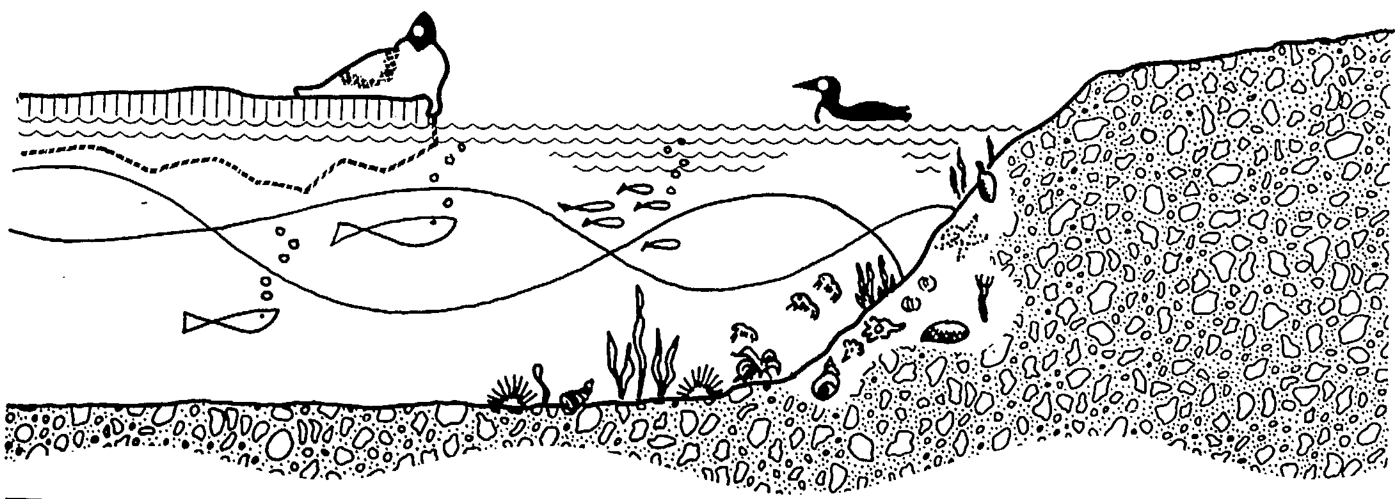
ICE CONDITIONS



Baffin Island Oil Spill Project

WORKING REPORT SERIES

1980 STUDY RESULTS

BIOS Working Report Series

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BAFFIN ISLAND OILSPILL PROJECT
CAPE HATT ICE CONDITIONS

for

Environment Canada
Environmental Protection Service
Edmonton, Alberta

February 1, 1981

Prepared by: D.F. Dickins Engineering
& Arctic Laboratories Ltd. - R. Brown

Under DSS Contract #VSS80-00061

ABSTRACT

Up to nine time lapse camera stations were operated with a greater than 80% reliability factor, on Cape Hatt, between July 23 and October 20, 1980, to document ice break-up, summer movements, freeze-up, and ice/shoreline interaction processes.

This program, combined with 20 days of field observations, showed that while dynamic ice thrust events do not occur in the Ragged Channel test bays, a great deal of ice layering within the beach face overturns and redistributes material in the intertidal zone. Also bottom sediment and animal life is potentially stripped clean each spring out to a depth of about 3 m by ice adfreeze nearshore. Most of this material is carried offshore, but the potential exists for minor cross contamination of the test bays by loose ice floes, at break-up in 1982.

This study examines historical ice conditions in the Cape Hatt, Pond Inlet area. Variations of up to two weeks are possible in break-up dates. Summer incursions of old ice fragments will likely be associated with steady NW winds down Navy Board Inlet. A minimum open water operating "window" of 6 weeks can be expected between August 10 and September 20.

Recommendations are made for starting the time lapse stations in May, 1981, with minor improvements. A forecast of 1981 break-up should be attempted in late April, using available snowfall, ice thickness and temperature records from Pond Inlet, and refined through June and July by monitoring the thawing index.

Regular ice reconnaissance to the north should commence after any 48 hour period of NW winds, to guard against the unexpected arrival of floe ice in Ragged Channel in August or September.

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1.0 INTRODUCTION AND OBJECTIVES

Oil on Arctic shorelines will be in contact with ice and snow for nearly ten months of the year. The BIOS experiment is dependent on local ice conditions in terms of 1981 scheduling of the main discharges, camp sealift operations and the long term fate of oil in the test bays. Ice scour, push and adfreeze may overturn substantial areas of oil bearing sediment. Individual ice floe movements could provide a method of removing oil from the beach face during break-up, and perhaps redepositing this oil in an adjacent bay.

Documentation of ice conditions in the Cape Hatt area will be required for the duration of the project in order to comment on both the long term effects of ice/oil/sediment interaction, and the likely annual variation in impact of ice/shoreline processes.

The 1980 BIOS ice monitoring program was intended to:

- gain a knowledge of break-up and freeze-up patterns for purposes of scheduling the 1981 program.

- determine the significance of sea ice scouring in affecting the long term fate of oil in the nearshore sediments.

- determine the dominant processes and order of magnitude of sediment removal or turnover in the intertidal zone, due to sediment incorporation in, and movement by the ice foot.

Figure 1 shows the general location of Cape Hatt in the North Baffin region.

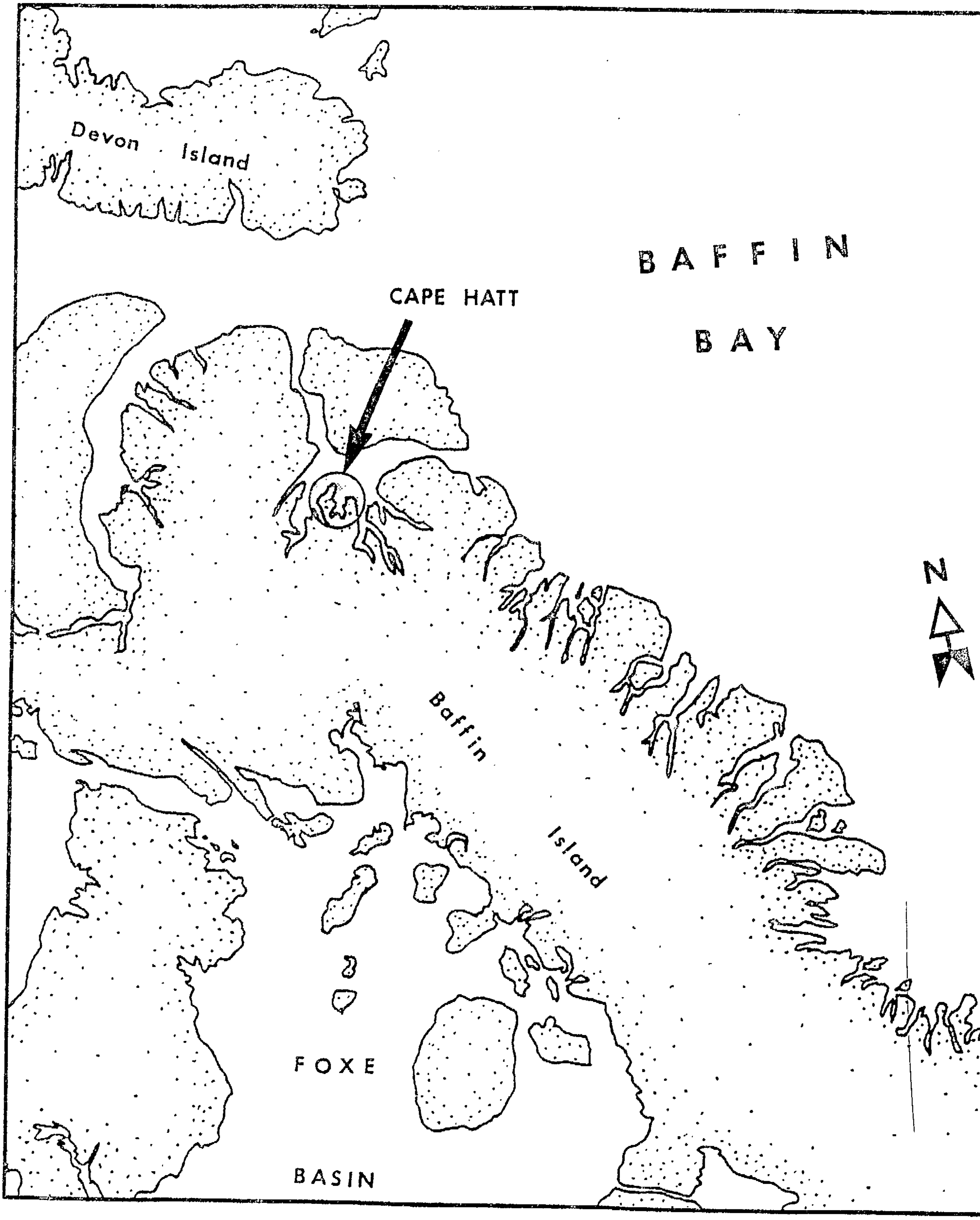


FIGURE 1 Location of Cape Hatt, Baffin Island.

2.0 METHODOLOGY

Principal data sources in order of usefulness were:

Regional

1. A.E.S. Ice Charts
2. Helicopter Surveys
3. Super 8 Time Lapse over Eclipse Sound
4. Landsat Imagery

Shoreline

1. Time Lapse 8 mm
2. Shore Surveys and Still Photography - Field Notes

Nine time lapse camera stations were installed July 24-26, at various locations around Cape Hatt - three overview cameras viewing Z-Lagoon, Eclipse Sound and Ragged Channel, two close-up beach face positions, and four stations covering specific bays 101/102, 9, 10 and 13 (subsequently changed to 11). Figure 2 shows areas of coverage of the individual stations. Details of the cameras, timers, power source, and deployment, are contained in Appendix A.

Six cameras left unattended on October 6, ran until about October 20.

Altogether, over 550 camera days of good quality time lapse footage was obtained over the duration of the program. Interruptions in coverage due to lens fogging, and animals chewing cables averaged less than 15%. Appendix A documents each camera's performance, analyses faults, and recommends minor improvements which should be incorporated in future stations.

Successive Super 8 movie films have been spliced into 250 foot reels for each station, and reviewed according to ice conditions and ice movement on a daily basis. Periods of reduced image quality due to natural fog or malfunction, are flagged along with times of interest to other potential users (waves intersecting beach fronts, currents [ice circulation] and sea state).

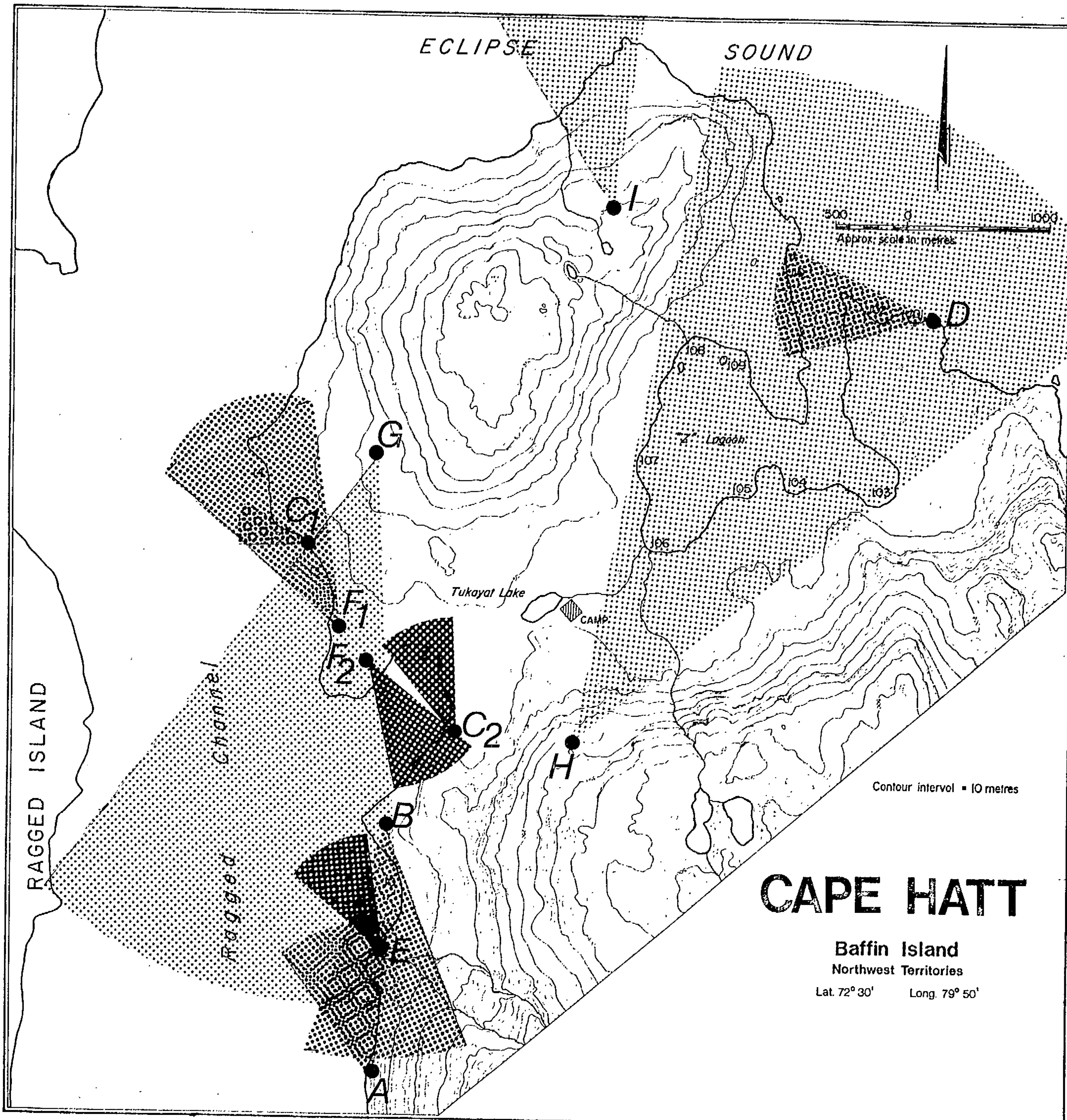


Figure 2 Camera Locations on Cape Hatt, July to October 1980

Of the fifty potential Landsat images covering Cape Hatt between June and October, only 5 usable prints were received due to persistent cloud cover. The best of these shows open water conditions on August 5, 1980 (Appendix B).

Aerial photography taken in 1958 for topographic mapping, provided a useful historical perspective and appears to depict an unusually early break-up (Section 3.1).

Ice thickness and snow depth records for Pond Inlet, were extracted from A.E.S. statistics for the winters of 1964, 67, 69, 74, 75, (Appendix B). In addition, ice core results were obtained from the 1970 S.S. Manhattan cruise (Billelo, 1972). Ice observers were on site during the periods July 22 to August 4, and September 25 to October 6. A daily synopsis of field notes is contained in Appendix C. Additional ice information was obtained from other researchers on site in August and September.

Baseline data relevant to ice growth and decay (air temperature) and movement (wind speed and direction), is available through A.E.S. Summaries of selected data are contained in Appendix B.

3.0 REGIONAL ICE CONDITIONS

3.1 Historical

The Navy Board Inlet, Eclipse Sound, Pond Inlet area is covered every winter by a continuous sheet of shore-fast ice (see Plate 1 showing a Landsat image of June 30, 1980). Maximum, mean and minimum recorded June ice thickness at Pond Inlet are 196 cm, 157 cm and 112 cm respectively (Allen 1977). First melting occurs in late June or early July along shorelines, particularly at points of fresh water inflow. The eastern entrance to Pond Inlet clears first, and the open water spreads west to Eclipse Sound by late July. Similarly but rather later, the ice retreats southward in Navy Board Inlet. When final break-up occurs, any remaining ice usually drifts south into the west end of Eclipse Sound which is almost always the last area to become completely clear of ice. It is interesting to note that Cape Hatt is geographically, directly in line to receive any floes moving south through Navy Board Inlet. In late July and early August, loose ice is driven back and forth in Eclipse Sound, and in and out of Milne Inlet until it is completely melted (Sailing Directions of Arctic Canada - Vol. II).

Available historical ice and snow thickness statistics for Pond Inlet can be summarized as follows:

TABLE 1

Year	Maximum Ice Thickness (cm)	Date First Ablation	Max. Snow Depth (cm)
1964/65	147	June 23	15
1967/68	142	June 15	25
1969/70	116**	N/A	28
1974/75	178	N/A	12
1975/76	195	N/A	15
1976/77	N/A	N/A	22
1977/78	157	June 10	12

First Permanent New Ice	30 November 1975, 22 Oct. 1976, 21 Oct. 1977
First Ice Deterioration	18 June 1976, 15 June 1977, 17 June 1978
Water Clear of Ice	29 August 1976, 30 July 1977, ------

** Note: S.S. Manhattan reported ice thickness values between 137 and 183 cm at eastern entrance to Pond Inlet, May 11-15, 1970. On May 16, Manhattan ice observers reported 122 cm of ice, 10 miles WNW of the village, in Eclipse Sound. Snow depth at the time was 43 cm (Billelo, 1972).

1970 was a year with ice thickness' much less than normal. This was reflected in a break-up starting July 16, up to 2 weeks ahead of the mean (Table 2).

Table 2 summarizes nine years of break-up and freeze-up dates for Cape Hatt.

TABLE 2
Break-up and Freeze-up Summary
Cape Hatt 1964-72 (Ice Charts)

Year	Break-up Date	Freeze-up Date
1964	July 23 - 30	Sept. 24 - Oct. 8
1965	July 23 - 30	September 24
1966	July 23 - 30	October 15
1967	August 10	Sept. 24 - Oct. 8
1968	August 3	Oct. 10 - 15
1969	August 3	Sept. 24 - Oct. 8
1970	July 16 - 23	October 8 - 20
1971	July 23	October 8 - 20
1972	August 20 ? **	September 24
1980	July 30 - Aug. 5	October 1 - 5

Note: The range of dates indicates the approximate time span (where known) between first significant fracturing and concentration less than 2/10 and first new ice and a stable cover.

Note: Break-up is a function of maximum ice thickness (dependent largely on snow cover and freezing degree days) and June, July thawing air temperature and solar radiation. The 1980/81 winter will be evaluated in an attempt to predict break-up at Cape Hatt in 1981.

** This date is in doubt

Plate 1 Landsat Image of June 30, 1980 showing first fracturing of ice in the vicinity of Cape Hatt. Note open water to the North in Lancaster Sound.

Landsat imagery for the Cape Hatt site have been evaluated according to snow and ice cover between 1972 and 1979 (McLaren, November 19, 1979). This data shows remarkably little annual variation, but the timing of Landsat is such that 10 to 15 day data gaps often occur, particularly at freeze-up when overcast, fog conditions are common and new ice is difficult to separate from open water.

The only other historical ice information available is a series of high level aerial photographs taken in 1958. Plate 2, from July 25, 1958 shows Eclipse Sound ice still relatively intact, to the North with Ragged Channel and Milne Inlet completely clear of ice. By August 12, 1958 the only ice remaining in the area was in the form of loose floes congested in Bays 101, 102, and at the entrance of Z-Lagoon. The three test bays, 9, 10, 11 had minor concentrations of small floes less than 1/10 overall.

Mean monthly temperatures for June 1958 (Arctic Bay) were about 1.5°C above normal, which does not explain the very early melt of ice in Ragged Channel shown in Plate 2. Solar radiation can dramatically effect the surface melt of the ice cover so 1958 must have seen unusually clear sky conditions over the Cape Hatt site, combined with a reduced ice growth during the winter of 1957/58.

Based on ice charts, and Landsat, regional ice conditions at the Cape Hatt site (Ragged Channel) can be summarized as follows:

TABLE 3

Summary of Regional Ice Conditions

	1980	Mean	Earliest	Latest
Clear of Ice < 2/10	July 27	July 31	July 15 (1958)	Aug. 20 (1972)
Freeze-Up	Sept. 30	Oct. 6	Sept. 24	Oct. 15

Plate 2 Aerial Photograph of Cape Hatt taken July 25, 1958, showing unusually early break-up of ice in Ragged Channel. Pile-ups near the entrance to Z Lagoon, similar to those observed in 1980, are visible in the photograph.

3.2 1980 Ice Conditions

The winter of 1979/80 was characterized by an early freeze-up in the North Baffin region, significantly lower than normal winter freezing degree day accumulations (91% of normal, November-April) and a reduced snow cover. The net effect of these influences was thicker land fast ice than normal (eg. 182 versus a mean of 143 cm @ Clyde River). First evidence of a weakening in the ice cover in the Pond Inlet/Eclipse Sound area was near the end of June, with major fracture patterns visible on the Landsat image of June 30 (Plate 1). The ice remained completely intact until July 15, when the first patches of open water appeared along the west side of Navy Board Inlet. By the 22nd, ice charts showed a patch of open water extending N.W. off Ragged Island. East of Emerson Island was beginning to break-up (Figure 3). Eclipse Sound ice was still in place but rotting quickly with many open holes.

Ice in Ragged Channel was in a similar state of deterioration, with small areas of open water near the extreme ends at points of maximum current and between Bays 9 and 10 (Plate 3). All bays along the Cape Hatt shore had narrow bands of open water 5 to 10 m wide, seaward of the main tidal hinge zone. By July 24 open water areas had appeared in the centre of Ragged Channel off Bays 13 and 14. Twenty-four hours later, there was extensive open water as far south as Bay 10 (Plate 4). Z-Lagoon ice was still essentially intact at this point but melted well out from shore, particularly at its western end. Early in the morning on July 26, the wind strengthened to a maximum of 19 km/h from the N.E., and carried most of the loose ice out of Bays 13, 14, 11, 12, 10 and the north half of Bay 9, to accumulate in the south end of Ragged Channel. Plates 5 and 6 show ice conditions in Bays 9 and 10 on July 27. To the north an ice edge was formed from Ragged Island to Cape Hatt. By July 27 part of this ice had moved south into the Channel and started to break-up (Figure 4). S.W. winds on July 30 moved rotting ice back into the test bays for a 48 hour period (Figure 5a and Plate 7). By August 2 Ragged Channel was essentially clear of ice except for scattered fragments (Plate 8).

North of Cape Hatt, Eclipse Sound ice was well broken-up by July 30. (See Cover Photograph.) Between July 26 and 30 ice at the entrance to Z-Lagoon and in Bays 101/102 started to drift away (Plates 9 to 11).

Z-Lagoon ice melted slowly from the shore towards the centre (Plates 12 and 13).

Plate 14 shows ice conditions around Cape Hatt on August 2. Three days later, ice charts indicated less than 1/10 ice coverage in Eclipse Sound (Figure 3d).

The Cape Hatt/Eclipse Sound area remained clear of ice until about September 18, when a string of old ice fragments entered Ragged Channel after moving down Navy Board Inlet under the influence of steady northerly winds for the previous 3 days. Initially, this ice was concentrated along the west shore of Ragged Channel, but starting on September 20, easterly winds (Hill top site #2) quickly brought the floes across and clogged the test bays. Many of these fragments remained to help stabilize the new ice sheet a week later.

Open water conditions existed in the Eclipse Sound area from August 12 to mid-September, 1980. On September 23, Navy Board Inlet was up to 4/10 covered with new ice in a strip stretching down to the tip of Cape Hatt. By September 30 this new ice had increased to 7/10 concentration north of Cape Hatt with first evidence of freezing as far east as the Pond Inlet community (Figure 7).

Fall field observations of the test Bays commenced on September 25. At this time, there were scattered old ice fragments stranded in all test areas, with Bays 101/102 having up to 60% of the intertidal area covered with ice 1 to 2 m thick. The ice foot was commencing to build up in bays 101/102 near the high tide mark, being 30-60 cm thick and 1 to 2 m wide by September 26.

On September 29, S.W. winds concentrated more loose ice in Bays 11/12. Grease ice was observed near shore along Ragged Channel. The following day, new ice began to form at the east end of Z-Lagoon and amongst stranded floes in all the test bays (Plates 15 to 18).

By October 1, this new ice had reached 9 cm in thickness in Bays 11/12, and formed out to about 5 m from the low tide point. The wide intertidal area in Z-Lagoon was covered with up to 5 cm of large crystals clinging to rocks, rather than a distinct layer. Some submerged ice was visible below the low tide mark.

New ice began forming in the centre of Ragged Channel on October 3 but was constantly broken up by the light N.W. winds. Bay 11/12 was covered by ice thick enough for seals to haul out on by October 5 (Plate 19). At the time of camp closure Ragged Channel, and Z-Laggon were almost completely covered by new ice (Plates 20 to 23). Eclipse Sound commenced freeze-up about September 30 and was greater than 9/10 covered in new ice by October 7 (Plate 24 and Figure 7). By November 4 Eclipse Sound was classified as predominantly grey-white or older ice but Pond Inlet continued to be predominantly grey ice or younger until mid-December (Figure 9).

Plate 3 Ragged Channel Ice Conditions looking towards Bays 9, 10, and 11, July 23, 1980

Plate 4 Ragged Channel looking South, July 25

Plate 5 Bay 9, July 27, 1980

Plate 6 Bay 10, July 27

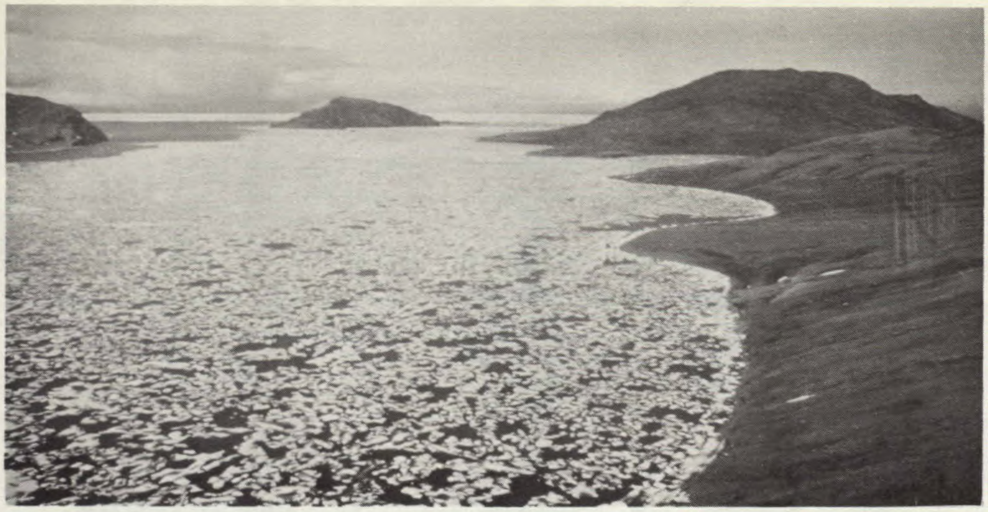


Plate 7 Ragged Channel, July 30. Winds are from the SW

Plate 8 View North up Ragged Channel, August 2.
Note accumulation of melting floes at South
end of Bay 10.

Plate 9 Bay 101, July 26. Tidal cracks are still clearly
visible.

Plate 10 Ice Pile-ups near Bay 101, July 27, 1980

Plate 11 Entrance to Z Lagoon and Bays 101/102, July 27

Plate 12 Z Lagoon, July 27, 1980

Plate 13 Z Lagoon, August 3

Plate 14 View from Eclipse Sound towards C. Hatt
August 2, 1980

Plate 15 New ice coating the intertidal zone of Bay 9, with many old fragments frozen in place, Sept 30. Grease ice is beginning to form offshore.

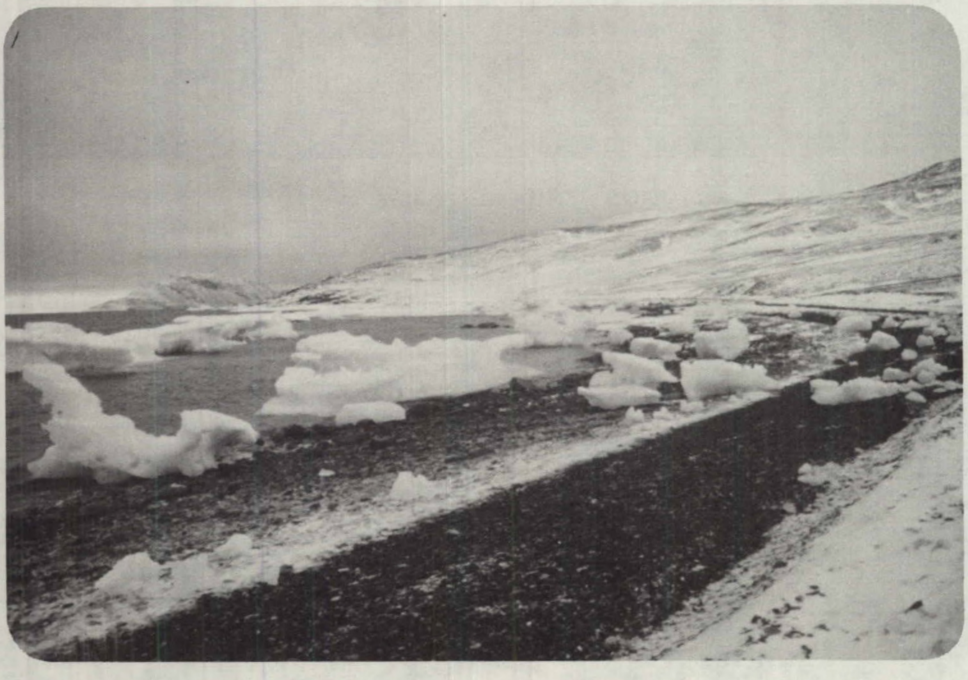


Plate 16 Old floes stranded in the intertidal zone of Bay 10, September 30.

Plate 17 View South along Ragged Channel, October 1, showing old ice concentrated in Bays 11 and 12.

Plate 18 New ice forming between old floes in Bay 11 October 2.

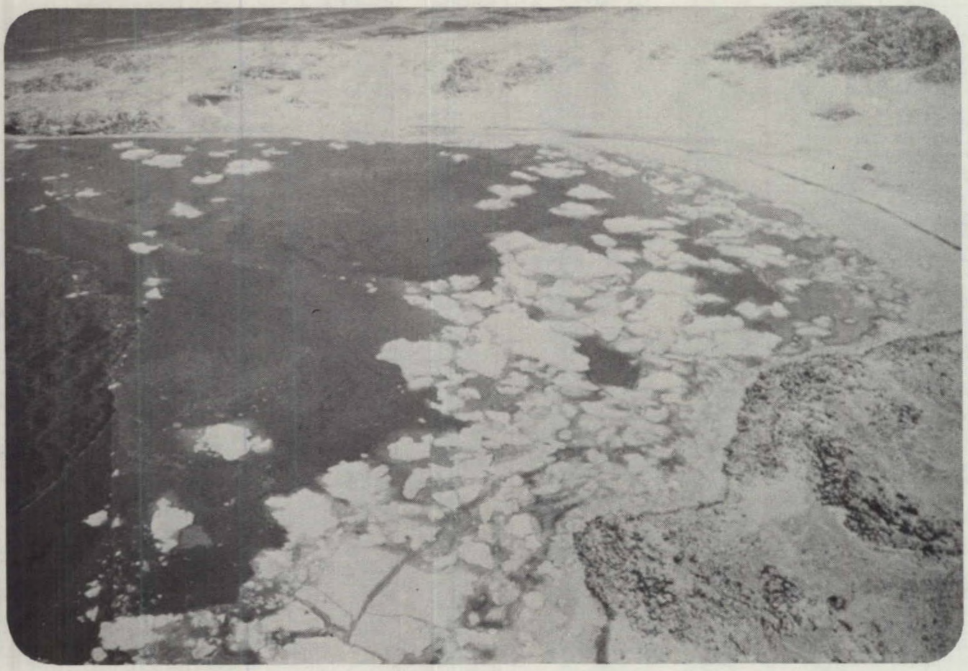


Plate 19 Bays 11 and 12, October 6

Plate 20 New ice sheet growing out into Ragged Channel from Bays 10, 11 and 12, October 5.

Plate 21 New ice off Bay 9, October 6, 1980. Note old floes stabilizing young ice near shore

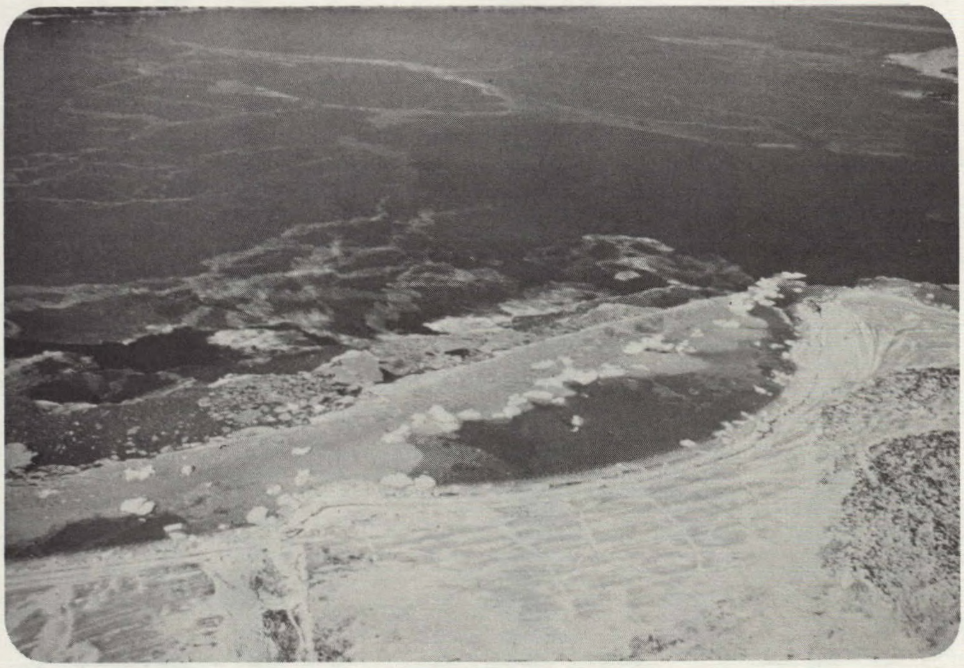


Plate 22 Grey white ice formed completely across Bay 10, October 6. See Plate 20 for October 5 conditions.

Plate 23 New ice forming across the entrance to Z Lagoon, October 6, 1980

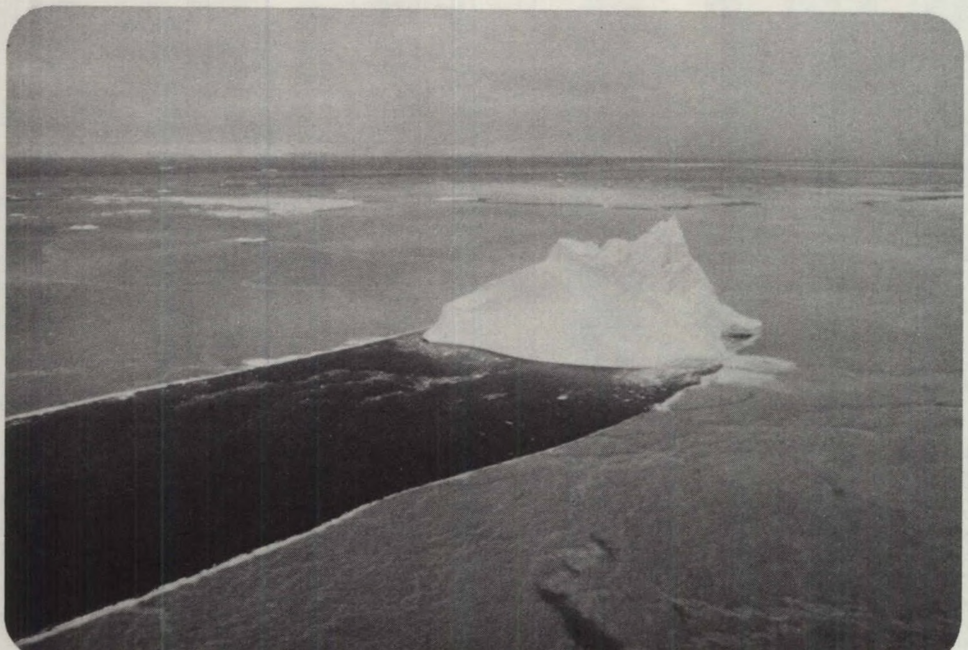
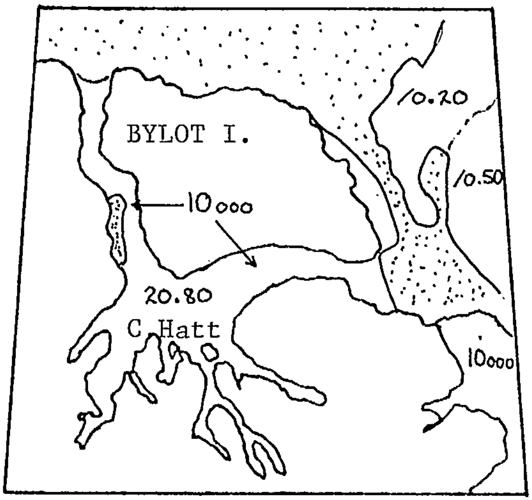
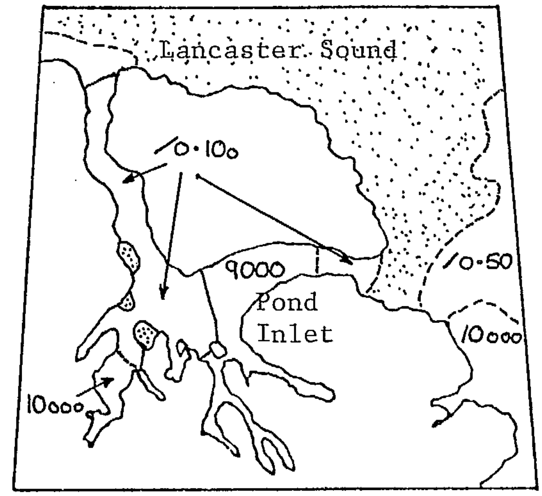


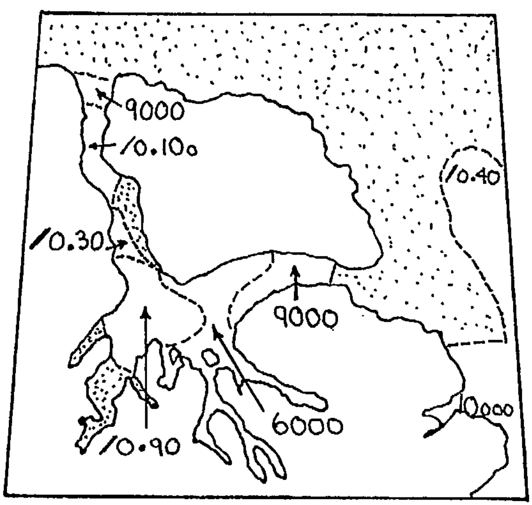
Plate 24 Iceberg moving through new ice in Eclipse Sound, October 1



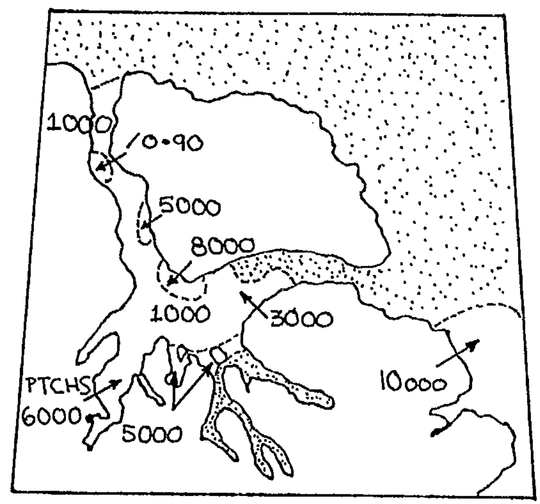
3 a July 15



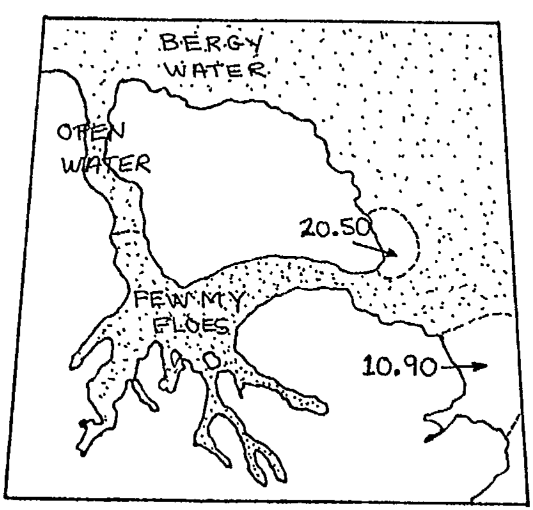
3 b July 22



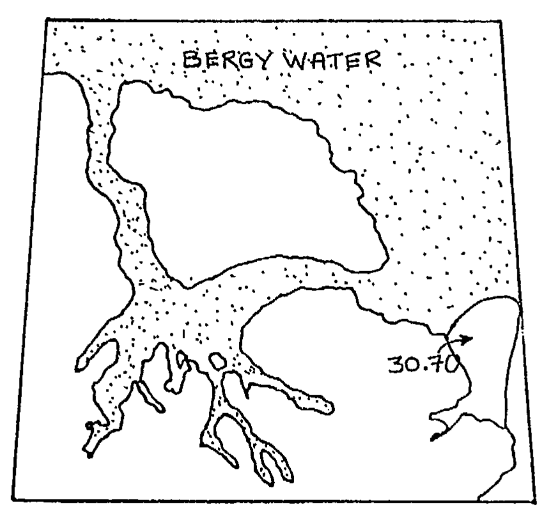
3 c July 29



3 d August 5



3 e August 12



3 f August 19

Figure 3 Ice Charts, July 15 to August 19, 1980

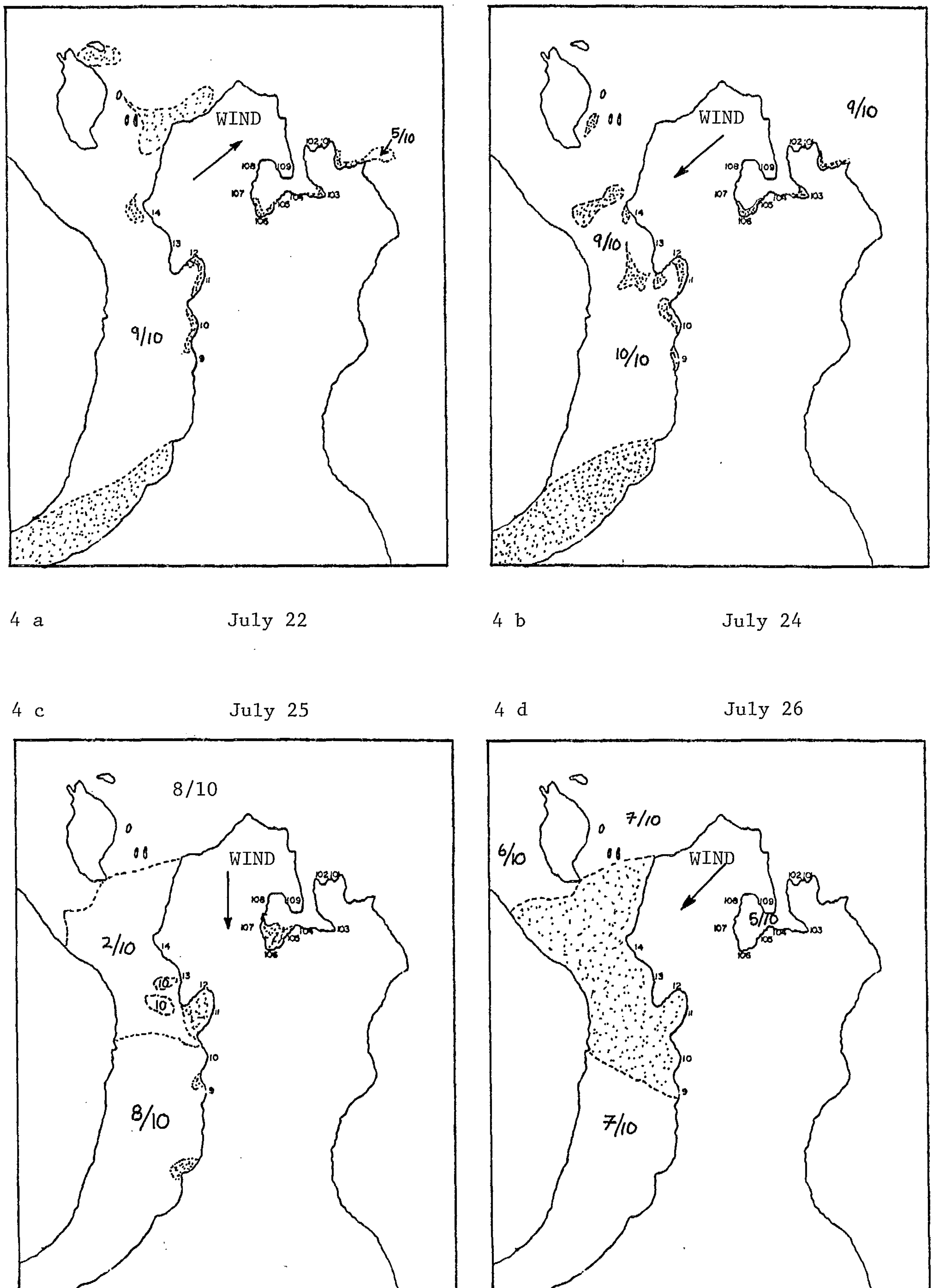
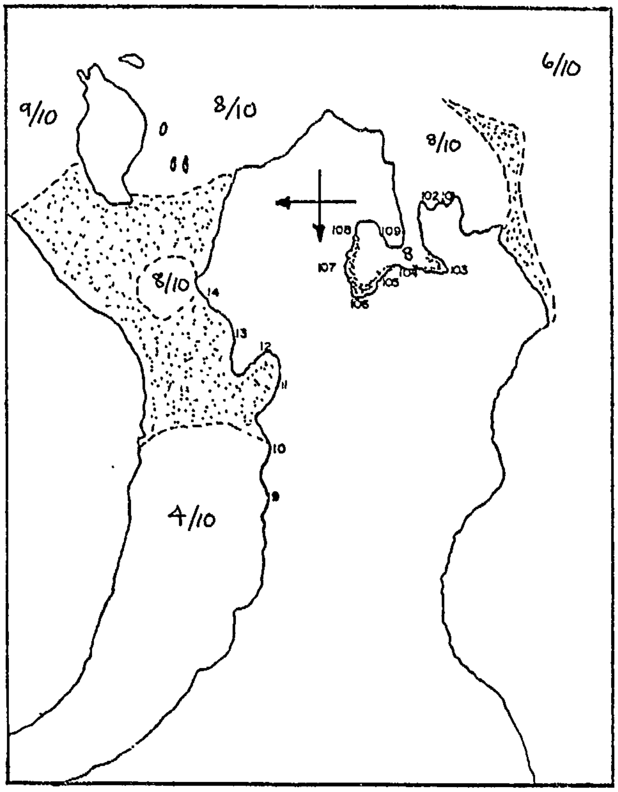
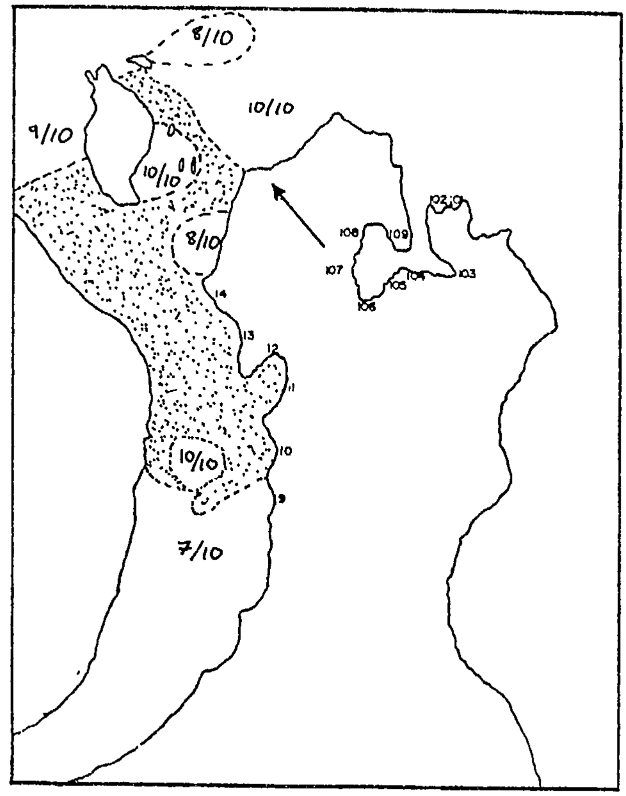


Figure 4 Ice Distribution in Ragged Channel, July 22 to July 26

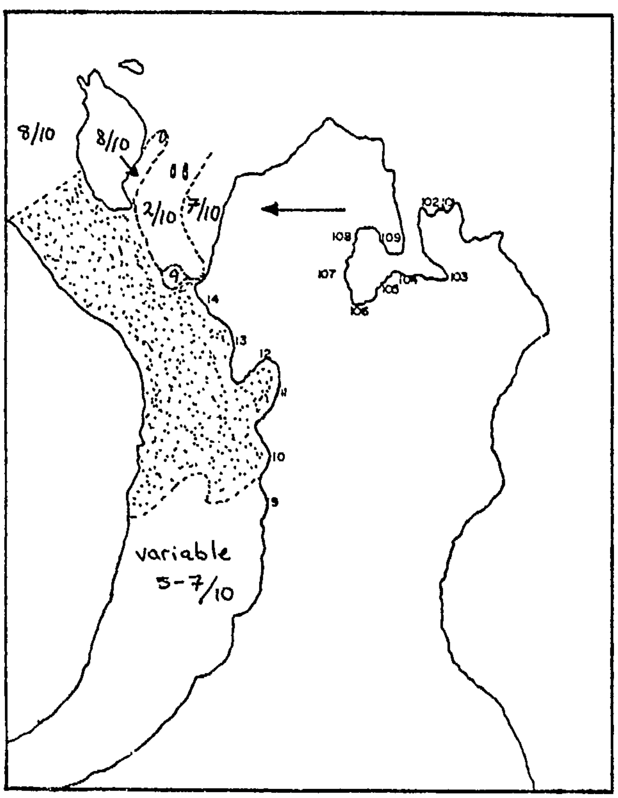


5 a July 27



5 b July 28

5 c July 29



5 d July 30

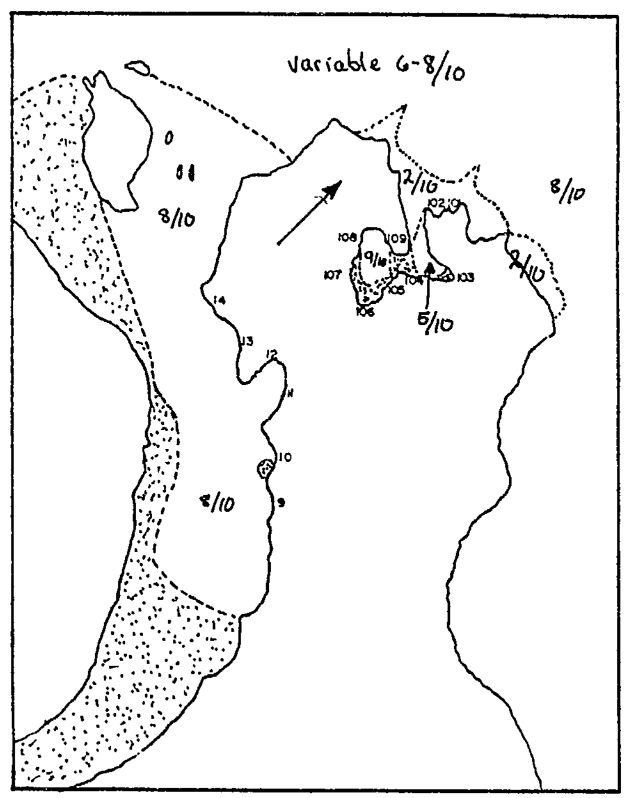
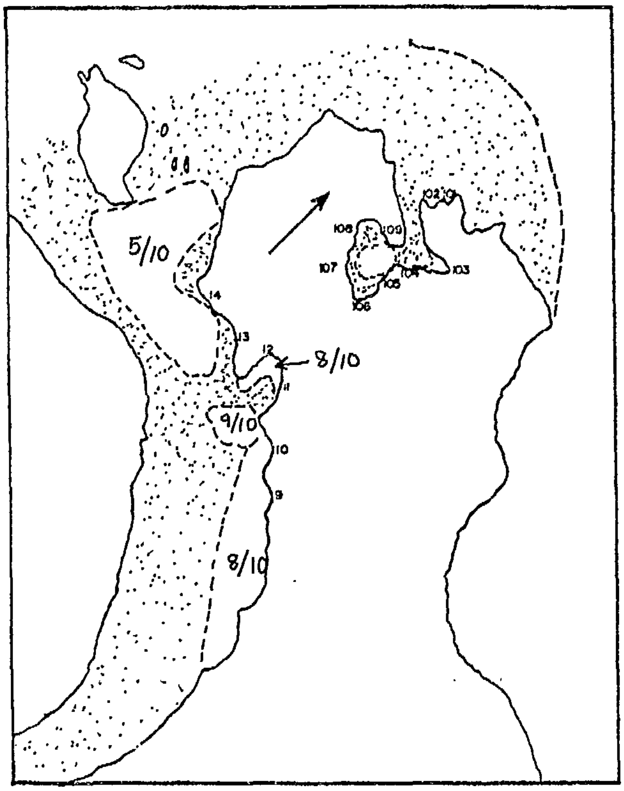
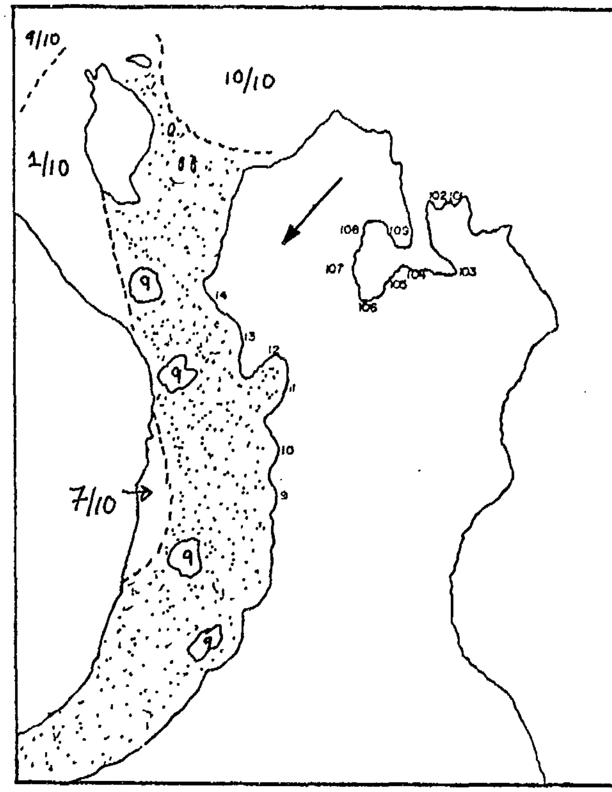


Figure 5 Ice Distribution in Ragged Channel, July 27 to 30, 1980

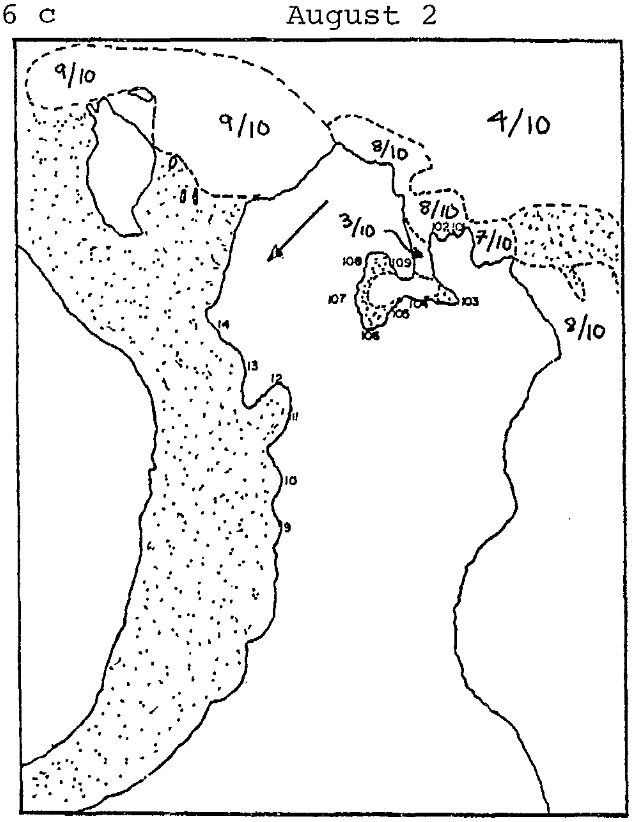


6 a July 31



6 b August 1

6 c August 2



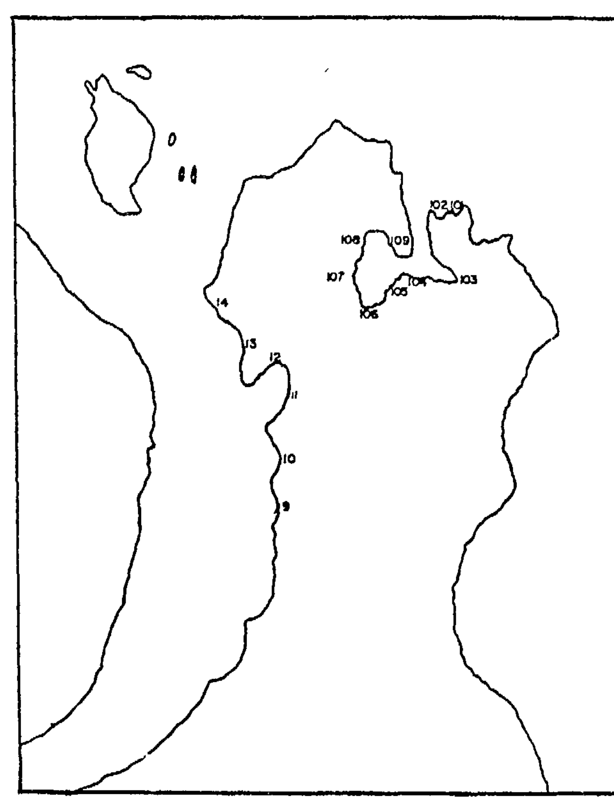


Figure 6 Ice Distribution in Ragged Channel, July 31 to August 2

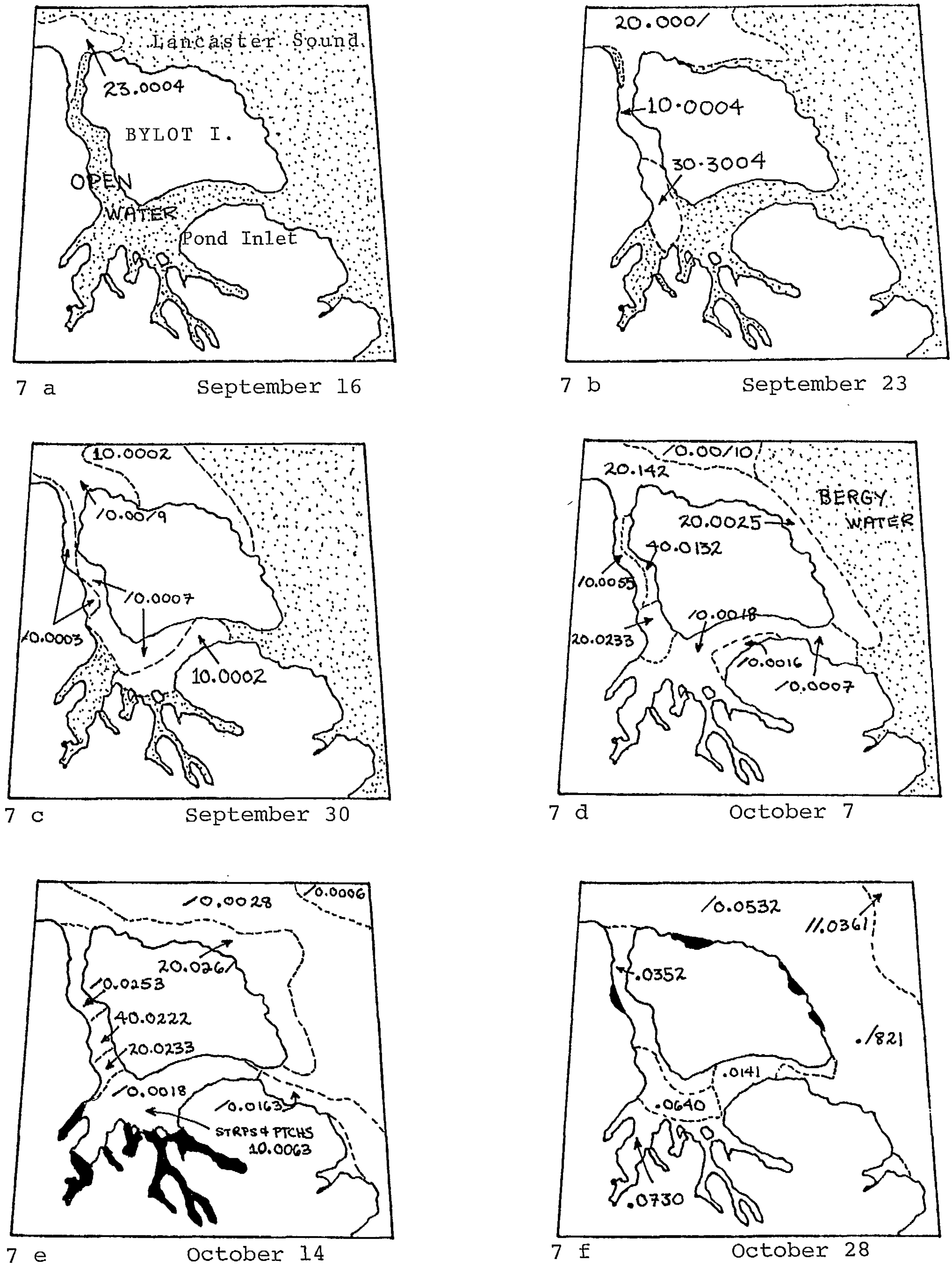
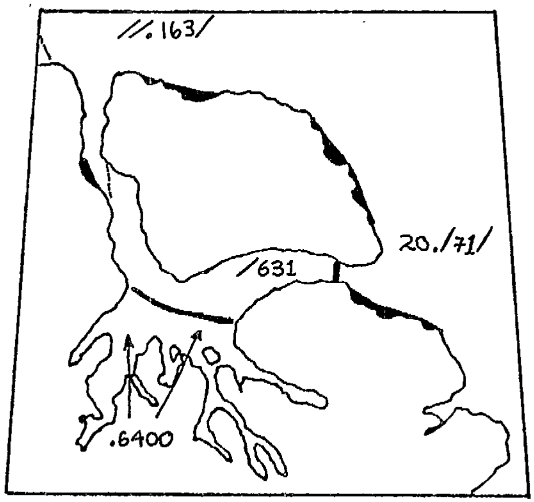
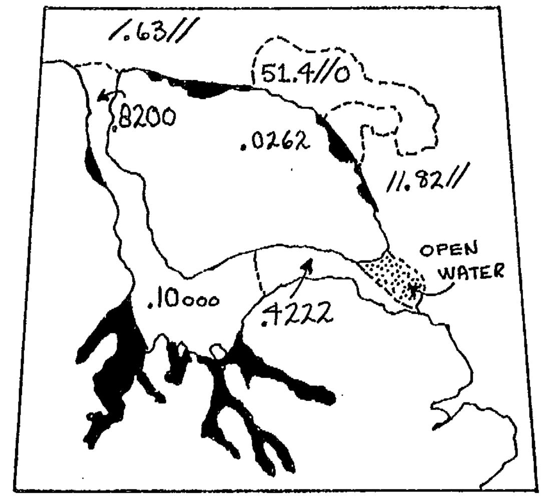


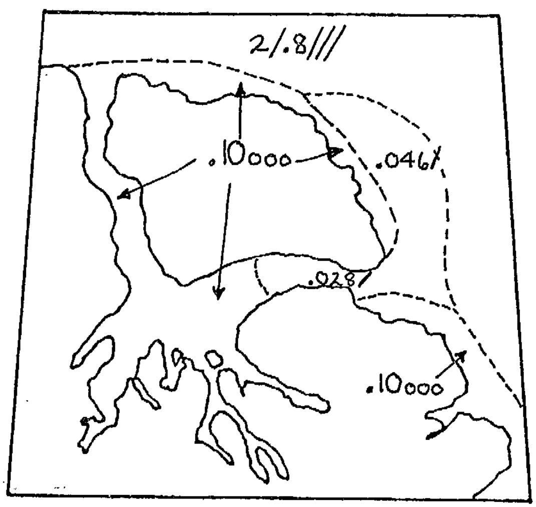
Figure 7 Ice Charts, September 16 to October 25



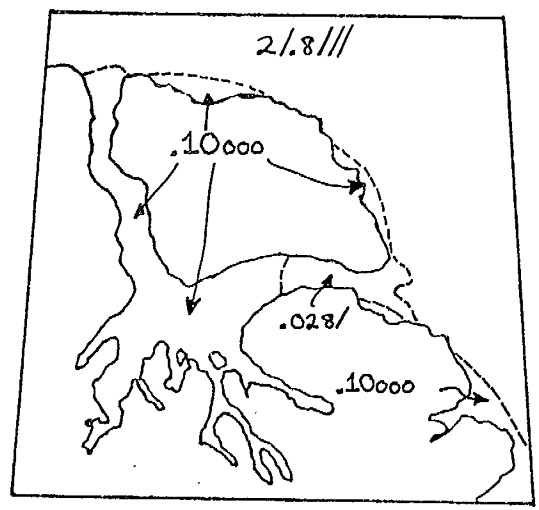
8 a November 4



8 b November 11



8 c November 25



8 d December 9

Figure 8 Ice Charts, November 4 to December 9

See Appendix B for explanation of Chart Symbols

4.0 ICE INTERACTION WITH THE SHORELINE

4.1 Ice in and on the Beach

On arrival at Cape Hatt, July 22, all snow had gone from the beaches. The ice nearshore was starting to break-up and narrow strips of open water were present in the vicinity of the winter tidal cracks. The remains of the original ice foot were melting in the intertidal zone, and individual floes from immediately offshore were being lifted up on high tides and left stranded on the beach. Many of these floes contained heavy layers of sediment frozen to their underside. This sediment quickly melted out and drained off onto the beach, particularly when the floe was overturned and exposed to the sun. (Plates 25 and 26.) The most striking shore ice features associated with the entire Cape Hatt shoreline were linear ice mounds or berms running the length of all beaches between the mid and low tide points. This ice extended on the bottom out to 10 m offshore in areas of very shallow slope, and several meters on steeper beach fronts (Plates 27 and 28.)

Beach deposits ranging from coarse gravel and boulders to sand, covered the ice mound to depths up to 20 cm, and slumped seaward to overlay the bottom fast ice shown submerged in Plate 28. The mound features were extremely linear and ranged in height from 30 cm to over 1.0 m (see Plate 29 taken in Bay 12). Plates 30 to 32 show various configurations of this remnant ice foot feature in Bays 10, 12 and Z-Lagoon.

In addition to prominent ice cored gravel mounds, scattered ice blocks incorporating thick layers of beach material were actively melting in situ and depositing their contents in the intertidal zone (Plate 33). The only experimental area of Cape Hatt where possible ice ploughing or "bulldozing" of the beach could occur through wind generated ice driving forces, is along Bays 101, 102. Plates 34 and 35 show the remains of such an event in Bay 102, with large embedded ice blocks overlain with thick beach deposits.

The ice cored mound feature is an effective agent in thoroughly mixing the upper layer of intertidal material. By acting as a sort of fence, the ice berm prevents many loose floes blown in by wind after break-up, from actually lodging on the beach. By the same argument, any floes which do pass over this mound on extreme high tides are effectively trapped for long periods, and usually melt out in the intertidal area. Some floes ground firmly on this mound on the way in and remain in a "teeter-totter" position, pivoting with the tide for several days (Plate 36).

Camera E on Bay 10, observed the gravel covered ice mound throughout the break-up period and film footage shows it gradually diminishing over a ten day period between August 5 and August 15. At one point the gravel slumped clear of the shoreward side and revealed an ice mound containing three distinct layers of sediment.

The actual physical processes involved in formation of these shore-ice features cannot be clearly defined without further investigations prior to any melt taking place (preferably April or May). One hypothesis suggests that as the surface layer of the intertidal zone is covered by sea ice accretion over successive tidal cycles at freeze-up (time lapse - October 6 - 20), the active layer in the sediments is also diminishing. Any remaining groundwater in the beach sediments is effectively sandwiched in a natural "aqueduct". Ice lensing in the beach face then forces layers of material upwards into a mound concentrated near the low tide point. Meanwhile the ice foot continues to build-up, forming an ice/sediment sandwich with sea ice on top and fresh water ice beneath. Other theories involve anchor ice forming on the beach and being covered by wave washed gravel and sand in stages, forming multiple ice/material layers. 1980 freeze-up observations did not support this concept. They showed new ice forming out from shore over a matter of hours, and rapidly becoming a stable sheet, without the successive break-up and premature freeze-up cycles characteristic of more exposed Arctic shorelines. Time lapse photography between October 6 and 23 show this new ice sheet rising and falling with the tide and ice accretion associated with over flooding of the ice in the intertidal area.

For a period of 5 to 10 days, these rotting floes circulate between bays, occasionally becoming stranded for short periods, and leaving some of their load behind. (Plate 38)

The ice in the upper intertidal zone largely melts in place and only lifts off the beach when much of its incorporated material has been redeposited essentially where it came from.

It is very difficult to make a quantitative estimate of the actual amount of material removed by ice, but it appears that within the test bays, at least the upper 5 cm of beach material is stripped away by ice in the lower intertidal zone and out to about the 3 m mean tide water depth, over 50% of the area. A very small percentage of this material finds its way to other test bays. Prevailing winds in 1980 cleared ice out of Bays 11, 12 by July 27. This ice moved back and forth in Ragged Channel several times before completely melting, but spent most of the time in the south end of the channel. For several days, this rotting ice was concentrated in an area extending as far north as Bay 9. The circular current gyre suggested from current measurements within Bay 10, was visible in ice floe motion on the time lapse photography. Any ice that did ground along the shores of Ragged Channel was concentrated on beaches with northerly exposures. Camera Station E in Bay 10 was one of these favoured locations. Plate 37 shows ice floes grounded there on July 25. The floe with the marker visible, moved south around the point and melted just offshore in Bay 9.

Of the three test bays #9 and the south half of #10 collected most of the transient ice floes during 1980 break-up. Bay 11 is least likely to "attract" sediment laden ice from the other two test bays.

Nearshore ice drift observed from camera stations did not always correspond to ice motion in the centre of Ragged Channel. Often, floes within 30 m of shore would remain static or more in a reverse direction to the main ice flow for several hours, before being finally caught up and carried away from the field of view.

The ice cored mounds appear too linear to be simply explained by ice lensing in the beach face. Possibly, there is some plowing and re-freezing phenomena at the first tidal crack formed in October, which could explain this linearity.

Ice in the beach face is essentially a process of mixing the material in place rather than longshore transport, removal, or addition of new material. The following section discusses the significance of ice at Cape Hatt as a material transfer agent.

4.2 Sea Ice Transfer of Beach Material

Ice can act:

1 - to transfer material from one section of shoreline to another via sediment laden ice floes, floating free in the spring, and coming aground to melt and deposit their contents on some other beach.

2 - to remove material from a beach via floes moving offshore to melt and drop their aggregate or sand on the sea bottom.

3 - to plough beach material through wind generated ice push or thermal expansion (more common with lake ice).

Apart from Bays 101/102 which are exposed to more dynamic ice forces, the test Bays in Ragged Channel are unlikely to experience any ice ride-up and/or associated beach ploughing . Ice out to about the 2 m water depth (at low tide) is in at least partial contact with the bottom. When this ice breaks-up and drifts away in late July, it carries a substantial portion of the bottom material with it. Most of this material is deposited in Ragged Channel, predominantly in the south end, as rotting floes congregate under the prevailing northerly winds. A small proportion of these floes simply stay near to where they grew, and scatter accumulated deposits over the nearshore region in a random manner as they melt.

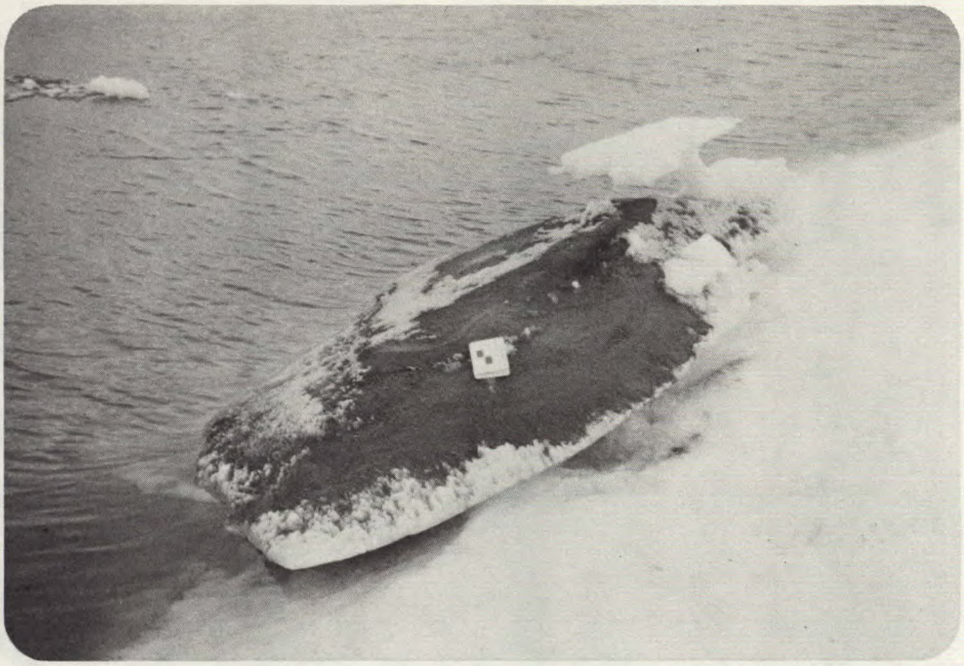


Plate 25 Overturned ice fragment in Bay 10.

Plate 26 Close-up view of sediment layer frozen to the underside of floe shown in Plate 25

Plate 27 Ice cored gravel mound in Bay 14 at high tide July 26

Plate 28 Gravel covered ice submerged at high tide in Bay 14, July 24.

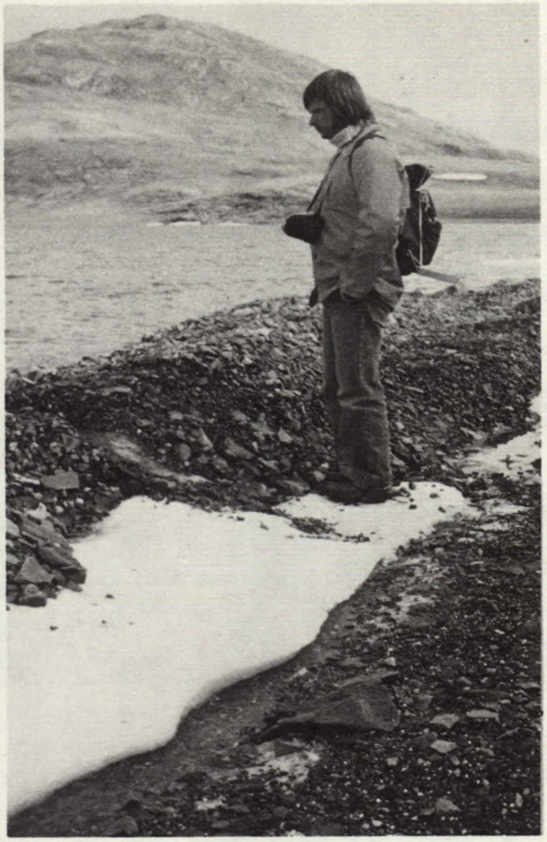


Plate 29 Gravel covered ice mound, Bay 12, July 27

Plate 30 Partially melted ice mound feature with layers of incorporated gravel visible, Bay 10, July 25

Plate 31 Gravel and boulders being exposed within melting ice in the intertidal zone of Bay 12, July 25

Plate 32 Ice mound covered with gravel and undercut by melting, Z Lagoon, July 26, low tide.

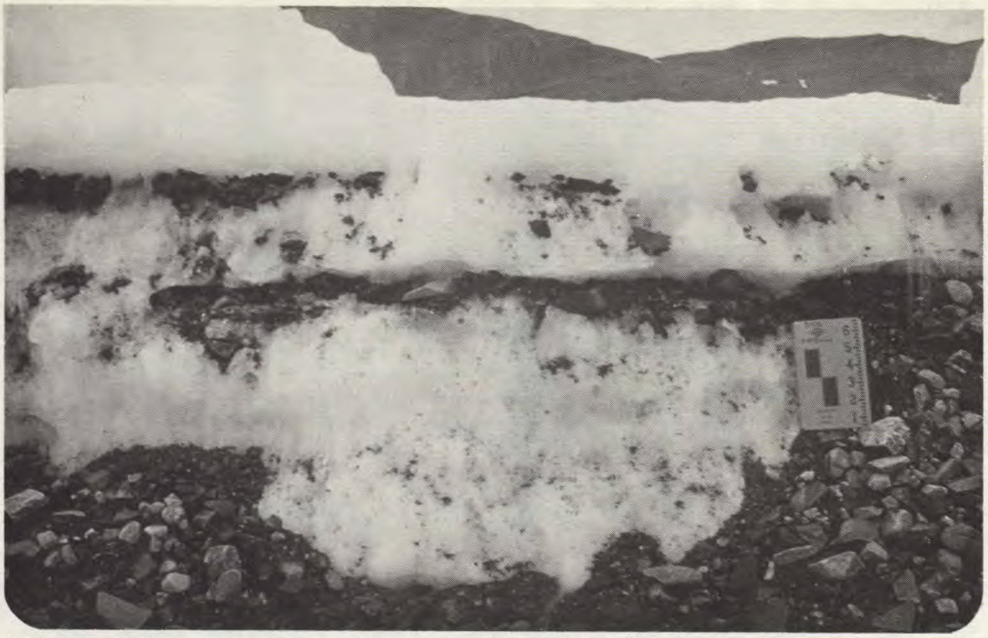


Plate 33 Layers of gravel contained in melting ice foot Bay 10, July 29

Plate 34 Stranded ice in beach in Bay 102 showing multiple layers of gravel and sediment, July 31

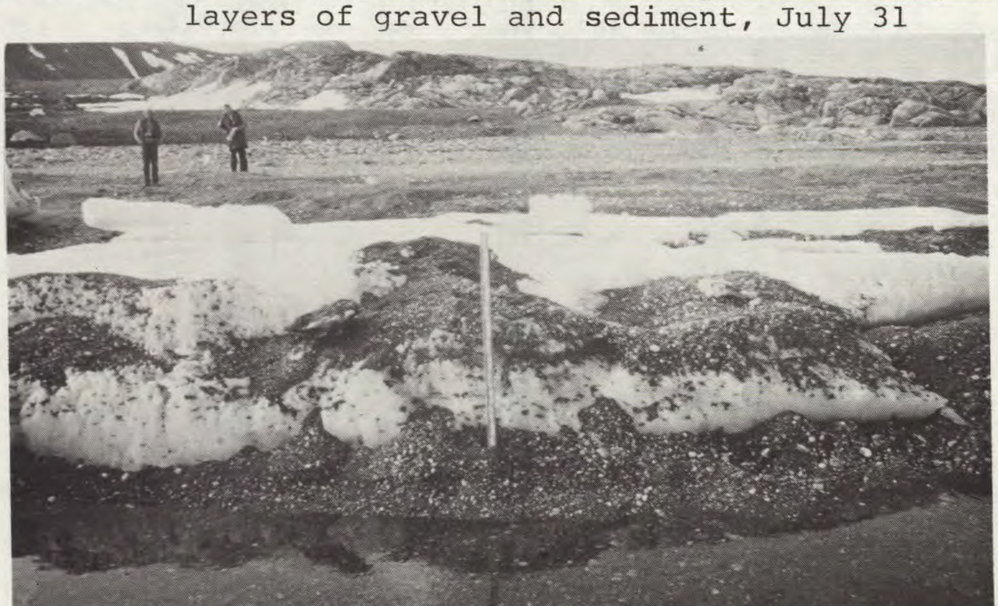


Plate 35 Stranded ice overlain with beach material within the intertidal zone of Bay 102, July 30

Plate 36 Ice floe stranded on top of ice mound at low tide in Bay 10, August 2. Note gravel slumping as ice core melts.

Plate 37 Stranded sediment laden ice floes by Camera Station E, Bay 10, July 25. Marked floe in picture moved S. into Bay 9 overnight.

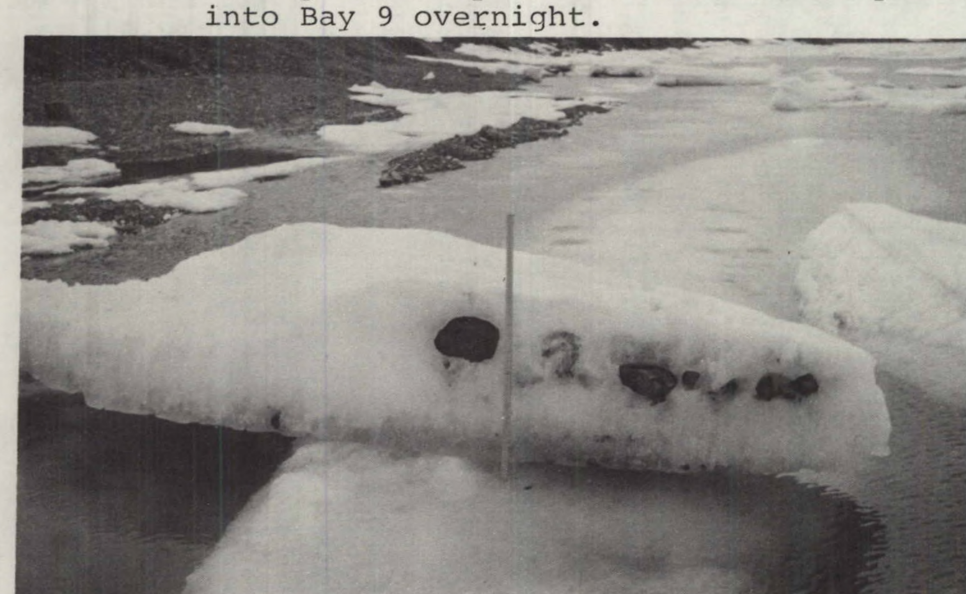


Plate 38 Boulders melting out of a stranded floe in Bay 9 July 25.

5.0 CONCLUSIONS

The Cape Hatt area experiences less than seven weeks in the year when ice is not in direct contact with the shore, both in the intertidal and immediate nearshore zones. The interaction of this ice with the beach plays a major role in mixing and redistributing the entire upper layer of beach material, ranging in coarseness from silt to large boulders. A prominant feature in 1980 along all test bays, including Z-Lagoon was an extremely regular ice mound up to 1 m in height, overlain by beach material, situated near the low water mark. This ice melted completely by late August, and had not reappeared before field observations ceased on October 6. Ice ploughing or piling up on the beach face was only observed near the entrance to Z-Lagoon along the so called "high energy" shoreline.

The ice cover in Ragged Channel largely melts in situ, and the possibility exists for rotting floes to move incorporated beach material between bays. Ice at break-up responds quickly to local winds, and the prevailing northerlies act to keep the northern half of the channel clear, while concentrating rotting floe ice to the south in the vicinity of Bay 9. Any beach with a northerly exposure will be a natural catch basin for loose floes throughout the summer (eg. south end of Bay 10). In terms of decreasing potential for receiving oiled beach material through ice transfer, the bays have been subjectively rated as 9, 10, 11.

General ice break-up patterns in 1980 followed what is thought to be the norm for the Eclipse Sound area, with open water conditions prevailing between August 5 and September 30. Historical data suggests that there have been large annual variations of over 30 cm in maximum ice thickness in the Pond Inlet area, which could retard or advance break-up dates by up to two weeks depending on solar radiation and thawing degree days in June and July.

Cape Hatt is directly in line with Navy Board Inlet. Steady N.W. winds over several days can bring in old ice fragments from Lancaster Sound, and may effectively direct enough of this into Ragged Channel to impede nearshore marine operations at any time during the summer.

The time lapse camera stations proved to be an economical method of documenting ice conditions with an overall reliability factor better than 80%.

6.0 RECOMMENDATIONS

The ice cored gravel mound feature documented in 1980 could play a major role in redistributing oil spilled on the beach during open water. An early spring project is required to examine these ice/sediment features, if not in 1981, then definitely in 1982 on the beach selected for the neat oil spill.

Time lapse camera stations should be established by May 1981 to look primarily at ice melt in the intertidal zone, and with the aid of coloured markers, ice movement in Ragged Channel, between Bays 9, 10 and 11. With suitable erosion and deposition markers, a time lapse station should be established to provide continuous coverage of the fate of the 1981 shoreline spill plots.

This winter's ice growth, snow cover and air temperatures in the Pond Inlet area should be carefully monitored, beginning April 1, 1981, in an effort to comment first of all on the likelihood of an early or late break-up, and later in early July, on the actual time of ice disintegration in Ragged Channel.

During the summer of 1981, close watch should be maintained on the movements of any significant streams of old ice fragments in the Cape Hatt and Navy Board Inlet area, particularly under conditions of steady N.W. winds for more than 48 hours. Prior warning of any ice intrusion into Ragged Channel is essential to scheduling the 1981 discharge experiments.

Minor improvements should be made to further improve the reliability, and ease the analysis of time lapse data (Appendix A).

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APPENDIX A TIME LAPSE CAMERA SYSTEM

Nine time lapse camera systems were assembled and deployed at various locations around Cape Hatt. The cameras used were Sankyo EM-60XL Super 8 mm movie cameras, operating in a single frame mode (see specification sheet attached). These cameras have automatic aperature control which permits operation at a wide range of light levels. The cameras were used with a wide-angle lens setting, giving a 40° field of view. Kodachrome K-40 film was used in all installations. After processing, successive rolls (for each installation) were spliced together.

The time lapse between frames was controlled by a built in timer in the camera body (1 frame per minute, slowest setting) or special external timing circuits prepared for intervals of one frame every 4, 8 or 16 minutes. The larger time intervals were employed in an effort to reduce the volume of film and the number of film changes required. Table 1 shows the film usage for various time lapse intervals.

TABLE 1

TIME LAPSE INTERVAL	DAYS OF DATA/50 FT ROLL
1 frame per 1 minute	2.5 days
1 frame per 4 minutes	10. days
1 frame per 8 minutes	20. days
1 frame per 16 minutes	40. days

To provide a time reference for events noted in the field of view of the camera, a lightweight battery powered clock was affixed to each camera to display the time in the upper edge of the field. The clock was supported at such a distance (70 cm) that it remained in focus at all but the lowest light levels.

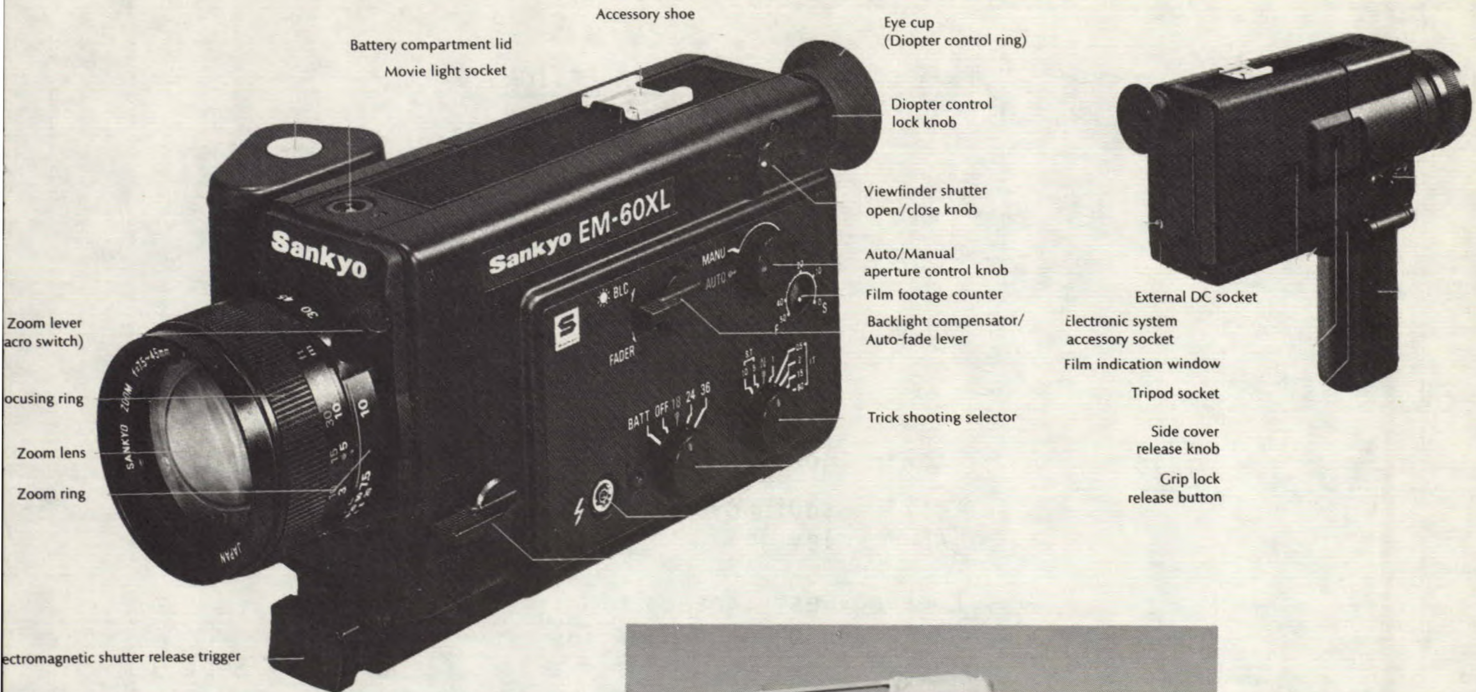
The time circuitry and camera operation were powered by an external 6V dry cell battery.

Each camera was mounted on a standard photographic - type tripod. These tripods were heavily ballasted with rock to provide a steady and secure platform. A lightweight plastic bag was employed to protect the camera installation from the elements. Plate ____ shows a typical camera installation.

The cameras were inspected frequently when the monitoring personnel were on site. During the period August 6 to September 25, the camp staff attended to film changes at certain of the installations.

From October 5 to October 21 six stations ran unattended through the freeze-up period.

TIME LAPSE CAMERA SYSTEM



SPECIFICATIONS

CAMERA: Sankyo EM-60XL
- f1.2, 7.5 to 45 mm zoom lens
- focusing, 0 to infinity
- external DC power socket
- built in timer, 0.5 to 60 sec
- dimensions, 19.7x10.1x5.5 cm
- weight, 800 g
- filming, 18, 24, 36 and single frame

FILM: Kodachrome Type A, 25 ASA in daylight, 15 m, Super 8

TIMERS: Phitek Electronics, Yellowknife, 4, 8 and 16 minutes

POWER: Mallory, MN9180, 6 V, Alkaline

CLOCK: Westclock Quartz Alarm

RUNNING TIME: maximum unattended with 3 batteries at 16 minute interval, 4 to 5 weeks, depending on temperature

TIME LAPSE CAMERA INSTALLATIONS

CAMERA	LOCATION AND FIELD OF VIEW	INTENDED PERIOD OF OPERATION
A	Looking north over Bay 9	July 24 - Oct 6
B	Looking south over Bay 10 (40 m elev.)	July 24 - Oct 6
C_1	Looking west-closeup of the beach between Bays 13 and 14	July 24 - Sept 9
C_2	Looking north over inter-tidal area of Bays 11 and 12	Sept 9 - Oct 6
D	Looking west (towards entrance to Z lagoon) over Bays 101 and 102) ~10 m elevation	July 24 - Oct 6
E	Looking northwest from the delta separating Bays 9 and 10 closeup of the beach	July 25 - Aug 22
F_1	Looking to the northwest over Bay 13 (~12m elevation)	July 24 - Sept 9
F_2	Looking south over Bays 11 and 12 (~20 m elevation)	Sept 9 - Oct 6
G	Looking south over Ragged Channel from above Bay 14 (~130 m elevation)	July 24 - Aug 23
H	Looking to the northeast over Z lagoon and Eclipse Sound from the mountain to the south of the camp (~290 m elev.)	July 23 - Sept 14
I	Looking north over Eclipse Sd. and Navy Board Inlet from north side of mountain. (~250 m elevation)	July - Sept 14

TIME LAPSE CAMERA INSTALLATIONS (July 24 to October 6)
PERFORMANCE DATA

Camera	A	B	C_1	C_2	D	E	F_1	F_2	G	H	I
Intend Days of Operation	75	75	46	28	75	42	48	28	30	69	67
Days of Film Footage Obtained	46	75	46	28	72	43	48	28	4	22	41
Days Lost to Camera System Malfunction	0	0	0	0	3	2	0	0	26*	47**	26**
Days Lost Due to Lens Fogging	6.3	11.5	7.3	0.2	10	3.2	126	0	0	2.7	14.3
% Loss Due to Equipment Malfunctions	0	0	0	0	0	0	0	0	86.7	68.1	38.8
% Loss Due to Lens Logging	8.4	15.3	9.3	0.7	13.3	7.6	26.3	0	0	3.9	31.3
% Recovery	91.6	84.7	90.7	99.3	86.7	92.4	73.7	100	13.3	28	39.9
Field of View Bay Number	9	10	13	12	101/102	9/10	13	11	RAGGED CHANNEL	ECLIPSE SOUND	Z LAGOON

* Light Meter Failure

** Wires Chewed

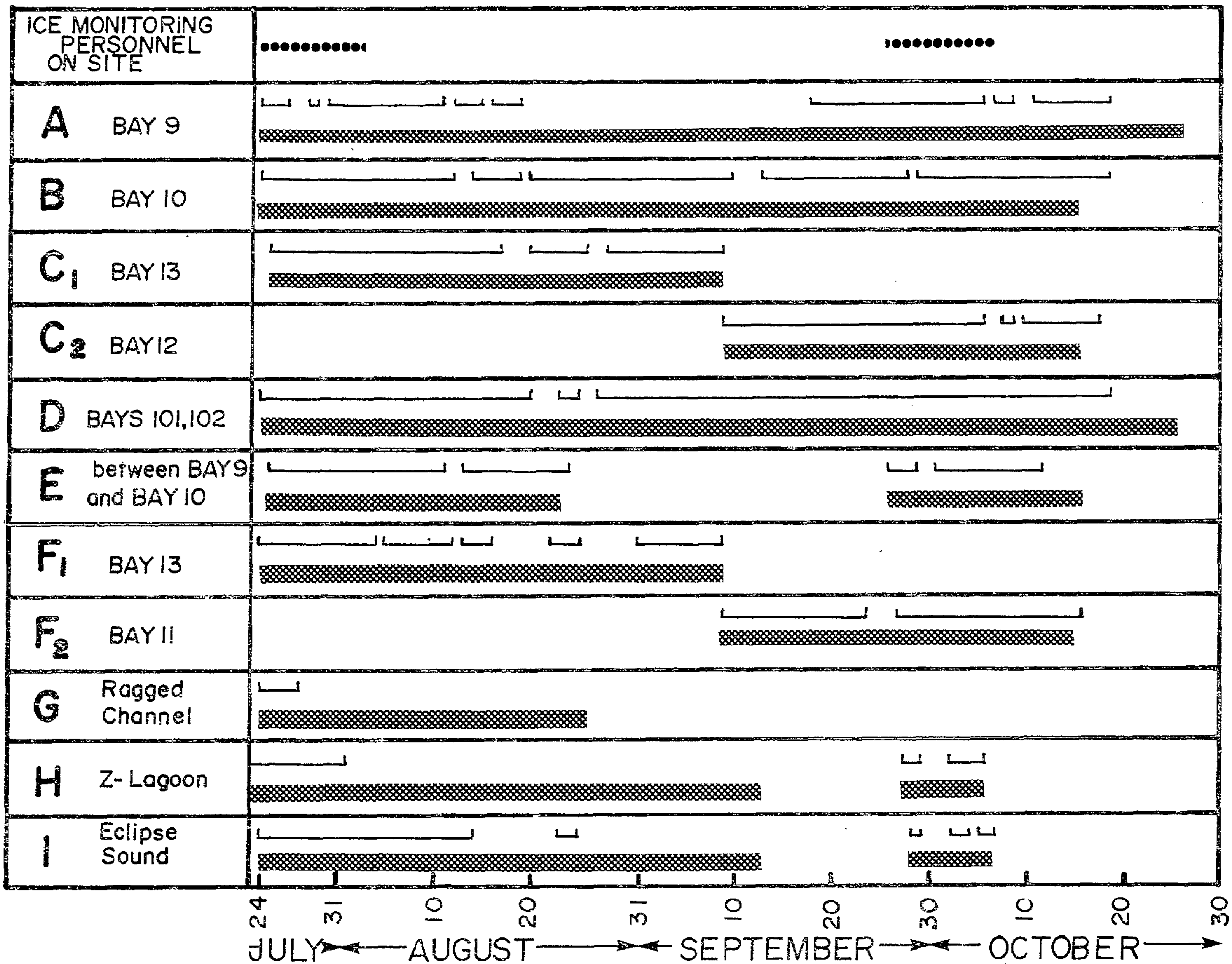


Table A-1 Time Lapse Film Coverage Showing Intended Period of Operation and Actual Times

Time Lapse Camera System: Problems and Recommendations

The time.lapse camera system as used in 1980 was quite successful. In general, the cameras seemed to be fairly rugged and trouble free and the quality of the image was good. However, several problems cropped up during the 1980 season that lowered the data return rates.

1. Most of the cameras suffered from fogging between the filter and the lens elements. Removal of the filter resulted in fogging within the lens elements, which is nearly impossible to remove. The fogging problem was most severe in the warmer summer weather, when the cameras were essentially unattended. In the cooler weather around breakup and freezeup, this condensation on the inside of the filter seemed to be less of a problem. The data loss due to fogging was greater than 10% for several installations and exceeded 25% for a single installation (camera F).

2. Several of the camera installations suffered from animals gnawing the wires leading to the battery pack. This was remedied by fitting protective conduit covers to these wires or attaching the batteries to the tripods, holding the batteries up off the ground.

3. Camera G suffered from chronic overexposure. The cause of this is not entirely clear but it is probably due to a malfunction in the light metering or automatic inis functioning.

4. During the freezeup period, the high altitude cameras (H and I) became covered in ice each evening, as the persistent low level clouds descended at night. The only way to get any useful footage under these conditions was to clean the camera lens daily.

5. The small clocks in the field of view of the cameras proved to be extremely reliable and were very inexpensive but it was difficult to determine exactly what day certain frames of the film were taken, without rewinding the film to some known date (such as a film change) and counting the days. It would be better to fit some sort of large display digital 24 hour clock that also displayed the date. This would greatly improve the accessibility of the information on the films.

Recommendations

1. utility of continuous film footage of the water conditions around the experimental area is clear. In order to ensure that the cameras are operating properly when ice monitoring staff are not on site, someone on-site should be instructed in the care and maintenance of the camera systems. An appropriate maintenance schedule would be two visits a week to all camera installations. This would require less than 4 man-hours a week (assuming that the helicopter is available).

2. The clocks used in the field of view of the camera should be replaced with large display digital clocks (liquid crystal or gas discharge type) that displayed 24 hour clock time and date. Such a clock could also be used to trigger the cameras. A further possibility is that the triggering circuit could be used to turn on the display such that the display is only on when a picture is being taken. This would reduce the battery drain. Such a clock system should be available on a custom-made basis for approximately $200 per system.

3. The persistent filter fogging problem should be attacked by using one or more step-up adapters to create a larger air space between the lens and the filter. This space could be sealed (with silicone sealer) with dessicant inside. Steps should also be taken to seal the actual filter into its mounting ring. This modification would require approximately $50 per system for the necessary adapters and large diameter filters

APPENDIX B

Ice Chart Nomenclature

Pond Inlet Ice Thickness Data (A.E.S.,1980)

1980 Cape Hatt Ice Coverage

1980 Cape Hatt Wind and Temperature Statistics

Pond Inlet Climatological Table (C.H.S. Sailing Directions)

reprinted from Atmospheric Environment Service
1980 Seasonal Outlook

INTERPRETING CANADIAN ICE CHARTS

A unique digital code has been developed in Canada for depicting the total ice concentration in an area, the number of tenths of ice in each development stage (age), and the proportion of each age category with floe size in the medium floe (or greater) range (ie; over 100 m across).

The basis of the code is the reporting of the amount of ice in each of six age categories, in an invariable order. For sea ice these categories are:

my	sy	fy	gw	g	n

n - new ice

g - grey ice

gw - grey white ice

fy - first year ice

sy - second year ice

my - multi year ice

(see page A iii for definition of terms)

Ice Concentration and Stage of Development (Age)

The initial development stage - new ice - is always in the units column, grey ice is always in the tens column, first year ice is always in the thousands column, etc. Older forms of ice, if not present in an area, should be represented by a zero, but in practice, they are not reported.

Thus: *8000 indicates 8/10 of first year ice, with no other ice present.*

62 indicates 8/10 ice cover, 6/10 being grey ice and 2/10 being new ice.

5 indicates 5/10 of new ice and nilas, with no other ice present.

In southern Canadian waters where second year and multi year ice are not normally encountered, the numerical code is compact and convenient. In the Arctic area, where the oldest ice growth stages can be encountered, and where ice development stages younger than first year may not be found for much of the year, a report like 514000 showing 10/10 ice cover would be common. A coding of 91000 could also be found.

To make these coded values more manageable, a second reference mark is introduced. Where 'old' ice forms are being reported, a decimal point is placed between the digits showing amounts of first year ice and second year ice present, and this becomes an integral part of the code where second year and/or multi year ice is reported. Thus, 35.0000 would indicate 3/10 of multi year ice and 5/10 of second year ice, with no first year, grey white, grey, or new ice. Now, using this reference mark, we are able to drop the zeros which show no ice of the younger ages (but we must retain at least one figure to the right of the decimal point). Now 35.0 can represent the same ice types as in the previous example. Note, however, when new ice begins to form in this area, the full code must be used: 35.0001 (with the decimal retained). This would be a normal type of report from the Queen Elizabeth Islands area during the initial stage of freeze-up.

Now 21.4102 shows a complete ice cover made up as follows:

2/10 of multi year ice, 1/10 of second year ice,
4/10 of first year ice, 1/10 of grey white ice,
no grey ice, and 2/10 of new ice.

As shown, this would indicate a compact or a consolidated ice cover. If any floe motion is visible or if any water openings exist, this is indicated by circling the figure thus: (21.4102). This condition is referred to as nine plus tenths (9+/10).

Floe Size

As the ice concentration in an area increases to 50 per cent or more, the size of the ice floes in the pack (see definitions page A iv) begin to have a more significant effect on navigation. Even at low concentrations, larger floes may pose a serious threat to stationary drill rigs. Our code makes provision for reporting the proportion of floes in each age category which are medium floe size or larger (over 100 m across). This is done by using a second line in the digital report, as follows:

$\frac{2.4101}{1\ 3}$ *indicating total ice cover of 8/10; 2/10 second year ice of which 1/10 (or 50 per cent) of the floes are medium floe size or greater; 4/10 first year ice of which 3/10 (or 75 per cent) are medium floe size or greater, 1/10 grey white ice and 1/10 new ice of which all floes are smaller than medium floe size.*

Other Features

a) A solidus (/) is used to indicate the presence of some floes but less than 1/10 of any age category. (40/1 - 4 tenths first year ice; less than 1 tenth grey ice; 1 tenth new ice - total is 5 tenths ice cover).

b) *To distinguish between 1 tenth of an age category and 10 tenths of the next younger category, a change in size of zeroes of the younger ages is manditory. Thus, 1000 shows 1 tenth of first year ice, but 10oo indicates 10 tenths of grey white ice.*

c) *A hatching pattern has been devised which is based on the total amount of ice present and the predominant age of the ice. This was designed on the basis of restriction to navigation presented by the ice and, to some extent, incorporates floe size.*

d) *Fast ice areas are generally indicated by a solid black shading.*

DEVELOPMENT STAGES (AGES) OF SEA ICE

New Ice: *A general term for recently formed ice which includes frazil ice, grease ice, slush, and shuga. These types of ice are composed of ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat.*

Frazil Ice: *Fine spicules or plates of ice suspended in water.*

Grease Ice: *A later stage of freezing than frazil ice when the crystals have coagulated to form a soupy layer on the surface. Grease ice reflects little light, giving the sea a matte appearance.*

Slush: *Snow which is saturated and mixed with water on land or ice surfaces, or as a viscous floating mass in water after a heavy snowfall.*

Shuga: *An accumulation of spongy white ice lumps, a few centimeters across; formed from grease ice or slush and sometimes from anchor ice rising to the surface.*

Nilas: *A thin elastic crust of ice, easily bending on waves and swell and, under pressure, thrusting in a pattern of interlocking 'fingers' (finger rafting). Has a matte surface and is up to 10 centimetres in thickness.*

Ice Rind: *A brittle shiny crust of ice formed on a quiet surface by direct freezing or from grease ice, usually in water of low salinity. Thickness to about 5 centimetres. Easily broken by wind or swell commonly breaking into rectangular pieces.*

Young Ice: *Ice in the transition stage between nilas and first year ice, 10 to 30 centimetres in thickness. May be subdivided into grey ice and grey white ice.*

Grey Ice: Young ice 10 to 15 centimetres thick. Less elastic than nilas, and breaks on swell. Usually rafts under pressure.

Grey White Ice: Young ice 15 to 30 centimetres thick. under pressure more likely to ridge than to raft.

First Year Ice: Sea ice of not more than one winter's growth, developing from young ice; thickness from 30 centimetres to 2 metres or more.

Old Ice: Sea ice which has survived at least one summer's melt. Most topographic features are smoother than on first year ice. May be subdivided into second year ice and multi year ice.

Second Year Ice: Old ice which has survived only one summer's melt. Because it is thicker and less dense than first year ice, it stands higher out of the water. In contrast to multi year ice, summer melting produces a regular pattern of numerous small puddles. Bare patches and puddles are usually greenish-blue.

Multi Year Ice: Old ice up to 3 metres or more thick, which has survived at least two summers' melt. Hummocks even smoother than on second year ice, and the ice is almost salt-free. Colour, when bare, is usually blue. Melt pattern consists of large interconnecting irregular puddles and a well-defined drainage system.

Fast Ice: Sea ice which forms and remains fast along the coast, where it is attached to the shore, between shoals or grounded icebergs. Fast ice may be formed in situ from freezing of sea water, or by freezing of pack ice to the shore. It may extend a few metres or several hundred kilometres from the coast, and it may be more than one year old (second year or multi year fast ice).

Floe Sizes

Floe: Any relatively flat piece of ice 20 m or more across. Floes are subdivied according to horizontal extent as follows:

Giant Floe: Over 10 km across.

Vast Floe: 2 - 10 km across.

Big Floe: 500 - 2000 m across.

Medium Floe: 100 - 500 m across.

Small Floe: 20 - 100 m across.

Ice Cake: Any relatively flat piece of ice less than 20 m across.

Small Ice Cake: An ice cake less than 2 m across.

Brash Ice: Accumulations of floating ice made up of fragments not more than 2 m across; the wreckage of other forms of ice.

Ice Concentration Ranges

Consolidated Pack Ice: Pack ice with concentration 10 tenths and ice floes are frozen together.

Compact Pack Ice: Pack ice with concentration 10 tenths, no water is visible but floes are not frozen together.

Very Close Pack Ice: Pack ice with concentration 9 to 9+ tenths.

Close Pack Ice: Pack ice with concentration 7 through 8 tenths composed of floes mostly in contact.

Open Pack Ice: Pack ice with concentration 4 through 6 tenths, many leads and polynyas, and floes generally not in contact with one another.

Very Open Pack Ice: Pack ice with concentration 1 through 3 tenths; water preponderates over ice.

Open Water: Area of freely navigable water with less than 1 tenth ice present. There may be icebergs and growlers in the area.

Bergy Water: Area of freely navigable water with <u>no</u> sea ice but there are icebergs and growlers present.

Ice Free: No ice of any kind present in the area.

TOPOGRAPHY

$\frac{\Lambda\Lambda}{n}$	Rafted Ice
$\frac{\Lambda\Lambda\Lambda}{n}$	Ridged Ice
$\frac{\Omega\Omega}{n}$	Hummocks
n	Number of tenths

PRESSURE RIDGE DATA

$\frac{h_f}{h_x}$ — $\frac{\text{Mean Ridge Height (metres)}}{\text{Maximum Ridge Height (metres)}}$. frequency per nautical mile

■ Fast Ice

POND INLET, N.W.T.

OBSERVATION SITE: One mile north of Hudson Bay Co. Store.

DATE 1964	ICE THICKNESS (INCHES)	SNOW DEPTH (INCHES)	DATE 1965	ICE THICKNESS (INCHES)	SNOW DEPTH (INCHES)
Nov. 07	15.5		Apr. 03	54	6
Nov. 14	17		Apr. 10	55.5	6
Nov. 24	19.5		Apr. 17	56	6
Dec. 05	23		Apr. 24	57	6
Dec. 12	25		May 01	57	6
Dec. 19	26.5		May 08	58	6
Dec. 26	23		May 15	57	6
			May 22	56	6
1965			May 29	55.5	6
Jan. 02	24.5		June 05	56	6
Jan. 12	25		June 12	57	6
Jan. 16	36.5		June 19	56	6
Mar. 06	44.5	5.5	June 26	52	6
Mar. 13	47.5	6	July 03	41	6
Mar. 20	50	6	July 10	35	
Mar. 27	52	6	July 17	29	

POND INLET, NWT

OBSERVATION SITE: 1 Mile north of settlement.

DATE 1968	ICE THICKNESS (inches)	SNOW DEPTH (inches)	DATE 1968	ICE THICKNESS (inches)	SNOW DEPTH (inches)
Nov. 15	4.0	01	Dec. 13	19.0	03
Nov. 22	6.0	03	Dec. 20	24.0	06
Nov. 29	9.0	06	Dec. 27	26.0	06
Dec. 06	15.0	02			

POND INLET, N.W.T.

OBSERVATION SITE: One mile North of Settlement

DATE 1968	ICE THICKNESS (inches)	SNOW DEPTH (inches)	DATE 1968	ICE THICKNESS (inches)	SNOW DEPTH (inches)
Mar. 15	37.0	07	May 24	55.0	10
Mar. 22	38.5	08	May 31	55.5	10
Mar. 29	40.0	08	June 07	50.0	08
Apr. 05	41.5	08	June 14	47.0	06
Apr. 12	43.0	09	June 21	46.0	04
Apr. 19	44.0	10	June 28	45.0	00
Apr. 26	49.5	09	July 05	37.5	00
May 03	51.0	09	July 12	34.0	00
May 10	51.0	10	July 19	30.0	00
May 17	53.0	10	July 26	24.0	00

POND INLET, N.W.T.

OBSERVATION SITE: 1 MILE NORTH OF HUDSON BAY COMPANY POST

DATE 1970	ICE THICKNESS (inches)	SNOW DEPTH (inches)	DATE 1970	ICE THICKNESS (inches)	SNOW DEPTH (inches)
Mar. 08	36.0	04	Apr. 17	44.0	11
Mar. 13	37.0	06	Apr. 24	44.0	10
Mar. 20	40.0	07	May 01	46.0	10
Mar. 27	40.5	06	May 08	46.0	08
Apr. 03	42.0	07	May 15	45.0	10
Apr. 10	44.0	07	May 22	46.0	10
			May 29	46.0	10

POND INLET, N.W.T.

OBSERVATION SITE: 800 metres offshore. 320 degrees from R.C. church.

DATE 1975	ICE THICKNESS (inches)	SNOW DEPTH (inches)	DATE 1976	ICE THICKNESS (inches)	SNOW DEPTH (inches)
Dec. 05	19.0	2	Jan. 02	32.0	7
Dec. 12	24.0	3	Jan. 09	36.0	6
Dec. 19	27.0	4	Jan. 16	40.0	3
Dec. 26	29.5	7	Jan. 23	41.0	7
Dec. 31	31.0	7	Jan. 30	41.5	7
			Jan. 31	42.0	7
			Feb. 06	46.5	8
			Feb. 13	47.0	6
			Feb. 20	53.0	5
			Feb. 27	57.0	5
			Feb. 28	59.0	4
			Mar. 04	57.5	4
			Mar. 11	58.0	4
			Mar. 18	63.0	6
			Mar. 25	64.0	4
			Mar. 31	65.0	4
			Apr. 02	66.5	5
			Apr. 09	68.5	5
			Apr. 16	68.5	5.5
			Apr. 23	67.0	4.5
			Apr. 30	74.0	7
			May 07	72.5	5.5
			May 14	76.0	5
			May 21	77.0	5
			May 28	76.0	5
			May 31	76.0	5

First permanent new ice:

Freeze over: 30 Nov. 1975

First breaks or deterioration: 18 June 1976

Water clear of ice: 29 August 1976

POND INLET, N.W.T.

OBSERVATION SITE: Eclipse Sound. 800 meters NW from Southerly Church.

Date 1974	*Ice Thickness (inches)*	*Snow Depth (inches)*	*Date 1975*	*Ice Thickness (inches)*	*Snow Depth (inches)*
Dec. 20	32.0	3	Jan. 03	33.0	3
Dec. 27	32.0	3	Jan. 10	42.0	3
Dec. 30	35.0	3	Jan. 17	43.0	4
			Jan. 24	46.0	4
			Jan. 31	52.0	4
			Feb. 07	50.0	4
			Feb. 14	57.0	5
			Feb. 21	59.0	5
			Feb. 28	61.0	5
			Mar. 07	60.5	5
			Mar. 14	64.5	5
			Mar. 21	66.5	6
			Mar. 28	67.5	6
			Apr. 04	69.0	6
			Apr. 18	70.0	6
			Apr. 25	70.0	8

POND INLET, N.W.T./T.N.-O.

MEASUREMENT SITE: 800 metres offshore; northwest of H.B.C. store.
SITE DE MESURE: à 800 mètres de la rive, au nord-ouest du magasin de la compagnie de la Baie d'Hudson.

DATE 1977	ICE THICKNESS EPAISSEUR DE LA GLACE cm	SNOW THICKNESS EPAISSEUR DE LA NEIGE cm	DATE 1978	ICE THICKNESS EPAISSEUR DE LA GLACE cm	SNOW THICKNESS EPAISSEUR DE LA NEIGE cm
Nov. 05	17	02	Jan. 08	94	06
11	27	04	15	102	08
18	32	05	21	104	08
25	32	04	31	111	11
Dec/ 02	53	03	Feb/ 08	116	08
Déc. 09	66	03	Fév. 14	118	10
16	79	05	19	117	10
23	80	04	28	118	10
31	86	07	Mar/ 07	124	10
			Mars 12	108	10
			23	138	11
			29	141	17
			Apr/ 04	145	14
			Avr. 16	149	18
			28	152	17
			May/ 06	152	20
			Mai 11	155	21
			29	157	12
			Jun/Juin 05	156	30

First permanent new ice/
Première glace nouvelle permanente:
21 October/octobre 1977.

Total ice cover/
Couverture de glace totale:
21 October/octobre 1977.

First breaks or deterioration/
Premières fissures ou détérioration:
17 June/juin 1978.

POND INLET, N.W.T./T.N.-O.

MEASUREMENT SITE: Approximately 600 metres offshore, west of R.C. Church.

SITE DE MESURE: à environ 600 mètres de la rive, à l'ouest de l'église Catholique.

DATE 1976		ICE THICKNESS EPAISSEUR DE LA GLACE cm	SNOW THICKNESS EPAISSEUR DE LA NEIGE cm	DATE 1977		ICE THICKNESS EPAISSEUR DE LA GLACE cm	SNOW THICKNESS EPAISSEUR DE LA NEIGE cm
Oct.	15	20	03	Jan.	07	108	19
	27	32	03		14	111	22
	29	32	05		21	112	20
	31	33	05		28	114	25
Nov.	05	42	10	Feb/	04	119	23
	12	42	09	Fév.	11	119	28
	19	51	10				
	26	62	05				
Dec/	03	67	08				
Déc.	10	78	08				
	17	81	09				
	24	91	10				
	31	93	18				

Date of/Date de: 1976

First permanent new ice/
Première glace nouvelle permanente:
07 October/octobre.

Total ice cover/
Couverture de glace totale:
22 October/octobre.

Date of/Date de: 1977

First breaks or deterioration/
Premières fissures ou détérioration:
15 June/juin.

Water clear of ice/
Eau libre de glace: 30 July/juillet.

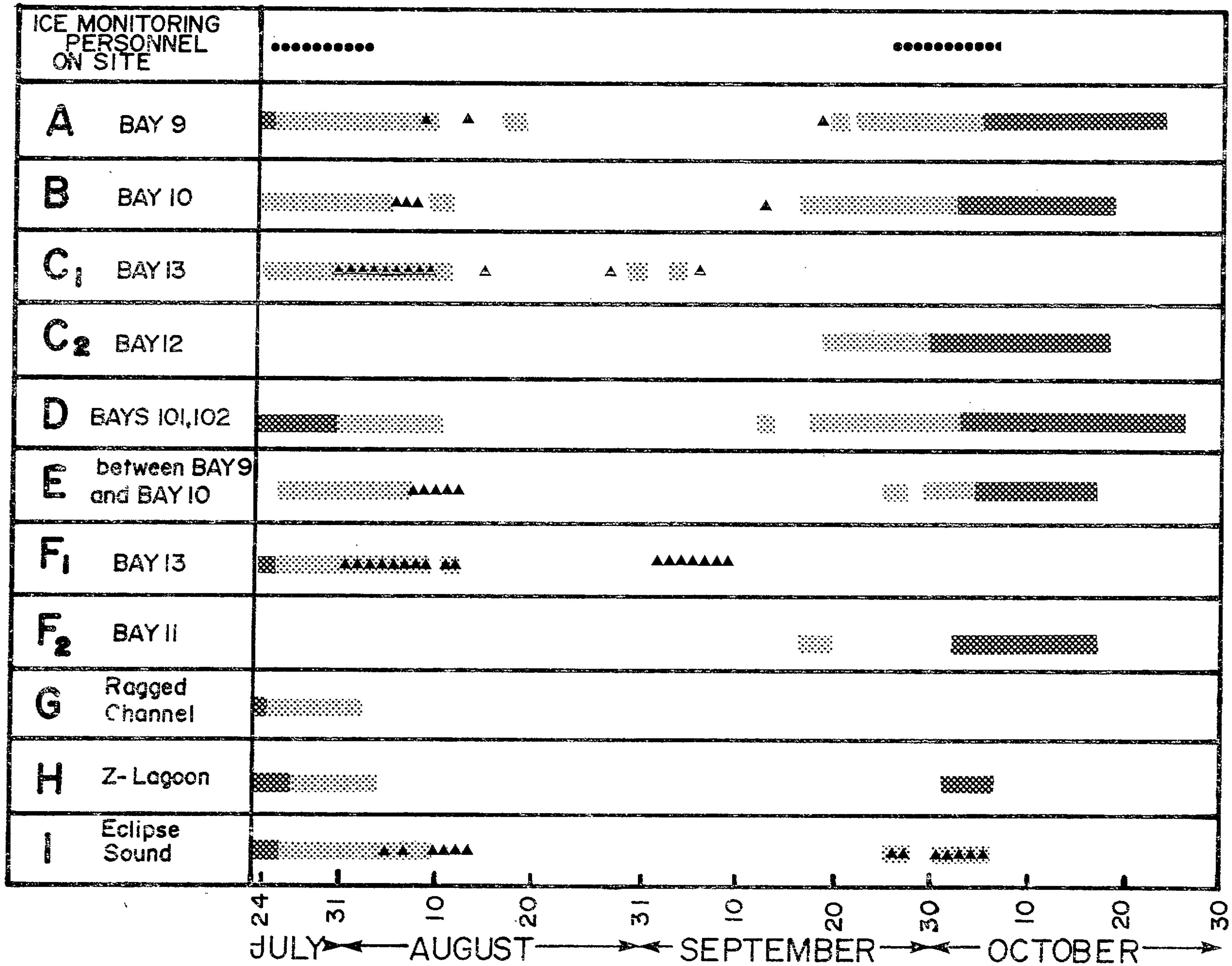


Figure B-1 Ice Condition Summary for each Camera Station

Dark Shading - solid ice cover, Light Shading - broken ice floes, ▲ - iceberg in field of

Plate B-1 Landsat Image of August 5, 1980 showing open water conditions in Eclipse Sound. Note how a NW wind could easily bring loose floes from Navy Board Inlet into Ragged Channel.

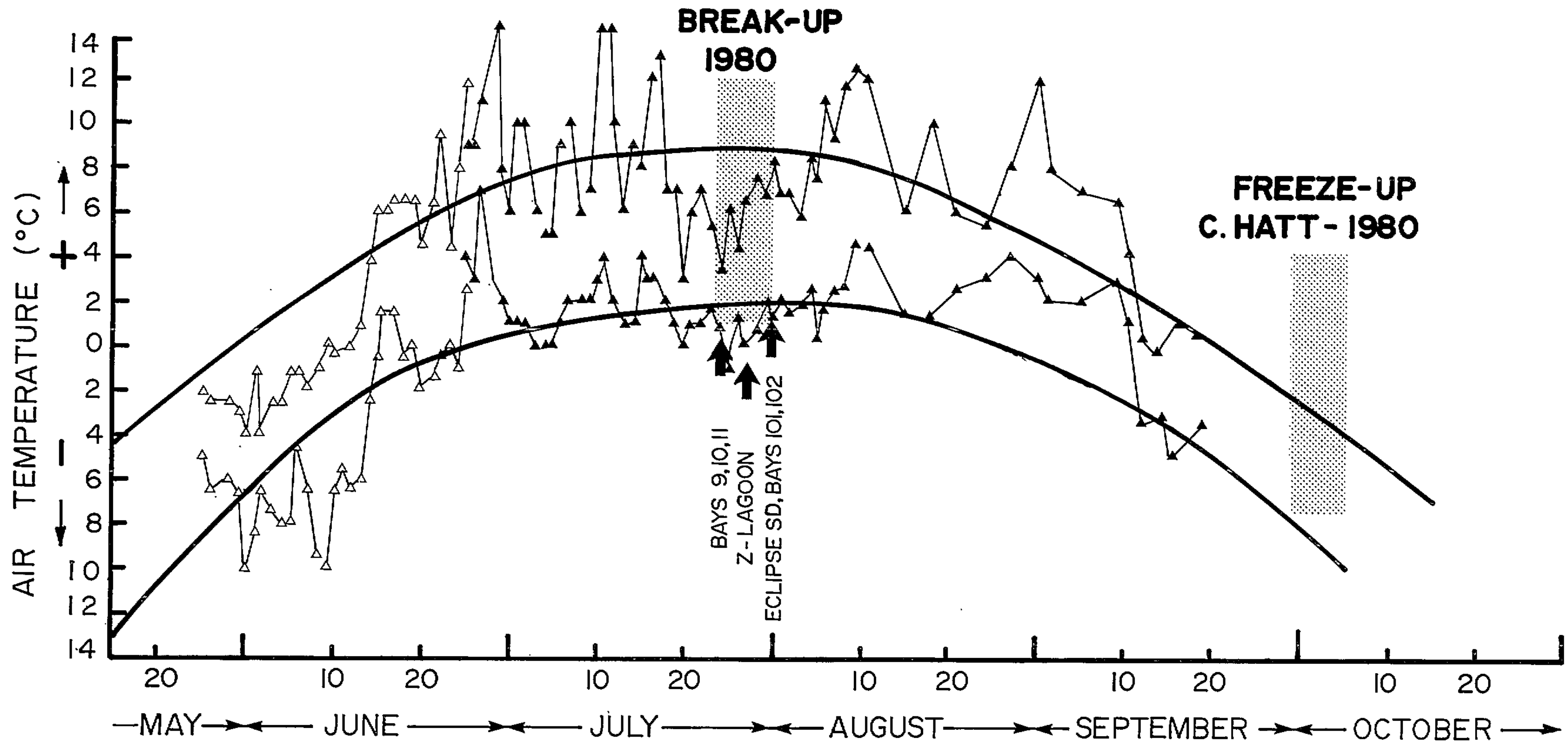


Figure B-2 Air Temperatures (max/min) compared to Break-up and Freeze-up at Cape Hatt, May to October 1980.

Note: June 22 to July 26 temperatures are from Pond Inlet

Smooth curves represent Pond Inlet Historical Normals

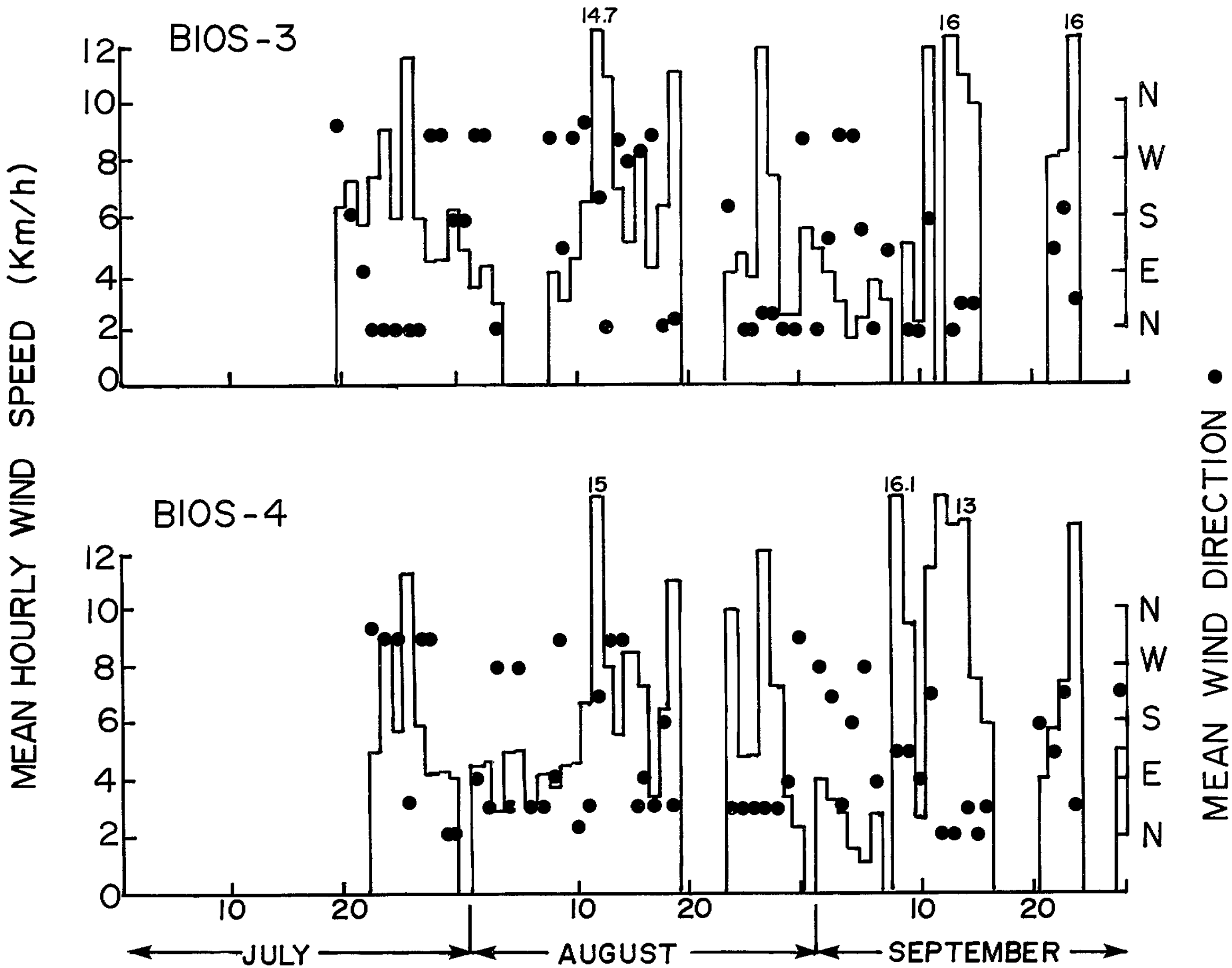


Figure B-3 Ragged Channel Wind Speeds and Direction, Break-up to Freeze-up, 1980

BIOS-3 is Bay 14, BIOS-4 is Bay 12

Climatological Table — POND INLET Latitude 72°43′ N Longitude 77°30′ W

Month	MSL Pressure (kPa)	Air Temperature: Daily Mean (°C)	Mean of Daily: Max. (°C)	Mean of Daily: Min. (°C)	Mean of Monthly: Max. (°C)	Mean of Monthly: Min. (°C)	Absolute Extremes: Highest Recorded (°C)	Absolute Extremes: Lowest Recorded (°C)	Mean Relative Humidity (%)	Precipitation: Mean Total (mm)	Max. Fall in 24 Hrs. (mm)	Mean Snowfall (cm)
January	[illegible]	−30.9	−26.4	−35.3	−15.0	−44.4	0.0	−48.9		5.6	7.6	5.6
February	101.6	−32.3	−27.7	−36.9	−16.1	−46.1	2.2	−53.3		8.1	19.1	7.4
March	101.7	−30.8	−26.9	−34.7	−12.8	−44.4	0.0	−48.3		6.9	19.1	6.9
April	102.1	−21.6	−17.1	−26.0	−6.1	−35.0	6.1	−42.2		4.6	16.5	4.6
May	101.9	−8.8	−4.4	−13.2	3.9	−24.4	8.9	−31.7		14.2	10.4	14.2
June	101.2	1.3	4.3	−1.7	11.7	−6.7	17.2	−12.2		7.6	9.9	5.1
July	100.8	5.1	8.6	1.5	15.0	−1.7	20.0	−6.1		25.9	23.6	0.0
August	101.0	4.7	7.8	1.6	12.8	−1.1	17.2	−3.3		21.6	58.4	1.5
September	101.1	−1.1	1.4	−3.6	7.8	−10.0	15.6	−17.8		19.3	24.6	11.4
October	100.9	−10.3	−7.2	−13.3	1.1	−22.2	7.2	−28.9		16.3	20.3	15.5
November	101.3	−21.2	−17.4	−24.8	−5.6	−35.6	3.9	−46.1		10.9	10.2	10.9
December	101.4	−28.2	−24.2	−32.2	−13.3	−41.7	0.0	−46.7		5.3	15.2	5.3
Mean	101.3	−14.5	−10.8	−18.2								
Extreme or Total							20.0	−53.3		146.3	58.4	88.4
Period of observations	1941 to 1954	1941 to 1970			1922 to 1960		1941 to 1970					

Month	Number of Days with: Rain ≥ .25 mm	Snow Depth ≥ .25 cm	Frost	Fog (vis. ≤ 1 km)	Gale (≥ 34 knots)	Thunder	% of Time: Clear Sky (≤ 2/10)	Overcast (≥ 8/10)	Cloud Amount Tenths of Sky Covered: 0600 GMT	1200 GMT	1800 GMT	0000 GMT
January	0	5	31	1		0	47	33		4.7		3.4
February	0	3	28	1		0	54	27		4.2		3.1
March	0	4	31	*		0	58	30		4.0		3.6
April	0	2	30	0		0	58	32		3.0		3.7
May	*	5	31	1		0	28	57		6.6		6.4
June	1	3	22	1		0	24	56		6.7		6.3
July	6	0	6	1		0	24	54		6.5		6.6
August	5	*	5	*		0	19	59		7.0		6.8
September	2	4	23	1		0	11	66		7.8		7.4
October	*	6	31	*		0	16	59		7.6		6.6
November	0	5	30	1		0	28	50		6.7		5.3
December	0	3	31	1		0	45	33		4.9		3.8
Mean							34	44		5.8		5.2
Extreme or Total	14	40	299	x		0						
Period of observations	1941 to 1970			1942 to 1952 (BREAKS)			1942 to 1952 (BREAKS)					

Month	Wind Direction, Percentage Frequencies: N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
January																	
February																	
March																	
April																	
May																	
June																	
July																	
August																	
September																	
October																	
November																	
December																	
Mean																	
Extreme or Total																	
Period of observations																	

Altitude above MSL — 3.1 metres

* Average less than 0.5

APPENDIX C

FIELD NOTES

July 22

- Dave Dickins and Robin Brown departed Pond Inlet by helicopter for Cape Hatt. Eclipse Sound ice sheet intact but there is a wide area of open water along the shore in the vicinity of Pond Inlet (see photos 2-1, 2-2). The ice sheet in Eclipse Sound showed several major leads (2-4, 2-5). Narwhales were observed in these leads. Some of the leads were radiating from the positions of large ice bergs (2-8). The ice sheet in Ragged Channel was still basically intact, but some open areas as the NE end (2-28, 3-6, 3-8) and at the extreme south end of Ragged Channel were present. In addition there were narrow bands of open water (5-10 m wide) seaward of the tidal crack at beaches 13, 12, 11 and 10 (3-11). In bays 13 and 14 we observed gravel berms at the shoreline that were covering mounds of ice (2-23, 2-17). Just offshore from this berm were pieces of ice with an extensive layer of gravel incorporated in them (2-36). In some cases, there was sufficient gravel incorporated to submerge the ice floe.

July 23

- assembled nine time lapse camera systems at camp.

July 24

- installed camera F at Bay 13 (looking north, see 3-26). This camera was equipped with a 4 min timer (one frame every 4 mins)
- installed camera G above Bay 14, looking south over Ragged Channel (see 3-33). This camera was equipped with an 8 min timer.
- installed camera B, looking south over Bay 10 (see 6-24). This camera was equipped with a 4 min timer.

Note: Numbers in text indicate slides on file

- installed camera A looking north over Bay 9. This camera was equipped with a 4 min timer.

- installed camera I on the north face of the mountain at approximately 300 m altitude. This camera looks north over Eclipse Sound and Navy Board Inlet (see 4-2). This camera was equipped with an 8 min timer.

- installed camera D overlooking Bays 101 and 102 (4-8). This camera was equipped with an 8 min timer.

- the ice sheet in Ragged Channel was still essentially intact, but the open water area to the south has enlarged and areas of open water in central Ragged Channel (in the vicinity of Bays 13 and 14) were apparent (3-34, 4-1)

- some minor compression and rafting features were noted in the vicinity of Bays 101 and 102 (4-8, 4-9, 4-10).

July 25

- installed camera E, looking NW from the delta between Bay 9 and 10 (4-19). This camera was equipped with a 1 min timer. An orange marker was placed on the ice to look at the movement of an ice block that was observed to contain a layer of gravel and sediment.

- ice cored gravel berms were observed almost continuously from Bay 11 to Bay 9 (4-11, 4-14, 4-15, 4-16, 4-17, 4-18, 4-19, 4-21, 4-22, 4-23, 4-24).

- of particular interest was the large rock sitting on submerged ice (4-24).

- the ice in Ragged Channel in the vicinity of Bays 9 and 10 was beginning to break up (4-28).

- installed camera C, looking west between Bays 13 and 14 (1 min timer).

- inspected camera F

- the ice is beginning to clear away from the beaches in Bays 14, 13, 12 and 11 (4-30, 4-31, 4-34, 4-36, 5-5, 5-9, 5-13). with extensive areas of open water in Ragged Channel, north of Bay 10 (5-18, 5-22, 5-23, 5-24).

- ice cored gravel mounds observewd at Bays 13 (5-2, 5-3, 5-4) and between Bay B and Bay 12 (5-12).

-Z lagoon ice sheet still essentially intact, but there has been considerable melting at the western end (5-14, 5-17).

July 26

- ice cored gravel mounds observed along south shore of Z lagoon (Bays 105 and 104, see photos 5-27, 5-28, 5-29). Some incorporation of beach sediments into the ice was also observed (5-25).
- inspected camera D - battery voltage = 5.8 v
- ice piled up on the point between 101 and 102 to a height of approximately 3.5 m (5-31). Large pile ups also present over the reef in Bay 102 (5-34, 5-35, 5-36, 5-37).
- inspected camera G
- strong NE wind carried all the loose ice out of Bays 14, 13, 12, 11, 10 and the northern half of Bay 9. The open water area at the southern end of Ragged Island has closed. A stable ice edge was formed running from Ragged Island to Cape Hatt, touching the south tip of the unnamed island that divides Ragged Channel (6-1 to 6-9).
- the NE wind also appeared to move extensive open water area south down Navy Board Inlet to within 7-15 km of Cape Hatt.
- inspected camera C; orange marker in foreground has gone.
- inspected camera F.

July 27

- inspected camera G; battery voltage = 5.71 v; footage = 5 ft.
- large ice sheet has moved south from between Ragged Island and the unnamed island to a point opposite Bay 14 (compare 6-10, 6-11, 6-12, 6-13 with 6-4, 6-5, 6-6, taken the previous day).
- inspected camera C; voltage = 5.77 v; footage = 32 ft.
- thin film of ice on the water due to low temperatures during the night.

- inspected camer B; voltage = 5.69 v; footage = 40 ft (6-24, 6-25, 6-26 show the distribution of loose ice)
- inspected camera A; 5.65 v
- the orange marker originally put out at the south end of Bay 10 (in the view of camera E, July 25) has moved to the south end of Bay 9, in the view of camera A.
- inspected camera H; voltage = 5.58 v
- inspected camera E; new film installed (#2). Timer changed from 1 min to 4 min.
- helicopter survey of ice distribution undertaken (7-11 to 7-35)

July 28

- D. Dickins left.
- inspected camer G
- inspected camera C; camera had stopped running (reason unknown). New film installed (#2) and timer changed from 1 min to 4 min.
- inspected camera F; footage = 20 ft.
- considerable amount of ice stranded at the south end of Bay 13 (8-8 to 8-16).
- hiked to Bays 106 and 107 (Z lagoon). The ice sheet in the lagoon in still fairly solid, with approximately 5-10 miles of open water between the ice and shoreline (8-17, 8-18, 8-19, 8-20, 8-21, 8-22).
- inspected camera G; voltage = 5.62 v; footage = 9 ft.

July 29

- Bay 11 - considerable loose ice (both floating and stranded (8-28, 8-29)
- inspected camera B; voltage = 5.54 v; footage = 16 ft. Bay 10 has very little ice (8-30, 8-31).
- inspected camera E; voltage = 5.57 v; footage = 5 ft.
- stranded ice is concentrated on the north-facing beaches of Bay 9 and 10 (9-16, 9-8). Some of the stranded ice shows layers of gravel and sediment (9-9, 9-

10, 9-12, 9-13, 9-14).

- inspected camera A; 5.52 v; footage = 21 ft. Slight amount of condensation inside. The filter was removed.
- inspected camera H; voltage = 5.48 v; footage = 13 ft. Plastic cover repaired. Some condensation on inner face. Filter removed.
- inspected camera I; voltage = 5.5 v; footage = 5.5 ft.
- helicopter survey of local ice conditions; northern end of Ragged Channel showed large floes breaking up into smaller chunks (9-19). The larger floes were more apparent in Eclipse Sound to the north of Cape Hatt (9-20, 9-21, 9-22, 9-23). Area immediately offshore of the entrance to Z lagoon and Bays 101 and 102 is still covered by a solid ice sheet (9-25). Central area of Ragged Channel (opposite Bays 11, 12 and 13) was almost entirely clear of ice (9-33, 9-34, 9-35, 10-1, 10-2, 10-3, 10-4).

July 30

- made up battery harnesses for unattended camera operations
- SW wind has moved ice north in Ragged Channel, essentially reversing the distribution of ice in Ragged Channel. Bays 9, 10, 11, 12 and 13 are covered in loose ice (mostly small pieces - 1 to 3 m in size). The south end of Ragged Channel is clear (10-5, 10-6, 10-7, 10-35, 10-36, 10-37 and 11-1 to 11-7).
- the ice to the NE of Cape Hatt has begun to break up. Large areas of open water extend along Bylot Island almost as far west as the 'corner' of Navy Board Inlet and Eclipse Sound (10-10 to 10-28).
- the ice sheet offshore from Bays 101 and 102 moved further offshore creating an area of open water along the shore and in front of the entrance to Z lagoon (10-30 to 10-34).
- inspected camera H; voltage = 5.38 v; no condensation
- inspected camera G; voltage = 5.51 v; some condensation - so the filter was removed, dried and reinstalled (photos 11-1, 11-2, 11-3, 11-4 show the general distribution of ice in Ragged Channel taken from camera G position)
- inspected camera C; voltage = 5.50 v

- inspected camera F; voltage = 5.46 v
- loose ice was blown out of Z lagoon by SW winds, but there is still a large ice sheet covering most of the lagoon

July 31

- there was a band of stranded ice approximately 50 m wide in the intertidal area of Bay 102. This stranded ice showed signs of rafting and piling (11-12, 11-14, 11-13, 11-15, 11-16, 11-17). Jean-Marie Semples reported that this piling and rafting was evident in the spring prior to the melt period.
- some pieces of ice showed multiple layers of gravel and sediment incorporated (11-17).
- ice-cored gravel mounds were also observed at Bay 102 (11-22, 11-26)
- inspected camera D; voltage = 5.44 v; footage = 15 ft.
- inspected camera F; voltage = 5.47 v
- Bays 11 and 12 are mostly filled with loose ice (due to the SW winds)
- inspected camera C; voltage = 5.49 v
- ice berg grounded off weather station point (12-15, 12-19)
- inspected camera G; voltage = 5.59 v. Considerable condensation inside the filter, so it was dried and replaced.

August 1

- checked out I.R. spectrophotometer and called Dave Green.
- ice samples taken from Bay 12 from floating ice and buried ice for comparison of salinities
- inspected camera G; voltage = 5.49 v. There was a lot of condensation on the filter so I removed the filter to see if this might prevent the fogging.
- very little ice is left in Ragged Channel (12-11, 12-12, 12-13, 12-14, 12-5)
- inspected camera C; voltage = 5.44 v
- inspected camera F; voltage = 5.42 v

August 2

- very clear weather, blue sky
- helicopter survey of area undertaken. Very little ice remained in Ragged Channel (12-23 to 12-30 and 13-20 to 13-21)
- some ice remained in Miline Inlet (12-31, 12-32)
- there was relatively little ice in Navy Board Inlet and eastern Eclipse Sound (12-32 to 12-37 and 13-1 to 13-12)
- loose ice moved into Bays 101 and 102 (13-12 to 13-16)
- inspected camera B; voltage = 5.38 v. Condensation on filter, so it was removed and the filter replaced.
- inspected camera E; voltage = 5.38 v
- inspected camera A; voltage = 5.36 v.

August 3

- inspected camera H; timer changed from 8 min to 16 min. Two more batteries added. Film changed (#2 installed).
- inspected camera I; timer changed from 8 min to 16 min. Two more batteries added. Film changed (#2 installed), footage = 22 ft.
- inspected camera D; footage = 22 ft. New film installed (#2) and new battery pack (3 new batteries plus 1 old battery) attached.
- inspected camera E; footage = 28 ft. Timer changed from 4 min to 8 min. New film installed (#3). One new battery attached.
- inspected camera A; footage = 44 ft. New film installed (#3) and new battery pack (3 new plus 1 old) attached.
- inspected camera B; footage = 35 ft. New film installed (#2) and new battery pack (3 new batteries) attached.
- inspected camera F; footage = 50 ft (fully exposed). New film installed (#2) and battery pack (1 old plus 3 new) attached
- inspected camera C; footage = 26 ft. New film installed (#3) and battery pack (1 old and 3 new) attached.
- inspected camera G; footage = 20 ft. New film (#2) and battery (1 new) attached.

- ice sheet in the inner area of Z lagoon is still intact (15-7, 15-11) but the ice in the entrance channel is broken up (15-13, 15-8).
- Ragged Channel had very little ice remaining (15-17 to 15-25)
- there was relative little ice remaining in Eclipse Sound (15-16, 15-31, 15-32, 15-34, 15-35).

Camera maintenance by Camp Staff between August 3 and September 26

August 13

- changed film in camera B

August 14

changed film in cameras F and C

August 17

- protective conduit fitted to camera C power supply

August 23

- changed film in cameras B, A, F, C, D

August 25

- protective conduit fitted to camera F battery pack

August 26

- protective conduit fitted to camera G battery pack

September 3

- film changed in cameras B, F and C

<u>September 9</u>

- cameras F and C moved to new positions designated as F_2 and C_2.

<u>September 13</u>

- changed film in cameras B, A, F, C, D

<u>September 25</u>

- R. Brown arrived in Pond Inlet. Helicopter flight from Pond Inlet to Cape Hatt
- there was essentially no ice present in Eclipse Sound except some icebergs (16-7, 16-8, 16-9, 16-10, 16-11).

<u>September 26</u>

- inspected camera D; footage = 28 ft., voltage = 5.24 v. The clock was approximately 15 minutes slow.
- there was a large iceberg grounded off Bay 102 (16-11, 16-13, 16-20)
- gravel beach of Bay 101 seemed very steep, compared to the ice breakup period
- "bands" of floating ice (small pieces) are evident parallel to shore (16-13, 16-14) perhaps indicating some current action that is concentrating them.
- there was a lot of stranded ice on the beach of Bay 102. Ice fragments were 1 to 2 m thick and covered 50-60% of the intertidal area (16-15, 16-16).
- a small ice foot was beginning to form just above high tide line (16-16, 16-17, 16-18?). This ice foot is 1 to 2 m wide and 30-60 cm thick.
- inspected camera I; camera had failed when the battery pack wires were eaten through. Footage was stopped at 20 ft.
- inspected camera C_2 in its new position looking north over the intertidal area of Bay 11. Film #7 for this camera was completed and replaced with #8. Battery voltage was 5.09 v. Photos 16-22, 16-23 show the conditions in Bay 11 at this date.
- inspected camera H; footage = 5 ft., battery voltage was 4.6 v so the batteries were replaced. This camera apparently failed during the unattended period -

but a test showed that the film would advance properly.

- inspected camera A; footage = 20 ft., voltage = 5.3 v. Very little ice present in this area and there is no evidence of an ice foot. Note that the orange marker used to track an ice floe in July is visible 10-15 metres seaward of the high tide line.

- inspected camera E; roll was fully exposed so a new film (#8) was installed (#4), voltage = 1.3 v so the battery was replaced

- inspected camera B; footage = 40 ft. The last film change was on September 13, so it should have run out by this time. I replaced the battery pack (old battery voltage = 5.08 v).

- inspected camera G; (footage = 50 ft - so this film was removed). The lens of this camera showed fogging within the elements so the camera was removed for drying.

- more ice was present at the north end of Ragged Channel than the south end.

<u>September 27</u>

- inspected camera D; removed snow from lens

- revived camera I by installing a repaired 16 min timer and a new battery

- inspected camera E; footage = 2 ft., the clock was approximately 20 minutes slow

- inspected camera A; voltage = 5.28 v. Some snow was removed from the lens

- inspected camera B; footage = 45 ft. so the film was changed (#7 installed)

- inspected camera F; looking south over Bays 11 and 12 (see photo 16-30); battery voltage = 5.13 v.

- reinstalled clock on camera C; clock is 1 hour slow.

- inspected camera H; voltage = 5.83 v. Some snow was removed from the lens.

<u>September 28</u>

- most of the morning spent on the beach in Bay 11 collecting samples for Bill Barrie (16-31 to 16-37 and 17-1 to 17-9)

- helicopter survey in afternoon

- loose ice concentrated in northward facing unbayments of Ragged Island, Cape Hatt and Curry Island (17-15).

- there was very little ice in Ragged Channel (17-10, 17-11, 17-12, 17-13).
- within Ragged Channel, there were high concentrations at the north end
- no ice-cored gravel berms have been observed at Bays 11, 13, 14, 106, 101 and 102.

September 29

- 0815, Bay 11 - air temperature = 13.3 KΩ = 5.8°C;
  water temperature = 10.66 KΩ = -1.64°C
- moderate SW wind, lots of floating ice grounded in Bays 11 and 12 (17-27 to 17-30)
- inspected camera C; voltage = 5.09 v.
- collected more samples for Bill Barrie (17-20 to 17-30)
- excavated gravel berm in Bay 11 to a depth of approximately 2 ft. - no ice core was detected.
- in Bay 13, there was a band (approximately 70 m wide) of floating ice pushed against the shore by the wind. Grease ice was observed to be forming from the shore out to about 1/3 of this distance.
- no sign of ice cored mounds in Bay 13.
- Bill Werner notes that he encountered parallel ice ridges in the gravel area where he built the loading dock (west of Bay 12). These parallel ridges of ice were located under parallel gravel mounds (above high tide level)
- overheard from Polar Haf: grease ice forming extensively in Lancaster Sound
- conversations with Mark Gilbert (helicopter pilot): shore-fast ice (approximately 1/4 mile wide) forming near north end of Navy Board Inlet in the vicinity of Tay Bay.
- very little ice in Eclipse Sound, especially between Cape Hatt and Pond Inlet.

September 30

- 0800-0830. helicopter reconnaissance. Ice beginning to form at the east end of Z lagoon (Bay 103). Grease ice is beginning to form in amongst the ice floes stranded at Bays 10, 11, 12 and 13 (18-3, 18-5).
- 0830. inspected camera A; footage = 26 ft; voltage = 5.23 v
- walked the length of Bays 9 and 10 plus the beach between Bays 10 and 11 looking for ice cored mounds in the intertidal zone. The tide was low. I dug down in several places, but did not encounter any buried ice. No distinct gravel mounds were present.

Bay 9 profile:

(18-6, 18-7, 18-8, 18-9, 18-10)

The beach seemed steeper than I remembered from the July/August trip. The gravel berm (at and above high tide) had no ice core. There was an ice foot forming at a level lower than the high tide level - possibly this ice could then be buried by the loose gravel from above - however this does not explain how large rocks could end up on top of the ice core.
- 17-37, 17-38 show this beach profile and the beginnings of the ice foot formation
- 18-1 to 18-5 show grease ice forming and early stages of ice foot development at the north end of Bay 9
- 18-9 and 18-9 show an unstable (eroding) gravel face being stabilized by the formation of the ice foot. These shots were taken on the delta between Bays 9 and 10.

October 1

- the wind has been blowing fairly hard from the SW. The wind is much reduced.
- 0830, inspected camera H; footage - 6 ft (suspect malfunction as September 26 footage = 5 ft, therefore check this camera!); voltage = 5.40
- date
- 0840, inspected camera I; footage = 35 ft; voltage = 5.39 v; date
- 0852, inspected camera D; footage = 40 ft; voltage = 5.05 v; date
- from these high points, I noticed that new ice was forming to the NE of Cape Hatt (approximately 5 nautical miles away). The visibility was poor, and hence it was difficult to establish the extent of this new forming ice.
- 18-26 to 18-33 show this new ice forming in Eclipse Sound
- 18a-1 to 18a-15 were taken from the helicopter and show ice forming in Z lagoon and offshore from Cape Hatt (other beaches - 9, 10, 11, 12, 13, 14 also photographed, as this was the best weather so far and very little ice activity has been noted since my arrival, 18a-16 to 18a-34)
- 1130 , inspected camera C; footage = 20 ft; voltage = 5.02 v; date
- in Bays 11 and 12 there was approximately 2 to 3" of fresh ice in the intertidal with new sea ice forming from the low tide mark out to about 5 m from this (in amongst the ice floes). The end frames of 18a show Bay 11 intertidal and new ice forming (18a-34 to 18a-38).
- 1200; inspected camera F; footage = 20 ft; voltage = 5.05 v; date. From camera F location, it appears that new ice is forming extensively at Bay 9 and under cliffs further south of Bay 9. Ice is only forming in the interstices of the floe ice in Bays 11 and 12.
- 1300; trip to Z lagoon; fresh ice is forming extensively - westerly winds are carrying this thin film of ice to the east, such that all west-facing bays are accumulating this newly frozen, slushy material. The intertidal zone in Z lagoon has approximately 2 inches of ice crystals throughout - the characteristics of the ice are much different than that observed in Bays 11 and 12. The Z lagoon intertidal ice is made up of large, frail crystals on rocks (mostly) whereas the ice in Bays 11 and 12 forms more of a layer.

- In Z lagoon some submerged ice is visible (where the ice has frozen onto rocks at low tide, and being flooded as the tide rises).

-19-3 to 19-10 are photos of the intertidal area of Z lagoon. All these photos were taken on the south shore - near the weather station.

<u>October 2</u>

- 0820; inspected camera A; footage = 30 ft; voltage = 5.21 v; date

- 0830; inspected camera E; footage = 5 ft (change to 4 min timer); clock is 20 minutes slow; voltage = 5.31

- 0845; inspected camera B; footage = 14 ft; voltage = 5.31; date; clock is 15 minutes slow

- 0855; inspected camera C; footage = 25 ft; voltage = 4.99 v - replaced battery pack with a single battery

- 0900; inspected camera F; footage = 21 ft; voltage = 4.04 v; date

- 0915; inspected camera H; footage = 5 ft; suspect timner malfunction so I changed it to an 8 min timer (the one from camera E); voltage = 5.31 v; clock is 20 minutes slow.

- 0930; inspected camera D; footage = 42 ft; voltage = 5.03 v; date; clock is 15 minutes slow

- 0940; inspected camera I; footage = 37 ft; voltage = 5.38 v; date

- 19-11 to 19-36 - show the ice distribution on and around Cape Hatt. Note there was floating ice to the NE of Cape Hatt, also in Bays 11, 12 and 13. Z lagoon was mostly covered by new ice.

- Roll 20 (B & W) was taken as we travelled around to dismantle the weather stations

- Roll 21 (Vericolour II) shot for scenery Thursday afternoon in the short session of sunny weather.

October 3

- after a clear, sunny late afternoon on October 2, the weather has returned to the gray, cloudy, snowy norm. The winds are light (5-7 knots) from the NW (down Navy Board Inlet). Ceiling is approximately 1100 ft and visibility was 4-6 nautical miles.

- 0845; inspected camera A; date; clock is approximately correct; footage = 32 ft (+ 2 ft from October 2); voltage = 5.19 (down from 5.21 yesterday)

- there is little ice forming on the beach at Bay 9, but some ice is forming mid-channel directly offshore from Bays 9 and 10. This ice is very thin grease ice and is being broken up and carried south by the wind. There should be some shots of this near the end of film 21.

- 0850; inspected camera E; date; note that the clock is approximately 20 minutes slow; footage = 8 ft (from 5 ft yesterday); voltage = 5.26 v (from 5.31 yesterday)

- 0903; inspected camera B; date; footage = 15 ft (+ 1 ft from yesterday) so check it tomorrow. This seems to be too little (with 8 min timer - film should advance approximately 2 ft/day) so I switched the timer to N. Film seemed to advance properly; voltage = 5.24 v (from 5.31 v yesterday)- the clock is approx. 15 minutes slow- some ice is forming at the north end of Bay 10

- 0915; inspected camera C; date; footage = 30 ft (from 25 ft yesterday); voltage = 5.79 (from 6.2 (warm) yesterday); clock is 1 hour slow

- 0920; inspected camera F; date; footage = 30 ft (from 21 ft. yesterday); voltage = 5.03 v (from 5.04 yesterday); clock is approx. 7 minutes slow

- 0935; inspected camera D; date; footage = 43 ft (from 42 ft yesterday); voltage = 5.03 v (from 5.03 v yesterday); clock is 20 minutes slow

- 0945; inspected camera I; date; lens and cover are covered in ice crystals; footage - 40 ft (from 37 ft yesterday); voltage = 5.32 v (from 5.38 v yesterday)

- 1000; inspected camera H; date; lens and cover are covered in ice crystals; footage = 7 ft (from 5 ft yesterday); voltage = 5.24 v (from 5.31 v yesterday); clock is 20 minutes slow.

- Following the camera inspection, we make a survey of the area by helicopter. Poor visibility resulted in only the near area being covered (Ragged Channel and the area to the north of Cape Hatt). The ice layer in Z lagoon is pretty much intact in the area shaded on the sketch map. There is a bit of new forming ice extending towards Cape Hatt from Eclipse Sound.

- There does not seem to be any ice forming at 101, 102. A small amount of ice has formed at Bay B and it extends around the point to Bays 12 ans 11 where there is considerable ice formed - both within the stranded floe ice and reading seaward. The photos should illustrate this (22-2 to 22-13).

October 4

- George Koenig arrived Friday p.m. Camp to shut on Saturday. CF-KOE goes to Pond Inlet first thing in the morning to bring out John Hunt, Petro-Canada (E.S.A.) and Jako Japuti (deputy major - Clyde River) to check oil spill site. Paul Idlout arrives with them. I took Paul Idlout with me to show him the camera locations.

- 1000; inspected camera A; date; took out cassette to show Paul - so the cassette new counter re-zeroed itself. October 3 footage = 32 ft therefore estimated October 4 footage = 34 ft. For subsequent days, total footage for this camera is equal to 34 ft + footage reading; voltage = 5.19 (from 5.19 on October 3)

- 1010; inspected camera E; date; footage = 10 ft (from 8 ft October 3); voltage = 4.83 v (from 5.26 v October 3)

- 1015; inspectewd camera B; date; footage = 17 ft (from 15 ft October 3); voltage = 5.22 (from 5.24 October 3)

- 1025; inspected camera C; date; footage = 33 ft (from 30 ft yesterday); voltage = 5.66 v (from 5.79 v yesterday)

- 1030; inspected camera F; date; footage = 30 ft, no advance from previous day! (from 5.03 v yesterday)

- 1040; inspected camera I; all frosted up, cleaned lens; footage = 40 ft (from 40 ft yesterday), no advance from yesterday; voltage = 5.26 v (from 5.32 yesterday)

- 1035; inspected camera D; footage = 45 ft (from 43 ft yesterday); voltage = 5.03 v (from 5.03 yesterday). Slush ice is forming extensively in Bay 101, but not in Bay 102 (see photos) (22-23)

- 1050; inspected camera H; all frosted up; footage = 10 ft (from 7 ft yesterday); voltage = 5.18 v (from 5.24 v yesterday)
- aerial photos to cover this area are 22-14 to 22-31
- flew to Pond Inlet - ice is forming in various areas, but there is still lots of open water and the new ice is not much more than slush

October 5

- Snowing heavily at Pond Inlet - helicopter flight to Cape Hatt delayed due to malfunction in gas producer gauge. Poor visibility between Pond and Cape Hatt, but it was clear (for a short time) at Cape Hatt. The wind was blowing out of the inlets fairly strongly (south wind at 10-15 knots). This has moved some of the slushy, newly formed ice from thesouth shore of Eclipse Sound and towards the centre of the channel. It is impossible to get an idea of the general distribution of ice in Eclipse Sound due to the persistent poor visibility.
- 1135; inspected camera D; date; clock is 20 minutes slow; footage = 47 ft (from 45 ft yesterday); voltage = 5.02 v (from 5.03 v yesterday)
- Bay 101 has slush ice cover but not Bay 102. Very little ice foot build-up is evident here, due to lack of strong winds from the north.
- 1145; inspected camera I; date; all frosted up, so I cleaned the lens; footage = 41 ft (from 40 ft yesterday - slight advance); voltage = 5.20 v (from 5.18 v yesterday)
- 1155; inspected camera H; date; all frosted up; footage - 12 ft (from 10 ft yesterday); voltage = 5.13 v (from 5.18 v yesterday)
- 1205; inspected camera A; date; footage = 2 ft (from 0 + 34 ft yesterday); voltage = 5.13 v (from 5.19v yesterday)
- note that ice is beginning to form in the middle of Bay 9 as well as the north end of 9 (near the delta). Ice has formed across Ragged Channel to Ragged Island (between Bays 13 and 14) (22-30 to 22-36).
- 1215; inspected camera E; date; footage = 12 ft (from 10 ft yesterday); voltage - 5.11 v (from 4.83 v yesterday), October 4 reading must have been screwed up. There is relatively thin ice float (approx. 4 ") in the intertidal.

The sea ice forming in Bay 10 is very soft and slushy.

- 1220; inspected camera B; date; footage = 20 ft (from 17 ft yesterday); voltage = 5.14 v (from 5.22 yesterday)
- 1230; inspected camera C; date; footage = 38 ft (from 33 ft yesterday); voltage = 5.52 v (from 5.66 v yesterday); clock is 1 hour slow
- 1235; inspected camera F; date; footage = 10 ft (from 30 ft yesterday); voltage = 5.00 v (from 5.03 yesterday)
- 22-33 to 22-36 show Ragged Channel (Bays 9, 10, 11, 12, from approx. 1100 ft)
- 22-37, 22-28 and 23-1 to 23-4 show Z lagoon and Bays 101 and 102 from the helicopter.
- poor visibility from Cape Hatt to Pond Inlet made it difficult to describe ice distribution in Eclipse Sound.

<u>October 6</u>

- 0955; shut down camer I; footage = 40 ft; film proceeds very slowly (low battery voltage)
- 1005; shut down camera H; footage = 15 ft
-1100; change film in camera A (8 mins); change battery
- 1110; camera E; change film; change battery; when I depressed the button to wind on the excess film the light meter needle drops from f5.2 to f2.3. This does not happen with a new battery (old battery voltage = 4.93 v).
- I screwed up the new film for this camera - 40 ft ran on by mistake therefore there was only 10 ft left for this camera (I did not have any more film).
- 1130; camera B; footage = 20 ft; replace film and battery
- 1140; camera C; footage = 42 ft; replace film and battery
- 1150; camera F; footage = 40 ft; replace film and battery
- 1205; camera D; footage = 50 ft; change film and battery
- 23-4 to 23-31 show the ice conditions around Cape Hatt.
- virtually all of Ragged Channel covered with a thin ice skin
- seals observed hauled out on the ice in Bay 11 and 12 and Z lagoon
- when cleaning up my gear. I could not find the DVM - checked the helicopter -it must have fallen out of my pack when hiking around the camera sites.

QH Baffin island oil spill project:
91.8 Cape Hatt ice conditions /
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