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# THE COASTAL MORPHOLOGY AND SEDIMENTOLOGY OF CAPE HATT: IMPLICATIONS FOR THE BAFFIN ISLAND OIL SPILL PROJECT (BIOS)

Project 760005

P. McLaren[1], W.B. Barrie[2], and J.M. Sempels[3]
Cordilleran Geology Division

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**Abstract**

*Cape Hatt, a small peninsula that protrudes into Eclipse Sound at the north end of Baffin Island is the site for an experimental oil spill to take place in the summer of 1981. Three small bays are required: one as a control; a second to study the effects of oil spilled on the surface and allowed to impinge the shoreline; and a third to use an oil-dispersant mix for comparison with the oil-only experiment.*

*The chosen site contains at least 13 bays potentially suitable for the experiments. Analyses of data from baseline studies in 1980 have resulted in selection of 3 suitable bays (bays 9, 10 and 11). Geomorphic and sedimentologic criteria indicate that the processes of winds, waves and ice action are greatest in bay 10 and least in bay 11. On the assumptions that cross-contamination must be minimal and longevity of the oil in the environment is desirable to ensure reasonable and measurable detrimental effects, we suggest that bay 10 should be used for control, bay 11 for the oil-dispersant mix and bay 9 for the oil-only experiments.*

## Introduction

### Background

Since 1978, staff of the Arctic Marine Oilspill Program (AMOP), of which Environment Canada is the lead agency, has undertaken to identify and co-ordinate research needs associated with experimental oil spills in cold Canadian waters (AMOP, 1979). Cape Hatt on the north coast of Baffin Island (Fig. 19.1), was chosen as the site for these experiments which had two principal objectives: (i) to determine if the use of dispersants in the arctic nearshore will reduce or increase the environmental effects of spilled oil; and (ii) to determine, under actual field conditions, the relative effectiveness and environmental impact of various shoreline protection and cleanup techniques. The most important site requirement demanded three small bays having similar physical and biological properties. Using one bay as a control, the experiment will document the various effects of oil and dispersant in the second bay and compare the results with the third bay in which oil alone has been placed.

During 1980 extensive biological, chemical, ice and sedimentological baseline studies were undertaken including some aspects of the oil-on-shoreline experiments (Environmental Protection Service, 1980). Cape Hatt, probably one of the few ideal locations in the arctic for the experiments, has over 13 bays (or "boomable" localities) potentially suitable for the spills (Fig. 19.1) which are to take place in August and September, 1981. As a result of the baseline studies, the three bays that have been chosen for the experiments are numbers 9, 10 and 11 located in Ragged Channel (Fig. 19.1).

The purposes of this report are to (i) describe the geomorphology and sedimentology for the Cape Hatt area as a whole using the data contained in Barrie et al. (1981); (ii) discuss each of the geomorphic and sedimentologic criteria with respect to the objectives of the spill experiments; and (iii) choose among bays 9, 10 and 11 the most suitable bay for each component of the experiment.

We have attempted the latter by assessing each geomorphic/sedimentologic criterion as a factor that may be considered in the selection of the bays. The relative importance of the factors are assessed qualitatively on a scale of 1 to 5. Each factor is by no means exclusive of the others and each demands slightly differing points of view and assumptions for an importance rating. The values we have provided may reflect assumptions that are invalid with respect to other aspects of the innumerable goals of the experiments and, if so, we encourage modifications.

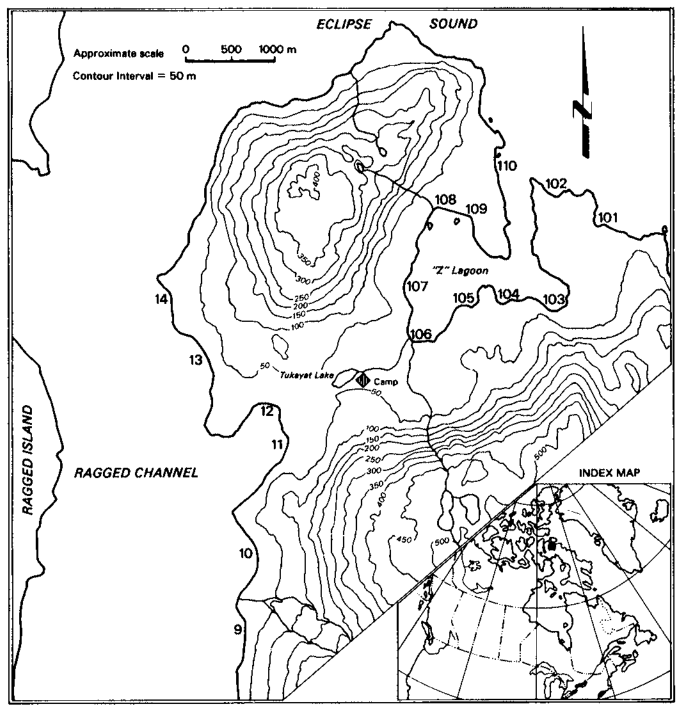


*Figure 19.1. Bay numbers, general topography and location of Cape Hatt.*

### Field Methods

In late May and early June 1980, sediment cores and grab samples were taken through the ice in bays 9, 10, 13, 102, 103, 104, 105, 106, 108 and 109 using a vibracorer and a

[1] Pacific Geoscience Centre, Sidney, B.C.

[2] Consultant

[3] Petro-Canada

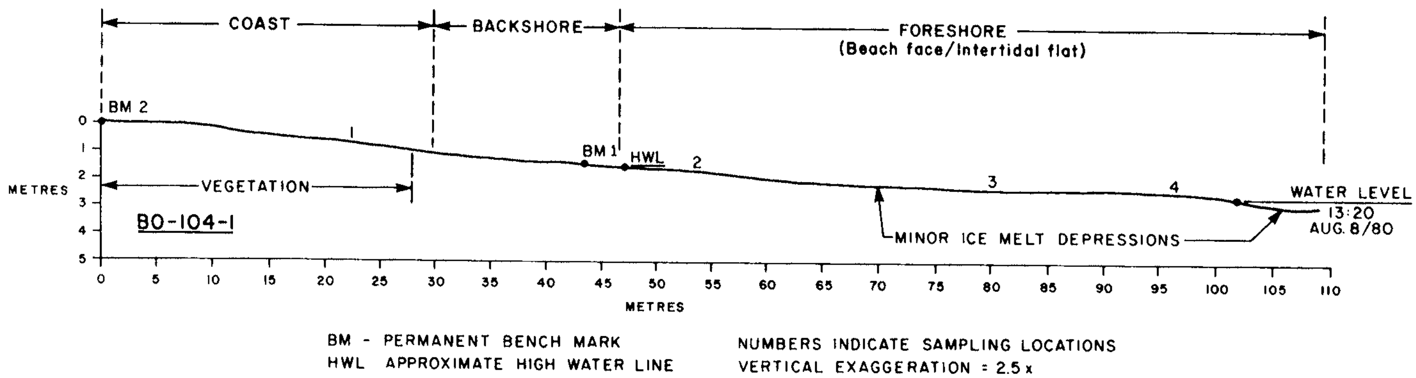


***Figure 19.2.*** *Beach profile in bay 104; "Z"-Lagoon.*

Table 19.1

Summary of shoreline morphology

| Morphologic Unit | Measured Parameter | | Bays in "Z" Lagoon | | | | | | | Bays in Eclipse Sound | | Bays in Ragged Channel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 101 | 102 | 9 | 10 | 11 | 13 |
| Backshore (including berm if present) | width (m) | max. | – | – | – | – | – | – | – | 30 | 30 | 2 | 5 | 7 | 15 |
| | | min. | – | – | – | – | – | – | – | 26 | 12 | 0 | 0 | 2 | 3 |
| | | mean | 10 | 16 | 5 | 0 | 0 | 3 | 6 | 28 | 21 | 1 | 2 | 4 | 10 |
| Berm | width (m) | max. | | | | | | – | – | 6 | 12 | 2 | 5 | 7 | 4 |
| | | min. | NP[1] | NP | NP | NP | NP | – | – | 8 | 12 | 0 | 0 | 2 | 0 |
| | | mean | | | | | | 3 | 6 | 7 | 12 | 1 | 2 | 4 | 2 |
| Beach face | width (m) | max. | | | | | – | – | – | 33 | 31 | 19 | 26 | 18 | 23 |
| | | min. | NP | NP | NP | NP | – | – | – | 30 | 26 | 12 | 15 | 40 | 14 |
| | | mean | | | | | 23 | 28 | 28 | 32 | 29 | 17 | 18 | 31 | 18 |
| | slope (°) | max. | | | | | – | – | – | 7.1 | 6.3 | 14.0 | 11.0 | 6.2 | 9.2 |
| | | min. | NP | NP | NP | NP | – | – | – | 6.4 | 5.8 | 8.2 | 6.8 | 3.1 | 5.6 |
| | | mean | | | | | 7.7 | 5.1 | 5.3 | 6.8 | 6.1 | 10.7 | 8.6 | 3.9 | 7.2 |
| Intertidal flat | width (m) | max. | – | – | – | – | | | | | | | | | |
| | | min. | – | – | – | – | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| | | mean | 50 | 64 | 42 | 75 | | | | | | | | | |
| Nearshore profile | slope (°) | max. | – | – | – | – | no | | | no | | 11.1[2] | 9.9[2] | | 7.4[2] |
| | | min. | – | – | – | – | data | – | – | data | | 9.9[2] | 7.4[2] | | 6.7[2] |
| | | mean | 2.2 | 3.5 | 2.5 | 2.2 | | 3.6 | 2.9 | | 4.7[2] | 10.5[2] | 8.3[2] | ≈ 4 | 7.1[2] |
| | No. of measurements | | 1 | 1 | 1 | 1 | | 1 | 1 | 2 | 2 | 7 | 7 | 6 | 6 |

[1] NP: not present

[2] measured from one profile only

Foerst-Peterson grab sampler. Bathymetric observations and sea bottom profiles were also obtained during this time period. In late July and early August, the beaches in all the bays were profiled using a method described by Emery (1961) and samples were obtained of all representative morphological and sedimentological features in a procedure described by McLaren et al. (in press). Diving was performed in bays 9, 10, 11 and 13 for detailed observation and sampling. Altogether 34 cores, 61 grabs, 29 diver-collected samples and 114 beach samples were obtained and analyzed for their grain size distribution (Barrie et al., 1981).

## Acknowledgments

The scope of the BIOS project necessitates complex logistics and unique interaction among scientists of many disciplines. Numerous individuals and organizations provided field, scientific and analytical support for this part of the total project. In expressing congratulations and thanks to P. Blackall, project manager of BIOS we hope to encompass the large number of people who gave the necessary support. Full details of the experiments can be obtained from him, c/o BIOS Project, Environmental Protection Service, No. 804, 9942 – 108 St., Edmonton, Alta., T5K 2J5 (telephone: 403-420-2592).

Special acknowledgment is made to Captain Pelland, Commanding Officer of **CCGS Pierre Radisson** and his officers and crew who, in October 1979, provided the means to choose Cape Hatt as the site for the spill experiments. His decision to use the ship and accompanying helicopter in support of the quest for a suitable location undoubtedly enabled BIOS to continue on schedule.

## Physical Setting

Cape Hatt is located on the northern tip of a small peninsula that extends into southwestern Eclipse Sound. The peninsula itself is roughly oval in shape with an average radius of about 3 km. It is bordered on the north by Eclipse Sound and on each side by fiords.

Table 19.2

Summary of Shoreline Sedimentology

| | Bay | Morphologic Unit | Texture % Gravel | Texture % Sand | Texture % Mud | Moment Measures[1] Mean Size | Moment Measures[1] Sorting | Moment Measures[1] Skewness | No. of Samples | Water Depth (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| Bays in "Z" Lagoon | 103 | Backshore | 19 | 74 | 7 | 1.30 | 2.12 | 1.49 | 2 | |
| | | Intertidal flat | 16 ± 7 | 82 ± 7 | 2 ± 1 | 0.46 ± .20 | 1.48 ± .28 | 2.01 ± .68 | 4 | |
| | | Ice mound | 13 | 83 | 5 | 1.50 | 2.01 | 1.77 | 2 | |
| | | Nearshore surface | 1 ± 0 | 15 ± 13 | 85 ± 13 | 6.11 ± .56 | 2.26 ± .84 | 0.88 ± .26 | 10 | 9 + 2 |
| | 104 | Backshore | 12 | 45 | 44 | 3.72 | 3.65 | 0.72 | 2 | |
| | | Intertidal flat | 20 | 70 | 11 | 1.40 | 2.51 | 1.79 | 2 | |
| | | Ice mound | 29 | 67 | 4 | 0.88 | 2.02 | 1.54 | 1 | |
| | | Nearshore surface | 3 ± 3 | 20 ± 9 | 78 ± 10 | 6.36 ± 1.15 | 3.31 ± .22 | 0.15 ± .37 | 9 | 11 + 4 |
| | 105 | Backshore | 15 | 55 | 30 | 2.58 | 3.30 | 0.99 | 1 | |
| | | Intertidal flat | 14 ± 5 | 51 ± 8 | 36 ± 12 | 3.08 ± 1.01 | 3.67 ± .19 | 0.87 ± .33 | 4 | |
| | | Nearshore surface | < 1 | 5 ± 1 | 95 ± 1 | 6.60 ± 1.73 | 2.56 ± .31 | 0.65 ± .72 | 7 | 7 ± 2 |
| | 106 | Intertidal flat | 12 ± 3 | 59 ± 2 | 29 ± 4 | 2.81 ± .37 | 3.28 ± .10 | 1.06 ± .11 | 3 | |
| | | Intertidal flat - subsurface | 2 | 15 | 83 | 6.91 | 3.46 | -0.16 | 1 | |
| | | Nearshore | < 1 | 5 ± 3 | 95 ± 3 | 7.71 ± .56 | 2.79 ± .13 | 0.00 ± .22 | 8 | 5 ± 1 |
| | 107 | Beach face | 13 | 51 | 36 | 3.32 | 3.46 | 0.99 | 2 | |
| | | Ice mound | 15 | 74 | 11 | 1.44 | 2.29 | 1.56 | 1 | |
| | 108 | Beach face | 15 | 67 | 19 | 2.14 | 2.94 | 1.28 | 2 | |
| | | Ice mound | 22 | 73 | 5 | 0.73 | 1.97 | 2.15 | 1 | |
| | | Nearshore | < 1 | 8 ± 4 | 92 ± 4 | 6.76 ± .61 | 2.59 ± .28 | 0.77 ± .46 | 9 | 9 ± 2 |
| | 109 | Beach face | 40 ± 22 | 51 ± 29 | 9 ± 7 | 0.30 ± .12 | 2.42 ± .78 | 2.77 ± .80 | 3 | |
| | | Ice mound | 13 ± 5 | 74 ± 10 | 13 ± 12 | 1.64 ± 1.18 | 2.62 ± .80 | 1.94 ± .68 | 3 | |
| | | Nearshore | 2 ± 1 | 16 ± 11 | 82 ± 12 | 6.86 ± .87 | 3.33 ± .46 | 0.08 ± .39 | 9 | 4 ± 2 |
| Bays in Eclipse Sound | 101 | Beach face | 25 ± 12 | 75 ± 12 | < 1 | 0.17 ± .22 | 1.04 ± .15 | 0.24 ± .22 | 5 | |
| | | Ice mound | 53 | 48 | < 1 | -0.51 | 0.86 | .86 | 2 | |
| | 102 | Back shore | 6 ± 9 | 92 ± 8 | 2 ± 1 | 0.68 ± .50 | 0.95 ± .23 | 1.95 ± 1.33 | 5 | |
| | | Berm | 16 ± 17 | 84 ± 17 | 1 ± 0 | 0.13 ± .55 | 0.71 ± .15 | 0.55 ± 1.53 | 5 | |
| | | Beach face | 40 ± 18 | 60 ± 17 | 1 ± 0 | -0.41 ± .43 | 0.67 ± .33 | 1.26 ± 1.04 | 8 | |
| | | Ice mound | 54 ± 23 | 46 ± 23 | 1 ± 0 | -0.73 ± .43 | 0.62 ± .25 | 3.42 ± 2.70 | 3 | |
| | | Nearshore surface | 26 | 59 | 15 | 1.77 | 2.82 | 2.22 | 2 | 12 |
| | | Nearshore subsurface | 4 | 30 | 66 | 6.65 | 4.30 | -0.23 | 1 | 15 |
| Bays in Ragged Channel | 9 | Eroding bluff | 23 ± 9 | 57 ± 13 | 19 ± 17 | 1.91 ± 1.76 | 3.08 ± 1.14 | 1.51 ± .89 | 6 | |
| | | Beach face | 19 ± 5 | 80 ± 6 | 1 ± 0 | 0.36 ± .19 | 1.16 ± .15 | 0.53 ± .56 | 9 | |
| | | Ice mound | 45 ± 27 | 55 ± 26 | 1 ± 0 | -0.03 ± .87 | 1.19 ± .34 | 1.85 ± 1.55 | 4 | |
| | | Nearshore surface | 3 ± 3 | 57 ± 14 | 40 ± 14 | 4.24 ± .73 | 3.00 ± .49 | 1.11 ± .50 | 16 | 11 ± 5 |
| | | Nearshore subsurface | 3 ± 1 | 41 ± 18 | 56 ± 19 | 5.35 ± 1.41 | 3.49 ± .39 | 0.45 ± .66 | 3 | 13 ± 6 |
| | 10 | Eroding bluff | 11 ± 6 | 57 ± 11 | 32 ± 17 | 3.02 ± 1.62 | 3.32 ± .49 | 1.23 ± .81 | 7 | |
| | | Beach face | 17 ± 9 | 80 ± 10 | 4 ± 3 | 0.70 ± .49 | 1.57 ± .59 | 1.74 ± 1.50 | 8 | |
| | | Ice mound | 27 ± 12 | 71 ± 10 | 3 ± 3 | 0.54 ± .60 | 1.71 ± .45 | 1.60 ± .80 | 4 | |
| | | Nearshore surface | 3 ± 2 | 57 ± 20 | 41 ± 20 | 4.09 ± .85 | 2.54 ± .53 | 1.40 ± .80 | 20 | 10 ± 6 |
| | | Nearshore subsurface | 1 ± 1 | 53 ± 28 | 46 ± 28 | 4.54 ± 1.40 | 2.70 ± .74 | 1.25 ± .98 | 3 | 6 ± 1 |
| | 11 | Beach face | 24 ± 12 | 72 ± 11 | 4 ± 2 | 0.84 ± .68 | 1.76 ± .28 | 1.48 ± 1.02 | 13 | |
| | | Nearshore surface | 8 ± 7 | 59 ± 19 | 33 ± 22 | 3.39 ± 1.58 | 2.88 ± .75 | 0.86 ± .60 | 15 | 6 ± 5 |
| | 13 | Backshore | 9 ± 10 | 87 ± 13 | 4 ± 3 | 1.25 ± .18 | 1.53 ± .45 | 2.76 ± 1.04 | 3 | |
| | | Beach face | 14 ± 11 | 86 ± 11 | 1 ± 0 | 0.64 ± .47 | 0.97 ± .25 | 0.08 ± .62 | 6 | |
| | | Ice mound | 24 ± 4 | 76 ± 4 | 1 ± 0 | 0.08 ± .24 | 1.06 ± .23 | 0.67 ± .23 | 3 | |
| | | Nearshore surface | 4 ± 2 | 66 ± 16 | 30 ± 16 | 3.80 ± 1.03 | 2.97 ± .62 | 1.26 ± .62 | 19 | 10 ± 5 |
| | | Nearshore subsurface | 6 ± 2 | 50 ± 13 | 44 ± 15 | 4.52 ± 1.04 | 3.66 ± .56 | 0.61 ± .36 | 8 | 13 ± 3 |

[1] Moment measures are in $\phi$ units and refer to sand size and smaller fractions only (i.e. $>-1.0\phi$)

Two elongated hills, both trending northeasterly are present at the northwest and southeast ends of the peninsula (Fig. 19.1). Reaching altitudes of 400 m and 500 m respectively, they are separated by a northeasterly trending saddle-shaped valley that extends between an embayment on Ragged Channel (bays 11 and 12) and the southwestern end of "Z"-lagoon (bay 106). The valley is generally less than 50 m elevation.

The peninsula is divided geologically by a prominent fault which trends southeast from the southern end of bay 10 and is expressed morphologically by a deeply incised drainage valley. North of this fault the rocks consist mostly of Archean and Aphebian migmatites of highly variable composition as well as a few ultrabasic bodies. The migmatites are made up of alternating light and dark banks of quartz monzonite to granodiorite and amphibolites, paragneiss and minor ultramafics respectively (Jackson et al., 1974).

South of the fault are two Neohelikian sedimentary sequences; the Victor Bay Formation consisting of thinly bedded black shale, siltstone and limestone, and the Athole Point Formation composed principally of argillaceous limestone and calcareous shale and siltstone. The Athole

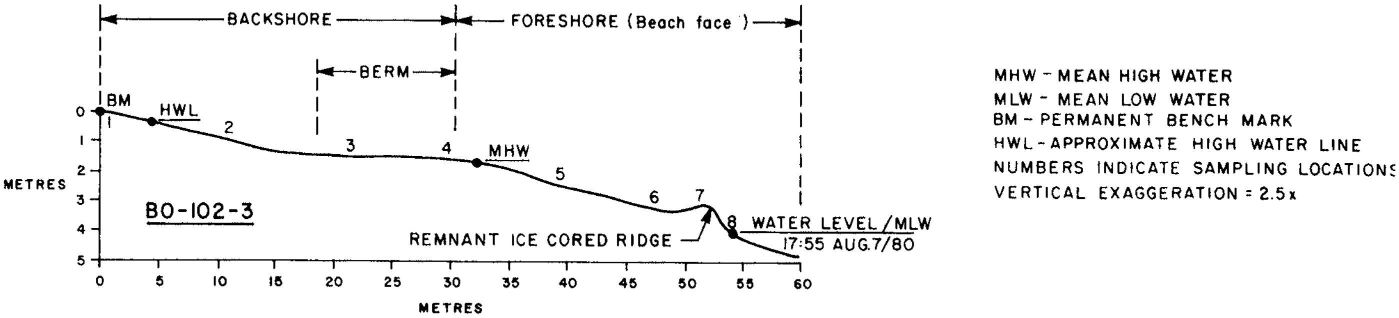


***Figure 19.3.*** *Beach profile in bay 102; Eclipse Sound.*

Point Formation overlies conformably the Victor Bay and in the area south of bay 9 it forms the core of a northwesterly plunging syncline.

The area was probably ice-covered during the late Wisconsin and an emerged ice-contact delta, the top of which is at 70 m elevation, is located immediately south of Tukayat Lake (Fig. 19.1) partially constricting the low valley between "Z" Lagoon and Ragged Channel. The delta represents the margin of the ice front during its retreat towards the south about 10 000 to 12 000 years ago. Since its retreat the peninsula has emerged at least 80 m, the result of isostatic re-adjustment (Hodgson et al., 1974).

The bays on the peninsula are separated by steep rocky promontories with the exception of a small delta separating bays 9 and 10. Coarse sand, gravel and cobble beaches within the bays owe their origin to till or glacial-marine deposits which blanket the valleys and lower slopes of the peninsula. The nearshore sediments in the outer bays are also derived from the glacial deposits although they have undergone modification by currents, waves and ice scouring. The sediments within "Z"-Lagoon are exceptional and consist mainly of poorly sorted mud probably derived from the bottomset beds of the uplifted delta which have since infilled the lagoon during Holocene emergence.

Ice covers the waters surrounding Cape Hatt for about 9 or 10 months each year. The mean date for the area to be free of ice is July 31 but can be as early as July 15 and as late as August 20. The mean date for freezeup is October 6 and extends from September 24 to October 15 (Dickens, 1981). As a result of the presence of ice the shoreline of Cape Hatt exhibits numerous features unique to polar beaches. These include ice push ridges, pitted beaches and ice mounds. The latter feature appears to play an important role on the Cape Hatt beaches and are described in some detail in Dickens (1981).

## Shoreline Morphology and Sedimentology

### Backshore/berm

Definition. The backshore is the part of the beach between the uppermost level of wave activity and the mean high water line. It normally includes a berm and overwash deposits; however at Cape Hatt such features are not always present because of ice effects which limit wave processes to only several weeks each year. A berm is a nearly horizontal terrace or bench formed by material thrown up and deposited by waves above the mean high water level.

"Z"-Lagoon. In "Z"-Lagoon most of the bays have gently sloping shorelines that grade into a backshore and foreshore with no morphological expression (Fig. 19.2). With the exception of bays 108 and 109 which have steeper slopes, the backshore reaches widths of about 16 m (Table 19.1).

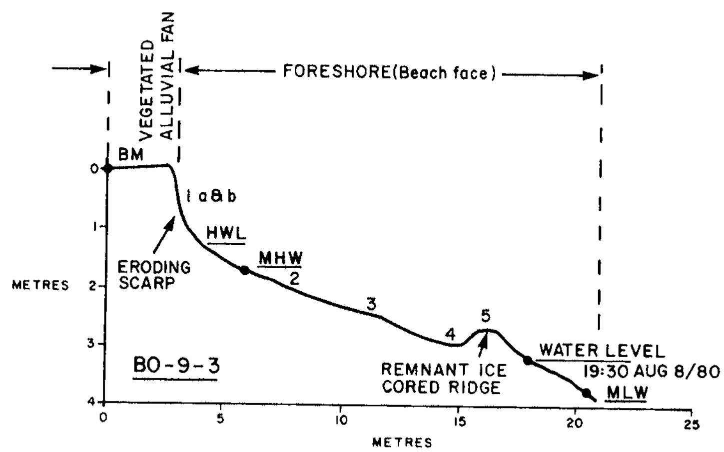


***Figure 19.4.*** *Beach profile in bay 9; Ragged Channel.*

In bays 108 and 109 small berms 3 and 6 m wide respectively are, probably the result of the steeper topography and waves derived from southwest winds funnelled through the valley separating "Z"-Lagoon from bays 11 and 12. Backshore samples from bays 103, 104 and 105 show a fairly consistent gravel content of about 15 per cent whereas the sand and mud contents show wide variability ranging from 45 to 74 per cent sand and from 7 to 44 per cent mud (Table 19.2). The mean grain size, excluding gravel, falls in the medium to very fine sand range and all samples are poorly sorted and positively skewed.

Eclipse Sound. These bays (101 and 102), exposed to the highest wave energies generated in Eclipse Sound, contain the widest backshores of 28 and 21 metres (Fig. 19.3). Within the backshore each bay contains a well developed berm, the largest being in the most exposed bay (102) and is about 12 m wide (Table 19.1). Samples from bay 102 show the backshore to be principally very coarse, fairly well sorted sand with gravel contents usually less than 20 per cent (Table 19.2).

Ragged Channel. In bays 9, 10 and 11 small berms, the maximum width being 7 m in bay 11 (Table 19.1), make up the entire backshore. They are, however, not always present around the length of the bay particularly where eroding bluffs adjoin the foreshore (Fig. 19.4). In bay 13, the most exposed of the bays in Ragged Channel, the backshore extends as much as 15 m and contains a berm (maximum 4 m) within this width (Table 19.1). Backshore samples were taken only from bay 13 and show a similarity with the sediments in the Eclipse Sound bays although the sand is finer and more poorly sorted. The gravel content is more or less the same at about 9 per cent.

Table 19.3

Factors affecting choice of bays for BIOS experiments

| Factor | Control | Oil | Oil/ Dispersant | Importance Rating[1] |
|---|---|---|---|---|
| Backshore | 10 | 11 | 9 | 1 |
| Beach face width and slope | 10 | 11 | 9 | 3 |
| Beach face grain size and sorting | 11 | 9 | 10 | 1 |
| Ice mounds | 10 | 11 | 9 | 1 |
| Ice scouring | 11 | 10 | 9 | 1 |
| Nearshore sediment sorting | 9 | 11 | 10 | 1 |
| Grain size parameters with depth | 10 | 9 | 11 | 4 |
| Cross-contamination | 10 | 9 | 11 | 5 |
| Longevity | 10 | 9 | 11 | 4 |

[1] This rating is a qualitative assessment of the importance of the factor in deciding the best sequence of bays for the experiments. The scale is 1 to 5 in increasing importance and can be manipulated as required.

Implications to BIOS. A berm is a depositional feature dependent on wave activity for its formation. At Cape Hatt the widest, best formed berms are found in the most exposed bays (Table 19.1) and reflect the relative energy levels. Because a berm is a potential reservoir for oil above normal wave activity, there is a greater probability for oil to be stored on the surface or buried on shorelines with a well developed berm should wave activity be sufficient to contaminate the backshore during the spill experiments.

In bays 9, 10 and 11 the width of the backshore and berm is least in bay 9 and greatest in bay 11 (Table 19.1). Bay 11 therefore has the greatest potential to retain oil on the shoreline for the longest time whereas in bay 9, the absence of a berm means the oil can only be retained on the beach face and will be subject to continuous tides, waves and ice activity.

Based on assumption that the experiments will yield the most useful results if the oil and oil-dispersant mixture have a maximum possibility of affecting the environment (i.e. longevity and interaction with biota and sediments is maximized) we suggest the following order:

1. Bay 11 for oil-only because there is the best probability for long term retention on the shoreline;
2. Bay 9 for the oil-dispersant mix because the lack of a backshore indicates a low energy regime and thus there is the maximum possibility of the mixture remaining in the water column and/or bottom sediments for greater lengths of time than the other two bays;
3. Bay 10 for control (by default).

Practical considerations during the spill experiments demand weather conditions amenable for boom handling, sampling, observations etc., thus it is unlikely that oil will be thrown by waves onto the backshore when the experiments take place. We have therefore placed a low importance to the backshore as a factor determining the choice of bays (Table 19.3).

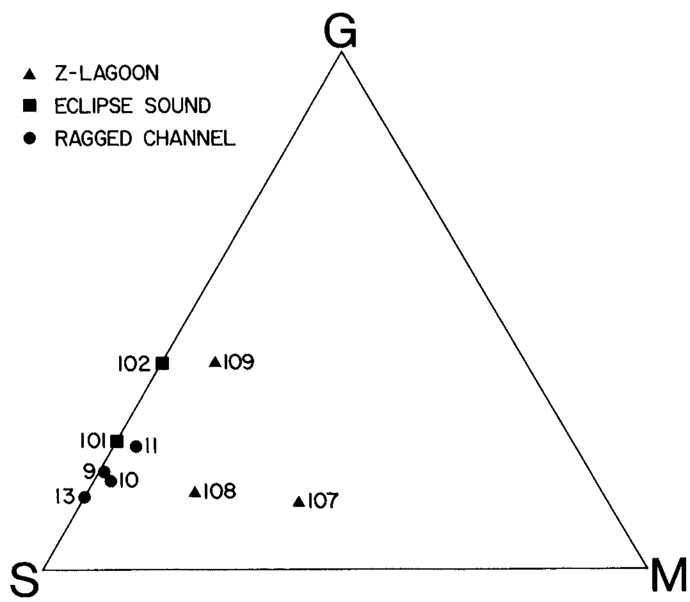


***Figure 19.5.*** *Textural diagram of beach face sediments (data from Table 19.2).*

Beach Face

Definition. The beach face is the part of the beach that is subject to wave uprush and lies roughly between mean high and mean low water levels.

"Z"-Lagoon. The gentle slopes and low wave activity in bays 103, 104, 105 and 106 preclude the formation of a berm and beach face (Table 19.1). Where the shoreline slopes are steeper in bays 107, 108 and 109 a beach face has developed which ranges from 23 to 28 m wide with slopes from 5.1 to 7.7 degrees. The beach face sediments have a relatively narrow range in their sand content (51 to 67%) but contain more variable amounts of gravel and mud (Fig. 19.5).

***Figure 19.6.*** *Sediments overlying and melting out of an ice mound.*

The range of the sand sizes is, however, quite variable extending from 0.30ϕ (coarse sand) to 3.32ϕ (very fine sand). Sorting is always poor and the skewness positive.

Eclipse Sound. The exposure to high wave activities in bays 101 and 102 have resulted in the widest beaches at Cape Hatt (Table 19.1). They are about 30 m wide, slopes are typically 6.5 degrees and they are composed almost entirely of sand and gravel having little or no mud content (Fig. 19.5). The sands are either very coarse or coarse, and compared with most of the other bays, they are well sorted (Table 19.2).

Ragged Channel. Of all the bays in Ragged Channel, bay 9 has the least beach width (average 17 m) and greatest slope (10.7 degrees) whereas bay 11 has the greatest width (31 m) and least slope (3.9 degrees). The controlling parameter for the slope is the mean grain size which is coarsest for bay 9 (0.36ϕ) and finest for bay 11 (0.84ϕ). The beach face sediments contain more sand than those in Eclipse Sound or "Z"-Lagoon (Fig. 19.5) and their texture tends to be more consistent than in the other environments. Mud content is generally less than 4 per cent and gravel ranges from about 14 to 24 per cent (Table 19.2). The mean grain size falls in the coarse sand category and the sediments are generally poorly sorted.

Ice Mounds. At the time of sampling (late July) nearly all the beaches contained a distinct linear ice mound or berm that paralleled the length of the beach close to the mean low water level (Fig. 19.6). The ice mound contained sediment both within and on its surface that was added to the beach face during its melt. These sediments were sampled in an effort to determine the origin of the ice mounds which is not clearly understood. Dickens (1981) has a more complete description and reviews possible processes that could result in ice mound formation.

The sediments within the ice mounds show no significant differences from the corresponding tidal flat or beach face sediments they are formed on. In "Z"-Lagoon there is a tendency for the ice mound sediments to contain more sand than the beach face sediments whereas in Eclipse Sound and Ragged Channel the ice mound sediments have greater amounts of gravel than the corresponding beach face sediments (Table 19.2). Generally the sediments in the ice mounds are coarse relative to beach face sediments although there appear to be no constant trends among sorting and skewness values.

Implications to BIOS Experiments. In bays 9, 10 and 11 the beach face width becomes progressively larger and the slope progressively smaller (Table 19.1). Thus oil alone should be spilled in bay 11 because there is a greater area of beach available for contamination, a better chance of oil being retained in the sediments and a greater probability for increased oil longevity due to wave attenuation over the shallow slope than in the other two bays. To ensure the oil-dispersant mixture remaining in the nearshore for as long as possible the bay with the steepest beach face should be chosen which may help to minimize nearshore turbulence (i.e. bay 9).

This factor of beach face width and slope will have a significant effect on the fate and behaviour of the oil. There is little difference between bays 9 and 10 (Table 19.1) but bay 11 has substantially smaller slopes. We suggest that the importance rating should be higher than for the backshore factor and we have arbitrarily placed the rating at 3 (Table 19.3).

Grain size and the degree of sorting of beach face sediments may also have an effect on the behaviour of the spilled oil. In general, coarser, better sorted sediments will have a greater permeability and porosity than those which are finer and poorly sorted. On this basis, oil will have a better chance to penetrate and be retained by the sediments in bay 9, which contains the coarsest and best sorted beach face (Table 19.2). The beaches in bay 10 are coarser and better sorted than those in bay 11 indicating bay 10 to be a better choice for the oil-dispersant mix and leaving bay 11 for control. The variability of grain-size among the beaches is not, however, very great and we have put the lowest importance rating of 1 for this as a factor affecting the choice of bays (Table 19.3).

Ice mound development on the beach face is apparently ubiquitous in each of the three bays. The exact effects of oil on its formation and decay are presently unknown; however, it seems clear that the net result of the ice mound will be either to remove oil from the beach during the melt or to "dilute" the oil-in-sediment concentration through excessive disturbance and admixing of sediments. Removal of contaminated sediments may occur if the ice mound rafts away during breakup. Such an occurrence is most likely in bay 10, the most exposed of the three bays. Therefore bay 11, the least exposed bay, should be used for the oil-only experiment to maximize its residence time on the beach face. Bay 9 is slightly less exposed than bay 10 and should have the oil-dispersant mixture. The importance rating of the ice mound as a factor in choosing the bays has been kept very low because there is little understanding of this phenomenum and we can only speculate on how it may affect the experiments (Table 19.3).

Intertidal Flat

Wide, gently sloping, intertidal flats occur only in bays 103 to 106 of "Z"-Lagoon. They range in width from about 42 to 75 m (Table 19.1) and are composed principally of poorly sorted coarse to fine sand. There is a tendency for the sediments to become finer and more poorly sorted with increasing shelter inside the lagoon. Intertidal flats do not occur in any of the bays selected for the spill experiments.

Nearshore

Nearshore profiles perpendicular to the shoreline in each of the bays indicate consistently shallow slopes in "Z"-Lagoon of less than 4 degrees (Table 19.1). Sediments contain a high mud content (>75%) and consist of poorly sorted medium and fine silt with gravel and sand making up

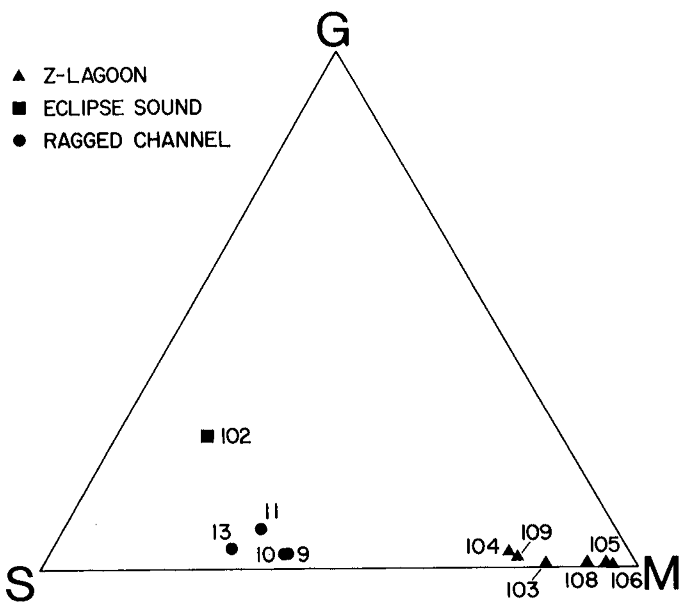


*Figure 19.7. Textural diagram of nearshore sediments (data from Table 19.2).*

less than 3 and 20 per cent respectively (Fig. 19.7). In several of the bays (i.e. 106 and 109) there is a good relationship between grain size parameters and water depth. Mean grain size decreases, sorting becomes poorer and the positive skewness becomes less with increasing depth (data in Barrie et al., 1981). These relationships are not, however, consistent from bay to bay and no simple generalized model is apparent to explain these observations.

One profile in Eclipse Sound (bay 102) indicates a nearshore slope of about 5 degrees and corresponding bottom samples contained relatively high amounts of sand and gravel compared with either "Z"-Lagoon or Ragged Channel (Fig. 19.7). In the latter, bays 9 and 10 have similar nearshore slopes (8 and 10 degrees respectively) but bay 11 is significantly shallower at approximately 4 degrees. The sediments in Ragged Channel have a similar gravel content to those in "Z"-Lagoon (generally less than 8 per cent) whereas the sand content is much greater and ranges from about 50 to 70 per cent (Table 19.2).

All of the nearshore samples in Ragged Channel have a good correlation between the grain size measures and water depth. As water depth increases, the mean grain size becomes finer, the sorting poorer and the skewness less positive (data in Barrie et al., 1981). The sediments, on average, are principally poorly sorted very fine sand or coarse silt (Table 19.2).

Implications to BIOS. In arctic environments the dominant process affecting nearshore sediments is moving ice, gouging and scraping the bottom resulting in considerable sediment disturbance. This process has increasing impact with decreasing depth. Thus oil that has been deposited onto the substrate, as is to be hoped for the oil-dispersant mix experiment, will be subject to burial, mixing or even resuspension and removal by ice scouring in shallow water. It is suggested that oil in or on the substrate will have a better chance of remaining on bottoms where ice scour is least. Although diving observations show that ice scour has occurred in all three bays, the bay with the greatest slope (bay 9) should have the largest area unaffected by ice impinging on the bottom and bay 11, with the least slope, should have considerably more. We suggest that this factor (ice scouring; Table 19.3) indicates that bay 9 would be best for the oil-dispersant mix, bay 10 for oil only and bay 11 for control. We recognize that there are factors such as exposure, ice ridging, probability of multi-year ice blocks entering the bays etc. that may complicate this concept and therefore the importance rating is very low (1; Table 19.3).

Similar to the arguments used for the beach face, sediment sorting may affect the behaviour of oil in the nearshore. The best sorted sediment may enable maximum penetration of the oil; therefore bay 10 (sorting 2.54$\phi$) would be the choice for the oil-dispersant mix, bay 11 for oil only and bay 9, with the poorest sorting (3.00$\phi$), would be control (Table 19.3). The spread of values is, however, insufficient to increase the importance rating of this factor above one (Table 19.3).

The relationship of the grain size parameters with depth is a probable indication of the relative importance or the energy level of the processes operating in each bay. The best correlations of mean grain size, sorting and skewness with depth are found in bay 10 (r = 0.89) the most exposed of the three bays: bay 9 is next (r = 0.81), followed by bay 11 which is much lower (r = 0.53). Bay 11 appears to be the least energetic of the three bays suggesting that the oil-dispersant mix would have the best chance for long term interaction with the biota. Oil only should be placed in bay 9 because its longevity will be greater than in bay 10 which should be kept for control. This factor (grain size parameters with depth) is considered by us to be important and we have given it a high importance rating (4; Table 19.3).

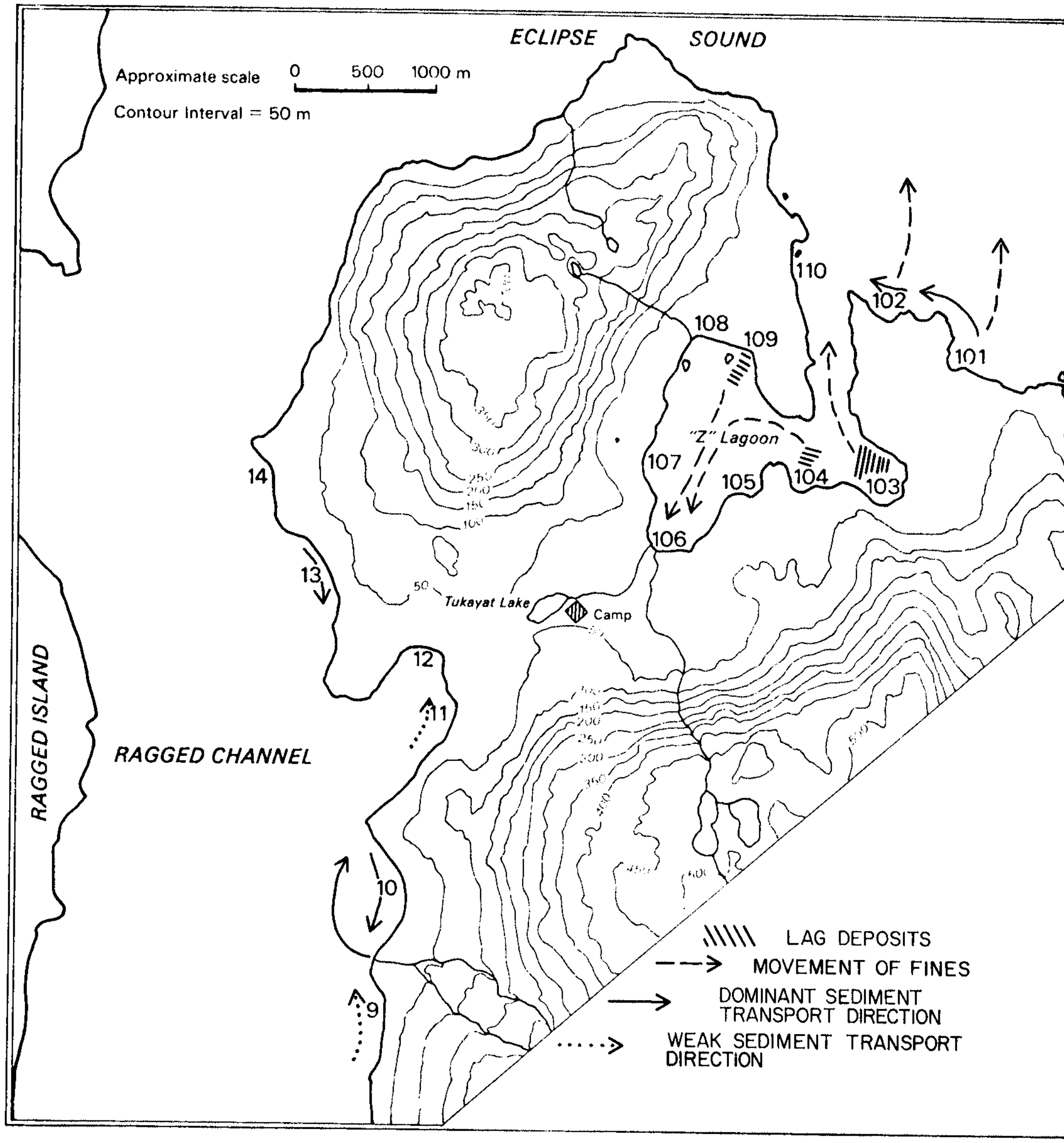


***Figure 19.8.*** *Sediment transport directions, Cape Hatt.*

## Sediment Trends

Introduction

The mean grain size, sorting and skewness of a sedimentary deposit are dependent on the sediment grain size distribution of its source and the sedimentary processes of (i) winnowing (erosion), (ii) selective deposition of the grain size distribution in transport, and (iii) total deposition of the sediment in transport. If a source sediment undergoes erosion, and the resultant sediment in transport is deposited completely, the deposit must be finer, better sorted and more negatively skewed than the source. This trend is referred to as Case I. The lag remaining after erosion, on the other hand, must be coarser, better sorted and more positively skewed (Case II). If sediment in transport undergoes selective deposition, the resultant deposit can either be finer (Case IIIA) or coarser (Case IIIB) than the source, but the sorting will be better and the skew more positive (McLaren, in press). In a system of related environments, these trends can be used to identify both the probable source and the probable deposit and, by inference, the net sediment transport paths among sedimentary deposits. The transport paths represent an integration of all the time-dependent variables such as winds, waves and currents and may suggest the probable fate and behaviour, particularly in the long term, of oil in coastal environments (McLaren, 1980).

Sediment trends at Cape Hatt based on the data presented in Barrie et al. (1981) and in Table 19.2 suggest the following conclusions.

"Z"-Lagoon

1. The deposits in the lagoon are the source sediments for the intertidal and beach sediments. In general the shoreline deposits are a lag of the lagoon sediments that have undergone winnowing of fines (Case II) by the small levels of wave and ice activity.
2. Bay 103 is the most exposed and the nearshore sediments are a lag derived from the original sediments deeper in the lagoon. The fines winnowed from bay 103 do not appear to be deposited in the rest of the lagoon and are evidently lost through the channel exiting into Eclipse Sound (Fig. 19.8).

3. Bays 104 and 109 are partially lag deposits; however fines from these two bays appear to be undergoing total deposition in bay 106. The latter is the most sheltered in the lagoon and is the only bay that may be receiving sediments from both the land and the other bays (Fig. 19.8).
4. Source-deposit relationships between all sediment samples and ice mound deposits show no consistent trends. It appears probable that they are derived from the in situ beach face deposits present at the time of their formation.

Eclipse Sound

1. The original source for all the nearshore and beach sediments is the subsurface deposits found in a core from bay 102 (Table 19.2). This sediment, composed of sandy silt, is probably of glacial marine origin from which the surface deposits are a lag. Through the processes of ice and wave action, fines are increasingly lost as the water shallows resulting in the coarsest, best sorted and most positively skewed sediments at the beach. The fines are probably transported and deposited farther offshore below the depth of ice scour (McLaren, 1980).
2. The beach sediments in bay 101 appear to be the source for those in bay 102 and suggest net movement of sediments from east to west. The same east to west movement of sediments is particularly strong within bay 102 (Fig. 19.8).
3. Similar to the ice mounds in "Z"-Lagoon their sediments are not clearly derived from farther up on the beach face or from the nearshore suggesting an in situ mode of formation incorporating the existing beach sediments.

Ragged Channel

1. Similar to "Z"-Lagoon and Eclipse Sound, the shoreline sediments in Ragged Channel are a winnowed lag derived from the subsurface sediments in the nearshore (Table 19.2). The source sediment is also evident in the eroding bluffs that occur in bays 9 and 10.
2. In bay 9, both nearshore and beach sediments show very few consistent trends indicating that longshore sediment transporting processes are rare in either direction. There is a slight northward trend in the beach face sediments that may suggest a preferred direction of south and southwest winds at this location (Fig. 19.8).
3. Sediment trends suggest that the bluffs in bay 10 are more actively eroding than the bluffs in bay 9. Consistent trends show that the bluffs as well as the nearshore sediments are supplying the beach deposits. Storms probably erode the bluffs and deposit the sediments in the nearshore where they are further modified in their transport to the beach.

   Both nearshore and beach sediments have dominant trends in the southward direction (Fig. 19.8) indicating that north and northwest winds are more effective than the south and southwest winds that move sediments in bay 9.
4. The delta that divides bays 9 and 10 is also a sediment source for the deposits in the two bays. Sediment trends clearly show that bay 10 receives a much greater sediment input from the delta than in bay 9 indicating a northward transport in opposition to southerly transport indicated by the beach and nearshore sediments. We suggest that a clockwise gyre in bay 10 would account for these observations (Fig. 19.8). There is supporting evidence for such a gyre in the time-lapse photography showing ice movements in the bay (Dickens, personal communication) and in current data (de Lange Boom and Buckley, 1981).
5. In bay 11 there is an indication of northeast sediment movement in both the nearshore and beach sediments (Fig. 19.8). The trends, though not particularly strong may be the result of south and southwest winds or of the refraction of waves into bay 11 generated by northwest winds.
6. Beach face sediments in bay 13 show a strong southward transport direction which is not reflected in the nearshore sediments (Fig. 19.8).

Table 19.4

Summary of importance ratings for the bay selection

| | Total Importance Rating | | |
|---|---|---|---|
| Bay | Control | Oil | Oil-Dispersant |
| 9 | 1 | 14 | 6 |
| 10 | 18 | 1 | 2 |
| 11 | 2 | 6 | 13 |

Implications to BIOS

One of the most important considerations in the selection of bays is minimizing the possibility of cross-contamination between the bays with oil in them, and particularly, contamination of the control bay. This problem is two-fold because contamination must be considered on both the short term (immediately after the spills have taken place) and in the long term (over the three years of data gathering and observation). The insights provided by the sediment trends (Fig. 19.8) are especially valuable in assessing long-term cross-contamination potential because they indicate the probable transport paths if oil becomes entrained in the sediments.

The most difficult experiment to control is the oil-dispersant mix. Because bay 10 shows the strongest trends and is therefore the most "active" of the bays, we suggest bay 10 is a poor choice for this experiment. Bay 11, on the other hand, has weak trends in a direction away from the other bays (Fig. 19.8) and is consequently the best choice for the oil-dispersant mix experiment. Bay 9 also has weak trends compared to bay 10 and is the next least possible source for cross-contamination. Thus bay 9 is a logical choice for the oil only experiment which leaves bay 10 as the control. The factor of cross-contamination is sufficiently important to receive the highest importance rating (5; Table 19.3).

Finally, the strength of the sediment trends summarizes the level of activity in each of the bays. We suggest that the overall longevity of the oil in the environment is maximized in the least active of the bays. Therefore oil and dispersants should be put into bay 11, oil in bay 9 and bay 10 left for control because this is the sequence of increasing energy in each bay. We have placed an importance rating of 4 on this factor, only slightly less than the cross-contamination factor.

## Conclusions

1. The coastal sediments in the Cape Hatt bays originate from glacial and glacial-marine deposition during late Wisconsin or early Holocene time. These sediments, presently occurring in the nearshore subsurface or in eroding bluffs, are modified at the shoreline by waves and ice action resulting in sediments that become increasingly coarser, better sorted and positively skewed as water depth decreases.
2. In general the coarsest and best sorted sediments occur in bays 101 and 102 which have the highest exposure to wave and ice activity. "Z"-Lagoon is the most sheltered environment and contains finer and more poorly sorted sediments. The bays in Ragged Channel fall between these two extremes.
3. Trends in sediment grain size distributions indicate westerly transport directions in the Eclipse Sound bays (101 and 102). In "Z"-Lagoon fines are winnowed in the most exposed bays (103, 104 and 109) and are either deposited in the vicinity of bay 106 or are removed out of the lagoon into Eclipse Sound. Bays 10 and 13 in Ragged Channel show strong southerly trends whereas bays 9 and 11 have weak northerly and northeasterly transport directions. There is an indication of a clockwise gyre in bay 10.
4. Based on a qualitative importance rating value applied to each geomorphic/sedimentologic criterion that may affect the BIOS experiments it is suggested that bay 10 should be used for a control, bay 9 for the oil-only and bay 11 for the oil-dispersant mix experiments.

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