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SPRING BREAKUP AND FLUSHING OF AN ARCTIC LAGOON ESTUARY

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ABSTRACT

The oceanographic conditions during the breakup of-winter ice in the Simpson Lagoon and Kuparuk River channel on the Beaufort Sea coast of Alaska are presented. At the beginning of the breakup, bottom-fast ice of 2 m thickness covers most of the lagoon and water in deeper channels has a salinity in-excess Of 40°/°°. Statistical analysis of satellite-images. "' shows that coastal rivers overflow the ice on 30 May with a standard deviation of 8 days. 1979 was an anomalous year with overflow beginning in mid-May. Complete flushing of brine from ice covered river channels occurred in an eight hour period during which time the salinity fell from 36°/°° to 0°/°° and the temperature rose to -1.1°C to 0°C. 80% of the annual river flow occurred in the first 10 days of the breakup period. . Sea level rose 64 cm due to river overflow in 1978. Lagoon ice subsequent ? y melted in place and appeared to move out of the lagoon under the influence of wirtd-driven currents..: Temperatures in excess of 8°C were observed in late June in the fresh meltwater. By mitt-July cold (~ 0°C) saline (~ 24°/°°) water re-entered the lagoon from-the Beaufort Sea. Conditions necessary for the re-establishment of saline water in the lagoon appear to occur by 12 July with a standard duration of 5 days.

INTRODUCTION

The study reported here was stimulated by an ecological process study of Simpson Lagoon, Alaska (Johnson and Richardson, 1981) which showed that much of the annual biological activity in the region occurred with spring runoff and while the lagoon was still partly ice-covered. Previous physical oceanographic studies. in Simpson Lagoon (e.g. Dygas (1974), Matthews (1980]) had been concerned with the open-water season, approximately July through September, when it is relatively straightforward to make conventional physical oceanographic measurements in the shallow lagoon waters.

The Simpson Lagoon-Gwydyr Bay system is a shallow lagoon (T-3 m depth) between the mainland coast of Alaska west of Prudhoe Bay and an almost continuous string of barrier islands. Gwydyr Bay (Figure 1) is the eastern part of the lagoon system. The Kuparuk River flows into its southern part and the 6 m deep Egg Island Channel connects it to the Beaufort Sea through the barrier islands. Gwydyr Bay has depths of 2 m or less everywhere except for Egg Island Channel. Simpson Lagoon depth is 2 m or less except for 3 m deep channels in its extreme western end.

Annual sea ice growth in the region is about 2 m (Kovacs and Mellor, 1974]. Therefore, Simpson Lagoon and Gwydyr Bay are almost completely frozen and filled with landfast ice much of which is bottom fast-as well, by late spring each year (Figure 1). Very high salinities, (> 180°/••), have been reported in isolated remaining pockets of water in coastal lagoons of the Beaufort Sea (Schell, 1974) due to brine exclusion during the freezing process. The summer observations on the contrary showed very low salinities (~ 24°/••) in the lagoons by late July (Matthews, 1980). Walker (1974) reported that winter accumulation of brine in the Colville River delta was flushed out in less-than 2 days. The purpose of this study was thus to examine the oceanographic conditions under the ice in the Simpson Lagoon complex during spring runoff until open water conditions were established..

The study site was chosen because it is a major channel of the Simpson Lagoon complex. During the open water season it was known that water entered the lagoon through this channel from the Beaufort Sea under the influence of the prevailing easterly winds. The channel is a submerged river channel and therefore could be expected to carry the waters of the Kuparuk River after breakup. Moreover the channel was deep enough to allow the mooring of conventional current meters under the ice.

Spring breakup of arctic rivers is difficult to monitor by conventional methods (stream gauges) because of icing problems compounded by the remoteness of the location. However, the sharp contrast between snow and water in the near-infrared makes possible satellite monitoring of river flow and consequent flooding of the ice by flood waters. This method of monitoring is facilitated by a high degree of cloud-free weather during spring along the Alaskan Beaufort coast. For almost a decade, a-series of meteorological satellites operated by the National Oceanic and Atmospheric Administration (NOAA) have provided daily comprehensive imagery of the earth's surface. Imagery is available in a variety of wavelength bands at a spatial resolution of 1 km. Two of these passbands include the near-infrared. In addition, higher resolution Landsat near-infrared imagery is available, which includes the same Beaufort coastal feature for a period of three consecutive days because of the convergence of orbit paths at the earth's poles. Since Landsat orbits repeat every eighteen days, coverage is therefore possible on three days out of every eighteen. Occasionally, two Landsats have been available with their orbits arranged such that coverage is possible on three days out of every nine. Landsat resolution is approximately 80 meters. The combination of oceanographic data and satellite imagery provides a good means of measuring the effects of breakup on the lagoon system.

METHODS

Aanderaa current meters, fitted with conductivity and temperature sensors, and tide gauges were used. The instruments were calibrated before and after deployment for pressure, conductivity and temperature. The calibration range was extended to 10 to 40°/•• salinities, and -2 to 20°C temperatures, because our measurements lay outside the standard calibration ranges. Observed data were corrected using the mean of 'before' and 'after' calibration constants. Details of the deployment system have been reported elsewhere and will be briefly presented here (Matthews, 1981). In 1978 an Aanderaa current meter was mounted just above the sea floor on a staff set into a concrete block. The tide gauge and a location pinger were set into the concrete block. The second installation in 1979 used a similar system but with a second current meter supported by a float with 20 kg buoyancy above the first meter. The configuration was designed to provide measurements as close to the sea floor and the ice cover as possible while having the instruments free to operate normally. River stage data were taken from published U.S.G.S. reports. The quality of these data are generally listed as being fair for most of the record and poor before the river gauge was installed. The gauges are only installed when breakup has begun and pre-breakup records are estimates (U.S.G.S. 1978, 1979).

The Geophysical Institute maintains an extensive archive of NOAA meteorological satellite and Landsat imagery. One of the chief uses of this imagery is the monitoring of ephemeral events such as the springtime flooding reported here. Because of the great contrast between dry snow and water in the near-infrared, springtime flooding of even the relatively small Kuparuk River can be easily monitored through it-s various stages as waters course down the frozen riverbed in the arctic coastal plain from the "relatively warmer headwaiters in the foothills of the Brooks Range. These waters can then be seen flooding across the relatively flat shorefast ice of Simpson Lagoon.

Annual logs of Kuparuk River flooding activity fram 1973 through 1982 were compiled from daily meteorological satellite imagery. This imagery was also enlarged to allow measurement of the areal extent of flooding upon the lagoon ice. The occasional Landsat imagery was used to provide detailed confirmation of flood geometry identified on a daily basis on the'meteorological satellite imagery.

RESULTS

Figure 2 shows salinity, temperature current vectors and sea level records from Egg Island Channel for May to July 1978. River runoff retards taken from U.S. Geologi cal Survey records are al so included (U. S.G. S. 1978). The instrument sensors were located 50 cm above the sea bed. The salinity fell steadily from a maximum of 43.6°/oo on 15 May to 36.0°/oo on 7 June, a rate of approximately 0.33°/oo day-1. In the first eight hours of 8 June the salinity fell from 36.0°/oo to 0°/oo indicating complete flushing. The temperature record shows complementary features with a minimum temperature of -2°C on 15 May steadily rising to -1.5°C by

7 June. The temperature rose from -1.1°C at 1400 hours local time on 6 June to 0°C by 1800 hours the same day. The salinity record continued to remain near zero until 13 July when an increase from 1°/•• to 18°/•• occurred over a period of about 20 hours. Thereafter the salinity rose to reach a high of 30.0°/•• on 26 July. The temperature rose to a high of 6.9*C on 9 July which was followed by a trough of low temperature (~ 0°C) extending to 15 July. The increases in temperature in June preceded the associated salinity drop as did the temperature increase in July precede tine salinity increase.

The current vectors show southerly flowing currents in May and early June of mean speed 2 cm sec^{-1}. The current rose rapidly in the first few hours of 8 June and turned towards the north to reach a maximum of 20 cm sec^{-1}. The current dropped to zero at 1000 hours local time 8 June. When one of the authors (J.B.M.) dived onto the instrument array for recovery, a pebble was found on the current meter rotor suggesting that the lack of record from 8 June resulted from this situation.

The sea level record in Figure 2 shows the normally semi-diurnal tide of range 15 cm until 8 June. From 0700 hours local time on that date the sea level rose from a mean level of 500 cm above datum to reach a high of 543 cm at 0400 hours on 9 June. The sea level remained near 540 cm above datum until 10 June after which it gradually fell to the 500 cm level by 15 June subsequently it again showed clear semi-diurnal fluctuations. In the remainder of the record shown in Figure 2 the sea level showed typical variations in sea level larger than the semi-diurnal tidal mean range of 15 cm. A marked drop in sea level coincided with the temperature drop between 9 and 15 July.

The Kuparuk River runoff shows a peak of 3340 m^3 sec^{-1} on 7 June. This fell to 1132 m^3 see-l by 10 June and 625 m^3 sec^{-1} on 11 June. The Kuparuk River gauge was located 10 km upstream front Gwydyr Bay. No river flow was measured between 27 November, 1977 and 5 June, 1978. Gauge-height records are estimated for the period 5 October, 1977 and 7 June, 1978 and are reported to be fair in quality. The flow of 3340 m3 sec^{-1} reported on 7 June, 1978 is an extreme record for this gauge for the period of record from June 1971 (U.S.G. S. 1978).

Figure 3 is a tracing from a Landsat image of the Beaufort Sea coast taken at 1128 hours local time on 8 June, 1978. The river overflow onto the land-fast ice can be seen for the major rivers including the Kuparuk River. The dark sediment-laden river water can be seen extending beyond the barrier islands near the Egg Island Channel "and covering most of Gwydyr Bay. The total area covered by Kuparuk River water in the image is 116 km2.

The records for 1978 breakup clearly show that breakup occurred with the river overf lowing the ice and completely fl ushing the 5 m-deep Egg Island Channel in early June. The failure of the current meter occurred after initial currents flowing seaward (north) of 20 cm sec^{-1} had been retarded. Two recording current meters were installed in 1979 in order to obtain current meter records. Unfortunately the sea level gauge was buried by sediment and not recovered in 1979.'

Figure 4 shows the records from the upper instrument in Egg" Isl and Channel in 1979 and the river runoff record. A similar drop in salinity was recorded on 17 May, 1979, two weeks earlier than the previous year. Values will be given for the upper instrument 2 m above the channel floor (Figure 4) and in parentheses far' the lower instrument 1 m above the floor.

The salinity rose from 43.4°/°° (43.2°/°°) to a maximum of 47.8°/°° (47.6 °/°°) on 11 May then fell slowly to 47.5°/°° (47.3°/°°) on 17 May. It fell from 47.5°/°° (47.3*/°°) at 1300 hours to 5.1°/°° (5.0°/°°) at 2000 hours on 17 June. It increased to 17.1°/°° (28.0°/°°) by 0600 on 18 May and fell to 5.4°/°° (6.0°/°°) by 0800 hours. It rose to 8.2°/°° (20°/°°) by 1500 hours on 18 June then fell again to 3.7°/°° (4°/°°) by 2000 hours. Thereafter salinity was close to zero on both instruments until late June. The temperature showed corresponding increases from '- -2.5°C to -0.2°C during the same period.

Mean currents were less than 1 cm/sec^{-1} before 17 May and were towards the northwest. The current rose from 0 cm sec^{-1} at 1200 hours to 36 (20) cm sec^{-1} at 1100 hours 17 May. A maximum hourly mean 'current of 86 cm sec^{-1} was observed on 30 May. The river runoff records shows a peak flow of 640 m3 sec^{-1} on 1 June, but the 'record is estimated before that date arid is probably inaccurate (U.S.G.S. 1979).

Figure 5 shows progressive vector plots for current meters approximately 1 and 2 m above the sea floor during the period of peak current between 15 May and 4 June. The lower instrument recorded northerly (seaward) transport of 140 km during the period. The upper instrument showed first a southerly then an easterly transport for a net easterly transport of 200 km.

The combined Landsat and NOAA satellite 'imagery was used to identify the date at which the Kuparuk River flooded unto the ice for the 9 years, 1974 through 1982. The average flooding date was found to be 30 May with a standard deviation of 8 days. The floodwaters reach the barrier islands about 3 days after flooding begins. The flooding which occurred in 1979 appears to be anomalously early: while all other eight flooding dates were within one standard deviation of the average date, the 1979 flooding was more than two standard deviations earlier than the average date.

Figure 6 shows successive flooded areas of Gwydyr Bay as measured from the satellite imagery during the 1979 season. The flooding chronology as determined from satellite imagery is as follows:

May 12.	Flood waters have not yet reached the river delta.
May 13.	Two extensions of the flooded area reach the vicinity of the edge of the lagoon.
May 14.	Broad pools develop beyond the edge of the lagoon. These pools cover approximately 7 km² and are located upon the bottomfast ice.
May 15.	The flooding has expanded considerably and now almost reaches Egg Island Channel. However, the plume appears to avoid the Egg Island Channel. 25 km² are now covered by flood waters.
May 16-19.	Cloudy weather precludes accurate measurement of flooded areas.
May 20.	The flooding has expanded across the lagoon and to the east and west.
May 21-22.	Cloudy again.
May 23.	The flood has spread toward the west and now covers 65 km².
May 24-26.	Cloudy.
May 27.	The flood spreads along the lagoon and spills out around Egg Island. Now covers 95 km².
May 28-30.	Cloudy.
May 31.	Flooding appears to reach peak. Now covers 100 km².

DISCUSSION

The observations reported here for the Kuparuk River confirm the processes reported for the larger Colville River by Walker (1974). Brine excluded during ice formation is flushed rapidly, over a period of a few hours, by the spring river flow. in 1978 the salinity dropped 20°/00 in one 20-minute sampling period. In 1979 the flushing was less rapid, probably because it occurred anomalously earlier than average so that refreezing occurred during the first few days river flow. Data from the two instruments also clearly showed early stratification-as the winters accumulation of brine was eroded by the flood waters. The. pre-breakup salinities of 43.6°/°° in 1978 and 47.6°/°° in 1979 compare well with the values in excess of 40°/°° reported for the" Colville Delta by Walker (1974) and values of 48.9 and 56.2°/°° in Elson Lagoon by Schell (1974}. The pre-breakup salinity decrease of 0.33°/°° day^{-1} is comparable to the 0.04°/°° day^{-1} increase reported during freezeup (Matthews, 1981) and is consistent with fairly sluggish advection.

The process by which the flood waters enter the ocean has been described by Walker (1974) and Reimnitz and Broder (1972): the water overflows the ice out to points at which the ice is no longer bottomfast and enters cracks through the ice. - As water pours through; the relatively warm river water enlarges the passageway and a drainage vortex develops. As a result, large quantities of flood water are drained from the ice surface within a relatively short time. At locations where the ice is not bottomfast, these drainage vortices can scour a depression into soft seabed sediments. Reimnitz (1982) discovered one of these drainage vortex scours just—south of the Egg Island Channel in the-summer of 1978. Debris and the pebble found on the current meter rotor probably came from this scour hole. Drainage through these holes appears to be common in areas where the ice is not bottomfast. Reimnitz and Kempema (1982).'

estimate their density at between two and three per km^2. Hence, it is likely that drainage vortices develop in the vicinity of the Egg Island Channel each year, draining off a portion of the Kuparuk flood through the channel. This probably restricts the extent of the overflow area to some extent in this location.

The oceanographic instruments allow us to make some quantitative estimates. Figure 3 is a tracing from an enlarged satellite image. It shows that 116 km^2 are covered by river water on 8 June, 1978. At that time the sea level was 64 cm above mean level suggesting that there was 0.075 km^3 of river water over the ice. River stage records show that by that time 0.44 km^3 had flowed down the Kuparuk. Since the river gauge was not installed until runoff had begun (U.S.G.S. 1978) the cumulative flow is probably underestimated. Thus about 17-20% of the river flow is over the ice while the remainder must be beneath the ice canopy.

Flushing occurred within a two-day period in 1979. The maximum flushing currents observed were comparable to those observed during summer storms when the waters are wind-driven (Matthews, 1980, 1981). If we assumed a 6 m deep channel. 20 m wide with 4 m of water beneath "the ice, we can estimate the total flux of water through the Egg Island Channel including and following flushing. The excursion was 200 km at the upper meter and 170 km at the lower meter. This yields a total volume of 0.015 km^3. River stage records before June were estimated and, therefore, cannot be relied upon. However, it is interesting to compare these values with the area flooded as measured on satellite imagery and the flood volume estimated from these area measurements (Table 1).

In order to perform this estimate, some value must be used for the depth of the flood. Our tide gauge measurements yielded a depth of .6 m the previews year. However, the tide gauge was located in the vicinity of drainage vortices near the Egg Island Channel. Reimnitz et al. (1974) estimated the depth of the Kuparuk flood to be between 1 and 1.5 meters in 1970. Walker (1974) found the flood of the much 'larger Colville River to be as great as 5 m. Based on these observations, we have used a nominal flood depth of 1 m in estimating the overflow flood volume.

Comparing the estimated river discharge and estimated flood volume, we see a remarkable agreement for 15 May and a disagreement by a factor of 2 by 31 May. The flooded area could not be accurately mapped after this date however, the estimated discharge had increased to .25 km3 by 4 June. Thus"the flux through the Egg Island Channel is approximately 6% of the estimated river discharge. This suggests that the bulk of the flood waters remain in the lagoon.

The early and extended flood in 1979 allows a detailed examination of the areal extent of the advancing flood waters (Figure 6)." Between 12 and 15 May the flood waters expanded upon the bottomfast ice in all directions from the Kuparuk River delta. By 15 May, these waters reached the vicinity of the Egg Island Channel where water depths were sufficient for vortex drainage to take place. Cloudy condit ions prevented further mapping of the flood until 23 May. Prior to that date the flood had advanced dramatically everywhere except near the Egg Island Channel. It seems clear that following 17 May much of the flood water was drained through the ice since the flood actually expanded elsewhere. However during the peak runoff period the flood-waters did extend beyond Egg Island

Channel. Presumably either the flood went around the drained area or the channel simply couldn't accommodate the extreme volume of water available. The peak currents of 86 cm sec^{-1} were observed on 30 May, during this final advance of the flood waters.

Reintroduction of Saline Water into Simpson Lagoon

Figures 4 and 5 show that low salinity water was retained in Simpson Lagoon for a considerable time following its introduction there by the Kuparuk River. By mid-July in both years brackish, {- 24°/••} waters typical for the open-water season were observed. We take. this as an indication. that water fram the Beaufort Sea has been introduced into the lagoon displacing the almost fresh water created by the river overflow and lagoon ice melting in place.

In order to elucidate more details of the processes by which the sea water is re-established, satellite imagery for 1978 and 1979 were examined. During 1978 the ice in the eastern portion of the lagoon melted in a pattern nearly identical to that of the earlier over-ice flooding. Comparison with images from other years suggests that this is a normal occurrence. It appears to result from the markedly decreased albedo of the water and detritus on the ice and from the high isolation at this time of year. By 6 July the remaining ice in the lagoon melted in place though the salinity of the Egg Island Channel did not rise significantly until 13 July when a sharp increase was recorded.

The strongest correlation between the increase in salinity in Egg Island Channel with other phenomena appears to be with coastal winds. Following the melting of the ice in the lagoon the winds measured at nearby Deadhorse Airport began increasing on 9 July reaching hourly average speeds of 11 ms^{-1} with gusts to 14 ms^{-1} on 11 July. These windy conditions continued until 15 July. Fram Figure 4, it can be seen that this windy period coincided with a decrease in sea level within the lagoon starting on 10 July and a rapid increase in salinity starting on the 13 July. A Landsat scene obtained on 12 July shows a great amount of westward, slang-shore transport of suspended sediment. During the open-water season wind-driven currents of about .3% of the wind speed typical l y flowi ng westwards have been reported for the region (Matthews, 1981). Thus, longshore currents up to 0.5 ms^{-1} would be generated by the observed winds for a transport of about 30 km day^{-1}. The length of the lagoon from the Kuparuk River to Oliktok Point is 40 km. This suggests that removal of the lagoon ice could take place in a little more than a day under the wind conditions reported. Thus it appears that lagoon ice meTts in place until easterly winds can move the remnants westward out of the lagoon. The opening of the lagoon then allows water to reverse in the Egg island.Chnnel and allow coastal water to enter the lagoon system.

In 1979 the ice in the lagoon had been removed by 11 July. Figure 5 shows that the lagoon salinity underwent a slow increase until 23 July when a series of sharp increases-were initiated. Winds at Deadhorse throughout this period varied over a wide range of magnitude (as high as 9 ms^{-1}). However, they were not coherent as the winds had been the previous year nor as large in magnitude. Finally, the wind increased to hourly average values as high as 10 ms^{-1} on 24 July.

These data suggest that in the absence of winds of-sufficient duration and strength to create steady currents; flushing of the meltwaters from the lagoon water does not take place. This suggests that two conditions must be met for flushing to occur. First the lagoon ice must decay sufficiently to allow it to move. 'Then easterly winds of the order of 10 ms^{-1} are needed to move the remnant ice if it does not melt in place.

We have examined satellite images to establish the range of dates for which ice is last observed in the lagoon. Although satellite observations were not always available every day, such observations were sufficiently frequent to establish a narrow window within which the ice was removed.. This window is established by noting the last day upon which ice could be seen and-the first day when ice could not be seen in the lagoon. The average date, between 1974 arid 1982, that ice was last seen in the lagoon was 8 July with a standard deviation of 6 days. Ice-f ree condi t ions were first seen on 12 July with a standard deviation of 5 days. These data suggest that meltwaters can normally be expected to persist in the lagoon for about six weeks. . It would not normally appear before 2 July which suggests that the minimum residence time of meltwaters is about one month.

CONCLUSIONS

Salinities of 40-50°/°° and temperatures near the freezing point are - the pre-breakup Conditions in the Egg Island Channel of the Kuparuk Estuary and Gwydyr Bay. During normal years breakup begins with the river water overflowing the ice and flushing the channel completely in a few hours. This occurs on 30 May with a standard deviation of 8 days in normal years. Floodwaters reach the barrier island and Egg Island Channel.. about three days later. Eighty percent of the annual runoff occurs during the first 10 days' flow. When breakup occurred two weeks, earlier than normal, the complete flushing took place over a period of 2 days. The river flow effectively took place over a 2 week period when transports of about 200 km were recorded in a 6 m-deep channel. Subsequent to the river overflow of lagoon ice, the ice melts under the 24-hour solar insulation. From analyses of satel l ite imagery far 9 years, ice was last seen on & July and ice-free conditions by 12 July during normal years with standard deviations of 6 and 5 days respectively. Establishment of ice-free conditions appears to correlate well with reversal of flow in Egg Island Channel and the reintroduction of brackish (~ 24*/**], cold (~ 0°C) seawater into the l agoon from the Beaufort Sea. We conclude that breakup of the l agoon ice takes place between 30 May - and 12 July with standard deviations of 8 and 5 days respectively.

ACKNOWLEDGEMENTS

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REFERENCES

Dygas, J. A., A study of wind, waves and" currents in Simpson Lagoon, p. 15-44, In Alexander, Vera (Ed) Environmental studies of an arctic estuarine system, Report R74-1, Institute of Marine Science, University of Alaska, Fairbanks, Alaska, 538 pp, 1974.

Kovacs, Austin and Malcom Muller, Sea ice morphology and ice as a geologic agent in the southern Beaufort Sea, pp. 113-161, In Reed, J. C. and J. E. Sater (Eds) The coast and shelf of the Beaufort Sea, Arctic" Institute of North America, Arlington, Virginia, 750 pp, 1974.

Matthews, J. R.,' Modeling and verification in an arctic barrier island-lagoon system - an ecological process study, p. 220-231, In Sundermann, Juergen and K. P. Holtz (Eds) Mathematical modelling of estuarine physics, Springer Verlag, New York, 265 pp, 1980.

Matthews, J. B., Observations of surface and bottom currents in the Beaufort Sea near Prudhoe Bay, Alaska, J. Geophys. Res., 86(C7), 6653-6660, 1981.

Reimnitz, E. and K. F. Bruder, River discharge into an ice-covered ocean and related sediment dispersal, Beaufort Sea, Crest of Alaska, Geol. Sot. America Bull., 83, 861-866, 1972.

Reimnitz, E., Strudel scours - a new concern. Attachment E, 18 pp, In Barnes, Peter, Erk Reimnitz, Ralph Hunter; and Larry Phillips, :" Geological processes and hazards of the Beaufort and Chukchi Sea shelf and coastal regions, Annual Report, Research Unit 205, Outer continental Shelf Environmental Assessment Project, National Oceanic and Atmospheric Administration, Box 1808, Juneau, Alaska 99802.

Schell, D. M., Regeneration of nitrogenous nutrients in arctic Alaskan estuarine waters, p. 649-664, In Reed, J. C. and J. E. Sater (Eds) The coast and shelf of the Beaufort Sea, Arctic Institute of North America; Arlington, Virginia, 750 pp, 1974. -

U.S.G.S., Water Resources Data for Alaska, Water-Data Report AK-78-1, Water "Year 1978, U.S. Dept. Interior, Geological Survey, Anchorage, Alaska, p. 269-276, 1978.

U.S.G.S., Water Resources Data for Alaska, Water-Data Report AK-79-1, Water Year 1979, U.S. Dept. interior, Geological Survey, Anchorage, Alaska, p. 261 -266, ?979.

Walker, H. J., The Colville River and the Beaufort Sea: Some interactions, ., pp. 513-539, In Reed, J. C. and J. E. Sater (Eds) The coast and shelf of the Beaufort Sea, Arctic Institute of North America, Arlington, Virginia, 750 pp, 1974.

Figure Captions:

Figure 1. Bathymetry of Gwydyr Bay, eastern part of Simpson Lagoon' and location of study area.

Figure 2. Salinity (°/oo), temperature (°C) and current vectors (cm s⁻¹) recorded approximately 50 cm above sea floor in 5m-deep Egg Island Channel 15 May 1978 through 26 July 1978. Kuparuk River gauge records (m^3s^{-1}) from 10 km above the Gwydyr Bay delta.

Figure 3. River overflows onto landfast ice traced from a Landsat image taken at 1100 hrs local time on 8 June 1978.

Figure 4. Salinity (0/00), temperature (°C) and current vectors recorded approximately 2 m above the sea floor in 5m-deep Egg Island Channel 5 May through 28 July, 1979. Kuparuk River gauge records (~~M35-1~~ m^3s^{-1}) from 10 km upstream of the delta for the same period.

Figure 5. Progressive vector plots from records from instruments approximately 1 and 2 m above the sea floor in 5 m deep Egg Island Channel during peak flows of spring runoff 15 May through 4 June, 1979.

Figure 6. Advance of the spring floodwaters on coastal ice traced from Landsat images 14 through 31 May, 1979.

TABLE 1

Date, May 1979	Flooded Area	Estimated Discharge	Estimated Flood Volume
15	25 km^2	.026 km3	.025 km^3
23	65 km2	.086 km3	.065 km3
31	100 km^2	.190 km^3	.100 km3

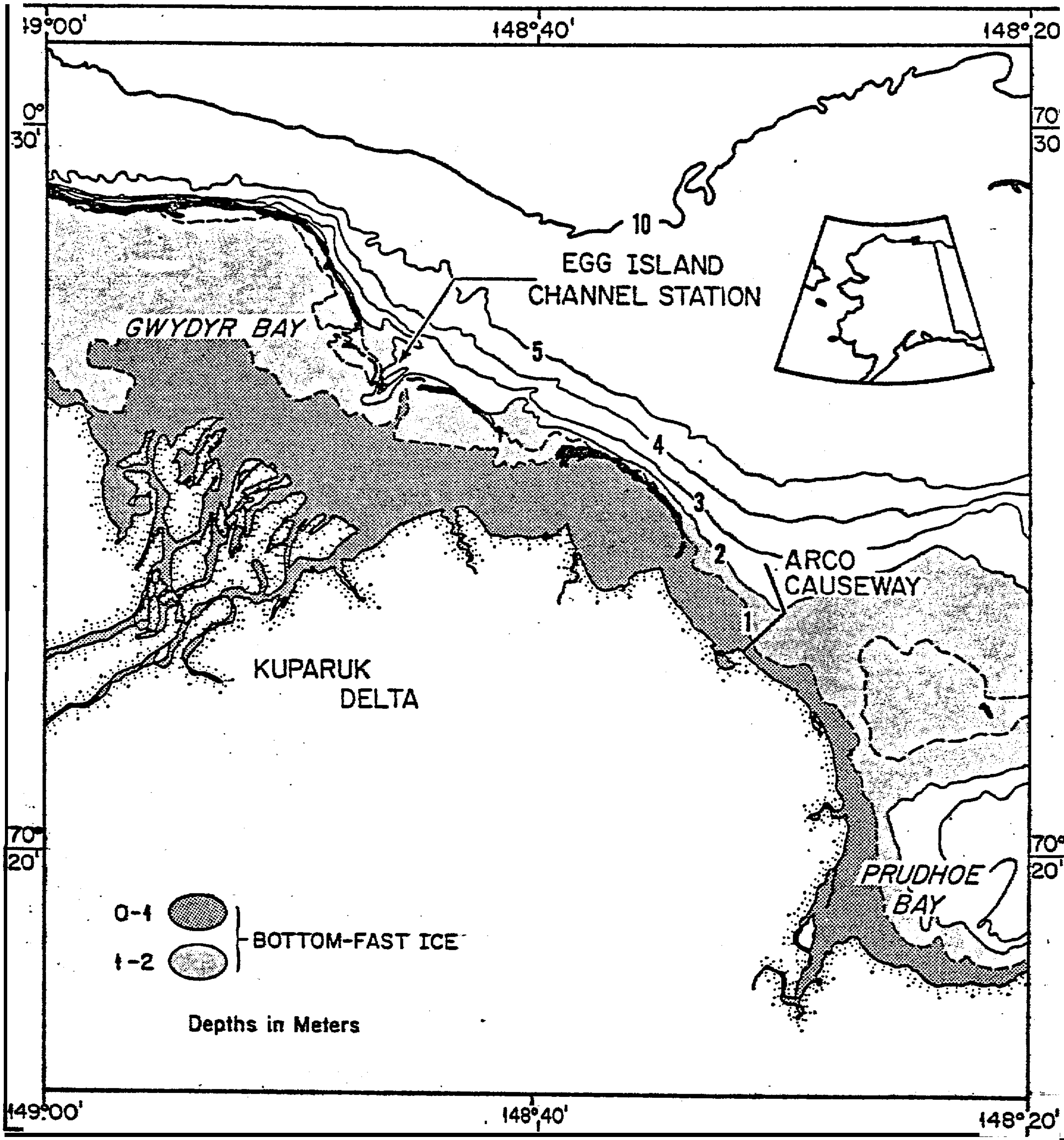
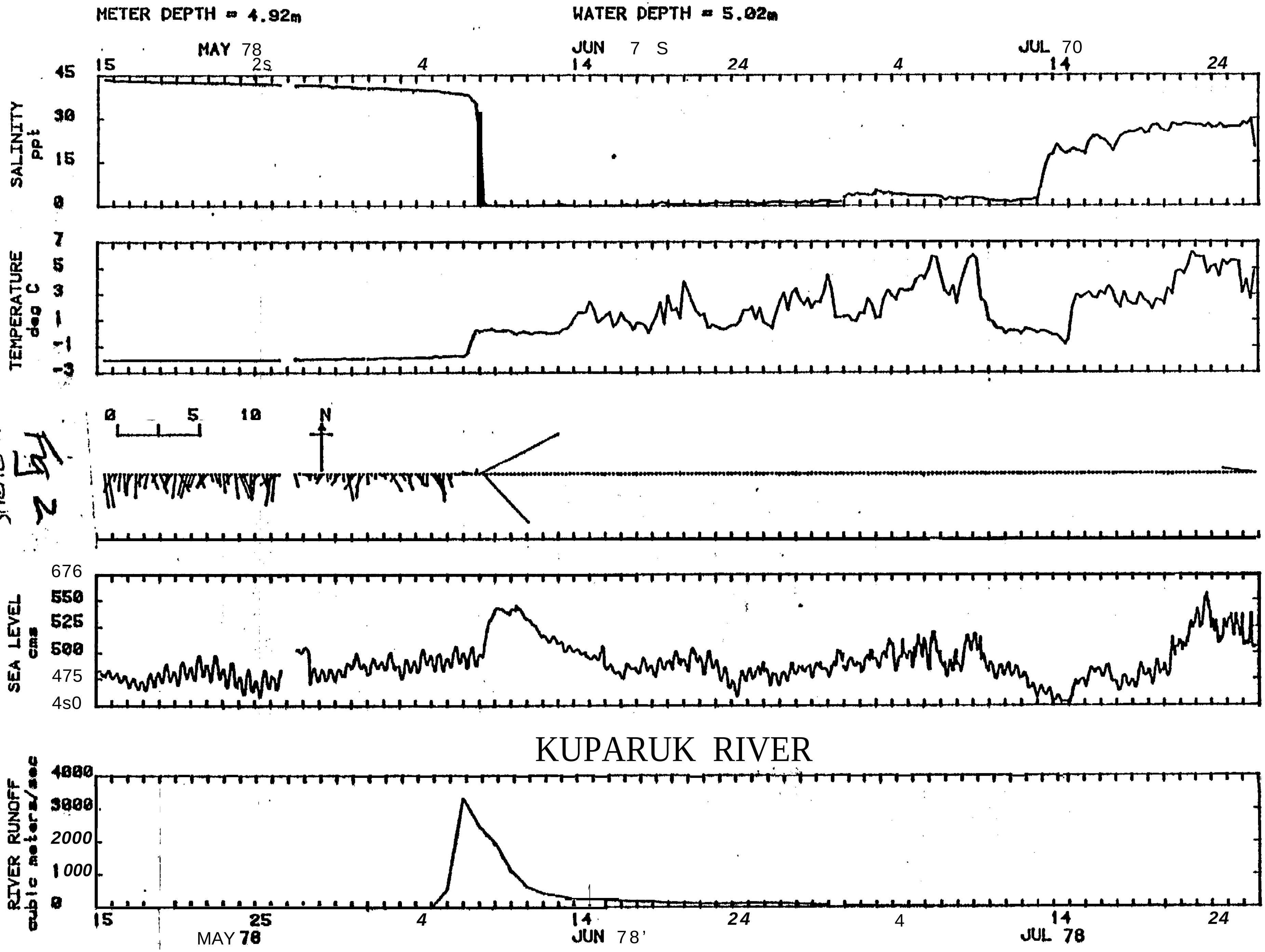


Figure 1

MATTHEWS + STRINGER.

EGG ISLAND CHANNEL



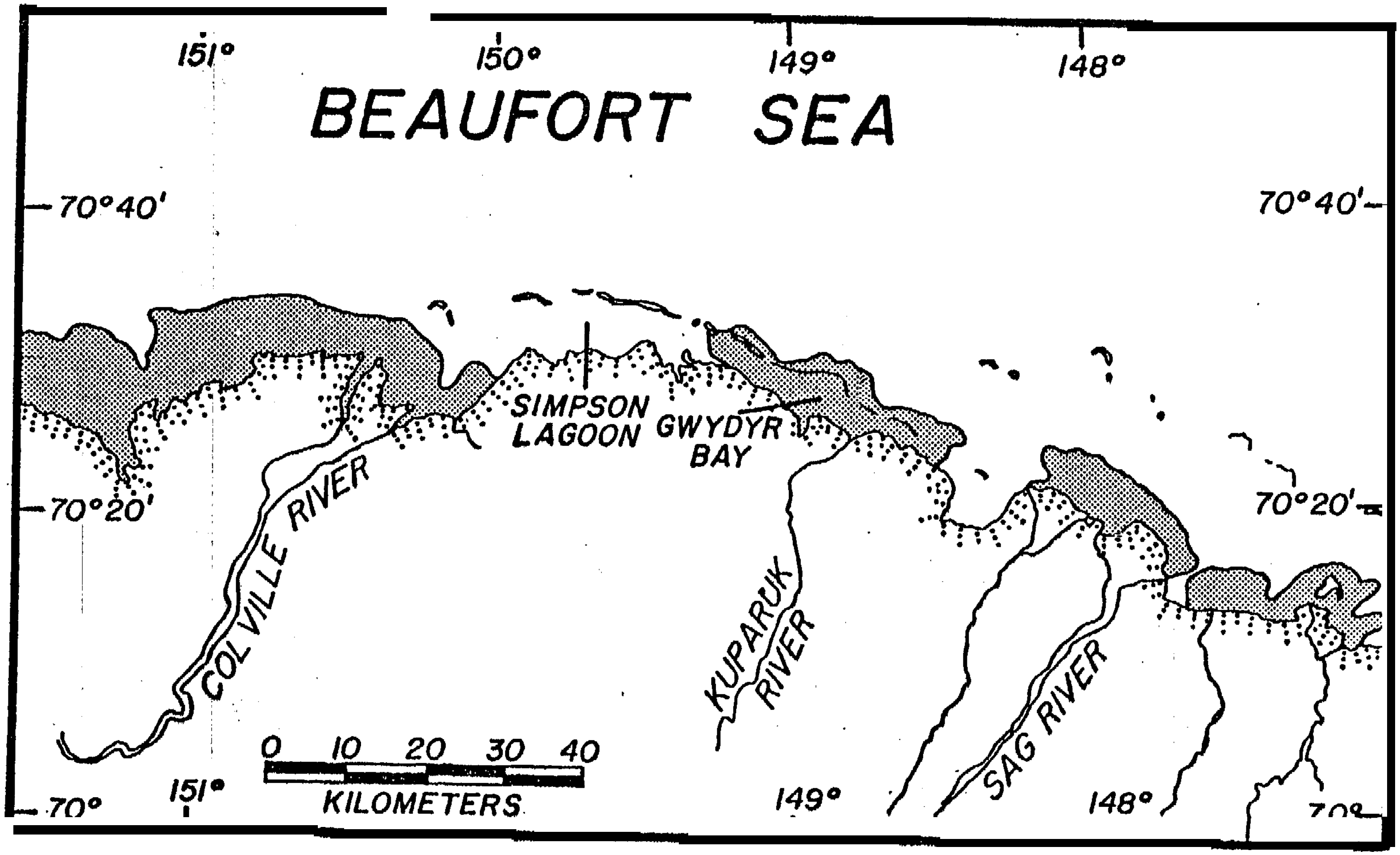
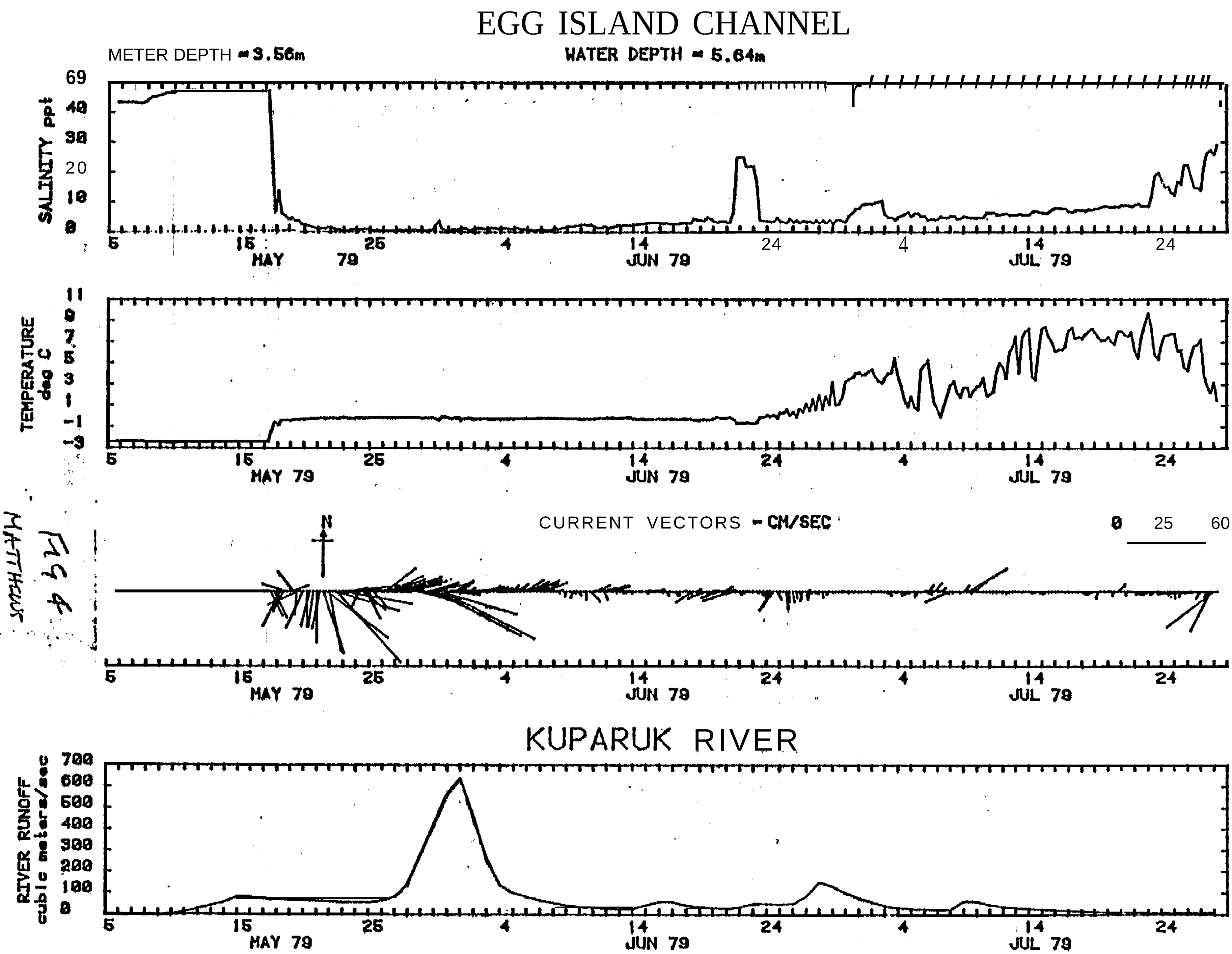
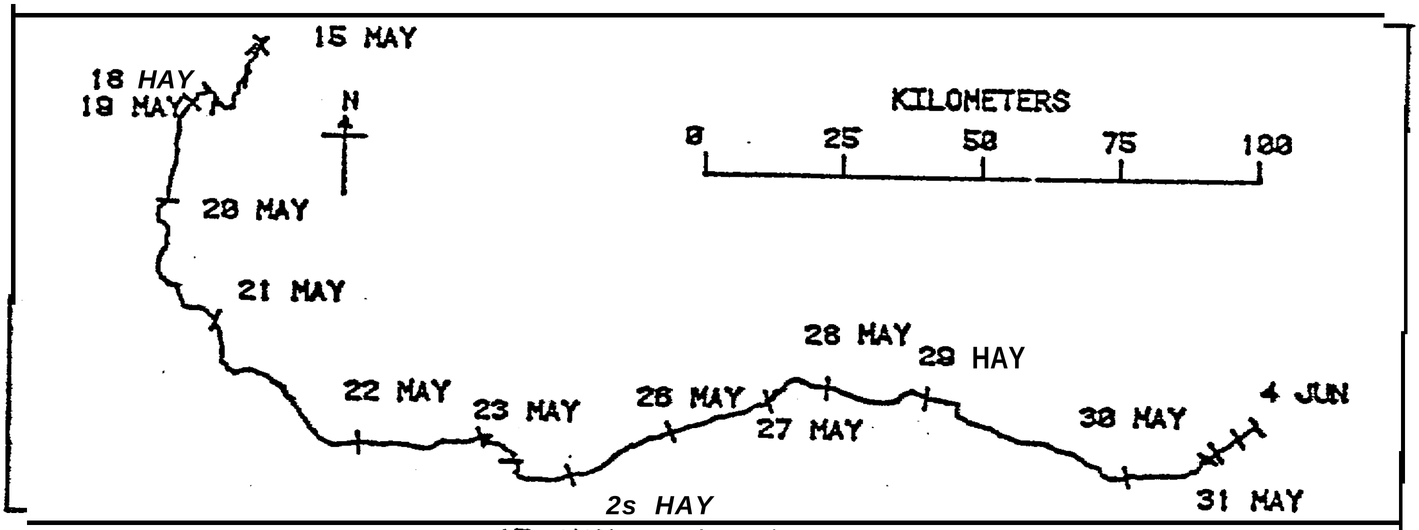


Fig 3
MATTHEWS + STRINGER


EGG ISLAND CHANNEL
METER DEPTH = 3.56m
WATER DEPTH = 5.64m
SALINITY ppt
69
40
30
20
10
0
5
15
25
4
14
24
4
14
24
MAY 79
JUN 79
JUL 79
TEMPERATURE deg C
11
9
7
5
3
1
-1
-3
CURRENT VECTORS - CM/SEC
N
0 25 60
KUPARUK RIVER
RIVER RUNOFF cubic meters/sec
700
600
500
400
300
200
100
0

EGG ISLAND CHANNEL

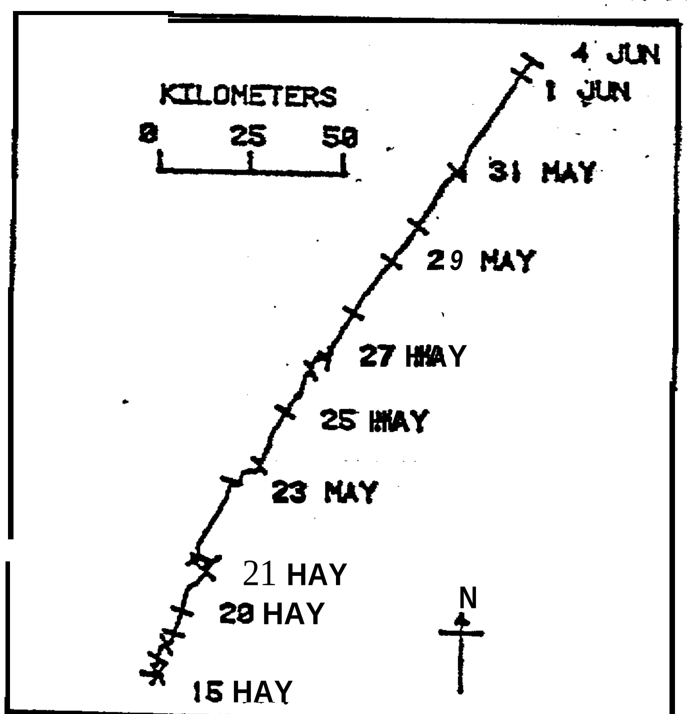
WATER DEPTH = 5.64m METER DEPTH = 3.56m



15 MAY 79 TO 4 JUN 79

PROGRESSIVE VECTOR PLOT OF CURRENT TRANSPORT

WATER DEPTH = 5.64m METER DEPTH = 4.62m



15 MAY 79 TO 4 JUN 79

PROGRESSIVE VECTOR PLOT OF CURRENT TRANSPORT

Fig. 5
MATTHEWS & STRINGER

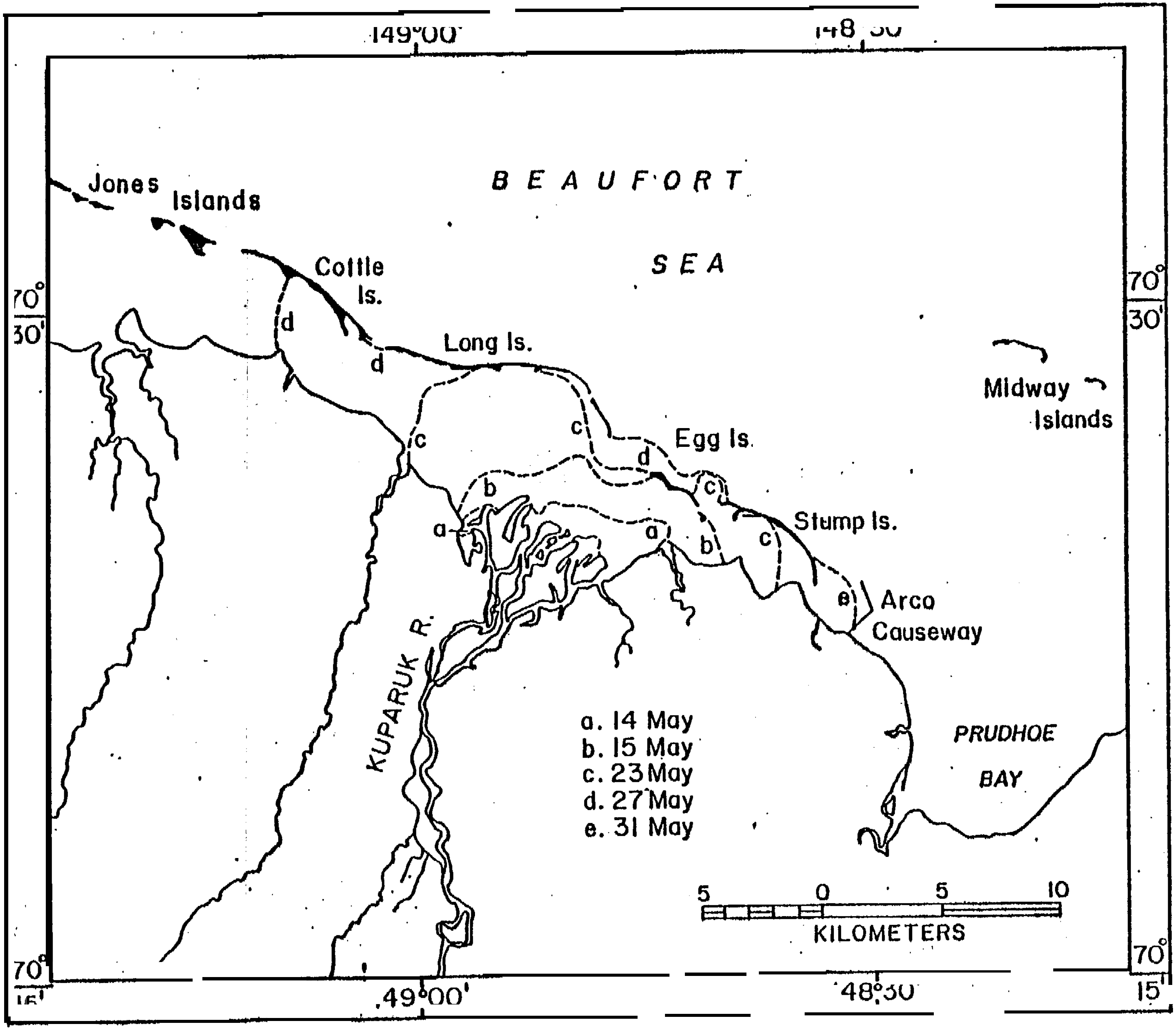


FIG 6
MATTHEWS
&
STRINGER