1687 # AERIAL RECONNAISSANCE SURVEY OF ICE BREAK-UP PROCESSES IN THE CANADIAN BEAUFORT SEA COASTAL ZONE

D.F. Dickins Associates Ltd.

PREAMBLE

This open file report presents the results of a field survey carried out from May 31 to June 21 1987 along the Canadian Beaufort Sea coast. The study documents the break-up of sea ice and the features of nearshore ice which play a role in coastal sediment transport using oblique aerial photography and videotaping. Several pile-up features and strudel scours were identified during the study.

A slide collection and set of videotapes, on which this report is based, is available for viewing at the Atlantic Geoscience Centre, Dartmouth, N.S. Contact Susan Merchant (902) 426-3410.

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Aerial Reconnaissance Survey of Ice Break-up Processes in the Canadian Beaufort Sea Coastal Zone

for

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SUMMARY

This report describes a 22 day field program carried out in the Canadian Beaufort Sea from May 31 to June 21, 1987. The field studies concentrated on the documentation of specific features of nearshore ice which play a role in coastal sediment transport in the study area. Regular visits to selected sites were carried out on regional aerial surveys from the US/Canada border to Cape Dalhousie.

The study produced a comprehensive slide set together with video coverage of the entire Beaufort Sea coastline. Severe pile-up features, up to 12.5 m in elevation, were surveyed in 4 to 10 m of water off Atkinson Spit, in McKinley Bay, and west of Hershel Island along Nunaluk Spit. Strudel scour features were documented off the Babbage River delta in Phillips Bay. The maximum strudel scour pit depth was 2 m. This is the first known confirmation of strudel scour along the Canadian Beaufort Sea coast. Areas of ice overflow were mapped in the vicinity of Garry and Ellice Islands and off the deltas of the Blow River (Trent Bay), Babbage River, Running River, and Firth River.

The landfast ice was unusually smooth throughout the study area. There was no evidence in 1987 of significant ice-sediment interaction at any of the sites of interest for future development (King Point, North Head, Pullen Island, and Toker Point). These observations are not necessarily representative of typical conditions. We recommends carrying out additional surveys to establish the annual variation and extent of ice-sediment reworking at specific sites and to conduct detailed mapping of strudel scour. Follow-up side-scan surveys are required to determine whether severe ice pile-up features cause long lasting scour in the nearshore area inside of the 10 m isobath.

NOAA satellite images provide a valuable record of the extent of ice overflooding in previous years. We recommend using these images to relate ice overflooding and river discharge characteristics for particular years.

1.0 INTRODUCTION AND OBJECTIVES

The primary objective of this project was to study nearshore ice break-up along the Yukon coast, within the Mackenzie Delta, and along the Tuktoyaktuk Peninsula. The knowledge gained of both regional and site specific ice break-up processes will be used in assessing how different ice processes affect coastal sediment transport in the Beaufort Sea.

Although there is a general appreciation for the role of ice in reworking coastal sediments, there have been few observations or studies of the timing and location of such processes in the Canadian Beaufort. Offshore ice scour in water depths out to 60 m has been studied in detail in both the Canadian and US offshore areas. The frequency of ice scour events falls off sharply inside of the 20 m depth contour. Scour frequencies in water depths less than 5 m are typically 1/10 of the peak mean values observed in deeper water (Barnes and Reimnitz, 1984). In shallow water less than three meters depth, first-year sea ice can interact directly with bottom sediments without the requirement for ridge building. This interaction occurs principally in the fall (November, December) through wind driven ice movement events, and during the winter as the growing sheet gradually becomes fast to the bottom at depths out to about 2 m.

Significant ice movements of hundreds of metres have been observed along the Beaufort Sea coast as late as December (Dickins and Hill, 1979 - proprietary). Such movements result in shore ice pile-ups as high as 9 m with considerable energy dissipation into the beach sediments. Large ice movements within the landfast ice zone can occur as late as February under sustained storm winds, but by this time the ice is too thick (typically 1.5 m) for the available wind driving forces to cause shore pile-ups or ride-ups. Instead, the movement leads to the development of pressure ridge features. One such event in February 1976, documented by Spedding (1983), led to the formation of a 104 km long ridge in 7 m of water.

Ice-sediment interaction in the spring can occur through a number of mechanisms. As the Mackenzie freshet builds through May, the flood waters begin to overflow on top of the bottom fast sea ice. The relatively warm fresh water leads to rapid melting of the sea ice at the channel mouths, particularly in Shallow Bay and Kugmallit Bay. About 70 % of the Mackenzie discharge enters the Beaufort Sea through Reindeer Channel and East Channel. Observations of the Colville River delta in Alaska indicate that initial flooding from snow melt carries a relatively low sediment load but, within a few days of the initial overflooding, a heavy sediment load is carried out onto the fast ice, rapidly lowering the surface albedo and further accelerating the ice melt rate. Eventually, the bottom fast ice floats free and causes the vast overflooding volume of water to drain through melt-holes in the ice sheet. The violent swirling action associated with this drainage creates so called strudel scour features in the seabed. This phenomena has been observed to cause cylindrical depressions in the seabed up to 4 m deep and over 10 m across in the Alaskan Beaufort sea. Bottom sediments are resuspended and redeposited on the delta front by this turbulent action (Barnes and Hopkins, 1978). The extent and frequency of occurence of similar features in the Canadian Beaufort Sea have not been documented in the literature.

Although there was no evidence of any ice jams or ice override within the Delta during the 1987 surveys, natural bottlenecks are known to have caused ice jams and flooding in previous years. River break-up patterns are highly dependent on the thermal regime, snow cover, discharge rates, and channel configuration (for a detailed discussion of how these factors play a role in river break-up patterns the reader is referred to a recent textbook on river and ice engineering: Ashton, 1986). One known area of potential jams within the Mackenzie Delta is the horseshoe shaped bend in Middle Channel at Tununuk (Burns, 1973). *Note that Middle Channel is mislabelled on the Canadian Hydrographic Charts. Middle Channel is the channel entering Mackenzie Bay on the south side of Ellice Island.* Mackenzie Delta ice conditions and break-up patterns are documented in papers and reports (MacKay, 1966; Nuttal, 1974; Nuttal and Drage, 1975; Slaney 1974, 1975).

Once the initial spring melt waters have drained and the bottom fast sea ice has disintegrated, the peak spring river discharge is able to advance under the remaining landfast ice and cause melting from below. By late May, this process creates large areas of open water (referred to as coastal or melt lagoons) in Shallow Bay and Kugmallit Bay. At this time there is considerable annual variability in the extent of break-up. The area of inshore lagoons present on May 25 has ranged from zero (5 out of 9 years) to 75 km^2 (1973 to 1981 data plotted in Beaufort Environmental Impact Statement, 1982). By the first week in June, there is always some open water present. The most rapid expansion in open water area occurs between about May 25 and June 10. Eventually, flow from Middle Channel erodes the ice to the south and in the vicinity of Garry Island. By the third week in June, the boundary of the open water area often stretches from Shingle Point in the west to Toker Point in the east. At this time the open areas in Kugmallit and Mackenzie Bays are often connected by a narrow stretch of water rounding

North Head.

A series of maps showing the extent of coastal lagoons, along with the general progression of landfast ice break-up in the study area, are contained in Fraker (1979 -1982, 1985). Spedding (1978) conducted a detailed survey of landfast ice break-up during three consecutive spring seasons, from 1976 to 1978. His findings are summarized in Thomson (1983) along with additional maps of ice break-up derived from satellite imagery. The potential impact of artificial drilling islands on regional break-up patterns was studied in a report by Spedding and Danielewicz (1983).

The regional patterns of landfast ice break-up in the study area are well known. Expansion of the coastal or melt lagoons associated with the Mackenzie River spring flood continues from mid to late June. The lagoons extend out to the 5 to 6 m water depth and leave behind a remnant ice barrier. Continued melting of the landfast ice barriers leads to their fracturing between mid-June and mid-July. The Mackenzie Bay ice barrier normally fractures first (earliest June 15, latest July 7; from Spedding and Danielewicz, 1983), followed within two weeks by the Kugmallit Bay ice barrier. By late June, there is usually a narrow band of open water along shore throughout the study area, but break-up of the landfast ice along the Tuktoyaktuk Peninsula and the Yukon coast is usually not complete until mid-July. Fracturing of the weakened ice beyond the major influence of the Mackenzie River occurs from mid to late June. Large floes tens of kilometers in extent move offshore at this time under the influence of easterly winds. One of the last areas to clear is north of Pullen Island and Richards Island where grounded ice remnants can remain into early August in extreme years.

2.0 METHODOLOGY

2.1 Preparation and Planning

The time available in the field was restricted to less than 28 days by budgetary considerations. Break-up in the Beaufort Sea spans a time period of up to eight weeks from first river overflooding to final disintegration of the landfast ice along the Tuktoyaktuk Peninsula and Yukon shore. Consequently, the actual timing of the project was a compromise between arriving early enough to observe the river break-up processes and remaining in the field long enough to catch the start of regional break-up along the coast away from the Mackenzie River influence. The following calendar of historic break-up events was used as a guide to estimate the project schedule in advance.

Stage of Break-up	Approximate Timing
1. Initial stages of river flooding onto sea ice followed by drainage	mid to late May
2. First significant area of Coastal Lagoons	late-May
3. Rapid expansion of open water area in Mackenzie Bay and Kugmallit Bay	late-May to mid June
4. Joining of open water around North Point	mid to late June
5. Fracturing of Mackenzie Ice Barrier	late June to early July
6. Fracturing of Kugmallit Bay Ice Barrier	late June to early July
7. Final stages of Landfast Ice Break-up	mid July to early August

The field program actually commenced with the first development of significant open water areas in Shallow Bay and Kugmallit Bay in late May. The progression of Mackenzie River break-up was monitored through contact with the Water Survey of Canada in Inuvik (H. Wood). Stream gauge recorders are operated at Tununuk Point (Bar C) in Middle Channel, Kitigazuit in East Channel, and Ellice Island in Reindeer Channel. Real time data on Mackenzie River discharge is available through the Data Collection Program (DCP) for Norman Wells, Arctic Red River, and Inuvik.

Guidance as to whether 1987 break-up was proceeding ahead or behind normal was provided by the Atmospheric Environment Service (AES) Ice Center in Ottawa. Relevant forecasts and the AES seasonal outlook are included in Appendix B. Weekly ice charts, available from June 11 until July 9, document the regional progression of break-up during the latter half of the field program and until disappearance of all landfast ice in the study area (see Appendix C).

NOAA satellite images were received starting May 19 from the Arctic Weather Office in Edmonton to provide a near real time picture of the open water extent within the Delta. A number of the clearest images are used in this report to map the coastal lagoons present prior to the commencement of field observations (see Appendix B).

2.2 Study Approach

The primary means of data collection was by simultaneous video and still camera oblique photography of ice conditions along shore. This photographic record was supplemented by map sketches made during the flight to provide a picture of conditions over a larger field of view. Further details of the survey methods are provided in 2.3 below.

The field program started by focusing on the early stages of break-up within the areas most strongly affected by the Mackenzie River discharge. Consequently, the field surveys began with the Delta and branched out to cover the Yukon coast and Tuktoyaktuk Peninsula as the nearshore ice deteriorated. While waiting for break-up to proceed in areas removed from the Mackenzie discharge, ground observations and surveys of interesting ice features were conducted at four locations:

1. ice pile-ups along Nunaluk Spit west of Herschel Island;
2. strudel scour at previously drained holes off the Babbage River delta;
3. ice pileups off Atkinson Point; and
4. ice pile-ups off the north east shore of McKinley Bay.

Apart from minor rafting, occasional grounded multi-year fragments (between King Point and Kay Point), and isolated pile-ups associated with known shoals (e.g. Russell Inlet) there were no other significant sites of severe nearshore ice deformation within the study area.

2.3 Description of the Field Program

The field program began with the first aerial reconnaissance flight on May 31 and ended with a last flight on June 21. During this time there were only four days when fog and low ceiling conditions interfered with the surveys. On three of these days no flying was attempted and on one day (June 20) fog caused the flight to be aborted at Shingle Point. In all, 47.2 hours of Bell 206B and 206L helicopter time was used in covering the study area. Three trips were made along the Yukon coast past Herschel Island and two flights were made along the Tuktoyaktuk Peninsula as far as Cape Dalhousie. The remainder of the time was concentrated between Atkinson Point in the east and Ellice Island in the west. Fuel caches at Komakuk Beach, Shingle Point, and Atkinson Point were used to complete the flights.

Video coverage of the nearshore ice conditions and the coastline was obtained with a Hitashi half inch VHS camcorder. The camera was mounted on a tripod and aimed through a bubble rear window. Whenever possible, the camera operator was positioned on the same side as the front passenger (only on flights in the Bell 206L) who took frequent still photographs and provided a commentary noting significant features and geographic place names. The sound quaility is not of a professional standard as the short lead time to the study did not allow a direct hook-up between the video audio input and the helicopter's intercom system.

Video flights were normally made from an altitude of 200 to 250 m (600 to 800 ft) and about 400 m from shore, depending on the extent of open water along shore (as the width of the shore lead expanded with advancing break-up, a higher altitude and a greater distance from shore were used to provide a greater area of coverage). In a few cases, video footage was obtained at altitudes between 600 and 1500 m to provide a panoramic view of the expanding open water area along the seaward edge of the Mackenzie Delta. A combination of camera to shore orientations were used depending largely on the sun angle and direction of intended travel; in some instances the helicopter was positioned offshore with the camera shooting into the coast while at other times the helicopter was flown inside the shoreline with the camera pointing offshore. Still photographs were obtained at regular intervals during the video flights. At particular landmarks, the helicopter made a shallow banking turn to take photos along the coastline. Each photograph was marked automatically with time and date encoded from an LCD data back. Similarly a time and date overlay was recorded on the video image to cross-reference the photographs and video record.

Ground surveys relied on conventional level surveying gear for surface profiles of the ice pile-up features, and an ice drill and sounding line for measurements of water depths. Depths were obtained wherever possible on both the seaward and shoreward sides of the pile-ups. The location of tidal cracks on each side of the grounded ice made for convenient depth sounding. Strudel scour features were documented by measuring water depths within a pattern of holes drilled around the feature and then comparing these depths with the deepest sounding obtained through the centre of the strudel hole. Following each set of surface ice measurements, a bright red nylon marker, 1.5 x 4 m, was spiked to the ice and near vertical aerial photographs were taken with the helicopter in a tight spiralling turn. Altitudes for these photographs were chosen to ensure that a portion of the adjacent spit was visible along with the ice feature for future positioning (this was not possible with the strudel scour). Additional positioning was obtained for the pile-ups along Nunaluk Spit by timing the helicopter between known points and placing survey cones on the spit adjacent to each pile-up (these cones are not expected to survive severe summer storm events with waves overwashing the spit). For the pile-ups off Atkinson Point, the exact distance from the beach to the pile-up was chained off by walking from the feature to shore.

Following documentation of all significant pile-up features and potential strudel sites, the last week of the study concentrated on mapping the rapid expansion of open water in Kugmallit Bay through daily, high level (800 to 2000 m) reconnaissance between Tuktoyaktuk, Toker Point, and Hendrickson Island. By this time, the areas of open water off the Delta west of Richards Island were so large that mapping from the helicopter was difficult as visible geographic landmarks became more and more distant.

2.4 Analysis and Organization of Field Data

An extensive interpretation of the data was not feasible within the budgetary constraints placed on this study. The analysis portion of the study concentrated on presenting the photographic products in an organized fashion by: 1). cross referencing the field notes to slides and video; 2). providing detailed flightline maps keyed to the video and still photo display times; and 3). organizing selected slides according to geographic location.

Following the field program, a search was be made for several high quality Landsat images showing break-up in the study area in mid-June. Only four cloud free images were found, of which two are of the Mackenzie Delta. Recent price increases (minimum of $75.00 each), have made these images too costly to include in the report. The extent of initial ice overflooding off the Mackenzie Delta in late May was mapped from NOAA images aquired prior to the field program (see Appendix B).

Daily, mean Mackenzie River discharge values measured at three delta sites (Middle Channel, East Channel, and Reindeer Channel) will be available from the Water Survey of Canada in Yellowknife beginning in early October. The digitized chart records were not available at the time of writing (H. Wood, pers. comm.). Daily weather conditions from Tuktoyaktuk Airport are contained in Appendix D.

The daily field observations are contained in Appendix A. Maps showing the flightlines and sections of video coverage, selected slides, and a high level photo mosaic of the Mackenzie Delta from June 2 are in Appendix E. The times (hour and minute) indicated on the maps correspond to the times on the video to help the viewer locate what they are seeing. For flights without video, slide numbers are indicated where applicable.

The slides contained in Appendix E are ordered in groupings from west (Alaska/Yukon border) to east (Tuktoyaktuk Peninsula to Cape Dalhousie) and numbered consecutively. With few exceptions, the slides have the time and date imprinted on the transparency. When this information is obscured or difficult to see, the date has been pencilled in on the slide mount. The field of view is noted on each individual slide wherever possible. Note that only one set of slides and one photo mosaic exist and they are in the binder copy of the report.

3.0 RESULTS

The study was successful in covering the active period of ice break-up off the Mackenzie Delta and in documenting a number of significant nearshore ice pile-ups in 4 to 10 m of water (refer to the field notes in Appendix A). The largest pile-up off Atkinson Point (Site 4) had a peak height of 12.5 m and was in 6.6 m of water. All of the pile-ups were solidly grounded with well established tidal hinge cracks on both sides. One pile-up, Site 5 in McKinley Bay, was notable for a large section of almost black ice from sediment mixed into the blocks. Regional aerial photographs of ice show distinct bands of clean and dirty ice, indicating large scale ice motion in response to a northwest storm the previous fall. Interestingly, personnel at the Komakuk Beach DEW Line station remembered a particulary severe storm from the previous November which probably created the lines of pile-ups observed during this study along Nunaluk Spit. These features are documented in notes (Appendix A) and slides (Appendix E).

In general, the landfast ice throughout the study area in the spring of 1987 was notable for the absence of any well developed shear ridge systems which often parallel the Tuktoyaktuk Peninsula in water depths of 5 to 15 m. Without the anchoring usually provided by such grounded ridges, the landfast edge was easily broken up and moved offshore by wind stress acting on the ice surface in late June (see ice charts for June 25 and July 2 in Appendix C). Evidence of significant ice pile-ups and ice push onshore was limited to the three sites surveyed. Ice nearshore of Toker Point, Pullen Island, North Head, and King Point was smooth and featureless.

A number of well defined sites of strudel drainage, located in 2.3 to 3.5 m of water, were investigated off the Babbage River delta (see cover photograph). A series of drill holes and soundings confirmed the presence of scour pits at the centre of the strudel holes. The depths of the pits were from 1 to 2 m (see field notes in Appendix A, pages 11 to 13). These observations are the first known documentation of strudel scour in the Canadian Beaufort Sea.

The timing of break-up in 1987 followed the historical sequence of events. First evidence of ice overflow at the mouths of Arvoknar Channel and Reindeer Channel was evident on satellite imagery of May 19. By May 26, these areas expanded as far as the north tip of Garry Island (see maps prepared from the satellite imagery in Appendix B). Aerial and ground surveys on June 2 and 3 documented the extent of these ice overflow areas, which were still visible as lobes of discoloured ice, at the following locations (see photo mosaic of the Mackenzie Delta and flight maps in Appendix E):

1. West of Garry Island extending out as far as Adgo H-29 (abandonned 1984). Water depth at the furthest northerly limit was 3.2 m.

2. Northwest of the north tip of Ellice Island. This was the only area which still had an appreciable amount of water on the ice (17 cm) at the time of the study. Water depth at the most northerly extent was 1.9 m.

3. Blow River delta near Shingle Point

4. Babbage River delta in Phillips Bay (this was the only area with evidence of well formed strudel features as opposed to natural ice drainage patterns). Water depths surrounding the strudel holes ranged from 2.3 to 3.5 m, while water depths in the holes themselves ranged from 3.0 to 4.7 m. The water depth at the maximum northerly extent of the Babbage River overflow was 5.3 m.

5. Running River delta in Phillips Bay

6. Firth River delta west of the entrance to Workboat Passage

7. Kugmallit Bay south of Hendrickson Island (isolated area of upwelling)

Note: Ice thicknesses at the time of these initial survey flights ranged from 150 to 180 cm.

The Mackenzie River discharge peaked on June 2 and no further expansion of the areas of ice overflow occurred. The areal extent of open water expanded rapidly after June 6. By June 13, Shallow Bay and Kittigazuit Bays were completely clear of ice and open water off the Delta extended out to Pelly Island. During the last week of the field survey the open water area grew to include most of Kugmallit Bay as far north as Tibjak Point. West of Richards Island, the open water area included most of Beluga Bay, all around Kendall and Garry Islands, and extended across Mackenzie Bay to Shoalwater Bay in the Yukon. Although visibility was very poor, observations through the fog on June 20 indicated that the Mackenzie Bay ice barrier was probably breached on June 19 (median date from 1973 to 1983 is June 16). This observation is confirmed by the ice charts prepared for June 18 and 25 (Appendix C).

The Kugmallit Bay ice barrier was not breached until the last week of June, in line with the median historical date of June 30. Offshore, the smooth landfast ice rapidly broke away and, by July 2, the only stretch of landfast ice still tight to shore was along the Tuktoyaktuk Peninsula west of Warren Point. The summer of 1987 proceeded to be one with extremely favourable ice conditions and a near record extent of open water during August.

4.0 CONCLUSIONS

Good quality video footage can be obtained with minimum operator fatigue by using a lightweight camcorder mounted on a conventional tripod on the floor of the helicopter. With foam pads on the legs and bracing of the tripod by hand, the vibration is reduced to an acceptable level. There appears to be no noticeable difference in picture quality between shooting out of an open window and shooting through a clean, scratch free plexiglass bubble window (Note this is not the case for 35 mm still photography where the image quality is noticeably degraded shooting through the "bubble".). The Bell 206L Long Ranger helicopter is greatly superior to the shorter fusealage 206B Jet Ranger for video and camera work. The significantly lower noise and vibration levels make for an improved video product.

Strudel scour can be successfully documented by simply depth sounding in a pattern from the the ice around and through the strudel hole. The weakness of this approach is that it only detects residual scour remaining after an unknown amount of infilling has taken place.

Observations made during this single year's program should not be used to draw general conclusions regarding ice-sediment interaction at locations of interest for future development. As described in Section 3.0, the landfast ice cover was unusually smooth during the winter of 1986/87, indicating that few storm events occurred to drive the ice onshore during the critical fall period.

Areas of ice overflooding visible on the NOAA imagery in late May were clearly delineated during the field surveys by the discolouration left by stranded sediment. With the exception of the Babbage River delta, all of the overflow areas appear to have drained without leaving any evidence of well developed strudel scour. This is not surprising considering that water depths on top of the ice in overflow areas north of Ellice Island were less than 20 cm within 24 hours of peak discharge. These observations should not be taken as reliable evidence that strudel scour does not occur off the Mackenzie Delta. Spring 1987 was characterized by an extremely low runoff stage. With higher peak discharge levels, there is potential for significantly larger volumes of water to flow out over the ice, possibly leading to strudel drainage similar to that observed off the Babbage River.

Satellite imagery is an effective means of mapping the first signs of ice overflow. Even with the limitations imposed by cloud cover, there are usually enough NOAA images available to map the progression of overflooding on almost a daily basis. This is not true for the higher resolution Landsat which, by virtue of its infrequent coverage, is almost always unavailable when needed most.

5.0 RECOMMENDATIONS

A similar study should be carried out in subsequent years to provide a realistic assessment of the variability in nearshore ice-sediment interaction and strudel scour potential at sites of particular interest for future development. Consideration should be given to extending the field season to 28 days for observation of active strudel drainage features in late May. A simple and safe method of determining the peak scour depth while the strudel is draining will be required. Return visits should be made to acquire side scan sonar data over the seabed at pile-up sites documented in this study.

Analysis of historic NOAA imagery could provide an economical means of mapping the annual variations in the timing, location, and areal extent of ice overflooding off the Mackenzie Delta. By comparing these results with the corresponding Mackenzie River discharge values, it is possible to relate the degree of ice overflooding to river stage and to climatic conditions upstream.

Considering the size of the actual strudel holes (about 5 m) in comparison with the best resolution available with existing SAR imagery (about 10 m) and satellite imagery (30 to 100 m), the use of historical remote sensing imagery to map strudel scour cannot be recommended.

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APPENDIX A

Field Log
May 31 to June 21, 1987

Aerial Reconnaissance Survey of Ice Break-up Processes in the Canadian Beaufort Sea Coastal Zone

FIELD LOG
May 31 to June 21, 1987

Ice Conditions Prior to May 31

May 14 H. Wood, Water Survey, Inuvik

Break-up was running behind normal. The ice road was closed at Arctic Red River on May 10. The ice road between Inuvik and Tuktoyaktuk was reopened after being closed on April 30 due to local water overflow onto the ice. Some water was visible around sandbars. There is approximately a one week delay in placing water level recorders in the Delta due to insufficient water. Water levels at Norman Wells had reached 14 ft over winter levels. There is no visible snowmelt in the Mackenzie Delta area.

May 15 D. Coleman, Ice Central, Ottawa

The 30 day forecast shows temperatures continuing below normal along the coast until mid-June. Break-up of landfast ice is forecast to be about one week later than average. Winter of 1986/87 has seen milder than normal temperatures and increased snowfall. Note that there was an unusually early May snowfall of 40 cm in Inuvik. Ice Central seasonal outlook predicts that the area from Cape Bathurst to the Mackenzie Delta will be clear of ice by late July. Extracts from the seasonal outlook published in early June and the 30 day forecasts for June and July are included in Appendix B.

May 20 H. Wood, Water Survey, Inuvik

Ellice Island guage is installed and operating. Visible open water is limited to channel edges and around sandbars. The water level at Norman Wells is up 12 ft above the winter level (considered very low for this date). Discharge at Arctic Red was estimated at only 15,000 cms on May 19 (ice is still solid and snowmobiles are crossing the river).

May 22 Arctic Weather Central, Edmonton

Tuktoyaktuk is reporting 0 to -5°C (normal) and Inuvik is still 5°C below normal.

Mackenzie stations from Fort Norman south to Fort Simpson are reporting normal to above normal temperatures.

May 25 Polar Shelf, Tuktoyaktuk
The temperature is -7°C. Daily NOAA images from May 19 to 26 show the progression of flooding over the ice in the Mackenzie Delta (Appendix B).

May 26 A sharp rise in temperatures occurred; Inuvik was +7°C and Tuktoyaktuk was +2°C. Gradual cooling is forecast over the next four days. The decision was made to go into the field as soon as possible.

Field Observations of Beaufort Sea Ice Break-up

Note: Photographs are referenced by number. Where there is a corresponding section of video tape, the time of the photograph is also indicated in the text. Red dots on the slides indicate that there is a corresponding section of video. Maps in Appendix E show the flightlines followed each day. The video section of the flightline is highlighted on each map.

May 31, Flight over Kugmallit Bay, Map 1

18:46 to 19:30, Overcast 800 ft, Visiblity 8 mi, +1°C

Ice is still solid to the shore as far south as Whitefish Station where a narrow band of open water leads to East Channel. Ice surface in Kugmallit Bay is 80 to 90% snow covered with bare patches. In the immediate vicinity of Tuktoyaktuk and inshore of the ice road, the area is 60 to 70% ponded. The ice road to Inuvik is under water. Open water areas in Kugmallit Bay are restricted to the west shore where an open shore lead extends north to Kidluit Bay. There are two isolated open water patches along the east side of the bay south of Hendrickson Island

(159). These openings are surrounded by a narrow fringe of flooded ice which appears dark black and brown in places. According to the water depths, the ice in this area will be fast to the bottom. There is no evidence of previously flooded areas or of any developed drainage networks. Kittigazuit Bay is 50% clear of ice (remaining ice is in strips in the center) (155, 156, and 157).

June 1, Flight West to Shallow Bay, Maps 2 and 3
13:06 to 13:27, Overcast 300 to 800 ft, -2°C

East Channel is open along the edges as far as Tununuk (limits of visibility) with a strip of ice still intact in the centre (85 to 91). Westbound from East Channel to Reindeer Channel, most tributaries are completely open with ice remaining only in the centre of the main channels. The extreme south end of Shallow Bay is completely open for a distance of 16 km from the mouth of Napoiak Channel. Further north, the open water is concentrated on the east side of Shallow Bay, as shown on the NOAA images for late May. A three km wide band of open water is present starting south of Reindeer Channel and extending past the Oliver Islands to the north end of Ellice Island (82). However, strips of ice extend out from the centre of Reindeer and Middle Channels. *Note that Middle Channel is mislabelled on the Canadian Hydrographic Service charts. Middle Channel is located on the south side of Ellice Island.* Limited visibility prevents observation of the west side of Shallow Bay. Long tongues of open water and rotting ice extend up to 16 km northwest of the Delta between Ellice and Garry Islands (110). East of Garry Island, there is almost continuous open water in large areas between Garry and Kendall Islands, off Taglu Island, and beween Harry Channel and West Point. The progression of ice break-up in Kittigazuit Bay is shown in photos 160 and 161.

June 2, Flight East to Warren Point, Map 4
09:18 to 10:15, Clear, -2°C, Winds 070 at 18kt

Flight proceeded as far as Warren Point where fog was encountered and appeared to cover the Tuktoyaktuk Peninsula further to the east. Apart from local ponding around sandbars and wind blown sediment near shore, the remaining ice is solid with no evidence of surface melt. Bare ice patches are showing as the first signs of surface deterioration (typically less than 5%).

June 2, Flight West to Herschel Island, Maps 4, 5, and 6
Clear, +6°C, Winds 030 at 20 knots to westerly between the Delta and the Yukon shore.

Video Tape 1: Whitefish Station to Shingle Point (16:24 to 18:34)
Video Tape 2: Kay Point to Nunaluk Spit (19:50 to 20:30)
Oliver Islands to Kidluit Bay (22:37 to 23:38)

Kugmallit Bay conditions are relatively unchanged except for continued expansion of the two most northerly open water areas south of Hendrickson Island and north of Kidluit Bay (164 at 16:22 and 168 at 16:23). The major cause of this increase in open water area seems to be increased flooding of the ice to the north. Note that a crew with the Institute of Ocean Sciences observed water upwelling through holes in the ice at the edge of one of these open areas later in the day. (Video coverage of this phenomena was obtained by an Okanagan pilot, R. Bolton, and was transferred over to the end of Tape 2. The time was appoximately 21:30.) The ice on the Mackenzie River at Inuvik was beginning to move and the discharge was peaking, although well below previous levels (H. Wood, pers. comm., June 3). Except for a local tongue of surface melt extending out from the west shore of Summer Island, the ice in the lakes and around the shore of North Point is still completely solid.

Between West Point and Kendall Island, the open water edge appears to have advanced north by about 2 km (136 at 17:00, 132 at 17:05, 121 at 17:06, and 120 at 17:11, also see the fold out photo mosaic) . Immediately west of Garry Island, a large area of dry discoloured ice (approximately 20 km^2) appears as a northwest oriented lobe originating from the unnamed channel flowing around the east side of Nigligtak Island (22.59). Further to the west, off Arvoknar Channel, large areas of ice had a scattered, lattice pattern of open holes as if the ice is rotting through from below (17:21, 22:53). The largest expansion of open water in the past 48 hours appears to be off Ellice Island where a large open water lagoon extends up to 12 km north of the Delta and west to encircle the Oliver Islands (100 at 17:27, 22:40, 22:46). Proceeding south along the east side of Shallow Bay, the west shore of Ellice Island still has an intact band of ice extending as far as Middle Channel. Ice clearing in Middle Channel follows the charted deeper water while ice still remains in the shallow water (17:36). The open water area off the mouth of Reindeer Channel has expanded west almost half way across Shallow Bay (71 to 74 at 17:50 to 17:55). See the photo mosaic of the Mackenzie Delta photographed at 1500 m on the return flight (corresponds to the video coverage on Tape 2, 22:37 to 23:38).

Proceeding north along the west shore of Shallow Bay, the open water area is much less extensive and is confined to a narrow band along shore which enlarges wherever a channel or tributary enters the bay (75 to 84 at 18:00 to 18:18). The most significant area of open water between Shallow Bay and Trent Bay exists at the mouth of Ministicoog Channel, inshore of Tent Island. New slush ice could be seen forming as streamers on the open water in this area (18:24). The Blow River Delta is clear of ice and snow and mostly inundated with water. A large area of previously flooded ice from the Blow River is visible as a discoloured area in Trent Bay and extends almost to Shingle Point (55 at 18:30). This area contains the first evidence of significant surface water drainage, i.e. the water flooded seaward on top of the ice before draining as opposed to the inundated areas off the Delta which appear to have been caused by water upwelling in-situ. Minor strudel like surface features are visible in Trent Bay (18:30).

Proceeding north from Shingle Point as far as Kay Point, the ice is still solid to shore with only scattered bare patches showing as the first signs of surface melt. A distinct tidal crack network is visible close along the cliff shoreline with isolated melt pools at the base of some exposed bluffs. The first year ice is unusually smooth as far offshore as can be seen. The only visible grounded features consist of minor ridges, up to 1.5 m in height, nearshore between King Point and Kay Point (58 at 19:29). Just south of King Point, some minor finger rafting from the previous fall is visible nearshore. A small grounded ice feature is located between Sabine Point and King Point. Several grounded multi-year fragments and first-year ridge systems are situated nearshore, starting about 5 km south of Kay Point (61 at 19:47 and 62 at 19:48). These features are typically less than 50 m diameter. Several of the grounded multi-year floes show sediments in the surrounding rough ice around the edge of the floe.

Within Phillips Bay, the Babbage and Spring Rivers have overflowed onto the ice in the past two weeks leaving behind drained ice areas clearly delineated by sediment stranded on the ice (69 at 20:13). These appear as slightly discoloured areas. Sediment loading is extremely light. There are dozens of strudel-like drainage patterns left over from the period of active water drainage. Several of the larger holes are still draining (35, 43 to 46, and 66 at 19:56 to 20:11). Between the Spring River delta and Calton Point, the ice is still fast to shore with no significant melt features.

Workboat Passage is approximately 40% ice free with open areas in the centre from the freshwater discharge of the Firth River. The original extent of the ice overflow from the Firth is still visible with a lobe of discoloured ice extending east along Nunaluk Spit and entering Orca Cove between the Yukon shore and the south tip of Avadlek Spit (15 at 20:42). Further west, the area inside Nunaluk Spit is open as far as the Malcolm River. Isolated grounded ice features are scattered along the seaward side of the spit with sediment exposed on the melting faces (20 at 20:35). This survey was terminated at the western limit of visible open water inside the spit (20:30). Larger ice pile-ups and rough ice alongshore were visible to the west (see observations and ground surveys for June 6 and 7).

June 3, Flight West to Shingle Point, Map 7
13:39 to 19:08, Clear, +10°C

Proceeding directly to Hendrickson Island to investigate the area of upwelling seen by the crew from the Institute of Ocean Sciences in the late evening of June 2. The ice cover in Kugmallit Bay appears dry, as if the overall water level has dropped in the past twelve hours. The isolated open water areas have shrunk back to the size observed on June 1. The fringes of the previously inundated ice, which greatly expanded the apparent open water area, have drained and now appear as dry ice with melt holes (169 and 170).

A discoloured lobe of previously flooded ice extends from Arvoknar Channel west of Garry Island (111 to 113) (see also ground observations later in this flight). Kay Point is fogged in. The flight plan is altered to fuel at Shingle Point and return to Garry Island for an on ice survey. The area of previous ice overflooding from the Running River is visible (56). Enroute from Shingle Point to Garry Island, the lobe of open water extending northwest off Ellice and the Oliver Islands appears to be advancing north with local overflooding at the northern limit (102). Landed at the edge of this flooded area to check water depths and ice thickness (104).

Table 1. Measurements NW of Ellice Island

Water on the ice	17.0 cm	to hard ice
Ice thickness	151.0 cm	15 m from flooded edge
Water depth	190.0 cm	15 m from flooded edge
Snow depth	8-35.0 cm	clean drifts above flood level

Flew 32 km NE to land at the northern limits of the previously flooded ice area west of Garry Island (114 and 115).

Table 2. Measurements West of Garry Island

Ice thickness	181.0 cm	just outside flooded area
Water depth	3.2 m	just outside flooded area
Ice freeboard	10.0 cm	just outside flooded area
Water temperature	+0.53°C	open hole within flooded area , old crack
Water depths	3.2 m	open hole
	3.4 m	2nd hole within 50 m of 1st, strong north current under the ice bending the survey rod (115)
Snow depth	25.0 cm	within drifts remaining in flooded area (114)

The presence of clean snow drifts within the previously inundated ice area indicates that the depth of water on the ice was probably less than 15 cm.

Returning to Tuktoyaktuk via the north shores of Pelly, Hooper, and Pullen Islands. The ice is smooth between all of the islands and along the shore. Exceptions are isolated multi-year remnants melting on the beach along the north side of Pelly Island (131). Ponding on the ice surface increases from the west (20% or less) to the east and towards shore, where it reaches 70% in some areas. There is no visible melt off North Head or around Pullen Island (140 to 142).

Note: A discussion with H. Wood with Water Survey of Canada in Inuvik indicated that the ice started to go out at Inuvik on the evening of June 2. Water levels throughout the Mackenzie system are below normal with Norman Wells 4 m below average.

June 4, Flight East to Cape Dalhousie, Map 8

14:05 to 16:40, Clear at Tuktoyaktuk deteriorating to 300 ft in fog.

Ice along the coast from Tuktoyaktuk to Cape Dalhousie is solid to shore. The only evidence of melt is in the shallow areas nearshore or areas with wind blown sediment on the ice. Between 10 and 20% of the ice surface has bare patches. The ice road to McKinley Bay is still snow covered. Nearshore ice pile-ups are located at only three locations along the Tuktoyaktuk Peninsula: 5 km west of Drift Point (minor features); off Atkinson Point (217); and 2 km south of Phillips Island along the northeast side of McKinley Bay. The ice pile-up northeast of McKinley Bay has a high sediment load. An area of minor rubble is present off Cape Dalhousie.

High level observations of Kugmallit Bay show no visible change in conditions from the drained surface appearance noted on June 3 (167 at 4000 ft).

June 6, Flight West to Komakuk Beach, Maps 9, 10, and 11
09:11 to 15:10, 18:45 to 20:23, Clear,+3°C, Wind 180 at 20 knots.

Video Tape 2: Whitefish Station to Oliver Islands (09:11 to 10:06)
Phillips Bay (10:37 to 10:46 and 14:16 to 14:20)
Video Tape 3: Demarcation Point to Herschel Island (18:52 to 19:54)

Flying from Tuktoyaktuk to Phillips Bay via Whitefish Station, and Kidluit Bay (09:20). Initially flying at 800 ft around Kugmallit Bay and climbing to 3000 ft between Hendricksen Island and North Point (162 at 09:17 and 165 at 09:26). Kugmallit Bay shows significant surface drainage with less than 5% ponding. The previous fringe of black/brown indundated ice around the open water patches is replaced by a sharp transition from open water to relatively clean ice containing open holes left over from the flooding. The high levels of suspended sediment visible at the time of peak discharge on June 2 (see video portion shot by R. Bolton on Tape 2) are replaced by clear open water. High level video coverage and stills view the open water areas to the south from West Point to the north of Ellice Island (138 at 09:39, 125 at 09:43, 124 at 09:45, 122 at 09:49, 119 at 09:51, 116 at 09:54, 106 at 10:05, and 105 at 10:09). Refer to return flight observations of June 7 for inundated tundra and open water outlines mapped from 500 ft.

Strudel Scour Survey, Phillips Bay, Map 10 A

Before landing, carried out a video survey of Phillips Bay from 800 ft proceeding counterclockwise around the bay from the Spring River Delta to Kay Point (67 at 10:34 and 70 at 10:37).

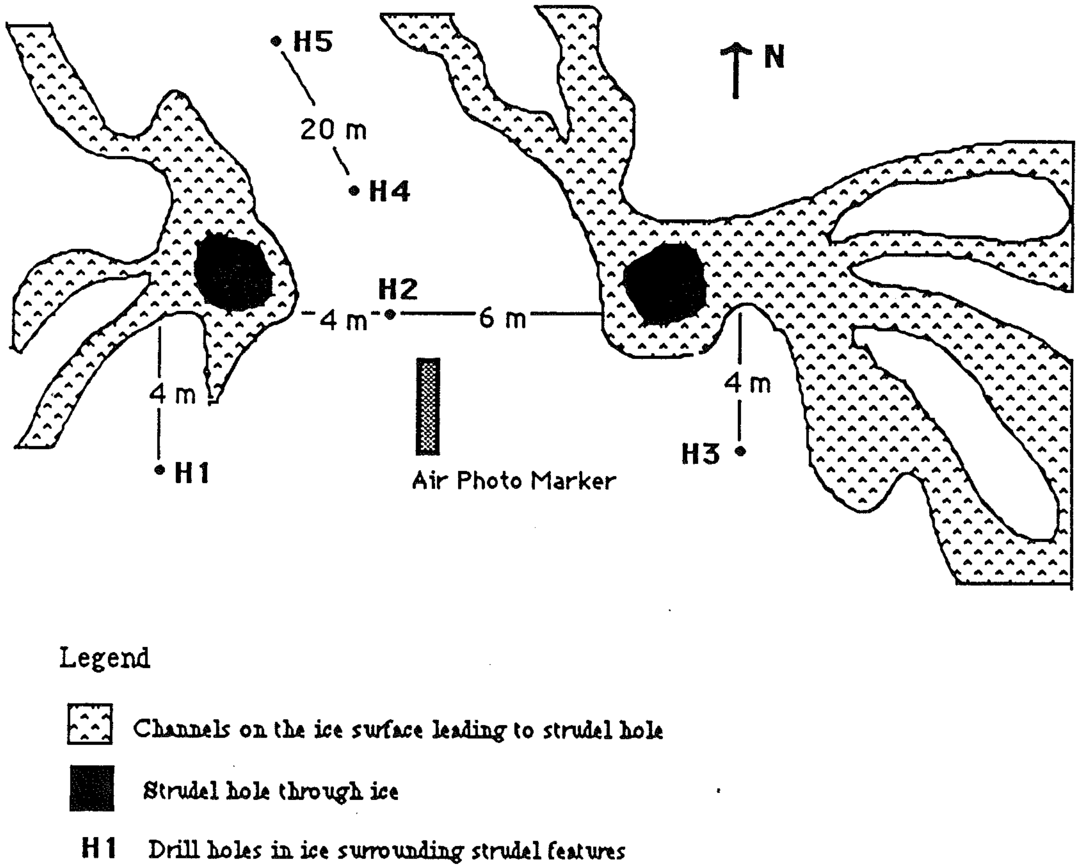


Figure 1. Strudel Site 1, Phillips Bay, June 6 (Not to Scale)

Table 3. Measurements at Strudel Site 1, Phillips Bay

Site	Ice Thickness	Freeboard	Water Depth
H1	140 cm	10 cm	3.1 m
H2	150 cm	16 cm	4.1 m
H3	150 cm	15 cm	3.4 m
H4	124 cm	13 cm	3.5 m
H5	150 cm	8 cm	3.2 m
West Strudel	N/A	N/A	4.5 m
East Strudel	N/A	N/A	4.2 m

Note: water in the channels had a thin crust of new ice forming on the downwind sides.
Photo 38 at 12:17

Table 4. Approximate Dimensions of Strudel Features at Site 1

	West Strudel	East Strudel
Overall strudel size	8 x 12 m	6 x 15 m
Distance, strudel edge to hole clear through	1 to 5 m	1 to 5 m

Set a 1.5 x 4 m ground marker and lifted off for aerial photographs of Site 1 at 2000 ft (39 at 12:26).

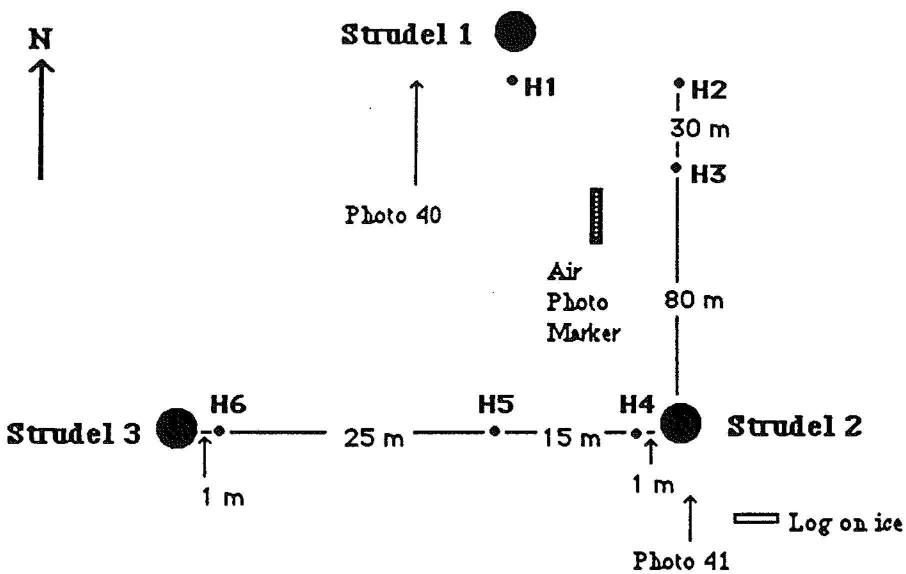


Figure 2. **Strudel Site 2, South Phillips Bay, June 6** (Not to Scale)

Table 5. Measurements at Strudel Site 2, South Phillips Bay

Site	Ice Thickness	Freeboard	Water Depth
S1	N/A	N/A	4.7 m
H1	151 cm	25 cm	2.7 m
H2	170 cm	21 cm	2.8 m
H3	180 cm	28 cm	2.6 m
S2	N/A	N/A	3.8 m
H4	120 cm	8 cm	2.6 m
H5	245 cm	11 cm	2.3 m
S3	N/A	N/A	3.0 m
H6	130 cm	10 cm	2.6 m

Note:

1. Strudel dimensions at Site 2 approx 4 x 6 m

2. Bottom felt sticky as rod was pressed down at H6
3. Bottom at Site 2 felt much softer than Site 1 (thawed vs. frozen?)

Set a 1.5 x 4 m ground marker and lifted off for aerial photographs and low level video survey of strudel areas (42 at 14:16 at 2000 ft).

Drilled holes through the ice at the far northern extent of the original Babbage River overflooding (boundary between clean and discoloured ice).

Table 6. Measurements Northern Limit of Babbage River Overflooding

Water Depth	5.3 m
Ice Thickness	177.0 cm
Freeboard	30.0 cm

Flying directly from Phillips Bay to Komakuk Beach for fuel.

Video survey of the Yukon coast from Demarcation Point to Workboat Passage and counterclockwise around Herschel Island (18:52 to 19:54). The landfast ice is solid to shore along the Yukon coast, except along Nunaluk Spit and where rivers and creeks have overflowed onto the sea ice and initiated local melt near shore; eg. Clarence River and Clarence Lagoon (2 at 19:00), Backhouse River (3 at 19:05), and Fish Creek (6 at 19:14 and 8 at 19:15). Ice pile-ups along the coast, inshore of the 10 m isobath, are concentrated in the area from Komakuk Beach DEW Line Site to the Malcolm River (9 at 19:17 and 10 at 19:19) and against the north facing bluffs of Herschel Island. The ice in Herschel Basin, Thetis Bay (49 at 19:42), and Pauline Cove is generally smooth right into shore. The first significant rough ice features are encountered on rounding Collinson Head (50 at 19:44). Isolated ridges and pile-ups tend to follow the 10 m isobath around the north side of the island (51 at 19:47). Slightly further from the coast, an almost continuous series of compression ridges follow the landfast ice edge bordering the open water offshore. This ice edge follows the 20 m contour, except off the north corner of Herschel Island where it extends out to about 30 m (52 at 19:50). Off the northwest coast of the island the ice edge follows the 20 m contour again (53 at 19:51) and then parallels the Yukon shore to Komakuk Beach where it curves away to the north.

June 7, Ground Survey of Nunaluk Spit, Map 11 A

Clear and calm

Video Tape 3: Nunaluk Spit (11:36 to 11:38)

Ice pile-ups along Nunaluk Spit were surveyed and aerial photographs of rough ice along the spit were taken. Markers (18 inch orange plastic cones) were spiked into the still frozen beach material on top of the spit adjacent to the ice features.

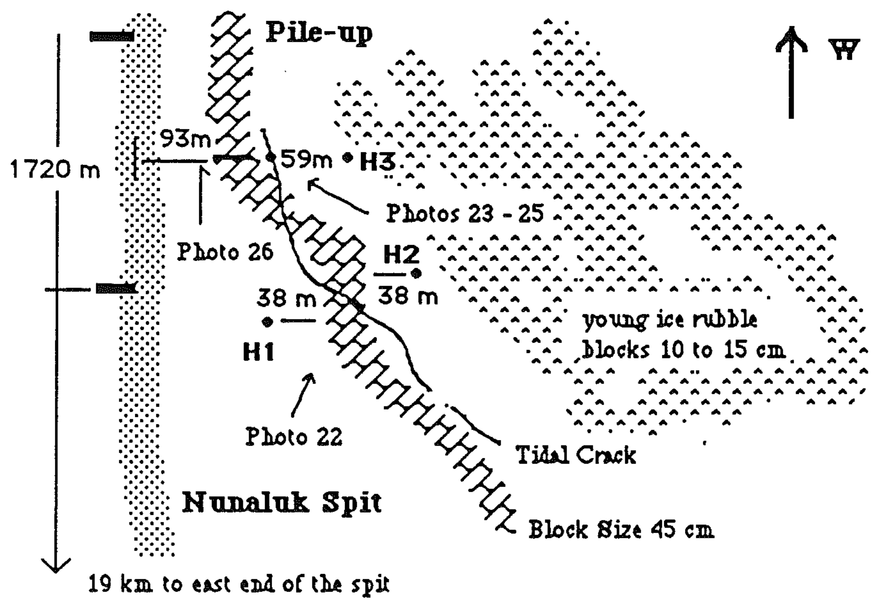


Figure 3. Ice Pile-Up Site 1, Nunaluk Spit, June 7 (Not to Scale)

Table 7. Measurements at Pile-up Site 1, Nunaluk Spit

Site	Ice Thickness	Freeboard	Water Depth
H1	195.0 cm	20.0 cm	9.4 m
H2	160.0 cm	15.0 cm	10.3 m
H3	157.0 cm	12.0 cm	7.6 m
Tidal Crack	N/A	N/A	6.8 m

Table 8. Survey Data at Pile-up Site 1, Nunaluk Spit

Location	Distance to Peak (m)	Elevation (m)	
H1 to Peak	0	10.8	
H3 to Peak	0	6.6	
	2	6.2	
	4	5.7	
	6	5.1	
	8	4.5	
	10	3.8	
	12	3.3	
	14	2.9	
	16	2.3	
	18	1.9	
	20	1.1	
	22	1.1	
	24	0.2	
	26	0.0	Sea Level
Peak to Spit	93	3.0	Spit Center

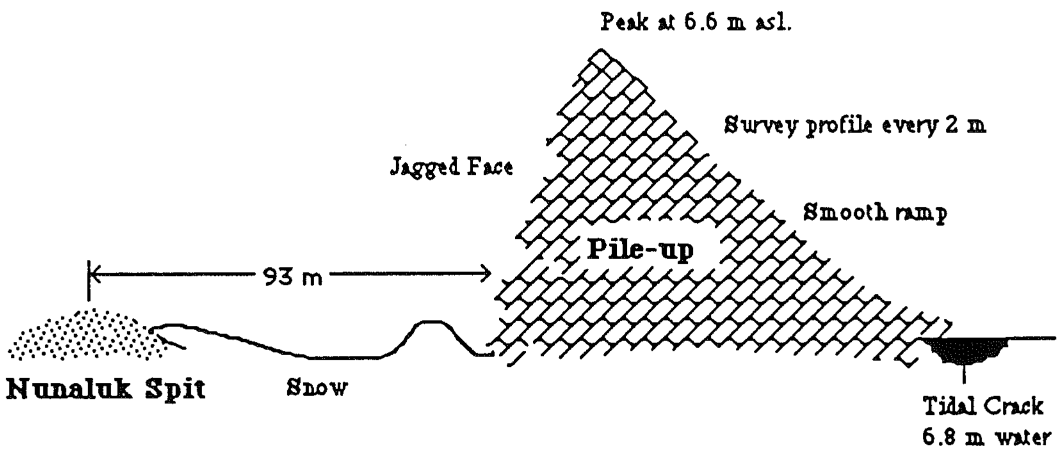


Figure 4. **Cross Section of Pile-up Closest to Nunaluk Spit, Site 1**
(Not to Scale)

Aerial photographs were taken at sharp oblique angles at 1500 ft with a 28 mm lens (28). A red ground marker, 1.5 x 12 m, was placed adjacent to the extreme peak (10.8 m by H1 in plan view, Figure 3).

A second ice pile-up is located 10 km east of Site 1 along Nunaluk Spit. The pile-up appears to follow the 10 m isobath shown on the CHS chart. The water depth, measured through the tidal crack on the seaward side, is 8.6 m.

Table 9. Photos at Pile-up Site 2, Nunaluk Spit (no diagram)

Photo Number	
29	aerial oblique view of pile-up with spit in background
30	ground view of seaward side of Pile-up 2
31	aerial oblique looking east along the spit

A third ice pile-up is located 5.46 km east of Site 2 and 3.62 km from the end of Nunaluk Spit. It appears to be a grounded pressure ridge rather than an ice pile-up. Sediment is visible mixed in with the ice blocks in the ridge sail. The water depth, measured through the tidal crack on the seaward side, is 4.6 m.

Table 10. Photos at Pile-up Site 3, Nunaluk Spit (no diagram)

Photo Number	
32	surface views with survey rod scale from seaward side
33	view across spit showing pile-up
34	aerial view east showing pile-up and spit (see June 15)

Return from Komakuk Beach to Tuktoyaktuk via Stokes Point, flying just south of the landfast ice edge from the Yukon Coast to the Mackenzie Delta. The ice is noticeably different in appearance from the previous day, with ponding over 10 to 30% of the surface. A long crack runs east /west several miles south of the landfast ice edge off the Delta. The first good southerly wind will carry away a significant section of the existing landfast ice in Mackenzie Bay.

There are still significant areas of inundated tundra along the north side of the Delta from Garry Island to Harry Channel (126 and 127). The open water extent appears essentially unchanged from June 2 (see Map 5). North facing oblique photos from 500 ft were taken over West Point (137) and along the east side of Richards Island towards Kidluit Bay (166). Richards Island is almost clear of snow and the lakes are starting to melt out around the edges. Mason Bay has a narrow strip of open water around the edge and the ice is 90% ponded. Kugmallit Bay appears unchanged from the previous day. The ice surface has a dry, drained appearance and isolated open holes are present as black areas (still less than 5% by surface area). The ice around the shore of Hendrickson Island is starting to open up in a narrow band.

June 8 and 9, Scheduled as no flying days.

June 10, 11, and 12, Fog and low ceiling conditions.

June 13, Flight East to Atkinson Point and McKinley Bay
Clear in Tuktoyaktuk by noon, low cloud east of Atkinson Point all afternoon.

Video Tape 3: Atkinson Point to Tuktoyaktuk (18:27 to 19:09)

Flew directly to Atkinson Point to survey the ice pile-ups observed on the previous eastern survey (June 4). Ice surface melt is now well advanced. The ice in Kumallit Bay is drained (190 at 19:03), but from Toker Point east the sea ice is about 50 to 70 % inundated by melt water. The only clear holes through the ice are in shallow water right along the coast where some local drainage has occurred. There is a narrow strip (50 to 100 m) of melt water along shore in many areas, particularly in shallows and around spit headlands and sand bars.

Pile-up Site 4, near Atkinson Point, June 13 and 14, Map 12 A

The base of the ice pile-up is located 838 m (chained distance) at a heading of 335 degrees (True) from the Racon marker tower on the Atkinson Spit. Tidal cracks are visible on both the north and south sides of the pile-up, indicating that the sheet ice is floating clear of the bottom on both sides at a distance approximately 40 to 60 m from the base of the pile-up. Fresh looking clean ice rubble on shore side of the pile-up is comprised of ice blocks from 45 cm up to 3 x 2 m. It appears that in early to mid November 1986 the ice moved onshore and started the formation of a grounded rubble field. This was quickly followed by localized ice ride-up at the seaward side of the rubble (ramps are clearly visible between the initial rubble field and the final pile-up). Eventually the resistance to further ride-up increased to the point where the advancing ice sheet was forced down into the seabed and extruded out the top in a dirty pulverized form. It is this pulverized ice which forms the highest part of the overall ice pile-up feature.

The survey profile of Pile-up Site 4 is south to north across the highest section, starting with level ice 35 m from the edge of the rubble on the south side and finishing at water level in the tidal crack running along the north side.

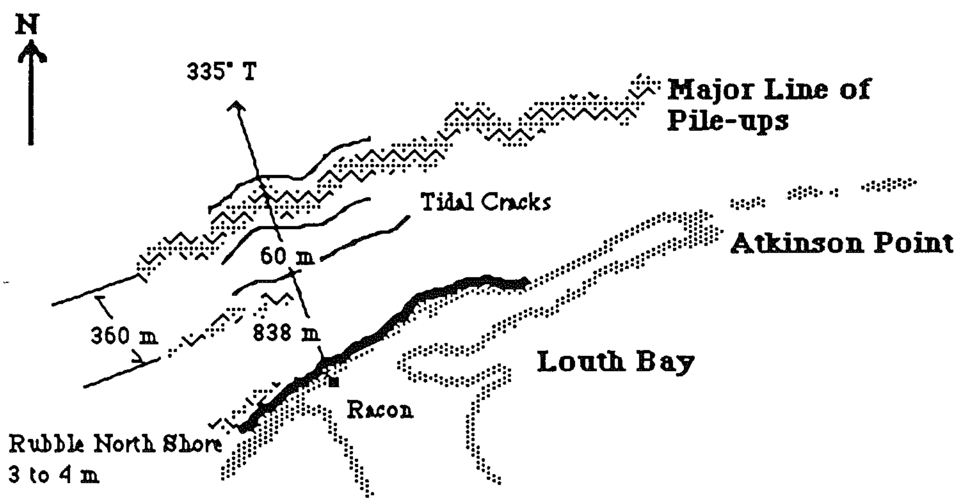


Figure 5. Ice Pile-up Site 4, Atkinson Point, June 13 (Not to Scale)

Table 11. Water Depths at Pile-up Site 4, Atkinson Point

30 m south of rubble edge	6.6 m.
North face of pile-up	6.6 m.

Table 12. Survey Data at Pile-up Site 4, Atkinson Point

Distance (m)	Elevation (m)	Comments
0	0.0	Start line on level ice
5	0.2	
10	0.43	
15	0.95	Tidal crack on shoreward side
20	1.27	
25	1.65	
30	1.98	
35	2.00	
40	2.22	
45	2.20	
50	2.53	North edge of rubble
55	2.06	
60	2.53	
65	2.93	
70	3.5	
75	4.1	Base of pulverized ice pile
80	4.72	
82	5.63	
84	6.67	
86	7.43	
88	7.53	
90	8.75	
94	11.2	
100	12.45	
102	11.93	
104	11.22	
106	10.25	
108	9.1	
110	7.75	
112	6.53	
114	5.36	
116	4.4	
118	3.61	
120	2.77	
122	1.92	
124	1.29	
131	0.24	Water level in tidal crack on seaward side

Table 13. Photography of Pile-up Site 4, Atkinson Point

June 13, 13:12 to 16:33

Ground Views	very poor light conditions
225	view north with spit in foreground and pile-up in distance
226, 227	views west showing melting bottom ice along the spit with sediments mixed in.
Aerial Views	very poor light conditions (replaced with June 14 photos)

Returned to Pile-up Site 4 on June 14 for better photographs with clear sky.

June 14, 18:40 to 19:30

Ground Views	
221, 222, 223	at the pile-up, photos plus video
Aerial Views	
218	low level aerial view north across Atkinson Point to pile-up
219, 220	low level aerial photos
224	28 mm from 3000 ft with red ground marker, 1.5 x 12 m
18:40 to 18:50	video

Pile-up Site 5, Northeast of McKinley Bay, June 13 and 14, Map 12 A

Surveyed peak elevation and took several ground shots of ice blocks with sediment (234 and 235) on June 13. Returned on June 14 as slightly better light and obtained low level video at 100 to 200 ft around the area (18:27). Set marker on extreme north end of spit adjacent to the ice pile-ups and took angles from the tower (Private Racon as marked on CHS chart) to new cone marker and to extreme peak surveyed on June 13.

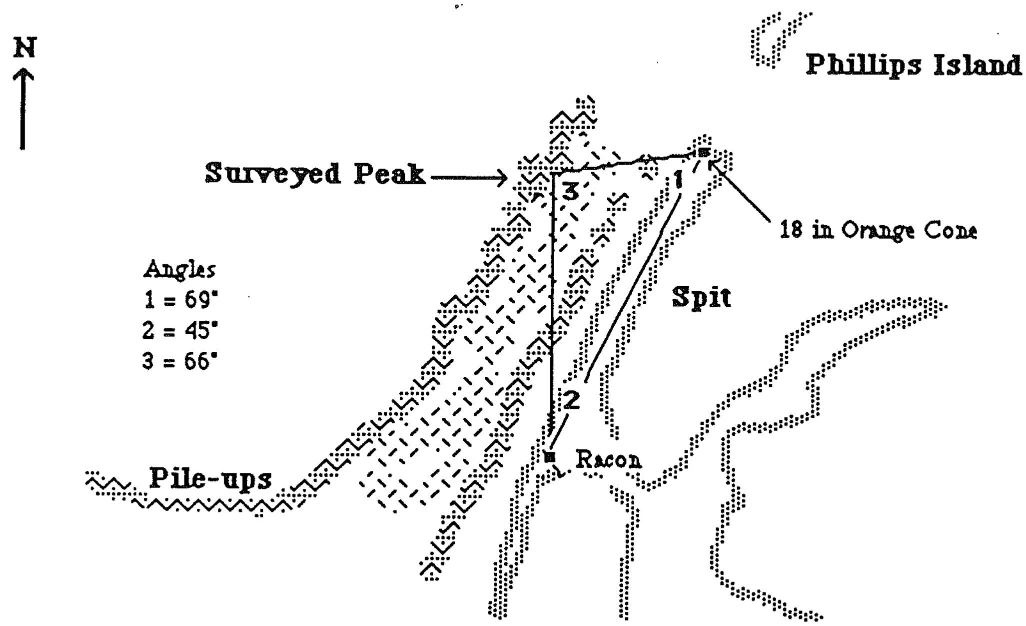


Figure 6. Ice Pile-up Site 5, Northeast of McKinley Bay, June 13
(Not to Scale)

Table 14. Measurements at Pile-up Site 5, Northeast of McKinley Bay

Peak height surveyed June 13	9.05 m
Water depth on seaward side	3.8 m

Video survey at 600 ft along the coast returning from Atkinson Point to Tuktoyaktuk. The most eastern area of open water, other than nearshore melt at Toker Point (202 at 18:57) and Tibjak Point (190 at 19:03), is over Topkak Shoal by Topkak Point (184 at 19:07).

June 13, Flight West over the Mackenzie Delta, Map 13
Clear

Video Tape 4: Tuktoyaktuk to Ellice Island (20:52 to 22:26)

Video survey from Tuktoyaktuk to Ellice Island via North Head. Over the past five days, the open water has extended north to include all of Kittigazuit Bay as far as Hendrickson Island and east along the shore as far as Peninsula Point (179 at 20:58). On reaching Whitefish Summit (180 at 21:03), flight proceeds north to Hendrickson Island with views to the south showing open water extending part way up the west side of Hendrickson Island (21:11). The flight then crosses over to the east side of Richards Island and carries on around to North Head (143 and 144 at 21:34).

There is no break-up of the ice in the vicinity of North Head. The area of rotting ice in the shallows on the west side of Richards Island has now become a large area of open water covering about 7 km. The altitude increases to 1200 ft and then 1800 ft off Harry Channel and the flight continues west to Garry Island (128 at 21:59) before turning south towards the north end of Ellice Island (107 at 22:18, 108 at 22:21, 109 at 22:23). Lobes of open water now extend up to 20 km from the Delta out beyond Garry Island (117 at 22:07)(this was the discoloured area of previous ice overflooding first documented on June 2). Remaining ice off the Delta appears flat white and drained and is rotting quickly. Returned to Tuktoyaktuk; photos 181 and 182 show the rotting ice along shore.

June 14, Flight East to Cape Dalhousie, Map 14
15:25 to 21:25, Clear, Winds 090 at 15 knots

Video Tape 5: Cape Dalhousie (17:05), Nuvorak Point (17:17)
McKinley Bay (18:19 to 18:26), Atkinson Point (18:38 to 19:13)

Followed the landfast ice edge from 70° 05'N, 131°36'W to 70°15'N, 130°58'W. The ice offshore, in water beyond 15 m depth, is very different in surface appearance from the ice nearshore between Atkinson Point and Tuktoyaktuk. Melt ponds cover between 15 and 30% of the surface with isolated areas of greater melt where the snow is blown clear. An isolated pile-up surrounded by smooth ice is located in Russell Inlet at 70°10' N, 130°17' W (215 and 216). Short video sections cover orbits of Cape Dalhousie (211 at 16:51), Nuvorak Point (209 at 17:18), and the pile-ups northeast of McKinley Bay and at Atkinson Point. The melt along the rest of the shore is not far enough advanced to make any further video coverage worthwhile at this point (see June 19). High level views over Kugmallit Bay show open water areas in Kittigazuit Bay (see print at 21:09) and over Topkak Shoal (see print at 21:00)(see Map 19).

June 15, Flight West to Komakuk Beach, Maps 15 and 16
15:50 to 23:16, Clear to high scattered cloud, Winds 090 at 25 knots

Video Tape 5: Canada/US Border to Shingle Point Spit (19:12 to 20:56)
Video Tape 6: Shingle Point to Shoalwater Bay (21:38 to 22:05)

Flew directly to Komakuk Beach to start video survey east and south from the US/Canada border. The landfast ice edge in Mackenzie Bay is approximately 9 km further south than the position mapped on June 6. The open water extending northwest of the Oliver Islands has advanced to within 7 km of the landfast ice edge. The Mackenzie ice barrier will likely be breached within the next few days. The landfast ice edge takes an abrupt change in direction just 6 km south of Kay Point and continues northwest along the 10 m contour to Collinson

Head on Herschel Island. West of Herschel Island, the landfast ice edge follows along the 12 to 15 m contour as far as Komakuk Beach (same point where it turned north on June 7, see Map 11).

The video survey runs from the US/Canada border (1 and 2 at 19:00) to Shoalwater Bay. Altitudes are 600 ft from the start to Komakuk DEW Line Site, 300 ft from Komakuk to Nunaluk Spit, and 500 ft for the remainder of the flight. Low level, close up video shows the major pile-up systems running between 3 and 6 km east of the Komakuk DEW Line Site (10 to 13 at 19:38). Rough ice is encountered almost continuously from shore out to the ice edge for about 12 km from the point where the ice edge curves north out of sight and the beginning of Nunaluk Spit. Further east, there are occasional severe ridges and pile-ups in excess of 5 m height close in to the spit (eg. Pile-up Site 3, 34 at 19:50). The ice out to the landfast edge is somewhat smoother. In general, features seem to be located either right along the beach or along the 10 m contour (500 to 1500 m from shore in this area).

The flight continues inside the south shore of Workboat Passage (48 at 19:56) where the extent of open water is little changed from June 6 (16 at 19:58, view looking east from Welles Point). Apparently, the early opening of this area is entirely due to the spring discharge from the Firth River. Once this is over, the remaining ice melts from above at the same rate as the regional ice cover. The ice edge between Herschel Island and Kay Point (20:25, 64 and 65) has retreated west by about 8 km over the past nine days, moving from the edge of Herschel Sill in 20 m of water to the rim of Herschel Basin. In other years, grounded ridge systems along the sill would act to keep the fast ice in place, but these systems are not present this year.

Along the rest of the Yukon shore, the ice becomes more heavily ponded moving southeast past King Point (57 at 20:43). The only significant open areas are in Phillips Bay (20:22) (Babbage River) and Trent Bay (Blow River). The actual areal extent of open water appears to be little changed from the previous nine days.

The first large extent of open water is encountered just beyond the Blow River flying east southeast into Shoalwater Bay (54 at 21:54). Past Moose Channel the open water extends up to 10 km north in large lobes oriented NW to SE along the 2 m isobath. The video coverage terminates 6 km east of the Yukon/NWT border. From this point south, Shallow Bay is competely clear of ice. The only remaining ice in this region appears as narrow strips in the centre of the main channels on the west side of the Delta (eg. Ministicoog Channel). Channels in the central Delta are completely ice free.

June 16, Flight over Kugmallit Bay, Map 19
10:15 to 10:50

Flew over Kugmallit Bay as far as Toker Point to map the advance of open water along the south shore and to begin a series of ground level shots at Toker Point to monitor local break-up over the next 7 days. Locations for repetative aerial photos at 600 ft are Beluga Point looking north (185), Tibjak Point looking north (191 and 195), and Toker Point looking east (203). A ground views taken at Toker Point immediately in front of the shipping Racon looks north (198). In addition, an aerial view immediately behind the Racon is taken from 100 ft (199). Returning to Tuktoyaktuk, a high level photo (195 at 2500 ft) just north of Lake Pingo (Tinnerk Bay) shows the extent of open water along the south shore with Tuktoyaktuk in the background.

The open water in Kugmallit Bay is advancing north at a rate of over 1 km/day (since June 14). Along shore, the open water extends in a narrow strip about 50 to 100 m in width. Remaining bottom ice in this strip is just awash and covered in sediment. Ice remaining intact nearshore (within about 1 km) is very dark in colour and rotted through with numerous holes. Further offshore, the ice in Kugmallit Bay is flat white in colour and almost completely drained of water.

June 17, Flight over Kugmallit Bay, Map 19
18:43 to 20:25, Clear, +15°C

Surveyed Kugmallit Bay north to Toker Point, repeating the sequence of photos taken on June 16 (186, 192, and 200). Open water is expanding rapidly to the north (approximately 4 km over the past 36 hours). Nearshore ice, out to the 2 m water depth, is rotting in patches and is dirty with sediment. On the west side of the bay, open water has progressed north about 5 km in the past three days, reaching the north end of Hendrickson Island. Around Richards Island there is a narrow band of open water nearshore following the 2 m isobath. Shallow bays along the east side of Richards Island are completely open (eg. Hansen Harbour). The remaining ice offshore is still solid out to the ice edge visible off to the north. Several high level shots at 3000 ft show the extent of open water in Kugmallit Bay (171 and 196).

Ice is still solid, although heavily ponded, between Pullen Island and North Head. High level shots from 6000 ft show the extent of open water in Beluga Bay (149) and in the vicinity of North Head, as well as the relative position of the landfast ice edge to Pullen Island (147 and 148). A marker is located on the beach at North Head for repeated ground shots over the next four days (145). The beach along a small embayment in North Head is covered with a shallow mound of black sediment covered ice. The ice surface appears in the sun reflection to have many long rectangular shaped forms as though the surface is scribed. This ice appears to be the remains of wave overwash from the previous fall (Sept/Oct). The ice probably built up in layers, with sediment laden water continually washing over and refreezing to build up on the beach face above the intertidal area.

June 18, Flight over Kugmallit Bay, Map 19
19:04 to 20:04, Clear sky, +15°C

Mapped the extent of open water in Kugmallit Bay (part of a series of local flights started on June 16), repeating still photos at 660 ft looking north over Beluga Point (187) and Tibjak

Point (193). A low level view from 100 ft, immediately behind the Racon tower at Toker Point, shows the open water extent along shore (201). The ice is still solid past the 2 m water depth. The sun angle prevented the usual photo from 2500 ft over Lake Pingo. This photo was replaced with a view to the south from several miles west of Toker Point (197).

Flew from Toker Point to the most southerly point of the landfast ice edge at the abandoned island, Arkak K-06, located in 6 m of water. Two views show the ice edge northeast (178) and northwest (177) from the island. A crack was observed running southeast from the artificial island towards Toker Point. With no ridge systems to act as anchors, the entire landfast ice sheet is vulnerable to an offshore blow.

Flying south from the ice edge to Hendrickson Island, several photos show the open water extent in Kugmallit Bay (172 at 2500 ft and 174 at 3500 ft). The northern boundary of the open water has progressed approximately 6 km in the past 24 hours to just south of Tibjak Point. A view of Tuktoyaktuk shows ice conditions in the harbour (183).

June 19, Flight East to Cape Dalhousie, Map 17

18:13 to 22:19, Clear, +20°C

Video Tape 6: Toker Point to Cape Dalhousie (18:26 to 19:46)

Carried out a video survey along the shore from Toker Point to Cape Dalhousie. Orbits off Atkinson Point and northeast of McKinley Bay show the ice pile-ups in the vicinity of Sites 4 and 5 surveyed on June 13. McKinley Bay and the southwest side of Russell Inlet are not included in the video track in order to save time and fuel. Also, the numerous indents along the southwest shore of Russell Inlet make referencing the video almost impossible.

Ice break-up east of Toker Point is at least one week behind the Kugmallit Bay/Richards Island area in terms of the state of ice deterioration and extent of water along shore. However, surface melt water has increased significantly in area since the last survey on June 14. Much of the ice east of Nuvorak Point is up to 100% covered with melt water and there is little evidence of drainage taking place (210 at 20:00). Ice alongshore in shallow areas less than 1 m deep is largely melted, leaving behind areas of rotting, submerged, bottomfast ice overlain with sediment. There are no ice pile-up features in the nearshore area between McKinley Bay and Cape Dalhousie (213 and 214 at 19:47). An isolated pile-up first spotted on June 14 is located approximately 5 miles east of Nuvorak Point (215 and 216).

The flight returns northeast of McKinley Bay to take aerial views of the ice pile-up at Site 5 which were previously missed due to poor light conditions. A series of low level (230, 238, and 239 at 100 to 200 ft) and high level photos (228 and 229 at 3000 ft) show the major pile-ups within 1 km of the shore. A line of sediment covered rubble is within several 100 m of the spit. This nearshore rubble has a maximum height of about 2 m, while the more massive ice features further offshore are as high as 9 m. These ice pile-ups are in 4 m of water (see Figure 6 showing the plan view of Site 5). Placed a 1.5 x 12 m marker near the pile-up. Aerial photo (231) shows the spit and pile-up and ground photos (232, 233, and 236) show the sediment covered rubble.

Now that the snow has melted, there are sharp divisions between dirty black ice areas and the clean ice patches. An almost continuous line of ridging runs from the abandoned drillsite at Kannerk over to the pile-up at Site 5. The ice on the shore side of the ridge is clean, while ice on the seaward side is black with what appears to be wind deposited sediment. The explanation for this sharp division is not clear; a section of the ice in northeastern McKinley Bay must have been displaced during November or early December creating the pile-ups and a distinct boundary between ice with and without sediment.

It is not clear at Site 5 how the most massive pile-up on the extreme northeastern end of the rough ice area can appear so dirty while the remainder of the ridges and rubble running southwest is sediment free. Even allowing for the advanced state of surface melt, the dirty pile-up section appears to have moved in from elsewhere and grounded during the summer of

1986. Individual features are obliterated on the dirty section as though it is a multi-year fragment which has already undergone a summer's melt. This hypothesis is not consistent with the water depths. It would be impossible for a feature with a 9 m sail height to float in water less than 25 m deep. It also seems highly improbable that a pile-up formed during the winter of 1985-86 could have survived the summer in such shallow water and become a site for new ice deformation the following winter. Surrounding rubble and ridging which formed during the late fall of 1986 still has the individual block structure clearly visible.

June 20, Flight West to Shingle Point, Map 18

18:47 to 22:10, Clear at Tuktoyaktuk with fog over open water areas

Video Tape 7: North Point (21:38 to 21:41)

Flew directly to Shingle Point to video ice conditions along Yukon coast as far west as King Point. The open water extent along the Yukon shore has now advanced to the Running River delta in Trent Bay. The ice along the shore north of Shingle Point is now drained of water. The only open areas further along shore are associated with local creeks and small melt ponds along the beach. Videoing was stopped as the coast from Shingle Point to Herschel Island was fogged in.

Returned to Tuktoyaktuk via North Head. Mapped the ice edge in Mackenzie Bay as well as possible through the fog patches. It appears that the landfast ice barrier has been breached northwest of Ellice Island. Off the Delta, open water now extends north of Garry Island and to the south shore of Pelly Island. There is an isolated open water area south of Hooper Island corresponding to the shallow water. The open water edge off Taglu Island cuts across Beluga Bay from Pelly Island to West Point (130), however, a long tongue of ice still remains between Hooper Island and Harry Channel (135). The area between Hooper and Richards Islands is still largely ice covered except for the shallow area along the west side of North Point which is ice free. A narrow strip of open water several hundred meters wide follows along the shore around North Head inside of the 2 m isobath. A short section of video shows this open water strip as far as North Head, proceeding from south to north and west to east before fog prevented futher photography. High level photos, from 3000 ft looking south along the west shore of North Point, show the extent of open water as far as West Point (151 at 21:34).

June 21, Flight over Kugmallit Bay, Maps 19 and 20
20:37 to 21:45, Clear sky

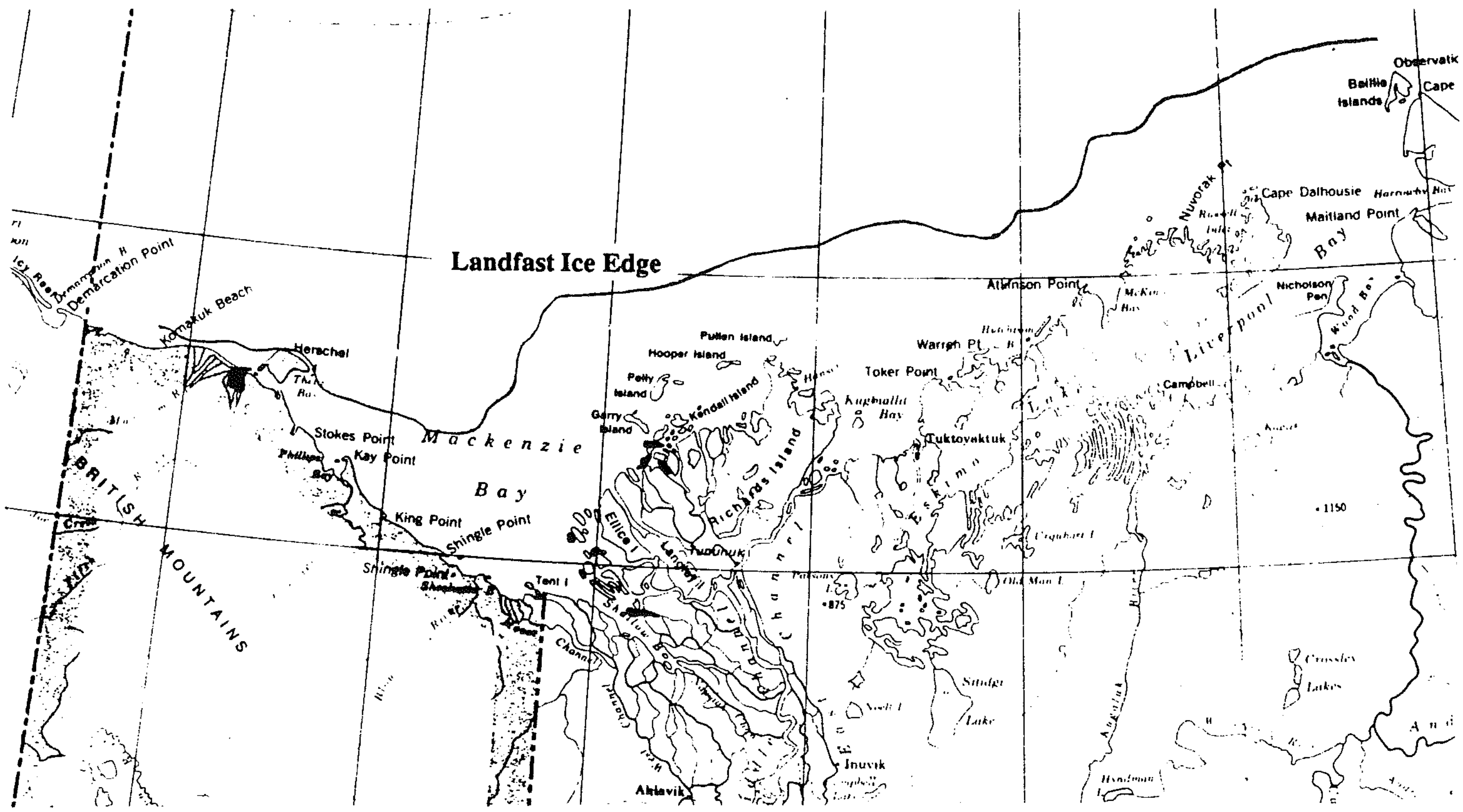
Video Tape 7: Peninsula Point to Toker Point (20:42 to 21:01)

Redid the video section from Peninsula Point (20:42) to Toker Point (21:01), flying at 500 to 600 ft (problems with video between Tuktoyaktuk and Toker Point on June 19). Open water is present within a few km of Tuktoyaktuk. A separate tongue of open water stretches down from Topkak Shoal to within 2 km of the entrance to Tuktoyaktuk Harbour. There is a band of open water several 100 m wide stretching along the entire east shore of Kugmallit Bay. This band tends to widen and extend further out from land points. Kugmallit Bay is clear of ice up to 69°30' N and open water lobes are rapidly expanding along the west and east sides as far as Summer Island and Tibjak Point, respectively. A view from 600 ft looking east (206) show the ice conditions around Toker Point. High level views from 4000 ft between Toker Point and Hendrickson Island (176), between Richards and Hendrickson Islands (173), and over Hendrickson Island looking southeast (175) show the extent of open water throughout Kugmallit Bay. Conditions along the east side of the bay are shown in a photo looking north over Beluga Point from 1000 ft (188). This view shows the open water originating in the vicinity of Topkak Shoal.

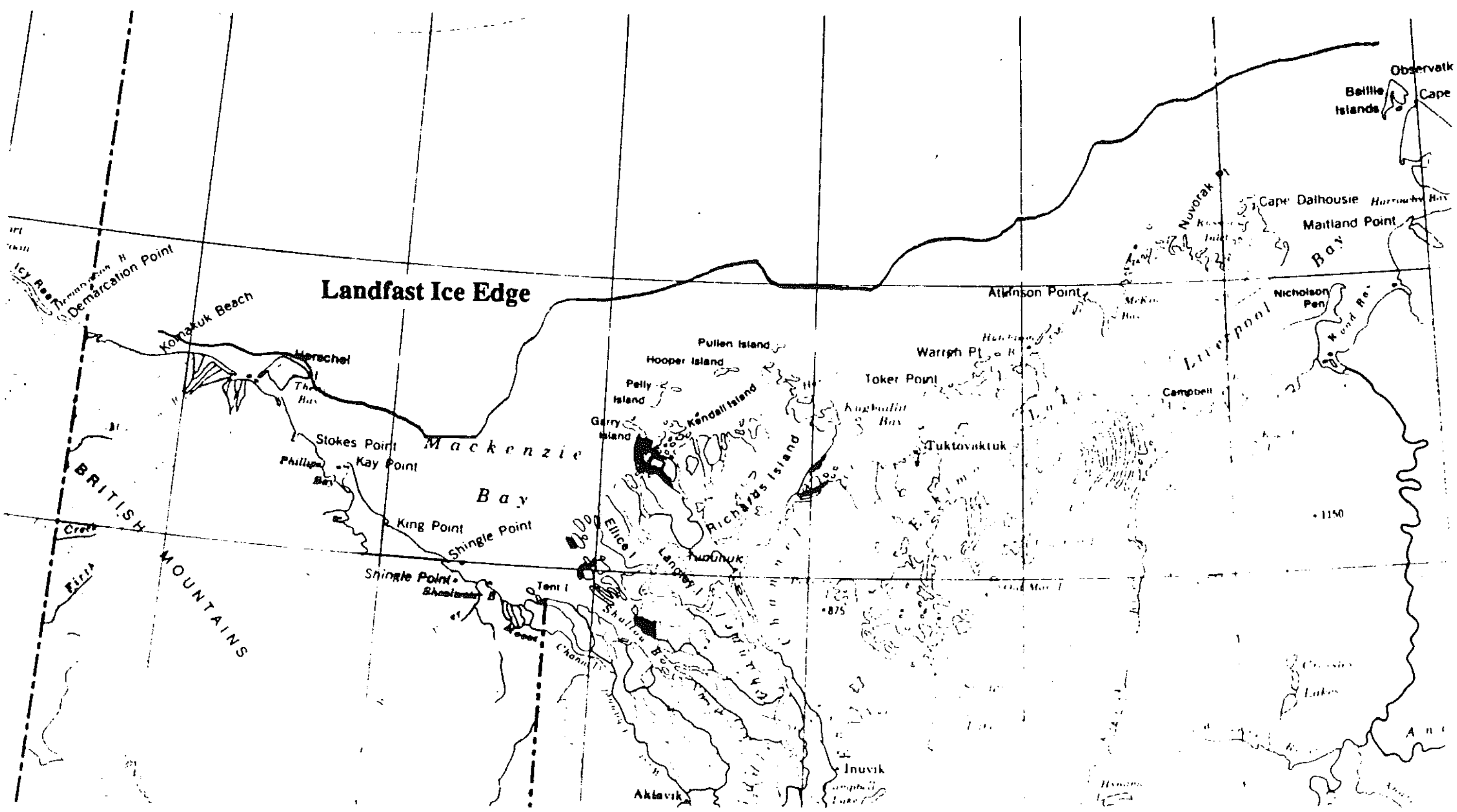
The progression of ice break-up between June 11 and July 2 is shown in the weekly ice charts included in Appendix C.

APPENDIX B

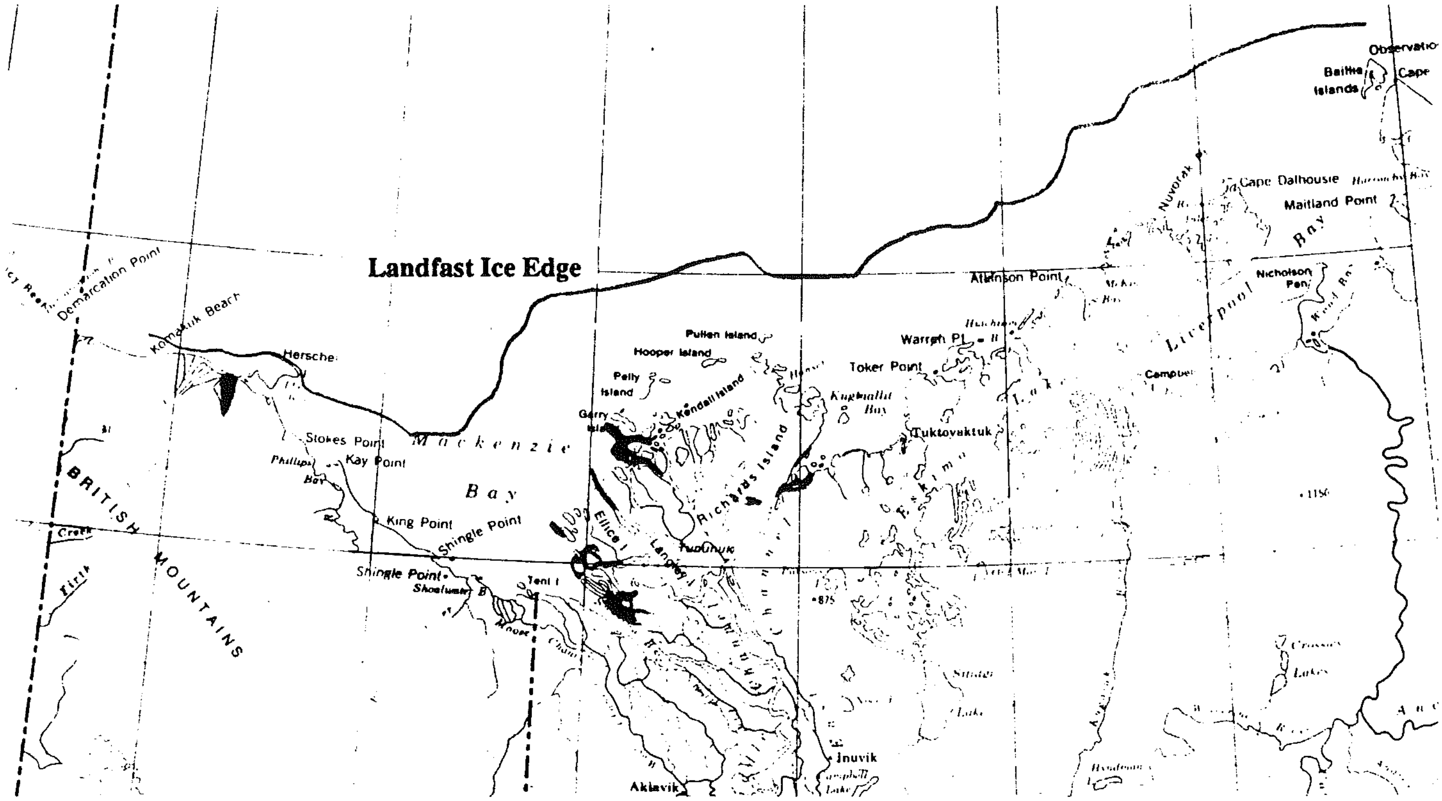
Ice Overflooding in May 1987 Mapped from NOAA Imagery
AES Seasonal Outlook for June 1897
AES 30 Day Forecasts for Mid June to Mid July



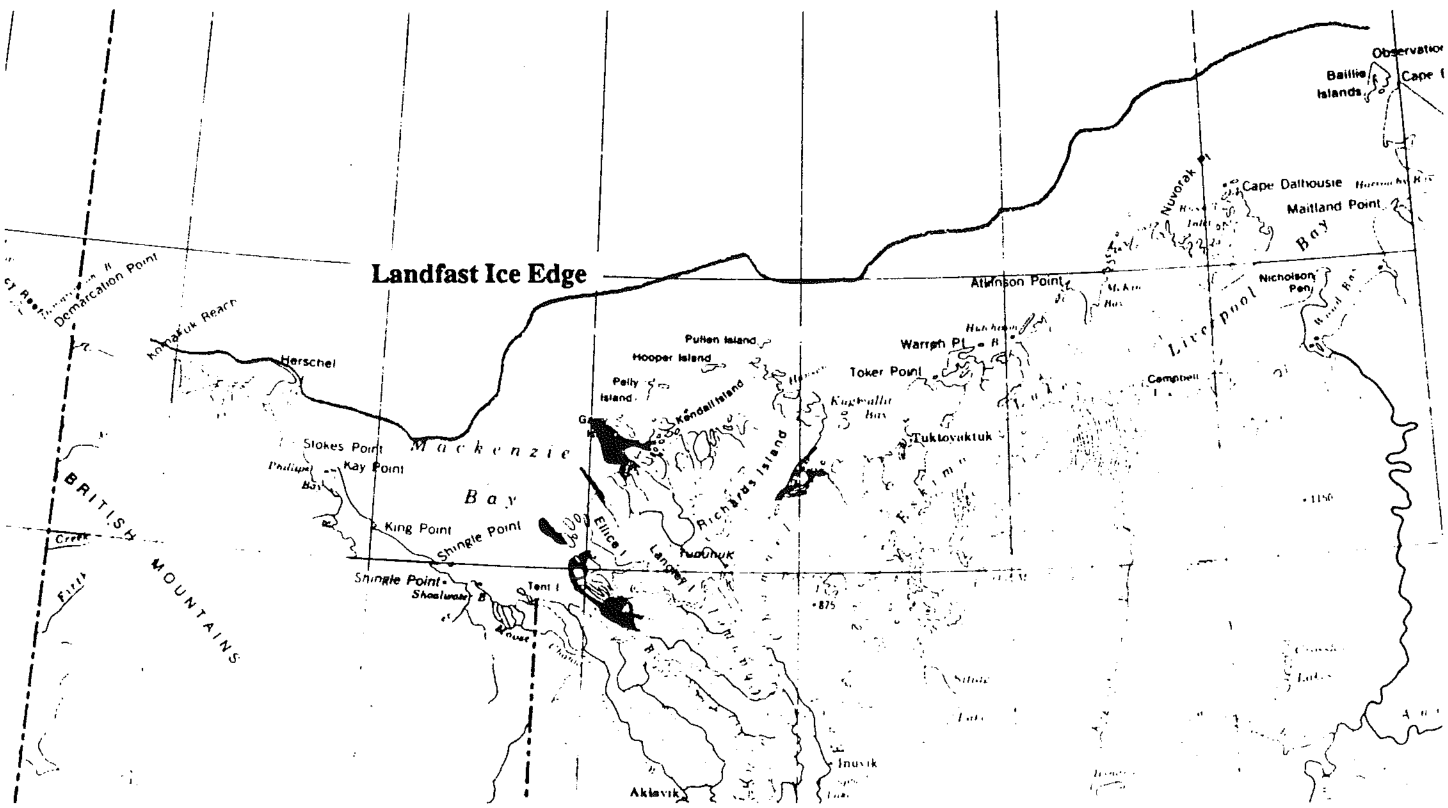
Open Water and/or Ice Overflooding Mapped from NOAA Satellite Image, May 19, 1987



Open Water and/or Ice Overflooding Mapped from NOAA Satellite Image, May 21, 1987



Open Water and/or Ice Overflooding Mapped from NOAA Satellite Image, May 22, 1987



Open Water and/or Ice Overflooding Mapped from NOAA Satellite Image, May 24 to 26, 1987

Environment Canada | Environnement Canada

Atmospheric Environment Service | Service de l'Environnement Atmospherique

SEASONAL OUTLOOK

NORTHERN CANADIAN WATERS

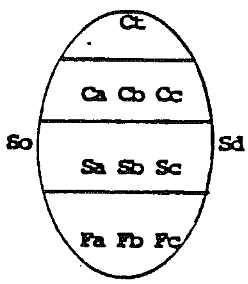
SUMMER 1987

ICE CENTRE
CENTRE des GLACES

ANALYSIS AND FORECASTING
ANALYSE ET PRÉVISION

KEY TO INTERNATIONAL SEA ICE SYMBOLS
(THE EGG CODE)

THE MAIN SYMBOLS



Ct – Total concentration of ice in the area, reported in tenths.

Ca Cb Cc – Partial concentration in tenths of thickest (Ca), second thickest (Cb), and third thickest (Cc) ice types. with Ca, Cb, and Cc one tenth or more. if only one thickness type present Ca equals Ct and the second level is left blank.

Sa Sb Sc – Stage of development (age) of ice concentration reported by Ca, Cb, and Cc.

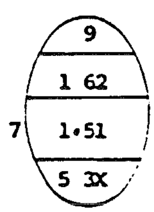
Fa Fb Fc – Predominant form of ice (floe size) corresponding to Sa, Sb, and Sc. respectively.

So Sd – Development stage (age) of remaining ice types. So if reported is a trace of ice type thicker/older than Sa. Sd is a thinner ice type which is reported when there are four or more ice thickness types.

Fa Fb Fc Form of Ice (width)			Sa Sb Sc Stage of Development (thickness cm)		
0	Pancake		1	New	– < 10 cm
1	Brash		2	Nilas	– < 10 cm
2	Ice Cakes	– < 20 m	3	Young	– 10-30 cm
3	Small floe	– 20-100 m	4	Grey	– 10-15 cm
4	Medium floe	– 100-500 m	5	Grey-white	– 15-30 cm
5	Big floe	– 500-2000 m	6	First Year	– > 30 cm
6	Vast floe	– 2-10 km	7	Thin First Year/White	– 30-70 cm
7	Giant floe	– > 10 km	1.	Medium First Year	– 70-120cm
8	Fast Ice		4.	Thick First Year	– > 120cm
9	Icebergs		7.	Old	no defined ranges
X	No Form		8.	Second Year	no defined ranges
∿C	Ice is in strips in which concentration is C.		9.	Multi-year	no defined ranges
			△	Icebergs	no defined ranges

Note: All ages to left of "." are decoded from table as having "." (see example)

Example



9 tenths ice present
1 tenth type 1. (medium first year) in big floes (1,1.,5 reading down)
6 tenths type 5 (grey-white ice) in small floes (6,5,3 reading down)
2 tenths type 1 (new ice) no floe size
THERE IS a trace of ice type 7, (old ice)

Additional Symbols

WESTERN ARCTIC

i) Freeze-up and Winter Ice Regime

In the Beaufort Sea new ice began to form as September drew to a close and by the end of the third week in October ice covered the waterway to Spence Bay. In late October shorefast ice began developing along the Alaskan and Beaufort coasts, with the main pack of old ice about 60 miles off the coasts. By the end of May the old ice had moved to 80 to 90 miles off the Beaufort and Alaskan coasts with generally thick first year and a trace of old ice along shore. Along the waterway east of Cape Parry to Spence Bay thick shorefast first year ice is the norm with about a tenth of old ice in eastern Queen Maud Gulf. Victoria Strait contains mostly old ice. The ice in Peel Sound is unusual in that mostly old ice lies in the southern portion. Little melt took place last summer in Viscount Melville Sound and M'Clintock Channel and thus old and second year ice predominates there.

During the winter period temperatures have been near to slightly above normal over the Beaufort Sea and western waterway and slightly below normal east of Victoria Island giving ice thicknesses a little thinner than normal. During April however, temperatures turned colder with readings of about 3C below normal reported over Beaufort Sea, 1C below normal over the western waterway and near normal temperatures persisting in eastern Queen Maud Gulf. Cold temperatures continued into May and were 3C below normal over most areas except along the Alaskan coast where near normal readings were reported. Due to the cold April and May freezing degree accumulations are now a little greater than normal.

ii) Observed Ice Conditions

The chart on page 12 was drawn on the basis of aerial reconnaissance in April and satellite imagery around mid-May. The following features are important.

a) In the southeastern Beaufort Sea old ice predominates except within 90 miles of the coast.

b) Along the Alaskan coast the ice is first year to about 80 miles offshore narrowing to 30 miles near Point Barrow. Old ice predominates farther offshore.

c) There is a small amount of old ice in eastern Queen Maud Gulf. Old ice predominates in Victoria Strait and southern Peel Sound.

d) Old and second year ice covers almost all of Viscount Melville Sound and M'Clintock Channel.

TABLE 3 Break-up Pattern and Outlook

WESTERN ARCTIC

		1986	MEDIAN	OUTLOOK FOR 1987
Mackenzie Delta	-clearing	28 Jun	14 Jun	15-20 Jun
Kugmallit Bay	-clearing	17 Jul	05 Jul	05-10 Jul
Tuktoyaktuk Peninsula	-fracture	17 Jul	05 Jul	05-10 Jul
Mackenzie Bay to Cape Bathurst	-open water	01 Aug	21 Jul	20-25 Jul
Amundsen Gulf	-fracture	10 Jul	11 Jul	10-15 Jul
	-clearing	23 Sep	16 Aug	15-20 Aug
Coronation Gulf	-fracture	02 Aug	17 Jul	20-25 Jul
	-clearing	22 Aug	03 Aug	10-15 Aug
Route to Spence Bay	-open water	01 Sep	26 Aug	05-10 Sep
Coastal Waterway Mackenzie Bay to Point Barrow	-open drift or less	03 Aug	06 Aug	05-10 Aug

Note: Fracture indicates complete breakage of consolidated ice cover

iii) Outlook

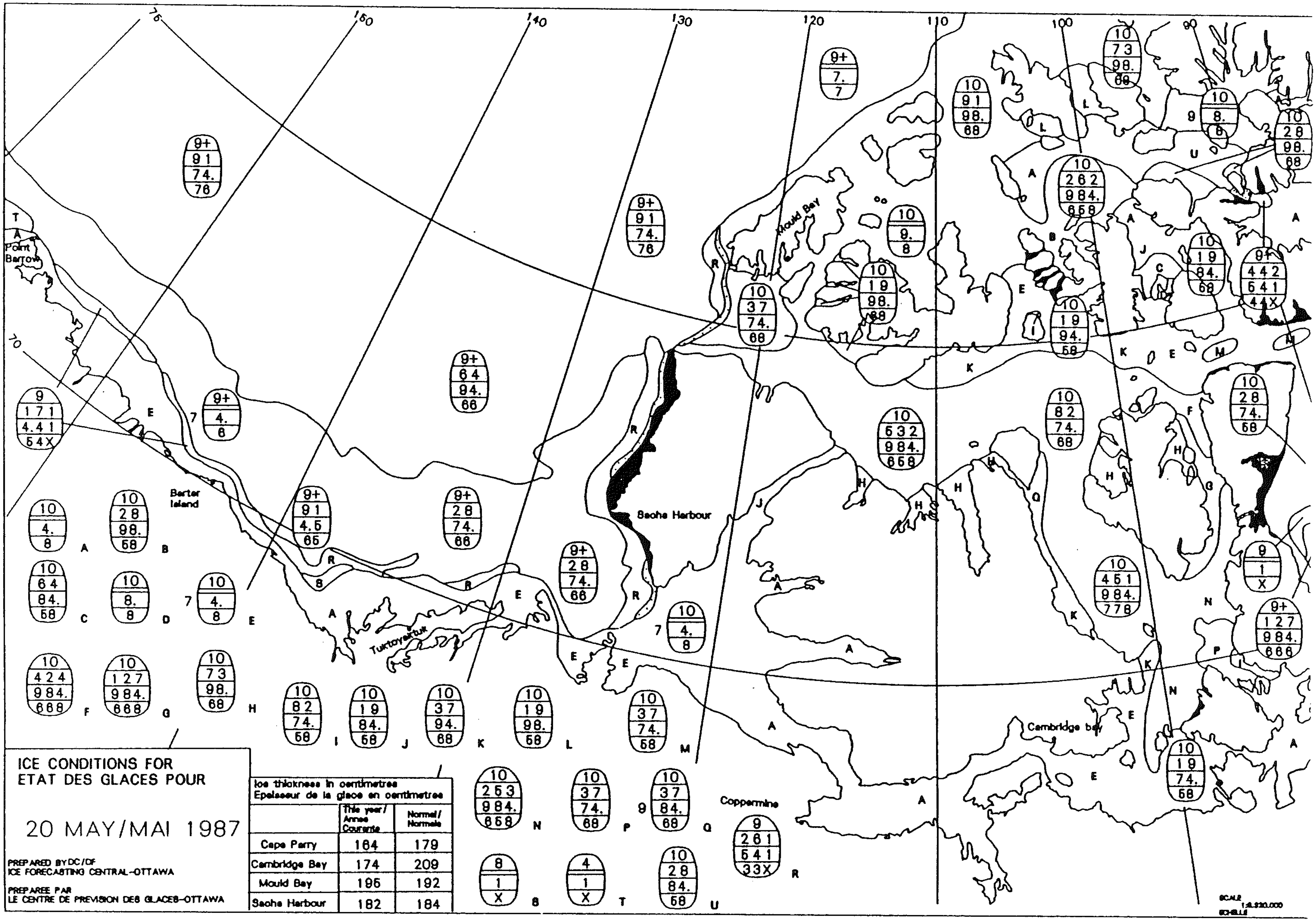
During May temperatures in the waterway east of Cape Parry were about 4 to 5C below normal and 2 to 3C below normal over the eastern Beaufort, while near normal temperatures were experienced over the Alaskan coast. The mean sea level prognostic chart for May shows a weak low pressure area over southwestern Alaska and a ridge of high pressure from Great Slave Lake to Banks Island and out into the Arctic Ocean. This pattern is expected to produce weak easterly winds which are normal for June. Temperatures are expected to be slightly below normal.

The main pack of old ice is about 80 to 90 miles off the Tuktoyaktuk Peninsula and Alaskan coast but narrows to about 30 miles near Point Barrow. With slightly below normal temperatures and mean easterly winds, a slightly late development of breakup events is expected in the western Arctic. The Mackenzie Delta should clear during the third week in June and Kugmallit Bay during the first week in July with fracture of the fast ice along Tuktoyaktuk Peninsula shortly thereafter. Coastal clearing between the Mackenzie Delta and Cape Bathurst is expected during the fourth week in August, or earlier if offshore winds should develop.

Along the coast from Mackenzie Bay to Point Barrow a near normal development of the waterway is expected. Thus ice concentrations of open drift or less should develop along the coastal waterway during the first week in August.

The ice in Amundsen Gulf is consolidated east of Cape Parry with only traces of old ice. Temperatures are expected to be slightly below normal in June but the ridge of high pressure is expected to give greater than normal hours of bright sunshine leading to a near normal breakup. Thus the fast ice in Amundsen Gulf should fracture during the second week in July and open water should develop there during the third week in August. In Coronation Gulf, colder than normal temperatures should lead to a fracture of the fast ice late in the third week in July and clearing is likely after the first week in August.

In Queen Maud Gulf fracture should take place in late July which is near normal. However, eastern Queen Maud Gulf contains about a tenth of old ice and Victoria Strait is in predominantly old ice. These factors indicate a late development of an open water route to Spence Bay near the end of the first week in September. Note that if temperatures are below normal or northerly winds prevail in July an open water route to Spence Bay may not develop.



ICE CONDITIONS FOR
ETAT DES GLACES POUR

20 MAY/MAI 1987

PREPARED BY DC/DF
ICE FORECASTING CENTRAL-OTTAWA

PREPAREE PAR
LE CENTRE DE PREVISION DES GLACES-OTTAWA

Ice thickness in centimetres / Epaisseur de la glace en centimetres	This year/ Annee Courante	Normal/ Normale
Cape Parry	164	179
Cambridge Bay	174	209
Mould Bay	195	192
Sachs Harbour	182	184

Environment Canada / Environnement Canada
Atmospheric Environment Service / Service de l'environnement atmosphérique

THIRTY DAY ICE FORECAST FOR NORTHERN CANADIAN WATERS
MID-JUNE TO MID-JULY 1987

Your file   Votre référence

WESTERN ARCTIC WATERS

Temperatures over the waterway during the first half of June have averaged about 1.5C below normal while near normal temperatures were experienced over the Beaufort and Alaskan coasts. Temperatures, however were 1.5 above normal in Inuvik. Mean easterly winds since the beginning of May have caused Amundsen Gulf to fracture eastward to Dolphin and Union Strait near the tenth of June about a month earlier than forecast. An extensive lead lies off the shorefast ice along Tuktoyaktuk Peninsula to about 30 miles west of Hershel Island and off the fast ice of Banks Island. West of Hershel Island the pack lies along the coast to Point Barrow and westward from Point Barrow a lead again lies off the fast ice.

The temperature outlook for mid-June to mid-July indicates below normal temperatures along the waterway and along the Beaufort and Alaskan coasts. The 30 day mean sea level prog charts indicates a trough of low pressure from central Alaska to Great Bear Lake and a ridge of high pressure much farther north over the Arctic Ocean. Thus mean easterly winds are again expected during the forecast period.

The wind and temperature pattern is similar to those expected when the Seasonal Outlook was issued and the following events closely follow those issued in the Seasonal Outlook. The mean easterly winds should keep ice along the coast from Hershel Island to Point Barrow and a coastal route of open drift or less is not espected to develop before August. The Mackenzie Delta fast ice shows signs of breaking and should do so in the next week. The fast ice along the Tuktoyaktuk Peninsula and Kugmallit Bay should break during the first week in July and by mid month the area of open water and loose ice ice along the Tuktoyaktuk Peninsula should expand significantly. However spring storms moving through the area could produce northerly winds which may close the open water area off Tuktoyaktuk Peninsula. Coronation Gulf is not expected to fracture til the third week in July and Queen Maud shortly after. However, easterly winds have caused Amundsen Gulf to fracture about a month earlier than normal and should result in clearing early in August about two weeks earlier than indicated by the Seasonal Outlook.

Issued by:

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Date.............15 June 1987

Environment Canada / Environnement Canada
Atmospheric Environment Service / Service de l'environnement atmosphérique

THIRTY DAY ICE FORECAST FOR NORTHERN CANADIAN WATERS
JULY 1987

Your file / Votre référence

WESTERN ARCTIC WATERS

During June temperatures have averaged about 1C below normal over the waterway to Spence Bay and about 1C above normal west of Cape Bathurst. Mean easterly winds have continued through June and the extensive lead along the fast ice west of Cape Bathurst has widened to as much as 150 miles off the Mackenzie Delta. The broken up ice from Amundsen Gulf has spread westward well north of the mainland into the 80 mile wide lead off western Banks Island. Little further breakup in the ice has occurred east of Amundsen Gulf since its fracture around June tenth but puddling is underway in the waterway. Along the Alaska coast the pack remains right on the coast to Point Barrow with the old ice about 80 to 120 miles offshore. West of Point Barrow there is a lead along the fast ice.

The 30 day mean sea level forecast chart shows a mean low over Bering Strait with a trough eastward over northern Alaska and towards Great Bear Lake and a high over the Arctic Ocean northwest of the Queen Elizabeth Islands. With this pressure pattern mean easterly winds can be expected through the month and temperatures only slightly below normal.

This wind and temperature pattern is much the same as foreseen when the Seasonal Outlook was issued although the strength and persistence of the easterly flow was not expected. Breakup events have tended to be advanced in the Canadian Beaufort. Kugmallit Bay has broken out in the last few days - about a week early and breakup along the Tuktoyaktuk Peninsula should occur within the next few days which should give an open water route along the coast to Cape Bathurst by about mid month if the easterlies persist as expected. However other breakup events appear to be still on the Seasonal Outlook schedule. Easterly winds are keeping the pack right on the Alaska coast but the open water area should gradually spread westwards to give a coastal route of open drift or less to Point Barrow in early August. In Coronation Gulf fracture is still expected in the third week in July and soon after in Queen Maud Gulf. However the presence of old ice and somewhat below normal temperatures still seem to indicate a September open water route to Spence Bay. Similarly there appear to be few prospects of significant open drift areas developing the the Larsen Sound area.

Issued by:

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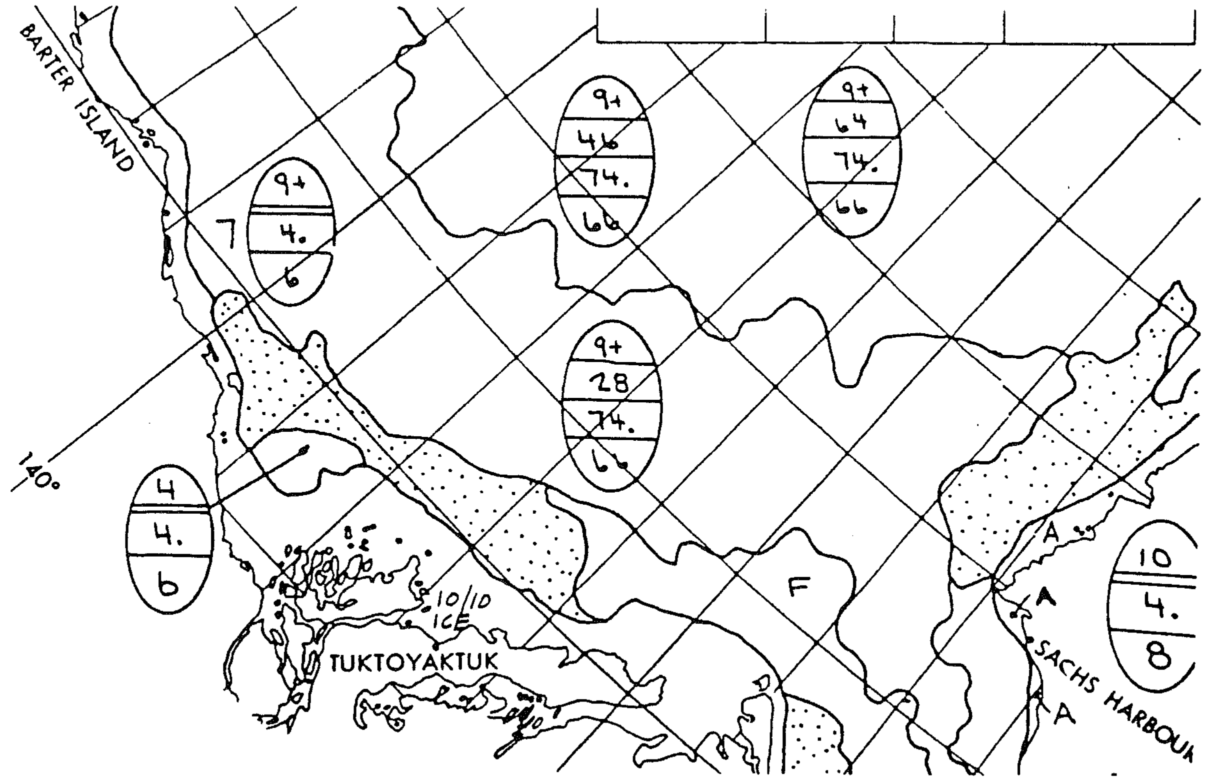
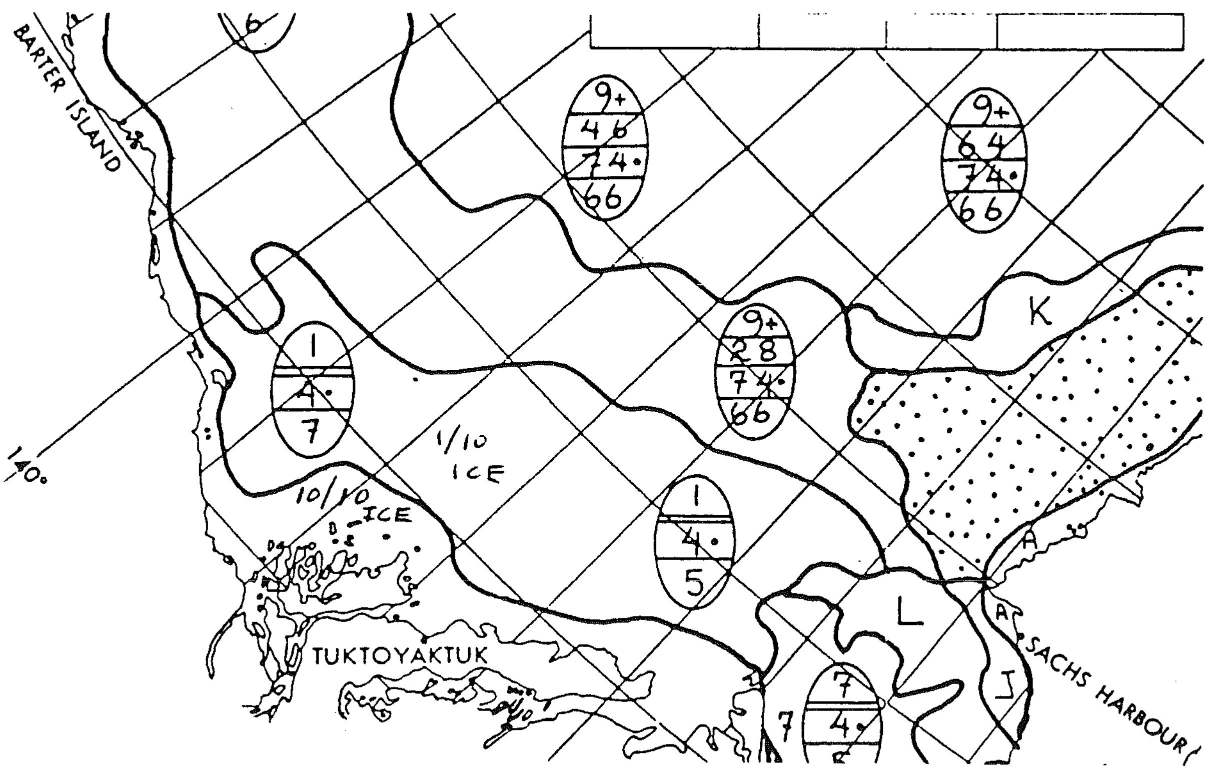
Telex...(Auto)..... 053-4103
Date.............02 July 1987

APPENDIX C

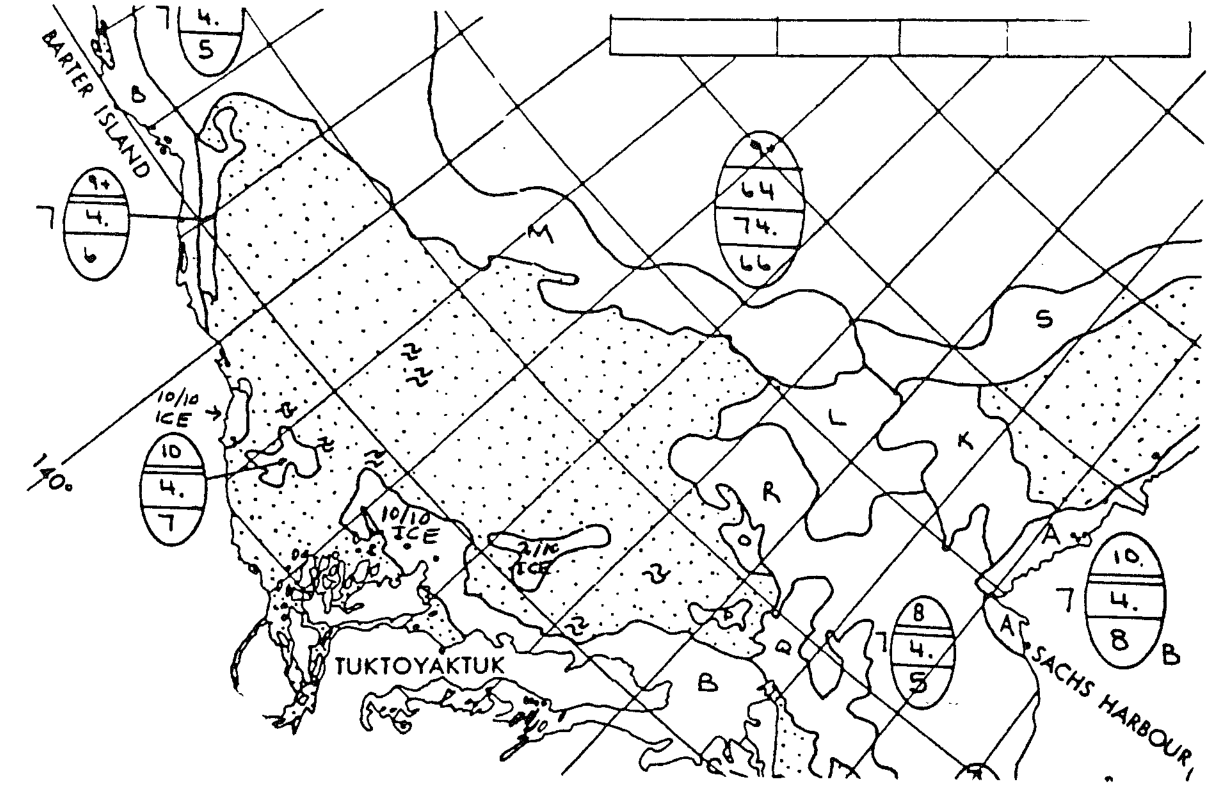
Weekly Ice Charts, June 11 to July 2, 1987



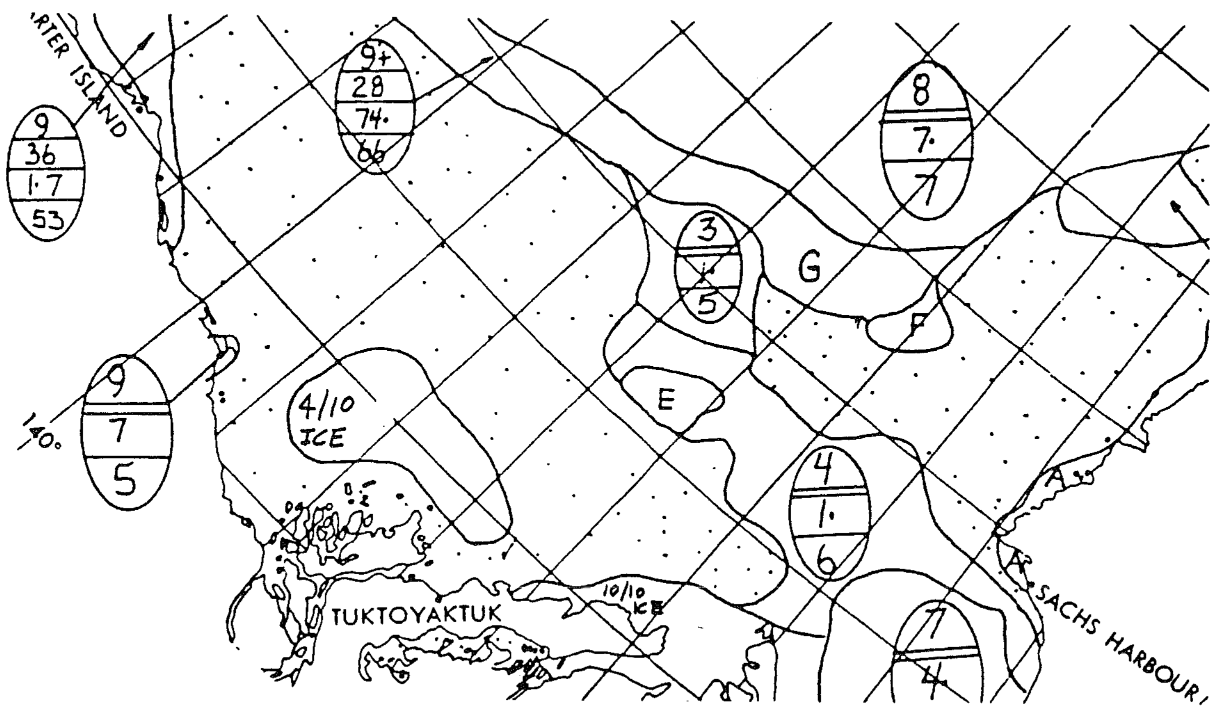
Ice Chart, June 11, 1987



Ice Chart, June 18, 1987



Ice Chart, June 25, 1987



Ice Chart, July 2, 1987

APPENDIX D

Climatic Records from Tuktoyaktuk Airport

Climatic Data
Tuktoyaktuk Airport, N.W.T.

Date	Temperature (°C) Min.	Max.	Mean	Sky Condition
May 15	-11.5	-9.0	-10.3	overcast
May 16	-8.2	-7.0	-7.7	overcast
May 17	-10.0	-5.4	-7.3	overcast
May 18	-10.0	-6.6	-7.1	overcast, broken
May 19	-15.1	-6.6	-9.7	clear, scattered
May 20	-15.5	-4.0	-7.4	scattered, broken
May 21	-12.1	-5.9	-7.6	scattered, broken
May 22	-14.2	-3.1	-7.2	scattered
May 23	-9.0	-3.1	-5.3	scattered
May 24	-8.9	-4.5	-6.3	scattered, broken
May 25	-9.4	-4.4	-1.6	broken
May 26	-6.1	1.8	-0.1	scattered, overcast
May 27	-1.8	-0.3	-1.0	broken, scattered
May 28	-4.5	1.9	-0.3	scattered, broken
May 29	-1.3	2.8	1.0	scattered
May 30	-1.4	0.2	-0.6	overcast, broken
May 31	-1.5	1.5	0.1	overcast
June 1	-1.4	3.5	1.2	scattered, broken
June 2	-2.4	6.6	3.3	scattered
June 3	1.4	8.5	5.7	scattered, clear
June 4	-3.4	1.0	-1.0	broken, scattered
June 5	-2.9	3.6	0.4	overcast, broken
June 6	0.6	10.2	6.7	scattered
June 7	2.3	12.7	8.8	clear, scattered
June 8	-0.7	8.7	5.1	scattered, broken
June 9	1.0	9.8	5.6	broken
June 10	0.1	1.6	0.7	broken, overcast
June 11	-0.4	1.2	0.5	overcast
June 12	-1.4	1.1	0.2	overcast, broken
June 13	-0.5	3.0	1.1	broken, scattered
June 14	-0.9	8.9	5.3	scattered
June 15	5.5	12.5	9.4	broken, scattered
June 16	4.0	11.0	8.6	broken
June 17	5.5	15.0	11.9	broken, scattered
June 18	7.9	17.0	13.7	scattered
June 19	10.0	20.5	17.1	scattered, broken

APPENDIX E

Video Tape Schedule

Flight Maps

Photo Mosaic (1 set in binder copy only)

Slides (1 set in binder copy only)

VIDEO TAPE SCHEDULE

June 2
Video Tape 1: Whitefish Station to Shingle Point

16:24	Whitefish Station
16:25 to 16:26	circle Whitefish Station
16:47 to 16:49	circle Kidluit Bay
17:40	south side Middle Channel
18:29	north end Shoalwater Bay
18:31	Blow River
18:34	Shingle Point

June 2
Video Tape 2: Kay Point to Nunaluk Spit

19:49	south Kay Point
19:50	Kay Point
19:55	circle Phillips Bay
stop	
20:02	Phillips Bay
stop	
20:08	ice edge offshore Phillips Bay
stop	
20:11 to 20:12	circle Phillips Bay
stop	
20:22	east side Workboat Passage
20:25	Firth River delta
20:27	Nunaluk Spit
20:30	circle west end Nunaluk Spit

June 2
Video Tape 2: Oliver Islands to Kidluit Bay

22:37	high level video (1500 m) north of Delta, west of Oliver Islands
22:39	circle open water area off Oliver Islands
22:59	previously flooded ice south of Garry Island
23:07	Kendall Island
23:14	Rae Island
22:28	West Point
stop	
23:38	Kidluit Bay, east side of Richards Island and Kittigazuit Bay

June 2
Video Tape 2: **Whitefish Station to Oliver Islands**

09:11	east Whitefish Station
09:13	Whitefish Station
09:14	circle south end Kittigazuit Bay
09:19	Gull Island, Kidluit Bay
09:20	north Kidluit Bay
stop	
09:39	West Point
09:42	Rae Island
09:43	north of Taglu Island
09:45	Kendall Island
09:50	Garry Island
stop	
10:03	north of Ellice Island
10:06	north of Oliver Islands

June 2
Video Tape 2: **Phillips Bay**

10:37	Spring River delta
10:39	Babbage River delta
10:40	spits extending from Kay Point
10:43	Kay Point
10:46	boundary landfast ice and open water
stop	
14:16	counter clockwise circle strudel scour area in Phillips Bay
14:20	strudel scour Site 1

June 2
Video Tape 2: **Upwelling in Kittigazuit Bay (Video from R. Bolton)**

about 21:30	water upwelling through ice southwest of Hendrickson Island

June 6
Video Tape 3: **Demarcation point to Herschel Island**

18:53	Demarcation Point
18:58	circle Clarence Lagoon
19:04	Backhouse River
19:09	circle Komakuk Beach
19:21	circle ice pile-up Site 3
19:30	circle east end of Nunaluk Spit and south end of Avadlek Spit
19:36	Calton Point

19:42	Pauline Cove
19:47	circle northwest corner of Herschel Island
19:52	Avadlek Spit
19:54	south end of Avadlek Spit, Workboat Passage

June 3
Video Tape 3: **Nunaluk Spit, Pile-up Site 1**

11:36 to 11:38	circle of ice pile-up Site 1, staring inshore of pile-up

June 13
Video Tape 3: **Atkinson Point to Tuktoyaktuk**

18:27	radar marker Atkinson Point
18:39 to 18:43	Hutchison Bay
18:43	Warren Point
18:44	circle Warren Point
18:54 to 18:58	circle Toker Point
19:02	Tibjak Point
19:06	circle Beluga Point
19:09	Tuktoyaktuk

June 13
Video Tape 4: **Tuktoyaktuk to Ellice Island**

20:52	Tuktoyaktuk
20:57	circle Naparotalik Spit
21:01	circle Whitefish Pingo
-	Kidluit Bay
-	Mason Bay
21:34	circle North Point , Pullen Island
21:41	West Point
21:51	Rae Island
21:59	Garry Island
22:20	north end of Ellice Island
22:24 to 22:26	circle between Ellice and Oliver Islands

June 14
Video Tape 5: **Cape Dalhousie, Nuvorak Point, McKinley Bay, and Atkinson Point**

17:05	circle Cape Dalhousie
stop	
17:17	circle Nuvorak Point
17:20	Crescent Bank
stop	
18:19	NE of McKinley Bay, south along spit looking onshore
18:21	circle beacon and north along spit looking offshore
18:24 to 18:26	circle ice pile-up Site 5
stop	
18:31	Dome fleet in McKinley Bay
stop	
18:38	Atkinson Point, ice pile-up Site 4
18:39	circle pile-up looking onshore
18:41	along pile-up looking offshore
18:46	close-up of pile-up, inshore side
stop	
18:58 to 19:13	ground shots on pile-up

June 15
Video Tape 5: **Canada/US Border to Shingle Point Spit**

19:12	Canada/US border interference from DEW Line Site
19:15	Clarence Lagoon
19:29	circle Komakuk Beach
19:34 to 19:38	offshore to ice edge and circle of pile-ups east of Komakuk Beach
19:40	most western cone placed on Nunaluk Spit
19:41	pile-up Site 1
19:48	circle pile-up Site 3
19:56	circle south end of Avadlek Spit
20:20	Phillips Bay
20:26	circle Kay Point
20:42	circle King Point
20:55	Shingle Point spit

June 15
Video Tape 6: **Shingle Point to Shoalwater Bay**

21:37	interference from DEW Line Site
21:39	Running River delta
21:52	circle Pillage Point
22:05	circle east of Ministicoog Channel, Shoalwater Bay

June 19
Video Tape 6: Toker Point to Cape Dalhousie

18:26	approaching Toker Point
18:27	Toker Point
18:33	Tuft Point
18:36	circle Warren Point
18:47	Bols Point
18:53	Drift Point
18:56	clockwise circle beacon Atkinson Point
18:58	counter clockwise circle pile-up Site 4
19:07 to 19:10	two circles of pile-up Site 5 northeast of McKinley Bay
19:10	clockwise circle of pile-up
19:11 to 19:14	circle pile-up, dirty ice is seaward side of ridge, clean ice is nearshore side of ridge
19:24	circle Nuvorak Point
19:25 to 19:33	Russell Inlet
19:44	circle Cape Dalhousie
19:46	circle Racon on spit off Cape Dalhousie

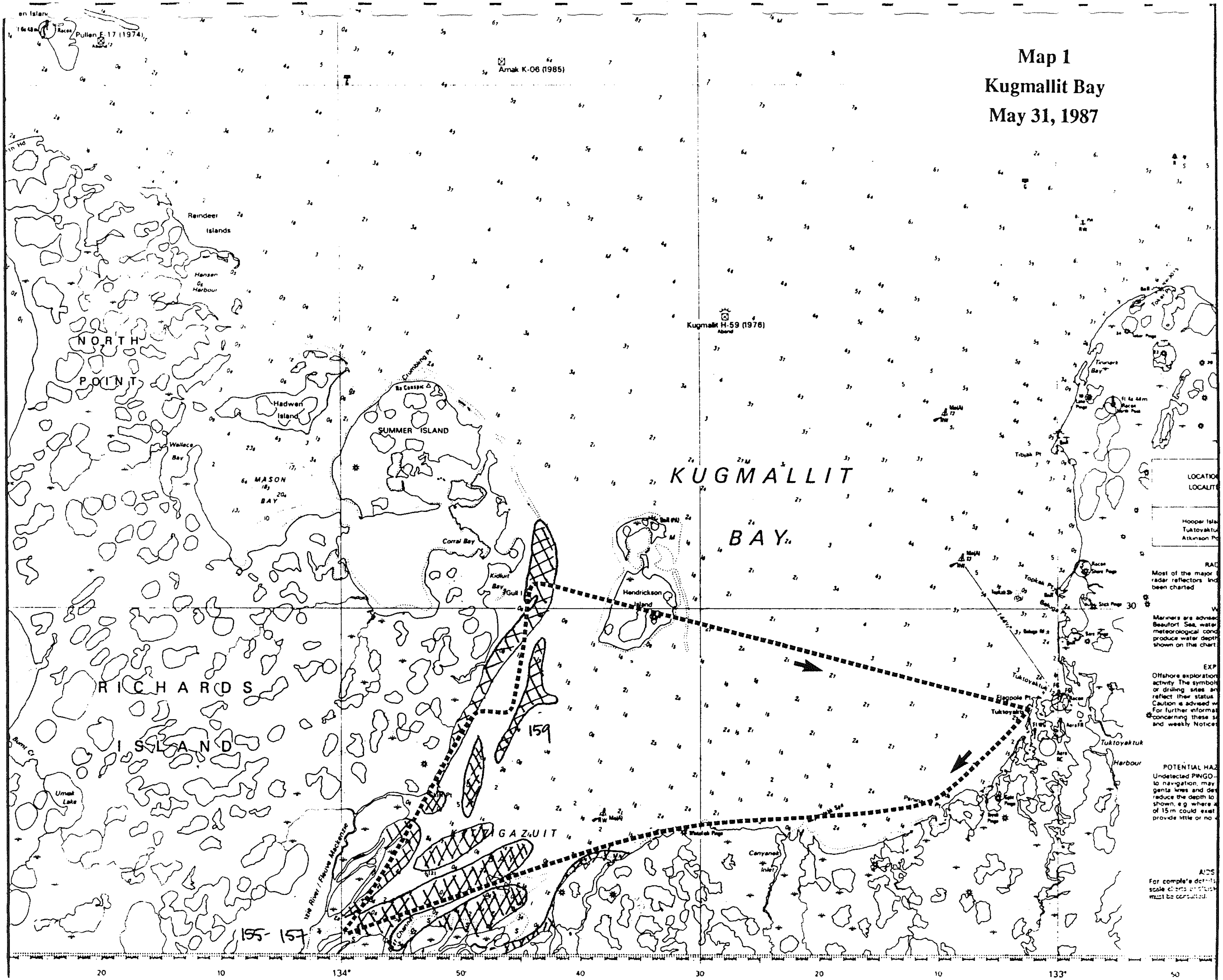
June 20
Video Tape 7: North Head

21:38 to 21:41	west side of North Head
	Fog encountered in patches between Shingle Point and Kugmallit Bay
	Fog west of Shingle Point

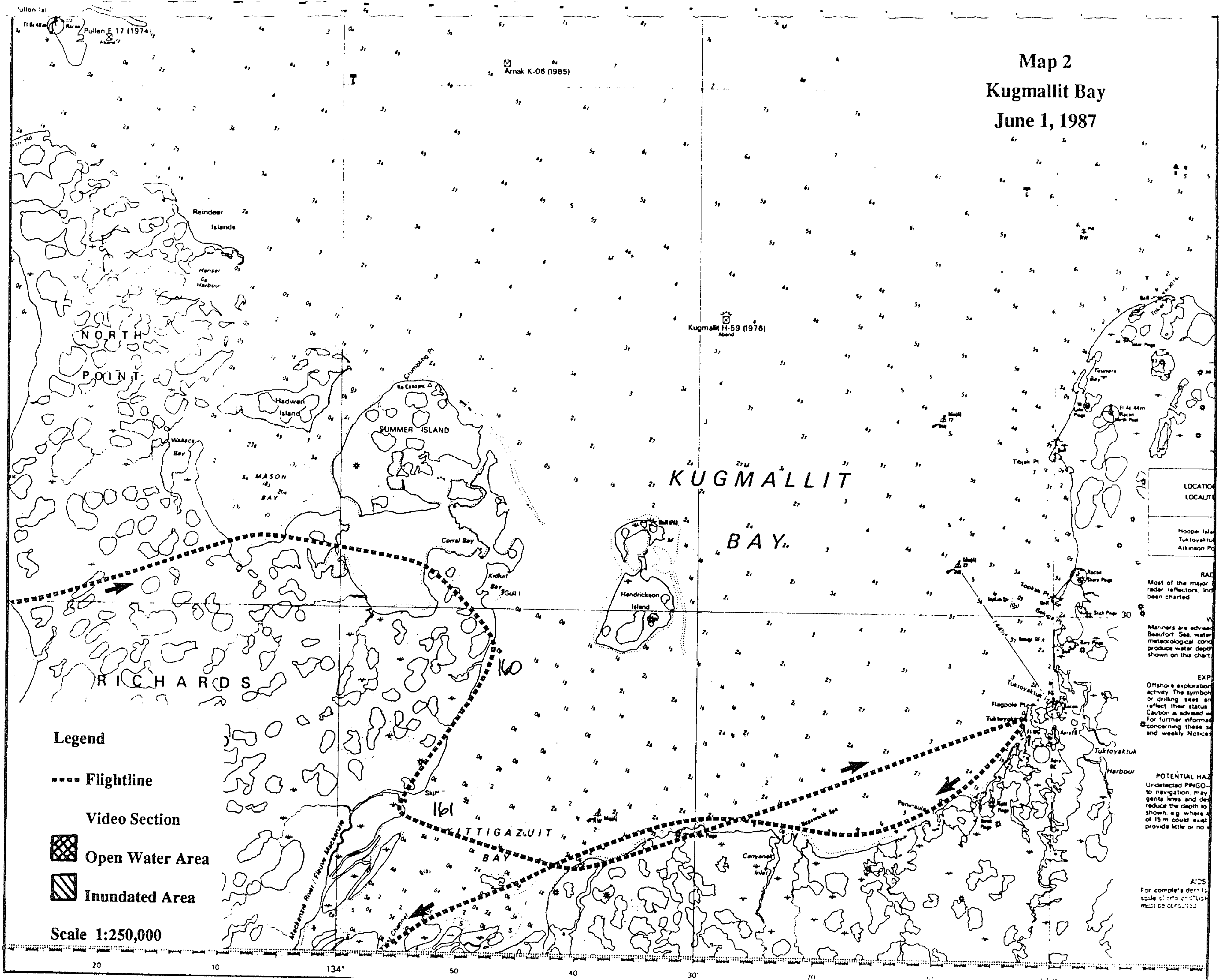
June 21
Video Tape 7: Peninsula Point to Toker Point

20:42	Peninsula Point
20:45	circle Tuktoyaktuk
20:47	Flagpole Point
20:49	Beluga Point
20:50	Topkak Point
20:53	Tibjak Point
20:59	Toker Point beacon
21:01	Toker Point

Map 1
Kugmallit Bay
May 31, 1987



Map 2
Kugmallit Bay
June 1, 1987



Legend

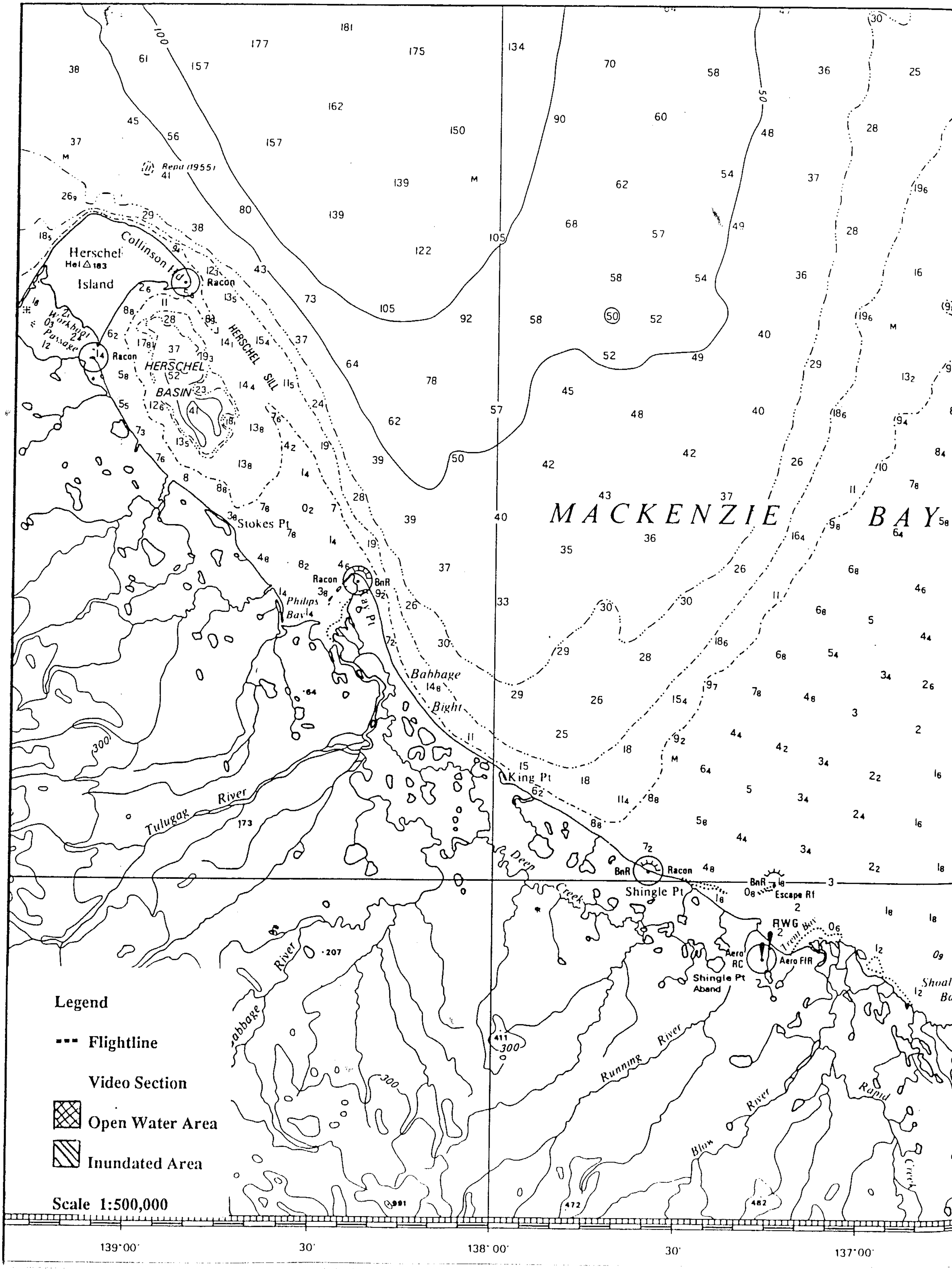
Flightline

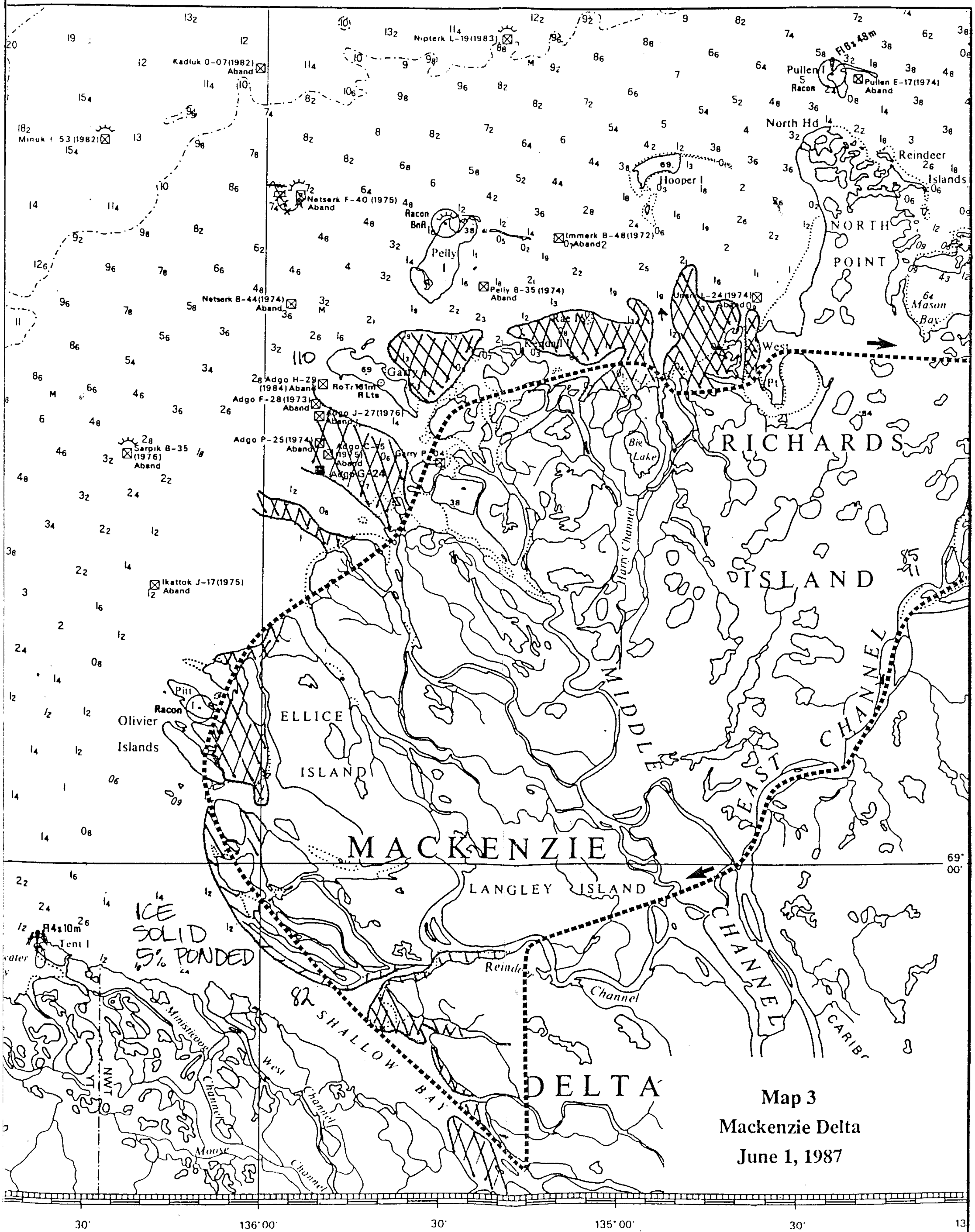
Video Section

Open Water Area

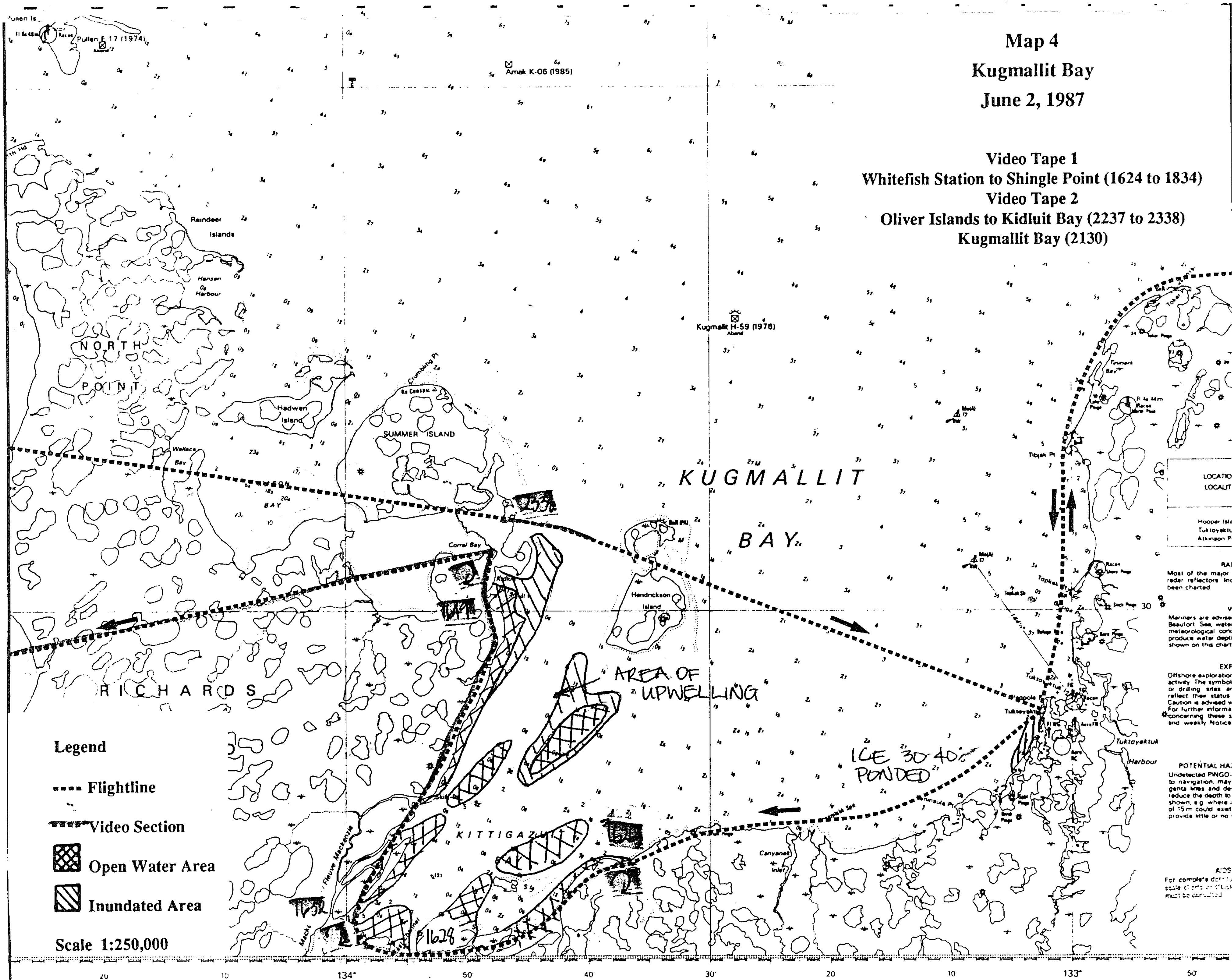
Inundated Area

Scale 1:250,000

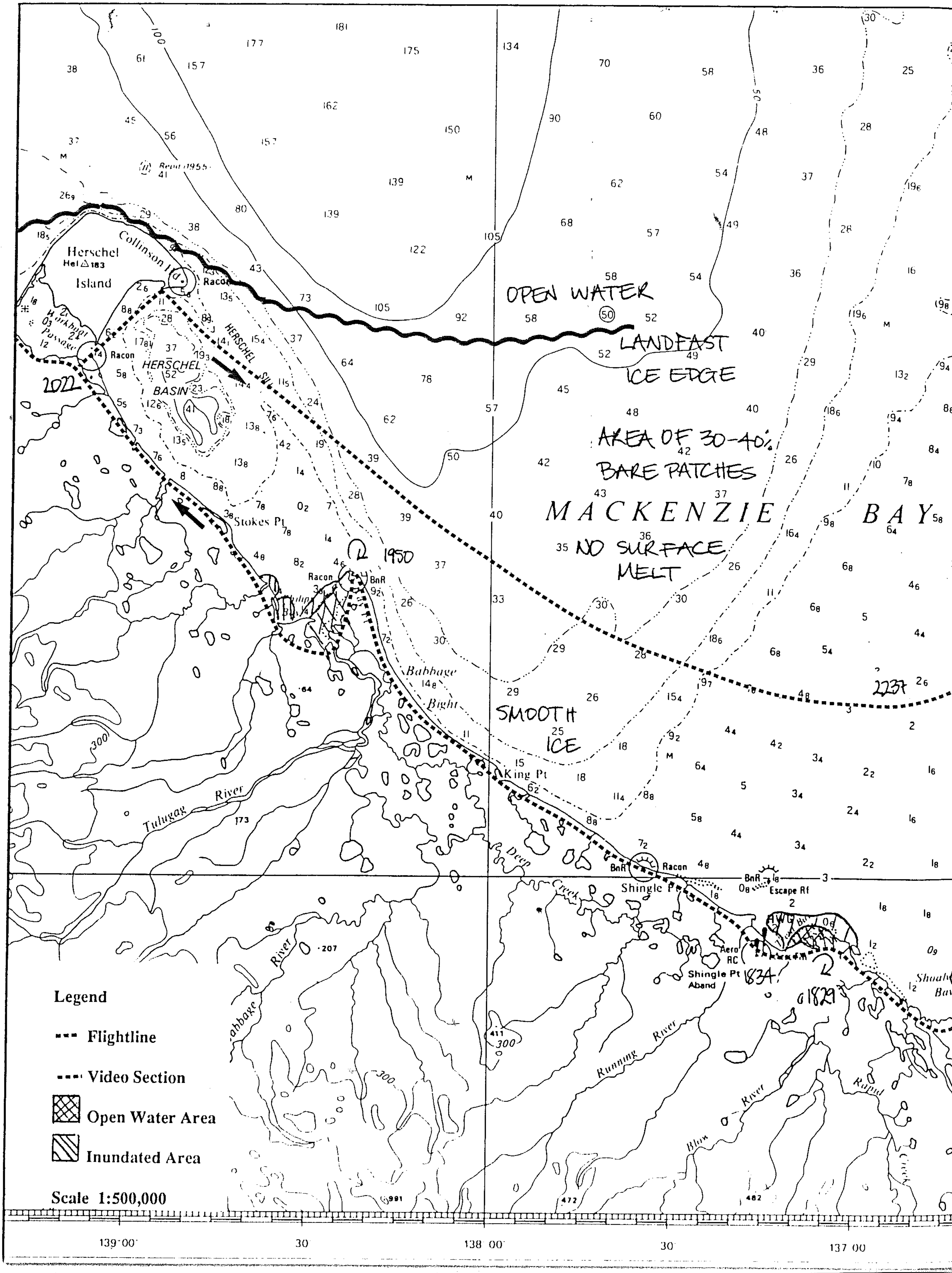

MACKENZIE BAY
Herschel Island
Hel △ 183
Collinson Hd
Racon
Workboat Passage
HERSCHEL BASIN
HERSCHEL SILL
Repd (1955)
Stokes Pt
Philips Bay
Kay Pt
BnR
Babbage Bight
King Pt
Shingle Pt
Escape Rf
RWG
Aero RC
Aero FIR
Shingle Pt Aband
Trent Bay
Deep Creek
Tulugaq River
Babbage River
Running River
Blow River
Rapid Creek
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
139°00'
30'
138°00'
30'
137°00'



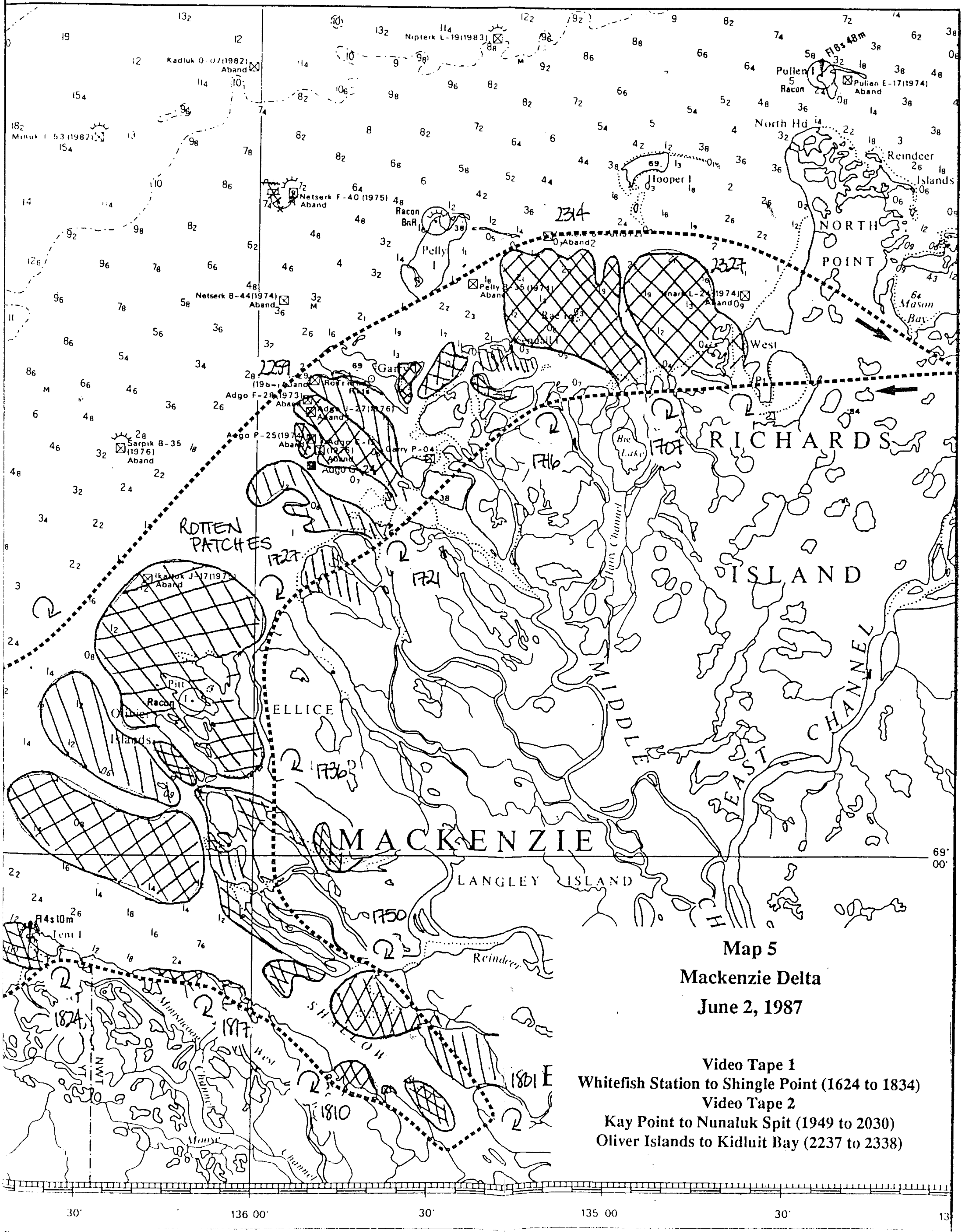
Map 3
Mackenzie Delta
June 1, 1987



Map 4
Kugmallit Bay
June 2, 1987
Video Tape 1
Whitefish Station to Shingle Point (1624 to 1834)
Video Tape 2
Oliver Islands to Kidluit Bay (2237 to 2338)
Kugmallit Bay (2130)
KUGMALLIT BAY
AREA OF UPWELLING
ICE 30-40% PONDED
NORTH POINT
RICHARDS
SUMMER ISLAND
Hadwen Island
Hendrickson Island
Reindeer Islands
Hansen Harbour
Corral Bay
Wallace Bay
Tibjak Pt
Topkak
Tuktoyaktuk
Tuktoyaktuk Harbour
Canyanek Inlet
KITTIGAZUIT
Pullen E 17 (1974)
Amak K-06 (1985)
Kugmallit H-59 (1976)
2338
1834
1628
1632
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:250,000



Herschel Island
Collinson Hd.
Racon
Workboat Passage
HERSCHEL BASIN
HERSCHEL SILL
Stokes Pt
Babbage Bight
King Pt
Shingle Pt
Shingle Pt Aband
Escape Rf
Aero RC
MACKENZIE BAY
Tulugak River
Babbage River
Running River
Blow River
Deep Creek
Rapid Creek
OPEN WATER
LANDFAST ICE EDGE
AREA OF 30-40% BARE PATCHES
NO SURFACE MELT
SMOOTH ICE
2022
1950
2237
1834
1829
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
139°00'
30
138 00'
30'
137 00

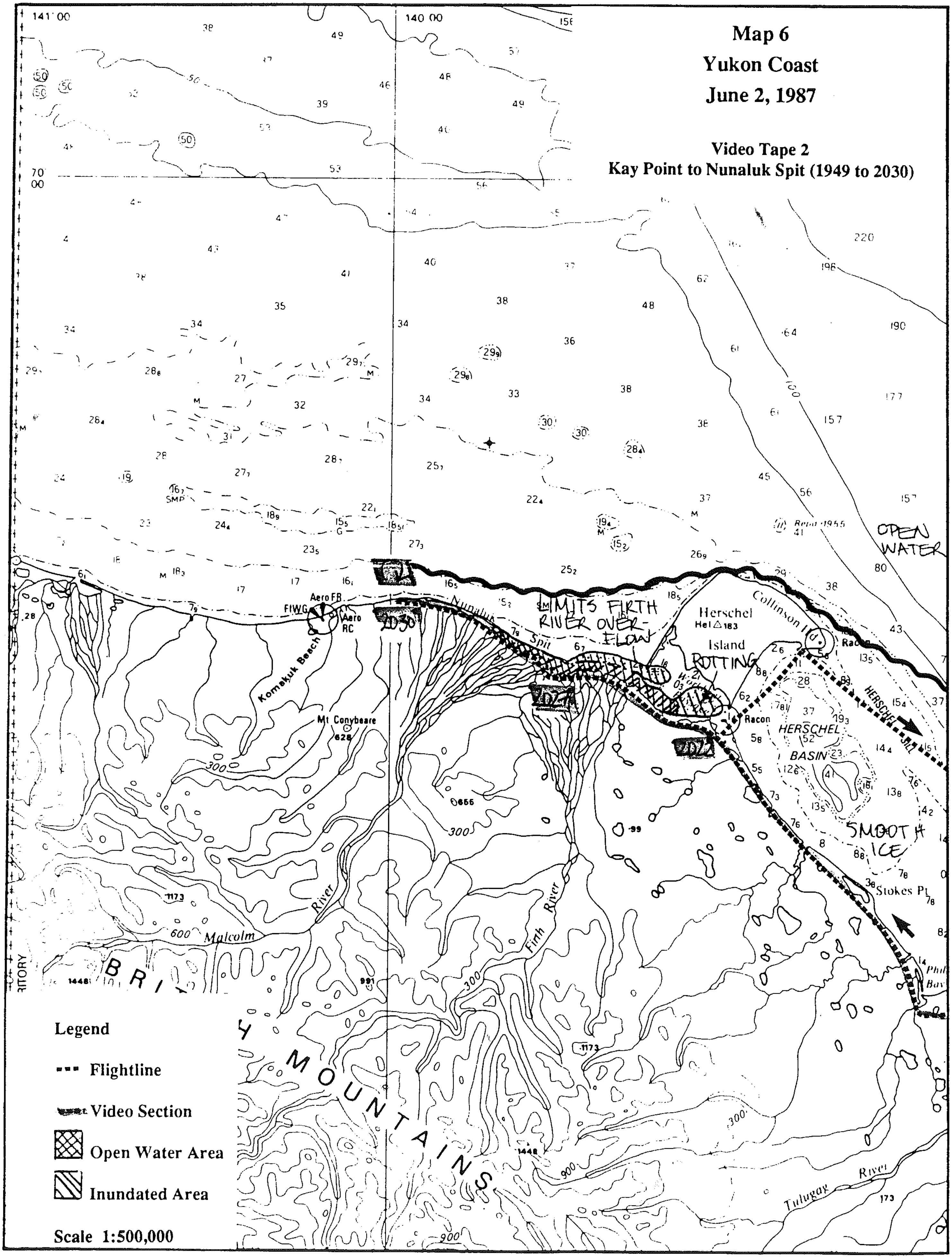


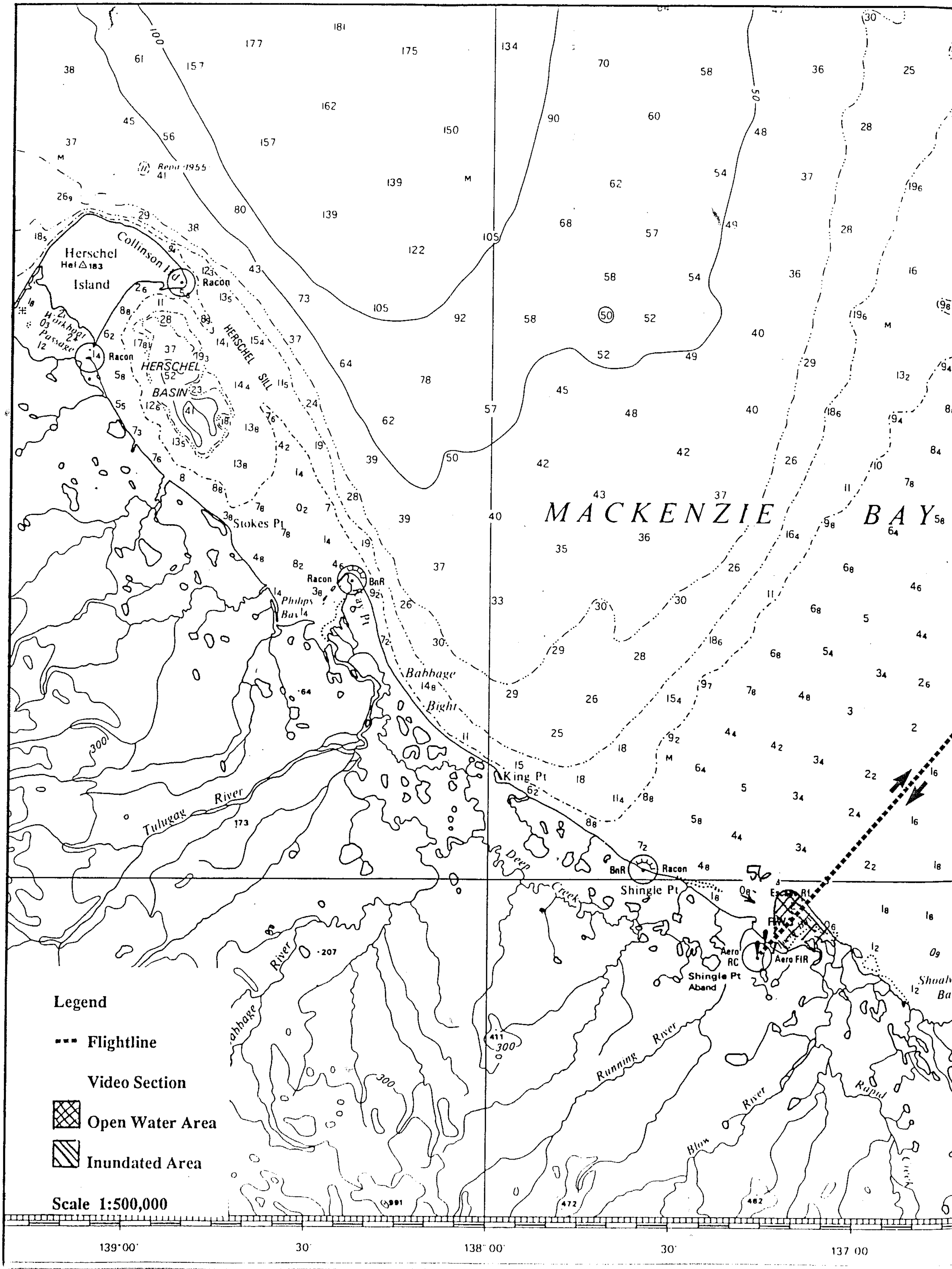
Map 5
Mackenzie Delta
June 2, 1987

Video Tape 1
Whitefish Station to Shingle Point (1624 to 1834)
Video Tape 2
Kay Point to Nunaluk Spit (1949 to 2030)
Oliver Islands to Kidluit Bay (2237 to 2338)

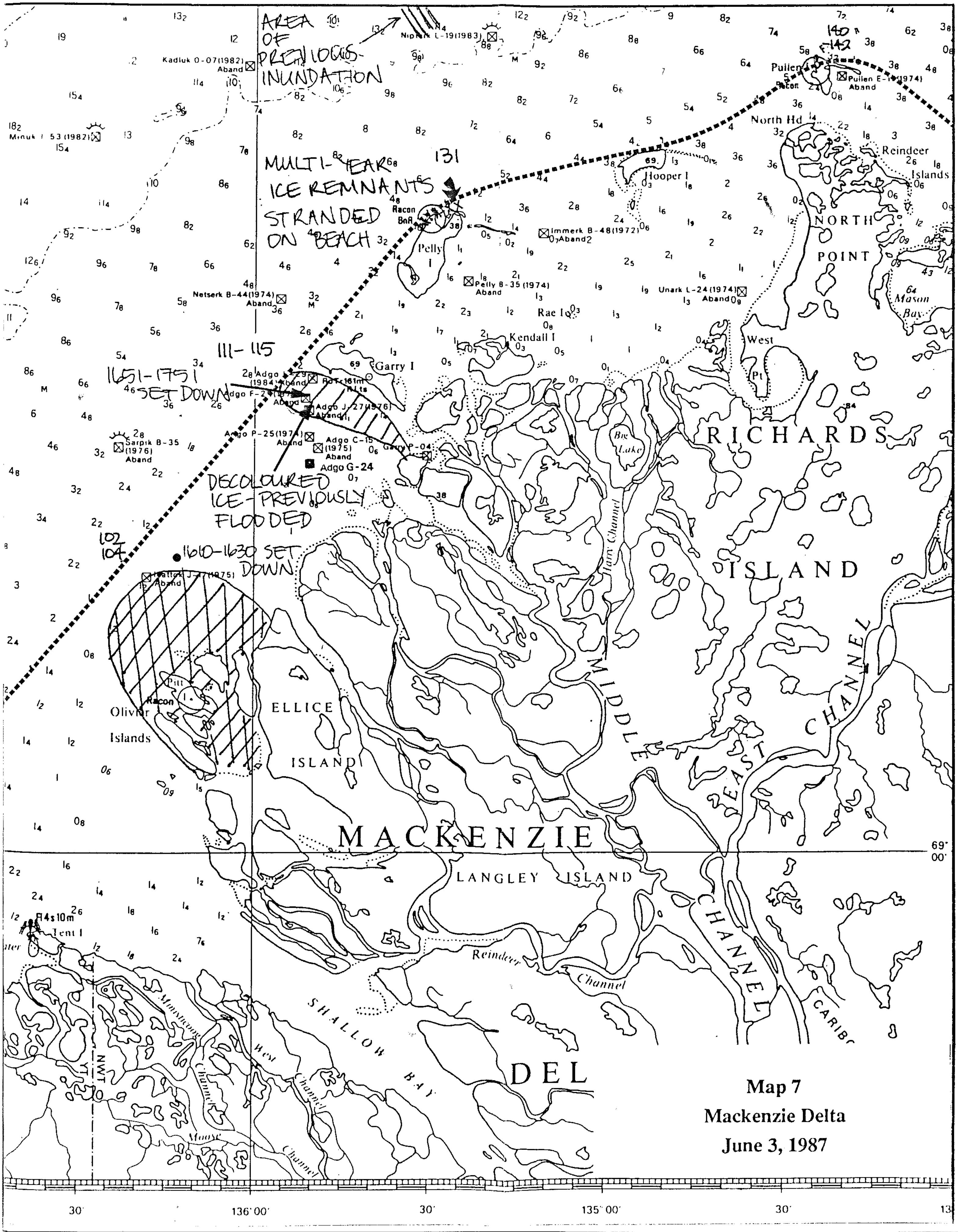
Map 6
Yukon Coast
June 2, 1987

Video Tape 2
Kay Point to Nunaluk Spit (1949 to 2030)

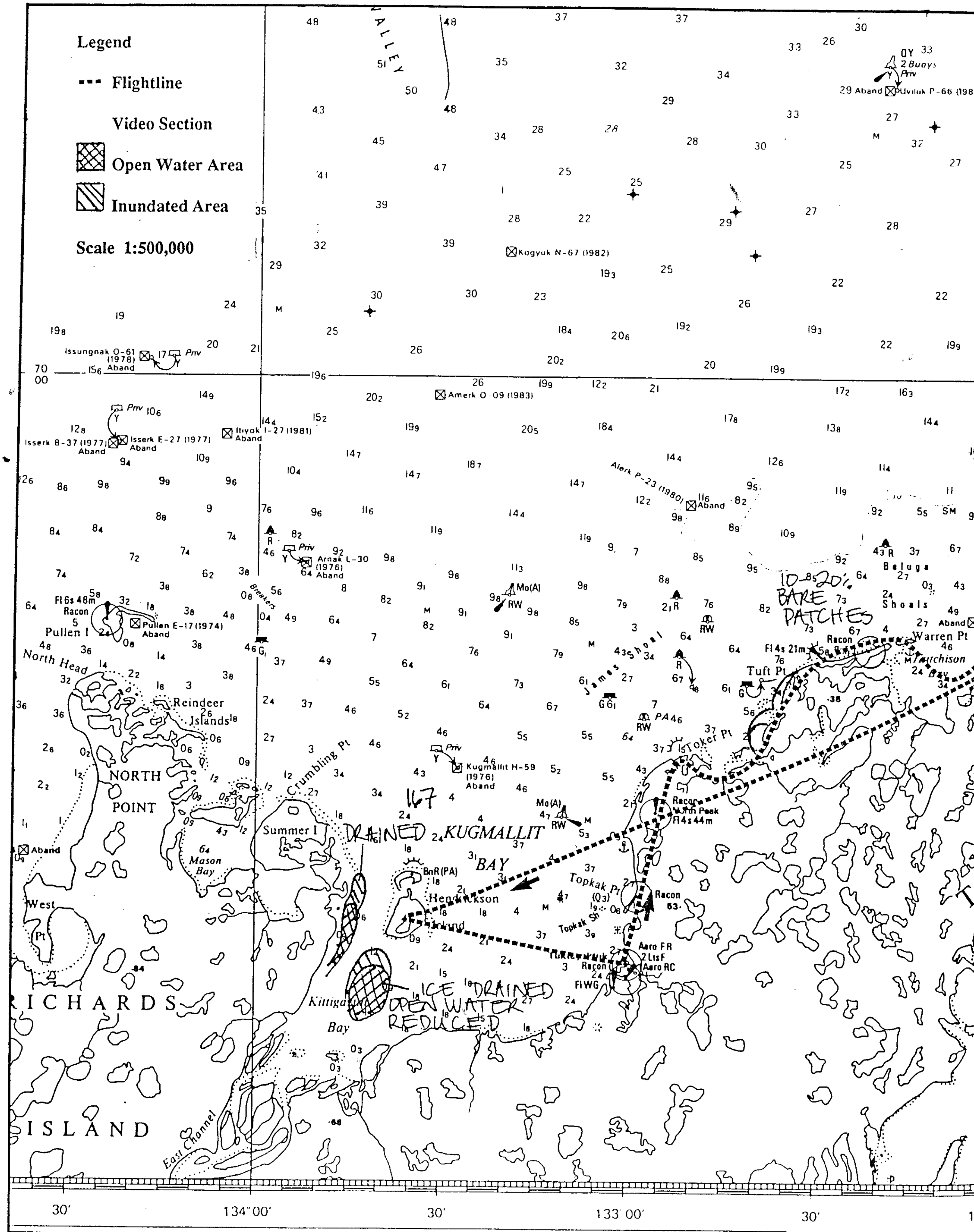




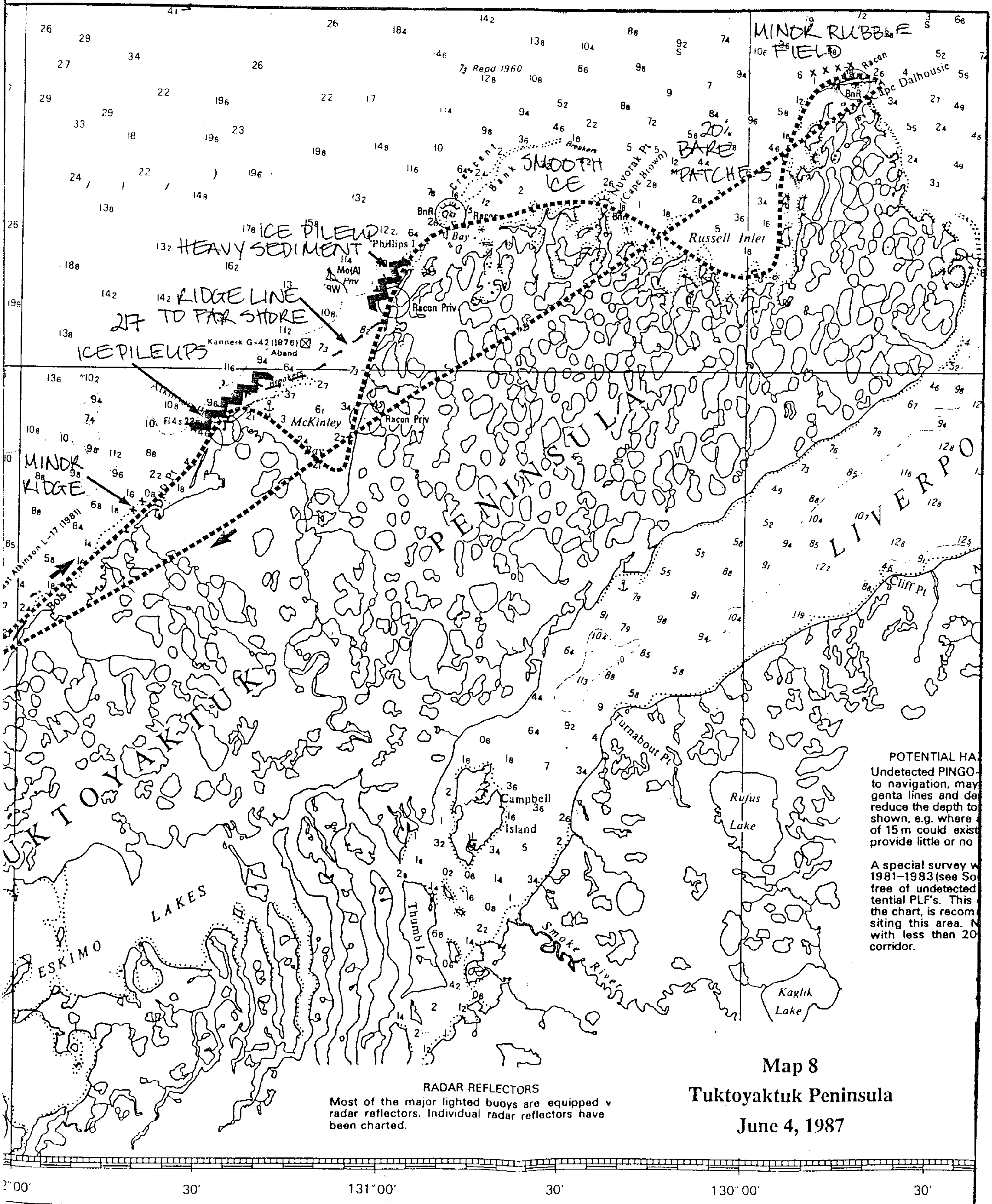
Herschel Island
Collinson Hd
Racon
Workboat Passage
HERSCHEL BASIN
HERSCHEL SILL
Stokes Pt
Philips Bay
Kay Pt
BnR
Babbage Bight
King Pt
Deep Creek
Shingle Pt
Shingle Pt Aband
Aero RC
Aero FIR
MACKENZIE BAY
Tulugak River
Babbage River
Running River
Blow River
Rapid
Shoalwater Bay
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
139°00'
30'
138°00'
30'
137 00



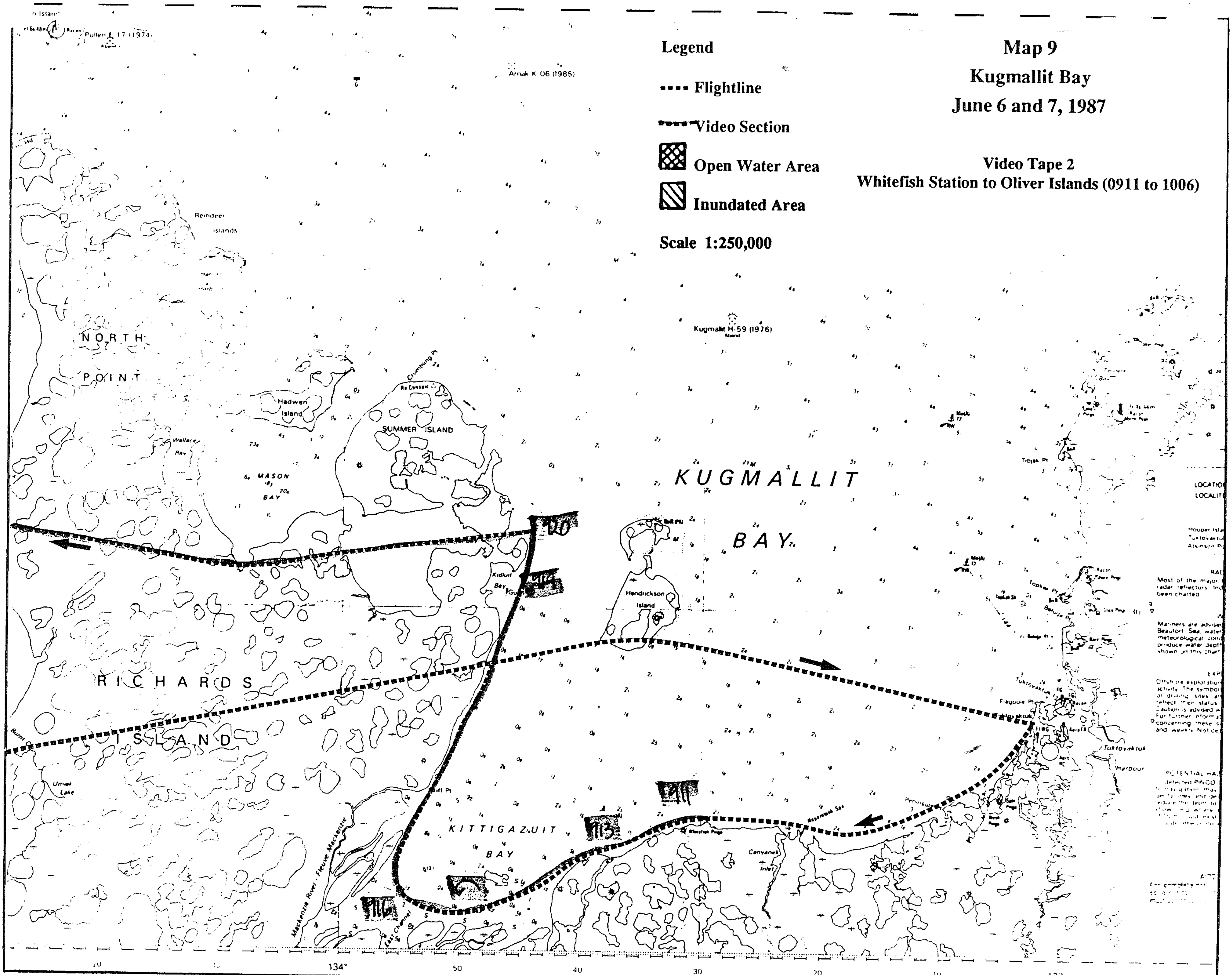
Map 7
Mackenzie Delta
June 3, 1987



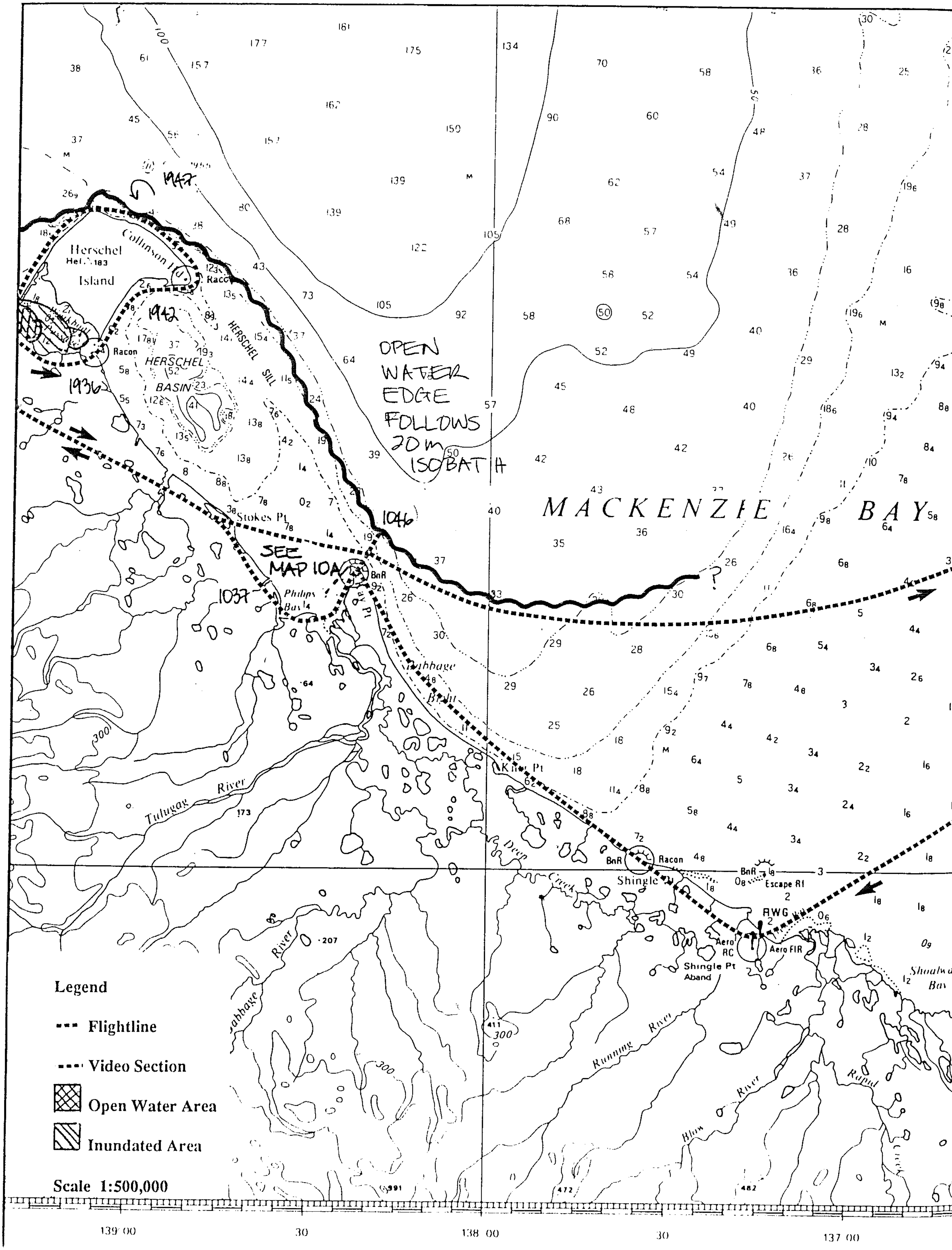
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
Kogyuk N-67 (1982)
Uviluk P-66
2 Buoys
Issungnak O-61 (1978) Aband
Amerk O-09 (1983)
Isserk B-37 (1977) Aband
Isserk E-27 (1977) Aband
Itiyok I-27 (1981) Aband
Alerk P-23 (1980) Aband
Arnak L-30 (1976) Aband
Pullen E-17 (1974) Aband
Kugmallit H-59 (1976) Aband
Fl 6s 48m Racon
Pullen I
North Head
Reindeer Islands
NORTH POINT
Mason Bay
West Pt
RICHARDS
ISLAND
East Channel
Summer I
Crumbling Pt
Breakers
KUGMALLIT BAY
Hendrickson Island
BnR (PA)
Topkak Pt
Topkak Sh
Tuktoyaktuk
Racon
Aero FR
2 Lts F
Aero RC
Fl WG
Kittigazuit Bay
James Shoal
Toker Pt
Tuft Pt
Warren Pt
Hutchison Bay
Beluga Shoals
Fl 4s 21m
Fl 4s 44m
167
DRAINED
ICE DRAINED
OPEN WATER REDUCED
10-20% BARE PATCHES
70 00
30′
134°00′
30′
133°00′
30′



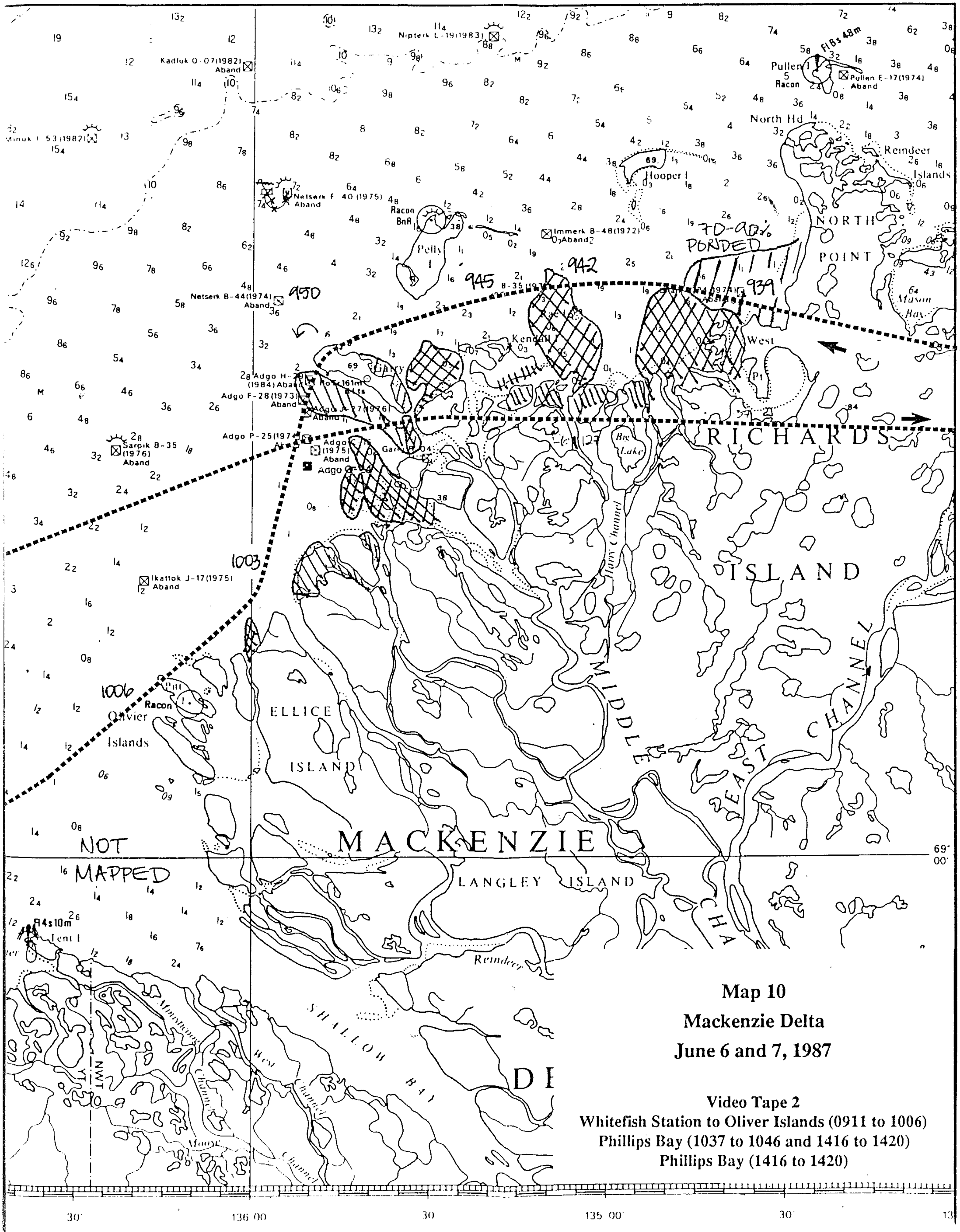
Map 8
Tuktoyaktuk Peninsula
June 4, 1987



Map 9
Kugmallit Bay
June 6 and 7, 1987
Video Tape 2
Whitefish Station to Oliver Islands (0911 to 1006)
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:250,000
KUGMALLIT BAY
KITTIGAZUIT BAY
RICHARDS ISLAND
NORTH POINT
SUMMER ISLAND
Hadwen Island
MASON BAY
Reindeer Islands
Wallace Bay
Hendrickson Island
Kidluit Bay
Kugmallit H-59 (1976)
Arnak K 06 (1985)
Pullen E 17 (1974)
Mackenzie River / Fleuve Mackenzie
East Channel
Umiak Lake
Canyanek Inlet
Tuktoyaktuk
Tuktoyaktuk Harbour
Tibjak Pt
Topkak Pt
Flagpole Pt
Whitefish Pingo
Peninsula
134°
50
40
30
20

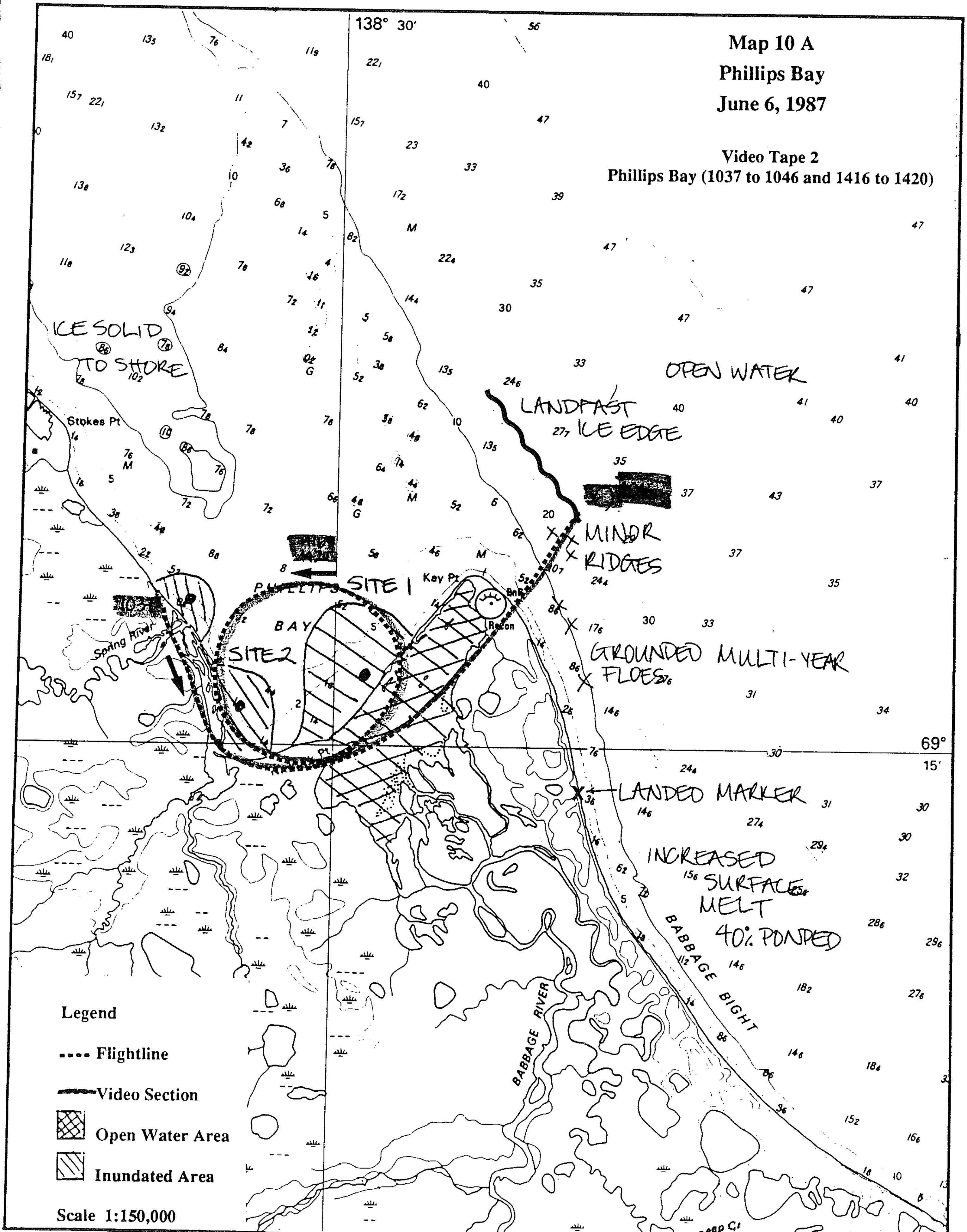


Herschel Island
Collinson Pt
Racon
HERSCHEL BASIN
HERSCHEL SILL
Stokes Pt
Philips Bay
Kay Pt
Babbage Bight
King Pt
BnR
Racon
Shingle Pt
Escape Rf
Aero RC
Aero FIR
Shingle Pt Aband
Shoalwater Bay
MACKENZIE BAY
Tulugaq River
Deep Creek
Babbage River
Running River
Blow River
Rapid
1947
1942
1936
OPEN WATER EDGE FOLLOWS 20 m ISOBATH
1046
SEE MAP 10A
1037
?
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
139°00
30
138 00
30
137 00



Map 10
Mackenzie Delta
June 6 and 7, 1987

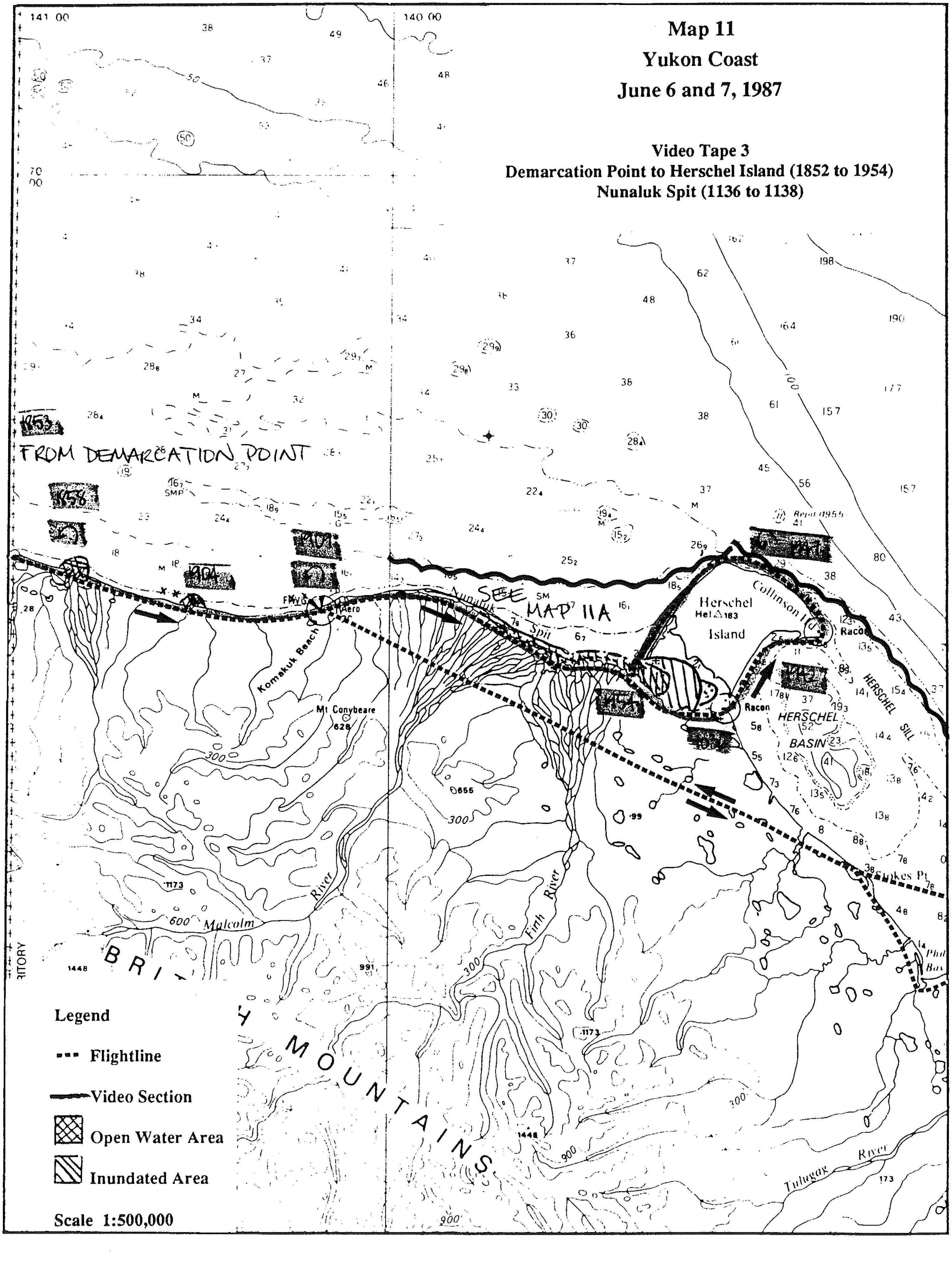
Video Tape 2
Whitefish Station to Oliver Islands (0911 to 1006)
Phillips Bay (1037 to 1046 and 1416 to 1420)
Phillips Bay (1416 to 1420)

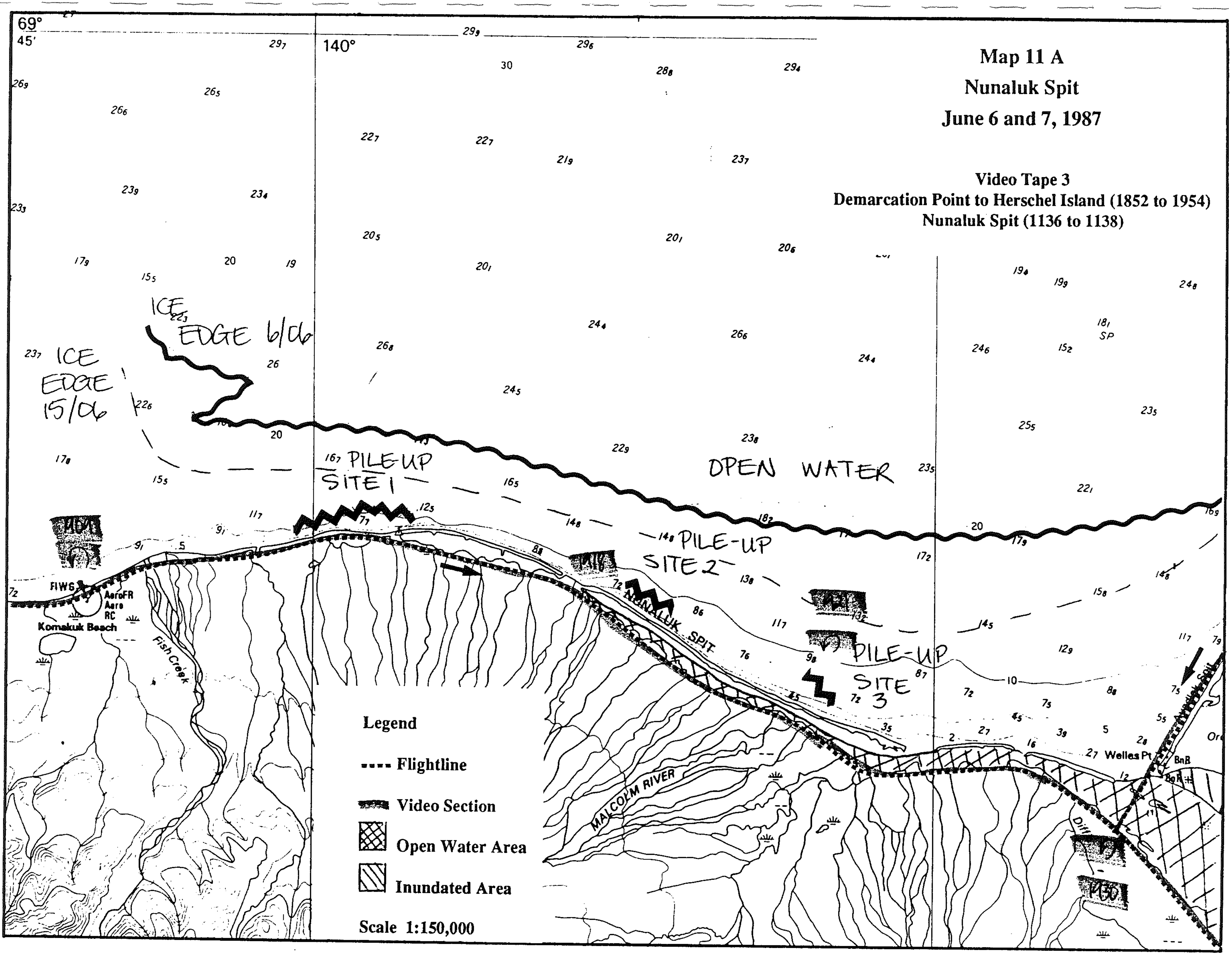


Map 10 A
Phillips Bay
June 6, 1987
Video Tape 2
Phillips Bay (1037 to 1046 and 1416 to 1420)
138° 30′
69° 15′
ICE SOLID TO SHORE
OPEN WATER
LANDFAST ICE EDGE
MINOR RIDGES
SITE 1
SITE 2
GROUNDED MULTI-YEAR FLOES
LANDED MARKER
INCREASED SURFACE MELT 40% PONDED
Stokes Pt
Kay Pt
Spring River
PHILLIPS BAY
Recon
BABBAGE RIVER
BABBAGE BIGHT
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:150,000

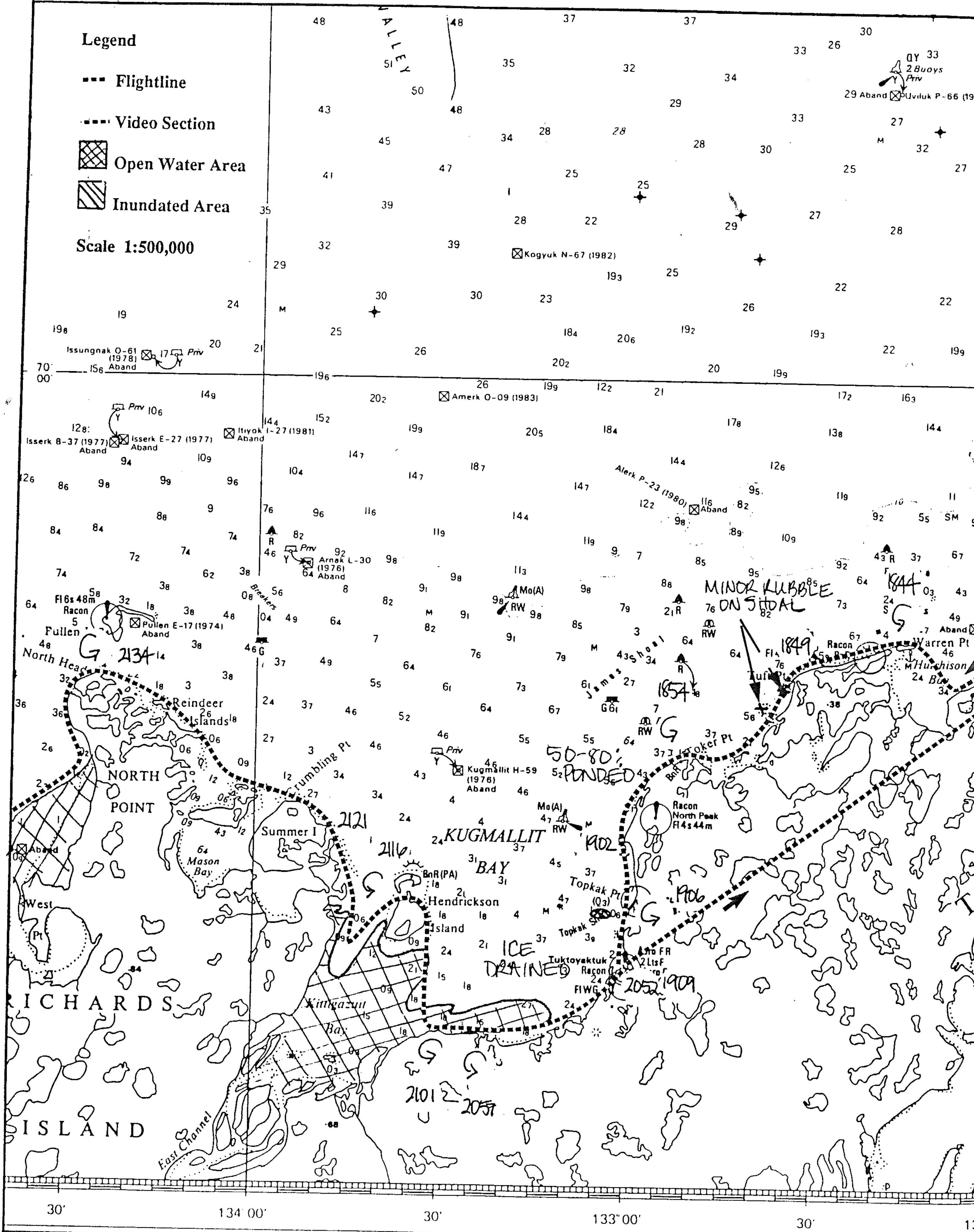
Map 11
Yukon Coast
June 6 and 7, 1987

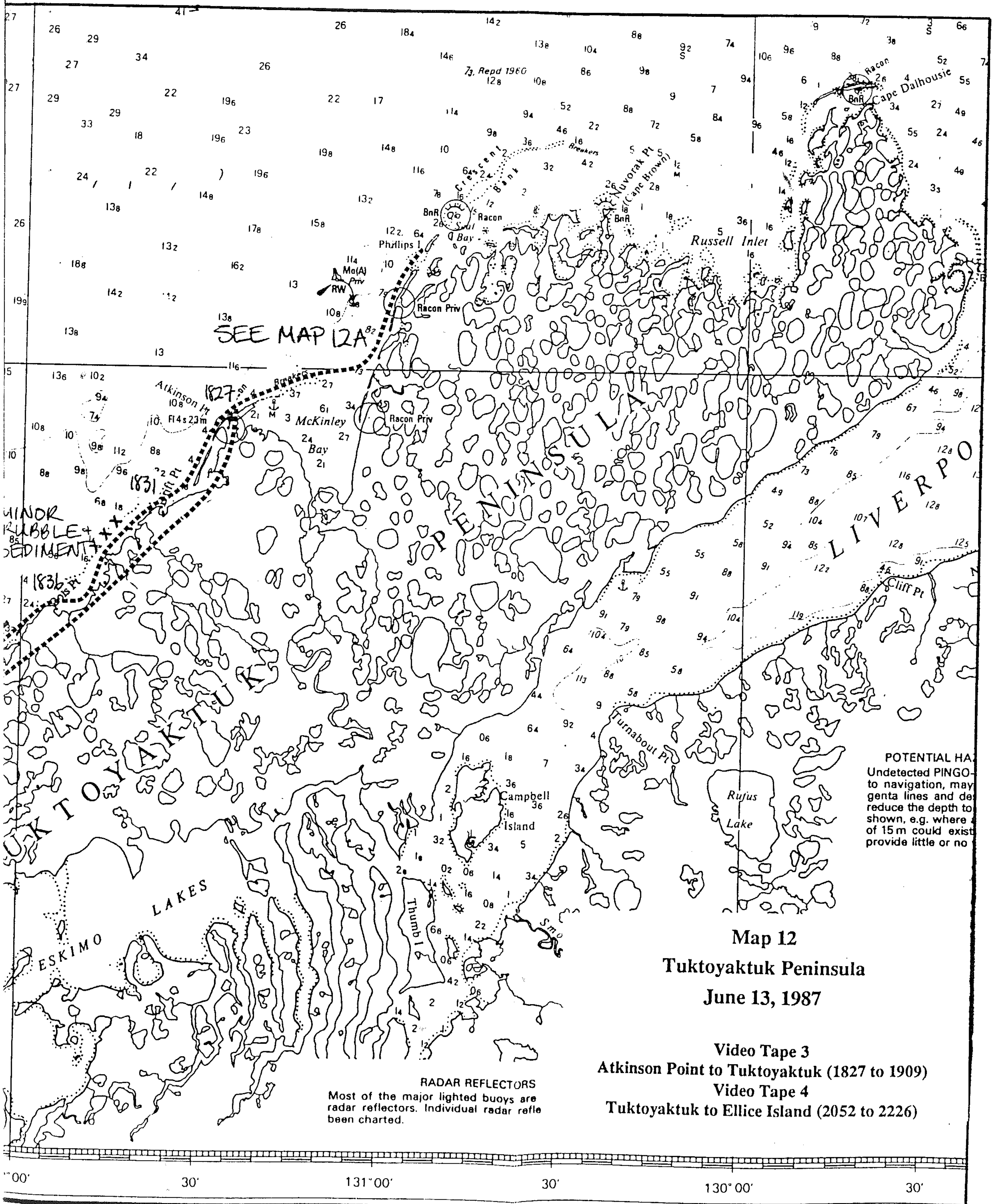
Video Tape 3
Demarcation Point to Herschel Island (1852 to 1954)
Nunaluk Spit (1136 to 1138)





Map 11 A
Nunaluk Spit
June 6 and 7, 1987
Video Tape 3
Demarcation Point to Herschel Island (1852 to 1954)
Nunaluk Spit (1136 to 1138)
69° 45'
140°
ICE EDGE 6/06
ICE EDGE 15/06
OPEN WATER
PILE-UP SITE 1
PILE-UP SITE 2
PILE-UP SITE 3
NUNALUK SPIT
MALCOLM RIVER
Fish Creek
Komakuk Beach
Welles Pt
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:150,000


Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
Issungnak O-61 (1978) Aband
Isserk B-37 (1977) Aband
Isserk E-27 (1977) Aband
Itiyok I-27 (1981) Aband
Arnak L-30 (1976) Aband
Amerk O-09 (1983)
Kogyuk N-67 (1982)
Alerk P-23 (1980) Aband
Uviluk P-66
2 Buoys Priv
Pullen E-17 (1974) Aband
Fl 6s 48m Racon
Fullen
North Head
Reindeer Islands
NORTH POINT
Mason Bay
Summer I
Tumbling Pt
Kugmallit H-59 (1976) Aband
KUGMALLIT BAY
Hendrickson Island
Kittigazuit Bay
East Channel
West Pt
RICHARDS ISLAND
Topkak Pt
Tuktoyaktuk
Racon North Peak Fl 4s 44m
Tuft Pt
Toker Pt
James Shoal
Warren Pt
Hutchison Bay
Breakers
MINOR RUBBLE ON SHOAL
50-80% PONDED
ICE DRAINED
30'
134°00'
30'
133°00'
30'
70°00'



Map 12
Tuktoyaktuk Peninsula
June 13, 1987

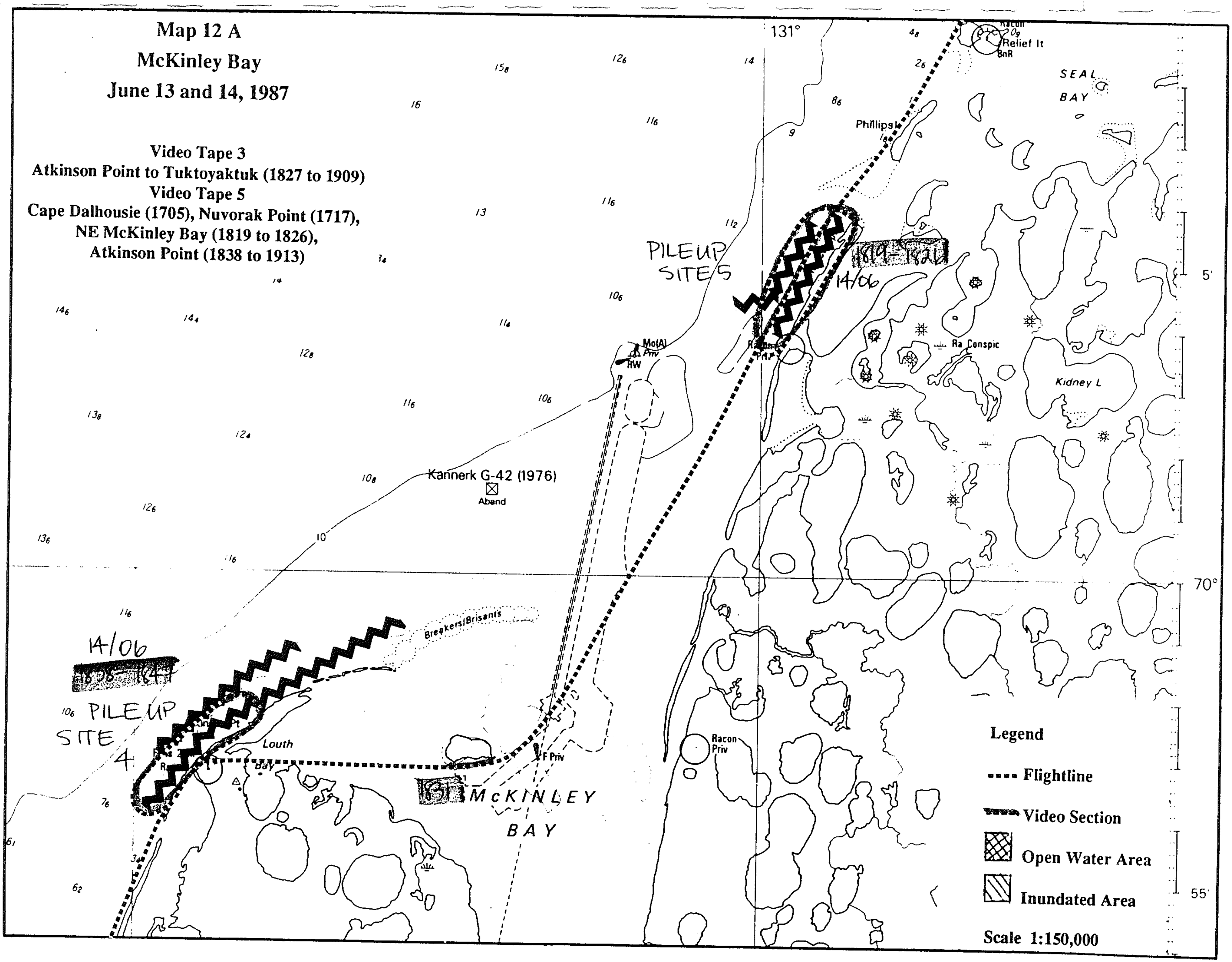
Video Tape 3
Atkinson Point to Tuktoyaktuk (1827 to 1909)
Video Tape 4
Tuktoyaktuk to Ellice Island (2052 to 2226)

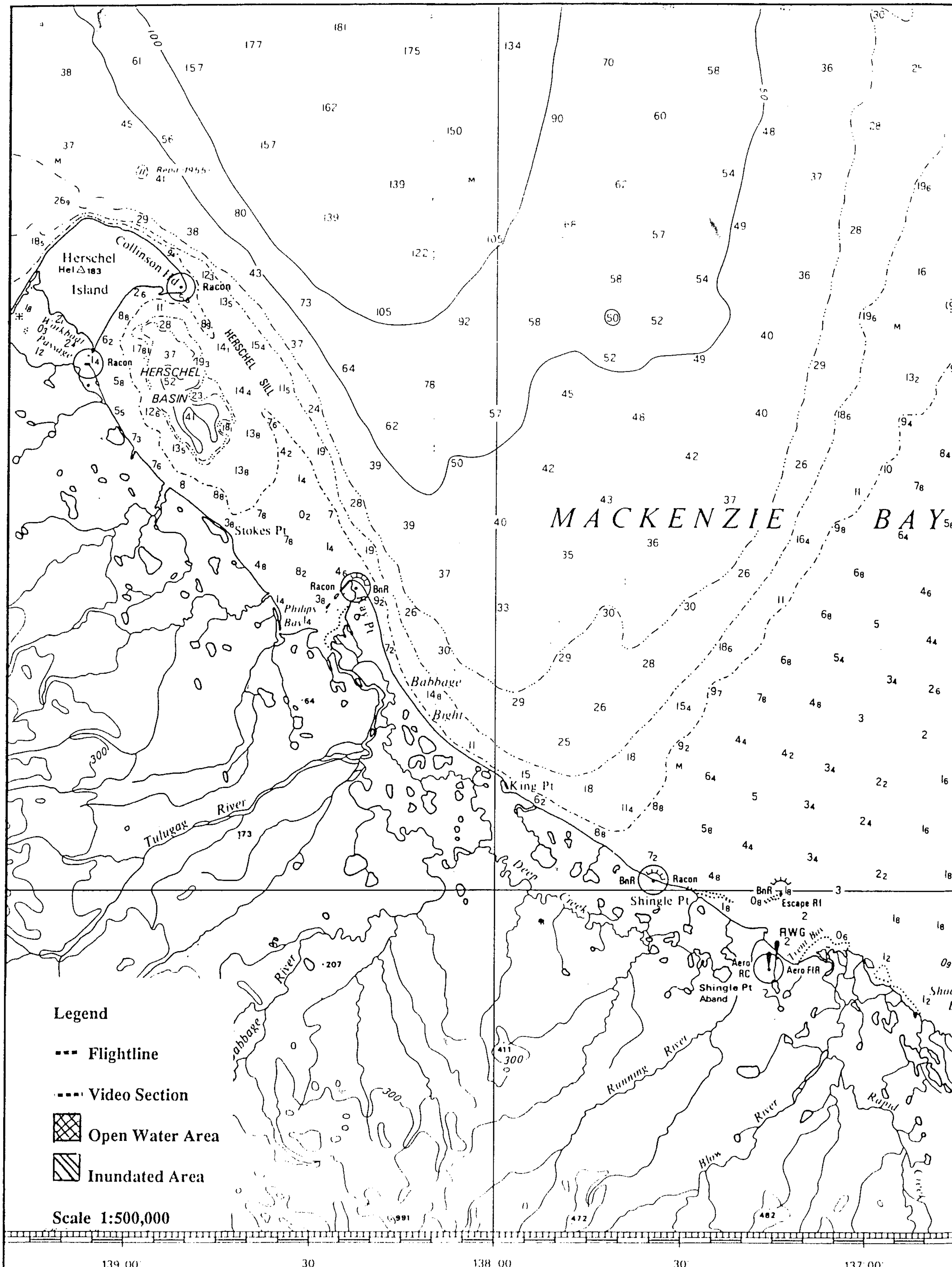
Map 12 A

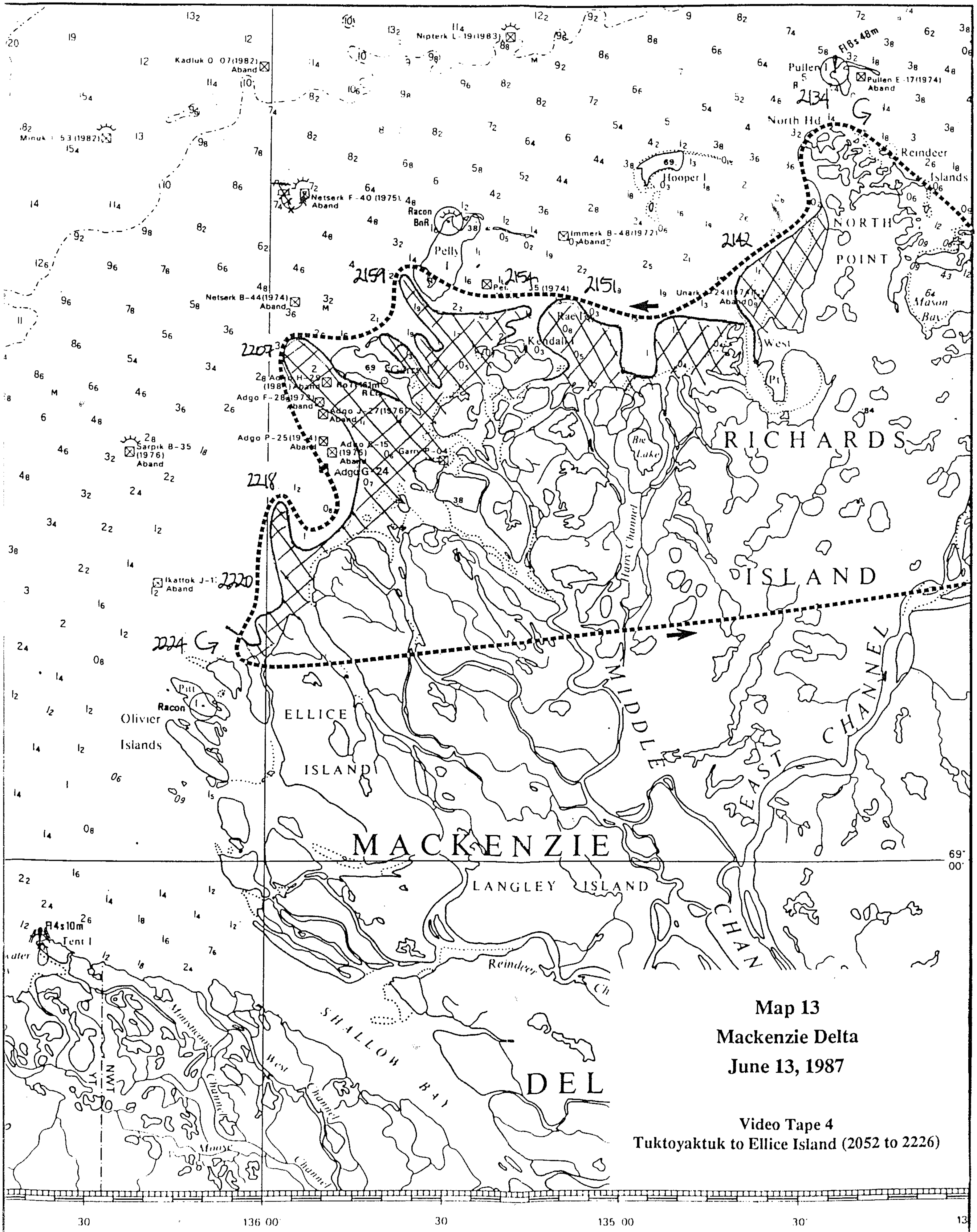
McKinley Bay

June 13 and 14, 1987

Video Tape 3
Atkinson Point to Tuktoyaktuk (1827 to 1909)
Video Tape 5
Cape Dalhousie (1705), Nuvorak Point (1717),
NE McKinley Bay (1819 to 1826),
Atkinson Point (1838 to 1913)

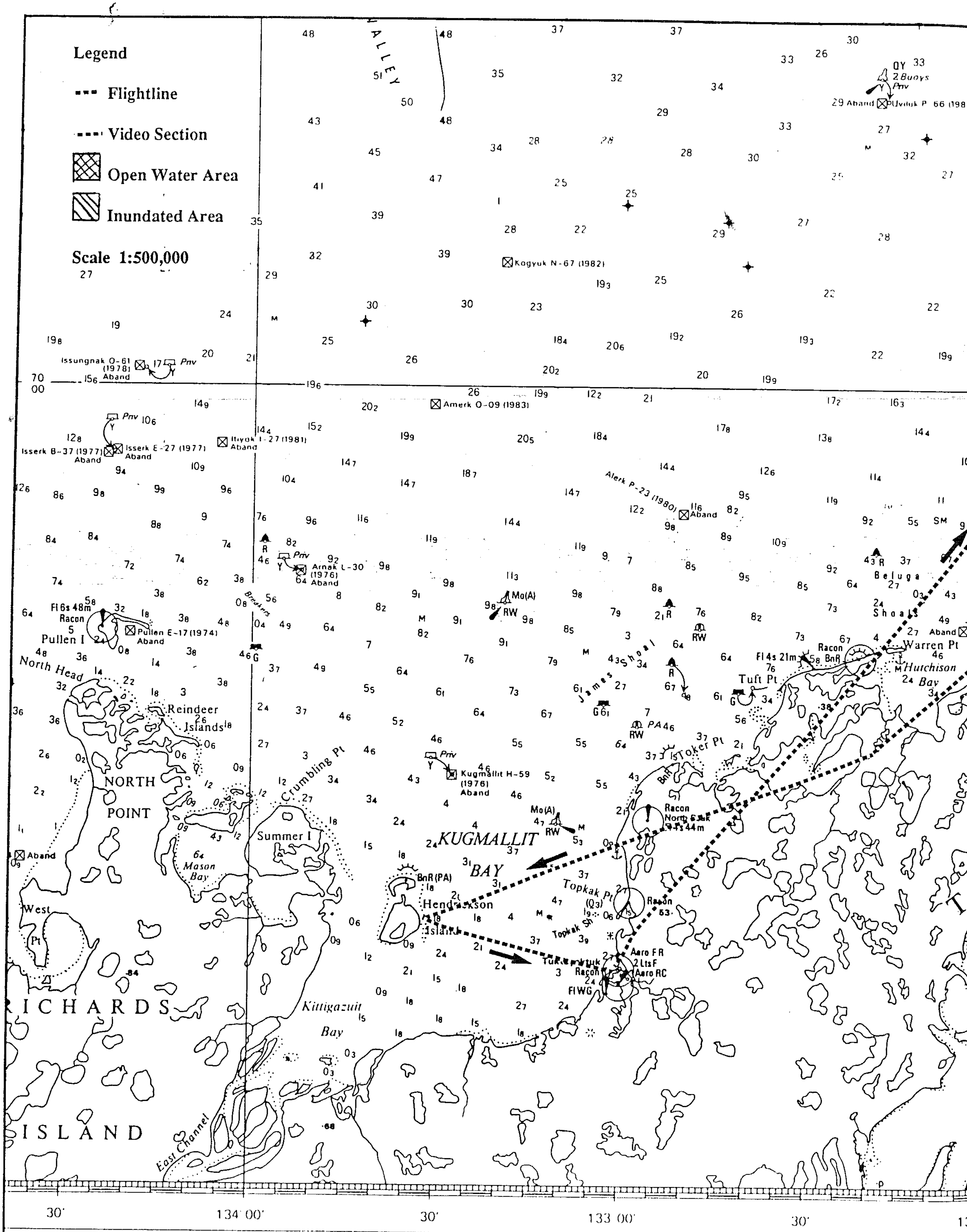



MACKENZIE BAY
Herschel Island
Collinson Hd
Racon
HERSCHEL SILL
HERSCHEL BASIN
Workboat Passage
Stokes Pt
Philips Bay
Kay Pt
BnR
Babbage Bight
King Pt
Shingle Pt
Escape Rf
Aero RC
Aero FIR
RWG
Shingle Pt Aband
Tulugaq River
Babbage River
Deep Creek
Running River
Blow River
Rapid Creek
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
139 00
30
138 00
30
137 00

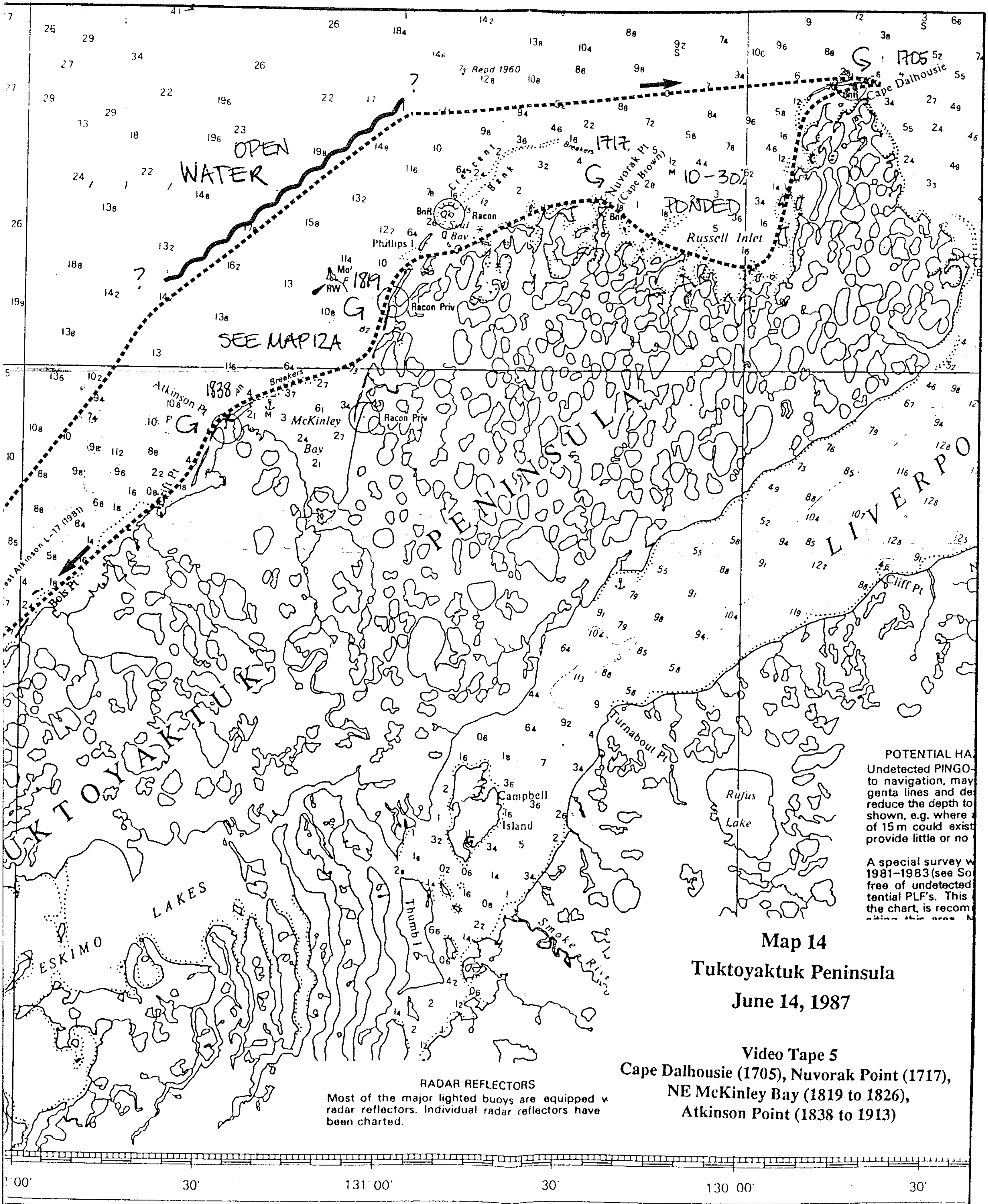


Map 13
Mackenzie Delta
June 13, 1987

Video Tape 4
Tuktoyaktuk to Ellice Island (2052 to 2226)

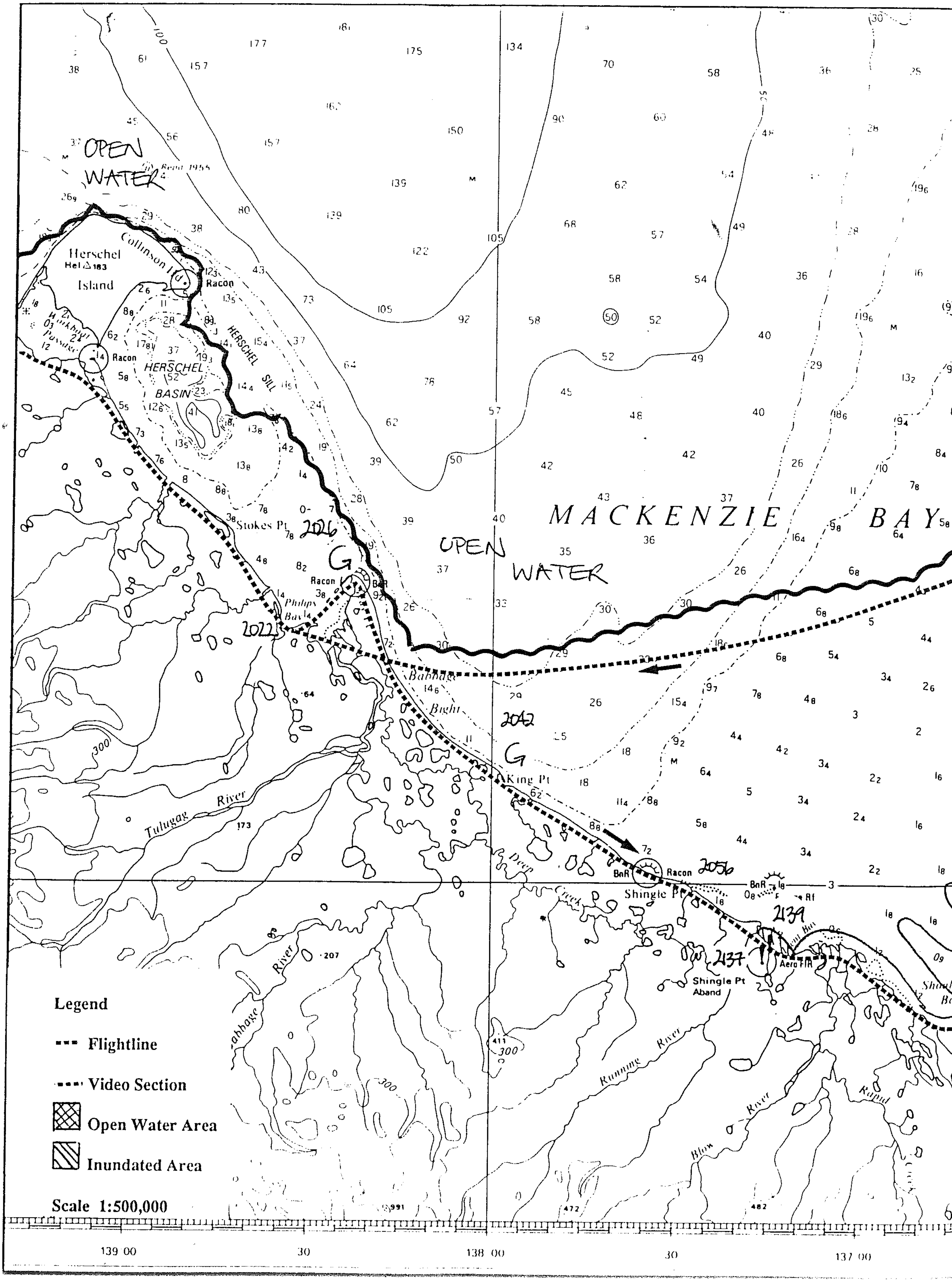


Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
KUGMALLIT BAY
Hendrickson Island
Summer I
NORTH POINT
Mason Bay
Reindeer Islands
Pullen I
North Head
Crumbling Pt
Kittigazuit Bay
East Channel
RICHARDS ISLAND
Topkak Pt
Toker Pt
Tuft Pt
Warren Pt
Hutchison Bay
Beluga Shoals
James Shoal
Issungnak O-61 (1978) Aband
Isserk E-27 (1977) Aband
Isserk B-37 (1977) Aband
Itiyok I-27 (1981) Aband
Arnak L-30 (1976) Aband
Pullen E-17 (1974) Aband
Amerk O-09 (1983)
Kogyuk N-67 (1982)
Alerk P-23 (1980) Aband
Kugmallit H-59 (1976) Aband
30'
134 00'
30'
133 00'
30'

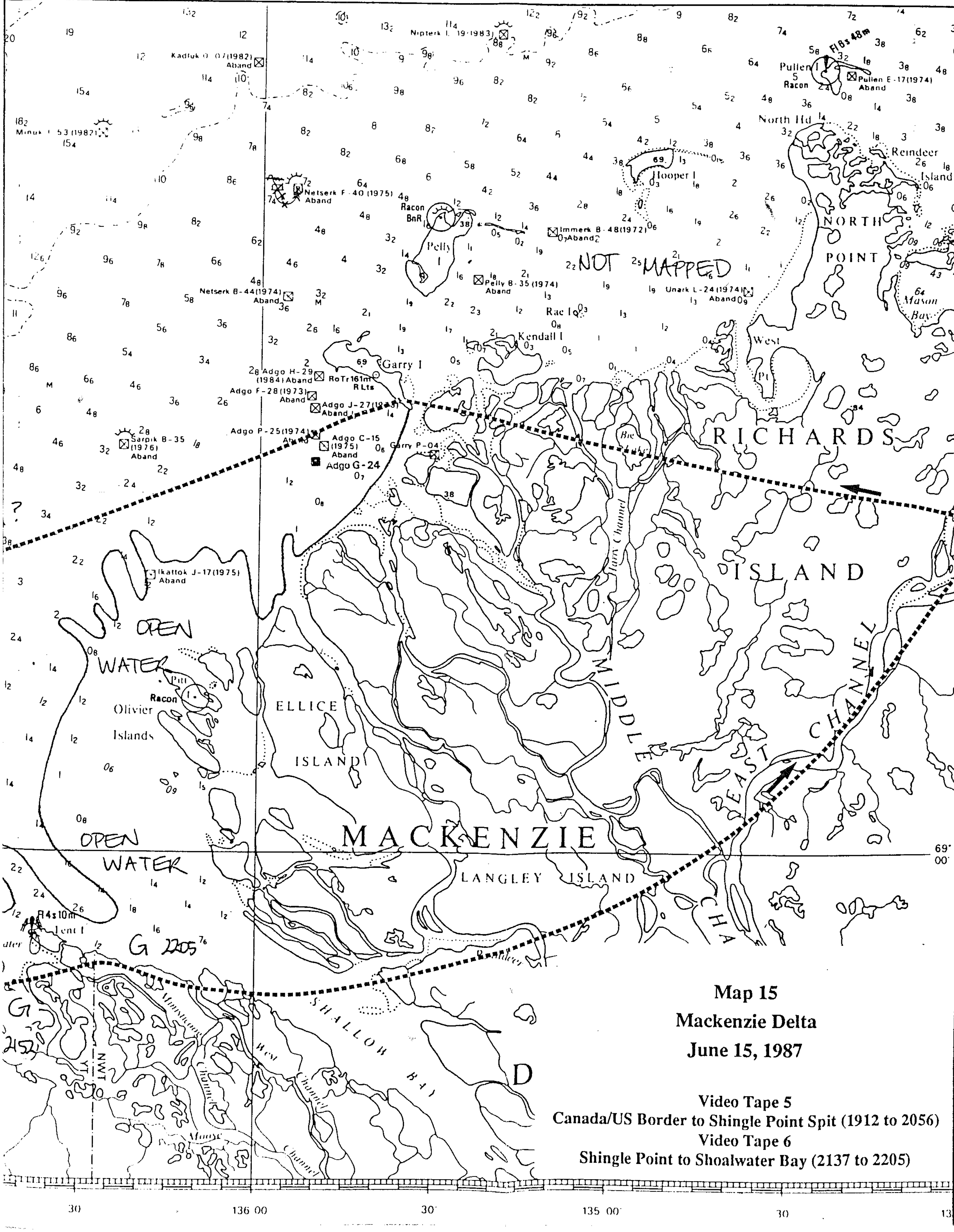


Map 14
Tuktoyaktuk Peninsula
June 14, 1987

Video Tape 5
Cape Dalhousie (1705), Nuvorak Point (1717), NE McKinley Bay (1819 to 1826), Atkinson Point (1838 to 1913)

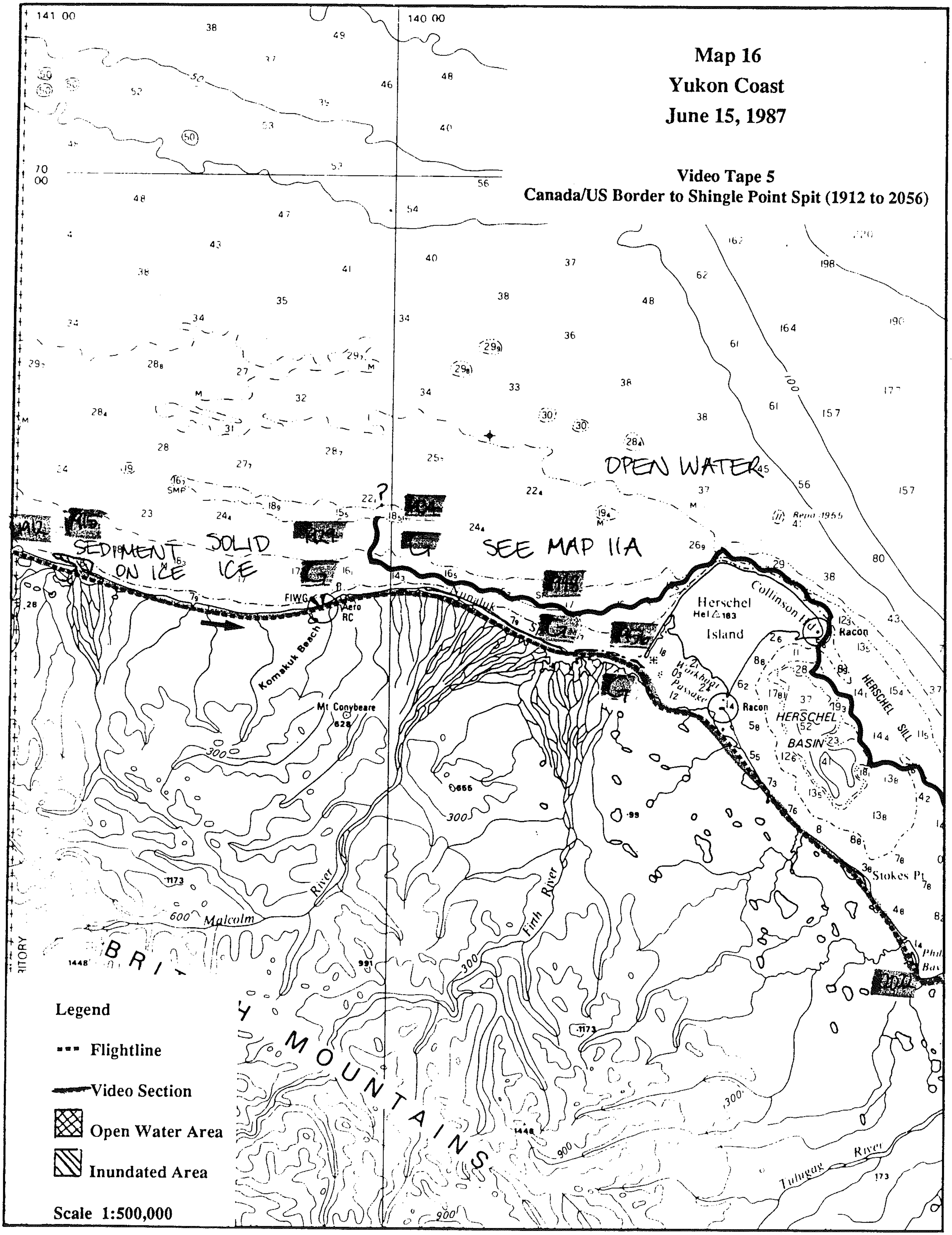


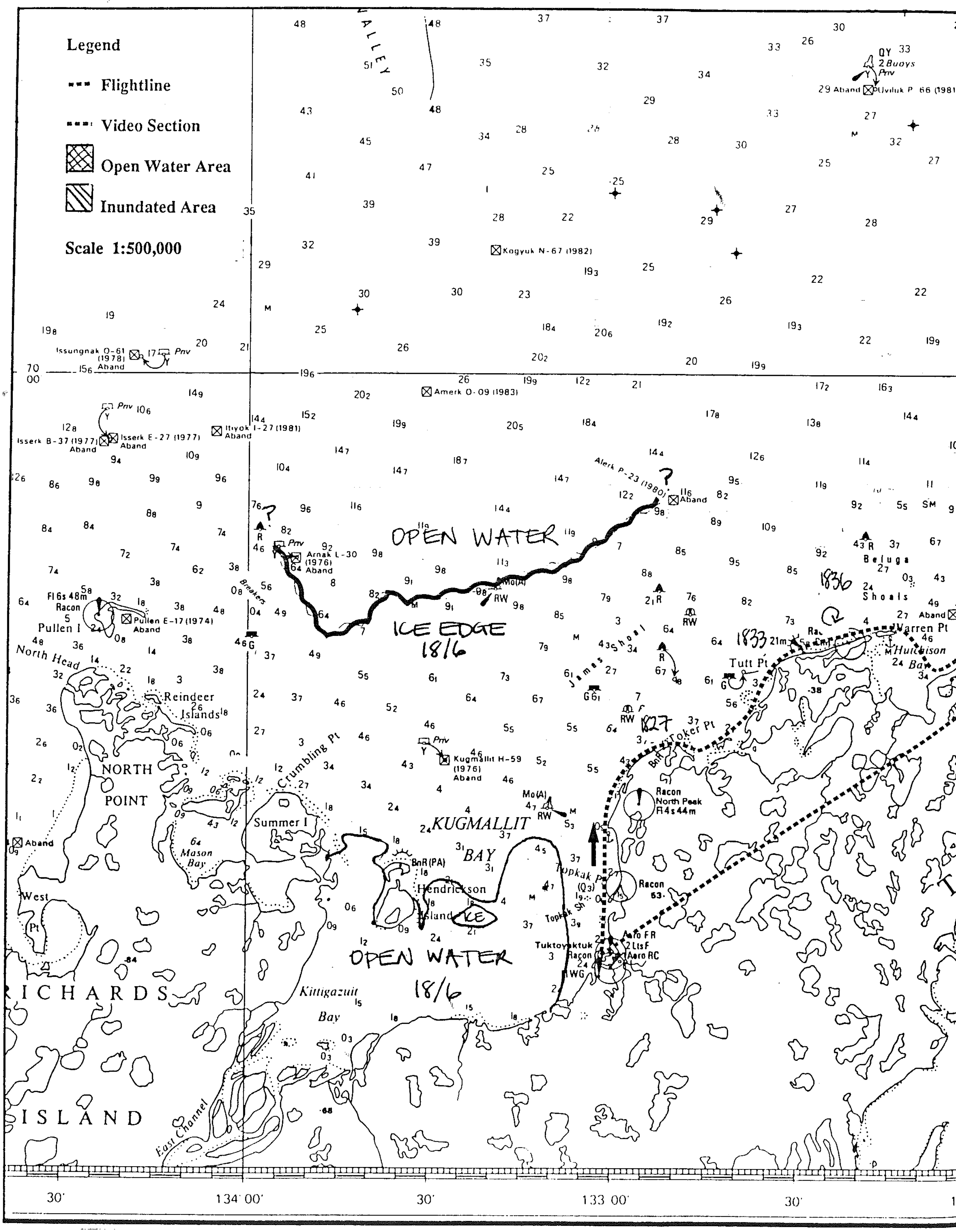
OPEN WATER
Herschel Island
Collinson Hd
Racon
HERSCHEL SILL
HERSCHEL BASIN
Stokes Pt
2026
G
Philips Bay
2022
OPEN WATER
MACKENZIE BAY
Babbage Bight
2042
G
King Pt
Tulugaq River
Racon
2056
Shingle Pt
2139
2137
Aero FlR
Shingle Pt Aband
Running River
Blow River
Deep Creek
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
139 00
30
138 00
30
137 00

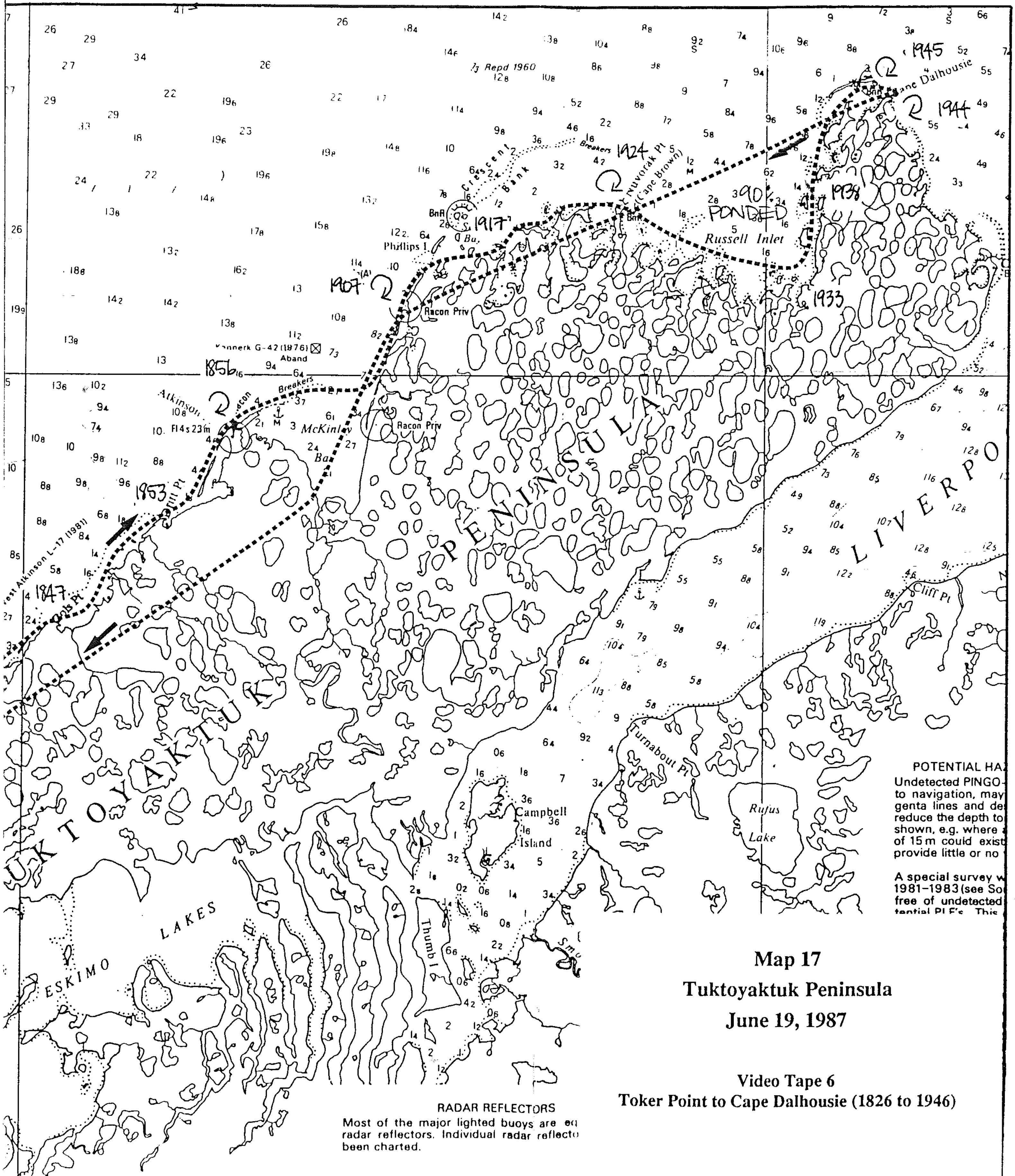


Map 15
Mackenzie Delta
June 15, 1987

Video Tape 5
Canada/US Border to Shingle Point Spit (1912 to 2056)
Video Tape 6
Shingle Point to Shoalwater Bay (2137 to 2205)

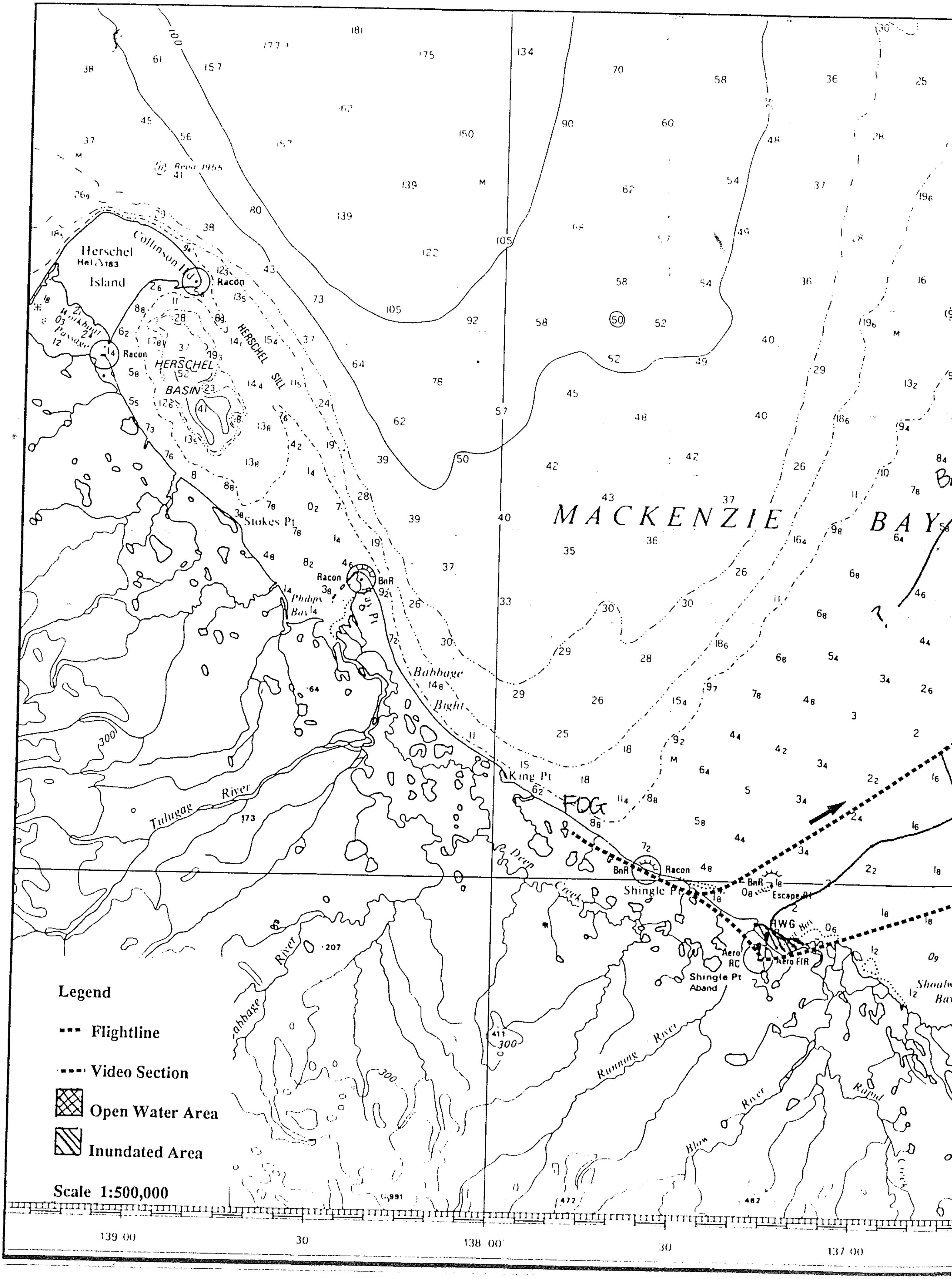

Map 16
Yukon Coast
June 15, 1987
Video Tape 5
Canada/US Border to Shingle Point Spit (1912 to 2056)
OPEN WATER
SEDIMENT ON ICE
SOLID ICE
SEE MAP IIA
Herschel Island
Collinson Hd
HERSCHEL BASIN
HERSCHEL SILL
Workboat Passage
Racon
Stokes Pt
Komakuk Beach
Mt Conybeare
Malcolm River
Firth River
BRITISH MOUNTAINS
Tulugag River
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000


Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
OPEN WATER
ICE EDGE
18/6
OPEN WATER
18/6
Issungnak O-61 (1978) Aband
Isserk B-37 (1977) Aband
Isserk E-27 (1977) Aband
Itiyok I-27 (1981) Aband
Amerk O-09 (1983)
Kogyuk N-67 (1982)
Alerk P-23 (1980) Aband
Arnak L-30 (1976) Aband
Pullen E-17 (1974) Aband
Kugmallit H-59 (1976) Aband
Uviluk P-66 (1981)
Pullen I
North Head
Reindeer Islands
NORTH POINT
Mason Bay
Summer I
Crumbling Pt
KUGMALLIT BAY
Hendrickson Island
Kittigazuit Bay
East Channel
RICHARDS ISLAND
West Pt
Tuktoyaktuk
Toker Pt
Tutt Pt
Warren Pt
Hutchison Bay
Beluga Shoals
James Shoal
Topkak Pt
Topkak Sh
Racon North Peak
1836
1833
1827
30'
134°00'
30'
133°00'
30'

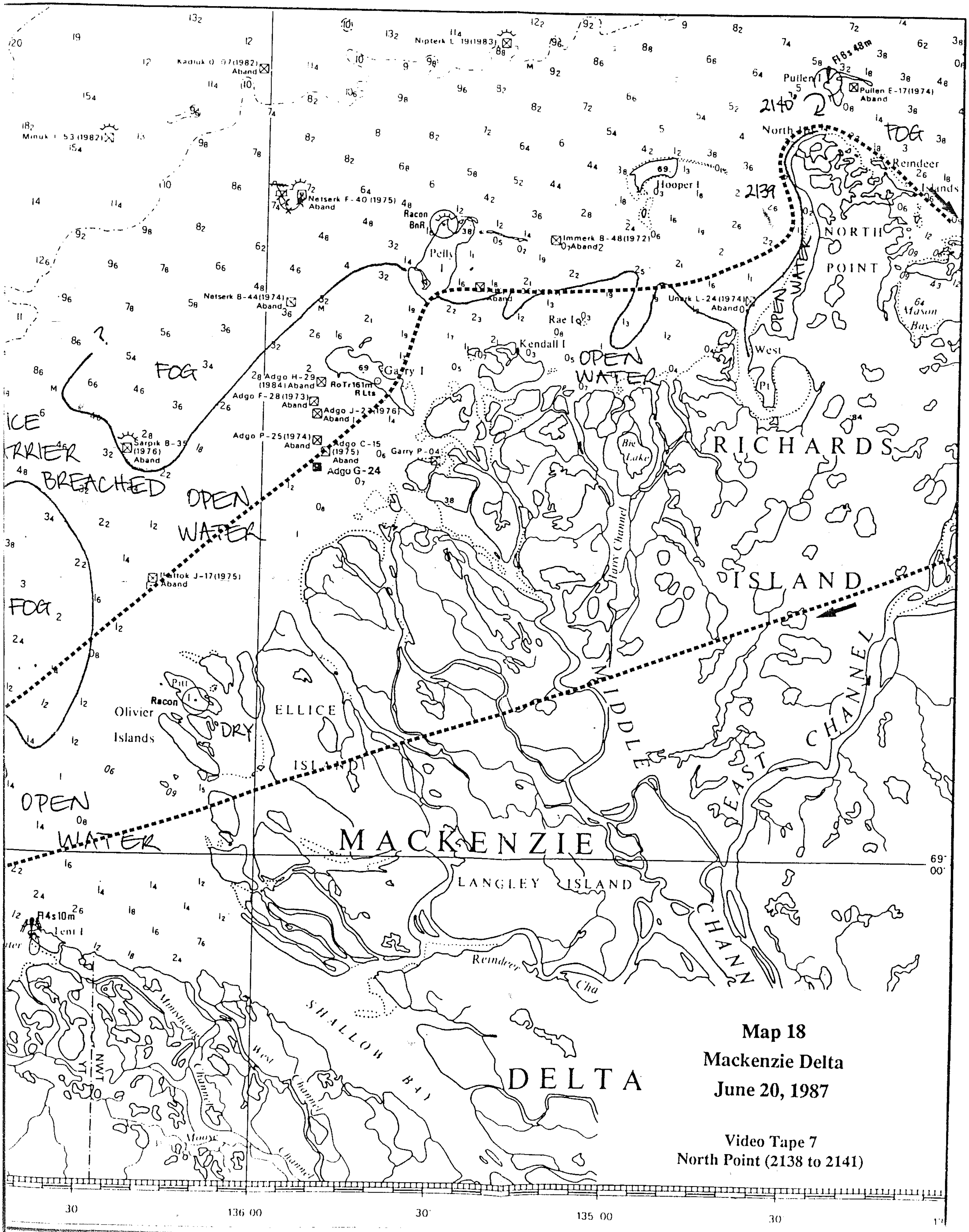


Map 17
Tuktoyaktuk Peninsula
June 19, 1987

Video Tape 6
Toker Point to Cape Dalhousie (1826 to 1946)



Herschel Island
Collinson Hd
Racon
HERSCHEL SILL
HERSCHEL BASIN
Stokes Pt
Philips Bay
Kay Pt
BnR
Babbage Bight
King Pt
FOG
Shingle Pt
Shingle Pt Aband
Escape Rf
HWG
Aero RC
Aero FIR
MACKENZIE BAY
Tulugaq River
Babbage River
Deep Creek
Running River
Blow River
Rapid Creek
Shoalwater Bay
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:500,000
139 00
30
138 00
30
137 00



Map 18
Mackenzie Delta
June 20, 1987

Video Tape 7
North Point (2138 to 2141)

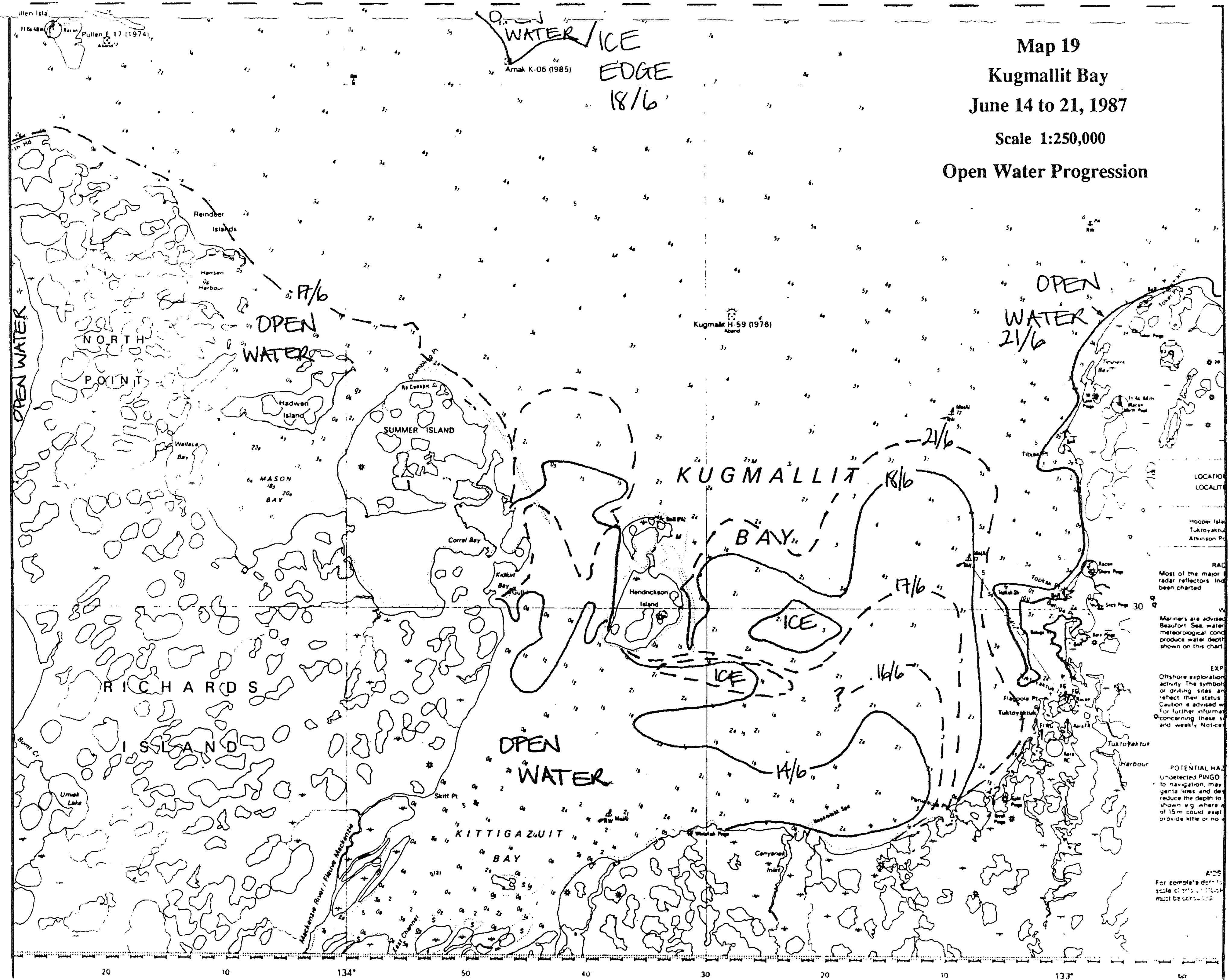
Map 19

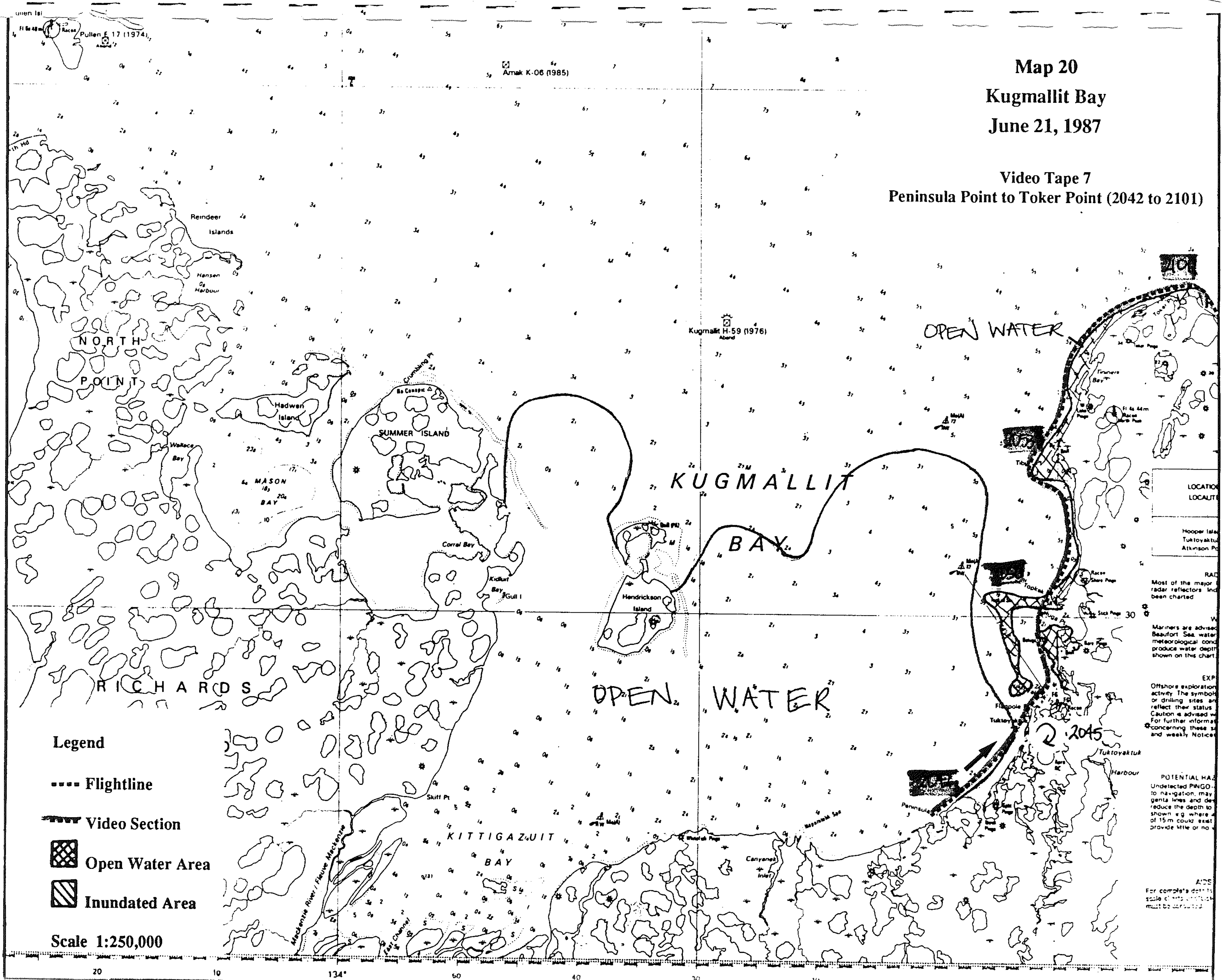
Kugmallit Bay

June 14 to 21, 1987

Scale 1:250,000

Open Water Progression





Map 20
Kugmallit Bay
June 21, 1987
Video Tape 7
Peninsula Point to Toker Point (2042 to 2101)
Legend
Flightline
Video Section
Open Water Area
Inundated Area
Scale 1:250,000
KUGMALLIT BAY
OPEN WATER
OPEN WATER
2045
NORTH POINT
RICHARDS
Reindeer Islands
Hansen Harbour
Hadwen Island
Wallace Bay
MASON BAY
SUMMER ISLAND
Crumbling Pt
Corral Bay
Kidluit Bay
Gull I
Hendrickson Island
KITTIGAZUIT BAY
Skiff Pt
Mackenzie River / Fleuve Mackenzie
East Channel
Canyanek Inlet
Tuktoyaktuk Harbour
Amak K-06 (1985)
Kugmallit H-59 (1976)
Pullen E 17 (1974)
134°