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ACOUSTIC TRACKING OF WOODHEAD SEABED DRIFTERS

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16. Abstract

The Langley Research Center, in collaboration with NOAA Atlantic Oceanographic and Meteorological Laboratories, Miami, Florida, has conducted an investigation to determine the feasibility of tracking Woodhead seabed drifters that have been instrumented with miniature acoustic transmitters having a range in water in excess of 1.0 n.mi. A trial cruise at the entrance of Delaware Bay, with the R.V. Annandale as the sonar-tracking vessel, verified acoustic communications and positioning of the bottom drifters. A demonstration cruise with the R.V. Annandale was also performed in the New York Bight to attempt to collect information on bottom water movement near the sewage-sludge dump site. Results from the tracking mission in the New York Bight suggested that bottom water currents were negligible near the dump site during the time interval from November 7-12, 1975, and that shipboard sonar tracking of acoustic Woodhead seabed drifters could provide useful Lagrangian information on bottom water movement caused by tidal and other nonstorm effects.

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ACOUSTIC TRACKING OF WOODHEAD SEABED DRIFTERS

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SUMMARY

The Langley Research Center, in collaboration with the Atlantic Oceanographic and Meteorological Laboratories of the National Oceanic and Atmospheric Administration, Miami, Florida, has conducted a study of an underwater tracking system utilizing Woodhead seabed drifters instrumented with miniature acoustic transmitters. With the R.V. Annandale as the sonar-tracking vessel, a trial cruise at the entrance of Delaware Bay verified acoustic communications and positioning of the bottom drifters. Results from this cruise encouraged continued studies to be undertaken in the New York Bight to attempt to collect information on bottom water movement near the sewage-sludge dump site. Two groups of acoustic seabed drifters (six in each group) were deployed in the New York Bight and monitored by the R.V. Annandale from November 7-12, 1975. Although individual trajectories were not identified, position data were obtained which suggested that there were no appreciable bottom currents near the dump site during the 5-day mission. The first group of drifters moved toward Long Beach (8° true) at a very slow rate of 0.03 n.mi./day, and the second group moved toward Rockaway Beach (322° true) at about 0.09 n.mi./day. The results from the New York Bight investigation showed that shipboard sonar tracking of acoustic Woodhead seabed drifters provides a method for collecting short-term Lagrangian measurements associated with bottom water movement caused by tidal and other nonstorm effects. It is believed that these measurements would be useful for interpretation of end-point data that are usually obtained with uninstrumented Woodhead seabed drifters.

INTRODUCTION

The Woodhead seabed drifter is a simple and economical device which has been used extensively for inference of bottom water movement. Typical results obtained from deployment and recovery of these drifters are reported in the shelf circulation studies of references 1 and 2 and in the offshore environmental studies of reference 3. Although definite trends of bottom drift are derived from these works, nothing is known of the time variation of drift rates and directions during the interval between deployment and recovery. If short-term perturbations of bottom flows during this time interval are of interest, Lagrangian measurements could be collected with Woodhead seabed drifters instrumented with low-cost, expendable acoustic transmitters and monitored by shipboard sonar. Until recently, acoustic transmitters have been too large and too heavy for this application and have been limited to use on large neutrally buoyant drifters as reported in reference 4. With the development of an acoustic transmitter for fish-tracking applications by the Langley Research Center (ref. 5), a practical method became available for instrumentation of

Woodhead drifters that could be detected at ranges in excess of 1.0 n.mi. In order to determine the feasibility of this acoustic system for positioning seabed drifters, a field investigation was conducted in collaboration with the Atlantic Oceanographic and Meteorological Laboratories (AOML) of the National Oceanic and Atmospheric Administration (NOAA), Miami, Florida. Specific objectives were to verify acoustic communications, to develop sonar-tracking techniques, and to demonstrate the method with an attempt to collect information on bottom water movement in the New York Bight. This paper presents the results of this investigation, which included a trial cruise at the entrance of Delaware Bay and a tracking mission in the New York Bight during the period from November 7-12, 1975.

The research vessel used for sonar tracking during this investigation was the R.V. Annandale, operated by the Delaware Bay Marine Science Center, Lewes, Delaware. (See fig. 1.) Captain Gary W. VanTassel and the crew were proficient in ship operations and dedicated to the research objectives. Donald V. Hansen, AOML, gave continued support and encouragement to these efforts in the development of underwater tracking systems.

APPARATUS

Measurements were made in the U.S. Customary Units. They are presented herein in the International System of Units (SI) with the equivalent values given parenthetically in the U.S. Customary Units. All times are given in Eastern Standard Military Time.

Acoustic Woodhead Seabed Drifters

The acoustic transmitter ("pinger") used to instrument the Woodhead seabed drifters is shown in figure 2. As described by Lovelady and Ferguson in reference 5, the pinger transmits a 30- to 40-kHz pulse-modulated omnidirectional signal for a period of about 240 hr. The range of detection in water is in excess of 1.0 n.mi. The instrument is packaged in an anodized aluminum capsule which is 1.5 cm (0.59 in.) in diameter with a length of 3.5 cm (1.38 in.). Including its power supply, the pinger weighs less than 8 g (0.28 oz) in water.

Figure 3 presents a photograph of a cluster of seabed drifters with pingers attached to the bottom of the stem. Two groups of drifters were instrumented for deployment in the New York Bight. The first group (group A) was made up of the basic drifter with the stem weight replaced by the pinger in an effort to minimize movement off the bottom in the event that strong vertical flows were present. The drifters in this group weighed about 6.2 g (0.22 oz) in water. The second group (group B) was also made up with the stem weight replaced by the pinger but with closed-cell foam added under the cap so that the negative buoyancy of the original drifter with the stem weight was maintained at about 1.5 g (0.053 oz) in water. With drift rates expected at 2 to 4 n.mi./day, the drifters were instrumented with pinger frequencies closely matched between 36.0 and 37.1 kHz. This was done to avoid repetitive frequency tuning during continuous sonar-tracking operations. An inventory of the two groups of instrumented drifters is given in table I.

R.V. Annandale Tracking Instrumentation

The sonar system on the R.V. Annandale is a Burnett Model 538 consisting of visual and audio display units and a hoist transducer unit. The transducer portion is powered to extend about 0.31 m (1.0 ft) below the keel, and it can be manually directed to tilt to angles from 2° above horizontal to 90° below horizontal. Beam direction (6° acoustic beam width) can be controlled for continuous azimuth scan from 0° to 180° and centered anywhere within a 360° arc. A PPI (plan position indicator) display tube and audio speaker were operated in the passive mode to give readout of drifter bearings. Navigation of the R.V. Annandale was from loran C with grid lines originating from the master station at Cape Fear, North Carolina, and slave stations at Dana, Indiana, and Nantucket Island, Massachusetts.

FIELD INVESTIGATIONS

Delaware Bay Trial Cruise

A trial cruise with the R.V. Annandale was made at the entrance of Delaware Bay on October 29, 1975, to check out performance of the acoustic system and to determine if a group of pinger signals could be monitored and roughly positioned. During calm seas and light winds, two groups of instrumented drifters (three drifters in one group and two in the other) were tethered to small surface floats and deployed in about 24.4 m (80 ft) of water. A simulated search operation was conducted which showed that sonar could easily direct the ship to the drifter locations as marked by surface floats. Tracking data obtained during this exercise are shown in figure 4. Sonar bearings to the group of drifter signals were in good agreement with visual bearings on the surface floats. From the results of this trial cruise, it was concluded that acoustic communications were satisfactory and that the instrumented drifters could be positioned by sonar and loran C with reasonable accuracies. At the request of AOML, a tracking demonstration in the New York Bight was undertaken.

New York Bight Cruise

The experimental site selected for the New York Bight tracking mission is illustrated in figure 5 where deployment locations for both groups are shown along with bottom contours in the area of expected drifter movement. Six instrumented drifters of group A were deployed near the sewage-sludge dump site at latitude 40°24.98' N and longitude 73°44.78' W. This group was thrown overboard on November 7, 1975, at 1058. Water depth at this site was about 24.4 m (80 ft). The six drifters of group B were deployed about 2.9 n.mi. further north at latitude 40°27.85' N and longitude 73°45.13' W in about 27.4 m (90 ft) of water. Time of deployment of this group was November 8, 1975, at 1311. Daily drifter positions derived from acoustic tracking of each group through

November 12, 1975, are presented in figure 6. Deployment sites are also noted in these plots.

The drifters did not disperse with expected drift rates. The bottom positions of group A were monitored by underway search for about 6 hours after deployment and showed no discernible movement. Sonar watch at anchor was then maintained up to 1230 on November 8, 1975. During this interval of 25.5 hr of anchor watch, the group still remained positioned near the drop site. This lack of movement caused concern about bottom conditions that may have trapped the drifters. A diving mission was conducted in an attempt to locate and photograph the drifters. Although the drifters were not located, the divers reported that the bottom consisted of a smooth, thin layer of silt which would not trap the drifters. Also, after disturbance of the silt, the particles resettled vertically to the bottom; this resettlement indicated that bottom currents were negligible at this time. Based on these results, original plans for continuous tracking were changed to once-a-day position checks as long as slow drift rates were maintained. Position data are not given in figure 6 for November 9 or 10 because the change in locations from November 8 to November 9 was small and no data were obtained on November 10 because of adverse weather conditions. (See table II.) No attempt was made to identify daily changes in locations of individual drifters throughout the rest of the mission because all signals were nearly the same frequencies. The measured locations of group A drifters on November 7 and 8 are shown enclosed by boundaries in figure 6. Since it was difficult to identify individual drifters that stayed so close together after deployment, the boundaries represent areas within which all drifters were believed to be positioned. The shape and extent of these boundaries were based upon drifter measurements with all tracking errors included.

Tracking methods and accuracy.- Two methods were used to monitor drifter positions in the New York Bight. When the drifters were close together after deployment, a random search was made in an attempt to position the ship directly over each drifter signal. After target acquisition, the ship's course was changed to look at the signal "head on," and the transducer was gradually tilted until directly over the drifter with the transducer tilted at 90°. This random search method was used to obtain drifter position data from deployment to November 11, 1975, and is illustrated in figure 7(a).

As the drifters began to separate, a perimeter search pattern was adopted to reduce the number of changes in the ship's course as illustrated in figure 7(b). Drifter position data for November 11 and 12, 1975, were obtained with this method. After target acquisition, azimuth bearing to the drifter signal was continuously monitored with no change in course. When the visual and audio display showed that the drifter was passed on the port or starboard beam, the position and heading of the ship were recorded. During this search, the transducer tilt angle was held constant at small angles to insure reception of drifter signals. With two or more bearings at 90° from the ship's heading, the position of the drifters was established from the graphical intersections of these bearings. Since the drifters were moving at very slow rates, the errors introduced by the time difference between bearings were assumed to be negligible. This method of locating drifter positions, however, resulted in errors as illustrated by bands around each data point in figure 8. All drifter positions and associated maximum errors are presented in tables III and IV.

The error bands on drifter positions, derived from perimeter search for the data of November 11-12, 1975, were estimated from the following assumed error sources:

Position errors:	
Loran C ship position	0.03 n.mi.
Charting errors	0.01 n.mi.
Readout errors	0.002 n.mi.
Bearing errors:	
Sonar acoustic beam width	$\pm 1.5^{\circ}$
Ship's heading errors	$\pm 1.5^{\circ}$

With a 6° acoustic beam width in these water depths, the only significant position errors associated with the random-search method were assumed to be the loran C positioning and readout error and charting errors. As listed, these error sources totaled 0.042 n.mi. Drifter position errors obtained from perimeter search varied with ship's position and averaged about 0.13 n.mi. for all data points. It should be noted that these are the maximum position errors possible based upon the error sources that were assumed.

Summary of New York Bight data.- Figures 9 and 10 present a summary of cluster drift from deployment to the end of the mission on November 12, 1975. Boundaries are shown which contained all drifter positions, including the extremities of the error bands on each measurement. Figures 9 and 10 also show the change in position of the center of mass for each cluster location. The cluster center of mass was computed from measurements of drifter positions and did not include possible tracking errors. The cluster center of mass closely approximated the centroid of cluster boundaries most of the time. The overall change in center of mass from group A drifters was in a northerly direction at about 8° true at a very slow rate of approximately 0.03 n.mi./day. The overall change of group B drifters with less negative buoyancy was at a little faster rate of about 0.09 n.mi./day. Drift direction of this cluster was further west at approximately 332° true. Maximum winds and sea states observed during the tracking mission are listed in table II.

The scale of these drifter cluster movements in relationship to the New York Bight area is illustrated in figure 11. Group A cluster appeared to be moving toward Long Beach, and group B cluster appeared to be heading a little farther west toward Rockaway Beach. Oceanographic interpretation of these data was not attempted.

CONCLUDING REMARKS

General results of an investigation of an underwater tracking system showed that shipboard sonar tracking of acoustic Woodhead seabed drifters is practicable for collecting short-term, Lagrangian measurements for inference of bottom water movement caused by tidal and other nonstorm effects. Although correlation between drifter movement and bottom water movement was not known, the New York Bight investigation suggested that bottom water currents were not appreciable near the sludge-dump site during the 5-day mission in November 1975. It is believed that these types of measurements would be used in interpretation of end-point data that are usually obtained with uninstrumented Woodhead seabed drifters. The concept of combining low-cost, expendable acoustic transmitters with the standard Woodhead seabed drifter seems to be attractive enough to warrant further work to improve shipboard tracking accuracies and to evaluate the possible use of fixed hydrophone arrays for tracking in critical areas independent of weather conditions. Calibration studies are also needed to correlate drifter translation to bottom water movement and to establish the significance of bottom drifter movement to sediment transports.

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January 12, 1977

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TABLE I.- INVENTORY OF ACOUSTIC SEABED DRIFTERS

Group identification	Drifter card number	Pinger number	Pinger frequency
A-1	10201	69	36.7
A-2	10217	66	37.1
A-3	4053	32	36.3
A-4	4054	55	36.4
A-5	10218	53	36.2
A-6	10231	54	36.0
B-1	10215	63	36.3
B-2	10207	80	36.3
B-3	10208	71	36.4
B-4	10206	38	36.8
B-5	10200	47	36.4
B-6	10221	60	36.2

TABLE II.- WINDS AND SEA STATES

Date	Time	Wind speed, knots	Wind direction, deg true	Maximum wind speed, knots	Direction of maximum wind, deg true	Maximum swells
11/7/75	1058	8	185			
	1200	13	185			
	1312	13	195			
	1400	15	195			
	1502	19	175			
	1552	16	175			
	1615	21	190	21	190	Very rough 2.4 to 3.6 m (8 to 12 ft) waves
	1849	13	190			
	2100	11	195			
	2300	14	185			
11/8/75	0000	13	190			
	0100	13	190			
	0200	14	190			
	0300	19	190			
	0400	19	190			
	0500	18	190			
	0600	19	190	19	190	Rough 1.5 to 2.4 m (5 to 8 ft) waves
	0700	13	193			
	0800	10	193			
	1200	13	190			
	1400	9	185			
	1500	12	185			
	1700	8	190			
11/9/75	1155	10	175			
	1316	12	175	12	175	Rough 1.5 to 2.4 m (5 to 8 ft) waves
11/10/75	Zero visibility (ship moored)					
11/11/75	1400			8	190	Moderate 0.9 to 1.5 m (3 to 5 ft) waves
11/12/75	1612			25	120	Very rough 2.4 to 3.6 m (8 to 12 ft) waves
11/13/75	1216			20	030	Rough 1.5 to 2.4 m (5 to 8 ft) waves

TABLE III.- SEABED DRIFTER DATA FOR GROUP A

Date	Time	Ship's heading, deg true	Ship's position SSO-Y (a)	Ship's position SSO-Z (a)	Sonar mark, bearing (b)	Drifter position SSO-Y (a)	Drifter position SSO-Z (a)	Drifter position Latitude	Drifter position Longitude	Maximum error, n.mi.
From random search										
11/7/75	1058		[c]50991.6	[c]69813.9	[c]Deployment			[c]40°24.98' N	[c]73°44.78' W	
	1434				Over	50991.3	69814.0	40°24.96' N	73°44.79' W	0.045
	↓				↓	50991.4	69814.2	40°24.92' N	73°44.79' W	↓
						50991.3	69813.8	40°24.98' N	73°44.82' W	
						50990.9	69814.4	40°24.93' N	73°44.68' W	
						50991.7	69814.0	40°24.94' N	73°44.85' W	
	1643					50991.6	69813.9	40°24.96' N	73°44.83' W	
From perimeter search										
11/11/75	1139	131	50990.9	69812.6	(1) Port					
	1140	↓	50990.7	69813.4	(1) Port	50989.5	69811.9	40°25.29' N	73°44.87' W	0.045
	1142		50990.5	69814.5	(1) Starboard	50988.2	69812.2	40°25.30' N	73°44.70' W	.045
	1308	271	50988.2	69812.2	(1) Port	50990.0	69813.3	40°25.07' N	73°44.70' W	.100
					(1) Over					
	1310	271	50989.2	69811.9	(1) Port	50991.3	69814.7	40°24.88' N	73°44.72' W	.130
					(1) Over					
	1316	35	50990.3	69816.3	(1) Port	50992.9	69813.7	40°24.94' N	73°44.98' W	.130
	1319	↓	50988.7	69815.7	(1) Port	50990.2	69812.6	40°25.19' N	73°44.86' W	.130
	1322		50986.8	69815.3	(1) Port					
	1334	310	50984.0	69811.4	(2) Port					
	1345	225	50988.1	69809.1	(1) Port					
	1347	↓	50990.2	69809.2	(1) Port					
	1348		50990.8	69809.3	(2) Port					
	1351		50993.8	69809.3	(1) Port					
	1359	132	50998.0	69813.2	(1) Port					
	1401	↓	50992.9	69813.8	(2) Port					
	1403		50997.6	69814.6	(2) Port					
	1405		50997.2	69815.6	(1) Port					
11/12/75	1245	253	50990.0	69813.2	(1) Port					
	1250	253	50991.7	69813.0	(2) Port					
	1325	180	50984.4	69812.8	(2) Starboard	50988.2	69811.7	40°25.37' N	73°44.78' W	0.270
	1330	180	50987.6	69815.2	(1) Starboard	50987.3	69811.9	40°25.38' N	73°44.64' W	.045
	1338	275	50991.6	69815.1	(1) Starboard	50990.5	69813.9	40°25.01' N	73°44.72' W	.130
	1340	275	50993.0	69814.5	(2) Starboard	50991.0	69814.7	40°24.91' N	73°44.65' W	.140
	1403	148	50987.4	69811.6	(1) Port	50991.8	69813.6	40°25.03' N	73°44.82' W	.100
		↓			(1) Starboard					
	1404		50987.3	69811.9	(1) Over	50992.4	69814.0	40°24.91' N	73°44.90' W	.120
	1408		50987.7	69813.3	(2) Starboard					
	1411		50988.2	69814.7	(1) Starboard					

[a]Loran C grid.
[b]Number in parentheses indicates number of signals.
[c]Cluster of six drifters.

TABLE IV.- SEABED DRIFTER DATA FOR GROUP B

Date	Time	Ship's heading, deg true	Ship's position SSO-Y (a)	Ship's position SSO-Z (a)	Sonar mark, bearing (b)	Drifter position SSO-Y (a)	Drifter position SSO-Z (a)	Drifter position Latitude	Drifter position Longitude	Maximum error, n.mi.
From random search										
11/8/75	1311		[c]50972.4	[c]69796.8	Deployment			[c]40°27.85' N	[c]73°45.13' W	
	1320				Over	50971.6	69796.5	40°27.89' N	73°45.19' W	0.045
	↓				↓	50970.9	69797.3	40°27.86' N	73°44.90' W	↓
						50971.6	69796.7	40°27.91' N	73°45.07' W	
						50971.5	69797.7	40°27.79' N	73°44.93' W	
						50970.9	69797.9	40°27.78' N	73°44.82' W	
	1430					50971.8	69797.1	40°27.85' N	73°45.02' W	
11/9/75	1155				Over	50971.3	69797.6	40°27.82' N	73°44.94' W	0.045
	↓				↓	50970.4	69796.4	40°27.98' N	73°44.97' W	↓
						50970.4	69796.3	40°27.99' N	73°44.98' W	
						50971.1	69796.4	40°27.95' N	73°45.04' W	
						50971.3	69796.5	40°27.93' N	73°45.07' W	
	1246					50971.3	69796.7	40°27.90' N	73°45.04' W	
11/11/75	1415				Over	50969.9	69795.7	40°28.09' N	73°45.00' W	0.045
	↓				↓	50970.8	69794.5	40°28.19' N	73°45.25' W	↓
						50971.3	69794.1	40°28.21' N	73°45.37' W	
						50970.4	69795.8	40°28.00' N	73°45.04' W	
						50972.0	69795.5	40°28.03' N	73°45.24' W	
	1534					50971.7	69795.2	40°28.08' N	73°45.26' W	
From perimeter search										
11/12/75	1450	322	50969.5	69795.1	(1) Port					
	1454	↓	50969.3	69793.7	(2) Port					
	1510		50971.9	69795.0	(3) Over	50969.2	69795.6	40°28.13' N	73°44.96' W	0.120
	1545	170	50973.0	69793.1	(1) Port	50970.0	69795.0	40°28.18' N	73°45.10' W	.045
	1546	↓	50973.5	69793.5	(1) Port	50971.0	69794.9	40°28.13' N	73°45.21' W	.140
	1548		50974.4	69794.1	(2) Port	50971.7	69793.9	40°28.22' N	73°45.42' W	.220
	1600	100	50974.1	69796.6	(1) Port	50970.2	69793.8	40°28.30' N	73°45.31' W	.180
	1601	↓	50973.6	69796.9	(2) Port	50971.2	69795.4	40°28.06' N	73°45.19' W	.190
	1603		50972.3	69797.5	(1) Port					
	1605	12	50968.1	69796.0	(1) Port					
	1619	217	50969.8	69794.5	(1) Port					

[a]Loran C grid.
[b]Number in parentheses indicates number of signals.
[c]Cluster of six drifters.

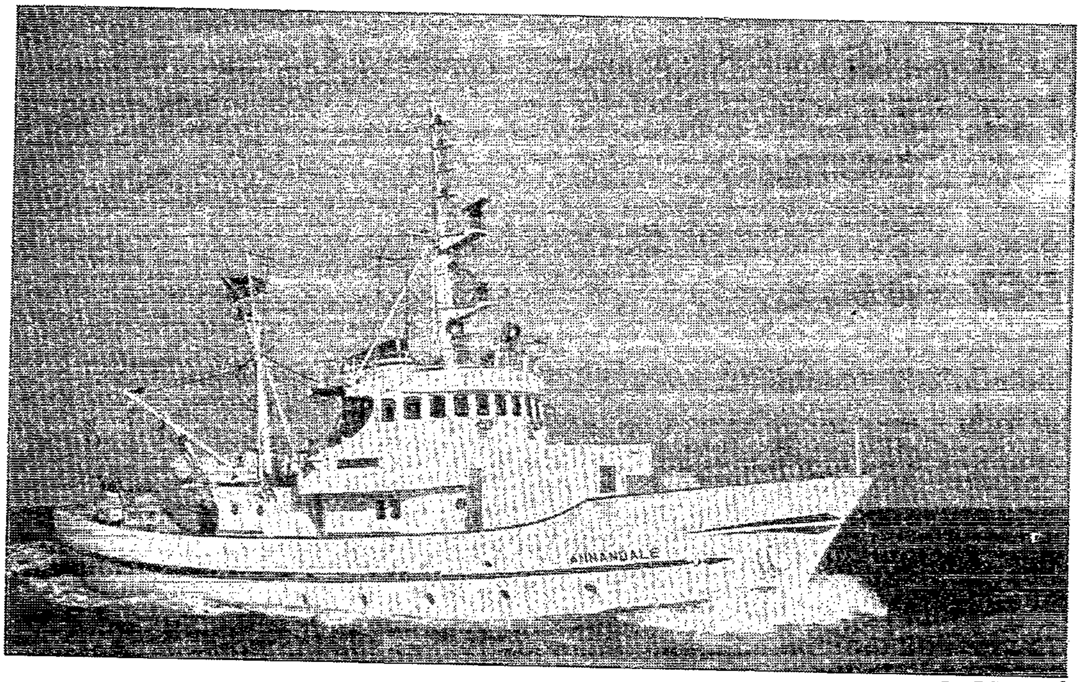

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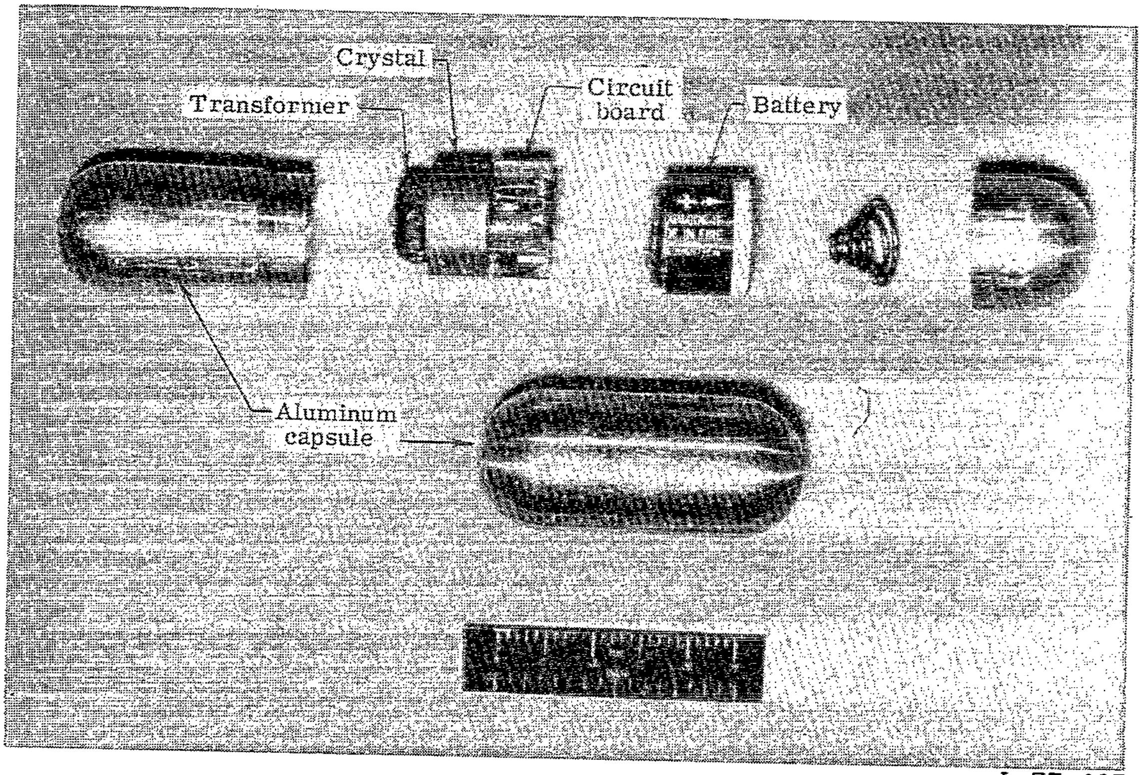
Figure 1.- R.V. Annandale.



L-77-107

Figure 2.- Acoustic transmitter.

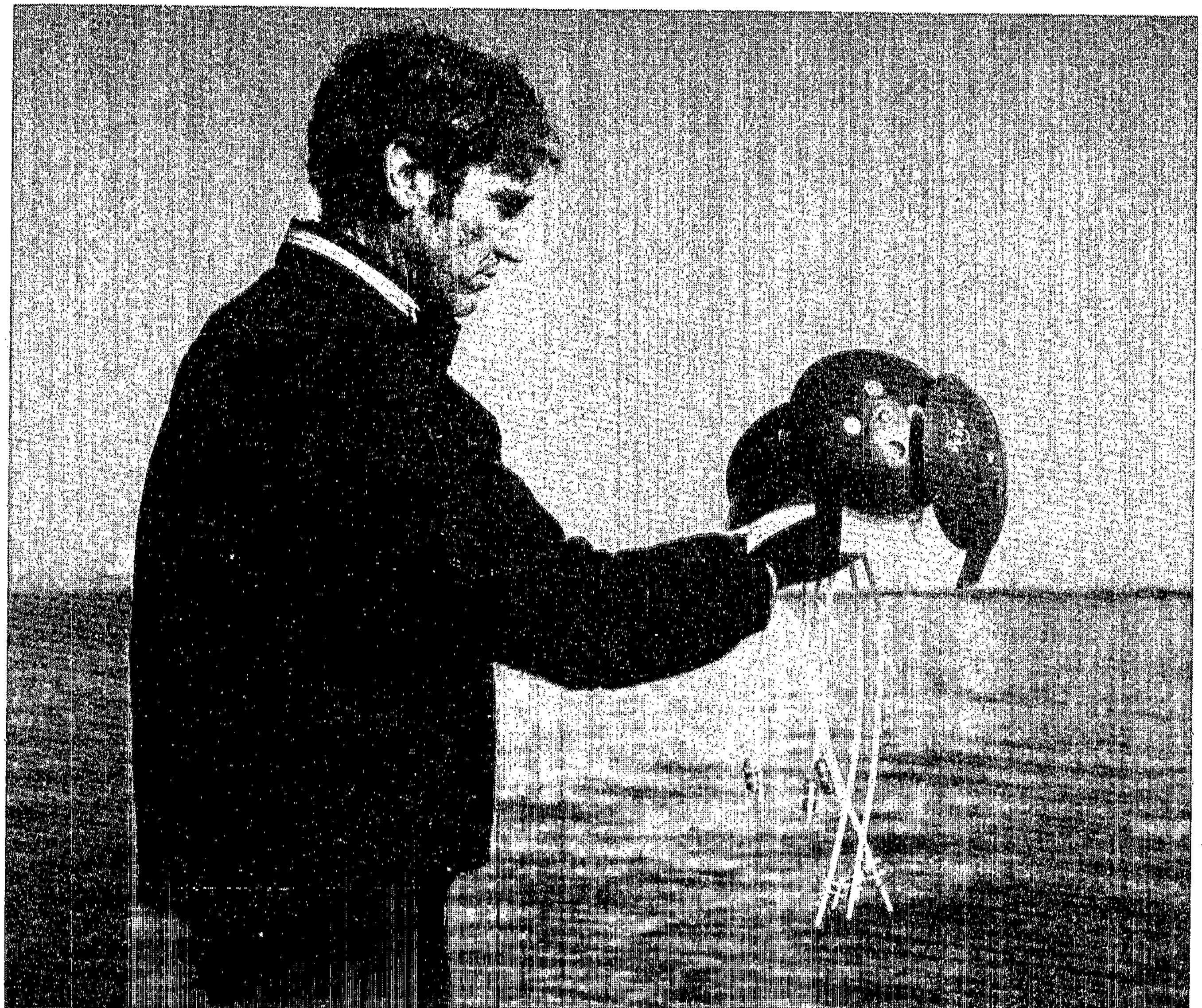


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Figure 3.- Acoustic seabed drifters.

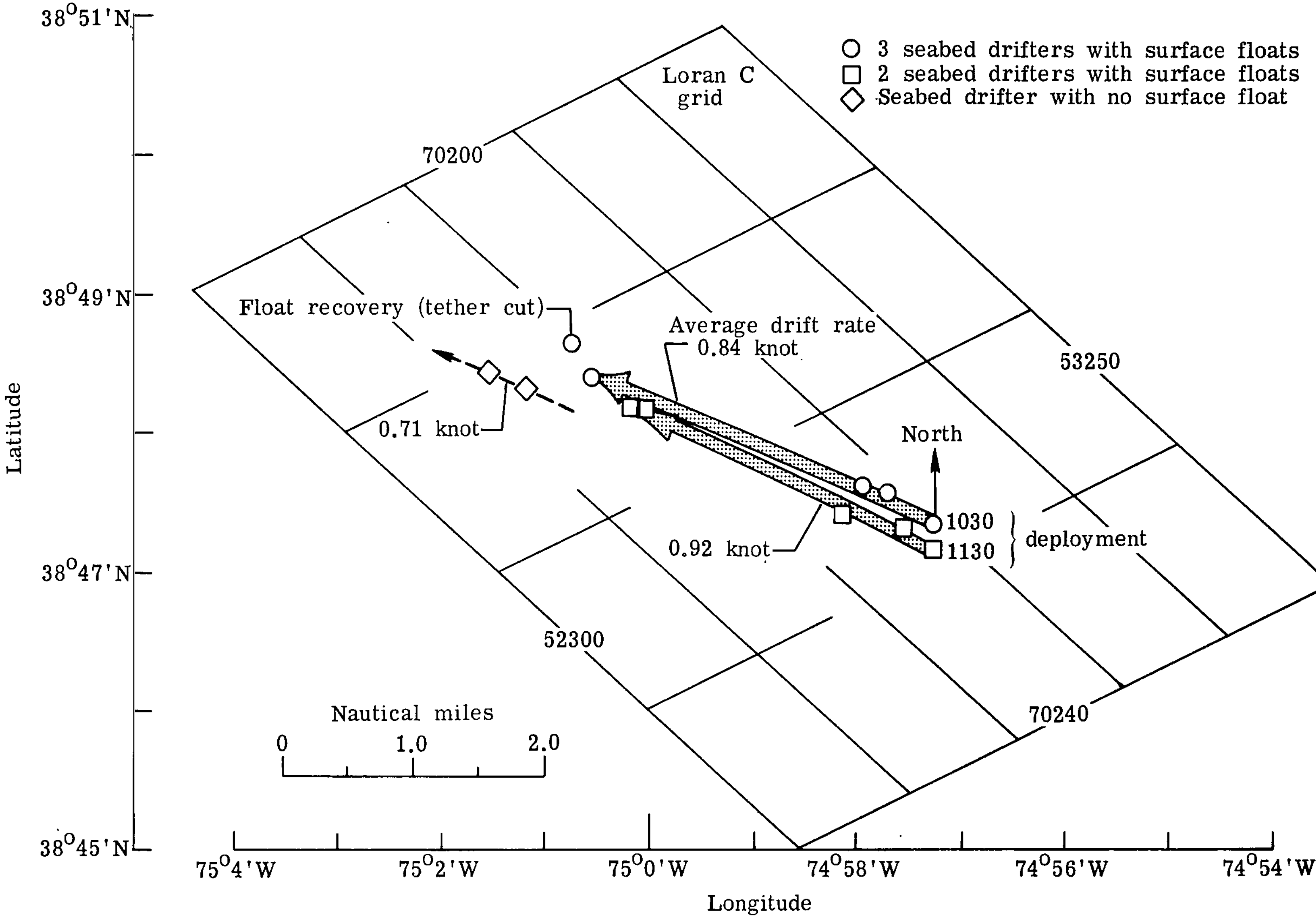


Figure 4.- Results of acoustic tracking trial cruise at entrance of Delaware Bay on October 29, 1975.

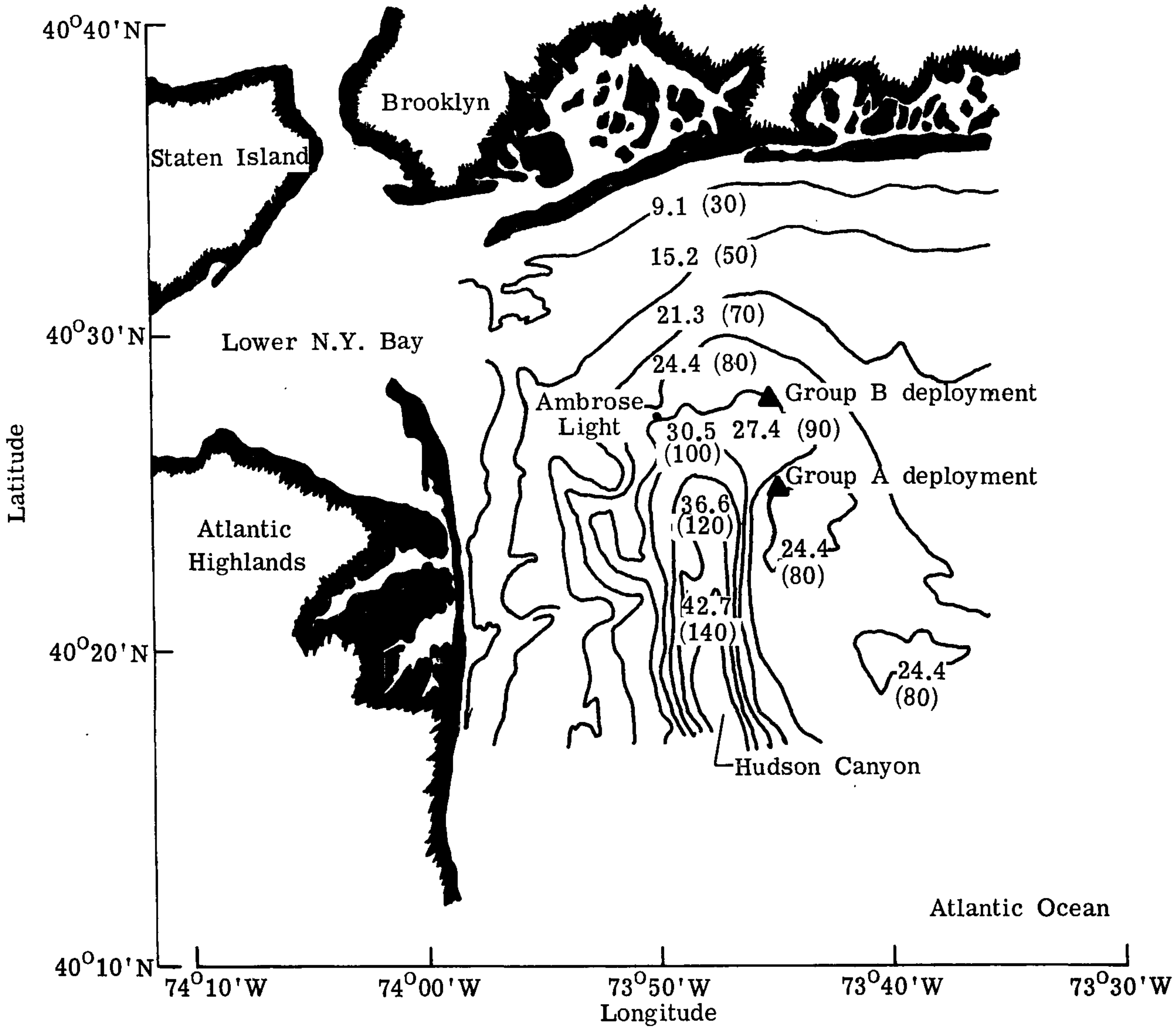


Figure 5.- New York Bight experimental site showing bottom contours in m (ft).

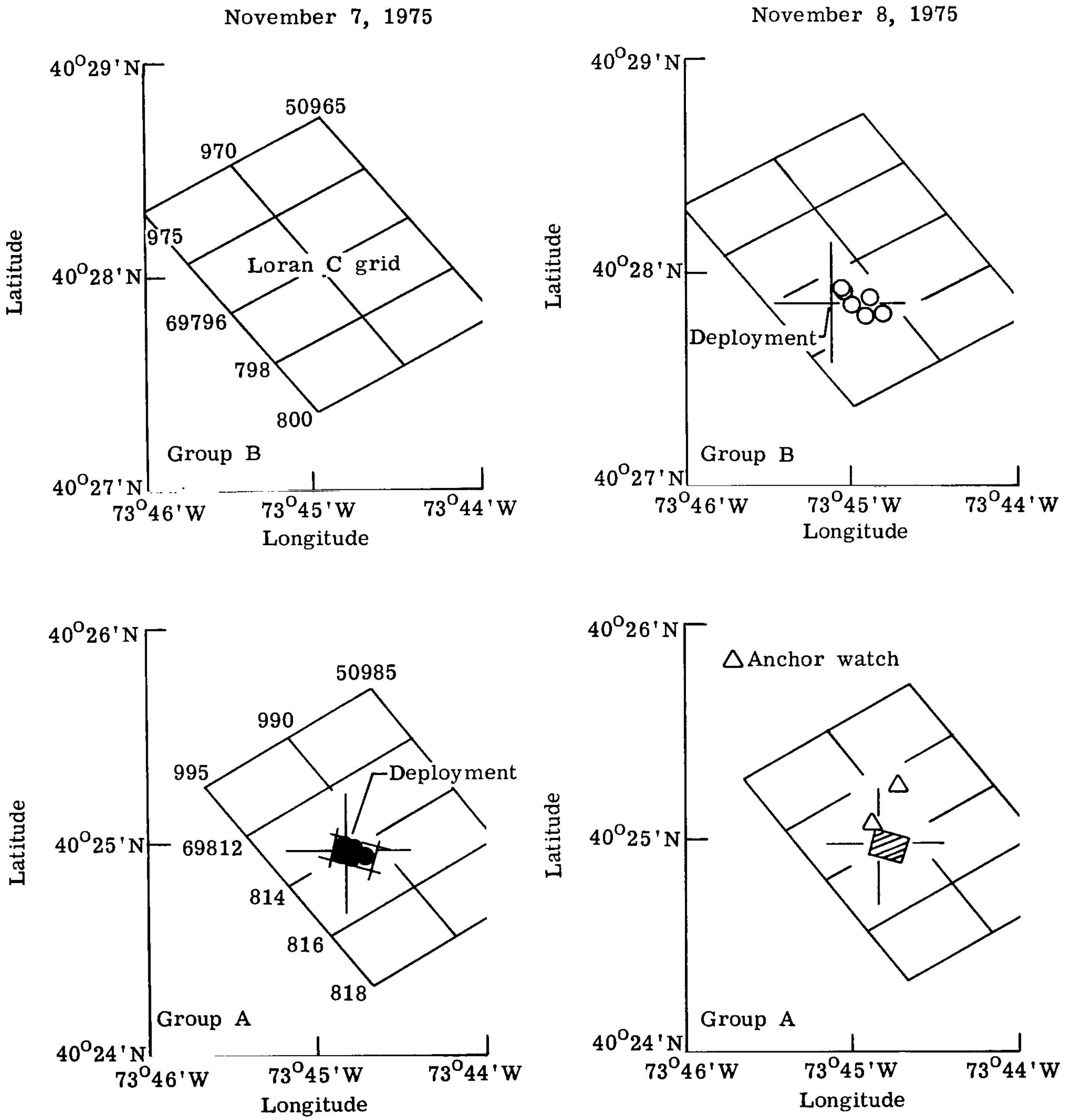


Figure 6.- Acoustic drifter positions in New York Bight.

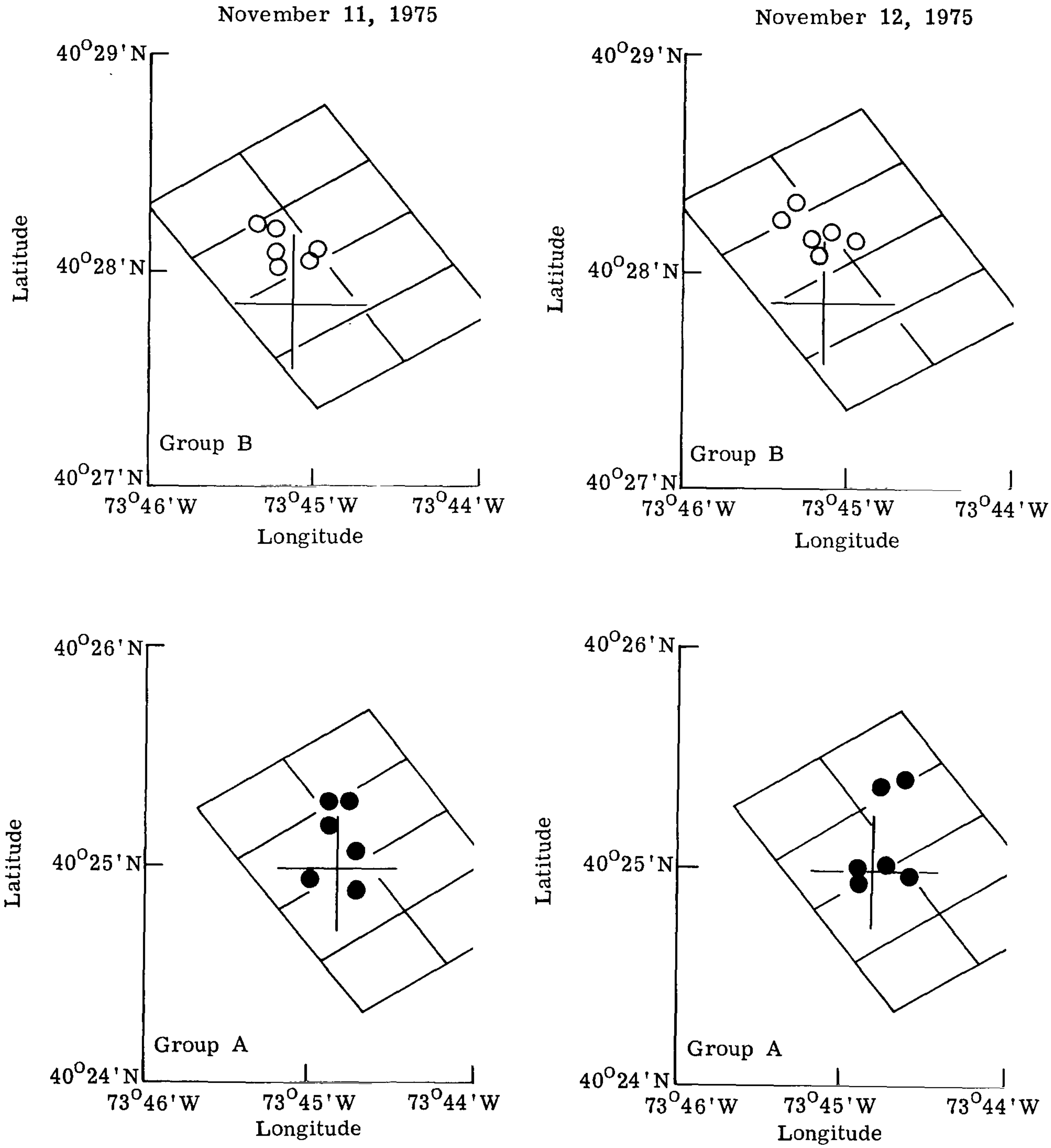
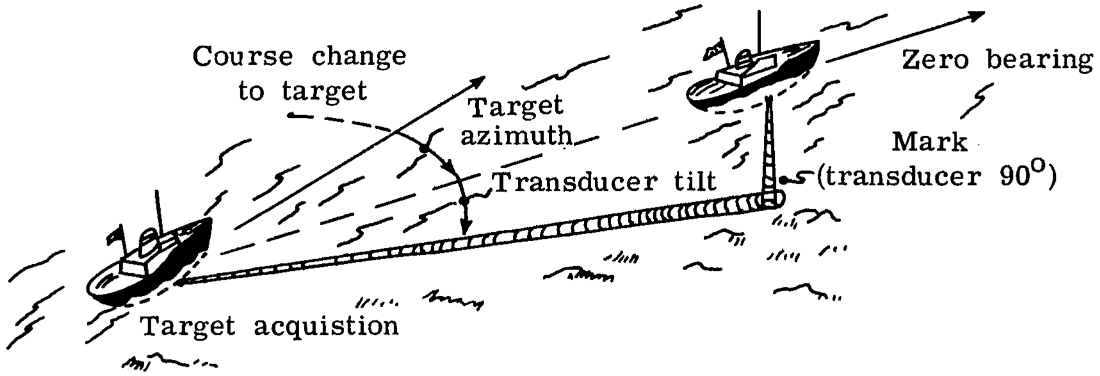
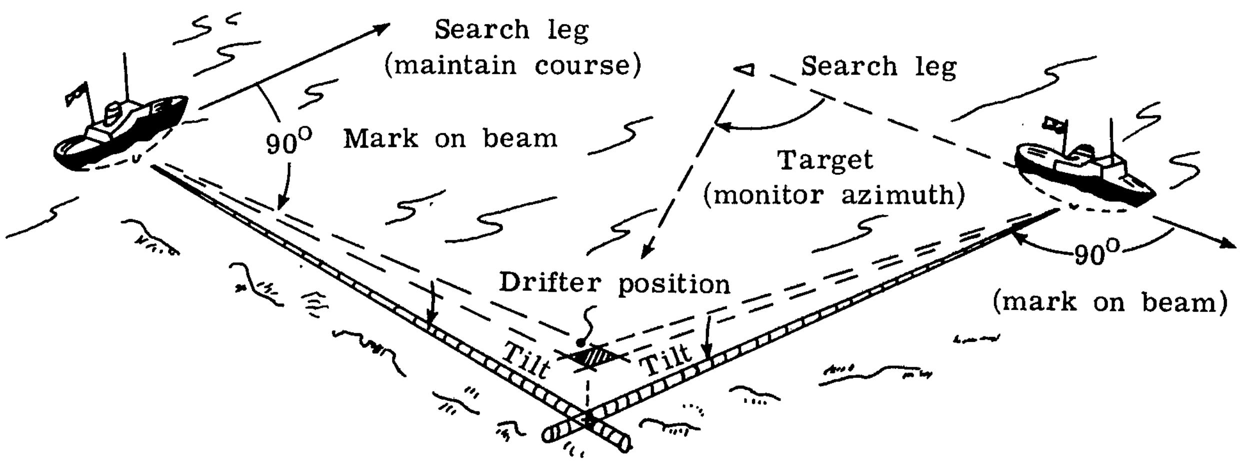


Figure 6.- Concluded.



(a) Random search.



(b) Perimeter search.

Figure 7.- Sonar tracking methods.

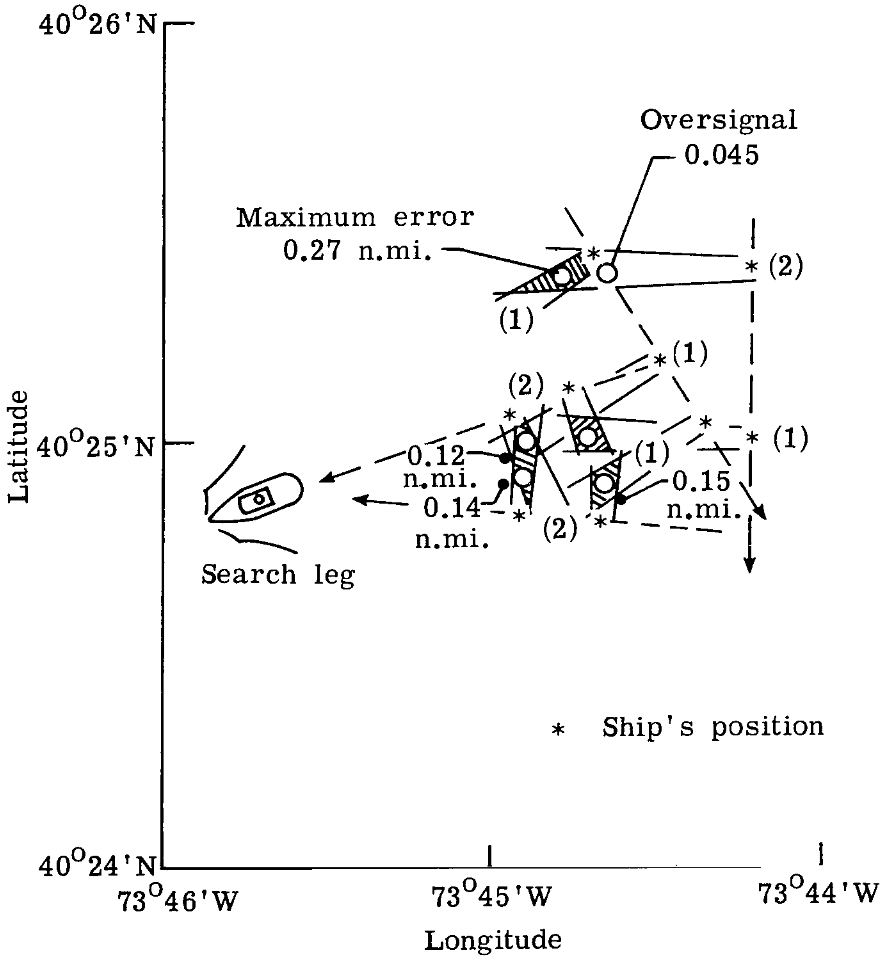


Figure 8.- Example of tracking accuracy. Number in parentheses indicates number of signals.

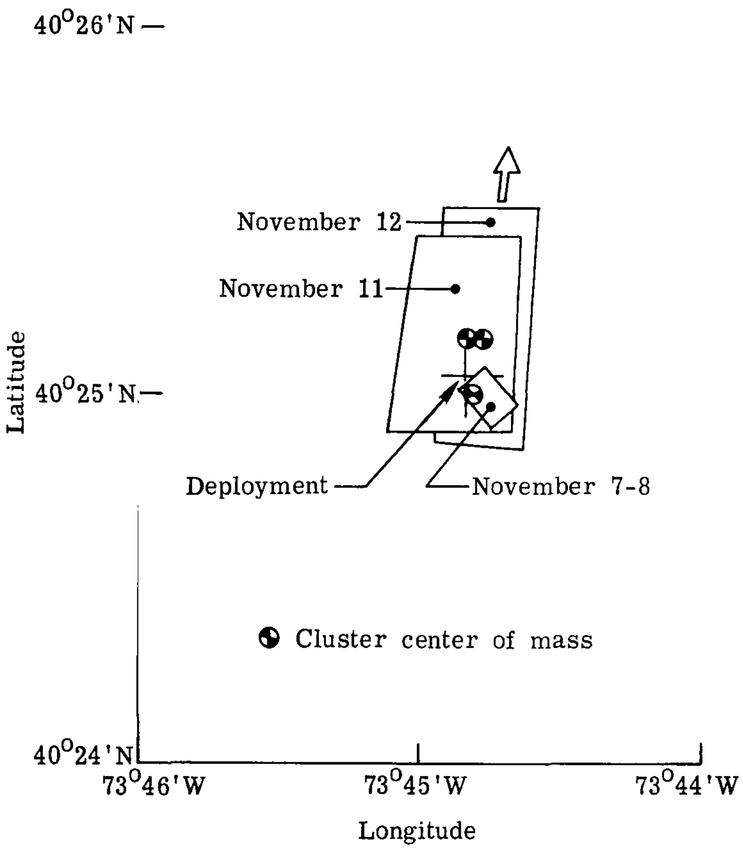


Figure 9.- Envelopes of group A drifter movement. Cluster drift rate, 0.03 n.mi./day at 8° true.

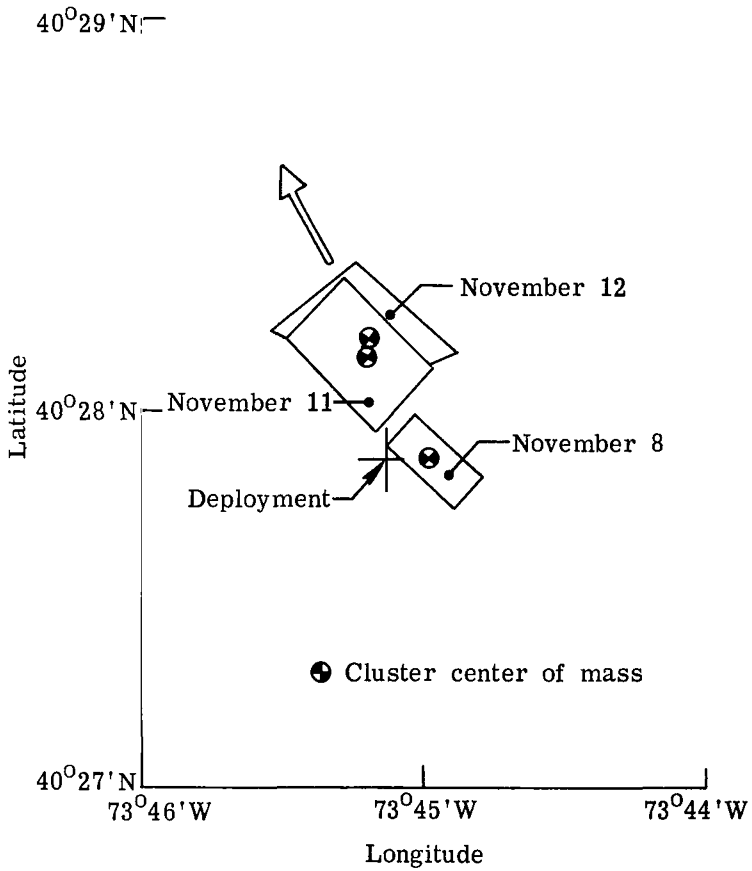


Figure 10.- Envelopes of group B drifter movement. Cluster drift rate, 0.09 n.mi./day at 332° true.

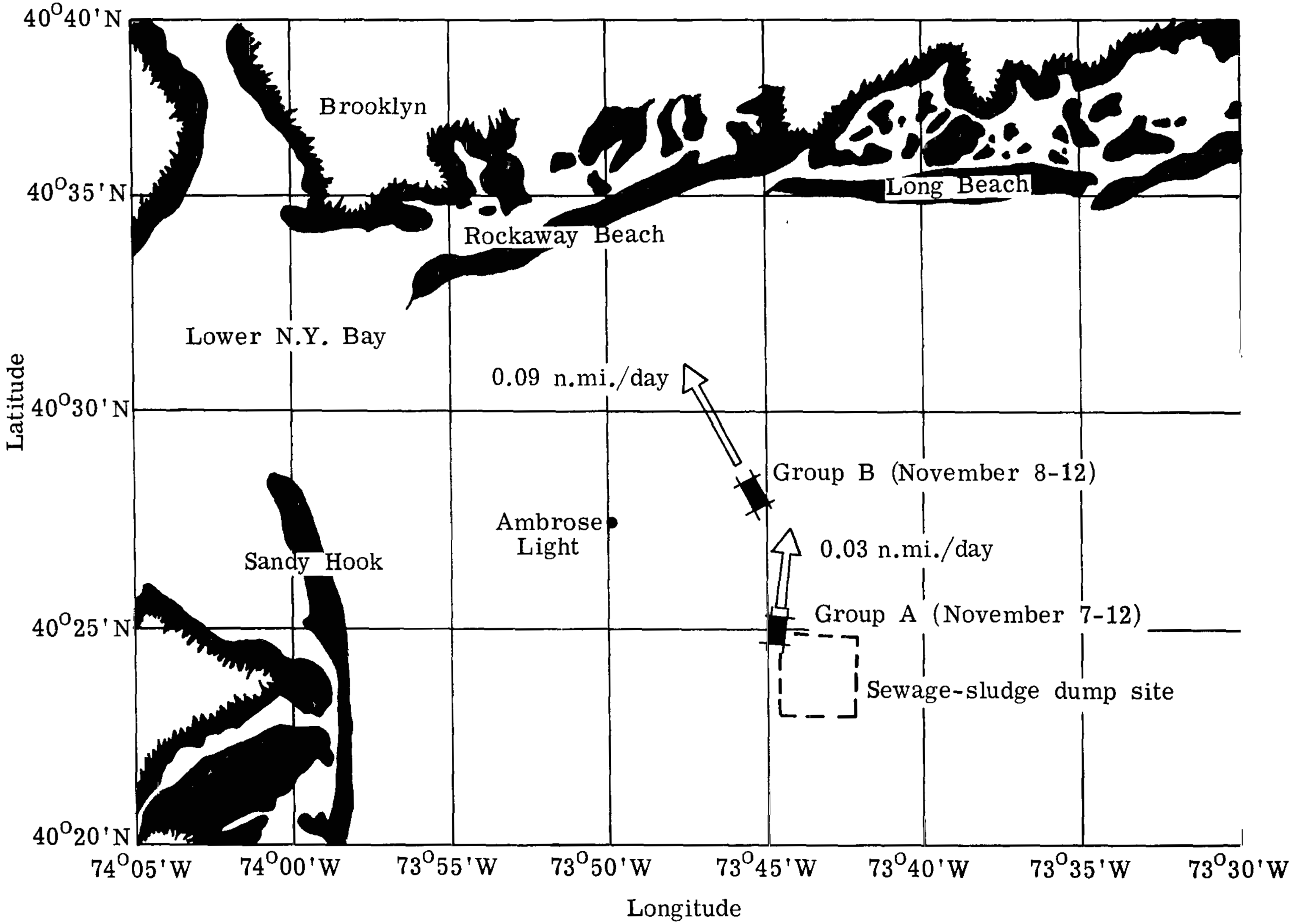


Figure 11.- Summary of drifter movements in New York Bight.

NASA-Langley, 1977 L-10836

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