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Special Publication No. 162

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1930

U. S. DEPARTMENT OF COMMERCE
R. P. LAMONT, Secretary
COAST AND GEODETIC SURVEY
R. S. PATTON, Director

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TIDES AND CURRENTS IN CHESAPEAKE BAY AND TRIBUTARIES

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By

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PREFACE

The growth of commerce, engineering, and scientific work during recent years has created an urgent and constantly growing demand from navigators, engineers, scientists, and the public generally for complete tide and current information for the important waterways of the United States. To meet this demand and to complete and coordinate the tide and current data on file in the archives of the Coast and Geodetic Survey, this bureau started in 1922 a series of comprehensive tide and current surveys of the important waterways of the country. This work has been completed for several of the more important harbors of the country, and is now being carried on as rapidly as the available funds permit.

This volume is the seventh of the series on tides and currents in the important waterways of the United States. These publications are listed on page 138.

The material presented in this volume is based on observations made at various times in Chesapeake Bay and its tributaries. In addition to the observations made by this bureau, some observations made by the United States Army Engineers and the United States Navy have been included. Approximately one-half the current stations for which data are given were occupied during the survey of 1927–28.

A. J. Hoskinson and G. L. Anderson, junior hydrographic and geodetic engineers, United States Coast and Geodetic Survey, were in charge of this work during the 1927 and 1928 seasons, respectively.

Part I of this volume which deals with the tides in Chesapeake Bay and tributaries was prepared by H. E. Finnegan and G. L. Anderson, junior hydrographic and geodetic engineers, United States Coast and Geodetic Survey, and Part II, which deals with the currents in Chesapeake Bay and tributaries was prepared by F. J. Haight, associate mathematician, United States Coast and Geodetic Survey.

The general characteristics of tides and tidal currents, which were discussed in Special Publication No. 111, are reprinted in the appendix to the present volume for convenience of reference.

Attention is also directed to the tide and current tables, which are published in advance annually by the Coast and Geodetic Survey. These tables contain data based upon the latest information available at the time of publication. They include the predicted tides and currents for every day in the year at a number of principal ports and also contain summaries of the principal tide and current elements for several thousand places throughout the world. Other publications of the Coast and Geodetic Survey relating to tides and currents are listed in the back of this volume.

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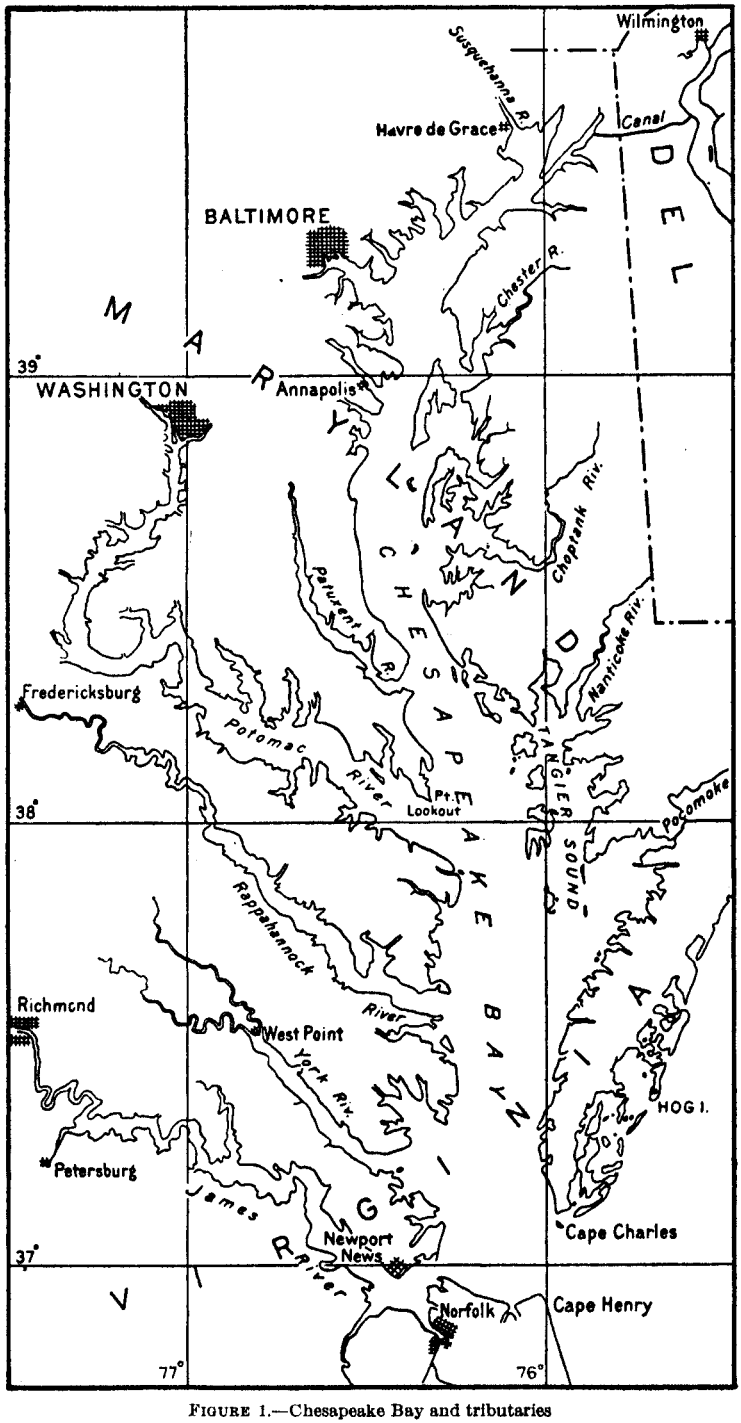


FIGURE 1.—Chesapeake Bay and tributaries

TIDES AND CURRENTS IN CHESAPEAKE BAY AND TRIBUTARIES

INTRODUCTION

Chesapeake Bay, with its tributaries forms one of the most important waterways on our Atlantic coast. On this waterway are located many important cities, including the ports of Baltimore, Norfolk, and Newport News, which have a large trade carried in foreign and domestic vessels. It is also the center of large oystering and fishing industries.

The main entrance to the bay, between Cape Charles and Cape Henry, has a width of 10 miles and a depth in the main channel of from 50 to 100 feet. The bay is approximately 170 nautical miles in length from the entrance to the mouth of the Susquehanna River. Throughout this stretch the channel depths are not less than 14 feet.

The bay forms also part of the inside route from northern to southern ports—through the Chesapeake & Delaware Canal northward; through the Dismal Swamp Canal and the Albemarle & Chesapeake Canal southward.

Numerous rivers empty into Chesapeake Bay, draining a total area of about 74,000 square miles. Among the largest of these are the Susquehanna, which rises in southern New York; the Potomac, the Rappahannock, York, and James, which rise in the Alleghany Mountains.

The earliest tidal observations on record at the Coast and Geodetic Survey for Chesapeake Bay were made at Annapolis, Md., on June 6, 1844. Observations were made at Old Point Comfort, Va., on July 1, 1844, when a 30-year series was begun. The earlier tidal observations were made primarily in connection with the charting of the coast. The methods and equipment used in the earlier days were in keeping with the reconnaissance nature of the work. With the introduction of the automatic tide gauge, which was put in use about the year 1854, tidal data became more accurate, being freed from errors due to personal equations. Further accuracy came with the use of standard time, which was adopted in 1883. With these improvements, a number of tide stations were established along the coasts to run over a period of years to furnish data for the prediction of tides, to establish tidal datum planes, and to furnish data for the study of tidal phenomena.

Part I.—TIDES IN CHESAPEAKE BAY AND TRIBUTARIES

THE CHESAPEAKE WATERWAYS

COMPONENT PARTS

For the purpose of discussion, the waterways that make up Chesapeake Bay and tributaries are divided into five parts: The lower bay, the middle bay, the upper bay, Hampton Roads and York River, and the Rappahannock and Potomac Rivers. For each of these parts one or more illustrating figures have been prepared showing the locations at which tide observations have been made.

THE LOWER BAY

The entrance from the ocean to Chesapeake Bay is between Cape Charles on the north and Cape Henry on the south. The main channel, which is broad and deep, leads along the south side. The northern half of the entrance is obstructed by shoals through which minor channels lead. The lower bay from the entrance to Point Lookout, a distance of about 70 miles, has an average width of about 15 miles and a maximum width of about 25 miles. The average depth is about 30 feet. A channel 35 feet deep leads from the ocean to Baltimore, a distance of about 150 miles. Through Hampton Roads the James, Nansemond, and Elizabeth Rivers enter the bay. The York, the Rappahannock, the Potomac, and many small rivers and bays form an irregular shore line on the western shore.

The eastern shore has many small creeks. Pocomoke Sound enters the bay from the northeast.

THE MIDDLE BAY

The middle bay extends from Point Lookout to the Severn River, a distance of about 56 miles, with an average width of about 6 miles. The main part of the middle bay has an average depth of about 40 feet. The western shore is regular, with a sand beach extending most of its length. The Patuxent River enters north of Cedar Point. The eastern shore is made up of irregular bays and sounds into which flow the Nanticoke and Choptank Rivers and numerous smaller streams.

THE UPPER BAY

The upper bay extends from the Severn River to the mouth of the Susquehanna River, a distance of about 40 miles. This part of the bay varies in width, the maximum being about 8 miles. The main channel for most of its length is close to the eastern shore. The western shore is covered with extensive shoals through which numerous small channels lead. The Chesapeake & Delaware Canal connects Chesapeake Bay and the Delaware River with a sea-level canal the effective depth of which is 12 feet at mean low water. The entrance to the canal is through Elk River and Back Creek. Patapsco River, on the western side of the bay, 136 miles from the entrance, is the approach to the city of Baltimore. The river is about 3½ miles

wide at the mouth, but the entrance is obstructed by extensive shoals. A dredged channel 35 feet deep and 600 feet wide leads from the entrance to Baltimore.

HAMPTON ROADS, JAMES AND YORK RIVERS

Hampton Roads, at the south end of Chesapeake Bay, about 16 miles west of Cape Henry, is the approach to Norfolk, Newport News, and points on the James River and is one of the important anchorages of the east coast of the United States. A channel of 37 feet leads to the anchorage. The Elizabeth River, on which Norfolk and Portsmouth are located, enters Hampton Roads from the southeast. Hampton Roads has an average width of about 5 miles and an average depth of about 20 feet. The James River, emptying into the western end of Hampton Roads at Newport News, is the approach to Richmond, Petersburg, Smithfield, and City Point. It is navigable to the city of Richmond, 89 miles above Newport News. The James River is being improved under a project to obtain a depth of 22 feet to the city of Richmond. Nansemond River, on the southwest side of Hampton Roads, is the approach to the city of Suffolk, 18 miles above the mouth. A 12-foot dredged channel leads to Suffolk from the mouth of the river.

York River is broad and comparatively straight from the mouth to West Point, a distance of 35 miles, where it divides and forms the Mattaponi and Pamunkey Rivers. A 20-foot channel leads to West Point.

RAPPAHANNOCK AND POTOMAC RIVERS

Rappahannock River, on the western side of Chesapeake Bay, 40 miles above the entrance and 111 miles below Baltimore, is the approach to the city of Fredericksburg, at the head of navigation 95 miles above the entrance, and to numerous villages and landings. A 9-foot channel leads to Fredericksburg.

Potomac River on the western side of Chesapeake Bay, 66 miles above the entrance and 84 miles below Baltimore, forms the boundary between the States of Maryland and Virginia, and is the approach to Alexandria and Washington and many villages and landings. It is navigable to Washington, 95 miles above the mouth, and by small craft to a point about 3 miles above Key Bridge. A channel 24 feet deep leads from the entrance to Washington.

THE TIDE AT BALTIMORE (FORT McHENRY)

THE SERIES OF OBSERVATIONS

One of the longer series of tide observations obtained in Chesapeake Bay and tributaries is that at Fort McHenry, Baltimore, Md. The observations began in July, 1902, and have been continuous since that time. For the tables and discussions that follow the period 1903 to 1927 will be used. A Coast and Geodetic Survey standard automatic tide gauge was used. The heights on a paper record were compared with a fixed zero by readings made on a fixed staff, these comparative readings being made several times weekly.

A fixed datum was established to which the heights on the curve were referred, by leveling between the tide staff and a number of

permanent bench marks on shore. The staff was at intervals connected by levels to the bench marks to insure that the elevation of the staff had not changed.

THE LUNITIDAL INTERVALS

The lunitidal intervals at Baltimore, or the intervals by which the high and low waters follow the moon's meridian passage, vary from day to day. A change in the wind or weather will vary the lunitidal interval; the principal variation, however, is due to the change in the positions of the moon and sun with respect to the earth.

In Table 1 are given the high and low waters for Fort McHenry, Baltimore, for the month of June, 1919. A summer month is used to exemplify the tides at Baltimore because it is less likely to be affected by changes in weather conditions. The change in the lunitidal intervals from day to day is shown in columns 7 and 8. In the second column the figures in parentheses refer to the lower transits of the moon, and the values derived from them are shown in parentheses in the lunitidal interval columns.

The corrected or local lunitidal intervals at the foot of the page are obtained by subtracting a correction of 0.28 hour from the mean for the month. This correction is necessary to refer the average interval to the local meridian, since for the sake of convenience the individual values are obtained directly from the standard times of high and low water and the Greenwich transits of the moon.

TABLE 1.—*Daily high and low waters, Fort McHenry, Baltimore, Md., June, 1919*

Date	Moon's transit meridian of Greenwich	Time of—		Duration of—		Lunitidal interval		Height of—		Range—	
		High water	Low water	Rise	Fall	High water	Low water	High water	Low water	Rise	Fall
	Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Feet*	*Feet*	*Feet*	*Feet*
1	(2.5)	8.4	1.0	7.4	-------	(5.9)	(−1.5)	6.2	4.3	1.9	-------
	14.9	21.5	16.2	5.3	7.8	6.6	1.3	5.3	4.4	0.9	1.8
2	(3.4)	9.6	3.2	6.4	5.7	(6.2)	(−0.2)	5.9	4.4	1.5	0.9
	15.9	22.0	16.9	5.1	7.3	6.1	1.0	5.5	4.4	1.1	1.5
3	(4.3)	10.5	4.3	6.2	6.3	(6.2)	(0.0)	5.6	4.4	1.2	1.1
	16.7	23.4	17.7	5.7	7.2	6.7	1.0	5.2	4.1	1.1	1.5
4	(5.1)	11.8	5.4	6.4	6.0	(6.7)	(0.3)	5.5	4.4	1.1	0.8
	17.4	-------	18.5	-------	6.7	-------	1.1	-------	4.3	-------	1.2
5	(5.8)	0.6	6.7	6.1	6.1	7.2	(0.9)	5.4	4.7	1.1	0.7
	18.2	11.9	19.4	5.2	7.5	(6.1)	1.2	5.4	4.2	0.7	1.2
6	(6.5)	1.3	7.7	5.9	6.4	7.1	(1.2)	5.7	5.0	1.5	0.7
	18.9	11.7	20.2	4.0	8.5	(5.2)	1.3	5.4	4.2	0.4	1.2
7	(7.3)	2.0	9.5	5.8	7.5	7.1	(2.2)	5.4	4.3	1.2	1.1
	19.6	13.8	20.9	4.3	7.1	(6.5)	1.3	4.7	3.6	0.4	1.1
8	(8.0)	2.8	10.3	5.9	7.5	7.2	(2.3)	5.1	4.0	1.5	1.1
	20.3	15.3	21.7	5.0	6.4	(7.3)	1.4	4.6	3.7	0.6	0.9
9	(8.7)	3.7	11.1	6.0	7.4	7.4	(2.4)	5.5	4.6	1.8	0.9
	21.1	15.8	22.3	4.7	6.5	(7.1)	1.2	5.1	4.4	0.5	0.7
10	(9.4)	4.6	12.2	6.3	7.6	7.5	(2.8)	5.8	4.4	1.4	1.4
	21.8	16.5	22.2	4.3	5.7	(7.1)	0.4	4.9	4.2	0.5	0.7
11	(10.2)	5.3	13.0	7.1	7.7	7.5	(2.8)	5.7	4.1	1.5	1.6
	22.6	17.4	22.8	4.4	5.4	(7.2)	0.2	4.4	3.7	0.3	0.7
12	(11.0)	6.3	13.4	7.5	7.1	7.7	(2.4)	5.3	4.0	1.6	1.3
	23.4	18.2	23.2	4.8	5.0	(7.2)	−0.2	4.6	3.9	0.6	0.7
13	(11.8)	6.8	-------	7.6	-------	7.4	-------	5.7	-------	1.8	-------
	-------	18.9	14.3	4.6	7.5	(7.1)	(2.5)	5.0	4.5	0.5	1.2
14	0.3	7.2	0.9	6.3	6.6	6.9	0.6	5.4	3.9	1.5	1.1
	(12.7)	19.6	14.7	4.9	7.5	(6.9)	(2.0)	5.1	4.2	0.9	1.2
15	1.1	8.0	0.4	7.6	4.8	6.9	−0.7	6.1	4.6	1.5	0.5
	(13.5)	20.2	15.3	4.9	7.3	(6.7)	(1.8)	5.0	4.5	0.5	1.6
16	1.9	8.1	2.1	6.0	5.9	6.2	0.2	5.6	4.3	1.3	0.7
	(14.3)	21.4	15.8	5.6	7.7	(7.1)	(1.5)	5.0	4.2	0.8	1.4

TABLE 1.—*Daily high and low waters, Fort McHenry, Baltimore, Md., June, 1919*—Continued

Date	Moon's transit meridian of Greenwich	Time of—		Duration of—		Lunitidal interval		Height of—		Range—	
		High water	Low water	Rise	Fall	High water	Low water	High water	Low water	Rise	Fall
	Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Feet*	*Feet*	*Feet*	*Feet*
17	2.7	8.8	2.1	6.7	4.7	6.1	−0.6	5.8	4.3	1.5	0.7
	(15.1)	21.7	16.7	5.2	7.9	(6.6)	(1.6)	5.1	4.4	0.7	1.4
18	3.5	9.8	3.5	6.3	5.8	6.3	0.0	5.5	4.2	1.3	0.9
	(15.9)	22.6	16.7	5.9	6.9	(6.7)	(0.8)	5.0	4.0	1.0	1.5
19	4.3	10.5	3.4	7.1	4.8	6.2	−0.9	5.7	4.5	1.2	0.5
	(16.7)	23.4	17.5	5.9	7.0	(6.7)	(0.8)	5.4	4.3	1.1	1.4
20	5.1	11.2	5.7	5.5	6.3	6.1	0.6	5.5	4.5	1.0	0.9
	(17.5)	-------	18.5	-------	7.3	-------	(1.0)	-------	4.1	-------	1.4
21	5.9	1.2	7.1	6.7	5.9	(7.7)	1.2	5.1	4.1	1.0	1.0
	(18.3)	11.8	19.3	4.7	7.5	5.9	(1.0)	4.8	3.2	0.7	1.6
22	6.8	1.1	7.8	5.8	6.7	(6.8)	1.0	4.8	3.3	1.6	1.5
	(19.2)	13.5	18.3	5.7	4.8	6.7	(−0.9)	3.9	3.4	0.6	0.5
23	7.6	2.4	9.6	8.1	7.2	(7.2)	2.0	5.6	4.4	2.2	1.2
	(20.1)	14.0	20.5	4.4	6.5	6.4	(0.4)	4.9	3.8	0.5	1.1
24	8.6	3.3	10.6	6.8	7.3	(7.2)	2.0	5.7	4.5	1.9	1.2
	(21.1)	14.8	21.4	4.2	6.6	6.2	(0.3)	5.0	3.8	0.5	1.2
25	9.6	4.8	10.9	7.4	6.1	(7.7)	1.3	5.7	4.6	1.9	1.1
	(22.1)	16.6	22.3	5.7	5.7	7.0	(0.2)	5.5	4.9	0.9	0.6
26	10.6	5.1	13.2	6.8	8.1	(7.0)	2.6	6.7	5.4	1.8	1.3
	(23.1)	17.2	23.4	4.0	6.2	6.6	(0.3)	6.0	4.7	0.6	1.3
27	11.7	5.9	13.1	6.5	7.2	(6.8)	1.4	5.9	4.4	1.2	1.5
	-------	17.6	-------	4.5	-------	5.9	-------	5.1	-------	0.7	-------
28	(0.2)	6.3	1.0	5.3	7.4	(6.1)	(0.8)	4.5	3.4	1.1	1.7
	12.7	20.4	14.2	6.2	7.9	7.7	1.5	3.4	2.4	1.0	2.1
29	(1.1)	8.2	0.8	7.4	4.4	(7.1)	(−0.3)	5.7	3.0	2.7	0.4
	13.6	20.1	14.2	5.9	6.0	6.5	0.6	6.2	4.9	1.3	0.8
30	(2.1)	8.2	2.2	6.0	6.1	(6.1)	(0.1)	6.5	5.1	1.4	1.1
	14.5	20.8	16.3	4.5	8.1	6.3	1.8	5.2	4.6	0.6	1.9
Sum		-------	-------	336.5	379.5	391.6	55.3	309.3	244.1	65.2	64.3
Means		-------	-------	5.80	6.66	6.75	0.95	5.33	4.21	1.12	1.13
Correction to intervals		-------	-------	-------	-------	−0.28	−0.28	-------	-------	-------	-------
Corrected intervals		-------	-------	-------	-------	6.47	0.67	-------	-------	-------	-------

It will be noted that consecutive high or low water lunitidal intervals frequently differ from each other by two or three hours, and that individual values often differ from the mean for the month by from one to two hours. Variations of this magnitude are due mainly to weather effects, and occur frequently at places where the range of tide is small. At Baltimore such meteorological fluctuations usually mask the smaller periodic variations due to astronomical conditions, and precise values for the last-named variations can be obtained only by averaging a large number of observations, in which case the nonperiodic weather effects tend to average out.

Partly due to this averaging out of meteorological effects and partly because several of the more important astronomic variations go through a complete cycle in approximately one month, the differences between monthly means of the lunitidal intervals are much smaller than those between the individual or daily values. Similarly the yearly means agree much more closely than the monthly means, and, as explained below, the values from 19-year periods of observations agree very closely with each other.

Tables 2 and 3 give the monthly values of the lunitidal intervals for the years 1903 to 1927, inclusive, and also the annual means of high-water interval and low-water interval for the 25-year period, divided into 5-year groups. A study of these tables reveals that the monthly high or low water intervals sometimes differ from each other by 3 or 4 tenths of an hour, while the yearly values differ by a maximum of 0.15 hour, and the means of the 5-year groups by a maximum of 0.07 hour. The means of the two 19-year groups differ by 0.02 hour for both the high-water and low-water intervals.

TABLE 2.—*High-water intervals, monthly means, Fort McHenry, Baltimore, Md.*

Year	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean	5-year mean
	Hrs.	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*
1903	6.56	6.57	6.37	6.47	6.45	6.58	6.43	6.50	6.61	6.56	6.52	6.66	6.52	
1904	6.66	6.66	6.58	6.53	6.50	6.54	6.53	6.55	6.46	6.50	6.57	6.56	6.55	
1905	6.48	6.51	6.52	6.39	6.61	6.46	6.63	6.66	6.42	6.55	6.55	6.67	6.54	6.52
1906	6.50	6.50	6.54	6.66	6.53	6.40	6.46	6.52	6.47	6.56	6.70	6.63	6.54	
1907	6.58	6.51	6.41	6.38	6.30	6.31	6.54	6.58	6.46	6.66	6.46	6.47	6.47	
1908	6.57	6.43	6.45	6.42	6.43	6.54	6.51	6.52	6.52	6.47	6.55	6.45	6.49	
1909	6.51	6.53	6.36	6.50	6.41	6.42	6.48	6.51	6.34	6.52	6.54	6.52	6.47	
1910	6.55	6.53	6.43	6.47	6.50	6.44	6.45	6.60	6.36	6.61	6.65	6.58	6.51	6.49
1911	6.48	6.48	6.44	6.34	6.37	6.48	6.43	6.47	6.49	6.54	6.25	6.58	6.45	
1912	6.51	6.50	6.50	6.39	6.57	6.50	6.60	6.57	6.50	6.45	6.48	6.51	6.51	
1913	6.51	6.43	6.35	6.49	6.46	6.44	6.48	6.40	6.48	6.54	6.40	6.54	6.46	
1914	6.35	6.36	6.51	6.38	6.41	6.45	6.48	6.56	6.44	6.55	6.34	6.50	6.44	
1915	6.39	6.51	6.44	6.42	6.49	6.41	6.58	6.65	6.36	6.44	6.47	6.58	6.48	6.46
1916	6.44	6.55	6.68	6.27	6.45	6.50	6.55	6.42	6.41	6.38	6.39	6.42	6.46	
1917	6.36	6.27	6.43	6.49	6.34	6.46	6.56	6.46	6.37	6.58	6.52	6.46	6.44	
1918	6.42	6.38	6.41	6.40	6.54	6.51	6.45	6.40	6.37	6.54	6.54	6.36	6.44	
1919	6.45	6.33	6.43	6.43	6.32	6.49	6.51	6.39	6.48	6.47	6.29	6.44	6.42	
1920	6.54	6.47	6.59	6.34	6.35	6.48	6.57	6.50	6.41	6.45	6.43	6.60	6.48	6.45
1921	6.48	6.46	6.44	6.37	6.43	6.39	6.44	6.46	6.47	6.47	6.47	6.34	6.44	
1922	6.50	6.60	6.45	6.38	6.42	6.42	6.47	6.52	6.52	6.51	6.52	6.62	6.49	
1923	6.37	6.46	6.38	6.34	6.46	6.55	6.50	6.51	6.52	6.52	6.50	6.38	6.46	
1924	6.49	6.33	------	6.35	6.37	6.58	6.50	6.54	6.47	6.47	6.45	6.50	6.46	
1925	6.43	6.41	6.60	6.44	6.41	6.45	6.53	6.49	6.53	6.41	6.59	6.45	6.48	6.46
1926	6.50	6.48	6.43	6.42	6.28	6.47	6.50	6.48	6.42	6.42	6.57	6.52	6.46	
1927	6.50	6.33	6.44	6.34	6.46	6.46	6.46	6.54	6.44	6.47	6.35	6.37	6.43	
Sum [1]	162.13	161.59	155.18	160.41	160.86	161.73	162.64	162.80	161.32	162.64	162.10	162.71	161.89	32.38
Mean	6.49	6.46	6.47	6.42	6.43	6.47	6.51	6.51	6.45	6.51	6.48	6.51	6.48	6.48

[1] 25 years.

Mean, 19 years, 1903 to 1921=6.48 hours. Mean, 19 years, 1909 to 1927=6.46 hours.

TABLE 3.—*Low-water intervals, monthly means, Fort McHenry, Baltimore, Md.*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean	5-year mean
	Hrs.	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*
1903	0.74	0.80	0.87	0.72	0.67	0.62	0.77	0.73	0.78	0.76	0.77	0.70	0.74	
1904	0.61	0.65	0.85	0.84	0.68	0.69	0.67	0.65	0.72	0.67	0.69	0.68	0.70	
1905	0.65	0.80	0.71	0.67	0.67	0.65	0.62	0.75	0.72	0.63	0.73	0.73	0.69	0.69
1906	0.82	0.69	0.60	0.77	0.61	0.65	0.59	0.73	0.73	0.72	0.74	0.63	0.69	
1907	0.67	0.76	0.73	0.60	0.54	0.57	0.66	0.65	0.77	0.64	0.62	0.63	0.65	
1908	0.74	0.64	0.88	0.81	0.72	0.75	0.51	0.65	0.66	0.58	0.57	0.54	0.67	
1909	0.63	0.77	0.69	0.61	0.80	0.59	0.69	0.65	0.63	0.69	0.72	0.80	0.69	
1910	0.82	0.73	0.84	0.53	0.48	0.66	0.66	0.68	0.60	0.57	0.70	0.53	0.65	0.66
1911	0.61	0.57	0.60	0.58	0.47	0.60	0.61	0.54	0.68	0.58	0.54	0.67	0.59	
1912	0.67	0.63	0.73	0.76	0.63	0.67	0.70	0.62	0.81	0.75	0.77	0.79	0.71	
1913	0.81	0.77	0.84	0.71	0.66	0.58	0.71	0.66	0.68	0.68	0.74	0.84	0.72	
1914	0.64	0.65	0.56	0.61	0.70	0.62	0.71	0.75	0.57	0.63	0.70	0.70	0.65	
1915	0.65	0.85	0.57	0.50	0.66	0.76	0.70	0.80	0.57	0.67	0.69	0.60	0.67	0.66
1916	0.74	0.70	0.41	0.60	0.65	0.64	0.70	0.58	0.72	0.47	0.53	0.69	0.62	
1917	0.57	0.54	0.57	0.68	0.62	0.88	0.72	0.66	0.61	0.72	0.74	0.58	0.66	
1918	0.54	0.66	0.60	0.71	0.71	0.66	0.70	0.66	0.69	0.66	0.60	0.84	0.67	
1919	0.75	0.57	0.71	0.47	0.57	0.67	0.63	0.66	0.67	0.70	0.71	0.48	0.63	
1920	0.65	0.74	0.69	0.63	0.51	0.67	0.62	0.67	0.53	0.60	0.67	0.74	0.64	0.64
1921	0.68	0.73	0.70	0.63	0.59	0.52	0.59	0.59	0.49	0.52	0.70	0.72	0.62	
1922	0.70	0.79	0.57	0.59	0.62	0.68	0.68	0.61	0.66	0.61	0.64	0.82	0.66	
1923	0.64	0.56	0.63	0.56	0.69	0.62	0.66	0.62	0.63	0.55	0.67	0.59	0.62	
1924	0.61	0.62	------	0.54	0.58	0.63	0.71	0.60	0.64	0.65	0.63	0.63	0.62	
1925	0.54	0.74	0.73	0.67	0.66	0.63	0.63	0.58	0.71	0.50	0.62	0.66	0.64	0.63
1926	0.66	0.46	0.70	0.67	0.57	0.55	0.57	0.66	0.63	0.82	0.45	0.66	0.62	
1927	0.70	0.77	0.80	0.63	0.74	0.64	0.61	0.72	0.66	0.65	0.53	0.60	0.67	
Sum	16.84	17.19	16.58	16.09	15.80	16.20	16.42	16.47	16.56	16.02	16.47	16.85	16.49	3.28
Mean	0.67	0.69	0.69	0.64	0.63	0.65	0.66	0.66	0.66	0.64	0.66	0.67	0.66	0.66

Mean, 19 years, 1903 to 1921=0.67 hours. Mean, 19 years, 1909 to 1927=0.65 hours.

In a period of approximately 19 years all of the more important variations of the tide-producing forces of the moon go through complete cycles. It is, therefore, customary to regard the values of tidal constants derived from a 19-year series as being mean values. The observations from 1903 to 1927 may be divided into two over-

lapping 19-year groups, 1903 to 1921 and 1909 to 1927. From the first 19-year group the high-water interval is 6.48 hours and the low-water interval is 0.66 hour. From the second 19-year group, these intervals are 6.46 hours and 0.65 hour, respectively. For the mean values of the lunitidal intervals at Baltimore we may take the results of the last 19 years, which is 6.46 hours for the high water and 0.65 hour for the low water.

THE DURATIONS OF RISE AND FALL

The duration of rise of the tide is the time required for the water to rise from its minimum height at low water to its maximum height at high water, and similarly, the duration of fall is the time required for the water to fall from high water to low water. In Table 1 are given the individual values for the durations of rise and fall for the month of June, 1919. These values show similar fluctuations to those of the lunitidal intervals and due to the same causes. As in the case of the lunitidal intervals, the monthly means show much less variation than the individual values, the yearly means less than the monthly means, and so on.

TABLE 4.—*Durations of rise and fall, Fort McHenry, Baltimore, Md.: Monthly means 1903 and 1927*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1903:	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*
Rise	5.82	5.77	5.50	5.75	5.78	5.96	5.66	5.77	5.83	5.80	5.75	5.96	5.78
Fall	6.60	6.65	6.92	6.67	6.64	6.46	6.76	6.65	6.59	6.62	6.67	6.46	6.64
1927:													
Rise	5.80	5.56	5.64	5.71	5.72	5.82	5.85	5.82	5.78	5.82	5.82	5.77	5.76
Fall	6.62	6.86	6.78	6.71	6.70	6.60	6.57	6.60	6.64	6.60	6.60	6.65	6.66

Table 4 gives the monthly means of the durations of rise and fall for the years 1903 and 1927, the first and last years of the 25-year series. In this table there is clearly shown a month to month variation. For any two consecutive months the greatest variation is 0.30 hour, while the greatest variation between any two months is 0.46 hour.

There is apparently no progressive or periodic change from month to month, and this fact leads to the belief that the fluctuations in the monthly values are due mainly to meteorological disturbances.

The durations of rise and fall as derived from the means of the 5-year groups are, respectively: First group, 5.83 hours and 6.59 hours; second group, 5.83 hours and 6.59 hours; third group, 5.80 hours and 6.62 hours; fourth group, 5.81 hours and 6.61 hours; and fifth group, 5.83 hours and 6.59 hours. The differences between the corresponding values are small.

If the two 19-year groups are used, the durations of rise and fall are, respectively, 5.81 hours and 6.61 hours for each group.

From the above it is evident that the tide at Baltimore is of the river type rather than the ocean type, for in the ocean type of tide the duration of rise and the duration of fall are very nearly equal. The river type of tide differs from the ocean tide in that the duration of rise is less than the duration of fall.

THE MEAN SEA LEVEL

The plane of mean sea level may be defined as the plane about which the tide oscillates or the height the water would assume if the sea were not affected by the rise and fall of the tide. Mean sea level is a

basic datum for elevations and is approximately the same everywhere. The determination of this plane is accomplished by averaging the hourly heights of the tide over a period of time. The precision of the determination depends upon the length of the series used, since sea level varies from day to day, due primarily to changing meteorological conditions.

The daily values of sea level for the month of June, 1919, are given in Table 5. The tabular values were derived by averaging the hourly heights for the 24 hours of each day. It will be noted that even for a summer month when the weather conditions are relatively stable the variation in daily sea level may be as much as 2.39 feet between the extremes for the month. Taking the means of the three 10-day series, the maximum variation is only 0.12 foot.

TABLE 5.—*Daily sea level on staff, Baltimore, Md., June, 1919*

Date	Feet	Date	Feet	Date	Feet
1	5.14	11	4.58	21	4.25
2	5.04	12	4.50	22	3.89
3	4.86	13	4.86	23	4.67
4	4.78	14	4.72	24	4.75
5	4.89	15	5.10	25	5.10
6	5.08	16	4.78	26	5.79
7	4.52	17	4.95	27	4.94
8	4.40	18	4.68	28	3.40
9	4.87	19	4.93	29	5.10
10	4.89	20	4.86	30	5.40
Sum	48.47	Sum	47.96	Sum	47.29
Mean	4.85	Mean	4.80	Mean	4.73

TABLE 6.—*Sea level on staff: Monthly means; Fort McHenry, Baltimore, Md.*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean	5-year mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1903	3.64	3.47	4.04	4.36	4.37	4.78	4.39	4.61	4.50	4.39	3.92	3.42	4.16	
1904	3.52	3.33	3.77	3.82	4.17	4.35	4.28	4.21	4.36	4.12	3.90	3.70	3.96	
1905	3.41	3.37	3.79	3.92	4.11	4.32	4.44	4.49	4.39	4.20	3.94	3.80	4.02	4.04
1906	3.90	3.50	3.62	3.97	4.09	4.52	4.57	4.57	4.37	4.34	3.74	3.46	4.05	
1907	3.72	3.52	3.87	3.78	4.14	4.44	4.23	4.27	4.25	4.01	4.00	3.95	4.02	
1908	3.64	3.56	3.85	3.76	4.24	4.37	4.33	4.55	4.51	4.46	3.70	3.72	4.06	
1909	3.72	3.63	3.71	3.96	4.44	4.37	4.28	4.54	4.46	4.03	3.95	3.87	4.08	
1910	3.84	3.50	4.00	4.42	4.17	4.36	4.49	4.45	4.65	4.37	3.77	3.75	4.15	4.08
1911	3.71	3.86	3.73	4.08	4.12	4.38	4.21	4.44	4.60	4.52	3.78	3.77	4.10	
1912	3.39	3.61	3.74	3.89	4.30	4.21	4.21	4.28	4.69	4.23	3.87	3.60	4.00	
1913	3.74	3.53	3.52	3.94	4.09	4.23	4.20	4.47	4.40	4.43	4.01	3.77	4.03	
1914	3.99	3.44	3.54	4.13	4.13	4.18	4.40	4.38	4.23	4.46	3.85	3.99	4.06	
1915	3.99	3.95	3.79	3.81	4.24	4.46	4.51	4.62	4.45	4.42	4.13	3.64	4.17	4.10
1916	3.80	3.48	3.72	4.18	4.18	4.61	4.51	4.51	4.44	4.34	4.08	3.67	4.13	
1917	3.73	3.49	4.05	3.99	4.33	4.34	4.47	4.51	4.42	4.32	3.99	3.69	4.11	
1918	3.85	3.73	3.99	4.35	4.18	4.49	4.40	4.48	4.41	4.38	4.11	4.12	4.21	
1919	3.67	3.85	3.86	4.07	4.63	4.77	4.70	4.61	4.54	4.61	4.48	3.87	4.30	
1920	3.67	3.75	3.62	4.37	4.40	4.40	4.29	4.44	4.44	4.40	4.20	4.09	4.17	4.22
1921	3.75	4.09	4.04	4.24	4.68	4.44	4.48	4.39	4.60	4.11	4.23	3.96	4.25	
1922	3.33	3.80	3.97	4.13	4.38	4.41	4.49	4.45	4.58	4.38	3.98	3.88	4.15	
1923	3.87	3.62	4.05	4.20	4.34	4.13	4.39	4.44	4.45	4.28	4.26	4.02	4.17	
1924	3.64	4.00	------	4.27	4.71	4.54	4.40	4.54	4.57	4.27	4.08	3.42	4.22	
1925	3.89	4.03	3.70	4.15	4.23	4.31	4.38	4.33	4.54	4.03	3.90	3.51	4.08	4.16
1926	3.45	3.88	3.57	3.88	4.10	4.25	4.28	4.60	4.73	4.45	4.10	3.88	4.10	
1927	3.47	4.12	3.99	4.11	4.31	4.44	4.41	4.50	4.49	4.49	4.13	4.02	4.21	
Sum	92.33	92.11	91.53	101.78	107.08	110.10	109.74	111.68	112.07	108.04	100.10	94.57	102.96	20.60
Mean	3.69	3.68	3.81	4.07	4.28	4.40	4.39	4.47	4.48	4.32	4.00	3.78	4.12	4.12

Mean, 19 years, 1903 to 1921=4.11 feet. Mean, 19 years, 1909 to 1927=4.14 feet.

Table 6 gives the average of the hourly heights of sea level on the tide staff for each month for the 25 years 1903 to 1927, inclusive. It also gives the yearly sea level on the staff at Baltimore for the same period, divided into 5-year groups. The maximum variation between

any two years in the 25-year group is 0.34 foot while the maximum difference between any two means of the 5-year groups is 0.18 foot. Dividing the series into two overlapping 19-year groups, the means are, 1903–1921, 4.11 feet and, 1909–1927, 4.14 feet. The mean for the 25-year group is 4.12 feet and this may be taken as the best determined value for mean sea level at Baltimore. The lowest yearly height of sea level on the staff was in the year 1904 and the highest in 1919, the difference between the two years being 0.34 foot.

From the above it is noted that the plane of mean sea level varies from day to day, from month to month, and from year to year. Even the 19-year periods vary somewhat. This variation in mean sea level is attributed to meteorological conditions. Since meteorological conditions vary from year to year, the variation in the height of sea level shown in Table 6 must be in large part, at least, caused by these conditions. It is noted that there was an apparent increase in the

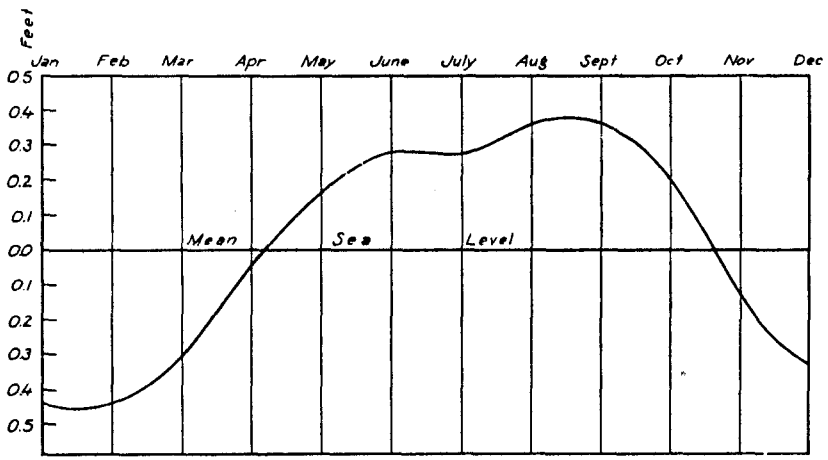


FIGURE 2.—Annual variation in sea level, Fort McHenry, Baltimore

height of sea level from 1903 to 1919, when a maximum was reached. Since 1919 it has decreased somewhat. A similar condition is found all along the Atlantic coast from Maine to Florida. The average variation in sea level from month to month is shown in Figure 2. The curve is an average curve for the 25-year series and shows that sea level is lower in February than in August and September by about 0.8 foot.

THE PLANES OF HIGH WATER

As in the lunitidal intervals and durations of rise and fall already discussed, so also in the heights of the high and low waters, the observations show considerable variation. In the ninth column of Table 1 are given the individual heights of high water for a month. During this period the maximum difference in the heights of successive high waters was 2.3 feet and the maximum difference between any two high waters was 3.3 feet. Again, as in the case of the time relations of the tide, the larger fluctuations are due to meteorological effects. There are, however, a number of periodic changes in the heights of high water, common to tides the world over which are due to the varying positions of the sun and moon with respect to the earth.

When the full or new moon occurs the tides rise higher than usual and are called spring tides; when the moon is in the first and third quarters the rise is less than usual and such tides are called neap tides. Likewise, when the moon is in perigee the high water rises higher than usual, while at the time the moon is apogee the rise of high water is less than usual. These variations give rise to perigean high water and apogean high water.

Several planes of high water are introduced by periodic changes in the declination of the moon. For any given tidal day there are two high waters and two low waters. One of the high waters will be slightly higher than the other, the higher being called higher-high water and the other lower-high water. When the declination of the moon is zero the two high waters will be nearly equal in height and as the moon's declination increases (north or south) the difference in height between the higher-high and lower-high waters becomes greater. When the moon's declination is a maximum the planes are known as tropic higher-high water and tropic lower-high water.

All these variations can not be traced in the observed heights for a single month, for most of them are masked by the combination of the various astronomic effects or by weather conditions. The declinational effect, however, may be traced in the column of high-water heights in Table 1. On June 5 and also on June 20 the moon was on the Equator, and on June 13 and June 26, the moon was at its maximum north and south positions, respectively. Taking the six high waters nearest to each of the above times, the average daily inequality in height for the two equatorial positions was 0.2 foot and for the two positions of greatest declination it was 0.6 foot.

TABLE 7.—*High water on staff: Monthly means, Fort McHenry, Baltimore, Md.*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean	5-year mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1903	4.24	4.09	4.66	4.93	4.93	5.34	4.96	5.23	5.06	4.91	4.48	3.95	4.73	
1904	4.16	3.86	4.32	4.41	4.75	4.94	4.87	4.77	4.94	4.64	4.45	4.19	4.52	
1905	3.99	3.92	4.34	4.46	4.68	4.89	4.98	5.06	4.99	4.80	4.37	4.30	4.56	4.60
1906	4.46	4.04	4.19	4.53	4.67	5.09	5.15	5.13	4.97	4.94	4.26	4.00	4.62	
1907	4.26	4.06	4.42	4.35	4.70	5.00	4.84	4.89	4.79	4.50	4.53	4.48	4.57	
1908	4.16	4.16	4.42	4.37	4.82	4.94	4.97	5.12	5.14	4.94	4.22	4.25	4.63	
1909	4.23	4.23	4.20	4.52	4.97	4.91	4.83	5.12	5.04	4.53	4.47	4.33	4.62	
1910	4.26	4.03	4.51	4.95	4.69	4.93	5.03	5.03	5.22	4.85	4.27	4.20	4.66	4.61
1911	4.13	4.36	4.24	4.62	4.66	4.91	4.67	4.96	5.10	4.98	4.26	4.24	4.59	
1912	3.99	4.16	4.28	4.44	4.81	4.73	4.77	4.85	5.21	4.75	4.37	4.13	4.54	
1913	4.24	4.07	4.06	4.46	4.61	4.74	4.78	5.04	4.96	4.94	4.50	4.26	4.56	
1914	4.51	3.93	4.07	4.65	4.68	4.73	4.98	4.94	4.82	4.99	4.35	4.49	4.60	
1915	4.52	4.45	4.29	4.33	4.76	5.00	5.04	5.23	5.00	4.94	4.62	4.13	4.69	4.63
1916	4.32	4.03	4.25	4.74	4.73	5.13	5.04	5.08	4.99	4.86	4.59	4.16	4.66	
1917	4.26	4.04	4.54	4.52	4.87	4.89	5.02	5.07	4.98	4.85	4.48	4.23	4.65	
1918	4.34	4.26	4.51	4.90	4.75	5.04	4.96	5.05	4.96	4.92	4.60	4.63	4.74	
1919	4.18	4.36	4.38	4.59	5.17	5.31	5.27	5.20	5.09	5.17	4.99	4.41	4.84	
1920	4.23	4.31	4.18	4.94	4.94	4.99	4.86	5.01	5.02	4.95	4.74	4.62	4.73	4.76
1921	4.28	4.64	4.59	4.78	5.23	5.00	5.06	4.97	5.16	4.64	4.75	4.45	4.80	
1922	3.85	4.35	4.51	4.66	4.92	4.99	5.09	5.01	5.15	4.93	4.52	4.39	4.70	
1923	4.38	4.14	4.57	4.74	4.88	4.68	4.97	5.01	5.01	4.82	4.79	4.52	4.71	
1924	4.20	4.54	------	4.81	5.26	5.08	4.97	5.12	5.11	4.81	4.60	3.95	4.77	
1925	4.45	4.56	4.23	4.68	4.75	4.85	4.90	4.90	5.09	4.59	4.41	4.02	4.62	4.70
1926	4.00	4.41	4.06	4.39	4.65	4.80	4.86	5.18	5.28	4.98	4.62	4.39	4.64	
1927	4.00	4.67	4.53	4.67	4.87	4.99	4.95	5.06	5.04	5.00	4.62	4.54	4.74	
Sum [1]	105.64	105.67	104.35	115.44	120.75	123.90	123.82	126.03	126.12	121.23	112.86	107.26	116.49	23.30
Mean [1]	4.23	4.23	4.35	4.62	4.83	4.96	4.95	5.04	5.04	4.85	4.51	4.29	4.66	4.66
Sum [2]	80.76	79.00	82.45	87.49	91.42	94.51	94.08	95.75	95.44	92.10	85.30	81.45	88.31	------
Mean [2]	4.25	4.16	4.34	4.60	4.81	4.97	4.95	5.04	5.02	4.85	4.49	4.29	4.65	------
Sum [3]	80.37	81.54	78.00	88.39	92.20	93.70	94.05	95.83	96.23	92.50	86.55	82.09	88.86	------
Mean [3]	4.23	4.29	4.33	4.65	4.85	4.93	4.95	5.04	5.06	4.87	4.56	4.32	4.68	------
Mean [4]	4.24	4.22	4.34	4.62	4.83	4.95	4.95	5.04	5.04	4.86	4.52	4.30	4.66	------

[1] 25 years. [2] First 19 years. [3] Last 19 years. [4] First and last 19 years.

Table 7 gives the monthly values of high water on staff for the 25-year period 1903 to 1927, inclusive. The maximum difference between any two months in the series is 1.49 feet. Averaging each of the 12 months for the 25-year period the maximum difference is 0.81 foot, the lowest values are in January and February and the highest in August and September.

Table 7 also gives the annual means of high water on staff at Baltimore for the 25-year period. The greatest difference between any two yearly values is 0.32 foot. The maximum variation between 5-year groups is 0.16 foot. It will be noted that the high water on staff was higher in 1919 than any other year. This was also found to be the case for mean sea level. The variation in sea level caused by a change in weather conditions obviously causes a change in the high water. To eliminate the variation in high water caused by the variation in sea level, Table 8 which gives high water above sea level for the 25-year period was prepared. This was obtained by subtracting the values in Table 6 from the corresponding values in Table 7. The maximum variation between any two yearly values is 0.08 foot. The maximum variation between the means of the 5-year groups is 0.03 foot. The variations are much smaller in Table 8 than in Table 7. It appears, therefore, that the planes of high water and sea level pass through a similar annual variation.

TABLE 8.—*High water above sea level, Fort McHenry, Baltimore, Md.: Annual means*

Year	Feet	Year	Feet	Year	Feet	Year	Feet	Year	Feet
1903	0.57	1908	0.57	1913	0.53	1918	0.56	1923	0.54
1904	0.56	1909	0.54	1914	0.54	1919	0.54	1924	0.55
1905	0.54	1910	0.51	1915	0.52	1920	0.56	1925	0.54
1906	0.57	1911	0.49	1916	0.53	1921	0.55	1926	0.54
1907	0.55	1912	0.54	1917	0.54	1922	0.55	1927	0.53
Sum	2.79	Sum	2.65	Sum	2.66	Sum	2.73	Sum	2.70
Mean	0.56	Mean	0.53	Mean	0.53	Mean	0.55	Mean	0.54

Mean, 1903 to 1927, 0.54 foot.

TABLE 9.—*High water above sea level, Fort McHenry, Baltimore, Md.: Annual means corrected for longitude of the moon's node*

Year	Feet	Year	Feet	Year	Feet	Year	Feet	Year	Feet
1903	0.56	1908	0.57	1913	0.54	1918	0.53	1923	0.53
1904	0.55	1909	0.54	1914	0.55	1919	0.53	1924	0.54
1905	0.53	1910	0.52	1915	0.53	1920	0.55	1925	0.53
1906	0.56	1911	0.50	1916	0.54	1921	0.54	1926	0.54
1907	0.54	1912	0.55	1917	0.54	1922	0.54	1927	0.53
Sum	2.74	Sum	2.68	Sum	2.70	Sum	2.69	Sum	2.67
Mean	0.55	Mean	0.54	Mean	0.54	Mean	0.54	Mean	0.53

Mean first 19 years=0.54. Mean of last 19 years=0.54. Mean of 25 years=0.54.

Theoretically, there should be a periodic variation in the rise of high water above sea level, having a period of about 19 years. This variation is due to a change in the longitude of the moon's node, causing a variation in the inclination of the moon's orbit to the plane of the earth's equator. Table 9 gives annual means of high water

above sea level corrected for the longitude of the moon's node for each of the 25 years of observation. It is noted that although the means of the 5-year groups in Tables 8 and 9 vary somewhat, the means of the 25-year groups are identical in both tables. In the latter table the

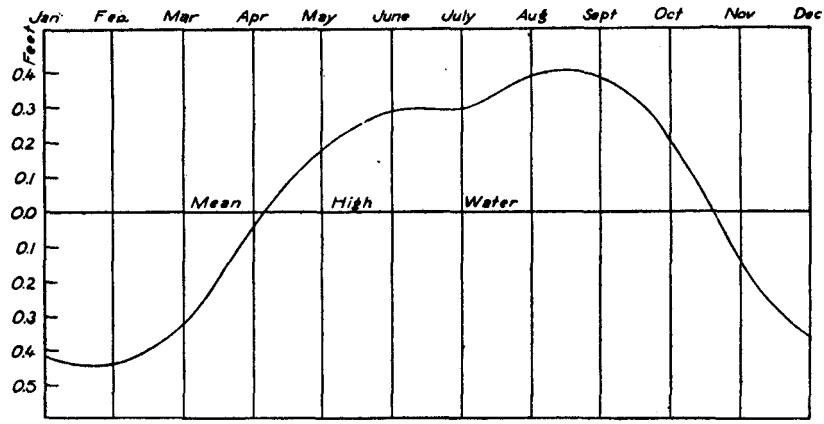


FIGURE 3.—Annual variation in high water, Fort McHenry, Baltimore

mean for the first 19-year period equals the mean for the second 19-year period, which also equals the mean for the 25-year period. The accepted value of mean high water above mean sea level at Baltimore is 0.54 foot.

In Table 7 there is noted a seasonal change in the plane of high water which is found to be similar to the corresponding change in

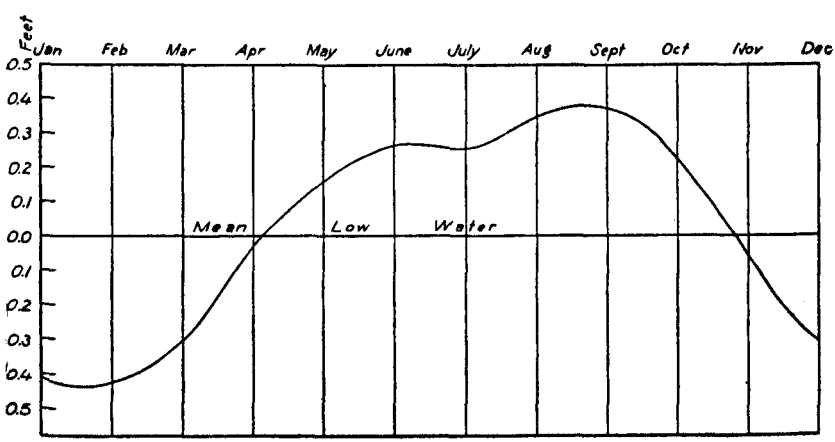


FIGURE 4.—Annual variation in low water, Fort McHenry, Baltimore

mean sea level, the lowest value occurring in February and the highest in August and September. Comparing Figures 2, 3, and 4, it will be seen that high water, low water, and sea level go through practically the same seasonal variations.

Spring high water occurs near the time of new or full moon. The tides do not come at the same time as their astronomic causes but follow them by more or less definite intervals. The interval of time

by which the tide follows the moons' various changes is called the age of the tide. The spring high water is obtained by adding the phase age to the time of new or full moon and taking the two consecutive high waters that fall nearest this time. As there are only four such high waters in a month and the values determined for one month differ from another month due to changes in the moon's parallax and declination, and to meteorological conditions, a period extending over a considerable number of years must be taken to get a precise plane for spring high water.

Since high water exhibits the same annual variations as sea level, we may assume that spring high water will do likewise. A study of the monthly values for this plane supports this assumption.

The plane of spring high water may be derived from harmonic constants by means of formulas developed by R. A. Harris. This method requires much less time than the former if the harmonic constants are at hand, but the values derived differ somewhat from the values obtained from direct tabulation. The accepted value for spring high water is 4.73 feet on staff. This value was obtained by adding the height of spring high water above sea level, obtained from harmonic constants for the year 1907, to the value of mean sea level on staff from 25 years' observations.

At Baltimore the ratio of spring high water above mean sea level to mean high water above mean sea level is 1.13.

The plane of neap high water is derived similarly to spring high water from high waters following the first and third quarters of the moon. The ratio of neap high water above mean sea level to mean high water above mean sea level at Baltimore is 0.83.

The values for tropic tides were obtained from harmonic constants for the year 1907. The value of tropic higher high water above mean sea level is 0.87 foot and that of tropic lower high water is 0.12 foot above mean sea level. Tropic higher high water is 0.33 foot higher than mean high water. Its rise above mean sea level is about 1.6 times that of mean high water. Tropic lower high water is 0.42 foot lower than mean high water. Its rise above mean sea level is about 0.2 that of mean high water.

Wind and weather conditions at times cause the water to rise abnormally high. This is especially true for a station such as Baltimore, situated at the head of a bay. A southeast wind blowing for several days will cause very high tides. To determine a plane of these high waters, the highest tide in each month is tabulated and a mean derived.

TABLE 10.—*Monthly highest high water above mean sea level, Fort McHenry, Baltimore, Md.*

Year	Average	Highest		Year	Average	Highest		Year	Average	Highest	
	Feet	*Date*	*Feet*		*Feet*	*Date*	*Feet*		*Feet*	*Date*	*Feet*
1903	1.98	June 25	2.6	1908	2.03	Jan. 12	2.8	1913	2.09	Oct. 20	3.5
1904	1.65	Jan. 22	[1] 1.9	1909	1.96	Dec. 13	2.7	1914	2.08	Jan. 3	3.2
1905	1.93	Sept. 2	2.7	1910	1.91	Apr. 18	[4] 2.4	1915	2.36	Aug. 4	*5.3
1906	1.87	Oct. 18	[5] 2.4	1911	1.78	Sept. 20	[6] 2.4	1916	1.96	June 16	2.8
1907	1.86	June 5	2.4	1912	1.88	Sept. 24	2.8	1917	1.95	Apr. 6	[7] 2.9
Sum	9.29		12.0	Sum	9.56		13.1	Sum	10.44		17.7
Mean	1.86		2.40	Mean	1.91		2.62	Mean	2.09		3.54

Year	Average	Highest		Year	Average	Highest	
	Feet	*Date*	*Feet*		*Feet*	*Date*	*Feet*
1918	2.02	June 22	2.8	1923	1.96	Oct. 24	†3.5
1919	2.16	June 26	[2] 2.6	1924	2.21	May 12	[3] †3.3
1920	1.95	Nov. 17	2.9	1925	1.86	Dec. 5	†2.4
1921	2.10	May 12	3.0	1926	2.01	Nov. 16	3.9
1922	1.85	May 19	2.3	1927	2.08	Oct. 12	3.0
Sum	10.08		13.6	Sum	10.12		16.1
Mean	2.02		2.72	Mean	2.02		3.22

[1] Same height on Sept. 14.
[2] Same height on Sept. 20 and Nov. 8.
[3] Same height on Sept. 29.
[4] Same height on Apr. 25.
[5] Same height on Oct. 19.
[6] Same height on Oct. 18.
[7] Same height on Oct. 12.
* ENE-SE gale.
† Fresh breezes.

Mean of yearly average, 1903–1927=1.98 feet.

Table 10 gives yearly averages of the monthly highest high waters and the highest tide each year for the 25-year period referred to mean sea level. The series is divided into 5-year groups. The highest tide recorded occurred on August 4, 1915, when the height was 5.3 feet above mean sea level, which is 4.8 feet above the average high water. The maximum variation between any two yearly averages is 0.71 foot and the maximum difference between the means of 5-year groups is 0.23 foot. The maximum difference between the mean for the 25 years and any yearly value is 0.38 foot. The average value for the 25-year series is 1.98 feet above mean sea level which is about 3.7 times the value for mean high water above mean sea level.

THE PLANES OF LOW WATER

For each of the high-water planes discussed in the previous section there is a corresponding low-water plane. The planes are defined and discussed in the same way as the high-water planes, and therefore a separate discussion will not be given. The plane of mean low water is the most important of the low-water planes. This plane exhibits the same variations as the high-water plane; that is, it varies from day to day, from month to month, and from year to year.

Table 11 gives yearly values of low water on staff for the period 1903 to 1927, inclusive. In computing the table the means for the full calendar month were used for the years 1903–1912 and 1925–1927, while for the years 1913 to 1924 the values are means for the first 29 days of each month. Upon inspection the variations in low water are found to be similar to the variations in high water.

TABLE 11.—*Low water on staff, Fort McHenry, Baltimore, Md.: Monthly means*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean	5-year mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1903	3.02	2.89	3.47	3.76	3.74	4.18	3.72	4.06	3.93	3.82	3.38	2.82	3.57	
1904	2.94	2.73	3.21	3.26	3.60	3.79	3.70	3.64	3.79	3.57	3.35	3.10	3.39	
1905	2.84	2.80	3.24	3.37	3.55	3.77	3.83	3.90	3.85	3.65	3.32	3.16	3.44	3.47
1906	3.39	2.92	3.11	3.41	3.55	3.90	3.98	3.95	3.83	3.83	3.19	2.92	3.50	
1907	3.15	2.93	3.28	3.25	3.56	3.86	3.63	3.67	3.66	3.43	3.48	3.36	3.44	
1908	2.98	2.92	3.23	3.17	3.62	3.77	3.74	4.01	3.92	3.82	3.14	3.15	3.46	
1909	3.08	3.10	3.10	3.44	3.85	3.79	3.66	3.95	3.91	3.42	3.41	3.27	3.50	
1910	3.27	2.92	3.44	3.89	3.62	3.78	3.87	3.89	4.08	3.72	3.27	3.18	3.58	3.50
1911	3.16	3.37	3.16	3.51	3.58	3.78	3.60	3.85	3.99	3.96	3.18	3.22	3.53	
1912	2.85	3.04	3.18	3.28	3.68	3.59	3.60	3.68	4.08	3.66	3.32	3.04	3.42	
1913	3.11	2.98	2.93	3.37	3.51	3.67	3.58	3.85	3.79	3.90	3.47	3.25	3.45	
1914	3.42	2.88	2.97	3.55	3.53	3.59	3.79	3.80	3.72	3.91	3.32	3.45	3.49	
1915	3.45	3.43	3.31	3.21	3.63	3.88	3.93	4.03	3.88	3.89	3.59	3.10	3.61	3.53
1916	3.25	2.91	3.14	3.60	3.62	4.00	3.94	3.92	3.87	3.80	3.55	3.12	3.56	
1917	3.18	2.91	3.49	3.44	3.74	3.77	3.87	3.94	3.85	3.76	3.46	3.13	3.54	
1918	3.31	3.18	3.43	3.77	3.58	3.87	3.79	3.91	3.85	3.82	3.58	3.58	3.64	
1919	3.16	3.34	3.27	3.52	4.04	4.19	4.11	4.01	3.98	4.04	3.93	3.32	3.74	
1920	3.08	3.19	3.02	3.77	3.80	3.80	3.70	3.86	3.86	3.85	3.65	3.53	3.59	3.65
1921	3.17	3.53	3.46	3.68	4.11	3.85	3.88	3.81	4.01	3.56	3.70	3.44	3.68	
1922	2.78	3.23	3.42	3.56	3.81	3.80	3.89	3.88	4.02	3.83	3.44	3.35	3.58	
1923	3.33	3.06	3.50	3.64	3.76	3.53	3.79	3.85	3.88	3.73	3.74	3.47	3.61	
1924	3.07	3.46	------	3.66	4.09	3.97	3.80	3.95	4.00	3.71	3.54	*2.85	3.65	
1925	3.30	3.48	3.16	3.61	3.68	3.73	3.80	3.71	3.96	3.47	3.36	2.94	3.52	3.59
1926	2.86	3.32	3.03	3.33	3.52	3.65	3.67	4.01	4.17	3.89	3.55	3.31	3.53	
1927	2.90	3.54	3.43	3.55	3.71	3.85	3.82	3.92	3.93	3.94	3.59	3.46	3.64	
Sum [1]	78.05	78.06	77.98	87.60	92.48	95.36	94.69	97.05	97.81	93.98	86.51	80.52	88.66	
Mean [1]	3.12	3.12	3.25	3.50	3.70	3.81	3.79	3.88	3.91	3.76	3.46	3.22	3.55	
Sum [2]	59.81	57.97	61.44	66.25	69.91	72.83	71.92	73.73	73.85	71.41	65.29	61.14	67.13	
Mean [2]	3.15	3.05	3.23	3.49	3.68	3.83	3.79	3.88	3.89	3.76	3.44	3.22	3.53	
Sum [3]	59.73	60.87	58.44	67.38	70.86	72.09	72.09	73.82	74.83	71.86	66.65	62.01	67.86	
Mean [3]	3.14	3.20	3.25	3.55	3.73	3.79	3.79	3.89	3.94	3.78	3.51	3.26	3.57	
Mean [4]	3.14	3.12	3.24	3.52	3.70	3.81	3.79	3.88	3.92	3.77	3.48	3.24	3.55	

[1] 25 years.
[2] First 19 years.
[3] Last 19 years.
[4] First and last 19 year groups.
* Storm.

TABLE 12.—*Low water below sea level, Fort McHenry, Baltimore, Md.: Annual means*

Year	Feet	Year	Feet	Year	Feet	Year	Feet	Year	Feet
1903	0.59	1908	0.60	1913	0.58	1918	0.57	1923	0.56
1904	0.57	1909	0.58	1914	0.57	1919	0.56	1924	0.57
1905	0.58	1910	0.57	1915	0.56	1920	0.58	1925	0.56
1906	0.55	1911	0.57	1916	0.57	1921	0.57	1926	0.57
1907	0.58	1912	0.58	1917	0.57	1922	0.57	1927	0.57
Sum	2.87	Sum	2.90	Sum	2.85	Sum	2.85	Sum	2.83
Mean	0.57	Mean	0.58	Mean	0.57	Mean	0.57	Mean	0.57

Mean of first 19 years=0.57 foot. Mean of last 19 years=0.57 foot. Mean of 25 years=0.57 foot.

Table 12 gives the annual means of low water referred to sea level at Baltimore. The annual means show approximately the same variation as the high waters in Table 8. The mean of the first 19 years equals the mean for the last 19 years and these equal the mean for 25 years. The maximum difference between yearly values is 0.05 foot.

Table 13 gives the low water below sea level after being corrected for the longitude of the moon's node. This correction does not change the means as given in Table 12. The mean value of low water below mean sea level is 0.57 foot.

The value of mean high water above mean sea level is 0.54 foot for the same period. Therefore, the rise of high water above mean sea level is 0.03 foot less than the fall of low water below mean sea level.

Figure 4 shows the annual variation in the heights of low water derived from the mean of the first and last 19-year groups of the 25-year series of observations. It is noted that the curve is similar to the ones for sea level and for high water. Low water is lowest in January and February and highest in August and September with an average variation of about 0.8 foot.

TABLE 13.—*Low water below sea level, Fort McHenry, Baltimore, Md.: Annual means corrected for longitude of moon's node*

Year	Feet	Year	Feet	Year	Feet	Year	Feet	Year	Feet
1903	0.58	1908	0.60	1913	0.59	1918	0.57	1923	0.55
1904	0.56	1909	0.58	1914	0.58	1919	0.55	1924	0.56
1905	0.57	1910	0.58	1915	0.57	1920	0.57	1925	0.55
1906	0.54	1911	0.58	1916	0.58	1921	0.56	1926	0.57
1907	0.57	1912	0.59	1917	0.57	1922	0.56	1927	0.57
Sum	2.82	Sum	2.93	Sum	2.89	Sum	2.81	Sum	2.80
Mean	0.56	Mean	0.59	Mean	0.58	Mean	0.56	Mean	0.56

Mean of first 19 years=0.57 foot. Mean of last 19 years=0.57 foot. Mean of 25 years=0.57 foot.

TABLE 14.—*Low-water planes, Fort McHenry, Baltimore, Md.*

Plane	Feet below mean sea level	Plane	Feet below mean sea level
Mean low water	0.57	Lower-low water	0.67
Spring low water	0.65	Higher-low water	0.47
Neap low water	0.48	Tropic lower-low water	0.72
Perigean low water	0.64	Tropic higher-low water	0.39
Apogean low water	0.46		

Table 14 gives values for low-water planes derived by harmonic and nonharmonic reductions of the observations. It is noted that the tropic lower-low water is the lowest of the low-water planes as was the tropic higher-high water the highest of the high-water planes. Tropic higher-high water is 0.87 foot above mean sea level and tropic lower-low water is 0.72 foot below mean sea level. Therefore the tropic higher-high water rises 0.15 foot higher above the plane of mean sea level than the tropic lower-low water falls below this plane. It will be noted that the differences between the low-water planes are less than the differences between the high-water planes.

Table 15 gives the average of the monthly lowest low waters and the date and height of the lowest low water in each year for the period 1903 to 1927. The plane of average monthly lowest low water as determined from the means of the 5-year groups shows a maximum variation of 0.33 foot. The best value for this plane as determined from the 25 years of observation is 2.20 feet below mean sea level. This fall is about four times as great as that of mean low water below mean sea level.

For the period 1903–1927 the highest tide was 5.3 feet above mean sea level and the lowest tide was 5.1 feet below mean sea level. Table

16 shows the distribution by months of the yearly highest and lowest tides that occurred during the 25-year period. The column headed "Number" gives the number of times the highest tide occurred during the month, and the column marked "Per cent" gives the monthly occurrence on a percentage basis. When the same yearly maximum or minimum height occurred in more than one month of the same year a fraction is used. For example, if the highest tide of the year occurred in both January and September, the number ½ was assigned to each of these months.

TABLE 15.—*Monthly lowest low water below mean sea level, Fort McHenry, Baltimore, Md.*

Year	Average	Lowest		Year	Average	Lowest		Year	Average	Lowest	
	Feet	*Date*	*Feet*		*Feet*	*Date*	*Feet*		*Feet*	*Date*	*Feet*
1903	2.56	Oct. 10	4.6	1908	2.44	Jan. 24	5.1	1913	2.29	Dec. 9	3.8
1904	2.27	Jan. 3	3.9	1909	2.22	Feb. 1	3.7	1914	2.20	Mar. 2	4.3
1905	2.44	Jan. 26	4.9	1910	2.10	Feb. 1	[1]3.3	1915	2.08	Jan. 13	3.3
1906	2.39	Feb. 28	4.8	1911	2.08	Mar. 23	3.5	1916	2.33	Feb. 14	3.8
1907	2.30	Jan. 23	3.2	1912	2.29	Feb. 4	3.5	1917	2.22	Feb. 5	3.9
Sums	11.96		21.4	Sums	11.13		19.1	Sums	11.12		19.1
Means	2.39		4.28	Means	2.23		3.82	Means	2.22		3.82

Year	Average	Lowest		Year	Average	Lowest	
	Feet	*Date*	*Feet*		*Feet*	*Date*	*Feet*
1918	2.05	Feb. 21	3.2	1923	2.21	Feb. 15	3.7
1919	1.99	Mar. 29	4.7	1924	1.88	Dec. 1	3.3
1920	2.04	Mar. 6	3.3	1925	2.30	Oct. 10	[2]4.0
1921	2.14	Jan. 18	3.4	1926	2.11	Jan. 29	3.3
1922	2.08	Nov. 25	3.2	1927	2.07	Jan. 16	3.7
Sums	10.30		17.8	Sums	10.57		18.0
Means	2.06		3.56	Means	2.11		3.60

[1] Same height on Nov. 4. [2] Same height on Dec. 29.

TABLE 16.—*Months of occurrence of highest and lowest tides, 1903–1927*

Month	Highest tides		Lowest tides		Month	Highest tides		Lowest tides	
	Number	*Per cent*	*Number*	*Per cent*		*Number*	*Per cent*	*Number*	*Per cent*
January	2½	10.0	8	32.0	August	1	4.0	0	0.0
February	0	0.0	7½	30.0	September	3⅚	15.4	0	0.0
March	0	0.0	4	16.0	October	5	20.0	1½	6.0
April	1½	6.0	0	0.0	November	2⅓	9.3	1½	6.0
May	2½	10.0	0	0.0	December	2	8.0	2½	10.0
June	4⅓	17.3	0	0.0					
July	0	0.0	0	0.0	Sums	25	100.0	25	100.0

Any tidal plane varies from different series, the longer the series from which it is determined the more precise are the values obtained. As mean low water is the plane of reference for hydrographic surveying, it is desirable to adopt a standard value.

A standard low-water plane with a fixed value was adopted for Baltimore by the Coast and Geodetic Survey in February, 1929. It is called the Baltimore low-water datum and is defined as follows:

Baltimore low-water datum is the mean low water as determined from 19 years of observations (1903–1921) at Fort McHenry and is 4.99 feet below bench mark No. 1, also known as the harbor board's bench mark, sea wall, Fort McHenry, which is a cross on the top of the sea wall at the first angle in the wall southeast from the United States Engineers wharf at Fort McHenry.

This datum has been in use by the Coast and Geodetic Survey and by the United States Engineer office at Baltimore since its determination in 1922. Bench mark No. 1 has been used as a primary bench mark since 1903 and from a comparison with other bench marks its elevation has not changed appreciably during 26 years.

THE PLANE OF HALF-TIDE LEVEL

The plane of half-tide level or mean-tide level is the plane lying halfway between mean high water and mean low water. If the tide curve were symmetrical about the plane of mean sea level—that is, if the rise of high water above sea level equaled the fall of low water below sea level—the planes of mean sea level and of half-tide level would coincide. At Baltimore the value of mean high water is 0.54 foot above mean sea level and the value of mean low water is 0.57 foot below mean sea level, the fall below mean sea level being 0.03 foot greater than the rise above mean sea level. Therefore, the plane of half-tide level is 0.015 foot below mean sea level. The curve of annual variation of half-tide level is a mean of the annual variation curves of the mean high-water and mean low-water planes. Since the plane of half-tide level has a nearly constant relation to the plane of mean sea level, the variation from year to year of the former plane will follow that of the latter. The two planes here have so nearly the same value that for most purposes they may be considered identical.

THE RANGE OF THE TIDE

The range of the tide or the amount of rise and fall varies with the varying positions of the sun and moon relative to the earth.

The daily range of the tide for the month of June, 1919, is given in Table 1. A scanning of this table shows considerable variations in the range from tide to tide and from day to day. During this month the moon was full and new on the 13th and 27th, respectively, and in its first and third quarters on the 5th and 21st, respectively. Taking the six tides nearest to each of the above times, the average range of the tides near the new and full moon was 1.2 feet and the average range of the tides near the quadratures was 1 foot. The spring and neap effect is evident from these values. The monthly and yearly ranges for the 25-year period 1903–1927 are given in Table 17.

Table 18 gives for the same period the yearly values for the mean range of the tide; that is, the range corrected for the longitude of the moon's node. The values in this table were obtained by multiplying the observed mean range for each year by a factor to correct for the longitude of the moon's node.

It is noted that the mean value for the entire series is the same for both tables but the individual yearly values agree more closely in Table 18, the effect of the correction factor being usually to bring the individual value closer to the mean.

The means of the 5-year groups do not vary appreciably, the maximum variation for each table being 0.04 foot. In Table 18 the mean for the first 19-year period is 1.12 feet. The mean for the last 19-year period is 1.11 feet, which latter is the mean for the 25 years. The mean range of tide at Baltimore is therefore taken as 1.11 feet.

TABLE 17.—*Monthly mean range, Fort McHenry, Baltimore, Md.*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean	5-year mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1903	1.22	1.20	1.19	1.17	1.19	1.16	1.24	1.17	1.13	1.09	1.10	1.13	1.17	
1904	1.22	1.13	1.11	1.15	1.15	1.15	1.17	1.13	1.15	1.07	1.10	1.09	1.14	
1905	1.15	1.12	1.10	1.09	1.13	1.12	1.15	1.16	1.14	1.15	1.05	1.14	1.12	1.14
1906	1.07	1.12	1.08	1.12	1.12	1.19	1.17	1.18	1.14	1.11	1.07	1.08	1.12	
1907	1.11	1.13	1.14	1.10	1.14	1.14	1.21	1.22	1.13	1.07	1.05	1.12	1.13	
1908	1.18	1.24	1.19	1.20	1.20	1.17	1.23	1.11	1.22	1.12	1.08	1.10	1.17	
1909	1.15	1.13	1.10	1.08	1.12	1.12	1.17	1.17	1.13	1.11	1.06	1.06	1.12	
1910	0.99	1.11	1.07	1.06	1.07	1.15	1.16	1.14	1.14	1.13	1.00	1.02	1.09	1.11
1911	0.97	0.99	1.08	1.11	1.08	1.13	1.07	1.11	1.11	1.02	1.08	1.02	1.06	
1912	1.14	1.12	1.10	1.16	1.13	1.14	1.17	1.17	1.13	1.09	1.05	1.09	1.12	
1913	1.13	1.09	1.13	1.09	1.10	1.07	1.20	1.19	1.17	1.04	1.03	1.01	1.10	
1914	1.09	1.05	1.10	1.10	1.15	1.14	1.19	1.14	1.10	1.08	1.03	1.04	1.10	
1915	1.07	1.02	0.98	1.12	1.13	1.12	1.11	1.20	1.12	1.05	1.03	1.03	1.08	1.10
1916	1.07	1.12	1.11	1.14	1.11	1.13	1.10	1.16	1.12	1.06	1.04	1.04	1.10	
1917	1.08	1.13	1.05	1.08	1.13	1.12	1.15	1.13	1.13	1.09	1.02	1.10	1.10	
1918	1.03	1.08	1.08	1.13	1.17	1.17	1.17	1.14	1.11	1.10	1.02	1.05	1.10	
1919	1.02	1.02	1.11	1.07	1.13	1.12	1.16	1.19	1.11	1.13	1.06	1.09	1.10	
1920	1.15	1.12	1.16	1.17	1.14	1.19	1.16	1.15	1.16	1.10	1.09	1.09	1.14	1.11
1921	1.11	1.11	1.13	1.10	1.12	1.15	1.18	1.16	1.15	1.08	1.05	1.01	1.11	
1922	1.07	1.12	1.09	1.10	1.11	1.19	1.20	1.13	1.13	1.10	1.08	1.04	1.11	
1923	1.05	1.08	1.07	1.10	1.12	1.15	1.18	1.16	1.13	1.09	1.05	1.05	1.10	
1924	1.13	1.08	------	1.15	1.17	1.11	1.17	1.17	1.11	1.10	1.06	1.10	1.12	
1925	1.15	1.08	1.07	1.07	1.07	1.12	1.10	1.19	1.13	1.12	1.05	1.08	1.10	1.11
1926	1.14	1.09	1.03	1.06	1.13	1.15	1.19	1.17	1.11	1.09	1.07	1.08	1.11	
1927	1.10	1.13	1.10	1.12	1.16	1.14	1.13	1.14	1.11	1.06	1.03	1.08	1.12	
Sum [1]	27.59	27.61	26.37	27.84	28.27	28.54	29.13	28.98	28.31	27.25	26.35	26.74	27.83	
Mean [1]	1.10	1.10	1.10	1.11	1.13	1.14	1.17	1.16	1.13	1.09	1.05	1.07	1.11	
Sum [2]	20.95	21.03	21.01	21.24	21.51	21.68	22.16	22.02	21.59	20.69	20.01	20.31	21.17	
Mean [2]	1.10	1.11	1.11	1.12	1.13	1.14	1.17	1.16	1.14	1.09	1.05	1.07	1.11	
Sum [3]	20.64	20.67	19.56	21.01	21.34	21.61	21.96	22.01	21.40	20.64	19.90	20.08	20.98	
Mean [3]	1.09	1.09	1.09	1.11	1.12	1.14	1.16	1.16	1.13	1.09	1.09	1.06	1.10	
Mean [4]	1.10	1.10	1.10	1.12	1.12	1.14	1.16	1.16	1.14	1.09	1.07	1.06	1.10	

[1] 25 years. [2] First 19 years. [3] Last 19 years. [4] First and last 19 years.

TABLE 18.—*Range of tide, Fort McHenry, Baltimore, Md.: Annual means corrected for longitude of the moon's node*

Year	Feet	Year	Feet	Year	Feet	Year	Feet	Year	Feet
1903	1.14	1908	1.17	1913	1.13	1918	1.10	1923	1.07
1904	1.11	1909	1.13	1914	1.13	1919	1.09	1924	1.10
1905	1.10	1910	1.11	1915	1.10	1920	1.12	1925	1.08
1906	1.10	1911	1.08	1916	1.11	1921	1.09	1926	1.10
1907	1.12	1912	1.15	1917	1.11	1922	1.08	1927	1.12
Sum	5.57	Sum	5.64	Sum	5.58	Sum	5.48	Sum	5.47
Mean	1.11	Mean	1.13	Mean	1.12	Mean	1.10	Mean	1.09

Mean range, first 19-year period=1.12 feet. Mean range, last 19-year period=1.11 feet. Mean range, 25 years, 1903 to 1927=1.11 feet.

TABLE 19.—*Tidal ranges, Fort McHenry, Baltimore, Md.*

	Feet		*Feet*		*Feet*
Mean range	1.11	Apogean range	0.95	Small tropic range	0.51
Spring range	1.26	Great diurnal range	1.44	Monthly extreme range	4.18
Neap range	0.93	Small diurnal range	0.78	Greatest range	10.4
Perigean range	1.31	Great tropic range	1.59		

Table 19 gives values for the various ranges for Baltimore obtained from the values for the various datum planes discussed under high-water and low-water planes. The names of the following ranges are apparent from the planes from which they are determined: Mean, spring, neap, perigean, and apogean ranges. Additional ranges are defined as follows: Great diurnal range is the distance between the mean higher-high water and the mean lower-low water, small diurnal range is the distance between the mean lower-high water and the mean higher-low water, the great tropic range is the distance between the tropic higher-high water and the tropic lower-low water, the small tropic range is the distance between the tropic lower-high water and the tropic higher-low water, the monthly extreme range is the distance between monthly extreme high water and monthly extreme low water, and the greatest range is the distance between the highest tide observed and the lowest tide observed.

HARMONIC CONSTANTS

Harmonic constants, which are derived by harmonic analysis of tidal hourly heights, are used in the prediction of tides. The tidal planes and also the ages of the tide can be derived from the harmonic constants.

The tidal hourly ordinates at Fort McHenry, Baltimore, have been analyzed and the harmonic constants determined for the years 1907 and 1925. A 369-day series was used in each analysis. Table 20 gives the harmonic constants for each of these years. The column marked: "H" gives the amplitudes of each of the components and the column marked κ gives the epochs.

TABLE 20.—*Harmonic constants, Fort McHenry, Baltimore*

Component	1907		1925		Component	1907		1925	
	H	κ	H	κ		H	κ	H	κ
	Feet	*Degrees*	*Feet*	*Degrees*		*Feet*	*Degrees*	*Feet*	*Degrees*
J_1	(0.012)	(290)	(0.012)	(290)	Q_1	0.033	267	0.032	281
K_1	0.221	296	0.218	296	$2Q$	(0.004)	(316)	(0.004)	(316)
K_2	0.024	202	0.025	229	R_2	(0.001)	(217)	(0.001)	(216)
L_2	0.017	218	0.019	230	S_1	0.047	228	0.075	222
M_1	0.014	130	0.007	68	S_2	0.084	217	0.087	216
M_2	0.474	191	0.461	190	S_4			0.001	55
M_3			0.002	62	S_6			0.001	36
M_4	0.023	304	0.021	310	T_2	(0.005)	(217)	(0.005)	(216)
M_6	0.008	225	0.004	191	λ_2	(0.003)	(203)	0.003	184
M_8			0.001	55	μ_2	0.003	97	(0.011)	(164)
N_2	0.098	171	0.090	167	ν_2	0.022	181	0.024	168
$2N$	(0.013)	(150)	0.010	106	ρ_1	0.007	310	(0.006)	(311)
O_1	0.172	306	0.168	306	Ms				
OO	(0.007)	(285)	(0.007)	(285)	Sa	0.501	129	0.369	122
P_1	0.075	284	0.066	286	Ssa	0.080	56	0.089	354

Values in parentheses are inferred.

The formulas for determining the various ages of the tide from harmonic constants are as follows:

Phase age, in hours ..... $0.984\ (S^\circ_2 - M^\circ_2)$
Parallax age, in hours ..... $1.837\ (M^\circ_2 - N^\circ_2)$
Diurnal age, in hours ..... $0.911\ (K^\circ_1 - O^\circ_1)$

The phase age of the tide at Fort McHenry, or the interval by which spring tides follow new or full moon and the interval by which neap tides follow the moon's first and third quarters, as derived from the above formula, is 25.6 hours.

The parallax age of the tide at Fort McHenry, or the interval by which perigean and apogean tides follow the time when the moon is in perigee and apogee, respectively, as derived from the formula, is 38.6 hours.

The diurnal age of the tide at Fort McHenry, or the interval by which the tropic tides follow the moon's semimonthly maximum north and south declination, as derived from the formula, is -9.1 hours, the minus sign indicating that time of tide is 9.1 hours before the maximum north or south declination.

EFFECTS OF WIND AND WEATHER

The average rise of extreme (monthly highest) high water above mean sea level at Baltimore was found to be 1.98 feet. That this rise is not due to astronomical causes alone is evident from the following considerations. The average rise of high water above sea level is 0.54 foot; at the time of spring tides this is increased by 13 per cent. At the time of perigean tides it is increased by 17 per cent and at the time of tropic higher high water the tide is increased by 61 per cent. The rise of the tide at the time of a tropic higher high water that occurs when the moon is full or new and is also in perigee should be $13+17+61=91$ per cent greater than the average, or 1.03 feet. This value is 0.95 foot less than the average extreme high water above sea level; therefore, we may conclude that the extreme high waters are caused partly by wind and weather.

The average fall below mean sea level of extreme low water was found to be 2.20 feet and the fall of extreme low water below mean low water was 1.63 feet. As in the case of the extreme high waters, we may conclude that the extreme low waters are due partly to wind and weather.

The highest high water at Baltimore for the 25-year period 1903 to 1927 occurred on August 4, 1915, when the tide rose to a height of 5.3 feet above mean sea level, or 4.8 feet above mean high water. The observed and predicted tide curves for that day are shown in figure 5. The unusual height reached was due to prolonged easterly weather during which the wind reached a maximum velocity of 39 miles per hour. The height of the astronomic high water on that day, as shown by prediction, should have been 0.7 foot above mean sea level. The high water should have risen 1.4 feet from the previous low water and fallen 0.9 foot to the succeeding low water. The tide at Baltimore registered a rise of 5.5 feet from the previous low water and a fall of 4.8 feet to the succeeding low water. The predicted duration of rise was 7.2 hours, while the actual duration of rise was 9.8 hours. The predicted duration of fall was 7.2 hours and the actual duration of fall was 16.3 hours. The value of sea level for the day was 2.7 feet above the value of mean sea level.

The lowest tide observed at Baltimore occurred on January 24, 1908, during a severe storm from the northwest. The height read 5.1 feet below mean sea level, or 4.5 feet below mean low water. Figure 6 shows the curve as recorded and the astronomic curve for the same period. An examination of the observational curve shows that the

tide began to fall at 8 p. m. on January 23 from a height of 0.2 foot below mean sea level. The tide continued to fall for 20 hours and the height reached was 5.1 feet below mean sea level. The tide then began to rise and continued to rise for 31 hours and reached a height

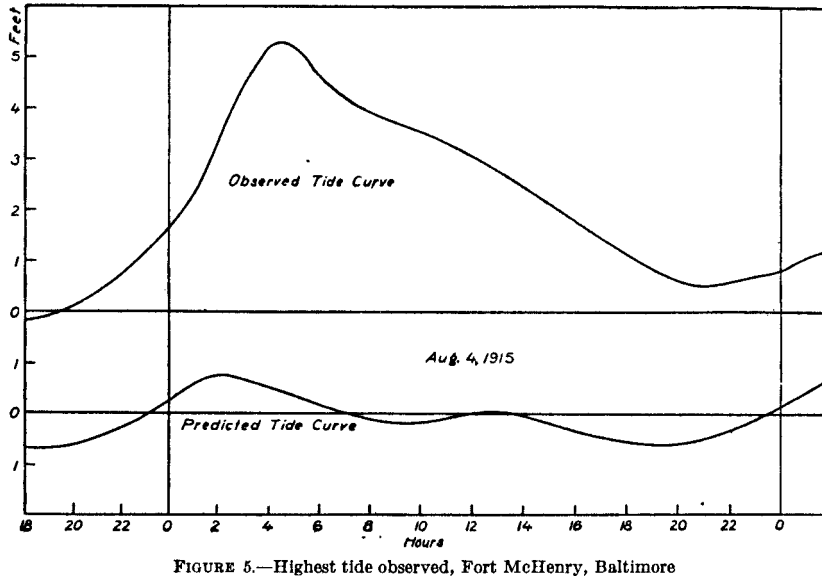


FIGURE 5.—Highest tide observed, Fort McHenry, Baltimore

of 2 feet above mean sea level, or a rise of 7.1 feet during 31 hours. The astronomic curve shows 4 high and 4 low waters, with an average range of 1.2 feet, during the period between the observed high waters. Here it is evident that the astronomic tidal influences are almost

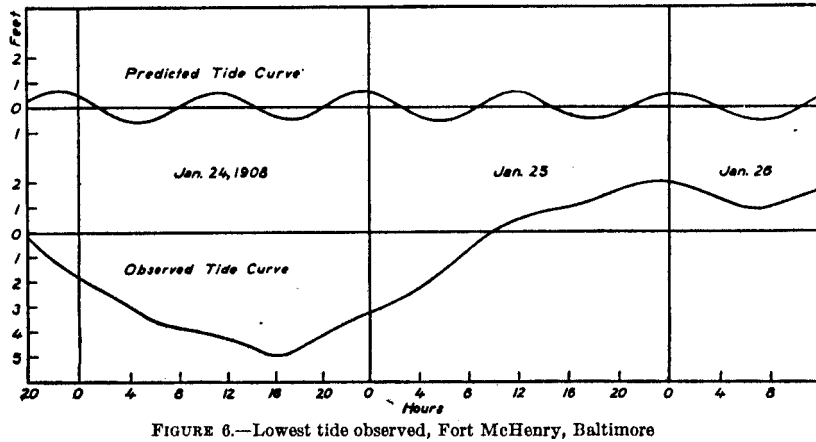


FIGURE 6.—Lowest tide observed, Fort McHenry, Baltimore

obliterated by the storm effect. The daily sea level on staff was about 3 feet below the mean on January 24 and more than 1 foot above mean sea level on January 26. On January 25, when the tide was rising all day, the plane of sea level was about normal, as the tide rose from below sea level to about the same distance above.

In general, weather conditions cause a greater change in the height of sea level than in the height of high water and low water above or below sea level. At Baltimore a strong wind seems to have complete control of the tide, as is seen from Figures 5 and 6. This is found to be the case with storm tides in general at this station. From a study of the weather conditions and tides during extreme tides it is noted that the effect of the astronomic tide is negligible in comparison with the meteorological tide. In general, a strong wind from the northwest blows the water from Baltimore Harbor and the tides are low during such winds. On the other hand, a strong wind from the south or east would be expected to pile up the water in the harbor.

Table 21 gives the general meteorological conditions at the time of extreme tides. The highest and lowest tides of each month at Baltimore, Md., for the year 1927, together with the meteorological conditions on the days when these extremes occurred, have been entered in the table. For purposes of comparison, the astronomic or theoretical tides and the mean annual barometric pressure are given.

TABLE 21.—*Extreme tides, with meteorological conditions, Fort McHenry, Baltimore, Md., 1927*

Date	Height of high water			Barometric pressure reduced to sea level			Wind	
	Observed	Astronomical	Difference	Average daily value	Annual mean	Difference	Prevailing direction	Average velocity
1927	*Feet*	*Feet*	*Feet*	*Inches*	*Inches*	*Inches*		*Miles per hour*
Jan. 4	5.5	4.6	+0.9	29.51	30.05	−0.54	SE	11
Feb. 20	6.7	4.2	2.5	29.70	30.05	−0.35	NE	20
Mar. 26	6.3	4.5	1.8	29.91	30.05	−0.14	N	8
Apr. 4	6.2	5.0	1.2	30.32	30.05	+0.27	E	14
May 31	5.9	5.5	0.4	29.96	30.05	−0.09	S	6
June 26	6.1	5.5	0.6					
July 3	6.3	5.3	1.0	29.87	30.05	−0.18	NW	8
Aug. 13	5.9	5.5	0.4	29.99	30.05	−0.06	SE	8
Aug. 14	5.9	5.5	0.4	29.92	30.05	−0.13	SSW	7
Sept. 19	6.1	5.3	0.8	29.90	30.05	−0.15	SW	8
Oct. 12	7.1	5.4	1.7	29.86	30.05	−0.19	SE	24
Nov. 18	6.1	4.6	1.5	29.99	30.05	−0.06	NW	16
Dec. 16	6.2	4.1	2.1	29.50	30.05	−0.55	SW	16
	Height of low water							
Jan. 16	0.4	3.2	−2.8	30.23	30.05	+0.18	NW	16
Feb. 28	1.7	3.0	−1.3	30.32	30.05	+0.27	NW	12
Mar. 3	0.8	3.3	−2.5	30.00	30.05	−0.05	NW	22
Apr. 23	1.7	3.7	−2.0	30.24	30.05	+0.19	S	15
May 27	2.4	3.9	−1.5	29.86	30.05	−0.19	NW	17
June 6	2.6	4.1	−1.5	30.24	30.05	+0.19	SW	10
July 4	2.6	4.0	−1.4	30.10	30.05	+0.05	NW	2
Aug. 9	2.8	4.0	−1.2	29.95	30.05	−0.10	SW	12
Aug. 27	2.8	4.0	−1.2	30.13	30.05	+0.08	N	12
Sept. 8	3.1	3.9	−0.8	30.06	30.05	+0.01	NE	7
Oct. 14	2.8	3.8	−1.0	30.24	30.05	+0.19	NW	11
Nov. 6	2.4	3.6	−1.2	30.11	30.05	+0.06	W	18
Dec. 21	1.3	3.1	−1.8	30.05	30.05	0.00	NW	17

TABLE 22.—*Summary of tidal data, Fort McHenry, Baltimore, Md.*

TIME RELATIONS		
High-water interval	hours	6. 48
Low-water interval	do	0. 66
Duration of rise	do	5. 82
Duration of fall	do	6. 60
Phase age	do	25. 6
Parallax age	do	38. 6
Diurnal age	do	−9. 1
RANGES		
Mean range	feet	1. 11
Great diurnal range	do	1. 44
Small diurnal range	do	0. 78
Great tropic range	do	1. 59
Small tropic range	do	0. 51
Spring range	do	1. 26
Neap range	do	0. 93
Perigean range	do	1. 31
Apogean range	do	0. 95
Average monthly extreme range	do	4. 18
Greatest range	do	10. 4
Spring range ÷ mean range		1. 13
Neap range ÷ mean range		0. 84
Perigean range ÷ mean range		1. 18
Apogean range ÷ mean range		0. 86
Great diurnal range ÷ mean range		1. 30
Great tropic range ÷ mean range		1. 43
HEIGHT RELATIONS		
Mean high water above mean sea level	feet	0. 54
Mean higher high water above mean sea level	do	0. 77
Mean lower high water above mean sea level	do	0. 31
Tropic higher high water above mean sea level	do	0. 87
Tropic lower high water above mean sea level	do	0. 12
Spring high water above mean sea level	do	0. 61
Neap high water above mean sea level	do	0. 45
Perigean high water above mean sea level	do	0. 67
Apogean high water above mean sea level	do	0. 49
Average monthly highest high water above mean sea level	do	1. 98
Highest high water above mean sea level	do	5. 3
Mean low water below mean sea level	do	0. 57
Mean lower low water below mean sea level	do	0. 67
Mean higher low water below mean sea level	do	0. 47
Tropic lower low water below mean sea level	do	0. 72
Tropic higher low water below mean sea level	do	0. 39
Spring low water below mean sea level	do	0. 65
Neap low water below mean sea level	do	0. 48
Perigean low water below mean sea level	do	0. 64
Apogean low water below mean sea level	do	0. 46
Average monthly lowest low water below mean sea level	do	2. 20
Lowest low water below mean sea level	do	5. 1
Half-tide level below mean sea level	do	0. 02

THE TIDE AT WASHINGTON, D. C.

NAVY YARD

Tide observations have been made at the navy yard for periods totaling about 10 years. Observations were first made in 1858 and a number of series were made between that time and 1898. The longest series was made during the years 1891–1898, when 7½ years of continuous observations were taken. In the discussion that follows the height relations are based on the 7-year period 1892–1898.

The time relations are based on the observations for 17 months in 1891–92.

Lunitidal intervals.—The lunitidal intervals or the times by which the tides follow the transits of the moon have been determined for the navy yard from periods of observation totaling about 5 years. The results from each series of observations are shown in Table 50. The monthly intervals for 17 months in 1891 and 1892 are given in Table 23.

From Table 50 it appears that the high-water interval increases from about 7.7 hours in 1860 to about 7.9 hours in 1892. The monthly means, Table 23, indicate a seasonal change in the high-water interval; from January to May it is about 7¾ hours and from June to December about 8 hours.

The monthly means indicate that the low-water interval is higher from November to April than from May to October. It appears to reach a maximum of about 2½ hours in December and March and remains at about 2 hours during July, August, and September.

TABLE 23.—*Lunitidal intervals, navy yard, Washington, D. C.*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sum	Mean
	Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*
HIGH-WATER INTERVAL														
1891	------	------	------	------	------	------	------	7.91	7.93	7.93	7.96	7.89	39.62	7.92
1892	7.77	7.70	7.80	7.71	7.71	7.93	8.06	8.01	8.04	7.93	8.13	8.12	94.91	7.91
LOW-WATER INTERVAL														
1891	------	------	------	------	------	------	------	2.03	2.13	2.18	2.34	2.23	10.91	2.18
1892	2.35	2.23	2.56	2.43	2.25	2.30	2.06	2.03	2.03	1.76	2.22	2.50	26.72	2.23
DURATION OF RISE														
1891	------	------	------	------	------	------	------	5.88	5.80	5.75	5.62	5.66	28.71	5.74
1892	5.42	5.47	5.24	5.28	5.46	5.63	6.00	5.98	6.01	6.17	5.91	5.62	68.19	5.68

Durations of rise and fall.—Monthly values for duration of rise for the period August, 1891, to December, 1892, are given in Table 23. The greatest difference between any two of the 17 monthly values is 0.93 hour. The duration of fall for any month may be obtained by subtracting the value of duration of rise for that month from the tidal cycle of 12.42 hours, and it follows that variations in the duration of fall are numerically equal to those in the duration of rise.

Mean river level.—In the upper reaches of a long tidal river the plane obtained by averaging the hourly heights of the tide is, because of the slope of the river, somewhat higher than the sea level similarly obtained at a point on the open coast. The term river level has been applied to the former plane to distinguish it from the latter. Because of fluctuations in the fresh-water discharge, the daily variations in river level are usually greater than those of sea level. While the daily values of river level at Washington sometimes vary by several feet, the monthly values seldom vary more than 1 foot and the yearly values seldom vary more than 0.2 foot. Table 24 gives the monthly and yearly values of river level on staff at the navy yard for the 7-year

period 1892 to 1898, inclusive. The maximum variation between monthly values is 1.37 feet and the maximum yearly variation is 0.22 foot.

The last column of the table gives evidence of a seasonal change in the value of river level. From May to October it remains about 4.8 feet and from November to March it is about 0.4 foot less.

TABLE 24.—*River level on staff, monthly means, navy yard, Washington, D. C.*

Month	1892	1893	1894	1895	1896	1897	1898	Sum	Mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
January	4.36	[1] 4.48	4.42	4.37	4.44	4.05	4.09	30.21	4.32
February	4.67	[1] 4.50	4.27	3.87	4.26	5.10	4.28	30.95	4.42
March	4.34	4.51	4.49	4.27	3.79	4.62	4.54	30.56	4.37
April	4.34	4.75	4.70	4.78	4.47	4.42	4.74	32.20	4.60
May	4.69	4.92	5.10	4.60	4.79	4.84	5.16	34.10	4.87
June	4.76	4.92	4.63	4.88	4.77	4.86	4.91	33.73	4.82
July	4.44	4.73	4.59	4.78	4.70	4.90	4.93	33.07	4.72
August	4.79	4.86	4.80	4.71	4.71	4.90	4.91	33.68	4.81
September	4.69	4.88	4.95	4.79	4.78	4.88	4.81	33.78	4.83
October	4.25	5.03	4.80	4.58	4.93	5.10	5.07	33.76	4.82
November	4.19	4.55	4.14	4.36	4.57	4.34	4.40	30.55	4.36
December	4.24	3.98	4.34	4.45	4.39	4.33	4.37	30.10	4.30
Sum	53.76	56.11	55.23	54.44	54.60	56.34	56.21	386.69	55.24
Mean	4.48	4.68	4.60	4.54	4.55	4.70	4.68	32.23	4.60

[1] Interpolated values.

Curves plotted from the monthly means of high water, low water, and river level from the seven years of observations at the navy yard are reproduced in Figure 7. It will be noted that the curves are

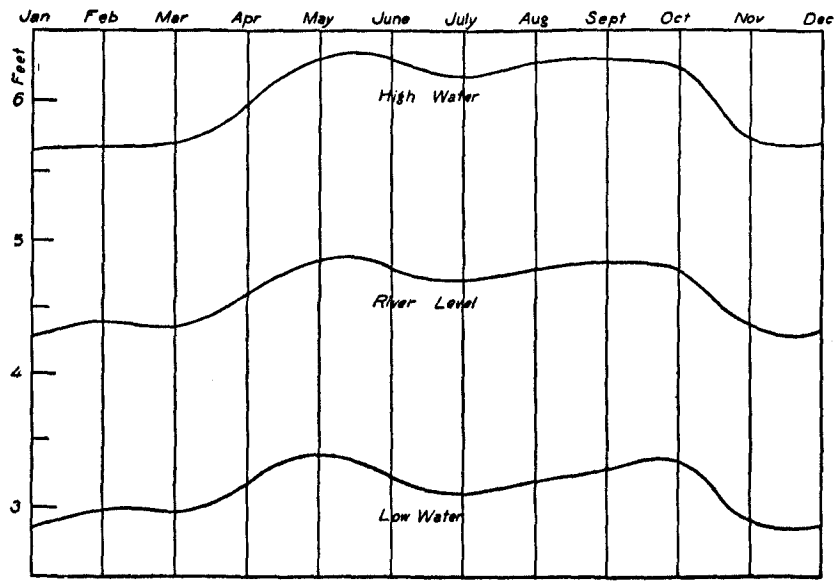


FIGURE 7.—Annual variations in high water, low water, and river level, Navy Yard, Washington

similar, showing that the three planes undergo nearly the same seasonal changes.

The planes of high water.—Table 25 gives the monthly and yearly mean values of high water on staff at the navy yard for the 7-year

period 1892 to 1898, inclusive. The lowest monthly value is 5.02 feet, which is about 1 foot below mean high water, while the highest monthly value is 6.64 feet, a difference of 1.62 feet. The maximum difference between any two years shown in the table is 0.23 foot.

To eliminate the effect of variations in river level on high water, it is only necessary to subtract from the values in Table 25 the corresponding values in Table 24. The results, which give the monthly and yearly means of high water above river level for the navy yard are shown in Table 26. The maximum monthly variation is 0.46 foot. The maximum variation of the means of the monthly values in the last column of the table is 0.19 foot and the maximum yearly variation is 0.06 foot. The value of mean high water above mean river level as determined for the 7-year series is 1.40 feet. Table 27 gives a value of 1.43 feet for mean high water above mean river level, corrected for the longitude of the moon's node.

TABLE 25.—*High water on staff, monthly means, navy yard, Washington, D. C.*

Month	1892	1893	1894	1895	1896	1897	1898	Sum	Mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
January	5.70	[1] 5.70	5.86	5.70	5.72	5.48	5.48	39.64	5.66
February	5.99	[1] 5.81	5.60	5.02	5.62	6.35	5.64	40.03	5.72
March	5.67	5.92	5.83	5.59	5.13	5.89	5.93	39.96	5.71
April	5.70	6.18	6.07	6.15	5.86	5.77	6.07	41.80	5.97
May	6.16	6.32	6.52	6.01	6.31	6.21	6.59	44.12	6.30
June	6.22	6.33	6.18	6.37	6.27	6.36	6.40	44.13	6.30
July	5.89	6.17	6.11	6.18	6.11	6.39	6.42	43,27	6.18
August	6.22	6.27	6.28	6.16	6.23	6.36	6.35	43.87	6.27
September	6.05	6.33	6.42	6.19	6.24	6.34	6.26	43.83	6.26
October	5.57	6.64	6.24	5.90	6.35	6.54	6.55	43.79	6.26
November	5.50	5.96	5.47	5.75	5.94	5.72	5.70	40.04	5.72
December	5.59	5.37	5.73	5.79	5.83	5.73	5.72	39.76	5.68
Sum	70.26	73.00	72.31	70.81	71.61	73.14	73.11	504.24	72.03
Mean	5.86	6.08	6.03	5.90	5.97	6.09	6.09	42.02	6.00

[1] Interpolated values.

TABLE 26.—*High water above river level, monthly means, navy yard, Washington, D. C.*

Month	1892	1893	1894	1895	1896	1897	1898	Sum	Mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
January	1.34	[1] 1.22	1.44	1.33	1.28	1.43	1.39	9.43	1.35
February	1.32	[1] 1.31	1.33	1.15	1.36	1.25	1.36	9.08	1.30
March	1.33	1.41	1.34	1.32	1.34	1.27	1.39	9.40	1.34
April	1.36	1.43	1.37	1.37	1.39	1.35	1.33	9.60	1.37
May	1.47	1.40	1.42	1.41	1.52	1.37	1.43	10.02	1.43
June	1.46	1.41	1.55	1.49	1.50	1.50	1.49	10.40	1.49
July	1.45	1.44	1.52	1.40	1.41	1.49	1.49	10.20	1.46
August	1.43	1.41	1.48	1.45	1.52	1.46	1.44	10.19	1.46
September	1.36	1.45	1.47	1.40	1.46	1.46	1.45	10.05	1.44
October	1.32	1.61	1.44	1.32	1.42	1.44	1.48	10.03	1.43
November	1.31	1.41	1.33	1.39	1.37	1.38	1.30	9.49	1.36
December	1.35	1.39	1.39	1.34	1.44	1.40	1.35	9.66	1.38
Sum	16.50	16.89	17.08	16.37	17.01	16.80	16.90	117.55	16.81
Mean	1.38	1.41	1.42	1.36	1.42	1.40	1.41	9.80	1.40

[1] Interpolated values.

TABLE 27.—*High water above river level, navy yard, Washington, D. C.: Annual means corrected for longitude of the moon's node*

1892	1893	1894	1895	1896	1897	1898	Sum	Mean
Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1.41	1.45	1.46	1.40	1.45	1.43	1.42	10.02	1.43

The planes of low water.—The plane of mean low water as determined from seven years of observations, 1892–1898, is 3.12 feet on staff, or 1.48 feet below mean river level. The latter value becomes 1.52 feet after correcting the annual means for the longitude of the moon's node. Table 28 gives the monthly and yearly heights of low water on staff at the navy yard. The maximum difference between any two monthly values is 1.38 feet. The maximum difference between any two means of the monthly values in the last column of the table is 0.57 foot and the maximum difference between yearly values is only 0.21 foot. It is noted that the values for low water on staff show much more variation than the same values referred to river level. Table 29 gives the monthly and yearly values of low water below river level. The maximum difference between any two months is 0.35 foot, the maximum difference between yearly averages of the monthly values in the last column of the table is 0.23 foot and the maximum difference between yearly values is 0.07 foot. Table 30 gives the annual means corrected for the longitude of the moon's node.

The plane of half-tide level.—Since the plane of half-tide level is the plane halfway between mean high water and mean low water and from the 7-year series 1892–1898, the value of mean high water (uncorrected) is 6 feet on staff, or 1.40 feet above mean river level, and mean low water is 3.12 feet on staff, or 1.48 feet below mean river level; half-tide level is 4.56 feet on staff, or 0.04 foot below mean river level.

TABLE 28.—*Low water on staff, monthly means, navy yard, Washington, D. C.*

Month	1892	1893	1894	1895	1896	1897	1898	Sum	Mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
January	2.99	[1] 2.88	2.88	3.00	2.98	2.65	2.79	20.17	2.88
February	3.25	[1] 2.99	2.84	2.70	2.79	3.78	2.92	21.27	3.04
March	2.99	3.10	3.07	2.93	2.40	3.30	3.13	20.92	2.99
April	2.96	3.25	3.28	3.36	2.99	2.94	3.32	22.10	3.16
May	3.19	3.52	3.65	3.14	3.22	3.45	3.69	23.86	3.41
June	3.25	3.28	2.97	3.34	3.20	3.28	3.34	22.66	3.24
July	2.90	3.08	2.95	3.13	3.14	3.31	3.31	21.82	3.12
August	3.21	3.18	3.16	3.06	3.16	3.30	3.40	22.47	3.21
September	3.21	3.31	3.37	3.15	3.23	3.32	3.20	22.79	3.26
October	2.74	3.70	3.29	3.02	3.47	3.61	3.74	23.57	3.37
November	2.77	3.08	2.75	2.85	3.04	2.92	2.98	20.39	2.91
December	2.78	2.50	2.88	2.99	2.95	2.87	2.93	19.90	2.84
Sum	36.24	37.87	37.09	36.67	36.57	38.73	38.75	261.92	37.43
Mean	3.02	3.16	3.09	3.06	3.05	3.23	3.23	21.84	3.12

[1] Interpolated values.

TABLE 29.—*Low water below river level, monthly means, navy yard, Washington, D. C.*

Month	1892	1893	1894	1895	1896	1897	1898	Sum	Mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
January	1.37	[1] 1.60	1.54	1.37	1.46	1.40	1.30	10.04	1.43
February	1.42	[1] 1.51	1.43	1.17	1.47	1.32	1.36	9.68	1.38
March	1.35	1.41	1.42	1.34	1.39	1.32	1.41	9.64	1.38
April	1.38	1.50	1.42	1.42	1.48	1.48	1.42	10.10	1.44
May	1.50	1.40	1.45	1.46	1.57	1.39	1.47	10.24	1.46
June	1.51	1.64	1.66	1.54	1.57	1.58	1.57	11.07	1.58
July	1.54	1.65	1.64	1.65	1.56	1.59	1.62	11.25	1.61
August	1.58	1.68	1.64	1.65	1.55	1.60	1.51	11.21	1.60
September	1.48	1.57	1.58	1.64	1.55	1.56	1.61	10.99	1.57
October	1.51	1.33	1.51	1.56	1.46	1.49	1.33	10.19	1.46
November	1.42	1.47	1.39	1.51	1.53	1.42	1.42	10.16	1.45
December	1.46	1.48	1.46	1.46	1.44	1.46	1.44	10.20	1.46
Sum	17.52	18.24	18.14	17.77	18.03	17.61	17.46	124.77	17.82
Mean	1.46	1.52	1.51	1.48	1.50	1.47	1.45	10.39	1.48

[1] Interpolated values.

TABLE 30.—*Low water below river level, navy yard, Washington, D. C.: Annual means corrected for longitude of the moon's node*

1892	1893	1894	1895	1896	1897	1898	Sum	Mean
Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1.49	1.56	1.55	1.52	1.54	1.50	1.46	10.62	1.52

Mean range—Table 31 gives the monthly and yearly values for range at the navy yard for the years 1892–1898. The annual means corrected for the longitude of the moon's node are given in the last line of the table, the mean value being 2.95 feet.

The maximum difference between monthly means for this period is 0.64 foot and the maximum difference between yearly means is

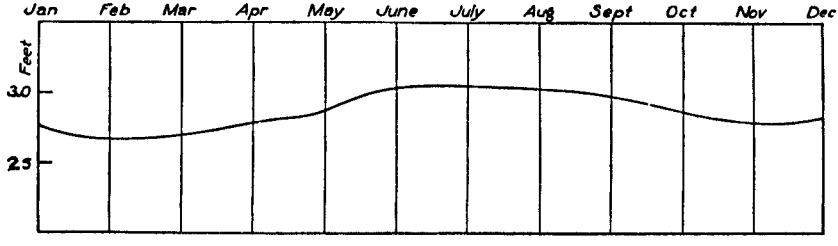


FIGURE 8.—Annual variation in range, Navy Yard, Washington

0.10 foot. There is also a seasonal change in the column of mean monthly values, the range varying from 3.07 feet in June to 2.68 feet in February, a difference of 0.39 foot.

The maximum difference between monthly means for Baltimore from 25 years of observations is 0.12 foot, the largest range occurring in July and the smallest in November. At Philadelphia on the Delaware River, the average seasonal variation in range is about 1 foot, whereas at Boston, near the open coast, it is only 0.2 foot. It appears, therefore, that such variation is largely a river effect, and it is probably due to varying quantities of drainage water in the river.

TABLE 31.—*Range of tide, monthly means, navy yard, Washington, D. C.*

Month	1892	1893	1894	1895	1896	1897	1898	Sum	Mean
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
January	2.71	[1] 2.82	2.98	2.70	2.74	2.83	2.69	19.47	2.78
February	2.74	[1] 2.82	2.76	2.32	2.83	2.57	2.72	18.76	2.68
March	2.68	2.82	2.76	2.66	2.73	2.59	2.80	19.04	2.72
April	2.74	2.93	2.79	2.79	2.87	2.83	2.75	19.70	2.81
May	2.97	2.80	2.87	2.87	3.09	2.76	2.90	20.26	2.89
June	2.97	3.05	3.21	3.03	3.07	3.08	3.06	21.47	3.07
July	2.99	3.09	3.16	3.05	2.97	3.08	3.11	21.45	3.06
August	3.01	3.09	3.12	3.10	3.07	3.06	2.95	21.40	3.06
September	2.84	3.02	3.05	3.04	3.01	3.02	3.06	21.04	3.01
October	2.83	2.94	2.95	2.88	2.88	2.93	2.81	20.22	2.89
November	2.73	2.88	2.72	2.90	2.90	2.80	2.72	19.65	2.81
December	2.81	2.87	2.85	2.80	2.88	2.86	2.79	19.86	2.84
Sum	34.02	35.13	35.22	34.14	35.04	34.41	34.36	242.32	34.62
Mean	2.84	2.93	2.94	2.84	2.92	2.87	2.86	20.20	2.88
Corrected mean	2.90	3.01	3.02	2.92	2.99	2.92	2.88	20.64	2.95

[1] Interpolated values.

Extreme tides.—In Table 32 are given the dates and heights on staff of the highest and lowest tides of each year for the years 1892–1898. For this period the highest tide observed occurred on October 14, 1893, and was due to a hurricane. The tide reached a height of 12.5 feet on staff, or 7.9 feet above mean river level. The lowest tide observed was on March 3, 1896, when the height recorded was −0.7 foot on staff, or 5.3 feet below mean river level. This unusual height resulted from a prolonged northwesterly wind. The average of the highest high water each year for the seven years is 9.1 feet on staff. The average of the yearly lowest low water for the same period is 0.4 foot. The average yearly extreme range for this period is, therefore, 8.7 feet and the greatest range is 13.2 feet. The yearly average of the highest high water in each month is 7.40 feet on staff, or 2.8 feet above mean river level, and the yearly average of the lowest tide of each month is 1.84 feet on staff, or 2.8 feet below mean river level. The average monthly extreme range is, then, 5.6 feet.

TABLE 32.—*Extreme high and low waters on staff, navy yard, Washington, D. C.*

High				Low			
Year	Monthly average feet	Highest		Year	Monthly average feet	Lowest	
		Date	Feet			Date	Feet
1892	7.02	Sept. 14	7.9	1892	1.85	Mar. 21	1.1
1893	7.81	Oct. 14	12.5	1893	2.09	Dec. 26	0.9
1894	7.33	Sept. 28	8.3	1994	1.88	Nov. 28, 29	1.2
1895	7.13	Jan. 11	7.6	1895	1.82	Feb. 10	0.2
1896	7.55	Sept. 30	9.8	1896	1.47	Mar. 3	−0.7
1897	7.37	Feb. 23, Oct. 23	8.0	1897	2.03	Dec. 24	0.1
1898	7.58	Oct. 18	9.7	1898	1.73	Nov. 27	0.0
Sum	51.79		63.8	Sum	12.87		2.8
Mean	7.40		9.11	Mean	1.84		0.4

An examination of the table shows that the highest and lowest tides for the year usually occur during the autumn or winter months.

In connection with extreme tides an account is given of two freshets in the vicinity of Washington. The freshet which occurred on November 25 and 26, 1877, which was one of the highest on record, was investigated by Charles Junken, of this office. The United States Coast and Geodetic Survey Report for 1878, page 24, gives the following:

At the Chain Bridge the water reached fully up to the level of the top of the old piers, and Mr. Junken found that the rise amounted to 36 feet above the level of mean high tide. At Lockmills the rise was 27 feet; at the aqueduct, 13 feet 9 inches; at the Philadelphia Steamboat Co.'s wharf, Georgetown, the rise was 10 feet 7 inches; at the Long Bridge, 6 feet 2 inches; at the Arsenal Wharf, 5 feet 6 inches; and at Alexandria the water rose 3 feet above the level of mean high tide.

Following are the heights reached by this freshet at the points mentioned referred to mean river level:

	Feet		Feet
Chain Bridge	37. 4	Long Bridge	7. 6
Lockmills	28. 4	Arsenal Wharf	7. 0
Aqueduct	15. 2	Alexandria	4. 4
Philadelphia Steamboat Co. Wharf, Georgetown	12. 0		

The report of the Chief of Engineers, United States Army, 1889, Part II, page 985, gives an account of a freshet in the Potomac River on June 2, 1889.

Quoting from the report:

On the 2d of June there occurred the greatest freshet in the Potomac River of which there is any authoritative record. The Potomac at Harpers Ferry rose to the height of 35 feet above the low stage. The water was at one time 2.8 feet above the rails of the Baltimore & Ohio Railroad on the bridge and 6.8 feet higher than the freshet of 1877. At the Great Falls the maximum height was 4 feet above the freshet of 1877. * * * At the Chain Bridge it was 43.3 feet above the tide level. From these facts it will be seen that the unusual height attained at Washington was due to the vast volume of water pouring down from the river above. The freshet was preceded by strong southeast winds, which made the tides at this point unusually high. Observations were taken while the freshet was running, to determine the levels at various points from Chain Bridge down to Arsenal Point, some of which are plotted on the accompanying sheet. The freshet attained its maximum height at about 10 a. m. on June 2. It was within 3 feet of that height for a period of about 24 hours and within 6 feet of it for about 30 hours. After the river began to fall it fell quite rapidly, but for more than 24 hours the river was too high for the sewers in the low part of the city to discharge their contents. Hence, if a heavy rainfall had occurred during this period the sewers could not have carried off the rain water at all and a still larger area of the city would have been flooded. The highest point reached by the water at the sewer canal at the foot of Seventeenth Street was 13.26 feet. Before this height was reached the water backed up in the B Street sewer and came into the streets from the sewer outlets. After the water rose above the level of B Street it came into the city from the sewers and from the river direct.

A diagram in the above-mentioned report gives the following heights of maximum high water during the freshet of June 2, 1889.

	Feet above low water		Feet above low water
Chain Bridge	43. 1	Sewer Canal	13. 3
Aqueduct Bridge	19. 5	Long Bridge	12. 7
Easby Point	13. 3	Arsenal	11. 1

On two stone gateposts and a stone tool house near the corner of Fifteenth and B Streets NW. lines and inscriptions indicate the water heights reached by freshets on the following dates: November 26, 1877; February 12, 1881; and June 2, 1889. Some of the marks have been obliterated by the weathering of the stone. Recent levels, however, run to the marks that are still legible indicate that at this location the freshet of 1889 rose to a height of approximately 11 feet above sea-level datum and that lesser heights were reached by the two earlier freshets.

In Table 33 is given a summary of tidal data for the navy yard, Washington. Some of the values given were derived from harmonic

constants for the year 1894. It will be noted that all height relations are referred to mean river level instead of mean sea level. The relation between mean river level and mean sea level as determined from precise levels is given.

TABLE 33.—*Summary of tidal data, navy yard, Washington, D. C.*

TIME RELATIONS		
High-water interval	hours	7. 82
Low-water interval	do	2. 14
Duration of rise	do	5. 68
Duration of fall	do	6. 74
Phase age	do	43. 3
Parallax age	do	47. 7
Diurnal age	do	−18. 2
RANGES		
Mean range	feet	2. 95
Great diurnal range	do	3. 20
Small diurnal range	do	2. 70
Great tropic range	do	3. 21
Small tropic range	do	2. 69
Spring range	do	3. 21
Neap range	do	2. 66
Average monthly extreme range	do	5. 56
Greatest range	do	13. 2
Spring range÷mean range		1. 09
Neap range÷mean range		0. 90
Great diurnal range÷mean range		1. 08
Great tropic range÷mean range		1. 09
HEIGHT RELATIONS		
Mean river level above mean sea level datum	feet	0. 29
Mean high water above mean river level	do	1. 43
Mean higher high water above mean river level	do	1. 62
Mean lower high water above mean river level	do	1. 24
Tropic higher high water above mean river level	do	1. 65
Tropic lower high water above mean river level	do	1. 21
Spring high water above mean river level	do	1. 56
Neap high water above mean river level	do	1. 29
Average monthly highest high water above mean river level	do	2. 80
Highest high water above mean river level	do	7. 9
Mean low water below mean river level	do	1. 52
Mean lower low water below mean river level	do	1. 58
Mean higher low water below mean river level	do	1. 46
Tropic lower low water below mean river level	do	1. 56
Tropic higher low water below mean river level	do	1. 48
Spring low water below mean river level	do	1. 65
Neap low water below mean river level	do	1. 37
Average monthly lowest low water below mean river level	do	2. 76
Lowest low water below mean river level	do	5. 3
Half tide level below mean river level	do	0. 04

SEVENTH STREET WHARF

An automatic tide gage was in operation from July, 1898, to March, 1901, on the Norfolk & Washington steamboat wharf at the foot of Seventh Street. The monthly lunitidal intervals computed from 18 months of observations are given in Table 34. It will be noted that for the year 1899 the highest value for both the high and low water intervals came in February and the lowest value for the high-water interval came in May. The lowest value for the low-water interval came in July, when it reached 1.78 hours. For the

18-month series the mean value for the high-water interval is 7.80 hours and for the low-water interval 2.11 hours. The duration of rise is found to be least in March, when it is about 5.2 hours, and greatest in the months from July to October, when it remains about 0.3 hour greater than the mean value. The mean duration of rise for the series is 5.69 hours. The duration of fall is 6.73 hours. This difference between duration of rise and duration of fall is typical of river tides.

The mean range of tide at this station, as determined from 32 months of observations, is 2.90 feet. There is noted a seasonal change in the range, the lowest value for the year 1899 being 2.35 feet in the month of February and high values occurring from April to August, with a maximum of 3.21 feet in June. There is an apparent relation between the range and time of tide, both high and low water intervals being generally greater than the average when the range is less than the average, and vice versa.

TABLE 34.—*Lunitidal intervals and range, Seventh Street Wharf, Washington, D. C.*

Month	High-water interval		Low-water interval		Duration of rise		Mean range			
	1898	1899	1898	1899	1898	1899	1898	1899	1900	1901
	Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Feet*	*Feet*	*Feet*	*Feet*
January	-------	7.80	-------	2.37	-------	5.43	-------	2.92	2.65	2.76
February	-------	8.23	-------	2.98	-------	5.25	-------	2.35	2.68	2.50
March	-------	7.82	-------	2.67	-------	5.15	-------	2.57	2.77	2.72
April	-------	7.74	-------	2.38	-------	5.36	-------	3.01	2.99	-------
May	-------	7.61	-------	2.27	-------	5.34	-------	3.03	3.02	-------
June	-------	7.62	-------	1.96	-------	5.66	-------	3.21	3.06	-------
July	7.86	7.80	1.74	1.78	6.12	6.02	3.12	3.17	3.13	-------
August	7.76	7.73	1.94	1.79	5.82	5.94	3.03	3.10	3.18	-------
September	7.83	7.80	1.78	1.86	6.05	5.94	3.02	2.87	3.04	-------
October	7.61	7.93	2.02	1.91	5.59	6.02	2.78	3.04	3.03	-------
November	7.84	7.85	2.00	2.07	5.84	5.78	2.79	2.87	2.85	-------
December	7.77	7.84	2.30	2.10	5.47	5.74	2.79	2.74	-------	-------
Sum	46.67	93.77	11.78	26.14	34.89	67.63	17.53	34.88	32.40	7.98
Mean	7.78	7.81	1.96	2.18	5.82	5.64	2.92	2.91	2.95	2.66
Corrected for longitude of moon's node							2.94	2.91	2.92	2.61

TABLE 35.—*High water, low water, and river level, Seventh Street Wharf, Washington, D. C.*

Month	Mean river level on staff				Low water below river level				High water above river level			
	1898	1899	1900	1901	1898	1899	1900	1901	1898	1899	1900	1901
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
January	-------	4.77	4.44	4.75	-------	1.48	1.36	1.40	-------	1.44	1.29	1.36
February	-------	5.08	4.53	4.06	-------	1.23	1.38	1.30	-------	1.12	1.30	1.20
March	-------	5.45	4.88	4.79	-------	1.33	1.42	1.39	-------	1.24	1.34	1.33
April	-------	5.29	4.87	-------	-------	1.52	1.52	-------	-------	1.49	1.47	-------
May	-------	5.49	5.06	-------	-------	1.57	1.54	-------	-------	1.46	1.48	-------
June	-------	5.26	5.39	-------	-------	1.65	1.55	-------	-------	1.56	1.51	-------
July	5.38	5.14	5.09	-------	1.60	1.64	1.62	-------	1.52	1.53	1.51	-------
August	5.41	5.61	5.25	-------	1.55	1.59	1.65	-------	1.48	1.51	1.53	-------
September	5.39	5.51	5.24	-------	1.61	1.43	1.57	-------	1.41	1.44	1.47	-------
October	5.69	5.30	5.27	-------	1.41	1.55	1.55	-------	1.37	1.49	1.48	-------
November	4.85	5.36	4.90	-------	1.39	1.47	1.47	-------	1.40	1.40	1.38	-------
December	4.95	4.86	-------	-------	1.49	1.46	-------	-------	1.30	1.28	-------	-------
Sum	31.67	63.12	54.92	13.60	9.05	17.92	16.63	4.09	8.48	16.96	15.76	3.89
Mean	5.28	5.26	4.99	4.53	1.51	1.49	1.51	1.36	1.41	1.41	1.43	1.30
Corrected for longitude of moon's node					1.52	1.49	1.49	1.33	1.42	1.41	1.41	1.27

Monthly values for river level at Seventh Street Wharf, as determined from 32 months of observations, are given in Table 35. The value for river level, as determined from this series, is 5.10 feet. As at the navy yard, it is noted that during the winter months river level on staff is generally below the average value.

The value of high water above river level is 1.41 feet and the value of low water below river level is 1.49 feet, as determined from the 32 months of observations. On the last line of the table are given the yearly means corrected for the longitude of the moon's node. The planes of high water and low water show a seasonal variation similar to that of river level.

In Table 36 are given the date and height of the highest and lowest tides in each month for the two years beginning December 1, 1898. The mean of the monthly highest tides for the two years is 2.82 feet above mean river level and the mean of the monthly lowest tides for the same period is 2.64 feet below mean river level. The average monthly extreme range is, therefore, 5.46 feet. The highest high water was 4.4 feet above mean river level and the lowest low water was 3.8 feet below mean river level. The greatest range is, then, 8.2 feet. The greatest range for the navy yard from seven years of observation was 13.2 feet.

TABLE 36.—*Highest and lowest observed tides, Seventh Street Wharf, Washington, D. C.*

Month	Highest				Lowest			
	1898–99		1899–1900		1898–99		1899–1900	
	Date	*Feet* [1]	*Date*	*Feet* [1]	*Date*	*Feet* [2]	*Date*	*Feet* [2]
December	4	4.4	24	2.8	9	3.2	30	3.2
January	26	2.2	20	1.8	1	3.8	29	3.8
February	23	2.7	22, 24	2.2	12	2.9	18, 20	3.3
March	5	3.7	1	2.3	13, 20	2.1	21	2.8
April	7	3.1	29	2.4	16	2.5	5	3.1
May	4, 5, 11	2.8	28	2.9	26, 29, 31	1.8	9	2.7
June	23, 24	2.6	19	2.7	16	2.3	3	2.2
July	25	2.8	12	2.4	9	2.8	10, 13, 14, 19	2.3
August	21, 29	2.9	16	2.5	4, 20, 23	1.8	12	2.2
September	11, 13, 19, 24	2.6	11	2.5	21, 30	2.0	18	2.7
October	31	3.6	7	2.7	1, 7, 20	2.2	17	2.3
November	1	3.9	26	3.3	6	2.4	10	3.0
Sum		37.3		30.5		29.8		33.6
Mean		3.11		2.54		2.48		2.80

[1] Above mean river level. [2] Below mean river level.

Mean of monthly highest = 2.82 feet above mean river level. Mean of monthly lowest = 2.64 feet below mean river level. Highest tide observed = 4.4 feet above mean river level. Lowest tide observed = 3.8 feet below mean river level.

EASBY POINT

Table 37 gives the results of 12 months of observations at Easby Point from April, 1901, to March, 1902. Examining the monthly values, it is noted that the high-water interval is largest in February and smallest in July. The low-water interval is greatest in March and smallest in October.

The seasonal variation in the high-water intervals appears to be opposite in direction to that indicated by observations at the navy yard. (See Table 23.) The variations in the low-water intervals at the two places, however are more consistent.

A careful study of the intervals for each of the four stations in Washington, for which a year or more of observations has been taken, reveals that usually the high-water intervals are a few tenths of an hour greater in winter than in summer, and the low-water intervals are about three-fourths hour greater in winter than in summer. The values for range and river level, or tide level, are usually below the average in winter, when the intervals are large. It would seem, therefore, that during the low stages of the river the range of the tide is generally reduced and the time of tide delayed by the shoalness of the water. As would be expected, the delay in the time of low water is decidedly more pronounced than that for the high water.

TABLE 37.—*Tidal data, Easby Point, Washington, D. C.*

Year and month	High-water interval	Low-water interval	Duration of rise	Mean high water on staff	Mean low water on staff	Mean range	Mean tide level on staff	Highest tide		Lowest tide	
								Date	Height	Date	Height
1901	*Hours*	*Hours*	*Hours*	*Feet*	*Feet*	*Feet*	*Feet*		*Feet*		*Feet*
April	7.94	2.64	5.30	7.14	4.55	2.59	5.84	22	9.8	1	1.5
May	7.76	2.65	5.11	7.40	4.53	2.87	5.96	24, 31	8.3	4	3.2
June	7.70	2.72	4.98	7.26	4.22	3.04	5.74	17	8.6	30	3.4
July	7.69	2.43	5.26	7.18	3.94	3.24	5.56	14	8.6	3	3.1
August	7.75	2.32	5.43	7.23	3.94	3.29	5.58	7	8.3	4	3.1
September	7.70	2.12	5.58	7.23	4.08	3.15	5.66	28	8.5	30	3.3
October	7.80	2.01	5.79	6.65	3.57	3.08	5.11	12	7.9	18	2.4
November	7.86	2.17	5.69	6.15	3.31	2.84	4.73	24	7.6	28	1.3
December	8.09	2.40	5.69	6.46	3.72	2.74	5.09	29, 31	8.4	21	2.4
1902											
January	8.09	2.76	5.33	6.12	3.45	2.67	4.78	22	8.0	4	1.2
February	8.46	2.91	5.55	6.02	3.85	2.17	4.94	27	[1]11.4	10	2.0
March	8.07	3.03	5.04	6.87	4.59	2.28	5.73	2	[1]12.3	20	2.1
Sum	94.91	30.16	64.75	81.71	47.75	33.96	64.72		107.7		29.0
Mean	7.91	2.51	5.40	6.81	3.98	2.83	5.39		8.98		2.42
Corrected for longitude of moon's node						2.77					

[1] Estimated.

The mean range determined for the year is 2.83 feet; corrected for the longitude of the moon's node, it becomes 2.77 feet. The monthly range is largest in August and smallest in February, a maximum difference for the 12 months of 1.12 feet. The plane of mean high water on staff is determined as 6.81 feet and the plane of mean low water is 3.98 feet on staff. Mean tide level is 5.39 feet on staff. Monthly high water reaches a maximum of 7.40 feet in May and a minimum of 6.02 feet in February. Monthly low water reaches a maximum of 4.59 feet in March and a minimum of 3.31 feet in November.

The mean of the highest tide in each month is 8.98 feet and the highest tide is 12.3 feet on staff. The mean of the monthly lowest observed tides is 2.42 feet and the lowest is 1.2 feet on staff. The monthly extreme range is 6.56 feet and the greatest range for the 12 months is 11.1 feet.

LIGHTHOUSE WHARF

An 18-month series of continuous observations was made at the Lighthouse Wharf from December, 1924, to May 1926. The monthly means for the time and height relations, together with the date and height of extreme tides, are given in Table 38. The intervals, as determined from the 18-month series, are, high-water interval, 7.77

hours; low-water interval, 2.22 hours. The duration of rise is 5.55 hours and the duration of fall is 6.87 hours. The high-water interval remains nearly constant throughout the year. The low-water interval increases to a maximum of 2.73 hours in February and decreases to 1.84 hours in September, a variation of about 0.9 hour.

TABLE 38.—*Tidal data, Lighthouse Wharf, Washington, D. C.*

Year and month	High-water interval	Low-water interval	Duration of rise	Mean high water on staff	Mean low water on staff	Mean range	Mean river level on staff	Mean tide level on staff	Highest tide		Lowest tide	
									Date	Height on staff	Date	Height on staff
1924	*Hours*	*Hours*	*Hours*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*		*Feet*		*Feet*
December	7.79	2.27	5.52	5.35	2.49	2.86	3.93	3.92	9, 13, 24	6.5	1	0.4
1925												
January	7.73	2.16	5.57	5.89	3.13	2.76	4.53	4.51	13	6.8	23	1.5
February	7.85	2.73	5.12	6.17	3.42	2.75	4.80	4.80	11	7.6	28	1.7
March	7.76	2.38	5.38	5.64	2.81	2.83	4.24	4.22	8	6.8	3, 15	1.4
April	7.71	2.12	5.59	6.19	3.20	2.99	4.70	4.70	22, 23	7.0	8, 9, 11	2.4
May	7.66	2.32	5.34	6.27	3.32	2.95	4.80	4.80	1	7.0	18	2.2
June	7.73	2.02	5.71	6.30	3.18	3.12	4.75	4.74	24	7.3	6	2.4
July	7.83	2.02	5.81	6.34	3.19	3.15	4.79	4.76	5	7.1	8, 9	2.5
August	7.77	1.93	5.84	6.41	3.20	3.21	4.84	4.80	29	7.3	1, 2, 3, 5	2.5
September	7.76	1.84	5.92	6.55	3.41	3.14	5.00	4.98	7, 20	7.3	1, 30	2.5
October	7.89	2.01	5.88	5.99	3.04	2.95	4.54	4.52	1	7.4	10	[1] 1.0
November	7.63	2.09	5.54	5.87	3.11	2.76	4.50	4.49	13	7.7	18	[1] 1.6
December	7.91	2.32	5.59	5.67	2.81	2.86	4.25	4.24	2	7.2	28	[1] 1.0
1926												
January	7.77	2.37	5.40	5.44	2.70	2.74	4.09	4.07	21	6.5	29	1.3
February	8.15	2.56	5.59	5.96	3.29	2.67	4.63	4.62	25	7.9	7	2.2
March	7.60	2.27	5.33	5.49	2.75	2.74	4.13	4.12	12, 15	6.5	5	1.1
April	7.61	2.36	5.25	5.87	3.00	2.87	4.45	4.43	13	6.9	20	1.6
May	7.69	2.25	5.44	6.11	3.07	3.04	4.61	4.59	10, 14, 29	6.8	4	1.8
Sum	139.84	40.02	99.82	107.51	55.12	52.39	81.58	81.31		127.6		31.1
Mean	7.77	2.22	5.55	5.97	3.06	2.91	4.53	4.52		7.09		1.73
Corrected for longitude of moon's node						2.86						

[1] Estimated values.

The range of tide as determined for the entire series is 2.91 feet. This value becomes 2.86 feet when corrected for the longitude of the moon's node. During the winter months the range apparently averages 0.4 foot less than in the summer.

Mean river level and mean tide level differ by 0.01 foot for this period of observation, mean river level being 4.53 feet on staff and mean tide level 4.52 feet on staff. Mean high water on staff is 5.97 feet; mean low water on staff is 3.06 feet. If curves are plotted as for the navy yard from the monthly values of mean river level, mean high water, and mean low water, these curves show a similar seasonal change for each of the three planes.

The average of the monthly highest tides for the period is 7.09 feet and the highest is 7.9 feet on staff. The average of the monthly lowest tides is 1.73 feet on staff and the lowest observed is 0.4 foot.

The monthly extreme range, as determined from 18 months of observations is, therefore, 5.36 feet and the greatest range is 7.5 feet.

TIDAL DATUM PLANES

The plane of mean sea level as adopted for use in the District of Columbia is 90.69 feet below bench mark No. 51, on the Senate wing of the Capitol, which is taken as the standard bench mark. The elevation of this bench mark was determined by precise levels run

between this mark and bench marks at Annapolis, Fredericksburg, and Richmond, and these values adjusted, taking into consideration the slope of the river. A detailed account of the adjustment of the Capitol bench mark is given on page 256, Coast and Geodetic Survey Report for 1896.

In 1923 this Capitol bench mark was connected by precise levels with many bench marks in the District of Columbia, including those in the vicinity of the navy yard and Seventh Street Wharf. Special Publication No. 119, Tidal Bench Marks, District of Columbia, gives the descriptions and elevations of 83 bench marks in the District of Columbia.

The relations between the mean sea-level datum and the values determined for the tide stations in Washington are given in Table 39. The value of mean sea-level datum on staff was determined by levels run to each station and the values given show the heights above or below this plane.

The values given for the four Washington stations, navy yard, Seventh Street Wharf, Easby Point, and Lighthouse Wharf, were obtained direct from observations. The values in the fifth column, accepted values for Washington, are given in previous publications. The accepted values for the mean high and low waters refer to the navy yard. The elevations of the various planes below the Capitol bench mark are given in the last column.

It is noted from the table that values determined at the navy yard and Seventh Street Wharf for the mean high water and mean river level check closely with the accepted values for Washington. The accepted value for mean low water is higher than those determined at the above stations.

TABLE 39.—*Tidal datum planes, Washington, D. C.*

	Observations at—				Accepted values	
	Navy yard, 7 years, 1892–98	Seventh Street Wharf, 2⅔ years, 1898–1901	Easby Point, 1 year 1901–2	Lighthouse Wharf, 1½ years, 1924–1926	Referred to mean sea-level datum	Elevation below Capitol bench mark
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
Mean sea-level, datum	0.00	0.00	0.00	0.00	0.00	90.69
Mean river level	0.26	0.26	0.60	0.16	0.29	90.40
Mean high water	1.70	1.67	1.95	1.58	1.74	88.95
Mean low water	−1.25	−1.22	−0.82	−1.28	−1.16	91.85
United States Engineers mean low water					−1.26	91.95

THE TIDE AT OLD POINT COMFORT, VA.

THE INTERVALS AND RANGE

Tide observations were begun at Old Point Comfort on July 1, 1844, and continued, with some interruptions, until 1878.

The values for the range and intervals based on 25 years of observations from 1853 to 1877 are as follows: High-water interval, 8.73 hours; low-water interval, 2.30 hours; and mean range, 2.55 feet.

Table 40 gives the intervals, mean range, and length and date of series for all observations at the station. It is noted that the intervals

for the period 1844–1852 are lower by about 0.4 hour than those from the later series and the range is about 0.15 foot greater. The observations since 1918 indicate that intervals are about the mean value and the range is about 0.1 foot less than the mean value for the 25-year series.

Table 41 gives the yearly values for the high and low water intervals for the 26-year period 1853–1878. The mean value for the high-water interval is 8.74 hours and for the low-water interval it is 14.72, or 2.30 hours. The yearly values of both high and low water intervals remain nearly constant, the high-water interval varying with a maximum of 0.5 hour and the low-water interval with a maximum of 0.4 hour. For the 26-year period the value for duration of rise is 6.44 hours and duration of fall is 5.98 hours.

TABLE 40.—*Tidal data, Old Point Comfort, Va.*

High-water interval	Low-water interval	Duration of rise	Mean range	Date	Length of series
Hours	*Hours*	*Hours*	*Feet*		
8.33	1.92	6.41	2.70	1844–1852	8 years.
8.73	2.30	6.43	2.55	1853–1877	25 years.
8.62	2.18	6.44	2.81	1888	80 days.
8.47	2.08	6.39	2.55	1891	1 month.
8.93	2.14	6.79	2.55	1905	4 days.
8.71	2.40	6.31	2.55	1909	3 days.
8.60	2.20	6.40	2.44	1918–1919	5½ months.
8.82	2.35	6.47	2.40	1928	20 days.

TABLE 41.—*Lunitidal intervals, Old Point Comfort, Va.: Annual means*

Year	High-water interval	Low-water interval	Year	High-water interval	Low-water interval	Year	High-water interval	Low-water interval
	Hours	*Hours*		*Hours*	*Hours*		*Hours*	*Hours*
1853	8.8	14.7	1863	8.8	14.8	1873	8.6	14.6
1854	8.7	14.6	1864	8.7	14.8	1874	8.5	14.5
1855	8.7	14.6	1865	8.8	14.8	1875	8.5	14.6
1856	8.7	14.8	1866	8.7	14.6	1876	8.6	14.7
1857	8.7	14.7	1867	8.8	14.8	1877	8.6	14.7
1858	8.8	14.7	1868	9.0	14.9	1878	8.9	14.8
1859	8.8	14.8	1869	8.9	14.9			
1860	8.9	14.8	1870	8.8	14.7	Sum (26 years)	227.2	382.7
1861	8.8	14.7	1871	8.7	14.7	Mean	8.74	14.72
1862	8.7	14.7	1872	8.7	14.7			

Duration of rise=6.44 hours; duration of fall=5.98 hours.

TABLE 42.—*Range of tide, Old Point Comfort, Va.: Annual means*

Year	Feet	Year	Feet	Year	Feet
1846	2.89	1856	2.43	1866	2.59
1847	2.75	1857	2.45	1867	2.52
1848	2.68	1858	2.49	1868	2.57
1849	2.67	1859	2.46	1869	2.57
1850	2.75	1860	2.49	1870	2.67
1851	2.56	1861	2.52	1871	2.63
1852	2.56	1862	2.53	1872	2.63
1853	2.55	1863	2.56	1873	2.60
1854	2.45	1864	2.56	1874	2.49
1855	2.47	1865	2.61	1875	2.52
Sum	26.33	Sum	25.10	Sum	25.79
Mean	2.63	Mean	2.51	Mean	2.58

Mean, 30 years, 2.57.

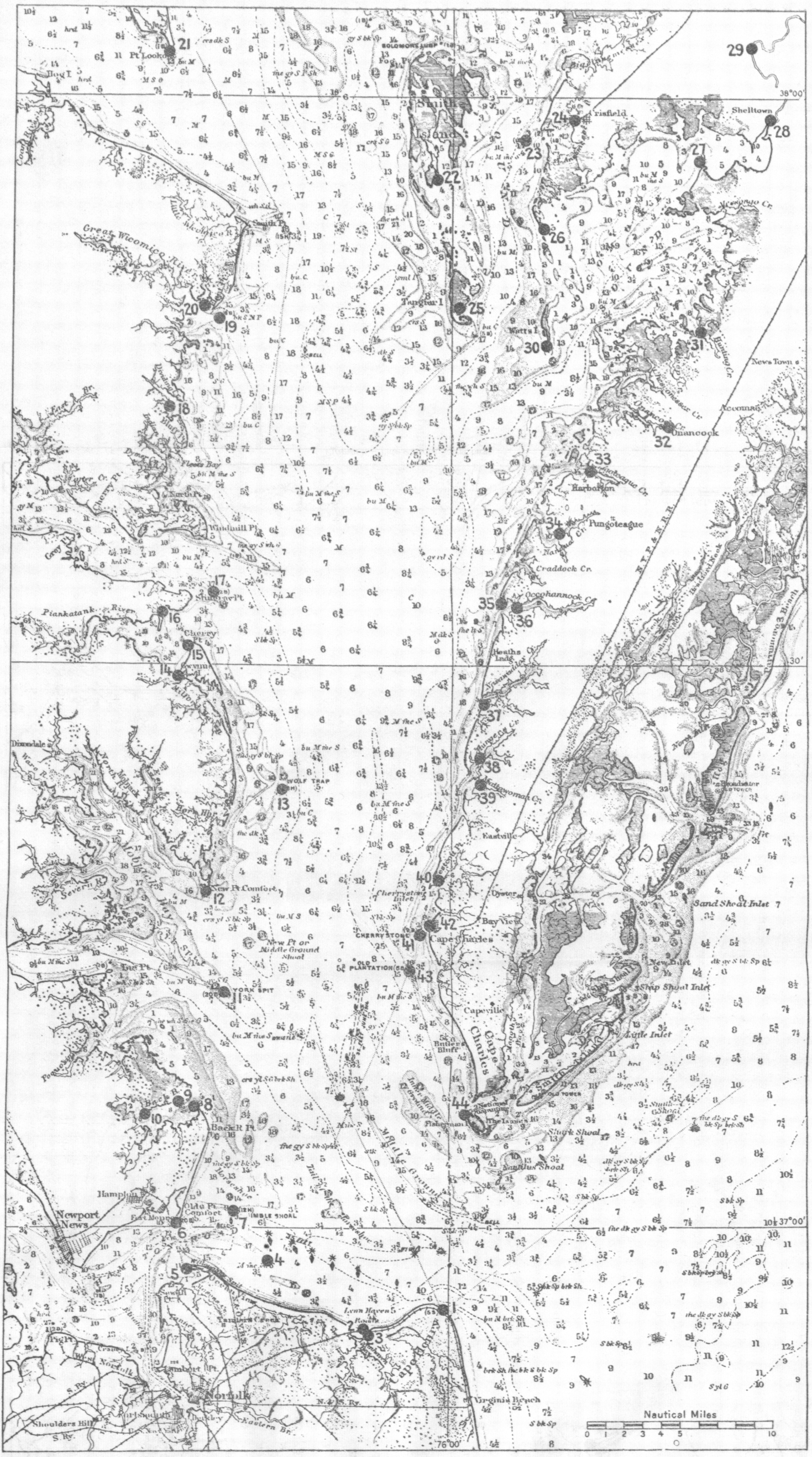


FIGURE 9.—Tide stations, lower bay

TABLE 43.—*Range of tide, Old Point Comfort, Va.: Annual means corrected for longitude of the moon's node*

Year	Feet	Year	Feet	Year	Feet
1846	2.82	1856	2.50	1866	2.51
1847	2.67	1857	2.52	1867	2.45
1848	2.60	1858	2.56	1868	2.51
1849	2.60	1859	2.52	1869	2.52
1850	2.69	1860	2.53	1870	2.64
1851	2.52	1861	2.54	1871	2.63
1852	2.54	1862	2.52	1872	2.65
1853	2.57	1863	2.52	1873	2.65
1854	2.49	1864	2.51	1874	2.55
1855	2.53	1865	2.54	1875	2.59
Sum	26.03	Sum	25.26	Sum	25.70
Mean	2.603	Mean	2.526	Mean	2.570

Mean for 30 years=2.57 feet; for first 19 years=2.57 feet; for last 19 years=2.55 feet.

Table 42 gives the annual range of tide for the 30-year period 1846–1875, divided into 10-year groups. Table 43 gives the same values corrected for the longitude of the moon's node. The uncorrected values have a maximum variation of 0.46 foot between any two years in the 30-year series. The maximum variation between the means of the 10-year groups is 0.12 foot. In the table of corrected values the maximum variation between any two years reduces to 0.37 foot and the maximum variation between 10-year groups is 0.07 foot. The mean value for the 30-year series is 2.57 feet, for the first 19 years it is 2.57 feet, and for the last 19 years 2.55 feet.

THE TIDES IN THE VARIOUS WATERWAYS

THE TIDE IN THE LOWER BAY

The lower bay, as previously defined, includes that part of the bay from the entrance, between Cape Charles and Cape Henry, to Point Lookout, at the mouth of the Potomac River.

Table 44 gives results derived for the 44 stations in the lower bay at which tide observations have been made. The locations of these stations are shown in Figure 9, the number of each station being the same in the figure as in the table. Hampton Roads and the large rivers on the western side of the bay will be discussed later. The values for each station have been reduced to approximate means by comparison with a standard station.

TABLE 44.—*Tidal data, Lower Chesapeake Bay*

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Western Shore	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
1	Cape Henry	7.82	1.30	6.52	2.83	1854	9
2	Lynnhaven Inlet	7.98	2.50	5.48	2.01	1905	18
	Do	8.33	2.64	5.69	2.13	1915	21
	Do	8.63	2.58	6.05	2.13	1916	29
	Do	8.04	2.28	5.76	2.11	1919	3
3	Lynnhaven Inlet	7.48	1.28	6.20	2.59	1891	24
	Do	7.44	1.47	5.97	3.08	1918	2
4	⊙ Beacon (off Ocean View)	8.43	2.25	6.18	2.58	1919	2
5	Willoughby Spit	8.50	2.40	6.10	2.65	1916	14
	Do	8.88	2.91	5.97	2.77	1918	1
6	Old Point Comfort	8.74	2.30	6.44	2.55	1853–1878 [1]	9,496
7	Thimble Shoal Light	8.15	1.89	6.26	2.43	1906–7	70
	Do	8.33	1.78	6.55	2.92	1909	3
	Do	7.91	1.77	6.14	2.48	1911	1
	Do	8.40	2.05	6.35	2.64	1918	31
8	Northend Point, Back River	7.98	2.01	5.97	2.55	1868	17
	Do	8.18	1.61	6.57	2.75	1906	1
	Do	7.83	1.38	6.45	2.31	1918	7
9	Bradshaw Wharf, Back River	8.28	2.28	6.00	2.55	1906	3
10	Amorys Wharf, Back River	7.91	1.48	6.43	2.80	1906	4
11	York Spit Light	8.28	2.74	5.54	2.09	1901	7
	Do	8.14	1.96	6.18	2.24	1906–7	6
	Do	8.57	2.38	6.19	2.45	1918	26
12	New Point Comfort	8.51	2.93	5.58	2.27	1906–7	1
13	Wolf trap Light	8.95	2.62	6.33	1.64	1918	33
	Do	9.29	3.08	6.21	1.01	1928	2
14	Cricket Hill, Piankatank River	9.82	4.54	5.28	1.38	1906	10
15	Cherry Point, Piankatank River	10.80	4.99	5.81	1.20	1851	19
16	Jackson Creek, Piankatank River	9.98	4.64	5.34	1.10	1868–69	150
17	Stingray Point Light	10.25	4.38	5.87	1.12	1898	28
	Do	10.63	4.65	5.98	1.11	1901	10
	Do	10.62	4.79	5.83	0.92	1911	27
	Do	10.60	4.53	6.07	1.17	1928	6
18	Dividing Creek	11.34	5.74	5.60	1.05	1869	24
19	Great Wicomico River Light	11.74	6.06	5.68	1.10	1898	20
	Do	11.59	6.31	5.28	1.15	1901	3
	Do	11.65	5.80	5.85	1.08	1909	11
20	Fleeton, Cockrell Creek	11.14	5.89	5.25	1.00	1909	3
21	Point Lookout	0.56	6.93	6.05	1.38	1849	140
	Do	0.83	7.00	6.25	1.22	1904–5	16
	Do	0.58	6.92	6.08	1.40	1908	7
	Do	0.75	6.91	6.26	1.21	1928	14
	Eastern Shore						
22	Tylers Creek, Smith Island	0.24	6.73	5.93	1.97	1902	4
23	Janes Island	12.40	6.48	5.92	2.06	1902	9
	Do	0.44	6.42	6.44	1.74	1906	2
	Do	0.33	6.47	6.28	2.30	1907	34
24	Crisfield, Md., Little Annemessex River	0.17	6.62	5.97	1.86	1868	27
	Do	0.04	6.58	5.88	1.93	1901–2	27
	Do	0.21	5.71	6.92	2.00	1928	7
25	Cod Harbor, Tangier Island	11.94	5.57	6.37	1.95	1906	5
	Do	11.63	6.24	5.39	1.31	1910	47
	Do	11.94	6.49	5.45	1.39	1911	60
26	Great Fox Island	12.36	6.37	5.99	1.82	1895	90
	Do	11.93	5.88	6.05	2.27	1906	5
27	Saxis, Pocomoke Sound	11.76	6.29	5.47	2.37	1907	30
28	Shelltown, Md., Pocomoke River	12.37	7.22	5.15	2.54	1869	32
29	Rehoboth, Md., Pocomoke River	0.47	7.69	5.20	2.17	1869	8
30	Watts Island Light	11.16	5.43	5.73	1.84	1868	71
	Do	11.37	5.70	5.67	1.69	1869	44
31	Hunting Creek	11.82	6.10	5.72	2.46	1869	34
32	Onacock	11.55	5.63	5.92	1.90	1914	52
33	Pungoteague Creek	10.80	5.05	5.75	1.85	1868	82
34	Nandua Creek	10.70	5.47	5.23	1.57	1914	156
35	Sandy Point	9.99	3.90	6.09	1.69	1853	8
36	Occohannock Creek	10.23	4.47	5.76	1.70	1868	3
37	Nasawaddox Creek	10.09	4.89	5.20	1.18	1914	6
	Do	8.75	3.22	5.53	1.46	1914	8
	Do	11.21	5.97	5.24	1.19	1868	26
38	Hungers Creek	8.97	3.12	5.85	1.85	1853	20
39	Mattawoman Creek	9.13	4.00	5.13	1.83	1868	15

[1] Lunitidal intervals from series 1853–1878; range from series 1857–1875.

TABLE 44.—*Tidal data, Lower Chesapeake Bay*—Continued

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Eastern Shore—Continued	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
40	Cherrystone Inlet	8.82	2.90	5.92	2.24	1874	18
41	Cherrystone Lighthouse (off Cape Charles City)	8.11	2.46	5.65	2.52	1868	30
	Do	8.11	2.16	5.95	1.76	1899	5
42	Cape Charles City	8.72	2.83	5.89	2.30	1913–14	240
	Do	8.23	2.55	5.68	2.10	1918	105
43	Old Plantation Flats Lighthouse	9.37	2.93	6.44	2.56	1901	8
	Do	8.42	2.53	5.89	2.46	1909–10	240
	Do	8.39	2.45	5.94	2.13	1914	8
	Do	9.02	2.31	6.71	2.30	1918	4
44	Fisherman Island	7.76	1.79	5.97	3.03	1852	12
	Do	7.75	1.92	5.83	3.02	1853	27
	Do	8.17	2.23	5.94	3.12	1869	39
	Do	7.94	2.34	5.60	2.60	1888	49
	Do	8.21	2.22	5.99	3.11	1906	3
	Do	7.94	1.94	6.00	2.99	1907	80
	Do	7.98	1.98	6.00	3.03	1911	26
	Do	7.72	1.66	6.06	2.91	1912	7
	Do	8.16	1.97	6.19	3.32	1913	28
	Do	7.96	1.98	5.98	3.06	1914	7
	Do	7.98	1.74	6.24	3.20	1918	52
	Do	7.87	1.77	6.10	3.21	1919	39
	Do	7.89	2.32	5.57	2.89	1921	35
	Do	7.75	1.72	6.03	3.11	1922	90
	Do	7.98	1.99	5.99	2.90	1925	90

An examination of the table reveals that considerable differences exist between the observational values for stations near together and even between different series of observations for the same station. These differences are generally due to meteorological conditions prevailing at the time the observations were taken, and they are therefore more pronounced when the values are based on short series of observations, for the weather effects average out when means are taken of a large number of observational values. For this reason, only the values derived from the longer series should be considered as precisely determined and the values from the very short series should be regarded as approximations to mean values.

From a consideration of the tabular data it is found that the time of tide becomes progressively later from the entrance toward the head of the bay. Both high and low water intervals show approximately uniform increase from the vicinity of the entrance to Point Lookout, the total increase for this distance of 70 miles being about five hours, or 0.07 hour per mile. In the same distance the range decreases from nearly 3 feet to about 1½ feet, an average decrease of about 0.02 foot per mile. The duration of rise shows no progressive change in this section of the bay. A discussion of the range and intervals in the entire bay is given on page 48.

THE TIDE IN THE MIDDLE BAY

The middle bay, for the purpose of this discussion, includes the bay and tributaries from Point Lookout to Thomas Point, a distance of 53 miles. The northern part of Tangier Sound connects with the bay through a series of straits between Smith Island and Bishop Head. Choptank River and Eastern Bay also enter the bay on the eastern shore and the Patuxent River on the western shore.

Table 45 gives the results, derived as in Table 44, for 50 stations for which tide observations have been made in this area. The locations of the stations are shown in Figure 10. In this part of the bay proper the values for the intervals and range show a continuation of the same progressive changes that were noted in the lower bay, the intervals showing a further increase of approximately three and one-half hours and the range a decrease of about one-half foot from Point Lookout to Thomas Point.

In the tributaries the time of tide generally becomes later and the range of tide greater from the mouth to the head of the waterway.

The tide in Tangier Sound has a greater range than at stations in the bay adjacent. It is noted also that the range on the eastern shore of Tangier Sound is greater than on the western shore and in turn this range is greater than that on the western shore of the bay. The mean range on the western shore of the bay is about 1.2 feet, on the western side of Tangier Sound it is about 1.6 feet, and on the eastern shore of the sound it is about 2.2 feet. The time of tide in Tangier Sound is about the same as at stations along the bay in the same latitude. The high-water intervals for stations Point No Point and Wenona are both about 0.9 hour. The high-water interval in the upper sound increases to about 1.2 hours at Sharkfin Shoal.

TABLE 45.—*Tidal data, Middle Chesapeake Bay*

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Western Shore	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
1	Point Lookout	0.56	6.93	6.05	1.38	1849	140
	Do	0.83	7.00	6.25	1.22	1904–5	16
	Do	0.58	6.92	6.08	1.40	1908	7
	Do	0.75	6.91	6.26	1.21	1928	14
2	Point No Point	0.84	7.49	5.77	1.11	1908–9	29
3	Drum Point	1.46	8.52	5.36	1.38	1847	20
	Do	1.52	8.50	5.44	1.38	1848	33
	Do	2.27	8.64	6.05	1.30	1848	19
	Do	1.29	7.82	5.89	1.20	1898	29
	Do	1.59	8.12	5.89	1.59	1908	33
	Do	1.77	8.49	5.70	1.43	1910	3
4	Solomons Island	1.52	7.87	6.07	1.08	1907	26
5	Williams Wharf	2.03	8.93	5.52	1.50	1908	6
6	Long Point	1.85	8.60	5.67	1.64	1857	3
7	Benedict	2.15	9.09	5.48	1.69	1908	10
8	Hunting Creek	2.81	9.83	5.40	1.95	1859	2
9	Nottingham	3.60	9.96	6.06	2.54	1859	1
10	Hills Bridge	5.02	12.10	5.34	2.92	1907	½
11	Fairhaven, Herring Bay	3.42	9.50	6.34	1.22	1846	32
	Do	3.76	9.72	6.46	1.31	1927	1
	Do	2.82	9.62	5.62	0.85	1903	2
12	Chester Creek	3.71	10.26	5.87	0.81	1903	3
13	Draw, South River Bridge	4.27	10.49	6.20	0.95	1903	2
14	Thomas Point Shoal Lighthouse	4.51	10.51	6.42	0.79	1927	3
	Eastern Shore						
15	Bloody Point Bar Lighthouse	3.80	10.42	5.80	1.06	1899	2
	Do	3.20	9.95	5.67	0.90	1903	3
	Do	4.01	11.17	5.26	1.08	1906	19
	Do	3.49	10.38	5.53	1.00	1909	26
16	Hilgard Point, Kent Island	3.58	10.66	5.34	1.47	1846	6
17	Greenwood Creek	3.52	10.69	5.25	1.10	1847	45
18	Claiborne	3.60	10.46	5.56	1.14	1899	54
	Do	3.87	10.57	5.72	1.75	1909	12
19	Deep Water Point	3.52	10.99	4.95	0.83	1899	5
20	St. Michaels	3.53	10.23	5.72	1.41	1870	24
	Do	3.66	10.34	5.74	1.07	1909	7

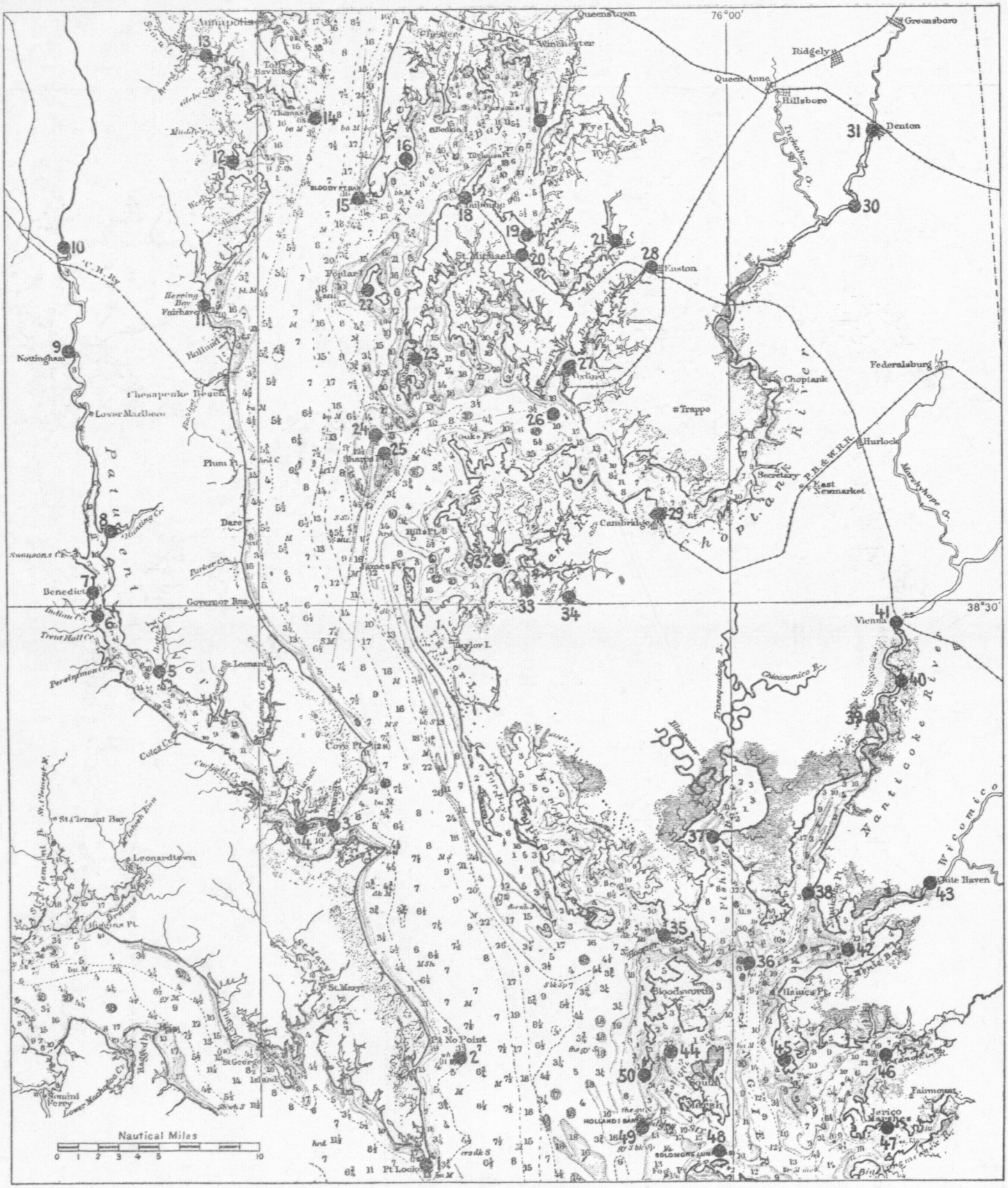


FIGURE 10.—Tide stations, middle bay

TABLE 45.—*Tidal data, Middle Chesapeake Bay*—Continued

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Eastern Shore—Continued	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
21	Miles River Bridge	4.36	11.55	5.23	1.18	1927	2
22	Poplar Island	3.69	10.71	5.40	1.00	1846	12
23	Tilghmans Island Wharf	2.95	9.47	5.90	1.45	1902	22
	Do	2.53	10.01	4.94	1.31	1909	12
24	Sharps Island Light	2.55	9.42	5.55	1.34	1898	40
	Do	2.91	9.51	5.82	1.17	1902	35
25	Sharps Island	3.37	10.23	5.56	1.33	1848	50
26	Choptank River Light	3.31	9.30	6.43	1.70	1902	50
	Do	3.11	9.25	6.28	1.62	1910	25
27	Oxford	3.01	9.33	6.10	1.56	1902	25
28	Easton	4.01	10.82	5.61	1.33	1927	2
29	Cambridge	3.85	10.86	5.41	1.63	1848	75
	Do	3.57	10.64	5.35	1.72	1871	22
	Do	3.28	9.83	5.87	1.87	1902	6
	Do	3.78	10.41	5.79	1.45	1927	3
30	Two Johns Landing	6.03	0.46	5.57	2.04	1870	21
	Do	6.81	0.40	6.41	1.39	1927	1
31	Denton	7.04	1.42	5.62	2.30	1870	2
	Do	7.41	0.90	6.51	1.82	1927	1
32	Casons Point	2.93	9.53	5.82	1.28	1903	7
33	Madison	3.03	9.67	5.78	1.31	1908	14
	Do	3.28	9.24	6.46	1.23	1910	2
34	Church Creek	3.01	9.85	5.58	1.53	1871	9
35	Hooper Strait Light	0.93	7.89	5.46	1.57	1901–2	19
	Do	0.81	7.73	5.50	1.41	1910	35
	Do	0.63	7.49	5.56	1.55	1912	22
36	Sharkfin Shoal Light	1.17	7.67	5.92	2.22	1902	30
	Do	1.88	7.51	6.79	2.26	1902	4
37	Elliott Island Wharf	1.50	7.78	6.14	2.47	1902	2
38	Roaring Point Wharf	0.84	7.79	5.47	2.26	1858	2
	Do	1.31	7.64	6.09	2.42	1902	2
39	Lewis Wharf	1.27	8.41	5.28	2.19	1858	3
	Do	3.20	10.26	5.36	1.95	1928	1
40	Point No Point	2.06	9.11	5.37	2.94	1858	2
41	Vienna	3.24	9.19	6.47	3.06	1858	2
42	Great Shoals Light	0.64	7.49	5.57	2.82	1902	2
	Do	1.08	8.12	5.38	2.25	1907	11
43	White Haven	1.37	8.30	5.49	2.42	1858	2
	Do	2.14	8.32	6.24	1.33	1928	1
44	Spring Island	0.95	8.61	4.76	2.59	1902	2
45	Wenona	0.89	7.52	5.79	2.17	1902	20
	Do	0.73	7.28	5.87	1.97	1902	10
46	Cox & Co's. Wharf, Manokin River	0.41	7.39	5.44	2.71	1902	3
	Do	0.50	7.50	5.42	2.43	1902	3
47	Big Annemessex River	0.47	7.26	5.63	2.13	1902	4
48	Solomons Lump Light	0.90	7.59	5.73	1.40	1901	6
	Do	0.34	6.96	5.80	1.87	1902	17
	Do	0.09	7.17	5.34	1.62	1907	11
	Do	12.32	6.90	5.42	1.68	1911	15
	Do	0.53	6.90	6.05	1.90	1912	35
49	Holland Island Bar Light	0.49	6.89	6.02	1.47	1898	27
	Do	0.43	7.63	5.22	1.49	1901	8
	Do	0.38	7.74	5.06	2.13	1902	2
	Do	0.25	5.11	7.56	1.45	1902	3
	Do	0.21	7.00	5.63	1.51	1905	9
50	Holland Island	1.43	7.87	5.98	1.74	1849	14

In Choptank River the high-water interval increases from about 2.7 hours at Sharps Island Light on the bay to about 7.2 hours at Denton and to about 4 hours at Easton. The range increases from about 1.2 feet at Sharps Island Light to about 2 feet at Denton. At Easton it is about 1.3 feet.

In Eastern Bay the high-water interval increases from about 3.5 hours at Bloody Point to about 4.4 hours at Miles River Bridge. The time of high water is about the same at Greenwood Creek as at Bloody Point. The range of tide increases from about 1 foot at Bloody Point to about 1.2 feet at Miles River Bridge.

In the Patuxent River the high-water interval increases from about 1.5 hours at Drum Point to about 2.1 hours at Benedict. The mean range apparently increases from about 1.4 feet at Drum Point to about 1.7 feet at Benedict and to about 2.9 feet at Hills Bridge.

THE TIDE IN THE UPPER BAY

Upper Chesapeake Bay, as considered here, includes the bay and tributary rivers from Thomas Point to the head of the bay, including the Chesapeake & Delaware Canal. Baltimore Harbor is discussed separately. Within this area are the cities of Baltimore and Annapolis, the towns of Havre de Grace, Elkton, Chesapeake City, and many smaller towns.

TABLE 46.—*Tidal data, Upper Chesapeake Bay*

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Western Shore						
		Hours	*Hours*	*Hours*	*Feet*		*Days*
1	Greenbury Point Light	4.80	11.22	6.00	0.86	1898	7
	Do	4.75	10.55	6.62	0.83	1903	4
	Do	4.67	10.93	6.16	0.68	1910	1
2	Annapolis	4.84	11.24	6.02	0.83	1844	120
	Do	4.80	11.18	6.04	0.88	1928	120
3	Railroad bridge, Severn River	4.83	11.07	6.18	0.79	1903	7
4	Eaglenest Point	4.81	11.33	5.90	0.84	1903	4
	Do	5.04	11.52	5.94	0.86	1927	2
5	Sandy Point	6.18	0.07	6.11	0.74	1897	2
6	Magothy River, near Ross Cove	5.47	0.02	5.45	0.99	1898	6
7	Magothy River, Deep Creek	5.78	0.02	5.76	1.02	1898	15
8	Bodkin Point	5.99	0.75	5.24	1.01	1845	180
	Do	6.04	0.63	5.41	0.89	1845	4
	Do	6.22	0.72	5.50	0.83	1845–46	60
	Do	6.25	0.69	5.56	0.97	1854	29
9	Seven Foot Knoll Light	6.70	0.68	6.02	1.02	1867	27
	Do	6.70	0.82	5.88	1.03	1897	2
	Do	6.32	0.31	6.01	1.00	1898	24
	Do	5.94	12.00	6.36	1.20	1906	4
10	Turkey Point, Middle River	6.97	1.44	5.53	0.81	1846	16
	Do	7.27	1.71	5.56	1.21	1897	7
11	Battery Point	7.23	1.49	5.74	1.15	1846	13
12	Gunpowder River, railroad bridge	7.37	1.89	5.48	1.52	1870	13
	Do	8.33	2.82	5.51	1.03	1927	2
13	Pooles Island Light	7.55	1.99	5.56	1.11	1846	60
	Do	7.52	1.60	5.92	1.24	1898	8
	Do	7.90	1.90	6.00	1.15	1901	7
	Do	7.75	1.41	6.34	1.06	1927	8
14	Sandy Point	7.93	2.50	5.43	1.43	1846	15
15	Towners Landing, Redmon Cove	7.72	1.98	5.74	1.36	1899	26
16	Bush River, railroad bridge	8.53	2.67	5.86	1.39	1927	2
17	Romney Creek	8.91	2.91	6.00	1.16	1899	5
18	Aberdeen Proving Ground	9.12	2.75	6.37	1.75	1919–1921	84
19	Locust Point	9.30	3.84	5.46	1.92	1846	7
20	Havre De Grace	9.36	4.30	5.06	2.12	1846	7
	Do	9.55	4.04	5.51	1.63	1866	23
	Do	9.39	4.09	5.30	2.09	1899	22
	Do	9.80	4.64	5.16	1.89	1927	11
21	Port Deposit, Susquehanna River	10.52	5.50	5.02	2.06	1927	3
22	Carpenters Point	9.12	3.56	5.56	2.01	1846	7
23	Turkey Point, Elk River	9.07	3.01	6.06	2.19	1846	3
24	Frenchtown	8.87	2.93	5.94	2.43	1899	14
	Chesapeake & Delaware Canal						
25	Chesapeake City	9.57	3.21	6.36	2.74	1898	6
	Do	8.92	2.59	6.33	3.15	1899	2
	Do	9.51	3.51	6.00	2.36	1923–24	300
	Do	9.69	3.46	6.23	2.35	1928	120
26	Summit Bridge	11.43	4.59	6.84	3.36	1928	129
27	Railroad bridge (Pennsylvania)	11.23	5.14	6.09	3.85	1928	2
28	Biddle Point	11.54	6.02	5.52	5.12	1928	43
29	Reedy Point Bridge	11.27	5.93	5.34	5.34	1928	1
30	Jetty	11.14	5.52	5.62	5.48	1928	77

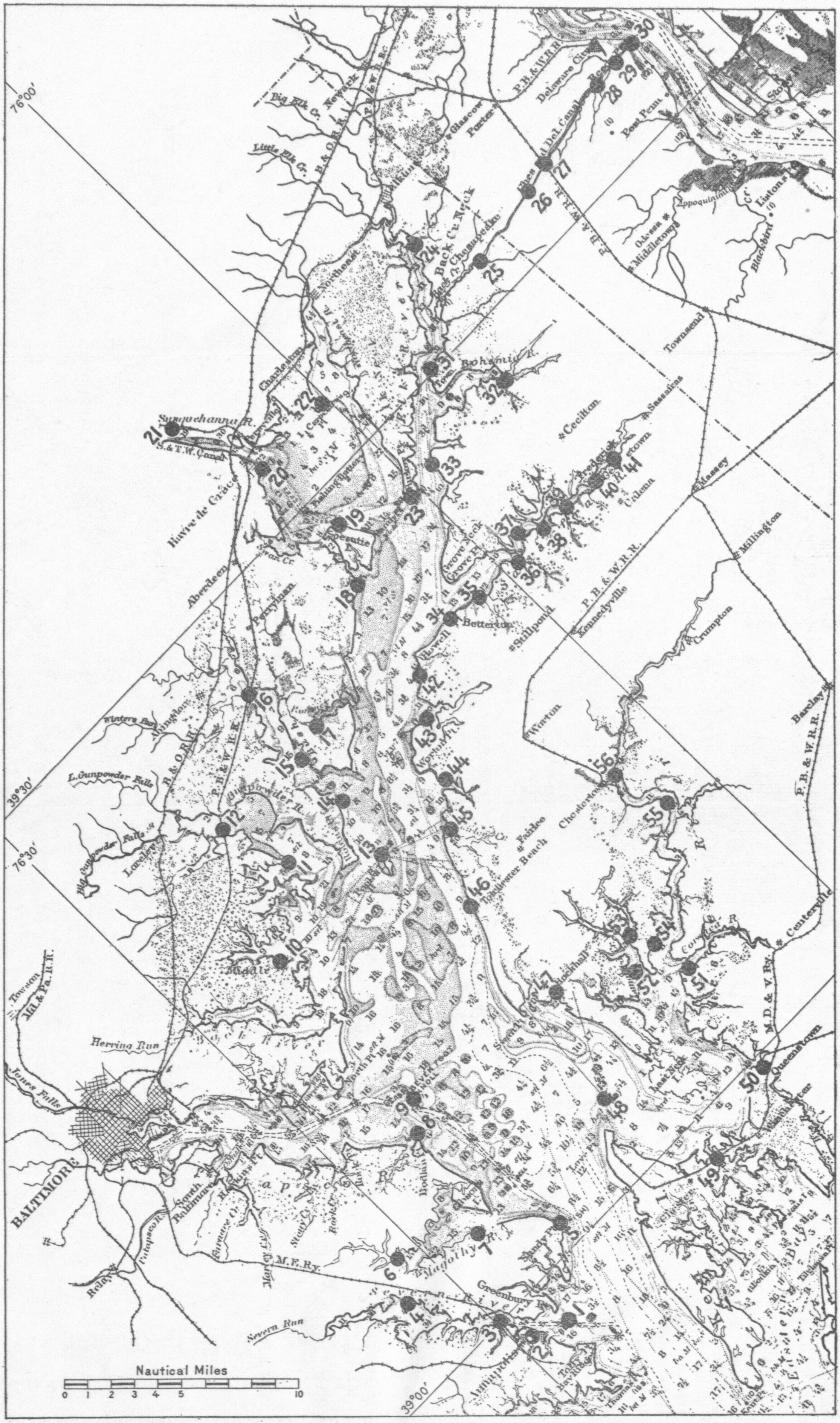


FIGURE 11.—Tide stations, upper bay

TABLE 46.—*Tidal data, Upper Chesapeake Bay*—Continued

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Eastern Shore	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
31	Town Point Wharf	8.62	2.87	5.75	2.43	1898	7
	Do	8.96	2.43	6.53	2.67	1899	3
	Do	9.24	3.14	6.10	2.28	1901	6
	Do	8.84	3.35	5.49	2.70	1902	3
	Do	9.18	3.27	5.91	2.02	1927	7
32	Bohemia River drawbridge	8.94	2.51	6.43	2.18	1899	3
33	Reybolds Wharf	8.29	2.56	5.73	2.14	1898	30
	Do	8.76	2.11	6.65	1.49	1898	4
	Do	8.81	2.71	6.10	2.45	1899	9
	Do	8.56	2.78	5.78	1.77	1901	6
	Do	9.40	2.29	7.11	1.82	1902	2
	Do	8.92	2.75	6.17	1.90	1927	7
34	Betterton, Md	8.67	2.46	6.21	1.89	1898	16
	Do	8.61	2.66	5.95	1.69	1901	8
	Do	8.83	2.75	6.08	1.54	1927	3
35	Lloyds Creek	9.05	3.52	5.53	2.24	1898	1
36	Turners Creek	8.53	3.20	5.33	2.14	1899	3
37	Cassidys Wharf	9.00	3.33	5.67	1.94	1847	6
	Do	9.04	2.91	6.13	2.01	1898	6
	Do	9.13	3.11	6.02	1.76	1927	5
38	Shellcross Wharf	9.09	3.00	6.09	2.49	1898	3
	Do	8.63	2.96	5.67	2.22	1899	3
39	Raisin Wharf	8.79	2.91	5.88	1.90	1899	6
40	Georgetown Bridge	9.31	3.08	6.23	2.53	1898	2
	Do	9.04	2.96	6.08	1.90	1899	4
41	Wilson Point Wharf	8.45	2.82	5.63	1.86	1870	5
	Do	8.87	3.09	5.78	2.46	1899	2
	Do	9.97	4.03	5.94	1.56	1927	5
42	Harris Wharf	7.93	2.05	5.88	1.76	1898	4
43	Rocky Point, Still Pond	8.67	3.70	4.97	1.14	1846	2
44	Gales Wharf	7.49	1.52	5.97	1.37	1898	10
45	Fairlee Creek	7.64	0.64	7.00	1.45	1898	3
46	Tolchester Beach Wharf	7.13	1.22	5.91	1.22	1897	8
	Do	7.03	0.80	6.23	1.23	1909	5
	Do	7.27	1.09	6.18	1.13	1927	8
47	Rock Hall	5.93	0.24	5.69	1.01	1847	27
48	Love Point Light	5.89	12.40	5.91	1.09	1898	45
	Do	6.31	0.67	5.64	1.10	1897	15
	Do	5.89	12.23	6.08	0.96	1909	15
49	Kent Island Narrows	5.15	11.65	5.92	1.18	1927	5
50	Queenstown	6.29	0.73	5.56	1.23	1870	27
	Do	6.16	0.17	5.99	1.34	1898	70
	Do	6.57	0.45	6.12	1.13	1927	6
51	Town Bar Point	6.29	0.24	6.05	1.65	1898	37
52	Deep Creek	5.72	0.07	5.65	1.16	1846	8
53	Kings Creek	6.40	0.54	5.86	1.52	1870	6
54	Cliffs Wharf	6.49	0.23	6.26	1.48	1909	10
55	Harrisons Wharf, Frying Pan Point	6.53	0.15	6.38	0.82	1846	15
56	Chestertown	6.97	0.89	6.08	1.89	1869	30
	Do	7.52	1.45	6.07	1.75	1927	4

In Table 46 are given data for 56 stations at which tide observations have been made in this area. The locations of the stations are shown in Figure 11. Figure 12 shows graphically the variation in range and high-water interval plotted from values derived for the stations nearest the main channel from Annapolis through the canal. As in the two sections of the bay already discussed, the intervals continue to increase toward the head of the bay. The range, however, reaches a minimum value near the mouth of the Severn River and increases from this vicinity northward.

It is noted from the table and from Figure 12 that the high-water interval increases from about 4.8 hours at Annapolis to about 7.1 hours at Tolchester Beach and to about 9.6 hours at Chesapeake City. The high-water interval continues to increase to a maximum

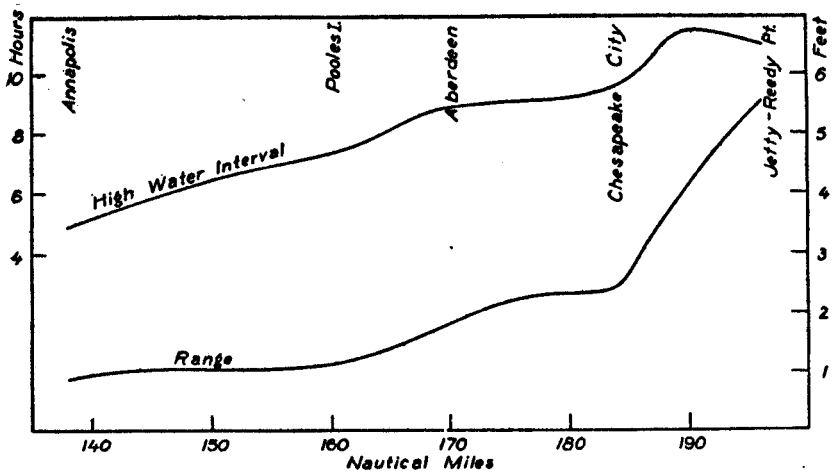


FIGURE 12.—Variations in interval and range, Annapolis to Reedy Point

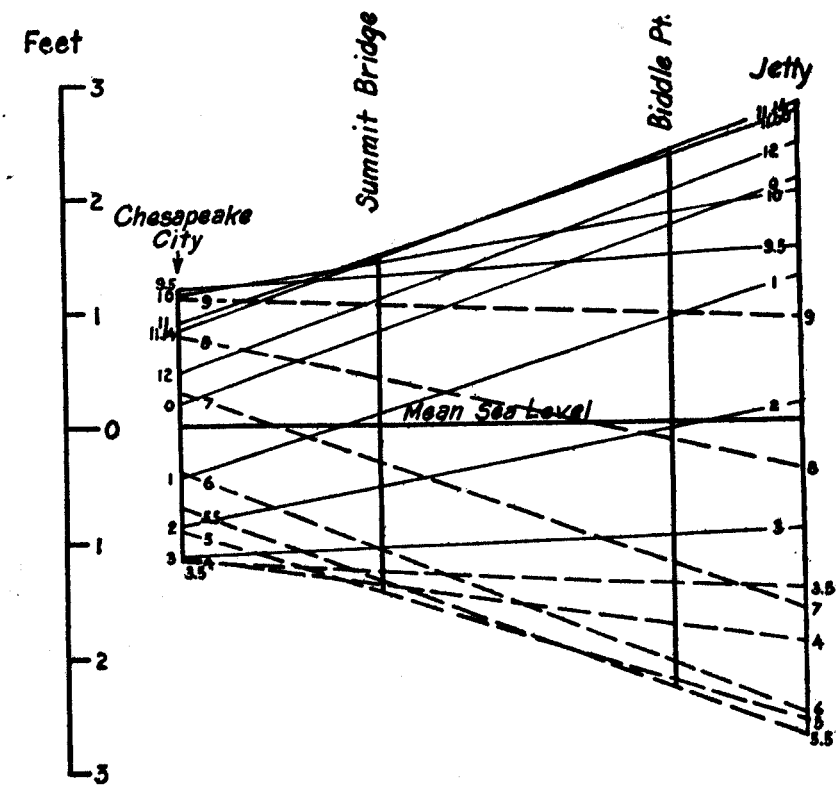


FIGURE 13.—Slope lines, Chesapeake and Delaware Canal

of about 11.5 hours near the center of the canal and then decreases slightly to about 11.1 hours at Reedy Point Jetty.

From Annapolis to Pooles Island the range increases about 0.3 foot in a distance of 24 miles. From Pooles Island to Turkey Point, Elk River, it increases about 1 foot in 16 miles, from Turkey Point to Chesapeake City it increases about 0.2 foot in 10 miles. From Chesapeake City to the Delaware River, a distance of about 12 nautical miles, the range increases from about 2.4 feet to about 5.5 feet.

In the Chester River the observed high-water interval increases from about 5.9 hours at Love Point Light to about 7 hours at Chestertown. Likewise the low-water interval increases from about 0.0 hours at Love Point Light to about 1 hour at Chestertown. The range also increases from about 1 foot in the bay to about 1.9 feet at Chestertown.

The tide in Sassafras River varies little from that in the bay near the mouth, the intervals and range increasing slightly from the mouth to Georgetown.

At Aberdeen, station 18, the high-water interval is about 9.1 hours; this increases to about 9.5 hours at Havre de Grace. The low-water interval increases from about 2.8 hours at Aberdeen to about 4.1 hours at Havre de Grace.

The tide in the Chesapeake & Delaware Canal is obviously due to the tides in Chesapeake Bay and Delaware River. As noted previously, the range of tide at Chesapeake City is about 2.4 feet and the range at the jetty in the Delaware River is about 5.5 feet, and the high-water intervals are 9.6 and 11.1 hours, respectively. These differences in the range and time of the tides at the two ends cause a hydraulic gradient through the canal, giving rise to variations in the height of the water surface in the canal.

In Figure 13 are shown slope lines constructed for the canal between Chesapeake City and Reedy Point Jetty. The simultaneous heights of the level of the water at the two ends were plotted. The lines joining the simultaneous heights represent the slope of the water surface in the canal. The slope lines represent the time and range of the tide in the canal, since the time and height of high water at any place will be represented by the highest point in the slope line passing that place, and the time and height of low water will be indicated by the lowest point on the slope line. On the vertical line to the left the hourly heights of the tide at Chesapeake City are plotted and on the vertical line to the right the hourly heights of the tide at the jetty are plotted. The figures along the vertical lines denote hours to which the indicated heights apply, the numerals being placed to the right of the vertical line when the slope is from Chesapeake Bay to Delaware River. The slope lines are drawn full when the slope is from Delaware River to Chesapeake Bay and dashed when the slope is in the opposite direction.

If the tidal movement in the canal is due to the difference in the elevation of the water at the two ends, the slope lines in the figure should indicate the approximate high water and low water lunitidal intervals, and range, through the canal. Consider the station at Summit Bridge: The highest slope line passing through this point is the 11-hour line, hence the high-water interval should be approximately 11 hours. From Table 46 the observed value is 11.4 hours. The lowest slope line going through this point is the

5-hour line, and hence the low-water interval should be approximately 5 hours. It is found to be 4.6 hours from the table. The range or distance between the extreme slope lines on the scale is about 2.8 feet. This is found to be 3.4 feet in the table. Similarly, the values for Biddle Point from the diagram are approximately: High-water interval, 11.1 hours; low-water interval, 5.5 hours; range, 4.6 feet. From the table these values are: High-water interval, 11.5 hours; low-water interval, 6 hours; range, 5.1 feet. From a consideration of the above relations it appears that the tidal movement in the canal, while largely hydraulic in character, is somewhat modified by other conditions.

VARIATIONS IN RANGE AND TIME OF TIDE

Figure 14 shows the ranges of tide for the two sides of Chesapeake Bay. The ranges of the tide in feet are plotted as ordinates and the

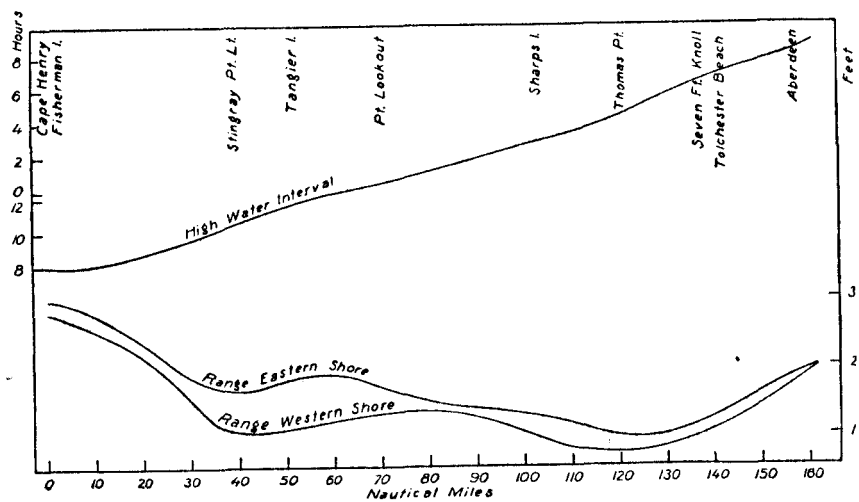


FIGURE 14.—Variations in interval and range, Chesapeake Bay

distances from a point 14 miles outside the entrance are plotted as abscissæ. The upper curve shows the range on the eastern side of the bay and the lower shows the range on the western side of the bay. It is noted from the curves that the range of tide on the eastern shore is greater than the range on the western shore throughout the length of the bay. The difference between the ranges on the two sides varies, the maximum being about three-fourths foot. The difference in range between Cape Charles and Cape Henry is about one-fourth foot and the ranges decrease for a distance of about 50 miles, with an approximately constant difference between the two sides of the bay. At Stingray Point Light the difference is about 0.60 foot. In this locality the range of the tide on each side of the bay begins to increase slightly and the difference in range between the two sides shows a marked increase. This increase in the range and large difference between the ranges continues to the vicinity of Point Lookout. At this point the range decreases again and the difference in range on the sides of the bay decreases to 0.10 foot in the vicinity of Cove Point, where the bay is narrow. The range decreases to the vicinity of

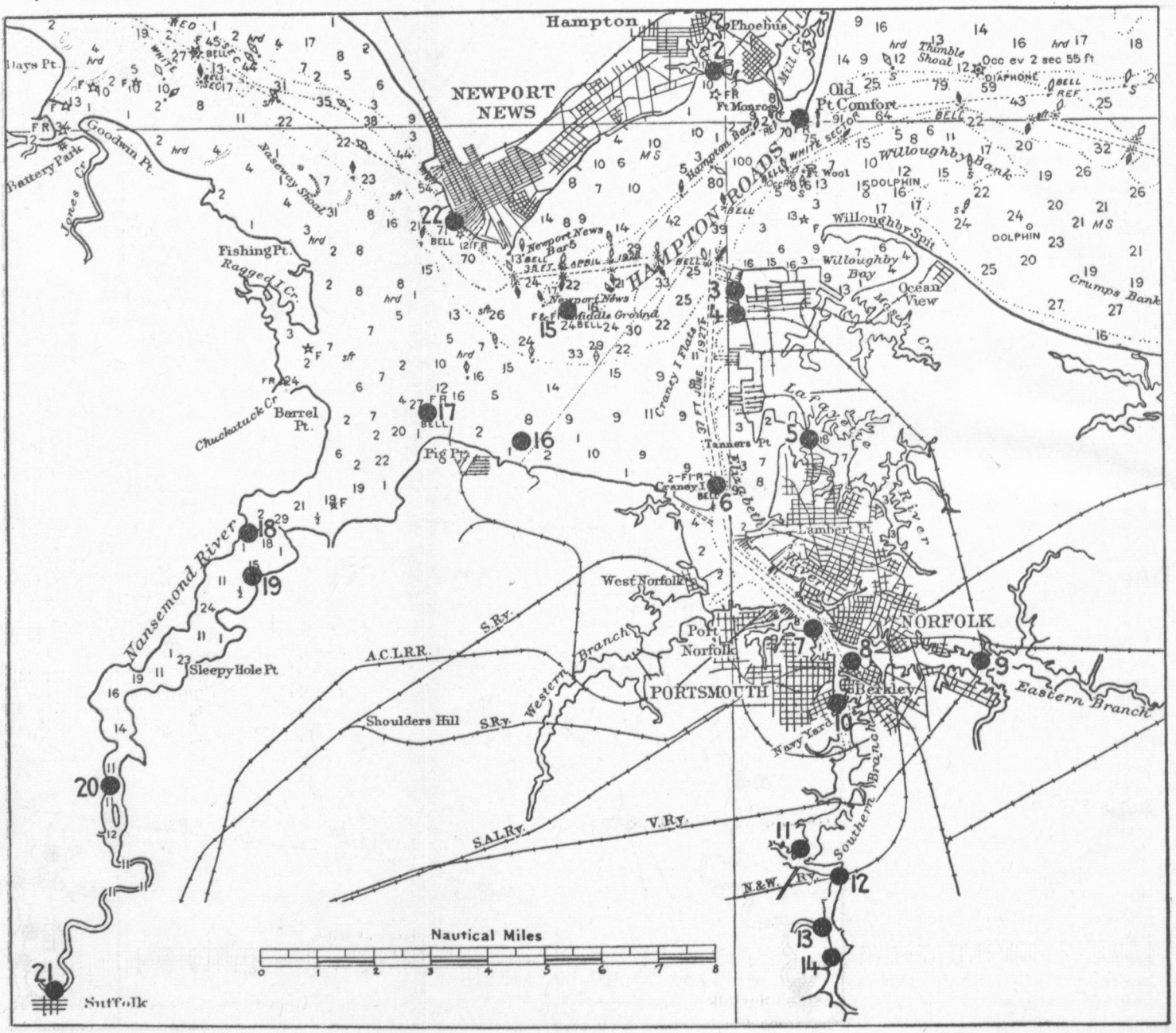


FIGURE 15.—Tide stations, Hampton Roads

Annapolis, and from here to the head of the bay the range increases and the difference in range decreases.

It appears that the difference in range between the two sides of the bay varies with the width of the bay. From Stingray Point to Point Lookout the width of the bay increases and large rivers enter the bay from both sides. In this area it is noted that the difference in range reaches its maximum value. Between Point Lookout and Annapolis the bay is relatively narrow and the difference in range between the two sides is correspondingly small, a slight increase in this difference occurring where the bay broadens out at the entrances of the Choptank River and Eastern Bay. From the vicinity of Thomas Point to the head of the bay the range of tide increases.

The difference in the ranges on the eastern and western shores of the bay finds explanation in the deflecting force of the earth's rotation, which tends to deflect all moving bodies to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. It would be expected in Chesapeake Bay that on the flood the water would be deflected toward, and on the ebb away from, the eastern shore. The high water would therefore rise higher and the low water fall lower on this shore, thus producing a range greater than that on the western shore.

Figures 12 and 14 show the variation in high-water lunitidal interval for Chesapeake Bay from the entrance to Chesapeake City and through the Chesapeake & Delaware Canal to Reedy Point, on the Delaware River. It is noted from the curves that the high-water interval increases from the entrance to the bay to Chesapeake City. From Chesapeake City to Summit Bridge the interval increases rapidly. The interval remains nearly constant from Summit Bridge to Biddle Point and from Biddle Point to the jetty in Delaware River the interval decreases.

The high-water interval at Cape Henry, is 7.8 hours; this increases to about 13 hours, or 0.6 hour, at Point Lookout; and to about 9.6 hours at Chesapeake City. This is an increase of 14.2 hours in a distance of 171 miles, or an average increase of about 0.083 hour per mile between the capes and the head of the bay.

THE TIDE IN HAMPTON ROADS

Hampton Roads as considered here, includes Hampton Roads proper and the Elizabeth and Nansemond Rivers.

Observations have been made at 22 stations in this area, the longest series covering a 30-year period at Old Point Comfort. The results of the observations are given in Table 47 and the stations are plotted on Figure 15.

As in other tributaries of the bay, both the range and intervals increase from the entrance toward the head of the waterway, the tide becoming later from Old Point Comfort westward and into the Elizabeth and Nansemond Rivers. The high-water interval increases gradually from 8.74 hours at Old Point Comfort to about 9 hours at Craney Island, to about 9.2 hours at Portsmouth Navy Yard, and to about 9.4 hours at the Norfolk & Western Railroad bridge. The range decreases from about 2.55 feet at Old Point Comfort to 2.47 at Sewalls Point (Hampton Roads naval base), and then increases to about 2.8 feet at Craney Island Light and Portsmouth

Navy Yard. In the Southern Branch it increases to about 3.1 feet at the Norfolk & Western railroad bridge.

From the above it is noted that the tide between Craney Island Light and Berkley has a nearly constant interval and range.

Considering Hampton Roads and Nansemond River, the time of tide becomes later from Old Point Comfort toward Suffolk. In a distance of about 25 miles the range increases about 1.4 feet and the time of tide becomes later by about 2 hours.

TABLE 47.—*Tidal data, Hampton Roads*

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
		Hours	*Hours*	*Hours*	*Feet*		*Days*
1	Old Point Comfort	8.74	2.30	6.44	2.55	1853–1878	[1] 9,496
2	Soldiers' Home	8.90	2.52	6.38	2.59	1918–19	16
3	Sewall Point	8.72	2.52	6.20	2.33	1873	62
	Do	8.87	2.37	6.50	2.74	1917	17
	Do	9.23	2.89	6.34	2.59	1918–19	23
	Do	8.83	2.44	6.39	2.39	1919	4
4	Hampton Roads Naval Base	8.79	2.69	6.10	2.47	1927–28	420
5	La Fayette River Drawbridge	9.09	3.18	5.91	2.77	1919	5
6	Craney Island Light	9.02	3.19	5.83	2.79	1919	17
7	Portsmouth, Hospital Point	9.08	2.62	6.46	2.78	1872–73	215
8	Berkley	8.98	2.88	6.10	2.70	1913	82
9	Baxters Landing	9.32	3.71	5.61	3.14	1876	1
10	Navy yard, Portsmouth	9.07	2.92	6.15	2.85	1896	30
	Do	9.17			2.74	1891–1894	457
	Do				2.77	1908–1915	2,922
11	Naval Magazine	8.56	2.39	6.17	2.86	1912	2
12	Norfolk & Western Railroad Bridge	9.38	3.23	6.15	3.08	1873	18
13	Deep Creek	8.77	2.46	6.31	3.09	1912	3
	Do	8.84	2.43	6.41	3.15	1912	2
	Do	9.48	3.11	6.37	2.84	1913	2
14	Millville	9.73	3.71	6.02	3.26	1876	1
15	Middle Ground Light	8.91	3.11	5.80	4.05	1918	3
	Do	9.05	2.84	6.21	2.73	1918–19	58
16	Watch House, Craney Island Flats	9.11	2.92	6.19	2.64	1918–19	19
	Do	9.07	2.98	6.09	2.64	1919	4
17	Nansemond River Light	9.59	3.84	5.75	2.74	1919	13
18	Wilsons Wharf	9.53	3.65	5.88	2.92	1874	14
19	Newman Point	9.61	3.29	6.32	3.03	1887	10
	Do	8.96	2.64	6.32	2.75	1909	4
20	Nansemond River, near Dumpling Island	9.43	3.22	6.21	3.24	1928	1
21	Suffolk, Va	10.73	4.28	6.45	3.93	1887	10
22	Newport News	9.12	3.11	6.01	2.75	1854	15
	Do	9.15	3.07	6.08	2.62	1871–72	65
	Do	8.60	2.38	6.22	2.70	1874	85
	Do	9.04	3.00	6.04	2.83	1909–10	25
	Do	9.56	3.36	6.20	2.82	1919	20
	Do	9.31	2.91	6.40	2.45	1928	6

[1] Lunitidal intervals from series 1853–1878; range from series 1857–1875.

THE TIDE IN THE JAMES RIVER

Observations have been made at 42 stations in the James River. The locations of the stations are shown in Figure 16, and Table 48 gives the observational data for each station. Newport News and Old Point Comfort are included for the purpose of comparison. Figure 17 shows graphically the variations in the high-water interval and the range for the tide stations in this area.

An examination of the table shows that the high-water interval and low-water interval increase with approximate uniformity from Old Point Comfort to Richmond, an increase of about 8 hours for the high-water interval and about 9.4 hours for the low-water interval occurring in a distance of about 90 miles.

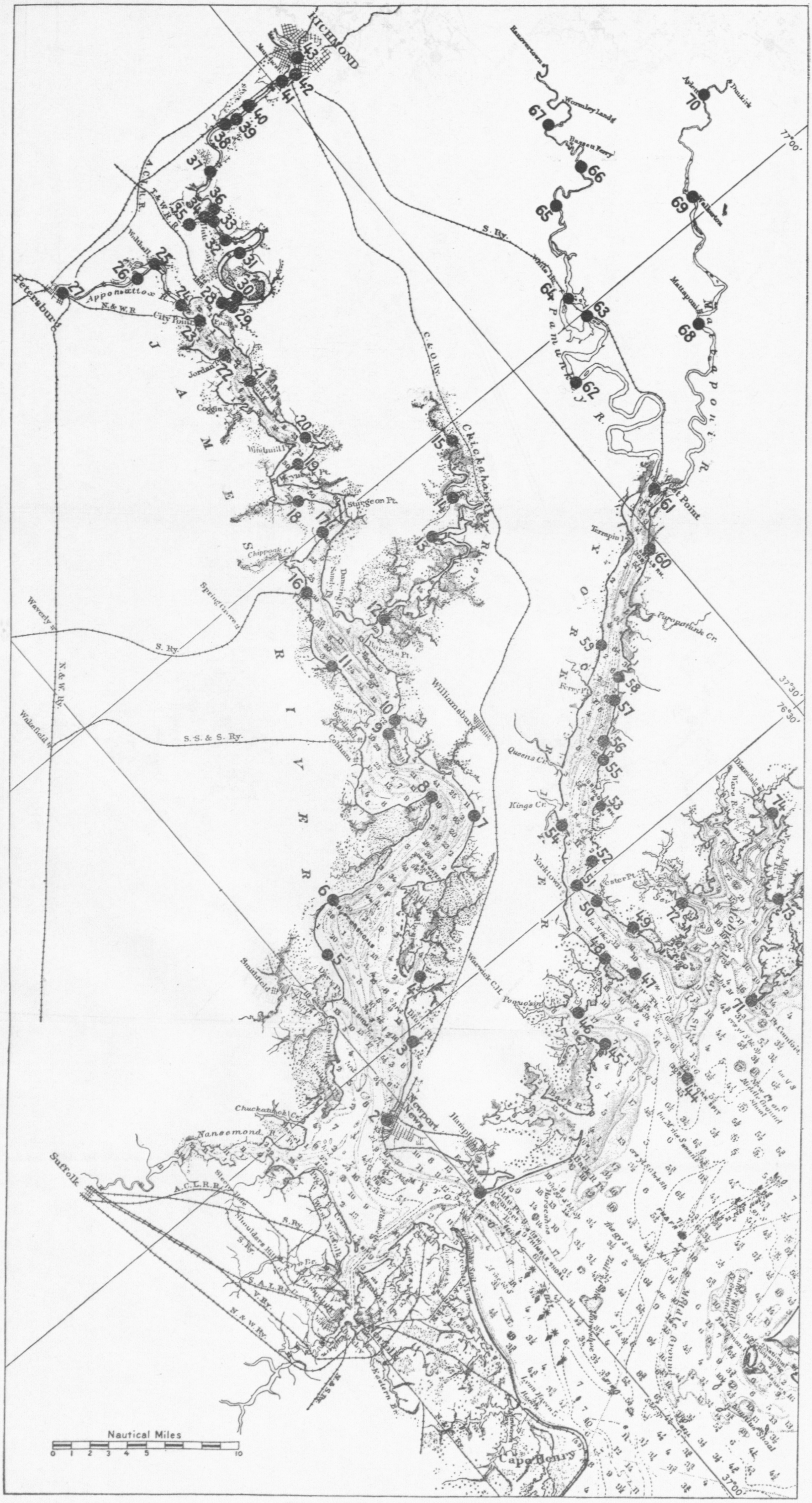


FIGURE 16.—Tide stations, James and York Rivers

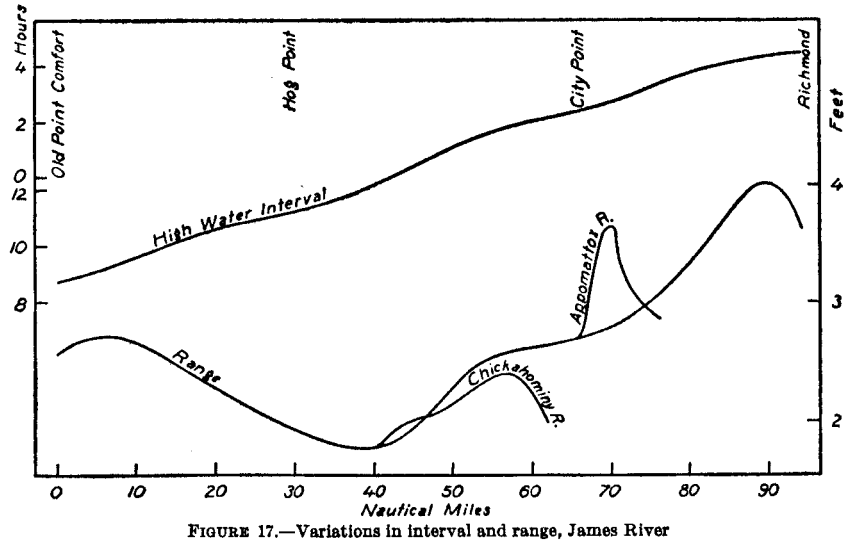


FIGURE 17.—Variations in interval and range, James River

The range increases from 2.55 feet at Old Point Comfort to about 2.7 feet at Newport News, decreasing slowly to about 1.8 feet in the vicinity of Jamestown and gradually increasing to about 3.7 feet at Richmond. The duration of rise decreases gradually from 6.44 hours at Old Point Comfort to about 5 hours at Richmond.

TABLE 48.—*Tidal data, James and York Rivers*

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	James River	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
1	Old Point Comfort	8.74	2.30	6.44	2.55	1853–1878	[1] 9,496
2	Newport News	9.12	3.11	6.01	2.75	1854	15
	Do	9.15	3.07	6.08	2.62	1871–72	65
	Do	8.60	2.38	6.22	2,70	1874	85
	Do	9.04	3.00	6.04	2.83	1909–10	25
	Do	9.56	3.36	6.20	2.82	1919	20
	Do	9.41	3.04	6.37	2.50	1928	12
3	Carrieville	9.51	3.32	6.19	2.73	1854	66
4	Youngs bathhouse	9.65	3.24	6.41	2.55	1872	30
5	Rocks Wharf	9.47	3.23	6.24	2.56	1854	2
6	Fergusons Wharf	10.38	4.14	6.24	2.28	1910	6
7	Grove Wharf	10.91	4.80	6.11	2.30	1855	44
8	Hog Point, Hog Island	11.06	5.14	5.92	1.99	1873	44
9	Jamestown Island	11.82	6.18	5.64	1.84	1874	30
	Do	12.00	5.73	6.27	1.98	1910	4
10	Coke Wharf	11.69	5.78	5.91	2.12	1856	12
11	Dillard Wharf	12.24	7.10	5.14	1.71	1874	10
12	Gordon Creek, Chickahominy River	0.40	7.39	5.43	1.94	1874	90
13	Mount Airy, Chickahominy River	1.43	8.30	5.55	2.14	1875	77
14	Graves Landing, Chickahominy River	2.23	9.05	5.60	2.38	1875	39
15	Windsor Shades, Chickahominy River	2.28	9.72	4.98	1.98	1875	2
16	Claremont Wharf	0.33	7.07	5.69	1.97	1910–11	252
	Do	0.38	7.08	5.72	2.08	1857	30
17	Brandon Point	1.16	8.05	5.53	2.09	1875	3
18	Stanley Wharf, Dunmore	1.71	8.49	5.64	2.48	1875	5
19	Weynoak Wharf	1.74	8.39	5.77	2.65	1857	12
20	Wilcox Wharf	1.61	8.14	5.89	2.65	1859	2
	Do	0.76.	7.93	5.25	2.45	1875	2
	Do	1.60	8.26	5.76	2.47	1910	13
21	Harrisons Landing	1.95	8.82	5.55	2.66	1852	11
22	Jordan Point	2.10	8.90	5.62	2.63	1875	26
23	City Point	2.55	9.41	5.56	2.67	1910–11	90
	Do	2.49	9.18	5.73	2.69	1928	1
	Do	2.35	9.15	5.62	2.75	1852	30
	Do	2.12	9.11	5.43	3.06	1852	30

[1] Lunitidal intervals from series 1853–1878; range from series 1857–1875.

TABLE 48.—*Tidal data, James and York Rivers*—Continued

Station	Locality	Lunitidal intervals		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	James River—Continued	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
24	Broadway, Appomattox River	2.57	9.09	5.90	3.06	1852	1
25	Walthall, Appomattox River	2.77	10.04	5.15	3.67	1852	15
26	Gatlings Wharf, Appomattox River	2.90	9.63	5.69	3.23	1892	19
27	Petersburg, Appomattox River	3.63	10.62	5.43	2.88	1892	14
28	Bermuda Hundred	2.21	9.37	5.26	2.62	1853	3
29	Shirley Wharf	2.46	9.56	5.32	2.77	1880	24
30	Watkins	3.11	9.97	5.56	2.87	1853	3
31	Curles Neck	3.18	9.94	5.66	2.96	1853	30
	Do	3.51	10.43	5.50	3.37	1852	38
	Do	3.18	9.96	5.64	2.90	1880	13
32	Meadowville	3.26	10.55	5.13	3.47	1911	7
33	Varina	3.86	10.32	5.96	3.90	1928	1
34	Dutch Gap	4.00	10.87	5.55	3.29	1875	270
	Do	3.73	10.72	5.43	3.48	1893–94	240
35	Trents Reach	3.44	10.07	5.79	3.54	1852–53	10
36	Cox Wharf	3.67	11.04	5.05	3.21	1853	5
37	Willis Wharf	4.11	11.54	4.99	3.57	1852	7
38	Falling Creek	3.80	11.39	4.83	4.28	1853	3
	Do	4.15	11.05	5.52	3.83	1911	2
39	Warwick Wharf	4.15	12.30	4.27	2.91	1852	11
40	Richmond Bar	4.37	11.37	5.42	4.04	1877	30
41	Drewry Island	3.22	10.80	4.84	3.98	1852	3
42	Opposite Rocketts	3.20	11.08	4.54	3.40	1853	4
43	Richmond, Rocketts Wharf	4.51	11.53	5.40	3.81	1875	30
	Do	4.49	11.90	5.01	3.60	1876–77	365
	Do				3.69	1879	330
	Do	4.22	11.69	4.95	3.62	1893–94	365
	Richmond, United States Engineers' wharf	4.06	11.48	5.00	4.00	1903–04	390
	Do	4.25	11.74	4.93	3.52	1911	60
	York River						
44	York Spit Light	8.28	2.74	5.54	2.09	1901	7
	Do	8.14	1.96	6.18	2.24	1906–07	6
	Do	8.57	2.38	6.19	2.45	1918	26
45	Marsh Point Watch House	8.58	2.41	6.17	2.47	1906	3
	Do	8.63	2.51	6.12	2.40	1911	1
46	York Point	8.07	2.28	5.79	2.36	1868	10
47	Tue Marshes Light	8.57	2.48	6.09	2.78	1894	1
	Do	8.88	2.26	6.62	2.37	1911	1
	Do	9.79	4.04	5.75	2.40	1918	2
48	Thorofare	9.17				1857	¼
49	Sedger Creek	8.53	2.43	6.10	2.29	1918	11
50	Quarter Point	8.86	2.45	6.41	2.35	1857	2
51	Gloucester Point	9.08	2.87	6.21	2.42	1911	28
	Do	8.97	2.70	6.27	2.47	1918	128
	Do				2.47	1911–13	293
	Do	9.19	2.96	6.23	2.45	1928	5
52	Mumfort Island	9.06	2.81	6.25	2.46	1857	4
53	Bush Creek	9.12	2.32	6.80	2.71	1857	1
54	Whittakers Pier	9.10	2.28	6.82	2.70	1857	1
55	Deans Creek (near Gum Point)	9.05	3.17	5.88	2.93	1857	2
56	Claybank	9.54	3.21	6.33	2.72	1911	7
57	Capahosic Wharf	9.36	3.06	6.30	2.90	1857	1½
58	Almonds Wharf	9.78	3.63	6.15	2.69	1911	15
59	Moodys Old Wharf (opposite Purtan Bay)	9.70	3.13	6.57	2.88	1857	1
60	Andersons Dock (Belleview)	10.18	3.95	6.23	3.06	1857	1
61	West Point	10.23	4.42	5.81	3.36	1857	1
	Do	10.79	5.11	5.68	2.82	1911–12	150
	Do	11.65	5.92	5.73	3.65	1918	3
	Do	10.92	5.56	5.36	3.16	1928	1
62	Morgan Landing, Pamunkey River	0.66	6.90	6.18	2.56	1912	2
63	Lester Manor, Pamunkey River	0.98	7.52	5.88	2.79	1912	100
64	White House, Pamunkey River	1.22	7.72	5.92	2.92	1912	1
65	Northbury Landing, Pamunkey River	2.28	8.81	5.89	3.32	1912–13	96
66	Carter Landing, Pamunkey River	2.78	9.41	5.79	2.85	1913	1
67	New Castle, Pamunkey River	4.57	10.36	6.63	1.51	1913	2
68	Wakema, Mattaponi River	12.00	6.40	5.60	3.43	1912	28
69	Walkerton, Mattaponi River	0.51	7.37	5.56	3.86	1912	60
70	Aylett, Mattaponi River	1.69	9.34	4.77	2.82	1912	2
	Mobjack Bay						
71	New Point Comfort	8.51	2.93	5.58	2.27	1906–7	1
72	Severn River	8.53	2.57	5.96	2.50	1854	12
73	Mobjack, Philpotts Wharf	8.60	2.58	6.02	2.41	1868	55
	Do	8.51	2.42	6.09	2.51	1906–7	19
	Do	8.56	2.39	6.17	2.75	1910–11	19
	Do	8.80	2.89	5.91	2.47	1928	1
74	Auburn Wharf	8.59	2.33	6.26	2.65	1911	2

The high and low water intervals in the Chickahominy River increase from about 0.4 and 7.4 hours, respectively, at the mouth to 2.2 and 9 hours at Graves Landing. The mean range is about 2 feet at the mouth and apparently increases somewhat toward the head of the river. The high and low water intervals in the Appomattox River increase from about 2.5 and 9.4 hours at City Point to 3.6 and 10.6 hours at Petersburg, a distance of about 9 miles. The range apparently increases from about 2.7 feet at City Point to about 3.7 feet at Walthall and decreases to about 2.9 feet at Petersburg.

THE TIDE IN THE YORK RIVER

The York River enters the west side of Chesapeake Bay about 30 miles from Cape Henry. The river is comparatively straight and

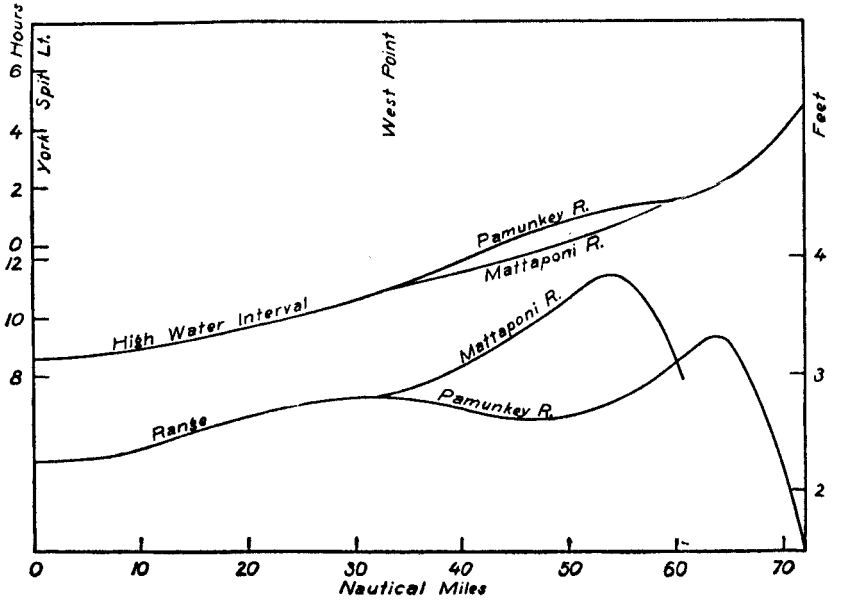


FIGURE 18.—Variations in interval and range, York River

has a 20-foot channel to West Point, at which place the river divides to form the Pamunkey and Mattaponi Rivers.

Table 48 gives data for the 26 stations plotted on Figure 16 at which tidal observations have been made in the York River, and Figure 18 shows graphically the variations in the range and the high-water interval.

The observations show that the high-water interval increases from about 8.5 hours at York Spit Lighthouse to about 9 hours at Gloucester Point and to about 10.8 hours at West Point. It is noted that the time of high water is earlier in the Mattaponi River than in the Pamunkey for equal distances from West Point. The duration of rise shows a slight decrease in value between York Spit Light and West Point. There is also a decrease in the duration of rise from West Point up the Mattaponi River. There is an apparent increase in the duration of rise in the Pamunkey River from 5.68 hours at West Point to 5.89 hours at Northbury Landing.

The range in the York River increases from about 2.2 feet at the entrance to about 2.5 feet at Gloucester Point and to about 2.8 feet at West Point. The range in the Mattaponi River increases from about 2.8 feet at West Point to about 3.9 feet at Walkerton. The range in the Pamunkey River increases from about 2.8 feet at West Point to about 3.3 feet at Northbury Landing.

In the upper reaches of the latter two rivers the range decreases rapidly.

THE TIDE IN THE RAPPAHANNOCK RIVER

The Rappahannock River, which empties into Chesapeake Bay on the western shore about 40 miles from Cape Henry, has a tidal length of about 95 miles from Stingray Point to Fredericksburg.

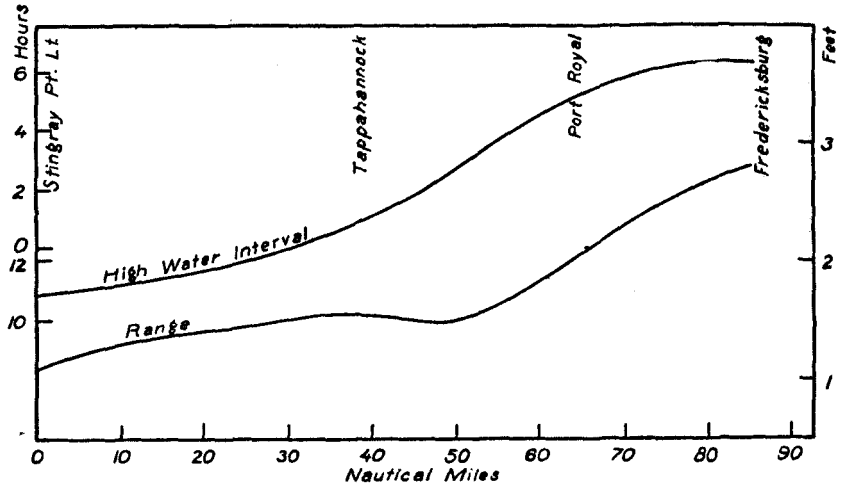


FIGURE 20.—Variations in interval and range, Rappahannock River

Table 49 gives tidal data for the 26 stations in the Rappahannock River, and Figure 20 shows graphically the variations in the range and the high-water interval. The locations of the stations are plotted on Figure 19. An investigation of the table shows that the high-water interval increases from about 10.5 hours at Stingray Point at the mouth of the river to about 13.1 hours, or 0.7 hour, at Tappahannock and to about 6.6 hours at Fredricksburg, this being an increase of about 8.5 hours in the high-water interval in a distance of 95 miles. The duration of rise decreases slightly from the Bay to Fredericksburg, the duration of rise at Fredricksburg being about one-half hour less than at the mouth of the river.

The mean range increases from about 1.1 feet at Stingray Point to about 1.6 feet at Tappahannock and to about 2.8 feet at Fredricksburg.

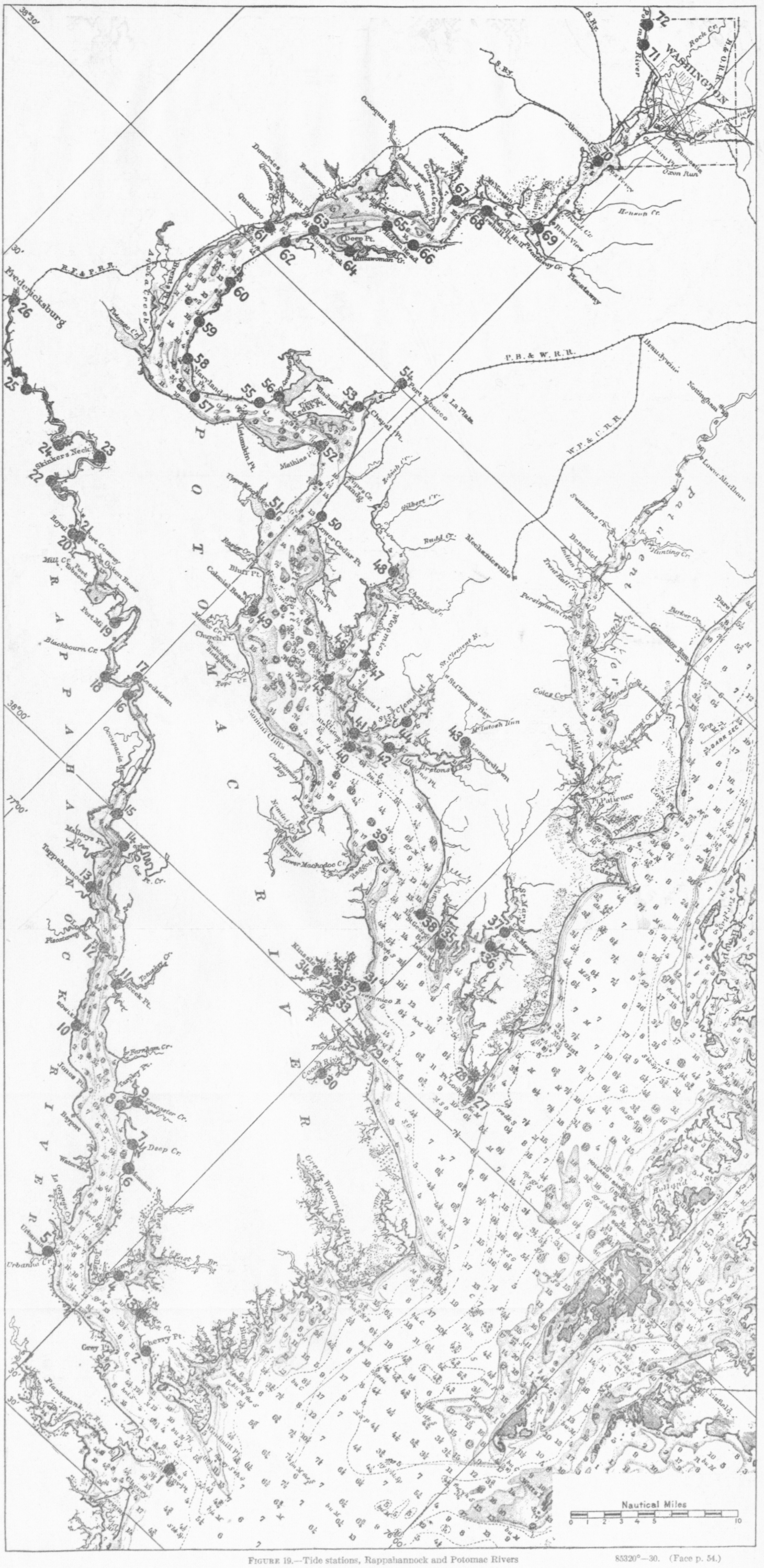


FIGURE 19.—Tide stations, Rappahannock and Potomac Rivers

TABLE 49.—*Tidal data, Rappahannock and Potomac Rivers*

Station	Locality	Lunitidal interval		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Rappahannock River	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
1	Stingray Point Light	10.25	4.38	5.87	1.12	1898	28
	Do	10.78	4.67	6.11	1.10	1901	7
	Do	10.62	4.79	5.83	0.92	1911	27
	Do	10.60	4.53	6.07	1.16	1928	6
2	Whitestone Wharf, Lawson Bay	10.63	5.27	5.36	1.34	1857	4
3	Carter Creek	11.21	5.62	5.59	1.20	1869	24
	Do	11.21	4.40	6.81	1.18	1909	5
4	Millenbeck Wharf, Corrotoman River	11.56	5.83	5.73	1.33	1928	3
5	Urbanna	11.14	5.14	6.00	1.53	1856–57	5
6	Monaskon, Carters Wharf	10.83	5.78	5.05	1.46	1856	2
7	Downman Creek	11.40	5.83	5.57	1.64	1856	1
8	Whealton, Morattico	11.57	5.87	5.70	1.54	1909	16
	Do	11.58	5.86	5.72	1.41	1910	4
9	Lancaster Creek	12.28	5.90	6.38	1.78	1856	2
10	McCartys Wharf	11.88	5.61	6.27	2.19	1856	1
11	Totouskey Creek	12.23	5.74	6.49	2.32	1856	1
12	Lowery Point	0.41	7.16	5.67	1.68	1855	1
13	Tappahannock	0.72	7.75	5.39	1.63	1856–57	365
	Do	0.71	7.68	5.45	1.54	1909	30
	Do	1.12	8.12	5.42	1.80	1928	2
14	Naylors Wharf	0.58	8.01	4.99	1.89	1855	1
15	Mulberry Point	1.53	8.45	5.50	1.37	1855	3
16	Laytons Wharf	2.33	9.80	4.95	1.43	1855	3
17	Leedstown	3.30	9.93	5.79	1.52	1909	9
18	Saunders Wharf	2.99	10.00	5.41	1.50	1854–55	38
19	Green Bay	3.75	10.00	6.17	1.31	1854	1½
20	Port Royal	4.15	11.33	5.24	1.94	1854	2
	Do	4.76	11.74	5.44	2.03	1909	24
	Do	5.02	11.78	5.66	2.22	1928	1
21	Walsingham	4.25	11.08	5.59	2.04	1854	2
22	Mole Mount	4.84	12.16	5.10	1.89	1854	1
23	Buckners	6.00	0.48	5.52	2.36	1854	1
24	Corbins Neck	5.75	12.38	5.79	2.25	1854	1½
25	Seddens Point	5.31	0.51	4.80	2.40	1854	1
26	Fredricksburg	6.02	0.88	5.14	2.73	1853–54	5
	Do	6.62	1.32	5.30	2.84	1909–10	66
	Potomac River						
27	Point Lookout	0.56	6.93	6.05	1.38	1849	140
	Do	0.83	7.00	6.25	1.22	1904–5	16
	Do	0.68	7.12	5.98	1.29	1908	7
	Do	0.75	6.91	6.26	1.21	1928	14
28	Smith Creek	0.80	7.20	6.02	1.29	1908	15
29	Hog Island	0.77	7.27	5.92	1.55	1860	2
30	Bundicks Wharf, Coan River	0.45	7.07	5.80	1.22	1868	10
31	Lynch Point, Yeocomico River	0.93	7.28	6.07	1.55	1905	20
32	Horn Point, Yeocomico River	1.47	8.70	5.19	2.07	1860	1
33	Mundy Point, Yeocomico River	1.05	7.47	6.00	1.60	1905	14
34	Kinsale, Yeocomico River	1.10	7.41	6.11	1.35	1868	48
35	St. George River	0.51	7.01	5.92	1.35	1868	1
36	Custom House Point, St. Marys River	12.29	6.66	5.63	1.52	1867	4
37	St. Marys, St. Marys River	0.61	7.20	5.83	1.34	1859	5
	Do	0.52	7.01	5.93	1.44	1908	6
38	Piney Point	0.87	7.22	6.07	1.91	1860	4
39	Coles Point	1.82	7.90	6.34	1.79	1905	26
40	Blakistone Island Light	1.38	7.52	6.28	1.75	1862	14
41	Coltons Wharf	1.37	7.49	6.30	1.84	1908	1½
42	Kaywood Point, Bretons Bay	1.22	7.70	5.94	1.67	1860	14
43	Leonardtown, Bretons Bay	1.62	8.03	6.01	1.69	1868	43
44	Shipping Point, St. Clement Bay	1.40	7.68	6.14	1.77	1860	1
45	Cobb Point Bar Light	2.03	8.25	6.20	1.81	1904	2
46	Rock Point, Wicomico River	1.67	8.15	5.94	1.80	1868	28
47	Bushwood, Wicomico River	2.52	8.68	6.26	1.51	1860	4
48	Stoddard Point, Wicomico River	2.52	8.60	6.34	1.75	1928	2
49	Colonial Beach	2.09	8.47	6.04	1.72	1902–1906	122
	Do	2.08	8.57	5.93	1.58	1906–1910	1461
	Do	2.13	8.74	5.81	1.68	1928	5
50	1 mile above Lower Cedar Point	2.61	9.61	5.42	1.40	1862	7
51	Dahlgren	2.38	8.88	5.92	1.48	1927	29
52	Mathias Point	2.87	9.55	5.74	1.12	1904	7
53	Brents Wharf, Port Tobacco River	3.73	9.74	6.41	1.41	1928	1
54	Port Tobacco, Port Tobacco River	2.12	9.62	4.92	1.57	1862	3
55	Riverside	3.75	10.28	5.89	1.19	1904	2
56	Bennie Grays Wharf, Nanjemoy Creek	3.92	10.43	5.91	1.18	1862	9
57	Maryland Point Light				1.13	1901–2	30
58	Lower Smith Shoal, Thomas Point				1.20	1901–2	29

TABLE 49.—*Tidal data, Rappahannock and Potomac Rivers*—Continued

Station	Locality	Lunitidal interval		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
	Potomac River—Continued	*Hours*	*Hours*	*Hours*	*Feet*		*Days*
59	Clifton Beach	5.37	11.38	6.41	1.38	1904	10
60	Liverpool Point Wharf	5.50	11.83	6.09	1.47	1862	4
61	Quantico	5.66	0.00	5.66	1.33	1928	4
62	Poseys Wharf	6.12	0.13	5.99	1.56	1904	10
63	Stump Neck	6.00	12.12	6.30	1.46	1862–63	16
64	Grinders Wharf, Mattawoman Creek	6.32	0.08	6.24	1.58	1902	1½
65	Indian Head	6.64	0.69	5.95	1.63	1928	3
66	Glymont	6.78	0.71	6.07	1.71	1863	9
	Do	6.72	1.00	5.72	1.80	1904	7
67	Whitestone Point	7.44	1.56	5.88	1.84	1926	3
68	Marshall Hall	7.03	1.30	5.73	2.11	1904	18
69	Fort Washington	7.17	1.45	5.72	2.30	1863	5
	Do	7.38	1.65	5.73	2.53	1904	4
70	Alexandria	7.86	2.12	5.74	2.88	1862	9
	Do	7.67	2.00	5.67	2.75	1904	29
	Do				2.82	1904	40
	Do	7.56	1.79	5.77	2.79	1913–1915	690
71	1 mile below Chain Bridge	7.77	2.30	5.47	2.91	1872	26
72	Chain Bridge	7.78	1.87	5.91	3.08	1914	8

THE TIDE IN THE POTOMAC RIVER

The Potomac River, which enters Chesapeake Bay at Point Lookout, is the water route to Alexandria and Washington. The earliest tidal observations in the river that are on record at this office were made at Point Lookout in 1849. Since that time observations have been made at numerous places throughout the length of the river.

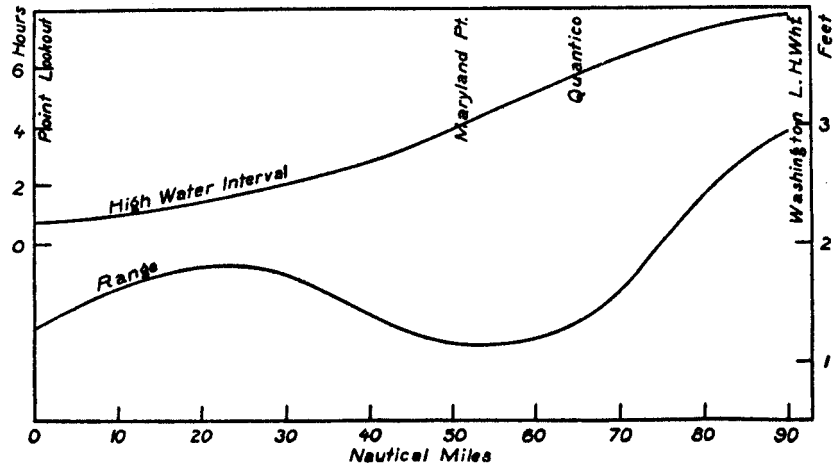


FIGURE 21.—Variations in interval and range, Potomac River

In Table 49 are given the results derived from observations at 46 stations in the Potomac River. The locations of these stations are shown in Figure 19. An examination of the table shows that the time of tide becomes later as the distance up the river increases.

The high-water interval at Point Lookout is about 0.6 hour. It increases to about 2.1 hours at Colonial Beach and to 7.8 hours at

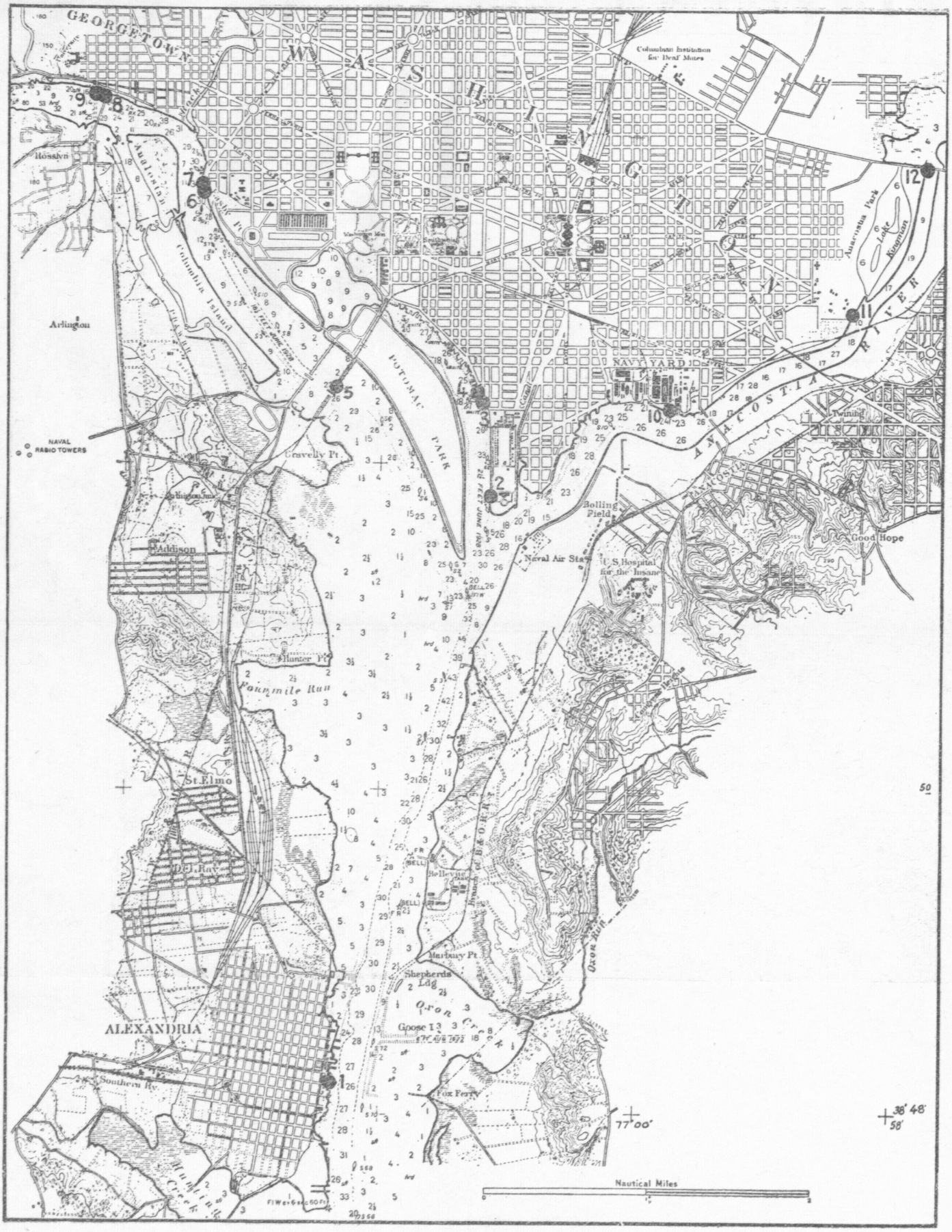
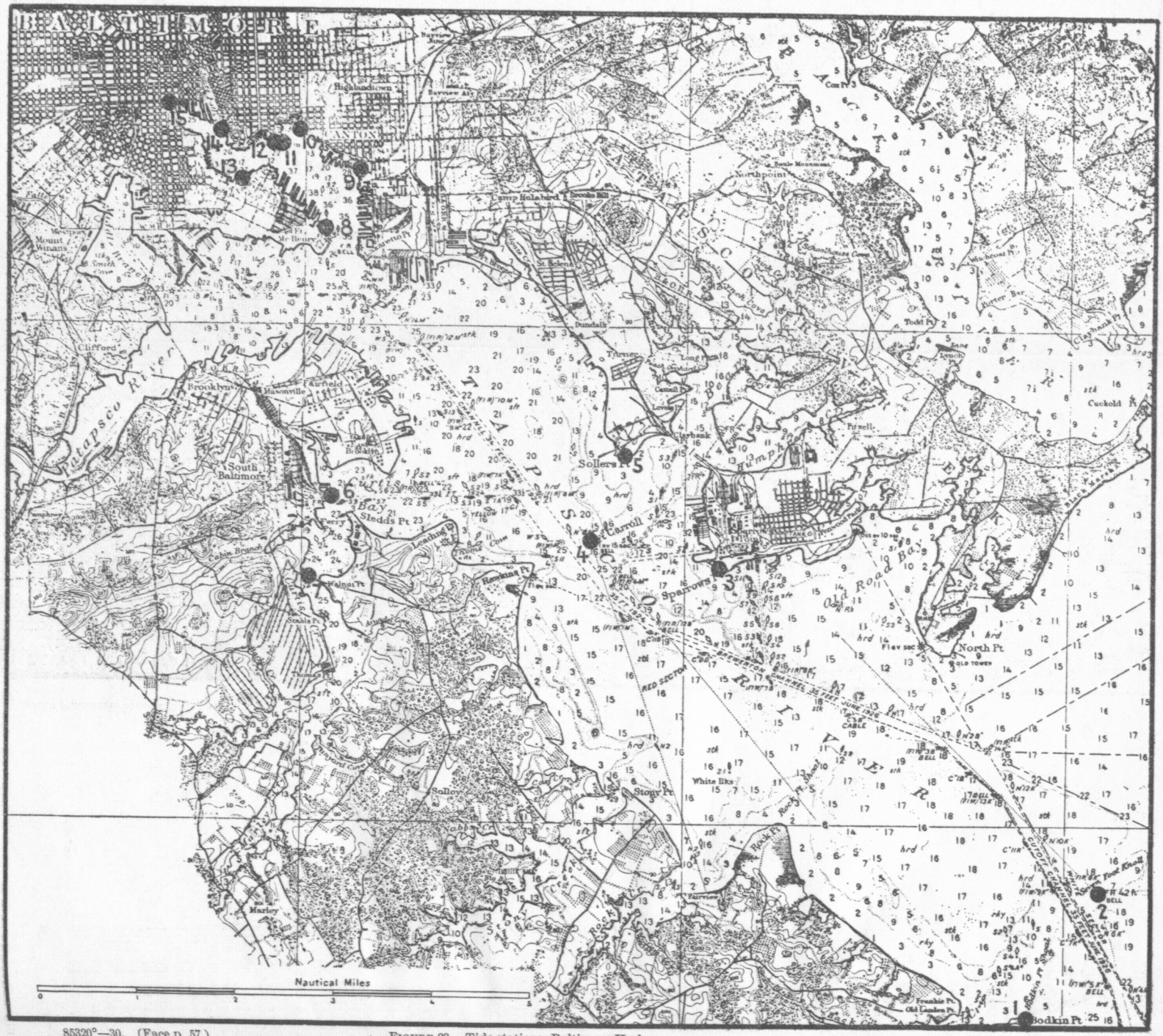


FIGURE 22.—Tide stations, Alexandria and Washington



85320°—30. (Face p. 57.)

FIGURE 23.—Tide stations, Baltimore Harbor

Washington. Between Point Lookout and Washington a distance of 90 miles, the high-water interval increases about 7 hours. The low-water interval is about 7¾ hours greater at Washington than at Point Lookout.

The mean range of tide is about 1.3 feet at Point Lookout; this increases to about 1.8 feet in the vicinity of Cobb Point. The range then decreases to about 1.1 feet at Maryland Point and again increases to about 2.9 feet at Washington.

Figure 21 shows the variations in range and high-water interval in the Potomac River from Point Lookout to Washington. It is noted from the curves that the high-water interval increases gradually from Point Lookout to Washington. It will be seen that the variations shown by the range curve are analogous to those in the James River (see fig. 17).

The locations of 12 stations at Alexandria and Washington are shown on a separate chart (fig. 22) and data for these stations are given in Table 50. Results for a number of these stations are discussed on pages 24 to 37.

THE TIDE IN BALTIMORE HARBOR

Table 51 gives tidal data for 15 stations in Baltimore Harbor. The observations have been reduced to mean values by simultaneous comparison with standard stations. The locations of the stations are shown in Figure 23.

From a study of the tidal data given in the table it will be noted that the high-water interval and the range increase slightly from the mouth to the head. The range of tide in this area is small and meteorological effects are therefore relatively important. For this reason discrepancies are to be expected between values derived from short series of observations.

TABLE 50.—*Tidal data, Alexandria and Washington*

Station	Locality	Lunitidal interval		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
		Hours	*Hours*	*Hours*	*Feet*		*Days*
1	Alexandria, Va	7.86	2.12	5.74	2.88	1862	9
	Do	7.67	2.00	5.67	2.75	1904	29
	Do				2.82	1904	40
	Do	7.56	1.79	5.77	2.79	1913–1915	690
2	Arsenal, Washington, D. C	7.76	2.46	5.30	3.08	1862	25
3	Lighthouse Wharf	7.77	2.22	5.55	2.86	1925–26	540
4	Seventh Street Wharf	7.78	1.96	5.82	2.94	1898	180
	Do	7.81	2.18	5.63	2.91	1899	365
	Do				2.85	1900–1	420
5	Long Bridge (railroad bridge)	7.24	1.65	5.59	2.91	1867	30
6	Easby Point	7.91	2.51	5.40	2.77	1901–2	365
7	New Hampshire Avenue	7.88	2.20	5.68	2.98	1862	12
8	Potomac Boat Club	8.01	2.38	5.63	2.78	1925	30
9	Aqueduct Bridge	8.02	1.84	6.18	2.88	1872	2
10	Navy yard	7.72	2.07	5.65	2.91	1858–1860	913
	Do	7.67	2.76	4.91	2.46	1861	5
	Do	7.74	1.98	5.76	2.79	1862	7
	Do	7.67	2.01	5.66	2.67	1863	10
	Do	7.92	2.18	5.74	2.97	1891	150
	Do	7.91	2.23	5.68	2.90	1892	365
	Do				2.95	1892–1898	2557
11	Almshouse	8.07	2.21	5.86	3.24	1865	6
12	Benning Bridge	7.95	2.21	5.74	2.83	1924	11

TABLE 51.—*Tidal data, Baltimore Harbor*

Station	Locality	Lunitidal interval		Duration of rise	Mean range	Observations	
		High water	Low water			Year	Length
		Hours	*Hours*	*Hours*	*Feet*		*Days*
1	Bodkin Point	5.99	0.75	5.24	1.01	1845	180
	Do	6.04	0.63	5.41	0.89	1845	4
	Do	6.22	0.72	5.50	0.83	1845–46	60
	Do	6.25	0.69	5.56	0.97	1854	29
2	Seven Foot Knoll Light	6.70	0.68	6.02	1.02	1867	27
	Do	6.70	0.82	5.88	1.03	1897	2
	Do	6.32	0.31	6.01	1.00	1898	24
	Do	5.94	12.00	6.36	1.20	1906	4
3	Sparrows Point	6.42	0.63	5.79	1.01	1896	37
	Do	6.96	1.31	5.65	1.06	1897	180
	Do	6.54	0.61	5.93	1.11	1898	2
	Do	6.66	0.79	5.87	1.02	1898	7
4	Fort Carroll	6.80	0.93	5.87	0.96	1866	5
	Do	6.42	0.39	6.03	1.11	1866	7
	Do	6.67	1.35	5.32	0.91	1869	21
	Do	6.52	0.69	5.83	1.13	1898–1900	1096
	Do	6.56	0.54	6.02	1.08	1927	3
5	Sollers Point	6.59	0.44	6.15	1.11	1853	19
6	Curtis Bay, Sugar House Wharf	6.42	0.32	6.10	1.54	1898	2
7	Curtis Creek Drawbridge	6.62	0.65	5.97	1.11	1924	5
8	Fort McHenry	6.48	0.66	5.82	1.11	1903–1927	9131
9	Bollmans Wharf	5.97	0.23	5.74	1.11	1876	11
10	Campbell and Zells Wharf	6.74	0.81	5.93	1.19	1898	5
11	Jacksons Wharf, Fells Point	6.94	0.98	5.96	1.15	1845	180
	Do	6.79	0.93	5.86	1.06	1846	150
12	Henderson Wharf, Fells Point	6.75	0.90	5.85	1.17	1876	47
13	Woodalls Dry Dock	6.64	0.72	5.92	1.48	1876	2
14	City dock	6.42	0.71	5.71	1.09	1927	4
15	Reeder's Machine Shop	6.77	0.62	6.15	1.20	1898	18

The range of the tide at Seven Foot Knoll is about 1 foot. This increases to about 1.1 feet at Fort McHenry and to about 1.2 feet at Reeder's machine shop (station 15).

Most of the tidal observations at short-series stations in the harbor were made prior to the establishment of the Fort McHenry gage. To reduce the results from these observations to mean values they were compared with a distant station which did not take into account the weather conditions in Baltimore Harbor. If all the observations in this harbor had been made while the Fort McHenry gage was in operation and simultaneous comparisons made with that station the effects of weather would have been largely eliminated.

HARMONIC CONSTANTS

Tidal harmonic constants, derived by the harmonic analysis of the hourly heights of the tide, have been determined for a number of stations in Chesapeake Bay. These constants, together with the locations of the stations to which they apply, and the length and date of series from which they were determined, are given in Table 52.

From these constants the characteristics of the tide may be derived as explained on page 129 of the appendix. The constants may also be used for predicting the tides. For a detailed discussion of the harmonic analysis and prediction of tides reference is made to Special Publication No. 98 of this bureau.

TABLE 52.—*Harmonic constants, Chesapeake Bay*

Component	Virginia								District of Columbia				Maryland					
	Old Point Comfort, 37° 00′ N., 76° 19′ W.		Richmond 37° 32′ N., 77° 25′ W.		Stingray Point Light, 37° 34′ N., 76° 16′ W.		Great Wicomico Light, 37° 48′ N., 76° 16′ W.		Washington, Navy Yard, 38° 52′ N., 77° 00′ W.		Washington, Seventh Street Wharf, 38° 52′ N., 77° 01′ W.		Holland Island Bar Light, 38° 04′ N., 76° 06′ W.		Drum Point Light, 38° 19′ N., 76° 25′ W.		Sharps Island Light, 38° 38′ N., 76° 23′ W.	
	H	κ	H	κ	H	κ	H	κ	H	κ	H	κ	H	κ	H	κ	H	κ
	Feet	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*
J_1			(0.011)	(227)					(0.007)	(257)	(0.009)	(263)						
K_1	0.186	119	0.202	238	0.086	133	0.078	157	0.155	272	0.157	274	0.092	201	0.087	240	0.146	272
K_2	0.062	277	0.061	173	(0.023)	(325)	(0.023)	(357)	0.071	253	0.064	270	(0.029)	(33)	(0.021)	(59)	(0.016)	(126)
L_2	0.064	270	0.216	148	(0.016)	(331)	(0.017)	(353)	0.112	262	0.095	255	(0.020)	(35)	(0.013)	(58)	(0.015)	(110)
M_1			0.018	238	(0.006)	(162)	(0.006)	(176)	0.008	88	0.024	37	(0.007)	(207)	(0.007)	(252)	(0.010)	(272)
M_2	1.220	248	1.723	122	0.529	296	0.507	337	1.421	226	1.377	228	0.707	12	0.555	39	0.582	80
M_3			0.026	136							0.012	79						
M_4	0.039	244	0.211	140	0.008	171	0.033	191	0.083	355	0.082	2	0.022	284	0.019	354	0.031	91
M_6	0.016	191	0.089	95	0.006	117	0.013	306	0.021	82	0.034	66	0.022	69	0.016	142	0.038	239
M_8			0.034	122							0.009	180						
N_2	0.269	226	0.317	97	0.112	261	0.114	322	0.294	200	0.243	205	0.138	349	0.089	19	0.102	51
2N			(0.042)	(72)	(0.015)	(226)	(0.015)	(307)	(0.055)	(188)	(0.032)	(182)	(0.018)	(326)	(0.012)	(0)	(0.014)	(31)
O_1	0.138	143	0.157	262	0.075	190	0.087	194	0.100	292	0.105	296	0.094	214	0.111	264	0.129	272
OO			(0.006)	(215)					(0.004)	(244)	(0.005)	(253)						
P_1	0.064	114	0.031	240	(0.028)	(133)	(0.026)	(157)	0.031	274	0.045	287	(0.030)	(201)	(0.029)	(240)	(0.048)	(272)
Q_1	0.044	130	(0.030)	(273)	(0.015)	(219)	(0.017)	(213)	0.015	307	0.020	294	(0.018)	(220)	(0.022)	(276)	(0.025)	(272)
2Q			(0.004)	(285)					(0.002)	(317)	(0.003)	(317)						
R_2			(0.002)	(160)					(0.002)	(268)	(0.002)	(269)						
S_1			0.100	120							0.045	214						
S_2	0.227	269	0.246	150	0.083	325	0.085	357	0.201	270	0.200	269	0.107	33	0.078	59	0.060	126
S_4			0.018	223							0.005	317						
S_6			0.002	229							0.002	200						
T_2			(0.014)	(160)	(0.005)	(325)	(0.005)	(357)	(0.026)	(330)	(0.012)	(269)	(0.006)	(33)	(0.005)	(59)	(0.004)	(126)
λ_2			(0.012)	(139)	(0.004)	(309)	(0.004)	(347)	(0.073)	(258)	(0.010)	(247)	(0.005)	(22)	(0.004)	(48)	(0.004)	(102)
μ_2	(0.029)	(228)	(0.041)	(84)	(0.013)	(266)	(0.012)	(318)			0.029	254	(0.017)	(351)	(0.013)	(18)	(0.014)	(34)
ν_2	(0.054)	(228)	(0.062)	(100)	(0.022)	(265)	(0.022)	(324)	(0.036)	(196)	0.063	213	(0.027)	(352)	(0.017)	(22)	(0.020)	(55)
ρ_1			(0.006)	(272)					(0.003)	(303)	(0.004)	(305)						
MS									0.024	207	0.026	42						
Sa	0.320	126	0.482	49					0.166	121	0.253	124						
Ssa	0.106	161	0.273	35					0.047	195	0.136	250						
Series	1865–1877		1903–4		1898		1898		1858–1894		1899–1925		1898		1898		1898	
Length	2 years		369 days		29 days		29 days		2 years		2 years		29 days		29 days		29 days	

Values in parentheses are inferred.

TABLE 52.—*Harmonic constants, Chesapeake Bay*—Continued

Component	Maryland—Continued															
	Thomas Point Shoal Light, 38° 54′ N., 76° 26′ W.		Love Point Light, 39° 03′ N., 76° 17′ W.		Seven Foot Knoll Light, 39° 09′ N., 76° 25′ W.		Baltimore, Fells Point, 39° 17′ N., 76° 35′ W.		Baltimore, Fort McHenry, 39° 16′ N., 76° 35′ W.		Pooles Island Light, 39° 17′ N., 75° 16′ W.		Elk River entrance, 39° 26′ N., 76° 59′ W.		Chesapeake City, 39° 32′ N., 75° 49′ W.	
	H	κ	H	κ	H	κ	H	κ	H	κ	H	κ	H	κ	H	κ
	Feet	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*	*Feet*	*Degrees*
J_1									(0.012)	(290)					(0.014)	(310)
K_1	0.206	268	0.252	275	0.274	284	0.129	299	0.220	296	0.276	293	0.338	307	0.245	315
K_2	(0.014)	(127)	(0.021)	(210)	(0.024)	(220)	0.034	242	0.024	216	(0.026)	(259)	(0.046)	(284)	0.067	318
L_2	(0.011)	(134)	(0.016)	(277)	(0.013)	(205)	0.032	249	0.018	224	(0.017)	(232)	(0.027)	(273)	0.084	284
M_1	(0.011)	(283)	(0.015)	(288)	(0.013)	(298)	0.024	170	0.010	99	(0.016)	(306)	(0.020)	(322)	0.027	19
M_2	0.367	119	0.501	168	0.438	185	0.572	190	0.468	190	0.572	212	1.012	246	1.046	263
M_3									0.002	62					0.008	16
M_4	0.015	62	0.004	177	0.022	43	0.011	329	0.022	307	0.006	304	0.033	8	0.021	6
M_6	0.009	21	0.004	212	0.010	217	0.006	185	0.006	208	0.012	314	0.012	62	0.016	140
M_8									0.001	55					0.006	276
N_2	0.078	103	0.112	159	0.092	165	0.092	163	0.094	169	0.114	192	0.184	219	0.197	238
2N	(0.010)	(88)	(0.015)	(149)	(0.012)	(145)			0.012	128	(0.015)	(173)	(0.025)	(192)	0.026	213
O_1	0.100	297	0.177	301	0.092	312	0.112	321	0.170	306	0.162	319	0.203	337	0.208	324
OO									(0.007)	(285)					0.007	306
P_1	(0.068)	(268)	(0.083)	(275)	(0.091)	(284)	0.051	314	0.070	285	(0.091)	(293)	(0.112)	(307)	0.052	341
Q_1	(0.019)	(312)	(0.034)	(314)	(0.018)	(326)			0.032	274	(0.031)	(331)	(0.039)	(352)	0.040	328
2Q									(0.004)	(316)					0.006	333
R_2									(0.001)	(216)					0.001	304
S_1									0.061	225					0.020	239
S_2	0.051	127	0.076	210	0.087	220	0.075	255	0.086	216	0.095	259	0.169	284	0.134	304
S_4									0.001	55						
S_6									0.001	36						
T_2	(0.003)	(127)	(0.005)	(210)	(0.005)	(220)			(0.005)	(216)	(0.006)	(259)	(0.010)	(284)	(0.008)	(304)
λ_2	(0.003)	(123)	(0.004)	(188)	(0.003)	(201)			0.003	194	(0.004)	(234)	(0.007)	(264)	(0.007)	(282)
μ_2	(0.009)	(110)	(0.012)	(126)	(0.011)	(150)			0.007	131	(0.014)	(165)	(0.024)	(208)	(0.025)	(222)
ν_2	(0.015)	(105)	(0.022)	(160)	(0.018)	(168)			0.023	174	(0.022)	(195)	(0.036)	(222)	(0.038)	(242)
ρ_1									(0.006)	(310)					(0.008)	(328)
Sa							0.260	123	0.348	126						
Ssa							0.060	35	0.087	67						
Series	1898		1898		1898		1845–46		1907–8, 1925		1898		1898		1923	1924
Length	29 days		29 days		29 days		369 days		2 years		29 days		29 days		163 days	250 days

Values in parentheses are inferred.

PART II. CURRENTS IN CHESAPEAKE BAY AND TRIBUTARIES

OBSERVATIONS AND REDUCTIONS

INTRODUCTORY STATEMENTS

The words *tide* and *current* are often confused or used synonymously and it is therefore desired to emphasize at the beginning of this discussion that the *tide* is the *vertical* rising and falling of the water surface, whereas the *current* is the *horizontal* flow of the water. It is important that this difference be recognized, as well as the fact that slack water and high or low water do not in general occur at the same time at a given point. For a detailed discussion of this subject see page 134 of the appendix to this volume.

The tidal movement in Chesapeake Bay, with its vertical and horizontal constituents—tide and current respectively—is a continuation of the tidal wave of the Atlantic Ocean, which sweeps through the entrance between the Virginia capes and is propagated up the bay and into each of its tributaries until stopped by rapids or other obstructions. As the movement progresses it is subjected to many variations by the differing hydrographic features that it encounters.

Current observations in Chesapeake Bay as recorded in the files of the Coast and Geodetic Survey began in the year 1845. Since that date information on currents in the bay and in its tributary arms and rivers has been gradually accumulating. Many of the observations, including all of the earlier ones, were taken by field parties engaged in making hydrographic surveys and the observing of currents was more or less incidental to the hydrographic work. The information from these early records is therefore meager. In some cases the observations were taken by liberating a float, following it around and occasionally locating its position; in others the periods of observation were brief. With the passage of time more systematic and uniform methods of observing currents have evolved and as a consequence the data furnish fuller information. In recent years comprehensive current surveys of several important waterways of the United States have been made and such a survey of Chesapeake Bay and its tributaries which has now been completed will be referred to later in this text.

METHODS OF OBSERVING

The general process of observing currents consists of measuring, usually at fixed intervals of time such as hourly or half hourly, the velocity of the current; noting the direction the current is flowing at each measurement of velocity; and recording the direction, the velocity and the time at which each measurement is made. Various means of taking such observations have been devised and three general methods which have recently been used in Chesapeake Bay are briefly outlined in the following paragraphs. Where other

methods have been used, they will be mentioned in connection with the observations to which they apply.

The *current-pole* method which was used in the recent survey for determining the velocity and direction of the surface currents, appears also to have been employed, with some variations in the kind of float used, for most of the current work prior to this survey. The present form of float is a wooden pole so weighted with lead that it will submerge for most of its length and assume a vertical position when placed in the water. The pole is attached to a log line and allowed to drift with the current while an observation is being made. The log line is marked in principal and secondary divisions, each secondary division being one-tenth of a principal division. The length of each principal division bears the same ratio to a nautical mile that the time the pole is allowed to drift bears to an hour. By this means, the velocity in nautical miles per hour or knots is read directly from the log line. The direction the pole drifts is observed, usually by compass and pelorus on the vessel, and when practicable is verified by sextant angles between the pole and fixed objects on shore. The velocity obtained by this method is considered the velocity at a depth equal to one-half the length of the submerged portion of the pole.

The *Price current meter* is used for taking subsurface observations. The working parts of this meter consist of a set of conical metal cups arranged on the periphery of a wheel which is mounted on a vertical shaft. The upper end of this shaft actuates a recording mechanism which makes and breaks an electric circuit, producing clicks in a telephone receiver connected in the circuit. When the meter is lowered into the water, the current striking the metal cups causes the wheel to rotate, the speed of rotation and consequently the frequency of the clicks in the telephone receiver depending upon the velocity of the current. To obtain the velocity of the current therefore, it is only necessary to count the clicks in the receiver for a specified length of time and from a previously prepared rating table take the velocity corresponding to the observed number of clicks. The direction of the subsurface current is not given by the Price meter.

The *Pettersson current meter*, which is used for subsurface observing, records automatically on a photographic film numerals representing both the direction and velocity of the current.

The recording mechanism of this meter is inclosed in a water-tight cylinder and consists of a small camera and electric light actuated by clockwork to photograph, at half-hourly intervals, numerals inscribed near the outer edges of two glass disks, a compass disk, and a velocity disk. The compass disk carries two compass needles and is free to move so that the needles assume a direction parallel to the earth's magnetic field. The meter is equipped with a vane which holds it always in the same position relative to the current and consequently the numeral on the compass dial at the instant it is photographed represents the direction of the current at that instant. The velocity disk is rotated by an anemometer wheel to which it is indirectly connected by means of parallel magnets and reducing gears. The anemometer wheel is rotated by the current and the difference between two successive half-hourly readings, as interpreted by a rating table, gives the average velocity of the current during the half hour.

For a more detailed discussion of current measuring instruments, reference is made to United States Coast and Geodetic Survey Special Publication No. 124, Instructions for Tidal Current Surveys.

METHODS OF REDUCING THE OBSERVATIONS

The method outlined below was used for the reduction of the observations made in the recent current survey of Chesapeake Bay and applies to most of the observations previous to that survey. Other methods of reduction used in some cases will be mentioned later in the discussion.

The records of the field party were first carefully verified to see that the velocities had been correctly entered from the rating tables, and that the observed directions were accurately reduced to true azimuths by applying to the pelorus readings the proper corrections for the ship's head, the deviation of the ship's compass, and the magnetic variation. The observed velocities for each depth were next plotted on cross-section paper. The times of observation were taken as abscissæ and the flood and ebb velocities plotted as ordinates, the flood velocities above and the ebb velocities below the horizontal line representing zero velocity or slack water.

Smooth curves were drawn following the general trend of the plotted velocities and from these curves the times of the slack waters and the times and velocities of the strengths of flood and ebb were taken. These times and velocities together with the average true direction for each period of flood and ebb were tabulated on forms prepared for this purpose.

The times of slack water and of strength of current were then compared with the times of high and low water at a primary tide station and average time differences computed for each depth for each of the four phases of current—namely, slack before flood, strength of flood, slack before ebb, and strength of ebb. Average true directions of flood and ebb were obtained for each series of observations and the average velocities of flood strength and ebb strength for each depth were reduced to mean values by applying a factor to correct for the range of tide at the primary tide station as explained in the last section of the appendix, page 137.

DISCUSSION OF THE RESULTS

EXPLANATORY STATEMENTS

For convenience in discussing the results of the current observations in Chesapeake Bay and its tributaries, the area involved has been divided into the 18 sections listed below:

1. Approaches to Chesapeake Bay.
2. Chesapeake Bay.
3. Hampton Roads.
4. Elizabeth and Nansemond Rivers.
5. James River and tributaries.
6. York River and tributaries.
7. Rappahannock River.
8. Pocomoke Sound and River.
9. Tangier Sound and tributaries.
10. Potomac River and tributaries.
11. Patuxent River.
12. Little Choptank and Choptank Rivers.
13. Eastern Bay.
14. South and Severn Rivers.
15. Chester River.
16. Patapsco River.
17. Sassafras and Elk Rivers.
18. Chesapeake & Delaware Canal.

Table 53 presents the data derived from the observations at each station. Italicized subheads in this table correspond in number and arrangement to the sections of the bay listed above. The times of slacks and the times, true directions, and corrected velocities of the strengths of current were tabulated directly from the reductions. The times of slacks and strengths are referred to the tides at Old Point Comfort, the slacks before flood and strengths of flood being referred to the low waters, and the slacks before ebb and strengths of ebb to the high waters. The true directions are reckoned from the true north (0°), through east (90°), south (180°), and west (270°). The duration of flood, from slack before flood to slack before ebb, and the duration of ebb from slack before ebb to slack before flood are given in the table.

The mean current hour as given in the last column of the table is expressed in solar hours and is the mean interval between the Greenwich transit of the moon and the time of the strength of the flood current modified by the times of slack water and strength of ebb. In computing the mean current hour an average is obtained of the intervals for the following phases: Flood strength, slack before flood increased by one-fourth semilunar day (3.10 hours), slack before ebb decreased by one-fourth semilunar day, and ebb strength increased or decreased by one-half semilunar day (6.21 hours). Before taking the average the four phases are made comparable by the addition or rejection of such multiples of the semilunar day (12.42 hours) as may be necessary.

The times are given in hours and decimals, the velocities in knots (nautical miles per hour) and decimals, and the directions in whole degrees. In the table a minus (−) sign indicates that the given phase of the current is earlier than the specified phase of the tide at Old Point Comfort. Where no sign is given, the plus (+) sign is understood and indicates that the phase of the current in question is later than the high water or low water at Old Point Comfort.

Each station has been designated by a number preceded by a letter or letters. The letters signify the party or the chief of the party, which occupied the stations and a number has been assigned to each station of that party. In the survey of 1927 and 1928, the numbers are those originally assigned to the stations. For the older observations this procedure was usually impossible, either because no numbers had been assigned to the stations or because of the duplication of numbers that were assigned.

The location of each station has been plotted on one or more of the 10 charts, Figures 24, 27 to 29, and 31 to 36, inclusive. On Figure 24 the indicated depths are in fathoms at mean low water. All soundings on the other illustrations are in feet at mean low water.

The various observing parties, with the dates of observation, the designating letters, the number of stations occupied, the localities, and the numbers of the illustrating figures on which the stations are plotted, are tabulated in approximate chronological order in Table 54.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*

[Referred to times of high water and low water at Old Point Comfort]

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(1) Approaches to Chesapeake Bay		*Days*		*Feet*	*Hrs.*	*Hrs.* (1)	*Deg.* (1)	*Knts.* (1)	*Hrs.* (1)	*Hrs.* (1)	*Hrs.* (1)	*Deg.* (1)	*Knts.* (1)	*Hrs.*	*Hrs.*
LV1	U. S. S. Brant, temporary light vessel (37° 04′.6 N., 74° 51′.1 W.).	Feb. 16–May 24, 1919	99	Pole	7	------									------	9.74
LV2	Cape Charles Light Vessel (37° 05′.3 N., 75° 43′.5 W.).	June 2–Aug. 27, 1912	87	do	7	1.40	4.20	298	[2]0.26	5.62	0.60	4.20	68	[2]0.36	6.80	11.84
		Sept. 1–Oct. 29, 1915	59	do	7	1.40	4.20	272	[2]0.23	5.52	0.50	4.10	80	[2]0.30	6.90	11.79
Se1	8⅝ miles, N. 78° E. of Cape Henry Light (36° 57′.4 N., 75° 50′.0 W.).	Sept. 22–26, 1919	3¾	do	------	2.72	5.40	292	0.26	5.10	1.40	5.06	92	0.52	7.32	0.46
S1	3¾ miles, S. 6° W. of Cape Charles Light (37° 03′.6 N., 75° 54′.8 W.).	Sept. 9–10, 1851	1	------	------	1.85	5.40	288	0.99	6.52	1.95	5.10	102	0.74	5.90	0.40
S2	6¼ miles, S. 12° W. of Cape Charles Light (37° 01′.2 N., 75° 56′.0 W.).	Sept. 11–12, 1851	1	------	------	3.25	5.92	295	1.00	5.50	2.33	5.83	104	1.70	6.92	1.15
	(2) Chesapeake Bay															
A98	½ mile S. of Fisherman I. (37° 04′.7 N., 75° 58′.4 W.).	July 24–26, 1928	1	Pole	7	2.78	5.13	306	1.47	5.25	1.61	5.51	156	2.27	7.17	0.58
				Meter	5	2.73	5.13	------	1.42	5.25	1.56	5.06	------	1.97	7.17	0.44
				do	12½	2.55	5.03	------	1.41	5.33	1.46	5.11	------	1.61	7.09	0.36
				do	20	2.28	4.93	------	1.21	5.65	1.51	5.21	------	1.16	6.77	0.30
A97	6⅞ miles N., 8° E. of Cape Henry Light (37° 02′.4 N., 75° 59′.4 W.).	June 24–25, 1928	1	Pole	7	2.98	5.08	299	1.23	4.85	1.41	6.06	132	1.68	7.57	0.70
				Meter	4	3.08	5.13	------	1.16	4.90	1.56	6.01	------	1.96	7.52	0.76
				do	10	2.88	5.18	------	1.09	5.25	1.71	5.66	------	1.09	7.17	0.68
				do	16	2.63	5.48	------	0.86	5.45	1.86	5.26	------	0.71	6.97	0.38
A96	4⅞ miles N. of Cape Henry Light (37° 00′.5 N., 76° 00′.5 W.).	July 24–27, 1928	2	Pole	7	3.38	6.00	299	1.18	5.72	2.68	6.58	134	1.45	6.70	1.48
			2	Meter	6, 8, 9	3.46	6.13	------	1.35	5.80	2.84	6.56	------	1.48	6.62	1.57
			½	do	15	2.58	5.18	------	1.37	6.20	2.36	------	------	------	6.22	0.67
			2	do	21, 24	1.86	5.28	------	1.29	7.60	3.04	5.96	------	0.92	4.82	0.86
			2	do	33	1.83	5.35	------	0.89	7.78	3.19	5.59	------	0.55	4.64	0.81
LV3	Tail of the Horseshoe Light Vessel, 3¼ miles N. of Cape Henry Light (36° 58′.8 N., 76° 00′.4 W.).	June 2–Aug. 27, 1912	87	Pole	7	3.64	6.49	301	[2]1.04	5.60	2.82	6.37	122	[2]1.55	6.82	1.65
		Aug. 23–Nov. 3, 1915	73	do	7	3.54	6.29	305	[2]0.90	5.45	2.57	6.22	129	[2]1.41	6.97	1.48
		Apr. 9–Oct. 31, 1919	160	do	7	3.72	6.44	312	[2]0.96	5.28	2.58	6.27	126	[2]1.50	7.14	1.57
A95	2 miles N., 11° W. of Cape Henry Light (36° 57′.5 N., 76° 00′.9 W.).	July 26–27, 1928	1	do	7	2.63	5.93	286	1.53	9.15	5.36	6.26	92	1.28	3.27	1.86
				Meter	13	2.68	6.28	------	1.74	8.94	5.16	6.16	------	1.49	3.48	1.89
				do	32½	2.03	5.63	------	1.59	8.95	4.56	6.96	------	0.94	3.47	1.62
				do	52	1.43	5.18	------	1.43	9.25	4.26	5.71	------	0.73	3.17	0.97

[1] Current rotary. See Tables 55, 56, and 57, pages 95 and 96.

[2] Velocity not corrected for range of tide.

TABLE 53.—*Current data, Cheaspeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(2) *Chesapeake Bay*—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
Ay12	½ mile N. of Cape Henry (36° 56′.2 N., 76° 00′.3 W.).	Aug. 16, 1853	½	Float	(3)	2.70	5.60	301	1.36	5.72	2.00	5.20	107	1.16	6.70	0.70
A94	Lynnhaven Roads (36° 55′.4 N., 76° 04′.9 W.).	July 27–28, 1928	1	Pole	7	3.58	6.08	262	0.47	5.25	2.41	5.76	80	0.72	7.17	1.28
				Meter	5	3.58	5.98		0.73	5.35	2.51	5.76		0.83	7.07	1.28
				do	12	3.53	6.18		0.94	5.90	3.01	6.31		0.69	6.52	1.58
				do	19	3.48	5.98		0.90	5.80	2.86	5.96		0.45	6.62	1.39
Ay11	Lynnhaven Roads (36° 56′.9 N., 76° 05′.6W.).	Sept. 4, 1854	½	Float	(3)	3.98	5.98	289	0.92	4.59	2.15	5.15	90	1.02	7.83	1.14
Ly10	Lynnhaven Roads (36° 56′.2 N., 76° 07′.2 W.).	Oct. 24–25, 1918	1	Pole		3.45	6.65	301	0.77	5.57	2.60	6.05	99	1.07	6.85	1.51
Ay10	⅝ mile N. of Thimble Shoal Channel (36° 59′.6 N., 76° 08′.5W.).	Sept. 5, 1854	½	Float	(3)	2.23	5.73	314	1.01	6.91	2.72	6.22	122	1.01	5.51	1.04
Ly7	¾ mile N. of Thimble Shoal Channel (36° 59′.9 N., 76° 09′.2 W.).	Oct. 10–11, 1918	1	Pole		2.60	5.25	256	0.80	6.02	2.20	6.00	127	0.85	6.40	0.83
A93	Thimble Shoal Channel (36° 59′.3 N., 76° 09′.9.W.)	July 27–28, 1928	1	do	7	3.68	6.38	261	1.02	5.00	2.26	7.06	121	1.02	7.42	1.66
				Meter	6½	3.68	6.23		1.18	4.70	1.96	6.56		1.28	7.72	1.43
				do	16½	3.63	6.28		1.03	5.20	2.41	6.86		0.78	7.22	1.62
				do	26½	3.13	6.43		0.89	5.95	2.66	7.06		0.79	6.47	1.64
Ay6	3¾ miles E. of Old Point Comfort Light (37° 00′.2 N., 76° 13′.7 W.).	Sept. 25–26, 1854	¾	Float	(3)	3.40	5.52	276	0.85	3.72	0.70	5.12	98	1.65	8.70	0.50
Ly4	2½ miles E. of Old Point Comfort Light (37° 00′.1 N., 76° 15′.2 W.).	Sept. 12–13, 1918	1	Pole		4.00	5.55	298	0.84	3.02	0.60	6.05	88	1.84	9.40	0.87
Ly11	6 miles southwestward of Fisherman I. (37° 02′.2 N., 76° 04′.5 W.).	Oct. 30–31, 1918	1	do		3.25	5.75	310	0.88	4.92	1.75	5.30	96	1.33	7.50	0.83
Ay5	5¼ miles E. of Back River Light (37° 05′.1 N., 76° 09′.7 W.).	Sept. 26–27, 1854	¾	Float	(3)	4.30	8.02	340	1.55	7.49	5.37	7.07	144	0.95	4.93	3.01
Ly1	⅞ mile W. of Fisherman I. (37° 05′.9 N., 75° 59′.8 W.).	July 25–26, 1918	½	Pole		2.10				6.32	2.00	4.80	156	2.46	6.10	0.34
E3	5½ miles S. 36° W. of Old Plantation Flats Light (37° 09′.2 N., 76° 06′.9 W.).	Aug. 6, 9, 10, 1909	1	do	8½	3.62	7.09	0	0.91	5.97	3.17	6.83	180	0.94	6.45	2.00
Ly5	3⅜ miles S. 19° E. of York Spit Light (37° 09′.4 N., 76° 13′.9 W.).	Sept. 30–Oct. 1, 1918	1	do		3.00	7.20	346	0.32	6.82	3.40	6.30	173	0.97	5.60	1.80
E2	4½ miles S. 43° W. of Old Plantation Flats Light (37° 10′.5 N., 76° 06′.7 W.).	Aug. 18, 19, 23, 1909	1	do		4.75	7.05	16	0.61	5.12	3.45	7.90	169	0.71	7.30	2.61
Ay4	2½ miles S. 46° E. of York Spit Light (37° 10′.9 N., 76°13′.0 W.).	Oct. 7, 1854	½	Float	(3)	2.47	6.25	327	0.60	6.10	2.15	5.15	149	0.60	6.32	0.82
E1	4 miles S. 49° W. of Old Plantation Flats Light (37° 11′.0 N., 76° 06′.6 W.).	May–July, 1909	1½	Pole	5½, 8½	4.20	7.09	7	0.80	5.70	3.48	6.87	176	1.12	6.72	2.23
Ay3	4¼ miles S. 75° E. of York Spit Light (37° 11′.5 N., 76° 10′.1 W.).	Oct. 8, 1854	½	Float	(3)	3.40	7.17	13	0.76	6.17	3.15	5.90	170	0.76	6.25	1.72
Sn1	York Spit Channel (37° 12′.9 N., 76° 08′.5 W.).	Oct. 31–Nov. 1, 1929	1	Pole	7	4.48	7.28	8	0.82	5.60	3.66	7.21	195	1.07	6.82	2.48
Ly3	3¼ miles S. 84° W. of Old Plantation Flats Light (37° 13′.3 N., 76° 07′.7 W.).	Sept. 10–11, 1918	1	do		4.80	7.20		0.16	5.12	3.50	7.75	183	1.31	7.30	2.63
A100	⅝ mile S. 89° W. of Old Plantation Flats Light (37° 13′.7 N., 76° 03′.6 W.).	Oct. 16–18, 1928	1	do	7	4.08	6.78	355	0.61	4.70	2.36	6.66	158	1.36	7.72	1.79
				Meter	16	4.08	6.88		0.89	5.40	3.06	7.01		1.34	7.02	2.08
				do	40	3.33	6.68		1.36	6.15	3.06	6.21		1.11	6.27	1.64
				do	64	3.03	6.43		1.63	6.85	3.46	6.56		0.73	5.57	1.69
Ly6	⅝ mile S. 85° E. of Old Plantation Flats Light (37° 13′.7 N., 76° 02′.0 W.).	Oct. 1–2, 1918	1	Pole		2.80	6.25	350	0.63	6.57	2.95	5.90	173	0.43	5.85	1.30
Y1	1¾ miles N. 50° W. of Old Plantation Flats Light (37° 14′.9 N., 76° 04′.6 W.).	Sept. 28–29, 1899	1			4.58	6.92	356	1.60	5.59	3.75	7.17	170	1.70	6.83	2.42
La5	2½ miles S. 56° E. of Tue Marshes Light (37° 12′.8 N., 76° 20′.6 W.).	Sept. 5–7, 1918	2	Pole		0.60	4.07	263	0.56	6.94	1.12	3.60	122	0.49	5.48	11.59
La4	3¼ miles S. 82° E. of Tue Marshes Light (37° 13′.7 N., 76° 19′.0 W.).	Sept. 5–7, 1918	2	do		1.73	4.43	271	0.98	6.34	1.65	4.88	116	1.03	6.08	12.41
A99	1¾ miles N. 78° W. of York Spit Light (37° 12′.9 N., 76° 17′.4 W.).	Aug. 16–17, 1928	1	Pole	7	1.83	4.88	309	0.98	6.55	1.96	5.11	104	0.88	5.87	0.26
				Meter	8	1.98	4.98		1.16	6.45	2.01	5.26		0.91	5.97	0.38
				do	20	1.93	4.88		0.99	6.45	1.96	5.26		0.84	5.97	0.33
				do	32	1.83	4.88		0.84	6.75	2.16	5.26		0.54	5.67	0.35
La6	1¾ miles S. 31° W. of New Pt. Comfort Light (37° 16′.5 N., 76° 17′.9 W.).	Sept. 5–7, 1918	2	Pole		1.12	4.17	340	0.75	6.03	0.73	3.58	133	0.90	6.39	11.64
Ly2	1½ miles S. 21° W. of New Pt. Comfort Light (37° 16′.7 N., 76° 17′.3 W.).	Aug. 27–28, 1918	1	do		0.00	3.25	301	0.46	6.67	0.25	3.40	144	0.46	5.75	10.96
A66	1¾ miles S. 75° W. of New Pt. Comfort Light (37° 17′.6 N., 76° 18′.8 W.).	July 25–27, 1928	1½	do	7	0.61	4.08	327	0.99	6.97	1.06	3.76	116	0.71	5.45	11.61
				Meter	6	0.78	3.98		1.05	6.60	0.96	3.86		0.78	5.82	11.64
				do	13	1.23	3.58		0.48	4.65	−0.54	3.26		0.68	7.77	11.12
				do	20	0.73	3.28		0.27	5.05	−0.64	3.31		0.52	7.37	10.91
A64	5¾ miles S. 87° E. of Wolf Trap Light (37° 23′.1 N., 76° 04′.3 W.).	July 16–Aug. 21, 1928	6	Pole	7	5.36	8.05	15	0.85	5.55	4.49	8.02	174	1.28	6.87	3.30
			6	Meter	8, 10, 12	5.30	8.16		0.99	5.66	4.54	8.09		1.40	6.76	3.34
			2	do	20, 25	5.28	8.63		1.33	5.77	4.63	7.69		1.55	6.65	3.38
			5	do	30, 32	4.57	7.65		1.26	6.67	4.82	7.78		0.96	5.75	3.02
			1	do	40	4.58	7.98		0.65	6.00	4.16	7.16		0.55	6.42	2.79
			4	do	48	4.43	7.62		1.06	6.48	4.49	7.53		0.75	5.94	2.84
Ly9	3½ miles S. 88° E. of Wolf Trap Light (37° 23′.3 N., 76° 07′.0 W.).	Oct. 15–17, 1918	1½	Pole		5.07	7.70	20	0.80	5.75	4.40	7.80	169	1.17	6.67	3.06

[3] Surface.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations: Date	Observations: Period	Observations: Method	Observations: Depth	Slack after LW	Flood strength: Time after LW	Flood strength: Direction (true)	Flood strength: Velocity	Flood duration	Slack after HW	Ebb strength: Time after HW	Ebb strength: Direction (true)	Ebb strength: Velocity	Ebb duration	Mean current hour
	(2) *Chesapeake Bay*—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
A63	½ mile W. of Wolf Trap Light (37° 23′.4 N., 76° 11′ .9 W.).	July 17–Aug. 21, 1928	1½	Pole	7	4.70	7.41	16	0.96	5.44	3.72	7.46	188	1.24	6.98	2.64
				Meter	5	4.70	7.45		1.08	5.38	3.66	7.26		1.38	7.04	2.59
				do	12	4.60	7.38		0.98	5.55	3.73	7.26		1.38	6.87	2.56
				do	20	4.66	7.31		0.73	5.45	3.69	7.56		1.20	6.97	2.62
Ay2	1⅛ miles N. 77° E. of Wolf Trap Light (37° 23′.7 N., 76° 10′.0 W.).	Nov. 16–19, 1851	2½			7.00	9.25	1	0.50	4.59	5.17	9.00	180	1.10	7.83	4.42
A65	Off Mattawoman Creek (37° 23′.9 N., 76° 01′.0 W.).	Aug. 19–21, 1928	1	Pole	7	4.58	7.98	14	0.89	6.45	4.61				5.97	3.02
				Meter	6	4.48	7.83		0.94	6.55	4.61				5.87	2.94
				do	15	4.48	7.58		0.89	6.60	4.66				5.82	2.87
				do	25	4.38	7.53		0.84	6.50	4.46				5.92	2.74
A62	Off Bland Point, Piankatank R. (37° 31′.8 N., 76° 21′.9 W.).	July 18–19, 1928	1	Pole	7	3.13	5.78	299	0.39	5.45	2.16	6.06	124	0.24	6.97	1.10
				Meter	6	3.33	5.53		0.38	3.95	1.86	6.06		0.33	7.47	1.02
				do	15	2.83	5.48		0.43	5.57	1.96	5.56		0.23	6.85	0.78
				do	24	1.93	5.33		0.43	6.65	2.16	5.46		0.23	5.77	0.04
FC6	Off Occohannock Creek (37° 33′.8 N., 76° 02′.3 W.).	Nov. 9–10, 1920	1	Eckman meter.	16	4.90	8.05	28	1.02	6.32	4.80	8.90	174	0.82	6.10	3.48
				do	33	4.75	8.05	25	1.01	6.22	4.55	8.30	186	0.71	6.20	3.23
				do	48	4.30	6.95	17	0.53	5.67	3.55	7.60	197	0.68	6.75	2.42
Ay1	2⅝ miles S. 63° E. of Windmill Pt. Light (37° 34′.7 N., 76° 11′.3 W.).	Nov. 20–23, 1851	3			6.67	8.92	20	0.44	4.67	4.92	8.25	159	0.94	7.75	4.01
L19	3⅛ miles N. 72° E. of Windmill Pt. Light (37° 36′.8 N., 76° 10′.5 W.).	Nov. 5–6, 1850	1			6.17	9.37	349	0.52	6.62	6.37	9.42	158	0.67	5.80	4.65
A101	4⅝ miles S. 2° E. of Tangier Sound Light (37° 42′.6 N., 75° 58′.2 W.).	Aug. 21–22, 1928	1	Pole	7	5.55	8.35	14	1.02	6.15	5.28	8.28	220	0.57	6.27	3.68
				Meter	9	5.45	8.10		1.21	5.80	4.83	8.08		1.01	6.62	3.44
				do	22½	5.05	7.70		1.38	6.05	4.68	7.93		0.98	6.37	3.16
				do	36	3.95	7.45		1.39	6.95	4.48	7.28		0.92	5.47	2.61
A53	E. of Sandy Point, Great Wicomico R. (37° 49′.3 N., 76° 18′.0 W.).	July 16–17, 1928	½	Pole	7	3.98				5.50	3.06	6.96	140	0.33	6.92	2.04
				Meter	5	3.98				5.50	3.06	6.86		0.33	6.92	2.00
				do	12	3.58				5.90	3.06	6.66		0.33	6.52	1.80
				do	19	3.38				6.10	3.06	6.46		0.33	6.32	1.67
A38	6 miles N. 2° W. of Smith Pt. Light (37° 58′.9 N., 76° 11′.4 W.).	July 4–5, 1928	1	Pole	7	7.65	10.00	350	0.30	4.90	6.13	9.93	135	0.95	7.52	5.25
				Meter	11	7.55	10.15		0.50	5.20	6.33	9.83		1.05	7.22	5.28
				do	28	7.35	9.95		0.60	5.30	6.23	9.58		0.80	7.12	5.10
				do	44	6.95	9.80		0.75	6.05	6.58	9.53		0.65	6.37	5.04
L18	4⅝ miles W. of Smith I. (37° 59′.4 N., 76° 09′.0 W.).	Aug. 30–31, 1849	1		(3)	6.82	10.37	3	0.51	7.22	7.62	10.02	164	0.51	5.20	5.53
L17	2¼ miles S. 37° E. of Pt. Lookout Light (38° 00′.5 N., 76° 17′.6 W.).	June 25–26, 1849	1		(3)	7.77	10.72	329	0.57	4.87	6.22	9.92	150	0.62	7.55	5.48
FC5	3¾ miles S. 70° E. of Point No Point Light (38° 06′.4 N., 76° 13′.0 W.).	Jan. 25–26, 1921	1	Eckman meter.	0	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
				do	33											
				do	66											
				do	98											
				do	112											
FC4	3⅝ miles S. 73° E. of Point No Point Light (38° 06′.6 N., 76° 13′.1 W.).	1920–1922	5½	do	0	7.92	10.80	8	0.43	6.02	7.52	10.43	161	0.48	6.40	5.99
			4	do	33	7.61	10.34	6	0.47	6.06	7.25	10.46	169	0.51	6.36	5.74
			3	do	66	6.90	9.93	359	0.50	6.02	6.50	10.02	176	0.81	6.40	5.16
			2	do	98	6.57	10.19	346	0.46	6.42	6.57	10.50	155	0.70	6.00	5.28
			2	do	124	7.59	10.69	333	0.56	5.97	7.14	10.24	166	0.59	6.45	5.74
FC3	3 miles S. 76° E. of Point No Point Light (38° 07′.0 N., 76° 13′.7 W.).	Mar. 30–31, 1921	1	do	0	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
				do	33											
				do	79											
A39	1 mile N. 4° W. of Point No Point Light (38° 08′.6 N., 76° 17′.5 W.).	July 4, Aug. 24, 1928	1	Pole	7	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
				Meter	8, 9											
				do	20, 22											
				do	32, 35											
A40	3 miles N. 63° E. of Point No Point Light (38° 09′.1 N., 76° 14′.0 W.).	July 4–Aug. 25, 1928	2½	Pole	7	8.38	11.50	354	0.42	6.38	8.34	11.50	151	0.56	6.04	6.75
		Aug. 24–25, 1928	1	Meter	22	7.88	12.88		0.79	6.95	8.41	12.06		0.59	5.47	6.98
		do	1	do	55	6.78	12.18		1.00	8.55	8.91	12.21		0.50	3.87	6.84
		do	1	do	88	5.98	11.48		0.78	9.70	9.26	12.16		0.43	2.72	6.54
L16	2⅜ miles N. 22° E. of Point No Point Light (38° 09′.9 N., 76° 16′.3. W.).	Aug. 26–27, 1849	1		(3)	8.67	12.07	338	0.42	7.47	8.72	11.62	141	0.52	4.95	7.09
A41	4½ miles S. 40° W. of Hooper Strait Light (38° 10′.2 N., 76° 08′.2 W.).	July 4–5, Aug. 24–25, 1928.	1	Pole	7	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
				Meter	5											
				do	12½, 13½											
				do	20, 21½											
L15	1⅛ miles S. 71° W. of Hooper Strait Light (38° 13′.2 N., 76° 05′.8 W.).	Sept. 30–Oct. 1, 1849	1		8	6.22	8.72	43	0.40	4.72	4.52	8.42	225	0.50	7.70	3.79
L14	2⅞ miles N. 62° W. of Hooper I. Light (38° 16′.7 N., 76° 18′.2 W.).	Oct. 8–9, 1849	1		8	8.02	12.22	354	0.61	9.32	10.92	12.07	141	0.31	3.10	7.63
Wk2	1⅛ miles off Barren I. (38° 19′.0 N., 76° 17′.1 W.).	Sept. 4–5, 1900	½		4¾		11.82	341	0.87		9.22	11.52	139	0.47		7.19
Wk1	1½ miles off Barren I. (38° 19′.5 N., 76° 17′.6 W.).	Sept. 5–6, 1900	½		4¾	6.22	11.42	345	1.30	9.72	9.52		151	0.30	2.70	6.35
Fa3	3⅞ miles E. of Drum Pt. Light (38° 19′.1 N., 76° 20′.4 W.).	Oct. 28–Nov. 11, 1897	14	Pole	6	8.99	12.07	358	0.52	6.43	9.00	12.00	159	0.47	5.99	7.34
L13	1½ miles N. 84° E. of Drum Pt. Light (38° 19′.3 N., 76° 23′.5 W.).	Oct. 4–5, 1849	1		8	8.12	10.42	251	0.28	4.67	6.37	10.12	80	0.53	7.75	5.58
L12	2 miles S. 84° E. of Cove Pt. Light (38° 23′.0 N., 76° 20′.4 W.).	Oct. 12–13, 1849	1		8	10.87	0.55	349	0.22	4.17	8.62	0.25	186	0.87	8.25	8.10
H74	3⅜ miles N. 86° W. of Cove Pt. Light (38° 23′.4 N., 76° 18′.6 W.).	Sept. 14–16, 1927	1½	Pole	7	8.70	11.37	8	0.23	6.10	8.38	0.06	160	0.78	6.32	7.06
			¼	Meter	5	8.30	11.50		0.49							6.61
			1½	do	11, 12½	8.60	11.30		0.30	6.15	8.33	0.06		0.73	6.27	7.05
			1½	do	17½, 20	7.85	11.20		0.36	6.90	8.33	11.43		0.48	5.52	6.52

[3] Surface.

[4] Current irregular.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(2) *Chesapeake Bay*—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
H73	1⅞ miles N. 88° E. of Cove Pt., Light (38° 23′.2 N., 76° 20′.5 W.).	Sept. 2-15, 1927	8	Pole	7	8.79	12.03	348	0.56	6.51	8.88	11.93	163	0.78	5.91	7.23
				Meter	15, 16, 17	8.81	12.01		0.54	6.49	8.88	11.97		0.77	5.93	7.24
				do	38, 39, 43	8.46	12.12		0.81	7.11	9.15	12.01		0.73	5.31	7.26
				do	60, 63, 69	8.26	11.66		0.65	6.85	8.69	11.62		0.65	5.57	6.88
H72	⅝ mile N. 78° E. of Cove Pt. Light (38° 23′.3 N., 76° 22′.2 W.).	Sept. 15-16, 1927	1	Pole	7	8.25	11.80	355	0.68	6.80	8.63	11.98	139	1.08	5.62	6.98
				Meter	10	8.20	11.60		0.87	7.00	8.78	11.98		1.07	5.42	6.96
				do	24	8.05	11.40		0.84	6.95	8.58	11.83		0.84	5.47	6.78
				do	38	8.10	11.20		0.60	6.30	7.98	11.18		0.90	6.12	6.44
Fa2	3⅞ miles W. of James I. (38° 31′.1 N., 76° 25′.8 W.).	Oct. 4-19, 1897	14¾	Pole	6	9.03	0.24	352	0.35	7.19	9.80	0.21	162	0.48	5.23	7.85
H70	1 mile S. 43° W. of Hills Pt. Little Choptank River entrance (38° 33′.0 N., 76° 19′.6 W.).	Sept. 13-14, 1927	1	do	7	7.55	10.75	101	0.35	6.50	7.63	10.48	267	0.30	5.92	5.92
				Meter	7	7.30	10.75		0.39	6.85	7.73	10.28		0.29	5.57	5.84
				do	17	7.20	10.25		0.30	6.80	7.58	10.28		0.30	5.62	5.65
				do	27	7.25	10.50		0.17	6.75	7.48	10.18		0.32	5.77	5.67
M4	1¾ miles S. 60° E. of Sharps I. (38° 36′.2 N., 76° 19′.8 W.).	July 25, 1848	½		(3)	7.62	10.12	26	0.82			9.52	228	0.92		5.35
H63	1⅜ miles N. 33° W. of Cooks Point, Choptank River (38° 39′.1 N., 76° 18′.5 W.).	Sept. 9-10, 1927	1	Pole	7	8.10	11.10	50	0.70	6.20	7.88	11.38	238	0.60	6.22	6.44
				Meter	12	8.15	11.05		0.69	6.10	7.83	11.38		0.69	6.32	6.42
				do	30	7.65	10.65		0.75	6.15	7.38	10.48		0.50	6.27	5.86
				do	48	6.05	9.65		0.85	7.05	6.68	9.43		0.40	5.37	4.77
L11	3½ miles N. 87° E. of North Chesapeake Beach (38° 42′.5 N., 76° 27′.5 W.).	Oct. 20-21, 1849	1		8	11.72	2.20	6	0.47	5.02	10.32	1.95	197	0.57	7.40	9.58
T7	3⅞ miles N. 51° E. of North Chesapeake Beach (38° 44′.8 N., 76° 28′.0 W.).	Aug. 16-28, 1897	13	Pole	6	10.51	1.73	6	0.43	7.23	11.32	1.89	184	0.48	5.19	9.39
H62	½ mile off Great Marsh Pt. (38° 44′.9 N., 76° 21′.2 W.).	Sept. 6-7, 1927	1	do	4½	9.00	0.38	1	1.01	7.70	10.28	12.13	170	0.61	4.72	7.87
				Meter	7½	9.20	0.28		0.91	7.40	10.18	11.93		0.66	5.02	7.82
				do	12	9.05	0.03		0.79	6.90	9.53	11.78		0.54	5.52	7.52
L10	3⅜ miles S. 47° W. of Bloody Pt. Bar Light (38° 47′.8 N., 76° 26′.7 W.)	Oct. 18-19, 1849	1		8	11.67	2.15	34	0.31	5.27	10.52	2.05	197	0.46	7.15	9.63
H57	1⅞ miles S. 22° E. of Bloody Pt. Bar Light (38° 48′.3 N., 76° 22′.6 W.).	Sept. 2-3, 1927	1	Pole	7	10.65	1.23	30	0.40	5.25	9.48	1.76	187	0.50	7.17	8.81
				Meter	8	10.70	1.18		0.40	5.20	9.48	1.16		0.50	7.22	8.66
				do	20	10.80	1.28		0.41	5.05	9.43	0.86		0.61	7.37	8.62
				do	32	10.85	1.98		0.40	5.75	10.18	2.06		0.50	6.67	9.30
H56	¾ mile N. 27° W. of Bloody Pt. Bar Light (38° 50′.7 N., 76° 24′.0 W.).	Aug. 10-11, 1927	1	do	7	11.70	2.13	16	0.77	6.10	11.38	1.91	199	0.87	6.32	9.81
				Meter	9	11.55	1.98		0.72	6.35	11.48	1.91		0.67	6.07	9.76
				do	22	10.85	1.48		0.77	6.95	11.38	1.76		0.57	5.47	9.40
				do	35	9.70	1.13		1.17	8.05	11.33	1.71		0.52	4.37	9.00
H55	1¾ miles N. 65° W. of Bloody Pt. Bar Light (38° 50′.8 N., 76° 25′.6 W.).	Aug. 8-Sept. 2, 1927	11	Pole	7	12.01	2.19	14	0.49	5.49	11.08	1.91	192	0.81	6.93	9.83
				Meter	7½, 8, 8½	11.52	1.48		0.49	6.07	11.17	2.02		0.77	6.35	9.58
				do	19, 20, 21	11.49	2.18		0.61	6.28	11.35	2.02		0.67	6.14	9.79
				do	30½, 32, 33½	11.40	2.26		0.66	6.38	11.36	1.92		0.67	6.04	9.76
H54	3⅜ miles N. 80° W. of Bloody Pt. Bar Light (38° 50′.6 N., 76° 27′.7 W.).	Aug. 9-10, 1927	1	Pole	7	11.70	2.28	345	0.06	4.00	9.28	1.46	198	0.86	8.42	9.21
				Meter	4	11.50	2.27		0.16	4.30	9.38	1.36		0.71	8.12	9.16
				do	9	11.70	2.08		0.16	3.80	9.08	1.36		0.76	8.62	9.08
				do	14	11.20	1.98		0.21	4.60	9.38	1.21		0.61	7.82	8.97
H53	Off Cheston Point, West River (38° 51′.4 N., 76° 31′.2 W.).	Aug. 8-9, 1927	½	Pole	4½		11.20	279	0.23		7.28	11.28	111	0.13		6.26
				Meter	6½		11.70		0.35		7.68	11.28		0.25		6.56
				do	10		11.50		0.24		7.28	11.18		0.24		6.33
Fa1	1⅝ miles S. 28° E. of Thomas Pt. Shoal Light (38° 52′.5 N., 76° 25′.2 W.).	Sept. 2-Oct. 1, 1897	26	Pole	6	12.01	0.82	14	0.49	5.56	11.15	2.25	194	0.79	6.86	9.59
L8	1⅜ miles S. 50° E. of Thomas Pt. Shoal Light (38° 53′.1 N., 76°24′.9 W.).	Oct. 17-18, 1849	1		8	0.70	2.10	31	0.23	3.67	10.37	2.55	201	0.68	8.75	10.06
H51	Mid-channel, off Marshy Point, South River (38° 54′.3 N., 76° 28′.8 W.).	Aug. 11-12, 1927	1	Pole	7	9.45	0.08	347	0.09	5.15	8.18	12.13	156	0.09	7.27	7.38
				Meter	9	9.95	0.18		0.18	4.40	7.93	0.01		0.18	8.02	7.55
				do	14	9.00	12.40		0.17	7.79	7.63	11.28		0.22	7.37	6.90
H50	3 miles N. 49° E. of Thomas Pt. Shoal Light (38° 55′.9 N., 76° 23′.4 W.).	Aug. 22-23, 1927	1	Pole	7	10.30	2.03	2	0.50	7.40	11.28	1.41	198	0.85	5.02	9.28
				Meter	23	11.55	1.98		0.95	6.45	11.58	1.91		0.85	5.97	9.78
				do	57	11.60	2.23		0.95	6.50	11.68	1.96		0.85	5.92	9.90
				do	92	11.15	1.73		1.15	6.75	11.48	1.96		0.65	5.67	9.61
T6	3⅛ miles N. 37° E. of Thomas Pt. Shoal Light (38° 56′.4 N., 76° 23′.8 W.).	July 28-Aug. 12, 1897	15	Pole	6	11.87	2.31	26	0.53	5.55	11.00	2.12	202	0.90	6.87	9.86
Bc6	2¾ miles S. 66° E. of Greenbury Pt. Shoal Light (38° 57′.0 N., 76° 24′.1 W.).	July 14-16, 1845	2					344	0.72	5.86			202	0.87	6.56	
H47	¾ mile S. 35° E. of Greenbury Pt. Shoal Light (38° 57′.4 N., 76° 26′.7 W.).	Aug. 23-24, 1927	1	Pole	7	10.00	0.83	344	0.36	4.40	7.98	12.28	183	0.41	8.02	7.70
				Meter	5	10.15	1.38		0.51	4.95	8.68	0.26		0.51	7.47	8.15
				do	10½	10.05	1.23		0.51	4.85	8.48	0.06		0.51	7.57	7.98
				do	17	10.10	1.18		0.41	4.70	8.38	12.28		0.51	7.72	7.91
Fg1	⅝ mile S. 30° E. of Greenbury Pt. Shoal Light (38° 57′.5 N., 76° 26′.9 W.).	June 14, 1910	½	Pole		8.72	1.40	329	0.61	7.82	10.12	0.10	163	0.41	4.60	8.12
T5	1 mile S. 70° E. of Sandy Pt. Light (39° 00′.6 N., 76° 21′.9 W.).	Dec. 5-8, 1896	3	do	7½	12.20	2.54	11	0.78	5.84	11.62	2.57	180	0.83	6.58	10.26
T4	⅞ mile S. 81° E. of Sandy Pt. Light (39° 00′.8 N., 76° 22′.0 W.).	June 22-July 22, 1897	27½	do	6	11.93	2.57	9	0.80	6.41	11.92	2.72	192	0.82	6.01	10.32
Bc5	1¼ miles S. 88° E. of Sandy Pt. Light (39° 00′.9 N., 76° 21′.6 W.).	July 17-19, 1845	1½					19	0.69	6.18			176	0.73	6.24	

[3] Surface.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations: Date	Period	Method	Depth	Slack after LW	Flood strength: Time after LW	Direction (true)	Velocity	Flood duration	Slack after HW	Ebb strength: Time after HW	Direction (true)	Velocity	Ebb duration	Mean current hour
	(2) Chesapeake Bay—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
H42	1¼ miles N. 86° E. of Sandy Pt. Light (39° 01′.0 N., 76° 21′.6 W.).	Aug. 24–25, 1927	1	Pole	7	0.03	3.38	1	0.23	5.65	11.68	1.96	176	0.93	6.77	10.40
				Meter	11½	12.20	2.48		0.77	5.55	11.33	1.96		0.97	6.87	9.77
				do	28½	10.80	2.38		1.22	7.40	11.78	1.86		0.62	5.02	9.74
				do	45½	10.60	2.33		1.03	8.20	12.38	2.11		0.48	4.22	9.88
H41	Off Mountain Pt., Magothy River entrance (39° 03′.4 N., 76° 26′.1 W.).	Sept. 1–2, 1927	1	Pole	7	10.05	0.98	313	0.70	6.80	10.43	0.86	115	0.50	5.62	8.61
				Meter	10	9.85	0.93		0.70	6.95	10.38	0.96		0.50	5.47	8.56
				do	16	9.50	1.18		0.75	7.85	10.93	0.96		0.45	4.57	8.67
Bc4	2 miles E. of Gibson I. (39° 04′.6 N., 76° 22′.8 W.).	Aug. 21–23, 1845	1½					345	0.70	5.12			189	0.63	7.31	
H40	2⅜ miles N. 34° E. of Love Pt. Light (39° 05′.4 N., 76° 15′.3 W.).	Aug. 3–4, 1927	1	Pole	7	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
				Meter	7½											
				do	12											
H39	2¼ miles N., 27° W. of Love Pt. Light (39° 05′.4 N., 76° 18′.3 W.).	July 25–Aug. 20, 1927	11	Pole	7	11.70	2.26	30	0.55	6.53	11.81	2.58	193	0.51	5.89	10.12
				Meter	7½, 8	11.67	2.26		0.55	6.40	11.65	2.55		0.55	6.02	10.06
				do	19	11.82	2.79		0.69	6.63	12.03	2.71		0.32	5.79	10.37
				do	30	12.36	2.91		0.58	6.03	11.97	2.84		0.36	6.39	10.55
H38	Craighill Channel (39° 05′.5 N., 76° 23′.6 W.).	Aug. 3–4, 1927	1	Pole	7	12.20	2.73	356	0.81	6.00	11.78	2.86	182	0.86	6.42	10.42
				Meter	7	12.10	2.83		0.82	6.15	11.83	2.86		0.97	6.27	10.44
				do	17½	12.25	2.93		0.66	6.65	0.06	3.36		0.51	5.77	10.78
				do	28	11.10	2.18		0.68	7.30	11.98	2.06		0.18	5.12	9.86
Bc2	Off Patapsco River entrance (39° 08′.1 N., 76° 22′.5 W.).	July 9–12, 1845	2					325	0.55	5.76			183	0.65	6.66	
Bc3	Off Patapsco River entrance (39° 08′.2 N., 76° 19′.8 W.).	Aug. 4–6, 1845	2					356	0.76	6.48			194	0.82	5.94	
FC2	Off Patapsco River entrance (39° 08′.4 N., 76° 20′.0 W.).	Mar. 6–Dec. 11, 1920	6	Eckman meter.	(3)	0.78	3.24	39	0.51	5.44	12.22	3.50	136	0.74	6.98	11.07
		Jan. 27–Mar. 27, 1921	6	do	16	12.16	2.76	11	0.78	6.79	0.11	3.51	150	0.64	5.63	10.77
		Mar. 29–June 4, 1922	5	do	36	11.11	2.05	11	0.73	7.33	12.02	2.35	181	0.47	5.09	9.91
FC1	Off Patapsco River entrance (39° 09′.0 N., 76° 23′.0 W.).	Oct. 15–16, 1920	1	do	(3)	12.12	3.70	39	0.87	7.32	0.60	3.55	231	0.57	5.10	11.13
				do	16	12.12	3.50	39	0.77	7.17	0.45	3.55	236	0.72	5.25	11.04
				do	38	11.42	3.00	28	0.77	7.22	12.22	2.70	194	0.62	5.20	10.36
T3	Off Patapsco River entrance (39° 09′.2 N., 76° 21′.1 W.).	June 11, 1897	½	Pole	6	1.80	3.80	13	0.36	4.02	11.82	3.60	196	0.96	8.40	11.39
T2	Off Patapsco River entrance (39° 09′.3 N., 76° 19′.8 W.).	May 17–June 16, 1897	29¼	do	6	0.78	3.36	3	0.52	5.23	12.01	3.15	199	0.80	7.19	10.96
Wb7	Off Patapsco River entrance (39° 10′.1 N., 76° 23′.8 W.).	June 7–25, 1867	14		(3)	12.03	3.05	355	0.62	6.68	12.29	2.70	171	0.49	5.74	10.55
Bc1	Off Patapsco River entrance (39° 10′.3 N., 76° 21′.5 W.).	Sept. 17, 19, 1845	1½					31	0.59	6.31			202	0.59	5.11	
Wb8	Off Patapsco River entrance (39° 11′.3 N., 76° 24′.0 W.).	June 4, 1867	½		(3)	12.22	2.60	6	0.37	6.22	12.02	1.80	212	0.77	6.20	10.19
Wb9	Off Patapsco River entrance (39° 11′.5 N., 76° 25′.2 W.).	May 27, 1867	½		(3)	3.20	5.60	24	0.24	5.12	1.90				7.30	0.87
T1	Off Patapsco River entrance (39° 12′.5 N., 76° 24′.4 W.).	Apr. 28–May 7, 1897	7	Pole	4	0.26	3.16	30	0.24	5.78	12.04	.99	219	0.32	6.64	10.75
H27	½ mile off Tolchester Beach (39° 13′.1 N., 76° 15′.2 W.).	July 8–9, 1927	1	do	7	1.21	3.78	19	0.81	5.32	0.11	2.91	218	0.81	7.10	11.24
				Meter	5	1.28	3.88		0.69	5.15	0.01	3.46		0.79	7.27	11.40
				do	11	1.08	3.58		0.80	5.30	12.38	2.56		0.75	7.12	11.04
				do	18	1.21	3.28		0.54	5.07	12.28	3.26		0.54	7.35	11.14
H26	3½ miles S. 45° W. of Pooles I. (39° 14′.0 N., 76° 19′.6 W.).	July 11–12, 1927	1	Pole	7	0.53	3.23	32	0.83	5.55	12.08	2.86	230	0.78	6.87	10.81
				Meter	5	0.58	3.38		0.72	5.30	11.88	2.81		0.77	7.12	10.80
				do	11	0.73	3.18		0.77	5.40	12.13	2.91		0.72	7.02	10.88
				do	18	0.53	2.78		0.65	5.85	12.38	3.28		0.40	6.57	10.88
H28	Off Lynch Point, Back River (39° 15′.0 N., 76° 26.3 W.).	Aug. 4–5, 1927	1¼	Pole	5	11.94	2.21	311	0.55	6.11	11.63	2.56	131	0.37	6.31	10.12
				Meter	5	11.94	2.01		0.43	6.06	11.58	2.51		0.35	6.36	10.04
				do	8	11.90	1.91		0.40	6.20	11.68	2.51		0.40	6.22	10.03
H24	1½ miles SE. of Pooles I. (39° 15′.9 N., 76° 14′.3 W.).	Aug. 17, 1927	½	Pole	7	0.58	3.08	32	0.83	5.70	12.28	3.76	201	1.23	6.72	11.06
				Meter	6	0.68	3.18		0.93	5.70	12.38	3.86		1.23	6.72	11.14
				do	14	0.58	3.08		1.11	5.90	0.06	3.46		1.21	6.52	11.04
				do	22	0.18	2.98		1.03	6.50	0.26	3.26		1.13	5.92	10.91
L7	1⅛ miles SE. of Pooles I. (39° 16′.7 N., 76° 14′.3 W.).	June 11–12, 1846	2					34	0.44	4.14			228	1.12	8.28	
H23	⅜ mile SE. of Pooles I. (39° 16′.8 N., 76° 15′.3 W.).	Aug. 16–17, 1927	1	Pole	7	12.25	2.98	24	1.32	6.65	0.06	3.06	201	0.97	5.77	10.72
				Meter	8	12.30	2.98		1.04	6.55	0.01	2.96		0.79	5.87	10.70
				do	19	12.20	2.73		1.00	6.65	0.01	2.66		0.80	5.77	10.54
				do	30	12.15	2.53		0.96	6.75	0.06	2.61		0.71	5.67	10.47
H22	¼ mile NW. of Pooles I. Light (39° 17′.6 N., 76° 16′.3 W.).	do	½	Pole	4	11.50	2.58	48	0.69	6.60	11.68	2.26	217	0.69	5.82	10.04
				Meter	7	11.70	2.48		0.78	6.50	11.78	2.16		0.68	5.92	10.06
				do	11	11.80	2.38		0.69	6.30	11.68	2.26		0.69	6.12	10.06
H25	Off Carroll Pt. Gunpowder River (39° 18′.5 N., 76° 18′.9 W.).	Aug. 15–16, 1927	1	Pole	7	12.10	2.53	52	0.61	6.30	11.98	2.61	203	0.41	6.12	10.34
				Meter	4	12.15	2.48		0.42	6.30	12.03	2.61		0.37	6.12	10.35
				do	10	12.20	2.78		0.42	6.20	11.98	2.56		0.42	6.22	10.42
				do	16	12.15	2.78		0.42	6.45	12.18	2.71		0.42	5.97	10.48
L6	1 mile W. of Worton Pt. (39° 18′.9 N., 76° 12′.4 W.).	May 25–29, 1846	3½					30	0.96	5.73			209	1.46	6.69	
H20	⅜ mile NW. of Worton Pt. (39° 19′.6 N., 76° 11′.1 W.).	Aug. 18–19, 1927	½	Pole	7	11.80	2.78	56	1.38	7.00	12.38	2.06	208	0.98	5.42	10.28
				Meter	5	11.70	2.88		1.18	7.20	0.06	2.06		0.88	5.22	10.31
				do	12½	11.60	2.68		1.08	7.30	0.06	1.86		0.78	5.12	10.18
				do	20	11.50	2.68		0.88	7.20	12.28	1.86		0.68	5.22	10.06
H19	1 mile NW. of Worton Pt. (39° 20′.1 N., 76° 11′.8 W.).	July 22–Aug. 19, 1927	4	Pole	7	0.89	3.75	45	1.07	5.74	0.21	3.63	228	1.45	6.68	11.36
		July 9–Aug. 19, 1927	11	Meter[5]	6½, 7, 8	1.42	4.33	[6]42	1.21	5.59	0.59	3.86	[6]215	1.42	6.83	11.79
		July 22–Aug. 19, 1927	4	do	16, 18	0.82	3.81		1.07	6.08	0.48	3.54		1.22	6.34	11.40
		July 14–Aug. 19, 1927	5	do[5]	24, 25½, 28	0.87	3.96	[6]38	1.08	6.30	0.75	3.81	[6]216	1.05	6.12	11.59

[3] Surface.
[4] Current irregular.
[5] Part of the observational record obtained with a Pettersson current meter.
[6] Directions from Pettersson current meter only.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(2) *Chesapeake Bay*—Continued															
			Days		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
H18	1⅞ mile NW. of Worton Pt. (39° 20′.7 N., 76° 12′.4 W.).	Aug. 17-18, 1927	½	Pole	4	1.58	3.78	62	0.46	5.40	0.56	3.66	238	0.66	7.02	11.64
				Meter	6½	1.18	3.88		0.56	5.60	0.36	3.26		0.76	6.82	11.41
				do	10	1.18	3.68		0.56	5.60	0.36	3.26		0.76	6.82	11.36
H21	Off Sandy Pt., Bush River (39° 21′.0 N., 76° 14′.8 W.).	Aug. 15-16, 1927	1	Pole	4	0.08	2.38	319	0.58	6.50	0.16				5.92	10.59
				Meter	5	0.03	2.48		0.43	6.55	0.16	2.76		0.23	5.87	10.60
				do	8	12.40	2.38		0.43	6.75	0.31	2.86		0.23	5.67	10.62
L5	1¼ mile SE. of Taylor's I. Pt. (39° 21′.7 N., 76° 09′.6 W.).	June 3-6, 1846	3					44	0.93	5.78			236	1.10	6.64	
H15	1⅜ miles W. of Grove Pt. (39° 23′.4 N., 76° 04′.3 W.).	July 21-22, 1927	½	Pole	7	0.58	3.58	61	0.90	6.10	0.26	3.96	254	0.90	6.32	11.34
				Meter	4	0.48	3.78		0.90	6.80	0.86	4.16		0.80	5.62	11.56
				do	10	0.58	3.68		0.90	6.60	0.76	3.96		0.80	5.82	11.48
				do	16	0.48	3.38		0.80	6.80	0.86	3.86		0.70	5.62	11.64
L4	1¾ miles NW. of Grove Pt. (39° 24′.4 N., 76° 04′.6 W.).	June 22-25, 1846	3					59	0.73	5.74			236	0.81	6.68	
H14	¾ mile S. of Cherry Tree Pt. (39° 24′.6 N., 76° 07′.2 W.).	July 22, 1927	½	Pole	7	0.38	4.28	44	0.57	6.30	0.26	3.36	250	0.67	6.12	11.56
				Meter	8	0.43	3.88		0.57	6.15	0.16	3.36		0.67	6.27	11.20
				do	13	0.48	3.78		0.48	6.00	0.06	3.26		0.68	6.42	11.14
L3	1½ miles SW. of Turkey Pt. (39° 26′.0 N., 76° 02′.1 W.).	June 26-27, 1846	1					48	0.68	6.36			208	0.98	6.06	
H9	⅝ mile NW. of Turkey Pt. Light (39° 27′.3 N., 76° 01′.2 W.).	July 15, 1927	½	Pole	7	1.18	4.48	19	0.64	6.10	0.86	4.56	190	0.64	6.32	12.01
				Meter	4	1.38	4.08		0.63	5.90	0.86	4.86		0.73	6.52	12.04
				do	9	1.28	4.28		0.73	6.00	0.86	4.66		0.63	6.42	12.01
				do	14	1.28	4.18		0.64	5.90	0.76	4.26		0.54	6.52	11.86
H8	1 mile E. of Spesutie I. (39° 27′.2 N., 76° 02′.3 W.).	July 14-15, 1927	1¼	Pole	5½, 7	1.88	4.68	358	0.66	5.63	1.09	3.86	163	0.53	6.79	12.12
				Meter	3	1.88	4.88		0.51	5.77	1.23	3.86		0.56	6.65	12.20
				do	6	1.78	4.73		0.46	5.80	1.16	3.69		0.49	6.62	12.08
				do	9	1.83	4.53		0.66	5.58	0.99	3.43		0.49	6.84	11.94
H7	⅜ mile E. of Spesutie I. (39° 27′.3 N., 76° 03′.3 W.).	July 14, 1927	½	Pole	4½	2.48	4.88	352	0.67	4.70	0.76	3.76	148	0.87	7.72	12.21
				Meter	3	2.48	5.08		0.67	4.60	0.66	3.96		0.87	7.82	12.28
				do	6	2.48	5.08		0.67	4.50	0.56	3.86		0.77	7.92	12.24
				do	9	2.38	5.08		0.67	4.80	0.76	3.76		0.67	7.62	12.24
L2	1¼ miles NW. of Spesutie I. (39° 28′.2 N., 76° 02′.5 W.).	June 27, 1846	1					336	0.73	6.28			169	0.73	6.14	
L1	⅜ mile NE. of Locust pt. Spesutie.I. (39° 28′.8N., 76° 04′.2 W.).	June 30-July 3, 1846	2¼					305	0.80	5.74			140	0.84	6.68	
H6	⅜ mile W. of Rocky Pt. (39° 29′.2 N., 76° 00′.2 W.).	July 15-16, 1927	½	Pole	7	1.93	5.58	31	0.53	5.95	1.46	3.66	190	0.63	6.47	12.40
				Meter	3	2.08	5.38		0.53	5.40	1.06	3.76		0.63	7.02	12.31
				do	7	2.03	5.18		0.53	5.55	1.16	3.56		0.63	6.87	12.22
				do	11	1.93	5.28		0.53	5.55	1.06	3.46		0.63	6.87	12.17
Wb6	Channel near Fishing Battery Light (39° 29′.5 N., 76° 05′.2 W.).	Apr. 19-20, 1867	⅔		(3)	(7)	(7)	(7)	(7)				170	0.81		
H5	Channel near Fishing Battery Light (39° 29.7 N., 76° 05′.3 W.).	July 15-16, 1927	½	Pole	5½	2.68	5.58	357	0.98	5.10	1.36	4.96	168	0.98	7.32	0.46
				Meter	3	2.68	5.48		0.80	5.10	1.36	4.76		0.80	7.32	0.39
				do	6	2.73	5.58		0.79	5.15	1.46	5.06		0.99	7.27	0.53
				do	10	2.73	5.88		0.98	4.95	1.26	5 06		0.98	7.47	0.55
Wb5	1⅛ miles N., 71° E. of Fishing Battery Light (39° 30′.0 N., 76° 03′.7 W.).	July 10-12, 1867	1½		(3)				0.09					0.29		
Wb4	½ mile N. 22° W. of Fishing Battery Light (39° 30′.2 N., 76° 05′.3 W.).	Apr. 23-25, 1867	⅔		(3)	(7)	(7)	(7)	(7)				190	0.85		
Wb3	Channel SE. of Havre de Grace (39° 32′.1 N., 76° 05′.0 W.).	Apr. 16-18, 1867	⅔		(3)	(7)	(7)	(7)	(7)				205	0.74		
Wb2	⅜ mile off Havre de Grace, Susquehanna River (39° 32′.9 N., 76° 05′.0 W.).	July 6-9, 1867	1⅔		(3)			340	0.18				140	0.50		
H1	¼ mile off Havre de Grace, Susquehanna River (39° 32′.9 N., 76° 04′.8 W.).	July 12-13, 1927	1	Pole	7	3.73	5.13	(8)	0.05	2.45	12.18	4.06	150	0.30	9.97	−0.01
				Meter	3	3.98	5.43		0.10	2.40	12.38	4.19		0.37	10.02	0.21
				do	7	3.88	5.38		0.10	2.43	12.31	4.03		0.37	9.99	0.12
				do	11	3.43	5.23		0.15	2.63	12.06	4.03		0.30	9.79	−0.10
Wb1	⅛ mile off Havre de Grace, Susquehanna River (39° 32′.9 N., 76° 04′.7 W.).	July 2-5, 1867	1½		(3)	(7)	(7)	(7)	(7)				142	0.46		
H3	⅛ mile off Havre de Grace, Susquehanna River (39° 33′.0 N., 76° 05′.2 W.).	July 13, 1927	½	Pole	7	3.78	5.88	313	0.10	3.30	0.66				9.12	0.74
				Meter	4	3.48	5.78		0.10	3.90	0.96				8.52	0.71
				do	9	3.78	5.88		0.10	3.50	0.86				8.92	0.81
				do	14	3.78	5.88		0.02	3.40	0.76				9.02	0.77
H2	½ mile off Havre de Grace, Susquehanna River (39° 33′.1 N., 76° 04′.7 W.).	do	½	Pole	7	2.58	4.48	328	0.20	4.80	0.96				7.62	−0.03
				Meter	4	3.18	4.78		0.02	3.40	0.16				9.02	0.01
				do	10	2.28	4.28		0.20	5.00	0.86				7.42	−0.23
				do	16	1.28	4.08		0.20	6.10	0.96				6.32	−0.59
	(3) *Hampton Roads*															
P6	½ mile S. of Old Pt. Comfort Light (36° 59′.6 N., 76° 18′.2 W.).	Mar. 10-12, 1919	2	Pole	6¾	2.52	5.02	259	1.60	5.02	1.12	5.05	74	2.30	7.40	0.25
A71	¼ mile S. of Old Pt. Comfort (36° 59′.8 N., 76° 18′.7 W.).	July 30-Aug. 15, 1928	1	do	7	2.33	5.28	258	1.77	5.80	1.71	4.56	65	1.92	6.62	0.29
				Meter	14, 15	2.18	5.23		1.81	5.95	1.71	4.66		1.91	6.47	0.26
				do	34½, 37	2.13	5.28		1.67	6.20	1.91	4.86		1.92	6.22	0.36
				do	55, 59	1.98	5.33		1.44	6.15	1.71	4.66		1.84	6.27	0.24
C1	¼ mile S. of Old Pt. Comfort (36° 59′.8 N., 76° 18′.8 W.).	1898	69	(9)		2.73				5.91	2.22				6.51	0.85
A72	½ mile S. of Old Pt. Comfort (36° 59′.6. N., 76° 18′.7 W.).	July 30-Aug. 16, 1928	5	Pole	7	2.39	5.20	248	1.76	5.95	1.92	4.77	59	1.80	6.47	0.39
				Meter	12	2.37	5.16		1.87	5.98	1.93	4.80		1.88	6.44	0.38
				do	30	1.99	5.01		1.78	6.13	1.70	4.72		1.73	6.29	0.18
				do	48	1.37	4.57		1.10	6.28	1.23	4.39		1.19	6.14	−0.29
			1½	Pettersson meter.	30, 33	2.18	4.88	252	1.65	5.93	1.69	4.78	80	1.52	6.49	0.20

[3] Surface.
[7] Current does not flood.
[8] Flood velocities too small to admit of an accurate direction determination.
[9] Observed times of swinging of ship.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(5) *Hampton Roads*—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
A73	⅜ mile W. of Fort Wool (36° 59′.2 N., 76° 18′.6 W.).	July 31–Aug. 15, 1928	1	Pole	7	1.93				6.05	1.56	4.06	54	2.05	6.37	12.31
				Meter	11	1.78				6.00	1.36	4.46		1.96	6.42	12.32
				do	27	1.63				6.05	1.26	4.36		1.65	6.37	12.21
				do	44	1.38				6.00	0.96	4.31		1.51	6.42	12.01
A74	¾ mile NW. of Willoughby Spit (36° 58′.6 N., 76° 18′.4 W.).	July 31–Aug. 1, 1928	1	Pole	2	1.38	4.48	260	0.70	5.70	0.66	3.36	39	0.95	6.72	11.71
				Meter	4½	1.43	4.08		0.90	5.70	0.71	3.26		0.95	6.72	11.61
				do	7	1.13	4.18		0.80	6.05	0.76	3.36		0.80	6.37	11.60
A75	Willoughby Bay entrance (36° 57′.7 N., 76° 17′.9 W.).	Aug. 1–2, 1928	½	Pole	2	0.68	3.28	134	0.28	5.75	0.01	3.66	330	0.38	6.67	11.15
				Meter	4	0.48	3.18		0.28	6.10	0.16	3.76		0.38	6.32	11.14
				do	6½	0.48	3.08		0.28	6.00	0.06	3.66		0.38	6.42	11.06
Ay8	⅜ mile S. of Old Pt. Comfort (36° 59′.6 N., 76° 18′.6 W.).	Oct. 9, 1854	½	Float	(3)	2.02	4.40	253	1.34	5.33	0.93	4.68	47	1.54	7.09	12.25
Ay7	⅜ mile SW. of Old Pt. Comfort (36° 59′.8 N., 76° 19′.1 W.).	Aug. 24, 1854	½	do		2.67	5.38	253	1.20	5.15	1.40	4.57	60	1.40	7.27	0.32
A76	Channel W. of naval operating base (36° 57′.2 N., 76° 20′.3 W.).	Aug. 1–2, 1928	1	Pole	7	2.23	4.23	190	0.91	3.95	12.18	3.66	8	1.26	8.47	11.71
				Meter	8	1.98	4.28		0.85	4.30	12.28	3.81		1.35	8.12	11.72
				do	20	1.93	4.18		0.87	4.75	0.26	3.76		0.87	7.67	11.77
				do	32	1.88	4.03		0.87	5.55	1.01	4.86		0.92	6.87	12.18
Wt1	Off piers, naval operating base (36° 56′.8 N., 76° 20′.1 W.).	Aug. 10–Sept. 7, 1917	10	Pole	7	1.30	4.26	195	0.56	5.70	0.58	3.94	9	0.79	6.72	11.76
P5	⅝ mile off submarine base (36° 57′.4 N., 76° 20′.5 W.).	Mar. 7–8, 1919	1⅓	Pole	6¾	2.23	5.05	211	1.33	4.99	0.80	5.00	1	1.55	7.43	0.09
Ay9	1⅜ miles W. of naval operating base (36° 57′.2 N., 76° 21′.4 W.).	Oct. 10, 1854	½	Float	(3)	1.20	4.38	208	1.24	6.94	1.72	4.47	7	0.94	5.48	12.18
P2	Newport News Channel (36° 57′.6 N., 76° 21′.7 W.).	Feb. 13–18, 1919	2¼	Pole	6¾	2.12	6.04	231	1.08	7.05	2.75	4.90	61	1.36	5.37	0.77
P1	2⅛ miles SE. of Newport News Point (36° 56′.0 N., 76° 23′.2 W.).	Oct. 11–13, 1919	2	do	6¾	3.22	6.67	268	1.08	6.04	2.84	5.95	98	1.21	6.38	1.49
P3	Newport News Channel (36° 57′.3 N., 76° 23′.6 W.).	Feb. 27–Mar. 1, 1919	2	do	6¾	2.45	5.72	268	1.12	6.21	2.24	5.38	70	1.22	6.21	0.77
A82	Channel off Newport News Pt. (36° 57′.3 N., 76° 24′.7 W.).	Aug. 9–16, 1928	1½	do	7	2.68	5.11	290	1.24	5.40	1.66	5.29	111	1.30	7.02	0.50
			1½	Meter	7½, 10	2.58	5.05		1.51	5.47	1.63	5.46		1.64	6.95	0.50
			½	do	18½	2.08	4.48		1.41	5.90	1.56	5.11		1.26	6.52	0.13
			1½	do	25, 29½	1.98	4.58		1.32	6.00	1.56	4.93		0.96	6.42	0.08
			¾	do	40	1.63	4.63		1.18	6.20	1.41	4.46		0.73	6.22	−0.15
			1	Pettersson meter.	20	1.53	4.43		1.28	6.40	1.51	4.71		0.88	6.02	−0.14
A83	¾ mile NE. of Nansemond River Light (36° 55′.3 N., 76° 26′.0 W.).	Aug. 10–16, 1928	1½	Pole	4½, 7	1.61	4.81	278	0.52	6.37	1.56	4.53	79	0.85	6.05	−0.05
				Meter	4, 6½	1.58	4.65		0.84	6.43	1.59	4.56		0.81	5.99	−0.08
				do	10, 10½	1.55	4.51		0.83	6.63	1.76	4.66		0.90	5.79	−0.06
				do	16	1.18	4.98		0.74	7.20	1.96	4.91		0.59	5.22	0.08
				Pettersson meter.	6½	1.63	4.28		0.91	6.60	1.81	5.31		1.16	5.82	0.08
	(4) *Elizabeth and Nansemond Rivers*															
P7	⅛ mile S. of Craney I. Light (36° 53′.4 N., 76° 20′.3 W.).	Mar. 12–14, 1919	2	Pole	6¾	0.80	3.97	165	0.70	5.54	12.34	3.92	8	1.16	6.88	11.39
A77	Channel W. of Lambert Pt. (36° 52′.6 N., 76° 20′.1 W.).	Aug. 3–14, 1928	2	Pole	7	1.70	4.40	175	0.28	5.58	0.86	4.44	337	0.53	6.84	12.09
				Meter	8	2.03	4.53		0.46	5.07	0.68	4.38		0.71	7.35	12.14
				do	18, 20	1.88	4.60		0.47	5.68	1.14	4.34		0.47	6.74	12.23
				do	28, 32	1.30	4.63		0.57	6.60	1.48	4.16		0.44	5.82	12.13
			1	Pettersson meter.	18	1.48	4.43		0.60	6.35	1.41	4.26		0.60	6.07	12.14
A81	West Norfolk Bridge, Western Branch (36° 51′.5 N., 76° 20′.6 W.).	Aug. 3–4, 1928	1	Pole	7	0.93	3.48	(10)	0.60	5.90	0.41	4.06	(11)	0.70	6.52	11.46
				Meter	3	1.13	3.58		0.69	5.85	0.56	4.11		0.79	6.57	11.58
				do	7½	0.73	3.68		0.61	6.50	0.81	4.16		0.66	5.92	11.58
				do	12	0.78	4.28		0.34	6.25	0.61	3.91		0.49	6.17	11.64
W2	Off Berkley, Eastern Branch (36° 50′.5 N., 76° 17′.3 W.).	May 20–21, 1876	1½			0.92	4.42	100	0.60	6.00	0.50	3.33	260	0.60	6.42	11.53
A78	Berkley Bridge, Eastern Branch (36° 50′.5 N., 76° 16′.9 W.).	Aug. 13–14, 1928	1	Pole	7	0.78	4.23	(11)	0.50	6.60	0.96	4.16	(10)	0.60	5.82	11.77
				Meter	5½	1.38	4.63		0.59	6.05	1.01	4.16		0.69	6.37	12.04
				do	13½	0.88	4.28		0.64	6.65	1.11	4.01		0.59	5.77	11.81
				do	21½	0.78	4.13		0.56	6.70	1.06	3.91		0.51	5.72	11.71
Fg31	Near N. & W. Ry. Bridge, Eastern Branch (36° 50′.4 N., 76° 16′.6 W.).	May 8–22, 1913	1			1.50	4.62	114	0.54	6.09	1.17	3.55	287	0.64	6.33	11.95
A79	Virginian Ry. Bridge, Eastern Branch (36° 50′.2 N., 76° 14′.7 W.).	Aug. 13–14, 1928	1	Pole	7	1.23	4.23	(11)	0.45	6.00	0.81	4.06	(10)	0.60	6.42	11.82
				Meter	5	1.23	4.13		0.49	5.90	0.71	4.01		0.64	6.52	11.76
				do	12	1.13	4.18		0.45	6.00	0.71	4.16		0.65	6.42	11.78
				do	19	1.28	4.18		0.40	5.80	0.66	4.16		0.60	6.62	11.81
W1	Off St. Helena, Southern Branch (36° 49′.6 N., 76° 17′.6 W.).	May 20–21, 1876	1½			2.50	4.67	170	0.80	4.42	0.50	4.50	350	0.80	8.00	12.28
A80	¼ mile N. of N. & P. B. L. Ry. Bridge, Southern Branch (36° 48′.9 N., 76° 17′.5 W.).	Aug. 3–4, 1928	1	Pole	7	2.08	5.28	184	0.43	5.75	1.41	4.56	338	0.53	6.67	0.15
				Meter	9	1.38	5.23		0.59	6.70	1.66	4.46		0.34	5.72	0.00
				do	22½	1.58	5.23		0.45	6.50	1.66	4.46		0.35	5.92	0.05
				do	36	1.18	5.18		0.41	7.05	1.81	4.26		0.16	5.37	−0.07
A83	¾ mile NE. of Nansemond River Light (36° 55′.3 N., 76° 26′.0 W.).	Aug. 10–16 1928	1½	Pole	4½, 7	1.61	4.81	278	0.52	6.37	1.56	4.53	79	0.85	6.05	−0.05
				Meter	4, 6½	1.58	4.65		0.84	6.43	1.59	4.56		0.81	5.99	−0.08
				do	10, 10½	1.55	4.51		0.83	6.63	1.76	4.66		0.90	5.79	−0.06
				do	16	1.18	4.98		0.74	7.20	1.96	4.91		0.59	5.22	0.08
				Pettersson Meter.	6½	1.63	4.28		0.91	6.60	1.81	5.31		1.16	5.82	0.08
A84	Off Town Pt., Nansemond River (36° 53′.0 N., 76° 29′.9 W.).	Aug. 10–11, 1928	½	Pole	7	1.28	4.58	224	1.06	6.48	1.36	4.96	35	1.36	5.94	12.28
				Meter	5½	1.28	4.58		1.06	6.20	1.06	4.86		1.26	6.22	12.18
				do	14	1.28	4.48		1.07	6.20	1.06	4.76		1.17	6.22	12.14
				do	22½	1.28	4.38		1.07	6.00	0.86	4.86		0.97	6.42	12.08

[3] Surface. [10] Westerly. [11] Easterly.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations: Date	Observations: Period	Observations: Method	Observations: Depth	Slack after LW	Flood strength: Time after LW	Flood strength: Direction (true)	Flood strength: Velocity	Flood duration	Slack after HW	Ebb strength: Time after HW	Ebb strength: Direction (true)	Ebb strength: Velocity	Ebb duration	Mean current hour
	(4) Elizabeth and Nansemond Rivers—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
A85	Off Dumpling I., Nansemond River (36° 48′.5 N., 76° 33′.5 W.).	Aug. 10–11, 1928	1	Pole	4½	1.13	4.28	174	1.02	7.10	1.81	4.16	347	0.97	5.32	12.08
				Meter	4½	1.18	4.33		1.02	7.15	1.91	4.26		0.97	5.27	12.16
				do	7	1.18	4.38		0.97	7.10	1.86	4.36		0.97	5.32	12.18
	(5) James River and tributaries															
P4	½ mile off railroad docks, Newport News (36° 57′.7 N., 76° 26′.1 W.).	Mar. 3–5, 1919	2	Pole	6¾	4.00	6.70	340	1.10	5.15	2.73	5.95	142	1.70	7.27	1.66
A86	½ mile W. of Old Dominion Pier, Newport News (36° 58′.5 N., 76° 26′.8 W.).	Aug. 9–10, 1928	1	do	7	3.38	5.78	330	1.20	5.60	2.56	6.56	134	1.80	6.82	1.39
				Meter	7	3.58	5.93		1.10	5.35	2.51	6.56		1.80	7.07	1.46
				do	18	2.98	5.43		1.20	5.95	2.51	5.86		1.40	6.47	1.02
				do	29	2.48	5.33		0.95	6.30	2.36	5.86		1.00	6.12	0.83
A87	1⅛ miles E. of Fishing Pt. (36° 58′.1 N., 76° 28′.2 W.).	do	½	Pole	4½	2.48	5.18	344	0.80	6.10	2.16	5.16	117	0.90	6.32	0.56
				Meter	6½	2.38	5.18		0.90	6.20	2.16	5.16		0.90	6.22	0.54
				do	8½	2.28	5.08		0.70	6.30	2.16	5.16		0.80	6.12	0.49
Fg23	⅛ mile off ship building plant, Newport News (36° 59′.4 N., 76° 26′.9 W.)	June 27–July 11, 1910	1			3.62	6.05	342	1.46	5.55	2.75	5.92	145	1.16	6.87	1.40
Fg24	Near Fergusons Wharf (37° 03′.9 N., 76° 39′.6 W.).	July 20–22, 1910	1¾			6.45	8.62	326	0.34	4.00	4.03	7.63	196	0.90	8.42	3.50
Ma1	⅞ mile E. of Hog I. (37° 11′.0 N., 76° 39′.0 W.).	July 31–Aug. 2, 1855	1½			5.50	8.60		0.44	5.35	4.43	8.13		0.72	7.07	3.48
A88	½ mile N. of Hog Pt. (37° 12′.3 N., 76° 41′.5 W.).	Aug. 6–9, 1928	2½	Pole	7	5.10	7.48	270	1.20	5.86	4.54	8.44	69	1.40	6.56	3.21
				Meter	8	5.00	7.43		1.21	5.94	4.52	8.44		1.55	6.48	3.17
				do	20	4.96	7.96		1.30	6.10	4.64	8.48		1.42	6.32	3.33
				do	32	4.68	7.53		1.23	6.42	4.68	8.30		1.07	6.00	3.12
			2	Pettersson meter.	18	5.25	7.80		1.17	6.03	4.86	8.53		1.50	6.39	3.43
A89	1 mile N. of Hog Pt. (37° 12′.8 N., 76° 41′.5 W.).	Aug. 7–9, 1928	1½	Pole	7	5.31	8.28	255	0.93	5.84	4.73	7.86	76	1.18	6.58	3.36
				Meter	5	5.51	8.48		0.98	5.64	4.73	7.83		1.18	6.78	3.46
				do	12½	5.23	8.08		0.98	6.02	4.83	8.03		1.01	6.40	3.36
				do	20	4.58	8.03		0.83	6.73	4.89	7.69		0.65	5.69	3.12
A90	1¼ miles above Ferry Pt. Chickahominy River (37° 16′.8 N., 76° 52′.9 W.).	Aug. 6–7, 1928	1	Pole	7	5.25	8.00	353	1.13	6.30	5.13	7.73	182	1.13	6.12	3.35
				Meter	12	5.10	8.00		1.23	6.40	5.08	7.63		1.13	6.02	3.27
				do	30	5.15	7.90		1.22	6.45	5.18	7.78		1.17	5.97	3.32
				do	48	5.15	8.00		1.04	6.35	5.08	7.73		0.99	6.07	3.31
Fg25	¼ mile above Sloop Pt. (37° 14′.0 N., 76° 57′.2 W.).	July 30–Aug. 17, 1910	1			6.42	9.17	290	1.48	5.97	5.97	9.47	127	1.46	6.45	4.58
Fg26	Off Windmill Pt. (37° 18′.7 N., 77° 05′.7 W.).	Sept. 22–Oct. 12, 1910	1¼			6.67	8.92	310	1.26	6.63	6.88	9.75	66	0.99	5.79	4.88
Fg27	⅛ mile E. of City Pt. (37° 19′.0 N., 77° 16′.3 W.).	Nov. 2–21, 1910	1			7.75	9.84	322	1.32	6.14	7.47	10.09	133	1.15	6.28	5.61
Fg28	¼ mile N. of City Pt. (37° 19′.3 N., 77° 16′.6 W.).	Jan. 25, 1911	½				10.59	335	1.22		6.75	10.92	150	1.80		5.76
A91	Mouth of Appomattox River (37° 18′.7 N., 77° 18′.0 W.).	Aug. 8–9, 1928	1	Pole	7	7.60	9.95	265	0.94	5.65	6.83	9.88	84	1.09	6.77	5.38
				Meter	4	7.55	9.95		1.04	5.60	6.73	9.78		1.19	6.82	5.32
				do	10½	7.50	9.85		0.99	5.75	6.83	9.73		1.19	6.67	5.30
				do	17	7.50	9.80		0.94	5.80	6.88	9.68		1.04	6.62	5.28
Fg29	Off Meadowville (37° 22′.8 N., 77° 19′.5 W.).	Feb. 3, 1911	½			9.59	11.17	270	0.48	4.50	7.67	10.59	89	1.27	7.92	6.58
A92	⅝ mile below Dutch Gap Canal (37° 22′.8 N., 77° 20′.8 W.).	Aug. 6–7, 1928	1	Pole	7	8.55	10.90	270	0.84	5.35	7.48	10.68	92	0.89	7.07	6.22
				Meter	5½	8.35	10.90		0.84	5.50	7.43	10.63		0.89	6.92	6.15
				do	14	8.40	10.70		0.85	5.50	7.48	10.58		0.85	6.92	6.11
				do	22½	8.45	10.80		0.85	5.25	7.28	10.53		0.85	7.17	6.08
Fg30	⅛ mile below mouth of Gillis Creek (37° 31′.2 N., 77° 25′.0 W.).	Mar. 20–30, 1911	1			(7)	(7)	(7)	(7)	(7)			160	0.99		
	(6) York River and tributaries															
La2	⅜ mile off Tue Marshes Light (37° 14′.5 N., 76° 23′.2 W.).	Aug. 26–28, 1918	2	Pole		2.46	5.50	254	0.95	5.76	1.80	4.98	91	1.00	6.66	0.50
A67	½ mile off Tue Marshes Light (37° 14′.6 N., 76° 23′.4 W.).	July 26–Aug. 17, 1928	3½	Pole	7	2.29	5.10	271	0.93	6.32	2.19	5.29	63	0.84	6.10	0.54
			3½	Meter	11, 14	2.26	5.03		0.86	6.35	2.19	5.30		0.86	6.07	0.52
			1	do	27	1.90	4.90		0.87	5.92	1.40	4.05		0.67	6.50	−0.12
			3	do	35	2.13	4.80		0.59	6.17	1.88	5.24		0.81	6.25	0.33
			1	do	43	1.70	4.80		0.69	5.82	1.10	4.05		0.69	6.60	−0.27
			3	do	56	0.77	4.24		0.68	7.78	2.13	4.62		0.44	4.64	−0.24
La1	¾ mile off Goodwin Neck (37° 13′.9 N., 76° 26′.6 W.).	Aug. 21–23, 1918	2	Pole		2.45	5.70	260	0.89	6.62	2.65	5.45	80	0.82	5.80	0.88
Fg9	¼ mile SE. of Gloucester Pt. (37° 14′.6 N. 76° 30′ .1 W.).	Apr. 27–May 11, 1911	1			2.13		292	1.13	5.96	1.67	5.01	104	1.23	6.46	0.31
A68	¼ mile SW. of Gloucester Pt. (37° 14′.5 N., 76° 30′ .4 W.).	July 27–28, 1928	1	Pole	4½	2.25	4.80	280	1.36	6.07	1.90	5.35	127	1.81	6.35	0.40
				Meter	20	2.55	4.80		1.12	5.67	1.80	5.70		1.77	6.75	0.53
				do	40	2.25	5.20		0.75	6.27	2.10	5.25		0.95	6.15	0.52
				do	60	0.90	5.20		1.41	7.57	2.05	4.70		0.71	4.85	0.03
La3	¼ mile above Yorktown steamboat landing (37° 14′.5 N., 76° 30′.7 W.).	Aug. 28–30, 1918	2	Pole		2.72	5.50	323	1.26	5.62	1.92	5.42	121	1.16	6.80	0.71
Fg10	⅛ mile above Claybank Wharf (37° 20′.9 N., 76° 36′.9 W.).	Aug. 16, 1911	½			3.73	6.31	338	1.08	5.62	2.93	6.43	147	1.48	6.80	1.67
Fg11	¼ mile above Almondsville Wharf (37° 23′.6 N., 76° 39′.7 W.).	Aug. 23–Sept. 6, 1911	1			3.64	6.39	329	1.39	5.41	2.63	6.59	137	1.74	7.01	1.63
Fg12	¾ mile below West Pt. (37° 30′.9 N., 76° 47′.5 W.).	Nov. 8, 1911	½			4.31	6.64	340	1.14	6.20	4.09		152	1.54	6.22	2.31
Fg13	Mouth of Mattaponi River, off West Pt. (37° 31′.7 N., 76° 47′.4 W.).	Nov. 11, 1911	⅙			4.06										2.32
Fg14	Mouth of Mattaponi River, off West Pt. (37° 31′.7 N., 76° 47′.4 W.).	Mar. 4, 1912	½				6.23	344	0.67		3.18	6.43	172	0.91		1.62

[7] Current does not flood.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(6) York River and tributaries—Con.															
			Days		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
A69	Bridge near West Pt., Mattaponi River (37° 32′.4 N., 76° 47′.3 W.).	July 30-31, 1928	1	Pole	4	4.43	6.83	(12)	1.30	5.40	3.41	6.71	(13)	1.50	7.02	2.16
				Meter	4	4.38	6.88		1.31	5.45	3.41	6.76		1.61	6.97	2.18
				do	10	4.28	6.83		1.29	5.65	3.51	7.06		1.09	6.77	2.24
				do	16	4.28	6.88		1.07	5.55	3.41	7.11		0.92	6.87	2.24
Fg15	Off Wakema, Mattaponi River (37° 39′.2 N., 76° 54′.0 W.).	Apr. 12, 1912	½			5.23		260	1.41	5.28	4.09	7.26	80	1.71	7.14	2.90
Fg16	Off Walkerton, Mattaponi River (37° 43′.4 N., 77° 01′.5 W.).	Apr. 24-May 13, 1912	1			6.48	8.56	275	0.87	4.95	5.01	9.19	95	0.95	7.47	4.13
Fg17	Off Aylett, Mattaponi River (37° 47′.2 N., 77° 06′.2 W.).	June 10, 1912	½			(7)	(7)	(7)	(7)	(7)		10.73	100	1.00		6.10
Fg18	Off West Pt., Pamunkey River (37° 31′.7 N., 76° 48′.1 W.).	Nov. 10, 1911	½			5.06	7.73	334	1.53	5.29	3.93		154	1.78	7.13	2.87
Fg19	Off West Pt., Pamunkey River (37° 31′.8 N., 76° 48′.1 W.).	Mar. 5, 1912	½			5.06	7.73	328	0.70	5.37	4.01	7.26	151	1.00	7.05	2.84
A70	Bridge at West Pt., Pamunkey River (37° 32′.1 N., 76° 48′.5 W.).	July 30-31, 1928	1	Pole	4½	4.98	7.93	(14)	1.73	5.67	4.23	7.66	(15)	1.88	6.75	3.02
				Meter	4	5.03	7.63		1.74	5.62	4.23	7.51		2.04	6.80	2.92
				do	11	4.88	7.78		1.73	5.73	4.19	7.71		1.78	6.69	2.96
				do	18	4.78	7.78		1.51	5.87	4.23	7.71		1.46	6.55	2.94
Fg20	Off Lester Manor, Pamunkey River (37° 34′.9 N., 76° 59′.4 W.).	Sept. 3-Oct. 17, 1912	1	Pole	5½	5.89	9.35	237	1.20	6.29	5.76	8.56	55	1.00	6.13	4.21
Fg21	Off Northbury, Pamunkey River (37° 37′.5 N., 77° 07′.3 W.).	Jan. 13-30, 1913	⅓	do	5½	6.89		290	0.49	6.29	6.76	10.81	100	1.26	6.13	5.52
Fg22	Bridge at Newcastle, Pamunkey River (37° 40′.0 N., 77° 11′.6 W.).	Feb. 6, 1913	⅓	do	5½								175	1.05		
	(7) Rappahannock River and tributaries															
A54	¾ mile S. of Mosquito Pt. (37° 35′.8 N., 76° 21′.5 W.).	July 20-21, 1928	1	do	7	3.83	7.08	292	0.64	6.65	4.06	7.11	114	0.64	5.77	2.34
				Meter	12½	3.88	6.98		0.74	6.65	4.11	7.31		0.59	5.77	2.39
				do	31½	3.73	6.48		0.83	6.75	4.06	7.16		0.58	5.67	2.18
				do	50½	3.58	6.18		0.83	6.70	3.86	7.31		0.58	5.72	2.05
A55	1⅜ mile S. of Mosquito Pt. (37° 35′.1 N., 76° 21′.7 W.).	do	½	Pole	4½	4.08	6.58	288	0.27	5.40	3.06				7.02	1.87
				Meter	5	4.18	6.58		0.36	5.40	3.16				7.02	1.94
				do	12	4.38	6.98		0.55	5.60	3.56				6.82	2.27
				do	19	4.08	6.88		0.46	5.70	3.36				6.72	2.07
Br7	Carter Creek (37° 39′.3 N., 76° 26′.3 W.).	Jan 6-11, 1881	½	Pole	2		6.17	48	0.45			5.25	230	0.25		0.87
A56	Corrotoman River, off Millenbeck Wharf (37° 40′.2 N, 76° 28′.8 W.).	July 23-24, 1928	1	do	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	6											
				do	15											
				do	24											
A57	Eastern Branch, Corrotoman River (37° 42′.8 N., 76° 27′.5 W.).	do	½	Pole	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	4											
				do	9½											
				do	15											
A58	Western Branch, Corrotoman River (37° 42′.9 N., 76° 29′.6 W.).	July 24, 1928	½	Pole	7	4.38				5.10	3.06	7.16	154	0.26	7.32	2.24
				Meter	4	4.68				4.90	3.16	7.06		0.39	7.52	2.34
				do	9½	4.18				6.00	3.76	7.26		0.26	6.42	2.44
				do	15	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
A59	¾ mile W. of Rogue Pt. (37° 40′.2 N., 76° 33′.3 W.).	July 18-19, 1928	1	Pole	7	5.00	7.40	338	0.59	6.35	4.93	8.58	174	0.44	6.07	3.30
				Meter	8	5.15	7.40		0.58	6.05	4.78	8.58		0.58	6.37	3.30
				do	20	4.95	7.60		0.58	6.20	4.73	8.28		0.53	6.22	3.21
				do	32	4.60	7.05		0.59	5.65	3.83	7.83		0.49	6.77	2.65
Fg7	¼ mile below Tappahannock Bridge (37° 55′.9 N., 76° 50′.8 W.).	Mar. 22-23, 1910	1			7.09	9.55	338	0.80	5.83	6.50	9.67	147	0.85	6.59	5.02
Fg8	⅛ mile below Tappahannock Bridge (37° 56′.0 N., 76° 50′.9 W.).	Mar. 24, 1910	½			7.25	9.75	324	1.25	6.09	6.92		150	1.06	6.33	5.27
A60	Tappahannock Bridge (37° 56′.0 N., 76° 51′.2 W.).	July 19-20, 1928	1	Pole	4½	6.70	9.90	(14)	1.27	6.30	6.58	10.48	(15)	1.17	6.12	5.24
				Meter	3	7.20	9.80		1.17	5.90	6.68	10.48		1.22	6.52	5.36
				do	7	7.05	9.75		1.23	6.00	6.63	10.43		1.08	6.42	5.28
				do	12	6.95	9.65		1.05	6.20	6.73	10.38		0.95	6.22	5.25
A61	Off Port Royal (38° 10′.5 N., 77° 11′.4 W.).	July 20-25, 1928	1½	Pole	4½, 7	9.23	0.25	(14)	0.69	6.67	9.48	12.23	(15)	0.71	5.75	7.72
				Meter	2	8.00	12.30		0.28	8.20	9.78	11.88		0.08	4.22	7.31
				do	4, 5	9.27	0.38		0.73	6.85	9.70	12.23		0.56	5.57	7.82
				do	8, 10	9.85	0.45		0.76	6.25	9.68	12.13		0.56	6.17	7.95
	(8) Pocomoke Sound and River															
A101	4⅝ miles, S. 2° E. of Tangier Sound Light (37° 42′.6 N., 75° 58′.2 W.).	Aug. 21-22, 1928	1	Pole	7	5.55	8.35	14	1.02	6.15	5.28	8.28	220	0.57	6.27	3.68
				Meter	9	5.45	8.10		1.21	5.80	4.83	8.08		1.01	6.62	3.44
				do	22½	5.05	7.70		1.38	6.05	4.68	7.93		0.98	6.37	3.16
				do	36	3.95	7.45		1.39	6.95	4.48	7.28		0.92	5.47	2.61
Br3	3½ miles W. of Parkers I. (37° 42′.4 N., 75° 55′.9 W.).	May 27-31, 1881	1			4.92	7.17	64	0.48	5.17	3.67	7.08	229	1.28	7.25	2.53
Br4	3⅛ miles W. of Parkers I. (37° 42′.6 N., 75° 55′.5 W.).	May 30, 1881	⅙								4.40					2.88
Br6	Mouth of Pungoteague Creek (37° 40′.5 N., 75° 51′.8 W.).	May 16, 1881	⅓								2.10	5.40	290	0.35		0.67
Br5	⅛ mile E. of Parkers I. (37° 42′.1 N., 75° 50′.7 W.).	May 21, 1881	¼			5.00										3.26
Br2	2 miles NW. of Thicket Pt. (37° 44′.3 N., 75° 52′.0 W.).	Mar. 3-May 20, 1881	1½	Pole	5	4.90	7.09	82	0.75	4.84	3.32	8.10	222	0.85	7.58	2.67
Br1	Mouth of Chesconessex Creek (37° 45′.4 N., 75° 48′.4 W.).	Feb. 28, 1881	¼	do	5						3.60	6.20	230	0.34		1.82

[7] Current does not flood. [12] Northerly. [13] Southerly. [14] Northwesterly. [15] Southeasterly. [16] Current weak and irregular.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations: Date	Period	Method	Depth	Slack after LW	Flood strength: Time after LW	Direction (true)	Velocity	Flood duration	Slack after HW	Ebb strength: Time after HW	Direction (true)	Velocity	Ebb duration	Mean current hour
	Pocomoke Sound and River—Contd.															
			Days		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
A52	2¼ miles E. of Watts I. (37° 47′.8 N., 75° 50′.6 W.).	July 17-21, 1928	1	Pole	7	5.05	7.00	22	1.56	4.90	3.53	7.13	212	1.36	7.52	2.50
				Meter	20	5.10	7.20		1.56	4.80	3.48	6.98		1.46	7.62	2.51
				do	50	4.95	7.50		1.55	4.90	3.43	6.68		1.25	7.52	2.46
				do	80	4.80	6.80		1.45	5.10	3.48	6.68		0.95	7.32	2.26
A50	½ mile below Shelltown, Pocomoke River (37° 58′.3 N., 75° 38′.7 W.).	July 13-14, 1928	½	Pole	4½	7.30	9.30	43	1.07	5.10	5.98	9.28	171	0.87	7.32	4.78
				Meter	4½	7.10	9.20		1.15	5.30	5.98	9.68		1.05	7.12	4.81
				do	9	7.20	9.30		1.16	5.30	6.08	9.28		0.86	7.12	4.78
				do	14½	7.00	9.10		1.07	5.40	5.98	9.28		0.77	7.02	4.66
	(9) *Tangier Sound and tributaries*															
A51	1⅛ miles NE. of Tangier Sound Light (37° 48′.2 N., 75° 57′.5 W.).	July 16-Aug. 22, 1928	¾	Pole	7	5.35	8.20	5	1.17	5.75	4.68	7.08	213	1.27	6.67	3.15
				Meter	10	5.30	8.15		1.22	5.80	4.68	7.38		1.17	6.62	3.20
				do	25	5.25	8.25		1.21	5.95	4.78	7.18		0.96	6.47	3.18
				do	40	5.25	8.25		0.90	5.65	4.48	7.58		0.75	6.77	3.21
A102	1⅛ miles W. of Janes Is. (38° 00′.0 N., 75° 54′.5 W.).	Aug. 21-22, 1928	1	Pole	7	7.40	9.70	1	0.90	5.30	6.28	9.88	211	0.90	7.12	5.14
				Meter	22	7.70	9.85		0.93	4.95	6.23	9.88		1.08	7.47	5.24
				do	55	7.15	9.75		0.80	5.45	6.18	10.03		1.00	6.97	5.10
				do	88	6.90	9.85		0.78	5.85	6.33	9.78		0.88	6.57	5.04
A49	Kedges Straits, off Solomons Lump Light (38° 03′.1 N., 76° 00′.8 W.).	July 5-6, 1928	½	Pole	7	3.58	7.28	105	1.07	7.10	4.26				5.32	2.34
				Meter	5	3.68	7.08		1.16	7.00	4.26				5.42	2.31
				do	11	3.78	7.08		1.16	6.80	4.16				5.62	2.31
				do	17	3.68	7.38		1.07	6.70	3.96				5.72	2.31
A48	Manokin River, 1 mile W. of Prickly Pt. (38° 05′.4 N., 75° 53′.6 W.).	do	½	Pole	7	5.30	8.40	32	0.29	5.90	4.78	8.18	171	0.59	6.52	3.48
				Meter	6½	5.20	8.40		0.78	6.05	4.83	8.38		0.58	6.37	3.52
				do	16½	5.30	8.50		0.78	6.05	4.93	8.58		0.58	6.37	3.65
				do	26½	5.40	8.60		0.78	5.95	4.93	8.78		0.48	6.47	3.75
A43	Nanticoke River, 1⅜ miles off Halls Pt. (38° 12′.5 N., 75° 57′.3 W.).	July 9-10, 1928	½	Pole	7	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
				Meter	6											
				do	16											
				do	26											
A46	Wicomico River, off Victor (38° 14′.3 N., 75° 51′.8 W.).	July 11, 1928	½	Pole	4½	6.80	9.30	34	0.61	6.10	6.48	9.88	242	0.91	6.32	4.94
				Meter	2	6.90	9.40		0.61	6.00	6.48	9.98		0.91	6.42	5.01
				do	5	6.70	9.30		0.61	6.20	6.48	9.68		1.01	6.22	4.86
				do	8	6.80	9.30		0.61	6.00	6.38	9.98		1.01	6.42	4.94
A47	Wicomico River, off White Haven (38° 15′.9 N., 75° 47′.5 W.).	July 9-10, 1928	1	Pole	4½	6.60	10.35	89	1.06	6.50	6.68	9.38	284	1.14	5.92	5.07
				Meter	5	6.70	10.05		1.09	6.40	6.68	9.38		1.19	6.02	5.02
				do	12	6.40	10.15		1.09	6.75	6.73	9.13		0.94	5.67	4.92
				do	19	6.35	10.25		0.94	6.90	6.83	9.23		0.69	5.52	4.98
A44	Nanticoke River, off Sandy Pt. (38° 15′.0 N., 75° 55′.6 W.).	July 10-11, 1928	½	Pole	7	7.30				5.80	6.68	10.18	168	1.72	6.62	5.42
				Meter	5	7.70				5.50	6.78	10.38		1.31	6.92	5.66
				do	12	7.30				6.00	6.88	10.28		1.52	6.42	5.52
				do	19	7.00				6.30	6.98	10.28		1.62	6.02	5.46
A45	Nanticoke River, off Chapter Pt. (38° 22′.6 N., 75° 52′.0 W.).	July 11-12, 1928	½	Pole	7	8.35	10.00	14	1.39	5.70	7.63	11.58	204	1.39	6.72	6.21
				Meter	4	8.30	10.10		1.49	5.60	7.48	11.58		1.29	6.82	6.18
				do	10½	8.30	10.20		1.49	5.65	7.53	11.68		1.19	6.77	6.25
				do	17	8.25	10.40		1.49	5.80	7.63	11.58		1.09	6.62	6.28
A42	Fishing Bay, off Roasting Ear Pt. (38° 16′.9 N., 76° 00′.6 W.).	July 10, 1928	½	Pole	7	5.90	8.70	334	1.31	6.50	5.98				5.92	4.16
				Meter	5	6.20	8.90		1.01	5.90	5.68				6.52	4.20
				do	13	5.90	9.10		1.21	6.30	5.78				6.12	4.20
				do	21	6.00	8.80		1.31	6.30	5.88				6.12	4.17
	(10) *Potomac River*															
L17	2¼ miles S. 37° E. of Pt. Lookout Light (38° 00′.5 N., 76° 17′.6 W.).	June 25-26, 1849	1		(3)	7.77	10.72	329	0.57	4.87	6.22	9.92	150	0.62	7.55	5.48
A37	3¾ miles S. of Cornfield Pt. (37° 59′.4 N., 76° 21′.5 W.).	July 3-Aug. 23, 1928	1	Pole	7	5.45	9.50	313	0.69	6.65	5.68	8.78	102	0.59	5.77	4.17
				Meter	8	5.35	9.50		0.69	6.98	5.91	8.68		0.49	5.44	4.18
				do	21	5.35	9.50		0.69	7.18	6.11	8.58		0.49	5.24	4.20
				do	34	5.25	8.90		0.39	6.78	5.61	8.48		0.49	5.64	3.88
A36	2½ miles S. of Cornfield Pt. (38° 01′.1 N., 76° 21′.3 W.).	July 2-24, 1928	2½	Pole	7	7.54	10.54	280	0.47	5.66	6.78	10.26	112	0.55	6.76	5.60
				Meter	11	7.20	10.40		0.64	6.02	6.80	10.23		0.51	6.40	5.48
				do	27, 28	7.42	10.34		0.61	5.78	6.78	10.01		0.48	6.64	5.46
				do	43, 44	7.20	10.30		0.45	5.70	6.48	9.98		0.58	6.72	5.31
A35	⅞ mile S. of Cornfield Pt. (38° 02′.2 N., 76° 21′.2 W.).	July 3-Aug. 23, 1928	1½	Pole	7	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
				Meter	9, 9½											
				do	22, 22½, 23½											
				do	35, 36, 37½											
Fg5	Smith Creek entrance (38° 05′.2 N., 76° 24′.2 W.).	May 5, 1908	⅓			5.10	8.52	305	0.30							3.52
Fg6	Smith Creek entrance (38° 05′.8 N., 76° 24′.3 W.).	May 4, 1908	⅓			4.80	8.52	310	0.27							3.37
A34	St. Marys River (38° 07′.8 N., 76° 26′.9 W.).	July 3, 1928	½	Pole	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	6											
				do	14½											
				do	23											
A33	Yeocomico River entrance (38° 02′.1 N., 76° 31′.2 W.).	do	½	Pole	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	3											
				do	8											
				do	13											
A31	2⅜ miles off Piney Pt. (38° 05′.9 N., 76° 33′.1 W.).	June 29-30, 1928	1	Pole	7	6.90	9.40	278	0.47	4.65	5.13	9.08	131	0.47	7.77	4.45
				Meter	5	6.90	9.40		0.59	4.85	5.33	8.98		0.59	7.57	4.47
				do	13	6.80	9.50		0.48	5.00	5.38	9.08		0.58	7.42	4.51
				do	21	6.70	9.50		0.59	5.10	5.38	9.08		0.59	7.32	4.48

[3] Surface.

[4] Current irregular.

[16] Current weak and irregular.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(10) *Potomac River*—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
A30	1¼ miles off Piney Pt. (38° 06′.9 N., 76° 32′.5 W.).	June 29-July 2, 1928	1	Pole	7	7.85	10.00	290	0.36	4.78	6.21	10.03	148	0.61	7.64	5.34
				Meter	13	7.35	10.30		0.56	5.95	6.88	10.33		0.56	6.47	5.54
				do	34	6.95	10.30		0.56	6.82	7.35	10.23		0.51	5.60	5.53
				do	55	6.20	9.60		0.78	6.97	6.75	9.63		0.53	5.45	4.88
A32	¼ mile off Piney Pt. (38° 07′.8 N., 76° 32′.0 W.).	July 2, 1928	½	Pole	7	6.40	9.00	280	1.50	5.60	5.58	10.08	147	0.70	6.82	4.58
				Meter	11	5.60	8.80		1.07	7.30	6.48	9.68		0.47	5.12	4.46
				do	28	5.60	8.90		0.96	8.30	7.48	9.88		0.36	4.12	4.78
				do	49	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
A29	Machodoc River entrance (38° 08′.7 N., 76° 39′.3 W.).	June 28-29, 1928	½	Pole	4½	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	3											
				do	7½											
				do	12											
A28	Bretons Bay entrance (38° 14′.5 N., 76° 41′.7 W.).	June 27, 1928	½	Pole	7	5.10	8.90	28	0.61	6.90	5.58	8.58	202	0.41	5.52	3.86
				Meter	3½	5.00	8.90		0.61	7.00	5.58	8.58		0.41	5.42	3.84
				do	8½	4.90	8.60		0.49	7.00	5.48	8.18		0.39	5.42	3.61
				do	13½	4.90	8.20		0.49	6.90	5.38	8.18		0.39	5.52	3.48
A25	1¾ miles SE. of Blakistone I. (38° 11′.7 N., 76° 42′.5 W.).	June 26-28, 1928	1½	Pole	7	9.43	11.10	250	0.43	3.64	6.65	11.08	86	0.90	8.78	6.38
				Meter	6, 8	9.53	11.15		0.38	3.67	6.78	11.05		0.90	8.75	6.45
				do	15, 20	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				do	24, 32											
A26	Channel off White Pt., Nomini Creek (38° 08′.1 N., 76° 43′.3 W.).	June 28, 1928	½	Pole	4½	7.10	10.10	153	1.20	5.70	6.38				6.72	5.16
				Meter	1½	7.30	9.90		1.20	5.30	6.18				7.12	5.09
				do	4	7.30	9.80		1.32	5.40	6.28				7.02	5.09
				do	6½	7.30	9.80		1.32	5.40	6.28				7.02	5.09
A27	Off Long Pt., St. Clement Bay (38° 14′.5 N., 76° 43′.7 W.).	June 26-27, 1928	½	Pole	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	3½											
				do	9											
				do	14½											
A24	½ mile off Rock Pt. Wicomico River (38° 16′.5 N., 76° 49′.3 W.).	June 28-29, 1928	1	Pole	4½	6.10	9.00	10	0.89	7.35	7.03	9.68	142	0.49	5.07	4.77
				Meter	8	6.15	8.90		0.90	6.75	6.48	9.43		0.65	5.67	4.56
				do	21	6.25	8.70		0.58	6.15	5.98	9.18		0.63	6.27	4.35
				do	34	6.10	8.30		0.46	6.55	6.23	9.08		0.46	5.87	4.25
A21	½ mile NE. of White Pt. (38° 15′.8 N., 76° 57′.4 W.).	June 25-26, 1928	½	Pole	7	8.80	0.18	346	0.45	6.95	9.33	0.26	125	0.35	5.47	7.67
				Meter	3½	9.70	0.08		0.57	5.90	9.18	0.36		0.47	6.52	7.86
				do	8½	9.70	0.08		0.57	5.80	9.08	0.36		0.47	6.62	7.84
				do	13½	9.70	0.08		0.35	5.85	9.13	0.16		0.45	6.57	7.80
A22	½ mile SW. of Swan Pt. (38° 17′.1 N., 76° 55′.9 W.).	June 26, 1928	½	Pole	7	10.60	0.28	340	0.45	4.50	8.68	0.06	133	0.85	7.92	7.94
				Meter	3½	10.10	0.18		0.45	4.70	8.38	12.38		0.85	7.72	7.68
				do	9	9.90	0.18		0.55	5.00	8.48	12.38		0.75	7.42	7.66
				do	14½	10.10	0.08		0.53	4.80	8.48	12.38		0.63	7.62	7.68
A23	1¼ miles NE. of White Pt. (38° 16′.4 N., 76° 56′.7 W.).	June 25-26, 1928	1	Pole	7	9.10	0.23	348	0.27	6.80	9.48	0.96	140	0.77	5.62	7.97
				Meter	7	9.70	0.28		0.27	6.10	9.38	0.96		0.77	6.32	8.11
				do	18	10.20	0.08		0.36	5.15	8.93	0.46		0.56	7.27	7.95
				do	29	9.65	12.20		0.63	6.35	9.58	0.36		0.58	6.07	7.87
A20	Off Beabors Pt., Upper Machodoc Creek (38° 18′.9 N., 77° 01′.9 W.).	June 23, 1928	½	Pole	4½	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)
				Meter	2½	7.50		(10)		6.10	7.18	10.18	(11)	0.43	6.32	5.66
				do	6½	7.50				6.10	7.18	10.18		0.32	6.32	5.66
				do	10½	7.50				6.10	7.18	10.18		0.32	6.32	5.66
A19	1⅛ miles S. 71° E. of Persimmon Pt. (38° 22′.1 N., 76° 59′.4 W.).	June 22-23 1928	1	Pole	7	10.70	1.23	337	1.16	5.80	10.08	0.76	175	1.36	6.62	8.72
				Meter	14	10.30	1.18		1.06	6.15	10.03	0.96		1.36	6.27	8.65
				do	35	10.20	1.13		1.36	6.40	10.18	0.86		1.06	6.02	8.62
				do	56	9.75	0.68		1.24	6.60	9.93	0.16		0.84	5.82	8.18
				Pettersson meter.	15	10.30	0.98		1.18	6.30	10.18	1.06		1.53	6.12	8.66
A18	½ mile S. 64° E. of Persimmon Pt. (38° 22′.3 N., 77° 00′.2 W.).	do	½	Pole	7	9.90	0.18	340	1.01	5.50	8.98	0.86	180	1.51	6.92	8.01
				Meter	8	9.90	0.08		1.01	5.32	8.88	0.86		1.41	7.10	7.96
				do	20	9.90	0.08		1.11	5.50	8.98	0.86		1.31	6.92	7.98
				do	32	9.90	0.28		1.01	5.50	8.98	0.86		1.31	6.92	8.04
A17	Off Brents Wharf, Port Tobacco River (38° 27′.9 N., 77° 02′.2 W.).	June 26-27, 1928	1	Pole	3	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)
				Meter	2											
				do	5											
A16	1⅛ miles SE. of Maryland Pt. (38° 20′.6 N., 77° 11′.8 W.).	June 21, 1928	½	Pole	7	10.80	0.98	265	0.80	5.25	9.63	1.16	72	1.00	7.17	8.67
				Meter	3	10.80	0.98		0.78	5.20	9.58	1.16		1.08	7.22	8.66
				do	7½	10.80	0.88		0.88	5.45	9.83	1.26		0.98	6.97	8.72
				do	12	10.80	0.88		0.80	5.20	9.58	1.46		0.98	7.22	8.71
A15	⅞ mile SE. of Maryland Pt. (38° 20′.8 N., 77° 11′.8 W.).	June 20-22, 1928	2	Pole	7	10.95	1.18	270	1.08	5.43	9.96	0.96	82	1.43	6.99	8.79
				Meter	6	10.90	1.10		1.05	5.42	9.90	1.06		1.40	7.00	8.77
				do	14	10.85	0.98		0.82	5.50	9.93	1.16		1.05	6.92	8.76
				do	22	10.80	0.96		0.84	5.55	9.93	1.26		1.07	6.87	8.77
				Pettersson meter.	16	10.40	0.88		0.92	6.15	10.13	1.26		1.22	6.27	8.70
A14	⅝ mile SE. of Maryland Pt. (38° 21′.2 N., 77° 11′.9 W.).	June 21, 1928	½	Pole	7	11.10				5.20	9.88	1.06	90	1.58	7.22	8.86
				Meter	7½	11.20				5.00	9.78	0.76		1.67	7.42	8.76
				do	19	11.10				5.40	10.08	0.96		1.58	7.02	8.89
				do	30½	11.10				5.40	10.08	1.16		1.50	7.02	8.96
A13	Aquia Creek entrance (38° 23′.6 N., 77° 18′.9 W.).	June 20-21, 1928	½	Pole	4½	8.80				7.70	10.08	12.28	84	0.49	4.72	7.76
				Meter	1½	8.80				7.70	10.08	12.18		0.57	4.72	7.72
				do	4	8.80				7.60	9.98	12.18		0.57	4.82	7.69
				do	6½	8.80				7.60	9.98	11.98		0.57	4.82	7.62
O2	1⅝ miles N. of Brents Pt. (38° 25′.4 N., 77° 18′.9 W.).	Sept. 28-29, 1928	⅔	Pole	4½	9.77	0.60	(17)	0.56	6.97	10.32	0.65	(13)	0.51	5.45	8.36
A12	¾ mile E. of Quantico Dock (38° 31′.2 N., 77° 16′.1 W.).	June 19-20, 1928	½	Pole	7	10.90	1.38	7	0.98	5.50	9.98	0.96	195	0.58	6.92	8.84
				Meter	6	10.90	1.38		0.94	5.50	9.98	0.96		0.74	6.92	8.84
				do	15	10.90	1.38		0.97	5.50	9.98	0.96		0.67	6.92	8.84
				do	24	11.00	1.18		0.88	5.40	9.98	1.06		0.68	7.02	8.84

[10] Westerly.
[11] Easterly.
[13] Southerly.
[16] Current weak and irregular.
[17] Northerly.
[18] Pole observations bad due to wind.
[19] Practically no current.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations: Date	Observations: Period	Observations: Method	Observations: Depth	Slack after LW	Flood strength: Time after LW	Flood strength: Direction (true)	Flood strength: Velocity	Flood duration	Slack after HW	Ebb strength: Time after HW	Ebb strength: Direction (true)	Ebb strength: Velocity	Ebb duration	Mean current hour
	(10) Potomac River—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
A11	½ mile N. 74° E. of Quantico Dock (38° 31′.3 N., 77° 16′.6 W.).	June 18-20, 1928	1¾	Pole	7	11.08	1.28	21	0.66	5.65	10.31	1.03	200	0.93	6.77	8.96
				Meter	5½	11.18	1.28		0.62	5.52	10.28	1.29		0.73	6.90	9.04
				do	14½	11.20	1.20		0.56	5.50	10.28	1.19		0.71	6.92	9.00
				do	21½	11.22	1.18		0.57	5.48	10.28	1.13		0.62	6.94	8.98
				Pettersson meter.	15	11.10	1.18		0.62	5.63	10.31	1.46		0.79	6.79	9.04
A10	¼ mile N. 43° E. of Quantico Dock (38° 31′.4 N., 77° 16′.9 W.).	June 19, 1928	½	Pole	7	11.70	1.18	21	0.67	4.80	10.08	2.36	201	0.97	7.62	9.36
				Meter	6½	11.70	1.28		0.67	5.20	10.48	1.96		0.97	7.22	9.38
				do	16	11.60	1.28		0.61	5.30	10.48	2.06		0.91	7.12	9.38
				do	25½	11.60	1.18		0.60	5.20	10.38	1.96		0.80	7.22	9.31
A9	Railway Bridge, Quantico Creek (38° 31′.7 N., 77° 17′.3 W.).	June 18, 19, 1928	½	Pole	4½	9.70	1.28	306	0.47	6.80	10.08	1.26	115	0.47	5.62	8.61
				Meter	2	9.90	1.18		0.47	6.30	9.78	1.06		0.47	6.12	8.51
				do	5½	9.80	1.18		0.47	6.50	9.88	1.16		0.47	5.92	8.54
				do	9	9.80	1.18		0.47	6.40	9.78	1.16		0.47	6.02	8.51
A8	⅞ mile N. 41° E. of Hallowing Pt. (38° 38′.8 N., 77° 07′.2 W.).	June 15, 1928	½	Pole	4½	12.30	2.88	348	0.31	5.10	10.98	0.86	176	0.61	7.32	9.78
				Meter	2½	12.30	2.78		0.67	5.20	11.08	0.66		0.67	7.22	9.72
				do	5	12.20	2.78		0.67	5.10	10.88	0.66		0.67	7.32	9.66
				do	10½	12.20	2.38		0.59	5.20	10.98	0.86		0.59	7.22	9.64
A7	⅝ mile N. 16° E. of Hallowing Pt. (38° 38′.7 N., 77° 07′.6 W.).	June 15-16, 1928	1	Pole	7	0.03	1.98	340	0.96	5.35	11.38	1.96	168	1.11	7.07	9.97
				Meter	7	12.40	2.13		0.93	5.40	11.38	2.36		1.03	7.02	10.10
				do	16	12.35	2.38		0.87	5.40	11.33	2.26		1.12	7.02	10.11
				do	26	12.40	2.28		0.80	5.45	11.43	2.06		0.95	6.97	10.07
R4	Off Marshall Hall (38° 41′.4 N., 77° 06′.1 W.).	Mar. 23-26, 1914	½		(3)	12.29										10.55
A6	Mid-channel, east of Jones Pt. (38° 47′.5 N., 77° 02′.3 W.).	June 11-15, 1928	3½	Pole	7	0.34	2.48	0	1.10	5.14	11.48	2.45	180	1.04	7.28	10.32
				Meter	6	0.29	2.41		1.09	5.17	11.46	2.43		0.97	7.25	10.28
				do	15	0.35	2.27		1.00	5.02	11.37	2.47		0.95	7.40	10.25
				do	24	0.31	2.24		0.85	4.97	11.28	2.47		0.84	7.45	10.21
			1	Petterson Meter.	15	0.01	1.78		0.96	4.77	10.78	2.36		0.81	7.65	9.87
R3	Mid-channel, off Alexandria (38° 48′.2 N., 77° 02′.2 W.).	Nov. 10, 1913-June 2, 1915.	205	Float	(3)	0.31		(17)		4.77	11.08		(13)		7.65	10.27
A4	Off Bolling Field, Anacostia River (38° 51′.8 N., 77° 00′.6 W.).	June 11-12, 1928	½	Pole	4½	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	5											
				do	12											
				do	19											
A5	Anacostia Bridge, Anacostia River (38° 52′.3 N., 76° 59′.4 W.).	June 12-13, 1928	1	Pole	4½	12.15	1.98	70	0.40	5.90	11.63	2.26	240	0.25	6.52	10.04
				Meter	5	12.25	1.88		0.50	5.75	11.58	2.21		0.35	6.67	10.01
				do	12	12.35	1.88		0.50	5.60	11.53	2.11		0.35	6.82	10.00
				do	19	12.35	1.88		0.50	5.55	11.48	2.06		0.35	6.87	9.97
R2	Benning Bridge, Anacostia River (38° 53′.8 N., 76° 57′.7 W.).	Dec. 18, 1914	¼		(3)	11.72		(17)					(13)			9.98
A3	Washington channel, E. of Potomac Park (38° 51′.8 N., 77° 01′.2 W.).	June 11, 1928	½	Pole	4½	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)
				Meter	5½											
				do	15											
				do	23											
A2	Off Gravelly Pt. (38° 52′.2 N., 77° 02′.0 W.).	June 14-15, 1928	½	Pole	7	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)
				Meter	5											
				do	13											
				do	21											
F2	West of Potomac Park (38° 52′.4 N., 77° 02′.3 W.).	Nov. 27, 1867	½			12.37	1.85	322	0.49	5.02	10.97	2.75	122	0.69	7.40	10.02
F1	⅛ mile above Highway Bridge, Georgetown Channel (38° 52′.6 N., 77° 02′.7 W.).	Nov. 26, 1867	½			0.25	2.15	291	0.36	5.12	11.37	3.05	100	0.46	7.30	10.34
A1	Key Bridge, off Georgetown (38° 54′.2 N., 77° 04′.2 W.).	June 13-14, 1928	1	Pole	4½	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)
				Meter	5											
				do	13											
				do	21											
R1	Chain Bridge (38° 55′.8 N., 77° 07′.0 W.).	Aug. 19, 1914-June 10, 1915.			(3)	(20)	(20)	(20)	(20)	(20)	(20)	(20)	(20)	(20)	(20)	(20)
	(11) Patuxent River															
L13	1½ miles N. 84° E. of Drum Pt. Light (38° 19′.3 N., 76° 23′.5 W.).	Oct. 4-5, 1849	1		8	8.12	10.42	251	0.28	4.67	6.37	10.12	80	0.53	7.75	5.58
Fg2	⅝ mile E. of Drum Pt. (38° 19′.2 N., 76° 24′.5 W.).	Aug. 8-19, 1908	¾	Pole		6.92				5.92	6.42	9.82	60	0.80	6.50	5.09
H75	⅜ mile S. of Drum Pt. (38° 18′.8 N., 76° 25′.3 W.).	Sept. 16-17, 1927	1	do	7	6.70	9.85	245	0.65	6.35	6.63	9.48	40	0.55	6.07	4.98
				Meter	14	6.80	9.75		0.60	6.25	6.63	9.58		0.60	6.17	5.01
				do	36	6.55	9.30		0.55	6.25	6.38	9.48		0.55	6.17	4.75
				do	58	5.65	8.05		0.60	6.25	5.48	8.93		0.60	6.17	3.85
Fg3	Off Pt. Patience (38° 19′.7 N., 76° 29′.3 W.).	Aug. 11-12, 1908	¾	Pole		5.52	9.82	306	0.91	7.57	6.67	9.32	178	0.52	4.85	4.65
Fg4	Off Broome I. (38° 23′.8 N., 76° 33′.3 W.).	Aug. 13-28, 1908	¾	do		7.97	10.02	284	0.50	4.52	6.07				7.90	5.32
H76	Off Benedict (38° 30′.7 N., 76° 40′.3 W.).	Sept. 16-17, 1927	1	do	7	7.25	10.40	31	0.98	6.85	7.68	10.48	217	0.48	5.57	5.77
				Meter	7	7.35	10.50		0.93	6.65	7.58	10.38		0.48	5.77	5.77
				do	17½	7.40	10.35		0.98	6.70	7.68	10.58		0.48	5.72	5.82
				do	28	6.90	10.50		0.85	7.60	8.08	10.78		0.40	4.82	5.88

[3] Surface.
[13] Southerly.
[16] Current weak and irregular.
[17] Northerly.
[18] Practically no current.
[19] Current weak; did not flood during observations.
[20] Observations of slack water scattered over 22 days indicate that current ebbs most of the time.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations: Date	Period	Method	Depth	Slack after LW	Flood strength: Time after LW	Direction (true)	Velocity	Flood duration	Slack after HW	Ebb strength: Time after HW	Direction (true)	Velocity	Ebb duration	Mean current hour
	(11) Patuxent River—Continued		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
H77	Off Lyons Creek Wharf (38° 44′.8 N., 76° 41′.1 W.).	Sept. 16–17, 1927	1	Pole	7	8.60	11.30	315	1.08	6.10	8.28	11.18	141	0.93	6.32	6.66
				Meter	7	8.65	11.30		0.93	6.15	8.38	11.28		0.93	6.27	6.72
				do	18	8.70	11.30		0.98	6.20	8.48	11.28		0.93	6.22	6.76
				do	29	8.65	11.50		1.03	6.20	8.43	11.18		0.88	6.22	6.76
	(12) Little Choptank and Choptank Rivers															
H70	1 mile S. 43° W. of Hills Pt., Little Choptank River entrance, (38° 33′.0 N., 76° 19′.6 W.).	Sept. 13–14, 1927	1	Pole	7	7.55	10.75	101	0.35	6.50	7.63	10.48	267	0.30	5.92	5.92
				Meter	7	7.30	10.75		0.39	6.85	7.73	10.28		0.29	5.57	5.84
				do	17	7.20	10.25		0.30	6.80	7.50	10.28		0.30	5.62	5.65
				do	27	7.25	10.50		0.17	6.75	7.48	10.18		0.32	5.77	5.67
H71	Off Casons Pt., Little Choptank River (38° 31′.9 N., 76° 14′.5 W.).	do	1	Pole	7	7.20	9.60	62	0.57	5.85	6.63	9.58	244	0.52	6.57	5.07
				Meter	6	7.30	9.55		0.57	5.70	6.58	9.63		0.52	6.72	5.08
				do	15	7.10	9.55		0.47	6.00	6.68	9.68		0.62	6.42	5.07
				do	24	7.10	9.70		0.41	6.10	6.78	9.68		0.46	6.32	5.14
M4	1¾ miles S. 60° E. of Sharps I. (38° 36′.2 N., 76° 19′.8 W.).	July 25, 1848	½		(3)	7.62	10.12	26	0.82			9.52	228	0.92		5.35
H63	1⅜ miles N., 33° W. of Cooks Pt., Choptank River (38° 39′.1 N., 76° 18′.4 W.).	Sept. 9–10, 1927	1	Pole	7	8.10	11.10	50	0.70	6.20	7.88	11.38	238	0.60	6.22	6.44
				Meter	12	8.15	11.05		0.69	6.10	7.83	11.38		0.69	6.32	6.42
				do	30	7.65	10.65		0.75	6.15	7.38	10.48		0.50	6.27	5.86
				do	48	6.05	9.65		0.85	7.05	6.68	9.43		0.40	5.37	4.77
B2	2¼ miles N. of Todds Pt., Choptank River (38° 39′.9 N., 76° 15′.1 W.).	Aug. 12–14, 1902	1½	Pole		7.45	11.32	69	0.27	6.39	7.42	10.29	272	0.30	6.03	5.94
M3	2 miles N. of Todds Pt., Choptank River (38° 39′.7 N., 76° 15′.0 W.).	July 18–19, 1848	1		(3)	9.57	0.35	87	0.67	5.67	8.82	11.82	271	0.77	6.75	7.56
H64	½ mile S. of Choptank River Light, Choptank River (38° 38′.8 N., 76° 10′.9 W.).	Sept. 8–9, 1927	1	Pole	7	9.35	11.00	78	0.27	4.25	7.18	12.03	282	0.42	8.17	6.71
				Meter	7	9.40	11.00		0.27	4.15	7.13	12.03		0.52	8.27	6.71
				do	17½	8.85	11.10		0.28	5.05	7.48	11.18		0.33	7.37	6.47
				do	28	8.50	10.90		0.18	4.95	7.03	10.58		0.33	7.47	6.07
H65	W. of Oxford, Tred Avon River (38° 41′.5 N., 76° 10′.8 W.).	Sept. 7–8, 1927	1	Pole	7	8.10	10.20	16	0.44	5.30	6.98	10.48	200	0.39	7.12	5.76
				Meter	6	8.25	10.10		0.44	5.45	7.28	10.48		0.39	6.97	5.85
				do	15	8.10	10.20		0.33	5.35	7.03	9.98		0.43	7.07	5.65
				do	24	7.90	10.30		0.33	5.15	6.63	9.78		0.33	7.27	5.47
B1	N. of Oxford, Tred Avon River (38° 41′.9 N., 76° 10′.4 W.).	Aug. 1–2, 1902	½	Pole		9.02				4.52	7.12	9.92	229	0.42	7.90	6.06
H66	½ mile below Easton Pt., Tred Avon River (38° 45′.8 N., 76° 06′.2 W.).	Sept. 6, 1927	½	Meter	6	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)
H67	Off Hambrooks Bar, Choptank River (38° 35′.8 N., 76° 04′.8 W.).	Sept. 12–13, 1927	1	Pole	7	8.85	11.55	111	0.61	5.85	8.28	11.18	315	0.51	6.57	6.78
				Meter	9	8.85	11.60		0.61	5.95	8.38	11.53		0.51	6.47	6.91
				do	22½	8.80	11.30		0.52	6.05	8.43	11.88		0.52	6.37	6.92
				do	36	8.60	11.45		0.54	6.45	8.63	11.73		0.44	5.97	6.92
H68	B. C. & A. Ry. Bridge, Choptank River (38° 44′.7 N., 75° 59′.8 W.).	do	1	Pole	7	10.20	0.43	340	0.66	6.40	10.18	0.71	148	0.76	6.02	8.41
				Meter	8	10.20	0.43		0.70	6.40	10.18	0.51		0.80	6.02	8.36
				do	13	10.00	0.43		0.64	6.45	10.03	0.31		0.64	5.97	8.22
	(13) Eastern Bay															
H57	1⅞ miles S. 22° E. of Bloody Pt. Bar Light (38° 48′.3 N., 76° 22′.6 W.).	Sept. 2–3, 1927	1	Pole	7	10.65	1.23	30	0.40	5.25	9.48	1.76	187	0.50	7.17	8.81
				Meter	8	10.70	1.18		0.40	5.20	9.48	1.16		0.50	7.22	8.66
				do	20	10.80	1.28		0.41	5.05	9.43	0.86		0.61	7.37	8.62
				do	32	10.85	1.98		0.40	5.75	10.18	2.06		0.50	6.67	9.30
L9	1¼ miles SE. of Kent Pt. (38° 49′.5 N., 76° 20′.7 W.).	Oct. 15–18, 1846	3					31	0.57	5.29			255	0.41	7.13	
		Oct. 15–16, 1849	1		8	8.47	11.52	25	0.37	7.17	9.22	12.12	236	0.17	5.25	7.16
H58	1 mile SE. of Long Pt. (38° 50′.6 N., 76° 19′.6 W.).	Sept. 2–3, 1927	1	Pole	7	8.20	11.20	39	0.50	6.35	8.13	11.13	234	0.40	6.07	6.48
				Meter	8½	8.10	11.15		0.45	6.10	7.78	10.93		0.45	6.32	6.31
				do	21	9.50	11.30		0.29	4.00	7.08	10.68		0.54	8.42	6.46
				do	33½	8.80	11.35		0.56	5.40	7.78	10.93		0.41	7.02	6.54
M1	1¾ miles S. of Turkey Pt. (38° 52′.4 N., 76° 17′.6 W.).	July 31, 1847	½		(3)			48	0.81	6.11			228	0.71	6.31	
H59	1⅛ miles N. of Tilghman Pt. (38° 53′.0 N., 76° 15′.1 W.).	Sept. 9–10, 1927	1	Pole	7	8.30	11.55	73	0.33	5.85	7.73	10.88	260	0.48	6.57	6.44
				Meter	9	8.50	11.45		0.34	5.95	8.03	10.98		0.44	6.47	6.56
				do	22½	8.35	11.55		0.34	6.20	8.13	10.83		0.39	6.22	6.54
				do	36	7.05	10.60		0.49	7.35	7.98	10.48		0.24	5.07	5.85
M2	1⅛ miles S. 70° W. of Bennett Pt. (38° 50′.8 N., 76° 13′.7 W.).	June 17–18, 1847	1		(3)	8.62	12.07	190	0.43	6.27	8.47	11.22	354	0.43	6.15	6.92
H60	Off Deep Water Pt. Miles River (38° 48′.2 N., 76° 12′.6 W.).	Sept. 8–9, 1927	1	Pole	7	8.45	11.45	206	0.61	6.15	8.18	11.58	358	0.36	6.27	6.74
				Meter	9	8.45	11.50		0.57	6.05	8.08	11.68		0.37	6.37	6.75
				do	23	8.20	11.15		0.57	5.95	7.73	11.48		0.37	6.47	6.46
				do	37	8.30	11.15		0.38	6.20	8.08	11.18		0.18	6.22	6.50
H61	¾ mile above Long Pt. Miles River (38° 46′.4 N., 76° 09′.4 W.).	Sept. 7–8, 1927	1	Pole	4½	8.20	11.60	50	0.28	5.30	7.08	10.68	244	0.43	7.12	6.21
				Meter	7½	7.95	11.50		0.38	6.00	7.53	10.88		0.33	6.42	6.28
				do	12	7.70	11.40		0.38	6.35	7.63	10.98		0.23	6.07	6.25
	(14) South and Severn Rivers															
H51	Midchannel, off Marshy Pt. South River (38° 54′.3 N., 76° 28′.8 W.).	Aug. 11–12, 1927	1	Pole	7	9.45	0.08	347	0.09	5.15	8.18	12.13	156	0.09	7.27	7.38
				Meter	9	9.95	0.18		0.18	4.40	7.93	0.01		0.18	8.02	7.55
				do	14	9.00	12.40		0.17	7.79	7.63	11.28		0.22	7.37	6.90
H52	Off Lee's Wharf, South River (38° 57′.0 N., 76° 33′.2 W.).	Aug. 12–13, 1927	½	Pole	4½	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	9											
				do	14											
H47	¾ mile S. 35° E. of Greenbury Pt. Shoal Light (38° 57′.4 N., 76° 26′.7 W.).	Aug. 23–24, 1927	1	Pole	7	10.00	0.83	344	0.36	4.40	7.98	12.28	183	0.41	8.02	7.70
				Meter	5	10.15	1.38		0.51	4.95	8.68	0.26		0.51	7.47	8.15
				do	10½	10.05	1.23		0.51	4.85	8.48	0.06		0.51	7.57	7.98
				do	17	10.10	1.18		0.41	4.70	8.38	12.28		0.51	7.72	7.91
Fg1	⅝ mile S. 30° E. of Greenbury Pt. Shoal Light (38° 57′.5 N., 76° 26′.9 W.).	June 14, 1910	½	Pole		8.72	1.40	329	0.61	7.82	10.12	0.10	163	0.41	4.60	8.12

[3] Surface. [16] Current weak and irregular. [18] Practically no current.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(14) South and Severn Rivers—Contd.		*Days*		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Deg.*	*Hrs.*	*Knts.*	*Hrs.*	*Hrs.*
H48	Off Naval Academy, Severn River (38° 59′.1 N., 76° 28′.7 W.).	Aug. 25–26, 1927	1	Pole	7	9.25	11.90	323	0.28	6.05	8.88	134	12.38	0.18	6.37	7.42
				Meter	6	9.25	11.90		0.28	6.05	8.88		12.38	0.18	6.37	7.42
				do	15	9.25	11.95		0.28	6.25	9.08		12.38	0.18	6.17	7.48
				do	24	9.20	12.15		0.14	6.20	8.98		12.28	0.09	6.22	7.47
H49	Off Brewer Pt., Severn River (39° 01′.8 N., 76° 31′.9 W.).	Aug. 26–27, 1927	1	Pole	7	9.80	0.08	318	0.13	5.70	9.08	159	12.18	0.38	6.72	7.71
				Meter	5½	9.85	0.33		0.13	5.90	9.33		12.28	0.38	6.52	7.87
				do	13½	9.45	0.03		0.18	6.20	9.23		12.08	0.28	6.22	7.62
				do	22	9.30	0.03		0.14	6.35	9.23		11.68	0.19	6.07	7.48
	(15) Chester River															
H43	2¼ miles S. 12° E. of Love Pt. Light (39° 01′.3 N., 76° 16′.4 W.).	Aug. 25–26, 1927	1	Pole	7	11.80	1.93	206	0.13	5.15	10.53	336	1.51	0.38	7.27	9.47
				Meter	8	11.30	2.13		0.32	5.50	10.38		1.46	0.42	6.92	9.35
				do	20	11.05	2.33		0.51	6.35	10.98		1.36	0.36	6.07	9.46
				do	32				0.56					0.31		
H44	½ mile NE. of Hail Pt. (39° 01′.0 N., 76° 11′.2 W.).	Aug. 29–30, 1927	1	Pole	7	11.40	1.43	352	0.62	6.05	11.03	160	2.01	0.37	6.37	9.50
				Meter	9	11.50	1.53		0.67	6.30	11.38		2.16	0.37	6.12	9.67
				do	22	11.75	1.48		0.53	5.10	10.43		1.81	0.73	7.32	9.40
				do	35	10.30	1.13		0.68	6.60	10.48		0.91	0.58	5.82	8.74
H45	⅜ mile NE. of Deep Pt. (39° 06′.7 N., 76° 06′.7 W.).	Aug. 30–31, 1927	1	Pole	7	11.85	2.03	38	0.76	5.65	11.08	220	1.91	0.76	6.77	9.75
				Meter	7	11.75	1.93		0.81	5.70	11.03		1.91	0.76	6.72	9.68
				do	17	11.75	1.88		0.76	5.85	11.18		1.91	0.76	6.57	9.71
				do	28	11.30	1.63		0.70	5.70	10.58		1.26	0.65	6.72	9.22
H46	Off Chestertown (39° 12′.5 N., 76° 03′.6 W.).	Aug. 31–Sept. 1, 1927	1	Pole	5	11.85	2.73	47	0.75	5.25	11.68	226	1.81	0.90	6.17	10.30
				Meter	7	11.85	2.78		0.75	6.20	11.63		1.91	0.90	6.22	10.07
				do	11	11.55	2.53		0.74	6.50	11.63		1.86	0.69	5.92	9.92
	(16) Patapsco River															
H31	½ mile off Frankie Pt. (39° 08′.7 N., 76° 26′.2 W.).	Aug. 4–5, 1927	1	Pole	7	12.00	1.48	281	0.15	4.25	9.83	136	1.71	0.25	8.17	9.28
				Meter	8	11.90	1.63		0.28	4.80	10.28		1.81	0.33	7.62	9.44
				do	13	11.70	1.58		0.28	5.40	10.68		1.76	0.33	7.02	9.46
H30	1¾ miles E. of Rock Pt. (39° 10′.0 N., 76° 26′.4 W.).	Aug. 5–6, 1927	1	Pole	7	12.00	2.58	314	0.33	5.80	11.38	148	2.31	0.28	6.62	10.10
				Meter	4	0.08	2.48		0.34	5.05	11.13		2.26	0.34	7.37	10.12
				do	9	12.10	2.18		0.35	5.15	10.83		2.26	0.40	7.27	9.87
				do	14	12.35	2.28		0.21	5.00	10.93		2.21	0.26	7.42	9.97
H29	Channel 1 mile S. of North Pt. (39° 10′.7 N., 76° 26′.4 W.).	Aug. 19–20, 1927	1	Pole	7	11.20	1.78	340	0.25	6.15	10.93	1.83	150	0.40	6.27	9.47
				Meter	8	11.35	1.73		0.35	6.00	10.93	1.76		0.40	6.42	9.47
				do	18	10.55	1.63		0.30	6.75	10.88	1.58		0.30	5.67	9.19
				do	28	10.35	1.33		0.35	6.09	10.68	1.01		0.30	6.33	8.87
Wb10	Channel, S. of North Pt. (39° 10′.8 N., 76° 26′.5 W.).	June 5, 1867	½		(3)	0.60				5.12	11.72	2.70	184	0.75	7.30	10.66
Wb11	⅜ mile SW. of North Pt. (39° 11′.5 N., 76° 27′.1 W.).	May 28–29, 1867	1		do	11.77	1.75	316	0.24	4.82	10.17	12.32	134	0.17	7.60	8.93
Wb12	1¼ miles NE. of Rock Pt. (39° 11′.1 N., 76° 27′.8 W.).	May 30, 1867	½		do	10.82	1.30	298	0.49	5.22	9.62	2.70	135	0.19	7.20	9.14
Wb13	¾ mile NE. of Rock Pt. (39° 10′.7 N., 76° 28′.2 W.).	May 31–June 4, 1867	1		do	11.22	1.45	342	0.23	5.25	10.05	1.10	104	0.28	7.17	8.98
H32	Brewerton Channel, S. of Sparrows Pt. (39° 11′.6 N., 76° 29′.0 W.).	Aug. 19–20, 1927	1	Pole	7	10.60	0.88	292	0.30	6.85	11.03	1.46	110	0.15	5.57	9.02
				Meter	7	10.50	0.88		0.20	6.80	10.88	1.36		0.25	5.62	8.94
				do	17½	10.75	1.18		0.20	6.60	10.93	1.66		0.25	5.82	9.16
				do	28	10.30	0.58		0.30	6.95	10.83	1.31		0.20	5.47	8.78
H33	Bear Creek entrance (39° 13′.8 N., 76° 29′.9 W.).	July 28–29, 1927	1	Pole	4½	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	8											
				do	13											
H34	Channel, N. of Hawkins Pt. (39° 13′.4 N., 76° 32′.1 W.).	July 26–27, 1927	½	Pole	7	10.80	1.98	324	0.09			1.66	126	0.19		9.35
				Meter	7	10.80	1.98		0.19			1.66		0.19		9.35
				do	17½	10.80	1.98		0.19			1.66		0.19		9.35
				do	28	11.00	1.98		0.19			1.66		0.19		9.42
H35	Curtis Creek entrance (39° 13′.1 N., 76° 34′.6 W.).	July 27–28, 1927	1	Pole	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	5½											
				do	13½											
				do	22											
H36	Northwest Harbor entrance, off Ft. McHenry (39° 15′.8 N., 76° 34′.5 W.).	July 25–26, 1927	1	Pole	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	7											
				do	17½											
				do	28											
K1	Northwest Harbor entrance, off Ft. McHenry (39° 15′.9 N., 76° 34′.5 W.).	January–June 1903	4	Float	(3)	10.90	1.48	(17)	[21] 0.10	6.21	10.69	1.27	(13)	[21] 0.08	6.21	9.12
H37	Middle Branch (39° 15′.4 N., 76° 37′.0 W.).	July 29–30, 1927	1	Pole	7	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
				Meter	6											
				do	13½											
				do	21											
	(17) Sassafras and Elk Rivers															
H16	Off Grove Point, Sassafras River (39° 22′.7 N., 76° 02.6 W.).	July 21–22, 1927	1	Pole	5½	0.33	3.13	95	0.40	6.25	0.16	3.16	288	0.40	6.17	10.94
				Meter	3	0.28	3.33		0.35	6.35	0.21	3.26		0.30	6.07	11.01
				do	7	0.28	3.28		0.40	6.00	12.28	3.06		0.35	6.42	10.86
				do	11	0.33	3.18		0.35	6.05	12.38	3.16		0.30	6.37	10.90
H17	Georgetown-Frederick Bridge, Sassafras River (39° 21′.9 N., 75° 53′.0 W.).	July 20–21, 1927	1	Pole	7	0.43	3.18	42	0.39	6.15	0.16	3.96	226	0.24	6.27	11.17
				Meter	5	0.53	2.88		0.38	6.05	0.16	4.01		0.33	6.37	11.14
				do	12	0.68	2.88		0.33	5.90	0.16	4.11		0.38	6.52	11.20
				do	19	0.78	2.88		0.33	5.75	0.11	4.06		0.38	6.67	11.20

[3] Surface. [13] Southerly. [16] Current weak and irregular. [17] Northerly. [21] Velocity not corrected for range of tide.

TABLE 53.—*Current data, Chesapeake Bay and tributaries*—Continued

Station No.	Location	Observations				Slack after LW	Flood strength			Flood duration	Slack after HW	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time after LW	Direction (true)	Velocity			Time after HW	Direction (true)	Velocity		
	(17) Sassafras and Elk Rivers—Con.															
			Days		*Feet*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*	*Hrs.*	*Deg.*	*Knts.*	*Hrs.*	*Hrs.*
H10	N. from Reybolds Wharf, Elk River (39° 27′.6 N., 75° 58′.7 W.).	July 19–20, 1927	1	Pole	7	0.78	3.58	30	0.65	6.05	0.41	3.86	216	0.70	6.37	11.40
				Meter	4	0.88	3.68		0.56	6.00	0.46	3.81		0.51	6.42	11.45
				do	11	0.83	3.68		0.56	5.90	0.31	3.81		0.61	6.52	11.40
				do	18	0.78	3.88		0.46	5.90	0.26	3.76		0.46	6.52	11.41
H13	Off Hendersons Pt., Elk River (39° 33′.2 N., 75° 51′.6 W.).	July 18–19, 1927	½	Pole	5½	2.08	4.58	30	0.54	5.30	0.96	4.46	209	0.74	7.12	12.26
				Meter	3	1.98	4.68		0.45	5.50	1.06	4.26		0.75	6.92	12.24
				do	6	1.98	4.48		0.46	5.40	0.96	4.16		0.56	7.02	12.14
				do	10	2.18	4.58		0.55	5.30	1.06	4.36		0.55	7.12	12.28
H11	Off Sandy Pt., Back Creek (39° 31′.7 N., 75° 52′.0 W.).	July 19, 1927	½	Pole	5½	0.98	4.48	19	0.57	6.20	0.76	3.56	225	1.47	6.22	11.68
				Meter	3	0.88	4.08		0.60	6.10	0.56	3.46		1.10	6.32	11.48
				do	7	0.88	4.38		0.58	6.10	0.56	3.56		1.38	6.32	11.58
				do	11	0.78	4.48		0.49	6.30	0.66	3.86		1.29	6.12	11.68
H12	77 yards W. of Chesapeake City Bridge, Back Creek (39° 31′.7 N., 75° 48′.7 W.).	July 19–20, 1927	1	Pole	4½	1.83	5.03	131	0.43	5.40	0.81	4.06	310	1.33	7.02	12.17
				Meter	6	1.88	5.03		0.49	5.20	0.66	3.96		1.09	7.22	12.12
				do	10	1.88	4.93		0.44	5.10	0.56	3.81		1.04	7.32	12.04
	(18) Chesapeake and Delaware Canal [22]															
Ca1	Chesapeake City Bridge (39° 31′.7 N., 75° 48′.7 W.).	June 4–5, 1928	1	Pole	4½	0.98	4.03	(11)	1.35	6.80	1.36	3.81	(10)	1.83	5.62	11.78
				Meter	3	0.93	4.23		1.13	6.90	1.41	3.81		1.65	5.52	11.84
				do	9	0.98	4.23		0.90	6.85	1.41	3.86		1.52	5.57	11.86
E4	Near Chesapeake City Bridge (39° 31′.7 N., 75° 48′.7 W.).	May 13, 1927	½		(3)	1.60		(11)		6.92	2.10		(10)		5.50	12.64
		1928–29	5	Meter	7	1.34	4.53	(11)	1.05	6.14	1.06	3.92	(10)	1.39	6.28	11.95
E5	1 mile E. of Chesapeake City Bridge (39° 31′.9 N. 75° 47′.7 W.).	May 13, 1927	½		(3)	1.20		(11)		7.12	1.90		(10)		5.30	12.34
E6	1½ miles W. of Summit Bridge (39° 32′.6 N., 75° 45′.2 W.).	do	½		(3)	0.80	4.20	(11)	1.17	7.12	1.50	3.50	(10)	1.17	5.30	11.74
E7	¼ mile E. of Summit Bridge (39° 32′.7 N., 75° 43′.1 W.).	May 13, 1927	½		(3)	0.80		(11)		7.12	1.50		(10)		5.30	11.94
		1928–29	5	Meter	7	1.24	4.26	(11)	1.09	5.93	0.75	3.40	(10)	1.17	6.49	11.65
Ca2	Pennsylvania R. R. Bridge (39° 32′.8 N., 75° 42′.2 W.).	June 4–6, 1928	2	Pole	4½	0.34	3.98	(11)	1.37	7.26	1.18	3.54	(10)	0.92	5.16	11.50
				Meter	3	0.38	3.80		1.61	7.25	1.21	3.48		1.11	5.17	11.46
				do	13	0.34	3.72	(11)	1.30	7.26	1.18	3.34		0.97	5.16	11.38
E8	1 mile E. of P. R. R. Bridge (39° 32′.6 N., 75° 41′. 2 W.).	May 13, 1927	½		(3)	0.50		(11)		7.42	1.50		(10)		5.00	11.79
E9	⅛ mile E. of St. Georges Bridge (39° 33′.2 N., 75° 38′.7 W.).	do	½		(3)	0.00	3.30			7.62	1.20	3.30	(10)		4.80	11.24

[3] Surface. [10] Westerly. [11] Easterly. [17] Northerly. [22] Current data for stations near the eastern end of the canal are given in Table 62, p. 118.

TABLE 54.—*Current observations, Chesapeake Bay and tributaries*

Year of observations	Party of—	Designating letters	Number of stations	Locality	Locations plotted on figures
1845	G. M. Bache	Bc	6	Bay: Patapsco River to Severn River.	29, 35.
1846, 1849, 1850	S. P. Lee	L	19	Bay: Upper end to Rappahannock River.	27-29, 34, 35.
1847, 1848	W. P. McArthur	M	4	Eastern Bay; Choptank River	28, 29, 35.
1851, 1853, 1854	John J. Almy	Ay	12	Lower Bay; Hampton Roads	24, 27, 31, 34.
1851	B. F. Sands	S	2	Entrance to Bay	24, 27.
1855	J. N. Maffitt	Ma	1	James River near Hog Island	32, 33.
1867	C. Fendall	F	2	Potomac River at Washington	35.
1867	F. P. Webber	Wb	13	Bay: Near Susquehanna River and Patapsco River.	29.
1876	J. B. Wier	W	2	Elizabeth River	31.
1881	G. Bradford	Br	7	Bay: South of Pocomoke Sound; Rappahannock River.	27, 33, 34.
1896, 1897	E. H. Tillman	T	7	Bay: Patapsco River to Herring Bay.	28, 29, 35.
1897	R. L. Faris	Fa	3	Bay: South River to Patuxent River.	28, 29, 35.
1898	U. S. S. Cassius, Sam W. Very, U. S. N., commanding.	C	1	Hampton Roads	27, 31.
1899	C. C. Yates	Y	1	Lower Bay near Cape Charles City.	27.
1900	P. A. Welker	Wk	2	Bay near Patuxent River	28, 35.
1902	J. B. Boutelle	B	2	Choptank River	28, 35.
1903	F. A. Kummel	K	1	Baltimore Harbor	29.
1908, 1910, 1911, 1912, 1913.	O. W. Ferguson	Fg	31	Bay and tributaries: Severn River to Elizabeth River.	27-29, 31-35.
1909	U. S. Engineers	E	11	Lower Bay at Old York Spit Channel; Chesapeake & Delaware Canal.	27, 36.
1912, 1915, 1919	Crews of light vessels	LV	3	Bay entrance and approaches	24, 27.
1913, 1914, 1915	H. P. Ritter	R	4	Upper Potomac River	35.
1917	P. C. Whitney	Wt	1	Hampton Roads	27, 31.
1918	Harry Leypoldt	Ly	10	Lower Bay: Wolf Trap Light to entrance.	24, 27, 31, 33.
1918	E. B. Latham	La	6	York River mouth	27, 32, 33.
1919	H. A. Seran	Se	1	Approach to bay	24, 27.
1919	L. A. Potter	P	7	Hampton Roads; Elizabeth River	27, 31, 32.
1920, 1921, 1922	U. S. Fish Commission.	FC	6	Bay: Patapsco River to Rappahannock River.	27, 28, 29, 35.
1927	A. J. Hoskinson	H	75	Bay and tributaries: Susquehanna River to Patuxent River.	28, 29, 35, 36.
1928	G. L. Anderson	A	102	Bay and tributaries: South of Patuxent River.	24, 27, 28, 31-35.
1928	G. L. Anderson	Ca	3	Chesapeake & Delaware Canal	29, 36.
1928	H. J. Oliver	O	1	Potomac River near Aquia Creek	35.
1929	Jack Senior	Sr	1	York Spit Channel	27.

THE CURRENT IN THE APPROACHES TO CHESAPEAKE BAY

Because of the relationship between the current movements inside the bay and those off the entrance, the latter are included in this discussion. For convenience, the lower limit of the bay is taken as a straight line drawn from Cape Charles Light to Cape Henry Light. Five current stations plotted on Figure 24 lie eastward of this line and are therefore in the approaches to Chesapeake Bay. At the easternmost of these, station LV1, the tidal current is rotary and turns in a clockwise direction. The characteristics of the rotary type of current, which is the type generally found offshore, are discussed in detail on page 132 of the appendix. Following the method usually employed for the reduction of rotary currents, the observed velocities were resolved into their north and east components and then tabulated with reference to the times of high and low water at Old Point Comfort. The average velocity and direction of the current as obtained from the tabulation is given in Table 55 for each hour

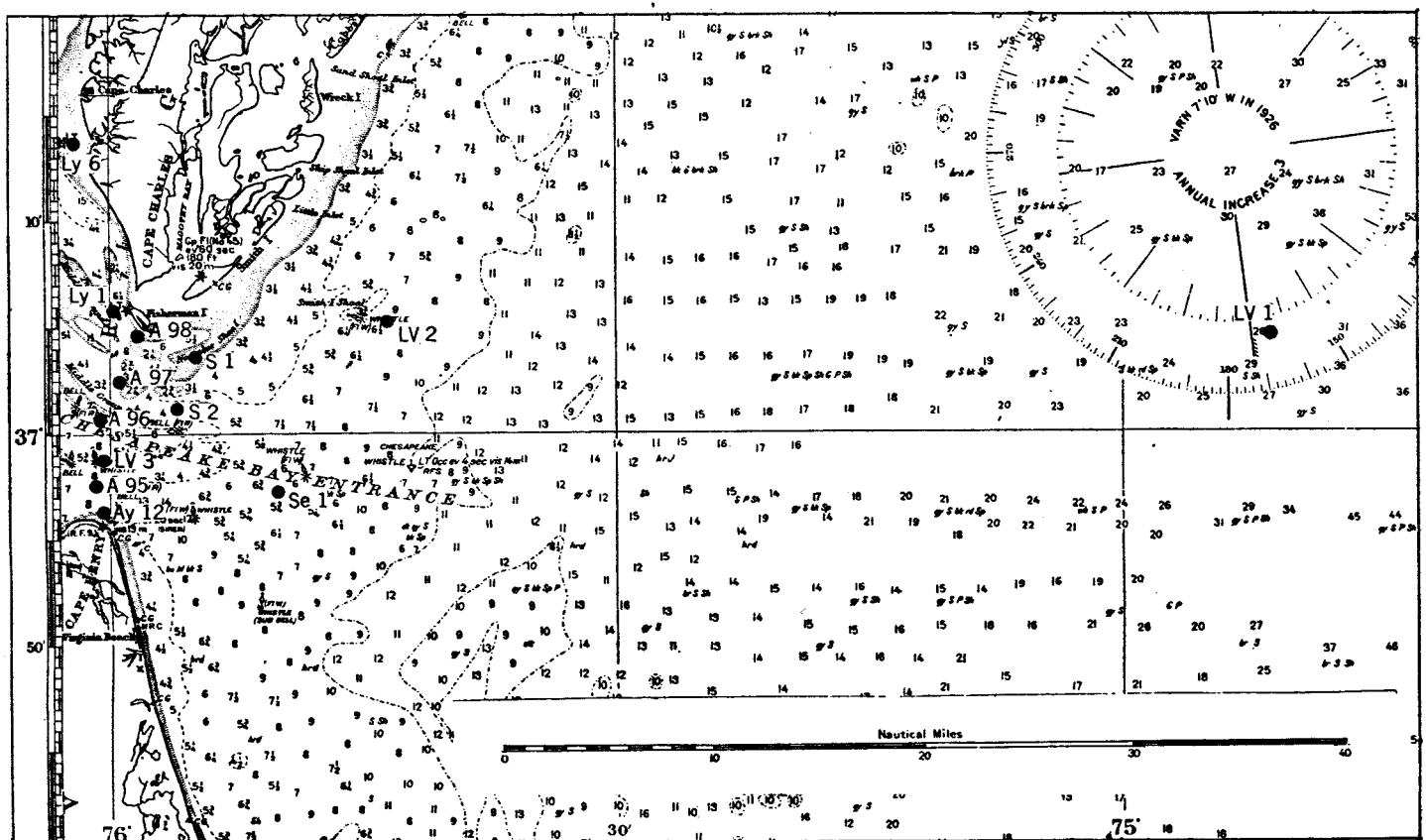


FIGURE 24.—Current stations, approaches to Chesapeake Bay

from three hours before to three hours after high and low water. The nontidal current was determined by averaging the resolved hourly velocities for all times of the tide, a process which eliminates the tidal current since the mean value of the resolved tidal current is approximately zero. This was done in groups of 29 days and the velocity and direction of the nontidal current for each group is given in Table 56. The mean velocity and direction of the set as derived from the resolved currents for the entire series are also given in Table 56. Because of the irregularity of the direction of set, these resultant values differ from direct means of the values for the individual groups.

TABLE 55.—*Currents, station LV1*

[Observations, Feb. 16 to May 24, 1919.]

Time referred to high water and low water at Old Point Comfort	Observed current		Tidal current	
	Velocity	Direction (true)	Velocity	Direction (true)
	Knots	*Degrees*	*Knots*	*Degrees*
3 hours before high water	0.14	281	0.17	326
2 hours before high water	0.09	258	0.10	335
1 hour before high water	0.04	169	0.09	35
High water	0.08	109	0.15	54
1 hour after high water	0.11	134	0.13	74
2 hours after high water	0.21	131	0.20	98
3 hours after high water	0.21	149	0.17	115
3 hours before low water	0.22	152	0.17	120
2 hours before low water	0.22	179	0.12	157
1 hour before low water	0.22	212	0.11	225
Low water	0.22	229	0.13	255
1 hour after low water	0.24	244	0.17	272
2 hours after low water	0.22	247	0.16	279
3 hours after low water	0.16	271	0.16	314

TABLE 56.—*Set of nontidal current, station LV1*

Date of observations	Direction (true)	Velocity
1919	*Degrees*	*Knots*
Feb. 16–Mar. 16	211	0.13
Mar. 1–29	207	0.24
Apr. 1–29	155	0.04
Apr. 26–May 24	180	0.05
Series Feb. 16–May 24	201	0.12

A graphic representation of both the observed current and the tidal current, which is the observed current with the nontidal current eliminated, is given in Figure 25.

In this diagram each line drawn from the origin O represents by its length the mean observed velocity of the current for its particular hour of tide, and by its direction the average observed direction of the current for that hour. The letters H and L refer to the times of high and low water, respectively, and the numbers following them indicate the number of hours before, or after, the designated phase of tide, a minus sign signifying before and a plus sign after. The outer ends of the lines thus drawn form an approximate ellipse, indicated by the dashed line. A point C was next plotted from the same origin O, its distance from O denoting the velocity and its direction from O

the direction of the computed nontidal current. The point C now becomes the origin from which the velocities and directions of the tidal current may be measured, a line joining H and C denoting the velocity and direction of the tidal current at the time of high water and so on.

The velocity and direction of the tidal current for each hour of the

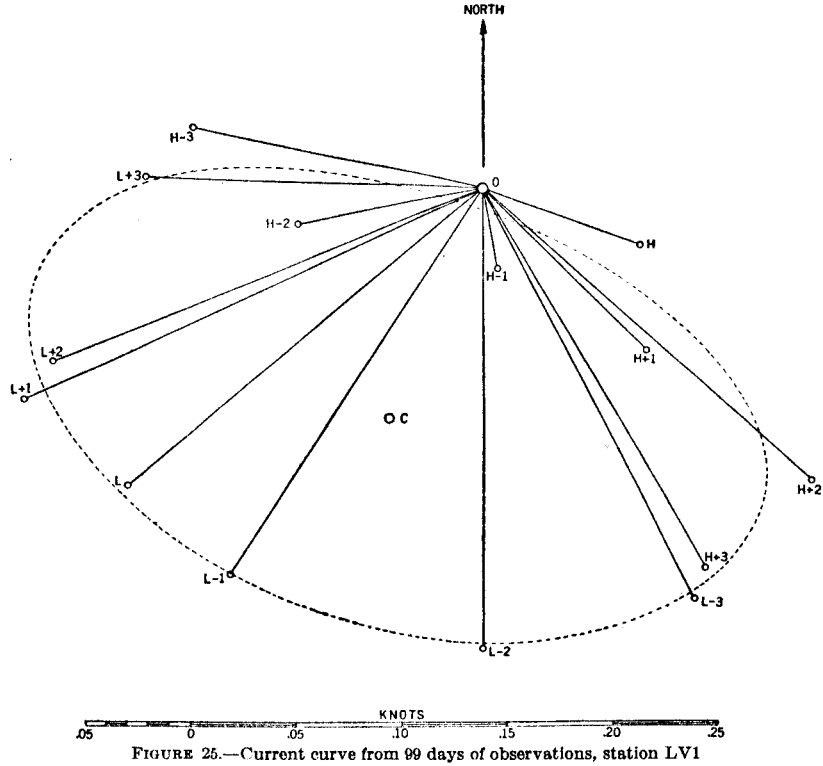


FIGURE 25.—Current curve from 99 days of observations, station LV1

tide taken from this diagram are given in the last two columns of Table 55.

To determine the current due to wind at station LV1, the resolved hourly currents were grouped according to the direction of the wind.

Average values computed for each group are given in Table 57.

TABLE 57.—*Current due to wind, station LV1*

(Directions true)

Direction from which wind is blowing	Velocity of wind	Velocity of current	Direction of current	Deviation from wind direction	Direction from which wind is blowing	Velocity of wind	Velocity of current	Direction of current	Deviation from wind direction
	Statute mi. per hour	*Knots*	*Degrees*	*Degrees*		*Statute mi. per hour*	*Knots*	*Degrees*	*Degrees*
North	20.7	0.48	197	17	South	17.3	0.14	24	24
Northeast	17.7	0.33	230	5	Southwest	16.9	0.24	54	9
East	16.3	0.17	250	−20	West	18.1	0.24	84	−6
Southeast	16.1	0.12	275	−40	Northwest	22.0	0.41	174	39

Results for station LV1 as given in Figure 25 and Tables 55 to 57 show a rotary tidal current turning clockwise and having a velocity at strength of about 0.2 knot and a minimum velocity midway between the times of strength of about 0.1 knot. The strengths of flood and ebb of this tidal current occur approximately two hours after low and high water, respectively, at Old Point Comfort. At strength of flood this current sets approximately 290° true and at strength of ebb 110° true. The minimum current sets approximately 200° true one hour before low water, and approximately 20° true one hour before high water at Old Point Comfort.

Nontidal currents of variable velocity and mostly southerly in direction occurred during the period of observation.

Wind currents which are frequently the predominating currents usually set somewhat to the right of the direction toward which the wind is blowing, but there seem to be some marked exceptions to this rule. The average velocity of the wind current in knots is about 1.8 per cent of the velocity of the wind in statute miles per hour. The observations indicate that wind currents of from 1 to 2 knots are not uncommon at this station, the stronger currents generally setting in a southerly direction.

At Cape Charles Light Vessel, station LV2, two series of observations were obtained—87 days in 1912 and 59 days in 1915. Each series was reduced independently, the average velocity and direction of the current for each hour of tide at Old Point Comfort being determined by the method just outlined for station LV1. As the results of these reductions showed the current to be essentially of the reversing type with only a slight rotary tendency, the average hourly velocities obtained were plotted and the strengths and slacks tabulated as explained on page 63. The values thus obtained are given in Table 53, page 65.

These results show that the average current as observed sets westward at strength of flood with a velocity of about one-quarter knot and eastward at strength of ebb with a velocity of one-third knot. The strengths of flood and ebb occur about 4.2 hours after low and high water, respectively, at Old Point Comfort. The ebb current runs about 1.3 hours longer and attains a velocity about 0.1 knot greater than the flood. This condition suggests a nontidal easterly set of approximately 0.05 knot due probably to drainage from the bay. The average velocity and direction of this nontidal set for each series of observations, derived from the resolutions as explained for station LV1, are as follows: For the 87-day series 0.11 knot 27° true, and for the 59-day series 0.05 knot 67° true.

For the 1915 series a wind reduction was made, the results of which are given in Table 58. As at station LV1, the wind current sets generally to the right of the direction toward which the wind is blowing. The velocity of the wind current in knots averages about 1.6 per cent of the velocity of the wind in statute miles per hour. Currents of from 1 to 2 knots, however, due chiefly to winds are not unusual.

TABLE 58.—*Current due to wind, station LV2, September 1–October 29, 1915*

(Directions true)

Direction from which wind is blowing	Velocity of wind	Velocity of current	Direction of current	Deviation from wind direction	Direction from which wind is blowing	Velocity of wind	Velocity of current	Direction of current	Deviation from wind direction
	Statute mi. per hour	*Knots*	*Degrees*	*Degrees*		*Statute mi. per hour*	*Knots*	*Degrees*	*Degrees*
North	22.8	0.30	198	18	South	18.6	0.37	45	45
Northeast	22.3	0.34	233	8	Southwest	17.6	0.34	54	9
East	16.2	0.12	324	54	West	19.3	0.29	88	−2
Southeast	18.2	0.19	19	64	Northwest	22.6	0.21	161	26

The resolved hourly velocities for the 87-day series were reduced by harmonic analysis (see appendix, pp. 128 and 137) the north and east components being analyzed separately. The harmonic constants

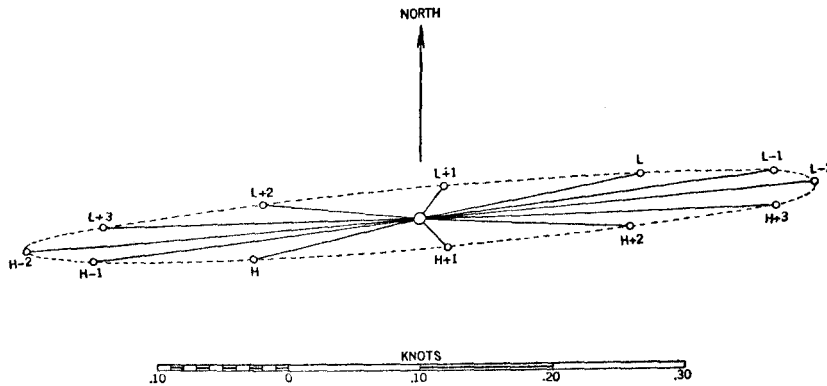


FIGURE 26.—Current ellipse for component M_2, station LV2

from these analyses are given in Table 59. The current ellipse for the principal component M_2 based on the data of Table 59 is shown in Figure 26. This ellipse represents the tidal current only since the harmonic analysis eliminates the nontidal current. It shows the tidal current to be only slightly rotary, the maximum velocity being 0.30 knot and the minimum velocity only about 0.02 knot. It is interesting to note that the rotation is counterclockwise or opposite to that at station LV1. The strength of flood sets 265° true and occurs approximately two hours before high water at Old Point Comfort. The strength of ebb sets 85° true and occurs approximately two hours before low water. The minimum current, which corresponds to the slack of the reversing current, sets northward about one hour after low water and southward about one hour after high water at Old Point Comfort.

It will be noted that in the approaches to the bay the current velocities as given in Table 53, p. 65, increase as the entrance is approached due doubtless to the decreasing cross section of the mass of water entering or leaving the bay.

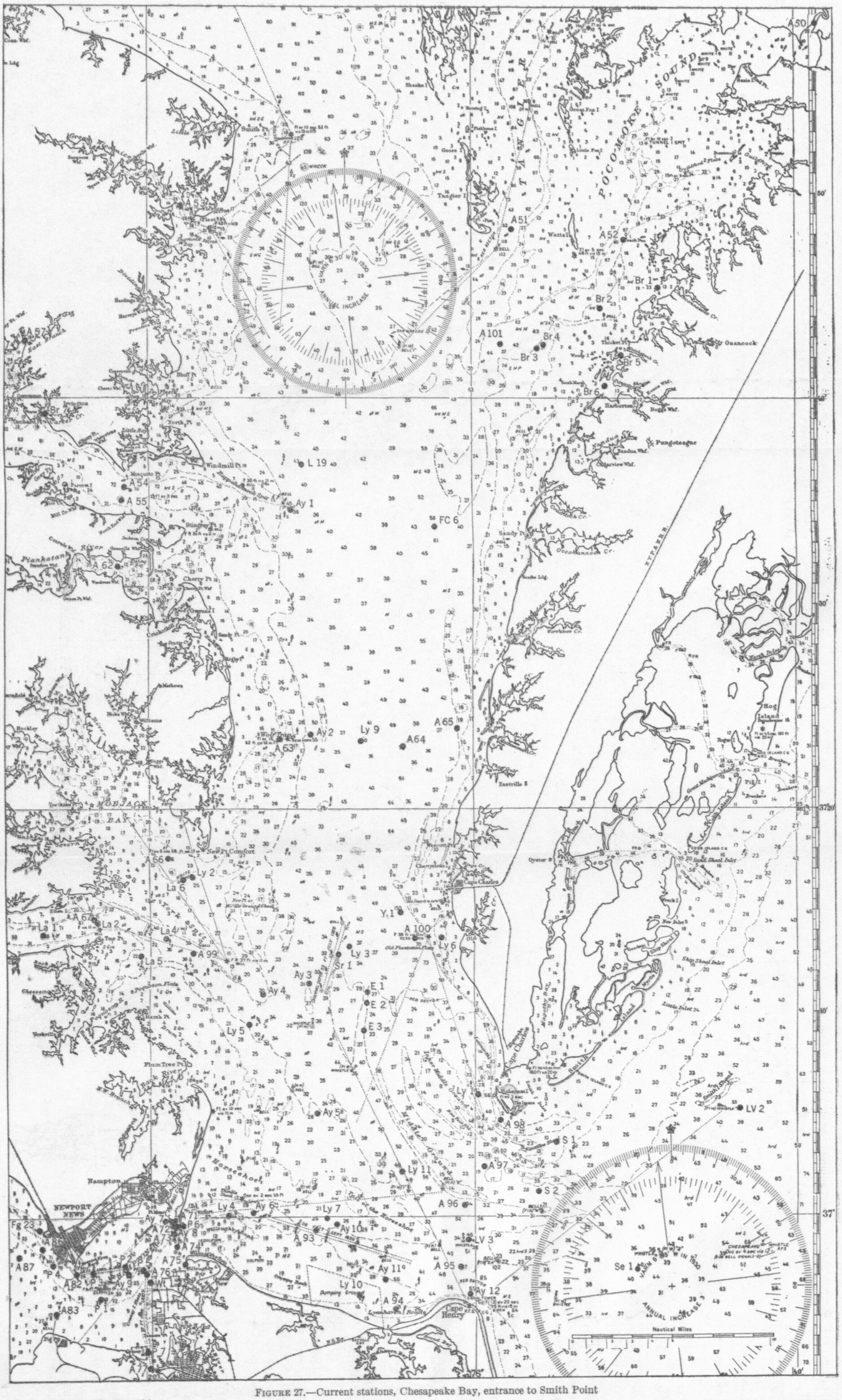


FIGURE 27.—Current stations, Chesapeake Bay, entrance to Smith Point

TABLE 59.—*Current harmonic constants, station LV2*

[From 87-day series, June 2–Aug. 27, 1912]

Harmonic component	North component (true)		East component (true)		Harmonic component	North component (true)		East component (true)	
	H	κ	H	κ		H	κ	H	κ
	Knots	*Degrees*	*Knots*	*Degrees*		*Knots*	*Degrees*	*Knots*	*Degrees*
K_1	0.138	118	0.172	211	O_1	0.053	46	0.046	250
M_2	0.036	50	0.301	9	S_2	0.016	163	0.065	10
N_2	0.012	345	0.070	354					

An examination of the mean current hours for the stations in the approaches to the bay shows that the current becomes progressively later from Station LV1 toward the entrance. The current hours for stations Se1, S1, and S2 also indicate that the current is later in mid-channel than in the shoaler water near shore. This condition is a general characteristic of currents in the cross section of a stream or passage. It is to be noted that, since the length of the tidal cycle is 12.42 hours, the current hours in Table 53 have been kept within the limits 0.00 hour to 12.41 hours, inclusive, 12.42 hours being taken as 0.00 hour. It follows that if the difference between the mean current hours at two stations is greater than 6.21 hours (one-half the tidal cycle) a smaller time difference may be obtained by adding 12.42 hours to the smaller current hour before taking the difference.

The results for all the stations outside the entrance with the exception of station S1 indicate a nontidal easterly set of the current, and it seems probable that the westerly set indicated by the one day of observations at this station was due to temporary meteorological conditions.

THE CURRENT IN CHESAPEAKE BAY

The results discussed up to this point apply to the current at or near the surface. As observations below the 14-foot depth were secured at only about 40 per cent of the current stations in the bay and tributaries, and since it is frequently desirable to compare the results at the various stations, the discussion except where otherwise stated will apply to currents within 14 feet of the surface, and these currents will be referred to as surface currents. It may be well to mention here that the current throughout the length of the bay proper is particularly susceptible to meteorological conditions and for this reason results from short series of observations may differ considerably from the general trend of results for stations in the vicinity. Mean values from the longer series are generally quite consistent because the meteorological effects tend to average out.

Between Fisherman Island and Cape Henry are six current stations, see Figure 27, distributed across the entrance to the bay. At four of these stations subsurface as well as surface observations have been obtained. At station LV3 three relatively long series of pole observations were secured—87 days in 1912, 73 days in 1915, and 160 days in 1919. Data for these stations are given in Table 53, p. 65. In general the observed velocities of strength of current across the narrowest part of the entrance are from 1 to 1½ knots for the flood stream and from 1 to 2 knots for the ebb stream. The velocity varies from the surface to the bottom, there being usually a slight increase

for several feet of depth and then a marked decrease as the bottom is approached. From Fisherman Island southward to station A95 the current appears to occur progressively later. Near the Cape Henry shore however it becomes earlier again. In mid-channel the current is approximately an hour later than at points close to the shore. At station LV3 the strength of the flood current occurs simultaneously with high water at Old Point Comfort.

In addition to the data given in Table 53 other information for station LV3, including average values from all the observations at the station, is given in Table 63. The results from the harmonic analysis of an 87-day series of hourly velocities at station LV3 are given in Table 60. Chesapeake Bay entrance is a principal current station for which daily predictions are given in the current tables published annually by this bureau.

TABLE 60.—*Current harmonic constants, station LV3*

[From 87-day series, Aug. 1–Oct. 26, 1919]

Component	H	κ	Component	H	κ	Component	H	κ
	Knots	*Degrees*		*Knots*	*Degrees*		*Knots*	*Degrees*
J_1	(0.014)	(202)	M_4	0.042	55	Q_1	(0.034)	(111)
K_1	0.156	179	M_8	0.010	41	S_2	0.236	278
K_2	0.068	326	N_2	0.254	227	S_4	0.014	350
L_2	(0.031)	(279)	2N	(0.034)	(201)	T_2	(0.014)	(278)
M_1	0.017	194	O_1	0.176	134	μ_2	(0.026)	(228)
M_2	1.101	253	P_1	(0.052)	(179)	ν_2	(0.049)	(231)

Inferred constants are in parentheses. The epochs refer to the times of flood strength of their respective components.

In the portion of the bay to the westward of the entrance cross section just discussed 11 current stations have been occupied for periods of from one-half to one day. In this area the strengths of current attain an average velocity of about 1 knot. The observations indicate that in the vicinity of Fisherman Island the velocities are greater, while close to shore in Lynnhaven Roads they are somewhat less than this value. The periods of observation are too short for well-determined time relations, but a decided tendency of the current to occur earlier inside the entrance is apparent. This tendency is particularly noticeable in the channel to Hampton Roads, the current in the channel off the entrance to Hampton Roads being about one hour earlier than the current at the entrance to the bay. Southward of Old Point Comfort the current is still earlier as may be seen on page 105 of this text. Subsurface currents at station A93 and A94 have characteristics similar to those outlined for stations at the entrance to the bay. The value for mean current hour at station Ay5 appears too large and it seems probable that it has been influenced by some unusual condition.

From the latitude of Cape Charles northward to the vicinity of Windmill Point the observations indicate a current velocity at strength of slightly less than 1 knot on the average. The ebb stream as would be expected is generally somewhat stronger than the flood. The surface current appears to have an approximately uniform velocity for the entire width of the bay, including the approaches to York River and Mobjack Bay, stations in mid bay showing no consistent variation from those near shore. Velocities at the lower depths are usually somewhat less than near the surface.

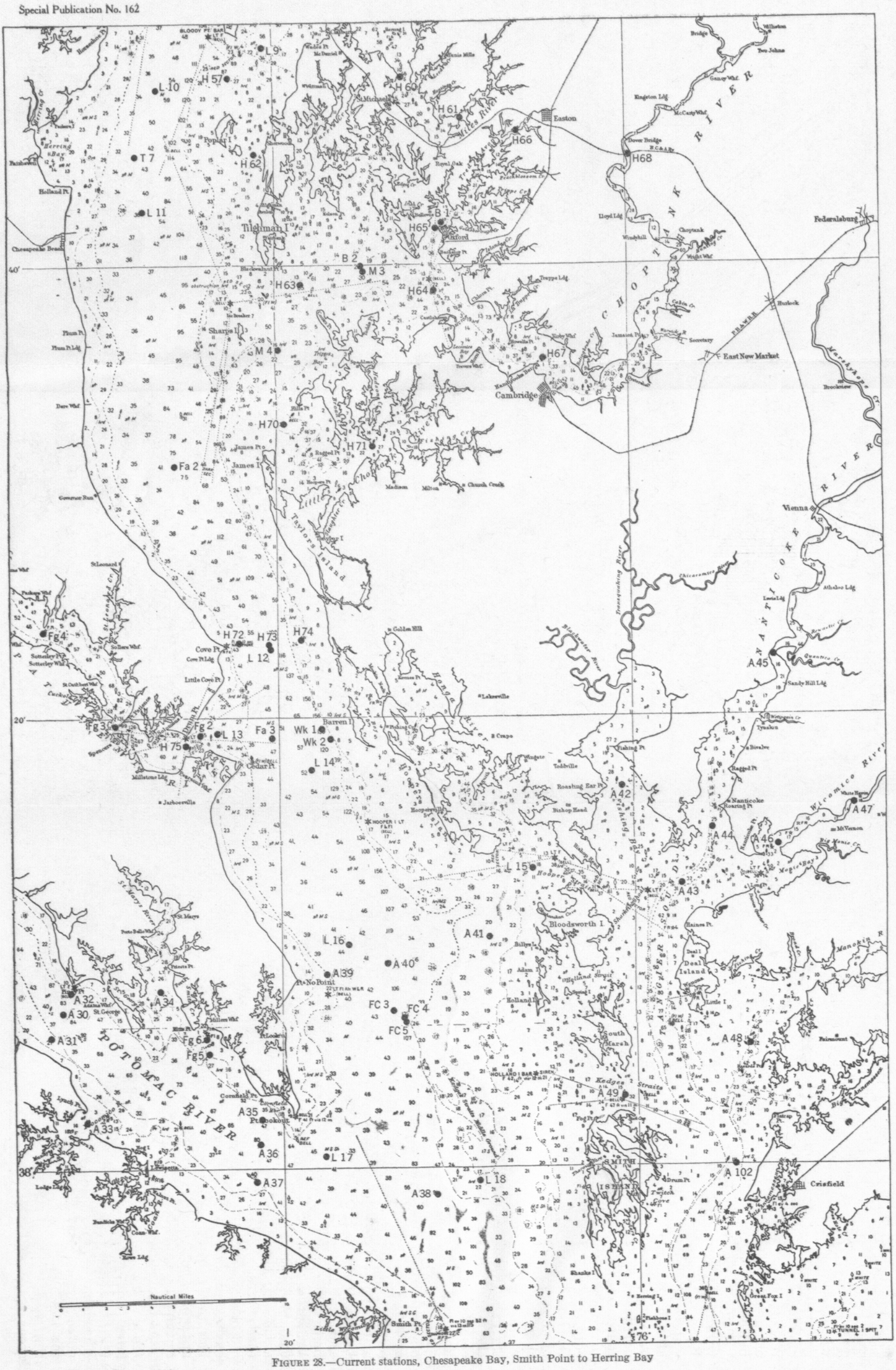


FIGURE 28.—Current stations, Chesapeake Bay, Smith Point to Herring Bay

At station FC6 and other stations occupied by the United States Fish Commission observations were taken with an Eckman meter. This meter records on a dial the revolutions of a propellorlike element which is actuated by the current. At the same time it automatically drops shot on a grooved compass needle which is pivoted above a circular box divided into a number of compartments. From the revolutions recorded during a given interval of time the velocity is calculated, and the average direction is determined from the distribution of the shot in the various compartments.

Following the axis of the bay northward the current becomes later with approximate uniformity. Off the mouth of the Rappahannock River it is apparently about two hours later than in mid-bay west of Cape Charles, the strength of flood occurring two and one-half hours after high water at Old Point Comfort. Along the shores the current is considerably earlier than at the axis of the bay, and it appears that northward of New Point Comfort it is earlier on the western shore than on the eastern by about half an hour. In the channels leading to York River and Mobjack Bay the time of current becomes decidedly earlier as these waterways are approached. At station A62 in the Piankatank River the observations indicate a strength of current of about one-third knot occurring approximately three hours earlier than the current in the middle of the bay off the mouth of the river. A similar velocity and a similar time with respect to the current in the bay is indicated by the half day of observations at station A53 in the Great Wicomico River. At station A101 in the entrance to Pocomoke Sound the strengths apparently have a velocity of about 1 knot and occur about one hour earlier than in mid-bay off the entrance.

Continuing up the bay, the next observational data are for stations off the mouth of the Potomac River. (See fig. 28.) Here velocities at strength average from one-half to three-fourths knot and strengths of flood occur about three and three-fourths hours after high water at Old Point Comfort. In the broad portion of the bay above Point Lookout the currents exhibit considerable irregularity in velocity and direction, the observational values for several of the stations being too erratic to admit of the usual tabulation and reduction. Velocities of half a knot at strength of current prevail in this area. One day of observations at station L15 near Hooper Strait indicates a velocity at strength of half a knot and a time about three hours earlier than in mid-bay to the westward.

From the vicinity of Cedar Point northward to the head of the bay average velocities of strength of current vary from about one-half knot to approximately 1 knot, the first-mentioned value generally applying to the broader portions of the bay and the last mentioned to the more constricted parts.

As the current movement progresses northward the time of occurrence of a given phase of the current continues to become later and later until at the northern extremity of the bay it is a tidal cycle (12 hours 25 minutes) later than it is a few miles off the entrance. Throughout the length of the bay the same general characteristics noted in the lower part prevail. In the upper part of the bay, as in the lower reaches, the velocity is smaller at the lower depths, and the time of the current is earlier near shore especially over shoal areas and in the entrances to tributary waterways.

The distribution of the surface velocity in several cross sections of the bay has been studied, and it has been found that generally the velocity at strength for the stations near shore is substantially the same as for stations in mid-channel in the same cross section. The velocities obtained from the observations in some cases seem to indicate considerable differences in velocity at different stations in a cross section, but the values for the stations near shore are in practically all cases based on very short series of observations and can not, therefore, be taken as representing average conditions. Moreover, where simultaneous observations are available for a cross section they show in nearly all cases very small differences in velocity at the different stations. The most pronounced exception to this general condition was noted at the cross section off Worton Point (see fig. 29), where a half day of simultaneous observations at stations H18 and H19 gave a tidal-current velocity of 0.6 knot at station H18 and a corresponding velocity at station H19 in mid-channel of 1.7 knots. Similar observations at stations H19 and H20 covering half a day gave tidal current velocities of 1.8 knots at station H19 and 1.2 knots at station H20.

Throughout the length of the bay the general direction of the tidal current at times of strength is parallel to the axis of the bay. In the broader parts where the current is relatively weak and therefore easily modified by meteorological conditions, considerable variations in direction frequently occur. For a similar reason directions at most stations become somewhat irregular near the times of slack water. It also appears that there is a slight rotary tendency at some stations in the broader parts of the bay. This tendency is evidenced chiefly by the seeming reluctance of the current to come to a definite slack, but rather to reverse by a shifting of direction.

The currents setting into and out of the various tributary waterways usually flow in the general direction of the channels leading to these waterways.

In the upper part of the bay (fig. 29) currents have been observed at a single station near the mouth of each of the following tributary rivers: West River, Magothy River, Back River, Gunpowder River, and Bush River.

One-half day of observations at station H53 in the West River showed a current of about one-fourth knot at strength occurring between three and four hours earlier than the current in mid-bay off the entrance.

One day of observations at station H41, in the mouth of the Magothy River, gave a current of slightly more than half a knot, occurring about one hour earlier than the current in mid-bay.

At station H28 in the Back River one and one-fourth days of observations showed a current of less than one-half knot about one hour earlier than in midbay.

A 1-day series at station H25 in Gunpowder River gave a current of less than one-half knot about one-half hour earlier than in midbay. One day of observations at station H21 in the Bush River showed currents of less than half a knot about one hour earlier than in midbay.

Results for the above-mentioned stations, including the times of the various phases of current referred to the times of tide at Old Point Comfort, are given in Table 53, pages 71 to 74.

FIGURE 29.—Current stations, Chesapeake Bay, Herring Bay to Havre de Grace

At the mouth of the Susquehanna River, off Havre de Grace, five short series of observations show a flood current up to 0.2 knot at strength and an ebb current of approximately one-half knot at strength. The current here is approximately 11 hours later than in the vicinity of Chesapeake Bay entrance, the strength of flood occurring at about the time of the moon's transit at Greenwich, or about one and one half hours before high water at Old Point Comfort. At this time under normal conditions there is also a strength of flood outside the entrance to the bay. There is a strength of ebb and two slacks in the bay at this time, a strength of ebb in the vicinity of Hooper Island Light, a slack before flood in the vicinity of Wolf Trap Light, and a slack before ebb in the vicinity of Holland Point.

The hourly velocities for eight of the stations observed by Tillman and Faris in 1897 were resolved into north and east components and reduced by harmonic analysis as explained on page 98 for station LV2. The resulting constants are given in Table 61. Since the currents at all these stations run in a general north-and-south direction the amplitudes (H's) for the north component are considerably larger than those for the east component. The magnitude of the amplitudes of components K_1 and O_1 relative to that of M_2 for station T4 indicates that the diurnal constituents of the current are of considerable importance in the vicinity of this station. The north component of the principal element M_2 has for each station a value somewhat less than the tidal current velocity given in Table 63, due to the fact that the effects of the other constituents of the tidal current are included in the latter value. The resultant amplitude of the north and east components will in each case differ but little from the value for the north component since the east components are relatively small.

Table 61 also contains the average velocity and direction of the nontidal set as derived from the resolved velocities for each series of observations. These values may be compared with the corresponding values given in Table 63 which were obtained graphically from the average observed flood and ebb currents.

TABLE 61.—*Current harmonic constants and nontidal set for eight stations in the upper part of Chesapeake Bay*

Station	Length of series	Average nontidal set from resolved velocities		Harmonic component	North component (true)		East component (true)	
		Direction (true)	Velocity		H	κ	H	κ
	Days	*Degrees*	*Knots*		*Knots*	*Degrees*	*Knots*	*Degrees*
Fa3	15	65	0.063	M_2	0.383	56	0.078	193
Fa2	15	165	0.067	M_2	0.290	72	0.092	273
				S_2	0.046	90	0.017	329
T7	13	215	0.021	M_2	0.315	121	0.033	155
Fa1	29	190	0.221	M_2	0.555	131	0.211	137
T6	15	205	0.168	M_2	0.539	132	0.181	125
				S_2	0.093	156	0.043	129
				K_1	0.220	211	0.041	213
T4	29	101	0.013	M_2	0.644	147	0.140	134
				O_1	0.166	231	0.019	255
				S_2	0.069	181	0.049	100
T2	29	218	0.125	M_2	0.513	161	0.222	206
				S_2	0.060	188	0.015	314
T1	7½	236	0.044	M_2	0.149	142	0.128	164

The effect of winds in modifying a reversing tidal current is shown in Figure 30. In this figure the curve A represents the average current at station H55 as derived from an 11-day series of pole observations. The curves *B* and *C* are plotted from pole observations taken during northerly and southerly winds, respectively, and the differences between these curves and the curve A show in each case the approximate distortion due to wind at the time the observations were taken. It will be noted that the normal tidal current even at its strength is sometimes overcome completely and reversed in direction by the wind current. Observations throughout the length of the bay frequently show similar effects. Wind effects in the approaches to the bay are discussed on pages 96 and 97.

The tidal movement in the bay is primarily of the progressive wave type. (See appendix, p. 134.) According to the theory of this type of

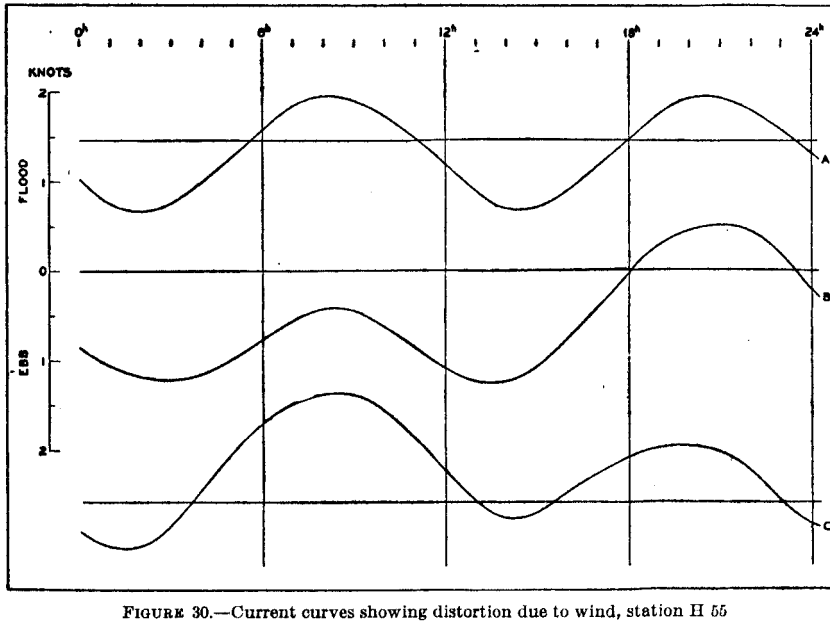


FIGURE 30.—Current curves showing distortion due to wind, station H 55

movement, the strengths of flood and ebb current at a given place should occur at the times of high and low water, respectively, at that place. While a rough approximation to this condition prevails over the greater part of the bay and its tributaries, the simple relation of the theoretical wave movement is in places considerably modified. It is evident that the above-mentioned relation can not exist at the extreme upper limit of the tidal movement where the horizontal flow of the water in a flood direction is prevented by obstructions, for at such a place flood strength must come when the water is rising most rapidly, which is midway between low and high water. It is not suprising, therefore, that in approaching the upper reaches of these tidal waterways the time relation of current to tide is gradually so modified that the flood strength occurs when the local tide is rising most rapidly, which is about three hours before high water.

Comparing the observed times of current in midstream, from the entrance to the head of the bay, with the times of local high water,

FIGURE 31.—Current stations, Hampton Roads and Elizabeth River

it is found that in the lower part of the bay the strength of flood follows the high water by about one hour. Passing up the bay the current becomes gradually earlier with respect to the tide. Off Sandy Point the flood strength and high water have become practically simultaneous and at the mouth of the Susquehanna River the flood current precedes the high water by about two hours. It will be noted that the time relation of current to tide has changed about three hours between the Virginia capes and Havre de Grace. The high water of the tidal movement covers this distance in about 14 hours and the current progresses over the same path in approximately 11 hours. The ratio of the rate of advance of the current movement to that of the tide averages for the entire bay about one and one-fourth. It is not uniform, however, but shows a considerable increase toward the head of the bay. Tide and current advance at nearly the same rate in the lower reaches of the bay, whereas near the head the rate of advance of the current movement is about twice that of the tide.

THE CURRENT IN HAMPTON ROADS

The locations of the current stations which have been occupied in Hampton Roads are plotted on Figure 31, and the data derived from the observations are given in Table 53, pages 75 to 77. The results show that in general the strengths of current in the channels have velocities of from 1 to 2 knots. In mid-channel southward of Old Point Comfort the average strength of the flood is about 1¾ knots and that of the ebb about 2 knots. In Newport News channel and the deep water southward of the middle ground, strengths of flood and ebb appear to have average velocities of about 1¼ knots and 1½ knots, respectively.

In the channel leading southward to Norfolk and Portsmouth observations indicate average velocities of three-fourths knot and 1¼ knots for strengths of flood and ebb, respectively.

It should be noted that considerable variations from the average velocities given above may be produced by meteorological conditions as well as by periodic astronomical effects.

Results from a 5-day series of observations at station A72, which is representative of a group of stations in the immediate vicinity, show that in mid-channel southward of Old Point Comfort the current is 1.2 hours earlier than at station LV3 in Chesapeake Bay entrance, and that the strength of flood occurs 1.2 hours before high water at Old Point Comfort. These values apply to the surface current as defined on page 99. At the lower depths the velocities are somewhat less and the times slightly earlier. To the westward in the channel to Newport News the current is a few tenths of an hour later than at station A72. In the shoal areas, near shore, and in the channel to Norfolk the currents generally are about one hour earlier than in Hampton Roads channel.

Navigators familar with conditions near the dock at Old Point Comfort state that in the immediate vicinity of the dock the current turns from 45 minutes to one hour earlier than in mid-channel to the southward. It follows that during the period of about an hour which elapses between each slack water at the dock and the corresponding slack water in midstream, the currents at the two locations

are flowing in opposite directions. The boundary between these two streams is generally visible as a line of tide rips the normal position of which is said to be about 100 yards off the dock. Its position, however, changes with meteorological conditions, northerly and southerly winds causing it to move from its average position away from and toward the dock, respectively.

The value 0.85 for mean current hour at station C1 appears too large by four or five tenths of an hour, and since it is based on times of slack water as indicated by the swinging of a ship at anchor it seems likely that the swinging of the ship lagged behind the actual slack water by this amount.

THE CURRENTS IN THE ELIZABETH AND NANSEMOND RIVERS

In the Elizabeth River 2 current stations have been occupied near the entrance, 4 in the Eastern Branch, 2 in the Southern Branch, and 1 in the entrance to the Western Branch. The locations of these stations are plotted on Figure 31, and the results derived from the observations are given in Table 53, page 77. The general trend of these results indicates a flood velocity of from one-half to three-fourths knot and an ebb velocity of from one-half to 1 knot in the river and in each of its three branches. The current movement from the mouth of the river to station A79 in the Eastern Branch appears to be practically simultaneous, the strength of flood occurring on the average two and one-fourth hours before high water at Old Point Comfort. The current in the Southern Branch appears to be from one-half to three-fourths hour later than in the eastern and western branches.

Station A83 in the approach to the Nansemond River and stations A84 and A85 in the river are plotted on Figure 32, and the results from the observations are given in Table 53, pages 77 and 78. Results from one and one-half days of observations at station A83 show a flood strength of 0.7 knot and an ebb strength of 0.8 knot, the flood strength occurring 1.6 hours before high water at Old Point Comfort. Results for the two stations in the river indicate strengths of more than a knot at station A84 and of 1 knot at station A85. The current appears to become slightly earlier from the mouth toward the head of the stream.

THE CURRENT IN THE JAMES RIVER

Observations have been obtained at 15 stations in the James River and at one station in each of its principal tributaries, the Chickahominy and Appomattox Rivers. The locations of the stations are plotted on Figure 32, and the results derived from the observations are given in Table 53, pages 78 and 79. The velocities in mid-channel appear to be approximately uniform over the greater part of the length of the river. From Newport News to the mouth of the Appomattox River the observational values indicate average velocities of from 1 to 1.5 knots for the strength of flood and from 1 to 1.8 knots for the strength of ebb. Observations above Jones Neck indicate average strengths somewhat less than 1 knot. At station Fg30 near Richmond the current did not flood during the one day of observations, the ebb velocity during that period varying from about 0.5 knot to 1 knot. The few stations in the lower part of the river that are in the

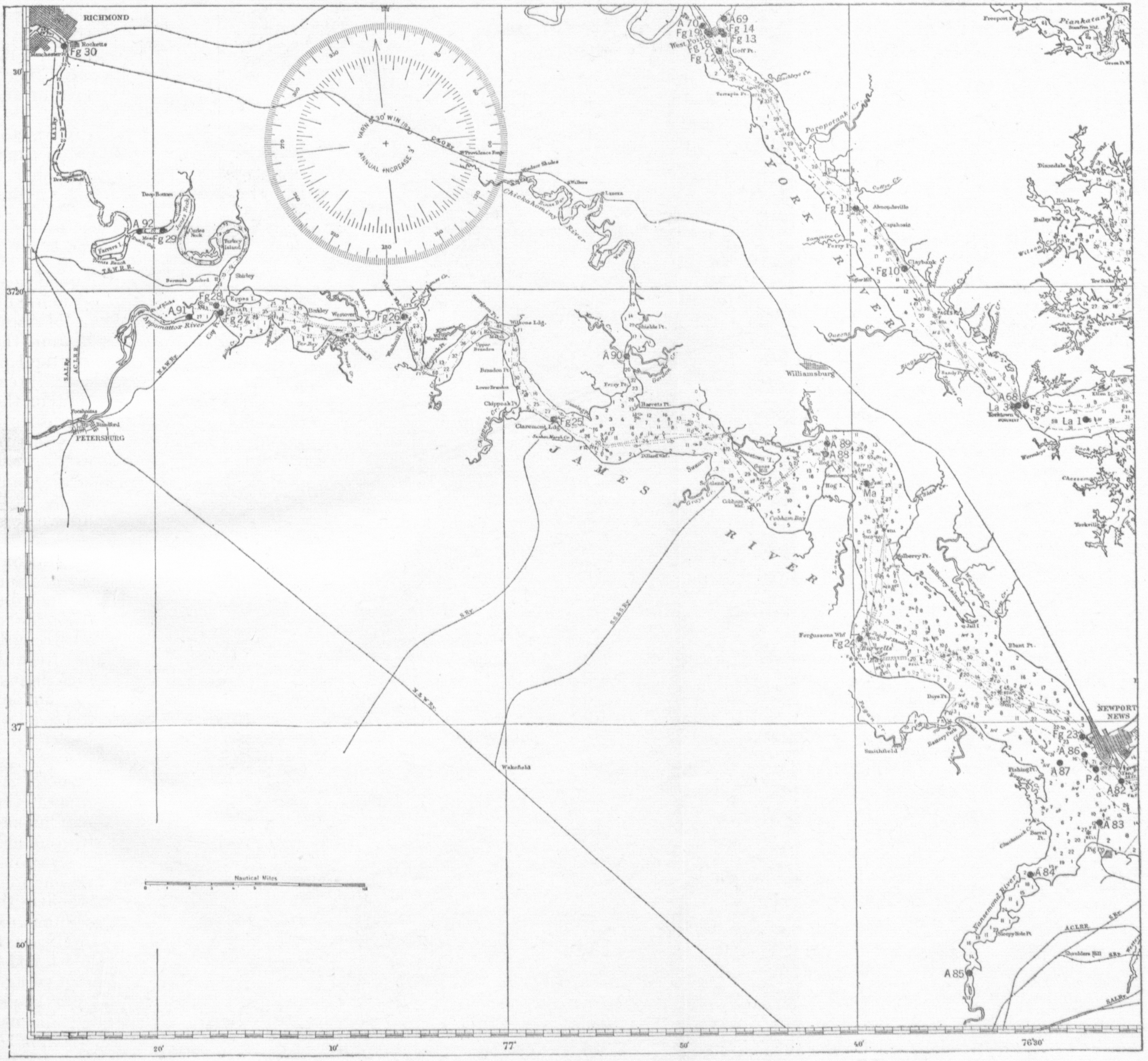


FIGURE 32.—Current stations, Nansemond and James Rivers

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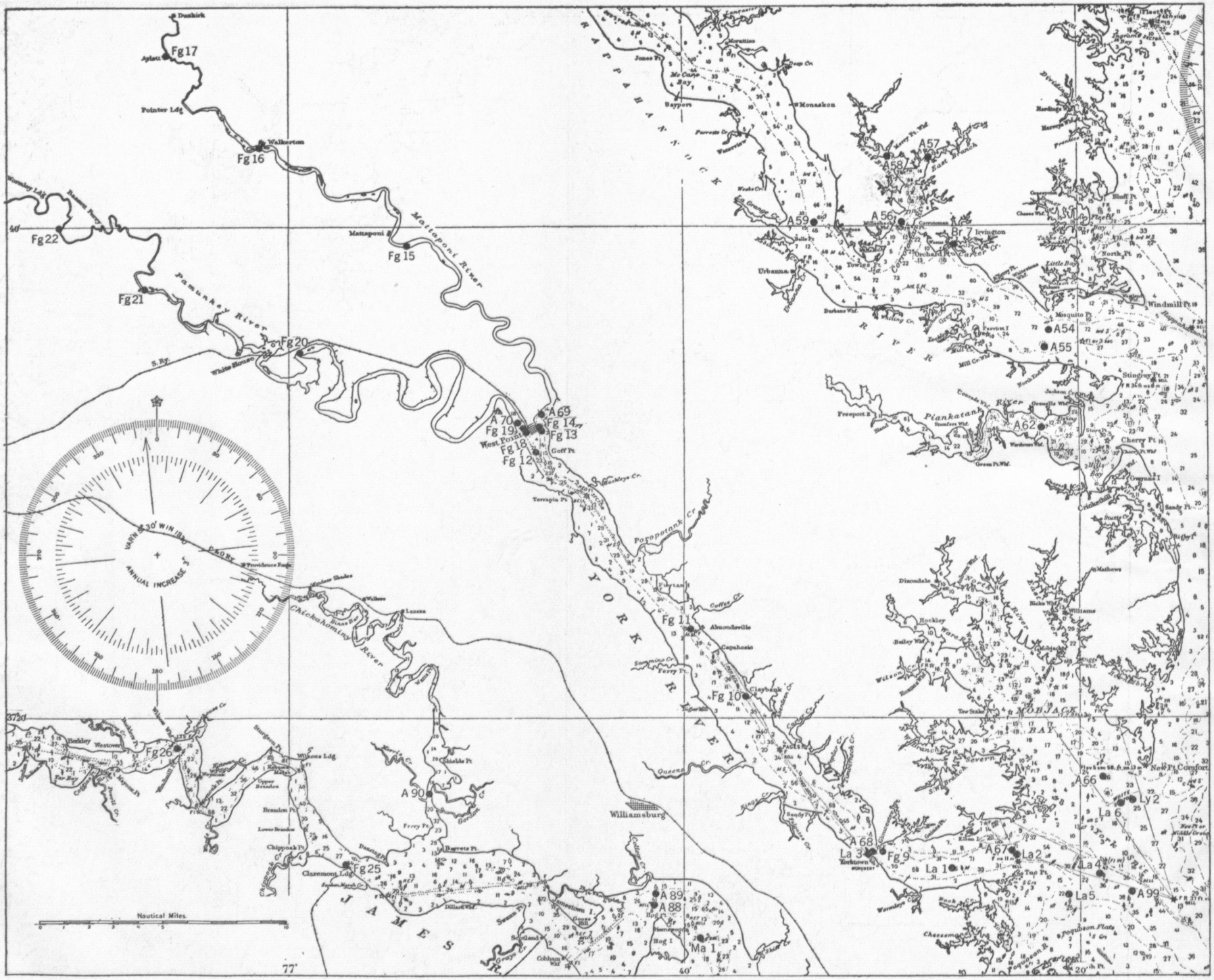


FIGURE 33.—Current stations, York River and tributaries

shoaler water away from the channel show velocities considerably less than those in mid-channel. Average velocities at strength of slightly more than a knot were obtained for stations A90 and A91 in the Chickahominy and Appomattox Rivers, respectively.

Time relations for stations in the channel westward of Newport News show that the strengths of flood are approximately simultaneous with the high waters at Old Point Comfort. Progressing up the river, the current becomes gradually later until in the vicinity of Dutch Gap it is about four and one-half hours later than at Newport News. The high water of the tide wave requires about seven hours to travel this distance, and the average rate of advance of the current movement for this stretch of the river is therefore about one and one-half times that of the high water. As in the bay this rate is not uniform but increases toward the head of the river.

At station A90 in the Chickahominy River the strength of flood occurs about one and three-fourths hours after high water at Old Point Comfort which appears to be about one hour earlier than the strength of flood in the channel off the mouth. At station A91 in the Appomattox River the flood strength occurs about three and three-fourths hours after high water at Old Point Comfort which is approximately one-half hour before flood strength in mid-channel off the mouth.

THE CURRENTS IN THE YORK RIVER AND TRIBUTARIES

Nine current stations have been occupied in the York River and six each in the Mattaponi and Pamunkey Rivers. The locations of the stations are shown on Figure 33, and the results of the observations are given in Table 53, pages 79 and 80. Two stations off Tue Point at the mouth of the river and a third about 3 miles above the mouth show current velocities at strength of slightly less than 1 knot. Observations at station A68 in mid-channel between Gloucester Point and Yorktown show an average velocity of 1.4 knots at strength of flood and 1.8 knots at strength of ebb. Two stations near by, one near either side of the channel, give strength velocities of about 1.2 knots for both flood and ebb in these locations. Velocities for three stations between Yorktown and West Point range from 1.1 to 1.4 knots for strength of flood and from 1.5 to 1.7 knots for strength of ebb.

At the bridge over the Mattaponi River near West Point, station A69, velocities of 1.3 knots for the flood strength and 1.4 knots for the ebb strength were indicated by the observations. At station Fg15 the flood and ebb strengths were 1.4 and 1.7 knots, respectively. At Walkerton, station Fg56, the observed flood and ebb strengths were both slightly less than 1 knot. At station Fg17 the current did not flood during 10 hours of observation, the maximum velocity being about 1 knot in an ebb direction.

Flood and ebb strengths of 1.7 and 1.9 knots, respectively, were obtained from observations at the bridge over the Pamunkey River near West Point. At station Fg20 one day of observations gave a flood velocity of 1.2 knots and an ebb velocity of 1 knot. At station Fg21 a similar series gave flood and ebb strengths of 0.5 knot and 1.3 knots, respectively. At station Fg22 during 7 hours of observation the current did not flood, the maximum ebb velocity being about 1 knot.

Inspecting the time relations for the York River some roughness appears in the observational values, but from a general consideration

of the results the following approximate relations are derived. From the mouth of the river to Yorktown the strength of flood occurs about one hour before high water at Old Point Comfort. Above Yorktown the current becomes later, the strength of flood in the general vicinity of Ferry Point being simultaneous with high water at Old Point Comfort, and that at West Point about one hour later than high water at Old Point Comfort.

Results of observations at the two bridges near West Point, substantiated by other observations near by, indicate that at the bridge over the Pamunkey River the current is 0.8 hour later than at the bridge over the Mattaponi River. Above West Point in the Mattaponi River the current becomes progressively later. At Walkerton, station Fg16, observations covering one day show that strengths of flood occur about two and one-half hours after high water at Old Point Comfort or three and one-half hours after the corresponding phase of the current at the mouth of the York River.

Similarly the current becomes later in the Pamunkey River, observations at stations Fg20 and Fg21 indicating strengths of flood approximately two and one-half and four hours, respectively, after high water at Old Point Comfort.

In the York River the current and tide appear to advance up the river at about the same rate, each movement requiring about two hours to travel from the mouth of the river to West Point. Above West Point in the Mattaponi and Pamunkey Rivers the current becomes progressively earlier with respect to the tide.

THE CURRENT IN THE RAPPAHANNOCK RIVER

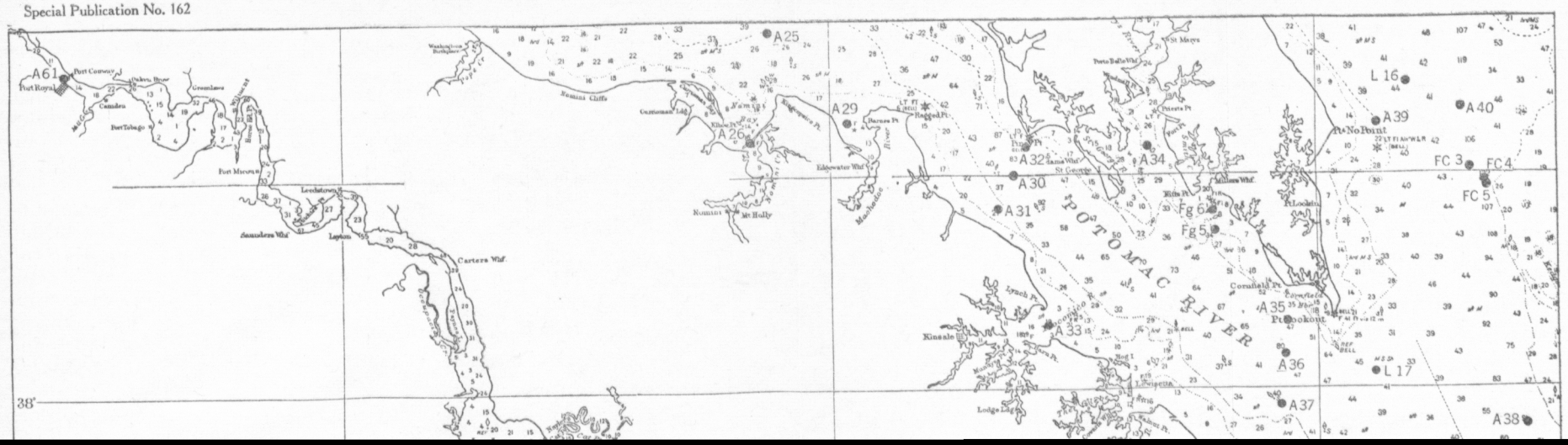
The positions at which current observations have been obtained in the Rappahannock River are plotted on Figure 34, and the results derived from the observations are given in Table 53, pages 80 and 81.

The results for stations A54 and A59 indicate that in the lower part of the river the strengths of flood and ebb have in mid-channel velocities of about 0.6 knot. In the channel at Tappahannock Bridge flood and ebb strengths of 1.2 and 1.1 knots, respectively, were derived from one day of observations. For station A61 in the channel off Port Royal strengths of flood and ebb of 0.6 and 0.5 knot, respectively, were obtained. The few observations taken in the shoaler water away from the channel generally show velocities somewhat smaller than those in the channel.

In the Corrotoman River the observed currents were too weak and irregular to admit of the usual tabulation and reduction except at station A58, at which a single strength of ebb of 0.3 knot was obtained. At station Br7 in Carter Creek the observed velocities were also small.

Observations at four stations in the channel indicate that strengths of flood occur as follows after high water at Old Point Comfort: Off Mosquito Point, 0.8 hour; off Rogue Point, 1.7 hours; off Tappahannock, 3.8 hours; and off Port Royal, 6.1 hours. As in other waterways already discussed the currents in the Rappahannock generally occur earlier near shore and in the mouths of the tributaries than in mid-channel of the river.

In the stretch of the river between Mosquito Point and Tappahannock the strength of the flood current occurs approximately one hour before local high water. At Port Royal the strengths of flood apparently precede the local high waters by two and one-half hours.


A61
Port Royal
Port Conway
Dahlgren
Greenlawn
Camden
Port Tobago
Fort Micou
Leedstown
Saunders Whf
Lepton
Carters Whf
Washington Birthplace
Nomini Cliffs
Cartesman Lab
A25
A26
Rosier
Mt Holly
A29
Barnes Pt
Ragged Pt
Edgewater Whf
Machodoc River
A32
A30
A31
Lama Whf
St George
Millers Whf
Porto Bello Whf
St Marys
Cherry Pt
A34
Fg 6
Fg 5
POTOMAC RIVER
Lockett
Coakley
Cornfield Pt
A35
Pungoteague
A36
A37
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FC 4
FC 5
L 17
A38
38°

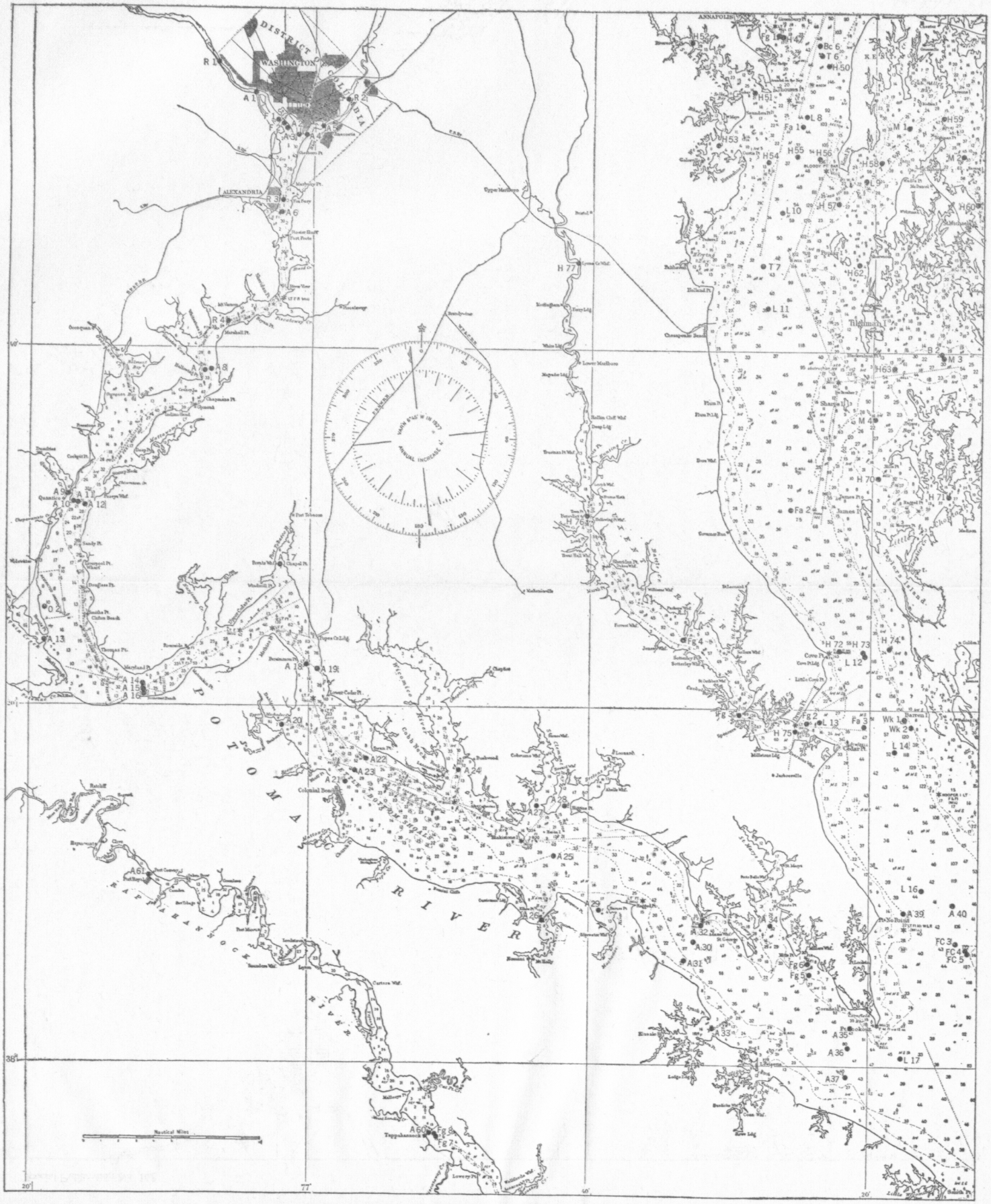

FIGURE 35.—Current stations, Potomac and Patuxent Rivers

THE CURRENT IN POCOMOKE SOUND AND RIVER

The current stations occupied in this arm of the bay are plotted on Figure 27, and the results derived are given in Table 53, pages 81 and 82.

Along the axis of greatest depth between stations A101 and A50 the average velocity of the tidal current at strength appears to range from 1 to 1.5 knots. In the shoaler areas observations indicate somewhat smaller velocities. The roughness of the observational values appears to be due to wind effects, and this situation leads to the conclusion that the currents in this area are particularly subject to meteorological modifications.

The time relations derived from the observations indicate that at stations A101, A52, and A50 the strengths of flood occur about two hours, one hour, and three and one-fourth hours, respectively, after high water at Old Point Comfort. From these values it appears that the current becomes earlier from the entrance toward the middle of the sound and then later toward the mouth of the Pocomoke River. Results from the short periods of observation at stations eastward of the entrance to the sound show currents generally earlier than in mid-channel.

THE CURRENTS IN TANGIER SOUND AND TRIBUTARIES

The stations in Tangier Sound and tributaries are plotted on Figures 27 and 28, and the data derived from the observations are given in Table 53, pages 82 and 83.

Series of observations covering periods of one day each were obtained at stations A102 and A47. At the other stations series of less than one day were secured. From such short periods of observation some inconsistencies in the results are to be expected. It appears that in mid-channel from station A51 northward to station A45 the average velocity at strength of current is from 1 to 1½ knots. Similar velocities are indicated by half-day series of observations at station A49 in Kedges Straits and station A42 in Fishing Bay. Velocities at strength of about 0.6 knot, 0.8 knot, and 1.1 knots were obtained for stations A48, A46, and A47, respectively.

Observations at station A51 indicate that strength of flood occurs 1.6 hours after high water at Old Point Comfort. Progressing up the channel the current becomes gradually later until at station A45 the observations show strengths of flood occurring 4.6 hours after high water at Old Point Comfort or three hours later than at station A51. At stations in the tributaries, excepting the Nanticoke River, the current appears to be earlier than in the axis of the sound. The observed current at station A49 in Kedges Straits is about 2.8 hours earlier than at station A102, the strength of flood setting eastward about three fourths hour after high water at Old Point Comfort.

THE CURRENTS IN THE POTOMAC RIVER AND TRIBUTARIES

The current stations which have been occupied in this important tributary of Chesapeake Bay are plotted on Figure 35, and in Table 53, pages 83 to 87, are given the results of the observations.

Considering first the velocities in mid-channel, it is found that from the mouth of the river to Alexandria the average strengths of the tidal current range in velocity from one-half to one and one-fourth knots, but meteorological disturbances and fresh-water discharge may

give rise to stronger currents. From the mouth to the vicinity of Colonial Beach strengths of five or six tenths of a knot prevail. Above Colonial Beach the river becomes narrower and observations in mid-channel from Persimmon Point to Alexandria give average tidal velocities at strength of 1 knot or more, except off Quantico where the observed velocity is about 0.8 knot. In the vicinity of Washington the strengths generally have velocities less than one-half knot, and at stations A1 and R1 it appears that the current due to drainage is usually stronger than the tidal current and that consequently the current seldom runs upstream.

From an examination of the results for the several cross sections of the river at which observations have been taken it appears that generally the velocities at the stations in mid-channel are approximately the same as at those nearer the shore. In the cross section off Cornfield Point the velocity seems to decrease somewhat from station A37 northward, and at the cross section just above Hallowing Point it is noted that at station A8, which is well away from the channel, the velocity is considerably less than at station A7 in mid-channel.

Observations in the tributaries of the Potomac indicate that in the mouths of most of the tributaries velocities at strength of less than one-half knot occur. At the stations in St. Marys River, Yeocomico River, Machodoc River, St. Clement Bay, and Port Tobacco River the observed currents were too weak and irregular to admit of the usual tabulation and reduction. In the narrow channel leading to Nomini Creek a single observed strength of flood showed a velocity of one and one-fourth knots. One day of observations in the Wicomico River gave a flood velocity of 0.9 knot and an ebb velocity of 0.6 knot.

Studying the time relations for the stations in mid-channel, it is found that in the mouth of the river the strength of the flood current occurs about four hours after high water at Old Point Comfort, and it appears that a similar relation applies off Piney Point. Above Piney Point the current becomes progressively later to the vicinity of Persimmon Point where the strength of flood occurs about 7.1 hours after high water at Old Point Comfort. In the stretch of the river between Persimmon Point and Quantico it appears that there is very little variation in the time of current, the observed current off Quantico being only about 0.3 hour later than that off Persimmon Point. Above Quantico the change in time again becomes pronounced, and in the vicinity of Alexandria and Washington the strength of flood occurs about eight and three-fourths hours after high water at Old Point Comfort or four and three-fourths hours later than at the mouth of the river.

The current for a given cross section is generally earlier away from the channel and in the mouths of the tributaries than in mid-channel of the river. In the lower part of the river where there is a broad expanse of water the stations near the edge of the channel show times roughly an hour earlier than those in the center of the channel. In the more constricted parts the differences in time from center to edge of channel are considerably less than the above value.

The observations in the mouths of the tributaries show considerable variation in the time relations between these locations and the mid-channel of the river. In the mouths of Nomini Creek and Aquia

Creek the currents appear to be approximately one hour earlier than in the river channel. For Bretons Bay, Wicomico River, and Upper Machodoc Creek the corresponding value is about three hours. For Quantico Creek the value is about one-half hour and for the Anacostia River it appears to be still smaller.

Comparing the times of flood strength with those of the local high water, it appears that near the mouth of the river the strength of the flood current occurs about one-half hour before high water. In the vicinity of Colonial Beach and Persimmon Point the flood strength of the current occurs about one-half hour later than the local high water. Above this vicinity the current becomes progressively earlier with respect to the tide and at Washington the strength of flood precedes the high water by about three hours.

THE CURRENT IN THE PATUXENT RIVER

The positions of the current stations in the Patuxent River are plotted on Figure 35, and the results derived from the observations are given in Table 53, pages 87 and 88. The stations are all located in the channel, and the results indicate that velocities at strength approximating one-half knot prevail near the mouth, and that the velocity gradually increases toward the head of the river, the value for station H77, off Lyons Creek Wharf, being about 1 knot.

Off Drum Point the strength of the flood current occurs about three and one-half hours after high water at Old Point Comfort or two and one-half hours earlier than flood strength in mid bay off the mouth. Off Point Patience the observations show it is still earlier by about one-third hour. Above this point the current appears to become progressively later, the strength of flood at Lyons Creek Wharf being approximately five hours later than high water at Old Point Comfort.

In the stretch of the river between the mouth and Benedict it appears that the strength of the flood current precedes the local high water by about two hours. The corresponding value for Lyons Creek Wharf is very nearly two and one-half hours.

THE CURRENTS IN THE LITTLE CHOPTANK AND CHOPTANK RIVERS

The locations of current stations in these streams are shown in Figure 28, and the observational data are given in Table 53, pages 88 and 89.

Two stations were occupied in the Little Choptank River. A strength of current of about one-third knot with flood strength occurring 4.3 hours after high water at Old Point Comfort was obtained for station H70, and a velocity of about one-half knot with flood strength three and one-half hours after high water at Old Point Comfort for station H71.

In the Choptank River the observed strengths of the tidal current range in velocity from 0.3 to 0.9 knot. In the Tred Avon River the velocity appears to be less than one-half knot, and at station H66 a half day of observations showed practically no current.

Considering the time relations, it is noted that the results for stations B2 and M3 are not consistent, and it appears that accidental conditions or observational errors may have influenced one or both of these series of observations. From a general consideration of the time relations, it appears that in the broad part of the river from

Cooks Point to Castlehaven the strength of the flood current occurs about five hours after high water at Old Point Comfort. Above Castlehaven it appears that the current becomes later and at station H68 the strength of flood occurs about six and three-fourths hours after high water at Old Point Comfort. At station H65, in the Tred Avon River, the strength of the flood current occurs about 4.2 hours after high water at Old Point Comfort.

In the Choptank River, as in other waterways already discussed, the time of current with reference to the time of local tide becomes earlier from the mouth toward the head of the stream. Near the mouth the strength of flood precedes the local high water by about 1.5 hours, at station H68 by 2.2 hours, and at station H65 in the mouth of the Tred Avon River by 2.5 hours.

THE CURRENT IN EASTERN BAY

Current stations in Eastern Bay are plotted on Figure 29 and the results of the observations are given in Table 53, page 89. The currents are relatively weak, the strengths having velocities usually less than half a knot. As seems to be universally true of the tributaries of Chespeake Bay, the current in the mouth is considerably earlier than in the bay outside, the channel to the eastward of Kent Point experiencing a current about three hours earlier than the one to the westward. The observations from station H58 east of Kent Point to station H61 in the Miles River show no marked variation in time of current, and it appears that in this stretch of water the strength of flood current occurs approximately five hours after high water at Old Point Comfort. Over most of this distance the strength of flood in the channel precedes the local high water by about 2½ hours. At station H61 the observations indicate that strengths of flood occur approximately three hours before local high water.

THE CURRENTS IN THE SOUTH AND SEVERN RIVERS

The positions of the current stations in these tributaries are plotted on Figure 29, and the results derived from the observations are given in Table 53, pages 89 and 90.

The observations in the mouth of the South River, station H51, indicate a weak tidal current with strength of flood occurring about five and three-fourths hours after high water at Old Point Comfort, or about two hours before local high water. At station H52 the observed currents were too weak and irregular to admit of the usual tabulation and reduction.

Values derived for stations in the Severn River indicate that in the dredged channel at the mouth of the river velocities at strength average about one-half knot. From Annapolis to Brewer Point, station H49, it appears that velocities at strength of about one fourth knot prevail.

In the channel southward of Greenbury Point strength of flood normally occurs about six and one-half hours after high water at Old Point Comfort.

Between Annapolis and Brewer Point the current is somewhat earlier, the strength of flood occurring about six hours after high water at Old Point Comfort. At Annapolis the strength of flood apparently precedes the local high water by about two and one-half hours.

THE CURRENT IN THE CHESTER RIVER

The locations of the stations are plotted on Figure 29 and the data derived from the observations are given in Table 53, page 90.

The mean velocities at strength of current as derived from the observations increase gradually from about 0.3 knot near the mouth of the river to about 0.8 knot at Chestertown.

The current becomes progressively later from the mouth toward the head of the river. At the mouth the strength of flood occurs about seven and three fourths hours and at Chestertown about eight and one-half hours later than high water at Old Point Comfort. The strength of the flood current precedes the local high water by about one and one-fourth hours at the mouth of the river and by about two and one-half hours at Chestertown.

THE CURRENT IN THE PATAPSCO RIVER

The locations of the stations in the Patapsco River are plotted on Figure 29, and the results of the observations are given in Table 53, pages 90 and 91.

The tidal currents are weak and meteorological effects are therefore relatively more important. Near the mouth the strengths of current have average velocities of about 0.3 knot. Above Sparrows Point and in the tributary creeks the observed velocities were very small and irregular in direction. The time of current appears to be approximately the same for the entire river. Strength of flood occurs on the average about seven and three-fourths hours after high water at Old Point Comfort or about two and one-half hours before local high water.

THE CURRENTS IN THE SASSAFRAS AND ELK RIVERS

The locations of the stations are plotted on Figure 29, and the results derived from the observations are given in Table 53, pages 91 and 92.

The observations in the Sassafras River indicate current velocities at strength of between 0.3 and 0.4 knot. Strength of flood occurs about nine and one-half hours after high water at Old Point Comfort and precedes the local high water by about two and one-half hours at the mouth and by nearly three hours at Georgetown.

In the Elk River the average velocity at strength is approximately half a knot and in Back Creek it is nearly a knot. At station H10 the observations show that strength of flood occurs about two and one-half hours before high water at Old Point Comfort. In the upper part of the river and in Back Creek flood strength occurs about two hours before high water at Old Point Comfort. The strength of flood precedes the local high water by about two and one-fourth hours at the mouth of the river and by about three hours in Back Creek.

THE CURRENT IN THE CHESAPEAKE & DELAWARE CANAL

The locations of the stations are plotted on Figure 36, and data derived from the observations are given in Tables 53 and 62.

In the Chesapeake & Delaware Canal the east-going and west-going currents are designated flood and ebb, respectively, for all parts of the canal. The velocities at strength of current average about one and one-third knots throughout the length of the canal. In the western part from Chesapeake City to the Pennsylvania

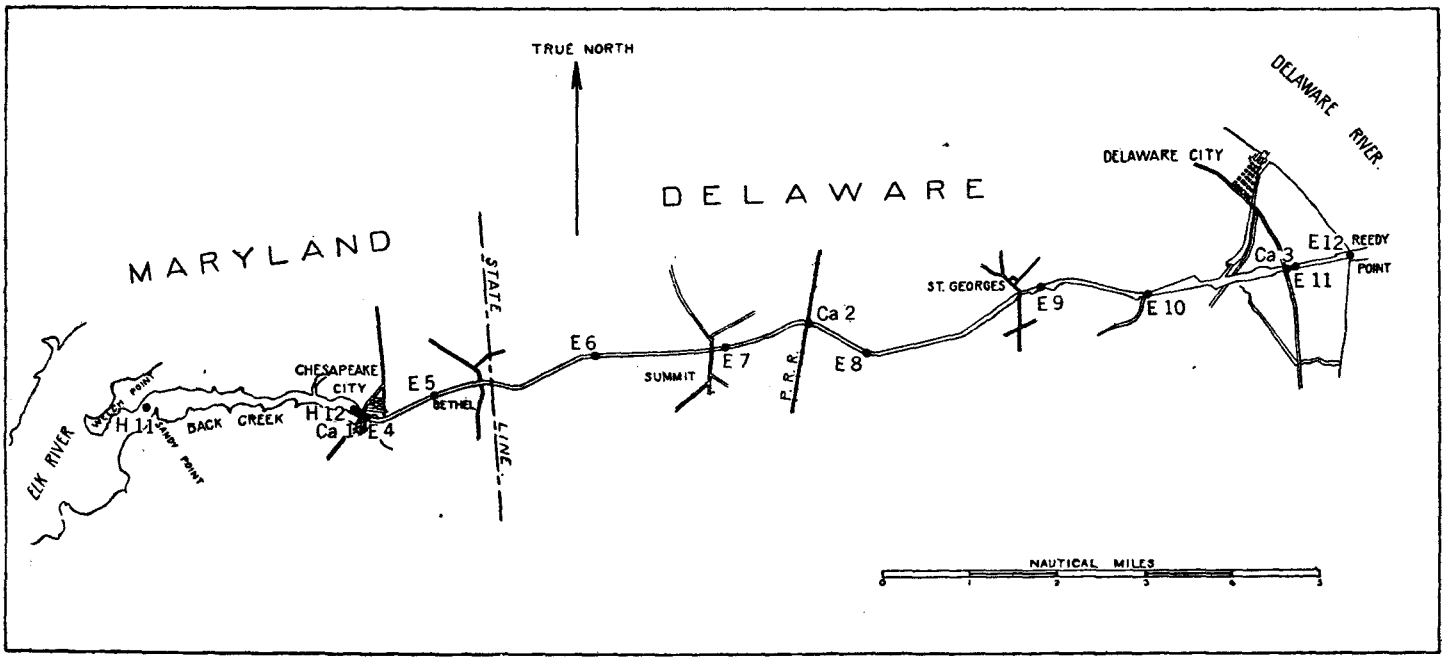

FIGURE 36.—Current stations, Chesapeake and Delaware Canal

Railroad bridge there appears to be very little variation in the time of current. In this part of the waterway and apparently as far eastward as St. Georges the east-going current reaches its strength about two and one-fourth hours before high water at Old Point Comfort. In the eastern end of the canal observations show a rather unusual

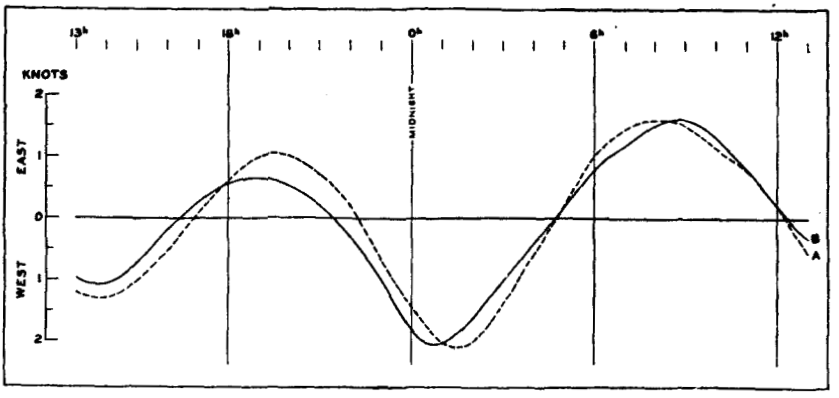

FIGURE 37.—Simultaneous current curves, June 4 and 5, 1928. A. Curve for station Ca 1; B, Curve for station Ca 2

current condition which, together with its relation to the currents in the western part of the canal is discussed below.

To aid in a study of the current movement in the canal curves were constructed which are reproduced on Figures 37 to 41, inclusive. Curve *A* is the current curve for station Ca1 plotted direct from pole

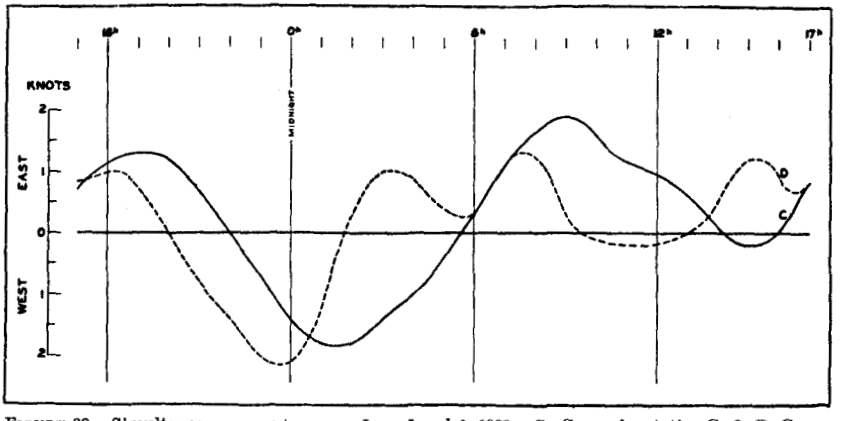

FIGURE 38.—Simultaneous current curves, June 5 and 6, 1928. C. Curve for station Ca 2; D, Curve for station Ca 3

observations and covering the 24-hour period between 1 p. m., June 4, and 1 p. m., June 5, 1928. Curve *B* is a similar observational curve for station Ca2, covering the same period of time. The similarity between these two curves indicates that the current is essentially the same at the two stations.

Curves *C* and *D* are simultaneous observational curves for stations Ca2 and Ca3, respectively. Curve *E* is the observed tide curve for

Chesapeake City at the western end of the canal, and curve F is the predicted tide curve for Reedy Point at the eastern end. Curve G was obtained by plotting the hourly differences between curve E and curve F, and represents the difference in water level between Chesa-

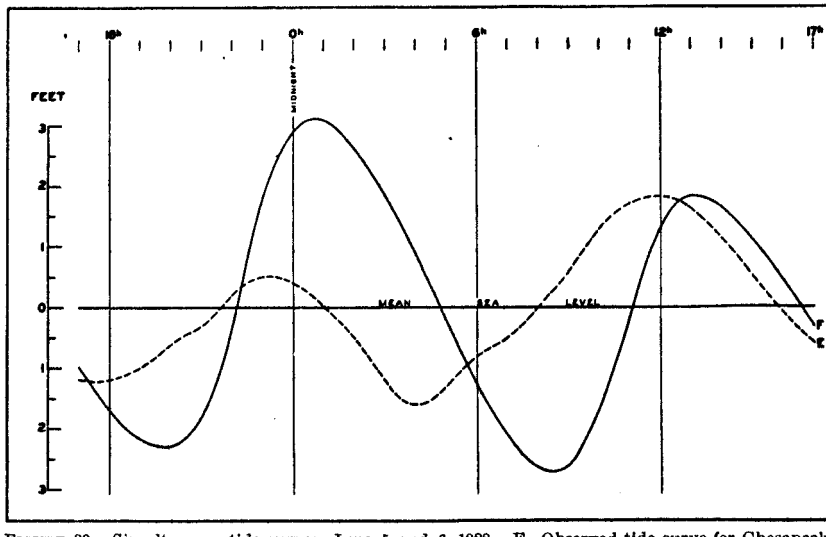

FIGURE 39.—Simultaneous tide curves, June 5 and 6, 1928. E. Observed tide curve for Chesapeake City; F, Predicted tide curve for Reedy Point

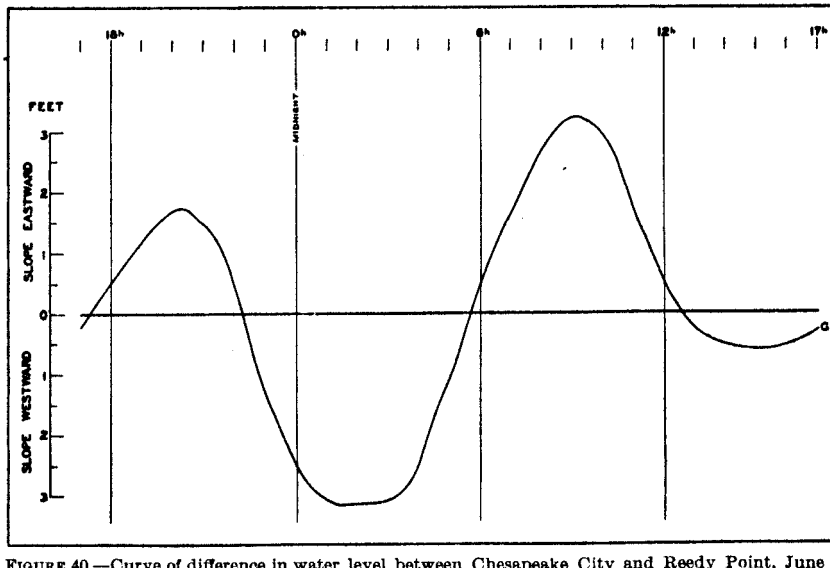

FIGURE 40.—Curve of difference in water level between Chesapeake City and Reedy Point, June 5 and 6, 1928

peake City and Reedy Point. Curve H was similarly obtained from curves C and D, and it represents algebraic differences in current velocity between station Ca2 and station Ca3. Curves C to H, inclusive, are all simultaneous, covering the period 5 p. m., June 5, to 5 p. m., June 6, 1928.

Considering the relation between the current at station Ca2, curve *C*, and the difference in water level at the two ends of the canal, curve *G*, it is noted that the times when the two reach their maximum and zero values are approximately the same, and the direction of flow is generally the direction of slope. This condition together with the fact that currents at stations Ca1 and Ca2 are practically simultaneous, leads to the conclusion that the current movement in the western half of the canal is hydraulic in character, depending upon the differences in water level at the two ends of the canal.

Comparing current curves *C* and *D*, it is evident that the current at station Ca3 differs from the hydraulic flow at stations Ca1 and Ca2. The nature of this difference is indicated by the curve *H* plotted from the hourly velocity differences between stations Ca2 and Ca3. This curve follows the Reedy Point tide curve with an average lag of about one and three-fourths hours and represents approximately the type of

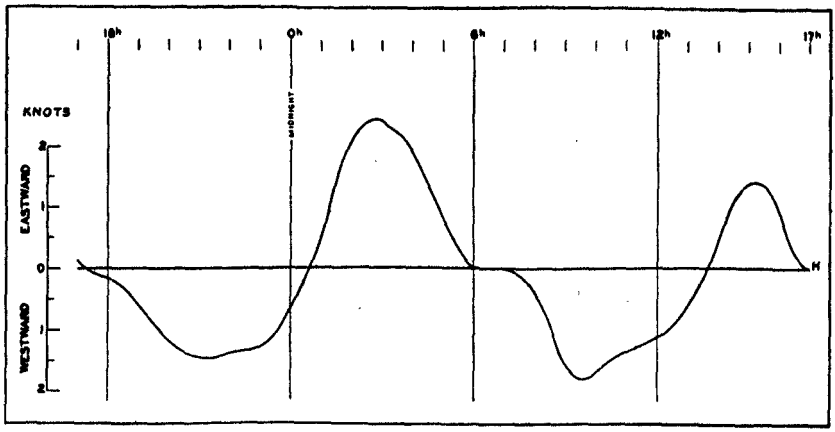

FIGURE 41.—Curve of velocity differences, June 5 and 6, 1928, showing the amount by which eastward and westward velocities were greater at station Ca 3 than at station Ca 2 (obtained by subtracting curve C from curve D)

current that would be expected to result from the rise and fall of the tide at Reedy Point if uncomplicated by other effects. It seems, therefore, that the peculiar current observed at station Ca3 is a combination of two currents. One the hydraulic current, flowing through the canal as a whole due to varying differences in water level at the two ends, and the other an inflow and outflow limited to the eastern end of the canal and due to the rising and falling of the tide in the Delaware River.

The condition just outlined is apparently made possible by the existance of a marshy area of considerable size located about half way between station Ca3 and St. Georges. This area appears to act as a reservoir, storing up water when the tide is rising and releasing it when the tide is falling. A careful study of curves *C*, *D*, and *F* reveals the fact that for some hours while the tide is rising at Reedy Point the water flows into this marshy area from both directions and for a similar period while the tide is falling at Reedy Point an outflow in both directions occurs.

TABLE 62.—*Current data, eastern end of Chesapeake & Delaware Canal*

[Referred to times of high water and low water at Old Point Comfort]

Station No.	Location	Observations				Slack	Flood or eastward current						Slack	Ebb or westward current strength	
		Date	Period	Method	Depth		First strength		Minimum flood		Second strength				
							Time	Velocity	Time	Velocity	Time	Velocity		Time	Velocity
			Days		*Feet*	*Hours after LW*	*Hours after LW*	*Knots*	*Hours after LW*	*Knots*	*Hours after LW*	*Knots*	*Hours after HW*	*Hours after HW*	*Knots*
E10	1½ miles E. of St. Georges Bridge (39° 33′.1 N., 75° 37′.0 W.).	May 13, 1927	½		(1)	10.0							11.87		
		1928–1929	5	Meter	7	10.21	11.17	0.38	0.36	0.09	3.18	1.03	11.65	1.80	0.87
Ca3	Reedy Point Bridge (39° 33′.4 N., 75° 35′.0 W.).	June 5–6, 1928	1	Pole	4½	9.40	11.20	1.14	0.73	0.47	2.73	1.20	10.38	0.81	1.20
				Meter	3	9.45	11.15	1.34	0.48	0.82	2.63	1.60	10.63	0.76	1.15
				do	12	9.40	11.10	1.19	0.53	0.72	2.68	1.45	10.68	0.76	1.05
E11	½ mile E. of Reedy Point Bridge (39° 33′.5 N., 75° 34′.9 W.)	May 13, 1927	½		(1)	10.5							10.1		
E12	Reedy Point (39° 33′.6 N., 75° 34′.0 W.)	1928–1929	5	Meter	7	9.78	11.01	1.01	0.73	0.47	2.69	1.06	10.32	1.07	1.30

[1] Surface.

It will be noted that at station Ca3 the flood or easterly current increases from slack to strength, then decreases to a smaller velocity which has been designated minimum flood, and again increases to a second strength. In Table 62 are given observational times and velocities of the various phases, including first strength of flood, minimum flood, and second strength of flood. As in Table 53, the times are referred to the tides at Old Point Comfort and the velocities are corrected to a mean value.

Results derived from recent observations made by United States Army Engineers at four stations in the canal have been incorporated in Tables 53 and 62. A total of approximately five days of observations each were taken at stations E4, E7, E10, and E12, Figure 36. The tabular values show that data obtained from these observations compare favorably with the observational information previously obtained, upon which the foregoing discussion is based.

The values for stations E10 and E12, Table 62, are of special interest, as they furnish additional examples of the unusual current movement observed at station Ca3 and give conclusive evidence that this type of current prevails from station E10 eastward to the jetties at Reedy Point.

SUMMARY OF SURFACE CURRENTS FROM THE LONGER SERIES

For convenient reference the values derived for the surface currents from the longer series of observations are compiled in Table 63. In the table are given data derived from all the observations taken at and above the 14-foot depth for each station where the series of observations covered a period of seven days or more. As in Table 53, the times are referred to the tide at Old Point Comfort and the velocities are reduced to mean values by correcting for range of tide. The direction and velocity of the nontidal current, derived graphically for each station from the average flood and ebb directions and velocities, are given in the last two columns of the table.

TABLE 63.—*Summary of surface currents at stations where observations covered a period of seven days or more*

[Referred to times of high water and low water at Old Point Comfort]

Station No.	Latitude	Longitude	Observations		Slack	Flood strength			Flood duration	Slack	Ebb strength			Ebb duration	Mean current hour	Set	
			Year	Period		Time	Direction (true)	Velocity			Time	Direction (true)	Velocity			Direction (true)	Velocity
	North ° ′	*West* ° ′		*Days*	*Hours after L. W.*	*Hours after L. W.*	*Degrees*	*Knots*	*Hours*	*Hours after H. W.*	*Hours after H. W.*	*Degrees*	*Knots*	*Hours*	*Hours*	*Degrees*	*Knots*
Approaches to Chesapeake Bay																	
LV1	37 04.6	74 51.1	1919	99	------	------	------	------	------	------	------	------	------	------	9.74	201	0.12
LV2	37 05.3	75 43.5	1912, 1915	146	1.40	4.20	285	0.24	5.57	9.55	4.15	74	0.33	6.85	11.82	47	0.08
Chesapeake Bay																	
LV3	36 58.8	76 00.4	1912, 1915, 1919	320	3.63	6.41	306	0.97	5.45	2.66	6.29	126	1.49	6.97	1.57	126	0.26
Fa3	38 19.1	76 20.4	1897	14	8.99	12.07	358	0.52	6.43	9.00	12.00	159	0.47	5.99	7.34	73	0.09
H73	38 23.2	76 20.5	1927	8	8.79	12.03	348	0.56	6.51	8.88	11.93	163	0.78	5.91	7.23	150	0.12
Fa2	38 31.1	76 25.8	1897	14¾	9.03	0.24	352	0.35	7.19	9.80	0.21	162	0.48	5.23	7.85	138	0.08
T7	38 44.8	76 28.0	1897	13	10.50	1.73	6	0.43	7.23	11.32	1.89	184	0.48	5.19	9.39	170	0.03
H55	38 50.8	76 25.6	1927	11	11.76	1.83	14	0.49	5.78	11.12	1.96	192	0.79	6.64	9.70	189	0.15
Fa1	38 52.5	76 25.2	1897	26	12.01	0.82	14	0.49	5.56	11.15	2.25	194	0.79	6.86	9.59	194	0.15
T6	38 56.4	76 23.8	1897	15	11.87	2.31	26	0.53	5.55	11.00	2.12	202	0.90	6.87	9.86	196	0.19
T4	39 00.8	76 22.0	1897	27½	11.93	2.57	9	0.80	6.41	11.92	2.72	192	0.82	6.01	10.32	252	0.03
H39	39 05.4	76 18.3	1927	11	11.68	2.26	30	0.55	6.47	11.73	2.56	193	0.53	5.95	10.09	105	0.08
T2	39 09.3	76 19.8	1897	29¼	0.78	3.36	3	0.52	5.23	12.01	3.15	199	0.80	7.19	10.96	225	0.17
Wb7	39 10.1	76 23.8	1867	14	12.03	3.05	355	0.62	6.68	12.29	2.70	171	0.49	5.74	10.55	10	0.06
T1	39 12.5	76 24.4	1897	7	0.26	3.16	30	0.24	5.78	12.04	2.99	219	0.32	6.64	10.75	241	0.05
H19	39 20.1	76 11.8	1927	11	1.28	4.18	43	1.18	5.64	0.50	3.80	218	1.43	6.78	11.68	197	0.14
Hampton Roads																	
C1	36 59.8	76 18.8	1898	69	2.73	------	------	------	5.91	2.22	------	------	------	6.51	0.85	------	------
Wt1	36 56.8	76 20.1	1917	10	1.30	4.26	195	0.56	5.70	0.58	3.94	9	0.79	6.72	11.76	354	0.12
Potomac River																	
R3	38 48.2	77 02.2	1913–1915	205	0.31	------	(1)	------	4.77	11.08	------	(2)	------	7.65	10.27	------	------

[1] Northerly.

[2] Southerly.

CURRENT CHARTS

The direction and velocity of the current at a number of locations in Chesapeake Bay and tributaries for each hour of the tide at Old Point Comfort are represented in Figures 42 to 54, which are based on observations taken within 14 feet of the surface. The general direction of flow is represented by arrows and the average velocities for the designated hour of the tide by numerals near the arrows. An "S" on the chart indicates slack water. At times of spring tides and perigean tides, the velocities will normally be greater, and at times of neap tides and apogean tides less than those given on the charts. Winds and other meteorological conditions at times greatly modify both the direction and the velocity of the current.

It happens that on the average high water at Old Point Comfort and strength of flood current at Chesapeake Bay entrance, station LV3, occur at the same time; and since the directions and velocities indicated on the charts apply to times reckoned from high water at Old Point Comfort they apply to the same times reckoned from strength of flood at station LV3.

Daily predictions of the times of high water at Old Point Comfort and the times of flood strength at Chesapeake Bay entrance (station LV3) are included in the Atlantic Coast Tide Tables and the Atlantic Coast Current Tables, respectively.

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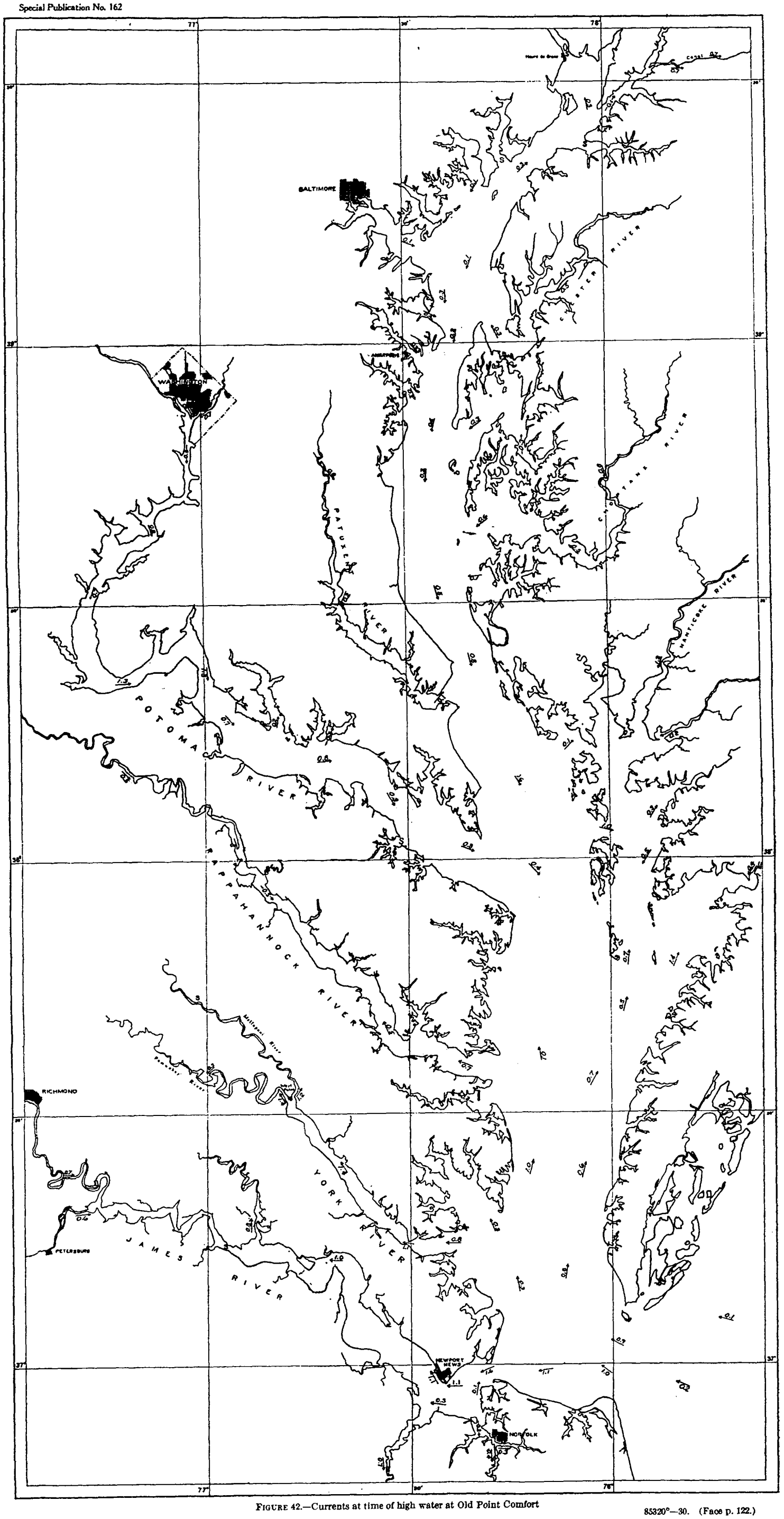

FIGURE 42.—Currents at time of high water at Old Point Comfort

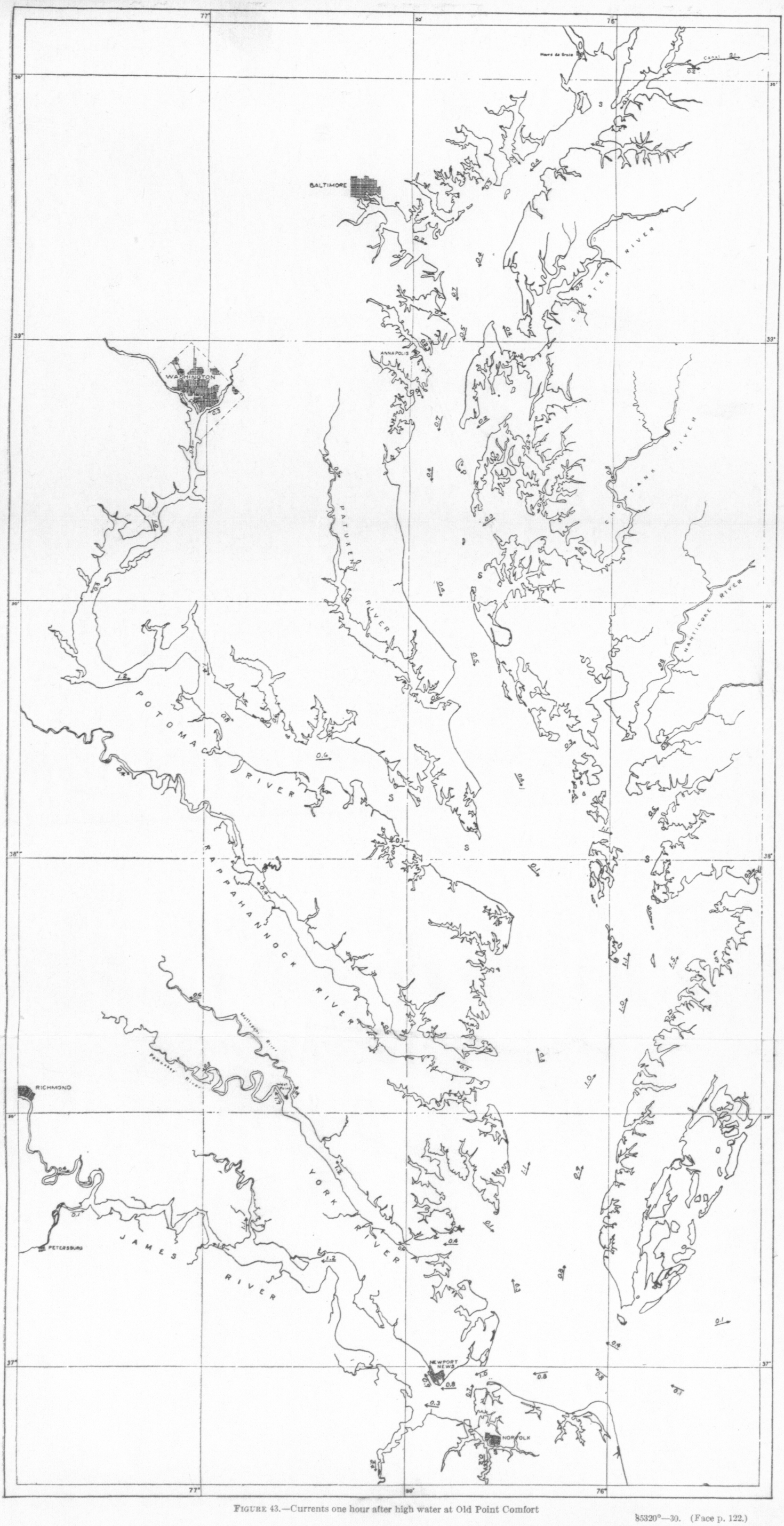

FIGURE 43.—Currents one hour after high water at Old Point Comfort

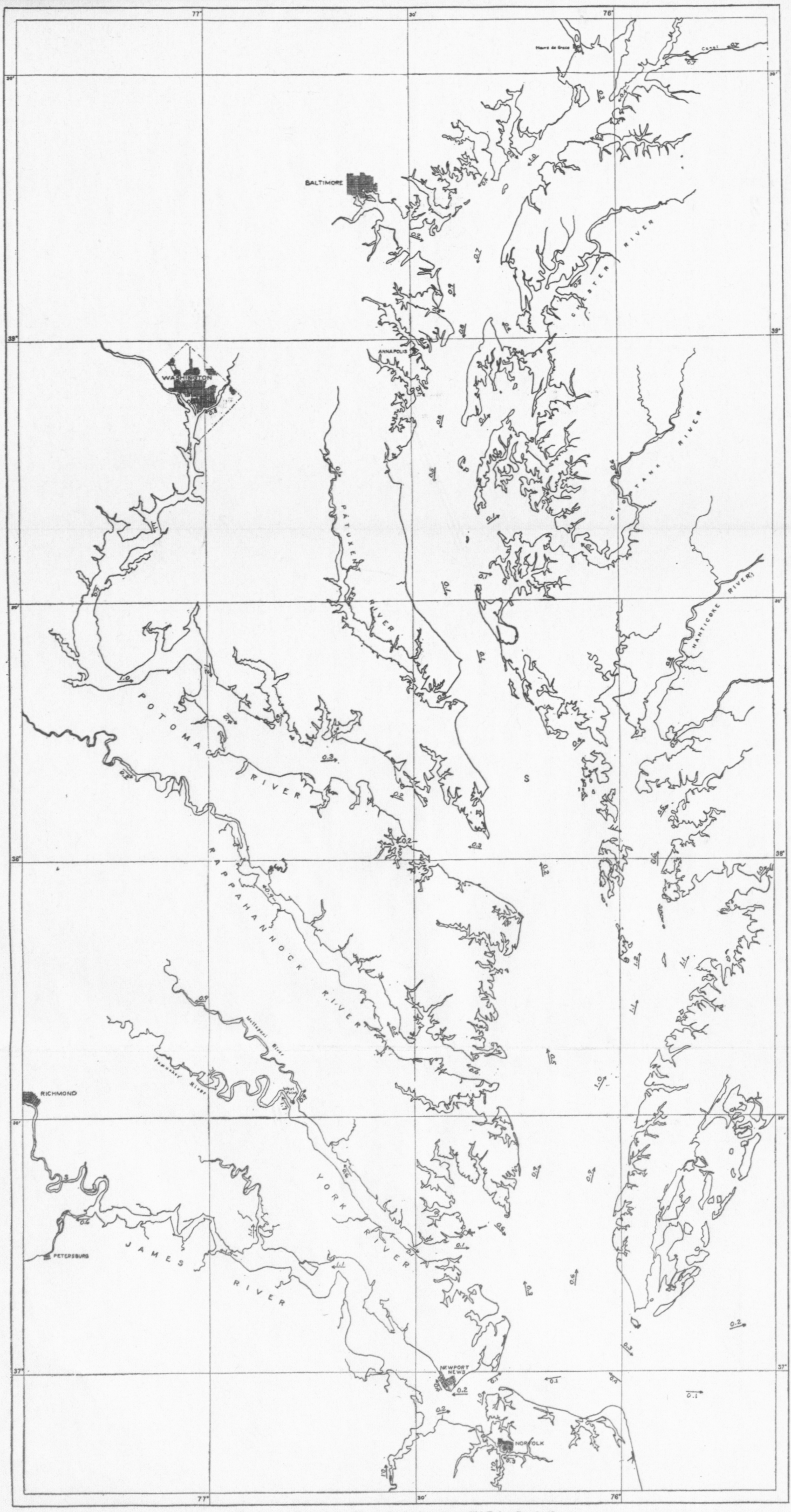

FIGURE 44.—Currents two hours after high water at Old Point Comfort3

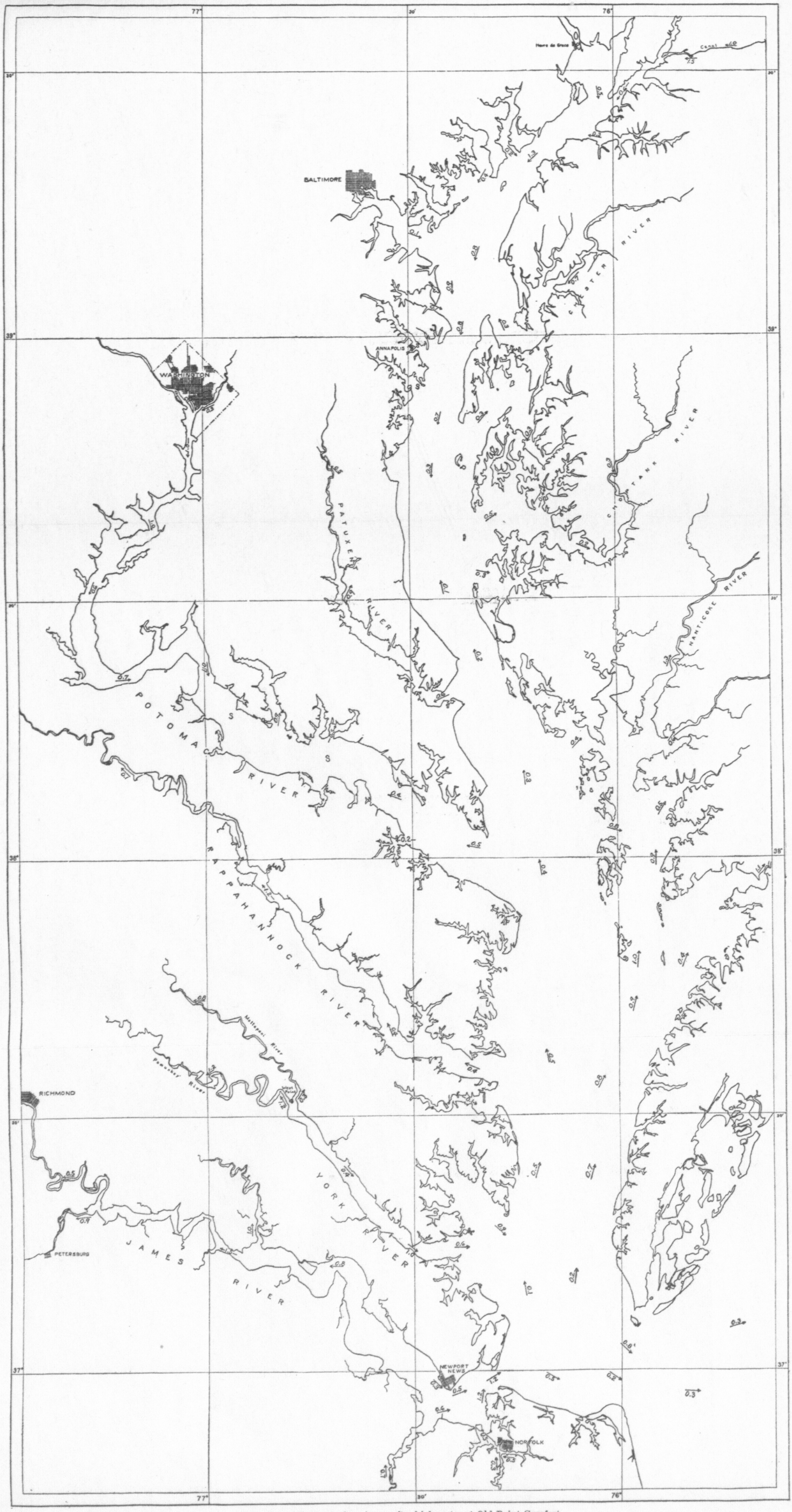

FIGURE 45.—Currents three hours after high water at Old Point Comfort

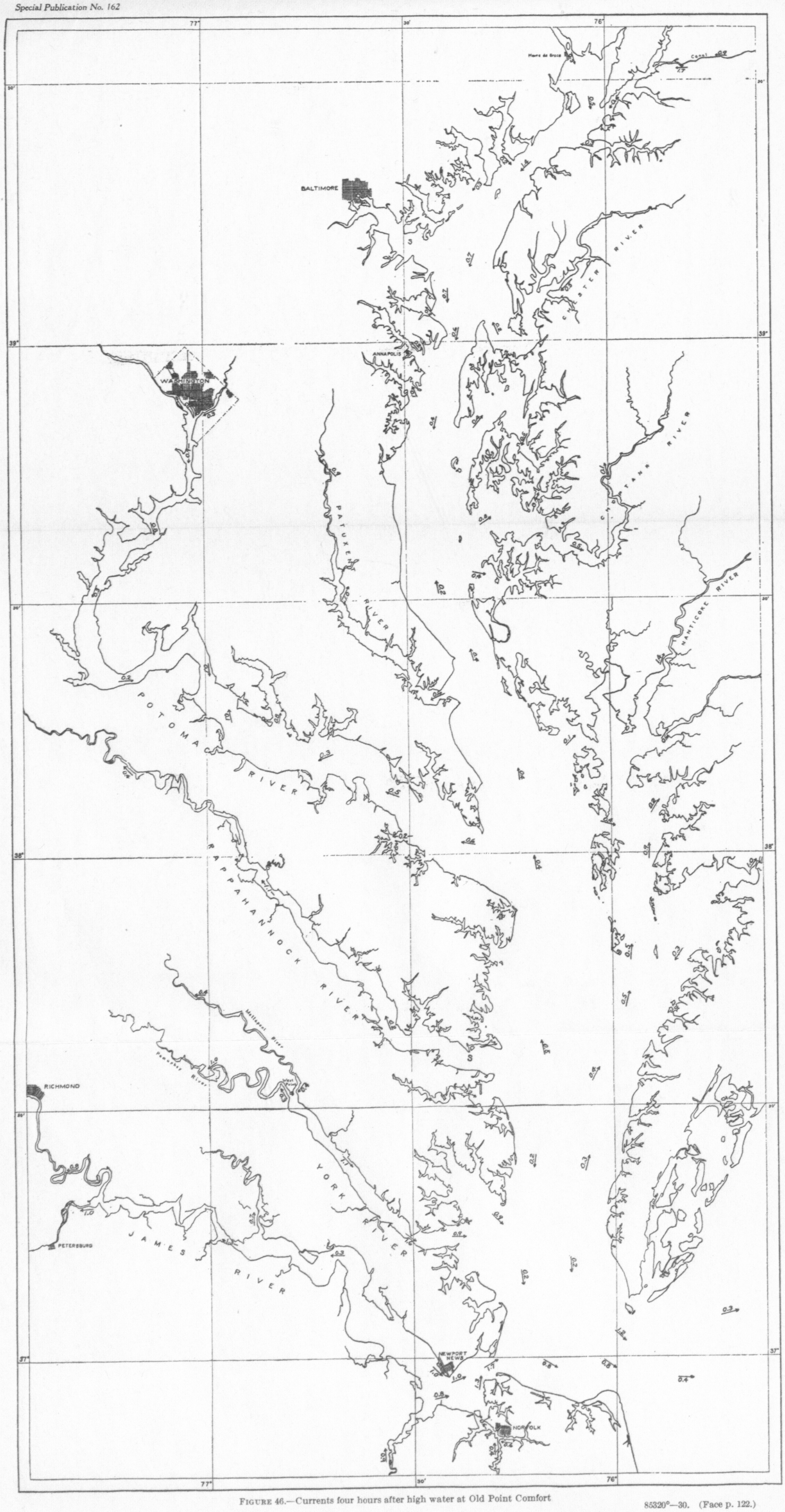

FIGURE 46.—Currents four hours after high water at Old Point Comfort

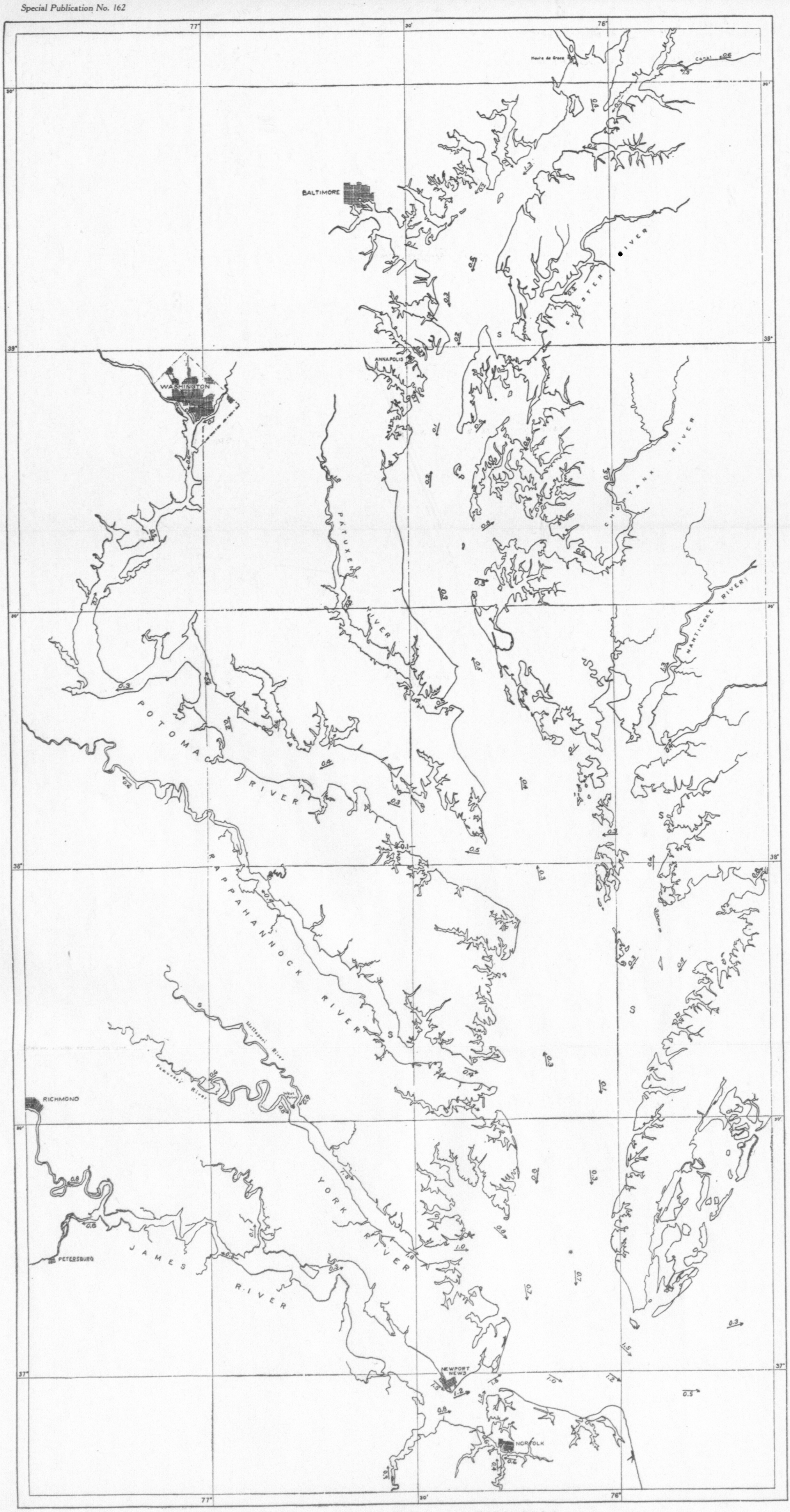

FIGURE 47.—Currents five hours after high water at Old Point Comfort

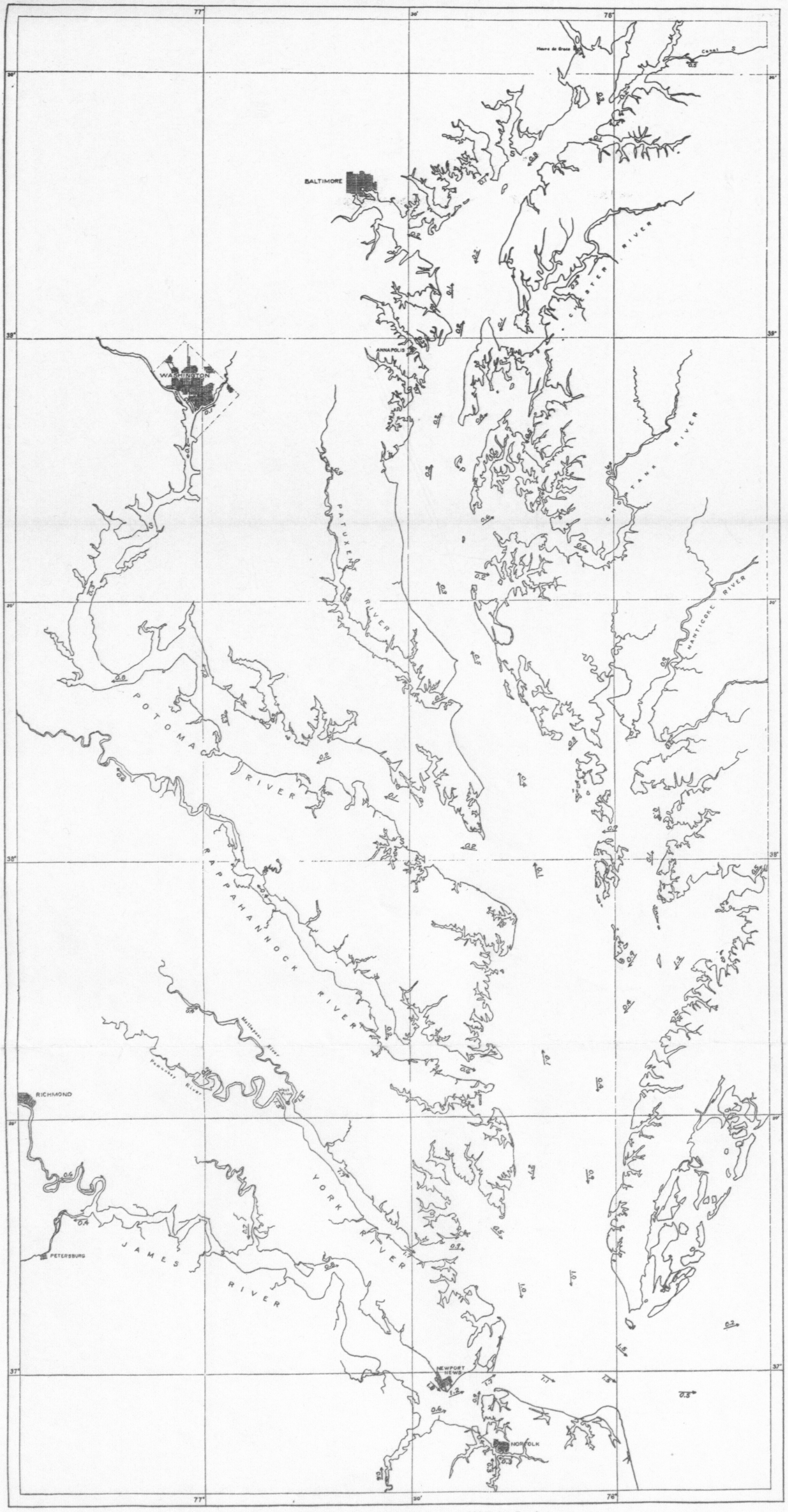

FIGURE 48.—Currents six hours after high water at Old Point Comfort

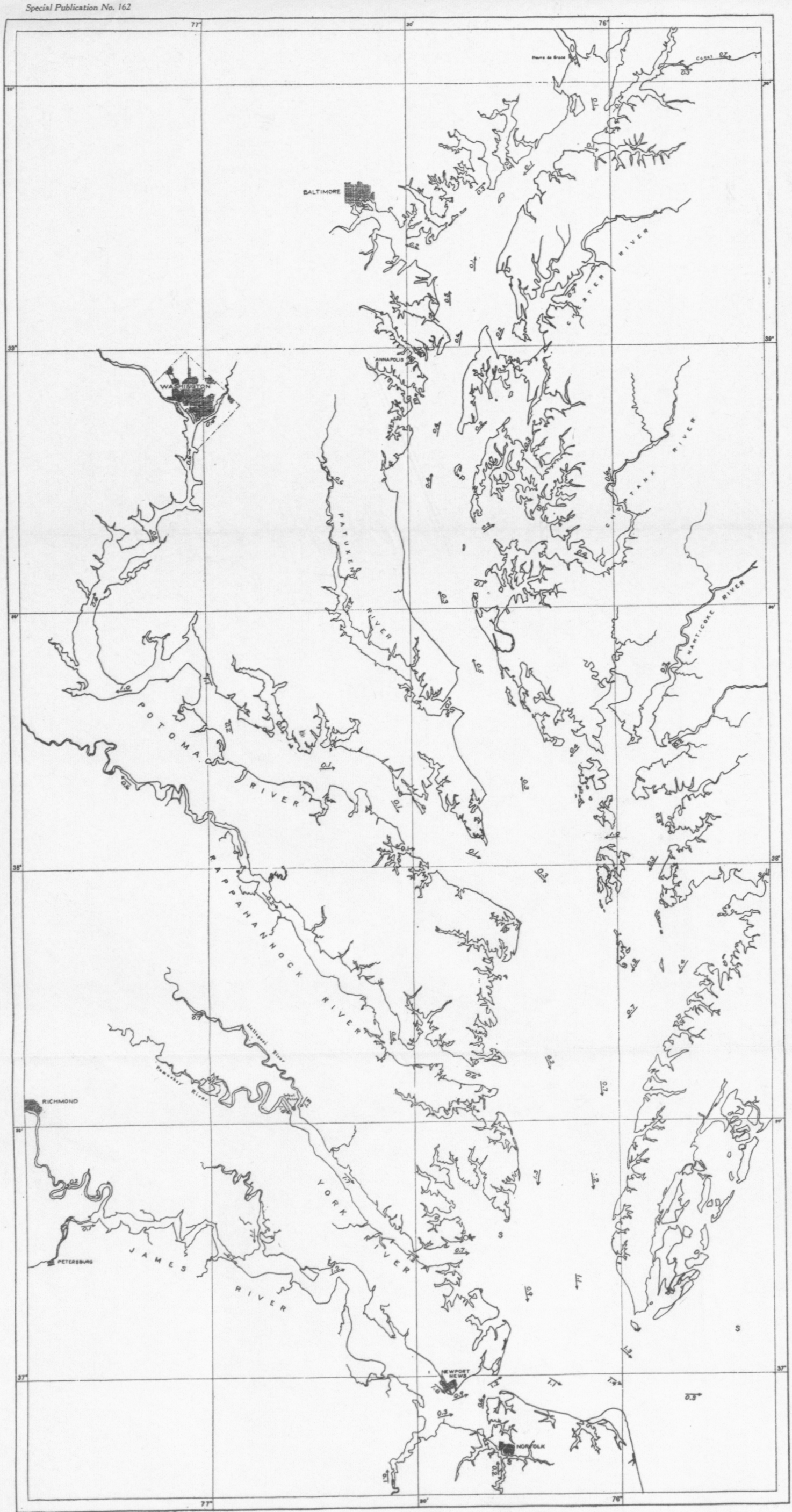

FIGURE 49.—Currents seven hours after high water at Old Point Comfort

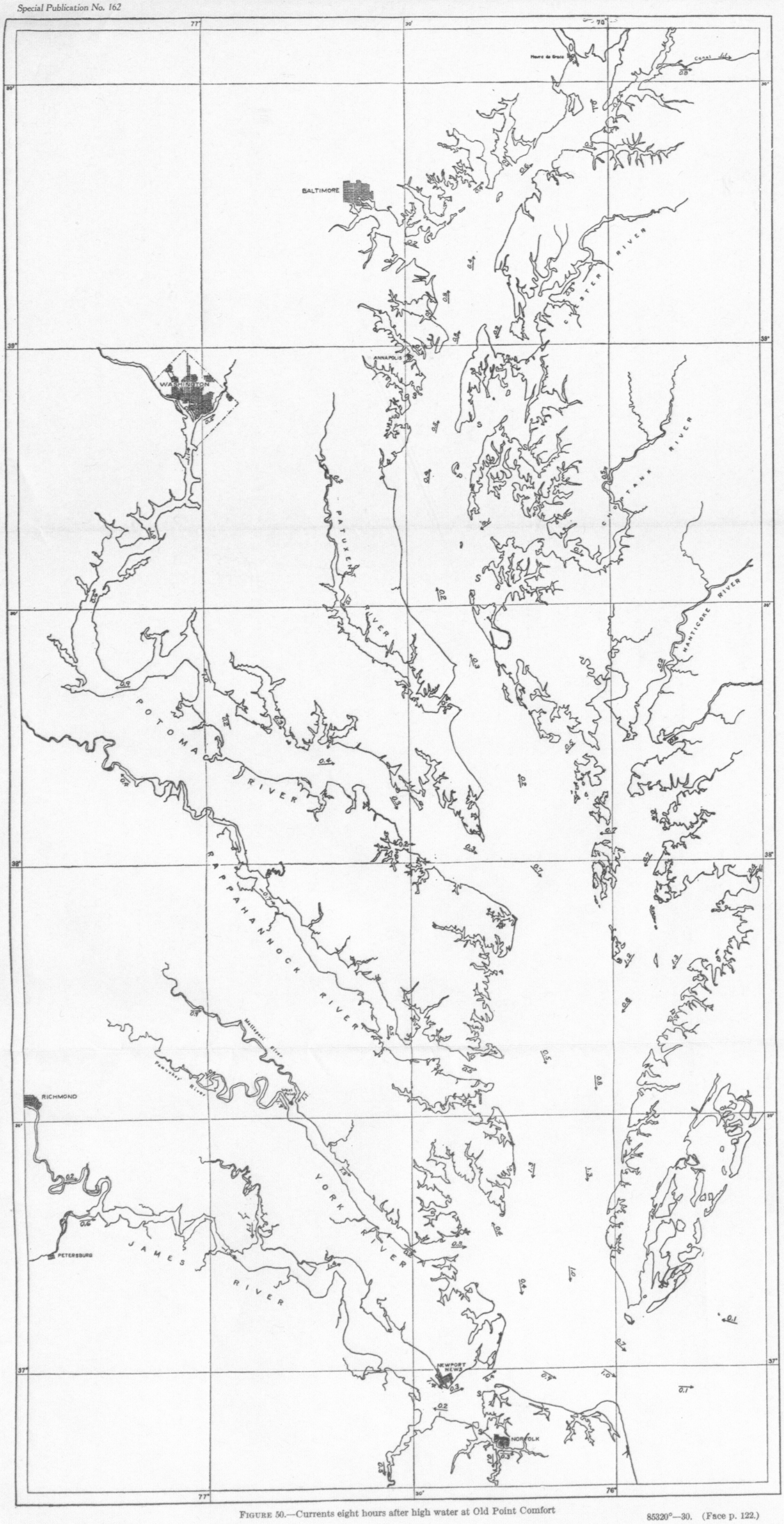

FIGURE 50.—Currents eight hours after high water at Old Point Comfort

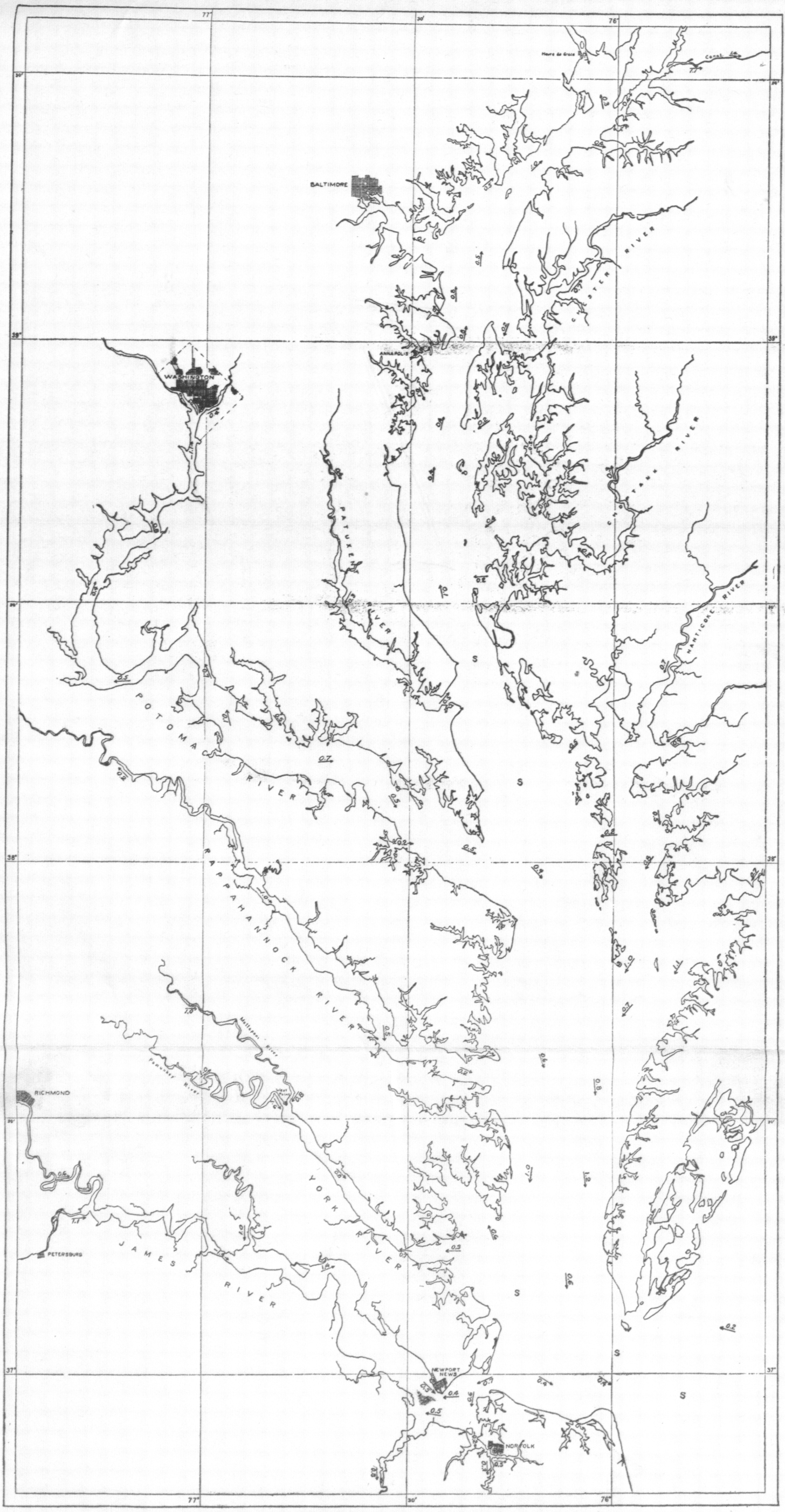

FIGURE 51.—Currents nine hours after high water at Old Point Comfort

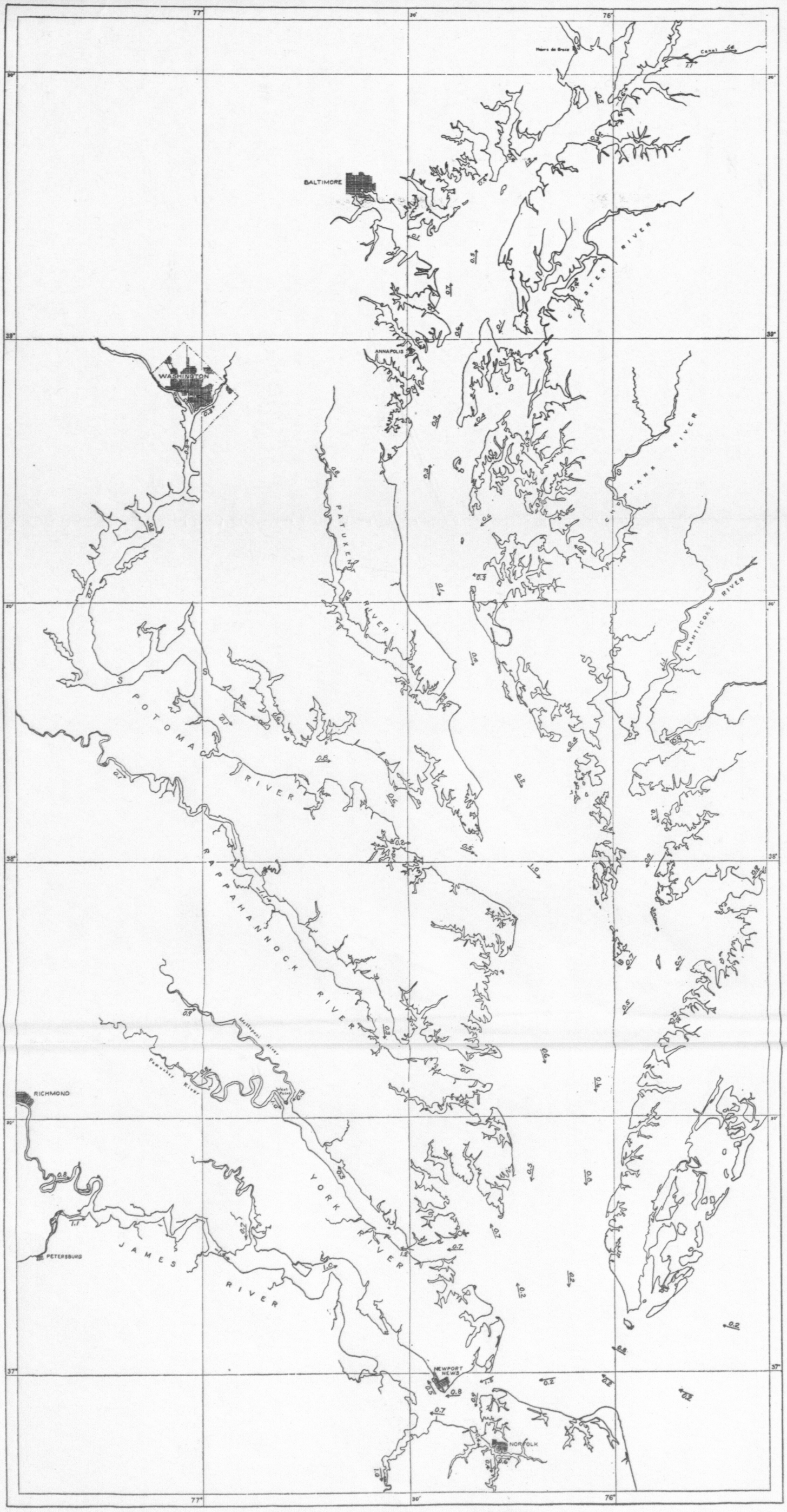

FIGURE 52.—Currents ten hours after high water at Old Point Comfort

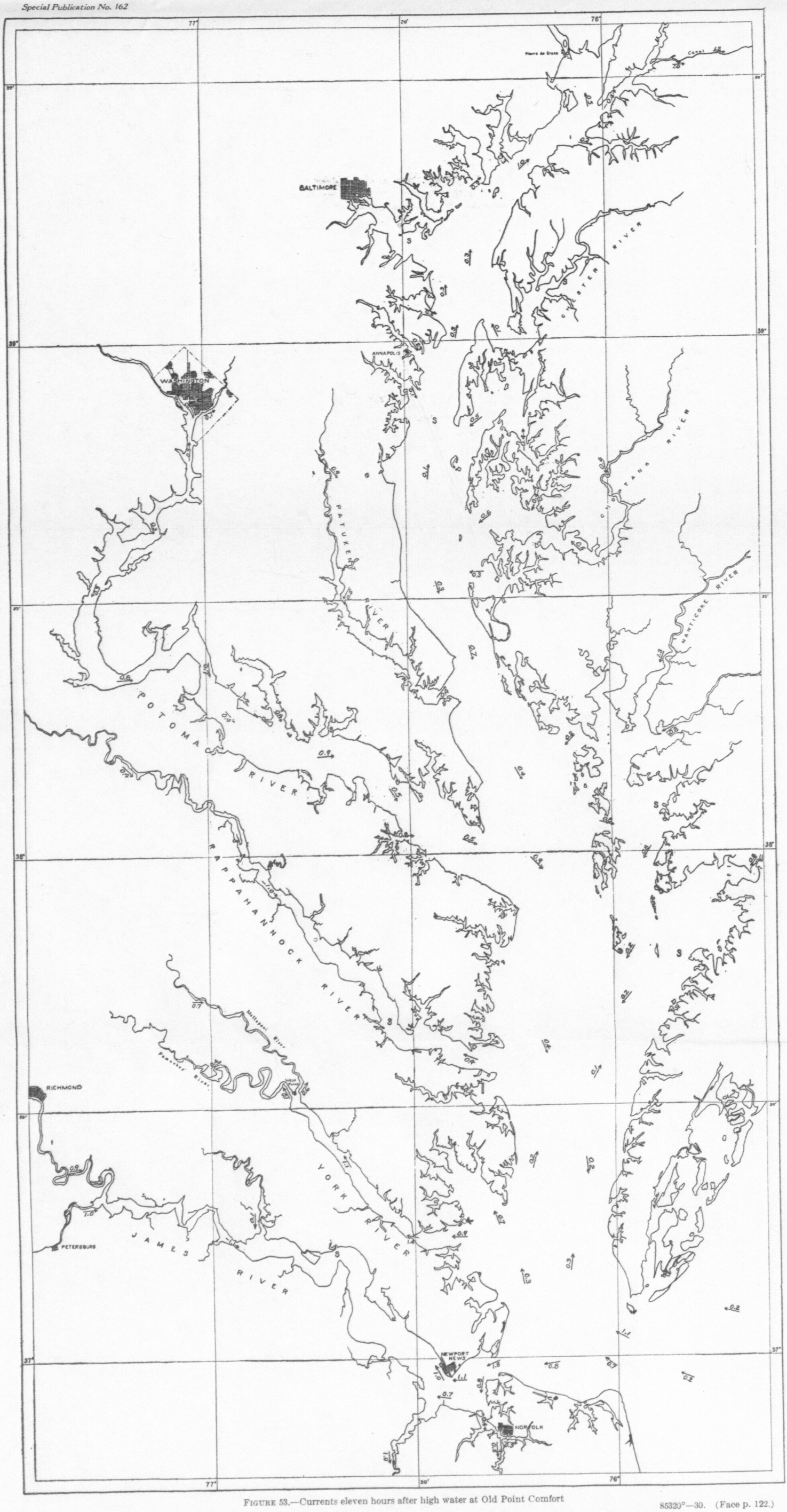

FIGURE 53.—Currents eleven hours after high water at Old Point Comfort

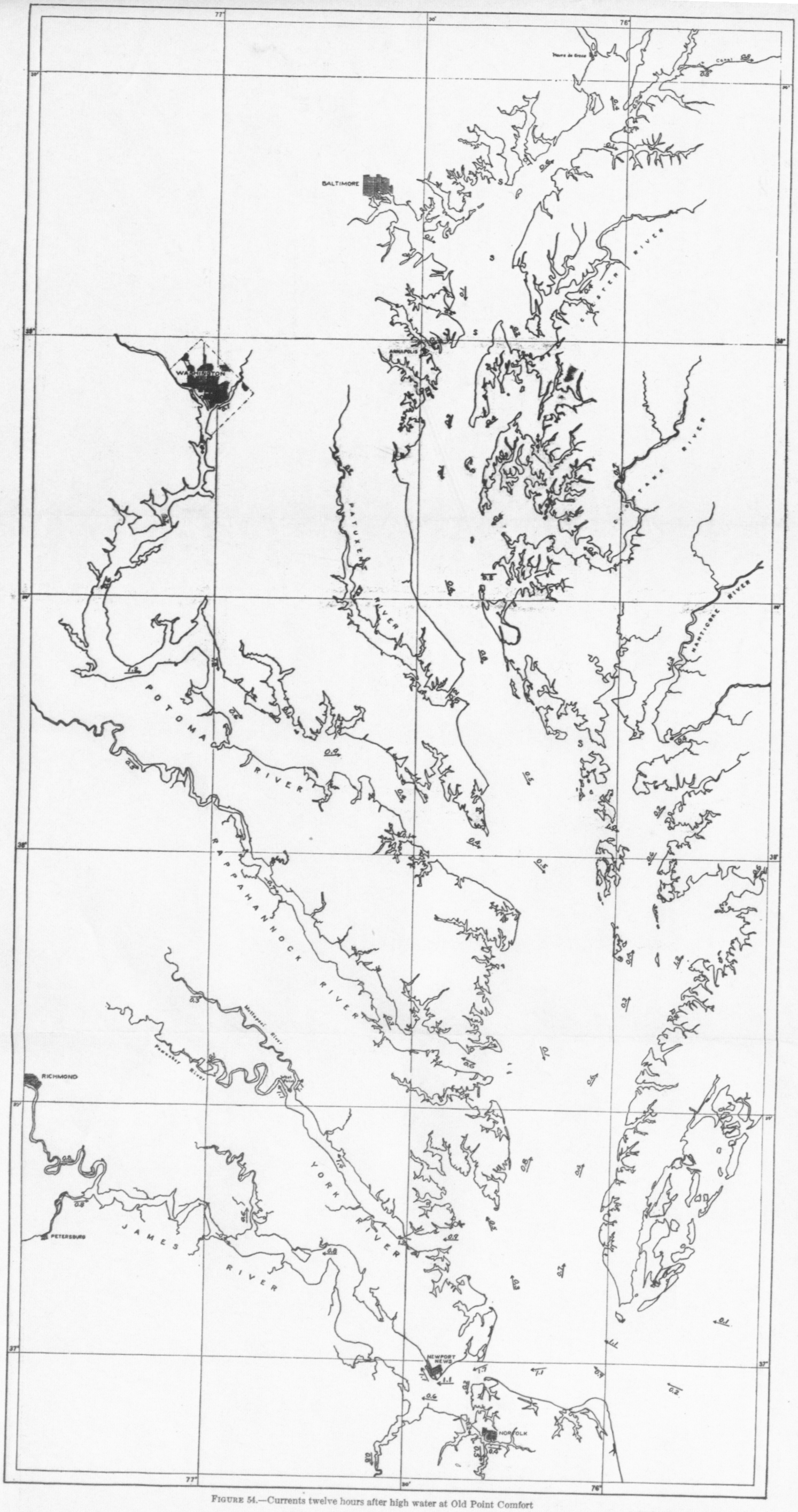

FIGURE 54.—Currents twelve hours after high water at Old Point Comfort

APPENDIX

GENERAL CHARACTERISTICS OF TIDES AND CURRENTS

[Reprinted from United States Coast and Geodetic Survey Special Publication No. 111]

I. TIDES, GENERAL CHARACTERISTICS

DEFINITIONS

The tide is the name given to the alternate rising and falling of the level of the sea, which at most places occurs twice daily. The striking feature of the tide is its intimate relation to the movement of the moon. High water and low water at any given place follow the moon's meridian passage by a very nearly constant interval, and since the moon in its apparent movement around the earth crosses a given meridian, on the average, 50 minutes later each day, the tide at most places likewise comes later each day by 50 minutes, on the average. The tidal day, like the lunar day, therefore has an average length of 24 hours and 50 minutes.

With respect to the tide, the "moon's meridian passage" has a special significance. It refers not only to the instant when the moon is directly above the meridian, but also to the instant when the moon is directly below the meridian, or 180° distant in longitude. In this sense there are two meridian passages in a tidal day, and they are distinguished by being referred to as the upper and lower meridian passages or upper and lower transits.

The interval between the moon's meridian passage (upper or lower) and the following high water is known as the "high-water lunitidal interval." Likewise the interval between the moon's meridian passage and the following low water is known as the "low-water lunitidal interval." For short they are called, respectively, high-water interval and low-water interval and abbreviated as follows: HWI and LWI.

In its rising and falling the tide is accompanied by a horizontal forward and backward movement of the water, called the tidal current. The two movements—the vertical rise and fall of the tide and the horizontal forward and backward movement of the tidal current—are intimately related, forming parts of the same phenomenon brought about by the tidal forces of sun and moon.

It is necessary, however, to distinguish clearly between tide and tidal current, for the relation between them is not a simple one nor is it everywhere the same. At one place a strong current may accompany a tide having a very moderate rise and fall, while at another place a like rise and fall may be accompanied by a very weak current. Furthermore, the time relations between current and tide vary widely from place to place. For the sake of clearness, therefore, tide should be used to designate the vertical movement of the water and tidal current the horizontal movement.

It is convenient to have a single term to designate the whole phenomenon which includes tides and tidal currents. Unfortunately no such distinct term exists. For years, however, "the tide" or "the tides," or even "flood and ebb," have been used in this general sense, and usually no confusion arises from this usage, since the context indicates the sense intended; but the use of the term "tide" to denote the horizontal movement of the water is confusing and is to be discouraged.

With respect to the rise and fall of the water due to the tide, high water and low water have precise meanings. They refer not so much to the height of the water as to the phase of the tide. High water is the maximum height reached by each rising tide and low water the minimum height reached by each falling tide.

It is important to note that it is not the absolute height of the water which is in question, for it is not at all infrequent at many places to have the low water of one day higher than the high water of another day. Whatever the height of the water, when the rise of the tide ceases and the fall is to begin, the tide is at high water; and when the fall of the tide ceases and the rise is to begin, the

tide is at low water. The abbreviations HW and LW are frequently used to designate high and low water, respectively.

In its rising and falling the tide does not move at a uniform rate. From low water the tide begins rising, very slowly at first, but at a constantly increasing rate for about three hours, when the rate of rise is a maximum. The rise then continues at a constantly decreasing rate for the following three hours, when high water is reached and the rise ceases. The falling tide behaves in a similar manner, the rate of fall being least immediately after high water, but increasing constantly for about three hours, when it is at a maximum, and then decreasing for a period of three hours till low water is reached.

The rate of rise and fall and other characteristics of the tide may best be studied by representing the rise and fall graphically. This may be done by reading the height of the tide at regular intervals on a fixed vertical staff graduated to feet and tenths and plotting these heights to a suitable scale on cross-section paper and drawing a smooth curve through these points. A more convenient method is to make use of an automatic tide gage by means of which the rise and fall of the tide is recorded on a sheet of paper as a continuous curve drawn to a suitable scale. Figure A shows a tide curve for Fort Hamilton, N. Y., for July 4, 1922.

In Figure A the figures from 0 to 24, increasing from left to right, represent the hours of the day beginning with midnight. Numbering the hours con-

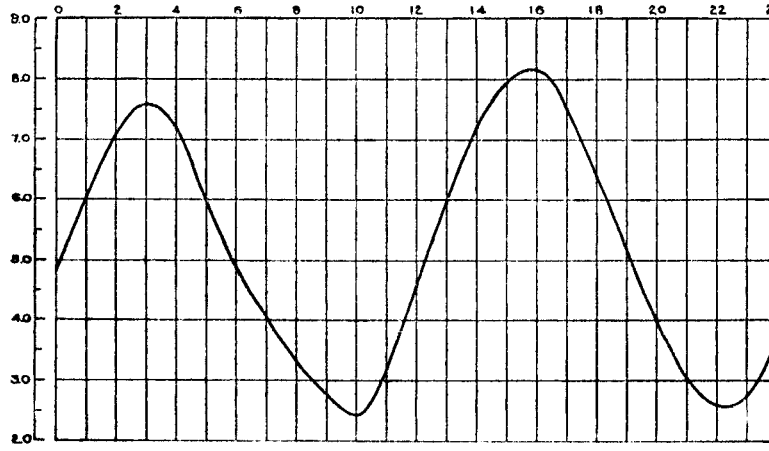

FIGURE A.—Tide curve for Fort Hamilton, N. Y., July 4, 1922

secutively to 24 eliminates all uncertainty as to whether morning or afternoon is meant and has the further advantage of great convenience in computation. The figures on the left, increasing upward from 2.0 to 9.0, represent the height of the tide in feet as referred to a fixed vertical staff. The tide curve presents the well-known form of the sine or cosine curve.

The difference in height between a high water and a preceding or following low water is known as the "range of tide" or "range." The average difference in the heights of high and low water at any given place is called the mean range.

THE TIDE-PRODUCING FORCES

The intensity with which the sun (or moon) attracts a particle of matter on the earth varies inversely as the square of the distance. For the solid earth as a whole the distance is obviously to be measured from the center of the earth, since that is the center of mass of the whole body. But the waters of the earth, which may be considered as lying on the surface of the earth, are on the one side of the earth nearer to the heavenly bodies and on the other side farther away than the center of the earth. The attraction of sun or moon for the waters of the ocean is thus different in intensity from the attraction for the solid earth as a whole, and these differences of attraction give rise to the forces that cause the ocean waters to move relative to the solid earth and bring about the tides. These forces are called the tide-producing forces.

The mathematical development of these forces shows that the tide-producing force of a heavenly body varies directly as its mass and inversely as the cube of its distance from the earth. The sun has a mass about 26,000,000 times as great as that of the moon; but it is 389 times as far away from the earth. Its tide-producing force is therefore to that of the moon as 26,000,000 is to $(389)^3$ or somewhat less than one-half.

When the relative motions of the earth, moon, and sun are introduced into the equations of the tide-producing forces, it is found that the tide-producing forces of both sun and moon group themselves into three classes: (*a*) Those having a period of approximately half a day, known as the semidiurnal forces; (*b*) those having a period of approximately one day, known as diurnal forces; (*c*) those having a period of half a month or more, known as long-period forces.

The distribution of the tidal forces over the earth takes place in a regular manner, varying with the latitude. But the response of the various seas to these forces is very profoundly modified by terrestrial features. As a result we find the tides, as they actually occur, differing markedly at various places, but apparently with no regard to latitude.

The principal tide-producing forces are the semidiurnal forces. These forces go through two complete cycles in a tidal day, and it is because of the predominance of these semidaily forces that there are at most places two complete tidal cycles, and therefore two high and two low waters in a tidal day.

VARIATIONS IN RANGE

The range of the tide at any given place is not constant but varies from day to day; indeed, it is exceptional to find consecutive ranges equal. Obviously, changing meteorological conditions will find reflection in variations of range, but the principal variations are due to astronomic causes, being brought about by variations in the position of the moon relative to earth and sun.

At times of new moon and full moon the tidal forces of moon and sun are acting in the same direction. High water then rises higher and low water falls lower than usual, so that the range of the tide at such times is greater than the average. The tides at such times are called "spring tides," and the range of the tide is then known as the "spring range."

When the moon is in its first and third quarters, the tidal forces of sun and moon are opposed and the tide does not rise as high nor fall as low as the average. At such times the tides are called "neap tides," and the range of the tide then is known as the "neap range."

It is to be noted, however, that at most places there is a lag of a day or two between the occurrence of spring or neap tides and the corresponding phases of the moon; that is, spring tides do not occur on the days of full and new moon, but a day or two later. Likewise neap tides follow the moon's first and third quarters after an interval of a day or two. This lag in the response of the tide is known as the "age of phase inequality" or "phase age" and is generally ascribed to the effects of friction.

The varying distance of the moon from the earth likewise affects the range of the tide. In its movement around the earth the moon describes an ellipse in a period of approximately 27½ days. When the moon is in perigee, or nearest the earth, its tide-producing power is increased, resulting in an increased rise and fall of the tide. These tides are known as "perigean tides," and the range at such times is called the "perigean range." When the moon is farthest from the earth, its tide-producing power is diminished, the tides at such times exhibiting a decreased rise and fall. These tides are called "apogean tides" and the corresponding range the "apogean range."

In the response to the moon's change in position from perigee to apogee, it is found that, like the responses in the case of spring and neap tides, there is a lag in the occurrence of perigean and apogean tides. The greatest rise and fall does not come on the day when the moon is in perigee, but a day or two later. Likewise, the least rise and fall does not occur on the day of the moon's apogee, but a day or two later. This interval varies somewhat from place to place, and in some regions it may have a negative value. This lag is known as the "age of parallax inequality" or "parallax age."

The moon does not move in the plane of the Equator but in an orbit making an angle with that plane of approximately 23½°. During the month, therefore, the moon's declination is constantly changing, and this change in the position of the moon produces a variation in the consecutive ranges of the tide. When the moon is on or close to the Equator—that is, when its declination is

small—consecutive ranges do not differ much, morning and afternoon tides being very much alike. As the declination increases the difference in consecutive ranges increases, morning and afternoon tides beginning to show decided differences, and at the times of the moon's maximum semimonthly declination these differences are very nearly at a maximum. But like the response to changes in the moon's phase and parallax, there is a lag in the response to the change in declination, this lag being known as the "age of diurnal inequality" or "diurnal age." Like the phase and parallax ages, the diurnal age varies from place to place, being generally about one day, but in some places it may have a negative value.

When the moon is on or close to the Equator and the difference between morning and afternoon tides small, the tides are known as "equatorial tides." At the times of the moon's maximum semimonthly declination, when the differences between morning and afternoon tides are at a maximum, the tides are called "tropic tides," since the moon is then near one of the Tropics.

The three variations in the range of the tide noted above are exhibited by the tide the world over, but not everywhere to the same degree. In many regions the variation from neaps to springs is the principal variation; in certain regions it is the variation from apogee to perigee that is the principal variation; and in other regions it is the variation from equatorial to tropic tides that is the predominant variation.

The month of the moon's phases (the synodical month) is approximately 29½ days in length; the month of the moon's distance (the anomalistic month) is approximately 27½ days in length; the month of the moon's declination (the tropic month) is approximately 27⅓ days in length. It follows, therefore, that very considerable variation in the range of the tide occurs during a year due to the changing relations of the three variations to each other.

DIURNAL INEQUALITY

The difference between morning and afternoon tides due to the declination of the moon is known as diurnal inequality, and where the diurnal inequality is considerable the rise and fall of the tide is affected to a very marked degree both in time and in height. Figure B represents graphically the differences in the tide at San Francisco on October 18 and 24, 1922. On the former date the moon was over the Equator, while on the latter date the moon was at its maximum south declination for the month. The upper diagram thus represents the equatorial tide for San Francisco, while the lower diagram represents the tropic tide.

It will be noted that on October 18 the morning and afternoon tides show very close resemblance. In both cases the rise from low water to high water and the fall from high water to low water took place in approximately six hours. The heights to which the two high waters attained were very nearly the same, and likewise the depressions of the two low waters.

On October 24, when the moon attained its extreme declination for the fortnight, tropic tides occurred. The characteristics of the rise and fall of the tide on that day differ markedly from those on the 18th, when the equatorial tides occured, these differences pertaining both to the time and the height. Instead of approximately equal duration of rise and of fall of six hours, both morning and afternoon, as was the case on the 18th, we now have the morning rise occupying less time than the afternoon rise and the morning fall more time than the evening fall. Even more striking are the differences in extent of rise and fall of morning and afternoon tides. The tide curve shows that there was a difference of a foot in the two high waters of the 24th and a difference of almost 3 feet in the low waters.

Definite names have been given to each of the two high and two low waters of a tidal day. Of the high waters, the higher is called the "higher high water" and the lower the "lower high water." Likewise, of the two low waters of any tidal day the lower is called "lower low water" and the higher "higher low water."

The diurnal inequality may be related directly to the ratio of the tides brought about, respectively, by the diurnal and semidiurnal tide-producing forces. Those bodies of water which offer relatively little response to the diurnal forces will exhibit but little diurnal inequality, while those bodies which offer relatively considerable response to these diurnal forces will exhibit considerable diurnal inequality. On the Atlantic coast of the United States there is relatively little diurnal inequality, while on the Pacific coast there is considerable inequality.

It is obvious that with increasing diurnal inequality the lower high water and higher low water tend to become equal and merge. When this occurs there is

but one high and one low water in a tidal day instead of two. This occurs frequently at Galveston, Tex., and at a number of other places.

TYPES OF TIDE

From place to place the characteristics of the rise and fall of the tide generally differ in one or more respects; but according to the predominating features the various kinds of tide may be grouped under three types, namely, semidiurnal, diurnal, and mixed. Instead of semidiurnal and diurnal the terms "semidaily" and "daily" are frequently used.

The simidiurnal type of tide is one in which two high and two low waters occur each tidal day with but little diurnal inequality; that is, morning and afternoon tides resemble each other closely. Figure A may be taken as representing this type of tide, and this is the type found on the Atlantic coast of the United States.

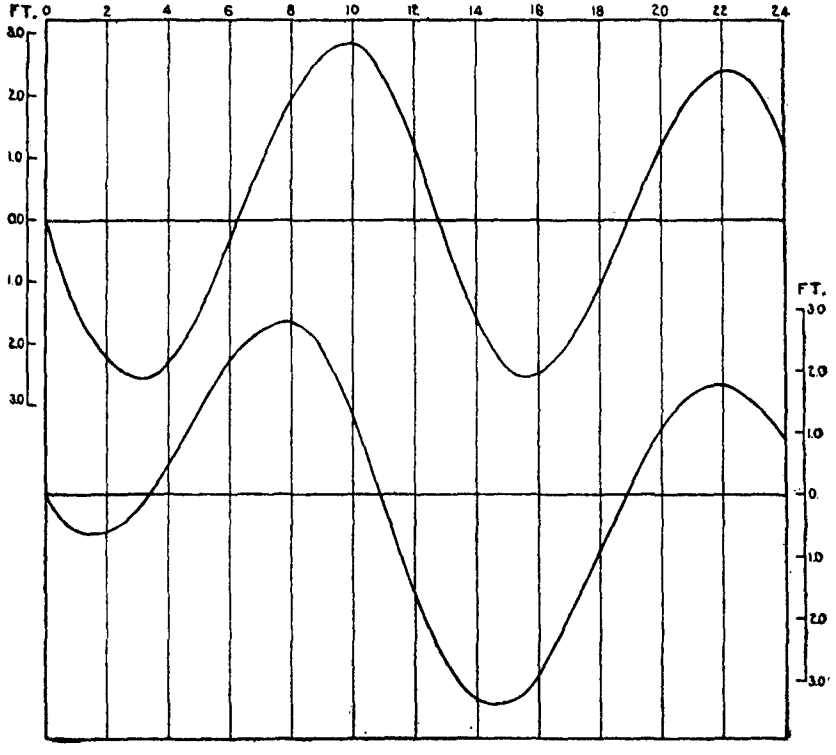

FIGURE B.—Tide curves, San Francisco, Calif., October 18 and 24, 1922

In the diurnal type of tide but one high and one low water occur in a tidal day. Do-Son, French Indo-China, may be cited as a place where the tide is always of the daily type, but it is to be noted that there are not many such places. When the moon's declination is zero the diurnal tidal forces tend to vanish, and there are generally two high and two low waters during the day at such times. Galveston, Tex., and Manila, P. I., may be mentioned as ports at which the tide is frequently diurnal, while St. Michael, Alaska, may be cited as a port at which the tide is largely diurnal.

The mixed type of tide is one in which two high and two low waters occur during the tidal day but which exhibits marked diurnal inequality. Several forms may occur under this type. In one form the diurnal inequality is exhibited principally by the high waters; in another form it is the low waters which exhibit the greater inequality; or the diurnal inequality may be features of both high waters and low waters.

It is to be noted that when the tide at any given place is assigned to any particular type it refers to the characteristics of the predominating tide at that place. At the time of the moon's maximum semimonthly declination the semidiurnal type exhibits more or less diurnal inequality and thus approaches the mixed type; and when the moon is on or near the Equator the diurnal inequality of the mixed type is at a minimum, the tide at such times resembling the semidiurnal type. It is the characteristics of the predominating tide that determine the type of tide at any given place. With the aid of harmonic constants the type of tide may be defined by definite ratios of the semidiurnal to the diurnal constituents.

Type of tide is intimately associated with diurnal inequality and hence depends on the relation of the semidiurnal to the diurnal tides; and it is the variation in this relation that makes possible the various forms of the mixed type of tide.

HARMONIC CONSTANTS

Since the tide is periodic in character, it may be regarded as the resultant of a number of simple harmonic movements. In other words, if h be the height of the tide, reckoned from sea level, then for any time t, we may write $h=A \cos (at+\alpha)+B \cos (bt+\beta)+ \ldots$ In the above formula each term represents a constituent of the tide which is defined by its amplitude or semirange, A, B, etc., by an angular speed, a, b, etc., and by an angle of constant value, α, β, etc., which determines the relation of time of maximum height to the time of beginning of observation.

We may also regard the matter from another viewpoint and suppose the moon and sun as *tide-producing bodies* to be replaced by a number of hypothetical tide-producing bodies, each of which moves around the earth in the plane of the Equator in a circular orbit with the earth as center. With the further assumption that each of these hypothetical tide-producing bodies gives rise to a simple tide, the high water of which occurs a certain number of hours after its upper meridian passage and the low water the same number of hours after its lower meridian passage, the oscillation produced by each of these simple tides may be written in the form $h=A \cos (at+\alpha)$ as above. The great advantage of so regarding the tide is that it permits the complicated movements of sun and moon relative to the earth to be replaced by a number of simple movements.

Each of the simple tides into which the tide of nature is resolved is called a component tide, or simply a component. The amplitudes or semiranges of the component tides, together with the angles which determine the relation of the high water of each of these component tides to some definite time origin and which are known as the epochs, constitute the harmonic constants.

The periods of revolution of the hypothetical tidal bodies or the speeds of the various component tides are computed from astronomical data and depend only on the relative movements of sun, moon, and earth. These periods being independent of local conditions are, therefore, the same for all places on the surface of the earth; what remains to be determined for the various simple constituent tides is their epochs and amplitudes, which vary from place to place according to the type, time, and range of the tide. The mathematical process by which these epochs and amplitudes are disentangled from tidal observations is known as the harmonic analysis.

The number of simple constituent tides is theoretically large, but most of them are of such small magnitude that they may for all practical purposes be disregarded. In the prediction of tides it is necessary to take account of 20 to 30, but the characteristics of the tide at any place may be determined easily from the 5 principal ones.

It is obvious that the principal lunar tidal component will be one which gives two high and two low waters in a tidal day of 24 hours and 50 minutes, or more exactly in 24.84 hours. Its speed per solar hour, therefore, is $\frac{2\times 360^\circ}{24.84}=28^\circ.98$. This component has been given the symbol M_2. Likewise, the principal solar tidal component is one that gives two high and two low waters in a solar day of 24 hours. Its angular speed per hour is therefore $\frac{2\times 360^\circ}{24}=30^\circ.00$. The symbol for this principal solar component is S_2.

Since the moon's distance from the earth is not constant, being less than the average at perigee and greater at apogee, the period from one perigee to another being on the average 27.55 days, we must introduce another hypothetical tidal body, so that at perigee its high water will correspond with the M_2 high water,

and at apogee its low water will correspond with the M_2 high water. In other words, the tidal component which is to take account of the moon's perigean movement must, in a period of 13.78 days, lose 180° on M_2, or at the rate of $\frac{180°}{13.78}=13°.06$ per day. Its hourly speed, therefore, is $28°.98-\frac{13°.06}{24}=28°.44$. This component has been given the symbol N_2.

The moon's change in declination is taken account of by two components denoted by the symbols K_1 and O_1. The speeds of these are determined by the following considerations: The average period from one maximum declination to another is a half tropic month, or 13.66 days. The speeds of these two components should, therefore, be such that when the moon is at its maximum declination they shall both be at a maximum, and when the moon is on the Equator they shall neutralize each other; that is, in a period of 13.66 days K_1 shall gain on O_1 one full revolution. The difference in their hourly speeds, therefore, is $\frac{360°}{24\times13.66}=1°.098$. The mean of the speeds of these two components must be that of the apparent diurnal movement of the moon about the earth, or $\frac{360°}{24.84}=14°.49$. The speeds are therefore derived from the equations $\frac{K_1+O_1}{2}=14°.49$ and $K_1-O_1=1°.098$, from which $K_1=15°.04$ and $O_1=13°.94$.

It is customary to designate the amplitude of any component by the symbol of the component and the epoch by the symbol with a degree mark added. Thus M_2 stands for the amplitude of the M_2 tide and $M_2°$ for the epoch of this tide. The five components enumerated above are the principal ones. Between 20 and 30 components permit the prediction of the time and height of the tide at any given place with considerable precision.

From the harmonic constants the characteristics of the tide at any place can be very readily determined.[1] The five principal constants alone permit the approximate determination of the tidal characteristics very easily. Thus, approximately, the mean range is $2M_2$, spring range $2(M_2+S_2)$, neap range $2(M_2-S_2)$ perigean range $2(M_2+N_2)$, apogean range $2(M_2-N_2)$, diurnal inequality at time of tropic tides $2(K_1+O_1)$, high-water lunitidal interval $\frac{M_2°}{28.98}$. The various ages of the tide can likewise be readily determined. Approximately, the ages in hours are: Phase age, $S_2°-M_2°$; parallax age, $2(M_2°-N_2°)$; diurnal age, $K_1°-O_1°$. The type of tide, too, may be determined from the harmonic constants through the ratio $\frac{K_1+O_1}{M_2+S_2}$. Where this ratio is less than 0.25, the tide is of the semidiurnal type; where the ratio is between 0.25 and 1.25, the tide is of the mixed type; and where the ratio is over 1.25, the tide is of the diurnal type.

The periods of the various component tides, like the periods of the tide-producing forces, group themselves into three classes. The tides in the first class have periods of approximately half a day and are known as semidiurnal tides; the periods of the tides in the second class are approximately one day, and these tides are known as diurnal tides; the tides in the third class have periods of half a month or more and are known as long-period tides. In shallow waters due to the effects of decreased depth, the tides are modified and another class of simple tides is introduced having periods of less than half a day, and these are known as shallow-water tides.

The class to which any component tide belongs is generally indicated by the subscript used in the notation for the component tides, the subscript giving the number of periods in a day. With long-period tides generally no subscript is used; with semidiurnal tides the subscript is 2; with diurnal tides the subscript is 1, and with shallow-water tides the subscript is 3, 4, or more. Thus Sa represents a solar annual component, P_1 a solar diurnal component, M_2 a lunar semidiurnal component, S_4 a solar shallow-water component with a period of one-quarter of a day, and M_6 a lunar shallow-water component with a period of one-sixth of a day.

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[1] See R. A. Harris, Manual of Tides, Pt. III (U. S. Coast and Geodetic Survey Report for 1894, Appendix 7).

TIDAL DATUM PLANES

Tidal planes of reference form the basis of all rational datum planes used in practical or scientific work. The advantage of the datum plane based on tidal determination lies not only in simplicity of definition, but also in the fact that it may be recovered at any time, even though all bench-mark connections be lost.

The principal tidal plane is that of mean sea level, which may be defined as the plane about which the tide oscillates, or as the surface the sea would assume when undisturbed by the rise and fall of the tide. At any given place this plane may be determined by deriving the mean height of the tide. This is perhaps best done by adding the hourly heights of the tide over a period of a year or more and deriving the mean hourly height. It is to be noted that in such a determination the mean sea level is not freed from the effects of prevailing wind, atmospheric pressure, and other meteorological conditions.

The plane of mean sea level must be carefully distinguished from the plane of half-tide level or, as it is frequently called, mean tide level. This latter plane is one determined as the half sum of the high and low waters. It is therefore the plane that lies halfway between the planes of mean low water and mean high water. The plane of half-tide level does not, at most places on the open coast differ by more than about a tenth of a foot from the plane of mean sea level, and where this difference is known the plane of mean sea level may be determined from that of half-tide level. Like all of the tidal planes, the plane of half-tide level should be determined by observations covering a period of a year or more.

For many purposes the plane of mean low water is important. This plane at any given place is determined as the average of all the low waters during a period of a year or more. Where the diurnal inequality in the low waters is small, as on the Atlantic coast of the United States, this plane is frequently spoken of as the "low-water plane" or "the plane of low water"; but strictly it should be called the plane of mean low water.

Where the tides exhibit considerable diurnal inequality in the low waters, as on the Pacific coast of the United States, the lower low waters may fall considerably below the plane of mean low water. In such places the plane of mean lower low water is preferable for most purposes. This plane is determined as the average of all the lower low waters over a period of a year or more. Where the tide is frequently diurnal, the single low water of the day is taken as the lower low water.

The plane of mean high water is determined as the average of all the high waters over a period of a year or more. Where the diurnal inequality in the high waters is small, this plane is frequently spoken of as "the plane of high water" or "the high-water plane." This usage may on occasion lead to confusion, and the denomination of this plane as the plane of mean high water is therefore preferable.

In localities of considerable diurnal inequality in the high waters the higher high waters frequently rise considerably above the plane of mean high water. A higher plane is therefore of importance for many purposes, and the plane of higher high water is preferred. This plane is determined as the average of all the higher high waters for a period of a year or more. Where the tide is frequently diurnal, the single high water of the day is taken as the higher high water.

The tidal planes described above are the principal ones and the ones most generally used. Other planes, however, are sometimes used. Where a very low plane is desired, the plane of mean spring low water is sometimes used, its name indicating that it is determined as the mean of the low waters occurring at spring tides. Another plane sometimes used, which is of interest because based on harmonic constants, is known as the harmonic tide plane and for any given place is determined as $M_2+S_2+K_1+O_1$ below mean sea level.

MEAN VALUES

Since the rise and fall of the tide varies from day to day, chiefly in accordance with the changing positions of sun and moon relative to the earth, any tidal quantities determined directly from a short series of tidal observations must be corrected to a mean value. The principal variations are those connected with the moon's phase, parallax, and declination, the periods of which are approximately 29½ days, 27½ days, and 27⅓ days, respectively.

In a period of 29 days, therefore, the phase variation will have almost completed a full cycle while the other variations will have gone through a full cycle and but very little more. Hence, for tidal quantities varying largely with the phase variation, tidal observations covering 29 days, or multiples, constitute a satisfactory period for determining these quantities. Such are the lunitidal intervals, the mean range, mean high water, and mean low water. For quantities varying largely with the declination of the moon, as, for example, higher high water and lower low water, 27 days, or multiples, constitute the more satisfactory period.

As will be seen in the detailed discussion of the tides at Fort Hamilton, the values determined from two different 29-day or 27-day periods may differ very considerably. This is due to the fact that these periods are not exact synodic periods for the different variations, and to the further fact that variations having periods greater than a month are not taken into account. Furthermore, meteorological conditions, which change from month to month, leave their impress on the tides. For accurate results the direct determination of the tidal datum planes and other tidal quantities should be based on a series of observations that cover a period of a year or preferably three years. Values derived from shorter series must be corrected to a mean value.

Two methods may be employed for correcting the results of short series to a mean value. One method makes use of tabular values, determined both from theory and observation, for correcting for the different variations. The other method makes use of direct comparison with simultaneous observations at some near-by port for which mean values have been determined from a series of considerable length.

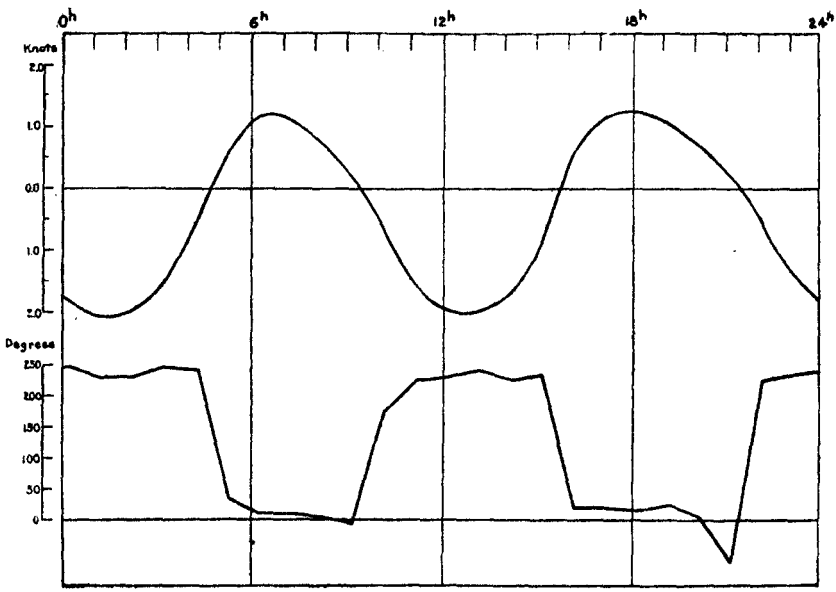

FIGURE C.—Velocity and direction curves for the current, Hudson River, July 22, 1922

II. TIDAL CURRENTS, GENERAL CHARACTERISTICS

DEFINITIONS

Tidal currents are the horizontal movements of the water that accompany the rising and falling of the tide. The horizontal movement of the tidal current and the vertical movement of the tide are intimately related parts of the same phenomenon brought about by the tide-producing forces of sun and moon. Tidal currents, like the tides, are therefore periodic.

It is the periodicity of the tidal current that chiefly distinguishes it from other kinds of currents, which are known by the general name of nontidal currents. These latter currents are brought about by causes that are independent of the tides, such as winds, fresh-water run-off, and differences in density and temperature. Currents of this class do not exhibit the periodicity of tidal currents.

Tidal and nontidal currents occur together in the open sea and in inshore tidal waters, the actual currents experienced at any point being the resultant of the two classes of currents. In some places tidal currents predominate and in others nontidal currents predominate. Tidal currents generally attain considerable velocity in narrow entrances to bays, in constricted parts of rivers, and in passages from one body of water to another. Along the coast and farther offshore tidal currents are generally of moderate velocity; and in the open sea, calculation based on the theory of wave motion gives a tidal current of less than one-tenth of a knot.

RECTILINEAR TIDAL CURRENTS

In the entrance to a bay or river and, in general, where a restricted width occurs, the tidal current is of the rectilinear or reversing type; that is, the flood current runs in one direction for a period of about six hours and the ebb current for a like period in the opposite direction. The flood current is the one that sets inland or upstream and the ebb current the one that sets seaward or downstream. The change from flood to ebb gives rise to a period of slack water during which the velocity of the current is zero. An example of this type of current is shown in Figure C, which represents the velocity and direction of the current as observed in the Hudson River off Fort Washington on July 22, 1922.

In Figure C the upper curve represents the velocity of the current in knots, flood being plotted above the axis of X and ebb below the axis. The velocity curve represents approximately the form of the cosine curve. The maximum velocity of the flood current is called the strength of flood and the maximum ebb velocity the strength of ebb. The knot is the unit generally used for measuring the velocity of tidal currents and represents a velocity of 1 nautical mile per hour. Knots may be converted into statute miles per hour by multiplying by 1.15, or into feet per second by multiplying by 1.69.

The lower curve of Figure C is the direction curve of the current, the direction being given in degrees, north being 0°, east 90°, south 180°, and west 270°. The directions are magnetic and represent the direction of the current as derived from hourly observations. During the period of flood the direction curve shows that the current was running practically in the same direction all the time, making an abrupt shift of about 180° to the opposite direction during the period of slack water. For the ebb period the direction curve likewise shows the current to have been running in approximately the same direction with an abrupt change of about 180° during slack.

ROTARY TIDAL CURRENTS

Offshore the tidal currents are generally not of the rectilinear or reversing type. Instead of flowing in the same general direction during the entire period of the flood and in the opposite direction during the ebb, the tidal currents offshore change direction continually. Such currents are therefore called rotary currents. An example of this type of current is shown in Figure D, which represents the velocity and direction of the current at the beginning of each hour of the afternoon on September 24, 1919, at Nantucket Shoals Light Vessel, stationed off the coast of Massachusetts.

The current is seen to have changed its direction at each hourly observation, the rotation being in the direction of movement of the hands of a clock, or from north to south by way of east, then to north again by way of west. In a period of about 12 hours it is seen that the current has veered completely round the compass.

It will be noted that the ends of the radii vectores, representing the velocities and directions of the current at the beginning of each hour, define a somewhat irregular ellipse. If a number of observations are averaged, eliminating accidental errors and temporary meteorological disturbances, the regularity of the curve is considerably increased. The average period of the cycle is, from a considerable number of observations, found to be $12^h\ 25^m$. In other words, the current day, like the tidal day, is $24^h\ 50^m$ in length.

A characteristic feature of the rotary current is the absence of slack water. Although the current generally varies from hour to hour, this variation from greatest current to least current and back again to greatest current does not give rise to a period of slack water. When the velocity of the rotary tidal current is least it is known as the minimum current, and when it is greatest it is known as the maximum current. The minimum and maximum velocities of the rotary current are thus related to each other in the same way as slack and strength of

the rectilinear current, a minimum velocity following a maximum velocity by an interval of about three hours and being followed in turn by another maximum after a further interval of three hours.

VARIATIONS IN STRENGTH OF CURRENT

Tidal currents exhibit changes in the strength of the current that correspond closely with the changes in range exhibited by tides. The strongest currents come with the spring tides of full and new moon and the weakest currents with

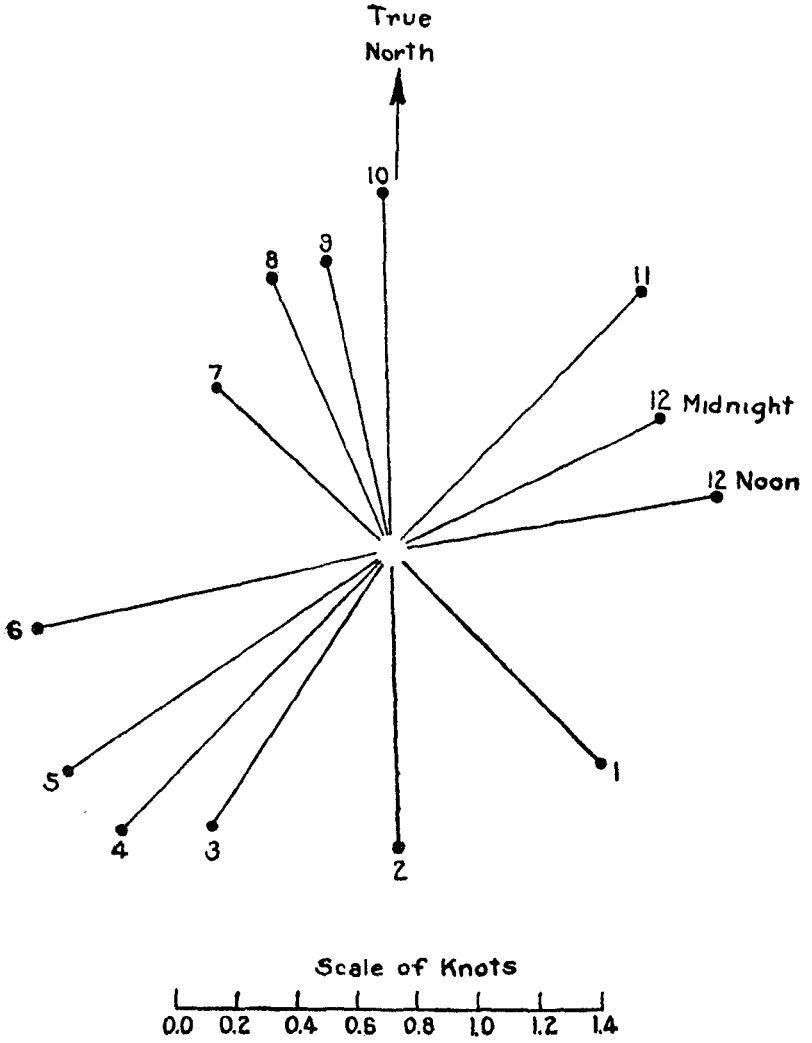

FIGURE D.—Rotary current, Nantucket Shoals Light Vessel, afternoon of September 24, 1919

the neap tides of the moon's first and third quarters. Likewise, perigean tides are accompanied by strong currents and apogean tides by weak currents; and when the moon has considerable declination, the currents, like the tides, are characterized by diurnal inequality.

As related to the moon's changing phases, the declination in the strength of the current from day to day is approximately proportional to the corresponding change in the range of the tide. The moon's changing distance likewise brings about changes in the velocity of the strength of the current which is approximately

proportional to the corresponding change in the range of the tide; but in regard to the moon's changing declination, tide and current do not respond alike, the diurnal variation in the tide at any place being generally greater than the diurnal variation in the current.

The relations subsisting between the changes in the velocity of the current at any given place and the range of the tide at that place may be derived from general considerations of a theoretical nature. Variations in the current that involve semidiurnal components will approximate corresponding changes in the range of the tide; but for variations involving diurnal components the variation in the current is about half that in the tide.

RELATION OF TIME OF CURRENT TO TIME OF TIDE

In simple wave motion the times of slack and strength of current bear a constant and simple relation to the times of high and low waters. In a progressive wave the time of slack water comes, theoretically, exactly midway between high and low water and the time of strength at high and low water; in a stationary wave slack comes at the times of high and low water, while the strength of current comes midway between high and low water.

The progressive-wave movement and the stationary-wave movement are the two principal types of tidal movements. A progressive wave is one whose crest advances, so that in any body of water that sustains this type of tidal movement the times of high and low water progress from one end to the other. A stationary wave is one that oscillates about an axis, high water occurring over the whole area on one side of this axis at the same instant that low water occurs over the whole area on the other side of the axis.

The tidal movements of coastal waters are rarely of simple wave form; nevertheless, it is very convenient in the study of currents to refer the times of current to the times of tide. And where the diurnal inequality in the tide is small, as is the case on the Atlantic coast, the relation between the time of current and the time of tide is very nearly constant. This is brought out in Figure E, which represents the tidal and current curves in New York Harbor for October 9, 1919,

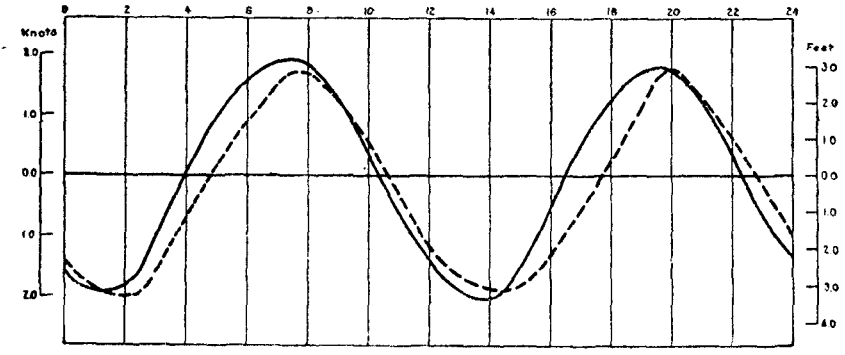

FIGURE E.—Tide and current curves, New York Harbor, October 9, 1919

the current curve being the dashed-line curve, representing the velocities of the current at a station in Upper Bay, and the tide curve being the full-line curve, representing the rise and fall of the tide at Fort Hamilton, on the eastern shore of the Narrows.

The diagrams of Figure E were drawn by plotting the heights of the tide and the velocities of the current to the same time scale and to such velocity and height scales as will make the maximum ordinates of the two curves approximately equal. The time axis or axis of X represents the line of zero velocity for the currents and of mean sea level for the tide, the velocity of the current being plotted in accordance with the scale of knots on the left, while the height of the tide reckoned from mean sea level was plotted in accordance with the scale in feet on the right.

From Figure E it is seen that the corresponding features of the tide and current in New York Harbor bear a very nearly constant time relation to each other, and this constancy in time relation of tides and currents is characteristic of tidal

waters in which the diurnal inequality is small. This permits the times of slack and of strength of current to be referred to the times of high and low water. Thus, from Figure E we find strength of ebb occurred about 0.6 hour after the time of low water, both morning and afternoon; slack before flood occurred 2.2 hours before high water; strength of flood 0.4 hour after high water; slack before ebb 3.0 hours before low water. In this connection, however, it is to be noted that the time relations between the various phases of tide and current are subject to the disturbing effects of wind and weather.

Apart from the disturbing effect of nontidal agencies, the time relations between tide and current are subject to variation in regions where the tide exhibits considerable diurnal inequality, as, for example, on the Pacific coast of the United States. This variation is due to the fact, previously mentioned, that the diurnal inequality in the current at any given place is, in general, only about half as great as that in the tide. This brings about differences in the corresponding features of tide and current as between morning and afternoon. However, in such cases it is frequently possible to refer the current at a given place to the tide at some other place with comparable diurnal inequality.

EFFECT OF NONTIDAL CURRENT

The tidal current is subject to the disturbing influence of nontidal currents which affect the regularity of its occurrence as regards time, velocity, and direction. In the case of the rectilinear current the effect of a steady nontidal current is, in general, to make both the periods and the velocities of flood and ebb

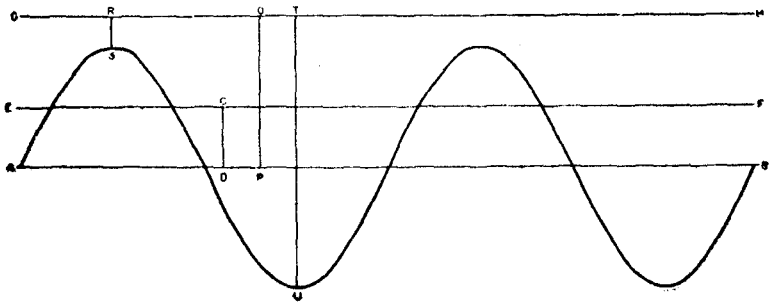

FIGURE F.—Effect of nontidal current on tidal current

unequal and to change the times of slack water but to leave unchanged the times of flood and ebb strengths. This is evident from a consideration of Figure F, which represents a simple rectilinear tidal current, the time axis of which is the line *AB*, flood velocities being plotted above the line and ebb velocities below.

When unaffected by nontidal currents, the periods of flood and ebb are, in general, equal as represented in the diagram, and slack water occurs, regularly three hours and six minutes after the times of flood and ebb strengths. But if we assume a steady nontidal current introduced which has, in the direction of the tidal current, a velocity component represented by the line *CD*, it is evident that the strength of ebb will be increased by an amount equal to *CD*, while the flood strength will be decreased by the same amount. The current conditions may now be completely represented by drawing, as a new axis, the line *EF* parallel to *AB* and distant from it the length of *CD*.

Obviously, if the velocity of the nontidal current exceeds that of the tidal current at the time of strength, the tidal current will be completely masked and the resultant current will set at all times in the direction of the nontidal current. Thus, if in Figure F, the line *OP* represents the velocity component of the nontidal current in the direction of the tidal current, the new axis for measuring the velocity of the combined current at any time will be the line *GH*, parallel with the line *AB* and passing through the point *O*, and the current will be flowing at all times in the ebb direction. There will be no slack waters, but at periods 6 hours 12 minutes apart there will occur minimum and maximum velocities represented, respectively, by the lines *RS* and *TU*.

In so far as the effect of the nontidal current on the direction of the tidal current is concerned, it is only necessary to remark that the resultant current will set in a direction which at any time is the resultant of the tidal and nontidal

currents at that time. This resultant direction and also the resultant velocity may be determined either graphically by the parallelogram of velocities or by the usual trigonometric computations.

VELOCITY OF TIDAL CURRENTS AND PROGRESSION OF THE TIDE

In the tidal movement of the water it is necessary to distinguish clearly between the velocity of the current and the progression or rate of advance of the tide. In the former case reference is made to the actual speed of a moving particle, while in the latter case the reference is to the rate of advance of the tide phase or the velocity of propagation of wave motion, which generally is many times greater than the velocity of the current.

It is to be noted that there is no necessary relationship between the velocity of the tidal current at any place and the rate of advance of the tide at that place. In other words, if the rate of advance of the tide is known, we can not from that alone infer the velocity of the current, nor vice versa. The rate of advance of the tide in any given body of water depends on the type of tidal movement. In a progressive wave the tide moves approximately in accordance with the formula $r=\sqrt{gd}$ in which r is the rate of advance of the tide, g the acceleration of gravity, and d the depth of the waterway. In stationary-wave movement, since high or low water occurs, at very nearly the same time over a considerable area, the rate of advance is theoretically very great, but actually there is always some progression present, and this reduces the theoretical velocity considerably.

The velocity of the current, or the actual speed with which the particles of water are moving past any fixed point, depends on the volume of water that must pass the given point and the cross section of the channel at that point. The velocity of the current is thus independent of the rate of advance of the tide.

DISTANCE TRAVELED BY A PARTICLE IN A TIDAL CYCLE

In a rectilinear current the distance traveled by the water particles or by any object floating in the water is obviously equal to the product of the time by the average velocity during this interval of time. To determine the average velocity of the tidal current for any desired interval several methods may be used.

If the curve of the tidal current has been plotted, the average velocity may be derived as the mean of a number of measurements of the velocity made at frequent intervals on the curve; as, for example, every 10 or 15 minutes. From the current curve the average velocity may also be determined by deriving the mean ordinate of the curve by use of the planimeter. For a full tidal cycle of flood or ebb, however, since the current curve generally approximates the cosine curve, the simplest method consists in making use of the well-known ratio of the mean ordinate of the cosine curve to the maximum ordinate, which is $2 \div \pi$, or 0.6366.

The latter method has another advantage in that the velocity of the tidal current is almost invariably specified by its velocity at the time of strength, which corresponds to the maximum ordinate of the cosine curve; hence, the average velocity of the tidal current for a flood or ebb cycle is given immediately as the product of the strength of the current by 0.6366. And though this method is only approximate, since the curve of the current may deviate more or less from the cosine curve, in general the results will be sufficiently accurate for all practical purposes. For a normal flood or ebb period of 6.2 hours the distance a tidal current with a velocity at strength of 1 knot will carry a floating object is, in nautical miles, $0.6366 \times 6.2 = 3.95$, or 24,000 feet.

DURATION OF SLACK

In the change of direction of flow from flood to ebb, and vice versa, the tidal current goes through a period of slack water or zero velocity. Obviously, this period of slack is but momentary, and graphically it is represented by the instant when the current curve cuts the zero line of velocities. For a brief period each side of slack water, however, the current is very weak, and in ordinary usage "slack water" denotes not only the instant of zero velocity but also the period of weak current. The question is therefore frequently raised, How long does slack water last?

To give slack water in its ordinary usage a definite meaning, we may define it to be the period during which the velocity of the current is less than one-tenth of a knot. Velocities less than one-tenth of a knot may generally be dis-

regarded for practical purposes, and such velocities are, moreover, difficult to measure either with float or with current meter. For any given current it is now a simple matter to determine the duration of slack water, the current curve furnishing a ready means for this determination.

In general, regarding the current curve as approximately a sine or cosine curve, the duration of slack water is a function of the strength of current—the stronger the current the less the duration of slack—and from the equation of the sine curve we may easily compute the duration of slack water for currents of various strengths. For the normal flood or ebb cycle of $6^h\ 12.6^m$ we may write the equation of the current curve $y=A \sin 0.4831t$, in which A is the velocity of the current in knots at time of strength, 0.4831 the angular velocity in degrees per minute, and t is the time in minutes from the instant of zero velocity. Setting $y=0.1$ and solving for t (this value of t giving half the duration of slack), we get for the duration of slack the following values: For a current with a strength of 1 knot, slack water is 24 minutes; for currents of 2 knots strength, 12 minutes; 3 knots, 8 minutes; 4 knots, 6 minutes; 5 knots, 5 minutes; 6 knots, 4 minutes; 8 knots, 3 minutes; 10 knots, 2⅓ minutes.

HARMONIC CONSTANTS

The tidal current, like the tide, may be regarded as the resultant of a number of simple harmonic movements, each of the form $y=A \cos (at+\alpha)$; hence, tidal currents may be analyzed in a manner analogous to that used in tides and the harmonic current constants derived. These constants permit the characteristics of the currents to be determined in the same manner as the tidal harmonic constants, and they may also be used in the prediction of the times of slack and the times and velocities of the strength of current.

It can easily be shown that in coastal or inland tidal waters the amplitudes of the various current components are related to each other, not as the amplitudes of the corresponding tidal components, but as these latter multiplied by their respective speeds; that is, in any given harbor, if we denote the various components of the current by primes and of the tide by double primes, we have

$$M'_2 : S'_2 : N'_2 : K'_1 : O'_1 = m_2 M''_2 : s_2 S''_2 : n_2 N''_2 : k_1 K''_1 : o_1 O''_1$$

where the small italic letters represent, respectively, the angular speed of the corresponding components. This shows at once that the diurnal inequality in the currents should be approximately half that in the tide.

MEAN VALUES

In the nonharmonic analysis of current observations it is customary to refer the times of slack and strength of current to the times of high and low water of the tide at some suitable place, generally near by. In this method of analysis the time of current determined is in effect reduced to approximate mean value, since the changes in the tidal current from day to day may be taken to approximate the corresponding changes in the tide; but the velocity of the current as determined from a short series of observations must be reduced to a mean value.

In the ordinary tidal movement of the progressive or stationary wave types the change in the strength of the current from day to day may be taken approximately the same as the variation in the range of the tide. Hence, the velocity of the current from a short series of observations may be corrected to a mean value by multiplying by a factor equal to the mean range of the tide divided by the range for the period of observations. It is to be noted that in this method of reducing to a mean value any nontidal currents must first be eliminated and the factor applied to the tidal current alone. This may be done by taking the strength of the tidal current as the half sum of the flood and ebb strengths for the period in question.

In some places the current, while exhibiting the characteristic features of the tidal current, is in reality a hydraulic current due to differences in head at the ends of a strait connecting two independent tidal bodies of water. East River and Harlem River in New York Harbor and Seymour Narrows in British Columbia are examples of such straits, and the currents sweeping through these waterways are not tidal currents in the true sense, but hydraulic currents. The velocities of such currents vary as the square root of the head, and hence in reducing the velocities of such currents to a mean value the factor to be used is the square root of the factor used for ordinary tidal currents.

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PUBLICATIONS BY THE UNITED STATES COAST AND GEODETIC SURVEY RELATING TO TIDES AND CURRENTS

TIDE AND CURRENT TABLES

	Price
Tide Tables, United States and Foreign Ports	$0.75
Tide Tables, Atlantic Coast, North America (reprinted from Tide Tables, United States and Foreign Ports)	.15
Tide Tables, Pacific Coast, North America, Eastern Asia and Island Groups (reprinted from Tide Tables, United States and Foreign Ports)	.15
Tide Table, New York Harbor	.05
Tide Table, Boston Harbor	.05
Tide and Current Tables, San Francisco Bay	.05
Current Tables, Atlantic Coast, North America	.10
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Current Diagram, Nantucket and Vineyard Sounds	.15
Current Diagram, Chesapeake Bay	.15
Tidal Current Charts, New York Harbor	.25

The tide tables contain the predicted times and heights of the tide for each day in the year at a number of principal ports and tidal differences and constants for many other places. The current tables give the predicted currents for each day in the year at a number of principal ports and current differences and constants for many other stations. The current diagrams are reproductions on an enlarged scale of similar diagrams contained in the current tables.

The tidal current charts consist of a set of 12 charts which give the direction and velocity of the current for each hour of the tide and in addition present a comprehensive view of the tidal current movement for the harbor as a whole.

The tide and current tables are issued in advance annually and may be purchased at the office of the United States Coast and Geodetic Survey or from any of its agencies.

TIDAL BENCH MARKS

Special Publication No. 83 (Serial 193), Tidal Bench Marks, State of New York, 1922	.20
Special Publication No. 119 (Serial 320), Tidal Bench Marks, District of Columbia, 1925	.05
Special Publication No. 128 (Serial 370), Tidal Bench Marks, State of Rhode Island, 1927	.10
Special Publication No. 136, Tidal Bench Marks, State of Connecticut, 1927	.10
Special Publication No. 141, Tidal Bench Marks, State of California, 1928	.15
Special Publication No. 148, Tidal Bench Marks, State of New Jersey, 1928	.10
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HARBOR PUBLICATIONS

Special Publication No. 111 (Serial 285), Tides and Currents in New York Harbor, 1925	.30
Special Publication No. 115 (Serial 311), Tides and Currents in San Francisco Bay, 1925	.20
Special Publication No. 123 (Serial 336), Tides and Currents in Delaware Bay and River, 1926	.25
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Special Publication No. 142, Tides and Currents in Boston Harbor, 1928	.30
Special Publication No. 150, Tides and Currents in Portsmouth Harbor, 1928	.20
Special Publication No. 162, Tides and Currents in Chesapeake Bay	

The above harbor publications aim to give in detail the results of all the observational data available for each harbor covered.

MISCELLANEOUS PUBLICATIONS

	Price
The Gulf Stream, by J. E. Pillsbury. Published as appendix to the Annual Report of the United States Coast and Geodetic Survey for the year 1890. This report is no longer available for distribution but may be consulted in any of the larger libraries.	
Manual of Tides, by R. A. Harris. This publication was issued in separate parts as appendices to the Annual Reports of the United States Coast and Geodetic Survey for the years 1894, 1897, 1900, 1904, and 1907. These reports are no longer available for distribution but may be consulted in any of the larger libraries.	
Arctic Tides, R. A. Harris, 1911	$0.20
Special Publication No. 23, United States Coast and Geodetic Survey. Discription of its work, methods, and organization. Includes illustrated sections on tides and currents. This publication can be obtained free of charge from the office of the United States Coast and Geodetic Survey.	
Special Publication No. 32 (Serial 16), Description of the United States Coast and Geodetic Survey Tide-Predicting Machine No. 2, 1915	.20
Special Publication No. 41 (Serial 60), Use of Mean Sea Level as the Datum for Elevations, 1917	.05
Special Publication No. 98 (Serial 244), A Manual of the Harmonic Analysis and Prediction of Tides, 1924	1.00
Serial 280, Tidal and Current Surveys, Methods, Instruments, and Purposes, 1924. This is a small pamphlet which may be obtained free of charge from the office of the United States Coast and Geodetic Survey.	
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