Institute of Oceanography
Old Dominion University
Norfolk, Virginia

Technical Report No. 20

Drogue Performance Evaluation
Part 1: Data Acquisition

by
Ronald E. Johnson

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Hampton, Virginia 23665

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INSTITUTE OF OCEANOGRAPHY
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS
OLD DOMINION UNIVERSITY
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DROGUE PERFORMANCE EVALUATION

PART 1: DATA ACQUISITION

By

Ronald E. Johnson[1]

LIST OF SYMBOLS

A, A'	Stern sextant angles for system release, and recovery points relative to ship's centerline, respectively.
c, c'	Bow sextant angles for system release, and recovery points relative to ship's centerline, respectively.
h, h'	Normal to ship's centerline distances to the release and recovery points from the bow and stern sextant positions, respectively.
L	Distance between bow and stern sextant positions along the ship's centerline.
s	Buoy/drogue system true speed.
T	Buoy/drogue system travel distance.
T_x, T_y	Components of T parallel and normal to ship's centerline, respectively.
t	Elapsed run time from release point to recovery point.
x, x'	Parallel to ship's centerline distances to the release and recovery points from the bow and stern sextant positions, respectively.
α	Buoy/drogue system direction angle relative to ship's centerline.

[1] Assistant Professor of Oceanography, Institute of Oceanography, Old Dominion University, Norfolk, Virginia 23508.

INTRODUCTION

The study of surface buoy/subsurface drogue drag coupling was initiated as a consequence of the investigation of circulation in the entrance to Chesapeake Bay using the Lagrangian technique of tracking drifters. These shore-based, radar tracked, buoys have subsurface x-shaped drogues or drag plates that are centered at 20 ft. The drag induced on the surface float by the differential current existing between top and bottom results in the buoy/drogue system moving at some different velocity than either the surface or subsurface current. This coupling effect needs to be known and, perhaps, minimized if subsurface circulation is to be accurately described.

Part 1 of the Drogue Performance Evaluation (this section), then, consists of the data acquisition methods and techniques derived from several experimental cruises and the processed data from the coupling studies conducted on board the R/V LINWOOD HOLTON in the entrance to Chesapeake Bay. Data from several different surface floats and drogue depth combinations have been processed during this study.

Part 2 will contain the analysis of the data; and, hopefully, the formulation of a prediction equation for the relationship between the observed true current velocity at the depth of the drogue, the measured system velocity, surface current velocity, and wind speed. The prediction equation is based on a system balanced drag equation and will utilize existing drag coefficients for body shapes similar to the buoys and drogues used in this study.

BUOY CONFIGURATIONS

Four different buoys were utilized during this study. Three were coupled to steel plates rigidly attached to each other at right angles forming a cross or "plus" shape. The drogue plates were located at various depths. The fourth buoy was a spar type approximately 10 ft long that did not require subsurface drag plates. While the data for this buoy is reported, no analysis is anticipated.

Figure 1A shows the layout of the Radio Buoy. This buoy is easily handled by three people, one for the buoy and two for the drogue plates. The system weight is about 100 lbs. Figure 1B shows the Radar Buoy configuration. This buoy requires at least three people to just pick up and required the use of the ship's winch to deploy and recover. The total system weight is about 250 lbs. The Radio Buoy is interrogated via radio frequencies, while the Radar Buoy is located via S-band tracking radar and sends its signal upon command. Dimensions in Figure 1A and 1B are in inches. Figure 1C shows the layout of the EOLE Buoy. This buoy is used primarily in offshore applications and is located and interrogated by satellite on every pass, approximately once a day in previous usage. This buoy is the heaviest of the three and is usually deployed by helicopter. Figure 1C dimensions are in meters.

Table 1 lists the various buoy/drogue plate size and depth combinations used throughout the testing period. Dates of data acquisition and number of runs, including runs with insufficient or questionable data, are also presented. Each data set consisted of at least 10 runs with the plates at the same depth. The set was spaced in time to allow data to be obtained over part of the local tidal cycle. The individual drogue plate size is either 5 ft by 5 ft or 2½ ft by 5 ft. Two plates of equal size are rigidly attached at right angles, as mentioned, with the first dimension being the height.

DATA ACQUISITION METHODS

The ship-board data gathering procedure described below was designed to provide the input for the system balanced drag equation. Items needed include the true current at the drogue depth, the true current at the surface, the system velocity, and the wind velocity. The drogue and surface float drag coefficients are obtained from the literature.

Simultaneous measurements of surface and subsurface current speed and direction are taken using two current meters suspended on

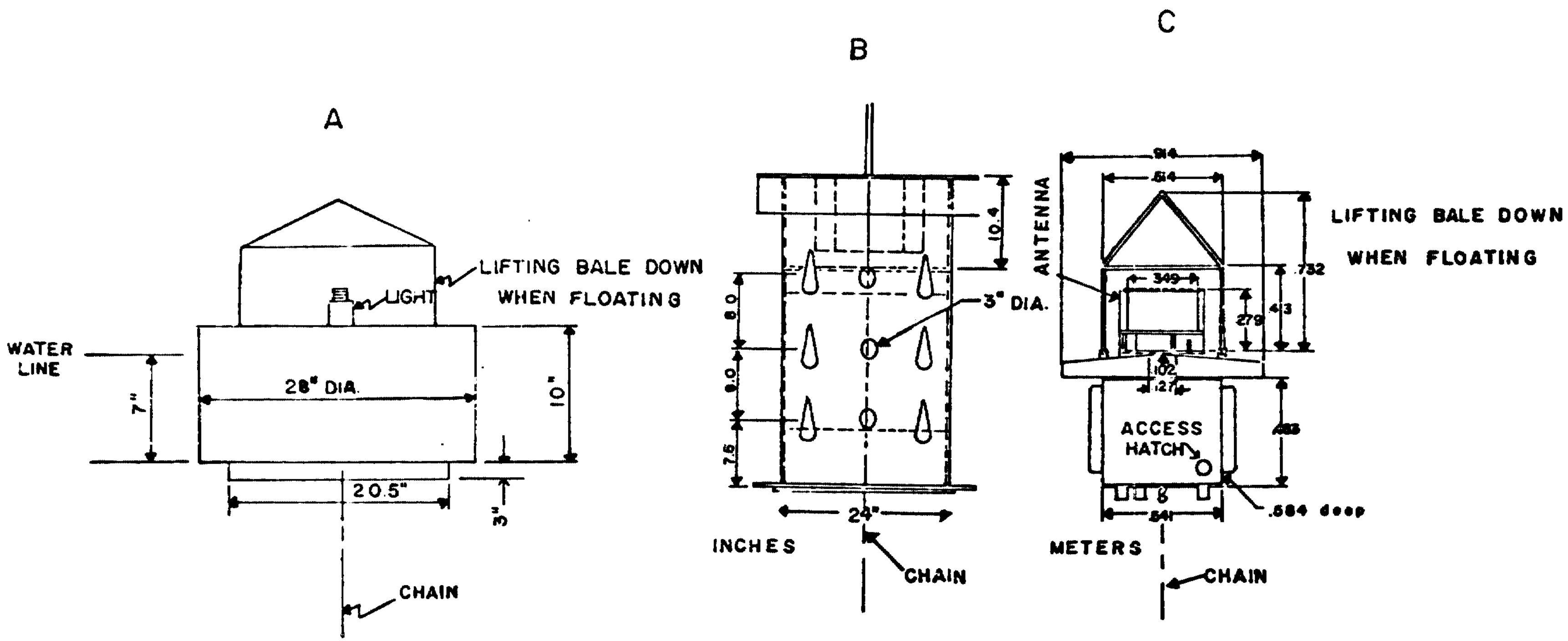

Figure 1. Buoy configurations.

Table 1. Summary of data acquisition runs.

Date	Data Set	Buoy Type	Drogue Size (ft)	Centerline Drogue Depth (ft)	Runs		
					Good	Questionable	Insufficient Data
1974							
Sep 3	1	Radio	2½ × 5	17	9	1	--
Sep 3	2	Radio	2½ × 5	22	10	--	--
Sep 3	3	Radio	2½ × 5	12	10	--	--
Sep 17	4	EOLE	5 × 5	18	7	3	--
Sep 17	5	EOLE	5 × 5	18	10	--	--
Sep 17	6	Radar	2½ × 5	8	15	--	--
1975							
Jan 28	7	Radar	2½ × 5	23	10	--	--
Jan 28	8	Radar	2½ × 5	15	10	--	--
Jan 28	9	Radar	None	--	10	--	--
Jan 28	10	EOLE	5 × 5	10	9	--	1
Jan 28	11	EOLE	None	--	8	--	2
Jan 28	12	Radio	2½ × 5	7.5	10	--	--
Jan 28	13	Radio	None	--	7	2	1
Jan 28	14	Radar	2½ × 5	15	10	--	--
Feb 11	15	Radio	2½ × 5	7	10	--	--
Feb 11	16	Radio	None	--	10	--	--
Feb 11	17	NOAA spar	None	--	15	--	--

either side of the ship as shown in Figure 2. The subsurface measurement is made on the opposite side of the ship as the buoy/drogue drift track. The system speed and direction are obtained by measuring the surface buoy's drift path length and dividing by the run time. The length is relative to the ship and must be corrected for ship's heading. The initial and final positions of the surface buoy are measured using paired horizontal sextant angles. During the timed run, wind speed and direction, and ship's heading are recorded.

The equations for determination of true buoy/drogue system speed and direction are presented here; refer to Figure 2 for the geometry. The true speed is

$$s = \frac{T}{t} = \frac{\left(T_x^{\,2} + T_y^{\,2}\right)^{\frac{1}{2}}}{t} \tag{1}$$

where s is the system speed, T is the travel distance, t is the time of travel, and T_x and T_y are the parallel and normal components of system travel distance relative to ship's centerline. The direction relative to ship's centerline and opening to the bow is

$$\alpha = \text{arc tan}\,\frac{T_y}{T_x} \tag{2}$$

A positive α is shown in Figure 2. All runs were made from bow to stern on the port side so true direction is

$$\text{Direction} = \text{ship's heading} - \alpha + 180° \tag{3}$$

where ship's heading has been corrected from magnetic to true. The travel distance components T_x and T_y were determined as follows:

$$T_x = L + x + x' \tag{4}$$

$$T_y = h - h' \tag{5}$$

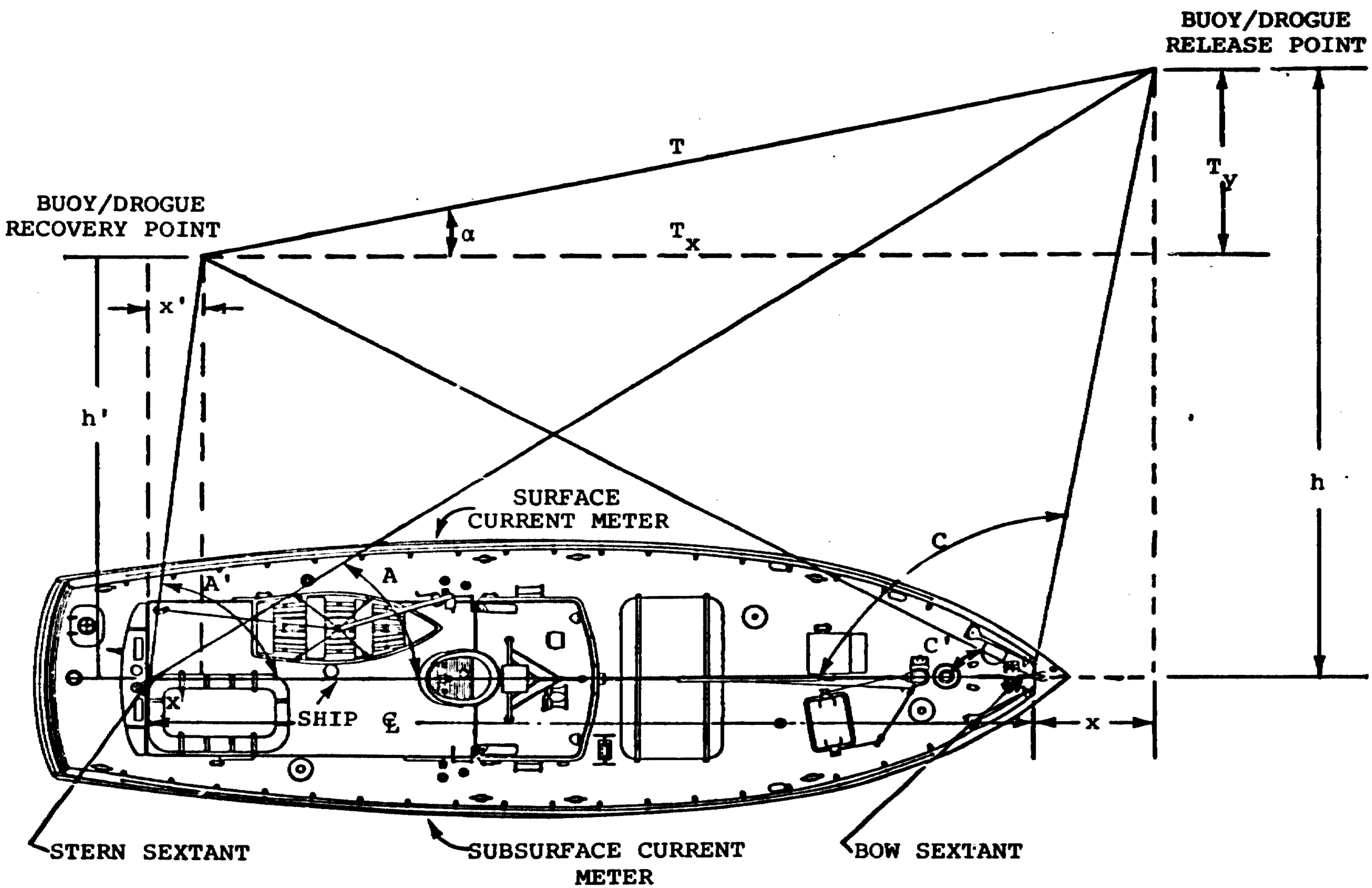

Figure 2. Typical on board equipment location and buoy/drogue release and recovery positions.

where L is the distance between bow and stern sextants along the ship's centerline, h and h' are the normal to ship's centerline distances to the release and recovery points from the bow and stern sextant positions, respectively , and x and x' are the parallel to ship's centerline distances to the release and recovery points from the bow and stern sextant positions, respectively. See Figure 2, again, for layout. From the law ot sines

$$h = \frac{L \sin C \sin A}{\sin (180° - A - C)} \tag{6}$$

$$h' = \frac{L \sin C' \sin A'}{\sin (180° - A - C)} \tag{7}$$

$$x = -h \cos C \tag{8}$$

$$x' = -h' \cos A' \tag{9}$$

where A and C are the system release point angles, and A' and C' are the system recovery angles. Both sets are relative to ship's centerline and for bow and stern, respectively, as shown in Figure 2. The h and h' values will always be positive, while the x and x' values may be positive or negative and, hence, added to or subtracted from L to get T_x in Equation (4). Upon substitution, Equations (4) and (5) are

$$T_x = L\left[1 - \frac{\sin C \sin A \cos C}{\sin (180° - A - C)} - \frac{\sin C' \sin A' \cos A'}{\sin (180° - A' - C')}\right] \tag{10}$$

$$T_y = L\left[1 - \frac{\sin C \sin A}{\sin (180° - A - C)} - \frac{\sin C' \sin A'}{\sin (180° - A' - C')}\right] \tag{11}$$

The system velocities for all runs of all sets were calculated using Equations (1), (2), (3), (10), and (11). In addition, all runs were plotted to check for errors and to better visualize the relationships between the three measured velocities and ship's heading. Figure 3 presents the results of set 13, runs 61-70. It may be seen that runs 68 and 69 are indeed questionable. Either the bow

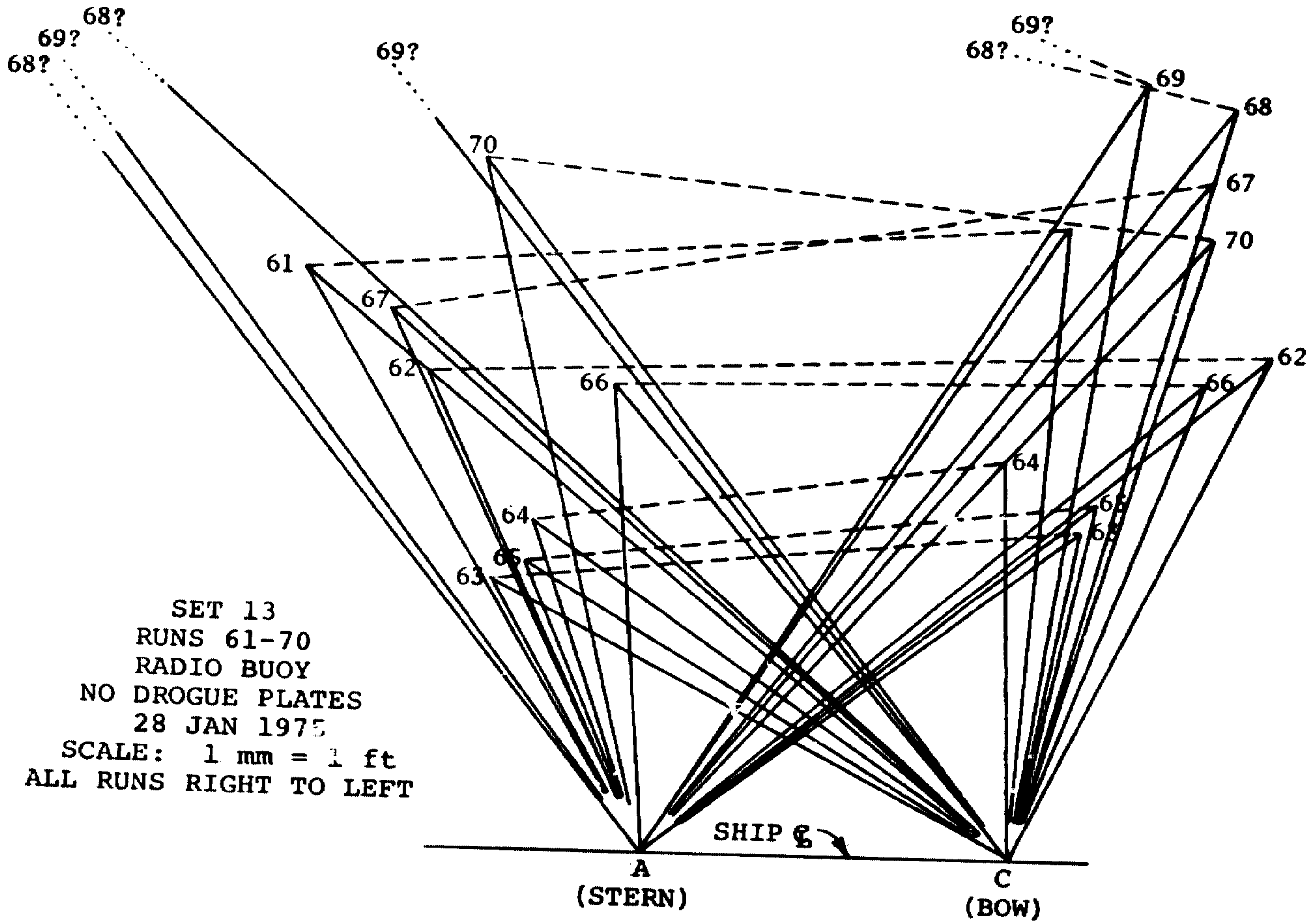

Figure 3. System drift tracks, Set 13.

or stern angles (or both) for the recovery point are questionable. In addition, run 70 is seen to have a negative α while all others have positive α. All doubtful runs (and those with missing data) are so indicated in Table 1.

Since the required data needs to be taken synoptically, approximately 10 people are needed. Two are needed in the small support boat to tow the buoy/drogue system back to start a new run, four are required for the bow and stern sextants, (two readers and two recorders) one for wind speed and ship's heading, three for the two current meters, and one to oversee the operation. This last person starts and stops a run and is responsible for timing the run as well.

The support boat used was the Institute's 19-ft inboard/outboard R/V PANGAEA. This boat, a Johnson Surfer, proved to be sufficiently powered to tow the various buoy/drogue combinations up current to start another run. In addition to hand signals, two-way radio communications were used to give the commands to release the system at the start and recover the system at the end of a run.

The measurement of the start and finish horizontal sextant angles from the bow and stern required the most concentration of any of the measurements taken. Each run usually lasted less than one minute, so the reader has to continually keep the sextant in position, adjusting the angle as the system passes by. Angles are read and recorded only at the start and end of each run.

The wind speed and direction are recorded atop the aftercabin at a height of 15 ft during the timed run. This person also records the ship's heading from the main ship's compass in the pilot house.

Both current meters are read and recorded at 5-second intervals for speed and at the start and finish for direction. Averages are taken and used in further calculations.

The last person has the overall responsibility to start and stop a run, to make certain that all are ready to start a run, to review the data from the previous run (for possible rerun), as well as to time the run. This position is usually filled by the Principal Investigator.

Equipment needed for this operation is listed in Table 2. A description of the equipment and possible errors in observation is included in the discussion.

Table 2. List of equipment needed for data acquisition.

1.	Buoys with drogues and connecting chain as required
2.	Two current meters (both speed and direction are needed)
3.	Two marine sextants
4.	Stop watch
5.	Data forms for each operation
6.	Clipboards
7.	Calculator (calc. of means)
8.	Nautical chart of area
9.	Three-armed protractor (position plotting)
10.	Hand-held anemometer
11.	Supplies for R/V PANGAEA
12.	Miscellaneous supplies (seizing wire and pliers, pencils, tape, tools, etc.)

DISCUSSION

Depending on sea state during the four successful sea days, the ship was either anchored on the east or west side of the Chesapeake Bay Bridge Tunnel about one nautical mile distant, and two to three nautical miles from the south shore. These areas are simply convenient to reach from port. Preliminary investigation of the processed data indicates a wide range in current velocity speed, and direction for some runs when the three currents are compared. The surface and drogue depth currents at times may be 90 degrees or greater different in direction with associated differences in speeds of up to 0.5 ft/sec or more. This is a direct consequence of using the entrance to Chesapeake Bay for the data acquisition.

The lower bay is a partially-mixed estuary which means that the upper and lower layers in the water column, while coupled, may exhibit quite different flow characteristics. For instance, the times of slack and maximum currents may be different by over one hour. This had the effect of causing the buoy/drogue system to occasionally move at large angles with respect to ship's centerline. Thus, errors in measurement could be hidden. This problem is now recognized and any future work will have enough on board data processing done to perform a simple balance of forces drawing. This will permit gross errors in measurement to be quickly spotted and additional runs taken.

The current at drogue depth was always measured with the Kelvin-Hughes Direct Reading Current Meter. This meter has had flume calibration and is within the error limit of ±2% of full scale reading on speed, a value of ±0.10 ft/sec. The threshold speed is approximately 0.2 ft/sec. The direction, while harder to calibrate, appears to be within the ±1.5° stated error range. Near iron (within 3 ft of ship's hull) the deviation may be as high as ±10°. Beyond 10-12 ft the error drops to the ±1.5°.

The surface current was always measured with the ENDECO Type 160 Remote Reading Current Meter. The speed sensor error range is ±3% of full scale, a value of ±0.25 ft/sec. Threshold speed is 0.08 ft/sec. Direction error is ±3% of full scale, a value of ±10°. The direction scale is rather difficult to read, being divided in 15° spacings. However, the direction was read to the nearest degree for all sets (presently, the direction is being read to the nearest five degrees). Near ship readings may be in error by up to 20 degrees due to ship's field. This error has not been investigated, however.

The sextant errors are very small and have been neglected. Errors in tracking the surface buoy, however, may result in ±2° for each sextant on beginning and end readings. This estimate has been determined from buoy diameter and average distance from ship considerations. An example error calculation using run 66, set 13, was made (refer to Figure 3). If the full two degrees error was assumed, the increase in the overall track length was about 3 ft (3.5% increase), the change in direction was less than one degree, and the change in speed was +0.1 ft/sec (3.7% increase). Other checks give about the same range of variation for speed and direction of the buoy/drogue system velocity. One suspects, however, that the sextant readers at times had trouble keeping the buoy within this error limit due to the strong currents which caused the horizontal angles to change very rapidly. Sextants are not designed for measuring rapidly changing horizontal angles.

The hand held anemometer (Airflo Instrument Co. model AN/PMQ-3C) may be read to the nearest ½ knot on the 0-15 knot scale and 1 knot on the 0-60 knot scale. Wind speed variability was averaged out by visually averaging while observing the gauge. Short term fluctuations of 5 knots or more were observed. Wind speed direction, relative to ship's heading, could be read to the nearest degree, again visually averaging out short term variations. Five to 10 degree fluctuations were noted.

The ship's heading was measured using the navigational compass in the wheel house. This compass is marked in 2-degree intervals, and may be interpolated to the nearest degree. Major corrections, up to 30 degrees, had to be made on several trips, however, due to welding onboard ship which changes the ship's magnetic field. The corrections were determined by a technique known as "swinging the compass." Normal compass errors were less than one degree. The magnetic readings were corrected to true readings using the local deviation.

Part 2 of this report will deal more fully with the combined error effect on data interpretation.

APPENDIX

PROCESSED FIELD DATA

SET 1

Radio Buoy, 2½ × 5 plates centered at 17 ft, 3 Sep 1974

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
1	1.26	282	1.20	284	1.39	297	24	200
2	1.16	285	1.27	279	1.25	289	29	194
3	1.13	278	1.11	284	1.34	286	24	208
4	2.14*	288	1.03	283	1.14	290	30	208
5	1.32	280	1.00	290	1.15	289	30	207
6	1.13	281	0.88	302	1.06	288	27	212
7	0.91	283	0.86	299	1.02	288	25	228
8	0.77	282	0.83	298	0.96	287	27	214
9	0.73	284	0.79	302	0.86	281	27	203
10	0.80	302	0.84	306	0.88	284	20	231

* Questionable value.

SET 2

Radio Buoy, 2½ × 5 plates centered at 22 ft, 3 Sep 1974

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
11	0.23	095	0.57	342	0.36	112	17	240
12	0.19	172	0.34	013	0.47	119	20	201
13	0.55	108	0.74	007	0.19	197	15	255
14	0.41	078	0.74	357	0.27	116	19	193
15	0.80	124	0.76	352	0.47	092	24	227
16	0.68	099	1.10	011	0.07	072	22	236
17	0.59	122	1.25	030	0.32	148	20	208
18	0.54	116	1.16	029	0.28	105	22	214
19	0.63	099	1.08	011	0.24	112	19	190
20	0.58	092	1.03	011	0.28	138	24	192

SET 3

Radio Buoy, 2½ × 5 plates centered at 12 ft, 3 Sep 1974

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
21	0.79	100	0.82	350	0.34	101	19	207
22	0.61	092	1.05	008	0.46	115	24	203
23	0.65	090	1.04	012	0.40	117	20	214
24	0.71	127	1.05	025	0.54	121	32	216
25	0.85	134	1.03	027	0.58	124	24	225
26	0.74	122	1.00	016	0.78	120	30	214
27	0.81	127	1.14	022	0.78	113	24	224
28	0.86	129	1.11	027	0.78	112	19	190
29	0.79	132	1.15	334	0.89	115	19	198
30	0.92	136	1.01	017	0.88	115	19	215

SET 4

EOLE Buoy, 5 × 5 plates centered at 18 ft, 17 Sep 1974

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
1	1.84	309	1.64	306	1.35	319	15	068
2	1.39	316	1.58	302	1.42	320	14	069
3	1.61	333	1.54	304	1.39	318	12	085
4	1.64	308	1.50	304	1.34	316	11	076
5	1.94*	302	1.52	300	1.28	316	14	077
6	2.35*	305	1.51	306	1.28	318	14	078
7	1.16	314	1.45	301	1.23	316	13	075
8	1.37	326	1.40	300	1.15	324	9	080
9	1.55*	311	1.33	300	1.07	324	9	087
10	1.29	319	1.27	298	1.02	326	8	068

* Questionable value.

SET 5

EOLE Buoy, 5 × 5 plates, centered at 18 ft, 17 Sep 1974

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
11	1.01	320	1.18	298	0.91	324	2	071
12	0.53	333	1.05	307	0.72	334	2	068
13	0.63	335	1.01	307	0.51	350	1	076
14	0.68	349	1.00	304	0.49	007	8	086
15	0.54	357	0.96	306	0.46	017	10	063
16	0.82	130	0.71	029	1.06	073	13	087
17	0.93	120	0.96	040	1.12	073	15	093
18	1.01	120	1.05	055	1.13	077	16	086
19	1.04	117	1.20	064	1.18	080	15	078
20	1.04	116	1.30	077	1.20	083	12	091

SET 6

Radar Buoy, 2½ × 5 plates centered at 8 ft, 17 Sep 1974

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
21	1.70	132	1.77	120	1.49	089	11	072
22	1.79	136	1.84	131	1.06	094	9	059
23	1.82	145	2.01	135	0.37	097	9	051
24	1.86	148	1.99	145	1.09	098	11	061
25	1.55	144	1.91	145	1.25	097	8	078
26	1.85	135	1.99	150	1.50	096	7	079
27	2.29	139	2.47	137	2.36	097	8	057
28	2.43	151	2.28	142	1.39	097	6	065
29	2.43	138	2.20	137	1.29	097	8	067
30	1.88	142	2.14	142	0.76	097	7	050
31	1.54	142	2.40	133	2.55	095	6	062
32	2.09	143	2.58	129	2.39	095	7	053
33	2.06	129	2.57	120	2.71	094	8	066
34	2.47	148	2.42	127	0.94	094	8	074
35	2.46	152	2.55	120	3.52	094	5	084

SET 7

Radar Buoy, 2½ × 5 plates centered at 23 ft, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
1	1.50	306	1.86	280	2.97	313	5	271
2	1.36	304	1.87	278	2.59	310	10	296
3	1.83	296	1.85	284	2.77	311	9	285
4	1.47	305	1.85	282	2.59	310	8	253
5	1.37	306	1.86	282	2.38	314	2	238
6	0.96	323	1.92	284	2.42	315	2	239
7	1.24	332	1.94	288	2.36	318	2	242
8	1.29	309	1.96	287	2.27	314	5	259
9	1.25	312	1.90	283	2.22	314	8	261
10	1.19	317	1.83	284	2.22	319	10	269

SET 8

Radar Buoy, 2½ × 5 plates centered at 15 ft, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
11	0.73	320	1.26	290	1.19	324	10	238
12	0.97	301	1.06	282	1.10	317	13	240
13	1.03	310	0.96	286	1.02	323	13	244
14	1.18	310	0.76	289	1.11	328	10	244
15	0.99	313	0.93	292	1.19	328	10	254
16	0.93	318	0.84	297	1.19	332	10	261
17	0.95	321	0.80	298	1.15	331	10	269
18	0.82	325	0.81	302	1.19	338	10	269
19	0.87	327	0.75	306	1.17	325	9	259
20	0.93	321	0.68	303	1.12	334	10	289

SET 9

Radar Buoy, no plates, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
21	1.13	109	1.13	049	--	--	2	269
22	1.04	117	1.00	053	--	--	2	273
23	1.22	117	1.18	058	--	--	1	272
24	1.24	099	1.11	058	--	--	2	275
25	1.07	115	1.18	057	--	--	0	--
26	1.29	117	1.17	060	--	--	0	--
27	1.10	115	1.22	061	--	--	1	270
28	1.22	117	1.22	060	--	--	0	--
29	1.19	120	1.00	063	--	--	2	255
30	0.98	122	1.20	063	--	--	3	251

SET 10

EOLE Buoy, 5 × 5 plates centered at 10 ft, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
31	1.50	101	1.35	070	1.35	084	5	012
32	1.04	108	1.38	070	1.39	084	0	--
33	1.70	116	1.47	090	1.38	078	2	016
34	1.43	118	1.64	103	1.48	082	8	359
35	1.50	122	1.74	124	1.40	083	8	021
36	1.57	121	1.66	120	1.51	088	8	024
37	Missing angle		1.89	107	1.68	088	11	029
38	1.69	122	2.04	110	1.70	089	14	029
39	1.90	114	1.99	108	1.83	086	14	023
40	1.93	122	1.86	112	1.83	086	14	029

SET 11

EOLE Buoy, no plates, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
41	1.65	138	2.30	134	--	--	11	035
42	2.18	128	2.28	134	--	--	11	038
43	1.97	119	2.33	132	--	--	12	028
44	2.59	141	2.36	132	--	--	8	039
45	Missing angle		2.28	134	--	--	9	036
46	2.70	135	2.31	142	--	--	10	035
47	2.48	115	2.47	144	--	--	10	030
48	2.72	133	2.40	134	--	--	9	035
49	2.45	136	2.47	137	--	--	9	034
50	Missing angle		2.50	132	--	--	10	036

SET 12

Radio Buoy, 2½ × 5 plates centered at 7.5 ft, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
51	2.98	116	2.77	134	2.47	098	13	040
52	2.70	126	2.69	147	2.65	102	9	049
53	2.69	133	2.57	142	2.74	102	11	043
54	2.34	124	2.67	140	2.76	102	10	050
55	2.69	124	2.60	139	2.71	102	9	061
56	2.74	136	2.58	140	2.66	102	9	057
57	2.47	135	2.45	134	2.57	103	9	053
58	2.34	124	2.45	142	2.28	114	9	052
59	2.96	128	2.90	137	2.74	114	9	050
60	2.39	130	2.77	134	2.82	112	9	052

SET 13

Radio Buoy, no plates, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
61	2.93	134	3.09	127	--	--	9	048
62	3.47	138	3.12	134	--	--	8	044
63	3.16	135	3.21	132	--	--	8	051
64	2.77	133	3.12	144	--	--	8	052
65	2.91	133	3.14	147	--	--	8	055
66	2.66	139	3.31	140	--	--	8	066
67	2.93	130	3.45	137	--	--	8	058
68	5.74*	154*	3.45	142	--	--	8	052
69	50.4*	196*	3.51	154	--	--	8	053
70	Missing time		3.51	150	--	--	11	061

* Questionable value.

SET 14

Radar Buoy, 2½ × 5 plates centered at 15 ft, 28 Jan 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
71	2.60	139	3.06	147	2.27	110	8	079
72	2.14	100	3.36	157	2.01	114	8	092
73	2.48	137	3.18	152	1.80	114	8	058
74	2.28	124	3.33	142	2.02	112	6	071
75	2.41	140	3.33	141	2.28	113	8	102
76	2.30	134	3.34	138	2.54	112	6	078
77	2.70	137	3.26	137	2.22	112	6	054
78	1.91	125	3.28	144	2.03	113	7	127
79	3.38	151	3.29	144	2.23	111	6	123
80	2.29	129	3.41	140	2.24	109	6	127

SET 15

Radio Buoy, 2½ × 5 plates centered at 7 ft, 11 Feb 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
1	1.15	332	0.98	312	1.30	350	19	256
2	1.40	342	0.96	315	1.26	350	14	248
3	0.98	352	0.95	317	1.26	003	14	259
4	1.11	349	1.00	320	1.29	003	13	258
5	0.81	342	0.88	324	1.27	008	13	261
6	0.88	358	0.96	327	1.28	004	11	260
7	1.22	355	1.00	332	1.28	003	11	256
8	0.85	019	1.01	330	1.35	004	9	250
9	1.05	005	0.96	337	1.36	004	11	275
10	1.01	006	1.05	335	1.41	004	10	283

SET 16

Radio Buoy, no plates, 11 Feb 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
11	0.86	052	1.00	350	--	--	11	292
12	1.39	072	1.18	356	--	--	14	294
13	1.32	059	1.11	000	--	--	17	303
14	1.32	071	1.05	010	--	--	20	304
15	1.00	076	1.15	012	--	--	19	298
16	1.11	078	1.06	012	--	--	17	299
17	1.31	065	1.15	007	--	--	16	295
18	1.38	074	1.15	017	--	--	15	292
19	1.38	084	1.10	012	--	--	14	289
20	1.46	066	1.20	012	--	--	18	289

SET 17

Spar Buoy (NOAA), no plates, 11 Feb 1975

Sequential Run	Buoy/Drogue System		Surface Current		℄ Drogue Current		Wind	
	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T	Speed ft/sec	Direction °T
21	1.51	059	1.27	020	--	--	21	289
22	1.48	069	1.30	030	--	--	17	296
23	1.15	090	1.22	045	--	--	16	280
24	1.34	088	1.35	030	--	--	19	284
25	1.45	090	1.28	035	--	--	18	267
26	1.30	108	1.49	042	--	--	22	268
27	1.80	111	1.45	040	--	--	19	264
28	1.60	100	1.54	040	--	--	19	273
29	1.70	093	1.47	040	--	--	18	266
30	1.72	098	1.52	042	--	--	19	265
31	1.56	107	1.49	052	--	--	25	268
32	1.59	094	1.52	042	--	--	23	254
33	1.71	101	1.64	047	--	--	27	266
34	1.70	104	1.59	052	--	--	25	265
35	1.60	105	1.60	055	--	--	25	261