.0
Kugmallit H-59[2]	Esso	1976	Aug., 1976	5.3	Sandbag retained sand (2)	Clamshell placed sand fill hauled by barge from Tuft Pt. (B)	Soft clays and silts over sand	100 Dia.	236,000	100 Dia.	4.6
Adgo J-27[2]	Esso	1976	Sept., 1976	1.8	Sandbag retained silt, gravel cap (2)	Clamshell placed local silt within sandbag retaining dyke (A)	Soft clays and loose silts	50x105	69,000	50x105	1.0
Arnak L-30[2,4]	Esso	1976	Sept., 1976	8.5	Sacrificial beach, sand (1)	Hydraulically placed sand, dredge with pipeline (D)	Soft clays and loose silts	100 Dia.	1,150,000	210 Dia.	5.2
Kannerk G-42[2,4]	Esso	1976	Sept., 1976	8.5	Sacrificial beach, sand (1)	Hydraulically placed sand, dredge with pipeline (D)	Sand	100 Dia.	1,150,000	180 Dia.	5.2
Isserk E-27[2] [4]	Esso	1977	Summer, 1977	13.0	Sacrificial beach, sand (1)	Hydraulically placed sand, dredge with pipeline (D)	Veneer of soft clay overlying sand	100 Dia.	1,908,000	227 Dia.	5.0
Issungnak O-61[2]	Esso	1978/79	Sept., 1979	19.0	Sacrificial beach, sand (1)	Hydraulically placed sand, below water fill dredged on site; above water fill hauled by dump barge to site, then placed hydraulically (D)	Stiff clay overlying sand	100 Dia.	4,100,000	100 Dia.	1.2
Issungnak 2-O-61[3]	Esso	1980	Summer, 1980	19.0	Sacrificial beach, sand (1)	Hydraulically placed sand, reclaimed from Issungnak O-61 (D)	Stiff clay overlying sand	100 Dia.	4,900,000	180 Dia.	5.0

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TABLE 1 ISLANDS CONSTRUCTED IN THE BEAUFORT SEA (continued)

ISLAND NAME	COMPANY	YEAR CONSTRUCTED	DATE ESTABLISHED	WATER DEPTH (m)	ISLAND TYPE[1]	CONSTRUCTION METHOD[1]	FOUNDATION CONDITIONS	SURFACE DIMENSIONS (m)	FILL QUANTITY (m^3)	WATERLINE DIMENSIONS (m)	FREEBOARD (m)
Alerk P-23[3]	Esso	1980/81	Fall, 1980/81	10.5	Sacrificial beach, sand (1)	Hydraulically placed sand, dredged on site, placed with pipeline (D)	Veneer of clay overlying sand	100 Dia.	1,500,000	200 Dia.	4.5
North Protection Island, McKinley Bay[3]	Dome	1980/81	Summer, 1980	4.6	Sacrificial beach, sand (1)	Hydraulically placed sand, dredged on site, placed with pipeline (D)	Sand	350x1200	2,000,000	?	4.0
West Atkinson L-17[2]	Esso	1981/82	Sept., 1982	7.5	Sacrificial beach, sand (1)	Hydraulically placed sand (D)	Soft clay overlying sand	100 Dia.	1,000,000	220 Dia.	4.5
Tarsiut N-44[3]	Gulf	1981	Oct., 1981	21.0	Caisson retained sand on sand berm (5)	Seabed subcut, hydraulically placed sand fill and barge and hopper haul from offshore source (D+E)	Soft clay overlying stiff clay and silt	170 Dia.	1,800,000	n.a.	-6.5
Uviluk P-66[3]	Dome	1981/82	Fall, 1982	29.7	SSDC on gravel capped sand berm (6)	Hydraulically placed sand berm, reinforced steel hull converted from VLCC ballasted onto berm surface (D)	Sand	103x212	1,900,000	n.a.	-9.0
Itiyok I-27[3]	Esso	1982	Oct., 1982	15.0	Sacrificial beach, sand (1)	Hydraulically placed sand, dredged onsite, placed with pipeline (D)	Sand	100 Dia.	2,000,000	225 Dia.	4.5
Nerlerk B-67[3]	Dome	1982/83	n.a.	45.1	Proposed SSDC on sand berm (6)	Hydraulically and hopper placed sand berm (construction stopped due to slope failures) (D+E)	Sand	n.a.	+4,000,000 when construction stopped)	n.a.	-9.0

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Kogyuk N-67[3]	Gulf	1982/83	Fall, 1983	28.1	MAC berm converted to SSDC on sand berm (6)	Mostly hopper placed sand berm, reinforced steel hull converted from VLCC ballasted onto berm surface (E)	Sand	103x212	1,450,000	n.a.	-9.0
Kadluk O-07[3]	Esso	1983	Fall, 1983	14.5	Caisson retained sand on sand berm (5)	Hopper-placed sand berm with steel caissons (E)	Soft clay overlying firm clays	n.a	450,000	n.a.	-9.0
Minuk[3]	Esso	1982/83	Summer, 1983 (1985 utilization)	14.0	Sacrificial beach, sand (1)	Hopper placed sand (E)	Soft clay overlying firm clay	n.a.	n.a.	n.a.	5.0
Amerk[3] P-09	Esso	1983/?	n.a.	27.0	Caisson retained sand on sand berm, extensive seabed sub-cutting (5)	Placed by suction dredge, sand berm with steel caissons (D)	Soft clay overlying sand	128 Dia.	2,700,000	n.a.	-9.0
Nipterk I-19[3]	Esso	1983/?	n.a.	13.0	Sacrificial beach, sand (1)	Hopper placed sand (E)	Soft clay overlying firm clay	110 Dia.	1,700,000	170 Dia.	5.0

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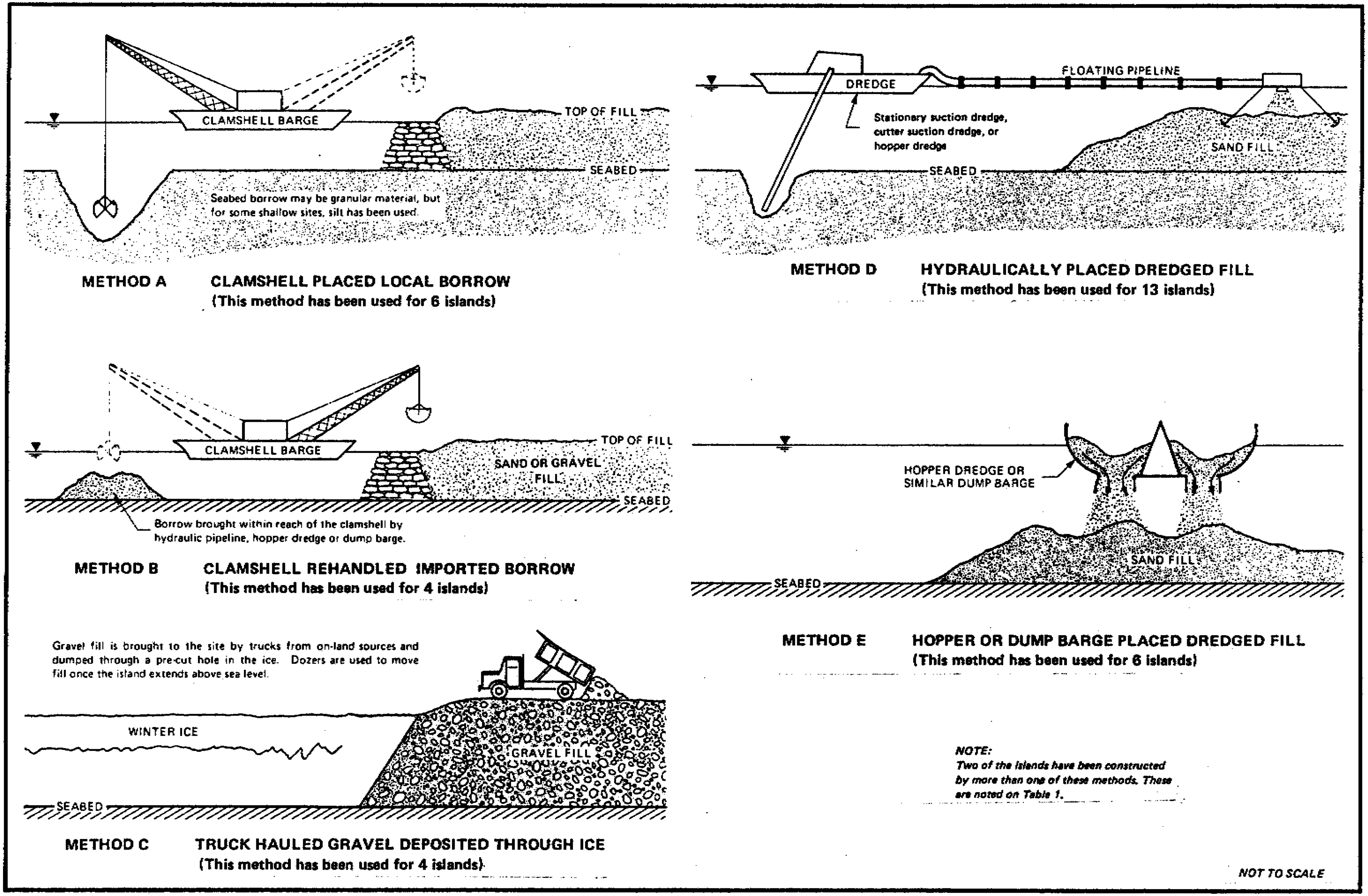

FIGURE 3 CONSTRUCTION METHODS USED FOR EXPLORATION ISLANDS

loaded onto barges by either clamshell or dredge, depending upon barge type. Barges were either utility barges or bottom-dump barges. Pipeline placement was usually used if sufficient borrow reserves were available within close proximity to the island site; hopper dredges and barges were used if fill material was imported. Islands were occasionally built with a combination of imported and local fill.

Berms were usually constructed in deeper water and were similar to islands, except that they were terminated about 6 to 10 metres below the waterline. Following berm completion, the surface was leveled and a steel or concrete gravity structure was ballasted onto the berm. The structure usually protruded several metres above the waterline and functioned in the same manner as did a surface piercing island except that the total fill volume was substantially less than that required for a surface piercing island in a similar water depth.

2.1.2 Surface Piercing Islands

Artificial island construction in the Beaufort Sea started in 1972, when Imperial Oil Limited, now operating in the Beaufort region as Esso Resources Canada Limited (Esso), constructed Immerk B-48. This island, built in about three metres of water from dredged sand and gravel (Riley, 1975), was termed a "sacrificial beach" island (Figure 2). It had a freeboard of about 4.6 metres, a working surface diameter of 90 metres, and a waterline diameter of approximately 145 metres.

Slope protection was provided above the waterline and consisted of sheets of plastic filter cloth placed on a graded 5H:1V (5 horizontal to 1 vertical) sideslope. The filter cloth was covered with chain link fencing and cable netting, which was in turn secured to timber and steel deadman anchors placed at the toe and crest of the sideslope (Riley, 1975).

Underwater sideslopes were constructed to about 20H:1V since it had been determined that this slope would be representative of a natural, moderately protected beach composed of similar soil. The flat slope led to the adoption of the "sacrificial beach" nomenclature, in that the gradually rising island sideslope caused incoming waves to break, thereby absorbing the wave energy (Croasdale and Marcellus, 1977). Any significant amount of erosion that occurred during extreme environmental conditions would be conveniently replaced afterward. Due to the large fill volume (approximately 180 000 cubic metres) it was considered unlikely that erosion caused by any one event would significantly affect the overall stability of the island.

The relatively flat underwater slope also provided defense against large ice forces, since an incoming ice sheet would be deflected upwards until flexural failure occurred (Croasdale and Marcellus, 1977). Breakage of the ice sheet not only caused a reduction in applied load, but caused the formation of a "rubble field" around the island (Abdelnour and Sayed, 1982; Bercha et al., 1982; Dunwoody, 1983; Kotras, et al., 1983). This grounded rubble field would not only effectively increase the size of the island, but would transmit incoming loads directly to the seabed.

In the late summer of 1973, following the successful construction of Immerk, Esso undertook construction of Adgo F-28. This island was termed a "sandbag-retained" island (Figure 2) and consisted of a seabed-founded sandbag retaining dike which was infilled with silt from the adjacent seabed. Following completion of construction, the island was capped with gravel. Freeboard was less than a metre. This type of island was only servicable when the silt was frozen. Damage to the unfrozen silt by wave action was minimized by limiting construction to the period immediately preceeding freeze-up. The gravel cap was required to improve trafficability on the silt.

In March, 1974, Esso completed construction of Pullen E-17, a gravel island (Figure 2) located in 1.5 metres of water on the leeward side of natural Pullen Island. This island was constructed through the winter of 1973/74 by cutting and removing blocks of ice and then filling the subsequent holes with gravel trucked from an on-shore borrow source. Sandbags were placed around the perimeter of the island above the waterline to provide erosion protection during the open water season. The island was provided with three metres of freeboard. Construction involved the removal of 18 000 tonnes of ice and subsequent placement of 65 000 cubic metres of compacted fill within 50 days.

A fourth type of surface piercing island appeared in 1975, when Sun Oil Co. Ltd. (Sun) grounded a drill rig carrying barge in 2.0 metres of water and built a protective berm around it (Pelly B-35). The berm was constructed from sandbag-filled gabion baskets; the annular space between the berm and the barge was filled with seabed silt placed with a clamshell (Figure 2). In the spring, following the completion of drilling, a portion of the berm and the silt infilling was removed, the barge was refloated, and removed. This type of drilling platform was only used once.

From 1975 to mid-1976, all new islands were constructed from either truck-hauled gravel in the winter or from clamshell-placed barged sand or local silt in the summer. The maximum water depth was at Esso's Kugmallit H-59 island, where 226 000 cubic metres of sandbag-retained sand fill was placed in 5.3 metres of water.

The sacrificial beach island concept was revived in 1976. This was due to:

a) the need to construct islands in deeper water in a single season,
b) the availability of seabed sand near proposed island sites, and
c) the availability of large scale dredging equipment.

Esso constructed two sacrificial beach islands in 1976. Arnak L-30, and Kannerk G-42 were both located in 8.5 metres of water and each required about 1 150 000 cubic metres of fill. Each island had a freeboard of five metres; the diameter of the working surface was around 100 metres, and the waterline diameter was approximately 200 metres. Large, 1.5 cubic metre sandbags were placed on the above-waterline portion of the slope for wave protection.

Isserk E-27, a sacrificial beach island, was constructed by Esso in 1977. Located in 13 metres of water, environmental conditions were considered to be more severe at this location than at any other previous island site. The relatively exposed location of the island (18 kilometres north of Pullen Island), combined with deeper water, was expected to allow development of substantially greater ice and wave forces than had previously been encountered. The fill volume required to construct the island was about 1.9 million cubic metres. All of the sand was placed hydraulically, with a stationary suction dredge and pipeline.

A well defined borrow pit must be identified prior to island construction. Based on the Isserk experience, Boone (1980) estimated that 30 percent of the delineated material cannot be economically recovered from a dredge pit, 30 percent of the material discharged is lost to waves and currents (predominantly silt), 5 to 10 percent of the material is effectively lost due to compaction and settlement of the fill, and 5 to 10 percent of the material is "recovered" through bulking once the fill is disturbed from its natural in situ density. About 3.2 million cubic metres of material would normally be identified within a borrow prospect for construction of an island with 1.3 million cubic metres of placed fill.

Construction of the largest sacrificial beach island to 1984 was initiated by Esso during the summer of 1978. Issungnak O-61, located in 19 metres of water, was to consist of slightly in excess of 4.1 million cubic metres of sand fill. This represented about a three-fold increase in fill volume compared to the next largest island, Isserk E-27, although the water depth of Issungnak was only 46 percent greater than that of Isserk.

Actual island construction spanned two open water seasons, the summers of 1978 and 1979. A single stationary suction dredge, the Beaver Mackenzie, was used during the first season. A second dredge, the Sceptre Mackenzie (also a stationary suction dredge) was involved during the second season, joining the Beaver Mackenzie in dredging sand to ensure that the island was completed by late September, 1979. The island was designed to have a 15H:1V underwater sideslope, a 25H:1V 25 metre wide sloping beach and a 3H:1V above water sideslope. Freeboard was to be about five metres, the working surface diameter 100 metres, and the water line diameter 180 metres. Slope protection was intended to consist of sandbags on the 3H:1V slope and a layer of wire net and filter cloth on the 25H:1V beach.

The island was nearing completion in September, 1979 when two storms eroded the exposed aerial portion of the island and damaged some of the dredging plant (Boone, 1980). Island re-building was hindered by freeze-up, resulting in a completed island with only 1.5 metres of freeboard and no slope protection. However, island erosion during the storms had resulted in the formation of a 100 metre wide sand apron around the central 100 metre diameter working surface. This apron, located just below the waterline, caused waves to break as far away as 150 metres from the island centre (Boone, 1980). The low freeboard required formation of a rubble field by late winter in order to ensure stability against extreme ice conditions.

A second Issungnak, 2-0-61, was constructed 40 metres west of the original island in the summer of 1980. This island was constructed in a single season from the sand forming Issungnak 0-61. Island construction was in accordance with the original 0-61 design.

Subsequent to the construction of Issungnak 2-0-61, Esso has constructed and drilled on three more sacrificial beach islands. Alerk P-23, located in 10.5 metres of water, contained 1.5 million cubic metres of fill; West Atkinson L-17, located in 7.5 metres of water, contained 1.0 million cubic metres of fill; and Itiyok I-27, located in 15 metres of water, contained 2.0 million cubic metres of fill. Two more sacrificial beach islands were under construction in 1983; Minuk was located in 14 metres of water, Nipterk I-19 was located in 13 metres of water.

Slope protection was provided by sandbags and filter cloth. Experimental techniques, such as articulated concrete mats described for use in the Alaskan Beaufort Sea (Wang et al., 1983; Leidersdorf, et al., 1982; 1981) have never been implemented in the Canadian Arctic.

Dome Petroleum Limited (Dome) constructed one permanent sacrificial beach island in 1980. This island, named the North Protection Island, is intended to provide relatively sheltered waters within Dome's selected harbour area of McKinley Bay. It is formed from spoil obtained during the dredging of access channels and mooring basins within McKinley Bay. An airstrip, camp facilities, and a temporary dock are located on the island.

The length of the island is about 1200 metres and it is approximately 350 metres wide. Freeboard is 4.0 metres; no slope protection has been provided.

2.1.3 Subsea Berms

The first subsea berm in the Canadian Arctic, Tarsiut N-44, was constructed by Dome during the summer of 1981 (Fitzpatrick and Stenning, 1983; Myers et al., 1983). The berm was situated in 21.0 metres of water and terminated at 6.5 metres below sealevel. Prior to island construction, the seabed was "subcut" by 3.0 metres in an effort to increase the stability of the berm. This was necessary since the immediate seabed clay did not have sufficient shear strength to provide an adequate safety margin against sliding during the design ice load. Sand was the predominant fill material, although gravel was used for the upper few metres of berm height. A total of 1.8 million cubic metres of fill was used to construct the berm. This represents less than half of the total fill requirements of sacrificial beach island Issungnak 2-0-61, although the water depth at Issungnak was 1.5 metres less than that at Tarsiut. Through different construction techniques steeper underwater sideslopes were achieved (Dikken and Brakel, 1982), resulting in a fill volume that was similar to that required to construct a sacrificial beach island in 15 metres of water. The shape of the berm was circular, approximately 170 metres in diameter.

Following berm construction, four reinforced vertical-walled concrete caissons were set-down and ballasted onto its surface. Each caisson was 69 metres in length, 15 metres wide, and 11.5 metres high. The two outside corners of each caisson were beveled, resulting in the completed structure having eight approximately 45 metre long sides. With a set-down draft of 6.5 metres, the caissons extended 5.0 metres above the waterline. After caisson placement, the square interior of the four caissons was filled with dredged sand to an elevation of +7.5 metres. A rock apron (Myers et al., 1983; Myers and Kirby, 1983) was placed around the toe of the caisson, to control erosion.

Exploratory drilling was conducted over the winter of 1981/82, a delineation well was advanced during the summer of 1982. Following these activities, the island was vacated. Dismantling of the caisson portion of the structure is scheduled for the summer of 1984 (Gulf, 1983).

Following the experience gained with the Tarsiut caissons, Dome developed the Single Steel Drilling Caisson (SSDC). This structure consisted of the forward half of a modified Very Large Crude Carrier (VLCC). It was 162 metres long, 53 metres wide, stood 25 metres high and was to be placed on a subsea berm. The structure was first deployed in the fall of 1982 when it was placed on the Uviluk P-66 berm, located in approximately 30 metres of water. Since the design set-down draft of the SSDC was 9.0 metres, a rectangular berm 21 metres in height was required. The berm was constructed from hydraulically-placed sand, with a gravel cap approximately one metre thick. Rock and gravel erosion protection was placed around the perimeter of the unit after it was ballasted onto the berm. The total fill volume was about 1.9 million cubic metres, berm sideslopes were between 8H:1V and 5H:1V. Subcutting was not necessary since the foundation soil was sand. Exploratory drilling was conducted over the winter of 1982/83, after which the SSDC was re-floated and removed from the berm.

The next deployment site for the SSDC was designated Nerlerk B-67. This lease was located in about 45 metres of water, the deepest to date for bottom-founded drilling in the Canadian Arctic. For the design 9.0 metre set-down draft of the SSDC, a subsea berm 36 metres in height was required. Dependent upon slope angle, fill volumes were to be between 4.0 million and 6.5 million cubic metres. Foundation soils were sand; berm fill sand was placed hydraulically with pipeline and hopper dredge (Berzins and Hewitt, 1984).

In the summer of 1983, during the second construction season, slope failures occurred within the fill, resulting in the abandonment of the berm (Berzins and Hewitt, 1984). In excess of 4.0 million cubic metres of fill had been placed when the soil failed; the geometry of the berm after the failure is not known. Research is currently underway at Dome to better understand the cause of the slope failures. The SSDC was re-assigned to a berm at Kogyuk N-67.

Simultaneous with the development of Dome's Tarsiut caisson and the SSDC, Gulf Canada Resources, Inc. (Gulf) developed their own bottom-founded exploration unit (Bruce and Harrington, 1982). Originally dubbed the Mobile Arctic Caisson (MAC), and now called the Molikpaq, the Gulf structure was an all-steel annular caisson with a steel topdeck. It was eight-sided, although nearly square in plan. The hollow 73 metre by 73 metre core underlying the topdeck was designed to be filled with dredged dewatered sand. The sand was required to provide the structure with sufficient resistance to environmental ice forces.

Design deployment depth for the Molikpaq was a constant 21.0 metres, resulting in a structure that could be placed in relatively deep Beaufort Sea waters with a minimal amount of berm. Structure deployment in 25 metres of water would only require about 200 000 cubic metres of berm fill, compared with the 4.1 million cubic metres of fill required for sacrificial beach Issungnak O-61 (19 metres of water), the 1.8 million cubic metres of fill required for construction of the Tarsiut N-44 berm (21 metres of water) and the 1.9 million cubic metres of fill required for the SSDC berm at Uviluk P-66 (30 metres of water).

Delivery of the Molikpaq is scheduled for the summer of 1984, however, it currently has no designated deployment site.

A caisson-type structure was also developed by Esso. Named the Caisson Retained Island (CRI), this structure consisted of eight all-steel caissons. Each caisson was 43 metres long, 12.2 metres high, and 13.1 metres wide (De Jong and Bruce, 1978; Mancini et al., 1983). When all eight caisson sections were joined together, the diameter of the unit was 117 metres. The design set-down water depth was identical to that of the SSDC, at 9.0 metres.

The CRI was operational and in-place at Kadluk O-07 in the winter of 1983-84. Deployment site water depth was 14.5 metres; approximately 450 000 cubic metres of fill were required to obtain a berm height of 5.5 metres. A gravel erosion protection system was installed at the toe of the caisson.

2.2 Factors Affecting Island Deterioration Upon Abandonment

Typical island abandonment procedure is to initially remove all exploration related equipment, followed by the removal of all erosion protection system components. Berm abandonment involves refloating and removal of the drilling caisson unit(s). However, only SSDC-type berms have been abandoned to date. The Tarsiut caisson structure, with its interior sand filling, is scheduled to be removed during the summer of 1984. Removal of the concrete caissons will involve the excavation of rock and sand around the outside perimeter of the structure as well as removal of a portion of the interior sand fill (Gulf, 1983).

Island and berm deterioration is controlled by the properties of the fill, the magnitude of the active environmental processes, and the integrity of the residual erosion protection system. Geotechnical properties of the fill that affect deterioration rates are the grain size of the material and to a small degree, the amount of ice-bonding. Most artificial islands have been constructed from fine-grained noncohesive sand with varying proportions of silt and clay. The clay occurs as discrete balls rather than as a uniform distribution within the fill. These balls are formed during the dredging process when the dredge encounters cohesive soil. Since all of the dredged and clammed cohesionless soils are fluvial or marine in origin, they are frequently poorly graded and often are very uniform in size. Gravels derived from on-shore borrow sources are glacio-fluvial in origin and are typically clean and well-graded. The maximum gravel aggregate size is about 75 millimetres.

Sub-zero, winter temperatures cause frost to penetrate the fill. The depth of frost penetration is dependent upon the meteorological conditions and the moisture content, salinity, and mineralogy of the fill material. Porewater salinity depresses the freezing point of the fill porewater. Typical Beaufort sea water has a salinity of about 30 parts per thousand; this results in a freezing point depression of around 1.7C°. Fills constructed from soils obtained from the seabottom have salinities similiar to that of sea water; fill material derived from onshore sources also has a salinity close to that of sea water, after placement.

In spite of the freezing point depression, it is normal for the frost to penetrate into exposed fill to the waterline by the end of the first winter (approximately four metres). Below waterline fill will have only slight frost penetration after the first winter. Since the normal summer thaw depth is 1.5 to 2.0 metres, a residual layer of frozen soil is left within the fill. This marks the initiation of permafrost.

Once an island is vacated and the slope protection is essentially removed, wave action starts to erode thawed fill and initiate permafrost degradation. It is assumed that the permafrost provides some resistance to erosion, although the degree to which the presence of permafrost affects the island deterioration rate is unknown.

Environmental factors affecting island deterioration are wind, wave, current, and ice forces. These interact with the fill comprising a berm or island causing erosion. Assuming that the slope protection system has been essentially removed, the degree of deterioration is dependent upon the magnitude and duration of the environmental forces and the integrity of the fill.

Once an island is vacated, typically in the spring, and the slope protection system is removed, typically in the summer, the aerial portion of the island is exposed to wind and wave forces. Waves rapidly erode the exposed portion of the island surface; deflation occurs at a much slower rate, particularly for the coarser-grained (i.e., gravel) fills. It is not unusual for a sand island in an exposed location to be eroded down to the waterline a few months after abandonment (i.e., Isserk E-27; Woodward-Clyde Consultants, 1982). Islands in less exposed locations, or constructed from terrestrial gravel, can be expected to remain above the waterline for up to several years (i.e., Pullen E-17; Woodward-Clyde Consultants, 1982).

Ice scouring of the seabed has been proven to be a major geomorphic process, although a study of ice-induced scour of island surfaces, or sediment transport effected by ice has not yet been conducted. Studies conducted by Esso (Spedding, 1976a, 1978a, 1978b, 1979a, 1979b, 1980, 1982) have indicated that rubble fields form around islands that penetrate the waterline and over islands that are submerged. Correlations between ice movement over or around islands and island morphology have not been attempted.

2.3 Government Regulations

Beaufort Sea artificial islands have been constructed under the authority of both the Territorial Lands Act (TLA) and the Public Lands Grants Act (PLGA). Land use permits are issued to operators under the TLA (and the associated Territorial Land Use Regulations), while the PLGA provides leases for the seabed. For the purpose of regulating island construction, Indian and Northern Affairs Canada (INAC) replaced the TLA with the PLGA in the spring of 1981. However, certain islands constructed after the inception of the PLGA system are covered under the TLA if island construction was approved prior to the spring of 1981. Of the 30 islands constructed or under construction, only 12 have been built under the PLGA. The TLA is still used to regulate on-shore activities.

The Canada Oil and Gas Lands Administration (COGLA) acts as the "lead" agency in the regulation of drilling in the Beaufort Sea. Most exploration operations are controlled through the Canada Oil and Gas Act , however, other avenues of legislation are also within COGLA's venue.

Each operator must submit an abandonment program to COGLA before they are allowed to vacate the island. COGLA then solicits "opinions" on the program from other government agencies (i.e., Navigable Waters). If the plan is satisfactory, permission to vacate the island is granted, with the stipulation that the island be "restored to original conditions". The lease covenants include environmental protection criteria, but there are no specific regulations stating exactly what materials must be removed from the island surface. It is believed by both COGLA and industry that to restore the island literally to "original conditions" is impractical.

In practice, it has been suggested by several individuals that COGLA directs most of their efforts towards actual drilling operations and well completion and abandonment, effectively ignoring the environmental aspects of island abandonment. INAC considers that it is their responsibility to ensure that environmental concerns are addressed and the vacated islands are cleaned-up, receiving their authority through the TLA land use permits and the PLGA leases.

INAC's interpretation of the TLA and the PLGA follows (Fenton, 1983):

Territorial Lands Act

(first passed in 1952, latest amendments made in March 1970; administered by INAC)

The Territorial Lands Act provides for the disposition, administration and management of all Territorial Lands. In the N.W.T. these lands are defined in the Northwest Territories Act and do not include offshore lands (i.e. seabed). Occupation of land is regulated under a system of leases or licenses (referred to as a land tenure agreement). Activities carried out on unleased land are regulated under the

Territorial Land Use Regulations (first passed in 1971 and amended in 1977 to include the Eastern Arctic). Land use activities are controlled under a system of land-use permits which authorize an individual or company to carry out a specific land-use operation at a specified place, during a specified time and subject to specific terms and conditions, during a specified period of time. It includes provisions to allow for adequate protection of the affected environment.

Public Lands Grants Act

(first passed in 1952; latest amendments made in 1982; administered by INAC)

The Public Lands Grants Act provides for the disposition of Crown lands (anywhere in Canada) not provided for in other legislation. In the N.W.T. this Act has been used to regulate allocation of offshore lands (i.e., Beaufort Sea seabed).

Dredging is regulated under the Public Lands Grants Act and the associated Public Lands Leasing and Licensing Regulations by requiring that proponents obtain a PLGA lease to "occupy" subsea "lands". The lease includes covenants that define which activities the proponent may carry out on the leased lands (i.e., construction of an island) and outlines environmental terms and conditions to be applied to that particular activity at that site. Enforcement is based upon assuring that the proponent meets the convenant of the lease. Should the proponent not meet these convenants then the company would essentially be in breech of its "contract" with the federal government to meet the conditions of that lease. INAC could then revoke the lease which would legally mean that if the proponent continued to carry out activities at that site he would be doing so without legally occupying the land (i.e., he would be trespassing) and would be charged.

Island abandonment is governed by the same legislation as island construction. If construction is authorized under the TLA, abandonment is also regulated under the TLA. The same procedure is to be followed with islands constructed under the PLGA, however, no islands have been officially abandoned under the PLGA.

Beaufort activities which are regulated under the TLA are administered from Inuvik, N.W.T. INAC officers (Land Use Inspectors) monitor adherence to land use regulations through site visits during construction, drilling, and clean-up operations. Abandonment criteria consists of removal of substances and materials "simultaneously toxic, persistent, and bio-accumulative and those essentially non-toxic but persistent and float or remain suspended in the sea" (Osborne, 1980). These substances and materials have been typified as "toxic" waste, such as drilling chemicals, and "persistent" objects such as timber or steel piles, filter cloth, plastics, sandbags, and miscellaneous debris remnant on the island surface. These criteria are consistent with the Arctic Waters Pollution Prevention Act and the Fisheries Act. If an island site is cleaned-up to the satisfaction of the Land Use Inspector, he recommends that the island be granted "final clearance". A "Land Use Engineer" (usually the District Manager) then recommends that the island be returned to the public domain. The actual transfer is performed at the discretion of the Regional Land Resources Manager (official abandonment). Only three official reports detailing site inspections were made available for this study. These reports were filed in 1976, 1978 and 1979 (Cuddy, 1979, 1978; Dobbyn, 1976).

This procedure appears to have been adequate insofar as environmental hazards were concerned; however, it does not deal with the physical presence of the islands. This is likely due in part to the performance of the earliest islands, which simply eroded away; and in part to the locations of the islands, which were generally near-shore in shallow water. As island construction progressed into deeper waters, it soon became apparent that the abandoned islands themselves were persistent to a degree and could possibly influence ice formation and break-up patterns as well as prove to be a hazard to navigation. However, the land use regulations have never been interpreted to consider the physical effects of island abandonment. Inspections continued to evaluate only the toxic and persistent aspects of man-made materials.

Only eight islands have been officially abandoned to date, with the last abandonment certified in 1979 (Table 1). Official abandonment of six other vacated islands was recommended by an INAC Land Use Inspector (Cuddy, 1979); however, the relevant land use files remain open (Heath, pers. comm., 1984). Since the last official abandonment, eight islands have been constructed and vacated (Table 1). Of the vacated islands, two are berms which require no environmental clean up. **Tarsiut N-44** remains an exception, since the sand-filled concrete caissons are still on top of the berm. Removal of these caissons is scheduled for summer 1984.

In 1981, INAC shifted responsibility for regulation of island construction, drilling, and clean-up to the Public Lands Grants Act. The new system was implemented because of concern over possible legal conflicts associated with the on-going presence of the artificial islands. This centered around the definition of territorial lands, which are considered to be those that extend to the territorial high water line. Thus, it became apparent that the TLA had no jurisdiction over any of the artificial islands.

Under the PLGA the seabed is leased to oil companies for the purpose of island or berm construction. All are considered to be structures. Leases run for five years, but can be repeatedly renewed. Lease applications are processed by INAC's Land Resources division. Environmental aspects of lease applications are addressed by the intergovernmental Arctic Waters Advisory Committee (AWAC) who then report back to Land Resources. Land Resources need not accept any or all of AWAC's recommendations when granting a lease.

Actual island abandonment is considered by some (i.e., Carlton, 1976; Osborne, 1980) to be ocean dumping. Other agencies (i.e., Water Resources (INAC)) believe that island abandonment is neither ocean dumping in a legal sense nor is it to be governed under ocean dumping regulations since abandonment is permited under the terms of the PLGA lease. There is agreement that toxic and persistent materials incidental to island construction should be regulated by some means, but the actual mechanism of regulation is not unanimous.

The <u>Ocean Dumping Control Act</u> (ODCA), administered by the Environmental Protection Service, Environment Canada, was "originally designed to control the deliberate disposal of persistent materials to the oceans surrounding Canada" (Osborne, 1980). An interpretation of the Act with regard to island abandonment is not clear. The language of the Act states that "dumping does not extend to the placement of the matter for a purpose other than the mere disposal thereof". However, Carlton (1976) argues that "if material as part of a structure of whatever sort is placed in the sea and serves a specific purpose for a stated time but thereafter becomes entirely useless to its owner so that retrieval or removal while possible is of no interest to the party who placed it there, abandonment would I think be considered dumping".

This, he considers to be a "reasonable understanding of the intention of the statute".

In general, EPS is satisfied that the intent of the ODCA (i.e., control of contaminants to the marine environment) is being adequately met through INAC administration of TLA and PLGA legislation. Should the situation change and undesirable materials be released to the sea in quantity or in an uncontrolled manner, EPS might reverse its position and consider the need for direct "permitting" of island "disposal" activities under the ODCA (Fenton, pers. comm., 1984).

As noted above, islands have been officially abandoned under the TLA. Official abandonment under the PLGA system has not yet occurred although several islands and berms are now vacant. The actual mechanics of clean-up under the PLGA are not clear. With the exception of lease covenants, there do not appear to be any guidelines as to what extent the island must be "cleaned-up" prior to official abandonment, nor are there any indications of when the clean-up should actually take place. If clean-up does not immediately follow removal of the majority of exploration-related equipment from the island, certain toxic or persistent materials could inadvertently become wasted into the sea through active environmental processes (Cuddy, 1979; Bannan and Bryant, 1976; Osborne, 1980).

In summary, all islands officially abandoned to date have been handled under the TLA; 10 more islands have yet to be abandoned under the TLA. Official abandonment of an island or berm under the PLGA has not yet occurred and it remains to be seen what the criteria will be. The ODCA appears to be somewhat enigmatic, having never become truly involved in actual island abandonment. The last INAC inspection report made available to this study was completed in the summer of 1979 (Cuddy, 1979).

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3.0 ENVIRONMENTAL EFFECTS OF ISLAND ABANDONMENT

3.1 Physical Effects

3.1.1 Physical Oceanography

The effects of artificial island abandonment on physical oceanography can be divided into local (small scale) effects and regional (large scale) effects. Although very little direct research has been done, it appears that any observed or expected effects can be classed as local. The scale of the local area in this case is about 1 or 2 island or berm length scales (i.e., approximately one kilometre). Most work done on the physical effects of island construction have been concerned with ice cover and island morphology.

3.1.1.1 Ice

A general review of ice movements, ice zones and annual cycles is found in Dome et al. (1982a). Briefly, the sea ice in the Beaufort Sea can be divided into three zones: the fast or landfast ice, the transition zone and the polar pack. The maximum seaward extent of the fast ice is generally the 20 metre depth contour although the actual location varies both with the time of year and from year to year. The area between the fast ice and the polar pack constitutes the transition zone. The southern extreme of the polar pack also shows seasonal and year to year variations.

In general, the main concerns with respect to the effect on the ice of artificial islands (Markham, 1983) are:

a) the islands may cause changes in the timing of freeze-up and break-up;
b) the islands may extend the area of landfast ice;
c) the abandoned islands become reefs which build ice rubble during the winter; and
d) the effects of the islands will increase as they extend into deeper water and the number of co-existing islands increase.

The work done to date in evaluating the above concerns has addressed mainly the first three of these; not enough information is available to answer the fourth concern (Dome et al., 1982b), although it is thought that island spacings greater than 5 to 10 kilometres would not present a problem (Markham, 1983).

Present studies have shown that there is no evidence that the artificial islands have increased the extent of the fast ice or delayed its break-up (outside of the local rubble fields) (Markham, 1983; Dome et al., 1982b; Spedding and Danielewicz, 1983). Local rubble fields may remain longer than the surrounding ice but the area affected is generally less than one square kilometre (Spedding and Danielewicz, 1983; Dome et al., 1982b). Due to the nature of their construction, caisson-retained islands produce smaller rubble fields than conventional islands (Markham, 1983; Spedding and Danielewicz, 1983).

A review of the available information indicates that natural climatic fluctuations are the main source of the yearly variations of fast ice conditions and far outweigh any effects of artificial islands (Spedding and Danielewicz, 1983).

3.1.1.2 Currents

A review of the currents in the Beaufort Sea is given by Dome et al., (1982a). On the inner continental shelf the water masses consist of two basic types: a shallow (5 to 20 metres thick) brackish surface layer and a lower more saline layer extending to the bottom in depths of 50 to 70 metres. The surface layer is non-existent in the winter except in the immediate vicinity of the Mackenzie Delta. In general the currents decrease in velocity with depth with the strongest currents occuring in the surface layer in the summer (open water) season.

The effects of artificial islands on the currents has not been documented so no firm conclusions can be drawn. However, the effects would be expected to be of a local nature since the scale of the islands is small compared to the size of the continental shelf. The waterline area of all islands constructed to 1984 is 0.38 square kilometres; the area of continental shelf is estimated to be 60 000 square kilometres.

Possible effects on currents are that the island changes the speed of the flow, the direction of the flow, or both of these. In addition, the island may produce a wake which would decay slowly with distance from the island. The effect on the mean flow would probably extend no more than 1 or 2 island waterline diameters from the island with a wake having a width in the order of the dimension of the island in the cross-stream direction. In the downstream direction the wake could extend for many island scale lengths. The wake would likely contain eddies with sizes from about that of the island on down.

More indirect effects could be enhanced mixing of the water downstream of the island due to increased turbulence in the water and upwelling of more saline water.

The artificial islands are likely to have the same sort of effect on currents as natural islands, the main differences being that the artificial islands are smaller and, in the case of more recent islands, in more exposed locations than natural islands. The effects on currents are likely to be greatest just after abandonment while the island is still above the waterline or just below the waterline. As the surface of the decaying island drops further below the waterline, it is expected that the island's effect will diminish.

Changes in shape of the island as it erodes will have some effect on how the island interacts with the currents. For example, bars or spits built out from the island by erosion may increase the effective size of the island and produce a sheltered back water where the local current is decreased. The spits may also confine the flow leading to local increased flow and possibly increased erosion (Woodward-Clyde Consultants, 1982).

The above-mentioned effects are not expected to be significant in terms of the general circulation. There have been no documented local effects attributed to localized change in currents (Section 3.2 and 3.3).

3.1.2 Sediment Transport and Dynamics

Only a crude understanding of sediment transport and dynamics on the Beaufort Sea shelf exists at the present time. Sediment sources and input rates, the general pattern of sedimentation and their variation with season are known; a detailed understanding of the redistribution of seabed sediments after initial deposition, however, is largely conjectural and qualitative. Woodward-Clyde Consultants (1982) proposed a conceptual model of sediment dispersal in their recent synthesis report of the information related to sediment dynamics on the Beaufort Sea shelf. The main features of the conceptual model were:

Sediment Transport Directions

- wave driven alongshore transport to the east or south
- nearshore (less than 20 metres of water) transport occurs to the northeast on central and eastern shelf, to the northwest or southeast on western shelf
- offshore (greater than 20 metres of water) transport is directed to the northeast in suspension (no transport as bedload)

Sediment Transport Potential

- coastal zone sediment transport is frequent due to wave or current action
- occasional nearshore sediment transport results from combined wave and current action
- offshore sediment transport is essentially dormant, except on the western shelf
- the potential for sediment transport varies with season. In winter, coastal and shelf sediment transport is regarded as dormant as a result of limited wave and current activity. In the open water season, substantial shelf sediment transport

is believed to occur in water depths up to approximately 20 metres. Direct evidence for this statement is scarce. However, considerable circumstantial evidence exists. For example, a recent analysis of wave climate, current, and turbidity data from the Beaufort Sea identifies a strong correlation between wind speed and bottom boundary layer turbidity, suggesting that a major mechanism of sediment re-suspension and advection is the coupling of surface wave energy to the seabed (Fissel, pers. comm., 1984). Near-bottom turbidity maxima have been noted in several previous Beaufort Sea studies (Bornhold, 1975; Herlinveaux and de Lange Boom, 1975; Matsumoto and Wong, 1977).

The effect of artificial island abandonment on sediment transport and dynamics in the Beaufort Sea has not been studied. Furthermore, there is insufficient information currently available to predict quantitatively the influence that abandoned islands would have on the scale or site-specific characteristics of alterations to sediment dynamics and depositional patterns. However, several general statements can be made:

1) changes to sediment dynamics and depositional patterns will occur. Analysis of time series photographs of various abandoned Beaufort Sea artificial islands indicates that morphological changes to the islands are highly variable. Some islands erode rapidly to shoals; others preserve relatively constant shorelines over periods of 4 to 5 years; some migrate with sediment

accumulating in downdrift spits (Woodward-Clyde Consultants, 1982);

2) the turbulence and water currents resulting from waves breaking on the islands or island berms will result in suspension of island sediment particles;

3) water column turbidity in the vicinity of the island will increase (the extent and duration of this effect will depend on oceanographic and meteorological conditions); and

4) sedimentation rates in the vicinity of the eroding island will increase.

Sediment transport in the Beaufort Sea occurs predominantly during high energy events (Woodward-Clyde Consultants, 1982). It is estimated that severe storm waves (greater than two metres in height) are responsible for 20 percent of the sediment transport attributable to waves, although these waves occur less than two percent of the time. Moderate storm waves (between 1 and 2 metres in height) cause 50 percent of the wave generated sediment transport even though these waves occur only 20 percent of the time. Thus, 70 percent of the wave generated sediment transport is caused by events that occur less than 22 percent of the time.

It is expected that any environmental effects of island abandonment will probably be local (100's of metres) rather than regional (kilometres) in scale. Table 2 provides support for this statement.

TABLE 2 APPROXIMATE SEDIMENT VOLUME RELOCATED TO ISLAND SITES

YEAR	VOLUME (m^3)
1972	180 000
1973	145 000
1974	368 000
1975	479 000
1976	2 247 000
1977	1 376 000
1978	2 100 000
1979	2 000 000
1980	7 100 000
1981	4 700 000
1982	6 450 000
1983	1 000 000
Total 1972 - 1983	28 145 000
Average Annual Mackenzie River Sediment Discharge[1]	87 204 000
Average Month of May Mackenzie River Sediment Discharge[1]	32 368 000

NOTES: 1. Thomas et al. (1983c)

The data indicate that the total volume of sediment used to construct all islands to date is only about 30 percent of the average annual particulate flux of the Mackenzie River. In fact, the average Mackenzie River particulate discharge for May exceeds the cumulative total volume of artificial islands. Bathymetric surveys conducted at abandoned artificial islands indicate that following the erosion of the upper portion of an island, the remainder is relatively stable (Woodward-Clyde Consultants, 1982). Consequently, the amount of annual sediment transport associated with the erosion of artificial islands would be insignificant compared to the particulate river flux and hence, would not be a regional concern. For comparison, we can calculate, very approximately, the scale of the effect of an eroding island on the area adjacent to the island. For this calculation we assume that a "typical" sacrificial beach island in the Beaufort Sea has a 100 metre working surface diameter; four metres of freeboard; and slopes of 3H:1V above the waterline and 15H:1V below the waterline. Furthermore, we assume that the island is eroded to a shoal three metres below the waterline within two years of abandonment and 50 percent of the soil is dispersed beyond 400 metres and up to one kilometre away. Under these conditions, the eroded material would form a layer about 30 millimetres thick up to 400 metres from the island but only five millimetres thick in the region between 400 metres and one kilometre from the island. The latter rate of accumulation is very similiar to natural sedimentation rates for the Beaufort Sea shoreward of the 10 metre isobath; the calculation shows that the effect of island abandonment on sediment transport would indeed likely be local.

3.1.3 Island Morphology Changes

3.1.3.1 Above-Waterline

Very little information is available regarding island morphology changes above the waterline. Qualitative information includes sequential photographs of some islands following abandonment (Woodward-Clyde Consultants, 1982); a small amount of quantitative information has been obtained by Esso (Esso, 1984).

Woodward-Clyde Consultants (1982) assembled data on changes in island shoreline with time for 17 artificial islands. Table 3 contains abstracted information from the Woodward-Clyde report regarding the time involved for abandoned islands to become shoals.

It is evident that the above-waterline persistence of the islands was predominantly dependent upon the material from which the island was constructed, as well as the water depth (or exposure) in which the island was situated. Generally, islands constructed from sand have disappeared within a few years, while islands constructed from gravel have remained above the waterline for a period of several years. The time required to reduce a sand island to a shoal decreased as the water depth (or exposure) increased. Islands constructed from sand in exposed locations with less than 10 metres of water have generally disappeared within two years, while islands in deeper water (i.e., Isserk E-27) have disappeared rapidly following removal of the slope protection system. In a similar manner, the above water portion of Issungnak O-61 was repeatedly washed away during the construction phase, whenever a large storm passed through the area.

TABLE 3 TIME REQUIRED FOR ISLANDS TO BECOME ERODED TO THE WATERLINE (to 1980)

ISLAND NAME	WATER DEPTH (m)	CONSTRUCTION MATERIAL	DATE VACATED	DATE ERODED TO THE WATERLINE	TIME REQUIRED FOR EROSION TO THE WATERLINE
Immerk B-48	3.0	Sand and silt	Spring, 1976	Summer, 1979	3 years
Adgo F-28	2.1	Silt, gravel cap	Spring, 1974	Fall, 1976	2 years
Pullen E-17	1.5	Gravel	Spring, 1976	– [1]	–
Unark L-24	1.3	Gravel	Summer, 1977	– [1]	–
Pelly B-35[2]	2.0	Silt	Summer, 1976	– [1]	–
Netserk B-44	4.6	Sand	Summer, 1976	Summer, 1978	2 years
Adgo P-25	1.5	Silt, gravel cap	Spring, 1975	– [1]	–
Adgo C-15	1.5	Gravel	Spring, 1975	– [1]	–
Netserk F-40	7.0	Sand	Summer, 1976	Summer, 1978	2 years
Sarpik B-35	4.3	Gravel	Summer, 1976	Summer, 1979	3 years
Ikattok J-17	1.5	Sand	Summer, 1976	– [1]	–
Kugmallit H-59	5.3	Sand	Summer, 1977	Summer, 1979	2 years
Adgo J-27	1.8	Silt, gravel cap	Summer, 1977	– [1]	–
Arnak L-30	8.5	Sand	Summer, 1977	Summer, 1979	2 years
Kannerk G-42	8.5	Sand	Summer, 1977	Summer, 1978	1 year
Isserk E-27	13.0	Sand	Summer, 1978	Summer, 1978	0 years

NOTES: 1. Island existed above the waterline in 1980.

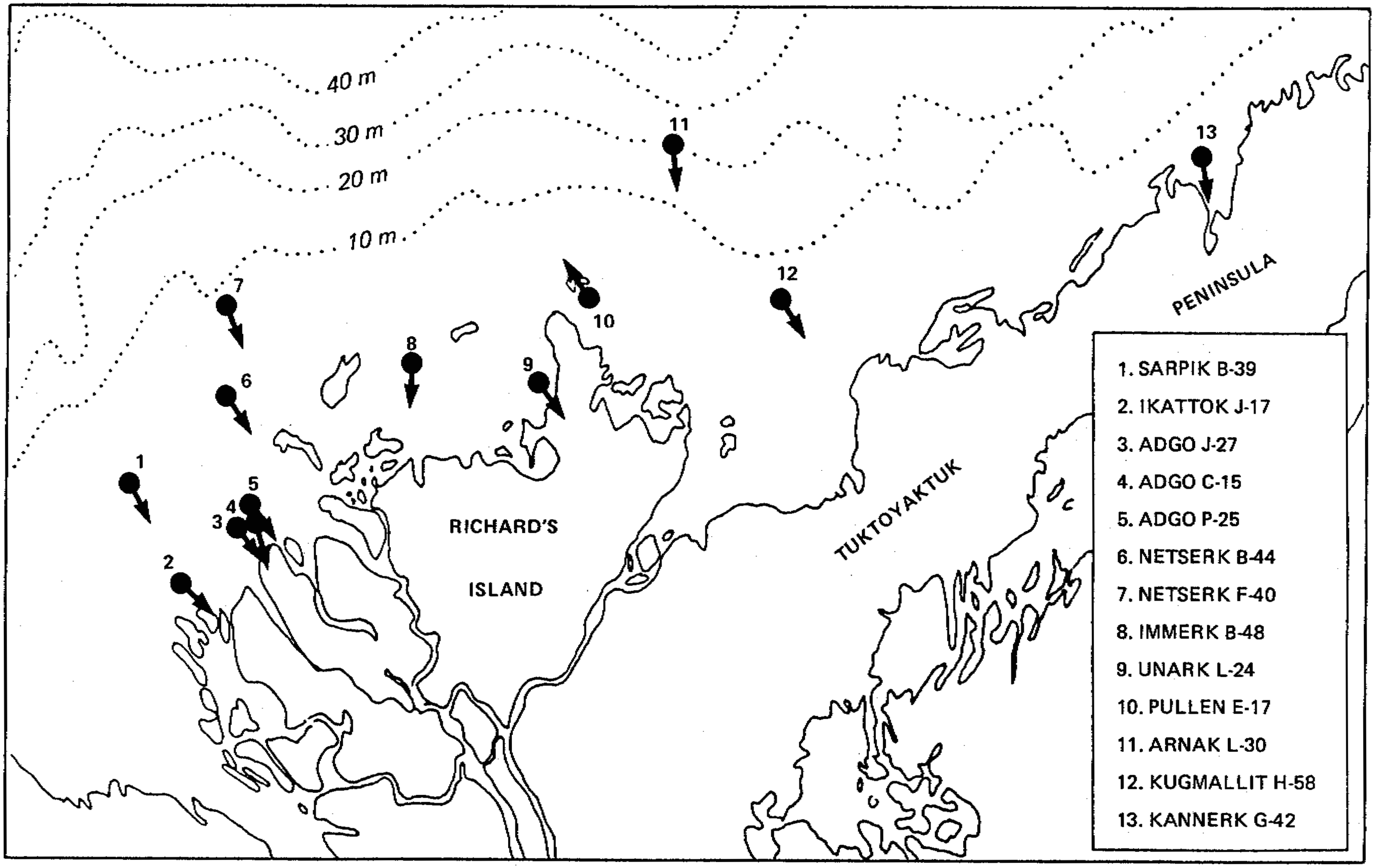
2. Retaining sandbags were never removed.

Three islands vacated in 1982 had not eroded to the waterline by the fall of 1983. Alerk P-23 and West Atkinson L-17 protruded approximately two metres above the waterline, Itiyok I-27 was at an elevation of four metres. All slope protection had been removed when the islands were vacated. Esso reported that unusually small waves (less than two metres in height) to date had not yet caused substantial island deterioration. Waves of 3 to 4 metres in height are required to rapidly erode exposed islands (Moir, pers. comm., 1984). It appears that the frozen fill possesses sufficient strength to resist the force of the small waves, however, the strength is inadequate to resist large storm-driven waves.

3.1.3.2 Below-Waterline

Wave action is the predominant sediment transport mechanism in the southern portions of the Beaufort Sea (Woodward-Clyde Consultants, 1982). Waves are capable of suspending and transporting bottom sediment in water up to 30 metres in depth. They induce oscillatory bottom currents that suspend seabed sediment, allowing it to be transported by tidal or wind-generated currents; they also cause longshore sediment transport when they break on a shoreline (i.e., island slope), releasing their energy. The longshore transport process is thought to play the dominant role in the deterioration of artificial islands.

Island morphology changes have been used as an aid in evaluating the longshore sediment transport process (Woodward-Clyde Consultants, 1982). Figure 4 illustrates sediment transport directions as indicated by the redistribution of artificial island sediments by wave action. It is shown that the transport direction is towards the southeast (with the exception of the relatively protected Pullen E-17). The sediment transport direction



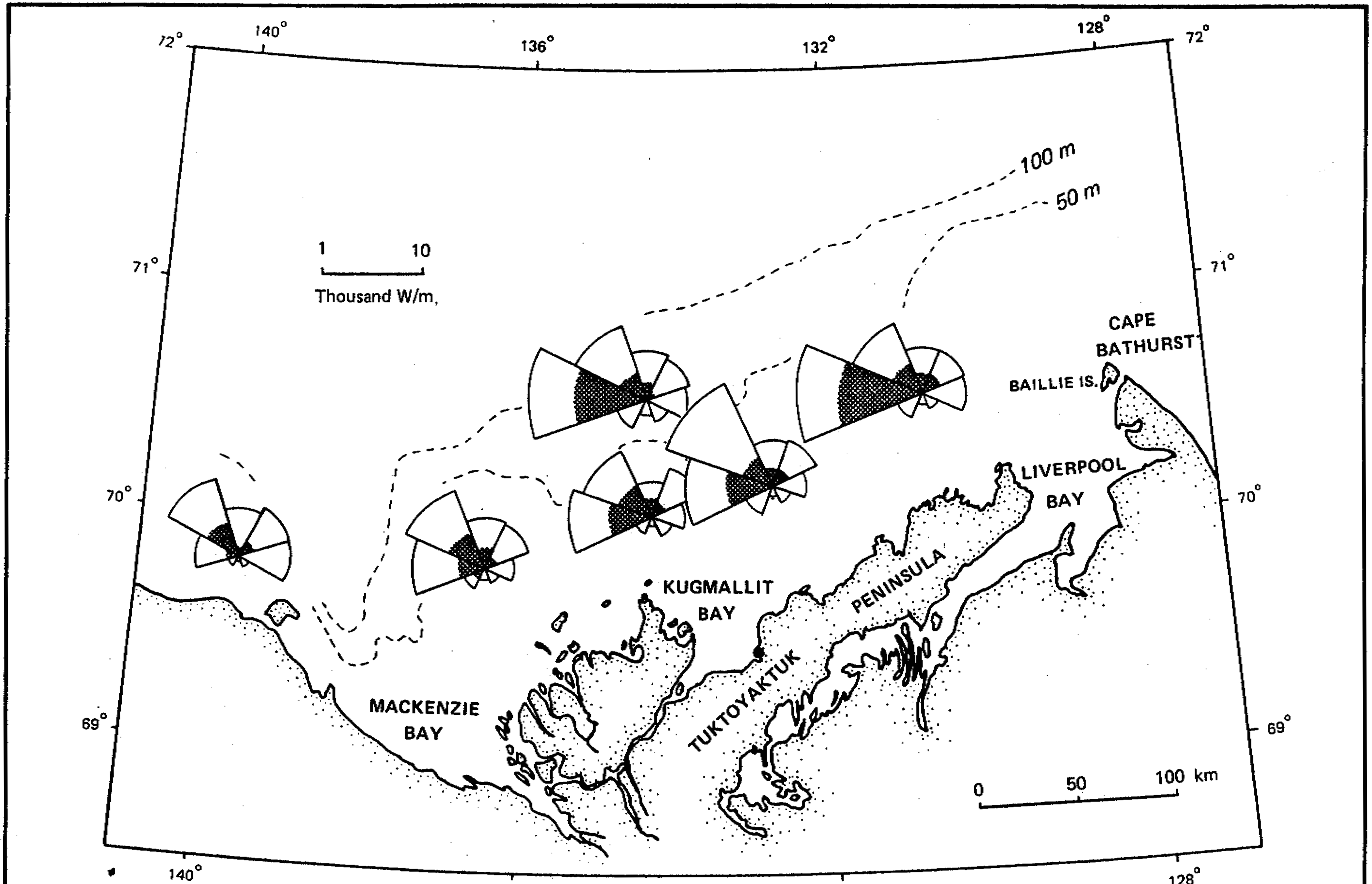
NOTE: Adapted from Woodward-Clyde Consultants (1982)

FIGURE 4 TRANSPORT DIRECTIONS AS INDICATED BY REDISTRIBUTION OF ARTIFICIAL ISLAND SEDIMENTS BY WAVE ACTION correlates well with wave power roses (Figure 5) which indicate that the predominant wave power approach is from the northwest.

Changes in below-waterline island morphology with time are represented in Figures 6 through 12, inclusive. These figures are cross sections of islands, east-west and north-south, and are adapted from information, predominantly bathymetric soundings, provided by Esso for Kannerk G-42, Isserk E-27, West Atkinson L-17, and Itiyok I-27. These islands were in 8.5, 13.0, 7.5, and 15.0 metres of water, respectively, and the sections are thought by Esso to be representative of all artificial islands abandoned to date.

Kannerk G-42 was constructed in 8.5 metres of water in the summer of 1976. Drilling was conducted during the winter of 1976-1977 and the island was vacated the following summer. Figure 6 illustrates the island in north-south section near the latter portions of island construction, and in 1980, 1981, and 1982 (3, 4, and 5 years after the island was vacated). Figure 7 presents the east-west sections of the island in 1980, 1981, and 1982. Information regarding the east-west shape of the island after construction is not available. These sections show that the island was gradually migrating towards the south-east, however, ongoing vertical erosion of the island surface was apparently not occurring. Island migration has also been observed in Alaska (Gadd et al., 1982). A series of hydraulic bedforms appeared to be forming on the island surface. The "exposed" northwest sideslope was gradually becoming smoother while the lee southeast slope was becoming steeper.

Isserk E-27 was a sacrificial beach island that was constructed in an exposed location in 13 metres of water. It was vacated in 1978. Figure 8 presents east-west sections through the island upon completion and in 1980 and 1981 (2 and 3 years after the island was vacated). North-south sections



NOTE: *Adapted from Woodward-Clyde Consultants, 1982*

FIGURE 5. WAVE POWER ROSES

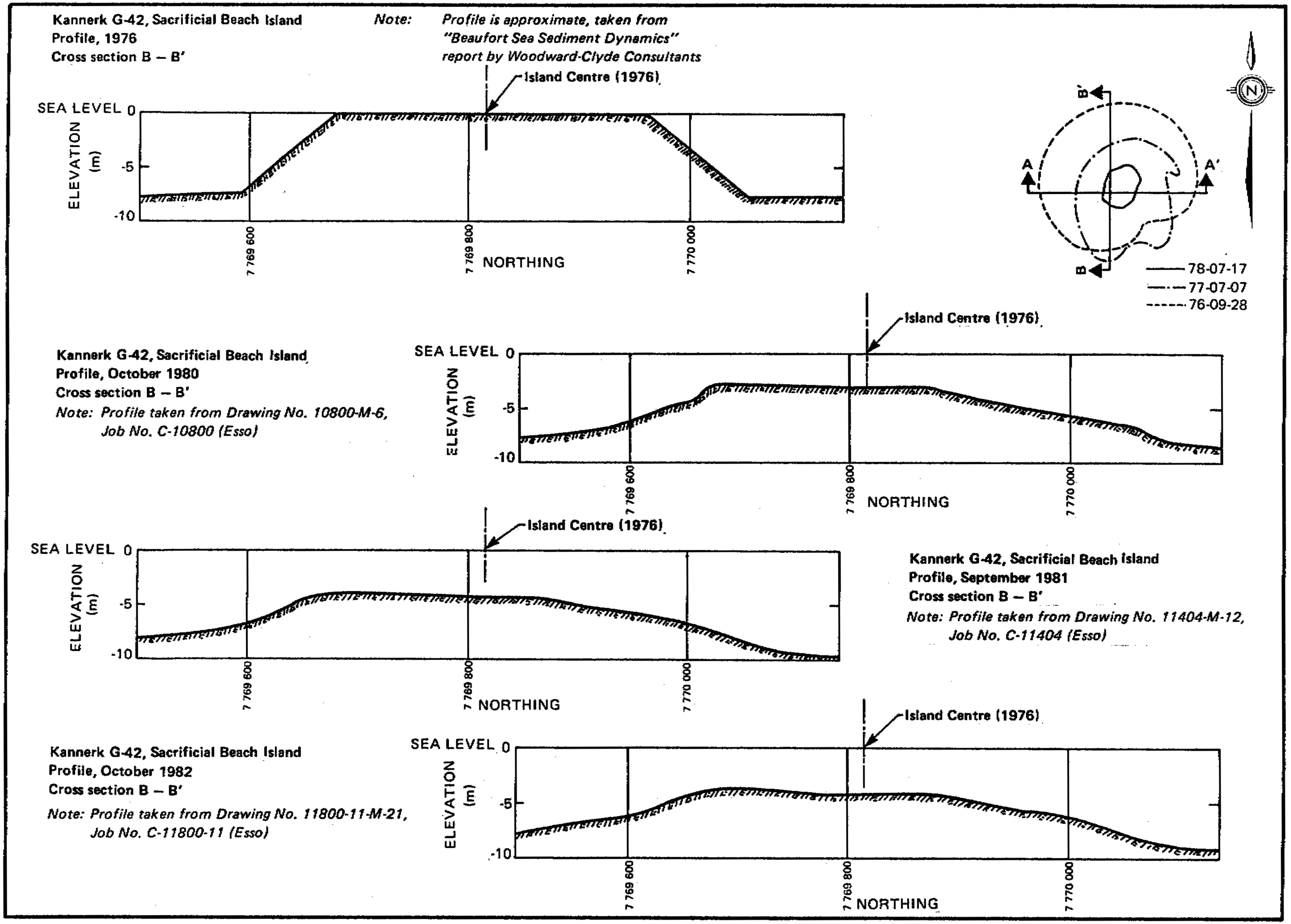


FIGURE 6 NORTH – SOUTH CROSS SECTIONS
KANNERK G-42

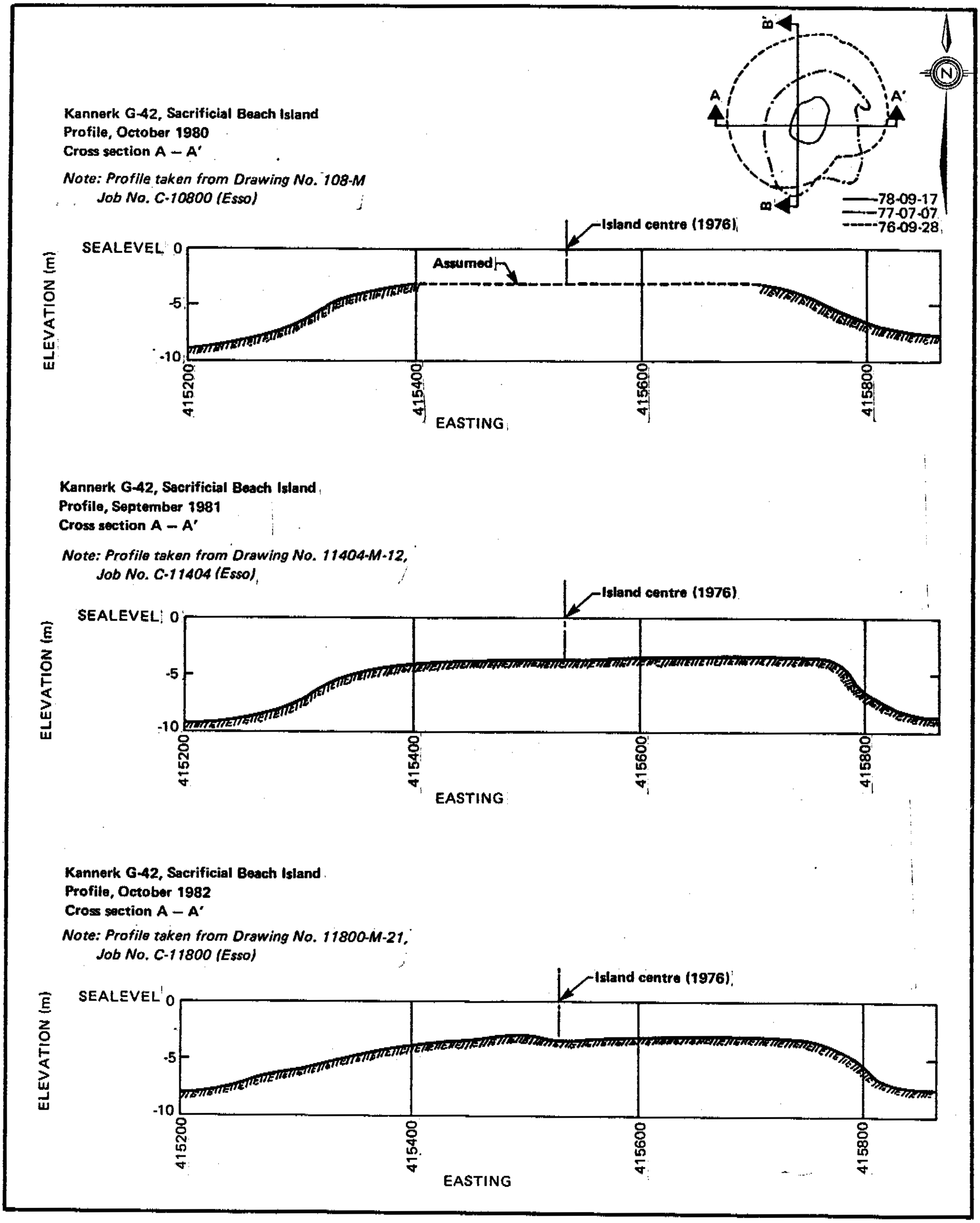


FIGURE 7 EAST – WEST CROSS SECTIONS
KANNERK G-42

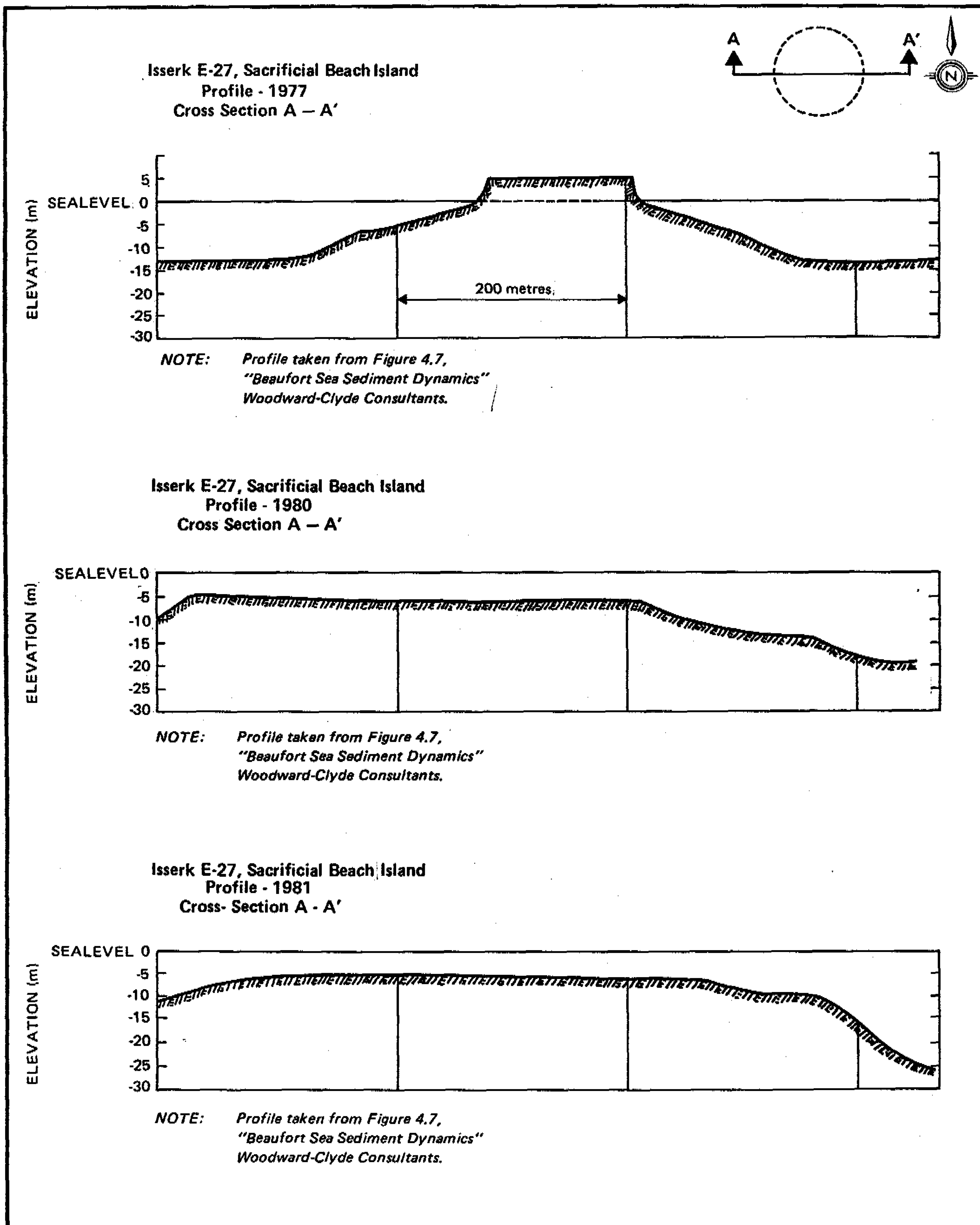


FIGURE 8 EAST – WEST CROSS SECTIONS
ISSERK E-27

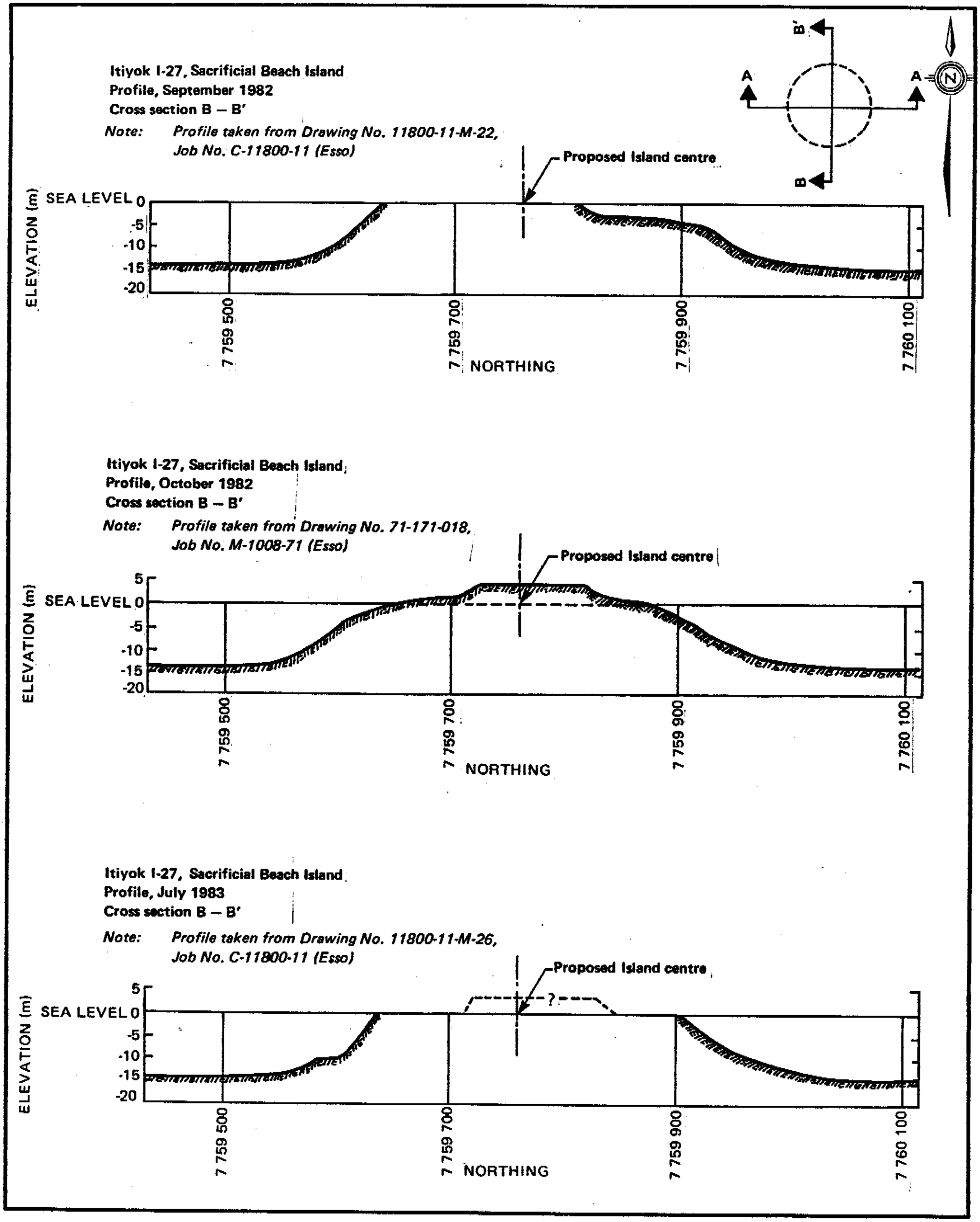


FIGURE 9 NORTH – SOUTH CROSS SECTIONS
ITIYOK I-27

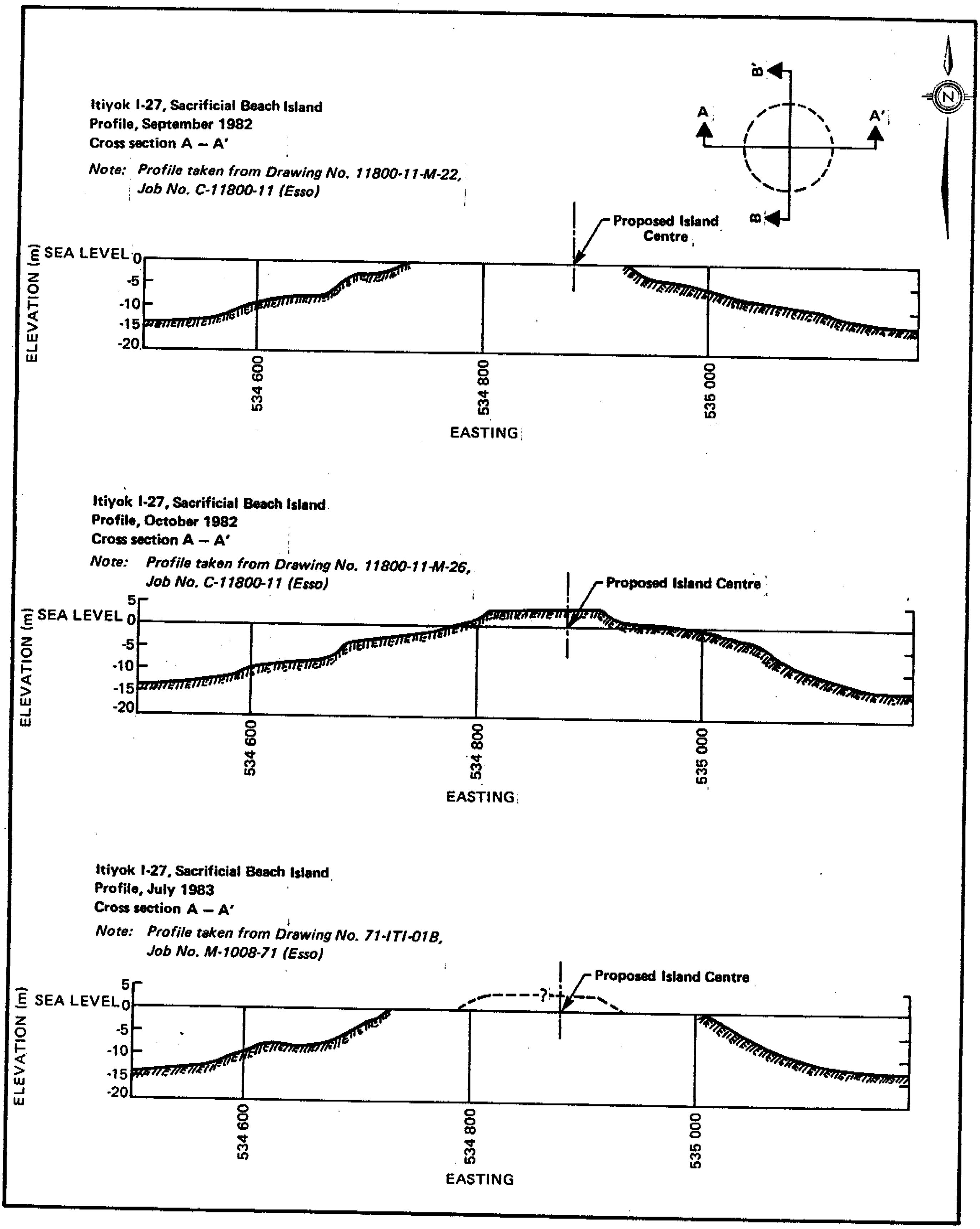


FIGURE 10 EAST – WEST CROSS SECTIONS ITIYOK I-27

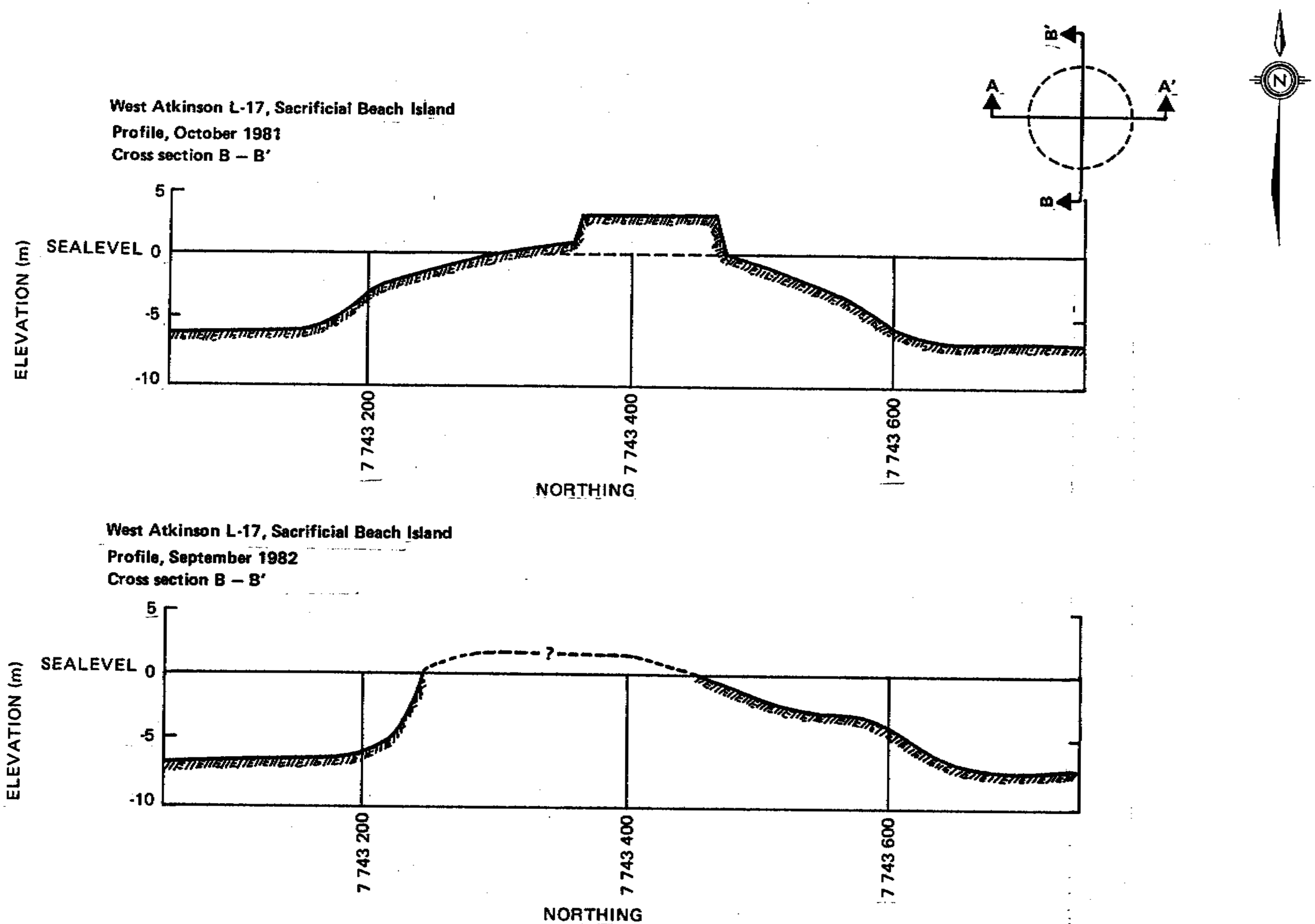


FIGURE 11 NORTH – SOUTH CROSS SECTIONS
WEST ATKINSON L-17

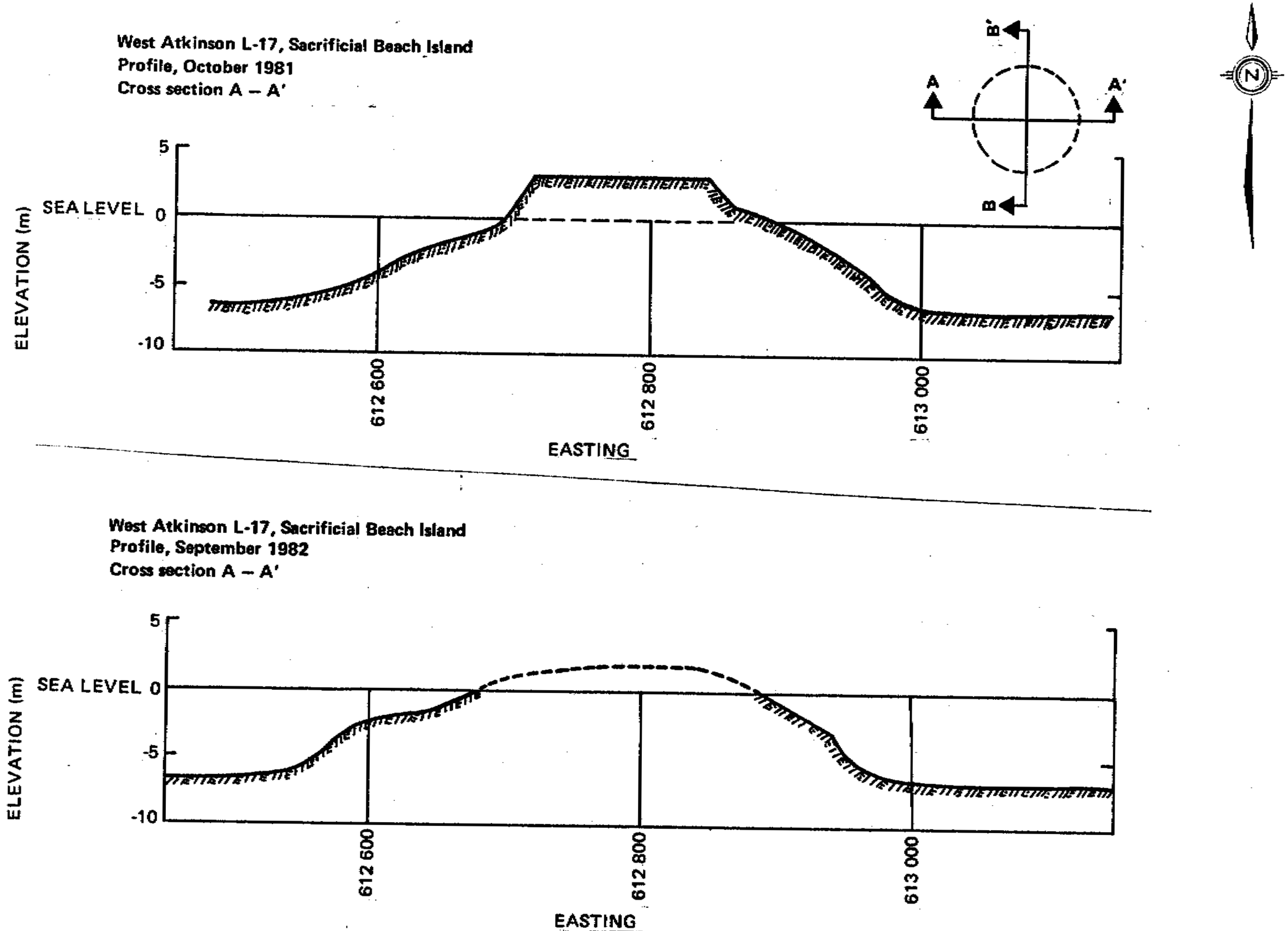


FIGURE 12 EAST – WEST CROSS SECTIONS
WEST ATKINSON L-17

were not available. The figures indicate that the island was behaving in a similar manner to Kannerk, through the formation of a gradually rising windward sideslope and a steeper leeward slope. It is also evident that the island had "flattened" out substantially, with this apparently occurring shortly after the island was vacated. Lack of horizontal survey control on supplied drawings make evaluation of this observation difficult.

Itiyok I-27 was a sacrificial beach island constructed in an exposed location in 15 metres of water. It was constructed in 1982 and abandoned in 1983. The change in subsurface island morphology following abandonment is presented in Figures 9 and 10, for the north-south and east-west directions, respectively. A survey conducted a few months after the island was abandoned showed that part of the aerial portion of the island had been re-distributed around the perimeter of the submerged portion of the island rather than just on the leeward side of the island. It is apparent that more sediment had been re-deposited on the exposed side of the island than had been re-deposited on the more protected side of an island. It is suggested that as waves start to erode the island (beach depletion) the entrained sediment is transported back into the water by backwash thereby increasing the diameter of the island slightly below the waterline on the windward side of the island. As the above-waterline portion of the island disintegrates and the island erodes to below the waterline, the waves pass over the island, redistributing the entrained sediment on the lee side of the island.

West Atkinson L-17, a sacrificial beach island situated in 7.5 metres of water, illustrates a similar trend. Constructed in 1981 and abandoned in 1982, West Atkinson also displayed erosion of the exposed portion of the island both towards and with the dominant wave power direction (Figures 11 and 12). Although only a few months had passed between the time that the island was vacated and the time of the survey (September, 1982) island deterioration appeared to be well underway. Results of any 1983 monitoring were not available although it was known that the island still protruded two metres above the waterline.

3.1.4 Long-Term Island Integrity

The rate of erosion is difficult to monitor once an island deteriorates to below the waterline. There is no available quantitative data describing this phase of the process other than the cross-sections presented in the previous section. These sections indicated that the top surface of the islands studied was about four metres below sea level within a few years of the island being abandoned.

In the summer of 1983, Esso measured the water depth over six of their vacated islands (Esso, 1984). Some of these islands had been vacated for up to eight years. This information is presented in Table 4. The depth of water over these islands varied from 3 to 4.5 metres, with no apparent relationship existing between site water depth and the depth of water over the island. It appears that the islands, once the slope protection was removed, deteriorated to a certain elevation, after which they remained static. The indicated water depth at which erosion ceased, or became undetectable, is approximately four metres. It is not possible to predict the time required for this erosion to occur since the erosion rate is extremely dependent upon the frequency, duration, and intensity of storms.

Woodward-Clyde Consultants (1982) suggested that island erosion to an average depth of five metres below the waterline was in direct response to a high frequency of occurrence of critical fluid velocity. Based upon a sediment orbital threshold velocity of about 400 millimetres per second,

TABLE 4 ISLAND TOP SURFACE EROSION[1]

ISLAND NAME	ISLAND TYPE	YEAR CONSTRUCTED	YEAR VACATED	WATER DEPTH (m)	DEPTH TO ISLAND TOP SURFACE FROM WATERLINE (1983)[2] (m)
Netserk F-40	Sandbag retained sand	1975	1976	7.0	3.0
Kugmallit H-59	Sandbag retained sand	1976	1977	5.3	3.0
Arnak L-30	Sacrificial beach, sand	1976	1977	8.5	3.5
Kannerk G-42	Sacrificial beach, sand	1976	1977	8.5	4.0
Isserk E-27	Sacrificial beach, sand	1977	1978	13.0	4.5
Issungnak 2-0-61	Sacrificial beach, sand	1980	1981	19.0	3.0

NOTES: 1. Information obtained from Esso, 1984.

2. Depths to top surface are uncorrected for tidal fluctuation or storm surge.

they predicted that sediment within the upper five metres of seawater was disturbed by waves 50 percent of the time. This would cause islands to erode rapidly to about the -5 metre elevation, after which erosion would continue, although at a greatly reduced rate.

Other studies have shown that the threshold velocity for typical Beaufort Sea sands may be closer to 150 millimetres per second. Using the rationale presented by Woodward-Clyde Consultants (1982), rapid island erosion to a depth of about eight metres below the waterline would be predicted.

The variation between the observed and the predicted erosional depths may be due to "self armoring" of the fill as it erodes. This armoring occurs as the finer materials are washed away, leaving behind a lag deposit consisting of coarser-grained materials. Since the orbital threshold velocity of the coarser materials would be substantially greater than that of the finer material, less erosion would occur. It should be noted that this process has not been observed in the Beaufort Sea and is only hypothesized.

3.2 Chemical Effects

3.2.1 Chemical Oceanography

The potential effects of island abandonment on water chemistry relate to the potential for dissolution of chemical wastes on the island and island slope through the resuspension of particulates in the water column. An increase in suspended particulate loads can be expected in the vicinity of artificial islands during periods of island erosion although the increases in suspended particulate concentrations from erosion will be less than that occurring during island construction. The effects on chemical water properties during island construction and dredging can therefore be viewed as a worst case situation for island erosion.

Dredging effects on water quality have been studied in some detail both in the Beaufort Sea and worldwide. Studies carried out during dredging in the Canadian Beaufort Sea have failed to document a response in water quality attributable to dredging other than increased suspended particulate loads and in some instances, increased oxygen demand (Erickson and Pett, 1981; Thomas, 1980; Envirocon Limited, 1977; Slaney, 1977). These effects are of short duration and limited extent. Increased suspended particulate loads during periods of rapid erosion are masked somewhat by the high natural suspended particulate loads in the open water period in the shallow areas of the Beaufort Sea where islands have been constructed. All island sites are within the summer plume of the Mackenzie River discharge and are therefore subject to highly variable suspended particulate loads through the open water season.

Studies undertaken in other regions on the release of heavy metals and organics from contaminated dredge spoils in sea water during ocean dumping suggest that dissolution of heavy metals or organics from contaminated island material during erosion would be undetectable, given the quantities of sediment involved and the rapid dilution concurrent with periods of rapid island erosion and sediment resuspension (Chen et al., 1976; Boehm and Feist, 1983). Dissolution of metals would be short-term and local. Most hydrocarbons have a low water solubility and would tend to remain associated with particulate material.

The Issungnak Oceanographic Survey (Erickson et al., 1983) provides the only comparative data for water chemistry around an artificial island after abandonment. Three sites were sampled around the Issungnak 0-61 island from March, 1981 to April, 1982. Water samples were collected seven times after abandonment in August, 1981. The study examined levels of heavy metals (Hg, Cd, Cu, Zn, Cr), polycyclic aromatic hydrocarbons (PAH's), nutrients, oxygen, alkalinity, total organic carbon, and suspended solids. With the exception of suspended solids, there was no alteration in levels of any parameters attributable to island erosion in agreement with water quality studies during dredging for island construction. Suspended solid levels were approximately five times higher in October 1981 at all locations compared to levels in water of similar salinity before abandonment. Suspended particulate measurements were made after severe erosion of the island during a late September and early October storm. A near-bottom maximum (18 metres) was thought to be either a result of a near-bottom turbidity flow from the island slope or settling out of resuspended material.

The only chemical measurements made in the October, 1981 sampling period were on reactive nutrients (silicate, phosphate, and nitrate). The increased suspended particulate loads in October did not result in an increase in phosphate or nitrate concentrations. Silicate levels did increase, but the levels observed were within the range observed in under-ice samples with low particulate loads (Pett et al., 1983).

3.2.2 Sediment Chemistry

No studies have been conducted in the Beaufort Sea specifically to evaluate the effects of artificial island abandonment on sediment chemistry. A number of studies, however, have been carried out around artificial islands to evaluate the effects of island construction (dredging) and the operational discharge of drilling wastes from exploration islands on the marine environment. Some of these studies may be useful for making inferences about the effect of island abandonment on sediment chemistry.

Erosion, for example, can be viewed as the slow reverse process of island construction (the time scale for island construction is months; that for island erosion is years). Time series measurements of drilling waste concentrations in sediments around islands may provide useful information about the fate of contaminants after abandonment because islands erode to some degree throughout their life, not just after abandonment.

A summary of those studies judged to be relevant to island abandonment are given below.

3.2.2.1 Previous Studies

NETSERK F-40

The exploratory well at Netserk F-40 was spudded in November, 1975 and completed in May 1976. The island was abandoned in September, 1976. Two sediment chemistry surveys were conducted; the first in August, 1976 (Slaney, 1977) after drilling was completed and the second in August 1977, approximately one year after island abandonment (Beak, 1978). The positions of stations sampled in each survey overlapped to a large extent. At the time of the first survey, considerable reworking of sediments along the perimeter of the island was evident; by the time of the second survey, the portion of the island above the waterline was reduced to approximately one-half its original surface area. In addition, a zone containing eroded sand and gravel with dimensions of about 100 metres by 600 metres was delineated on the seabed around the island.

Results of the two studies are difficult to compare because of sampling and analytical problems. However, two observed trends in the results of the studies relate directly to the effect of island abandonment on sediment chemistry. First, the level of heavy metals measured in the sediments did not change greatly from 1976 to 1977 despite the obvious presence of island construction materials that blanketed the stations. This suggests that as the island eroded little mixing of drilling waste with island sediment occurred. Second, erosion of the island did not appear to be a mechanism for dispersing contaminated sediment during the first year after abandonment as the enrichment of metals around the island appeared to be limited to distances of approximately 300 metres.

It must be stressed that the trends discussed above are only tentative since data from the two studies are not directly comparable.

ISSUNGNAK O-61

An oceanographic survey, including sediment geochemistry and water column particulate measurements, was conducted at Issungnak O-61 artificial island between March 1981 and April 1982 (Erickson et al., 1983). Sampling spanned pre- and post-island abandonment. Three stations were sampled, two of which were approximately 500 metres from the island and a third was approximately four kilometres west of the island. On the basis of this data set it was not possible to judge accurately the degree or geographical extent to which sediment chemistry was influenced by island abandonment. Some trends, however, are worthy of note. Storm events appear to be an effective mechanism for dispersing island material and associated drilling wastes. Concentrations of suspended particulates, for instance, increased as much as five-fold following storms in October, 1981. If discharged drilling wastes were present along the island slopes or shores in the wave-influenced zone, then they too would have been transported to the surrounding sediments. The range of transport, on the basis of the data collected in the study, appeared to be between 500 metres and 4 kilometres.

Trace metal and hydrocarbon concentrations in the sediments around Issungnak O-61 were consistent with the hypothesis that any short-term significant influence of island abandonment on sediment chemistry would be restricted to areas very near the island.

TARSIUT N-44

Sediment sampling was conducted twice; in August, 1981 and July, 1982. All sampling was completed before island abandonment. However, approximately 70 000 cubic metres of sand was lost through the northeast, northwest, and southwest caisson doors during a storm in 1981 (Heath and Thomas, 1983). Routine remedial dredging operations were conducted to replace the sand and provide additional support to the berm until September, 1982. Results of the sediment surveys (Thomas et al., 1982; Heath and Thomas, 1983) indicate that no alterations to the sediment texture around the island were detectable.

OTHER STUDIES

Pre- and post-dredging surveys of sediment chemistry were completed at Arnak L-30 during 1976. Approximately 1.1 million cubic metres of granular material was used to construct the island. No detectable difference in sediment chemistry was observed during the study (Slaney, 1977). Similar results were obtained for studies conducted during dredging operations at McKinley Bay (Thomas, 1979). The results from these dredging studies are relevant to island abandonment because the level of sediment redistribution in the area surrounding island construction sites is expected to be similar to or greater than that which would occur during the erosion of an island following abandonment.

3.2.2.2 A General Discussion of the Effects of Artificial Island Abandonment on Sediment Chemistry

As abandoned artificial islands in the Beaufort Sea erode, they become sources of uncontaminated sedimentary material (predominantly sand and gravel) and, to a far lesser degree, sources of contaminants associated with drilling waste discharges. Changes to sediment geochemistry will occur for two main reasons:

1) modification of sediment texture, and
2) introduction of contaminants.

Modification of Sediment Texture

All islands in the Beaufort Sea have been constructed of fill material obtained from distant sediment borrow areas or of material obtained from subsurface sediment layers at or near the island construction sites. The material comprising the island is usually sand and can be different in texture from the surficial sediments occurring naturally in the area where the island is constructed. The Arnak L-30 artificial island is an example; the surficial sediments in the area contain approximately 25 percent sand while the island itself, made up of material obtained from local subsurface sediments, contained 85 percent sand (Slaney, 1977).

It is known that the heavy metal and hydrocarbon content of Beaufort Sea sediments bear a direct relationship to sediment grain size (Dome et al., 1982b); the concentrations of metals and hydrocarbons usually increase as the silt/clay sediment fraction increases. Consequently, as artificial islands erode, the island materials will accumulate in the local surrounding sediments and tend to reduce the total metal and hydrocarbon content of those sediments. Natural sedimentation processes would counteract the above process, tending to alter the composition of the surficial sediments to the original background (pre-island) condition. It must be stressed that in this case, the main process is merely a redistribution of uncontaminated sediment from one part of the Beaufort Sea to another.

Introduction of Contaminants

Waste drilling fluids and cuttings have been discharged directly to the sea during routine exploratory drilling from artificial islands in the Beaufort Sea. Chemicals spilled upon the island surface are introduced to the sea during island erosion. These wastes contain many natural and synthetic chemicals including heavy metals, hydrocarbons (including refined oils), and persistent organic chemicals. The solid components of discharged fluids and cuttings sink rapidly and form piles on the island slope or on the seabed near the island. The extent to which the drilling wastes are dispersed will depend on their physical properties (density, cohesion, viscosity) and the dispersion characteristics of the receiving environment (currents, wave climate, tides, water column structure, water depth, etc.). Thomas *et al*., (1983) suggest, however, that in most cases it is expected that at least 80 percent of the total discharge will initially encounter the bottom within 10 to a few hundreds of metres from the point source discharge. Although some of the sedimented material will be redistributed by wave and current activity, most of it will remain intact as part of the island structure.

The influence which the drilling waste contaminants have on the geochemistry of the surrounding sediments will probably be limited for several reasons:

1) the volume of drilling wastes discharged from recently drilled Esso wells at artificial islands in the Beaufort Sea has been about 1500 to 2000 cubic metres. This volume comprises 25 percent well cuttings and 75 percent solid and liquid drilling fluid products (M. Psutka, pers. comm., 1984),

2) the volume of material available for erosion from the artificial island is usually much larger (100 000's cubic metres) providing for large dilution through sediment mixing, and

3) following island abandonment, rapid erosion of the upper portion of the island to about four metres below the waterline typically occurs. It appears that most of the eroded material is deposited down slope within a few hundreds of metres of its original location (Woodward-Clyde Consultants, 1982). In addition, it appears that once an island is below the waterline, it is far less susceptible to further erosion. The net effect, therefore, will be for the drilling discharges to become "capped" by the material eroded from the upper portions of the island and isolated from the environment. With time, waves, currents, and ice-scour would tend to redistribute and mix the drilling wastes with sediments and reduce their concentrations.

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3.3 Biological Effects

3.3.1 Benthos

3.3.1.1 Resource Description

Benthic invertebrates represent a major segment of biota on the seafloor of the southern Beaufort Sea. Benthic fauna are generally divided into broad categories according to size (macrofauna; meiofauna) and their position relative to the surface of the seafloor (infauna; epifauna). Macrofauna are those animals retained on a sieve of 0.5 millimetre mesh; meiofauna represent the fraction passing through it.

Benthic infauna are generally found within uncompacted sediments and often lead sedentary lives (i.e., burrowing bivalve molluscs and polychaetes). Epifauna usually inhabit the surface of the substrate, though some forms may briefly burrow into soft sediments. Sessile epifauna (i.e., hydroids, anemones, bryozoans) are attached to hard substrates, while mobile epifauna (i.e., amphipods, isopods, echinoderms, gastropods) are active animals moving about the seafloor.

Macroinfauna are the most commonly encountered benthos in the vicinity of offshore exploration islands in the southern Beaufort Sea. They are also most sensitive to the consequences of island construction and abandonment due to their limited mobility. They are susceptible to smothering by redistributed sediments, and in many cases they have preferences for a narrow range of sediment particle sizes.

Mobile macroepifauna are also prevalent in the vicinity of exploration islands but are more able to avoid the physical effects of island construction and abandonment. Sessile epifauna are greatly limited in distribution in the southern Beaufort by the relative lack of hard substrates.

Wacasey (1975) has described four zones of zoobenthos distribution in the southern Beaufort based on observed physical characteristics and zoobenthic diversity and biomass. Artificial islands and berms have been constructed within three of the zones, namely the Estuarine Zone (0 to 15 metres of water), the Transition Zone (15 to 30 metres of water) and the Marine Zone (30 to 200 metres of water).

In the nearshore Estuarine Zone which is strongly influenced by Mackenzie River run-off; water temperatures and salinities vary widely with season, and average levels of zoobenthic biomass (2 g/m^2) and diversity (1 to 32 species per station) are low. Most sacrificial beach islands have been constructed in this zone (Table 1, Figure 1).

The Transition Zone is only moderately affected by Mackenzie River run-off, hence temperature and salinities have a narrower range than in the Estuarine Zone and zoobenthic indices are generally higher (average biomass, 5 g/m^2; diversity, 20 to 40 species per station). A few sacrificial beach islands (i.e., Issungnak O-61) and caisson-retained islands (i.e., Tarsiut N-44) have been built in the Transition Zone (Table 1, Figure 1).

Water properties in the Marine Zone are less influenced by the Mackenzie River. Water temperatures and salinities are more stable seasonally and zoobenthic indices are relatively high for the southern Beaufort Sea (average biomass, 14 g/m^2; diversity, 3 to 81 species per station). The Uviluk and Nerlerk berms (Table 1, Figure 1) have been constructed in this zone.

3.3.1.2 Documented Case Histories of Biological Effects of Island Abandonment

The biological effects of island abandonment principally arise from the nature of the dredged sediments used in island construction and the redistribution of the sediments during erosion of the island slopes. The gravelly and/or sandy sediments used in island construction are much coarser than the natural clays and silts of the Mackenzie Delta area. The biological consequences of abandonment include smothering of benthic infauna and modification of benthic habitat by the dispersal of coarse sediments over the natural fine sediments of the surrounding seafloor. Available information sources are listed in Table 5. The information available from these studies indicates that any adverse effects will be only temporary, and certainly less severe than those associated with island construction.

Several studies in the vicinity of artificial islands provide information on the impacts on benthos of island abandonment in the Beaufort Sea. The island sites concerned include Netserk F-40, Issungnak 0-61, and Tarsiut N-44.

NETSERK F-40

In the summer of 1977, the Netserk F-40 island site in 7.0 metres of water was sampled for infaunal benthos (Beak, 1978; Crippen et al., 1980). Biological analyses included wet weight biomass and density estimates and taxonomic identifications of benthic infauna. At the time, Netserk F-40 was undergoing rapid erosion following completion of a drilling program in May 1976. The island was reduced in area above the waterline, and the indigenous dredged material forming the island was being reworked and transported to new deposition sites.

TABLE 5 SUMMARY OF LITERATURE ON EFFECTS ON BENTHOS RELATED TO ISLAND ABANDONMENT

REFERENCE	AGENCY	LOCATION	DATA COLLECTED	DATE
Beak (1978)	Beak Consultants Ltd.	Netserk F-40 Isserk F-27	- numerical density - biomass (wet) - taxonomic identities - heavy metals in sediment and biota	August 1977 (after Netserk abandonment) (Isserk - early construction)
Crippen, Greene and Hodd (1980)	Beak Consultants Ltd. and Esso Resources Canada Ltd.	Netserk F-40	as above	August 1977 (after abandonment) (symposium presentation)
Crippen and McKee (1981)	Beak Consultants Ltd.	Issungnak O-61	- numerical density - number of species/ station - equitability - community analysis - heavy metals in sediment and biota - sediment particle size distributions	August-September 1980 (after enhancement)
Erickson et al.(1983) Crippen (1983)	Arctic Laboratories Limited IEC Beak Consultants Ltd.	Issungnak O-61	- heavy metals - particle size distribution - numerical density - no. of species/ station - diversity - equitability - taxonomic identities	May 1981 - April 1982 (after abandonment)
Thomas et al. (1982) Heath and Thomas (1983)	Arctic Laboratories Limited	Tarsiut N-44 South Tarsiut Borrow Area	- numerical density - biomass (wet & dry) - no. of taxa/sample - community analyses - taxonomic identities - particle size distributions - heavy metals in sediment - hexane extractable compounds	September 1981 July 1982
Heath et al., 1982	Arctic laboratories Limited	Herschel Island vicinity (gravel borrow area)	- biomass (wet) - numerical density - taxonomic families - sediment particle size distributions	September 1981
Heath and Thomas, 1984a (in preparation)	Arctic Laboratories Limited	Herschel Island vicinity (gravel borrow area)	- biomass (wet & dry) - numerical density - taxonomic identities - sediment particle size distributions - bottom water salinities - community analyses	July 1982 September 1982
Heath and Thomas, 1984b (in preparation)	Arctic Laboratories Limited	Banks Island vicinity (gravel borrow area)	- biomass (wet & dry) - numerical density - no. taxa/sample - taxonomic identities - sediment particle size distributions - community analyses - side scan sonar records	July - August 1983

According to qualitative sediment descriptions, the sediments in the vicinity of Netserk F-40 exhibited a great deal of variability. The variability was attributed to natural physical effects such as ice scour at most depths, and sediment deposition from the Mackenzie River in addition to construction activities such as dumping of clean, dredged sand and gravel. Undisturbed natural sediments consisted of 5 to 40 millimetres of yellow-brown silt over grey clay. Several silt-filled depressions in the clay up to 220 millimetres deep likely represented previous disturbance by ice gouging. Some sand accumulation in the upper few centimetres of sediment was detected out to more than 300 metres offshore. This sand was thought to have originated from the construction or erosion of Netserk F-40. There was no evidence of deposition of sand from either the construction phase or the early erosional phase beyond 900 metres from the island shoreline.

Biomass and density of benthos were depressed within a distance of 300 metres from the island shoreline. Higher and more stable levels observed between 300 and 1800 metres offshore. The low values recorded up to 150 metres offshore were considered to reflect the smothering effects of rapid sediment accumulation which occurred during the construction phase and which was occurring during the summer of 1977 due to the erosion of the island. The relative stability of the population densities at the stations 300 metres and more offshore was considered to indicate that those stations were beyond the major influences of either the island or the drilling operations. The mean and range of population densities at the sampled radial distances from the island are presented in Table 6.

TABLE 6 BENTHOS DENSITIES MEASURED AT NETSERK F-40, 1977

DISTANCE OFFSHORE	45 metres	90 metres	150 metres	≥300 metres
Mean	190/m^2	1100/m^2	2000/m^2	2950/m^2
Range	20-450/m^2	500-1900/m^2	800-3750/m^2	1250-5300/m^2

These data suggest that benthic recolonization of the island slopes was very significant in areas 90 metres offshore and beyond. At 45 metres offshore recolonization was evident at low levels even in this dynamic shallow (three metre) zone.

The qualitative sediment data indicated that the maximum area affected by the redistribution of sediment at the time of the 1977 sampling was less than 2.8 square kilometres. However, the results for the faunal indices of density and biomass indicated no demonstrable impacts on benthos due to sedimentation beyond 300 metres from the island shoreline. Thus, the area of depressed abundance of benthos was less than 0.4 square kilometres.

Crippen et al. (1980) suggested that the effects of sediment redistribution would be temporary. Benthic populations will continue to re-establish themselves in the affected area through recruitment from planktonic larval stages and by immigration. According to Wacasey (1975) the re-establishment of a mature infaunal community may take up to 12 years based on the estuarine bivalve, Yoldiella intermedia. This process is slower in arctic regions than in temperate areas. Modification of benthic habitat at abandoned island sites by redistribution of coarse borrow materials may prolong the period for recolonization to pre-impact levels and influence benthic community structure until a blanket of natural fine sediment covers the sand.

Crippen et al. (1980) suggested that a possible advantage of the erosional process at Netserk F-40 was that the redistribution of surficial sediments may have diluted and/or buried the discharged drilling wastes which were contaminated with heavy metals, thereby reducing the exposure of aquatic organisms to these contaminants.

ISSUNGNAK O-61

Biological and chemical studies were performed around the Issungnak O-61 island in August-September 1980 (Crippen and McKee, 1981) and between May 1981 and April 1982 (Erickson et al., 1983; Crippen, 1983). The sampling in 1980 took place immediately after the completion of island enhancement by dredging, but before delineation well drilling. The sampling in 1981/82 was conducted before and following abandonment of the island.

Issungnak O-61, in 19 metres of water was constructed with fine- to medium-grained sand from nearby borrow pits and with smaller quantities of borrow material barged from Tuft Point. The underwater base of the island extended about 300 metres beyond its shoreline. Natural surficial sediments in the area consist of silt and clay. The island site is located in the Transition Zone (15 to 30 metres of water; Wacasey, 1975).

In 1980, benthic macroinvertebrates were sampled by grab at 20 stations on transects radiating from the island to document spatial variations in faunal indices (number of species, density, biomass, and diversity). Tissues of infaunal polychaetes and bivalves were analyzed for heavy metals.

Crippen and McKee (1981) identified at least two, and possibly three, biological zones around Issungnak O-61: an outlying background or undisturbed zone 900 metres offshore and beyond, a construction zone within 300 metres of the shoreline, and possibly an intermediate zone. The biological zones were similar to zones based on sediment particle size. Background sediments were defined as containing a clay-silt fraction of more than 75 percent, whereas those in the construction zone were defined as containing less than 50 percent clay and silt. The biological intermediate zone was suggested to have clay and silt fractions between 50 and 85 percent, although no stations fell within the intermediate zone based on biological indices.

The benthic community in the construction zone had depressed levels of population density, biomass and number of species present. Organisms found in this impacted zone were either able to maintain position in the sediment during construction and enhancement or they were early colonizers recruited from other locations. Several of the species present appeared to have a preference for the sandy sediments, such as the spionid polychaetes, *Microspio* sp., *Prionospio* sp. and *Scolecolepides* sp. since they were found only in the construction zone. These species all have meroplanktonic larval stages which facilitate wide dispersal and rapid colonization of new areas where conditions are favourable.

Crippen and McKee (1981) suggested that the adverse biological effects in the vicinity of Issungnak O-61 would be temporary since physical processes in the Mackenzie Delta region should promote the return of the surface sediment composition to its natural state. Benthic populations will re-establish themselves in the affected area through recruitment of planktonic larval stages and immigration of juveniles and adults.

In 1981 and 1982, benthos was sampled at three stations as part of the Issungnak Oceanographic Survey (Crippen, 1983) to further document the benthic species composition and distributions, and to examine evidence of benthic recolonization of affected areas around Issungnak and evidence of seasonal variation in benthos population levels. The island was abandoned in August, 1981.

Sediments at Stations 1 and 2 (500 metres offshore) consisted of fine and coarse fractions which varied in proportions between samplings. The variability in sediment composition was considered to reflect sediment patchiness or redistribution between seasons. Both explanations were considered probable since the island was constructed of material from more than one source, and was being eroded by waves or ice movement throughout the study. The area 500 metres offshore, in particular, was subject to considerable ice scour from the rubble field in winter.

The mean numerical densities of benthos increased with distance from the shoreline during 1981/82 as was the case in the previous study in 1980. Densities observed during 1981/82 range from 249 to 6445/m^2 compared with 345 to 1657/m^2 in 1980. Population densities for both years are presented in Tables 7 and 8, for 1981/82 and 1980, respectively.

TABLE 7 BENTHOS DENSITIES MEASURED AT ISSUNGNAK 0-61, 1981/82

DISTANCE OFFSHORE	500 metres (Station 1)	500 metres (Station 2)	4 kilometres (Station 4)
Mean	$941/m^2$	$1587/m^2$	$2520/m^2$
Range	$263-2728/m^2$	$249-3028/m^2$	$396-6445/m^2$

TABLE 8 BENTHOS DENSITIES MEASURED AT ISSUNGNAK 0-61, 1980

DISTANCE OFFSHORE	300 metres	900 metres	3 kilometres
Mean	$172/m^2$	$456/m^2$	$1152/m^2$
Range	$99-284/m^2$	$345-587/m^2$	$503-1657/m^2$

A comparison of data from the two studies at Issungnak indicates that benthic recolonization was actively proceeding despite the fact that densities in the immediate vicinity of the island were still depressed compared to background levels four kilometres away. Physical processes which deter benthic recolonization in the short-term at abandoned islands such as Issungnak include erosion of sediments by waves and currents in summer and ice scour in winter.

The total number, type, and distribution of macroinvertebrate taxa in the benthos samples was quite similar for the two study periods. The mean number of species at distances 500 metres and more from the island were very similar for both studies, although the range of taxa was greater in the 1981/82 study (Tables 9 and 10).

TABLE 9 MACROINVERTEBRATE TAXA DENSITIES MEASURED AT ISSUNGNAK O-61, 1981/82

DISTANCE OFFSHORE	500 metres (Station 1)	500 metres (Station 2)	4 kilometres (Station 3)
Mean	27/m^2	26/m^2	34/m^2
Range	13-54/m^2	14-44/m^2	25-51/m^2

TABLE 10 MACROINVERTEBRATE TAXA DENSITIES MEASURED AT ISSUNGNAK O-61, 1980

DISTANCE OFFSHORE	300 metres	900 metres	3 kilometres
Mean	18/m^2	28/m^2	35/m^2
Range	10-28/m^2	22-31/m^2	29-47/m^2

Most of the common taxa at Station 3 (four kilometres offshore) in 1981/82 were also common at 900 metres offshore and beyond in 1980, but were rare or absent 100 metres and 300 metres from the island. Members of the polychaete family Spionidae were most prevalent near the island, but were rare or absent at outlying stations in both studies.

Crippen (1983) concluded that alteration of the natural benthic community in the vicinity of Issungnak O-61 through construction and subsequent erosion (i.e., smothering of the benthic habitat and modification of the sediment composition) was still evident near the perimeter of the island base (Stations 1 and 2) one year and nine months after island construction (Section 2.1.2).

TARSIUT N-44

Studies of the benthos and sediment chemistry in the vicinity of the Tarsiut N-44 caisson-retained island were conducted in September 1981 (Thomas et al., 1982) and in July 1982 (Heath and Thomas, 1983). Grab sampling in 1981 was performed at 12 stations after construction of the island berm and installation of the concrete caissons, but prior to drilling operations. In 1982, sampling was performed at the same stations after the winter and spring 1982 drilling program, but before island abandonment.

The sub-sea berm of Tarsiut N-44 was constructed with dredged sand and gravel on a seabed of silty clay in 22 metres of water. The dredged sand was obtained from the Ukalerk, South Tarsiut, and Isserk borrow areas, the gravel was from the vicinity of Herschel Island. The perimeter of the base of the berm was about 350 metres from the centre of the island. Thus about 40 hectares of seabed were covered by the island berm. The Tarsiut N-44 site is located in the Transition Zone (15 to 30 metres of water; Wacasey, 1975).

Although the Tarsiut N-44 studies were conducted before abandonment of the island berm, the following results and conclusions of the final report (Heath and Thomas, 1983) are relevant to the effects of island abandonment.

1. The principal region of influence of island construction on zoobenthos was within 500 metres from the caissons. There were significantly lower levels of biomass, population density, and species diversity (number of taxa/sample) at stations on the berm (50 metres offshore) than at surrounding stations (500 metres and three kilometres offshore). Community analyses also indicated that the impact on zoobenthic community structure was confined to the sandy berm stations.

2. There was significant evidence of benthic recolonization on the upper berm in September 1981 with 31 taxa identified at stations 50 metres offshore. In July 1982 a total of 29 taxa were represented in benthos samples from the upper berm. Recolonization was still in the "pioneer stage" in 1982 with small populations of hardy species with affinities for the sandy sediments of the berm accounting for most of the biomass and numbers in many samples. Population densities and biomass levels at berm stations did not differ significantly between 1981 and 1982 sampling periods, indicating that the rate of recolonization will probably be slow. The eventual populations of colonizing species will likely be lower in diversity, density, and biomass than the surrounding benthos populations in deeper areas with finer grained sediments. Species diversity (number of taxa present) in the general area, however, will probably continue to be enhanced by the addition of species which prefer the coarser sediments of the berm, notably bivalves.

Recolonization by zoobenthos on the lower slopes of the berm (greater than 12 metres in depth) was not directly observed, but may have been more advanced than on the upper slopes. Wave action would be less severe at greater depths, but ice scour might still be important. In general, the more stable sediments of the lower berm would likely be more suitable for a higher diversity and biomass of zoobenthos than those of the upper berm.

Further trends in benthic recolonization of the Tarsiut N-44 berm will depend on the role of the island in oil exploration. If the island is maintained for further drilling or production activities, recolonization of the upper berm would likely proceed slowly due to the adversities of the dynamic physical regime. If the island is abandoned, wave and ice erosion would wear the berm down gradually. Improved stability of sediments and water properties and natural sedimentation of silt would likely favour development of a more complex and diverse benthic community. Eventually the benthos of the berm site should resemble that of the surrounding area.

3. The sediment particle size data suggest that the slope of the Tarsiut island is stable; there is no indication of a shift to coarser particle size in samples from stations 500 metres offshore.

4. The changes to benthic habitat and communities caused by the construction (and abandonment) of Tarsiut N-44 likely represent temporary disturbances to a highly resilient ecosystem which repeatedly recovers from harsh environmental perturbations, such as ice scouring, storm wave action, and seasonal fluctuations of temperature, salinity, and food supply.

Borrow Areas

Studies on the impacts of marine dredging on arctic benthos and the subsequent recolonization of the dredge trenches provide further information on the response of Beaufort Sea benthos to habitat alteration in shallow water. In addition, the relocation of dredged sediments (habitat) and possibly some viable benthos from the borrow areas to the artificial island sites (Heath and Thomas, 1983) supports the ecological association of borrow sites with artificial island sites. Following abandonment, the island berm returns to the state of a local deposit of sand and gravel which is subject to erosion and benthic recolonization.

On gravel bars in the vicinity of Herschel Island, Heath et al. (1982) observed that disturbance of the macrobenthos was confined to the dredge trenches. Most organisms removed during dredging were lost from the borrow area, although some survivors may have resettled to the seafloor. Recolonization of the trenches started very soon after dredging was completed. Video recordings were made of epifauna such as isopods, amphipods, errant polychaetes, tunicates, and soft coral in the trenches. Resettling of suspended sand and silt appeared to prepare a suitable substrate for colonization by infauna.

Heath and Thomas (1984a; in preparation) noted that in areas near Herschel Island which were affected by both dredging and ice scouring, the sediments were highly disrupted and benthic population distributions were patchy. Despite this, the mean population density, biomass, and community structure of the benthos at the dredged and ice scoured sites were quite similar to those of other stations with sediments of similar particle size. The benthos of the gravel bars near Herschel Island had relatively high faunal diversity (52 taxa/sample), but low levels of biomass (1.2 grams of dry weight/m^2) and population density compared to most other shallow study areas of the southern Beaufort Sea.

At Banks Island, dredged sites were observed about one year after dredging (Heath and Thomas, 1984b; in preparation). The shallow dredge trenches in 16 to 18 metres of water had collected several centimetres of fine silty sediments. Benthic recolonization by infauna and epifauna was well advanced although levels of population density, biomass, and diversity were still below that of areas adjacent to the trenches. The benthic community associated with samples from the trenches was similar to that of samples from outside the trenches. Re-establishment of the natural benthos populations of the Banks Island borrow area appeared to be occuring rapidly.

3.3.2 Fish

3.3.2.1 Introduction and Background

The Beaufort Sea supports at least 43 species of anadromous and marine fish (LGL and ESL, 1981), as well as several freshwater species which occur in nearshore habitats at certain times of the year (Wright, 1977). However, many of these species are not present in sufficient numbers to be considered common residents. In relative terms, only 12 are locally abundant or common. These are listed in Table 11, and are the focus of the present review. A detailed description of the Beaufort Sea fishery resources is provided in LGL and ESL (1981) and Dome et al. (1982b).

Anadromous fish comprise the dominant portion of domestic and commercial coastal fisheries in the southeastern Beaufort Sea. Seven species are known to commonly occur along the Beaufort coastline (Table 11). Although marine

TABLE 11 LOCALLY ABUNDANT OR COMMON FISHES OF THE SOUTHEASTERN BEAUFORT SEA (after LGL and ESL, 1981)

ANADROMOUS		MARINE	
Coregonus autmnalis	- Arctic cisco	Boreogadus saida	- Arctic cod
C. sardinella	- least cisco	Clupea harengus pallasi	- Pacific herring
C. clupeaformis	- humpback whitefish	Myoxocephalus (quadricornus)	- fourhorn (sculpin)
C. nasus	- broad whitefish		
Stenodus leucichthys	- inconnu	Liopsetta glacialis	- Arctic flounder
Salvelinus alpinus	- Arctic char	Platichthys (stellatus)	- starry (flounder)
Osmerus eperlanus	- boreal smelt		

fishes are less important than anadromous fishes to domestic and commercial fisheries, they are important to Arctic marine food webs, providing a primary source of food for many species of marine mammals and birds (Craig and Haldorson, 1981). There are five species of marine fish which are considered common in the region (Table 11).

The occurrence and distribution of fish in the southeastern Beaufort Sea is largely determined by the seasonal and spatial boundaries between the warmer fresh water associated with the Mackenzie River, and the colder marine offshore water mass. Anadromous fishes usually disperse into shallow (less than five metres deep), brackish nearshore waters during spring and summer, re-entering the freshwater environment during fall to overwinter. The brackish or estuarine zone does not extend far from shore in some areas, although the Mackenzie River plume can extend 50 to 100 kilometres seaward in summer. Within the plume, there is vertical stratification of the water column with relatively warm and turbid river water overlying the colder and less turbid marine water. Consequently, at some offshore sites, anadromous species may be present in the upper water layers, while marine species occur in the underlying layers.

Field surveys conducted to date in the Canadian Beaufort region have been concentrated in nearshore areas, with comparatively little sampling undertaken in waters deeper than 20 metres (LGL and ESL, 1981). The Arctic cod is the only species which has been commonly sampled during offshore trawls at water depths ranging from 10 to 180 metres. Flounders, fourhorn sculpin, and Pacific herring were the most common marine fishes found in nearshore areas. Least cisco, Arctic cisco, and boreal smelt are the most abundant anadromous species nearshore, although the others listed in Table 11 are also frequently sampled. In several studies, small numbers of Arctic cisco have been found at least 25 kilometres offshore, but within the

Mackenzie River plume (Galbraith and Fraser 1984; Envirocon 1977; Olmsted 1977). No other anadromous species are known to occur at this distance from shore, although sampling efforts in this area have not been extensive.

The following section examines the potential effects of artificial island abandonment in the southern Beaufort Sea on marine and anadromous fishes of this region. Following a review of available data regarding this potential interaction, it was concluded that effects of island abandonment on fish are not an area of significant concern. The effects of island construction are of greater potential concern than those associated with abandonment, but even these have been recognized as localized and of short duration (Dome et al. 1982c). Information sources examined in the present review are summarized and presented in subsequent text to (1) substantiate the above conclusion, and (2) describe the type and nature of the potential effects.

3.3.2.2 Potential Effects

The potential effects of artificial island abandonment on marine fishes have never been specifically investigated, although the potential interaction between fish and artificial structures in general was examined by ESL (1982). In a review of the biological effects of hydrocarbon exploration and production activities on marine flora and fauna in the Canadian Beaufort Sea, ESL (1982) stated that artificial structures used (or proposed) by the oil and gas industry (i.e., artificial islands, causeways, tanker loading terminals) could affect fish in this region through attraction. In many cases, however, the attraction would have positive but temporary effects on local fish communities. Overall, the potential effects associated with this interaction were identified as a negligible regional concern. Persons involved in research, monitoring, and/or management programs associated with

Beaufort development confirmed that the potential interaction between abandoned islands and fish is not a concern in both the Canadian (W. Bond, B. Gallaway, and J. Ward, pers. comms., 1984) and Alaskan (B. Gallaway, M. Fraker, pers. comms., 1984) Beaufort Sea regions.

Artificial structures in aquatic environments tend to attract a variety of pelagic and mid-water fish species (ESL, 1982). It is possible that at certain stages of erosion, abandoned artificial islands will result in the attraction of some fish species in the southeastern Beaufort Sea, although this has not been specifically examined in this region. The potential for fish to be attracted as a result of enhanced opportunities for feeding/shelter or for spawning will be discussed in the following text, although it is emphasized that the ecological significance of any attractions are considered inconsequential because (1) fish that are attracted could relocate to adjacent unaffected areas following the deterioration of the created habitat, (2) the number of individuals affected would be extremely limited, and (3) fishes in this region do not include species with a strong tendency for attraction to artificial structures.

Potential for Increased Feeding Opportunities/Shelter

The presence of an artificial structure can cause local changes in sediment deposition and current patterns, wave action, and the location of ice rubble fields, or lead to the development of areas of thin ice and open water in the lee of a structure (ESL, 1982). The resulting localized changes in the oceanographic patterns are known to result in a localized increase in species diversity and abundance (Carlisle *et al*. 1979; Turner *et al*. 1969; Gallaway *et al*. 1979). With respect to fish, artificial structures are known to create areas of refuge from predators, as well as areas of reduced currents and enhanced food production (Tarbox and Spight, 1979). Another factor contributing to the attraction of fish to artificial structures is the thigmotropic response (attraction to large stationary objects), a characteristic behaviour of some species.

In the southeastern Beaufort Sea, abandoned islands are known to affect local oceanographic patterns in some of the ways described above with respect to artificial structures in general (Section 3.1). Consequently, attraction of some fish due to increased opportunities for food/refuge is expected to occur. The potential for attraction would probably be greatest throughout the period when an abandoned island exists above sea level, since this is the time when the effects of the structure on the local oceanographic regime would be greatest. At this time, abandoned islands would provide sheltered and exposed environments comparable to those provided by natural barrier islands and spits in the region during the open water season.

Natural spits and barrier islands in the region are important habitats for fish, particularly as rearing areas for young of the year and juvenile fish. Slaney (1974b) reported that densities of fish were significantly higher along leeward shores of the Mackenzie Delta barrier islands than along seaward shores, while Olmsted (1977) reported a significantly greater abundance of epifaunal invertebrates in the lee of a Beaufort Sea artificial island (Arnak L-30). Since many fish species in this region feed almost exclusively on epifauna, they may be attracted to artificial structures which support higher standing stocks of epifauna than adjacent undisturbed areas.

However, as an abandoned island gradually deteriorates, the effects of its presence on local oceanographic patterns would decrease. When a structure erodes to a depth at which it becomes a relatively stable subsurface feature below the pycnocline, the potential for attraction of fish would be at a minimum. Individuals that had been attracted to the island would probably have relocated by the time the structure deteriorated to this form. At these stages of erosion, an abandoned structure would have negligible effects on the particular oceanographic parameters (Section 3.1) which when altered, can lead to fish habitat enhancement or increased food availability.

Potential for Increased Availability of Spawning Habitat

At any stage of deterioration, an abandoned artificial island is not expected to provide significant spawning habitat for local fish stocks. Spawning habitat preferences for the 12 common species in the region (Table 11) are generally well known (LGL and ESL, 1981). Since anadromous species prefer lotic freshwater habitats for spawning, an abandoned island would not provide suitable available spawning habitat for these species. Three of the common marine species in the region (Arctic cod, Arctic flounder, and starry flounder) have semi-bouyant eggs which are planktonic until hatching. Consequently, these species do not require a substrate for egg development, and would not spawn on an abandoned island. The fourhorn sculpin and Pacific herring are the only common marine species with demersal eggs. While herring typically spawn on seaweed or rocks, the fourhorn sculpin spawns in shallow coastal waters on sand/silt substrates. Therefore, the sculpin is the only common species in the region that could potentially utilize abandoned islands as spawning sites. However, the effects on this species would be inconsequential because it is ubiquitous, has no commercial or domestic value, and is not likely limited by availability of natural spawning habitat.

3.3.3 Birds

3.3.3.1 Introduction and Background

Offshore and coastal areas of the Beaufort Sea are visited annually by several species of marine-associated birds. In total, there are about 20 species which are considered common marine visitants, and these include loons, brant, diving ducks, shorebirds, jaegers, terns, gulls, guillemots, and murres. The major activities of birds during their residence in the region include spring and fall migration/staging, nesting, brood-rearing, and/or moulting. With the probable exceptions of the ivory gull, Ross' gull, and the black guillemot, marine birds do not overwinter in the Beaufort region (Barry et al. 1981). A detailed description of the abundance, distribution, and life histories of birds inhabiting this region during all or part of their annual cycle is provided in LGL and ESL (1981) and Dome et al. (1982b).

The following sections examine the potential direct and indirect effects of artificial island abandonment activities in the Canadian Beaufort Sea on marine birds. Following a review of published and unpublished data concerning this interaction, it was concluded that significant effects on birds as a result of this particular activity are unlikely. A summary of the data examined in the present review is presented in subsequent text to substantiate this conclusion.

3.3.3.2 Potential Direct Effects

The direct effects of artificial island abandonment on marine birds have not been specifically investigated, although the potential interaction has been addressed by some authors (Owens, 1977; Hopkins, 1978; BLM, 1979). In each of these documents, the effects of island abandonment on birds were reported as inconsequential. During a thorough review of the biological effects of hydrocarbon exploration and production activities on marine flora and fauna of the Beaufort Sea, ESL (1982) stated that the degree of regional concern with respect to artificial structures and birds ranged from negligible to minor. The 'minor' level of potential concern reflected the susceptibility of some birds to airborne noise, human activities, or artificial structures at active sites, while the 'negligible' level of concern related to industrial structures which are not characterized by activities known to disturb birds (i.e., abandoned islands).

Theoretically, abandoned islands could directly affect birds through attraction and subsequent redistribution of some individuals. Attraction is considered a probable response to the increased habitat and/or food resources (Sections 3.3.1 and 3.3.2) associated with an abandoned island during the period when it exists above the sea surface. In the Canadian Beaufort Sea, the length of this period of potential interaction could range from a few months to 1 to 2 years following abandonment (Section 2.2).

In the Canadian Beaufort Sea, species that could be attracted to an abandoned island would likely include those that occupy natural sand/gravel islands and spits in the region. Common nesters in these habitats include the common eider (Somateria mollissima), black brant (Branta bernicla nigricans), Arctic tern (Sterna poradisaea), glaucous gull (Lorus hyperboreaus), and Sabine's gull (Xema sabini). These habitats are particularly important to birds during the nesting season (June 1 to August 15) because they offer protection from terrestrial mammal predation, and from winds (Slaney, 1974b). Birds using these habitats during fall migration stop-overs include the tundra swan (Cygnus columbianus) and several species of shorebirds (Slaney, 1974b; Owens, 1977; Schamel, 1977; Johnson and Richardson, 1980).

Although it is possible that individuals of the species mentioned above could temporarily occupy an abandoned island during nesting/migration, overall, the positive or negative effects associated with this attraction would be insignificant in terms of both affected individuals and regional populations (Owens, 1977; J. Ward, pers. comm., 1984). Both the length of time that an abandoned island could attract birds, and the number of individuals that could be affected, would be extremely limited (T. Barry, L. Allen, J. Ward, pers. comms., 1984). T. Barry (pers. comm., 1984) was able to report only one instance during his studies in the Beaufort Sea where birds were observed on an abandoned artificial island (West Atkinson L-17). It was not determined if the glaucous gulls and Arctic terns observed on the island during the late spring of 1983 were nesting.

If future development plans in the Canadian Beaufort Sea region were to include abandonment of artificial islands that persisted above the sea surface for a period of several years, then it is likely that some birds would colonize the abandoned surfaces. However, the individuals utilizing the additional habitat and taking advantage of increased food availability would probably be affected in a positive manner.

In the Alaskan Beaufort Sea, D. Troy (pers. comm., 1984) has observed black guillemots and common eiders nesting on abandoned gravel islands offshore of the Sagavanirktok River. The design of islands abandoned in this area allows them to persist for much longer periods than islands constructed in the Canadian Beaufort Sea. The U.S. Fish and Wildlife Service recommends that artificial island operators be required to abandon (rather than remove) islands, as these structures have enhanced the available habitat for some species.

3.3.3.3 Potential Indirect Effects

As described earlier (Section 3.1.1.1), artificial islands constructed and abandoned to date have had no detectable effects on the landfast ice regime. Consequently, the potential interaction between birds and island-induced ice regime effects has not been identified as an area of potential regional concern (ESL, 1982). Assuming the ice regime is not affected to an extent beyond it's natural variability in the future, concerns associated with this potential interaction are not anticipated.

In the unlikely event that future offshore structures did affect the ice regime, the potential effects on biota would be evaluated at that time. Some marine birds are particularly dependent on the ice regime during spring, and it is during this period that changes in ice patterns could affect bird populations. The remainder of this section addresses the potential effects of ice regime changes on birds, although it is emphasized that the likelihood of abandoned islands affecting the ice regime beyond the natural variability of this system is remote.

During spring migration, several species of marine-associated birds stage in open water areas and leads of the Beaufort Sea region. Although the location of these important areas varies among years, they generally recur at the seaward edge of the landfast ice (flaw-lead). During surveys of this ice edge, Barry _et al_. (1981) and Barry and Barry (1982) recorded the common eider, king eider (S. spectabilis), oldsquaw (Clangula hyemalis), glaucous gull, and red-throated loon (Gavia stellata) as the predominant species. Most birds were sighted within about 1 to 2 kilometres of the landfast ice edge, and over waters 10 to 25 metres deep.

If artificial islands (operational and abandoned) did result in an extension of the landfast ice edge, some birds which stage in this area in spring could be prevented from reaching preferred feeding areas, or could become stranded. The depths to which common eiders, king eiders, and oldsquaw can dive for food has been estimated at 10, 20, and 40 metres, respectively (Palmer 1976, cited in Barry et al. 1981). If access to feeding areas of suitable depth is restricted, then fitness for migration and nesting would be less than optimum. Nevertheless, the potential for abandoned islands to result in effects on the ice regime that exceed the natural variability of this system is remote (Section 3.1.1.1).

3.3.4 Marine Mammals

3.3.4.1 Introduction and Background

The Canadian Beaufort Sea supports several resident and migratory populations of marine and marine-associated mammals. Major resident species include the ringed seal (Phoca hispida), bearded seal (Erignathus barbatus), Arctic fox (Alopex lagopus), and polar bear (Ursus maritimus), while major migrant species include the white whale (Delphinapterus leucas) and the bowhead whale (Balaena mysticetus). With the exception of the bowhead, all of the above species are harvested by local Inuit. The bowhead is subject to a subsistence hunt in Alaska, but it is illegal to hunt bowheads in Canada. Background information is included throughout the following text where necessary for describing or understanding potential effects, while a detailed description of the marine mammal resources of the Beaufort Sea region is provided in Dome et al., (1982b) and LGL and ESL (1981).

Although the potential exists for marine mammals in the region to be affected by artificial island abandonment activities, studies examined in the present review indicate that this is generally not an area of significant potential concern. Evidence in support of this conclusion is provided in the following sections. In most instances artificial islands would have fewer effects on marine mammals than dredge removal of the structure (Hopkins, 1978; BLM, 1979).

Unless otherwise indicated, the potential effects of abandoned islands described in this section are those associated with sacrificial beach islands. These structures could theoretically affect marine mammals during the period following abandonment to the time when the abandoned structure becomes a stable subsurface feature (Section 2.2). Since the length of this deterioration period varies among structures, the duration of potential interaction between islands and marine mammals cannot be accurately predicted and would not be equal for any two structures. Effects on marine mammals are not anticipated as a result of: (1) shallow water islands that have deteriorated into a stabilized subsea feature, or (2) subsea berms that persist on the seafloor following removal of the upper portion of the islands. These structures extend to within 3 to 10 metres of the sea surface, and therefore are similar to some naturally occurring shoals in the region.

3.3.4.2 Potential Direct Effects

The direct effects of artificial island abandonment on marine mammals have not been specifically addressed in any major review of the potential effects of offshore petroleum hydrocarbon exploration and production activities on Arctic marine mammals (Mansfield, 1980; Geraci and St. Aubin, 1980; Cowles et al., 1981; ESL, 1982; Richardson et al., 1983a). However, Richardson et al. (1983a) reported that the physical presence of structures used by the oil industry are not likely to affect marine mammals. In this context, "structures" include abandoned as well as operational islands. The potential effects on marine mammals associated with offshore structures generally relate to human and industrial activities at these sites, and not to the physical presence of a structure (Richardson et al., 1983a).

Although the direct effects of island abandonment on marine mammals have not been investigated, some studies have examined this potential interaction indirectly and these will be reviewed briefly in the following section.

White Whales

Theoretically, abandoned islands could directly affect white whales by interfering with migration and/or navigation, or by restricting access to traditional feeding and/or calving areas. This species is harvested by Inuit, so any direct effects on the population may also affect the harvest of this species (Section 4.2).

The relative abundance and distribution of white whales in the Mackenzie Estuary have been monitored for the past 12 years (Slaney, 1973, 1974, 1975, 1976; Fraker, 1977a,b; 1978; Fraker and Fraker, 1979, 1981; Norton Fraker and Fraker, 1982; Norton Fraker 1983; Robertson and Millar, in prep.). A major objective of these monitoring programs has been to document white whale distribution and hunting success in relation to offshore hydrocarbon exploration activities, and to detect and minimize possible adverse effects of these operations on the population.

With respect to the potential effects of artificial islands, identified concerns include the potential for islands to block important white whale travel routes and to restrict white whale access to calving, harvesting, or feeding grounds. However, in summarizing the results of the first seven years of the white whale monitoring programs, Fraker (1978) reported that the physical presence of artificial islands had not resulted in significant effects on white whale distribution or their abilities for navigation. In this case, "artificial islands" would have included abandoned as well as operational structures. P. Norton Fraker (pers. comm., 1984) confirmed that this conclusion also applies to the findings of the more recent studies of the white whale monitoring programs (i.e., 1979 to 1982).

Fraker (1977c) emphasized that white whales are well adapted to navigate in ice-infested waters, and therefore would have no difficulty navigating amongst abandoned artificial islands. Fraker (1977c) reports that white whales were not adversely affected when migrating past an artificial (operational) island situated within their main travel route. Slaney (1975, 1976) and Fraker (1977a,b) stated that while the presence of artificial islands does not disrupt white whale movements, in some instances, marine logistics traffic associated with operational islands can result in short-term changes in white whale distribution (Fraker 1977a,b, 1978, 1979). Marine logistics traffic, however, is not a concern with respect to island abandonment.

The studies described above indicate that white whales are not likely to be adversely affected by abandoned islands encountered during migration or local movements. Consequently, it is not expected that white whale access to traditional feeding and/or calving areas would be restricted.

Furthermore, the areal extent of habitat removed by abandoned islands would be the same as that removed during construction and operation of the island, and inconsequential in terms of total available feeding and/or calving habitat.

Attraction of fish to abandoned islands (section 3.3.2) may result in a concomitant attraction of some white whales to areas where fish are abundant. However, this attraction would be extremely localized, and overall have no significant effect on the white whale population.

Bowhead Whales

Theoretically, artificial island abandonment procedures could affect bowheads by blocking or interfering with migration/navigation, or by excluding individuals from feeding areas. There have been no studies on the potential effects of island abandonment on bowheads in the Beaufort region or elsewhere and this interaction has not been identified as an area of potential concern with respect to bowheads and offshore development (ESL, 1982; Richardson, 1983).

Major concerns regarding bowheads relate primarily to the overall effects of development on this species, and the potential for underwater noise associated with offshore operations to disturb bowheads, and therefore their distribution and access to feeding areas. Results from systematic aerial surveys conducted in the southeastern Beaufort Sea during the period from 1980 to 1983 indicated that the distribution of bowheads on their summer range varies markedly among years (Renaud and Davis, 1981; Davis et al., 1982; Harwood and Ford, 1983; McLaren and Davis, 1984). The natural factors influencing bowhead distribution in this region have not been well documented, but probably include zooplankton concentration and distribution, and type, concentration, and location of ice (Harwood and Ford, 1983; Richardson et al., 1983b; BEMP, 1984).

The effects of abandoned artificial islands on bowhead distribution would probably be: (1) indistinguishable from the overall effects of industry activities in the development zone, and (2) inconsequential in terms of the bowhead population since abandoned structures do not constitute a source of industrial underwater noise disturbance (Fraker, 1977c; Richardson, 1983).

Ringed and Bearded Seals

Abandoned artificial islands could affect seals by: (1) interfering with or blocking local or migratory movements, (2) excluding individuals from feeding areas, or (3) redistribution of individuals through attraction. Although the direct effects of artificial island abandonment activities on seals have not been examined, Kingsley et al. (1982) and Kinglsey and Lunn (1983) studied the effects of overall offshore development in the Canadian Beaufort Sea on seal distribution during the 1981 and 1982 spring haul-out period. These authors did not observe any changes in hauled-out seal densities that could be attributed to offshore oil and gas exploration activities (including abandoned islands) in this area.

Numerous published and unpublished anecdotal accounts of seals in the vicinity of industry activities lend support to the suggestion that ringed and bearded seals are generally tolerant of offshore Beaufort operations (Renaud and Davis, 1981; Ward, 1981; Harwood and Ford, 1983; McLaren and Davis, 1984).

Industry personnel have frequently observed seal pups and occasionally maternal females hauled-out on slopes of artificial islands during construction activities (M. Psutka, pers. comm., 1984). There is no

3.3.4.3 Potential Indirect Effects

There is concern that artificial islands (both operational and abandoned) may affect the landfast ice regime by delaying break-up, and/or extending the seaward edge of the landfast ice beyond its normal limits (Fraker, 1977c; Hopkins, 1978; Dome *et al*., 1982c,e; Crook, 1983; Thomson, 1983; BEMP, 1984). Effects on the landfast ice regime could in turn affect some Beaufort Sea marine mammals which depend on the landfast ice during all or part of their annual cycle. Information concerning the alteration of the landfast ice regime by artificial islands is discussed in Section 3.1.1.1, while a description of the nature of potential effects on marine mammals is provided here.

As described in Section 3.1.1, existing data on landfast ice break-up dates and seaward extent of the landfast ice edge indicate that artificial islands constructed and abandoned to date have had no detectable effects on the Beaufort Sea ice regime. However, given increases in the number, size, and types of islands proposed for the future (Dome *et al*., 1982a), it is not known whether effects will continue to be undetectable. For this reason, the following discussion is presented to briefly address the potential effects of an altered ice regime on Beaufort Sea marine mammals. It is emphasized that these effects have not been observed to date in the Beaufort region, although concerns regarding these issues have been identified with respect to three species of Beaufort Sea marine mammals (Fraker, 1977c; Dome *et al*., 1982c,e; Crook, 1983; BEMP, 1984). These species are the white whale, polar bear, and Arctic fox, all of which are important to Inuit harvests. Potential concerns with respect to indirect effects of island abandonment activities and other marine mammals in the region have not been identified (Dome *et al*., 1982e; Crook, 1983; BEMP, 1984).

evidence to suggest that seals would be adversely affected by abandoned artificial islands, although it is considered possible that some individuals may be temporarily attracted to these sites if the ice regime is significantly modified (Foster, 1977).

Overall, the potential effects of island abandonment on seal populations would be highly localized, and inconsequential in terms of local communities or regional seal populations (Foster, 1977). In the Alaskan Beaufort Sea, BLM (1979) describes the effects of island abandonment on seals as minor. In the Canadian Beaufort Sea, the degree of potential regional concern regarding the effects of artificial structures on seals was identified as negligible (ESL, 1982; Dome et al., 1982c).

Polar Bears and Arctic Foxes

Polar bears and Arctic foxes could be attracted to abandoned island sites to scavenge on materials not removed during the abandonment process. Although the potential for attraction of these species to abandoned islands has not been directly examined, it would be limited to islands above sea level, and then only to periods of ice cover when these species would have access. During the latter period, however, opportunities for attraction would be limited because abandoned sites would usually be covered with snow.

Thorough clean-up of artificial islands during abandonment operations and the fact that most islands would not persist above the waterline for a period in excess of a few months generally eliminates the potential for attraction of these species. ESL (1982) classified concerns related to effects of the physical presence of artificial structures (including abandoned islands) on polar bears and Arctic foxes as negligible, while Foster (1977) stated that artificial island abandonment activities would not directly affect these species or their habitat.

White Whales

Each year, white whales of the 'Mackenzie Estuary Stock' enter the Mackenzie Estuary following break-up of the landfast ice, and remain there for about three weeks (Norton Fraker, 1983). The current 'best' estimate of the number of white whales (excluding calves) recorded during a period of peak whale abundance in the Mackenzie River Estuary is 7000 (Fraker and Fraker 1979; Norton Fraker, 1983). However, during offshore systematic surveys in late July 1981, Davis and Evans (1982) reported an estimated 4400 white whales in the offshore Beaufort, and concluded that not all white whales of the population had migrated to the Estuary in July of that year. Norton Fraker and Fraker (1982) also suggested that at least some white whales remain in Amundsen Gulf during July. It is not clear why white whales occupy estuaries during summer, although Finley (1982) recently suggested that the whales moult while in these shallow areas. Fraker et al. (1979) suggested that estuaries provide a thermal advantage over non-estuarine areas, and that estuaries may have an important social function. It is generally agreed that white whales do not feed while in estuaries during summer (Fraker et al. 1979).

In the Mackenzie Estuary, the timing of break-up of the landfast ice determines the time at which white whales have access to the Estuary. Timing of break-up also influences, at least partially, which areas of the Estuary are ultimately occupied by the whales (Norton Fraker and Fraker, 1982; Norton Fraker, 1983). Consequently, the implications of delayed break-up with respect to the white whale population include: (1) the potential for delayed arrival of whales in the Estuary; and (2) changes in whale use of this area.

Although the abundance and distribution of this species within the Mackenzie Estuary has been extensively monitored (Slaney, 1973; 1974; 1975; 1976; Fraker, 1977a,b; 1978; Fraker and Fraker, 1979, 1981; Norton Fraker and Fraker, 1982; Norton Fraker, 1983; Robertson and Millar, in prep.), only one investigation of the factors influencing whale distribution within the Estuary has been conducted (Fraker et al., 1979). In the absence of definitive data regarding the factors influencing white whale distribution, and the function and importance of estuaries to white whales, the biological significance of changes in whale distribution within the Estuary cannot be predicted. BEMP (1984) recently recommended that the factors controlling white whale distribution in the Mackenzie Estuary be further investigated, and that the white whale monitoring programs be continued and revised.

Polar Bears and Arctic Foxes

In the Beaufort Sea region, polar bears occupy the sea ice throughout most of the year. Adult female polar bears with cubs of the year comprise the sex/age class typically associated with the landfast ice. Emerging from their coastal winter dens in late March or early April, this group occupies the landfast ice and preys on breeding ringed seals. Adult males, non-breeding females, females with yearlings, and subadults occupy the transition zone in winter and spring (Stirling et al., 1975; 1981). During late spring and summer, most of the polar bear population remains with the retreating pack ice and continues to prey on seals (Stirling et al., 1975; 1981). Polar bears are presently harvested under a community quota system administered by the N.W.T. government.

Arctic foxes are terrestrial throughout most of their range, although some individuals from arctic coastal populations move onto the nearshore landfast ice during winter to forage on seal carrion left by bears (Stirling and Smith, 1977), and to prey on ringed seal pups (Smith, 1976). This species is trapped on the landfast ice by Inuit from local communities (Section 4.2).

Identified concerns with respect to polar bears/Arctic foxes and the indirect effects of artificial island abandonment relate to the potential for extension of the seaward edge of the landfast ice, and a concomitant displacement of bears and foxes further offshore and therefore further from accessible hunting areas (Dome et al., 1982e; Crook, 1983). Artificial islands constructed and abandoned to date have had no detectable effects on the seaward extend of the landfast ice (Section 3.1.1.1). Potential extensions of the landfast ice associated with island abandonment activities, however, would probably be within the range of natural variabilty (Section 3.1.1.1), and therefore inconsequential in terms of the polar bear and Arctic fox populations.

Changes in Inuit hunting effort could occur if changes in the landfast ice regime affect polar bear or Arctic fox populations. Potential effects on hunting effort are described in Section 4.2, and could include increasing the harvest of females with dependant cubs. The ecological significance of increased pressure on maternal females cannot be predicted, however, because the extent of any potential increases in hunting pressure (if any) are not known.

4.0 POTENTIAL LAND USE CONFLICTS

4.1 Hazards to Vessel Navigation

4.1.1 Review of Published and Solicited Information

The subject of abandoned artificial islands and their actual and/or potential effects on Arctic navigation has received relatively little attention during previous "environmental effects" studies. Most of the published information consists of Federal government reports and memoranda. Additional information has been provided through discussion with shipping companies, oil industry personnel, and Canadian Coast Guard staff.

The discussion of effects of abandoned islands as hazards to navigation falls into two categories:

1. the hazards to collision and grounding of boat and barge traffic, and

2. the hazards, particularly to small craft, of residual materials left on some of these islands following completion of island abandonment procedures.

Bannon and Bryant (1978) prepared a report discussing the results of inspections to reveal the state of abandoned artificial islands before and after cleanup measures were initiated by industry. Inspection reports of 16 abandoned islands, all in the shallow waters were included.

The authors reported that island cleanup practices were inadequate and went on to conclude that the presence of polyfilter cloth, used on all the islands reported, posed a potential hazard to transportation, particularly since the plastics in the cloth are persistent in the environment and remain in the water for indefinite time periods. They recommended that in the future, INAC land use permits issued for construction of artificial islands used for drilling platforms should include a requirement that would make mandatory the cleanup of an island within a specified time period after rig release. They suggested that this cleanup should include "all plastics, cable, and wires used for shore protection on the islands".

A report prepared for the Department of Fisheries and Environment by Wright (1977) discussed briefly the navigational concerns posed by present island abandonment procedures. Steel pilings and mooring dolphins were identified as hazards. Abandoned sacrificial beaches or conventional sandbag retained islands could act as large shoals with the potential for damaging unsuspecting boat and barge traffic unless these islands were properly charted and marked. The abandoned sand bagging and filter material were identified as hazards to jet drive intakes and small craft propellers.

The two available reports (Wright, 1977; Bannon and Bryant, 1978) describing abandoned island inspections are 7 and 6 years old respectively. It is highly probable that the information on island abandonment deficiencies is now outdated. More recent inspection reports were not available for this study.

As a component of the present study, telephone interviews were held with Beaufort Sea transportation companies, Canadian Coast Guard personnel, and oil industry representatives. Discussions with senior personnel from several marine transportation companies yielded the following information:

1. The ocean-going supply vessels currently travelling in the region of the Beaufort islands operate with a draft of up to six metres. Icebreakers draw up to 10 metres of water.

2. None of the operators felt that polyfilter cloth and other floating debris from these islands posed a hazard to their vessels. The steel pilings left on some of the abandoned islands were mentioned as a concern to shipping.

3. The existing regulatory procedures for identifying islands through a "Notice to Mariners" was considered adequate to warn mariners of the islands, particularly while the islands are active and equipped with proper radar reflectors and visible drilling equipment.

4. One of the operators expressed concern about the running aground of ships on islands not equipped with locator equipment. He reported personally having three near misses of abandoned islands during the 1983 shipping season.

5. Concern was expressed about the quality of navigation charts. At least one operator felt that the base map information should be updated more frequently to make it more dimensionally accurate. Mariners report significant errors when attempting to fix charted islands to shore points. The errors appear to lie in the base map information and not in the island coordinates provided in the notices to shipping. As a result of these errors navigators give the charted artificial islands more berth than necessary.

6. There was a concern about the absence of physical markers or radar reflectors on abandoned islands. Although this equipment may be put in place as part of the abandonment activities, its replacement is required annually because of the erosive ice action. A suggestion was made to put Radar Beacons (Racons) and buoys on the islands, particularly once they are eroded to an elevation below the water surface.

Mr. J. Duduman, Senior Officer, Navigable Waters, Ministry of Transport, supplied the study team with a copy of the recently released policy proposal regarding the construction and abandonment of Beaufort Sea Artificial Islands. The policy document specifically addresses the hazard of collision or grounding posed by these islands. It has been designed to cover all vessels likely to operate within the region. It was presented at the 1984 Western Arctic Athabasca - Mackenzie Workshop on January 17 of this year for review by both the developers of the islands and the marine users of the Beaufort Sea. A meeting of interested parties will be convened later this year to develop the policy proposal. The proposed guidelines are quoted in their entirety as follows:

> "Because of the proliferation of artificial island and berm construction in the Beaufort Sea and the problems associated with their removal, it was felt that there should be some guidelines established to govern their removal as well as their construction.

It is recognized that those structures constructed in the Beaufort Sea that are not easily dismantled or removed, may represent a substantial hazard to present and future navigation in the area.

The following guidelines are intended to minimize this hazard by setting out the criteria to be used in assessing the impact of the proposed structures in any given area:

- Navigational Corridor Zone:
  This is a corridor approximately 10 nautical miles wide stretching from the Alaska/Yukon border, through the Beaufort Sea to the eastern Arctic. The Canadian Hydrographic Service has been conducting a survey in this zone to determine the safe drafts available. It is proposed that no structures be allowed to be constructed in this zone or a five nautical mile buffer zone on each side or that all structures constructed be reduced to original bed level.

- Deep Water Zone:
  All structures in this zone would be reduced to a level of at least 12 metres below the surface and no rock, piles, etc., be left in place from -12 metres to natural seabed level. In addition, drill stems, pipes, etc., would have to be cut at or below seabed level and at a level somewhat below -12 metres.

- Shallow Water Zones:
  Near shore areas where structures might not need to be removed or reduced to any particular level.

- The need for total removal or scalping in any zone would also be determined by the structure's exact location in the Beaufort Sea.

> In all cases, there would be a requirement for appropriate notices and markings. In addition, it is intended that the annual "Notice to Mariners" will contain a listing of all offshore structures, their current status and limiting depth"

The exact location of the corridor, as defined by the Canadian Coast Guard, is illustrated in Figure 13.

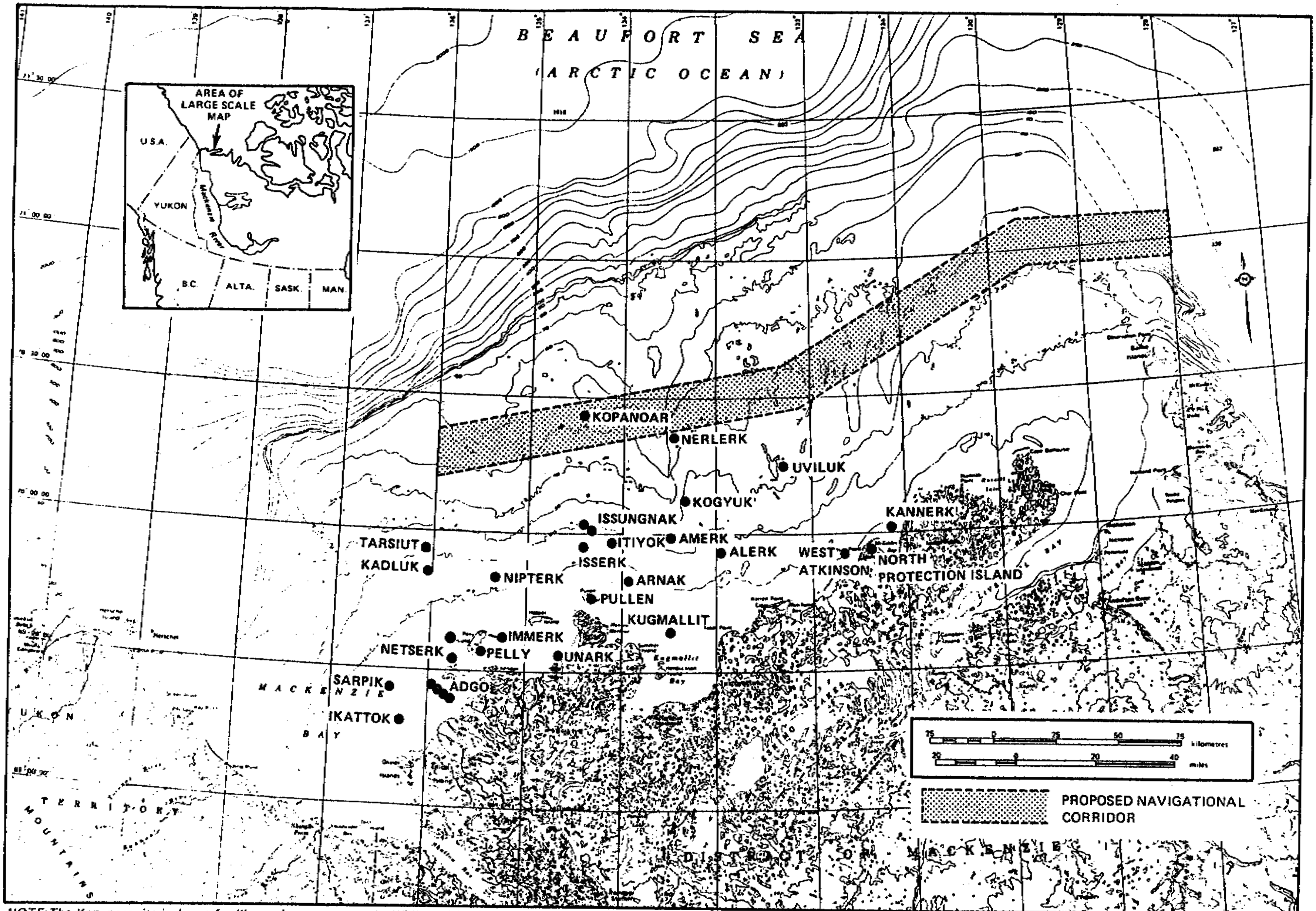
The proposed policy guidelines have been developed because a few ships have run aground or nearly run aground on abandoned islands. Mr. H. Debinski of the Canadian Coast Guard, Hay River reported two close calls by Coast Guard vessels due to poor visibility.

Oil industry personnel expressed economic concerns about this new policy for artificial island construction and abandonment. First, the establishment of an "island free" navigational corridor zone places severe restrictions on drilling activities within the zone. Second, the abandoned islands are viewed as a resource for the following reasons:

1. the materials of construction could serve as borrow material for new islands constructed nearby, reducing significantly the cost of constructing those new islands, and
2. if the islands were kept in place, they could serve as a base for construction of permanent drilling islands during future production.

Finally, the requirement for scalping of islands in the deep water zone to -12 metres or more adds a significant operational cost to the abandonment activities.

There appears to be general uncertainty within industry about the rationale for the new policy as it exists. At least one respondent felt it was geared toward future oil tanker traffic. Another indicated complete uncertainty with the rationale. There was concern expressed over the potential for



NOTE: The Kopanoar site is shown for illustration purposes only. While no island exists at this site, Kopanoar represents one of the few commercial finds in the region.

FIGURE 13 LOCATION OF ARTIFICIAL ISLANDS AND PROPOSED NAVIGATIONAL CORRIDOR

"penalization" of oil companies with leases in the deep water zone. The policy has minimal effect on companies exploring in the shallow water zone.

A final observation to be made is the location of the navigational corridor zone. It appears to traverse an area previously identified by industry as the initial production zone in the Beaufort Sea.

Industry personnel acknowledged the need to provide permanent markings for abandoned islands. One suggestion was made to use sacrificial radar reflectors. These are relatively inexpensive to replace and they could be deployed easily by helicopter at the start of each open-water season.

4.1.2 Identification of Key Concerns

The major concerns regarding hazards to vessel navigation may be summarized as follows:

1. Earlier (1977/78) island cleanup practices during abandonment were inadequate. Floating polyfilter fabric and steel pilings were potential hazards to small craft and large vessels.

2. The absence of adequate permanent aids to marine navigation in the form of radar reflectors, buoys, radar beacons, etc., poses a hazard to navigation. The problem is particularly acute where the islands have been eroded to an elevation just below the water surface. The erosive action of winter ice requires the annual deployment of whatever aids are used.

3. The proposed policy recently presented by the Canadian Coast Guard under the Navigable Waters Protection Act may have major economic implications for the industry. It places major restrictions on the

exploration and production activities within a defined "navigational corridor zone", increases the cost of island development in the "deep water zone", and has little effect on island development in the "shallow water zone". The need for defining a "navigational corridor zone" appears to be somewhat premature since there is not a consensus among oil industry personnel regarding the method by which future production oil will be moved from the Arctic.

4.2 Effects on Hunting and Trapping

The effects of abandoned artificial islands on hunting and trapping in the Beaufort Sea have been identified from the literature, transcripts from the Beaufort Sea Environmental Assessment Panel, and from a telephone questionaire administered to officials from local government, interest groups, Government of the Northwest Territories, and the Federal Government.

4.2.1 Review of Published Information

A brief review of published information shows that very little exists with respect to artificial islands in their abandoned state and their impact upon hunting, trapping, and fishing. Most of the literature concentrates on the impact of oil and gas exploration activities upon Inuit harvesting: such activities as seismic, island building, drilling, re-supply vessel traffic, etc., (Dome *et al.*, 1982d).

By way of further example, Matrix 2.5-1 of volume four of the Beaufort Sea Environmental Impact Statement (EIS) which summarizes the biological impact of normal hydrocarbon activities in the Beaufort Sea does not include island abandonment as a separate activity, but was included under the physical presence of artificial structures category for purposes of assessment (Dome et al., 1982b).

Numerous studies have been published with respect to white whale monitoring programs in the Mackenzie Estuary for the past 12 years (Section 3.2.4.2). As a result of these studies, it has been concluded by the authors that the physical presence of artificial islands (operational and abandoned) had not resulted in significant effects on white whale distribution or their abilities for navigation. This would therefore, suggest in an indirect way that whale hunting should also not be significantly affected by the physical presence of abandoned artificial islands.

The people who could be most affected by any adverse effects of abandoned artificial islands upon animals (including mammals) would be those who hunt and trap out of Aklavik, Inuvik, and Tuktoyaktuk. Order of magnitude figures have been summarized from the literature to illustrate the relative importance of hunting and trapping to these communities. As with any harvesting statistics, these should be treated with caution since they are dependent upon individual hunters/trappers accurately recording and reporting their annual take to the government. Table 12 summarizes available harvesting statistics. A crude estimate of the economic value of the annual harvests to each of the communities is presented in Table 13.

The economic value of the annual harvest from the Beaufort Sea attributed to residents of the three communitees has been estimated by taking reported harvests and applying average 1982 values for pelts and average yields for meat and estimating the cost to replace this meat with imported meats. These estimates are conservative since the information on harvesting is incomplete and no economic value has been assigned to whale blubber.

TABLE 12 ESTIMATES OF ANNUAL HARVEST (N.W.T. BEAUFORT SEA)
AKLAVIK/TUKTOYAKTUK/INUVIK

COMMUNITY	ARCTIC FOX	POLAR BEAR		WHITE WHALE	SEAL
	Harvest	Quota	Harvest	Harvest	Harvest
Aklavik	35	NIL	n.a.	19.3	n.a.
Tuktoyaktuk	800	22	17-22	48.2	10.0
Inuvik	n.a.	NIL	n.a.	52.5	n.a.

(Source: Dome et al., 1983d)

TABLE 13 ESTIMATES OF ANNUAL ECONOMIC VALUE
OF ANNUAL HARVEST (N.W.T. BEAUFORT SEA)
AKLAVIK/TUKTOYAKTUK/INUVIK
(1982 Dollars)

COMMUNITY	ARCTIC FOX	POLAR BEAR		WHITE WHALE	SEAL		TOTAL
		Pelts	Meat	Meat	Pelts	Meat	
Aklavik	$ 1 800	NIL	NIL	$ 23 000	n.a.	n.a.	$ 24 800
Tuktoyaktuk	$40 000	$24 200	$19 300	$ 57 600	n.a.	$1 600	$142 700
Inuvik	n.a.	n.a.	n.a.	$ 62 700	n.a.	n.a.	$ 62 700
	$41 800	$24 200	$19 300	$143 300	n.a.	$1 600	$230 200

NOTES: Yields based upon:
- White Whale - 239 lb of meat/whale
- Polar Bear - 175 lb of meat/bear
- Seal - 31 lb of meat/seal

Prices based upon:
- Arctic Fox - $ 50/pelt
- Polar Bear - $1 100/pelt
- Imported Meat - $ 5/lb

Present concerns over the abandonment of artificial islands are mostly concerns for future development rather than concerns over the development in the past of some 26 artificial islands. These concerns with respect to future development have been expressed in the final report of the joint Tuk-Industry task force established to examine the effects of artificial islands on Beaufort Sea ice (Dome et al., 1982e). There were two major concerns identified in the report, namely:

1. extending the limit of the landfast ice away from shore, and
2. delaying the breakup of the landfast ice in the spring.

Should the above two concerns prove to be well-founded, then the indirect effect on hunting and trapping in the area could be:

1. if the landfast ice limit was extended, hunters would be forced to travel a longer distance to their hunting areas at the shear zone (i.e. polar bears, seals, and Arctic foxes), and

2. if the breakup of the landfast ice in spring was delayed, it could restrict the entrance of white whales into Kugmallit Bay during their migration in late June and reduce the annual harvest, and affect their distribution within the Estuary.

It is emphasized that to date there is no evidence to suggest that artificial islands have extended the limit of the landfast ice away from the shore. In addition, delays to the breakup of landfast ice in the spring have been restricted to very small areas around some of the islands. The indirect effect on hunting and trapping in the area has been reported to be negligible to date.

There were a total of 11 conclusions reached by the task force. Some of the more significant conclusions are related to island abandonment are presented below:

- Between 1973 and 1981 historical satellite photographs have shown that there have been no evident changes in the landfast ice extent resulting from the construction of artificial islands.

- Historical satellite photographs have shown no evidence of delay in break-up in the years 1973 to 1978.

- The effect of a larger number of future artificial islands on landfast ice is not clear from existing data. Ice conditions should be closely monitored during further construction to determine if floes can lodge between islands that are close together.

- The white whale harvest in the Beaufort has shown a lot of variability from year to year, but it did not appear to be closely linked to breakup dates.

- The whale hunt is generally best between July 10 and 20. If the ice breakup is delayed such that larger cracks have not yet formed by that date, then the whale migration may by-pass Kugmallit Bay and the harvest will be reduced.

More recently, the effects of offshore artificial structures on white whales and polar bears were examined during the Beaufort Environmental Monitoring Project (BEMP, 1984). These series of workshops were attended by biologists from the Canadian Federal Government, Government of the Northwest Territories, Alaska, industy, and the consulting community. Hypotheses linking offshore structures with effects on the ice regime and harvests were formulated and examined with respect to validity.

The working group for the white whale harvest hypothesis concluded that:

- Delays in break-up resulting from the presence of offshore structures could lead to a reduction in the white whale harvest. However, on the basis of projections in the present development scenario, substantial industry-induced delays in break-up of barriers across Kugmallit and Niakunak bays have a low probability of occurrence. In addition, the timing of break-up is not the only factor determining the arrival time of white whales in the Estuary, although it is a good indicator in most years.

- It is not known if industry-induced delays in break-up could be of sufficient magnitude to result in a major reduction in the number of whales using the Mackenzie Estuary. However, within the range of natural variation observed between 1972 and 1982, there is a positive correlation between whale abundance and size of harvest, and a negative correlation between arrival date and size of harvest.

With respect to effects of artificial structures on the polar bear harvest, it was concluded that one link of the hypothesis was probably not valid. This link encompassed concerns related to changes in winter ice patterns to an extent that restricts or eliminates hunter access to polar bear harvest areas.

The major conclusions to be drawn from the published and unpublished literature to date are that:

1. The impact of abandoned artificial islands upon harvesting has been negligible to date.

2. Sufficient research or historical data does not exist to accurately predict the future behaviour of the ice in response to more artificial islands and/or production islands being constructed in the Beaufort Sea.

3. The location of the Shear Zone can vary from year to year by as much as 25 kilometres but generally can be predicted to occur between the 12 and 18 metre isobaths. In the Beaufort Sea this is usually 40 kilometres from shore.

4.2.2 Beaufort Sea EARP Hearings (Transcripts)

Transcripts from the Beaufort Sea hearings in Inuvik were reviewed in detail along with transcripts of community meetings in Tutoyaktuk and Aklavik. The Inuvik hearing occurred in November 1983, while the community sessions were held in September of 1983 (Beaufort Sea Environmental Assessment Panel, 1982).

Summaries of the key concerns identified at those sessions are outlined below:

CATEGORY	CONCERNS
Ice Regime	- Extension of landfast ice from shore. - Delays in landfast ice break-up. - Ice-ridge buildup around artificial islands could hold back landfast ice. - Shear zone will follow the artificial islands beyond the present shear zone without complete abandonment and removal down to the sea floor.

Hunting and Trapping	- Delays in landfast ice break-up due to artificial islands (mostly in the future) could adversely affect white whale harvest by delaying or preventing migration into Kugmallit Bay. - Extension of landfast ice and hence the shear zone could affect the polar bear harvest as well as making the harvest more costly.
Island Abandonment	- Environmental impact of disrupting early recolonization of new benthic communities on side slopes of artificial islands through abandonment procedures is unknown.
Kendall Island	- Possible delay in break-up of landfast ice by 7 to 10 days could affect growing season on Kendall Island and perhaps affect egg hatching of geese.
Production Islands	- Spacing between fields could be 10's of miles; whereas spacing between production islands in the same field (3 or 5) could be three kilometres. - Views of some government and local people, with respect to ice bridging between islands, at odds with industry. Government and local people say 5 to 10 kilometres spacing to avoid bridging: Industry says 300 metres. - Critical water depths for island abandonment programs 15 to 25 metres.
Ice Breaker Support	- The possible need for assistance in the ice breakup in Kugmallit Bay to allow white whales into the Bay. - Industry concerned with precedent and cost. - Inuit concerned with respect to effect on ice rubble between islands.

The major concerns identified in the hearing transcripts are more or less the same as those identified in the published literature. Almost all the concerns relate to the manner in which future oil and gas activities in the Beaufort Sea will affect the ice regime and the impact upon harvesting the white whale and polar bear.

4.2.3 Questionnaire Results

A telephone questionaire was administered to local leaders and government officials at both the territorial and federal levels. A copy of the questionaire is included in Appendix A-3. A total of seven questionaires out of 14 were successfully completed. Issues arising from the questionaire have been summarized in Table 14.

All but the last two issues have already been described elsewhere in this study. The concern expressed over island abandonment procedures related to changes of already approved island abandonment programs to those of a lesser scope.

Ice ridges around the artificial islands have inhibited passage through by snowmobile on the way to the shear zone. These ridges must either be bypassed or cut through resulting in time delays and additional cost. However, this appears to be more of a nuisance than a major issue at present.

A difference of opinion seems to exist between industry/COGLA on one hand and local people/Environment Canada on the other, with respect to the extent of the impact of artificial islands upon the ice regime. Industry and COGLA claim a very localized effect of about 300 metres; whereas local hunters and trappers, along with Environment Canada, say effects can be detected up to five kilometres from the islands.

The only use noted for an abandoned island has been for the establishment of Inuit camps on or near artificial islands near the shear zone for the purpose of polar bear hunting. The grounded ice ensures that the camp will not drift out on a moving ice flow.

TABLE 14 QUESTIONNAIRE CONCERNS

ISSUE	NUMBER OF TIMES RAISED (N=7)	GROUPS RAISING CONCERNS
Delays in landfast ice break-up	4	Municipal, THTA[1] Federal
Navigational hazard	1	Federal
Extension of landfast ice	1	THTA
Abandonment procedures	1	GNWT
Ice ridges hindering travel to the shear zone	2	Municipal, THTA[1]

NOTE: 1. Tuktoyaktuk Hunters and Trappers Association

To date no hardships have been experienced by hunters and trappers with respect to existing artificial islands. Concerns relate almost exclusively to the potential impact upon the ice regime of future development of exploration and production islands in the Beaufort Sea and their interaction with each other and existing abandoned islands. As a result of this concern there is a desire on the part of hunters and trappers that artificial islands be scalped to the sea bottom when they are located near the Mackenzie Delta.

4.2.4 Identification of Key Concerns

As a result of the literature review, a review of the Beaufort Sea EARP Hearing transcripts, and results from the questionaire, the following is a summary of the key concerns as they relate to the impact of artificial islands upon hunting and trapping:

1. The possibility of delaying the breakup of landfast ice in the spring due to the future development of artificial exploration and production islands and the resulting impact on white whale migration/distribution and harvesting.

2. The possibility of extending the landfast ice zone away from shore and the resulting impact on harvesting of polar bear, Arctic fox, and seal at the shear zone.

5.0 CONCLUSIONS

Information available to date suggests that abandoned islands have negligible direct effects on the physical, chemical, and biological environment of the southern portion of the Beaufort Sea. The only identified area of concern relates to the indirect effects of variations in the landfast ice cover on marine mammals and birds. It has been suggested that artificial islands could conceivably extend the yearly landfast ice sheet to deeper water or could delay the breakup of the landfast ice, however, this argument has never been extended to abandoned artificial islands. Significant alteration in the time of breakup or the location of the shear zone could conceivably alter the distribution and population of both white whales and birds. On a related issue, it has also been suggested that any extension of the landfast ice sheet will also affect the distances that hunters must travel to find game. On the basis of all information reviewed in conjunction with this study, there is no evidence to suggest that artificial islands, either in use or abandoned, have affected landfast ice in any measurable manner. However, should extensive use of artificial islands be continued in the future, further monitoring may be required to ensure that this conclusion remains valid.

Abandoned artificial islands constitute a hazard to navigation. Since most islands will naturally erode to an elevation of about -4 metres they must be marked. Accurate charting of island locations and the installation of appropriate devices (i.e., radar reflectors and buoys) at island sites should be sufficient to ensure that abandoned islands can readily be avoided by marine operators. It is believed that the proposed island scalping program is both premature and has no apparent basis. There also appears to be no basis for the implementation of the proposed navigational corridor since production scenarios have not been developed. As well, the program would penalize exploration companies that currently hold leases within the proposed corridor. If a demonstrated need for a navigational corridor arises in the future, an attempt should be made to locate the corridor relative to development centres. A program that requires complete removal of abandoned islands is unrealistic. It appears to be unreasonable to scalp an island to -12 metres, or to the seabed, unless a clear need for elimination of the hazard posed by the island exists.

The line of responsibility within the government is not clear at the present time. Many departments and agencies claim involvement in the regulatory process but only a few appear to be actively involved in actual abandonment programs. Numerous Acts are available but the application and interpretation of these Acts is not clear. It is recommended that responsibilities for abandoned islands be assigned to one department or agency and that they be provided with a clear mandate to aid them in establishing guidelines for the actual abandonment and subsequent monitoring of artificial islands.

Identified data deficiencies concern the dynamics of island abandonment. Monitoring of island erosion to determine deterioration rates and sediment dispersal paths appears to have been severely lacking to date. Only very limited information was available for this study. Further monitoring of the dynamics of island abandonment is recommended to address these data deficiencies.

APPENDIX A

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APPENDIX A

REFERENCES

APPENDIX A-2 INFORMATION SOURCES

A.2.1 Computer Literature Search: (Fish, Birds, Mammals)

The computer literature search accessed three data bases: CENV (Canadian Environment; 59,076 titles), AST (Arctic Science and Technology; 12,778 titles) and SWR (Selected Water Resources Abstracts; 64,700 titles). The program sought the following key words in various combinations in the titles of government, industry and consultant reports: "artificial island", "offshore island", "removal", "abandonment", "erosion", "recolonization", "fish", "biolog-".

A.2.2 Personal Communications and Agencies Contacted

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Arctic Offshore Limited
Hay River, N.W.T.

Arctic Transportation Limited
Calgary, Alberta

Canada Oil and Gas Lands Administration
Yellowknife, N.W.T.
Ottawa, Ontario

Dome Petroleum Limited
Calgary, Alberta

Atmospheric Environment Service
Environment Canada
Government of Canada
Edmonton, Alberta

Esso Resources Canada Limited
Calgary, Alberta

Executive Council
Government of the Northwest Territories
Yellowknife, N.W.T.

Gulf Canada Resources, Inc.
Calgary, Alberta

Hamlet of Aklavik
Aklavik, N.W.T.

Hamlet of Tuktoyaktuk
Tuktoyaktuk, N.W.T.

Indian and Northern Affairs Canada
Government of Canada
Inuvik, N.W.T.
Ottawa, Ontario

Northern Transportation Company Limited
Edmonton, Alberta

Renewable Resources
Government of the Northwest Territories
Yellowknife, N.W.T.

Tuktoyaktuk Hunters and Trappers Association
Tuktoyaktuk, N.W.T.

APPENDIX A

REFERENCES

APPENDIX A-3 TELEPHONE QUESTIONAIRE

ABANDONMENT OF OFFSHORE ARTIFICIAL ISLANDS
BEAUFORT SEA
HUNTING, FISHING & TRAPPING

NAME: ______________________ DATE: ____________

ORGANIZATION: __________________ TITLE: ____________

INTERVIEW TYPE: Local Interest Group ____ Municipal Gov. ____

Territorial Gov. ____ Federal Gov. ____

Industry Rep. ____ Other (Specify) ____

1.0 Do you have any concerns with regards to the present artificial island abandonment procedures in the Beaufort Sea?

1.1 Physical

- Extension of landfast ice ____________, Specify 1.1.1 ____________
- Delays in landfast ice breakup ____________, Specify 1.1.2 ____________
- Navigational hazards ____, Specify 1.1.3 ____________
- Abandonment procedures ____________, Specify 1.1.4 ____________
- Other ____________, Specify 1.1.5 ____________

1.2 Biological

- Whales:
  - white (Beluga) ____, Specify 1.2.1 ____________
  - bowhead ____, Specify 1.2.2 ____________

- Seals:
  - Ringed ____, Specify 1.2.3 ____
  - Bearded ____, Specify 1.2.4 ____
- Polar Bears ____, Specify 1.2.5 ____
- Arctic Fox ____, Specify 1.2.6 ____
- Birds ____, Specify 1.2.7 ____
- Fish ____, Specify 1.2.8 ____
- Benthic Communities ____, Specify 1.2.9 ____
- Plankton ____, Specify 1.2.10 ____
- Other ____, Specify 1.2.11 ____

2.0 Have you or anyone else you know used an abandoned artificial island?

YES ____ NO ____

If yes, for what purpose?	BENEFIT YES	BENEFIT NO	$
2.1 ____	____	____	____
2.2 ____	____	____	____
2.3 ____	____	____	____
2.4 ____	____	____	____

3.0 To your knowledge, have any of the abandoned artificial islands affected either positively or negatively hunting, fishing, or trapping activities?

YES _____ NO _____

If yes, how?

		IMPACT		ECONOMIC COST	
EFFECT	ISLAND	POSITIVE	NEGATIVE	$	$/YR
3.1					
3.2					
3.3					
3.4					
3.5					

4.0 Is there anything else you wish to say about the artificial island abandonment practices in the Beaufort Sea?

_____

_____

_____

_____

_____

_____

_____

THANK YOU FOR YOUR TIME.