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A STUDY OF CURRENTS IN
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A STUDY OF CURRENTS
IN SOUTHERN MONTEREY BAY

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Connelly D. Stevenson

A STUDY OF CURRENTS
IN SOUTHERN MONTEREY BAY

by

Connelly D. Stevenson
Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

United States Naval Postgraduate School

Monterey, California

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This work is accepted as fulfilling
the thesis requirements for the degree of

MASTER OF SCIENCE

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ABSTRACT

Measurements of surface and subsurface water circulation in shallow water in the extreme southern end of Monterey Bay were made by tracking drogues from the beach. A computer program included in the appendix was developed to transform the raw survey data into drogue courses and speeds, and to plot their trajectories. Analysis of the drogue tracks showed a predominance of shoreward flow. Interpretation of the effect of wind and sea conditions upon the observed water transport revealed a close dependence upon winds above five knots, in contrast to an apparent lack of dependence upon tidal variations and waves. Water motions in general responded to changes in the character of the wind with very little time lag, the lag increasing slightly with depth. Water flow commonly diminished and was deflected an increasing amount to the right of the wind with depth, presumably in response to Coriolis effect.

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1. Introduction.

The purpose of the research described herein is to shed light on the nearshore circulation of water immediately seaward of the surf zone off a long, continuous sand beach. The area selected for study is located in the extreme southern end of Monterey Bay, California, off the beach belonging to the U. S. Naval Postgraduate School, and is shown in figures 1 and 2. The circulation was traced using current drogues at several depths which were tracked from the shore by using transits. A computer program, included herein, was devised to calculate and print out the trajectories of the drogues. The drogue trajectories were then examined with respect to the prevailing wind, tide and surf conditions, and the gradient of bottom topography.

The investigator's work is a continuation and extension of surveys carried out cooperatively by the City of Monterey and the U. S. Naval Postgraduate School using personnel and equipment of both organizations, under the direction of Professor Warren C. Thompson. The City's interest was in obtaining information regarding dispersal of effluent from the outfall of their sewage treatment plant, located in the area of study. Professor Thompson, working under the Office of Naval Research Institution Grant to the USNPGS, directed his attention toward the nature of the nearshore

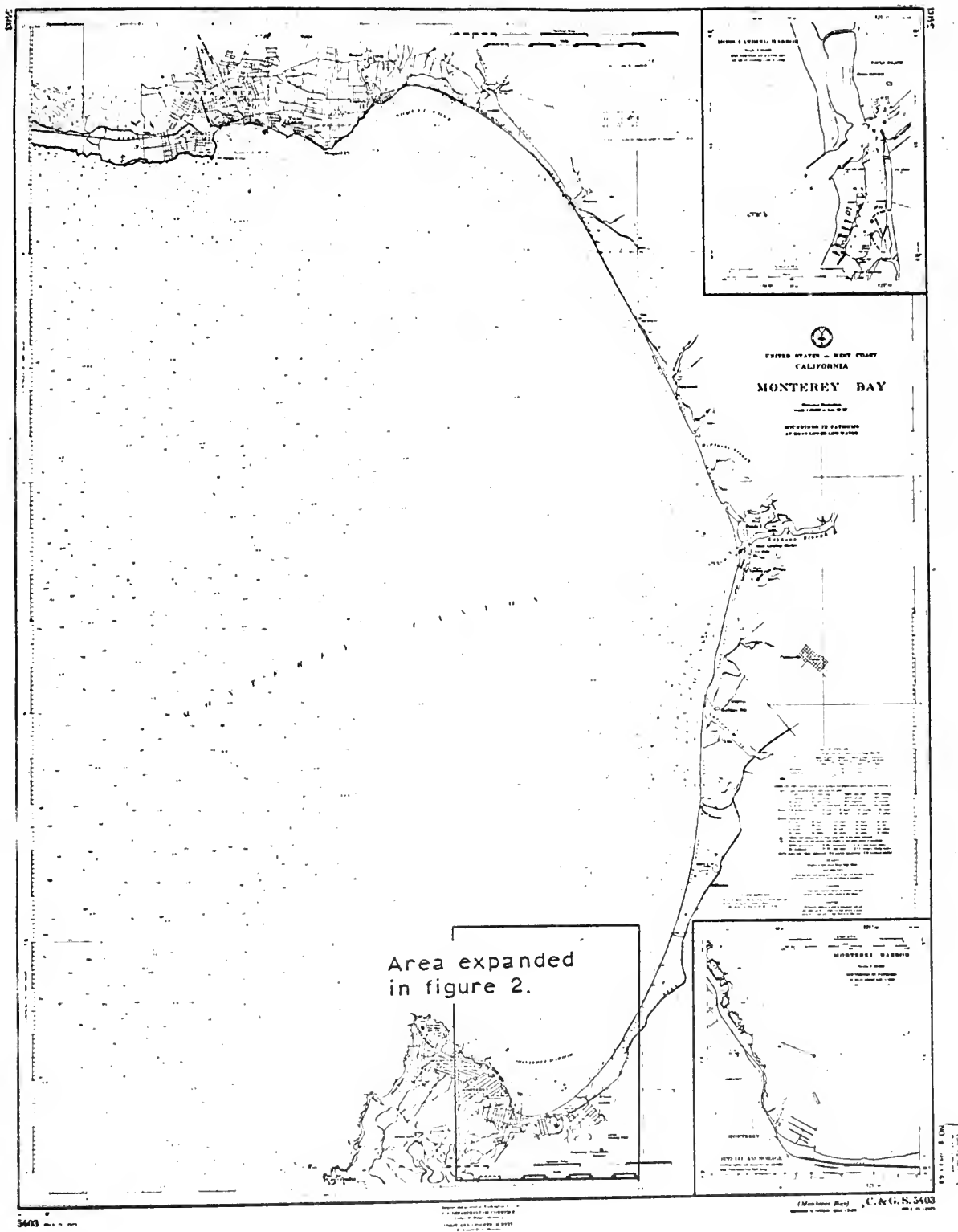
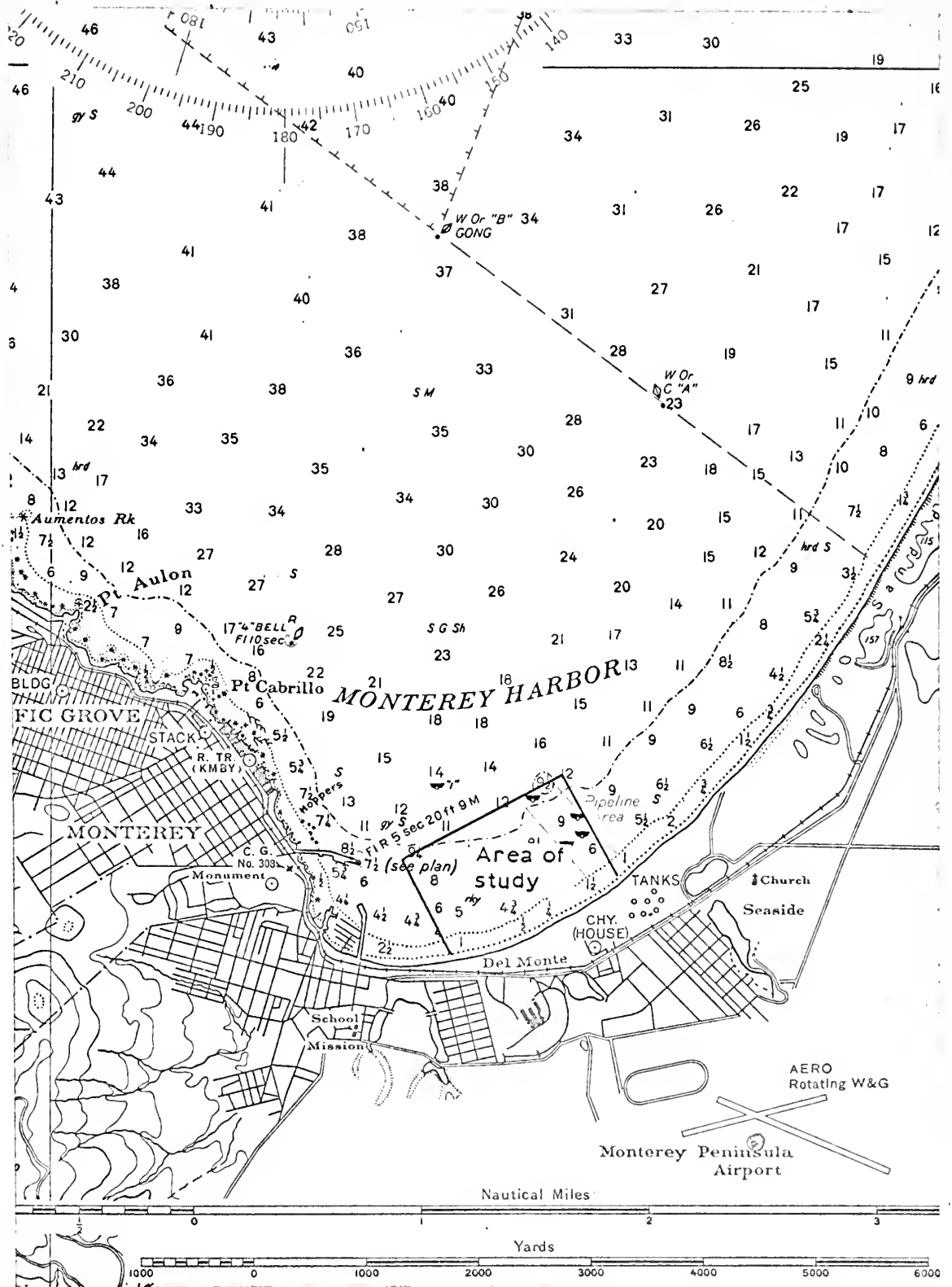


Figure 1. Monterey Bay, California.



C&GS 5403

Figure 2. Area of Study.

water circulation just seaward of the surf zone.

A total of ten surveys was made; two by the USNPGS and the City jointly in 1963, and eight under the supervision of the writer, assisted by City personnel, in 1964.

The writer's contributions toward the accomplishment of the research were: direction of all surveys subsequent to the first two; development of a computer program to reduce all survey data; analysis of the reduced survey data; and description and interpretation of the survey results.

Persons who participated in the field work include, besides the writer, Robin Loftus, Physical Science Aid with the USNPGS, and Norman Dubbs, Robert Ayres, David Bishop, and William Fisher, all of the office of the Monterey City Engineer. Their assistance, especially that of Messrs. Loftus, Dubbs, and Ayres, is gratefully acknowledged. Boats, instruments, and other equipment were made available by both organizations. The study was partially supported by the ONR Institution Grant to the USNPGS.

The area of interest is marked by features which make the oceanographic conditions unusual. The underwater gradient off Del Monte Beach is moderate, and the bottom contours closely parallel the shoreline. Accordingly, no topographic effects are considered to influence the nearshore water circulation other than the gradual shoaling towards shore.

The sheltering effect of the Monterey Peninsula is the largest single factor controlling the wave regime within the extreme southern end of the Bay. This barrier inhibits the generation of wind waves and causes a dominance of swell within the area of study. The moderately sloping bottom and the deep indentation of the Bay combine to produce such intense refraction that breaker heights are ordinarily very low. The wave angle is almost always very small or zero regardless of the orientation of the deep-water wave system outside the Bay. As a result, longshore currents are associated with local surf zone circulation and hence are commonly variable along the beach and temporal in nature. In addition, there are no net long-term longshore currents of any significance on this beach.

2. Equipment.

Current measurements were made using drogues like that shown in figure 3. The current cross, weighted with four two-pound iron sinkers, was suspended from the float by a length of nylon cord. The wooden surface float was filled with styrofoam to increase its bouyancy. Each float supported a staff from which was flown a flag for easy spotting and identification. Two drogues were used in the earlier surveys, and were arranged so that one current cross was suspended at a mean depth of two feet (four feet, in the first survey) below the water surface and the other at eight feet. In later surveys a third drogue was used, with the current cross fourteen feet below the surface.

Each cross was two feet in height, so that it integrated the current in a water layer of that thickness. Thus, the two-foot drogue gave a measure of the current between one and three feet below the surface.

Equipment used ashore consisted of two transits, two walkie-talkies, an accurate clock with a sweep-second hand, and a hand anemometer.

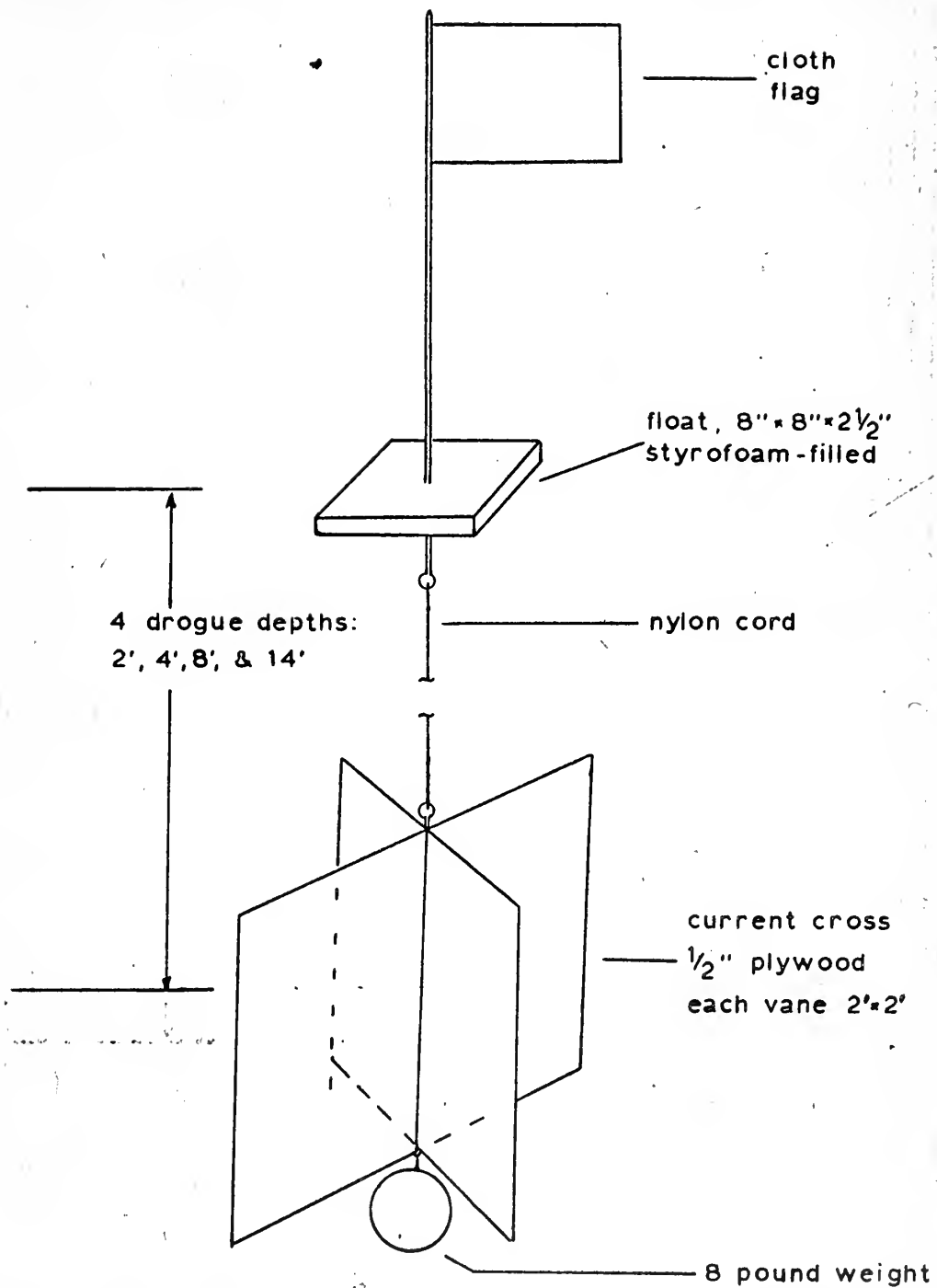


Figure 3. Drogue Design.

3. Survey Procedure.

For every survey the drogues were released from a boat within a few minutes of each other and in approximately the same location about 2000 feet from shore. When the boat had cleared the release area the drogues were tracked visually by the transits from two points on the beach, stations T and P, separated by a baseline of 1812 feet. The baseline was oriented roughly parallel to the shoreline, as shown in figure 4, and the two angles were turned from the baseline. Radio coordination by walkie-talkie allowed bearing observations to be made simultaneously with both transits, thus fixing the geographic position of the drogue at a given time by the intersection of the two lines of position.

Observations were made of each drogue at regular intervals, 10 minutes in most cases, in the following fashion. On the hour and at every ten-minute interval thereafter, observations were made of one drogue, then the second drogue one minute later, and the third drogue (when used) was observed one minute after the second. The drogues were always observed in the same sequence. The eight or nine minute period between each group of drogue sightings was devoted to making observations of wind speed and direction (by hand anemometer), significant height and

period of the breakers, the location of surface slicks, the direction of longshore currents (by drift of flotsam in the surf zone), and manifestations of small-scale circulations such as rip currents.

The durations of the surveys ranged from 40 minutes to 5 hours and 50 minutes. The tracking of an individual drogue was terminated when a drogue: grounded on the bottom; drifted into a quasi-permanent kelp bed and became fast or visibly impeded; was picked up by the boat to prevent its floating to sea; or was picked up by the boat before it drifted into the surf zone where the drogue may have been damaged by breakers or where retrieval would have been dangerous to the boat crew.

4. Data Reduction.

The basic data obtained from each survey were the lists of observation times and angles measured at the two transit sites relative to the baseline for each drogue, and the auxiliary observations mentioned above. Initially, the track of each drogue was reconstructed on a map of scale 1 inch to 200 feet by hand-plotting the angles from the ends of the scaled baseline and connecting the successive points where the simultaneous lines of sight crossed. The course between points was determined by protractor, and the speed was measured by determining the distance travelled and dividing by the time interval between observations. Although this method was satisfactory for intervals during which the drogues moved rapidly, plotting accuracy limited the accuracy of course and speed measurements over intervals of slow drogue movement.

To overcome this difficulty, and also to accelerate reduction of the considerable amount of data, the writer then decided to use the Control Data Corporation 1604 Digital Computer at the USNPGS to produce drogue travel information by trigonometric manipulations.

The objects of the computer program, which is presented in Appendix I and explained in Appendix II, were:

- a. to establish a shoreline trend line approximating

the actual shoreline to serve as an independent reference frame for measuring all water motions;

b. to rotate the coordinate system from the baseline to the shoreline trend line;

c. to calculate alongshore and offshore-onshore components of drogue travel;

d. to calculate speed and direction of drogue travel;
and

e. to machine-plot the trajectory followed by each drogue.

The computer program design incorporates considerable versatility to allow other investigators to adapt it easily to any locality with a baseline of any length or orientation relative to the shoreline for the solution of similar horizontal tracking problems. It also is able to accommodate any time intervals between observations, regular or irregular.

The program, named DROGONE, is written in FORTRAN language. Using the length of the baseline and the angle between the baseline and the shoreline trend as constants, and the sequential observation times and corresponding transit angles measured at the two stations as input variables, the program produces speed and direction of the drogue travel between successive observation times. It also yields running four-point (three-interval) means of drogue speed and

direction. A sample output, for the two-foot drogue on 4 January 1964, is included as Appendix III.

The drogue tracks for each survey, which are shown in figures 4 through 13 and described in detail below, were plotted by a modified version of DROGONE which included the curve-drawing subroutine DRAW from the USNPGS Computer Facility program library.

5. Description of Individual Surveys.

In this section the drogue trajectories for each survey are presented in figures 4 through 13. Also plotted in each figure are the wind and tide variations that accompanied each survey, except for the first two surveys, 15 August and 31 October 1963, for which no wind data were recorded.

The wind observations were obtained by using a hand anemometer atop the tower, station T, at the south end of the baseline, at a height above the water of about 65 feet. The tide curve shown was obtained from a standard recording tide gage installed in Monterey Harbor. The tide heights are relative to an arbitrary datum and can be referred to Mean Lower Low Water by adding two feet to all values. The shoreline and the bottom contours, referred to MLLW, were transferred from U. S. Coast and Geodetic Survey Smooth Sheet 5415 of 1933 and checked against later charts of the area.

Each plot is preceded by a description of the weather and sea conditions that prevailed during the survey. The description also includes auxiliary observations on the occurrence of slicks, white caps, kelp beds, beach cusps, and the behavior of the drogues.

Survey of 15 August 1963. Drogues at 4 feet and 8 feet.

Both drogues moved towards shore initially; then at 1100 they both changed direction sharply, the shallow one moving offshore and the deep one moving parallel to shore. At 1330 they again changed direction sharply, both moving towards shore. The sudden and sharp direction changes, both occurring simultaneously, were not unique to this survey. The approximately 90-degree shear that occurred between the drogue trajectories for the $2\frac{1}{2}$ -hour period beginning at 1100 is particularly interesting.

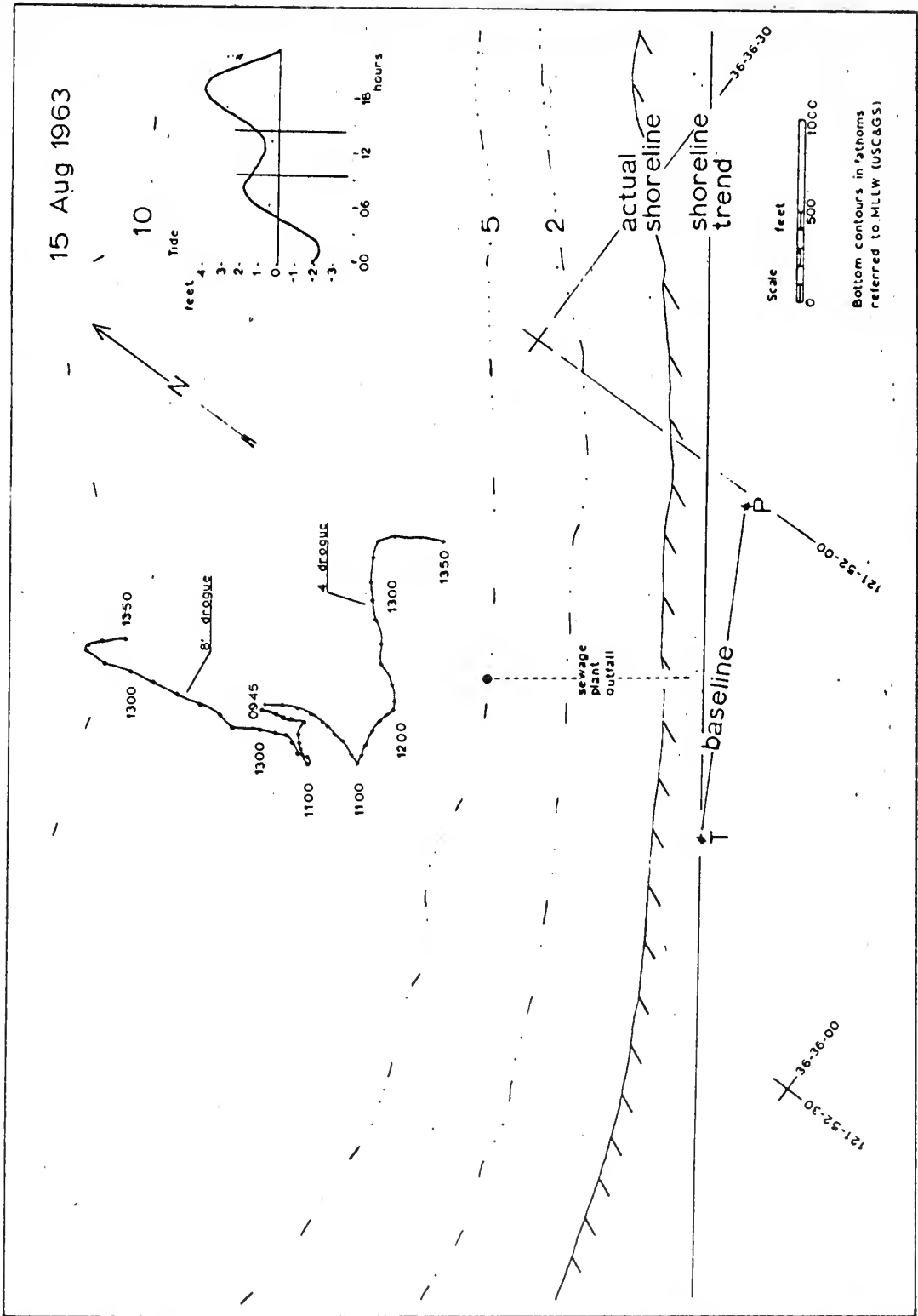


Figure 4. Drogue Trajectories; Survey of 15 August 1963.

Survey of 31 October 1963. Drogues at 2 feet and 8 feet.

From the start of the survey at 0840 when both drogues followed curious trajectories, especially the shallow one, the directions of motion diverged steadily until shortly before 1200 when the shear had reached 90 degrees and suddenly both drogues turned towards shore and accelerated.

The lack of supporting wind and sea data for this and the previous survey is particularly unfortunate since they are the two most intriguing trajectories.

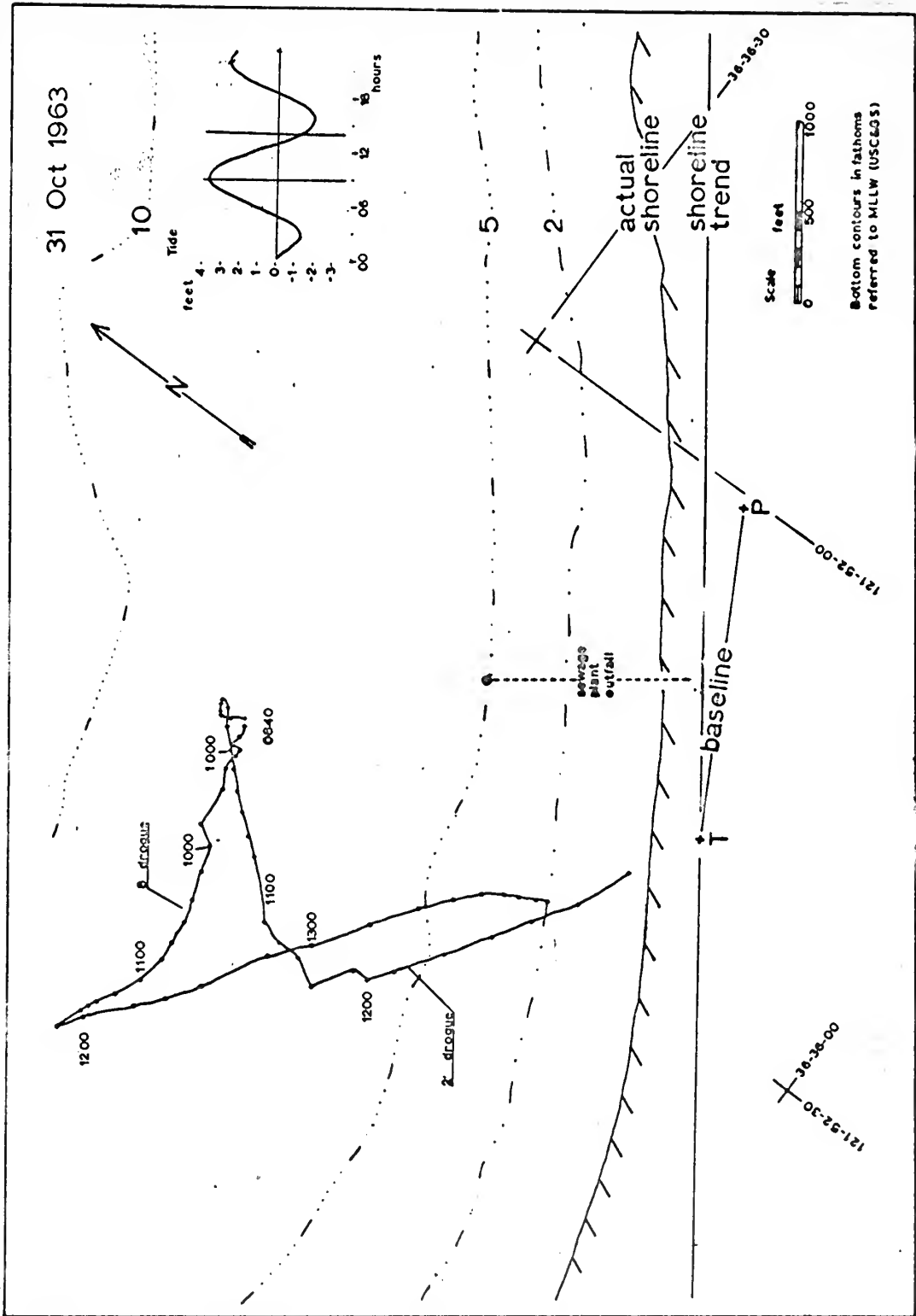


Figure 5. Drogue Trajectories; Survey of 31 October 1963.

Survey of 4 January 1964. Drogues at 2 feet and 8 feet.

The wind was initially very light and offshore, but veered and strengthened until by 1045 the dominant regime for the day, NE at 15 knots, had been established. White caps were present in the survey area from 1130 until about 1230.

The average breaker height was two feet throughout the survey; the average period was ten seconds. Numerous long, narrow slicks oriented parallel to the beach were observed occasionally throughout the day.

Several sports and fishing boats expressed curiosity towards the floats by passing them very slowly and closely, but fortunately there were no attempts to retrieve them. The survey was concluded when both drogues became fouled in a large kelp bed extending from the southwest corner of the Bay.

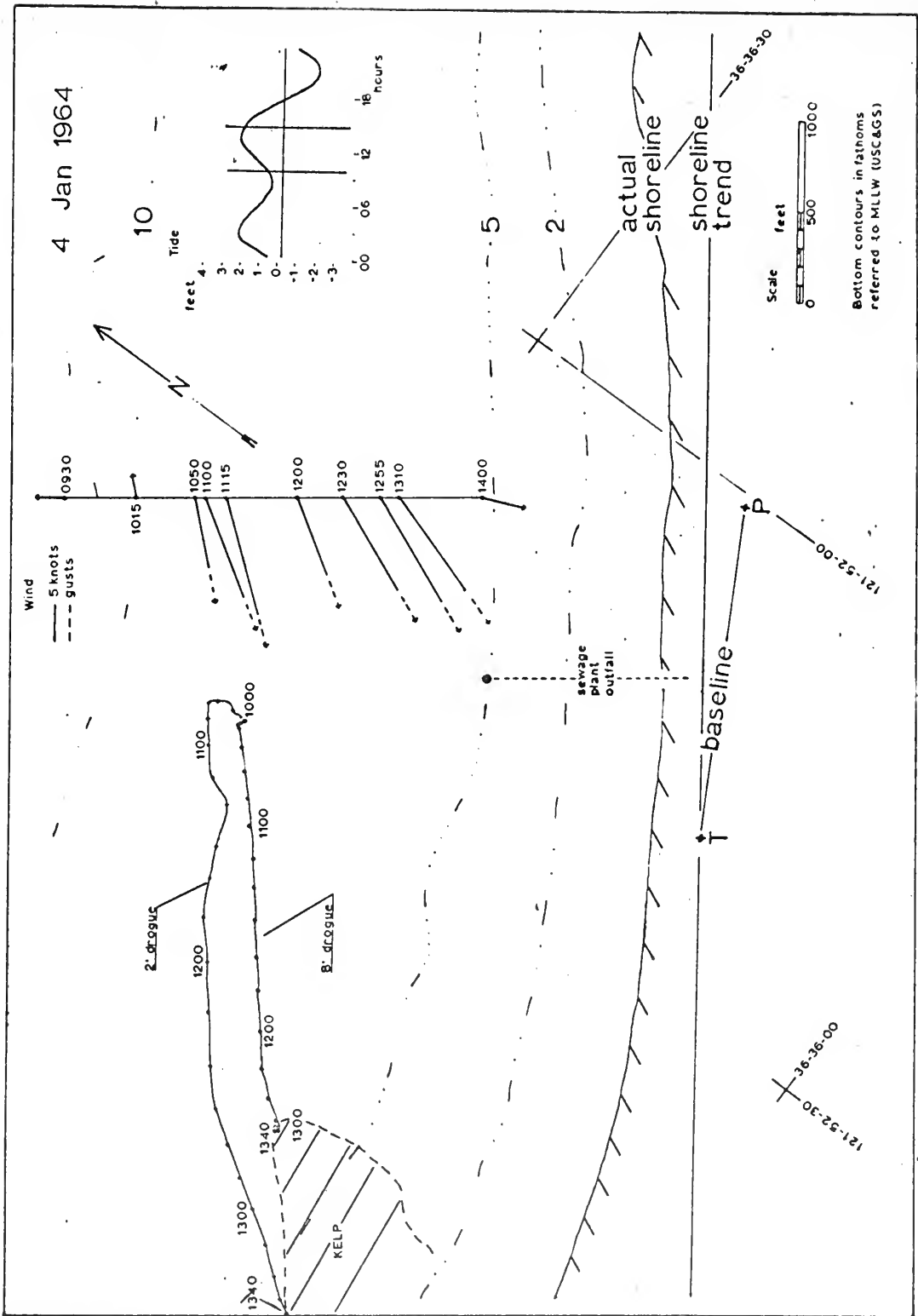


Figure 6. Drogue Trajectories; Survey of 4 January 1964.

Survey of 11 January 1964. Drogues at 2 feet and 8 feet.

The wind was initially light and directly onshore, but veered to the NNE and strengthened to 15 knots by 1015. The average speed remained at 15 knots until the end of the survey. The wind backed to the NNW in the early afternoon. No whitecaps were observed during the survey. The average breaker height was two feet, and the average period was seven seconds.

At 1215 the eight-foot drogue passed directly seaward of a pronounced rip current, which presumably explains the excursion experienced by the drogue from 1210 until 1300. Both drogues occasionally passed through areas of amorphous surface slicks with no apparent effect.

The eight-foot drogue was picked up by the boat while it was in a kelp bed. At the last observation the two-foot drogue was in the surf zone. It was retrieved from shallow water shortly afterward.

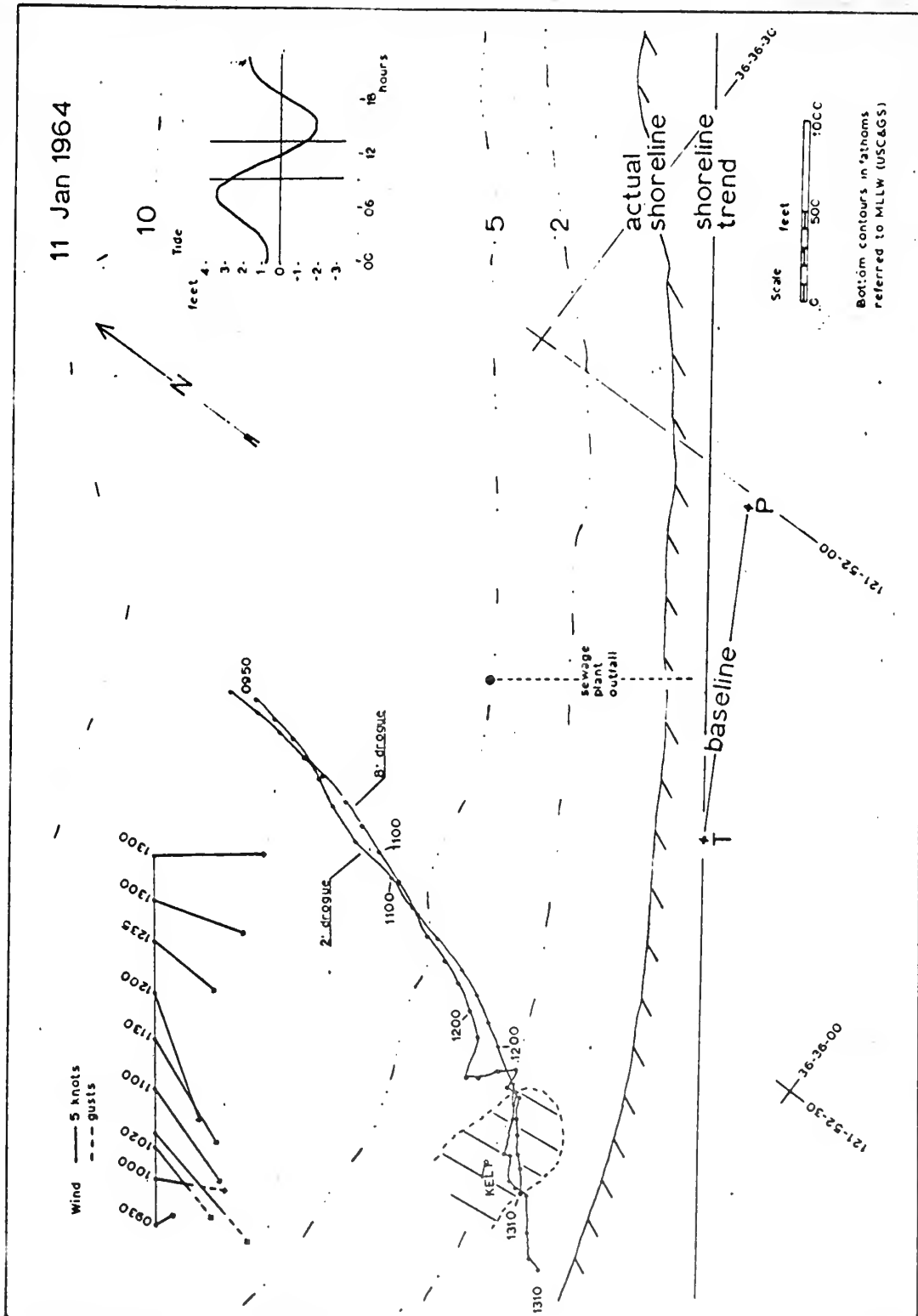


Figure 7. Drogue Trajectories; Survey of 11 January 1964.

Survey of 24 January 1964. Drogues at 2 feet and 8 feet.

Wind conditions throughout the survey were very light, with an average velocity of five knots from the NNE. The average breaker height was 1.5 feet, and the average period eleven seconds.

The sea surface was covered by separate, well-defined non-slick areas separated one from the other by an extensive, continuous slick. At 1430 this pattern disintegrated and the slicks disappeared.

The two-foot drogue was reset after having been fouled in kelp. With darkness impending, both drogues were picked up when the eight-foot drogue drifted into the same kelp bed.

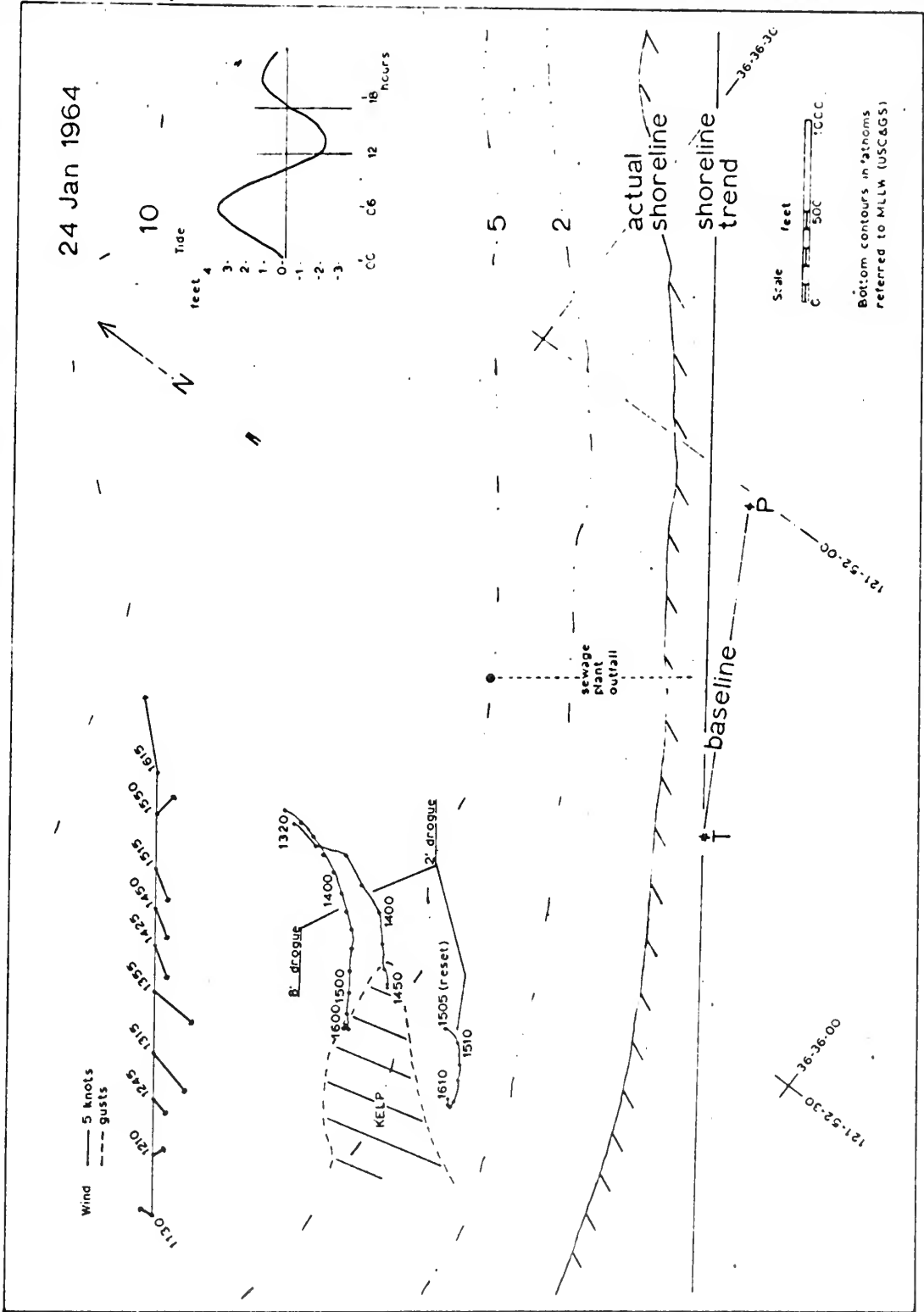


Figure 8. Drogue Trajectories; Survey of 24 January 1964.

Survey of 3 February 1964. Drogues at 2, 8, and 14 feet.

The wind was extremely light. Until long after noon the anemometer just barely registered the direction of the wind, and did not indicate the speed. From 1400 on, the wind was about five knots from the NNE.

The average breaker height was 2.5 feet, and was higher towards the end of the survey than at the beginning. The average period was 16 seconds. Longshore currents in the surf zone were observed to flow towards the NE in the morning, and to the SW in the afternoon.

A feature of the nearshore circulation was shown by the drift of surface floats released at 1225 the same day by other investigators (M.S. Thesis by J. F. Brennan and R. P. Meaux, USNPGS, 1964). One surface float moved NE and finally into shore after having been dropped about 15 yards NE of the City of Monterey outfall boil. The boil, shown in figure 9, marks the effluent from the sewage plant discharge emerging at the surface, and is normally revealed by a surface slick and a flock of birds on the water. Two other floats released at the same time about 30 yards SW of the boil drifted towards the SW.

At 1400 the fourteen-foot drogue began sinking slowly, and at 1540 when only the top of the flagstaff was visible, it was picked up. Although it had been desired to continue

observations of the shallower drogues, signals from the transit station were misunderstood by the boat crew and all drogues were picked up.

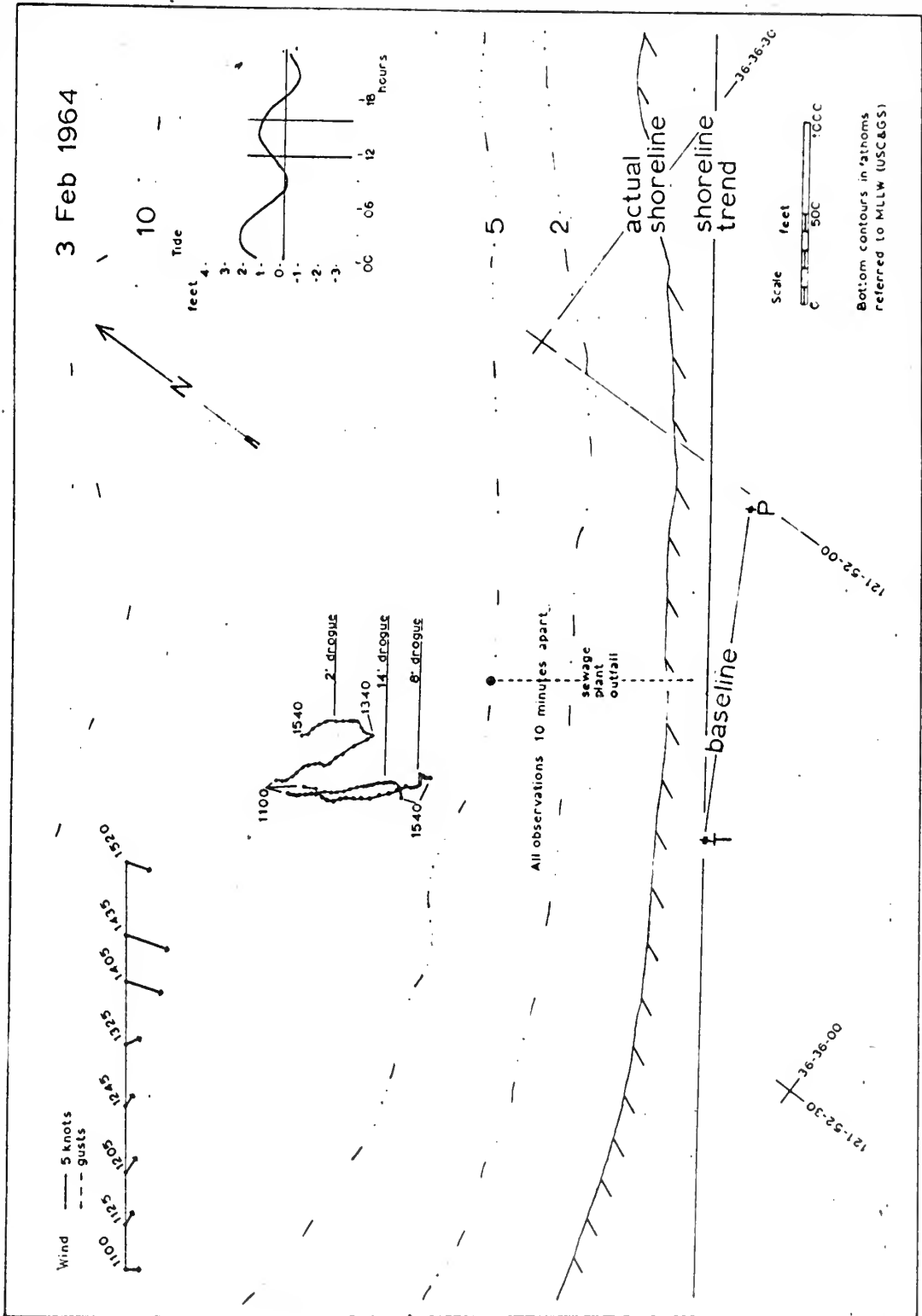


Figure 9. Drogue Trajectories; Survey of 3 February 1964.

Survey of 10 February 1964. Drogues at 2, 8, and 14 feet.

The wind was weak at the beginning of the survey, but from 1020 on it averaged 18 knots from the NW, except for a fluctuation in speed and direction at about 1100. The average breaker height was 1.5 feet, and the average period was 15 seconds.

Observations of flotsam and drifting kelp in the surf zone indicated a negligible longshore current. A large, continuous slick pattern, extending from Monterey Harbor towards the drogue area, existed until 1045. In the afternoon, the only slick visible was that from the outfall boil trailing to the NE.

At 1130 the current cross separated from the float of the eight-foot drogue, and the float capsized. At about 1220 the intersection angles at the two remaining drogues became so acute that the drogues were picked up. The two-foot and the fourteen-foot drogues were repositioned and allowed to drift until they approached the surf zone.

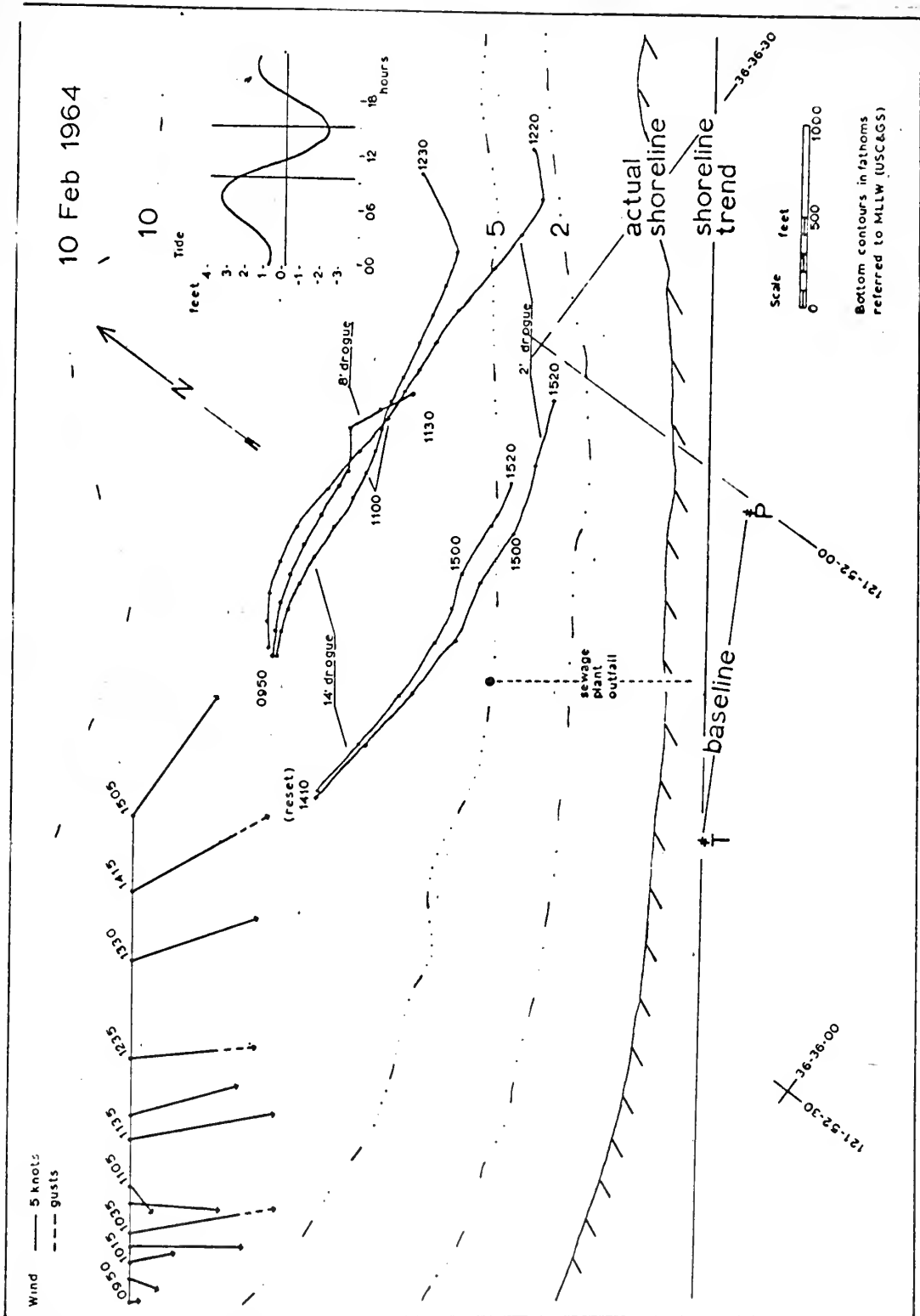


Figure 10. Drogue Trajectories; Survey of 10 February 1964.

Survey of 17 February 1964. Drogues at 2, 8, and 14 feet.

The wind was from a nearly constant direction, NNW, throughout the survey until the last hour and a half during which it backed slowly to the NW. The wind was light until about 1130, after which an average of 14 knots prevailed. A breaker-height observation was not made; the average breaker period was 10 seconds.

Throughout the morning an irregular and diffuse surface slick pattern existed. After noon only the slick emanating from the outfall boil was evident, trailing generally with the wind towards shore.

The two-foot drogue and the fourteen-foot drogue were retrieved by the boat near the surf zone. The eight-foot drogue was picked up in shallow water just off the beach.

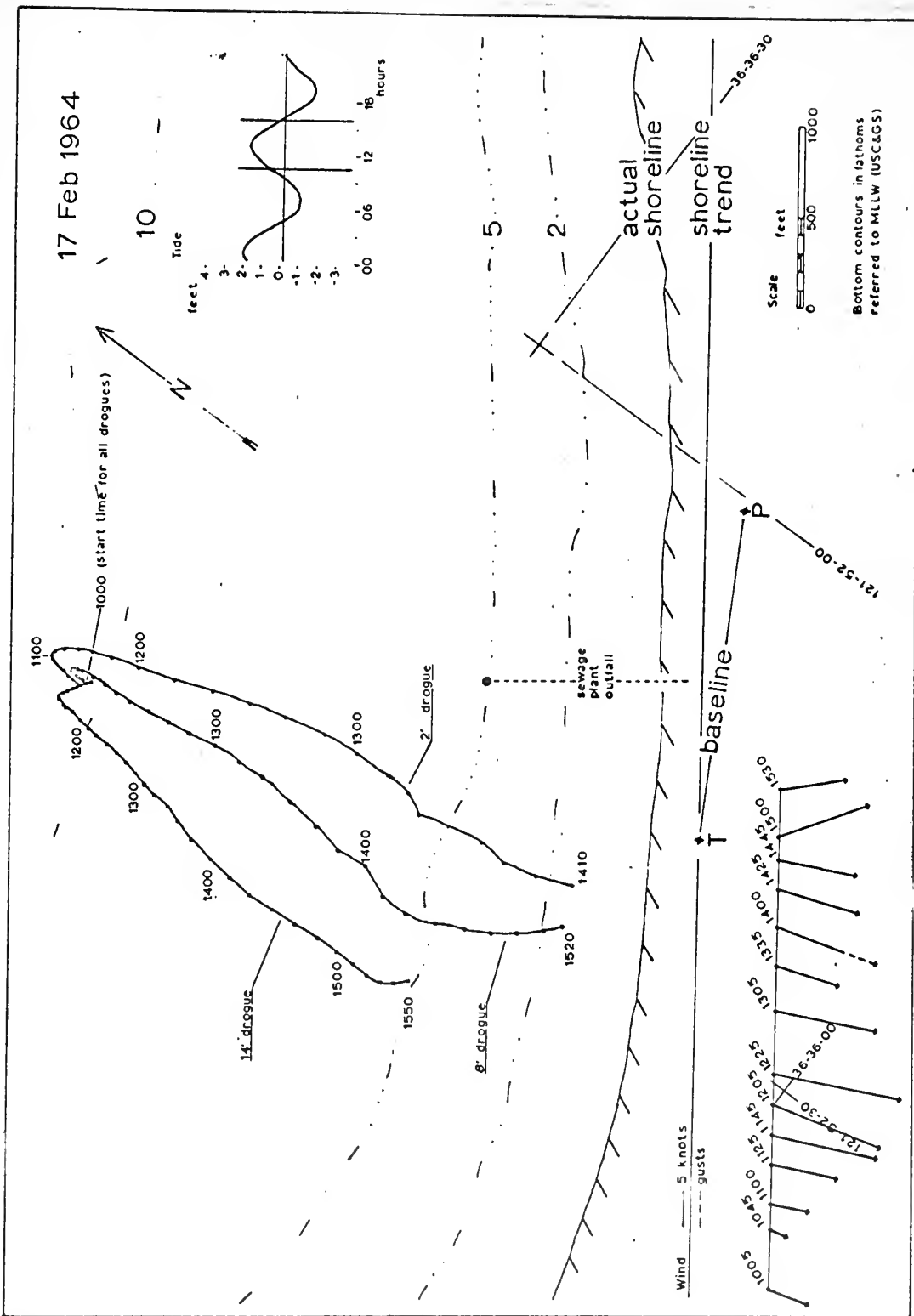


Figure 11. Drogue Trajectories; Survey of 17 February 1964.

Survey of 24 February 1964. Drogues at 2, 8, and 14 feet.

A constant wind regime was never established during this survey. Starting with a very light breeze from the NE, the wind backed and intensified until it was southwesterly at about 15 knots at the end of the survey.

The breaker height was initially about 1.5 feet and increased to about 2.5 feet. The average period was 14 seconds. A longshore current flowing to the SW was observed prior to the beginning of the survey. In the afternoon the longshore current was to the NE, but very weak. Surface slicks were visible throughout the survey, but no patterns persisted, except for the slick area surrounding the outfall boil.

Lack of reliable communications between the controlling transit station and the boat crew resulted in premature drogue retrieval.

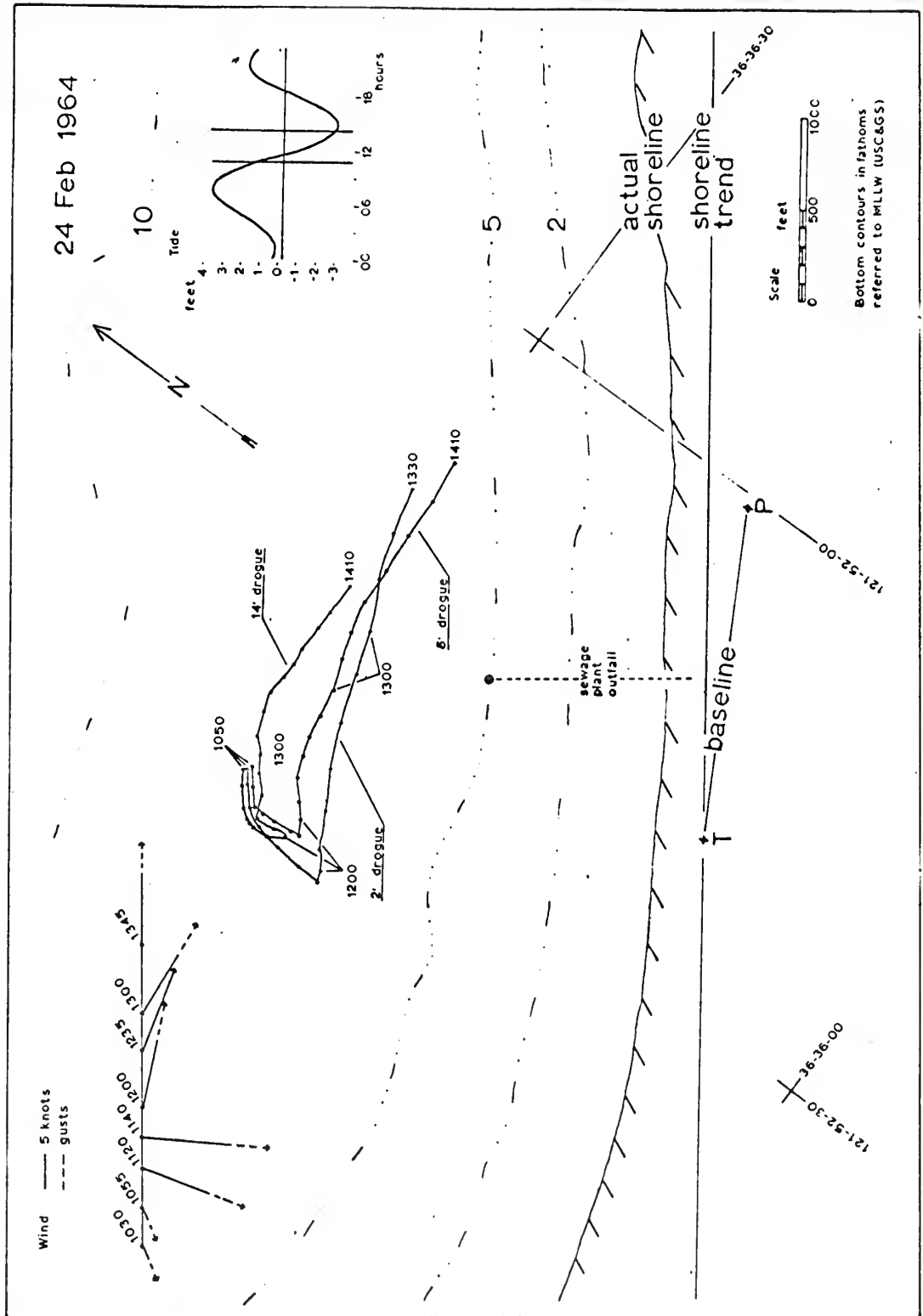


Figure 12. Drogue Trajectories; Survey of 24 February 1964.

Survey of 5 March 1964. Drogues at 2, 8, and 14 feet.

A constant wind regime had been established very early in the morning. Small-craft warnings had been displayed locally since the previous evening. Moderately strong winds with gusts exceeding 25 knots blew almost directly on shore throughout this short survey. The Bay was charged with whitecaps and surface striations aligned parallel to the direction of the wind. The average breaker height was two feet, and the average period seven seconds.

No surface slicks were observed, but a patch of light green water was noted issuing from the area of the outfall boil. No longshore currents existed. Beach cusps were more fully developed than during any preceding survey.

Weather and sea conditions dictated an early drogue pickup.

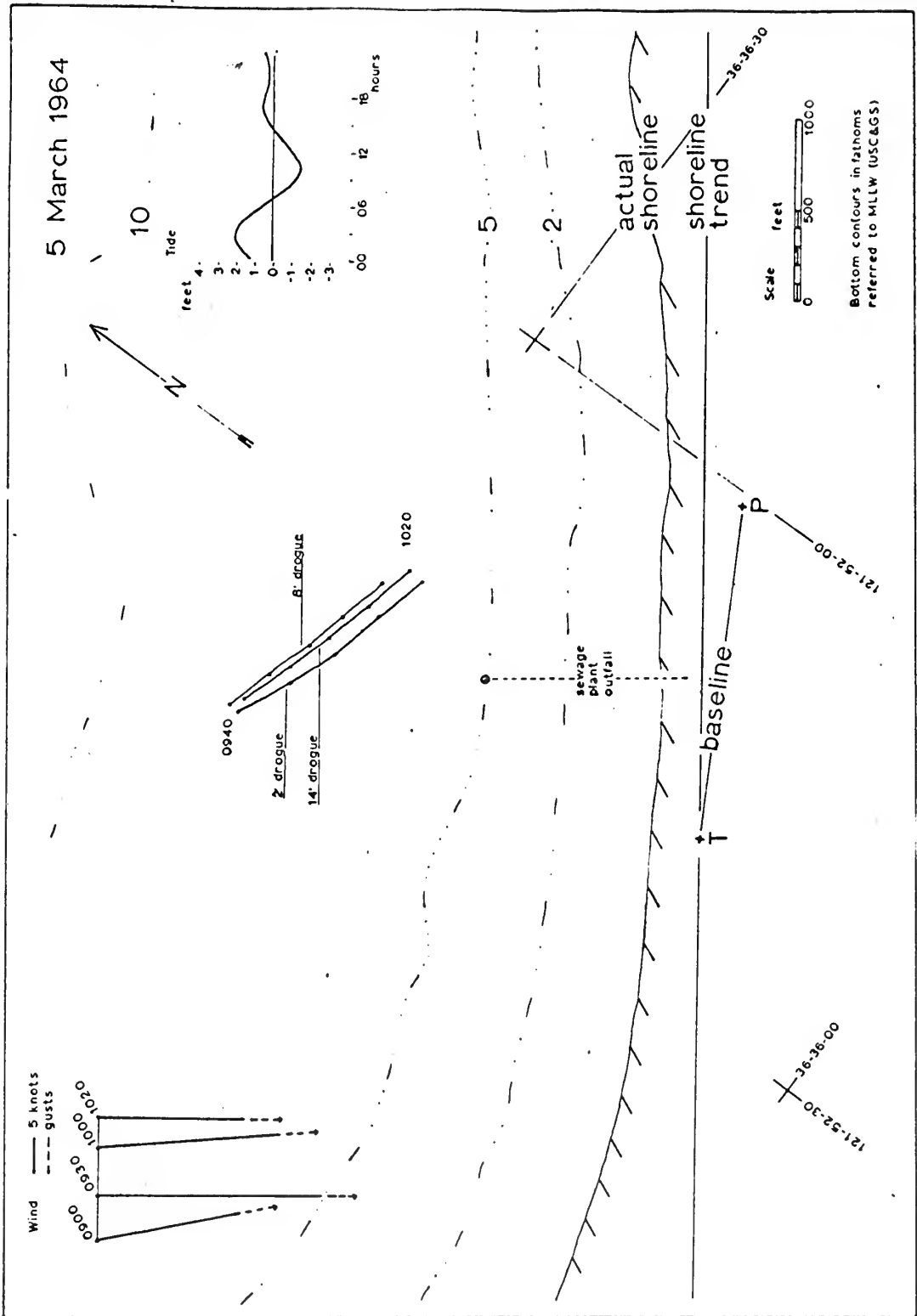


Figure 13. Drogue Trajectories; Survey of 5 March 1964.

6. Analysis of the Drogue Trajectories.

Considering the trajectories of the drogues of all the surveys together, without the evaluation of any possible controlling influences, the investigator observed certain dominant features of the water circulation.

Most drogue tracks are smooth throughout their durations, indicating uniformity in the speed and direction of the water motions. Drogue acceleration, when it is evident, also appears smooth throughout most of the surveys. The plots show an absence of eddies having periods in the range of a few minutes to several hours, as determined by the observation interval and the duration of the surveys. Some drogues made abrupt changes in their directions of travel, for example the drogues on 15 August and 31 October, the 2-foot drogue on 3 February, and all drogues on 24 February. The abruptness of the drogue course changes perhaps is emphasized by the sampling interval, usually ten minutes.

A net transport of water towards shore in the upper 15 feet in the area of study is indicated by the preponderance of shoreward trajectories. Only two drogues travelled any distance offshore (8-foot drogue on 15 August and 8-foot drogue on 31 October), but both eventually turned towards shore. Only one drogue was headed offshore at the time it

was retrieved (2-foot drogue, 3 February). Directly shoreward drift was seldom observed; rather the movement was generally at an angle of about 45 degrees to the shoreline trend, with the flow occurring towards the south (towards Monterey Harbor) a greater proportion of the time than towards the east.

Analysis of the trajectories by drogue depth provided an indication of the velocity profile of the water in the upper fifteen feet. It was found that not only did differences in the speed of drogues at different depths occur, but also large differences in the direction of drogue travel took place.

Most of the time all drogues in a given survey drifted in nearly the same direction; however, there were three cases in which marked directional shear persisted for extended periods. On 15 August and 31 October differences of direction between the 2-foot and 8-foot drogues of about 90 degrees occurred and lasted approximately $2\frac{1}{2}$ and $1\frac{1}{2}$ hours, respectively; on 3 February directional shear of about 180 degrees between the 2-foot drogue and the deeper two continued for two hours, and was terminated by the retrieval of all the drogues.

At all other times, except for brief excursions of individual drogues, drogues at all depths tended to move

in approximately the same direction at a given time. Major course changes tended to be experienced by all drogues of a given survey at the same time, or if a time difference existed, by the upper drogue first, followed by the mid-depth drogue, then by the lower one. About thirty minutes is the maximum lag observed between the turning of the 2-foot drogue and the associated turning of the 14-foot drogue in any survey.

The average speeds of the drogues in each survey were computed, and a summary is presented in table 1. Section A of the table lists the drogue speeds in feet per minute averaged over the common time interval during which all drogues in a given survey were being observed. Section B shows the ratios of the speeds referred to the speed of the eight-foot drogue which was adopted as a reference.

The table shows that a well-defined average vertical gradient of the drogue speeds occurred in nearly every survey, the gradient being directed downward, as expected, in all but the first and the last surveys. The averages of all the ratios, in the order of upper drogue to lower, are 1.2 : 1.0 : 0.9.

A visual examination of each drogue plot indicated that surface and subsurface water flowed slower or faster in coincidence. Where accelerations in the flow occurred,

TABLE 1
Average Drogue Speeds

Drogue Depth Date	A.			B.		
	Average Speeds (fpm)			Standardized Average Speeds		
	2 Feet	8 Feet	14 Feet	2 Feet	8 Feet	14 Feet
10/31	14.11	14.71	-----	0.96	1.0	-----
1/04	16.84	12.70	-----	1.32	1.0	-----
1/11	18.40	17.26	-----	1.07	1.0	-----
1/24	14.92	10.97	-----	1.36	1.0	-----
2/03	3.79	2.66	2.36	1.42	1.0	0.89
2/10	21.29	17.35	16.09	1.23	1.0	0.93
2/17	13.74	10.53	7.83	1.30	1.0	0.74
2/24	17.28	13.58	10.52	1.27	1.0	0.78
3/05	30.50	25.98	28.30	1.16	1.0	1.09

Section A. Average speed of each drogue during corresponding time periods during each survey.

Section B. Average speed of each drogue during corresponding time periods during each survey referred to the average speed of the 8-foot drogue.

the deeper drogues reacted successively later than the surface drogue, thus indicating the source of the acceleration to be at the sea surface. A particularly good example of a survey displaying accelerations is shown in figure 11 for 17 February.

7. Interpretation of the Drogue Trajectories.

In an attempt to determine the factors controlling the circulation patterns observed, the investigator studied the trajectories in the light of the wind conditions prevailing during each survey, the attendant tidal fluctuations, and bottom shoaling effects. It is regrettable that no wind information is available for the first two surveys, because those drogue paths are the most excursive of the entire survey series. An analysis and explanation of the velocity shear indicated by those two plots would enhance the value of the entire investigation.

A summary of the results of the examination of drogue travel in relation to the wind is presented in table 2. To eliminate the effects of transient conditions in this analysis, certain criteria were adopted to determine which parts of the data from each survey should be treated. Those periods during which the wind direction or the drogue direction was not steady were not considered. Hence the time periods during which the wind made a major change in direction and the subsequent lengths of time for the drogues to adjust to the new conditions were not used in this examination. In addition, those periods during which the wind speed was not at least five knots were not treated, nor were those times when the drogues were fouled in kelp.

TABLE 2

Drogue Travel in Relation to the Wind.

Date	Drogue Depth						Average Wind Speed
	2 Feet		8 Feet		14 Feet		
	$\bar{\alpha}$	σ	$\bar{\alpha}$	σ	$\bar{\alpha}$	σ	
1/04	R 14°	12°	R 11°	6°	---	---	14 Knots
1/11	R 10°	9°	R 6°	12°	---	---	15 "
1/24	R 9°	25°	R 16°	14°	---	---	6 "
2/03	R 73°	100°	R 50°	12°	R 52°	11°	5 "
2/10	L 37°	15°	L 56°	5°	L 43°	16°	18 "
2/17	R 12°	15°	R 20°	9°	R 34°	12°	14 "
2/24	R 9°	9°	R 8°	9°	R 19°	10°	12 "
3/05	L 30°	5°	L 33°	3°	L 32°	2°	28 "

Average deflection angle ($\bar{\alpha}$) is the statistical average angle between the direction of the wind and direction of drogue travel measured right (R) or left (L) of the wind direction.

The standard deviation (σ) is the statistical measure of scatter about the average angle.

The analysis performed upon the remaining observations consisted of referring all drogue motion to the direction of the wind. The deflection angles between the successive unit courses and the associated wind directions were computed, and their statistical means and deviations were calculated. These parameters are listed in the table for each drogue. It should be noted at this point that the wind was measured on a tower about 250 feet inland at a height of approximately 65 feet above the water. No attempt was made to refer the observations to a more nearly standard level.

On only two days did the drogues proceed in an average direction to the left of the wind, and in those cases the deflection was to the left at all depths. On both of those days, 10 February and 5 March, the wind blew almost directly onshore for the duration of the survey, the only days on which this condition existed. The investigator postulates that the boundary effect of the shoaling bottom and the shoreline were the factors controlling this anomalous water deflection. Not considering the results of the two days mentioned above, there was a tendency for the deeper water to be deflected farther to the right of the wind than the overlying water, in agreement with Coriolis considerations in water beyond boundary constraints.

Table 1 shows that the current speeds varied approximately with the wind speed, and ranged from 2 feet per minute associated with a 2-3 knot wind (survey of 3 February) to 40 fpm with an 18 knot wind (survey of 10 February). A study of the standard deviation columns of table 2 shows that the direction of water transport at all depths was closer to the average direction at higher wind speeds. Examination of the times of direction changes of the wind and of the water shown on the current charts reveals that whenever a wind shift occurred, the water direction changed almost immediately, as is illustrated in figure 12 for the survey of 24 February.

The close agreement of the speed and direction trends of both the wind and the water leaves no doubt that the main factor controlling the water movement was the wind.

Besides the possible effect of the rip current noted in the description of the 11 January survey and the two days in which deflection of water to the left of the wind is attributed to boundary conditions, no direct effects of the bottom boundary or the shoreline could be found. It may be seen that individual drogues increased their speed over the period of the last few observations in several surveys, for example, 10 and 24 February. This acceleration might be attributed to the effect of the increase in speed of the wave current as the wave steepness increases in approaching

the breaker point. However, there were other cases where drogues decelerated in approaching the surf zone, for example, the eight-foot drogue on 31 October. The surf zone generally extended about 200 feet out from shore. Only seldom did drogues come within 500 feet of the shoreline during the conduct of the surveys. The writer deduces that the wave current was of little consequence in producing water transport.

It was noted earlier that the preponderance of drogue drift was shoreward. The investigator can only ask (as surely the reader has), "Where does the water go?" Does a compensatory offshore flow exist below the levels measured? Does the tidal rise in water level accommodate the additional water? The writer can make no presumptions about motions below the levels of measurement or without the area of study. The effects of the astronomical tides are difficult to evaluate because of the obviously dominating effect of the wind. Onshore motion was observed through all stages of the tide on various days.

With the aim of finding a tidal influence on the water-motion patterns, the investigator considered those intervals during the several surveys in which the wind speed was less than five knots, and examined the directions of drogue travel and the attendant tides. No consistent

circulation pattern, either alongshore or offshore-onshore, could be related to any section of the tidal curve. Thus the investigator considered the tidal effect upon the circulation of water in the area of study to be negligible in contrast to the influence of the wind.

On the basis of this study, the investigator concludes that off the beach studied:

a. water at all levels down to at least fifteen feet responds to and closely follows the wind, regardless of the tide and waves, when the wind speed exceeds about five knots;

b. the horizontal component of water motion decreases with depth when the water moves in response to the wind, and displays a deflection to the right of the wind; and

c. time lags up to about ten minutes at the surface, and up to about twenty minutes for water at 15 feet, exist between changes in the character of the wind and adjustment of the water motions to those changes.

APPENDIX I

COMPUTER PROGRAM DROGONE

```

PROGRAM DROGONE
DROGONE IS DESIGNED TO PROCESS OCEAN CURRENT DATA. BY EMPLOYING
A TRANSIT AT EACH END OF A BASELINE OF KNOWN LENGTH ON THE BEACH,
AN INVESTIGATOR CAN MEASURE THE INTERIOR ANGLES BETWEEN THE
BASELINE AND THE LINE OF SIGHT TO AN OBJECT FLOATING AT SEA AT
INTERVALS, AND THUS FIX THE SEQUENTIAL POSITIONS OF THE FLOAT.
DROGONE USES THE SEQUENTIALLY MEASURED PAIRS OF ANGLES AND THE
CLOCK TIME OF EACH MEASUREMENT TO DETERMINE COURSE AND SPEED MADE
GOOD (OVER THE GROUND) BETWEEN EACH SPEED.
THREE-INTERVAL MEANS OF COURSE AND SPEED.
RATHER THAN BASE COURSES ON NORTH, COURSES ARE BASED ON THE DIREC-
TION PERPENDICULAR TO THE TEND OF THE SHORELINE, SENSE TO SEA
BEING 000, WITH COURSE INCREASING TO THE RIGHT IN THE CONVENTIONAL
MANNER THROUGH 360 (000). THUS 180 IS DIRECTLY SHOREWARD.
THETA IS THE ANGLE BETWEEN BASELINE AND 000.
THETA = 97.0 / 57.29578
SINT = SIN(THETA)
COST = COS(THETA)
BASLIN=1812.
DIMENSION TIME(40), ANGT(40), ANGP(40), CORANGT(40), CORANGP(40),
IX(40), Y(40), DIST(39), CS(39), SPDFPM(39), SPDFPS(39), SPDCPS(39),
2SPDKTS(39), AVCS(38), AVFPM(38), AVFPS(38), AVCPS(38), AVKTS(38),
3DEPTH(40), DATE(40)
1001 DO 60 II=1, 40
C READ 900, TIME(II), ANGT(II), ANGP(II), DEPTH(II), DATE(II)
IF (TIME(II)) 61, 61, 60
C TIME 0000 WILL BE LAST DATA CARD.
60 CONTINUE
STOP 60
61 NUM = II-1
900 FORMAT (F15.0, 2F10.1, F10.0, F10.2)

```

Section

A

B

C

D

E


```

1799 PRINT 1799
1800 FFORMAT (1H1 //////////////)
1800 FFORMAT (114H THIS PAGE CONTAINS INFORMATION DISPLAYED IN COLUMNS WH
1107H INCLUDE MEASURED DATA AND COMPUTED DISTANCES USED BY THE //,
3ETC.) WHICH WILL BE FOUND ON FOLLOWING PAGES. //,
4119H OBS (OBSERVATION) NUMBER, CLOCK TIME, ANGLE T AND A
5NGLE P ARE THE INPUT DATA AND REPRESENT THE SEQUENTIALLY //,
654H MEASURED TRANSIT ANGLES AND TIMES OF MEASUREMENT. //,
7117H BASE AND HEIGHT ARE DISTANCES (IN FEET) FROM THE CON
8TROL END OF THE BASELINE (TOWER) ALONG THE BASELINE AND)
PRINT 1801
18010 FFORMAT(116H PERPENDICULAR TO THE BASELINE (RESPECTIVELY) TO TH
1E DROGUE POSITION AT THAT TIME, IE BASE AND HEIGHT OF A RIGHT //,
2 99H TRIANGLE. A NEGATIVE PASE INDICATES THE DROGUE IS TO THE
3 LEFT (LOOKING SEAWARD) OF THE TOWER. //,
4117H X AND Y ARE SIMILARLY //, THE BASE AND HEIGHT OF A RI
5GHT TRIANGLE, BUT RELATED TO THE SHORELINE TEND RATHER. //,
6 82H THAN THE BASELINE. ANGLE BETWEEN BASELINE AND SHORELINE I
7S SEVEN (7) DEGREES.)
PRINT 1802
18020 FFORMAT( 92H DEPTH IS DISTANCE (IN FEET) OF CURRENT-CROSS
1BELOW SURFACE FOR DROGUE IN QUESTION. //,
2 46H DATE IS MONTH-DECIMAL-DATE OF SURVEY, //, //, H (HT
3102H OBS NUMBER CLOCK TIME ANGLE T ANGLE P B (BASE)
4) X Y DEPTH DATE, //)
G DO 700 I = 1, NUM
C SINCE THE TRANSITS MEASURE ANGLES CLOCKWISE FROM THE BASE LINE,
C CORRECTED ANGLES (CORANGT AND CORANGP) ARE COMPUTED BELOW AND
C USED THROUGHOUT THE MACHINE COMPUTATIONS.
H CORANGT(I) = 360.0 - ANGT(I)
I CORANGP(I) = 180.0 - ANGP(I)
J AT = CORANGT(I) / 57.29578
AD = AP - AT
K PSIDE = SINP(AP) * BASLIN / SINP (AD)
C PSIDE IS SIDE OF TRIANGLE OPPOSITE ANGLE P (ANGP), THUS DISTANCE
C FROM T TO FLOAT
B = PSIDE * COSP (AT)
H = PSIDE * SINP(AT)
C B AND H ARE BASE AND HEIGHT OF RT TRIANGLE. B IS MEASURED FROM T
C ALONG BASELINE. H IS PERPENDICULAR FROM FLOAT TO BASELINE.
C FOLLOWING STATEMENTS CONVERT MEASUREMENTS FROM BASELINE TO
C SHORELINE RELATIONSHIP BY TRANSFORMATION OF COORDINATES.
L X(I) = -H * COST + B * SINT
Y(I) = B * COST + H * SINT
M PRINT 901, I, TIME(I), ANGT(I), ANGP(I), B, H, X(I), Y(I),
1DEPTH(I), DATE(I)
901 FFORMAT (110,F13.0, 6F10.1, F10.0, F10.2)
700 CONTINUE

```


STATEMENTS 100, 101 AND 102 CONVERT CLOCK TIME TO ELAPSED TIME
 BETWEEN OBSERVATIONS IN A MANNER SUCH THAT FROM 0950 TO 1000 IS
 10 MINUTES RATHER THAN 50 MINUTES.

TIME1 = INTF(TIME(I)/100.) * 60. + MODF(TIME(I),100.)
 TIME2 = INTF(TIME(I+1)/100.) * 60. + MODF(TIME(I+1),100.)
 DELTIME = TIME2 - TIME1

SPDFPM(I) = DIST(I)/DELTIME
 SPDFPS(I) = 0.017 * SPDFPM(I)
 SPDCPS(I) = 0.508 * SPDFPM(I)
 SPDKTS(I) = 0.009 * SPDFPM(I)

OPRINT 902, I, TIME(I), DELTIME, DIST(I), CS(I), SPDFPM(I),
 1SPDFPS(I), SPDCPS(I), SPDKTS(I), DATE(I)
 902 FORMAT (I9, F10.0, F8.0, F12.2, F10.1, 4F10.3, F20.2, F10.2)
 89 CONTINUE

PRINT 1999
 1999 FORMAT (1H1 //) //

20000FORMAT(117H THIS PAGE CONTAINS COMPUTED AVERAGES OF DROGUE TRAVEL P
 1PARAMETERS DISPLAYED SIMILARLY TO THOSE ON THE PRECEDING PAGE.//, TH
 2 83HRUNNING FOUR-POINT (THUS THREE-INTERVAL) MEANS ARE SHOWN AS
 3E INDICATED AVERAGES.//, 103H SPAN INDICATES THE GROUP OF
 4 INTERVALS CONSIDERED.//, 103H DROGUE TRAVEL FROM OBSERVATION 1 TO 4,
 5//, 49H (INTERVALS 1, 2, AND 3) ARE SHOWN AS SPAN 2.//, 64H
 6 //, 49H START IS THE CLOCK TIME OF FIRST OBSERVATION OF SPAN.//,
 7 80H RUN IS THE LENGTH OF TIME IN MINUTES BETWEEN OBSERV
 8ATIONS CONSIDERED.//, 76H DISTANCE IS SUM ON INDIVIDUAL
 9DISTANCES OF INTERVALS WITHIN SPAN.)
 PRINT 2001

20010FORMAT(109H AVERAGE COURSE IS DIRECTION FROM FIRST OBSER
 1VATION OF SPAN TO LAST OBSERVATION OF SPAN MEASURED AS, //, 29H
 2COURSE ON PREVIOUS PAGE.//, 101H AVERAGE SPEED IS COMPUTE
 3D BY DISTANCE DIVIDED BY RUN AND IS INDICATED AS ON PREVIOUS PAGE.
 4//, 80H AVSPEED //, 118H FPS START KTS
 5SPEED AVSPEED AVSPEED //, 118H FPS START KTS
 6NCE COURSE FPM
 7 DEPTH DATE, //)

NUMM = NUMM - 2
 DO 160 J = 1, NUMM
 IDELY = Y(J+3) - Y(J)
 TDELX = X(J+3) - X(J)
 TDIST = DIST(J) + DIST(J+1) + DIST(J+2)

	151	IF (TDELY) 151,152,153
	152	IF (TDELX) 141,142,143
	153	IF (TDELX) 144,145,146
	141	IF (TDELX) 147,148,149
	141	AVCS(J+1)=270.-ATANF(TDELY/TDELX)*57.29578
	142	GO TO 200
	142	AVCS(J+1)=180.0
	143	GO TO 200
R'	143	AVCS(J+1) = 090. + ABSF(ATANF(TDELY/TDELX)) * 57.29578
	144	GO TO 200
	144	AVCS(J+1)=270.0
	145	GO TO 200
	145	AVCS(J+1)=000.0
	146	GO TO 200
	146	AVCS(J+1)=090.0
	147	GO TO 200
	147	AVCS(J+1)=270.+ABSF(ATANF(TDELY/TDELX))*57.29578
	148	GO TO 200
	148	AVCS(J+1) = 000.0
	149	GO TO 200
	149	AVCS(J+1)=90.-ATANF(TDELY/TDELX)*57.29578
C	200	SEE COMMENT BEFORE STATEMENT 100.
S'	200	TTIME1 = INTF(TIME(J)/100.) * 60. + MODF(TIME(J),100.)
		TTIME2 = INTF(TIME(J+3)/100.) * 60. + MODF(TIME(J+3),100.)
T'		TDELTIM = TTIME2 - TTIME1
		AVFPM(J+1) = TDELTIM
		AVFPM(J+1) = 0.017 * AVFPM(J+1)
		AVFPM(J+1) = 0.508 * AVFPM(J+1)
		AVKTS(J+1) = 0.009 * AVFPM(J+1)
		K=J+1
U'	903	OPRINT 903, K, TIME(J), TDELTIM, TDIS, AVCS(K), AVFPM(K),
	903	1AVEPS(K),AVCPS(K),AVKTS(K),DEPT+(J),DATE(J)
	160	FORMAT (19, F10.0, F8.0, F12.2, F10.1, 4F10.3, F20.2, F10.2)
	160	CONTINUE
		GO TO 1001
W		STOP
		END
		END

APPENDIX II

EXPLANATION OF PROGRAM DROGONE

1. Glossary. Refer to figures 14 through 17.

DROGONE	Name of program; FORTRAN language names are limited to seven characters.
THETA	Angle between survey baseline and a line perpendicular to the shoreline trend; figure 14.
SINT	Sine of angle THETA.
COST	Cosine of angle THETA.
BASLIN	Baseline; distance between transit station; figure 14.
(II)	FORTRAN subscript notation; as the program directs processing of the survey data, II becomes 1,2,3... in accordance with the observation number being treated.
NUM	Number of observations made during a particular survey.
(I)	Subscript notation used similarly to (II).
ANGT	Angle measured at transit station T in degrees; figure 14.
CORANGT	Corrected angle at T; $360^\circ - \text{ANGT}$; figure 14.
ANGP	Angle measured at transit station P in degrees; figure 14.
CORANGP	Corrected angle at P; supplement of ANGP; figure 14.
AT	CORANGT in radian measure; figure 14.
AP	CORANGP in radian measure; figure 14.
AD	Angle at drogue between the lines of sight from the two transits measured in radians; figure 14.

PSIDE Side of triangle opposite station P in triangle whose apices are stations T and P and the drogue position; figure 15.

B, BASE Base of right triangle formed by dropping a perpendicular from the drogue position to the baseline and including the angle at station T; figure 15.

H, HEIGHT Height of right triangle described above; figure 15.

X Base of right triangle formed by dropping a perpendicular from the drogue position to the line through station T parallel to the shoreline trendline; figure 15.

Y Height of the right triangle described immediately above; figure 15.

INT, INTERVAL Time interval between two consecutive drogue observations; figures 16 and 17.

NUMM Number of intervals between observations made during a particular survey; if the number of observations is NUM, the number of intervals is NUM-1.

DELY Difference between successive lengths of Y (described above); figure 16.

DELX Difference between successive lengths of X (described above); figure 16.

DIST Distance travelled by drogue in one interval (between two consecutive drogue positions); figure 16.

CS Course, or direction, of drogue travel during one interval measured in degrees from 000° clockwise to 360° (where 000° is the offshore direction); figure 16.

TIME 1 Time of the first of two observations marking a particular interval, corrected for use in the computer.

TIME 2 Time of the second of two observations marking a particular interval, corrected for use in the computer.

DELTIME Time interval between two consecutive observations, in minutes.

SPDFPM Speed of the drogue, in feet per minute, during the interval between two consecutive observations.

SPDFPS Speed of the drogue, in feet per second, during the interval between two consecutive observations.

SPDCPS Speed of the drogue, in centimeters per second, during the interval between two consecutive observations.

SPDKTS Speed of the drogue, in knots, during the interval between two consecutive observations.

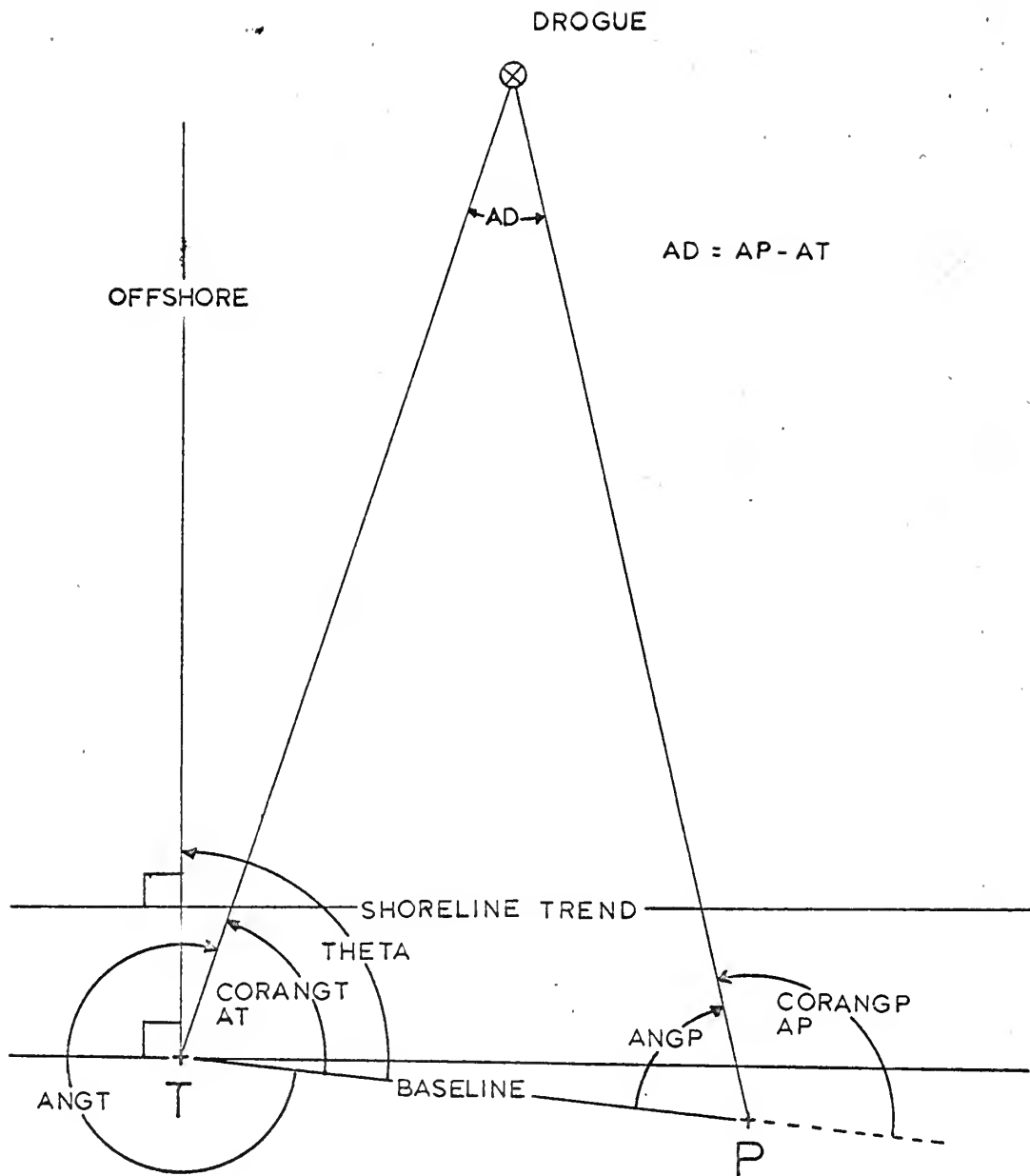
SPAN Period between the time of one drogue observation and the time of the third following observation; one SPAN includes three INTERVALS; figures 16 and 17.

NUMMM Number of spans included in a particular survey; NUM-3, or NUMM-2.

TDELY,
TDELX,
TDIST,
TTIME 1,
TTIME 2,
TDELTIM Similar to those parameters without the initial "T" described above, but referring to the duration of a span rather than to the duration of an interval.

AVCS Average course, or direction, of drogue travel during a span, measured in the same manner as CS; figure 16.

AVFPM
AVFPS
AVCPS
AVKTS Average speed of the drogue during a span, measured in the same speed units described above.



$$\text{CORANGT}(\text{°}) = 360\text{°} - \text{ANGT}(\text{°})$$

$$\text{AT}(\text{radians}) = \text{CORANGT}(\text{°})$$

$$\text{CORANGP}(\text{°}) = 180\text{°} - \text{ANGLEP}(\text{°})$$

$$\text{AP}(\text{radians}) = \text{CORANGP}(\text{°})$$

Figure 14. Survey Geometry.

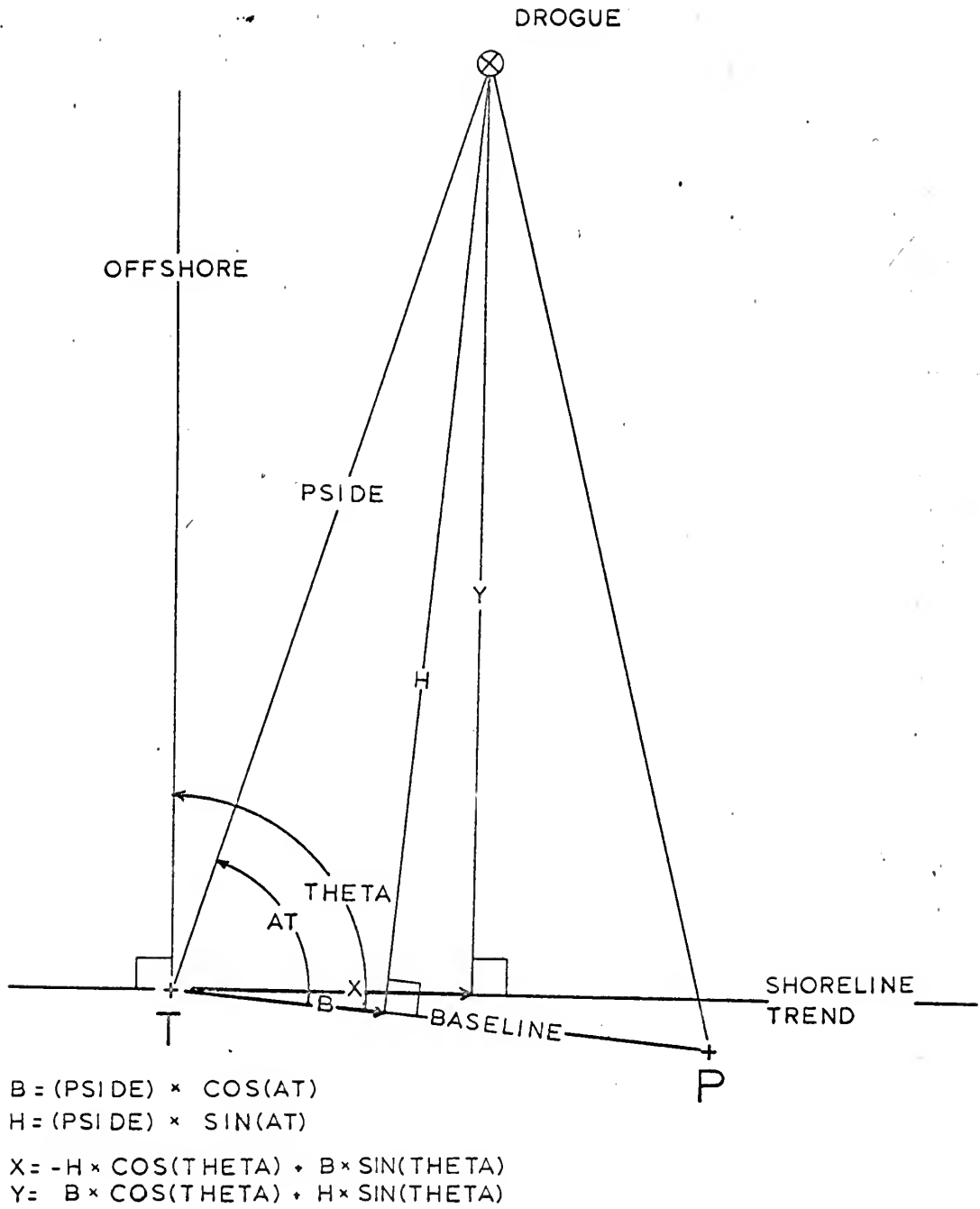


Figure 15. Survey Geometry, continued.

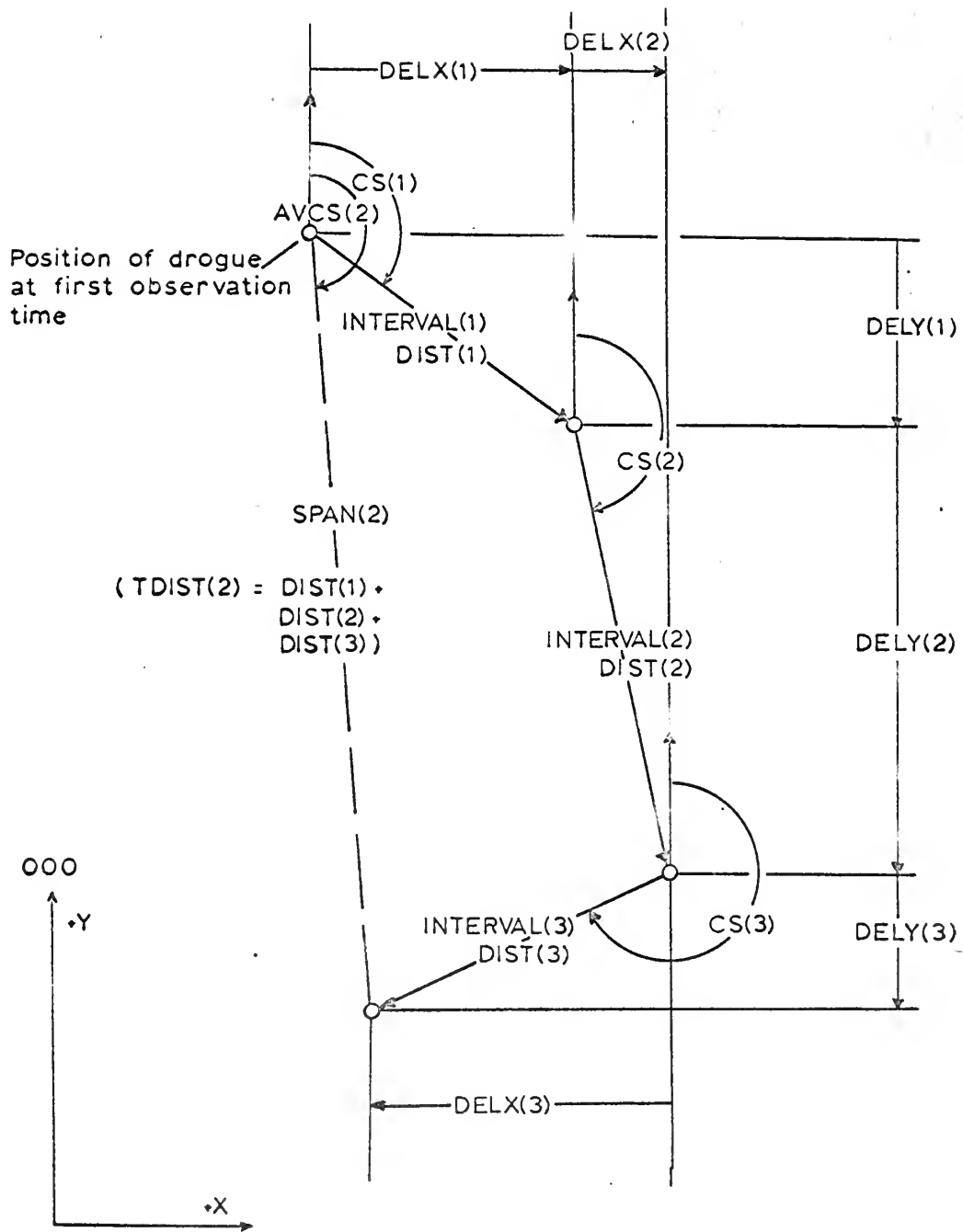


Figure 16. Survey Geometry, continued.

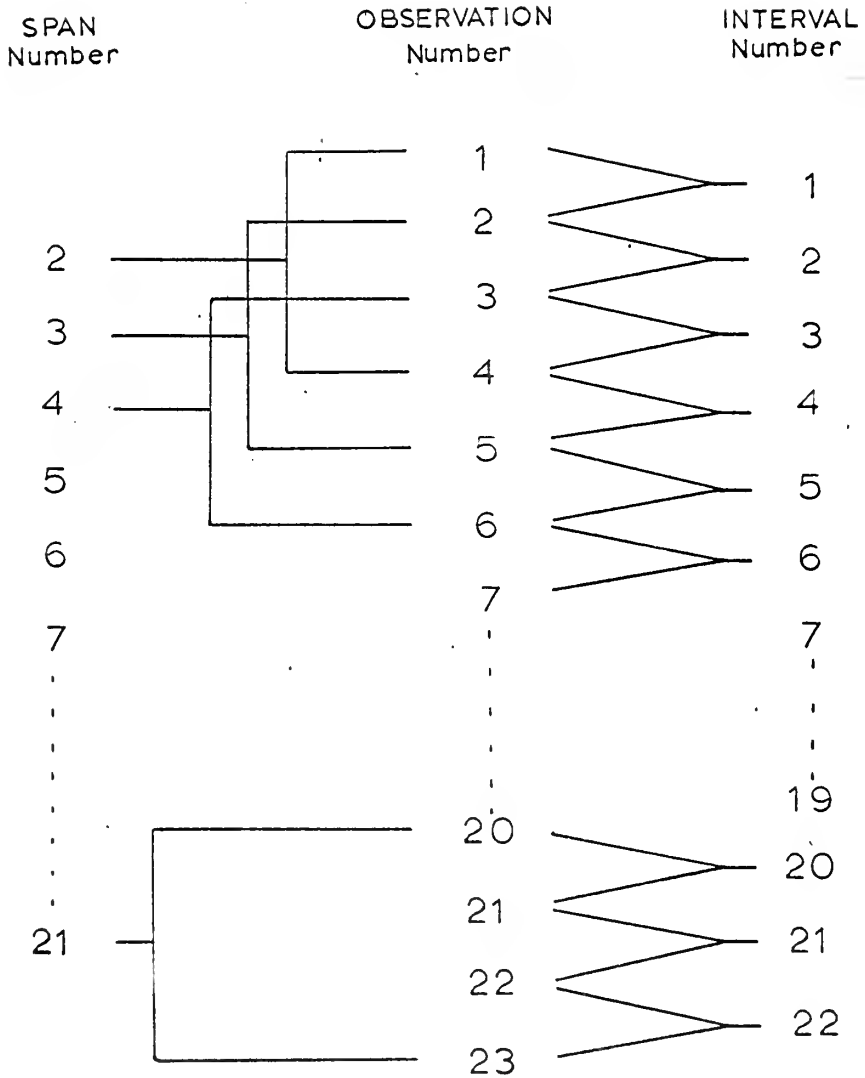


Figure 17. Relationship of OBSERVATION, INTERVAL, AND SPAN NUMBERS.

2. Program Description.

The computer program to reduce the raw survey data to meaningful drogue travel information was written in the FORTRAN language and incorporates maximum versatility to allow its application by other investigators to different survey geometries. An explanation of the program presented in Appendix I follows.

The machine-printed letter "C" in the left margin of the program denotes the ensuing statement to be a comment and not an executable statement. The numbers appearing in the margin between the occasional "C"'s are statement numbers used as references within the program. All angles introduced into the computer in degrees are converted to radian measure to allow FORTRAN operation.

Section A of the program establishes the magnitude of the two constants that apply in all the surveys and computes the necessary trigonometric functions of angle THETA once and for all to obviate their calculation when used later in the program.

Section B reserves computer memory space for the necessary input data and calculated travel parameters. Dimension (40) restricts the number of observations to a maximum of 40 per individual survey.

Section C includes the instructions for the machine to read and store the input data punched on cards, an example

of which is shown in figure 18. Time and the two measured transit angles are used in the computations in the following part of the program. Depth and date serve only to identify the cards and the output, as shown in Appendix III.

Groups of sequentially ordered data cards for each drogue depth and each date can be loaded behind the program deck, separated one group from the other by cards with 0000 punched in the TIME columns.

Statement D removes the information on the separation card, TIME 0000, from further consideration.

Statement E designates the format in which the input data cards are punched.

Section F prepares the annotation and column headings of the first output sheet. As seen in Appendix III, three output sheets are produced for each separate drogue.

Statement G directs that all succeeding statements through statement numbered 700 will be carried out NUM number of times (see Glossary above).

Section H corrects the measured transit angles to angles which can be manipulated in a more normal trigonometric fashion in ensuing operations.

Section I converts the corrected angles to radian measure.

Statement J calculates the angle at the drogue position

TIME	ANGT	ANGP	DEPTH	DATE
1008	277.8	60.4	02.0	1.04
000000000000	000000000000	000000000000	000000000000	000000000000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35	36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55	56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80	81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
111111111111	111111111111	111111111111	111111111111	111111111111
222222222222	222222222222	222222222222	222222222222	222222222222
333333333333	333333333333	333333333333	333333333333	333333333333
444444444444	444444444444	444444444444	444444444444	444444444444
555555555555	555555555555	555555555555	555555555555	555555555555
666666666666	666666666666	666666666666	666666666666	666666666666
777777777777	777777777777	777777777777	777777777777	777777777777
888888888888	888888888888	888888888888	888888888888	888888888888
999999999999	999999999999	999999999999	999999999999	999999999999
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35	36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55	56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80	

1805 MI

Figure 18. Example of a Punched Data Card.

between the two transit lines of sight.

Section K computes base B and height H by trigonometric manipulation.

Section L transforms the reference axis of measurement from a baseline-oriented system to a shoreline-oriented system by rotation of axis through the angle THETA.

Section M controls the printing of calculated information and input data on the first output sheet.

Section N prepares the annotation and column headings of the second output sheet.

Statement O calculates the number of intervals of a survey by subtracting one from the number of observations.

Statement P specifies that all following statements through statement numbered 89 will be accomplished NUMM number of times.

Section Q calculates the distance travelled by the drogue during one interval by the Pythagorean synthesis of the alongshore and onshore-offshore components of travel. Distances are calculated to a hundredth of a foot.

Section R computes the direction of drogue travel referred to the shoreline trend frame of reference. Analysis of the algebraic sign of the motion components found in section Q determines the trigonometric quadrant in which the course lies. Computation of the inverse tangent of

DELY/DELX produces the direction within the indicated quadrant. For example, if DELY is positive and DELX is negative, then drogue travel is in the direction of quadrant III and the course to the closest tenth of a degree is:

$$CS = 270^\circ + \left[\left| \tan^{-1} \left(\frac{DELY}{DELX} \right) \right| \times \frac{360}{2\pi} \right] .$$

If the drogue is motionless during the interval in question, i.e., DELY=DELX=0, the course is arbitrarily set at 000.0°. This did not cause errors in the analysis that was later performed upon the output travel parameters because the computed speed was always considered with the course; speed over the interval of no drogue motion is zero also. To prevent misinterpretation however, an investigator can indicate an impossible course for a zero speed interval by changing statement numbered 75 to, say:

75 CS(I) = 999.

Section S was designed by R. Hilleary of the USNPGS Computer Facility (personal communication) to allow sequential observation times to be subtracted to produce an interval of the correct number of whole minutes; e.g., 1000-0950 is properly read as ten minutes and not fifty minutes.

Section T computes drogue speed by dividing the distance travelled by the elapsed time to give a quotient having the units of feet per minute. Then, multiplication by appropriate conversion factors transforms the speed into feet per second, centimeters per second, and knots.

Section U directs the printing of the columnar information calculated in sections Q through T on the second output sheet.

Section V arranges the explanation and column headings of the third output sheet.

The preceding sections compute drogue travel information based upon consideration of the interval between only two successive observations at a time. The last series of sections performs a smoothing of the successive values of drogue speed and direction by the computation of running four-point (thus three-interval) means. The sections correspond to those above and are denoted by the same letters, primed. The calculation method is the same as described above.

Whereas the averaged speed is determined by considering the sum of the three individual distances comprising the span and the total elapsed time, the averaged course is based only upon the initial and final drogue positions (of the span), ignoring the intervening travel. Figures 16 and 17 show the relationship between interval and span.

Section W directs the computer to accept the following group of data for a different drogue and to respect the manipulations until the last group of input cards has been processed.

APPENDIX III

SAMPLE COMPUTER OUTPUT

Date 4 January 1964

Depth of Drogue 2 Feet

THIS PAGE CONTAINS INFORMATION DISPLAYED IN COLUMNS WHICH INCLUDE MEASURED DATA AND COMPUTED DISTANCES USED BY THE PROGRAM TO DETERMINE DROGUE TRAVEL PARAMETERS (COURSE, SPEED, ETC.) WHICH WILL BE FOUND ON FOLLOWING PAGES. SEQUENTIALLY OBS (OBSERVATION) NUMBER, CLOCK TIME, ANGLE, T, AND ANGLE P ARE THE INPUT DATA AND REPRESENT THE SEQUENTIALLY MEASURED TRANSIT ANGLES AND TIMES OF MEASUREMENT. X AND Y ARE THE INPUT DATA AND REPRESENT THE SEQUENTIALLY MEASURED BASE AND HEIGHT DISTANCES (IN FEET) FROM THE CONTROL END OF THE BASELINE (TOWER) ALONG THE BASELINE AND PERPENDICULAR TO THE BASELINE (RESPECTIVELY) TO THE DROGUE POSITION AT THAT TIME, LE BASE AND HEIGHT OF A RIGHT TRIANGLE. X AND Y ARE SIMILARLY THE BASE AND HEIGHT OF A RIGHT TRIANGLE, BUT RELATED TO THE SHORELINE TREND RATHER THAN THE BASELINE. ANGLE BETWEEN BASELINE AND SHORELINE IS SEVEN (7) DEGREES. DEPTHS ARE ANGLE BETWEEN BASELINE AND SHORELINE IS SEVEN (7) DEGREES. DEPTHS IS DISTANCE IN FEET OF SURFACE FOR DROGUE IN QUESTION. DATE IS MONTH-DECIMAL-DAY OF SURVEY

CBS NUMBER	CLOCK TIME	ANGLE T	ANGLE P	B (BASE)	H (HT)	X	Y	DEPTH	DATE
1	1002	277.0	60.4	352.0	2570.0	662.9	2507.9	.2	1.04
2	1012	278.0	61.2	365.7	2599.1	679.4	2535.0	.	.00
3	1022	278.8	62.6	383.7	2598.1	697.7	2532.0	.	.00
4	1032	278.4	62.8	416.4	2691.8	741.2	2620.9	.	.00
5	1042	276.5	61.2	404.4	2738.2	735.5	2669.1	.	.00
6	1102	276.8	59.9	311.4	2715.3	641.0	2671.9	.	.00
7	1112	270.0	55.6	180.0	2676.3	326.2	2656.4	.	.00
8	1122	262.1	52.2	147.8	2569.4	165.4	2634.2	.	.00
9	1132	258.4	48.1	-362.5	2609.5	-41.4	2664.6	.	.00
10	1142	254.0	45.7	-534.5	2618.6	-247.9	2701.8	.	.00
11	1152	249.7	43.6	-788.3	2629.5	-634.9	2676.5	.	.00
12	1202	238.0	39.6	-1253.5	2575.2	-1251.0	2669.7	.	.00
13	1212	234.3	37.3	-1535.7	2486.0	-1452.9	2654.3	.	.00
14	1222	230.2	34.9	-1752.4	2342.4	-1653.3	2629.3	.	.00
15	1232	226.3	32.8	-1952.4	2259.9	-1833.1	2549.6	.	.00
16	1242	223.0	29.8	-2283.3	2192.1	-2019.2	2435.1	.	.00
17	1302	222.0	27.5	-2463.0	2066.6	-2197.4	2330.7	.	.00
18	1312	221.5	25.4	-2653.8	1994.4	-2349.4	2230.7	.	.00
19	1322	221.3	23.2	-2783.8	1954.7	-2458.4	2223.8	.	.00
20	1332	221.3	22.2	-2833.8	1907.2	-2558.4	2223.8	2.	1.04
21	1342	221.3	22.2	-2833.8	1907.2	-2558.4	2223.8	.	.00
22	1352	221.3	22.2	-2833.8	1907.2	-2558.4	2223.8	.	.00
23	1362	221.3	22.2	-2833.8	1907.2	-2558.4	2223.8	.	.00

THIS PAGE CONTAINS COMPUTED INFORMATION REGARDING DROGUE TRACK, BASED UPON SUCCESSIVE POSITIONS OF THE DROGUE AND TIMES BETWEEN OBSERVATIONS AS DISPLAYED ON PREVIOUS PAGE, THE PROGRAM HAS COMPUTED COURSES AND SPEEDS TRAVELLED BY THE DROGUE FROM POINT TO CONSECUTIVE POINT. INTERVAL NUMBER 1

2 IS THE LENGTH OF TIME IN MINUTES BETWEEN OBSERVATIONS CONSIDERED. START IS THE CLOCK TIME OF FIRST OBSERVATION OF INTERVAL. RUN IS THE LENGTH OF TIME IN MINUTES BETWEEN OBSERVATIONS CONSIDERED. DISTANCE IS THE DISTANCE IN FEET BETWEEN OBSERVATIONS. COURSE IS THE ASSUME DIRECT COURSE OF DROGUE TRAVEL DURING RUN. COURSES ARE MEASURED CLOCKWISE FROM 000 THROUGH 300 IN DEGREES SEAWARD. 80 IS DIRECTLY LANDWARD. SPEED IS COMPUTED BY DISTANCE DIVIDED BY RUN. SPEED PER SECOND (FPS), FEET PER SECOND (FPS), FEET PER SECOND (FPS), CENTIMETERS PER SECOND (CPS) AND KNOTS (KTS).

INTERVAL	START	RUN	DISTANCE	COURSE	SPEED FPM	SPEED FPS	SPEED CPS	SPEED KTS	DEPTH	DATE
1	1002	10	32.09	31.4	3.209	.055	1.630	.029	2.00	1.04
2	1012	10	18.40	100.3	1.840	.031	.934	.017	.00	.00
3	1022	10	99.31	26.4	9.931	.169	5.045	.089	.00	.00
4	1032	10	48.67	352.4	4.867	.083	2.470	.044	.00	.00
5	1042	10	93.77	271.7	9.377	.159	4.681	.084	.00	.00
6	1052	10	131.57	270.6	13.157	.224	6.376	.118	.00	.00
7	1102	10	184.52	264.7	18.452	.316	9.451	.167	.00	.00
8	1112	10	166.09	239.6	16.609	.273	11.924	.157	.00	.00
9	1122	10	175.67	280.0	17.567	.299	11.924	.158	.00	.00
10	1132	10	240.74	279.9	24.074	.368	11.924	.197	.00	.00
11	1142	10	266.64	268.0	26.664	.409	12.597	.217	.00	.00
12	1202	10	240.74	267.0	24.074	.457	13.552	.241	.00	.00
13	1212	10	238.00	264.0	23.800	.405	14.022	.258	.00	.00
14	1222	10	205.38	261.0	20.538	.329	10.429	.175	.00	.00
15	1232	10	185.18	254.9	18.518	.275	9.840	.147	.00	.00
16	1242	10	120.19	249.8	12.019	.203	6.201	.109	.00	.00
17	1302	10	278.19	249.3	27.819	.340	10.578	.182	.00	.00
18	1312	10	179.49	255.9	17.949	.240	7.578	.132	.00	.00
19	1322	10	198.82	252.7	19.882	.261	6.589	.140	.00	.00
20	1332	10	198.82	246.1	19.882	.261	4.989	.088	2.00	1.04

THIS PAGE CONTAINS COMPUTED AVERAGES OF DROGUE TRAVEL PARAMETERS DISPLAYED SIMILARLY TO THOSE ON THE PRECEDING PAGE. RUNNING FOUR-POINT (THUS THREE INTERVAL) MEANS ARE SHOWN AS THE INDICATED AVERAGES. SPAN INDICATES THE GROUP OF INTERVALS CONSIDERED. THUS DROGUE TRAVEL FROM OBSERVATION 1 TO 4 (INTERVALS 1, 2, AND 3) ARE SHOWN AS SPAN 2. START IS THE CLOCK TIME OF FIRST OBSERVATION OF SPAN. RUN IS THE LENGTH OF TIME IN MINUTES BETWEEN OBSERVATIONS CONSIDERED. DISTANCE IS SUM OF INDIVIDUAL DISTANCES OF INTERVALS WITHIN SPAN. AVERAGE COURSE IS DIRECTION FROM FIRST OBSERVATION OF SPAN TO LAST OBSERVATION OF SPAN MEASURED AS COURSE ON PREVIOUS PAGE. AVERAGE SPEED IS COMPUTED BY DISTANCE DIVIDED BY RUN AND IS INDICATED AS ON PREVIOUS PAGE.

SPAN	START	RUN	COURSE	AVERAGE COURSE	AVSPEED FPH	AVSPEED FPS	AVSPEED CPS	KTS	DEPTH	DATE
2	1002	30	149.79	35.0	4.993	.085	2.577	.045	2.00	1.04
3	1012	30	166.39	32.7	5.504	.097	4.036	.072	.00	.00
4	1022	30	273.91	33.8	8.056	.137	4.093	.062	.00	.00
5	1032	30	409.86	26.8	9.120	.155	4.080	.063	.00	.00
6	1042	30	502.14	25.2	13.726	.226	8.523	.123	.00	.00
7	1052	30	586.81	25.0	19.960	.334	9.937	.171	.00	.00
8	1102	30	580.91	29.9	19.327	.327	9.837	.174	.00	.00
9	1112	30	711.65	29.3	20.357	.347	10.226	.183	.00	.00
10	1122	30	723.14	27.0	21.175	.371	10.729	.190	.00	.00
11	1132	30	794.95	26.6	24.475	.411	12.219	.218	.00	.00
12	1142	30	792.79	26.6	26.495	.450	13.444	.238	.00	.00
13	1152	30	727.14	26.6	24.326	.414	12.789	.219	.00	.00
14	1202	30	684.30	26.1	21.238	.361	10.789	.191	.00	.00
15	1212	30	580.99	24.8	19.477	.331	9.894	.175	.00	.00
16	1222	30	508.63	25.0	18.356	.329	9.838	.171	.00	.00
17	1232	30	512.93	25.7	17.098	.322	9.639	.171	.00	.00
18	1242	30	409.13	25.4	13.638	.291	8.638	.154	.00	.00
19	1302	30				.232		.123	.00	.00
20	1312	30							.00	.00
21		30							.00	.00

