NOS Oceanographic Circulatory
Survey Report No. 2

Tampa Bay Circulatory Survey 1963

Rockville, Md.
August 1978

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Survey

NOS Oceano[illegible]

This series of reports presents [illegible] surveys by the National Ocean Survey. Normal activity includes the measurements of water flow (currents), tides, temperature, salinity, and occasionally other parameters needed for understanding the physical processes. These surveys are made primarily for the Nation's navigational waterways; however, data are also obtained to describe the circulatory patterns of estuaries and harbors.

These reports offer information on sampling locations, measurement techniques, processing and analysis routines, data formats, and general information on the survey area. They do not present technical interpretations of hydrodynamics of the areas.

No. 1 Tide and Tidal Current Observations From 1965 Through 1967 in Long Island Sound, Block Island Sound, and Tributaries. Elmo E. Long, January 1978.

U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NOAA

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Stock Number 003-017-00430-9

NOS Oceanographic Circulatory
Survey Report No. 2

Tampa Bay Circulatory Survey 1963

Demetrio A. Dinardi

Rockville, Md.
August 1978

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

National Ocean Survey
Allen L. Powell, Director

Mention of a commercial company or product does not constitute an endorsement by the NOAA National Ocean Survey. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

CONTENTS

TAMPA BAY CIRCULATORY SURVEY, 1963

Demetrio A. Dinardi
Oceanographic Division
National Ocean Survey
National Oceanic and Atmospheric Administration
Rockville, Maryland

ABSTRACT. During the field season of 1963, an extensive tidal current survey was made in Tampa Bay, Hillsborough Bay, and Old Tampa Bay, Fla., using the Roberts Radio Current Meter Recording System. The study was carried out by the Coast and Geodetic Survey, now known as the National Ocean Survey. The report includes tables listing the findings in detail, graphs, and maps of the areas with 52 selected sites specified. The investigative methodology is discussed and the equipment for data gathering is described.

1.0 INTRODUCTION

The purpose of this survey was to obtain tidal current data pertaining to the circulation of the waterways in Tampa Bay, Hillsborough Bay, and Old Tampa Bay. The previous tidal current survey of 37 stations was completed in the field seasons of 1948 and 1950. Following 1950, several extensive changes were made in the form of new bridges, causeways, and channels. For this reason, new data were needed to update the Tidal Current Tables and other publications. This work was carried out by the Coast and Geodetic Survey (C&GS), now known as the National Ocean Survey, during the field season of 1963.

Improved current meter systems and photogrammetric techniques were used to obtain more accurate data from 52 sites than that collected during previous surveys. These data are included in the "Tidal Current Tables, Atlantic Coast of North America."

Currents were measured at specific depths below the water surface, referred to as "depths." An average of the top 25- to 30-foot depths was used in the Tidal Current Tables. The lower depths were observed to obtain data for other purposes. Each depth was tabulated separately for this report.

In the periodic rise and fall of the tide, there is an accompanying horizontal movement of the water called "tidal current." The two movements --tide and tidal current-- are intimately related, forming parts of the same phenomenon brought about by the tide-producing forces of the sun and the moon. It is necessary, however, to distinguish clearly between tide and tidal current.

The tide is the vertical rise and fall of the water level expressed in tide heights. The tidal current is the horizontal flow and is expressed in both speed in knots and direction in degrees true.

However, the data described in this publication concern only tidal currents.

2.0 USC&GS SHIP MARMER

Type

Circulatory Survey and Hydrographic Survey Vessel (See figure 1.)

Characteristics

Year built:	1932	Displacement:	220 long tons
Class:	IV	Cruising speed:	10 kts
Length:	100 ft	Range:	950 n.m.
Beam:	22 ft	Endurance:	4 days
Draft:	10 ft		

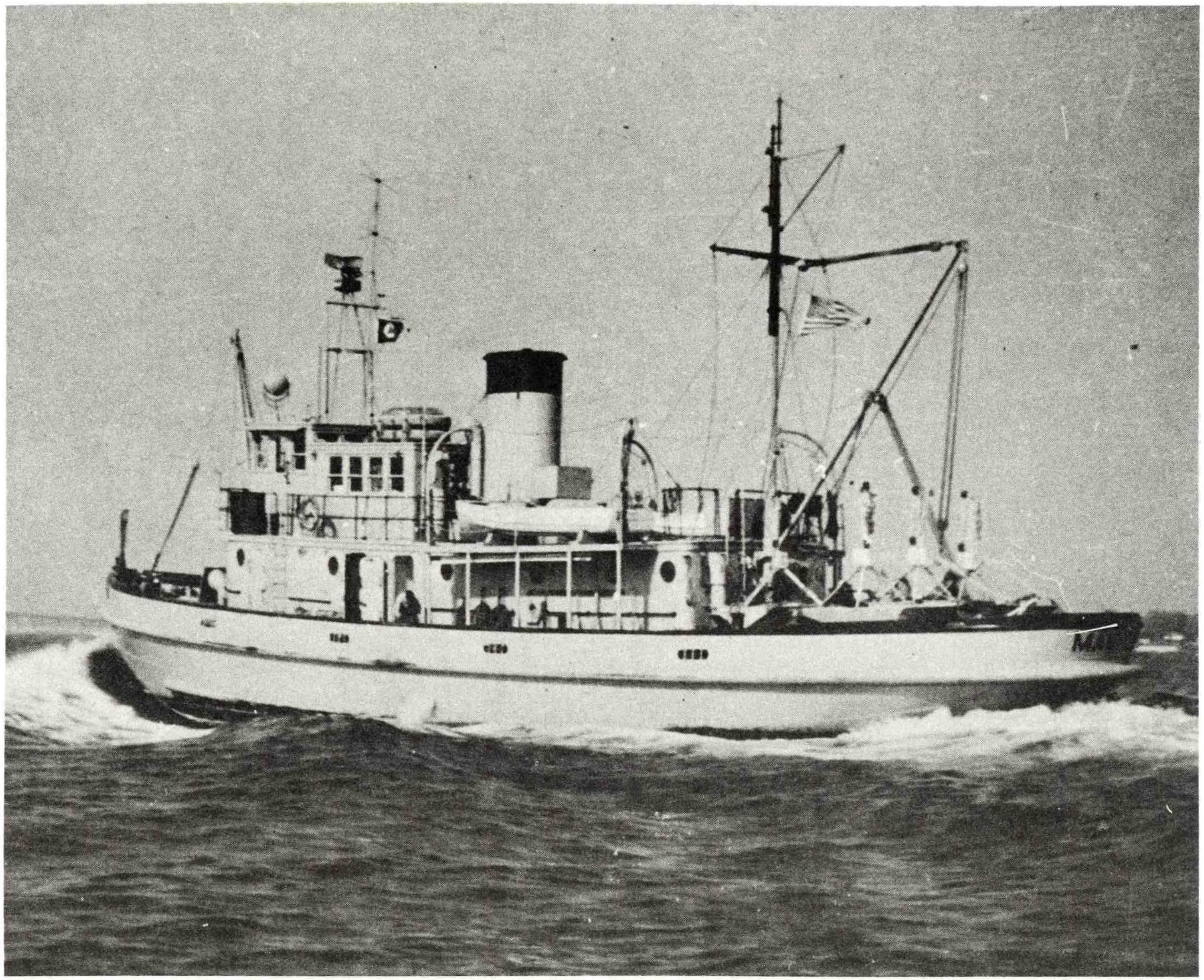


Figure 1. — USC&GS Ship Marmer

Party Organization

CDR Emerson E. Jones, Commanding Officer (reported Dec. 11, 1961)
LTJG C. Williams Hayes, Executive Officer (reported Oct. 3, 1961)
ENS David L. DesJardins, Jr., Junior Officer (report Dec. 20, 1962)

Engineering Dept.:	3 men	Yeoman Dept.:	1 man
Electronics Dept.:	2 men	Deck Dept.:	5 men
Survey Dept.:	1 man	Steward Dept.:	2 men

Propulsion

Single screw, diesel

Electrical Power

The vessel has sufficient electrical power to perform circulatory and hydrographic surveys.

Navigation Equipment

Magnetic compass; radar

Communications Facilities

Two radiotelephones: one 7-channel and one 8-channel

Winches

The vessel has a boom and winch after and a boom and anchor windlass forward for servicing buoys and current meters.

Acoustical Characteristics

The ship cannot be used for silent operations.

Laboratories

No wet laboratory space is available. A small dry laboratory is provided for data processing.

Habitability

The ship does not usually remain at sea more than a few days.

Other Features

Special equipment is onboard for servicing current meters and for remote monitoring of current observations.

Types of Observations

Observations include current speed and direction. Also, surface weather observations are made by the ship's crew.

Scientific Equipment

Scientific equipment includes a current-meter system and a remote current-meter monitoring facility.

3.0 STATION SELECTION

The tidal current stations were selected to depict adequately the tidal flow of the bay. The primary purpose was to obtain data for navigational needs. Most of these needs in the Tampa Bay are met by data obtained to depth of 30 feet below the surface.

The approximate station locations are shown in figure 2. The exact locations are determined by referring to the tabulations that describe the position of the station as well as listing the precise latitude and longitude in degrees, minutes, and seconds.

Meters were placed as follows. In charted depths of 35 feet or more, meters were set at 1/6th, 1/2, and 5/6ths of the depth. In charted depths of 25 to 35 feet, meters were placed at 1/6th and 1/5th of the depth and also at 6 feet above the bottom. In less than 25 feet, meters were set at 1/3rd and 2/3rds of the charted depth.

4.0 DURATION OF OBSERVATIONS AND DATA SAMPLING RATE

The duration of observations are classified as short periods of 100 hours or long periods of 15 or 29 days.

The short period station data are utilized in the nonharmonic analysis. (See Section 6.) These stations are designated as subordinate stations and are listed in Table 2 of the "Tidal Current Tables, Atlantic Coast of North and South America," published annually by the National Ocean Survey, National Oceanic and Atmospheric Administration.

The long period station data are most importantly used in the harmonic analysis (Section 7) and also the nonharmonic method. The analysis yields constants (amplitudes and epochs) of the harmonic constituents of the tidal currents.

All data obtained by Roberts radio current meters were observed at half-hourly intervals. Station 40, obtained in 1964 by Geodyne photorecording meters, was observed at 10-minute intervals.

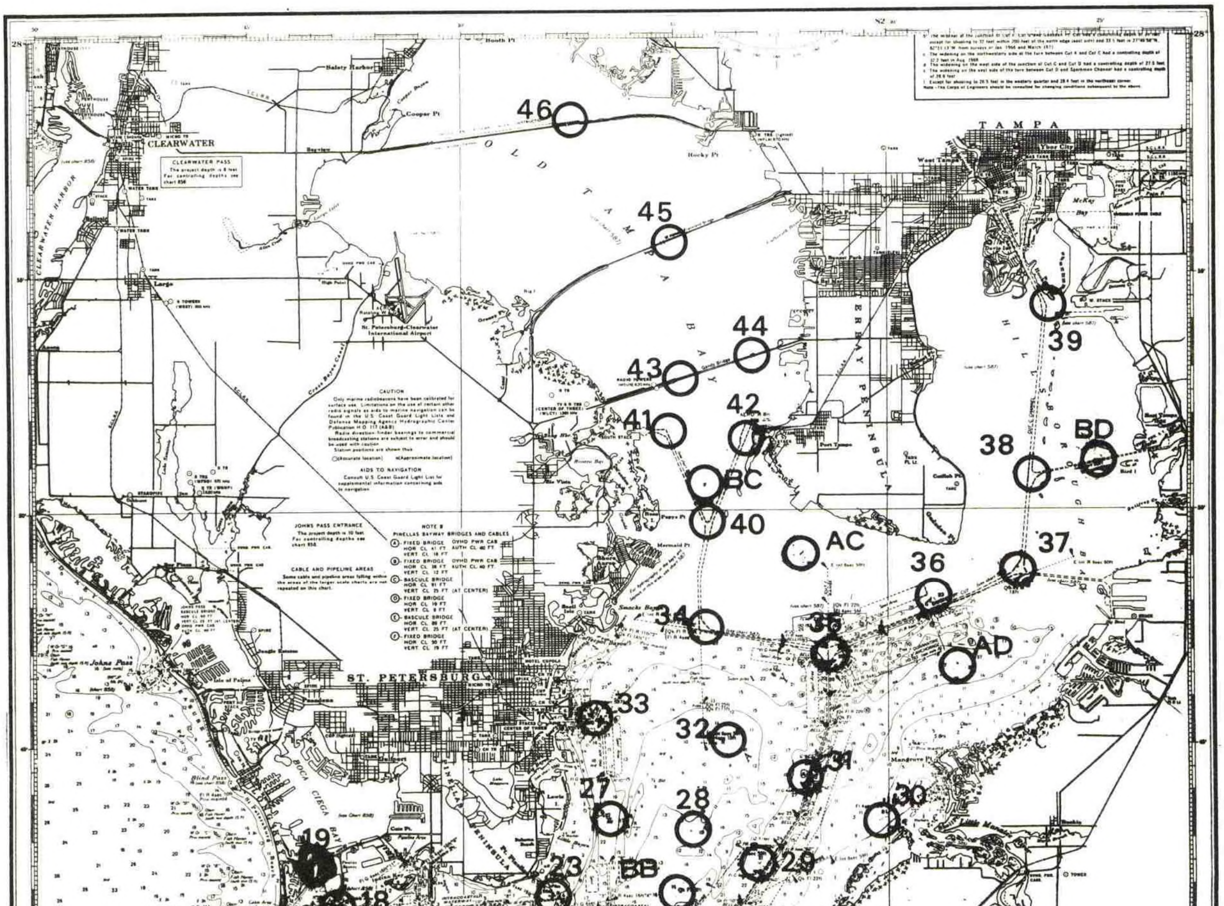


Figure 2. — Current Meter Station Locations, Tampa Bay

5.0 ROBERTS RADIO CURRENT METER RECORDING SYSTEM

The Roberts radio current meter system consists of a number of radio current meters, 102-inch buoys, telemetering system, and a data recording system at the base station. Because this system is now considered obsolete and the literature is not generally available, a somewhat comprehensive technical description follows.[1] The Roberts system was last used to observe three stations in the East River, New York Harbor in 1970.

5.1 The Radio Current Meter

The radio current meter was developed by Captain Elliott B. Roberts of the Coast and Geodetic Survey and was designed to measure both speed and direction. The meters can be operated unattended from an anchored buoy and the data are relayed to a remote base station. Thus, the necessity of maintaining a vessel and crew at each station was eliminated. The meter system is designed to measure current speeds in the range of 0.1 and 6.6 knots and to determine direction of flow with respect to magnetic north to within ±10 degrees of azimuth. The meter is illustrated in figure 3.

In the radio current meter, a rotating impeller is actuated by the current. The impeller is connected through a magnetic drive to an enclosed interior mechanism which makes and breaks an electric circuit by means of two contacting levers. One lever mounted on the compass is always oriented north. The other, fixed to the meter, is always oriented in the direction of flow. An overall view of the mechanism as well as a detail are shown in figure 4.

The contact-mechanism assembly consists of the direction- and velocity-contactors. Each mechanism comprises a lever, clevis, and pivot. The levers pivot the clevis and, when actuated, lift the lower contact point of the contact-receptacle assembly to close the circuit to the surface buoy. The clevis of the velocity-contact mechanism is mounted on the upper bearing pin of the compass assembly. The clevis of the direction-contact mechanism is attached to the underside of the movement upper frame.

5.2 Current Meter Recording System

A post, carried on a gear, revolves past the switch-actuating levers once for each revolution of the gear (five revolutions of the impeller). Each contact produces a radio signal. (See figure 5.) The frequency of these signals is determined by the velocity of the impeller, and therefore, can be translated into current velocity through the use of precomputed relationships as shown in table 1.

The speed of the current is determined by computing the average time in seconds for each revolution of the velocity contacts for a specified section of tape. The example of figure 5 shows that three contact intervals took

[1] The original publication was "Roberts Radio Current Meter Manual," No. 30-2, Coast and Geodetic Survey, U.S. Department of Commerce, 1964.

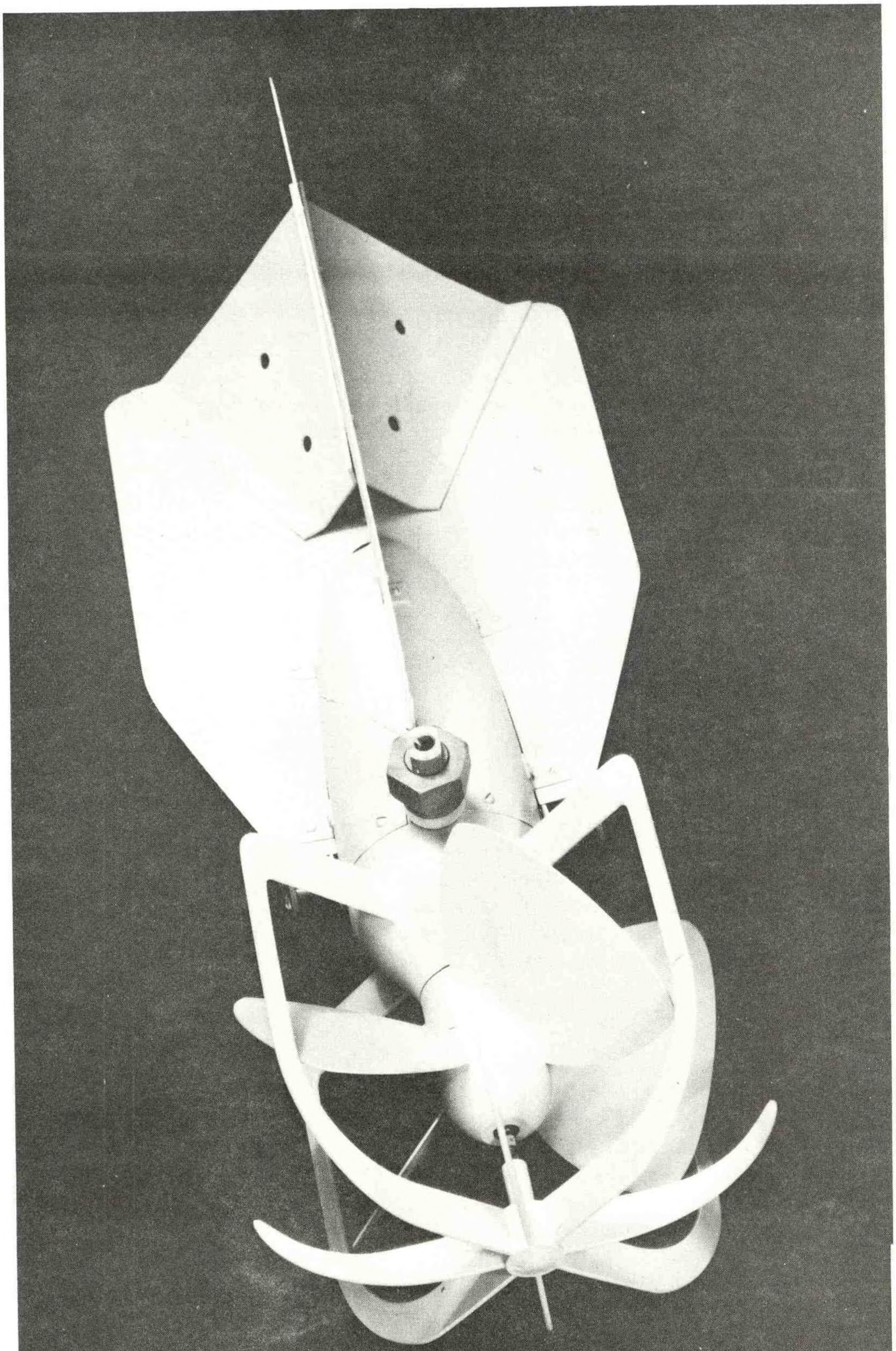
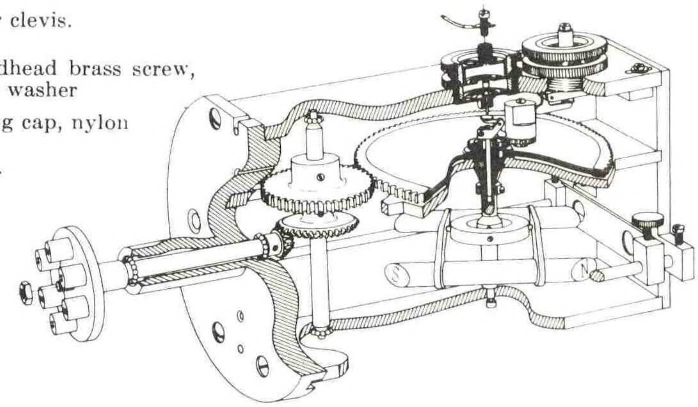


Figure 3. — Roberts Current Meter

		Description of Part
1	Coml. item	#1 x 72 threads, fillister-head brass screw, 3/16 in. long
2	70–97–A	Velocity-contact lever clevis
3	70–100–A	Contact-lever insulating cap, nylon
4	70–98–A	Velocity-contact lever
5	70–99–A	Contact-lever pivots
6	70–102–A	Direction-contact lever clevis.
7	Coml. item	#2 x 64 threads, roundhead brass screw, 3/8 in. long, and a #2 washer
8	70–100–A (hidden)	Contact-lever insulating cap, nylon
9	70–101–A	Direction-contact lever



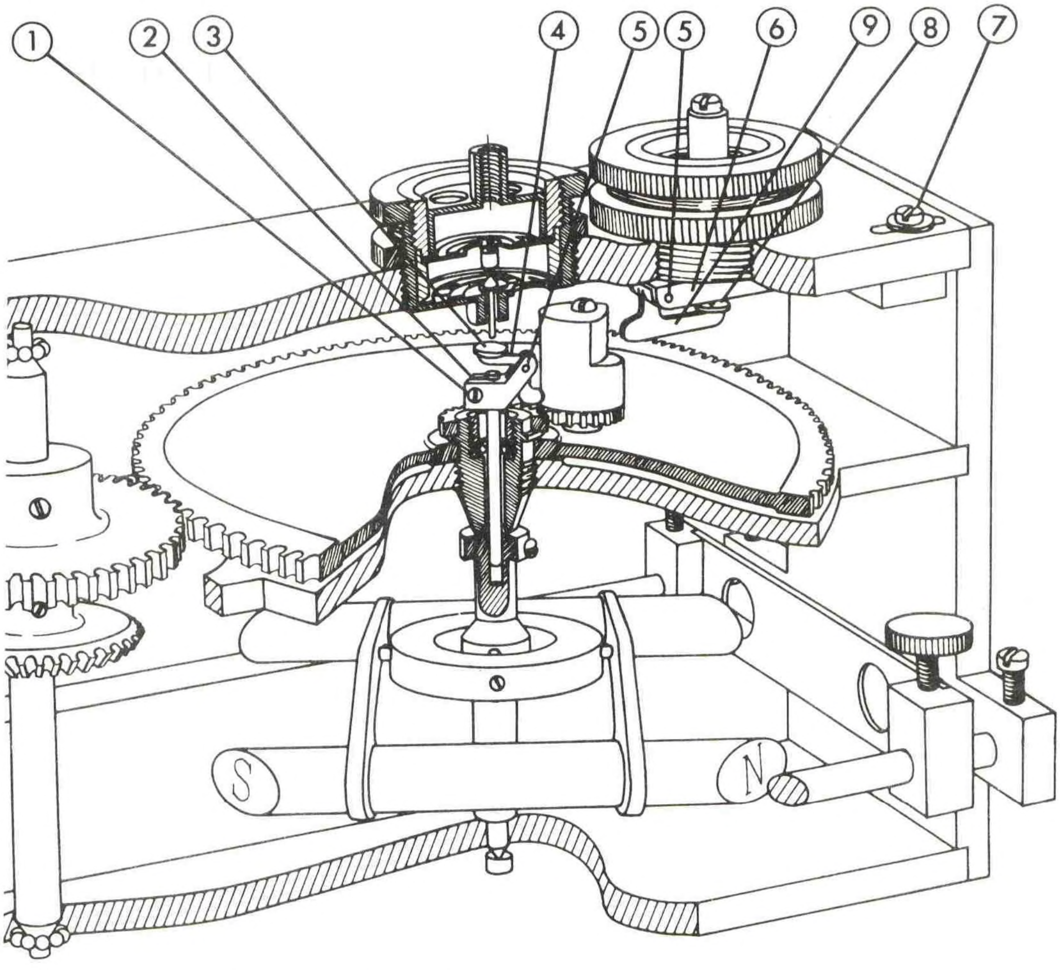


Figure 4. — Roberts Radio Current Meter Contact Mechanism

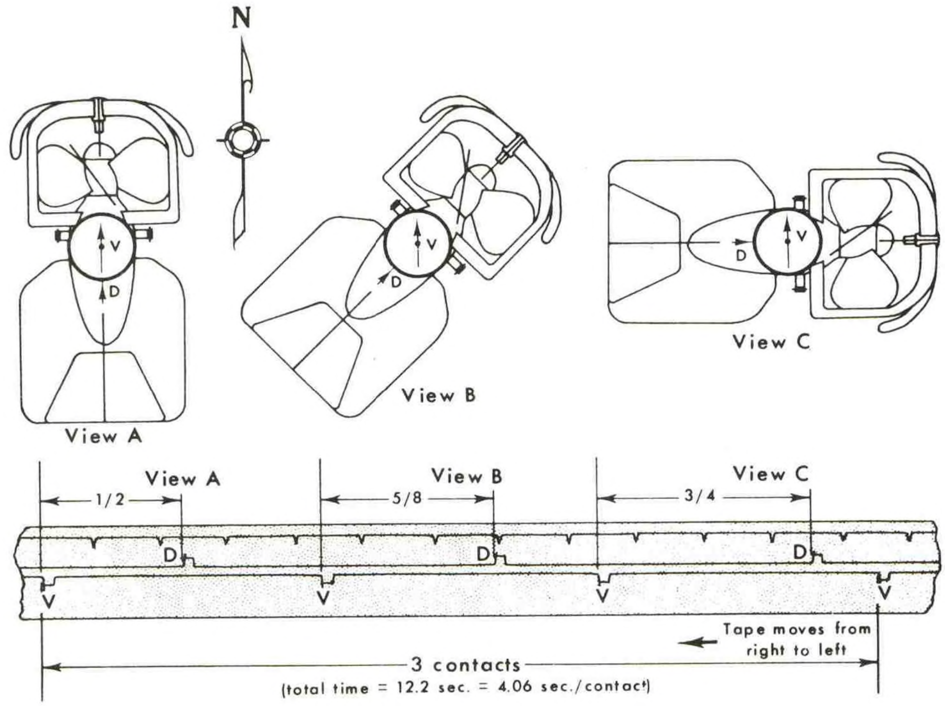


Figure 5. — Velocity Computing

Table 1. — Current Velocity vs Contact Interval

Contact interval	Velocity	Contact interval	Velocity	Contact interval	Velocity	Contact interval	Velocity
Seconds	Knots	Seconds	Knots	Seconds	Knots	Seconds	Knots
125.0 -46.3	.1	4.22- 4.00	1.8	2.16- 2.11	3.5	1.45- 1.44	5.2
46.2 -28.5	.2	3.99- 3.80	1.9	2.10- 2.06	3.6	1.43- 1.41	5.3
28.4 -20.6	.3	3.79- 3.62	2.0	2.05- 2.00	3.7	1.40- 1.38	5.4
20.5 -16.1	.4	3.61- 3.46	2.1	1.99- 1.95	3.8	1.37- 1.36	5.5
16.0 -13.2	.5	3.45- 3.31	2.2	1.94- 1.90	3.9	1.35- 1.33	5.6
13.1 -11.2	.6	3.30- 3.17	2.3	1.89- 1.85	4.0	1.32- 1.31	5.7
11.1 - 9.73	.7	3.16- 3.04	2.4	1.84- 1.81	4.1	1.30- 1.29	5.8
9.72- 8.60	.8	3.03- 2.93	2.5	1.80- 1.77	4.2	1.28- 1.27	5.9
8.59- 7.70	.9	2.92- 2.82	2.6	1.76- 1.73	4.3	1.26- 1.25	6.0
7.69- 6.97	1.0	2.81- 2.72	2.7	1.72- 1.69	4.4	1.24- 1.23	6.1
6.96- 6.37	1.1	2.71- 2.62	2.8	1.68- 1.65	4.5	1.22- 1.21	6.2
6.36- 5.86	1.2	2.61- 2.53	2.9	1.64- 1.62	4.6	1.20- 1.19	6.3
5.85- 5.44	1.3	2.52- 2.45	3.0	1.61- 1.58	4.7	1.18- 1.17	6.4
5.43- 5.08	1.4	2.44- 2.38	3.1	1.57- 1.55	4.8	1.16- 1.15	6.5
5.07- 4.76	1.5	2.37- 2.30	3.2	1.54- 1.52	4.9	1.14- 1.13	6.6
4.75- 4.48	1.6	2.29- 2.24	3.3	1.51- 1.49	5.0		
4.47- 4.23	1.7	2.23- 2.17	3.4	1.48- 1.46	5.1		

12.5 seconds or 4.06 seconds per contact. From the rating table of figure 6, a speed of 1.8 knots is designated for a contact interval range of 4.22 -- 4.00 seconds. Usually, the speed is resolved by averaging the time for 10 revolutions. The direction of the current is determined by the spacing of the direction signal between two successive velocity signals, as shown in figure 6[2].

The direction is determined by scanning the full two minutes of tape run to locate a section that appears to have a stablized direction pattern. By use of a plastic template, three directions are determined. An average of these represents the direction for that period of time. (See again figure 6.)

5.3 Roberts Radio Current Meter Buoy

The 120-inch current buoy was designated specifically for the Roberts system and is illustrated in figure 7. It is boat-shaped with a mooring yoke which swings fore and aft. A superstructure accommodates a light, very high frequency (VHF) whip antenna, and a radar reflector. The FM radio and telemetry equipment with batteries are housed inside the buoy and are accessible through a hatch.

In operation, the meters are suspended from the anchored buoy. Each buoy can accommodate up to three meters, although only one is shown in the figure. The number of meters depends, of course, on the depth of the water. The streamlined design of the meter allows it to align itself in the direction of the current flow, as does the anchored buoy.

5.4 Telemetering System

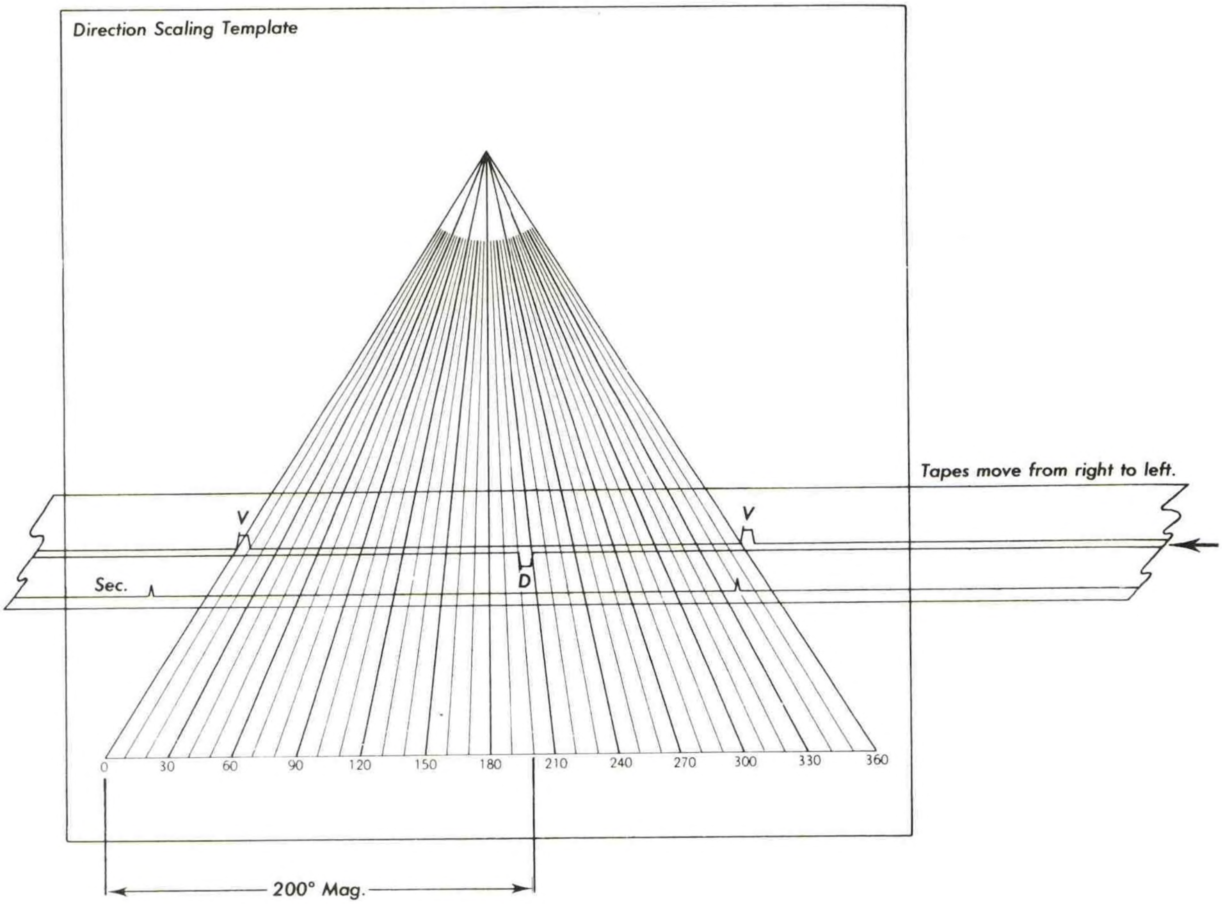
The telemetering system for the Roberts radio current meter consists of a single base station (usually located aboard ship) and one or more buoy stations, each capable of transmitting data from one, two, or three meters. Each buoy station transmits current-direction and current-velocity data when it is interrogated by a signal from one base station. At the base station, the signals are received, amplified, and recorded by means of a chronograph and filter keyer unit.

The transmitting cycle for each meter is approximately 2 minutes. The number of buoy stations that can be monitored by a single base station depends therefore on how frequently each buoy is to be queried.

5.5 Base Station

The base station consists of a 60-watt FM transceiver with variable-frequency audio oscillators, a chronography and filter keyer unit, and a timing unit.

[2]The illustration in figure 6 is taken from a Supplement to "Manual of Current Observations," U.S. Department of Commerce, Coast and Geodetic Survey, November 1961



SECTION OF TAPE SHOWING METHOD OF SCALING DIRECTION

Direction=200° Mag. (approx.) (scaled)

Figure 6. — Method of Scaling Direction

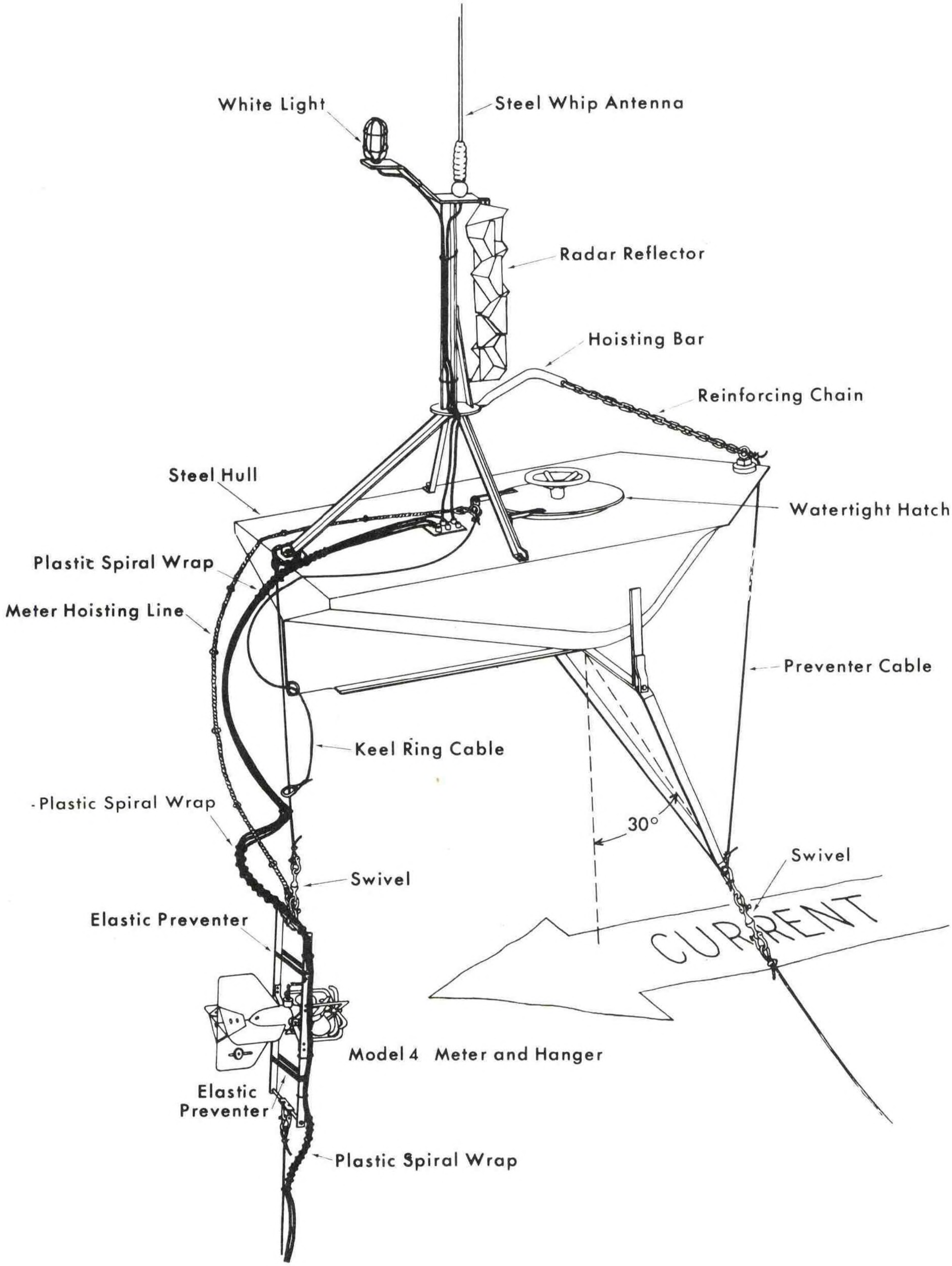


Figure 7. — Roberts Radio Current Meter System

This base station equipment performs five functions.

1. Receives and transmits FM radio signals.
2. Transmits audio frequencies for buoy station interrogation.
3. Discriminates between velocity and direction signals received from buoy stations.
4. Supplies a time reference.
5. Records three channels of information on standard 1/2-inch waxed paper; namely, the time reference, direction, and velocity signals.

5.6 Base Station Transmitter-Receiver

The base station transmitter-receiver includes an oscillator for generating the audio frequencies for buoy-station interrogation.

Either two types of audio oscillator is used.

1. Most systems use plug-in, solid-state modules with resonant-reed control and an individual battery power supply mounted in the base station cabinet. Frequencies are switch-selected. Interrogation of the buoy is accomplished by depressing the microphone button for a period of about six seconds.

2. An audio oscillator is mounted in the base station cabinet. A switch is installed on the base station control panel so that either the command tone or microphone may be used. The frequencies of the buoys in use in the system are marked on the audio oscillator dial. Selection of the desired interrogation of the buoy is accomplished by depressing the microphone button for a period of about six seconds.

The chronograph and filter keyer perform three functions:

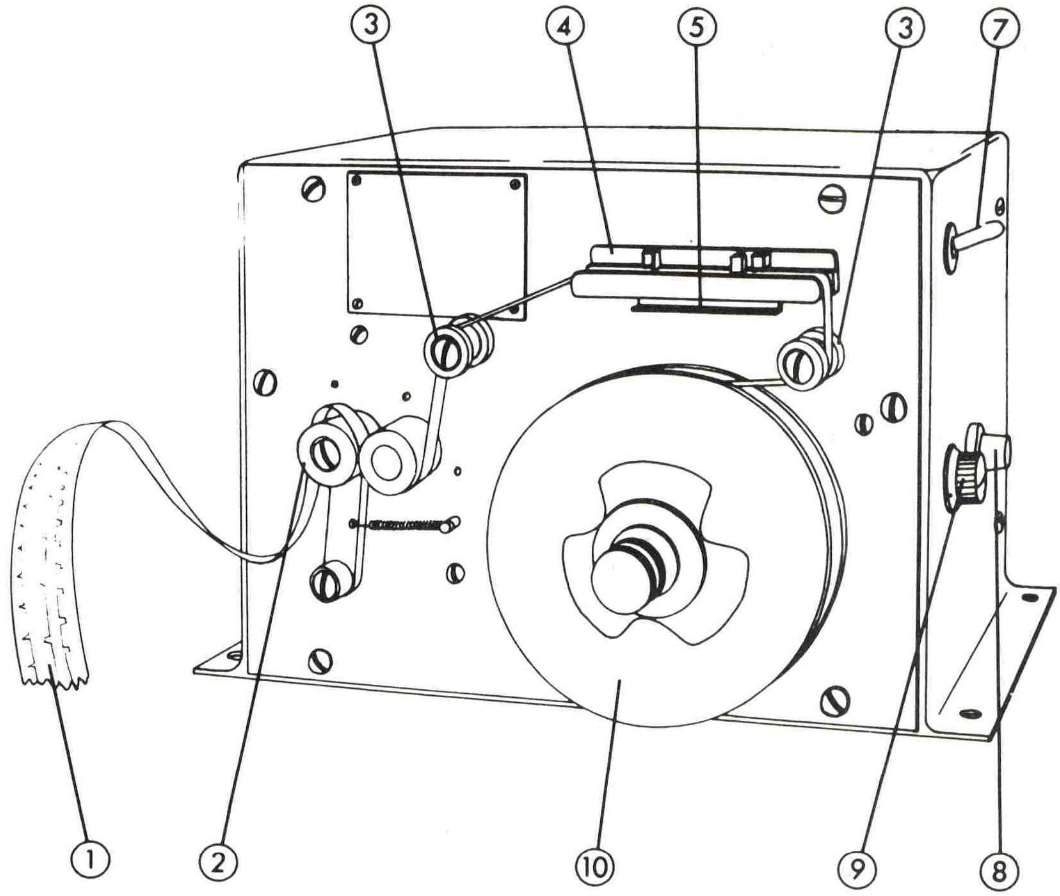
1. Discriminates between velocity and direction signals from the buoy station (filter keyer).
2. Furnishes a time reference (timing unit).
3. Records three channels of information.

The chronograph is illustrated in figure 8.

The chronograph produces the record from which the speed and directions of the current are determined. The record is run on a standard 1/2-inch waxed paper tape that provides the three channels of information. A separate stylus, actuated by signals from the filter keyer, marks each channel. The upper channel is marked at intervals of one second. A base line separates the lower and central channels designating the velocity and direction signals.

6.0 HARMONIC ANALYSIS

The harmonic analysis of tidal current data determines constants (amplitudes and epochs) of the harmonic constituents of the tidal currents at the place where the observations were obtained. A minimum period of 29 days of data is desired for such an analysis. The observational period must not include data that are greatly affected by meteorological conditions that may distort the data from the normal expected tidal influence.



	Identification of Part		Identification of Part
①	Tape	⑦	ON-OFF switch
②	Drive rollers	⑧	Fuse
③	Idler roller	⑨	Tape-speed control
④	Stylus assembly	⑩	Tape-storage reel
⑤	Lift bar		

Figure 8. — Roberts Chronograph

Through a modified Fourier analysis, using the periodicities of the movements of the moon and sun, the observed tidal current data are analyzed to separate the tidal currents into elementary harmonic constituents. For the 29-day series of observations, a direct analysis is made to determine the primary constituents M_2, S_2 and for N_2, K_1, or O_1. An indirect analysis is performed to compute the secondary constituents M_4, M_6, M_8, S_4, S_6, etc.

The determination of such characteristics as mean range, spring range (average near the times of new and full moon), perigean range (average when the moon is closest to the earth), apogean range (moon farthest from the earth), and the typical shape of the tidal current curve are best determined from the harmonic constants.

The harmonic constituents are used to predict tidal currents which are compared to the observed data. See figure 9.

6.1 Harmonic Analysis of the Reference Station

Harmonic constants, derived by harmonic analysis of the tidal currents, have been determined for the reference station at Tampa Bay Entrance (Egmont Channel).

These constants are tabulated on the ESSA-USC&GS Form 444 in use at the time of the study and are presented in figure 10. The harmonic constants shown contain both the original values derived from analysis and also the adjusted values needed for more precise predictions. The original analysis produced constants that were used to predict currents for the period of observation. The predicted data were compared to the observed values to determine the amount of adjustment needed to obtain the most practical agreement.

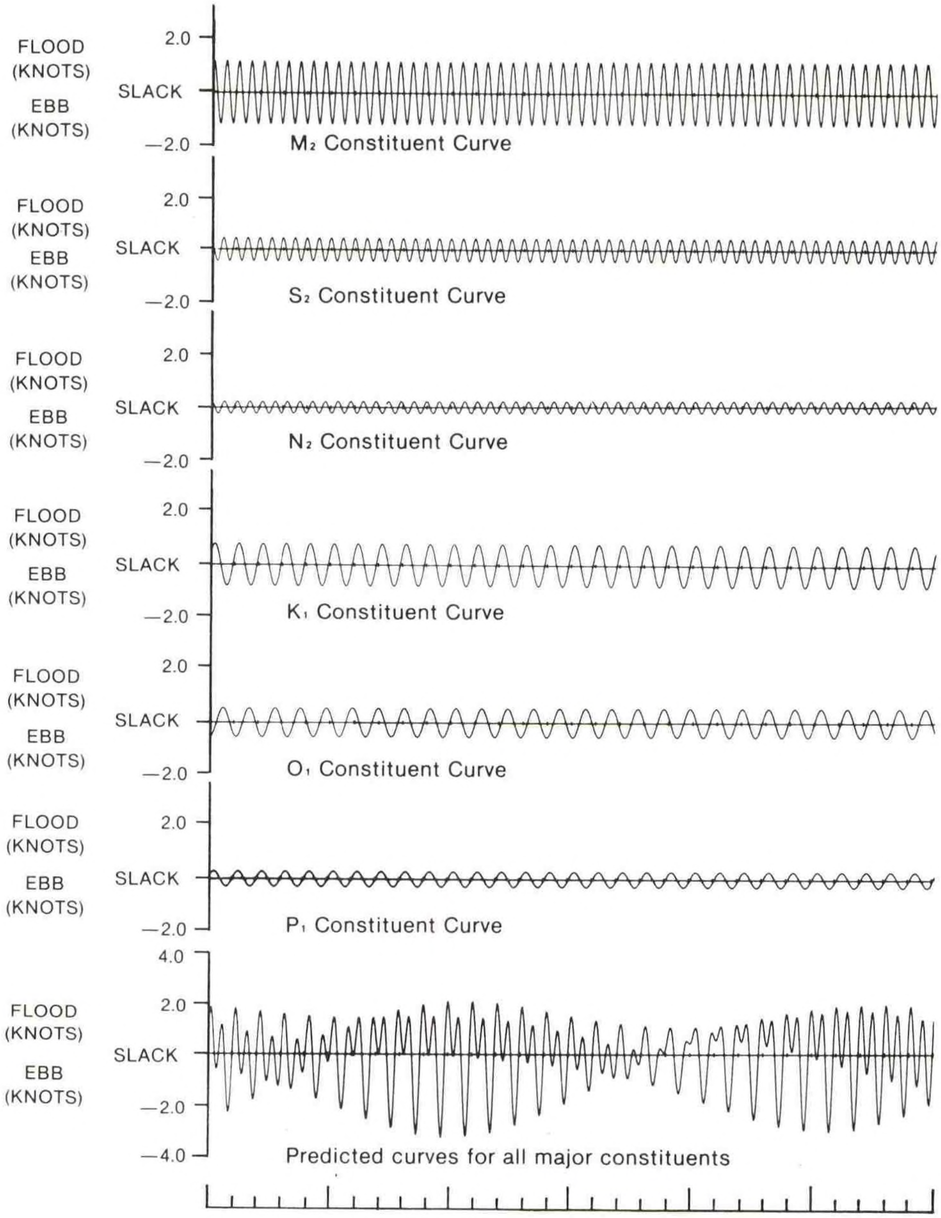
Columns B and D are the adjusted amplitudes and epochs that are used in the predictions of the tidal current tables published annually by the National Oceanic and Atmospheric Administration, National Ocean Survey.

6.2 References for Harmonic Analysis

The subject of harmonic analysis is treated academically in a number of sources. Three such references which are of particular use are cited and described below.

Dennis, Robert E. and Long, Elmo E., "A Users Guide to a Computer Program for Harmonic Analysis of Data at Tidal Frequencies" (NOAA Technical Report NOS 41), originally published by the Office of Marine Surveys and Maps, Oceanographic Division, U.S. Coast and Geodetic Survey, July 1971, 31 pp.

> This report describes a FORTRAN IV program for the harmonic analysis of a series of 15 or 29 days of uniformly spaced tidal data (observations). The program is usable with minor modifications on any computer with a 140k



Greenwich mean time of the moon's phases, Local Time (EST)
June 1976

	days	hrs	min		days	hrs	min
◐	5	07	20	E	18	17	00
E	5	17	00	◑	19	08	15
P	9	14	00	$\odot_2$	21	01	24
S	11	22	00	A	21	12	00
○	11	23	15	N	26	05	00
				●	27	09	50

●, new Moon; ◐, first quarter; ○, full Moon; ◑, last quarter; E, Moon on the Equator; N, S, Moon farthest north or south of the Equator; A, P, Moon in apogee or perigee; $\odot_1$, Sun at vernal equinox; $\odot_2$, Sun at summer solstice; $\odot_3$, Sun at autumnal equinox; $\odot_4$, Sun at winter solstice.

Figure 9. — Diurnal and Semidiurnal Constituent Curves

FORM C&GS-444
(11-67)

U.S. DEPARTMENT OF COMMERCE
ESSA- COAST AND GEODETIC SURVEY

TIDES / CURRENTS STANDARD HARMONIC CONSTANTS FOR PREDICTION

STATION Tampa Bay Entrance (Egmont Channel), Fla.

Lat. 27 ° 36 '.53 N.
Long. 82 ° 46 ' .1 W.
Long. 82 ° .77 W.

COMPONENT	H AMPLITUDE	κ EPOCH	A κ' − κ	B ×H	C 360° − κ'	D − κ'
	ft. kn.	°	°	ft. kn.	°	°
M_2	1.041	322.0	20.6	1.176	+	−342.6
S_2	0.398	334.6	15.5	0.450	+	−350.1
N_2	0.202	322.6	23.3	0.228	+	−345.9
K_1	0.783	251.1	7.6	0.885	+	−258.7
M_4	0.044	5.6	41.2	0.050	+	− 46.8
O_1	0.573	232.0	13.0	0.647	+	−245.0
M_6					+	−
$(MK)_3$					+	−
S_4					+	−
$(MN)_4$					+	−
ν_2	(0.039	322.5)	23.0	0.044	+	−345.5
S_6					+	−
μ_2					+	−
$(2N)_2$	(0.027	323.2)	26.1	0.031	+	−349.3
$(OO)_1$	(0.025	270.2)	2.1	0.028	+	−272.3
λ_2					+	−
S_1					+	−
M_1	0.041	241.6	10.3	0.046	+	−251.9
J_1	(0.046	260.6)	4.8	0.052	+	−265.4
Mm					+	−
Ssa					+	−
Sa					+	−
MSf					+	−
Mf					+	−
ρ_1	(0.022	223.8)	15.4	0.025	+	−239.2
Q_1	(0.111	222.4)	15.8	0.125	+	−238.2
T_2	(0.023	334.6)	15.8	0.026	+	−350.4
R_2					+	−
$(2Q)_1$	(0.015	212.9)	18.5	0.017	+	−231.4
P_1	(0.260	251.1)	8.0	0.294	+	−259.1
$(2SM)_2$					+	−
M_3					+	−
L_2	(0.029	321.4)	17.9	0.033	+	−339.3
$(2MK)_3$					+	−
K_2	(0.108	334.6)	15.1	0.122	+	−349.7
M_8					+	−
$(MS)_4$					+	−

REMARKS

Time meridian 75° W. = +5 h.
Extreme range ft. / kn.
Dial
Marigram gear
Marigram scale
Z_0 ft.
Permanent current −0.170 kn.
The DATUM is a plane ft. below mean low water springs / lower low water

short period components increased 13%

Source of constants 29 days of half hourly observations by C&GS at 8 ft. and 20 ft. depths beginning April 15, 1963.

Compiled by DCS 2-25-69 (Date) Verified by RAC 7-20-69 (Date)

USCOMM-DC 50180-P67

Figure 10. — Harmonic Constants at Tampa Bay Entrance

memory which accepts FORTRAN input. The mathematical basis and equations for the determination of tidal constants from observational data are given. The procedure described in this publication should be used in conjunction with "Manual of Harmonic Analysis and Prediction of Tides" (Special Publication No. 98) for reference to formulas and tables. (See below.)

Schureman, Paul, "Manual of Harmonic Analysis and Prediction of Tides" (Special Publication No. 98), Division of Tides and Currents, Oceanographic Division, U.S. Coast and Geodetic Survey, rev. ed. 1940, reprinted October 1971, 317 pp.

This volume is used primarily as a working manual by the National Ocean Survey (formerly Coast and Geodetic Survey), and describes the procedure used for the harmonic analysis and prediction of tides and tidal currents. It is based largely on the works of British physicists Sir William Thompson and Professor George H. Darwin as well as that of mathematician Dr. Rollin A. Harris. (In recent years, there also has been considerable work done on this subject by Dr. A. T. Doodson of the Tidal Institute of the University of Liverpool.)

"Manual of Harmonic Constant Reduction" (Special Publication No. 260), U.S. Coast and Geodetic Survey, reissued 1952, 74pp.

This manual is used for determining such quantities as tidal intervals, ranges, and inequalities from the tidal harmonic constants. An explanation of the process and the special tables needed in the computation is presented.

7.0 NONHARMONIC ANALYSIS OF SHORT PERIOD STATION

The short period (subordinate) stations were treated in this study primarily as reversing, that is, the maximum floods and ebbs were approximately opposite in direction with a slack water at each reversal of direction. This type of current occurs in rivers or tidal waterways where the directions of flow are more or less restricted to certain channels. When the movement is toward the shore or up a stream, the current is said to be flooding; when the movement is away from shore or downstream, it is said to be ebbing.

The tidal current analysis for the short period stations were obtained by nonharmonic analysis method of computation by reversing reduction. (These stations are listed in table 8, section 9; geographic positions are shown in figure 2.) The current data for the subordinate station are compared to a reference station that has the same tidal characteristics. The comparison base used for the Tampa Bay Survey data involved predicted currents at Tampa Bay Entrance (Egmont Channel), Fla. These data are published annually in "Tidal Current Tables, Atlantic Coast of North America" by the National Ocean Survey, National Oceanic and Atmospheric Administration.

The results obtained include (1) differences in times of strength of flood, strength of ebb, and slack waters; (2) mean velocity of current at times of strength of flood and strength of ebb; (3) mean direction of the current at times of strength of flood and strength of ebb; (4) speed and direction of the nontidal current and the mean current hour; and (5) average flood and ebb duration and speed factors.

7.1 Reversing Reduction by Comparison Method

In performing a reversing reduction by the comparison method, the prime requirements are to determine the time to the exact hour and minute of each data point (speed and direction) and also to specify the proper time zone. Then, ascertain the approximate directional flow of flood and ebb. The specific procedure follows.

1. Plot all speeds on rectangular graph paper. (See figure 11.) The graph paper should include a 24-hour scale with each hour divided into tenths. Make the speed scale suitable to the data. Draw a horizontal line representing zero speed (slack). All apparent flood velocities are plotted above the slack line and all ebb velocities below. Tabulate the current directions directly above the accompanying speeds. Plot the wind speeds and directions on the upper portion of the graph. These data are obtained from shipboard hourly observations.
2. Draw a curve to follow as nearly as practical the general trend of the plotted velocity points.
3. Use the mean curve to find values for analysis. (Ignore the data points since some may be irregular and depart to a large degree from the normal curve.)

7.2 Determination of Time of Slack

The time of slack is determined by the hand-drawn curve as it crosses the slack line during the reversal in direction of current flow. During short durations of slack water, the time selected would be at the midpoint of all the slack waters.

7.3. Determination of Time of Maximum Current

The times of maximums are determined by bisecting the horizontal chord of the smooth curve. The speed of each current phase is determined by the highest speed attained by the mean curve at maximum. The exact time of maximum current is indicated by a check mark on the graph for later tabulation.

7.4 Reduction of Subordinate Tidal Current Stations

Reduce the subordinate tidal current station using the following procedure;

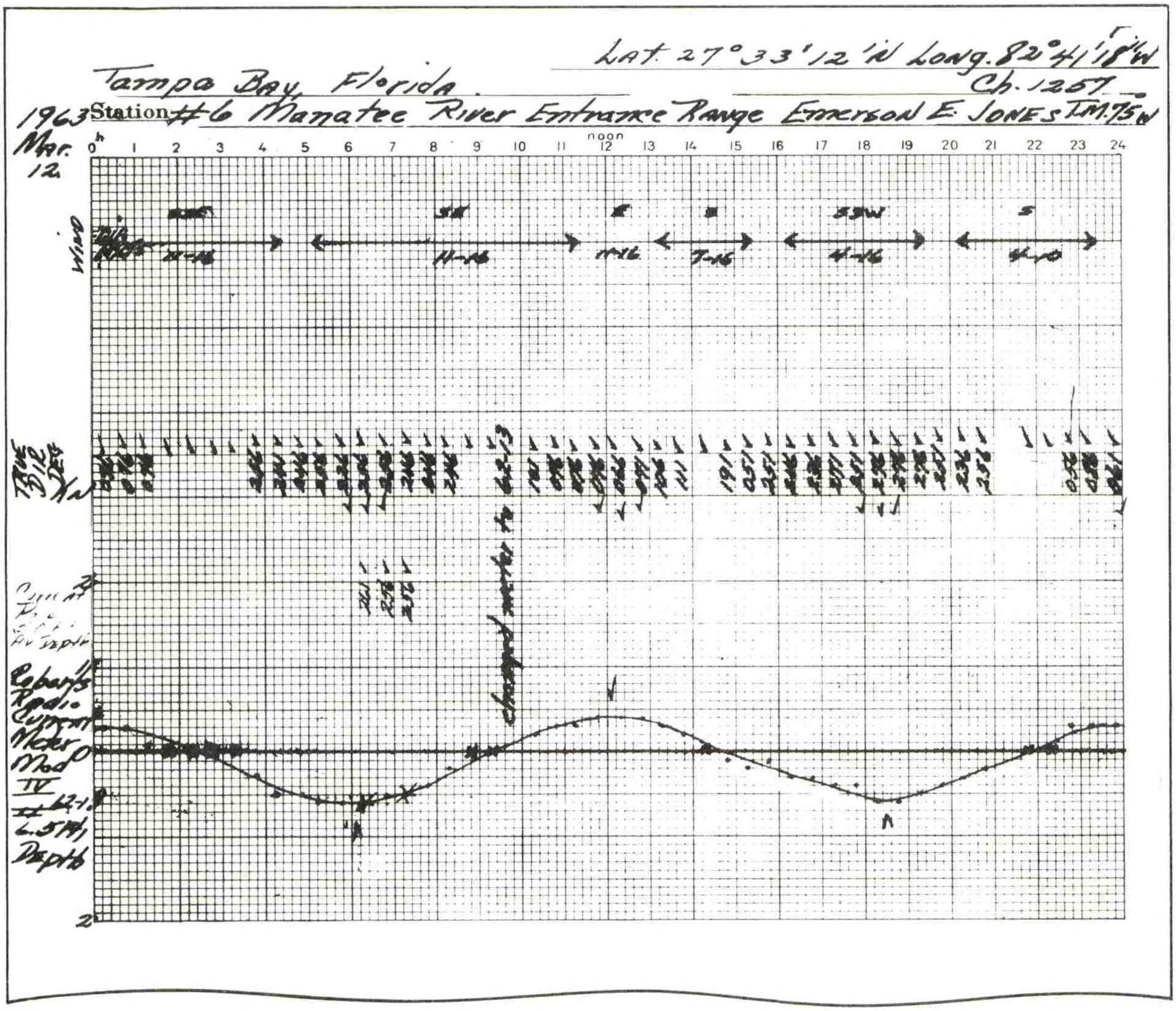


Figure 11. — Observed Tidal Current Speeds and Directions

7.4.1 Tabulation of Observed Times

The times of slack waters and maximum phases are obtained from the mean curve; these data values are tabulated on the proper form as shown in table 2. Enter the times in the appropriate columns of slack before flood, maximum flood, slack before ebb, and maximum ebb, in hours and tenths of hours.

7.4.2 Tabulation of Speeds and Directions for Strengths of Current Phases

Tabulate speeds and directions opposite the corresponding times of maximum floods and ebbs.

7.4.3 Tabulation of Predicted Tidal Currents at the Reference Station

Tabulate the predicted times of slacks and maximum currents (obtained from the tidal current tables) for the period corresponding to that of the observed data. The predicted times must be adjusted to the same time meridian (T.M.) as that of the observed data. Tabulate the predicted speeds of the floods and ebbs for the corresponding period.

7.5 Computing Time Differences for Subordinate Station

Compute time differences by comparing the tabulated times of the observed data to the corresponding predicted phases at the reference station. The time differences are designated as a minus (-) when the observed phase occurs earlier than the predicted phases; where none is given, the plus sign (+) is understood and indicates that the observed phase occurs later than the predicted phase. A mean time difference is determined for each phase. (Eliminate any time differences that vary greatly from the normal and would affect the mean value.)

7.6 Computing Correct Mean Speeds

The corrected mean speed is determined by averaging the observed speeds for the period of observation and adjusting it to a long-period average. When the period of observation is near the time of neaps (moon is in the first or last quarter), increase the speed by a velocity factor that will correct the observed average to a long-period mean. When the observations are at spring conditions (moon is new or full), decrease the observed average by a velocity factor to correct the observed data to a long-period mean. The computations presented in table 3 are applied to Station 6 at an instrument depth of 6.5 feet. (See table 7 below and figure 2 above).

Table 2. — Reduction of Subordinate Tidal Current Stations

FORM 451 (10-19-59)

COMPUTATION OF REVERSING CURRENTS

U.S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY

Lat. 27°33'12"N.

Station 6 MANATEE RIVER ENTRANCE RANGE T.M. 75° W Long. 82°41'18"W.

General locality TAMPA BAY, FLORIDA

Referred to PREDICTED CURRENTS AT TAMPA BAY ENTRANCE (EGMONT CHANNEL) Ref. sta. T.M. 75° W Chart No. 1257

Acc. No. T-15082 Party of EMERSON E. JONES Vel. cor. factor $f = \frac{1.20}{1.23} = 0.98$

Date Month (Year 1963)	Day	Instrument and depth	Observed current: Times: Slack before flood (h)	Observed current: Times: Strength of flood (h)	Observed current: Times: Slack before ebb (h)	Observed current: Times: Strength of ebb (h)	Observed current: Velocities: Strength of flood: Vel. (knots)	Observed current: Velocities: Strength of flood: Dir. true (°)	Observed current: Velocities: Strength of ebb: Vel. (knots)	Observed current: Velocities: Strength of ebb: Dir. true (°)	Reference current: Times: Slack before flood (h)	Reference current: Times: Strength of flood (h)	Reference current: Times: Slack before ebb (h)	Reference current: Times: Strength of ebb (h)	Reference current: Velocities: Strength of flood (knots)	Reference current: Velocities: Strength of ebb (knots)	Observed - Reference: Times: Slack before flood (h)	Observed - Reference: Times: Strength of flood (h)	Observed - Reference: Times: Slack before ebb (h)	Observed - Reference: Times: Strength of ebb (h)
MARCH	12	ROBERTS R.C.M. 6.5'	9.3	—	2.4	6.1	—	—	0.6	246	10.1	—	3.2	6.5		1.8	-0.8	—	-0.8	-0.4
			21.8	12.1	14.7	18.5	0.4	071	0.6	268	22.2	13.0	15.8	18.8	1.2	1.5	-0.4	-0.9	-1.1	-0.3
	13		9.7	0.3	3.1	6.4	0.3	069	0.6	241	10.4	1.1	3.8	7.0	1.1	1.6	-0.7	-0.8	-0.7	-0.6
			22.4	12.8	15.3	19.0	0.6	086	0.7	264	23.0	13.3	16.1	19.4	1.1	1.6	-0.6	-0.5	-0.8	-0.4
	14		11.0	2.0	4.3	7.6	0.5	066	0.5	224	10.6	1.8	4.6	7.5	1.0	1.1	0.4	0.2	-0.3	0.1
			23.8	14.3	16.3	18.8	0.4	076	0.7	269	23.8	13.6	16.4	19.9	1.0	1.8	0.0	0.7	-0.1	-1.1
	15		11.3	2.3	6.3	8.7	0.3	061	0.2	223	10.9	2.6	5.4	8.1	0.8	0.8	0.4	-0.3	0.9	0.6
			—	13.4	16.2	20.3	0.3	073	0.8	274	—	13.8	16.8	20.6	0.8	1.8	—	-0.4	-0.6	-0.3
	16		0.8	3.3	5.8		0.3	031	—	—	0.8	3.7	6.6		0.7		0.0	-0.4	-0.8	
						SUMS	3.1	533	4.7	2009				SUMS	7.7	12.0	-1.7	-2.4	-4.3	-2.4
						DIV.	8	8	8	8				DIV.	8	8	8	8	9	8
						MEANS	0.39	067	0.59	251				MEANS	0.96	1.50	-0.21	-0.30	-0.48	-0.30
							0.38 c		0.58 c				GR. INT. REF. STA.				1.82	4.47	6.82	10.57
													GR. INT. OBS. STA.				1.61	4.17	6.34	10.27
															(MCH)			4.04		

USCOMM-DC 27205-P59

Tabulated D.R.T 11/19/63 ✓ P.A.S. 11/19/63 Reduced D.R.T. 11/19/63 ✓ P.A.S. 11/19/63

Table 3.--Velocity Factor Computation

Best known mean current velocity at reference station
1/2 (F 1.0 + E 1.4) = 1.20

Velocity for observational period at reference station
1/2 (F 0.96 + E 1.50) = 1.23

Reduction factor for tidal current . . . . 1.20/1.23 = 0.98
Observed tidal current at this station . . . . 1/2(F 0.39 + E 0.59)= 0.49
Corrected tidal current. . . . . 0.49 x 0.98 = 0.48
Nontidal current . . . . 1/2(F 0.39 - E 0.59)= -0.10
Corrected flood current. . . . . 0.48 - 0.10 = 0.38c
Corrected ebb current. . . . . 0.48 + 0.10 = 0.58c

The Greenwich intervals for reference and subordinate stations at Tampa Bay Entrance (Egmont Channel) at Latitude 27°36.32"N and Longitude 82°46.05"W are presented in table 4.

Table 4.--Greenwich Intervals at Egmont Channel

Times Referred to Greenwich Transits. Directions True

Depth	Slack	Flood Strength			Slack	Ebb Strength			MCH
		Time	Vel.	Dir.		Time	Vel.	Dir.	
Feet	Hours	Hours	Knots	°	Hours	Hours	Knots	°	
8'& 20'	01:49 1.82	04:28 4.47	1.02	100	06:49 6.82	10:34 10.57	1.36	2.85	4:22 4.37

Semidiurnal "b" Transits
Average of 8' and 20' Depths

7.7 Computations of the Greenwich Intervals for Subordinate Stations

The time differences determined by comparison (observed-reference) are added to the Greenwich intervals on the reference stations as shown in table 5.

Table 5.--Computing Greenwich Intervals for Subordinate Stations

	Slack h m	Flood h m	Slack h m	Ebb h m
Greenwich Interval at reference station	1.82^h	$4:47^h$	6.82^h	10.57^h
Time differences at station 6@ 6.5' depth	-0.21^h	-0.30^h	-0.48^h	-0.30^h
Greenwich Interval station 6@ 6.5' depth	1.61^h	4.17^h	6.34^h	10.27^h

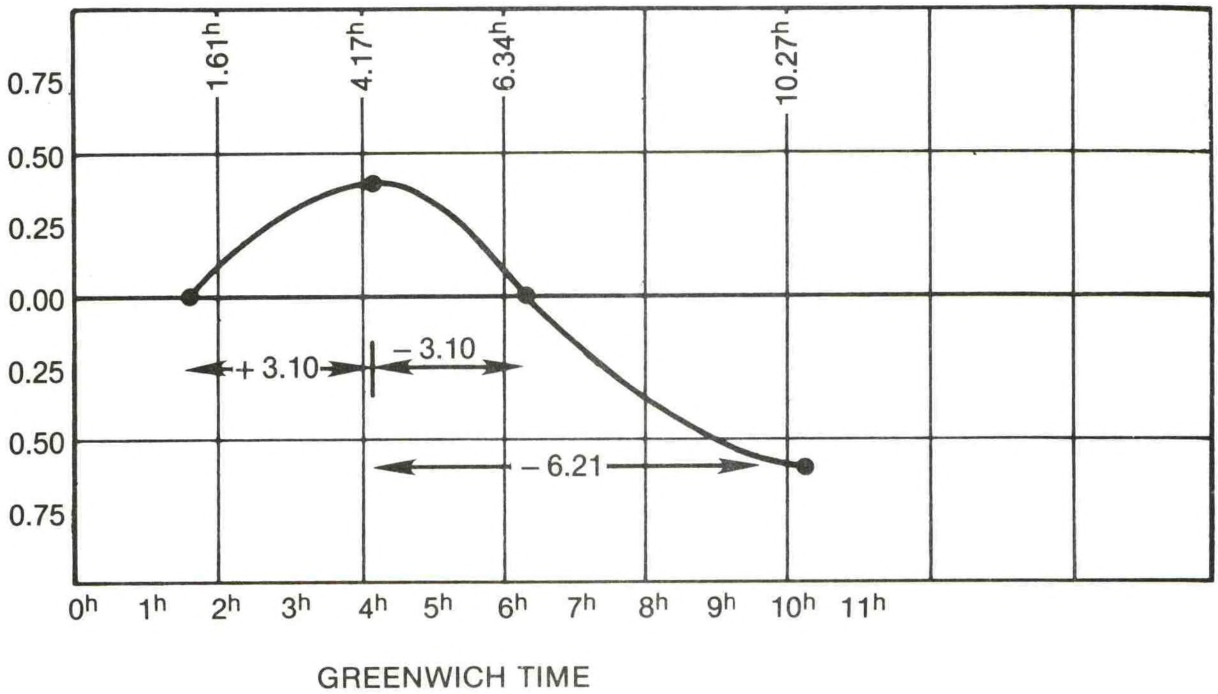
7.8 Computing Mean Current Hour (MCH)

The mean interval between the transit of the moon over the meridian of Greenwich and the time of the strength of flood current are modified by the times of slack water and strength of the ebb. (See figure 12.) In computing the mean current hour, an average is obtained of the intervals for four phases, that is, (1) flood strength, (2) slack before flood increased by 3.10 hours (one fourth of tidal cycle), (3) slack after flood decreased by 3.10 hours, and (4) ebb strength increased or decreased by 6.21 hours (one half of tidal cycle). Before taking the average, the four phases are made comparable by the addition or rejection of such multiples of 12.42 hours as may be necessary. The current hour is usually expressed in solar time but, if the use of lunar time is desired, the solar hour should be multiplied by the factor 0.966.

8.0 TAMPA BAY PHOTOGRAMMETRY

The measurement of surface currents by aerial photography supported the tidal current survey by furnishing data in areas not covered by moored meters and was executed by the Coastal Mapping Division (formerly Photogrammetry Division). The photogrammetry data of the surface currents were instantaneous measurements and are subject to influence by winds and other peripheral effects.

Aerial photography was scheduled during appropriate daylight in the period April 16 through April 30, 1963. The times of flights for photo purposes were selectively made to coincide with the hourly intervals to complement the meter data as depicted on the tidal current chart series, Tampa Bay. Therefore, the photogrammetry models are for the tidal periods of (1) two hours before flood, (2) one hour before flood, (3) maximum flood, (4) one hour after flood, (5) two hours before ebb, (6) one hour before ebb, (7) maximum ebb, and (8) one hour after ebb. For times of aerial photography for each tidal hour, see table 6.



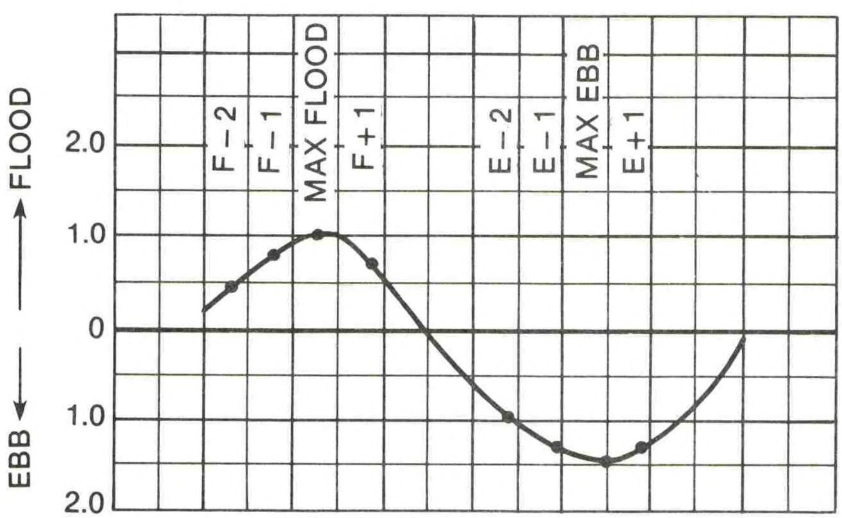
Slack before flood	1.61^h	+	3.10^h	=	4.71^h
Strength of flood	4.17^h			=	4.17^h
Slack before ebb	6.34^h	–	3.10^h	=	3.24^h
Strength of ebb	10.27^h	–	6.21^h	=	4.06^h
					16.18^h

Figure 12. — Mean Current Hour = 4.04^h

Table 6. — Photogrammetry for Tampa Bay, April 1963

	Predicted Times of Hourly Phase		Time of Photogrammetry				
Hourly Tidal Phase	Day	Hour	Day	Hours			
	20	07:37	20	07:27			
F – 2	21	08:10	21	08:16	08:32		
	25	10:09	25	10:09	10:22	10:38	
	20	08:37	20	08:37	08:48	08:54	
F – 1	21	09:10	21	09:13	09:25		
	25	11:09	25	11:02	11:15	11:24	
	20	09:37	20	09:34	09:47	09:53	
Flood	21	10:10	21	10:11	10:35		
	25	12:09	25	11:45	11:56	12:08	
	20	10:37	20	10:48	11:00		
FH	21	11:10	21	11:13	11:20	11:29	11:40
	25	13:09	25	13:16	13:26		
	20	13:37	20	13:46	13:51	14:08	
E – 2	21	14:12	21	14:10	14:20	14:28	14:39
	22	14:49	22	15:05	15:18		
	20	14:37	20	14:08	14:49	14:53	
E – 1	21	15:12	21	14:48	15:19	15:37	
	22	15:49	22	15:30	15:39	16:03	16:15
	20	15:37	20	15:32			
EBB	21	16:12	21	16:02	16:11	16:25	
	22	16:49	22	16:49	17:18		
	20	16:37	20	16:37	16:50		
E + 1	21	17:12	21	17:04	17:12	17:23	
	22	17:49	22	17:29	17:41		

Photogrammetry for each day was taken to coincide to the time of tidal hours referred to the predicted maximum floods and ebbs. Not all hourly intervals were photographed. The photography for each tidal hour was adjusted to a yearly mean value. See sketch below.



8.1 Photogrammetry

All photography was done with the Wild RF-9 superwide angle camera on panchromatic film. A photographic scale of 1:80,000 was used for Tampa, Old Tampa, and Hillsborough Bays. The small scale was necessary to avoid construction of numerous anchored and fixed objects offshore for orienting and clearing stereoscopic instrument models. The small area of Boca Ciega Bay and the Manatee River were photographed at a scale of 1:40,000.

8.2 Targets

Artificial foam replaced the plywood targets used on all previous current surveys because of the expense and safety hazards involved when using the latter for small scale photography. A 6% liquid solution identical to foam used by fire departments was used. The foam was generated in a special siphoning nozzle from a pump with a minimum discharge pressure of 50 psi and a rate of 30 gal/min at 60 psi.

Targets were spaced at intervals of approximately 0.5 nmi over the entire area scheduled for photography at any one time. Targets were not smaller than approximately 75 ft^2 in order to be compatible with the photographic scale.

Target size was determined by efficiency of foam generation and length of time generated. Water temperature is a controlling factor in the former and can be determined best by tests in water at the temperature anticipated in the area of operation. Water temperature during all tests made to date have been considerably lower than can be expected in the Tampa Bay area. Tests made after arrival on the working grounds found the length of time necessary to pump foam to obtain targets of the proper size.

8.3 Photogrammetry References

The material in the reference cited below are particularly germane to the subject discussed above.

Cameron H.L., The Measurement of Water Current Velocities by Parallax Methods. "Photogrammetric Engineering." March 1952

Cameron, H.L., Water Current Movement Measurement by Time Lapse Photography, "Photogrammetric Engineering," March 1952

Forrester, W.D., Plotting of Water Current Patterns by Photogrammetry, "Photogrammetric Engineering," December 1960

Harris, W.D., and Taylor, C.B., Jr., Measurement of Tidal Currents at Lituya Bay, Alaska, Introducing Aerial Photogrammetric Methods, "The International Hydrographic Review," January 1961

Keller, M., Technical Bulletin No. 22, "Tidal Current Survey by Photogrammetric Methods, " U.S. Department of Commerce, Coast and Geodetic Survey, "Photogrammetric Engineering," September 1963

9.0 CURRENT DIFFERENCES AND OTHER CONSTANTS

Tidal current data that will enable one to determine the approximate times of slack waters and times and speeds of maximum currents at various locations in Tampa Bay are furnished in table 7 which follows. These locations are designated as subordinate stations and are generally of short duration. These data were obtained in the 1963 field season. The subordinate stations in the table are referred to the reference station, Tampa Bay (Egmont Channel), Fla. Daily predictions for Tampa Bay are included in the "Tidal Current Tables, Atlantic Coast of North America." published annually by the National Oceanic and Atmospheric Administration, National Ocean Survey.

9.1 Station Location

The stations are listed to the nearest second or tenth of a minute so that they can be accurately located. Also, a station description designates the approximate location. See figure 2 above for an index chart which shows the location of the stations.

9.2 Observations

Date of observation includes the month and day for each station. The period shows the number of days of observed data obtained. The method indicates that the type of meter used was the Roberts Radio Current Meter (RRCM).

The depths of the meters depended on the depth of the water. The maximum number of meters possible was three per buoy. Each depth was tabulated separately to allow more accurate computations at specified depths by the user.

9.3 Times of Slacks

Separate time differences for slack before floods and slack before ebbs are given. Time differences, average maximum speeds, and directions are given for floods and ebbs. The time differences are given in hours and minutes. A minus (-) sign indicates that the given phase of the current is earlier than the specified phase of the current at the reference station. When no sign is given, the plus sign (+) is understood and indicates that the observed phase occurs later than that at the reference station.

9.4 Times and Speeds of Maximum Currents

The average maximum flood and ebb speeds and times are the computed mean of all the maximums for the year. These means include all the lower speeds during neap conditions (moon in the first or last quarter); all the higher speeds during spring conditions (moon is new or full); and, finally, the

Table 7. — Time Differences and Velocity Ratios

Sta. Number	Location	OBSERVATIONS					FLOOD STRENGTH					EBB STRENGTH				Mean	Velocity Ratio	
		Date	Period	Method	Depth	Slack	Time	Dir. True	Speed	Flood Dur.	Slack	Time	Dir. True	Speed	Ebb Dur.	Cur. Hour	Flood	Ebb
			Days		Feet	Hours After	Hours After	o	Knots	Hours	Hours After	Hours After	o	Knots	Hours	Hour		
1	Egmont Channel	March 4-10,	6	Roberts	42.5	-0:37	-0:06	071	1.20	6:16	0:39	-0:16	298	1.19	6:09	4:17	1.18	0.87
	27°36'33"N., 82°46'09"W.	1963		R.C.M.	70.8	-0:31	0:02	096	1.16	6:17	0:46	-0:13	280	1.02	6:08	4:23	1.14	0.75
2	Southwest Channel	March 4-9,	5	"	5.0	-0:55	-0:55	067	0.72	5:06	-0:49	-1:02	254	0.93	7:19	3:26	0.71	0.68
	27°34'10"N., 82°45'47"W.	1963			11.0	-0:56	-0:55	068	0.74	5:14	-0:42	-0:49	259	0.87	7.11	3:31	0.73	0.64
					17.0	-0:13	-1:07	070	0.60	5:43	-0:30	-1:01	262	0.76	6:42	3:24	0.59	0.56
3	Passage Key Inlet	March 4-9,			5.0	-1:26	-1:11	110	0.98	5:35	-0:50	-1:24	297	1.06	6:50	3:09	0.96	0.78
	27°32'26"N., 82°44'25"W.	1963	4 3/4	"	15.0	-1:39	-1:19	094	0.95	5:41	-0:58	-1:24	284	1.12	6:44	3:02	0.93	0.82
					25.0	-1:40	-1:17	088	0.81	5:38	-0:02	-1:10	267	1.09	6:47	3:05	0:79	0.80
4	Entrance Mullet Key Channel	March 12-16,	4 1/2	"	5.4	0:19	0:07	043	1.16	4:38	-0:03	0:06	247	1.41	7:47	4:29	1.14	1.04
	27°36'16"N., 82°43'26"W.	1963			16.5	-0:49	-0:20	050	1.10	5:49	0:00	-0:14	251	1.06	6:36	4:01	1.08	0.78
					27.0	-0:16	-0:28	079	1.03	6:15	-0:01	-0:34	265	0.84	6:10	3:47	1.01	0.65
5	3.1 n.m. East of Egmont Key	March 12-16,	4	"	6.0	-0:13	-0:08	069	0.78	5:17	0:04	-0:11	239	0.83	7:08	4:14	0.76	0.68
	27°35'06"N., 82°42'14"W.	1963			12.0	-0:47	-0:44	069	0.64	5:54	0:07	-0:12	258	0.56	6:31	3:58	0.63	0.41
6	Manatee River Entrance Range	March 12-16,	4 1/4	"	6.5	-0:13	-0:18	067	0.38	4:44	-0:29	-0:18	251	0.58	7:41	4:02	0.37	0.43
	27°33'12"N., 82°41'18"W.	1963																
7	1300 yds. S.W. of Mullet	March 18-22,	4 3/4	"	5.0	0:01	0:07	043	0.87	4:58	-0:01	0:13	256	1.06	7:27	4:27	0.85	0.79
	Shoal Light	1963			12.0	-0:17	-0:07	034	0.78	5:05	-0:12	-0:07	285	0.82	7:20	4:13	0.76	0.60
	27°36'58"N., 82°41'30"W.				18.0	-1:06	-0:05	053	0.67	6:22	0:16	0:10	239	0.65	6:03	4:11	0.66	0.48
8	3 n.m. N.W. of McGill Island	March 18-22,	4 1/4	"	6.0	-0:52	0:07	037	0.62	6:07	0:16	0:25	231	0.65	6:18	4:21	0.61	0.48
	27°35'30"N., 82°40'07"W.	1963			12.0	-1:06	0:01	063	0.41	6:10	0:04	0:19	234	0.48	6:15	4:11	0.40	
9	1 n.m. N.W. of McGill Island	March 25-27,	2 1/4	"	5.0	-1:00	0:47	036	0.32	5:48	-0:12	-0:31	212	0.90	6:37	3:44	0.31	0.35
	27°34'15"N., 82°38'38"W.	1963																
10	Sunshine Skyway Bridge	March 25-29,	4 1/4	"	5.0	-0:11	0:55	040	0.85	4:42	-0:29	-0:20	215	0.90	7:43	3:53	0.83	0.66
	27°37'53"N., 82°40'00"W.	1963			12.0	-0:26	-1:03	047	0.78	5:08	-0:18	-0:31	202	0.90	7:17	3:47	0.76	0.66
					18.0	-0:31	-0:59	046	0.68	5:31	-0:01	-0:23	218	0.91	6:54	3:54	0.67	0.67

Table 7. — Time Differences and Velocity Ratios (cont.)

Sta. Number	Location	OBSERVATIONS Date	Period	Method	Depth	Slack	FLOOD STRENGTH Time	Dir. True	Speed	Flood Dur.	Slack	EBB STRENGTH Time	Dir. True	Speed	Ebb Dur.	Mean Cur. Hour	Velocity Ratio Flood	Ebb
			Days		Feet	Hours After	Hours After	o	Knots	Hours	Hours After	Hours After	o	Knots	Hours	Hour		
11	Sunshine Skyway Bridge	March 25-29	4	Roberts	5.0	0:06	-0:09	070	0.83	5:04	0:10	0:08	188	1.14	7:21	4:26	0.81	0.84
	27°37'20"N., 82°39'40"W.	1963		R.C.M.	14.0	-0:09	-0:23	051	0.87	5:19	0:10	0:05	262	0.47	7:06	4:18	0.85	0.71
					22.0	-0:31	-0:14	054	0.73	5:45	0:14	0:04	236	0.80	6:40	4:15	0.72	0.59
12	Sunshine Skyway Bridge	March 25-29	4	"	5.0	-0:04	-0:20	052	0.70	5:07	0:03	-0:08	247	0.89	7:18	4:14	0.69	0.65
	27°36'33"N., 82°39'15"W.	1963			14.0	-0:23	-0:26	059	0.58	5:24	0:01	-0:07	247	0.85	7:01	4:08	0.57	0.62
					22.0	-0:29	-0:25	045	0.61	5:25	0:00	-0:07	227	0.80	6:00	4:07	0.60	0.59
13	Sunshine Skyway Bridge	April 2-6,	4	"	6.0	-0:49	-0:22	023	0.74	5:49	0:00	-0:52	258	0.88	6:36	3:52	0.73	0.65
	27°35'45"N., 82°38'27"W.	1963																
14	Junction Cut "A" & Cut "B"	April 2-6,	4 1/2	"	5.0	0:31	0:29	050	1.02	5:11	0:42	0:45	231	1.24	7:14	4:59	1.00	0.91
	27°38'20"N., 82°37'32"W.	1963			13.0	-0:12	-0:11	051	1.11	6:08	0:56	0:14	247	1.00	6:17	4:34	1.09	0.74
					20.0	-0:41	-0:37	051	0.84	6:19	0:37	0:12	200	0.67	6:06	4:15	0.82	0.49
15	3 n.m. West of Bishop Harbor	April 2-6,	4 1/4	"	6.0	-0:29	-0:20	068	0.70	5:27	-0:02	-0:24	247	0.88	6:58	4:03	0.69	0.65
	27°36'45"N., 82°37'30"W.	1963																
16	1.25 n.m. West of Bishop Harbor	April 2-6,	4 1/2	"	5.0	-1:22	-1:10	022	0.32	5:38	-0:44	1:01	158	0.41	6:47	3:18	0.31	0.30
	27°36'40"N., 82°35'40"W.	1963																
2b	400 yds. N.E. Aft. Range Cut "A"	April 15-19	4 1/6	"	5.0	-0:27	0:02	040	0.72	5:33	0:06	0:07	221	0.75	6:52	4:19	0.71	0.55
	27°39'02"N., 82°35'43"W.	1963			13.0	-0:37	-0:19	045	0.71	5:50	0:13	0:71	226	0.56	6:35	4:14	0.70	0.41
					20.0	-2:28	-0:31	018	0.52	8:16	0:48	-0:43	220	0.33	4:09	3:38	0.51	0.24
2c	1000 yds. N.W. Aft. Range Cut "F"	April 15-18	2 1/2	"	7.0	-0:24	0:23	330	0.36	6:54	1:30	-0:27	164	0.36	5:31	4:37	0.35	0.26
	27°49'02"N., 82°31'52"W.	1963																
2d	1 3/4 n.m. North Mangrove Pt.	April 15-19	4 1/2	"	7.0		-0:20	069	0.28			-0:47	245	0.36		3:52	0.27	0.26
	27°46'32"N., 82°28'27"W.	1963																

Table 7. — Time Differences and Velocity Ratios (cont.)

Sta. Number	Location	OBSERVATIONS: Date	OBSERVATIONS: Period	OBSERVATIONS: Method	OBSERVATIONS: Depth	Slack	FLOOD STRENGTH: Time	FLOOD STRENGTH: Dir. True	FLOOD STRENGTH: Speed	Flood Dur.	Slack	EBB STRENGTH: Time	EBB STRENGTH: Dir. True	EBB STRENGTH: Speed	Ebb Dur.	Mean Cur. Hour	Velocity Ratio: Flood	Velocity Ratio: Ebb
			Days		Feet	Hours After	Hours After	o	Knots	Hours	Hours After	Hours After	o	Knots	Hours	Hour		
bb	3 n.m. East of Pinellas Pt. 27°41'51"N., 82°34'59"W.	April 19-24 1963	5 3/4	Roberts R.C.M.	6.0 12.0	-0:07 -0:25	-0:04 0:01	006 030	0.64 0.59	5:28 5:43	0:22 0:18	0:07 0:07	181 205	0.65 0.50	6:57 6:42	4:26 4:22	0.63 0.58	0.48 0.37
bc	2.2 n.m. South of Gandy Bridge 27°50'36"N., 82°34'15"W.	April 19-25 1963	6	"	7.7 15.3	0:52 0:44	0:56 0:59	354 335	0.82 0.81	5:41 5:33	1:33 1:17	0:49 1:01	164 180	0.71 0.58	6:44 6:52	5:25 5:22	0.80 0.79	0.52 0.43
bd	Alafia River Cut 27°50'58"N., 82°25'17"W.	April 19-25 1963	6	"	5.0 14.5 23.0		 -2:11 -1:41	* 056 060	 0.20 0.28			-0:05 -0:22 -0:34	241 215 211	0.20 0.28 0.12		4:17 3:08 3:18	 0.20 0.27	 0.15 0.20
17	Bunces Pass 27°38'49"N., 82°44'22"W.	April 25-30 1963	4 3/4	"	8.0 16.0	-1:18 -1:20	-1:06 -0:52	128 121	1.00 0.96	5:30 5:37	-0:48 -0:43	-1:25 -1:24	315 315	1.10 0.98	6:55 6:48	3:13 3:17	0.98 0.94	0.81 0.72
18	Main Channel 27°41'33"N., 82°43'02"W.	April 25-29 1963	4	"	7.0 14.0	-1:02 -1:07	-0:39 -0:45	090 114	0.38 0.43	5:21 5:17	-0:41 -0:50	-1:20 -0:25	281 280	0.83 0.71	7:04 7:18	3:26 3:20	0.37 0.42	0.61 0.52
19	Vina Del Mar Channel 27°42'30"N., 82°43'29"W.	April 25-29 1963	4 1/4	"	7.0	-1:59	-2:54	015	0.56	5:09	-1:50	-1:46	148	0.74	7:16	2:15	0.55	0.54
20	2.0 n.m. South of Maximo Pt. 27°40'29"N., 82°41'00"W.	April 30- May 4, 1963	4	"	5.0	0:18	0:16	106	0.27	5:39	0:21	-0:13	304	0.33	6:46	4:23	0.26	0.24
21	2.0 n.m. S.W. of Pinellas Pt. 27°40'33"N., 82°39'32"W.	April 30- May 3, 1963	3	"	4.3	No Reduction, Observations Showed the Currents to be Weak and Variable.												
22	2.7. n.m. South of Pinellas Pt. 27°39'38"N., 82°38'30"W.	April 29- May 5, 1963	6 1/2	"	5.0 10.0	-1:02 -1:32	-0:34 -0:38	016 040	0.82 0.78	6:01 6:45	-0:01 0:13	-0:52 -1:01	209 208	0.93 0.82	6:24 5:40	3:44 3:37	0.80 0.76	0.68 0.60
23	0.5 n.m. S.E. of Pinellas Pt. 27°41'49"N., 82°37'57"W.	April 30, May 5, 1963	4 1/2	"	7.0	-2:01	-1:32	045	0.31	5:29	-1:31	-1:19	221	0.29	6:56	2:46	0.30	

*Long periods of slack. Current seldom floods.

Table 7. -- Time Differences and Velocity Ratios (cont.)

Sta. Number	Location	OBSERVATIONS Date	Period	Method	Depth	Slack	FLOOD STRENGTH Time	Dir. True	Speed	Flood Dur.	Slack	EBB STRENGTH Time	Dir. True	Speed	Ebb Dur.	Mean Cur. Hour	Velocity Ratio Flood	Ebb
			Days		Feet	Hours After	Hours After	o	Knots	Hours	Hours After	Hours After	o	Knots	Hours	Hour		
24	2.0 n.m. S.E. of Pinellas Pt. 27°41'05"N., 82°36'35"W.	May 5-9, 1963	4 1/3	"	5.0 10.0	0:06 -0:12	-0:42 -0:48	015 023	0.71 0.65	5:10 5:28	0:16 0:16	-0:04 -0:01	177 187	0.87 0.75	7:15 6:57	4:16 4:11	0.70 0.64	0.64 0.55
25	3.0 n.m. S.E. of Pinellas Pt. 27°40'23"N., 82°35'35"W.	May 5-9, 1963	4 1/4	"	5.0 14.5 23.0	0:23 -0:05 -0:26	0:31 -0:04 0:03	022 022 026	0.84 0.89 0.71	5:14 5:44 6:17	0:37 0:38 0:50	0:45 0:22 0:07	204 208 188	1.02 0.78 0.56	7:11 6:41 6:08	4:56 4:35 4:31	0.82 0.87 0.70	0.75 0.57 0.41
26	5.0 n.m. S.E. of Pinellas Pt. 27°39'13"N., 82°33'44"W.	May 5-9, 1963	4 1/4	"	7.0	-0:20	-0:42	356	0.35	4:57	-0:23	-0:22	214	0.52	7:28	3:55	0.34	0.38
27	1.0 n.m. East of Lewis Is. 27°43'28"N., 82°36'35"W.	May 9-13, 1963	4 1/4	"	5.0 13.5 21.0	0:37 0:26 0:18	-0:11 -0:19 0:05	007 022 352	0.86 0.79 0.70	4:37 4:56 5:01	0:14 0:22 0:19	0:09 0:28 0:41	186 143 152	1.02 0.74 0.51	7:48 7:29 7:24	4:34 4:37 4:43	0.84 0.77 0.69	0.75 0.54 0.37
28	2.5 n.m. East of Lewis Is. 27°43'10"N., 82°34'40"W.	May 9-13, 1963	4	"	6.5	0:12	0:01	014	0.53	4:44	-0:04	-0:05	187	0.48	7:41	4:23	0.52	0.35
29	2.0 n.m. West of Mary's Pt. 27°42'28"N., 82°33'00"W.	May 9-13, 1963	4	"	7.7 15.4	0:43 0:26	0:12 0:07	026 036	0.80 0.61	5:04 5:08	0:47 0:34	0:23 0:24	218 223	0.80 0.54	7:21 7:17	4:53 4:44	0.78 0.60	0.59 0.40
30	0.5 n.m. West of Sand Pt. 27°43'17"N., 82°30'13"W.	May 27-31, 1963	4 1/4	"	5.0		-0:53	063	0.29			-1:52	236	0.33		3:02	0.28	0.24
31	Cut "E" 27°44'10"N., 82°31'55"W.	May 27-31, 1963	4 1/2	"	5.0 13.5 21.0	0:00 0:06 -0:15	0:35 0:29 0:27	024 017 345	0.71 0.76 0.61	5:32 6:18 6:50	0:32 1:24 1:35	0:26 0:28 0:49	207 187 200	0.72 0.60 0.40	6:53 6:07 5:35	4:46 4:59 5:01	0.70 0.75 0.60	0.53 0.44 0.29
32	4.2 n.m. East of Three Stacks 27°45'15"N., 82°33'57"W.	May 27-31, 1963	4	"	5.0	-0:36	-0:10	015	0.48	5:30	-0:06	-0:33	210	0.50	6:55	4:01	0.40	0.37
33	1.2 n.m. East of Three Stacks 27°45'32"N., 82°37'00"W.	May 27 - June 1, 1963	4 1/2	"	7.7 15.3		0:28 0:27	358 053	0.30 0.26			-0:08 0:05	152 166	0.40 0.26		4:35 4:41	0.29 0.25	0.29 0.19

Table 7. — Time Differences and Velocity Ratios (cont.)

Sta. Number	Location	OBSERVATIONS Date	Period	Method	Depth	Slack	FLOOD STRENGTH Time	Dir. True	Speed	Flood Dur.	Slack	EBB STRENGTH Time	Dir. True	Speed	Ebb Dur.	Mean Cur. Hour	Velocity Ratio Flood	Ebb
			Days		Feet	Hours After	Hours After	o	Knots	Hours	Hours After	Hours After	o	Knots	Hours	Hour		
34	1.75 n.m. East of Snell Isle 27°47'37"N., 82°34'20"W.	June 2-6, 1963	4 1/4	"	5.0	1:18	1:03	343	0.32	4:32	0:50	1:12	181	0.43	7:53	5:28	0.31	0.32
					13.5	1:08	0:31	353	0.32	4:17	0:26	0:38	158	0.40	8:08	5:03	0.31	0.29
					21.0	0:37	0:05	000	0.34	4:51	0:28	0:24	165	0.44	7:34	4:46	0.33	0.32
35	North End of Cut "F" Channel 27°46'56"N., 82°31'25"W.	June 2-6, 1963	4	"	5.3		0:31	020	0.20			0:16	216	0.24		4:48	0.20	0.18
					16.0		0:34	006	0.24			0:42	206	0.14		5:02	0.24	0.10
					26.7		1:40	353	0.33					0.01		6:08	0.32	0.01
36	1 1/4 n.m. South of Gadsen Pt. 27°48'00"N., 82°28'47"W.	June 2-6, 1963	4	"	6.0	0:02	-0:34	069	0.33	4:53	-0:05	0:09	233	0.33	7:32	4:15	0.32	0.24
					18.0	-0:52	-1:04	061	0.57	7:10	1:18	0:03	249	0.06	5:15	4:13	0.56	0.04
					30.0	-1:30	-1:23	073	0.35	0:58	-0:32	-1:02	254	0.19	6:27	3:15	0.34	0.14
37	Junction Cut "A" and Cut "C" 27°48'45"N., 82°27'00"W.	June 6-10, 1963	4 1/4	"	6.0	0:15	-0:32	033	0.35	5:25	0:40	0:46	214	0.22	7:00	4:39	0.35	0.16
					18.0	-0:04	-0:01	036	0.37	5:58	0:54	0:42	210	0.10	6:27	4:45	0.36	0.07
					30.0	-0:30	-0:09	035	0.32	5:24	-0:06	0:11	207	0.09	7:01	4:14	0.31	0.07
38	1 1/4 n.m. East of Catfish Pt. 27°50'40"N., 82°26'43"W.	June 7-11, 1963	4 1/2	"	5.0		-0:20	023	0.26			0:43	165	0.15		4:56	0.25	0.11
					12.5		0:14	009	0.42			0:48	204	0.12		4:56	0.41	0.09
					19.0		0:01	022	0.46			0:29	153	0.10		4:40	0.45	0.07
39	West of Port Sutton 27°54'07"N., 82°26'14"W.	June 6-11, 1963	5 1/2	"	5.0	0:44	-0:28	060	0.25	3:52	-0:24	0:04	249	0.53	8:33	4:21	0.25	0.39
					15.0	0:18	-0:31	009	0.32	4:42	0:00	-0:22	186	0.34	7:43	4:13	0.31	0.25
					24.0	No Reduction, Data too Meager.												
40*	Ross Island, 1 Mile East of 27°49'54"N., 82°34'12"W.	Feb. 21 - March 20, 1964	29	Geodyne	15.0	2:45	5:36	358	0.86	5:18	8:05	11:46	179	0:72	7:07	5:35	0.84	0.53
41	0.4 n.m. East of Two Stacks 27°51'42"N., 82°35'12"W.	June 11-15, 1963	4	Roberts R.C.M.	5.8	0:04	-0:30	346	0.49	5:19	0:23	0:29	198	0.48	7:06	4:29	0.48	0.35
					17.5	0:09	0:27	329	0.65	5:40	0:49	0:07	197	0.29	6:45	4:45	0.64	0.21
					29.0	1:06	0:55	322	0.52	5:57	2:03	1:00	094	0.25	6:28	5:38	0.51	0.18

*Station 40 - Chief of Party - W.E. Randall (observations at 10-minute intervals).

Table 7. — Time Differences and Velocity Ratios (cont.)

Sta. Number	Location	OBSERVATIONS Date	Period	Method	Depth	Slack	FLOOD STRENGTH Time	Dir. True	Speed	Flood Dur.	Slack	EBB STRENGTH Time	Dir. True	Speed	Ebb Dur.	Mean Cur. Hour	Velocity Ratio Flood	Ebb
			Days		Feet	Hours After	Hours After	o	Knots	Hours	Hours After	Hours After	o	Knots	Hours	Hour		
42	West of Port Tampa 27°51'32"N., 82°33'27"W.	June 12-16, 1963	4 2/3	"	7.3 14.7	0:34 0:37	0:36 0:25	015 045	0.93 0.80	5:26 5:16	0:59 0:53	0:25 0:31	214 221	0.97 0.85	6:59 7:10	5:01 4:59	0.91 0.78	0.71 0.62
43	West End of Gandy Bridge 27°52'45"N., 82°34'50"W.	June 16-20, 1963	4 1/4	"	7.3 14.7	0:34 0:31	-0:19 -0:12	007 353	0.95 0.94	0:53 5:01	0:26 0:31	0:10 0:13	154 152	0.78 0.86	7:32 7:25	4:35 4:38	0.93 0.92	0.57 0.63
44	East End of Gandy Bridge 27°53'10"N., 82°33'05"W.	June 16-20, 1963	4	"	7.3 14.7	0:52 0:55	0:35 0:31	011 014	0.56 0.51	4:57 4:59	0:49 0:53	1:06 1:14	169 166	0.49 0.53	7:28 7:26	5:13 5:15	0.55 0.50	0.36 0.39
45	Howard Frankland Bridge 27°55'33"N., 82°35'10"W.	June 16-20, 1963	4 1/2	"	7.0	0:42	1:01	285	0.31	5:30	1:12	1:01	138	0.18	6:55	5:21	0.30	0.13
46	Courtney Campbell Parkway 27°58'05"N., 82°37'27"W.	June 16-20, 1963	4 1/3	"	7.0	1:00	0:37	338	0.49	4:49	0:49	1:01	138	0.61	7:37	5:14	0.48	0.45

higher speed ebbs that occur during the periods of extreme declination of the moon. Because of daily astronomical variations, accurate predicted speeds for the subordinate stations can be obtained by use of the speed ratios. See figure 13 for a plot of the tidal current throughout the month. Note the line indicating the average speed of flood as 1.02 knots and the average speed of ebb as 1.36 knots.

9.5 Flood and Ebb Duration

The duration of the flood phase is the interval of time in which the current is flooding. The average flood duration is computed by taking the difference between the time slack flood begins and slack ebb begins. The average duration of ebb is computed by subtracting the duration of flood from the half lunar day of $12^h 25^m$. Because of daily astronomical variations, accurate predictions of the maximum currents for any particular day can be best obtained by reference to a station where daily predictions are given; the speeds at the subordinate station is obtained by the speed ratios.

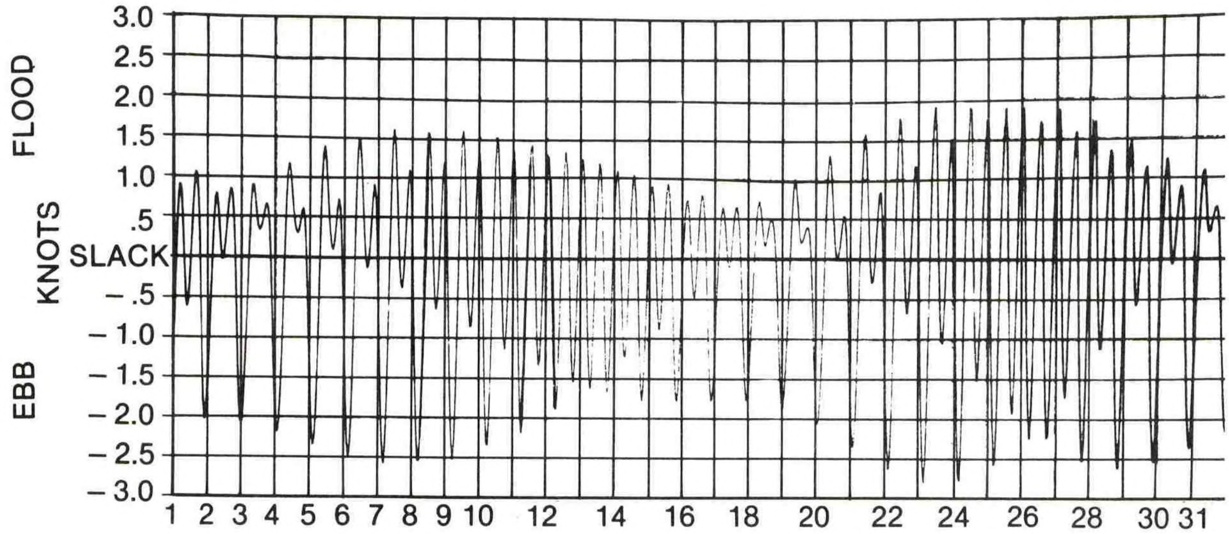
For example, suppose it is desired to find the time of slack water and the time and speed of the maximum current for the main channel (Station 18) at the 7-foot depth. On a given morning, the predicted currents at Tampa Bay Entrance are calculated as shown in the compilation below.

	Slack Water h	m	Maximum h	m	Ebb kts.	Slack Water h	m	Maximum h	m	Flood kts.
Tampa Bay Entrance	02	27	06	46	2.6	10	56	14	12	1.4
	-01	02	-00	39	x0.37 ratio	-00	41	-01	20	x .61 ratio
Main Channel (#18 @ 7' depth)	01	25	06	07	0.96	10	15	12	52	0.85

To determine the speed of the current at any time, refer to figure 14.

The speeds indicated in the above computations and also the data tabulation are speeds expected during periods of normal meteorological conditions. During periods of changing meteorological conditions, there is an accompanying changing nontidal effect. This is illustrated in figure 15.

TAMPA BAY ENTRANCE (Egmont Channel), FLA., 1963



ASTRONOMICAL DATA, 1963

Greenwich mean time of the moon's phases, apogee, perigee, greatest north and south declination, moon on the Equator, and the solar equinoxes and solstices.

March

	d.	h.	m.
◐	2	17	18
N	4	23	..
○	10	7	49
E	12	4	..
A	13	20	..
◑	18	12	08
S	19	15	..
$\odot_1$	21	8	20
●	25	12	10
E	25	23	..
P	26	8	..

●, new moon; ◐, first quarter; ○, full moon; ◑, last quarter; E, moon on the Equator; N, S, moon farthest north or south of the Equator; A, P, moon in apogee or perigee; $\odot_1$, sun at vernal equinox; $\odot_2$, sun at summer solstice; $\odot_3$, sun at autumnal equinox; $\odot_4$, sun at winter solstice.

0^h is midnight. 12^h is noon. The times may be adapted to any other time meridian than Greenwich by adding the longitude in time when it is east and subtracting it when west. (15° of longitude equals 1 hour of time).

This table was compiled from the American Ephemeris and Nautical Almanac.

Figure 13. — Tidal Current for One Entire Month

Interval between slack water and maximum current

Interval between slack water and desired time (rows, h m); interval between slack water and maximum current (columns, h m)

h	m	1 20	1 25	1 30	1 35	1 40	1 45	1 50	1 55	2 00	2 05	2 10	2 15	2 20	2 25	2 30	2 35	2 40	2 45
0	00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	05	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05
0	10	0.20	0.18	0.17	0.16	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.10
0	15	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.14
0	20	0.38	0.36	0.34	0.32	0.31	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.22	0.21	0.20	0.20	0.19
0	25	0.47	0.45	0.42	0.40	0.38	0.36	0.35	0.34	0.32	0.31	0.30	0.29	0.28	0.27	0.26	0.25	0.24	0.24
0	30	0.56	0.53	0.50	0.48	0.45	0.43	0.42	0.40	0.38	0.37	0.36	0.34	0.33	0.32	0.31	0.30	0.29	0.28
0	35	0.63	0.60	0.57	0.55	0.52	0.50	0.48	0.46	0.44	0.43	0.41	0.40	0.38	0.37	0.36	0.35	0.34	0.33
0	40	0.71	0.67	0.64	0.61	0.59	0.56	0.54	0.52	0.50	0.48	0.46	0.45	0.43	0.42	0.41	0.39	0.38	0.37
0	45	0.77	0.74	0.71	0.68	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.50	0.48	0.47	0.45	0.44	0.43	0.42
0	50	0.83	0.80	0.77	0.74	0.71	0.68	0.66	0.63	0.61	0.59	0.57	0.55	0.53	0.52	0.50	0.48	0.47	0.46
0	55	0.88	0.85	0.82	0.79	0.76	0.73	0.71	0.68	0.66	0.64	0.62	0.60	0.58	0.56	0.54	0.53	0.51	0.50
1	00	0.92	0.90	0.87	0.84	0.81	0.78	0.76	0.73	0.71	0.68	0.66	0.64	0.62	0.60	0.59	0.57	0.56	0.54
1	05	0.96	0.93	0.91	0.88	0.85	0.83	0.80	0.78	0.75	0.73	0.71	0.69	0.67	0.65	0.63	0.61	0.60	0.58
1	10	0.98	0.96	0.94	0.92	0.89	0.87	0.84	0.82	0.79	0.77	0.75	0.73	0.71	0.69	0.67	0.65	0.63	0.62
1	15	1.00	0.98	0.97	0.95	0.92	0.90	0.88	0.85	0.83	0.81	0.79	0.77	0.75	0.73	0.71	0.69	0.67	0.66
1	20	1.00	1.00	0.98	0.97	0.95	0.93	0.91	0.89	0.87	0.84	0.82	0.80	0.78	0.76	0.74	0.72	0.71	0.69
1	25		1.00	1.00	0.99	0.97	0.96	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.78	0.76	0.74	0.72
1	30			1.00	1.00	0.99	0.98	0.96	0.94	0.92	0.90	0.88	0.87	0.85	0.83	0.81	0.79	0.77	0.76
1	35				1.00	1.00	0.99	0.98	0.96	0.95	0.93	0.91	0.89	0.88	0.86	0.84	0.82	0.80	0.79
1	40					1.00	1.00	0.99	0.98	0.97	0.95	0.94	0.92	0.90	0.88	0.87	0.85	0.83	0.82
1	45						1.00	1.00	0.99	0.98	0.97	0.96	0.94	0.92	0.91	0.89	0.87	0.86	0.84
1	50							1.00	1.00	0.99	0.98	0.97	0.96	0.94	0.93	0.91	0.90	0.88	0.87
1	55								1.00	1.00	0.99	0.98	0.97	0.96	0.95	0.93	0.92	0.90	0.89
2	00									1.00	1.00	0.99	0.98	0.98	0.96	0.95	0.94	0.92	0.91
2	05										1.00	1.00	0.99	0.99	0.98	0.97	0.95	0.94	0.93
2	10											1.00	1.00	0.99	0.99	0.98	0.97	0.96	0.94
2	15												1.00	1.00	0.99	0.99	0.98	0.97	0.96
2	20													1.00	1.00	1.00	0.99	0.98	0.97
2	25														1.00	1.00	1.00	0.99	0.98
2	30															1.00	1.00	1.00	0.99
2	35																1.00	1.00	1.00
2	40																	1.00	1.00
2	45																		1.00

h	m	2 50	2 55	3 00	3 05	3 10	3 15	3 20	3 25	3 30	3 35	3 40	3 45	3 50	3 55	4 00	4 05	4 10	4 15
0	00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
0	10	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
0	15	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.09	0.09
0	20	0.18	0.18	0.17	0.17	0.16	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.12
0	25	0.23	0.22	0.22	0.21	0.20	0.20	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.17	0.16	0.16	0.16	0.15
0	30	0.27	0.27	0.26	0.25	0.24	0.24	0.23	0.23	0.22	0.22	0.21	0.21	0.20	0.20	0.20	0.19	0.19	0.18
0	35	0.32	0.31	0.30	0.29	0.28	0.28	0.27	0.26	0.26	0.25	0.25	0.24	0.24	0.23	0.23	0.22	0.22	0.21
0	40	0.36	0.35	0.34	0.33	0.32	0.32	0.31	0.30	0.30	0.29	0.28	0.28	0.27	0.26	0.26	0.25	0.25	0.24
0	45	0.40	0.39	0.38	0.37	0.36	0.36	0.35	0.34	0.33	0.32	0.32	0.31	0.30	0.30	0.29	0.28	0.28	0.27
0	50	0.45	0.43	0.42	0.41	0.40	0.39	0.38	0.37	0.36	0.36	0.35	0.34	0.34	0.33	0.32	0.32	0.31	0.30
0	55	0.49	0.47	0.46	0.45	0.44	0.43	0.42	0.41	0.40	0.39	0.38	0.38	0.37	0.36	0.35	0.34	0.34	0.33
1	00	0.53	0.51	0.50	0.49	0.48	0.46	0.45	0.44	0.43	0.42	0.42	0.41	0.40	0.39	0.38	0.38	0.37	0.36
1	05	0.56	0.55	0.54	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41	0.40	0.40	0.39
1	10	0.60	0.59	0.57	0.56	0.55	0.53	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.43	0.42
1	15	0.64	0.62	0.61	0.60	0.58	0.57	0.56	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.45
1	20	0.67	0.66	0.64	0.63	0.61	0.60	0.59	0.58	0.56	0.55	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.47
1	25	0.71	0.69	0.68	0.66	0.65	0.63	0.62	0.61	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.50
1	30	0.74	0.72	0.71	0.69	0.68	0.66	0.65	0.64	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.53
1	35	0.77	0.75	0.74	0.72	0.71	0.69	0.68	0.66	0.65	0.64	0.63	0.62	0.60	0.59	0.58	0.57	0.56	0.55
1	40	0.80	0.78	0.77	0.75	0.74	0.72	0.71	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.61	0.60	0.59	0.58
1	45	0.82	0.81	0.79	0.78	0.76	0.75	0.73	0.72	0.71	0.69	0.68	0.67	0.66	0.65	0.63	0.62	0.61	0.60
1	50	0.85	0.84	0.82	0.80	0.79	0.78	0.76	0.75	0.73	0.72	0.71	0.70	0.68	0.67	0.66	0.65	0.64	0.63
1	55	0.87	0.86	0.84	0.83	0.81	0.80	0.78	0.77	0.76	0.74	0.73	0.72	0.71	0.70	0.68	0.67	0.66	0.65
2	00	0.90	0.88	0.87	0.85	0.84	0.82	0.81	0.80	0.78	0.77	0.76	0.74	0.73	0.72	0.71	0.70	0.68	0.67
2	05	0.92	0.90	0.89	0.87	0.86	0.84	0.83	0.82	0.80	0.79	0.78	0.77	0.75	0.74	0.73	0.72	0.71	0.70
2	10	0.93	0.92	0.91	0.89	0.88	0.87	0.85	0.84	0.83	0.81	0.80	0.79	0.78	0.76	0.75	0.74	0.73	0.72
2	15	0.95	0.94	0.92	0.91	0.90	0.88	0.87	0.86	0.85	0.83	0.82	0.81	0.80	0.78	0.77	0.76	0.75	0.74
2	20	0.96	0.95	0.94	0.93	0.92	0.90	0.89	0.88	0.87	0.85	0.84	0.83	0.82	0.80	0.79	0.78	0.77	0.76
2	25	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.88	0.87	0.86	0.85	0.84	0.82	0.81	0.80	0.79	0.78
2	30	0.98	0.98	0.97	0.96	0.95	0.94	0.92	0.91	0.90	0.89	0.88	0.87	0.85	0.84	0.83	0.82	0.81	0.80
2	35	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82
2	40	1.00	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.84	0.83
2	45	1.00	1.00	0.99	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85
2	50	1.00	1.00	1.00	0.99	0.99	0.98	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87
2	55		1.00	1.00	1.00	0.99	0.99	0.98	0.97	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88
3	00			1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.90
3	05				1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91
3	10					1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96	0.96	0.95	0.94	0.93	0.92
3	15						1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96	0.96	0.95	0.94	0.93
3	20							1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.95	0.94
3	25								1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.95
3	30									1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96
3	35										1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97
3	40											1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.98
3	45												1.00	1.00	1.00	1.00	0.99	0.99	0.98
3	50													1.00	1.00	1.00	1.00	0.99	0.99
3	55														1.00	1.00	1.00	1.00	0.99
4	00															1.00	1.00	1.00	1.00
4	05																1.00	1.00	1.00
4	10																	1.00	1.00
4	15																		1.00

h	m	4 20	4 25	4 30	4 35	4 40	4 45	4 50	4 55	5 00	5 05	5 10	5 15	5 20	5 25	5 30	5 35	5 40
0	00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
0	10	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0	15	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07
0	20	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09
0	25	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12
0	30	0.18	0.18	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14
0	35	0.21	0.21	0.20	0.20	0.20	0.19	0.19	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.16	0.16
0	40	0.24	0.24	0.23	0.23	0.22	0.22	0.22	0.21	0.21	0.20	0.20	0.20	0.20	0.19	0.19	0.19	0.18
0	45	0.27	0.26	0.26	0.25	0.25	0.24	0.24	0.24	0.23	0.23	0.23	0.22	0.22	0.22	0.21	0.21	0.21
0	50	0.30	0.29	0.29	0.28	0.28	0.27	0.27	0.26	0.26	0.26	0.25	0.25	0.24	0.24	0.24	0.23	0.23
0	55	0.33	0.32	0.32	0.31	0.30	0.30	0.29	0.29	0.28	0.28	0.28	0.27	0.27	0.26	0.26	0.26	0.25
1	00	0.36	0.35	0.34	0.34	0.33	0.32	0.32	0.31	0.31	0.30	0.30	0.30	[illegible]	0.29	0.28	0.28	0.27
1	05	0.38	0.38	0.37	0.36	0.36	0.35	0.34	0.34	0.33	0.33	0.32	0.32	0.31	0.31	0.30	0.30	0.30
1	10	0.41	0.40	0.40	0.39	0.38	0.38	0.37	0.36	0.36	0.35	0.35	0.34	0.34	0.33	0.33	0.32	0.32
1	15	0.44	0.43	0.42	0.42	0.41	0.40	0.40	0.39	0.38	0.38	0.37	0.36	0.36	0.36	0.35	0.34	0.34
1	20	0.46	0.46	0.45	0.44	0.43	0.43	0.42	0.41	0.41	0.40	0.39	0.39	0.38	0.38	0.37	0.37	0.36
1	25	0.49	0.48	0.48	0.47	0.46	0.45	0.44	0.44	0.43	0.42	0.42	0.41	0.40	0.40	0.39	0.39	0.38
1	30	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.46	0.45	0.45	0.44	0.43	0.43	0.42	0.42	0.41	0.40
1	35	0.54	0.53	0.52	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.46	0.46	0.45	0.44	0.44	0.43	0.42
1	40	0.57	0.56	0.55	0.54	0.53	0.52	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.46	0.46	0.45	0.45
1	45	0.59	0.58	0.57	0.56	0.56	0.55	0.54	0.53	0.52	0.52	0.51	0.50	0.49	0.49	0.48	0.47	0.47
1	50	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.54	0.53	0.52	0.51	0.51	0.50	0.49	0.49
1	55	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.58	0.57	0.56	0.55	0.54	0.54	0.53	0.52	0.51	0.51
2	00	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.60	0.59	0.58	0.57	0.56	0.56	0.55	0.54	0.53	0.53
2	05	0.68	0.68	0.66	0.66	0.64	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.58	0.57	0.56	0.55	0.55
2	10	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.60	0.59	0.58	0.57	0.56
2	15	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.62	0.61	0.60	0.59	0.58
2	20	0.75	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.63	0.62	0.61	0.60
2	25	0.77	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64	0.64	0.63	0.62
2	30	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.66	0.65	0.64
2	35	0.80	0.80	0.78	0.77	0.76	0.75	0.74	0.74	0.72	0.72	0.71	0.70	0.69	0.68	0.67	0.66	0.66
2	40	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.72	0.71	0.70	0.69	0.68	0.67
2	45	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.72	0.71	0.70	0.69
2	50	0.86	0.85	0.84	0.82	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.72	0.71
2	55	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.74	0.73	0.72
3	00	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.76	0.75	0.74
3	05	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75
3	10	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.77
3	15	0.92	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.79	0.78
3	20	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80
3	25	0.94	0.94	0.93	0.92	0.91	0.90	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81
3	30	0.96	0.95	0.94	0.93	0.32	0.92	0.91	0.90	0.89	0.88	0.67	0.87	0.86	0.85	0.84	0.83	0.82
3	35	0.96	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.85	0.85	0.84
3	40	0.97	0.96	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.85
3	45	0.98	0.97	0.97	0.96	0.95	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.89	0.88	0.88	0.87	0.86
3	50	0.98	0.98	0.97	0.97	0.96	0.95	0.95	0.94	0.93	0.93	0.92	0.91	0.90	0.90	0.89	0.88	0.87
3	55	0.99	0.98	0.98	0.97	0.97	0.96	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.91	0.90	0.89	0.88
4	00	0.99	0.99	0.98	0.98	0.98	0.97	0.96	0.96	0.95	0.94	0.94	0.93	0.92	0.92	0.91	0.90	0.90
4	05	1.00	0.99	0.99	0.98	0.98	0.98	0.97	0.96	0.96	0.95	0.95	0.94	0.93	0.93	0.92	0.91	0.90
4	10	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.95	0.95	0.94	0.94	0.93	0.92	0.92
4	15	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.96	0.95	0.94	0.94	0.93	0.92
4	20	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.96	0.95	0.94	0.94	0.93
4	25		1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.96	0.95	0.95	0.94
4	30			1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.98	0.97	0.96	0.96	0.95	0.95
4	35				1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.98	0.97	0.97	0.96	0.96
4	40					1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.98	0.97	0.97	0.96
4	45						1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.98	0.97	0.97
4	50							1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.97
4	55								1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98
5	00									1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98
5	05										1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
5	10											1.00	1.00	1.00	1.00	1.00	0.99	0.99
5	15												1.00	1.00	1.00	1.00	1.00	0.99
5	20													1.00	1.00	1.00	1.00	1.00
5	25														1.00	1.00	1.00	1.00
5	30															1.00	1.00	1.00
5	35																1.00	1.00
5	40																	1.00

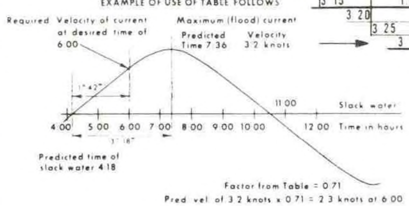
EXPLANATION

Tidal current is the periodic horizontal flow of water accompanying the rise and fall of the tide. Advance information for tidal currents is made available in the annually published National Ocean Survey Tidal Current Tables. These tables give daily predictions of the times of slack waters and the times and velocities of the maximum flood and ebb currents for current stations along the Atlantic Coast of North America and Pacific Coast of North America and Asia.

Though the predictions in the Tidal Current Tables give only the slack waters and the maximum currents, the velocity of the current at any intermediate time can be obtained approximately by the use of this Table. Directions for its use are as follows:

1. From the predictions find the time of slack water and the time and velocity of maximum current (flood or ebb), one of which is immediately before and the other after the desired time for which the velocity of the current is to be calculated.
2. Find the interval of time between the above slack water and maximum current, and enter the top of the Table with the interval which most nearly agrees with this value.
3. Find the interval of time between the above slack water and the desired time, and enter the side of the Table with the interval which most nearly agrees with this value.
4. Find, in the table, the factor corresponding to the above two intervals, and multiply the predicted maximum velocity by this factor. The result will be the approximate velocity of the current at the desired time.

EXAMPLE OF USE OF TABLE FOLLOWS



Find the velocity of the current in Tampa Bay at the desired time of 6:00 on a day when the predictions which immediately precede and follow 6:00 are as follows:

1. Slack Water — Time 4:18; Maximum (Flood) — Time 7:36, Velocity 3.2 knots
2. Interval between slack water and maximum flood is 7:36 − 4:18 = 3h 18m. Column heading nearest to 3h 18m is 3h 20m.
3. Interval between slack water and desired time is 6:00 − 4:18 = 1h 42m. Line labeled 1h 40m is nearest to 1h 42m.
4. Factor in column 3h 20m and on line 1h 40m is 0.71. The predicted flood velocity of 3.2 knots multiplied by 0.71 gives a flood velocity of 2.3 knots for the desired time.

Notes

1. When the interval between slack water and maximum current is greater than 5h 40m, enter the Table with one-half the interval between slack water and maximum current and one-half the interval between slack water and the desired time and use the factor thus found.
2. This Table is applicable to the phase of the current that approximates a sine curve during the semidiurnal period of the month (a). During the diurnal period (b) the table is not applicable to part of the flood cycle.

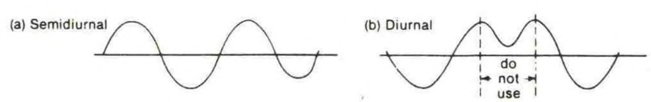
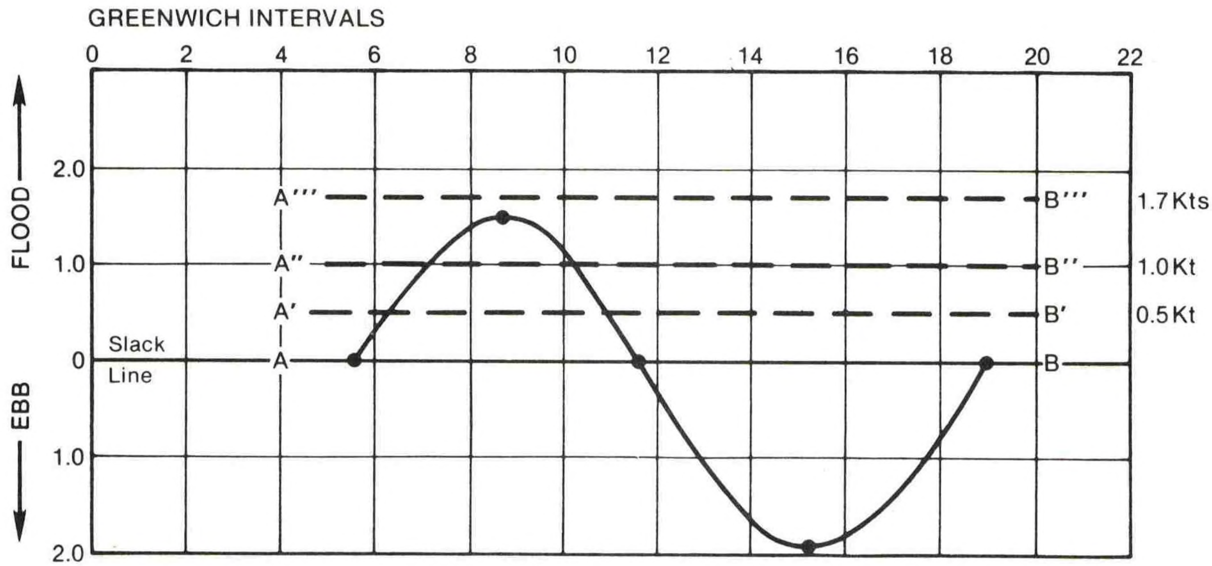


Figure 14. — Determination of Current Velocity at Any Time



Slack Lines	Slack Time		Flood Current				Slack Time		Ebb Current				Added Nontidal Knots
	h	m	h	m	Speed knots	Dir. °T	h	m	h	m	Speed knots	Dir. °T	
A—B	05	33	08	44	1.5	100	11	37	15	10	1.9	285	—
A'—B'	06	18	08	44	1.0	100	10	48	15	10	2.4	285	0.5
A''—B''	07	06	08	44	0.5	100	10	06	15	10	2.9	285	1.0
A'''—B'''	None		08	44	min.	285	None		15	10	3.6	285	1.7

Slack line A—B indicates currents during normal meteorological conditions and shows an average nontidal flow of 0.2 knot. Lines A'—B', A''—B'', and A'''—B''' indicate slack lines during nontidal increases of 0.5, 1.0, and 1.7 knots, respectively.

The increased nontidal current in the ebb direction has five results.

1. The times of slacks before flood occur progressively later.
2. The times and directions of maximum flood remain the same but the maximum speed is reduced by the amount of the nontidal current.
3. The times of slacks before ebb occur progressively earlier.
4. The times and directions of maximum ebb current remain the same but the maximum speed is increased by the amount of the nontidal current.
5. When the nontidal current has a speed that exceeds the speed of the tidal current, the result is represented by the current curve below the slack line A'''—B'''. (The curve depicts a continuous flow in the ebb direction with the minimum speed occurring at the time of the expected tidal flood current and a maximum speed at the time of strength of ebb current.)

Figure 15. — Effect of Changing Meteorological Conditions

☆ U.S. GOVERNMENT PRINTING OFFICE: 1978— 261-238/251

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Departr Commerce on October 3, 1970. The mission responsibilities of NOAA are to assess the socioeconomic of natural and technological changes in the environment and to monitor and predict the state of the solic the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical in tion in the following kinds of publications:

PROFESSIONAL PAPERS — Important definitive research results, major techniques, and special investigations.

CONTRACT AND GRANT REPORTS — Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS — Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS — Reports containing data, observations, instructions, etc. A partial listing includes data serials; prediction and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS — Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS — Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.

Information on availability of NOAA publications can be obtained from:

ENVIRONMENTAL SCIENCE INFORMATION CENTER (D822)
ENVIRONMENTAL DATA AND INFORMATION SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

6009 Executive Boulevard
Rockville, MD 20852

NOAA--S/T 76-2296