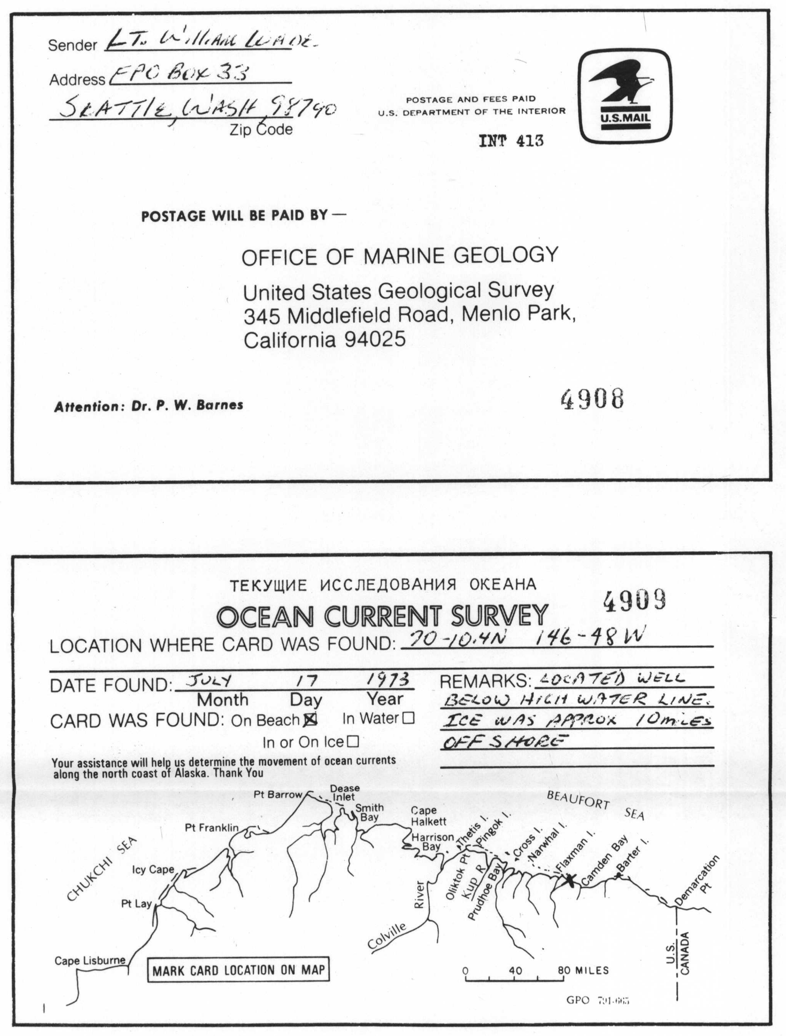

Figure 1. Reproduction of drift card used in this survey. Post Paid card was placed in 6-mil plastic envelope with a 2.5-cm washer and heat sealed.

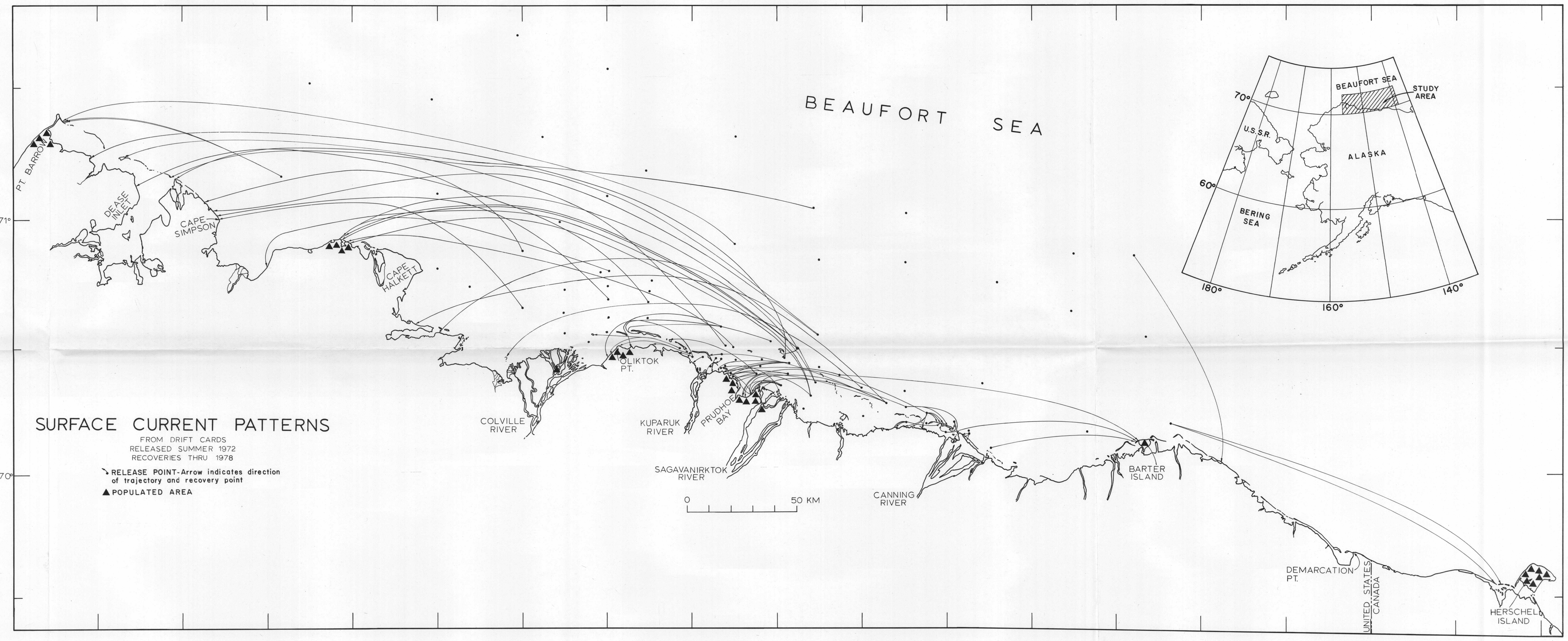

Figure 2. Idealized drift trajectories for surface drifters released in 1972, showing recovery locations through 1978. Population triangles are not representative of population density.

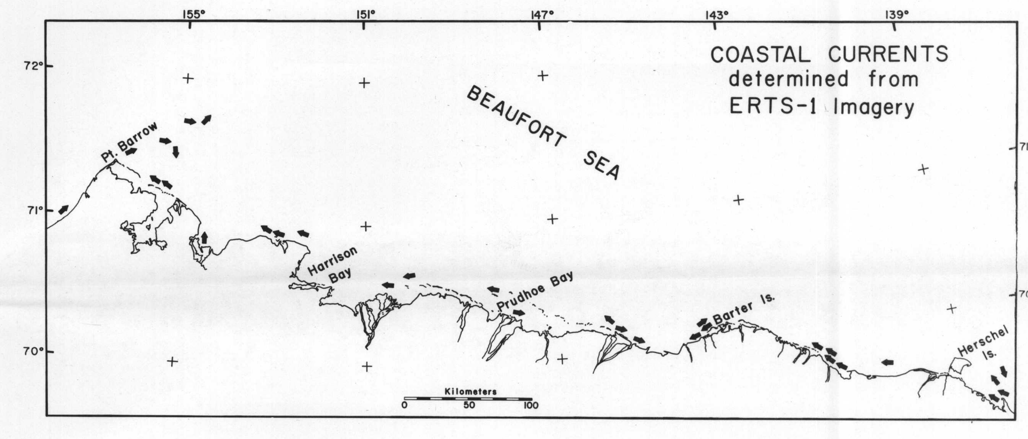

Figure 3. Coastal currents (arrows) as determined using displacement of turbid water plumes on LANDSAT imagery during summers of 1972 and 1973.

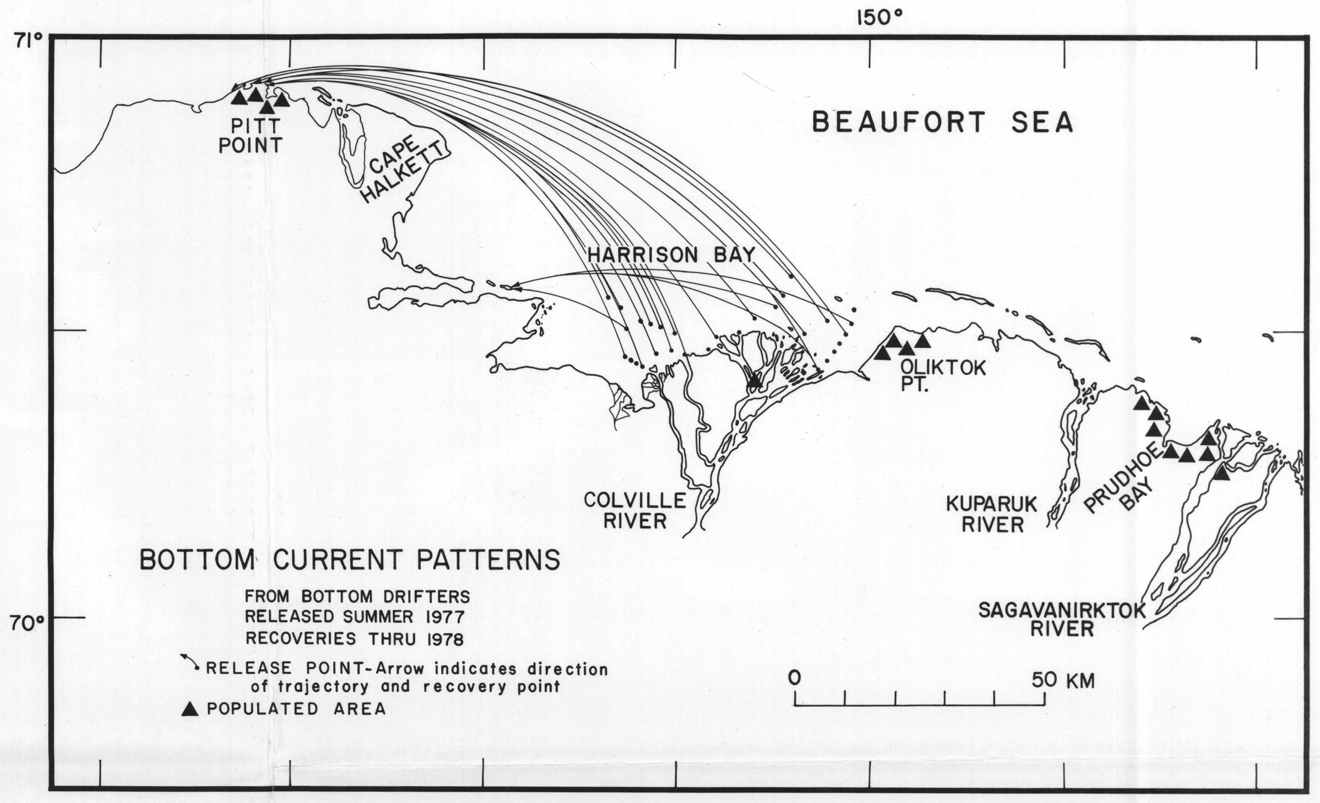

Figure 4. Idealized trajectories of bottom drifters released in July 1977. Population triangles are not representative of population density.

Inner shelf circulation pattern, Beaufort Sea

INTRODUCTION

One of the aims of geologic studies conducted in the Beaufort Sea since 1970 has been to define the pathways of sediment transport. Long term sediment transport vectors are significant in determining geologic processes. Sediment transport on the shelf is related to the movement of coastal waters which can be crudely observed using surface and bottom drifters returned by chance finders (Bumpus, 1965). As exploratory and developmental activities accelerate along the Beaufort coast of Alaska, a knowledge of drift trajectories of water, ice, sediment, and potential pollutants will be needed (Hufford and others, 1976). In addition, insight may be gained into circulation patterns on shelves influenced by ice. In this map report we define the probable paths of transport of surface and near-bottom waters during the summer for segments of the central part of the Beaufort Sea shelf.

Net flow patterns of surface and near-bottom waters of the Beaufort Sea inner shelf were studied during several open water seasons using drifters and satellite imagery. During the 1972 U.S. Coast Guard WEBSEC Studies of August and September (Hufford and others, 1974), 4,200 surface drift cards were released on the shelf between Barter Island and Cape Simpson. Initial results from this study have been reported by Barnes and Garlow (1975). Cloud-free LANDSAT 1 satellite imagery of the coastal zone area from Herschel Island to Barrow for 1972 and 1973 was analyzed for apparent displacement of coastal plumes. In June of 1977, 500 bottom drifters were released off the mouth of the Colville River. In view of the impending offshore development and sparsity of data on inshore currents, our data, albeit spatially and temporally meager, form a useful information set until more comprehensive studies become available.

The surface drifter used in this study is similar to that described by Emery (1960, p. 115); a 10- by 15- cm printed orange card encased in a 6 mil clear plastic envelope (fig. 1) containing a 2.5-cm steel washer sealed in the bottom as ballast. In order to reduce the direct effect of wind on the cards, the air trapped in the envelope was adjusted prior to sealing so that less than 2 cm of freeboard existed. During August 1972, drifters were released in groups of 25 and 50 from an inshore research vessel and an icebreaker. Because of problems met in achieving an adequate seal, an estimated 5 percent of the drifters sank when launched. Some drifters have been quite sturdy, surviving several arctic winters. More than 20 percent of the cards returned were found in 1975, when coastal visitation increased considerably as a major Federal research program was begun. Cards continued to be returned through 1978.

LANDSAT transparencies of the coastal waters used to discern sediment plumes and their displacement by longshore currents, were images taken on rare fog-free summer days, when coastal waters could be clearly seen. Because the turbid water is most clearly shown on MSS bands 4 and 5 (green and blue) (Wright and others, 1973; Carlson, 1974), these bands were used in our study. As the sediment plumes become elongate in the direction of flow, the direction of surface water flow can be easily determined.

Plastic sealed drifters (Lee and others, 1965) were used to measure the near-bottom drift of water in Harrison Bay--a yellow perforated saucer, 18 cm in diameter, mounted on a red plastic stem 55 cm long. Negative buoyancy for the drifter was assured by attaching a 5-gram brass collar to the lower end of the stem. Drifters were released from a low-flying aircraft during a single 2-hour flight in groups of 15 at each station. Range-range navigation information was obtained simultaneously to locate the release points within 100 m. Because the water depth in the area of release was less than 10 m, we assume that little lateral movement occurred during the vertical transit of the drifters to the bottom.

OBSERVATIONS

Surface and bottom drifter recovery

In view of the sparse population on the north slope of Alaska and the short season when beaches are not covered with ice and snow, the recovery rate is low relative to returns reported in studies made in central California by Conomos and others (1971). Recoveries have come predominately from the existing population centers of Barrow, Prudhoe Bay, Barter Island, and the DEW Line sites. The 1970 population of the North Slope Burough was 3,385 (Alaska Census), but even with the additional petroleum installation at Prudhoe Bay, the present population along the coast is probably no more than 6,000. A low rate of return is expected in this remote area. Most drifter returns were from releases in nearshore areas, a situation common to surveys of this type (Kolpack, 1971; Conomos and others, 1971). Release and recovery data are summarized in table 1.

The late summer (September) release of many of the surface drifters limited the time for transit to the beaches before freeze-up, when surface water motion ceases and the drifters can become incorporated into the coastal ice or the polar pack. Although cards have been found and returned in five consecutive summers following their release, there are no data to suggest that drifters were not already ashore before freezeup in 1972.

Bottom drifters were released during the initial stages of sea-ice breakup (July), giving them a full open-water season in which to drift. Returns have come only from the summer season in which they were released (1977). Relative to nearshore surface drifter returns (5.6 percent), a greater portion (8.4 percent) were returned in one season, suggesting that an early release of surface drifters might lead to a higher rate of return. Release and recovery data are given in table 1.

Direction of drift

Surface drifters moved predominately in a westerly direction with secondary directions onshore and easterly (fig. 2). Four times as many drifters moved to the west as to the east (see table 2).

The direction of surface drift as indicated by the displacement of sediment plumes in ice-free LANDSAT imagery (fig. 3) demonstrated the same basic water-movement patterns as can be seen in surface drifters. Although westerly movements dominate the overall pattern of sediment-plume displacement, well-defined easterly displacements were observed in the central and eastern portion of the shelf (see fig. 3). Sediment plume data is restricted to within 10-15 km of the coastline except in the vicinity of Point Barrow.

In Harrison Bay (fig.4) all bottom drifters moved in a westerly direction Some of the drifters moved essentially directly westward to the southwest part of Harrison Bay while another group moved northwestward around the tip of Cape Halkett and were recovered in the vicinity of the DEW Line Station at Pitt Point (fig. 4).

Rate of drift

Velocity data are sparse for surface drifter returns. Only nine cards were found before freeze-up in 1972, the year of release. The calculated rates of drift range from less than 1 cm/sec to almost 38 cm/sec. The lowest velocities are associated with two drifters that moved essentially southward (onshore). Drifters traveling to the west had the highest velocities, averaging 18 cm/sec. The one drifter that moved eastward showed an average velocity of 8 cm/sec. The tabulated velocities (table 3) are considered minimum values, as the cards may have been beached for some time before their discovery.

More than three fourths (78 percent) of the bottom drifters were found by one person 45 days after their release. The distance covered during this period ranged from 74 to 120 km. Corresponding minimum velocities were 2 and 3 cm/sec (table 3).

DISCUSSION

Surface current directions

Because the data are limited in both spatial and temporal resolution, only general considerations can be discussed. For example, surface drifters were released in 1972, only 1972 and 1973 imagery was examined. Bottom drifters were released in 1977. Further, oceanographic conditions are known to vary significantly. Hufford and others (1974) present data on ice regime, oceanographic parameters of temperature and salinity, and with nutrient distributions that suggest different shelf circulation patterns for 1971 and 1972.

Both the surface drifters and the sediment-plume displacements show a westward dominance of movement of shelf surface waters (figs. 2 and 3). During summer, currents on the Beaufort shelf are variable, although the winds are predominately from the east with wind drift of the polar pack to the west (U.S. Hydrographic Office, 1968, p. 13 and p. 100). Drifter data and the displacement of sediment plumes as seen on satellite imagery both indicate that east of Prudhoe Bay surface currents commonly move to the east,suggesting a divergence in surface flow off the Sagavanirktok River.

Oceanographic observations made the same year that surface drifters were released, 1972, also suggest a change in character east of Prudhoe Bay, where minimum surface-water salinity and temperature and maximum ice concentration and dissolved-oxygen concentration were observed (Hufford and others, 1974).

Surface wind data collected at the Prudhoe Bay Airport for 1972 and surface-drifter movement in the days following their release show no obvious correlation, assuming that the onshore airport wind data is reflecting offshore winds. The lack of correlation suggests that the drifters were not responding to short-term wind forces but that long-term processes were involved. A partial explanation for the observed current (wind?) divergence might be found in the work of Schwerdtfeger (1974), who noted that the mountain barrier effect of the Brooks Range causes dominant northeasterly geostrophic winds to become ageostrophic from the west at Barter Island. This phenomenon is well documented for the winter season but has not been studied in the summer season.

From our sparse data, we conclude that there is a recurring divergence in surface-drift patterns on the inner part of the central Beaufort shelf. Westerly currents are overwhelmingly dominant on the western part of the shelf, and eastward drift is common on the eastern part of the shelf.

Surface current velocities

In a more comprehensive and intensive study of surface currents in the Canadian Beaufort Sea, MacNeill and Garrett (1974) found surface currents generally moving at about 5 percent of the wind speed and less than 45° to the right of the wind direction. They reported surface drifter velocities similar (ranging from 2-70 cm/sec and averaging around 20 cm/sec) to those we observed (table 3). However, values reported in table 3 are not based on a sufficient number of recoveries or on recoveries associated with a single wind event to warrant comparison with wind data.

Bottom currents

The westward drift of bottom waters is not surprising considering the shallow water depth (2 - 10 m), the dominant westerly drift observed in surface drifter movement, and the westerly deflection of sediment plumes. The clustering of recoveries along a short stretch of coast to the west of Harrison Bay appears to be more than fortuitous, as much of the coast from the Colville River west to Barrow was visited during the summer following the release of drifters. The section of coast where the drifters clustered may represent a point where an eddy in the bottom water circulation out of Harrison Bay impinged on the coast during 1977.

The rates of bottom water drift that we observed in our data are of the same order as nontidal drift speeds noted in inner shelf bottom waters elsewhere (summarized in Conomos and others, 1971) and are approximately an order of magnitude less than the drift observed for surface waters (2 cm/sec vs 16 cm/sec, table 3).

CONCLUSIONS

In the inner shelf region of the Beaufort Sea west of the Sagavanirktok River both surface and bottom water movements are dominantly to the west during the summer. Sediments or entrained pollutants at the surface or at depth will move in a westerly direction at rates of 1 to 30 km per day (table 3).

To the east of the Sagavanirktok River, the net water-transport vectors on the inner shelf are more complex and commonly contain easterly components for the surface drift. The motion of bottom water in this area is unknown.

Table 1. Drifter release and recovery data

Date Released	Number Released	Number Recovered	Percent Recovered
	SURFACE DRIFTERS		
8 August - 11 Sept., 1972	2925 (released from ice breaker in waters deeper than 20 m)	13	0.4
21 August - 6 Sept., 1972	1275 (released from coastal vessel in water less than 20 m deep)	72	5.6
Totals	4200	85	2.0
	BOTTOM DRIFTERS		
30 June, 1977	489	41	8.4

Table 2. Summary of surface-drifter movements

Direction of movement	Number	Percent
East along coast	8	10
Onshore	45	52
West along coast	32	48

Table 3. Drifter velocity data for 1972 and 1977

Release Date	Recovery Date	Days adrift	Distance (km)	Rate (km/day)	Rate (cm/sec)	Direction	Recovery Location
			SURFACE DRIFTERS				
21 Aug. 1972	22 Aug.	1±	28	28±	32+	West	Lagoon
21 Aug.	27 Aug.	6	32	5	6	West	Lagoon
21 Aug.	27 Aug	6	44	7	9	West	Oliktok
23 Aug.	26 Aug.	3	31	11	12	West	Kuparuk River
23 Aug.	28 Aug.	5	15	3	1	South(onshore)	Prudhoe Bay
23 Aug.	9 Sept.	16	13	1	1	South (onshore)	Prudhoe Bay
29 Aug.	19 Sept.	21	135	6	8	East	Barter
3 Spet.	11 Sept.	8	198	25	29	West	Cape Simpson
6 Sept.	9 Sept.	3	98	33	38	West	Barrow
				Avg.	15		
			BOTTOM DRIFTERS				
-1977	-1977						
31 June	14 Aug.	45	74-120	2-3	2-3(32 drifters)	Northwest	Pitt Point
31 June	20 Aug.	51	56	1	1	West	Eskimo Islands
				Avg.	2		

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MAPS SHOWING INNER SHELF CIRCULATION PATTERNS, BEAUFORT SEA, ALASKA

By

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