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CURRENTS IN ST. JOHNS RIVER SAVANNAH RIVER, AND INTERVENING WATERWAYS

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PREFACE

The purpose of this volume is to present in usable form the data derived from current observations in the St. Johns River, the Savannah River, and the numerous navigable inland waterways between the two rivers, in order that detailed information on the current movements in these important traffic lanes may be available for the use of the many organizations and individuals desiring it, and at the same time be insured against loss or destruction to which all unpublished records are liable.

Most of the material presented is based upon the results of comprehensive current surveys conducted by the Coast and Geodetic Survey during the years 1933 and 1934. Acknowledgment is made to the United States Army Engineers who cooperated in the planning and execution of the current surveys of the St. Johns and Savannah Rivers, and who furnished valuable current data from previous investigations of these rivers.

The section on the general characteristics of tidal currents, which in this volume precedes the discussion of the currents in the various waterways, was taken from Tides and Currents in New York Harbor, United States Coast and Geodetic Survey Special Publication No. 111, Revised (1935) Edition.

In connection with this publication, attention is directed to the annual Current Tables, Atlantic Coast, North America. These tables contain data from which daily predictions of the currents may be readily obtained for numerous locations in the areas covered by this volume.

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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 in the sea, 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 current 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.

REVERSING TIDAL CURRENTS

In the entrance to a bay or in a river and, in general, where a restricted width occurs, the tidal current is of the reversing or rectilinear type; that is, the flood current runs in one direction for a period of about 6 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 1, which represents the velocity and direction of the current as observed on August 8–9, 1922, in the Narrows, the entrance to New York Harbor.

The curve of figure 1 was drawn by plotting the velocity of the current as observed at the beginning of each hour and drawing a smooth curve that conformed as nearly as possible with the plotted velocities. The northerly setting or flood velocities were plotted above the line of zero velocity and the southerly setting or ebb velocities were plotted below this line. The velocities are given in knots, which is the unit generally used in measuring tidal currents and represents a velocity of 1 nautical mile per hour. Since a nautical mile has a length of 6,080 feet, 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 curve of the reversing current resembles the tide curve. The maximum velocity of the flood current, called the strength of flood, corresponds to the high water of the tide curve, while the maximum velocity of the ebb, called the strength of ebb, corresponds to the low water. The current day, like the tidal day, has a length averaging 24 hours and 50 minutes.

The current curve shown in figure 1 represents the current near the surface in the axis of the channel of the Narrows. From observation and also from theory it is known that the tidal current extends from the surface to the bottom. In general it may be said that the

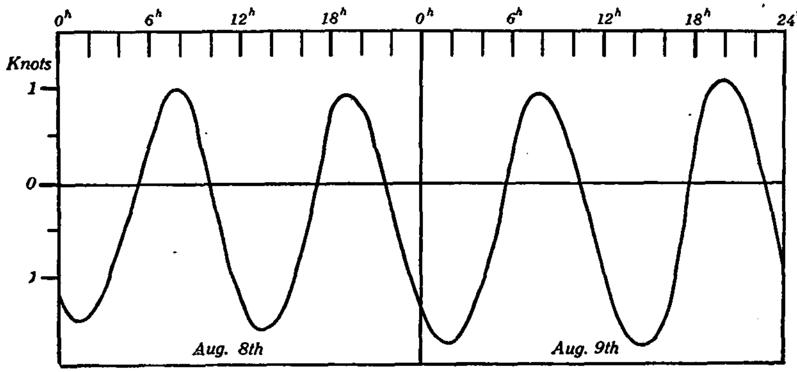

FIGURE 1.—Current curve, the Narrows, New York Harbor, August 8–9, 1922.

velocity of the tidal current decreases from the surface to the bottom, the velocity near the bottom being about two thirds that at the surface. But the effects of wind and fresh-water flow may bring about considerable variation in the vertical velocity distribution.

The current in a channel is also characterized by a variation in the horizontal distribution of velocity. In a rectangular channel of uniform cross-section, the velocity is greatest in the center of the channel, and decreases uniformly to both sides. Combining both the vertical and horizontal variations, it may be said that the average velocity of the current in a section of a regular channel is about three-quarters that of the central surface velocity.

Where the current is undisturbed by wind or fresh-water flow, the flood and ebb velocities, and the durations of flood and ebb are approximately equal. In this case, too, the characteristics of the current from the surface to the bottom are much the same. That is, the strengths of the flood and ebb currents, and also the slacks, occur at about the same time from top to bottom. If, however, nontidal currents are present, the characteristics of the tidal flow are modified considerably. The effect of nontidal currents on tidal currents may be derived from general considerations.

In figure 2 a purely tidal current is represented by the curve, referred to the line *AB* as the line of zero velocity. The strengths of the flood and ebb are equal, as are also the durations of flood and ebb. In this case slack water occurs regularly 3 hours and 6 minutes (one-quarter of the current cycle of 12 hours and 25 minutes) after the times of flood and ebb strengths. If now a nontidal current is introduced which sets in the ebb direction with a velocity represented by the line *CD*, the strength of ebb will obviously be increased by an amount equal to *CD* and the flood strength will be decreased by the same amount. The current conditions may now be represented by drawing, as the new line of zero velocities, the line *EF* parallel to *AB*, and distant from it the length of *CD*.

Figure 2 now shows that the nontidal current not only increases the ebb strength while decreasing the flood strength, but also changes

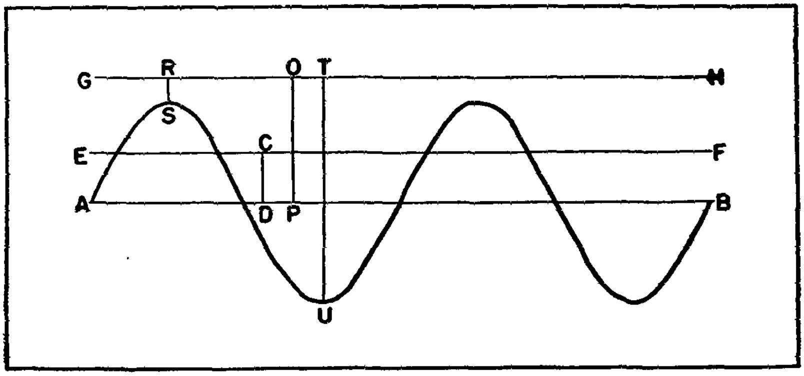

FIGURE 2.—Effect of nontidal current on reversing tidal current.

the times of slack water. Slack before flood now comes later, while slack before ebb comes earlier. Hence the duration of ebb is increased while the duration of flood is decreased.

If the velocity of the nontidal current exceeds that of the tidal current at time of strength, the tidal current in the opposite direction will be completely masked and the resultant current will set at all times in the direction of the nontidal current. Thus, if in figure 2 the line *OP* represents the velocity of the nontidal current, the new axis for measuring the velocity of the combined current at any time will be the line *GH* 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 lines *RS* and *TU*.

Insofar 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.

VARIATIONS IN STRENGTH OF CURRENT

Tidal currents exhibit periodic changes in the strength of the current that corresponds closely with the periodic changes in range exhibited by tides. Stronger currents than usual come with the spring tides of full and new moon and the weaker currents with the neap tides of the moon's first and third quarters. Likewise, perigean tides are accompanied by strong currents and apogean tides by relatively weaker 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 variation 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 a change 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.

TYPES OF REVERSING CURRENTS

Since tides and tidal currents are merely different aspects of the tidal movement of the waters, the former being the vertical movement and the latter the horizontal movement, it is to be expected that tidal currents would show different types, corresponding to the different types of tide. And observations prove this to be the case. Reversing currents may be readily classed under the three types of semidaily, daily, and mixed. The semidaily type is one in which two flood strengths and two ebb strengths occur in a tidal day, with but little inequality between morning and afternoon currents. Figure 1, illustrating the current in the Narrows, New York Harbor, may be taken as representative of this type.

The daily type of tidal current is characterized by one flood and one ebb in a day. The upper diagram of figure 3, which represents the current as observed in the entrance to Mobile Bay, Ala., on May 2–3, 1918, exemplifies this type of current. The mixed type of tidal current exhibits two floods and two ebbs in a day with considerable inequality between the forenoon and afternoon cycles. The lower diagram of figure 3, which represents the current observed in Rich Passage, Puget Sound, Wash., on March 29–30, 1917, illustrates this type of current.

In general, it may be said that with reversing currents a given type of current accompanies a like type of tide; that is, semidaily currents occur with semidaily tides, mixed currents with mixed tides, and daily currents with daily tides. But as noted in considering the variations in strength of current, the variations in the current that involve semidaily components will approximate corresponding changes in the range of the tide, while in those involving daily components the variation in the current is about half that in the tide. Hence the diurnal inequality in the current at any place is generally less than in the tide at that place.

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

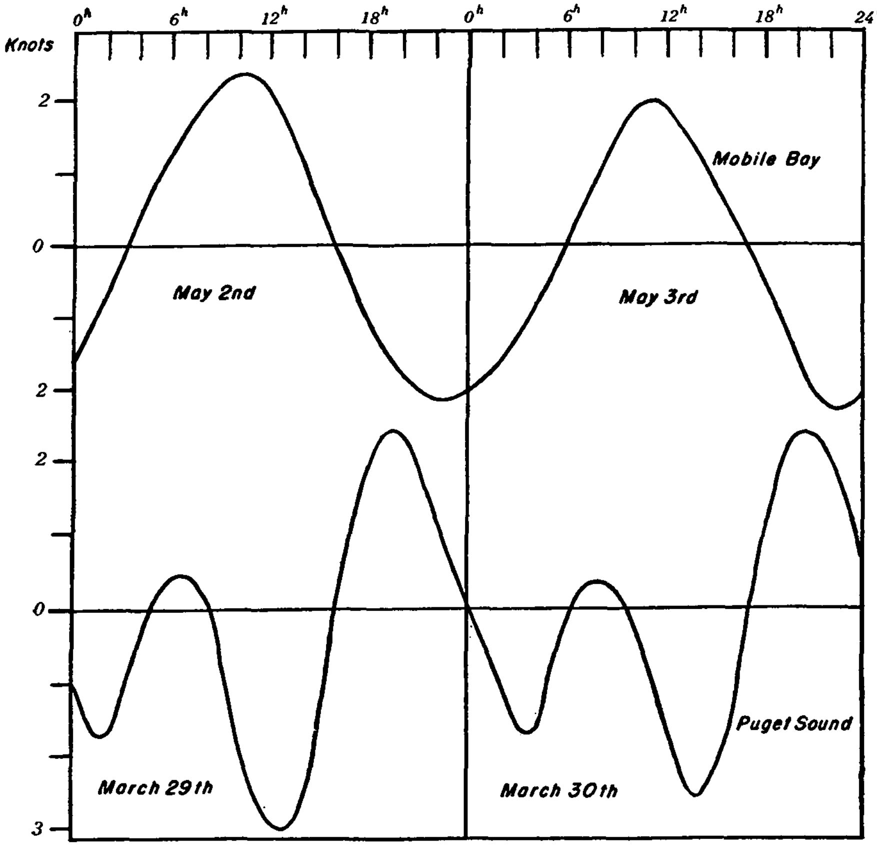

FIGURE 3.—Current curves of daily and mixed types of reversing currents.

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 4, which represents the tide and current curves in the Narrows, New York Harbor, for August 8–9, 1922, the current curve being the dashed-line curve, representing the velocities of the current in the center of the channel,

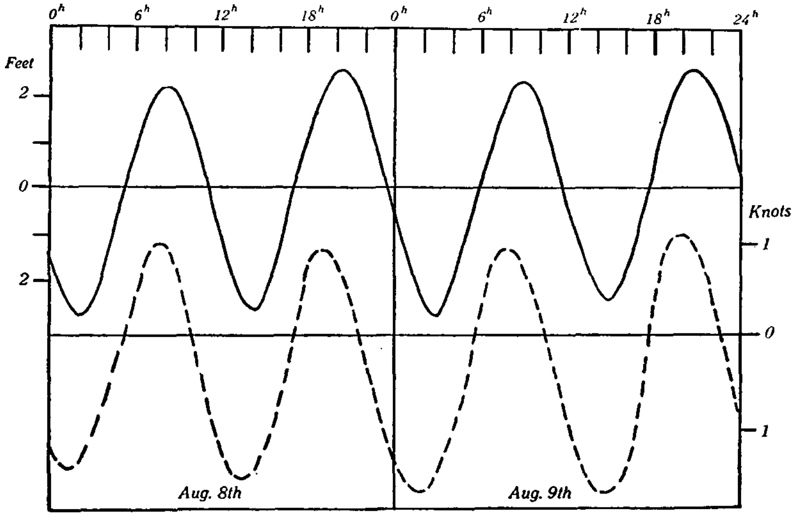

FIGURE 4.—Tide and current curves, the Narrows, New York Harbor, August 8–9, 1922.

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 4 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 right, while the height of the tide reckoned from mean sea level was plotted in accordance with the scale in feet on the left.

From figure 4 it is seen that the corresponding features of the tide and current at this station bear a nearly constant time relation to each other. This approximate constancy in time relations between current and tide is characteristic of tidal waters in which the diurnal inequality is small, and permits the times of slack and of strength of the current to be referred to the times of high and low water. Thus, from figure 4 we find that the strengths of the current come about an hour before the times of high and low water, while the slacks come about 1¾ hours after high water and 3 hours after low water. In this connection, however, it is to be noted that the time relations between corresponding phases of tide and current at any place frequently vary in consequence of disturbing effects of wind, weather, and fresh-water run-off.

Quite apart from the disturbing effects of nontidal agencies, the time relations between current and tide are subject to variations 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.

DISTANCE TRAVELED DURING A TIDAL CYCLE

The vertical distance traveled by a floating object during the tidal cycle at any place can be easily determined from the tide curve at that place, for the tide curve represents the successive heights of the surface of the water during the tidal cycle. Hence the vertical distance on the tide curve between a high water and low water gives the vertical distance through which a floating object moved during that tidal cycle.

The close resemblance between the curve of the reversing current and the tide curve might lead one to conclude that from the current curve the horizontal distance traveled by a floating object can be as readily derived as the vertical distance is from the tide curve. The current curve, however, gives the successive speeds of the horizontal movement, and not the successive positions of a floating object. Hence the current curve does not give directly the horizontal distance traveled by a floating object.

If the velocity of the current during a tidal cycle were constant, the horizontal distance traveled by the water particles or by any object floating in the water would be given by multiplying the velocity by the period of duration. The velocity of the current, however, is not constant but changes continually throughout a tidal cycle. The distance traveled by the water particles is, therefore, the average velocity during the flood or ebb period in question, multiplied by the duration.

The average velocity of the current during any given interval may be determined in several different ways. By measuring the velocity on the current curve at frequent intervals, say every 10 or 15 minutes, the average velocity during the interval is easily derived. Or the area of the surface bounded by the current curve and the zero line of velocities may be determined by means of a planimeter and the average velocity derived by dividing this area by the length of the zero line included within the current curve.

The simplest method, however, consists in making use of the fact that the current curve approximates the cosine curve. And on the cosine curve it is known that the ratio of the mean ordinate to the maximum ordinate is $2 \div \pi$, or 0.637. Since the strength of the tidal current corresponds to the maximum ordinate, it follows that during any given flood or ebb period the average velocity will be the strength of the current multiplied by 0.637.

In the semidaily or mixed types of current the duration of a flood or ebb period approximates 6.2 hours. Hence, in the case of such a current which has a velocity at strength of one knot, a floating object will, during a flood or ebb period, be carried a distance of $0.637 \times 6.2 =$ 3.95 nautical miles, or 24,000 feet. In a daily current of the same strength the distance will be twice as great.

It may be noted that the formula made use of in the preceding calculation can give only approximate results. For not only is the average current derived through the cosine relationship approximate, but what may be even more serious is the fact that in the formula it is assumed that the floating object during the various stages of its journey will experience the changes in velocity which occur at the point where it started. Where more exact results are desired, corrections to the above approximate results can be applied.

If the durations of flood and ebb are equal, and also the strengths of the flood and ebb currents, a floating object would be carried a given distance downstream and a like distance upstream. The presence of fresh water in tidal waterways, however, makes both the strength and duration of the ebb greater than the flood, and therefore floating objects tend to be carried out to sea.

DURATION OF SLACK

In the change of direction of flow from flood to ebb, and vice versa, the reversing 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 disregarded 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, 2½ minutes. For the daily type of current with a given strength, the duration of slack is obviously twice that of a semidaily current with like strength.

VELOCITY OF CURRENT AND PROGRESSION OF 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 cannot 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 $r=\sqrt{gh}$, in which r is the rate of advance of the tide, g the acceleration of gravity, and h 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.

ROTARY TIDAL CURRENTS

Within the channel of a bay or river, the current is compelled to follow the direction of the channel, upstream on the flood and downstream on the ebb. Out in the open sea, however, this restriction no longer exists, the current having complete freedom so far as direction is concerned. Offshore, therefore, tidal currents are generally not of the 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 5, which represents the velocity and direction of the current at the beginning of each hour of the forenoon of July 30, 1922, at Nantucket Shoals Lightship, 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 a little more than 12 hours it is seen that the current has shifted in direction completely round the compass.

It will be noted that the tips of the arrows, 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 for the rotary current, like the tidal day, is $24^h\ 50^m$ in length.

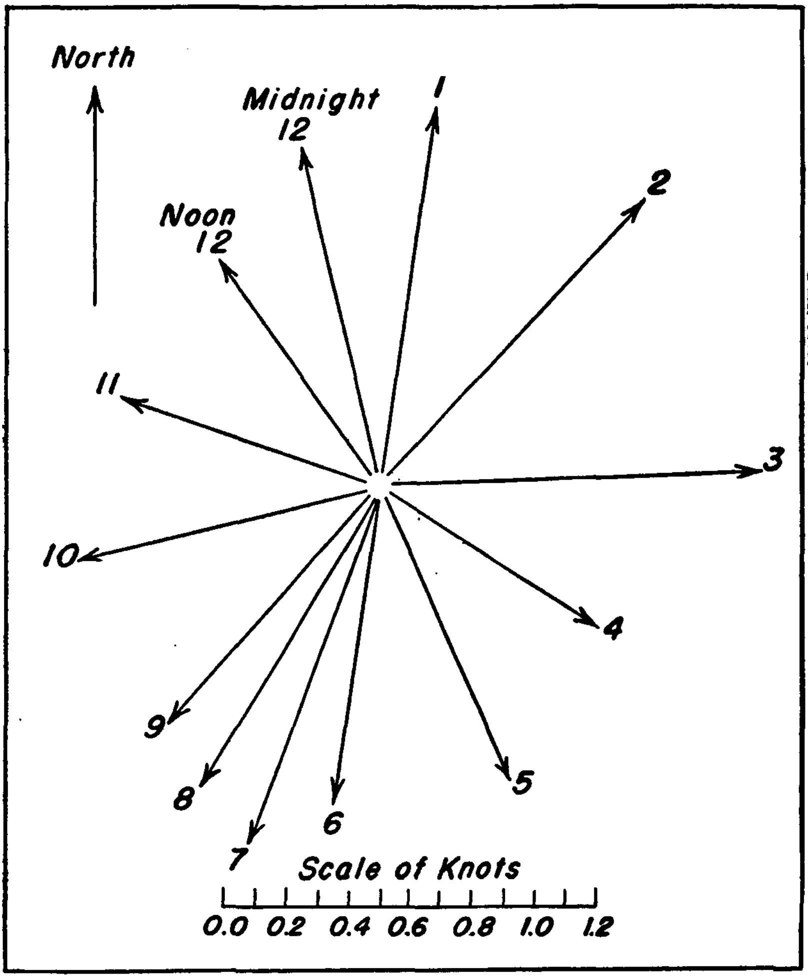

FIGURE 5.—Rotary current, Nantucket Shoals Lightship, forenoon of July 30, 1922.

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 3 hours and being followed in turn by another maximum after a further interval of 3 hours.

Since the current day corresponds to the tidal day, it is convenient, in determining the average hourly velocity and direction of the rotary current, to make use of the times of high and low water at some nearby place for purpose of reference. In figure 6 the average hourly

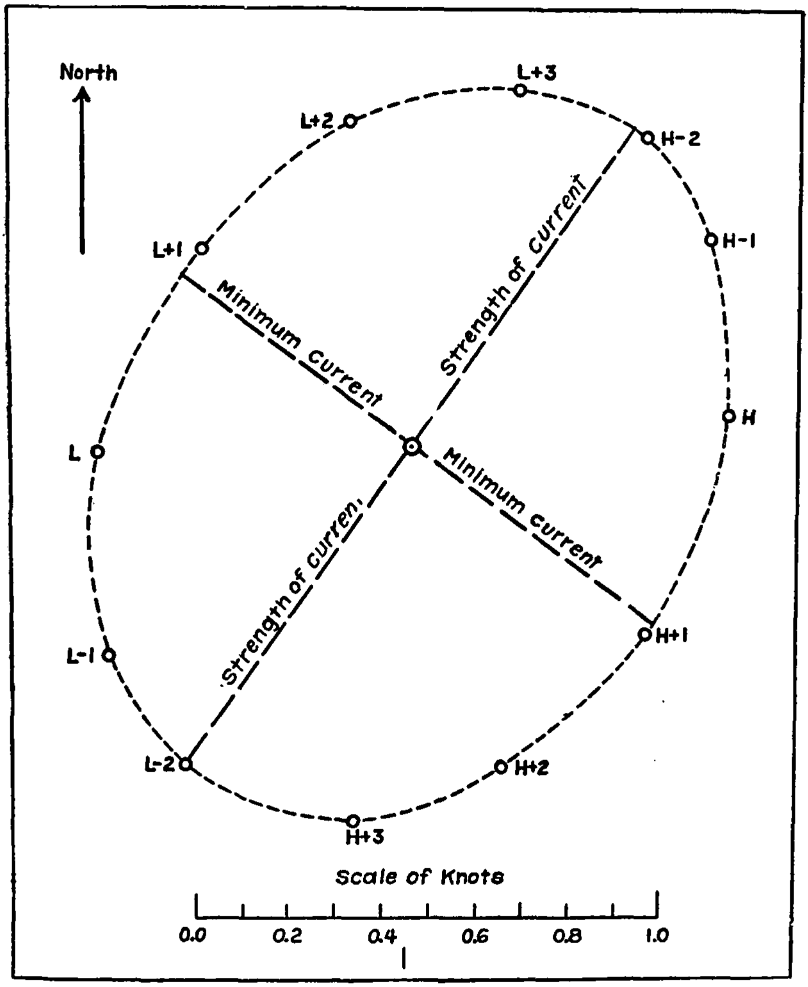

FIGURE 6.—Mean current curve, Nantucket Shoals Lightship.

velocity and direction of the tidal current at Nantucket Shoals Lightship is shown with reference to the times of high and low water at Boston, Mass., *H* standing for the time of high water, and *L* for the time of low water.

In figure 6 the velocity and direction of the current at the beginning of each hour is given by the length and direction of the line from the center of the ellipse to the hour in question. Thus at the time of high water at Boston the current at Nantucket Shoals Lightship has a velocity averaging 0.7 knot setting N. 85° E.

With regard to the current curve, or current ellipse as it may be called, which represents the rotary tidal current at any place, the basic features are the relation of the major and minor axes which determine the ellipticity of the curve, the direction of rotation, and the direction of the major axis. If the major and minor axes are nearly equal the ellipse will be nearly circular; if they differ greatly the ellipse will be flattened. In the Northern Hemisphere the direction of rotation of the rotary current is, as a rule, with the hands of a clock, while in the southern hemisphere it is counterclockwise. But local hydrographic features may bring about a reversal of this general rule.

Rotary tidal currents are subject to the periodic variations found in tides and reversing currents. These variations are related to the changes in the phase, parallax, and declination of the moon. At times of full and new moon the velocity of the rotary current is greater than the average, while at the times of the moon's first and third quarters the velocities are less than the average. Likewise when the moon is in perigee, stronger currents occur, while when the moon is in apogee the currents are weaker. In general it may be taken that the percentage of increase or decrease in the velocity of the current in response to changes in phase and parallax is the same as the like increase or decrease in the local range of the tide.

In response to changes in the declination of the moon the rotary current exhibits diurnal inequality like the tide and reversing current. This manifests itself as a difference between morning and afternoon current ellipses. When the moon is on the equator the two current ellipses of a day are much alike, but when the moon is near its maximum semimonthly declination the two current ellipses exhibit differences, principally in velocity.

Like tides and reversing currents, rotary tidal currents may be grouped under the three types of semidaily, daily, and mixed. The semidaily type of rotary current is one which exhibits two full cycles within a tidal day, morning and afternoon currents differing but little. The daily type is one in which but one cycle occurs in a day; and the mixed type is one which exhibits two cycles within a day, but with considerable differences between morning and afternoon currents.

EFFECTS OF NONTIDAL CURRENTS ON ROTARY CURRENTS

In addition to the periodic variations to which rotary tidal currents are subject, they also exhibit fluctuations arising from the effects of nontidal currents. These effects can most conveniently be studied diagrammatically.

Figure 6 represents the purely rotary tidal current at Nantucket Shoals Lightship. Now suppose that on a given day a wind begins blowing from the northeast such that it produces a wind-driven current of half a knot in a southwesterly direction. For that day, obviously, the velocity and direction of the current at Nantucket Shoals Lightship will be different than represented in figure 6. At 2 hours before low water at Boston, for example, the tidal current sets southwesterly with a velocity of 0.85 knot on the average; but with a nontidal current due to the wind of 0.5 knot setting in the same direction, the velocity of the current now experienced will be $0.85+0.50=1.35$ knots, setting southwesterly. On the other hand, about 2 hours before high water, the current will be setting $0.85-0.50=0.35$ knot northeasterly.

The current conditions at this time may be completely represented by changing the origin of the hourly velocity and direction lines in figure 6 from the center to a point 0.5 knot northeasterly of its previous position. The lines drawn to the various hourly points on the ellipse from this new origin will now represent the velocity and direction of the tidal current as affected by the nontidal current.

The average velocity of the tidal current at the times of flood or ebb strength at Nantucket Shoals Lightship is 0.85 knot. If the nontidal current due to the wind in the case just considered is greater than 0.85 knot, the origin of the velocity lines would lie outside the ellipse. In that case the current would throughout the day be setting either southeasterly or southwesterly, completely masking the rotary character of the tidal current. By plotting the observed hourly velocities and directions of the current, however, the tidal current would appear in its rotary character. This is illustrated in figure 7 for the current at Frying Pan Shoal Lightship under different wind conditions. This lightship is stationed off the coast of North Carolina about 20 miles southeasterly from Cape Fear. The hourly velocity and direction of the current here is referred to the times of high and low water at Charleston, S. C.

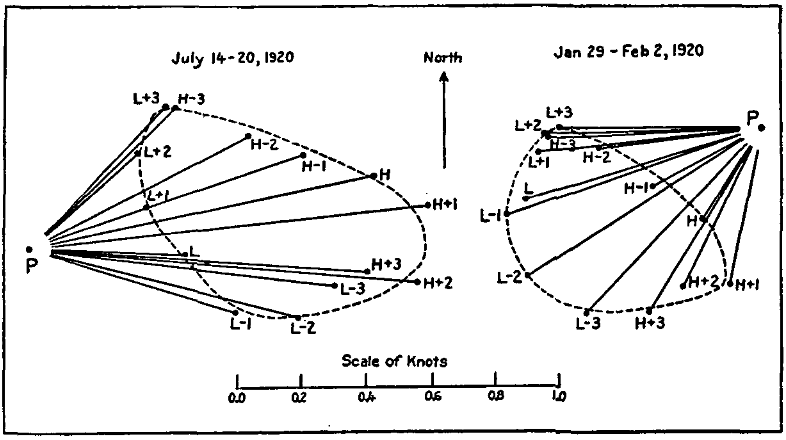

FIGURE 7.—Effect of nontidal current on rotary tidal current, Frying Pan Shoals Lightship.

Observations made at this lightship show the tidal current here to be rotary clockwise, the average velocity at strengths of flood and ebb being about a third of a knot and setting northwest and southeast, respectively. During the 5-day period January 29–February 2, 1920, the wind was blowing steadily from the northeast with a velocity of about 30 miles per hour, and the current was observed to be setting at all times southwesterly with a velocity varying from a little less than one-half a knot to a little more than three-quarters of a knot. Apparently the current here at this time was altogether nontidal. But if the hourly velocity and direction of the current during this period is plotted, the rotary character of the current is immediately apparent. The right-hand diagram of figure 7 represents the current conditions during this 5-day period, the velocity and direc-

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tion of the current at the different hours being given by the length and direction of the lines drawn from the point *P*.

Now, although the current at all times during this period set southwesterly, the diagram reveals clearly the existence of a rotary current with a strength of about a third of a knot in a northwest and southeast direction. Furthermore, the diagram shows that the current actually observed consisted of a tidal current which was masked by a nontidal current of greater velocity. In fact the diagram permits the evaluation of this nontidal current. For this must clearly be given by the line joining the point *P* with the center of the current ellipse, and this is found to have a length of about half a knot and a direction of S. 60° W. This nontidal current was brought about by the northeasterly wind during the 5-day period in question.

About 6 months later, throughout the 7-day period July 14–20, 1920, the current at Frying Pan Shoals Lightship was found to set easterly with velocities ranging from a little less than half a knot to more than a knot. On plotting the observations, as the left-hand diagram of figure 7 shows, the rotary character of the tidal current comes to light at once. During this 7-day period the wind was blowing steadily from the southwest with a velocity averaging approximately 30 miles per hour. This brought about a wind-driven current setting a little north of east with a velocity somewhat greater than half a knot, and this completely masked the tidal current.

HARMONIC CONSTANTS

The reversing 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, reversing 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 inland tidal waters, like rivers and bays, 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

$$M'_2 : S'_2 : N'_2 : K'_1 : O'_1 := m_2M''_2 : s_2S''_2 : n_2N''_2 : k_1K''_1 : o_1O''_1$$

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.

Rotary currents may likewise be analyzed harmonically, but in this case it is necessary to resolve the hourly velocity and direction of the current into two components, one in the north-and-south direction and the other in the east-and-west direction. Each set of hourly tabulations is then treated independently and analyzed in the usual manner. When the two sets of harmonic constants have been derived the like-named constants of the north-and-south and east-and-west directions may be combined into a single resultant, which will be an ellipse.

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 nearby. 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 which is the ratio of the mean range of the tide to the range for the period of the 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 strengths 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.

Part I.—ST. JOHNS RIVER

INTRODUCTION

The St. Johns River has its source near the Atlantic coast of Florida about midway between Jacksonville and Miami. It has a length of approximately 244 nautical miles and flows in a general northward direction nearly parallel to the coast for most of its length. Sixteen miles from its mouth it turns eastward and flows in that general direction to the sea.

For practical purposes, the tidal movement in the St. Johns River may be considered to end at Lake George, and it is the portion of the river below Lake George—a 96-mile stretch of navigable tidal waterway—that is covered by this publication.

From the sea to Jacksonville, a distance of about 24 nautical miles, there is a dredged channel having a depth of 30 feet at mean low water and a width of 300 to 600 feet. From Jacksonville to Palatka, a distance of 48 miles, the channel has a least depth at mean low water of 13 feet, and from Palatka to Lake George, the upper limit of the area under consideration, the least depth is 8 feet.

The portion of the river below Jacksonville varies in width from about one-fourth mile in the narrower parts to more than 2 miles at the expansion known as Mill Cove. Above Jacksonville for a distance of about 40 miles the river is from 1 to 3 miles in width. In the vicinity of Palatka it becomes narrower and for most of the distance between Palatka and Lake George the width is less than one-half mile, the minimum width in this stretch being in the neighborhood of 200 yards. Throughout the length of the tidal portion of the river the banks are much indented by coves and the broadened mouths of tributary streams. Sisters Creek on the north and Pablo Creek on the south, which form links in the Intracoastal Waterway, connect with the St. Johns River about 5 miles above its mouth.

The ocean tide at the entrance to St. Johns River has an average rise and fall of 4.9 feet. As the tide wave advances up the river its amplitude decreases continuously for a distance of about 35 miles. In the vicinity of Orange Park the average range of tide reaches a minimum of 0.7 foot. Above this point the range gradually increases for 35 miles to Palatka, where the average rise and fall is 1.2 feet. Above Palatka it again decreases and at Lake George it is practically zero.

The periodic currents that accompany the tidal rise and fall exhibit differences in velocity from place to place that are considerably more rapid and erratic than are the variations in range of tide. The smaller velocities usually occur where the river is broad and the larger ones, in the more constricted sections. Aside from these somewhat localized variations, there is a general decrease in velocity from the mouth toward the head of the stream. From the sea to Jacksonville the average velocity of the tidal current strengths in the channel varies from 1 to 3 knots. Above Jacksonville it is generally less than 1 knot, and in the 40-mile stretch ending at Lake George it is less than one-half knot.

The currents in the St. Johns River, at times, are modified considerably by winds and freshet conditions. Northerly and northeasterly winds increase the velocity and duration of the flood stream and decrease the ebb. Southerly and southwesterly winds have a reverse effect. Freshets, which usually occur in the autumn months, increase the flow in the ebb direction and diminish the flow in the flood direction. Daily predictions of the times and velocities of the current in the channel between the jetties at the entrance to St. Johns River are given in the annual Current Tables for the Atlantic Coast of North America.

OBSERVATIONS

The current data for the St. Johns River presented in this volume are based mainly upon observations taken during the winter of 1933–34 by a United States Coast and Geodetic Survey field party in charge of E. F. Hicks. Observations were taken at the surface and at several subsurface depths at 35 selected locations. The usual length of series at each location was 3 days. A continuous series of observations covering a period of 15 days was secured between the jetties at the entrance.

Previous to the 1933–34 survey, series of current observations were secured at various times by the United States Army Engineers in connection with projects for improvement of the channel, and a few by United States Coast and Geodetic Survey hydrographic parties. The shortness of most of these series and the extensive physical changes that have occurred since they were obtained render them of little value as an index to present-day conditions. They are therefore omitted from this publication, with the exception of the results of slack-water observations taken by the United States Army Engineers in 1909 at 10 stations distributed along the river from Mayport to Jacksonville. For the benefit of those who may desire information relative to the nature and results of the early investigations, reference is made to the following published material:

Annual Report of the Chief of Engineers, United States Army (pt. 2, 1890, p. 1558 et seq.).
Annual Report of the Chief of Engineers, United States Army (pt. 3, 1891, p. 1619).
Examination and Survey of St. Johns River, Fla. (H. Doc. No. 611, 61st Cong., 2d sess. (1910)).

METHODS OF OBSERVING

In general, the 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 employed. The two devices most used in recent years by this Bureau and which were employed in 1933 and 1934 in the St. Johns River work, are the *current pole* and the *Price current meter.*

The *current pole* 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 line and allowed to drift with the current while an observation is being made. The line, known as a current 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 knots (nautical miles per hour) and tenths is read directly from the current line. The direction toward which the pole drifts is observed usually by compass or 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 standard current pole now in use is 15 feet long and is so weighted as to float with 1 foot above the water surface. Shorter poles are used when the water is shallow.

The *Price current meter* is used for taking subsurface observations of velocity only. 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 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. Since the Price current meter does not give the direction of the current, it is generally used by this Bureau in conjunction with the current pole, the general direction of the subsurface current being inferred from the pole observations.

The times of slack water observed by the United States Army Engineers in 1909 were presumably determined by watching the movements of the water surface or of floating objects thereon.

METHODS OF REDUCING THE OBSERVATIONS

The following described method was used in reducing the 15-day series of observations secured at station 1 between the jetties at the St. Johns River entrance.

The records of the field party were first carefully verified to see that the observed directions of current had been accurately reduced to true azimuths by applying to the observed compass readings the proper corrections for the deviation of the ship's compass and the magnetic variation, and that the meter velocities had been correctly entered from the rating table.

The velocities observed by pole were next plotted on cross-section paper, the times of observations being taken as abscissae and the velocities plotted as ordinates, the flood velocities above and the ebb velocities below the horizontal line representing zero velocity. Curves were drawn following the general trend of the plotted velocities and from these curves the times of slack waters and the times and velocities of the strengths of flood and ebb were taken. These times and velocities, together with the true direction of each strength of flood and ebb were tabulated on forms prepared for the purpose. The times of slack water and of strength of current were then compared with the times of high and low waters at Mayport and average time differences computed 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 the series of observations and the average velocities of flood strength and ebb strength were computed.

The average velocities as directly obtained were then corrected by the application of a range factor as explained on page 15.

The velocities observed by meter were similarly treated, a separate plotting, tabulation and reduction being made for each depth at which meter observations were taken. In the case of the meter velocities, the general direction—flood or ebb—of the current was inferred from the directions observed by pole.

For the remaining stations occupied during the 1933–34 survey, the method of reduction outlined below was used.

The field records were verified as in the case of station 1. The half-hourly observations of velocity and direction were then tabulated in 25 groups, one group for each half hour from zero to 12 hours after the time of high water at Mayport. Each observed value was assigned to the group to which it most nearly corresponded in time. A separate tabulation was made for each depth observed at each station. For each half-hourly group, an average velocity and an average direction were computed for the surface current as observed by pole, and an average velocity was obtained for each meter depth. The average half-hourly velocities were plotted on cross-section paper and from the resulting curves the times of slack and the times and velocities of strength were tabulated. The velocities were then corrected to mean tidal conditions by applying the usual range factor, and the average flood and ebb directions were computed from the half-hourly averages of direction as observed by pole.

The times of slack water observed by the United States Army Engineers in 1909 were tabulated and compared with the times of tide at Fernandina and for each station average time differences were computed for the slack before flood and the slack before ebb.

For uniformity of presentation, the time relations obtained from all the above-mentioned reductions were finally referred, by means of time differences derived from long series of tide observations, to times of high water and low water at Mayport. The slacks before flood and strengths of flood were referred to high water and the slacks before ebb and strengths of ebb to low water.

The 15-day series of observations taken between the jetties was analyzed harmonically and the results corrected by comparison with the results of a similar analysis of a simultaneous series of tides at Mayport. Brief statements relative to the process of harmonic analysis will be found on page 14. For a detailed explanation of the application of harmonic analysis to the reduction of tides and tidal currents, reference is made to United States Coast and Geodetic Survey Special Publication No. 98, a Manual of the Harmonic Analysis and Prediction of Tides.

PRESENTATION OF THE RESULTS

DESIGNATION AND LOCATION OF STATIONS

Each current station in the St. Johns River has been given a designation which consists of two parts: First, a letter signifying the party or the chief of the party that occupied the station, and second, a number assigned to the particular station of that party. The letter H forms the first part of the designation for each station occupied by the current survey party of E. F. Hicks in 1933 and 1934. The number following this letter is that which was originally assigned to the station. The letter E precedes the number of each station at which observations were made by United States Army Engineers in 1909.

The locations of the stations occupied are indicated in figures 8 and 9 by red circles, together with the corresponding station designations. The stations from the river entrance to the bridges at Jacksonville are included in figure 8, those above Jacksonville, in figure 9.

EXPLANATION OF THE TABULAR DATA

Table 1 contains the results derived, as explained on page 19, from the observations at each station. The observations of each party are placed in a separate group under a subhead which indicates the observing party and the year or years during which the observations were taken. The station number in the first column of the table is the same as the designation of the station in figure 8 or figure 9. In the second column, a brief descriptive statement of the station location and its latitude and longitude to the nearest tenth of a minute are given.

Following the location, the dates of the beginning and end of the series of observations, the length of the series in days, the methods used in observing, and the depths at which observations were made, are given. The depth tabulated for the observations taken by pole is in each case one-half the length of the submerged portion of the pole.

In this table, all times are expressed in hours and hundredths. The times of slack water and of flood and ebb strength are referred to the times of tide at Mayport, the slack before flood and strength of flood being referred to high water and the slack before ebb and strength of ebb to low water. A minus sign preceding a time difference in a slack or strength column indicates that the current is earlier than the stated phase of the tide at the reference station. The true directions of the current at the times of flood and ebb strength are reckoned from true north (0°), through east (90°), south (180°), and west (270°). As directions were observed only by pole, no directions are given for the meter depths. At stations for which directions are given in points of the compass, general directions only were observed. The velocities are expressed in knots (nautical miles per hour) and hundredths, and have been corrected to refer them to mean tidal conditions.

The mean current hour 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

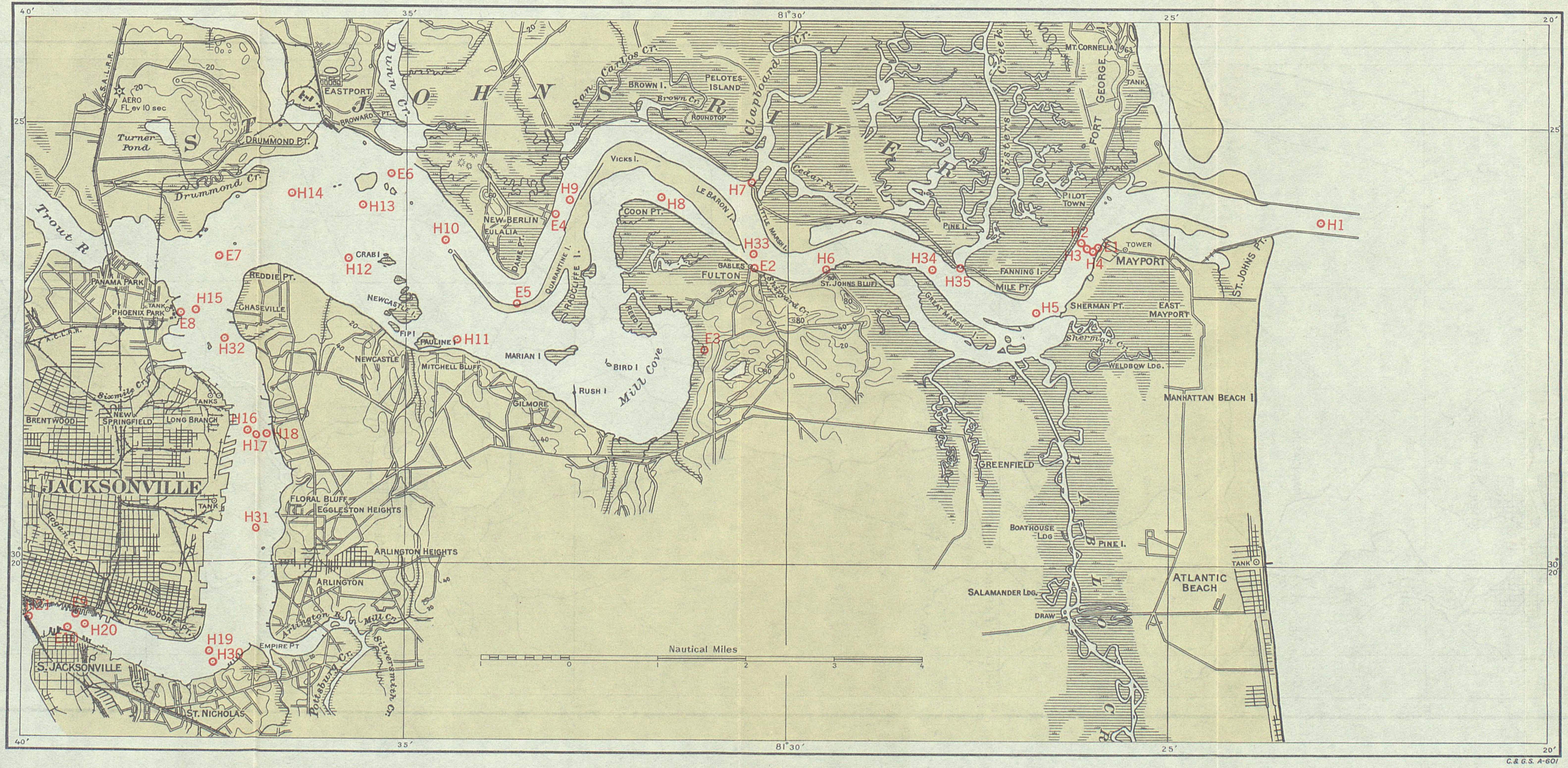


Fig. 8. Current stations, St. Johns River, jetties to Jacksonville.

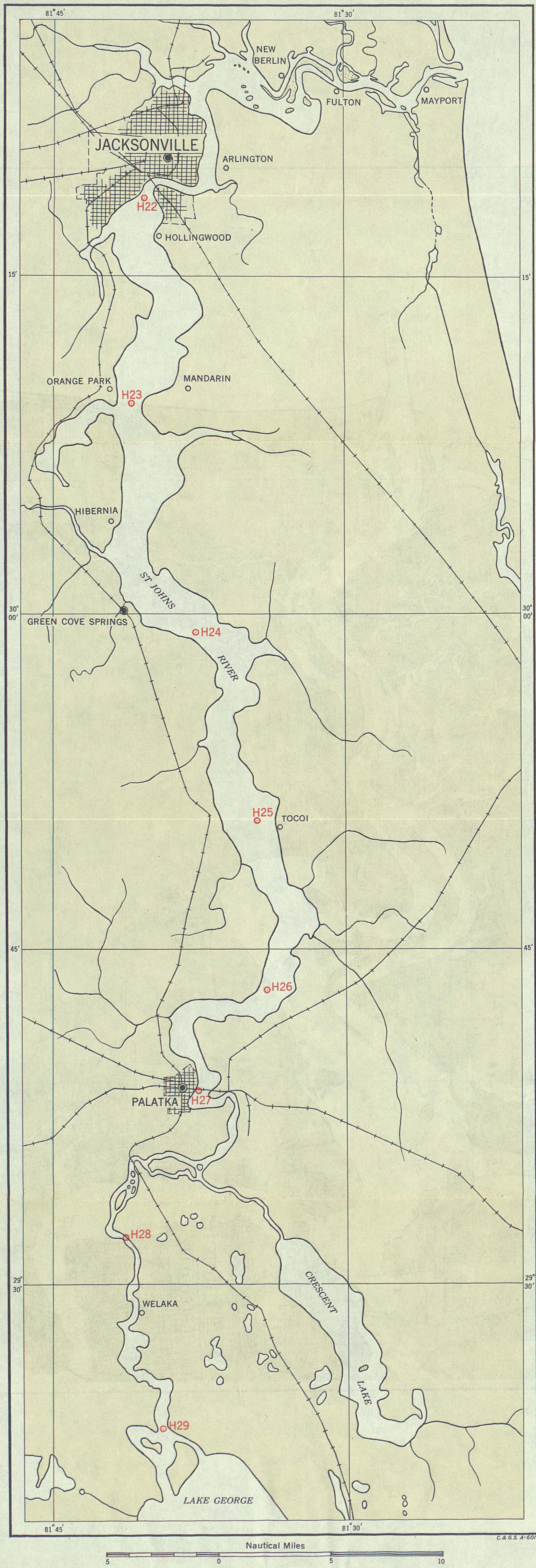


Fig. 9. Current stations, St. Johns River, above Jacksonville.

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 harmonic constants derived as explained on page 19 from the 15-day series of observations at station H 1 between the jetties, are given in table 2. These constants consist of the amplitudes (H's) and the phase lags or epochs of the more important periodic constituents of the current. The constants represent a reversing condition, the movement in the flood direction being positive and that in the ebb direction, negative. The phase lags or epochs apply to the maximum

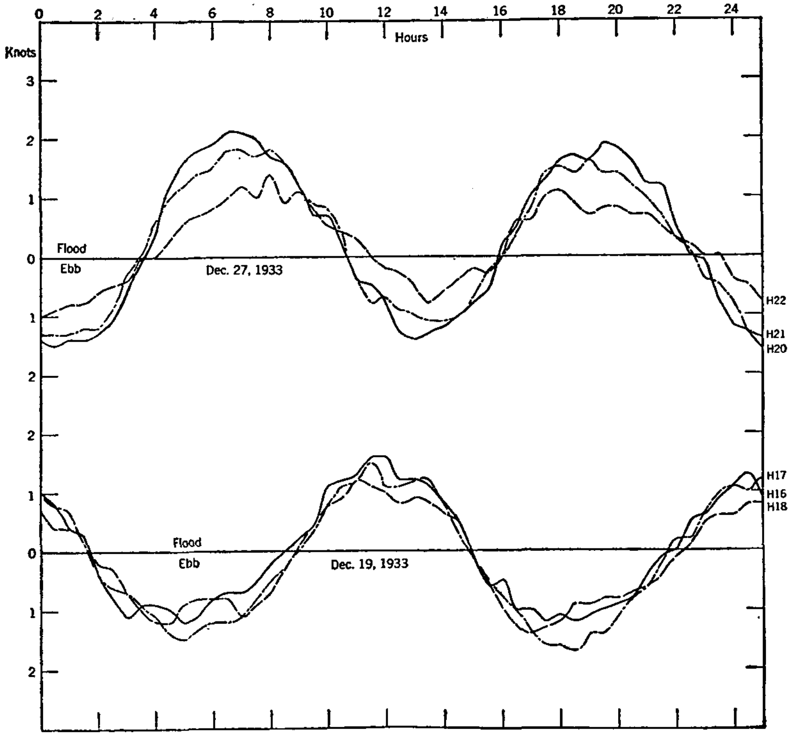


FIGURE 10.—Observed velocity curves, St. Johns River.

flood of each constituent. Such constants form the basis for daily predictions of the current. From them also may be determined the general characteristics of the current movement and various nonharmonic constants which are usually obtained directly from the observations.

OBSERVED CURRENT CURVES

To show the current movement as actually observed, there are reproduced in figure 10 velocity curves plotted directly from pole observations taken in December 1933 at six stations in the St. Johns River. The flood velocities are plotted above and the ebb velocities below the horizontal line representing zero velocity. Each group of three stations, plotted from a common datum line, represents a day of simultaneous observations at the stations indicated. The date of the observations is given for each group.

The individual curves give an accurate picture of the movement as observed at each station, and a comparison of the curves in a group shows the actual time and velocity differences observed at the several stations on the day indicated. As is usual with current velocity curves plotted directly from observations, these curves show considerable irregularity. The roughness is doubtless due largely to accidental conditions such as weather effects and observational discrepancies, both of which are usually present to a greater or lesser degree.

The velocity curves for December 27, 1933, at stations H 20, H 21, and H 22 show clearly the effect of wind on the currents in the vicinity of Jacksonville. The flood current at each of the three stations not only attained a greater velocity but it ran considerably longer than the ebb. This, obviously, was not an average condition, for the normal river flow is downstream instead of upstream.

An investigation of weather conditions at this time discloses that at St. Johns Lightship, where hourly directions and velocities of the wind were recorded, the average wind for December 27 had a velocity of 23 miles per hour from the north-northeast. On the preceding day, December 26, the velocity was 6 miles per hour from the west-southwest. It appears that on December 27 the wind current resulting from the above described condition overcame the drainage flow of the river and set up a considerable nontidal flow in an upstream direction.

The group of curves for December 19, 1933, as will be seen by reference to figure 10, stations H 16, H 17, and H 18, represents the current movement in a cross section of the river near Jacksonville. Wind velocities on this date were very small and the nontidal flow downstream evidenced by the relative velocities and durations of the ebb and flood, is doubtless a drainage flow. At station H 16, probably due to its location, the maximum flood velocity was greater than that of the ebb, but the greater duration of the ebb offset this greater flood velocity and the resultant flow, as determined by averaging algebraically the half-hourly ordinates of the curve, was practically zero. At the other two stations, both the velocities and the durations were greater for the ebb than for the flood..

RANGE OF TIDE AND VELOCITY OF CURRENT

The features of tide range and current velocity in the St. Johns River outlined on page 16 are shown graphically in figure 11. The two curves are plotted from the results of tide and current observations taken at numerous locations along the river, the current velocities used in the plotting being those derived from pole observations in or near the channel. The scale along the top of the illustration represents nautical miles measured along the channel from an initial point at the outer end of the jetties. Below this scale are given the names of a number of points along the river. The vertical scale reads in feet on the curve showing range of tide and in knots on the curve showing velocity of current. The curves represent the mean range of the tide and the mean velocity of the tidal current at strength, the nontidal current for each station used in the plotting having been eliminated by taking the half sum of the flood and ebb strengths. As the velocity of the tidal current depends upon a number of factors other than the range of tide, the two curves in figure 11 are somewhat dissimilar. They do, however, show a general decrease of both velocity and range from the mouth of the river to the locality where the range reaches a minimum value. Above this point the velocity shows a decrease with increasing range and a slight tendency to increase where the range again decreases. The changes in range of

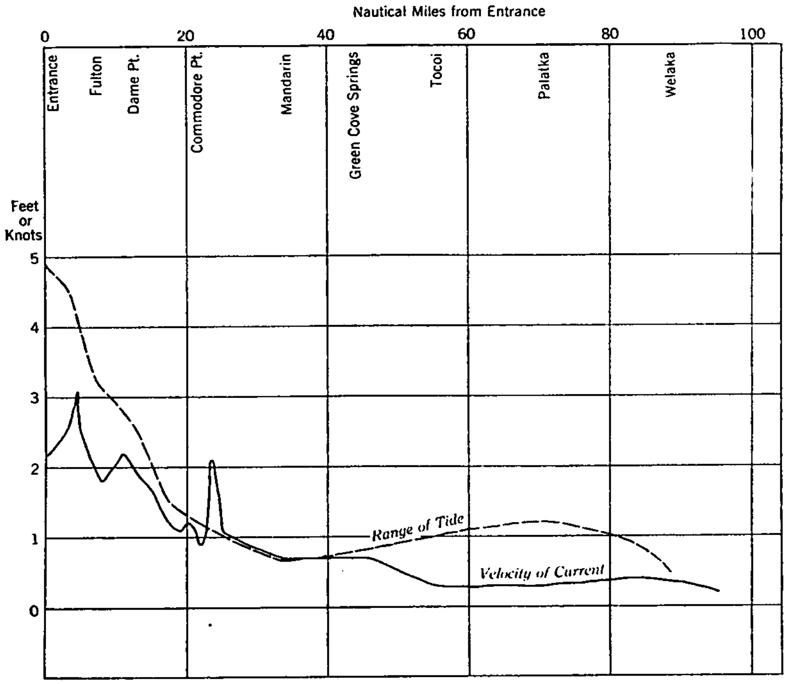


FIGURE 11.—Range of tide and velocity of current, St. Johns River.

tide in the St. Johns River may be attributed to the presence of a stationary tide wave, which in combination with a progressive wave advancing up the river, would tend to produce a tide of this character.

TIME RELATION OF CURRENT TO TIDE

Where time relations of current to tide have been given for St. Johns River in the tabular and graphical results discussed in the preceding pages, the reference used has been the tide at Mayport, Fla. To show the times of the slacks and strengths of current in the river channel in their relation to the times of local high and low waters, figure 12 has been prepared. The observed times of the four current phases at a number of stations in or near the channel from the jetties to Lake George were plotted and curves drawn through the plotted points. A few of the observed slack water times used in this plotting were modified to correct for the effect of northerly winds upon the observed values. On the same sheet, curves representing the times of high water and low water as determined from observations along the river were drawn. The same time reference, namely, the transit of the moon over the meridian of Greenwich was used for both tides and currents. The scale at the top of the figure is the same as for figure 11.

The curves show that the time relation of current to local tide varies from place to place along the river. In the lower portion of the river the strengths of flood and ebb occur near the times of high and low water respectively. Above Jacksonville the current becomes rapidly earlier with respect to the local tide and 50 miles from the sea the strengths of flood and ebb precede the high and low waters by about 3 hours, the slack waters occurring near the times of the highs and lows. Advancing up the river the current occurs later and later with respect to the tide and at a distance of 85 miles from the sea the strengths again come at about the times of high and low tide, which is the same relation that exists at Jacksonville.

The time relations shown by the curves of figure 12 give further evidence of the existence of a stationary tide wave in combination with a progressive wave, for the time relation of current to tide in the lower part of the river and also between Palatka and Welaka are approximately those of a progressive wave movement, as stated on page 5, whereas the time relation in a region about midway between these two localities is that of a stationary wave.

CURRENT CHARTS

The observed direction and velocity of the current at a number of locations in the St. Johns River for each hour from 2 hours before to 3 hours after high and low waters at Mayport, Fla., are represented in figures 13 to 36. The observations used in preparing the charts were taken in 1933 and 1934. They were all taken with a current pole within 14 feet of the surface. For a few locations where the currents during the observational periods were unduly affected by winds, the observed values have been modified to more nearly approximate normal conditions. The locations at which the observations were taken are marked by small circles. The observed directions of flow for the designated hour of the tide are represented by arrows drawn through the circles. The mean velocities for the designated hour are shown to the nearest tenth of a knot by numerals near the circles.

At times of spring tides and perigean tides the velocities normally are greater and at times of neap tides and apogean tides less than those given on the charts. In this locality the spring effect produces a velocity increase above the mean of about 17 percent, and the perigean effect an increase above the mean of about 20 percent. When spring and perigean effects combine, the velocities of the tidal current are greatest. When neap and apogean effects combine, the velocities of the tidal current are least. Winds and freshet conditions at times modify both the direction and the velocity of the current.

Daily predictions of the high and low waters at Mayport are included in the annual Tide Tables for the Atlantic Ocean, published by the Coast and Geodetic Survey.

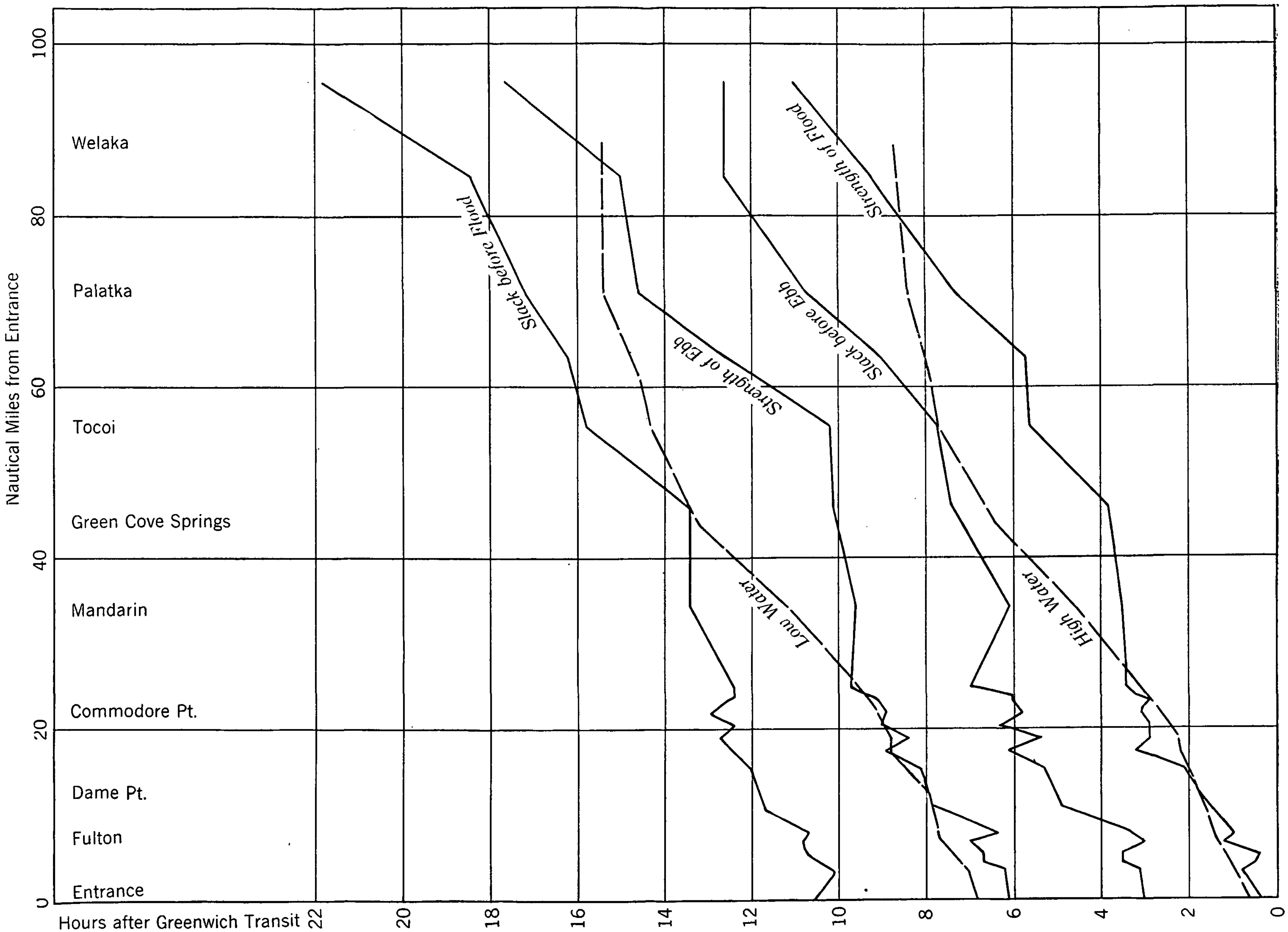


FIGURE 12.—Tide and current intervals, St. Johns River.

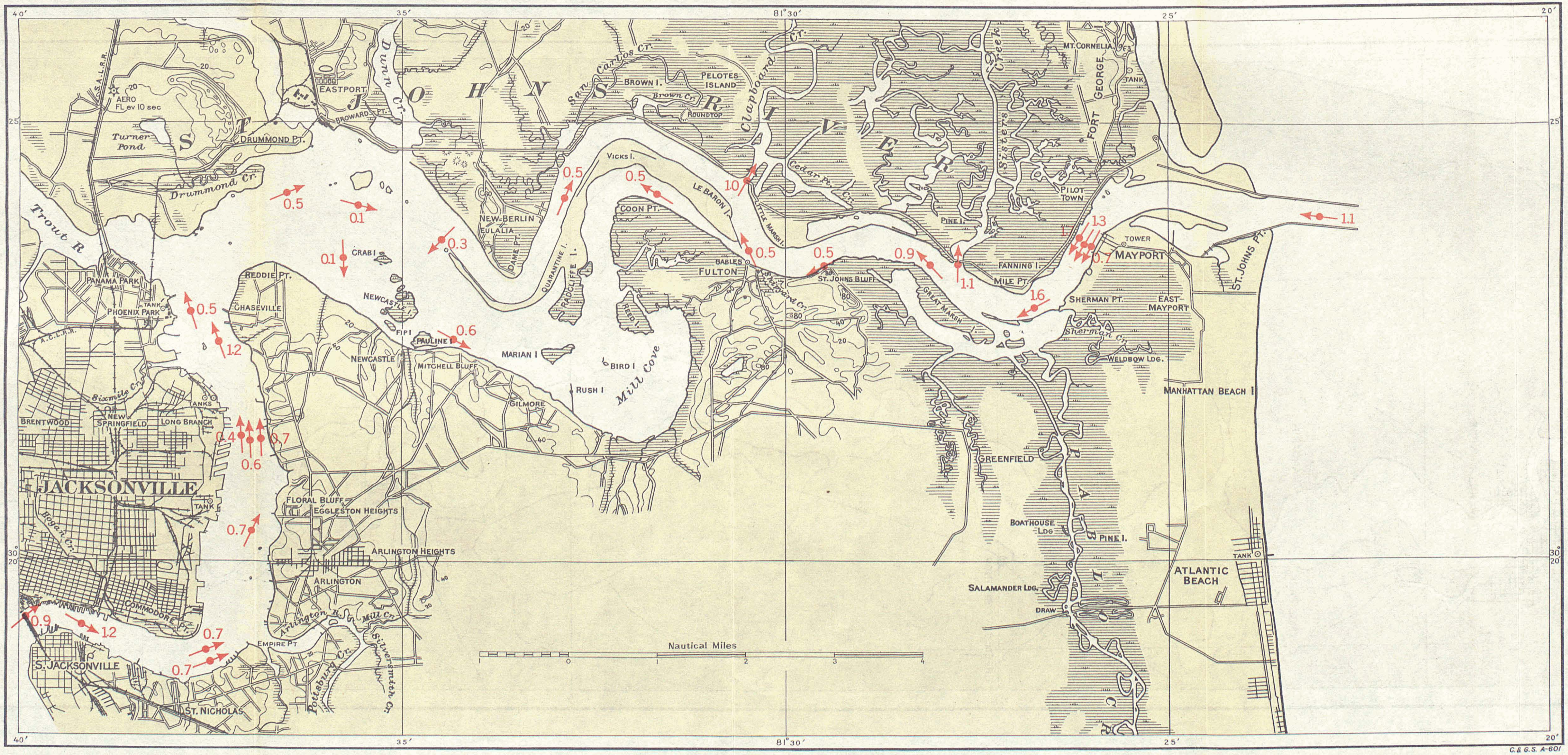


Fig. 13. Currents below Jacksonville 2 hours before high water at Mayport.

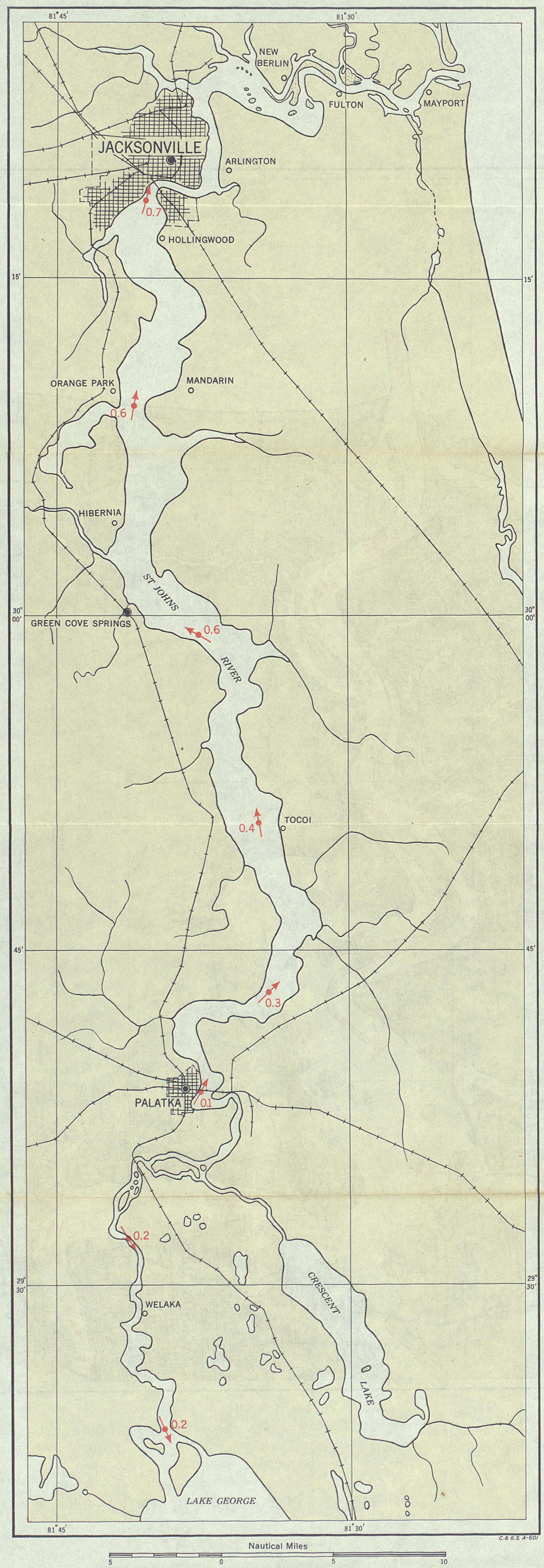
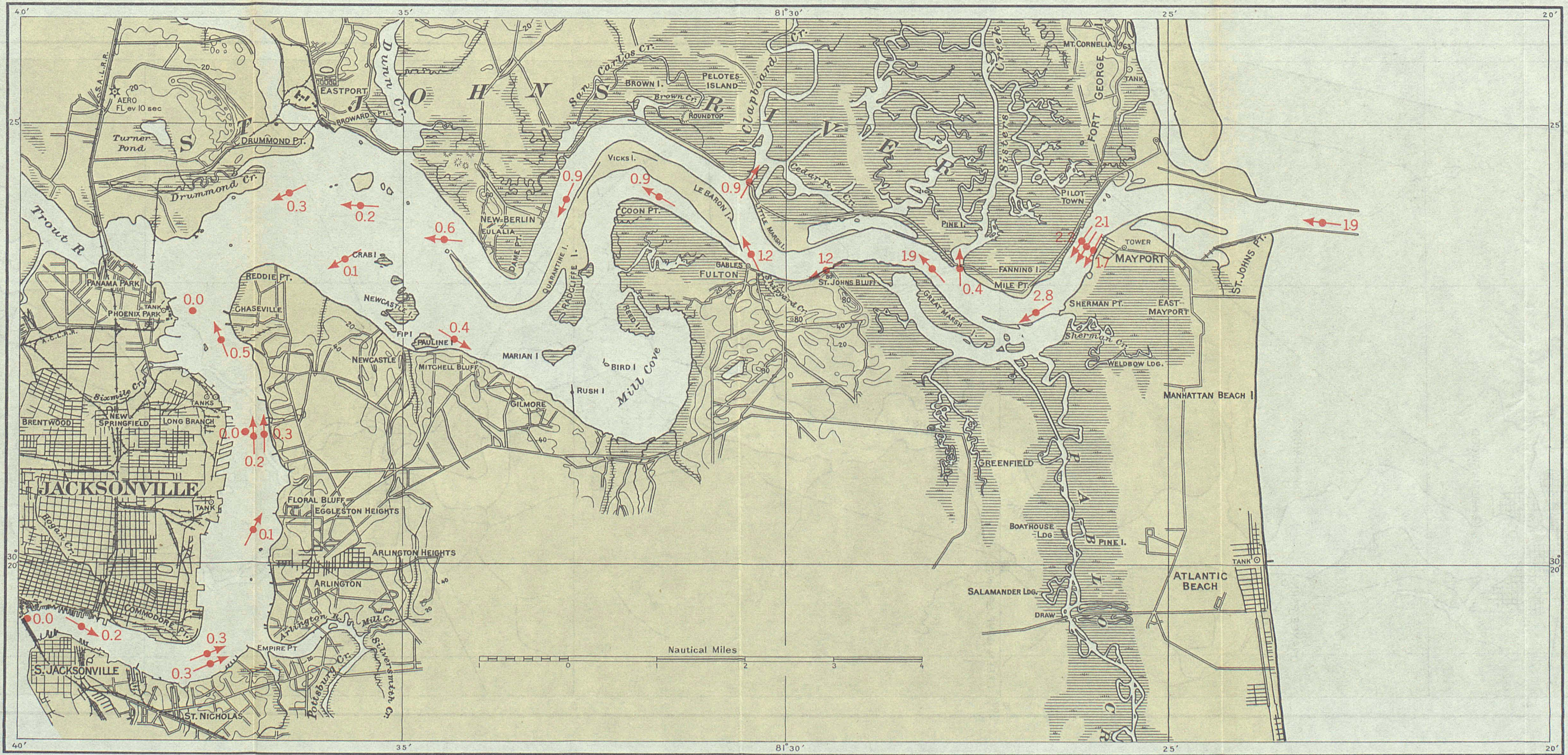


Fig. 14. Currents above Jacksonville 2 hours before high water at Mayport.



C. & G. S. A-601

Fig. 15. Currents below Jacksonville 1 hour before high water at Mayport.

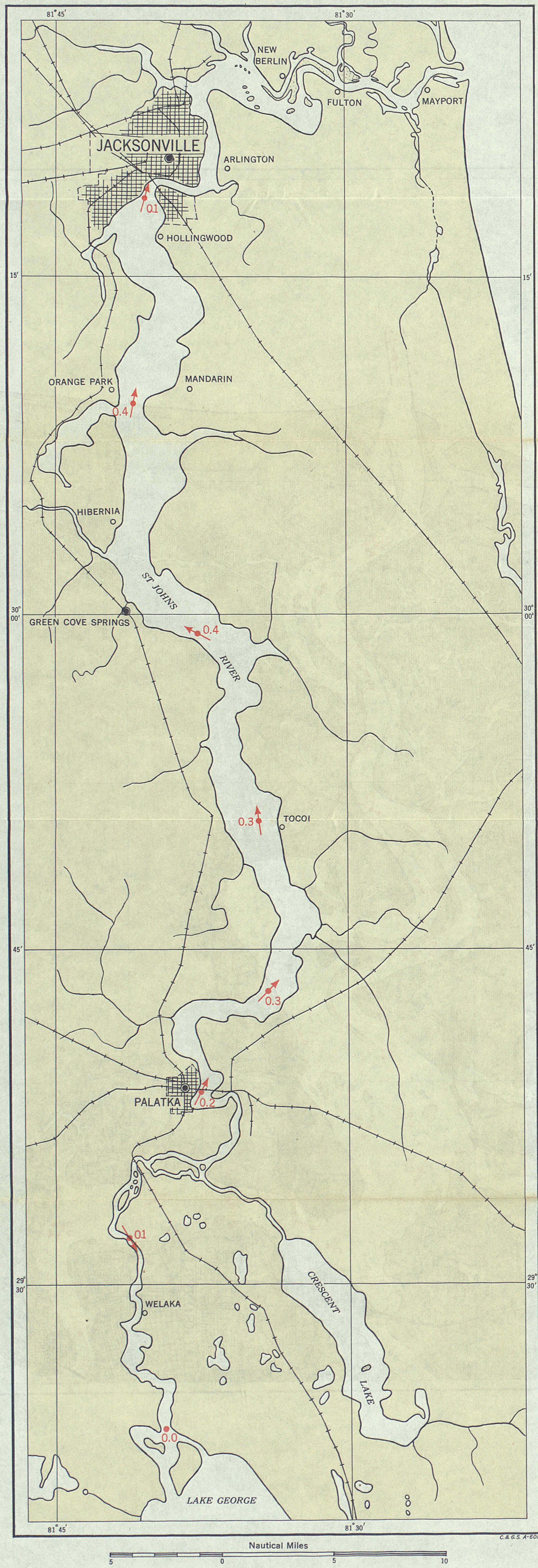


Fig. 16. Currents above Jacksonville 1 hour before high water at Mayport.

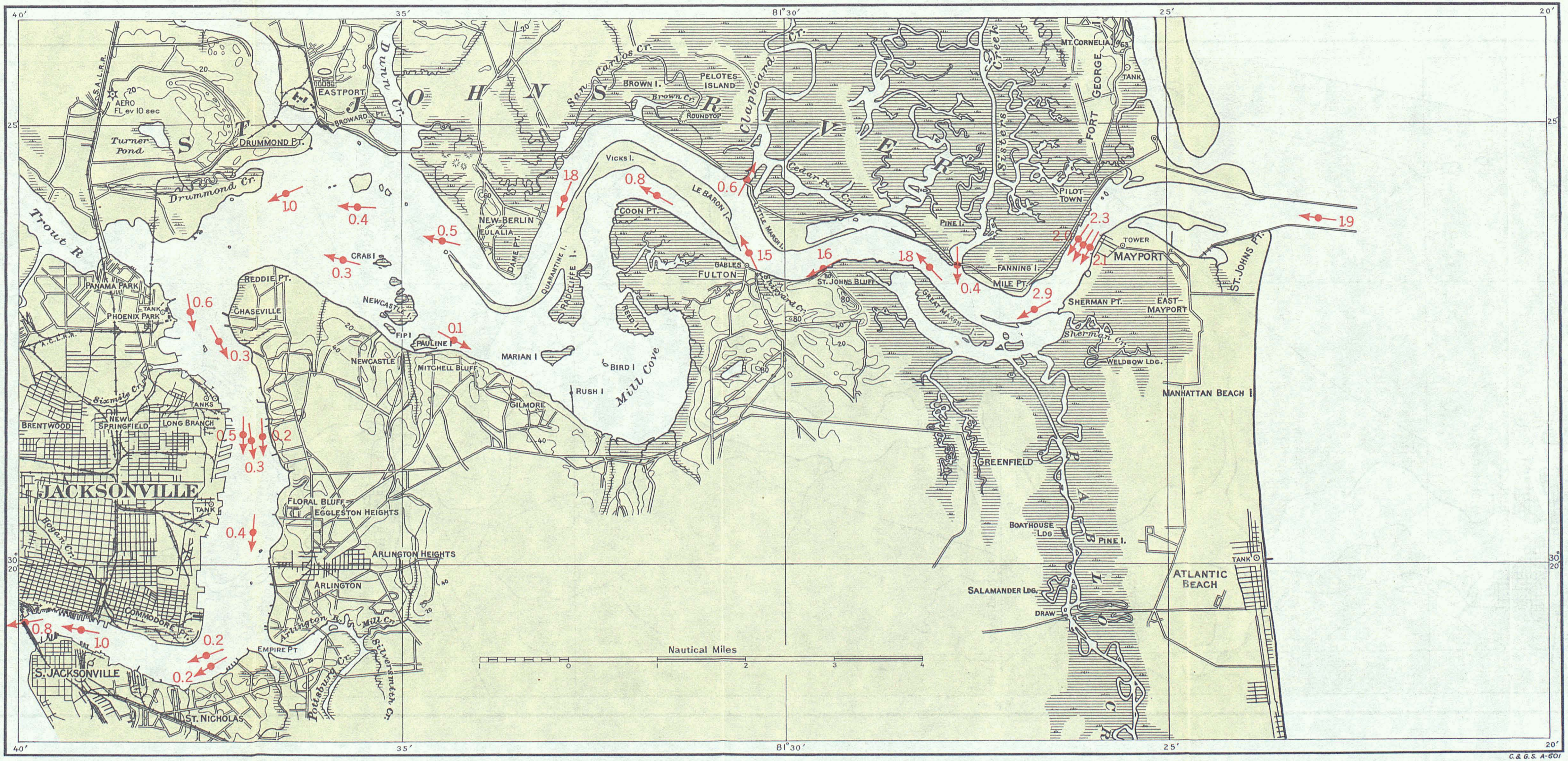


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Fig. 17. Currents below Jacksonville at time of high water at Mayport.

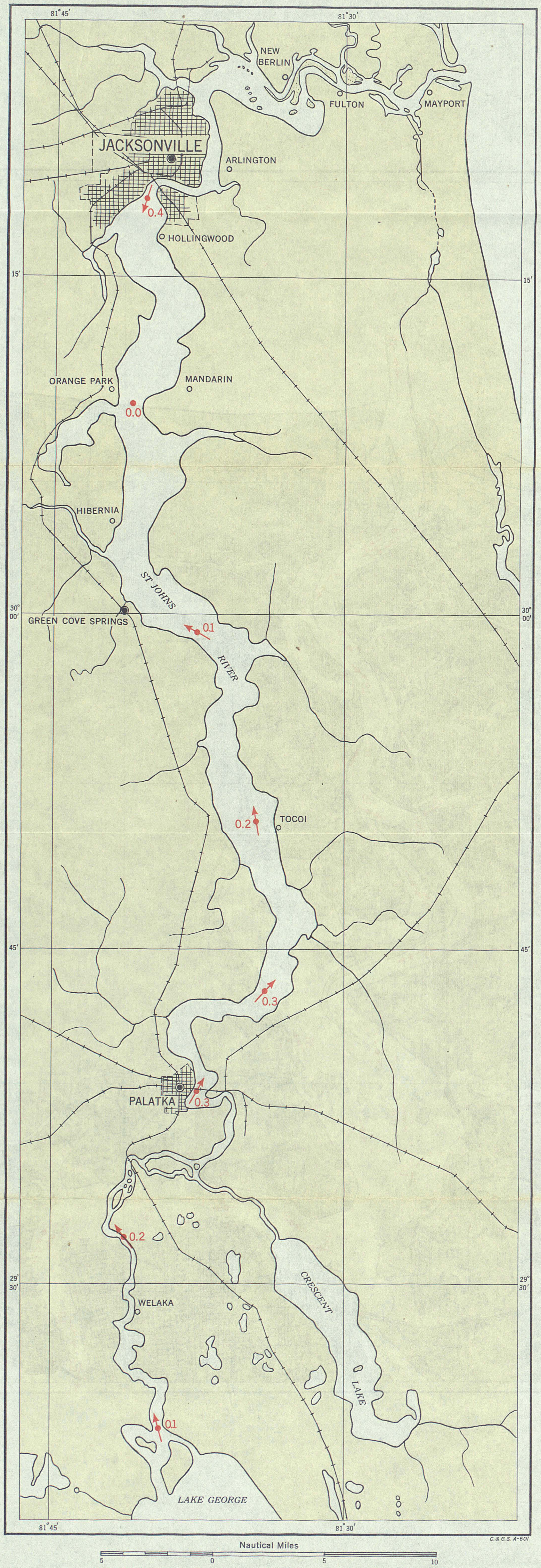

Fig. 18. Currents above Jacksonville at time of high water at Mayport.

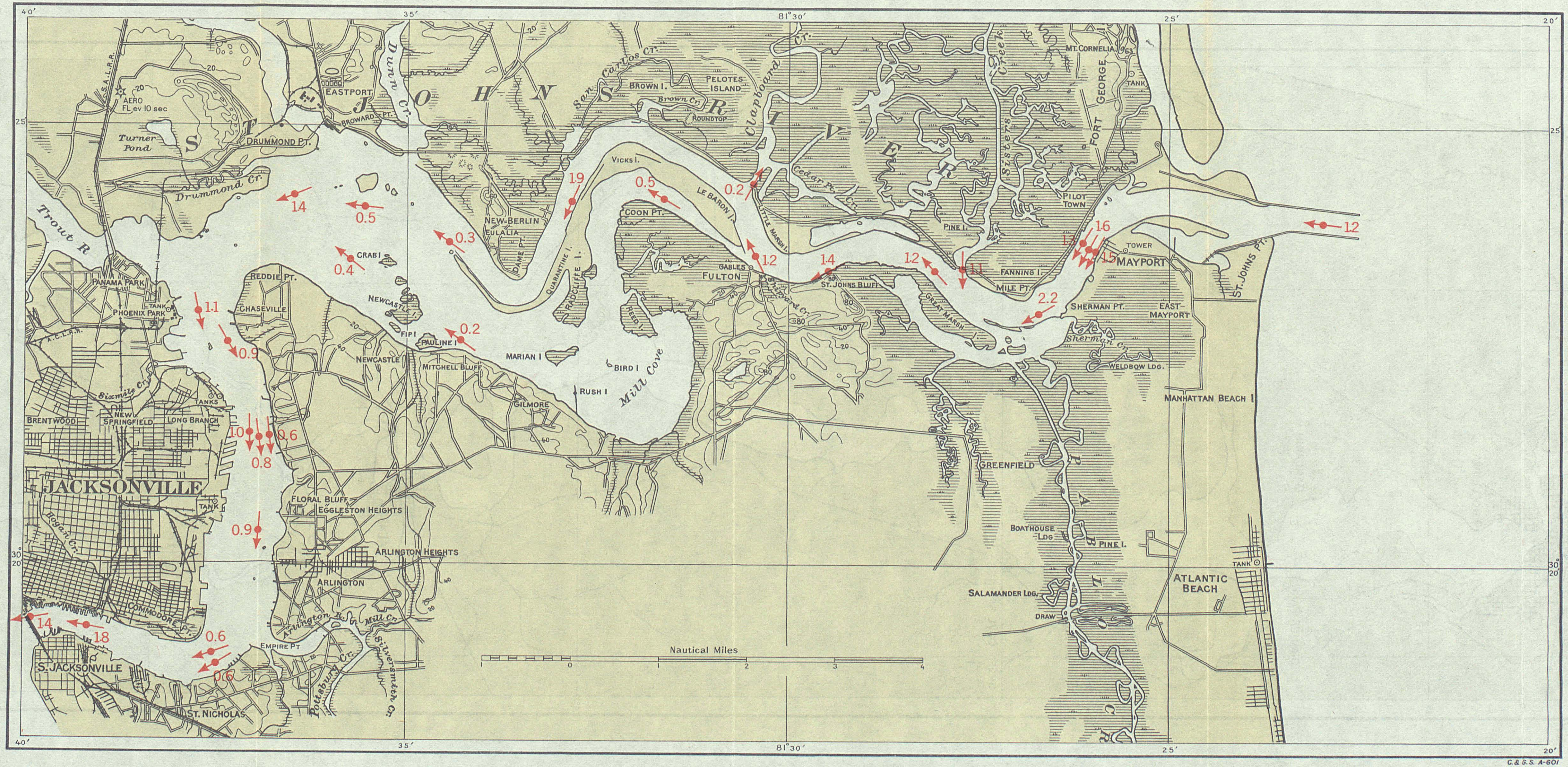

Fig. 19. Currents below Jacksonville 1 hour after high water at Mayport.

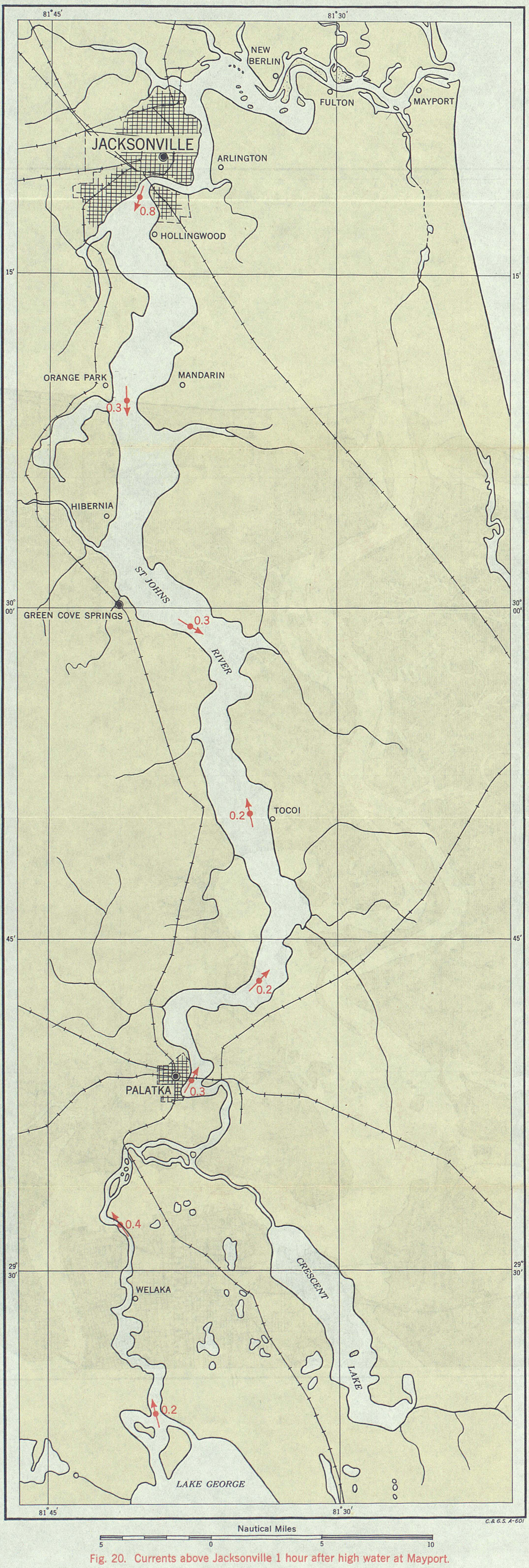

Fig. 20. Currents above Jacksonville 1 hour after high water at Mayport.

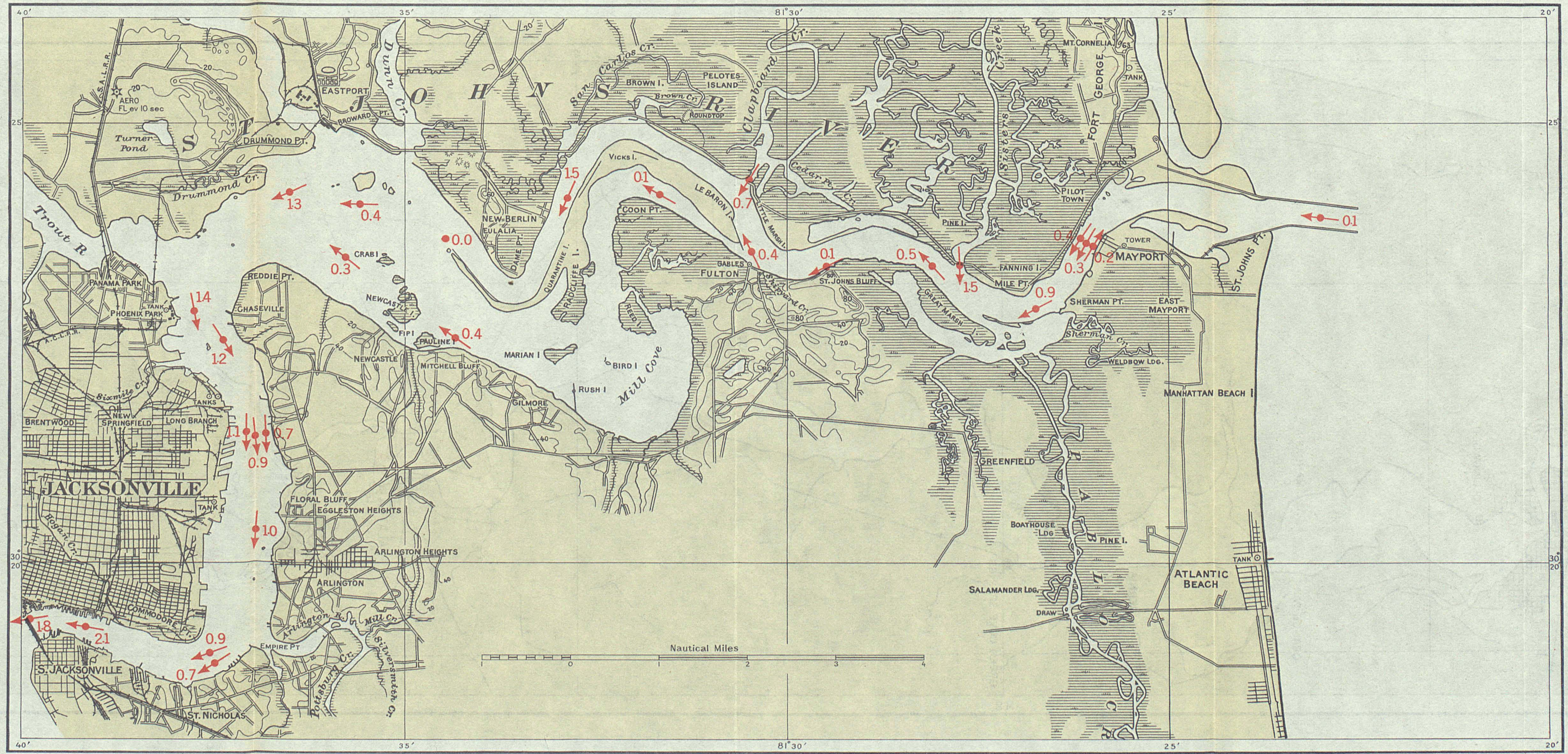

Fig. 21. Currents below Jacksonville 2 hours after high water at Mayport.

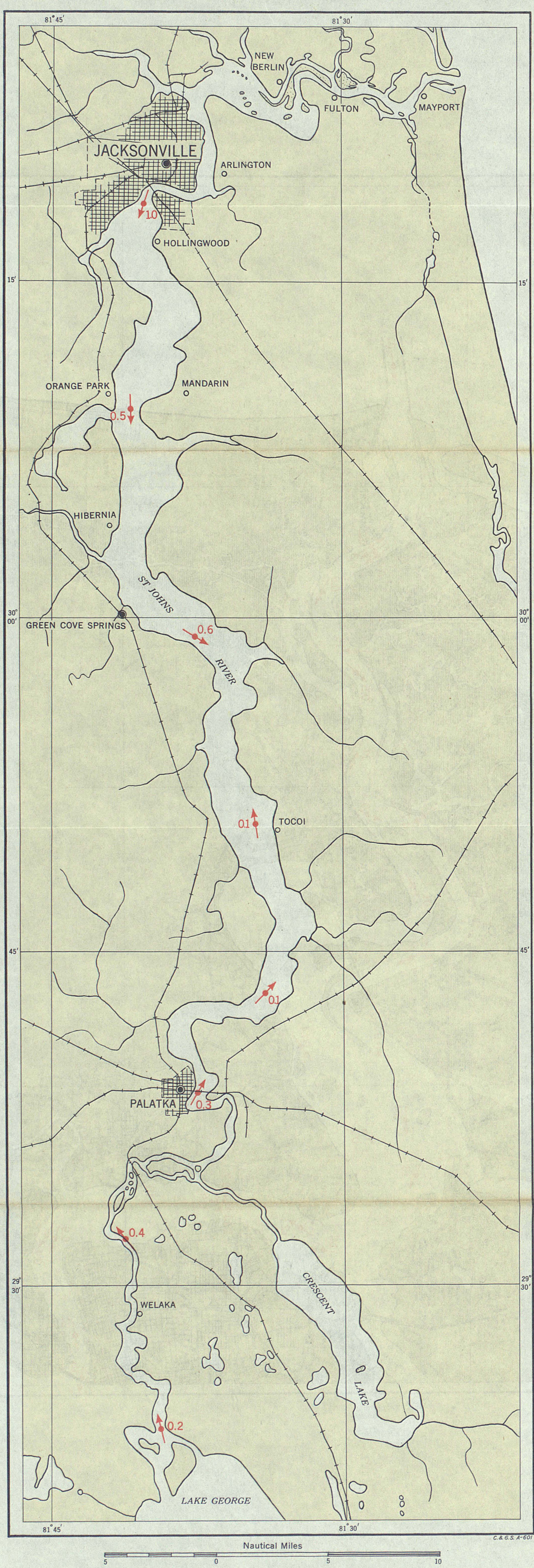

Fig. 22. Currents above Jacksonville 2 hours after high water at Mayport.

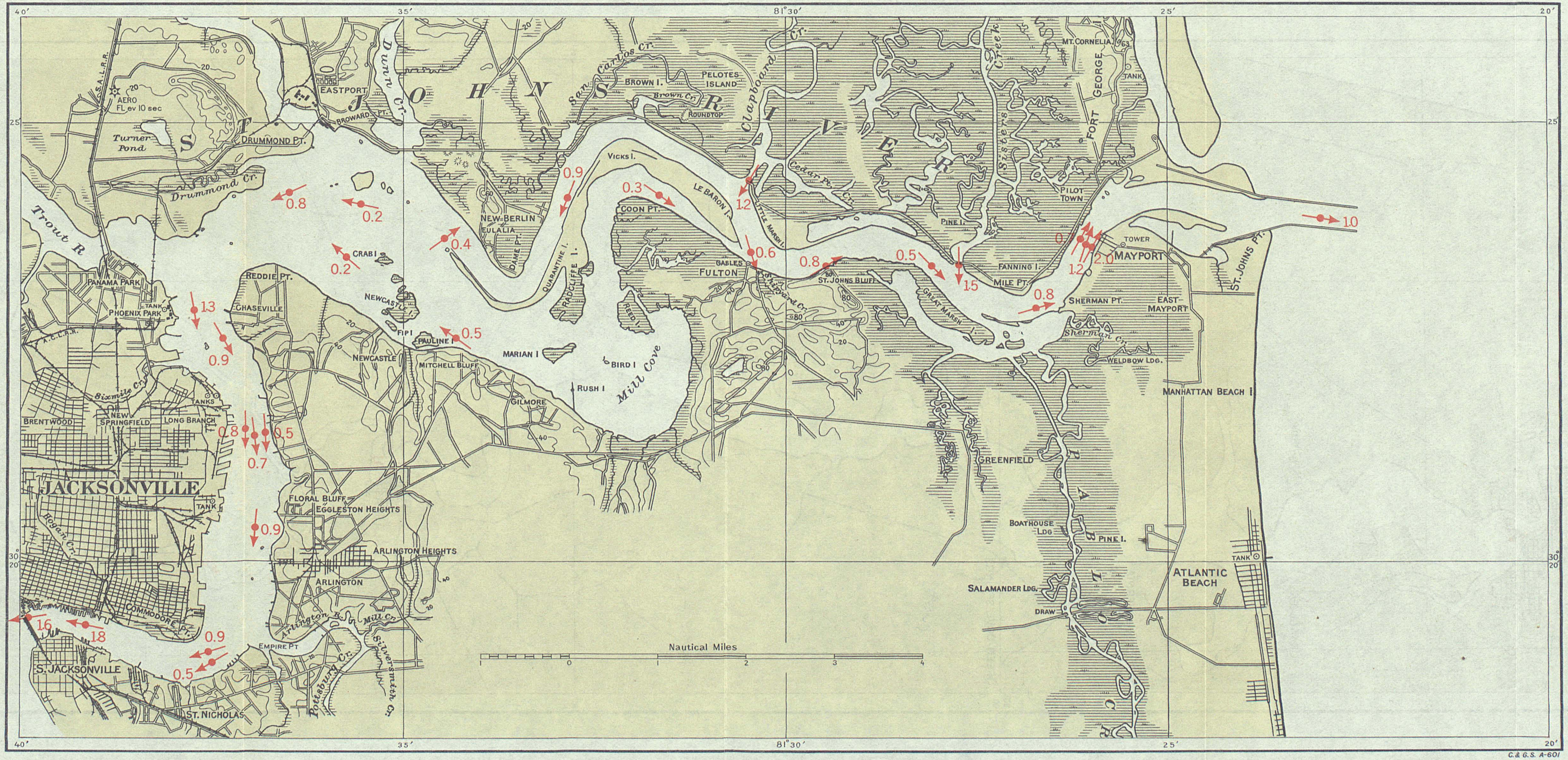

Fig. 23. Currents below Jacksonville 3 hours after high water at Mayport.

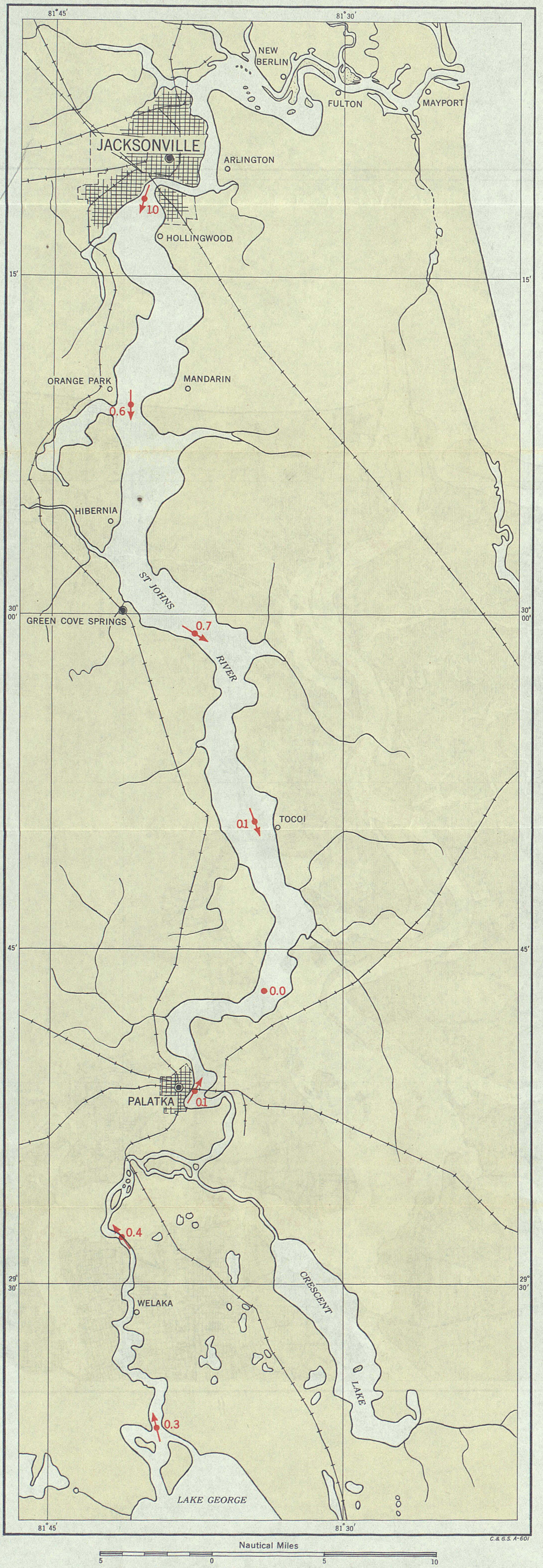

Fig. 24. Currents above Jacksonville 3 hours after high water at Mayport.

Table 1.—*Current Data, St. Johns River*

[Referred to times of high water and low water at Mayport, Fla.]

Station no.	Observer, location, and year	Observations: Date	Observations: Period	Observations: Method	Observations: Depth	Slack	Flood strength: Time	Flood strength: True direction	Flood strength: Velocity	Flood duration	Slack	Ebb strength: Time	Ebb strength: True direction	Ebb strength: Velocity	Ebb duration	Mean current hour
			Days		*Feet*	*Hours after high water*	*Hours after high water*	*Degrees*	*Knots*	*Hours*	*Hours after low water*	*Hours after low water*	*Degrees*	*Knots*	*Hours*	*Hours*
	U. S. ENGINEERS, 1909															
E 1	0.3 mile N. 86° W. of Mayport tower (30°23′.6 N., 81°25′.9 W.).	May 29–Sept. 20	[1] 39	([2])	0	−3.07	------	------	------	5.36	−3.82	------	------	------	7.06	0.54
E 2	Fulton, 0.1 mile offshore (30°23′.4 N., 81°30′.5 W.).	June 21–July 27	13	([2])	0	−2.16	------	------	------	5.12	−3.15	------	------	------	7.30	1.33
E 3	Live Oak Creek, 0.2 mile above mouth (30°22′.4 N., 81°31′.1 W.).	July 19–31	6	([2])	0	−4.57	------	------	------	6.06	−4.62	------	------	------	6.36	11.81
E 4	0.1 mile east of New Berlin church (30° 24′.0 N., 81°33′.1 W.).	June 21–July 31	10	([2])	0	−1.31	------	------	------	4.16	−3.26	------	------	------	8.26	1.70
E 5	0.3 mile south of Dame Point (30°23′.0 N., 81°33′.6 W.).	July 19–31	4	([2])	0	−0.73	------	------	------	4.18	−2.66	------	------	------	8.24	2.29
E 6	0.1 mile north of Crab Island (30°24′.5 N., 81°35′.2 W.).	Sept. 2–11	2	([2])	0	−0.66	------	------	------	5.29	−1.48	------	------	------	7.13	2.92
E 7	0.4 mile northwest of Reddie Point (30° 23′.5 N., 81° 37′.5 W.).	Sept. 9–16	1	([2])	0	−0.80	------	------	------	5.26	−1.65	------	------	------	7.16	2.76
E 8	0.2 mile S. 75° E. of Phoenix Park tank (30°22′.8 N., 81°38′.0 W.).	June 9–July 31	18	([2])	0	+0.29	------	------	------	4.67	−1.15	------	------	------	7.75	3.56
E 9	Foot of Market Street., waterfront, Jacksonville (30°19′.4 N., 81°39′.3 W.).	June 28–July 27	9	([2])	0	−0.43	------	------	------	4.83	−1.71	------	------	------	7.59	2.92
E 10	Ferry slip, South Jacksonville (30°19′.2 N., 81°39′.4 W.).	Aug. 2–7	3	([2])	0	−0.16	------	------	------	5.66	−0.61	------	------	------	6.76	3.60
	E. F. HICKS, 1933–34															
H 1	In channel between jetties (30°24′.0 N., 81°23′.0 W.).	Jan. 4–19, 1934	15	Pole	7	−2.84	−0.57	277	2.00	4.95	−4.00	−0.93	99	2.40	7.47	0.35
				Meter	7	−2.84	−0.53	------	1.79	5.07	−3.88	−1.02	------	2.12	7.35	0.37
				do	18	−3.65	−0.69	------	1.97	5.94	−3.82	−1.22	------	1.84	6.48	0.09
				do	29	−4.46	−0.69	------	1.83	6.82	−3.85	−1.37	------	1.61	5.60	12.26
H 2	0.5 mile N. 80° W. of Mayport tower (30°23′.7 N., 81°26′.1 W.).	Jan. 2–5, 1934	3	Pole	7	−3.62	−0.82	214	2.24	5.92	−3.81	−0.61	28	2.20	6.50	0.22
				Meter	7	−3.62	−0.92	------	2.19	5.82	−3.91	−0.41	------	2.17	6.60	0.22
				do	17	−3.72	−0.82	------	2.05	5.92	−3.91	−0.81	------	1.70	6.50	0.12
				do	27	−4.22	−0.62	------	1.85	6.52	−3.81	−0.91	------	1.16	5.90	0.04

See footnotes at end of table.

TABLE 1.—*Current Data, St. Johns River*—Continued

Station no.	Observer, location, and year	Observations				Slack	Flood strength			Flood duration	Slack	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time	True direction	Velocity			Time	True direction	Velocity		
	E. F. HICKS, 1933-34—Continued		*Days*		*Feet*	*Hours after high water*	*Hours after high water*	*Degrees*	*Knots*	*Hours*	*Hours after low water*	*Hours after low water*	*Degrees*	*Knots*	*Hours*	*Hours*
H 3	0.4 mile N. 89° W. of Mayport tower (30°23′.6 N., 81°26′.1 W.).	Jan. 2-8, 1934	6	Pole	7	−3.22	−0.12	212	2.26	5.42	−3.91	−0.81	20	2.99	7.00	0.42
				Meter	6	−3.12	−0.12	-------	2.15	5.32	−3.91	−1.01	-------	2.83	7.10	0.39
				do	15	−3.22	−0.42	-------	2.15	5.42	−3.91	−0.81	-------	2.32	7.00	0.34
				do	24	−3.72	−0.42	-------	1.89	6.02	−3.81	−1.01	-------	1.73	6.40	0.19
H 4	0.3 mile S. 88° W. of Mayport tower (30°23′.6 N., 81°26′.0 W.).	Jan. 5-7, 1934	2½	Pole	7	−2.62	0.10	210	2.12	4.52	−4.21	−1.41	32	3.64	7.90	0.40
				Meter	8	−2.62	0.00	-------	2.37	4.52	−4.21	−1.11	-------	3.51	7.90	0.45
				do	19	−2.92	−0.42	-------	2.33	4.72	−4.31	−1.11	-------	2.98	7.70	0.24
				do	30	−3.22	−0.82	-------	1.50	5.02	−4.31	−0.61	-------	1.90	7.40	0.19
H 5	Midchannel between Mile Point and Sherman Point (30°22′.9 N., 81°26′.7 W.).	Jan. 8-11, 1934	3	Pole	7	−2.92	−0.42	241	3.05	5.52	−3.51	−0.31	73	3.24	6.90	0.64
				Meter	7	−2.72	−0.22	-------	2.70	5.42	−3.41	−0.21	-------	2.92	7.00	0.79
				do	18	−3.22	−0.42	-------	2.50	5.92	−3.41	−0.11	-------	2.49	6.50	0.64
				do	29	−3.72	−0.42	-------	2.29	6.52	−3.31	−0.41	-------	1.77	5.90	0.47
H 6	Midchannel north of St. Johns bluff (30°23′.4 N., 81°29′.5 W.).	Jan. 11-14, 1934	3	Pole	7	−2.52	0.30	244	1.59	4.62	−4.01	−0.01	59	2.37	7.80	0.87
				Meter	7	−2.62	0.20	-------	1.52	4.82	−3.91	0.19	-------	2.15	7.60	0.90
				do	17	−2.72	0.00	-------	1.66	5.02	−3.81	−0.01	-------	1.96	7.40	0.80
				do	26	−3.22	0.00	-------	1.62	5.42	−3.91	0.19	-------	1.62	7.00	0.70
H 7	0.1 mile northward of highway bridge, Clapboard Creek (30°24′.4 N., 81°30′.5 W.).	Dec. 14, 1933-Jan. 26, 1934.	3	Pole	3½	−4.92	−1.72	30	1.03	6.22	−4.81	−2.81	214	1.33	6.20	11.29
				Meter	2, 3	−5.12	−1.22	-------	1.18	6.32	−4.91	−2.91	-------	1.49	6.10	11.31
				do	10, 12	−5.32	−1.72	-------	1.03	6.62	−4.81	−2.41	-------	1.19	5.80	11.29
H 8	Midchannel between Coon Point and Long Island (30°24′.2 N., 81°31′.7 W.).	Feb. 12-15, 1934	3	Pole	3½	−2.72	−0.92	301	0.90	4.92	−3.91	−0.61	126	0.90	7.50	0.39
				Meter	3	−3.02	−1.02	-------	0.97	5.32	−3.81	−0.71	-------	0.92	7.10	0.29
				do	11	−3.02	−0.22	-------	0.94	5.62	−3.51	−0.21	-------	0.70	6.80	0.69
H 9	0.3 mile N. 57° E. of New Berlin church (30°24′.2 N., 81°32′.9 W.).	Feb. 6-9, 1934	3	Pole	7	−1.62	0.60	204	1.97	5.62	−2.11	0.79	24	2.38	6.80	1.85
				Meter	7	−1.42	0.90	-------	1.95	5.42	−2.11	0.99	-------	2.38	7.00	2.02
				do	17	−2.02	0.40	-------	1.89	6.02	−2.11	0.89	-------	1.67	6.40	1.72
				do	27	−2.42	0.40	-------	1.26	6.42	−2.11	0.79	-------	0.81	6.00	1.60
H 10	0.6 mile N. 63° E. of east end of Crab Island (30°23′.7 N., 81°34′.5 W.).	Dec. 14, 1933-Jan. 4, 1934.	3	Pole	2¼	−2.72	−0.72	284	0.56	4.82	−4.01	0.29	79	1.14	7.60	0.64
				Meter	1	−2.72	−0.92	-------	0.56	4.92	−3.91	0.19	-------	1.28	7.50	0.59
				do	5, 6	−2.72	−0.32	-------	0.44	5.42	−3.41	−0.01	-------	1.14	7.00	0.82
H 11	0.2 mile N. 76° E. of east end of Pauline Island (30°22′.5 N., 81°34′.3 W.).	Dec. 14-16, 1933	2	Pole	3¾	5.80	−2.92	119	0.66	6.82	−5.91	−3.31	306	0.49	5.60	10.16
				Meter	3	5.90	−2.92	-------	0.66	6.72	−5.91	−3.11	-------	0.58	5.70	10.24
				do	12	(3)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
H 12	0.3 mile N. 81° W. of west end of Crab Island (30°23′.5 N., 81°35′.8 W.).	Dec. 11-14, 1933	3	Pole	2½	−1.32	0.90	298	0.36	5.02	−2.41	1.49	120	0.43	7.40	2.10
				Meter	2	−1.52	0.70	-------	0.41	5.52	−2.11	1.59	-------	0.54	6.90	2.10
				do	5	−1.42	0.70	-------	0.38	5.82	−1.71	1.89	-------	0.49	6.60	2.30
H 13	0.7 mile N. 15° W. of west end of Crab Island (30°24′.1 N., 81°36′.6 W.).	do	3	Pole	3½	−1.72	0.70	273	0.49	5.52	−2.31	0.69	96	0.76	6.90	1.77
				Meter	2	−1.62	0.60	-------	0.53	5.42	−2.31	0.89	-------	0.85	7.00	1.82
				do	7	−1.72	0.50	-------	0.51	5.42	−2.41	0.99	-------	0.64	7.00	1.77
H 14	Midchannel between Drummond Point and Reddie Point (30°24′.2 N., 81°36′.5 W.).	Jan. 24-26; 29-30, 1934.	3	Pole	7	−1.32	1.20	246	1.44	5.72	−1.71	1.09	68	1.77	6.70	2.25
				Meter	6	−1.42	1.00	-------	1.63	5.82	−1.71	1.19	-------	1.78	6.60	2.20
				do	15	−1.42	1.10	-------	1.65	5.82	−1.71	1.19	-------	1.57	6.60	2.22
				do	24	−1.42	1.10	-------	1.47	5.92	−1.61	1.49	-------	1.30	6.50	2.32
H 15	0.3 mile east of Phoenix Park tank (30°22′.9 N., 81°37′.8 W.).	Jan. 10-13, 1934	3	Pole	7	−0.92	2.30	169	1.39	6.12	−0.91	1.89	342	1.04	6.30	3.02
				Meter	6	−1.12	2.00	-------	1.44	6.32	−0.91	1.89	-------	0.98	6.10	2.90
				do	15	−1.22	2.10	-------	1.32	6.42	−0.91	2.19	-------	1.16	6.00	2.97
				do	24	−1.22	2.30	-------	1.09	6.62	−0.71	2.39	-------	0.40	5.80	3.12
H 16	0.2 mile N. 66° E. of U. S. Engineers dock, Long Branch (30°21′.5 N., 81°37′.1 W.).	Dec. 18-21, 1933	3	Pole	7	−0.92	1.90	181	1.13	5.22	−1.81	1.79	356	0.92	7.20	2.67
				Meter	4	−0.82	1.90	-------	1.12	5.02	−1.91	1.49	-------	1.00	7.40	2.60
				do	10	−0.92	1.90	-------	1.17	5.22	−1.81	1.59	-------	0.93	7.20	2.62
				do	16	−1.02	1.90	-------	1.21	5.22	−1.91	2.19	-------	0.83	7.20	2.72
H 17	0.3 mile N. 83° E. of U. S. Engineers dock, Long Branch (30°21′.4 N., 81°37′.0 W.).	do	3	Pole	7	−0.62	2.00	173	0.93	5.12	−1.61	1.39	359	1.22	7.30	2.72
				Meter	7	−0.62	2.00	-------	0.71	5.02	−1.71	1.49	-------	1.01	7.40	2.72
				do	16	−0.72	1.80	-------	0.87	5.32	−1.51	2.09	-------	0.97	7.10	2.85
				do	29	−1.02	1.70	-------	0.85	5.72	−1.41	2.49	-------	0.77	6.70	2.87
H 18	0.4 mile N. 82° E. of U. S. Engineers dock, Long Branch (30°21′.5 N., 81°36′.8 W.)	do	3	Pole	6¾	−0.52	1.60	178	0.69	5.02	−1.61	0.79	357	1.04	7.40	2.50
				Meter	5	−0.62	1.50	-------	0.56	5.02	−1.71	0.89	-------	0.93	7.40	2.45
				do	13	−0.62	1.80	-------	0.71	5.32	−1.41	0.69	-------	0.81	7.10	2.55
				do	20	−0.62	2.00	-------	0.55	5.32	−1.41	0.89	-------	0.64	7.10	2.65
H 19	0.5 mile S. 83° W. of Empire Point (30°19′.0 N., 81°37′.6 W.).	Jan. 15-18, 1934	3	Pole	7	−0.42	2.50	251	0.91	5.92	−0.61	1.99	69	0.85	6.50	3.30
				Meter	8	−0.52	2.70	-------	0.81	6.12	−0.51	2.29	-------	0.82	6.30	3.42
				do	20	−0.52	2.50	-------	0.94	6.22	−0.41	2.89	-------	0.79	6.20	3.55
				do	32	−0.62	2.70	-------	1.14	6.22	−0.51	3.09	-------	0.59	6.20	3.60
H 20	Midchannel, off Clyde steamship wharves, Jacksonville (30°19′.3 N., 81°39′.2 W.).	Dec. 26-29, 1933 [4]	3	Pole	8½	−1.12	2.00	281	2.39	6.42	−0.81	2.09	118	1.82	6.00	2.97
				Meter	6	−1.22	2.00	-------	1.74	6.22	−1.11	2.39	-------	1.35	6.20	2.95
				do	15	−1.22	1.90	-------	2.02	6.22	−1.11	2.29	-------	1.65	6.20	2.90
				do	24	−1.22	1.50	-------	1.86	6.22	−1.11	2.59	-------	1.44	6.20	2.87
H 21	Center of draw, Florida East Coast Ry. bridge, Jacksonville (30°19′.3 N., 81°39′.9 W.).	do.[4]	3	Pole	7	−1.22	2.30	SW.	1.98	6.52	−0.81	2.29	NE.	1.58	5.90	3.07
				Meter	6	−1.22	2.30	-------	1.92	6.52	−0.81	2.39	-------	1.36	5.90	3.10
				do	15	−1.22	2.00	-------	1.79	6.42	−0.91	2.39	-------	1.30	6.00	3.00
				do	24	−1.22	2.20	-------	1.29	6.42	−0.91	2.19	-------	1.05	6.00	3.00

See footnotes at end of table.

Station no.	Observer, location, and year	Observations				Slack	Flood strength			Flood duration	Slack	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time	True direction	Velocity			Time	True direction	Velocity		
	E. F. HICKS, 1933-34—Continued		*Days*		*Feet*	*Hours after high water*	*Hours after high water*	*Degrees*	*Knots*	*Hours*	*Hours after low water*	*Hours after low water*	*Degrees*	*Knots*	*Hours*	*Hours*
H 22	0.2 mile S. 60° E. of Winter Point (30°18'.5 N., 81°40'.5 W.).	Dec. 26-29, 1933 [4]	3	Pole	7	−1.12	2.50	200	1.23	7.42	0.19	2.69	15	0.98	5.00	3.50
				Meter	6	−1.22	2.00	------	1.30	7.42	0.09	2.79	------	1.07	5.00	3.35
				do	14	−1.12	2.00	------	1.08	7.32	0.09	2.59	------	1.00	5.10	3.32
				do	22	−1.12	2.90	------	0.84	7.52	0.29	2.89	------	0.79	4.90	3.67
H 23	0.7 mile S. 31° E. of Orange Park landing (30°09'.3 N., 81°41'.1 W.).	Jan. 31, Feb. 2, 14-16, 1934.	4	Pole	6	0.10	2.60	179	0.63	5.10	−0.91	2.59	13	0.77	7.32	3.53
				Meter	6	0.20	2.60	------	0.56	5.00	−0.91	2.69	------	0.67	7.42	3.58
				do	15	0.20	2.50	------	0.65	5.00	−0.91	2.59	------	0.71	7.42	3.53
				do	24	−0.22	2.50	------	0.53	5.42	−0.91	2.49	------	0.54	7.00	3.40
H 24	Center of draw, highway bridge, Old Field Point (29°59'.1 N., 81°37'.8 W.).	Jan. 29-31, 1934 [4]	2	Pole	6	−0.32	2.90	SE.	0.89	7.42	0.99	3.09	NW.	0.52	5.00	4.10
				Meter	4	−0.22	2.90	------	0.89	7.42	1.09	2.99	------	0.59	5.00	4.12
				do	14	−0.22	2.90	------	0.82	7.52	1.19	3.09	------	0.44	4.90	4.17
H 25	0.8 mile S. 89° W. of Tocoi wharf (29°50'.7 N., 81°34'.5 W.).	Jan. 31, Feb. 2, 1934.	2	Pole	3½	2.50	4.70	161	0.31	4.30	0.69	3.19	350	0.38	8.12	5.20
				Meter	3	(5)	4.40	------	0.44	------	(5)	------	------	0.45	------	------
				do	12	(5)	4.70	------	0.50	------	(5)	------	------	0.42	------	------
H 26	0.3 mile N. 85° E. of Verdiere Point (29° 43'.2 N., 81°34'.2 W.).	Feb. 7-9, 1934	2	Pole	3½	2.90	4.80	209	0.30	5.20	1.99	5.59	43	0.30	7.22	6.25
				Meter	3	2.70	4.90	------	0.24	5.00	1.59	5.49	------	0.32	7.42	6.10
				do	10	2.50	5.00	------	0.30	5.30	1.69	5.49	------	0.35	7.12	6.10
H 27	Center of draw, highway bridge, Palatka (29°38'.8 N. 81°37'.5 W.).	Feb. 5-7, 1934	2	Pole	6	3.80	6.40	SW.	0.33	6.00	3.69	7.51	NE.	0.32	6.42	7.78
				Meter	4	4.00	6.40	------	0.37	6.00	3.89	7.21	------	0.35	6.42	7.81
				do	14	3.80	6.60	------	0.35	6.30	3.99	7.31	------	0.35	6.12	7.86
H 28	Midstream, west of Smith's landing (29° 32' N., 81°41' W.).[7]	Feb. 8-10, 1934 [4]	2	Pole	6	4.50	8.30	148	0.60	7.70	6.09	7.91	324	0.27	4.72	9.13
				Meter	4	(6)	------	------	------	------	------	------	------	------	------	------
				do	15	(6)	------	------	------	------	------	------	------	------	------	------
H 29	0.2 mile east of Black Point (29°24' N., 81°39' W.).[7]	Feb. 12-14, 1934	2	Pole	6½	8.40	10.10	159	0.16	3.30	5.59	10.51	345	0.32	9.12	11.08
				Meter	3	(8)	------	------	------	------	------	------	------	------	------	------
				do	12	(8)	------	------	------	------	------	------	------	------	------	------
H 30	0.5 mile S. 66° W. of Empire Point (30°18'.9 N., 81°37'.5 W.).	Feb. 20-23, 1934	3	Pole	6	−0.42	1.90	239	0.69	4.62	−1.91	1.69	68	1.33	7.80	2.75
				Meter	4	−0.52	1.40	------	0.56	4.72	−1.91	1.99	------	1.00	7.70	2.67
				do	11	−0.42	2.10	------	0.73	5.02	−1.51	1.89	------	1.24	7.40	2.95
				do	18	−0.62	2.10	------	0.76	5.42	−1.31	1.59	------	1.15	7.00	2.87
H 31	1.1 miles S. 16° E. of U. S. Engineers dock, Long Branch (30°20'.4 N., 81°37'.0 W.).	Feb. 26-27, 1934	1	Pole	7	−0.92	2.00	187	1.05	6.32	−0.71	1.99	26	1.40	6.10	3.02
				Meter	6	−0.72	2.10	------	1.10	5.72	−1.11	1.69	------	1.30	6.70	2.92
				do	15	−0.62	2.30	------	1.04	5.62	−1.11	2.29	------	1.19	6.80	3.15
				do	24	−0.62	2.20	------	0.87	5.72	−1.01	2.29	------	1.07	6.70	3.15
H 32	0.7 mile S. 60° E. of Phoenix Park tank (30°22'.6 N., 81°37'.4 W.).	Feb. 19, 20, 22, 23, 1934.	3	Pole	6	−0.32	2.00	151	1.23	4.62	−1.81	2.49	337	1.70	7.80	3.02
				Meter	4	−0.11	2.20	------	1.05	4.32	−1.91	2.49	------	1.56	8.10	3.10
				do	11	−0.42	1.70	------	1.06	4.52	−2.01	2.69	------	1.57	7.90	2.92
				do	18	−0.72	1.50	------	0.83	5.12	−1.71	2.39	------	0.86	7.30	2.80
H 33	0.3 mile N. 23° W. of Shipyard Creek mouth (30°23'.6 N., 81°30'.4 W.).	Feb. 15-17, 19-20, 1934.	3	Pole	7	−2.62	0.10	333	1.54	5.02	−3.71	−0.61	161	2.09	7.40	0.72
				Meter	6	−2.42	0.10	------	1.52	4.72	−3.81	−0.61	------	2.12	7.70	0.75
				do	15	−2.62	−0.32	------	1.53	5.02	−3.71	−0.61	------	1.62	7.40	0.62
				do	24	−2.82	−0.12	------	1.44	5.32	−3.61	−0.41	------	1.19	7.10	0.69
H 34	0.3 mile S. 85° W. of draw, Sisters Creek Bridge (30°23'.4 N., 81°28'.1 W.).	Feb. 19-22, 1934	3	Pole	6½	−2.62	−0.52	317	2.02	5.22	−3.51	−0.31	136	2.82	7.20	0.69
				Meter	7	−2.62	−0.92	------	1.98	5.32	−3.41	−0.01	------	2.64	7.10	0.69
				do	17	−2.82	−0.72	------	1.87	5.62	−3.31	0.09	------	2.17	6.80	0.74
				do	26	−3.02	−0.32	------	1.62	5.72	−3.41	0.39	------	1.59	6.70	0.84
H 35	Center of draw, Sisters Creek Bridge (30°23'.4 N., 81°27'.7 W.).	Feb. 20-23, 1934	3	Pole	3½	−6.52	−3.82	N.	1.59	6.10	−6.53	−3.61	S.	1.61	6.32	9.73
				Meter	3	−6.62	−3.92	------	1.45	6.40	−6.33	−3.41	------	1.48	6.02	9.78
				do	10	−6.62	−4.12	------	1.22	6.30	−6.43	−3.61	------	1.22	6.12	9.66

1 Number of slack waters divided by 4. Stations E1 to E10 only.
2 Times probably determined by watching movements of water surface or of floating objects.
3 Times of slacks and strengths indefinite; velocity generally less than ½ knot.
4 Northerly winds.
5 Current weak and times of slack and ebb strength for the meter depths indefinite.
6 At meter depths, slacks and strengths are indefinite. Average observed velocity about ½ knot.
7 Latitude and longitude approximate.
8 At meter depths, slacks and strengths are indefinite. Average observed velocity about ¼ knot.

For reference to above table, see p. 20.

TABLE 2.—*Current Harmonic Constants, Between Jetties, St. Johns River Entrance*

[Jan. 5–19, 1934, 15 days]

Constituent	Velocity	Epoch		Constituent	Velocity	Epoch	
	H	Local (κ)	Greenwich		*H*	Local (κ)	Greenwich
	Knots	*Degrees*	*Degrees*		*Knots*	*Degrees*	*Degrees*
K_1	0.216	93	174	M_8	0.044	29	320
M_2	1.935	209	12	N_2	0.404	188	351
M_4	0.284	95	61	O_1	0.174	111	192
M_6	0.089	185	314	S_2	0.333	232	34

Epochs apply to the westward strengths of the several constituents.
The local epochs refer to the local meridian, Greenwich epochs to the Greenwich meridian.
For reference to above table, see p. 21.

Part II.—SAVANNAH RIVER

INTRODUCTION

The Savannah River for its entire length of several hundred miles forms the boundary between the States of South Carolina and Georgia. It flows in a southeastward direction and in about latitude 32° N. empties into the Atlantic Ocean through Tybee Roads, an area of relatively deep water surrounded by shoals. The river is navigable for small craft for a distance of more than 200 miles, and for vessels of 25-foot draft for about 20 nautical miles from its mouth. The city of Savannah, one of our important South Atlantic ports, is about 15 miles above the river entrance, and a dredged channel having a least depth of 28 feet at mean low water and a width of 400 to 500 feet leads from the sea to its wharves. The south jetty at the entrance together with Cockspur Island, Long Island, Bird Island, and Elba Island form a continuous barrier about 10 miles long which separates the portion of the river known as South Channel from the main channel which lies north of the barrier. Fields Cut and Wilmington River, which connect with the Savannah River on the north and south respectivly, are passageways to the intercommunicating rivers and sounds that lie within the South Carolina and Georgia coastline. The first two waterways just mentioned together with that portion of the Savannah River between their points of entrance form parts of the Intracoastal Waterway.

The water area covered in this discussion includes only the lower part of the Savannah River for a distance of about 25 nautical miles from its mouth, the approach to the river through Tybee Roads, and the nearby connecting inland waterways to the northward and southward.

The average rise and fall of the tide at the mouth of the river is 6.8 feet; in the vicinity of Savannah, it is 7.4 feet; at the Atlantic Coast Line Railway bridge, about 11 miles above Savannah, it is 6.2 feet; and 20 miles above Savannah, it is said to be less than 1 foot. This rise and fall is accompanied by tidal currents which in the channel between the sea and the Atlantic Coast Line bridge have average velocities at strength of from 1 to 3 knots. In Tybee Roads the average velocity at strength is between 1 and 2 knots; in the river from the entrance to Savannah it is between 2 and 3 knots, and from Savannah to the Atlantic Coast Line bridge it is generally between 1 and 2 knots, except at the Seaboard Railway bridge, where it is 3 knots. In the nearby connecting inland waterways the tidal current velocity is generally between 1 and 2 knots, except in the entrance to Calibogue Sound, where it is nearly 2½ knots.

The velocities mentioned above are those of the periodic flood and ebb which accompany the rise and fall of the tide. Combined with the tidal current velocities are those of nonperiodic currents which vary from time to time with changes in precipitation and in the velocity and direction of the wind. The drainage currents, of course, flow toward the sea and thus decrease the flood velocity and increase that of the ebb, whereas currents due to wind may set in either a flood or an ebb direction, modifying the flow accordingly. In most of the area under consideration the tidal flow predominates, its velocity being of sufficient magnitude to overcome the usual drainage and weather effects. At the Atlantic Coast Line Railway bridge across the Savannah River, however, and presumably at times below this point, it appears that the drainage current is of sufficient velocity to produce a continuous down-stream flow, the strengths of flood and ebb of the tidal current producing minimum and maximum velocities of this flow. In all parts of the area the velocities, as well as the times and directions of the tidal flow, are, of course, subject to the modifying influences of nontidal movements.

Daily predictions of the times and velocities of the current in the channel between the jetties at the entrance to the Savannah River are given in the annual Current Tables for the Atlantic Coast of North America.

OBSERVATIONS

Current observations at numerous locations in the Savannah River were secured by United States Coast and Geodetic Survey field parties during the years 1852 and 1874. As extensive physiographic changes have taken place in the area since these early observations were made, the results are not applicable to present conditions and they are, therefore, omitted from this publication.

At various times investigations of the currents in the Savannah River have been made by the United States Army Engineers in connection with improvement projects. Of these, only the results of observations taken in 1930 are included in this discussion. They comprise results from one-half day of observations at 3 depths at each of 5 stations in each of 8 cross-sections of the river, a total of 40 current stations. Published results of an earlier investigation are contained in the Annual Report of the Chief of Engineers, United States Army, part 2, 1890, page 1273 et seq.

In 1927, 2 days of current observations were secured in the channel between the jetties at the Savannah River entrance by a Coast and Geodetic Survey hydrographic party in charge of R. L. Schoppe. In April, May, and June 1934, a current survey party in charge of E. F. Hicks occupied 35 current stations in the river and vicinity. At each station observations were taken at the surface and at several subsurface depths, the usual length of series at each station being 3 days. A continuous series of observations covering a period of 16 days was secured at a location between the jetties at the entrance.

It is upon the results derived from the last-mentioned survey that the present discussion is chiefly based.

METHOD OF OBSERVING

In the 1934 current survey of the Savannah River, as in similar recent surveys conducted by the Coast and Geodetic Survey, the current pole and the Price current meter were used in making the measurements. These devices and their use are described on page 17 of this volume. The observations of Schoppe in 1927 were made

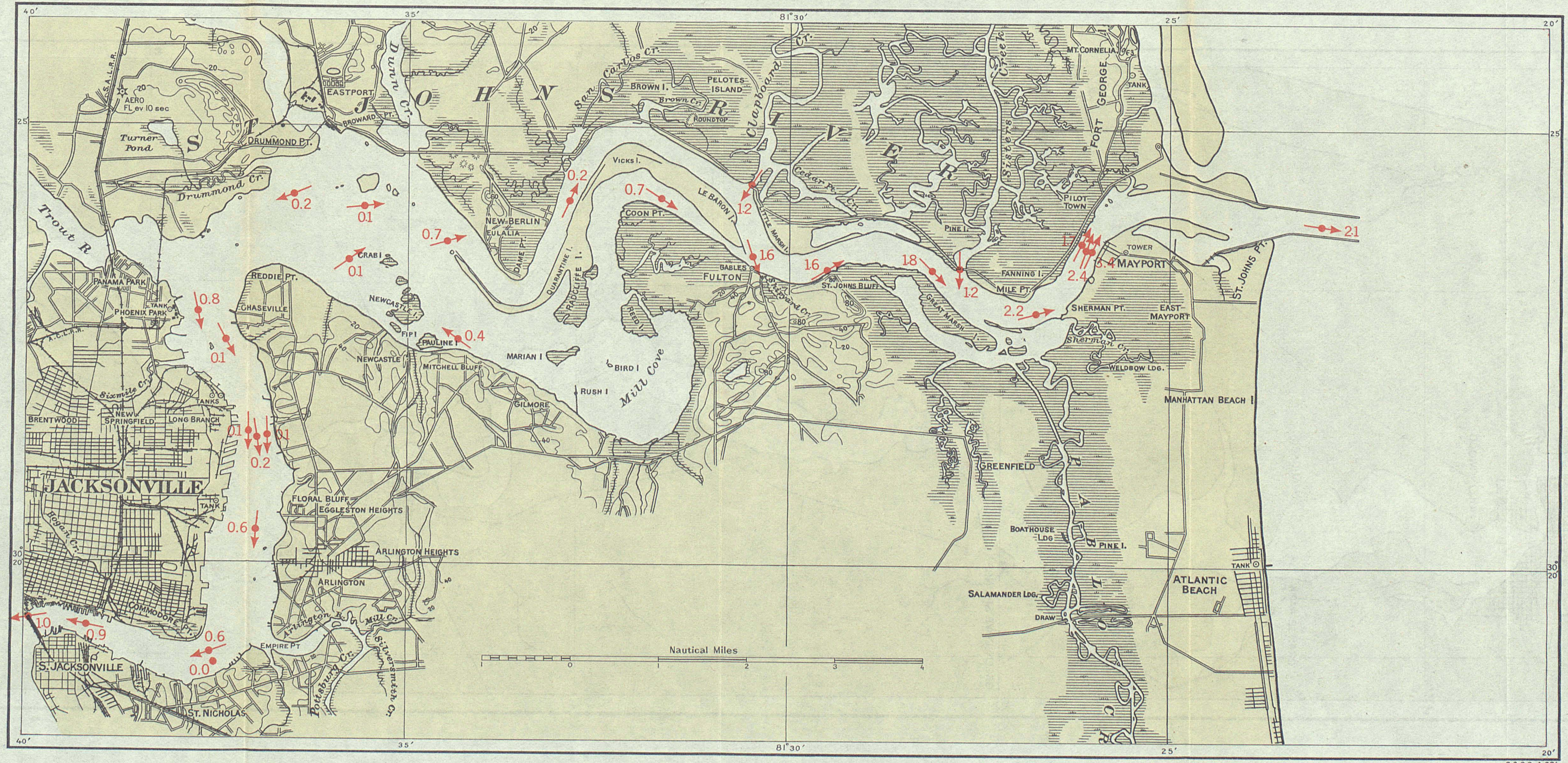

Fig. 25. Currents below Jacksonville 2 hours before low water at Mayport.

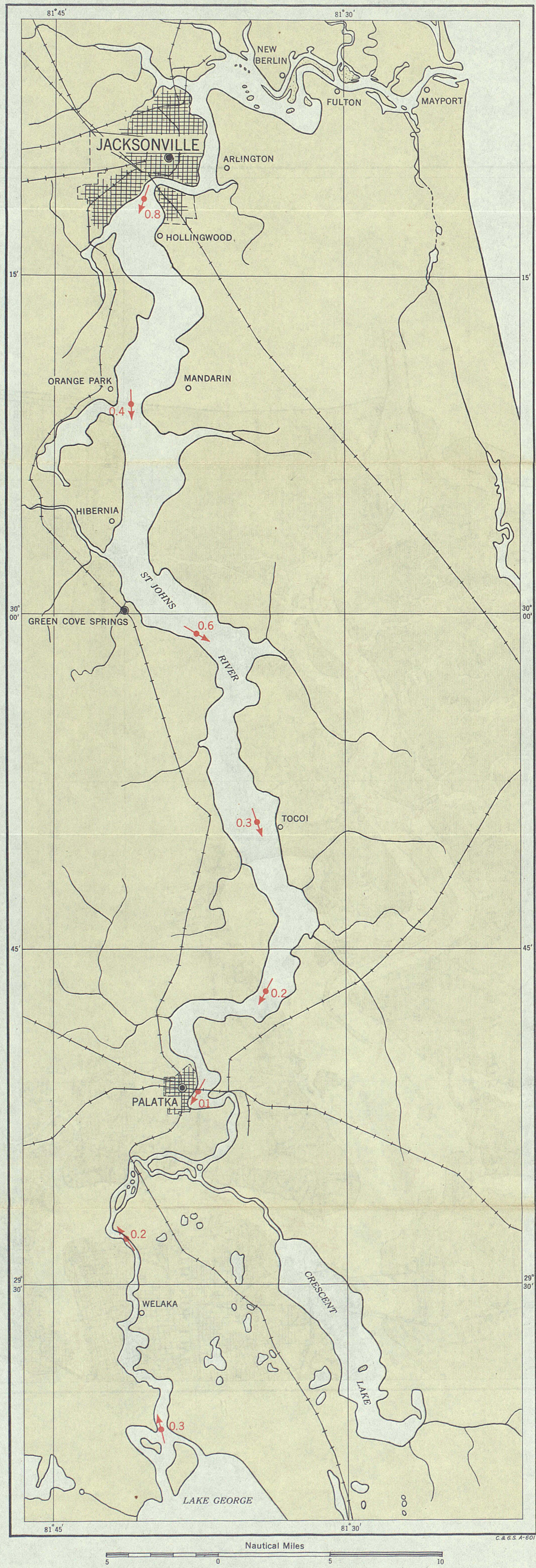

Fig. 26. Currents above Jacksonville 2 hours before low water at Mayport.

by pole only, and those of the Army Engineers in 1930 by current meter only.

METHODS OF REDUCING THE OBSERVATIONS

The method of reduction used for the current stations in the Savannah River was the same as that described on page 18, part I, for current station no. 1 in the St. Johns River, except that tides at Tybee Light instead of those at Mayport were used as a reference.

Two of the 1934 current stations, one in the entrance to Fields Cut and the other in the entrance to Wilmington River, show a departure from the usual reversing current in that the velocity in the flood direction increases to a maximum, decreases to a minimum, and then increases to a second maximum during each flood period of about 6 hours. Tabulations and reductions for these stations were made in the usual manner, except that the flood was divided into three phases designated first strength of flood, minimum flood, and second strength of flood. The times, directions, and velocities of each of these phases were subjected to the processes usually employed in reducing normal flood or ebb strengths.

The 16-day series of current observations taken between the jetties was reduced by harmonic analysis and comparison with Tybee Light tides as described on page 19, part I, for a similar series in the St. Johns River.

PRESENTATION OF THE RESULTS

DESIGNATION AND LOCATION OF STATIONS

Each current station occupied by the Coast and Geodetic Survey in the Savannah River area, for which results are included in this volume, has been given a designation which consists of two parts: First, a letter signifying the chief of the party that occupied the station and second, the number which was originally assigned to the particular station of that party. The letter H forms the first part of the designation of each station occupied by E. F. Hicks in 1934, and the letter S, that of the station occupied by R. L. Schoppe in 1927. The locations of the stations are indicated in figure 37 by red circles together with the station designations. The positions of the cross-sections in which observations were taken by the Army Engineers in 1930 are shown by red dashed lines accompanied by the numbers originally assigned to the sections by the engineers. The positions and numbers of the stations in the cross sections are not shown in the figure. In the results given in table 3 they are numbered from 1 to 5 in each cross section, the numbers running consecutively from north to south.

EXPLANATION OF THE TABULAR DATA

Tables 3 and 4 contain the results derived from current observations in the Savannah River and vicinity. The explanation given on page 20 for table 1, part I, of this volume applies to these two tables, except that for a reference Tybee Light instead of Mayport tides are used and the slack before flood is referred to low water instead of high water and the slack before ebb to high instead of low water. By this arrangement the time of each current phase, for the area as a whole, is referred to the nearest tide phase. Because of characteristic irregularities in the currents at stations H 9 and H 32, additional current phases are given in table 4.

The harmonic constants derived from the 16-day series of observations at station H 4 between the jetties are given in table 5. The explanation of the constants from a similar series in the St. Johns River given on page 21, part I, applies to these constants.

The daily predictions of the current in Savannah River entrance given in the Atlantic Coast Current Tables are based upon these harmonic constants.

OBSERVED CURRENT CURVES

In figures 38 and 39 are reproduced a number of velocity curves plotted directly from pole observations taken in 1934. The explanation and general remarks for similar curves for stations in the St. Johns River given on page 21 apply to these curves.

The curves for stations H 32 and H 9 in figure 38 are of particular interest in that they show very marked departures from the usual

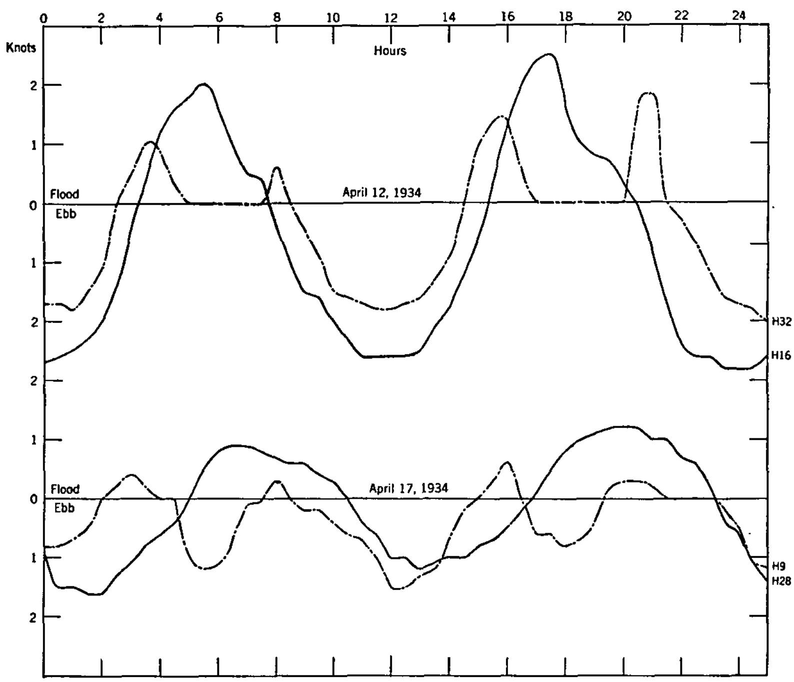

FIGURE 38.—Observed velocity curves, Savannah River and vicinity.

flood and ebb conditions typified by the curves for stations H 16 and H 28. Station H 32 is just inside the north entrance to the Wilmington River, which branches off from the Savannah River about 3 miles below the city of Savannah and flows into Wassaw Sound. The peculiar shape of the current curve at this station probably results from the fact that at this station the movement of the water is affected by the tidal currents in both streams. The excess of the ebb flow over that of the flood indicates that there is a considerable discharge of water from the Savannah River through the Wilmington River.

Station H 9 is at the south end of Fields Cut, which connects the Savannah River with Wright River. At this station also the currents are affected by the tidal movement in two different rivers, a fact which undoubtedly contributes to the irregularity of the current curve. Here also there is an excess in the ebb flow signifying some discharge of the waters of the Savannah River through Fields Cut into Wright River.

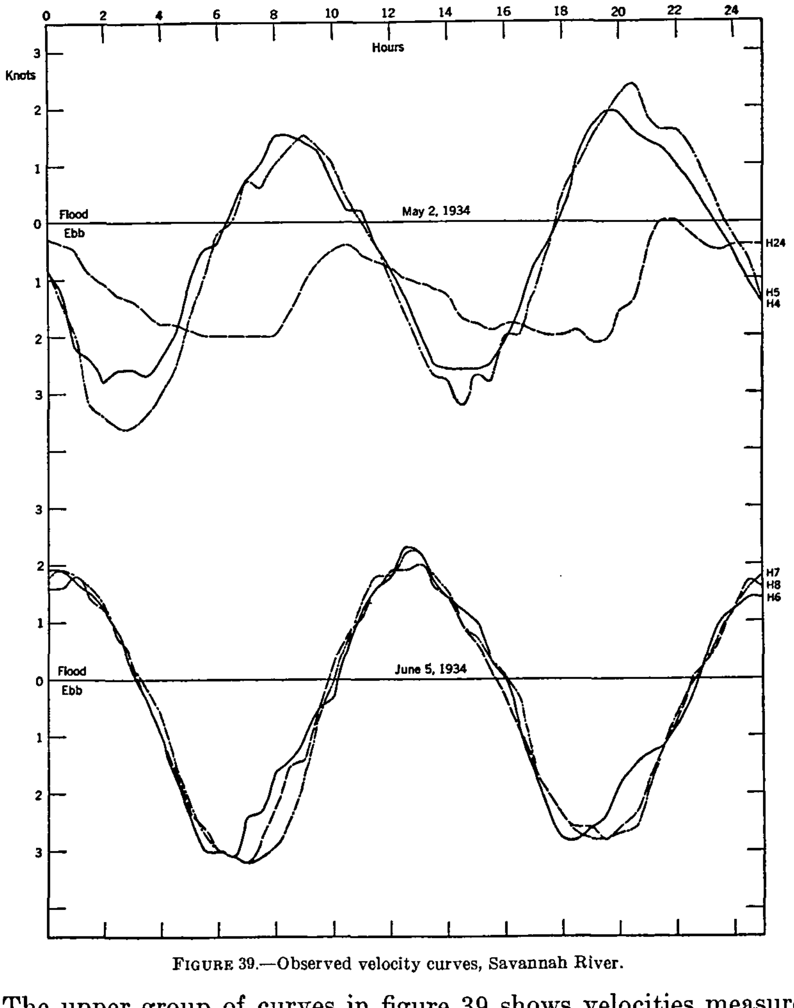

FIGURE 39.—Observed velocity curves, Savannah River.

The upper group of curves in figure 39 shows velocities measured onMay 2, 1934, at stations H 4 and H 5 near the mouth of the Savannah River and at station H 24 at the Atlantic Coast Line bridge. The curves for stations H 4 and H 5 indicate that the current is somewhat later and the velocities generally larger at station H 5 than at station H 4. Comparing the curves for stations H 4 and H 24 it is seen that the strengths of ebb at the Atlantic Coast Line bridge occur approximately 4 hours later than those between the jetties. The minimum ebb velocities, however, which correspond to flood strengths of the tidal current occur only about 2 hours later at the bridge than between the jetties. It appears from these values that the strength of flood advances up the river at a rate greater than the rate of advance of the strength of ebb. This difference in the rates of advance of the two strengths is accompanied by an alteration in the shape of the current curve, the change from flood strength to ebb strength being more gradual and that from ebb strength to flood strength more rapid at the Atlantic Coast Line bridge than in the lower part of the river. An examination of the curves for stations H 4 and H 24, figure 39, shows a resultant seaward flow of about one-half knot at station H 4 and about 1 knot at station H 24. As the average nontidal current from 16 days of observations at station H 4 was also one-half knot, it may be inferred that on May 2, 1934, conditions of stream flow were near average and that the three curves for that date reflect the usual drainage flow at the three stations.

The lower group of curves in figure 39 is plotted from simultaneous pole observations at stations H 6, H 7, and H 8 located in a section of the river between Long Island and Jones Island. Station H 7 is in the dredged channel with stations H 6 and H 8 to the southward and northward respectively, each outside the dredged area. The curves show that the current is very nearly the same in time and velocity at each of the three locations. The most noticeable differences appear during the ebb portion of the cycle when there seems to be a decided tendency for the current to run near its maximum velocity longer at the middle station, H 7, than at the other two stations. At station H 6 the period during which the current is near its maximum ebb velocity is particularly short and the ebb maximum occurs definitely earlier than at the other stations.

Most of the features brought out by the plottings of figures 38 and 39 are shown in the average results of tables 3 and 4. They are, however, more easily seen in the graphic form and it is believed that a brief study of the illustrations will aid in interpreting quickly the tabular results for these and other current stations.

TIME RELATION OF CURRENT TO TIDE

Figure 40 shows the times of the slacks and strengths of current in the channel of the Savannah River in their relation to each other and to the local high and low waters. The curves for the several current phases were drawn through points plotted from observations at a number of current stations in or near the channel from Tybee Roads to the Atlantic Coast Line Ry. bridge. The curves representing the times of high and low waters were similarly drawn through points plotted from the results of tide observations. The plotted times of both tide and current are reckoned from the moon's transit of the meridian of Greenwich. The scale along the top of the illustration represents nautical miles measured along the channel from the position of current station H 1 in the entrance to Tybee Roads. Below this scale are given the names of a number of points along the river.

The curves show that, in general, all the phases of the tide and current movements in the Savannah River become later as the distance from the sea increases. However, as pointed out for the flood and ebb strengths in the preceding section, the different phases of tide and current advance up the river at different rates with attendant changes in the character of the movements.

FIGURE 40.—Tide and current intervals, Savannah River.

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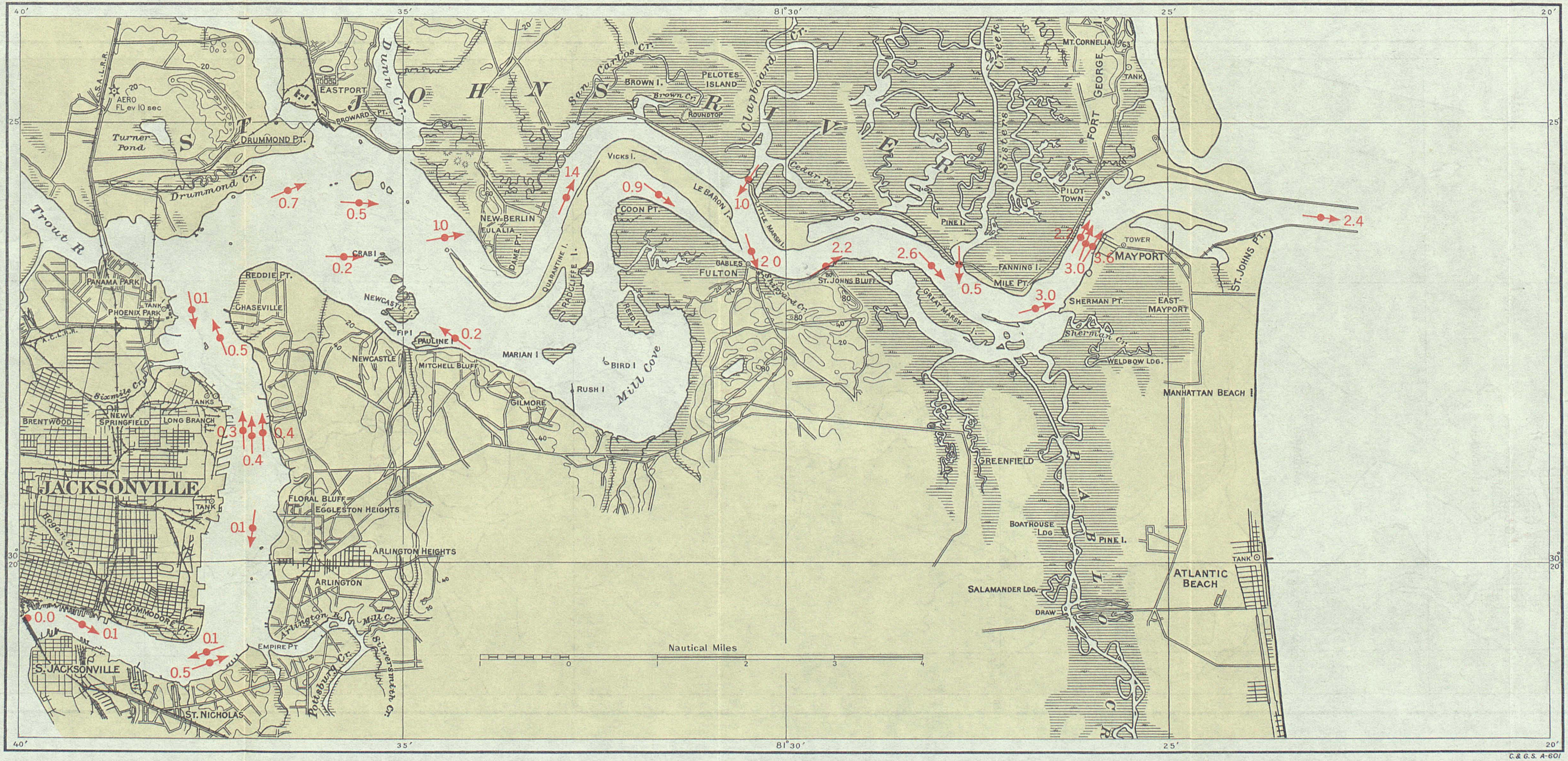

Fig. 27. Currents below Jacksonville 1 hour before low water at Mayport.

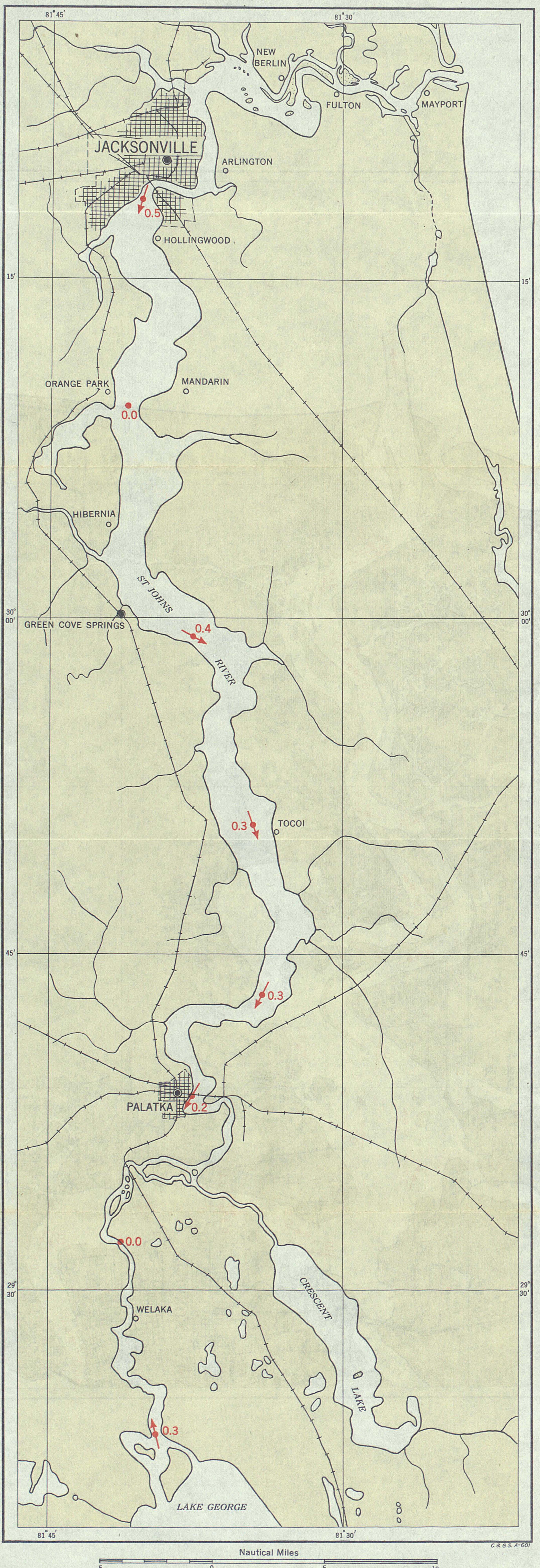

Fig. 28. Currents above Jacksonville 1 hour before low water at Mayport.

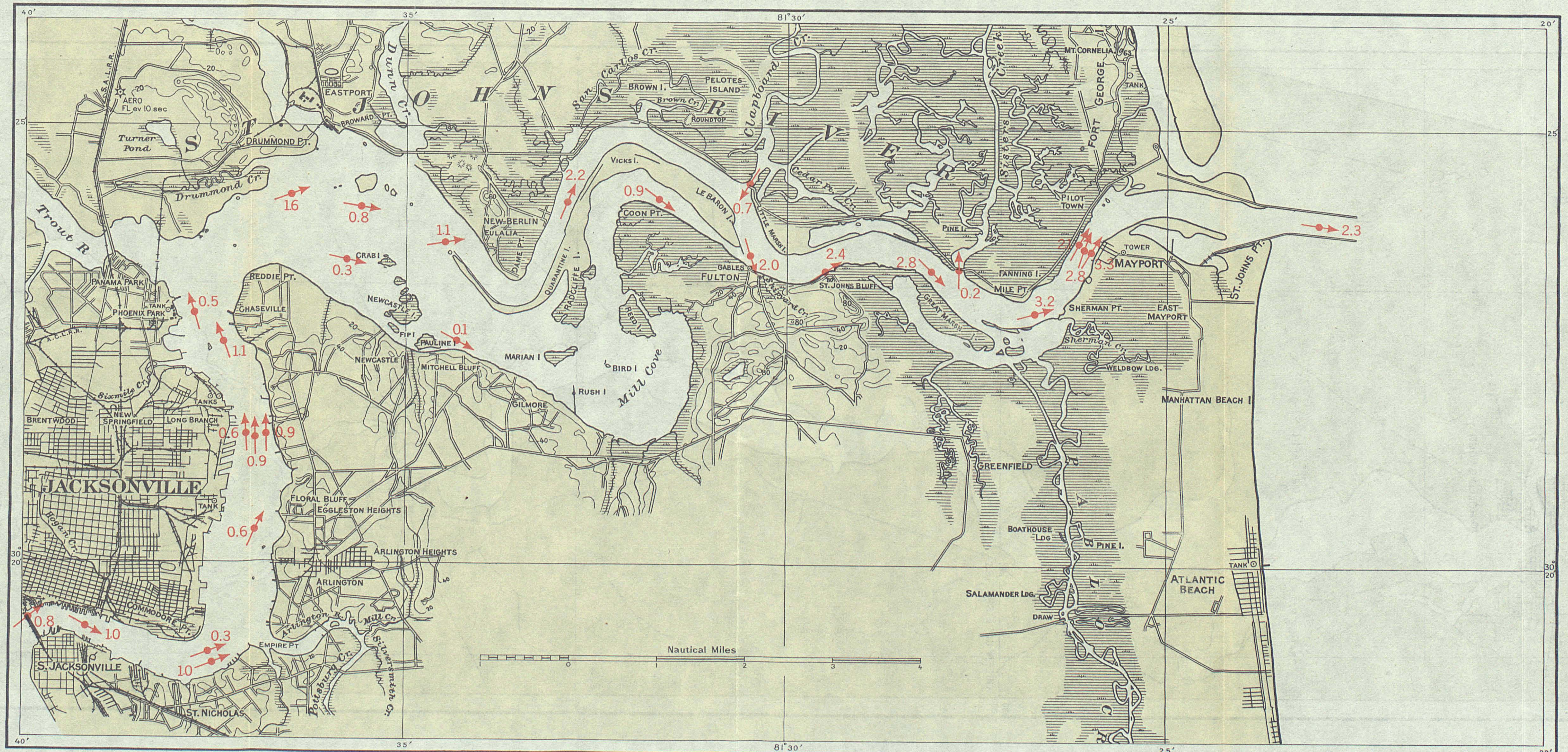

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Fig. 29. Currents below Jacksonville at time of low water at Mayport.

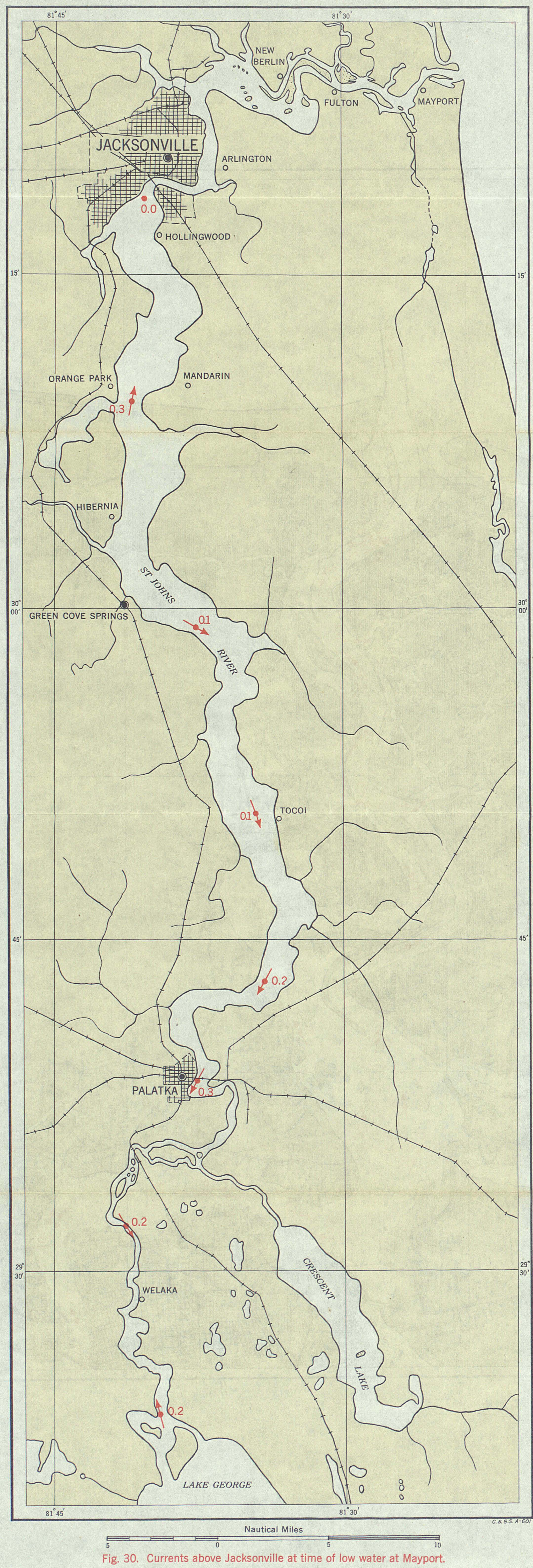

Fig. 30. Currents above Jacksonville at time of low water at Mayport.

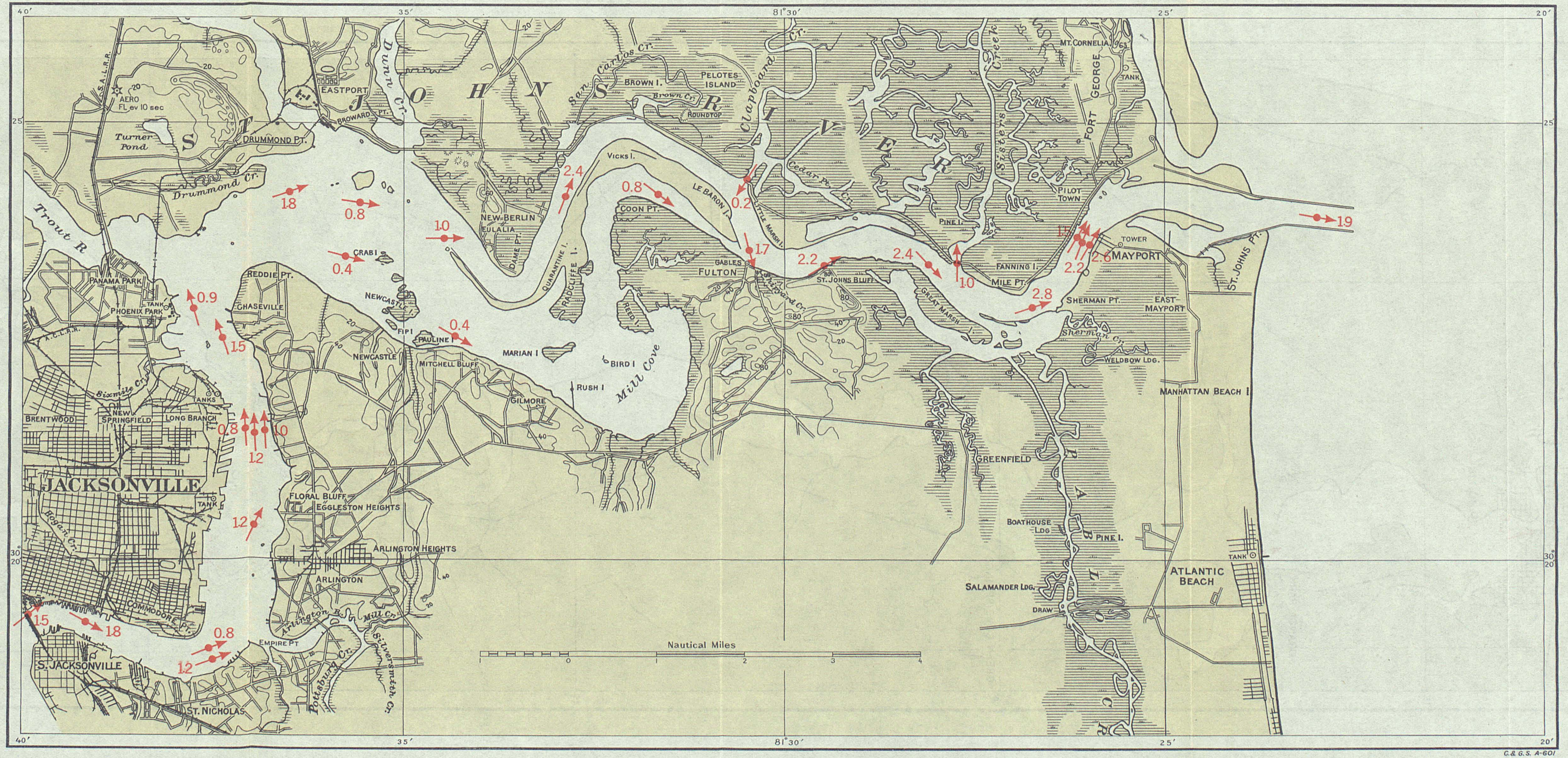

Fig. 31. Currents below Jacksonville 1 hour after low water at Mayport.

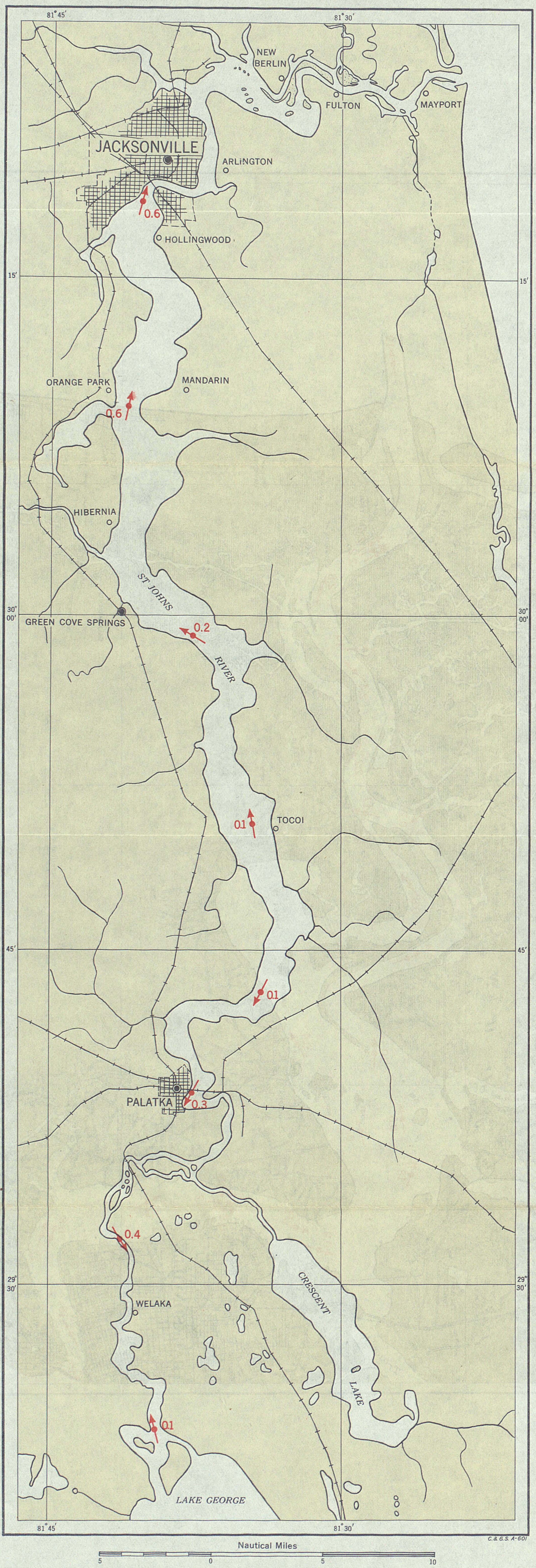

Fig. 32. Currents above Jacksonville 1 hour after low water at Mayport.

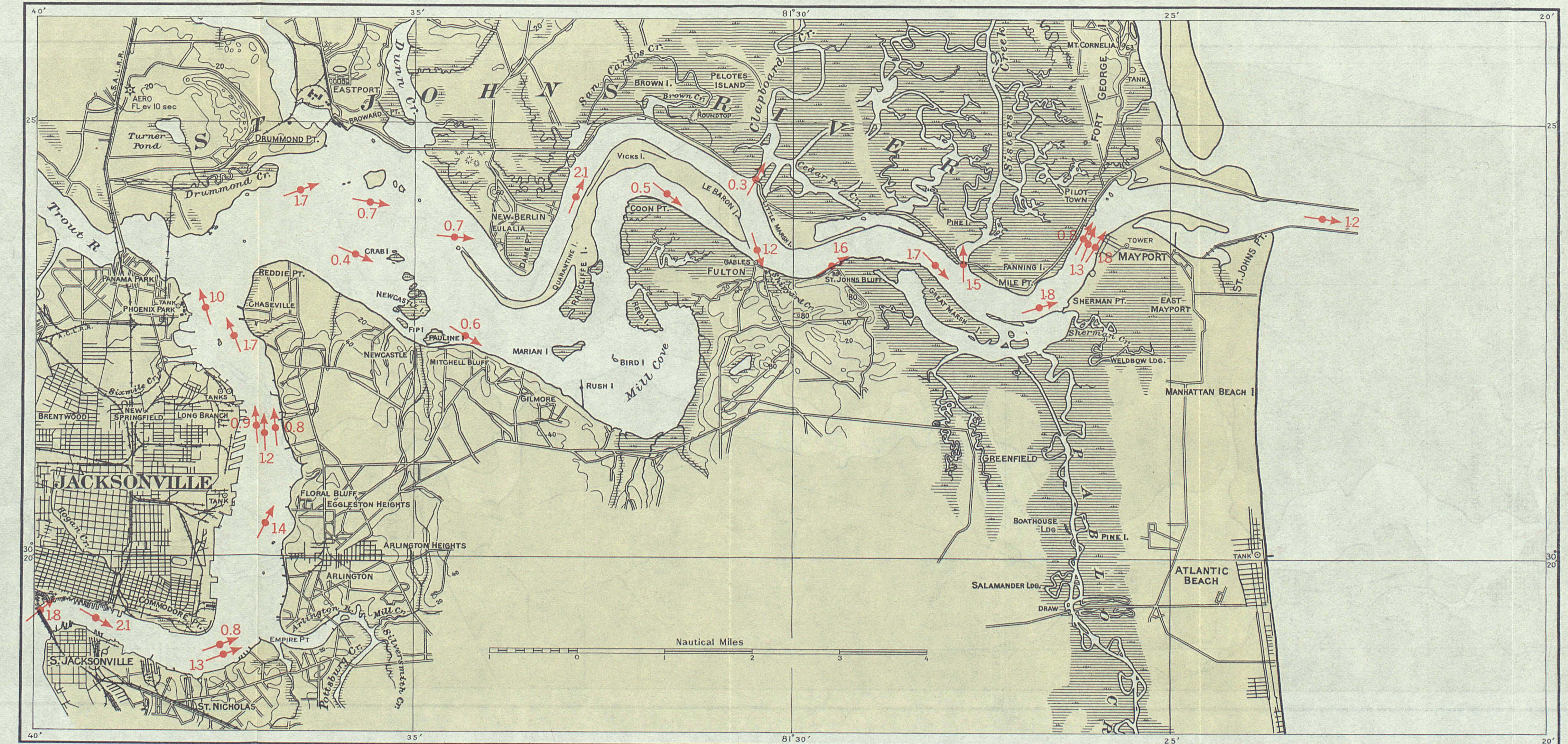

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Fig. 33. Currents below Jacksonville 2 hours after low water at Mayport.

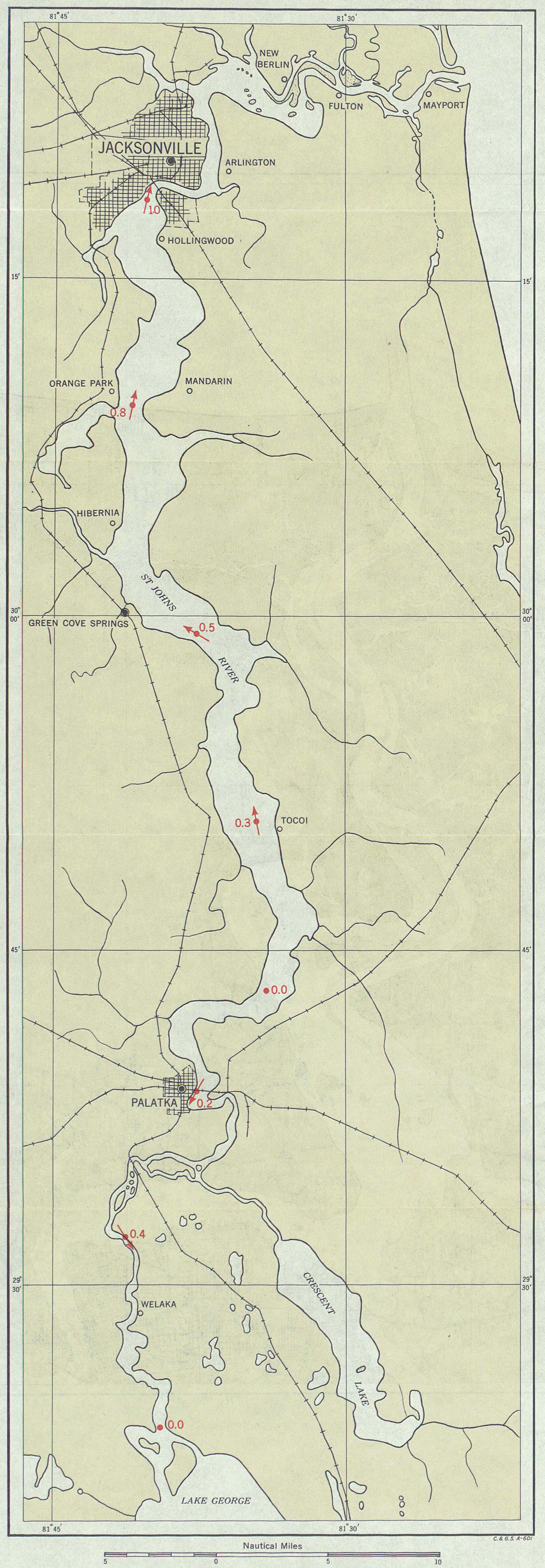

Fig. 34. Currents above Jacksonville 2 hours after low water at Mayport.

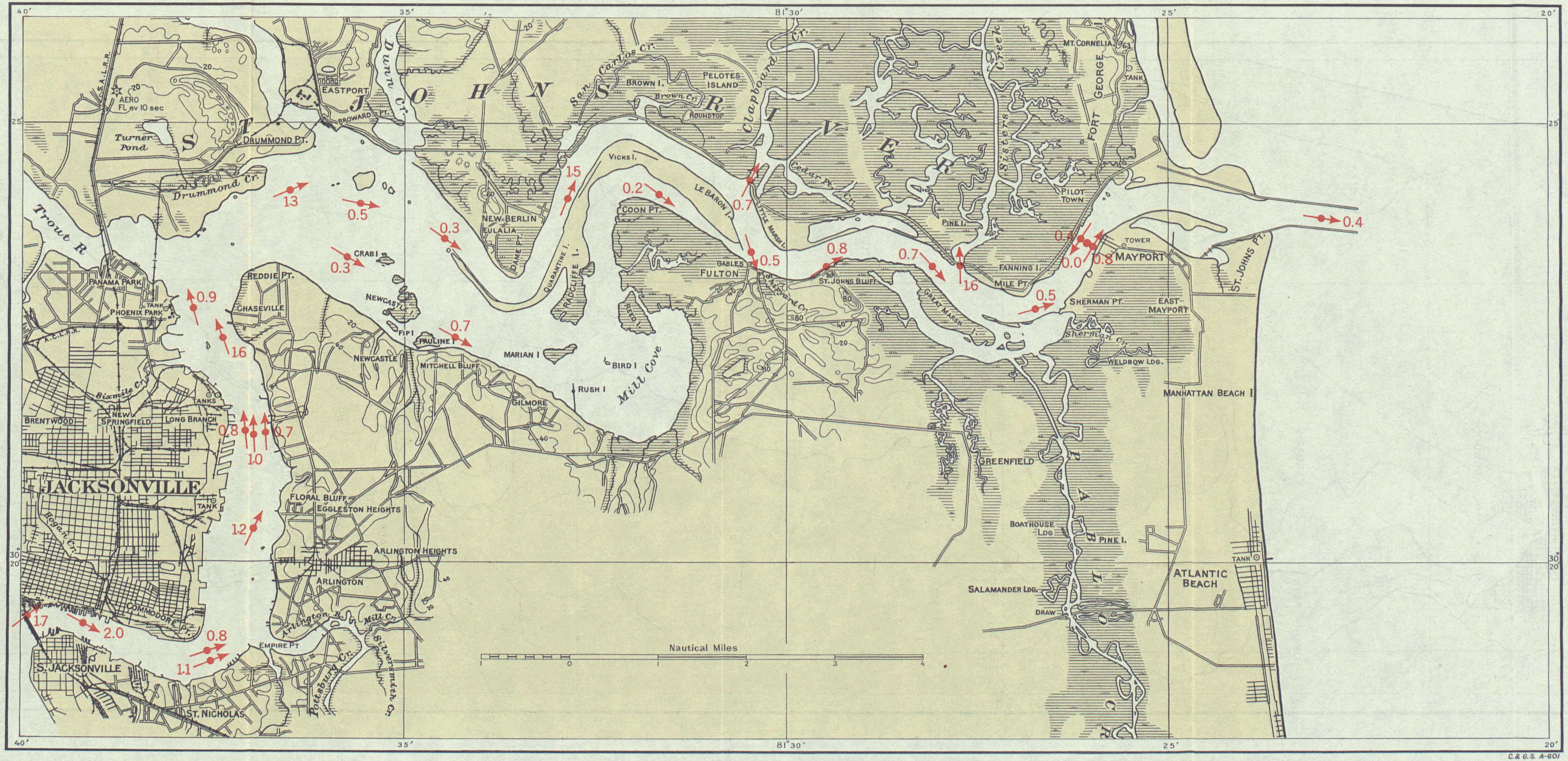

Fig. 35. Currents below Jacksonville 3 hours after low water at Mayport.

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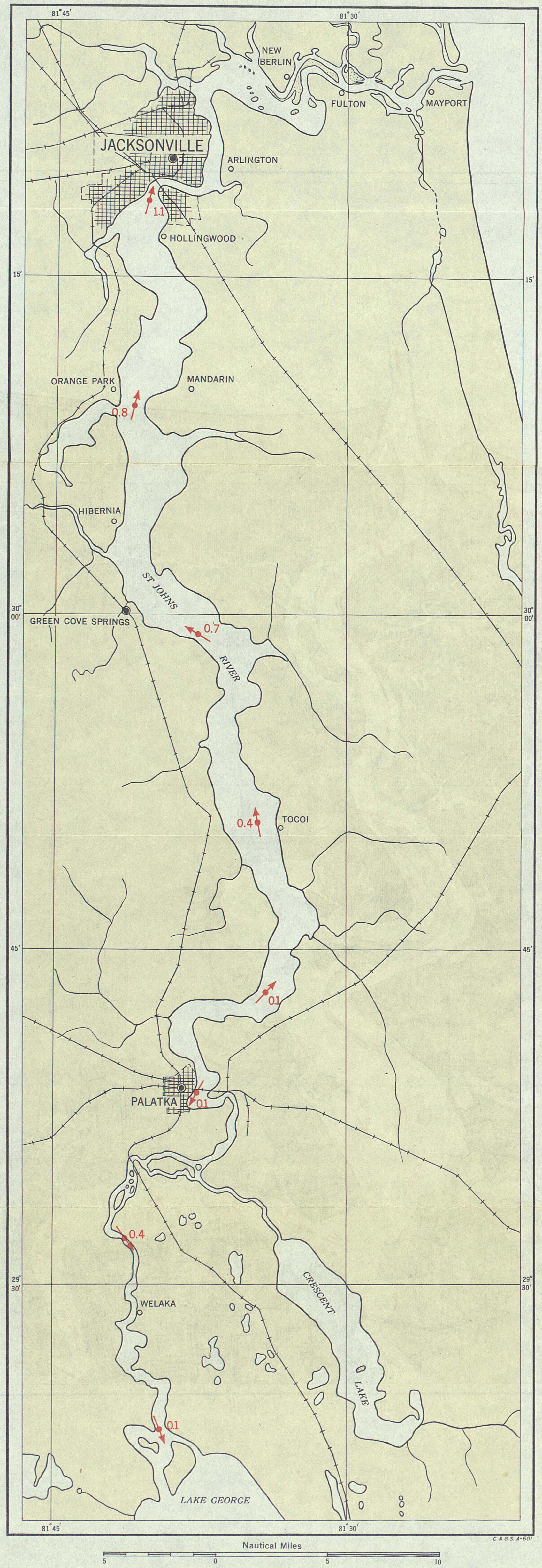

Fig. 36. Currents above Jacksonville 3 hours after low water at Mayport.

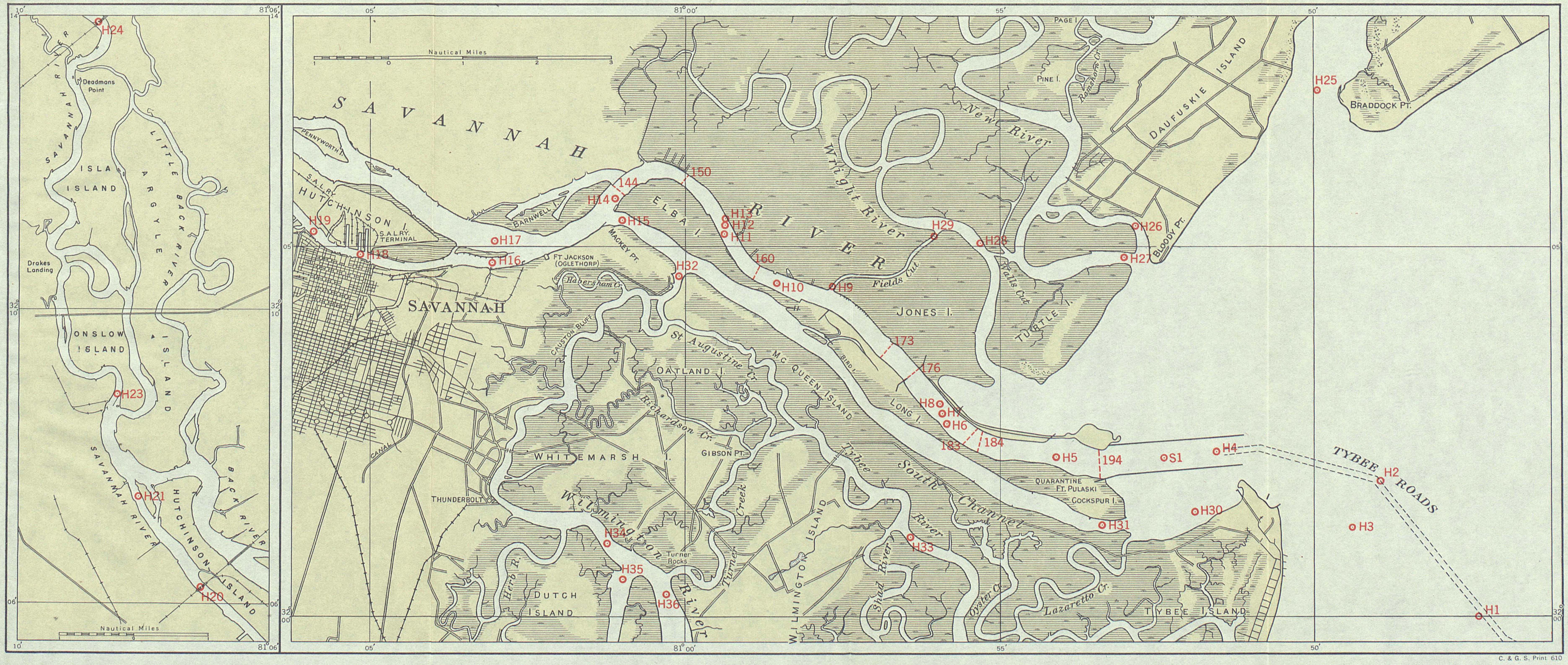

Fig. 37. Current stations, Savannah River.

The strength of ebb of the current requires about 2 hours longer than does the strength of flood to progress from the jetties to the Atlantic Coast Line Ry. bridge and the low water of the tide requires 1.2 hours longer than does the high water to travel the same distance.

Considering the portion of the river between the jetties and Port Wentworth where the observational time curves for the various phases of tide and current are complete, it is seen that the slack before flood generally occurs between 1 and 2 hours after local low water, and the slack before ebb, between one-half and 1½ hours after local high water. The strengths of flood and ebb, in general, occur between 3½ and 4½ hours after local low and high waters, respectively.

Above Port Wentworth the times of slack water are greatly modified by the drainage flow of the river, which gradually overcomes the flood current. In advancing up the river a place will be reached where the drainage flow equals or exceeds the flood velocity of the tidal current, and above this point the current will run continuously ebb with velocity varying as the current floods and ebbs in the lower portion of the river. The point where the current ceases to flood is not fixed but shifts with changes in river discharge and variations in tidal current conditions.

CURRENT CHARTS

The observed direction and velocity of the current at a number of locations in the Savannah River and nearby connecting waterways for each hour from 2 hours before to 3 hours after high and low waters at Tybee Light, Ga., are represented in figures 41 to 52. The observations used in preparing the charts were taken in April, May, and June 1934. They were all taken with a current pole within 14 feet of the surface. The locations at which the observations were taken are marked by small circles. The observed directions of flow for the designated hour of the tide are represented by arrows drawn through the circles. The mean velocities for the designated hour are shown to the nearest tenth of a knot by numerals near the circles. At times of spring tides and perigean tides the velocities normally are greater and at times of neap tides and apogean tides less than those given on the charts. In this locality the spring and perigean effects are practically equal, each producing a velocity increase above the mean of about 18 percent. When spring and perigean effects combine, the velocities of the tidal current are greatest. When neap and apogean effects combine, the velocities of the tidal current are least. Winds and freshet conditions at times modify both the direction and the velocity of the current.

Daily predictions of the high and low waters at Tybee Light are included in the annual Tide Tables for the Atlantic Ocean, published by the Coast and Geodetic Survey.

Table 3.—*Current Data, Savannah River and Vicinity*

[Referred to times of high water and low water at Tybee Light, Ga.]

Station no.	Observer, location, and year	Observations: Date	Period	Method	Depth	Slack	Flood strength: Time	True direction	Velocity	Flood duration	Slack	Ebb strength: Time	True direction	Velocity	Ebb duration	Mean current hour
						Hours after low water	*Hours after high water*	*Degrees*	*Knots*	*Hours*	*Hours after high water*	*Hours after low water*	*Degrees*	*Knots*	*Hours*	*Hours*
	R. L. SCHOPPE, 1927															
S 1	Channel between jetties (32°02′.1 N., 80°52.4 W.	Oct. 24-26	*Days* 2	Pole	*Feet* 7½	1.45	−2.55	266	1.65	6.03	1.38	−1.78	68	2.20	6.39	10.89
	U. S. ENGINEERS, 1930															
	Section 144, between Elba Island and Barnwell Island, no. 2 [4]															
144-1	32°05′.8 N., 81°01′.1 W	Aug. 28	½	Meter	(1)	2.05	−1.40	SW'd	1.26	5.85	1.80	−1.80	NE'd	1.14	6.57	11.42
			½	do	(2)	1.80	−1.40	SW'd	1.33	6.20	1.90	−1.70	NE'd	0.91	6.22	11.41
			½	do	(3)	1.75	−1.40	SW'd	1.12	6.05	1.70	−1.90	NE'd	0.70	6.37	11.30
144-2	32°05′.8 N., 81°01′.1 W	do	½	do	(1)	2.15	−1.20	SW'd	1.89	5.85	1.90	−2.20	NE'd	1.65	6.57	11.42
			½	do	(2)	1.95	−1.40	SW'd	1.70	6.15	2.00	−1.70	NE'd	1.11	6.27	11.48
			½	do	(3)	1.75	−1.50	SW'd	1.50	6.35	2.00	−2.10	NE'd	0.85	6.07	11.30
144-3	32°05′.8 N., 81°01′.0 W	do	½	do	(1)	2.20	−1.00	SW'd	1.65	5.80	1.90	−2.10	NE'd	2.78	6.62	11.51
			½	do	(2)	1.90	−1.20	SW'd	1.55	6.20	2.00	−2.20	NE'd	1.79	6.22	11.39
			½	do	(3)	1.55	−1.70	SW'd	1.20	6.25	1.70	−1.40	NE'd	1.14	6.17	11.30
144-4	32°05′.8 N., 81°01′.0 W	do	½	do	(1)	2.25	−1.30	SW'd	1.20	5.45	1.60	−1.90	NE'd	2.86	6.97	11.42
			½	do	(2)	2.10	−1.80	SW'd	1.18	5.80	1.80	−2.00	NE'd	2.25	6.62	11.29
			½	do	(3)	1.85	−1.20	SW'd	1.01	6.55	2.30	−1.00	NE'd	1.60	5.87	11.75
144-5	32°05′.8 N., 81°00′.9 W	do	½	do	(1)	2.15	−3.20	SW'd	1.12	4.05	0.10	−1.90	NE'd	2.31	8.37	10.55
			½	do	(2)	2.05	−2.50	SW'd	0.98	5.35	1.30	−1.80	NE'd	2.04	7.07	11.02
			½	do	(3)	1.90	−1.70	SW'd	0.59	5.80	1.60	−1.00	NE'd	2.01	6.62	11.46
	Section 150, between Elba Island and South Carolina shore [4]															
150-1	32°06′.0 N., 81°00′.0 W	Sept. 3	½	do	(1)	1.70	−1.80	NW'd	2.39	5.35	0.95	−2.10	SE'd	2.80	7.07	10.95
			½	do	(2)	1.30	−2.00	NW'd	2.06	6.15	1.35	−1.90	SE'd	2.06	6.27	10.95
			½	do	(3)	0.60	−3.40	NW'd	1.65	7.00	1.50	−2.20	SE'd	1.23	5.42	10.39
150-2	32°06′.0 N., 81°00′.0 W	do	½	do	(1)	1.80	−1.30	NW'd	2.88	5.80	1.50	−2.10	SE'd	2.88	6.62	11.24
			½	do	(2)	1.40	−2.30	NW'd	2.04	6.25	1.55	−2.00	SE'd	1.92	6.17	10.92
			½	do	(3)	1.00	−1.60	NW'd	0.79	6.70	1.60	−2.60	SE'd	0.61	5.72	10.86
150-3	32°05′.9 N., 81°00′.0 W	do	½	do	(1)	1.80	−1.50	NW'd	2.95	5.70	1.40	−1.70	SE'd	2.89	6.72	11.26
			½	do	(2)	1.40	−1.90	NW'd	2.33	6.15	1.45	−1.10	SE'd	2.03	6.27	11.22
			½	do	(3)	1.30	−2.30	NW'd	1.70	6.40	1.60	−0.50	SE'd	1.17	6.02	11.29
150-4	32°05′.9 N., 81°00′.0 W	do	½	do	(1)	1.80	−1.00	NW'd	3.05	5.40	1.10	−2.20	SE'd	2.63	7.02	11.19
			½	do	(2)	1.80	−1.70	NW'd	2.39	5.50	1.20	−2.00	SE'd	2.39	6.92	11.09
			½	do	(3)	1.70	−2.30	NW'd	1.61	5.60	1.20	−2.20	SE'd	1.85	6.82	10.86
150-5	32°05′.9 N., 81°00′.1 W	do	½	do	(1)	1.40	−0.60	NW'd	2.72	5.70	1.00	−2.90	SE'd	2.30	6.72	10.99
			½	do	(2)	1.30	−1.30	NW'd	2.30	5.90	1.10	−3.20	SE'd	1.89	6.52	10.74
			½	do	(3)	1.30	−1.90	NW'd	1.92	6.05	1.25	−2.70	SE'd	1.62	6.37	10.75
	Section 160, between Elba Island and South Carolina shore [4]															
160-1	32°04′.8 N., 80°58′.8 W	Sept. 19	½	do	(1)	1.50	−1.60	NW'd	2.02	5.65	1.05	−3.20	SE'd	2.50	6.77	10.70
			½	do	(2)	1.40	−1.70	NW'd	1.74	5.70	1.00	−3.20	SE'd	1.68	6.72	10.64
			½	do	(3)	1.30	−2.40	NW'd	1.57	5.85	1.05	−2.00	SE'd	1.21	6.57	10.75
160-2	32°04′.7 N., 80°58′.9 W	do	½	do	(1)	1.30	−2.70	NW'd	2.55	5.80	1.00	−2.80	SE'd	2.73	6.62	10.46
			½	do	(2)	1.50	−2.60	NW'd	2.15	5.85	1.25	−2.20	SE'd	1.97	6.57	10.75
			½	do	(3)	1.40	−2.40	NW'd	1.80	6.05	1.35	−1.50	SE'd	1.44	6.37	10.98
160-3	32°04′.7 N., 80°58′.9 W	do	½	do	(1)	1.90	−2.80	NW'd	2.14	5.20	1.00	−2.60	SE'd	2.62	7.22	10.64
			½	do	(2)	1.40	−2.40	NW'd	1.97	6.10	1.40	−2.30	SE'd	2.03	6.32	10.79
			½	do	(3)	1.40	−2.50	NW'd	1.57	6.25	1.55	−1.40	SE'd	1.21	6.17	11.02
160-4	32°04′.6 N., 80°58′.9 W	do	½	do	(1)	1.90	−2.30	NW'd	2.14	5.40	1.20	−2.30	SE'd	3.03	7.02	10.89
			½	do	(2)	1.60	−2.10	NW'd	2.27	5.90	1.40	−1.60	SE'd	1.79	6.52	11.09
			½	do	(3)	1.40	−1.70	NW'd	1.69	6.25	1.55	0.00	SE'd	0.86	6.17	11.58
160-5	32°04′.6 N., 80°58′.9 W	do	½	do	(1)	1.80	−2.40	NW'd	1.56	5.50	1.20	−2.10	SE'd	2.39	6.92	10.89
			½	do	(2)	1.70	−2.80	NW'd	1.80	5.70	1.30	−1.80	SE'd	1.80	6.72	10.86
			½	do	(3)	1.50	−2.60	NW'd	1.40	6.20	1.60	−1.90	SE'd	1.16	6.22	10.91
	Section 173, between Long Island and Jones Island [4]															
173-1	32°03′.7 N., 80°56′.7 W	Sept. 17	½	do	(1)	1.60	−2.80	NW'd	2.40	5.10	0.60	−1.90	SE'd	3.05	7.32	10.64
			½	do	(2)	1.10	−2.80	NW'd	2.13	6.00	1.00	−1.70	SE'd	1.89	6.42	10.66
			½	do	(3)	0.50	−2.70	NW'd	1.66	6.80	1.20	−1.50	SE'd	1.25	5.62	10.64
173-2	32°03′.6 N., 80°56′.7 W	do	½	do	(1)	1.60	−2.30	NW'd	3.32	5.00	1.10	−1.80	SE'd	3.62	6.82	10.91
			½	do	(2)	1.00	−3.00	NW'd	2.38	6.65	1.55	−1.90	SE'd	2.32	5.77	10.68
			½	do	(3)	0.40	−3.30	NW'd	1.72	7.35	1.65	−1.90	SE'd	1.19	5.07	10.48
173-3	32°03′.6 N., 80°56′.7 W	do	½	do	(1)	1.50	−2.20	NW'd	3.11	5.70	1.10	−1.70	SE'd	3.53	6.72	10.94
			½	do	(2)	1.10	−2.60	NW'd	2.26	6.30	1.30	−2.20	SE'd	2.44	6.12	10.66
			½	do	(3)	0.80	−2.40	NW'd	1.20	6.80	1.50	−1.80	SE'd	1.20	5.62	10.79

See footnotes at end of table.

TABLE 3.—*Current Data, Savannah River and Vicinity*—Continued

Station no.	Observer, location, and year	Observations				Slack	Flood strength			Flood duration	Slack	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time	True direction	Velocity			Time	True direction	Velocity		
	U. S. ENGINEERS, 1930—Continued															
	Section 173, between Long Island and Jones Island—Continued		*Days*		*Feet*	*Hours after low water*	*Hours after high water*	*Degrees*	*Knots*	*Hours*	*Hours after high water*	*Hours after low water*	*Degrees*	*Knots*	*Hours*	*Hours*
173-4	32°03′.6 N., 80°56′.8 W	Sept. 17	½	Meter	[1]	1.50	−2.00	NW'd	3.00	5.55	0.95	−2.40	SE'd	3.12	6.87	10.77
			½	do	[2]	1.30	−2.10	NW'd	2.04	5.85	1.05	−2.00	SE'd	2.28	6.57	10.82
			½	do	[3]	1.20	−2.80	NW'd	1.43	6.00	1.10	−1.80	SE'd	1.55	6.42	10.69
173-5	32°03′.5 N., 80°56′.9 W	do	½	do	[1]	1.30	−0.90	NW'd	2.47	5.50	0.70	−3.00	SE'd	2.53	6.92	10.79
			½	do	[2]	1.30	−1.60	NW'd	1.64	5.50	0.70	−2.90	SE'd	1.64	6.92	10.64
			½	do	[3]	1.30	−2.50	NW'd	1.34	5.60	0.80	−2.90	SE'd	1.28	6.82	10.44
	Section 176, between Long Island and Jones Island [4]															
176-1	32°03′.3 N., 80°56′.3 W	Aug. 26	½	do	[1]	2.00	−3.00	NW'd	1.17	5.55	1.45	−1.80	SE'd	2.65	6.87	10.92
			½	do	[2]	1.80	−2.80	NW'd	1.17	5.90	1.60	−1.70	SE'd	1.88	6.52	10.99
			½	do	[3]	1.60	−2.70	NW'd	0.90	5.90	1.40	−1.60	SE'd	1.26	6.52	10.94
176-2	32°03′.3 N., 80°56′.4 W	do	½	do	[1]	2.30	−2.60	NW'd	1.55	5.40	1.60	−1.90	SE'd	2.55	7.02	11.11
			½	do	[2]	1.70	−2.30	NW'd	1.63	6.10	1.70	−1.50	SE'd	1.57	6.32	11.16
			½	do	[3]	1.20	−2.30	NW'd	1.33	6.60	1.70	−1.00	SE'd	1.10	5.82	11.16
176-3	32°03′.3 N., 80°56′.4 W	do	½	do	[1]	2.00	−2.00	NW'd	1.95	5.65	1.55	−1.50	SE'd	2.55	6.77	11.28
			½	do	[2]	1.80	−2.00	NW'd	1.65	6.05	1.75	−1.50	SE'd	1.82	6.37	11.28
			½	do	[3]	1.50	−2.00	NW'd	1.42	6.25	1.65	−0.90	SE'd	1.18	6.17	11.32
176-4	32°03′.2 N., 80°56′.5 W	do	½	do	[1]	2.30	−2.80	NW'd	1.50	5.35	1.55	−1.40	SE'd	2.50	7.07	11.18
			½	do	[2]	2.30	−2.60	NW'd	1.02	5.45	1.65	−1.10	SE'd	1.85	6.97	11.32
			½	do	[3]	1.90	−2.30	NW'd	0.84	5.55	1.35	−1.10	SE'd	1.31	6.87	11.22
176-5	32°03′.2 N., 80°56′.5 W	do	½	do	[1]	2.30	−2.90	NW'd	1.41	4.90	1.10	−2.70	SE'd	2.01	7.52	10.71
			½	do	[2]	2.00	−2.80	NW'd	0.98	5.25	1.15	−2.80	SE'd	1.45	7.17	10.65
			½	do	[3]	1.90	−1.70	NW'd	0.67	5.35	1.15	−2.80	SE'd	1.03	7.07	10.90
	Section 183, between Long Island and Jones Island [4]															
183-1	32°02′.5 N., 80°55′.4 W	Sept. 12	½	do	[1]	1.20	−3.40	NW'd	1.06	4.50	−0.40	−2.50	SE'd	2.42	7.92	9.99
			½	do	[2]	1.00	−2.40	NW'd	1.01	5.80	0.70	−2.70	SE'd	1.49	6.62	10.41
			½	do	[3]	0.55	−2.30	NW'd	0.99	6.75	1.20	−2.70	SE'd	1.05	5.67	10.45
183-2	32°02′.5 N., 80°55′.4 W	do	½	do	[1]	1.65	−2.50	NW'd	2.04	5.25	0.80	−1.60	SE'd	3.22	7.17	10.85
			½	do	[2]	1.20	−2.50	NW'd	1.68	5.90	1.00	−1.90	SE'd	2.27	6.52	10.71
			½	do	[3]	1.05	−2.60	NW'd	1.26	6.25	1.20	−2.10	SE'd	1.44	6.17	10.65
183-3	32°02′.4 N., 80°55′.5 W	do	½	do	[1]	1.70	−1.90	NW'd	2.16	5.60	1.20	−1.90	SE'd	3.23	6.82	11.04
			½	do	[2]	1.10	−2.30	NW'd	1.72	6.30	1.30	−2.00	SE'd	1.84	6.12	10.79
			½	do	[3]	0.05	−2.70	NW'd	1.17	7.45	1.40	−2.70	SE'd	0.99	4.97	10.28
183-4	32°02′.4 N., 80°55′.5 W	do	½	do	[1]	1.75	−2.20	NW'd	1.85	5.55	1.20	−2.00	SE'd	3.27	6.87	10.95
			½	do	[2]	1.05	−2.10	NW'd	1.84	6.35	1.30	−1.90	SE'd	1.72	6.07	10.85
			½	do	[3]	−0.05	−2.30	NW'd	1.60	7.55	1.40	−2.70	SE'd	0.89	4.87	10.35
183-5	32°02′.3 N., 80°55′.6 W	do	½	do	[1]	1.70	−1.50	NW'd	1.70	5.20	0.80	−2.30	SE'd	2.89	7.22	10.94
			½	do	[2]	1.40	−1.80	NW'd	1.79	5.90	1.20	−2.30	SE'd	2.08	6.52	10.89
			½	do	[3]	1.20	−2.10	NW'd	1.32	6.50	1.60	−1.60	SE'd	1.44	5.92	11.04
	Section 184, between Long Island and Jones Island [4]															
184-1	32°02′.5 N., 80°55′.3 W	Nov. 11	½	do	[1]	0.90	−3.00	W'd	0.98	5.90	0.70	−2.80	E'd	1.39	6.52	10.21
			½	do	[2]	0.80	−2.60	W'd	0.90	6.10	0.80	−2.90	E'd	1.20	6.32	10.29
			½	do	[3]	0.75	−2.70	W'd	1.02	6.15	0.80	−3.50	E'd	1.14	6.27	10.10
184-2	32°02′.4 N., 80°55′.3 W	do	½	do	[1]	1.50	−2.80	W'd	1.87	5.80	1.20	−1.90	E'd	2.58	6.62	10.76
			½	do	[2]	1.30	−3.00	W'd	1.44	6.10	1.30	−1.80	E'd	1.86	6.32	10.71
			½	do	[3]	0.80	−3.00	W'd	1.41	6.60	1.30	−2.40	E'd	1.29	5.82	10.44
184-3	32°02′.4 N., 80°55′.3 W	do	½	do	[1]	1.80	−2.40	W'd	2.98	5.90	1.60	−1.90	E'd	3.22	6.52	11.04
			½	do	[2]	1.10	−2.20	W'd	1.70	6.60	1.60	−1.70	E'd	1.88	5.82	10.96
			½	do	[3]	0.30	−1.50	W'd	1.39	7.40	1.60	−3.00	E'd	1.04	5.02	10.61
184-4	32°02′.3 N., 80°55′.3 W	do	½	do	[1]	1.80	−2.40	W'd	2.68	6.00	1.70	−2.10	E'd	3.33	6.42	11.01
			½	do	[2]	1.10	−2.50	W'd	1.89	6.40	1.40	−2.20	E'd	1.95	6.02	10.71
			½	do	[3]	0.50	−3.40	W'd	1.38	7.00	1.40	−2.80	E'd	0.85	5.42	10.19
184-5	32°02′.3 N., 80°55′.3 W	do	½	do	[1]	1.95	−2.10	W'd	2.21	5.75	1.60	−2.00	E'd	2.92	6.67	11.12
			½	do	[2]	1.35	−2.10	W'd	2.21	6.35	1.60	−2.00	E'd	2.04	6.07	10.98
			½	do	[3]	0.75	−2.20	W'd	1.91	6.95	1.60	−1.80	E'd	1.14	5.47	10.85
	Section 194, between Cockspur Island and Oyster Bed Island [4]															
194-1	32°02′.2 N., 80°53′.4 W	Aug. 22	½	do	[1]	1.90	−3.00	W'd	1.05	5.10	0.90	−1.90	E'd	2.65	7.32	10.74
			½	do	[2]	1.70	−2.70	W'd	1.21	5.65	1.25	−1.40	E'd	1.86	6.77	10.98
			½	do	[3]	1.50	−2.90	W'd	1.30	6.10	1.50	−1.50	E'd	1.36	6.32	10.91
194-2	32°02′.1 N., 80°53′.4 W	do	½	do	[1]	2.00	−2.40	W'd	1.65	5.05	0.95	−2.30	E'd	2.78	7.37	10.82
			½	do	[2]	1.40	−2.60	W'd	1.50	6.10	1.40	−1.60	E'd	1.68	6.32	10.91
			½	do	[3]	1.10	−2.80	W'd	1.38	6.60	1.60	−1.70	E'd	0.96	5.82	10.81

See footnotes at end of table.

TABLE 3.—*Current Data, Savannah River and Vicinity*—Continued

Station no.	Observer, location, and year	Observations				Slack	Flood strength			Flood duration	Slack	Ebb strength			Ebb duration	Mean current hour
		Date	Period	Method	Depth		Time	True direction	Velocity			Time	True direction	Velocity		
	U. S. ENGINEERS, 1930—Continued															
	Section 194, between Cockspur Island and Oyster Bed Island—Continued		*Days*		*Feet*	*Hours after low water*	*Hours after high water*	*Degrees*	*Knots*	*Hours*	*Hours after high water*	*Hours after low water*	*Degrees*	*Knots*	*Hours*	*Hours*
194-3	32°02′.1 N., 80°53′.4 W.	Aug. 22	½	Meter	(1)	2.00	−2.10	W'd	1.66	5.40	1.30	−2.10	E'd	2.72	7.02	11.04
			½	do	(2)	1.30	−3.00	W'd	1.62	6.50	1.70	−2.10	E'd	1.62	5.92	10.74
			½	do	(3)	0.90	−3.70	W'd	1.57	6.80	1.60	−2.20	E'd	0.62	5.62	10.41
194-4	32°02′.0 N., 80°53′.4 W.	do	½	do	(1)	2.00	−2.00	W'd	1.95	5.55	1.45	−1.20	E'd	2.48	6.87	11.32
			½	do	(2)	1.30	−3.00	W'd	1.66	6.20	1.40	−1.30	E'd	1.78	6.22	10.86
			½	do	(3)	0.70	−2.70	W'd	1.43	6.65	1.25	−2.00	E'd	1.13	5.77	10.58
194-5	32°02′.0 N., 80°53′.4 W.	do	½	do	(1)	1.90	−1.60	W'd	1.34	5.40	1.20	−2.10	E'd	2.41	7.02	11.11
			½	do	(2)	1.70	−2.20	W'd	1.19	5.70	1.30	−1.70	E'd	1.37	6.72	11.04
			½	do	(3)	1.10	−2.10	W'd	1.05	6.00	1.00	−1.10	E'd	0.93	6.42	10.99
	E. F. HICKS, 1934 [4]															
H 1	Entrance channel, 3.1 miles S. 63° E. of Tybee Island signal tower (32°0′.0 N.; 80°47′.4 W.).	May 21-24	3	Pole	6¾	1.20	−2.40	293	1.10	5.75	0.85	−2.05	155	1.39	6.67	10.66
				Meter	6	0.87	−2.76		1.29	6.25	1.02	−1.73		1.57	6.17	10.61
				do	15	−0.12	−3.04		1.26	7.40	1.18	−2.70		1.19	5.02	10.09
				do	24	−0.48	−3.10		1.27	7.58	1.00	−2.93		1.03	4.84	9.88
H 2	Tybee Roads, 1.5 miles N. 74° E. of Tybee Island signal tower (32°01′.8 N.; 80°48′.9 W.).	do	3	Pole	7	0.77	−2.82	293	1.40	6.26	0.93	−2.30	121	1.93	6.16	10.41
				Meter	6	0.82	−2.60		1.56	6.08	0.80	−2.23		1.96	6.34	10.46
				do	15	−0.20	−2.92		1.61	7.28	0.98	−3.00		1.38	5.14	9.98
				do	24	−0.78	−2.44		1.55	8.05	1.17	−3.25		1.12	4.37	9.98
H 3	1.1 miles S. 78° E. of Tybee Island signal tower (32°01′.2 N.; 80°49′.4 W.).	do	3	Pole	3½	0.82	−2.10	325	1.12	6.06	0.78	−2.80	153	1.36	6.36	10.44
				Meter	2	1.20	−2.16		1.39	5.78	0.88	−2.20		1.76	6.64	10.69
				do	9	0.13	−2.78		1.15	6.77	0.80	−3.25		1.14	5.65	9.99
H 4	Channel between jetties (32°02′.2 N.; 80°51′.5 W.).	Apr. 30-May 16	16	Pole	6¾, 7	1.90	−2.02	260	1.61	5.35	1.15	−1.57	82	2.59	7.07	11.13
				Meter	6	2.06	−2.06		1.54	5.10	1.06	−1.38		2.66	7.32	11.18
				do	15	1.19	−2.95		1.75	6.16	1.25	−2.39		2.15	6.26	10.54
				do	24	0.41	−2.82		1.71	7.01	1.32	−2.70		1.77	5.41	10.32
H 5	0.1 mile N. 12° E. of quarantine dock (32°02′.2 N. 80°54′.1 W.).	Apr. 30-May 3	3	Pole	7	1.87	−1.38	283	1.69	5.71	1.48	−1.82	98	3.26	6.71	11.30
				Meter	5	2.02	−1.54		1.54	5.52	1.44	−1.85		3.18	6.90	11.28
				do	13	1.88	−1.66		2.07	5.94	1.72	−1.55		2.86	6.48	11.36
				do	21	1.40	−2.66		2.22	6.18	1.48	−1.53		1.92	6.24	10.94
H 6	1.5 miles N. 68° W. of quarantine tank (32°02′.6 N.; 80°55′.8 W.).	June 4-7	3	Pole	7	1.80	−1.70	322	2.02	5.53	1.23	−2.26	135	2.97	6.89	11.03
				Meter	5	1.85	−1.62		1.83	5.28	1.03	−1.94		3.50	7.14	11.09
				do	12	1.55	−1.53		2.22	5.83	1.28	−2.24		2.63	6.59	11.03
				do	19	1.33	−2.20		2.36	6.12	1.35	−2.26		1.82	6.30	10.82
H 7	1.6 miles N. 63° W. of quarantine tank (32°02′.7 N.; 80°55′.9 W.).	do	3	Pole	6	1.76	−1.77	316	2.09	5.61	1.27	−1.68	140	3.06	6.81	11.16
				Meter	6	1.86	−1.52		2.01	5.54	1.30	−1.70		2.87	6.88	11.25
				do	15	1.54	−2.57		2.54	5.99	1.43	−1.08		2.57	6.43	11.09
				do	24	1.18	−2.78		2.33	6.22	1.30	−1.07		1.96	6.20	10.92
H 8	1.7 miles N. 61° W. of quarantine tank (32°02′.9 N.; 80°55′.9 W.).	do	3	Pole	6¾	1.60	−1.82	318	1.92	5.58	1.08	−1.52	139	3.06	6.84	11.10
				Meter	4	1.84	−1.52		1.79	5.29	1.03	−1.78		2.99	7.13	11.16
				do	10	1.56	−1.88		2.01	5.91	1.37	−1.54		2.83	6.51	11.14
				do	16	1.40	−2.47		2.21	5.98	1.28	−1.04		2.43	6.44	11.06
H 10	Channel between Lower Flats Range and Upper Flats Range (32°04′.5 N.; 80°58′.6 W.)	May 3-8	3	Pole	7	1.90	−1.78	296	2.04	5.53	1.33	−2.23	116	3.09	6.89	11.07
				Meter	6, 7	1.95	−1.78		2.10	5.48	1.33	−1.92		2.97	6.94	11.16
				do	14, 17	1.88	−1.60		2.14	5.87	1.65	−1.73		2.90	6.55	11.31
				do	22, 27	1.33	−1.88		2.36	6.59	1.82	−1.53		2.08	5.83	11.20
H 11	Upper Flats Range, south side of channel (32°05′.2 N.; 80°59′.4 W.).	June 11-14	3	Pole	7	1.83	−1.84	329	2.43	5.45	1.18	−2.27	155	3.07	6.97	10.99
				Meter	5	1.83	−1.82		2.36	5.22	0.95	−2.18		3.29	7.20	10.96
				do	12	1.83	−1.76		2.51	5.55	1.28	−2.18		2.77	6.87	11.06
				do	19	1.73	−1.78		2.44	6.19	1.82	−1.93		1.99	6.23	11.28
H 12	Upper Flats Range, midchannel (32°05′.3 N.; 80°59′.4 W.).	June 11-15	3	Pole	7	2.10	−1.94	331	2.20	4.97	0.97	−1.68	152	3.10	7.45	11.12
				Meter	6	2.13	−1.92		1.93	4.85	0.88	−1.70		3.18	7.57	11.11
				do	15	2.12	−1.40		2.37	5.45	1.47	−1.62		2.81	6.97	11.40
				do	24	1.42	−1.68		2.31	6.48	1.80	−1.60		1.35	5.94	11.25
H 13	Upper Flats Range, north side of channel (32°05′.4 N.; 80°59′.4 W.)	June 12-15	3	Pole	6	2.10	−2.62	334	1.34	4.43	0.43	−1.55	144	3.03	7.99	10.85
				Meter	5	2.17	−2.58		1.03	4.21	0.28	−2.28		2.28	8.21	10.66
				do	12	2.02	−1.78		1.68	4.83	0.75	−1.42		2.77	7.59	11.16
				do	20, 24	1.95	−1.84		2.24	5.62	1.47	−1.48		2.52	6.80	11.29
H 14,	Midchannel between Elba Island and Barnwell Island no. 2 (32°05.7 N.; 81°01′.1 W.).	May 18-26	3	Pole	7	2.03	−1.45	208	1.90	5.37	1.30	−2.08	21	2.88	7.05	11.21
				Meter	6	2.10	−1.50		1.78	5.17	1.17	−2.07		2.69	7.25	11.19
				do	15	1.95	−1.42		2.40	5.87	1.72	−1.45		2.94	6.55	11.46
				do	24	1.93	−1.98		2.50	6.17	2.00	−1.43		2.79	6.25	11.39
H 15	Western end of South Channel (32°05′.3 N.; 81°01′.0 W.)	Apr. 5-10	3	Pole	3½	1.95	−1.98	300	1.05	4.90	0.75	−2.28	122	1.41	7.52	10.87
				Meter	2	2.10	−2.02		1.01	4.82	0.82	−1.40		1.51	7.60	11.14
				do	8	1.95	−1.86		1.02	4.98	0.83	−3.16		1.56	7.44	10.70

See footnotes at end of table.

TABLE 3.—*Current Data, Savannah River and Vicinity*—Continued

Station no.	Observer, location, and year	Observations: Date	Period	Method	Depth	Slack	Flood strength: Time	True direction	Velocity	Flood duration	Slack	Ebb strength: Time	True direction	Velocity	Ebb duration	Mean current hour
			Days		*Feet*	*Hours after low water*	*Hours after high water*	*Degrees*	*Knots*	*Hours*	*Hours after high water*	*Hours after low water*	*Degrees*	*Knots*	*Hours*	*Hours*
	E. F. HICKS, 1934—Continued															
H 16	Midchannel, south of Fig Island (32°04′.8 N.; 81°03′.0 W.).	Apr. 10-13	3	Pole	6¾	2.62	−1.65	276	1.65	4.94	1.46	−1.07	92	2.35	7.48	11.60
				Meter	5	2.63	−1.68	------	1.61	4.77	1.30	−1.13	------	2.28	7.65	11.54
				do	13	2.58	−1.48	------	1.70	5.34	1.82	−0.80	------	2.26	7.08	11.79
				do	21	2.47	−1.37	------	1.77	5.71	2.08	−1.05	------	2.07	6.71	11.80
H 17	0.1 mile north of Fig Island (32°05′.1 N.; 81°03′.0 W.).	Apr. 5-10	3	Pole	3½	1.50	−1.22	280	0.91	5.48	0.88	−2.66	94	1.45	6.94	10.89
				Meter	2	1.53	−1.36	------	0.93	5.44	0.87	−2.86	------	1.51	6.98	10.81
				do	6	1.58	−0.86	------	1.05	5.52	1.00	−2.54	------	1.49	6.90	11.06
[6] H 18	Midchannel off Seaboard Air Line Ry. terminal, Hutchinson, Island. (32°04′.9 N.; 81°05′.2 W.).	Apr. 18-21	3	Pole	7	2.30	−1.82	279	1.51	4.56	0.76	−1.82	106	2.40	7.86	11.12
				Meter	6	2.28	−1.72	------	1.47	4.56	0.74	−1.88	------	2.19	7.86	11.12
				do	14	2.17	−1.68	------	1.70	4.91	0.98	−1.87	------	2.41	7.51	11.16
				do	22	1.97	−1.16	------	2.01	5.89	1.76	−1.53	------	2.23	6.53	11.52
H 19	0.5 mile N. 42° W. of city hall dome, Savannah, Ga. (32°05′.2 N.: 81°05′.9 W.)	May 7-10	3	Pole	7	2.75	−1.05	320	1.41	5.10	1.75	−1.28	142	1.98	7.32	11.80
				Meter	6	2.67	−1.22	------	1.51	5.15	1.72	−1.48	------	2.06	7.27	11.68
				do	15	2.62	−1.10	------	1.45	5.26	1.78	−1.28	------	1.92	7.16	11.77
				do	24	2.57	−1.05	------	1.30	5.40	1.87	−1.20	------	1.74	7.02	11.81
H 20	Seaboard Air Line Ry. bridge (32°06′.2 N.; 81°07′.1 W.).	May 15-18	3	Pole	6¾	2.36	−1.44	NW'd	2.47	5.52	1.78	−0.86	SE'd	3.60	6.90	11.72
				Meter	6	2.40	−1.48	------	2.49	5.55	1.85	−0.75	------	3.55	6.87	11.77
				do	15	2.43	−1.54	------	2.33	5.50	1.83	−0.52	------	3.42	6.92	11.81
				do	24	2.38	−1.42	------	2.15	5.59	1.87	−0.45	------	3.26	6.83	11.86
H 21	Channel southwest of King Island (32° 07′.4 N.; 81°08′.1 W.).	May 10-19	3	Pole	7	2.62	−1.30	337	1.35	5.41	1.93	−0.90	160	1.90	7.01	11.85
				Meter	5	2.70	−1.36	------	1.43	5.28	1.88	−0.90	------	2.11	7.14	11.84
				do	13	2.63	−1.40	------	1.35	5.37	1.90	−0.87	------	1.98	7.05	11.83
				do	22	2.65	−1.26	------	1.31	5.37	1.92	−0.73	------	1.80	7.05	11.91
H 23	Channel west of Onslow Island 32°08′.8 N.; 81°08′.4 W.).	May 14-17	3	Pole	7	3.30	−0.64	22	0.91	4.55	1.75	−0.45	210	1.45	7.87	12.25
				Meter	4	3.30	−0.66	------	0.94	4.55	1.75	−0.35	------	1.51	7.87	12.27
				do	10	3.33	−0.62	------	0.89	4.50	1.73	−0.35	------	1.47	7.92	12.28
				do	16	3.33	−0.58	------	0.85	4.47	1.70	−0.23	------	1.37	7.95	12.32
H 24	Atlantic Coast Line Ry. bridge (32°13′.9 N.; 81°08′.7 W.).	Apr. 30-May 3	3	Pole	3½	------	[7] 0.28	------	[7] −0.24	------	------	2.43	SE'd	1.99	------	------
				Meter	3	------	0.20	------	−0.30	------	------	2.65	------	2.04	------	------
				do	13	------	0.20	------	−0.21	------	------	2.35	------	1.70	------	------
H 25	Calibogue Sound, west of Braddock Point (32°07′.1 N.; 80°50′.0 W.)	May 24-28	2½	Pole	6¾	0.66	−1.60	17	2.26	6.30	0.86	−3.12	190	2.51	6.12	10.46
				Meter	8	0.66	−1.47	------	2.22	6.46	1.02	−2.94	------	2.41	5.96	10.58
				do	21	0.52	−1.66	------	1.88	6.70	1.12	−2.92	------	2.14	5.72	10.53
				do	33	0.32	−2.00	------	1.70	6.68	0.90	−2.96	------	1.83	5.74	10.33
H 26	New River, 0.5 mile northward of Bloody Point (32°05′.3 N.; 80°52′.8 W.).	May 29-June 20	3	Pole	3½	0.42	−2.08	332	1.27	6.08	0.40	−4.00	147	1.36	6.34	9.95
				Meter	3	0.30	−2.26	------	1.10	6.14	0.34	−3.90	------	1.34	6.28	9.88
				do	9	0.07	−2.40	------	1.22	6.67	0.64	−3.82	------	1.25	5.75	9.88
H 27	New River, 0.4 mile westward of Bloody Point (32°01′.9 N.; 80°53′.0 W.).	Apr. 19-26	3	Pole	6¾	0.57	−2.48	267	1.64	6.23	0.70	−3.15	92	1.82	6.19	10.17
				Meter	6	0.57	−2.60	------	1.71	6.26	0.73	−3.18	------	1.88	6.16	10.14
				do	15	0.42	−2.70	------	1.66	6.48	0.80	−3.07	------	1.56	5.94	10.12
				do	24	0.50	−2.30	------	1.41	6.22	0.62	−3.18	------	1.21	6.20	10.17
H 28	Wrights River, 0.2 mile northwest of Turtle Island (32°05′.1 N.; 80°55′.3 W.).	Apr. 16-19	3	Pole	3½	0.63	−2.53	332	1.22	6.22	0.75	−2.92	142	1.54	6.20	10.24
				Meter	4	0.73	−2.50	------	1.17	6.04	0.67	−3.00	------	1.62	6.38	10.24
				do	15	0.58	−2.97	------	1.09	5.92	0.40	−2.97	------	1.16	6.50	10.02
H 29	Northeastern end of Fields Cut (32°05′ .2 N.; 80°56.′1 W.).	Apr. 19-25	3	Pole	3½	[8] 2.58	−2.18	226	1.23	3.09	−0.43	3.48	49	2.06	9.33	10.38
				Meter	2	2.52	−2.05	------	1.17	3.16	−0.42	−3.60	------	2.19	9.26	10.38
				do	8	1.44	−2.28	------	1.39	4.46	−0.20	−3.65	------	1.82	7.96	10.09
H 30	South Channel, south of Tybee knoll (32°01′.4 N.; 80°51′.9 W.).	Apr. 2-5	3	Pole	3½	0.65	−3.32	249	1.76	5.60	0.15	−2.90	68	1.62	6.82	9.91
				Meter	2	0.65	−3.44	------	1.82	5.63	0.18	−3.02	------	1.94	6.79	9.86
				do	8	0.58	−3.26	------	1.59	5.77	0.25	−2.85	------	1.23	6.65	9.94
H 31	South Channel, south of Fort Pulaski (32°01′.2 N.; 80°53′.4 W.).	do	3	Pole	3½	0.78	−2.64	287	1.58	5.94	0.62	−3.42	99	2.17	6.48	10.10
				Meter	5	0.78	−2.52	------	1.62	5.95	0.63	−3.42	------	2.30	6.47	10.13
				do	12	0.70	−2.22	------	1.54	6.05	0.65	−3.27	------	1.79	6.37	10.23
				do	19	0.33	−2.18	------	1.37	6.40	0.63	−3.32	------	1.63	6.02	10.13
H 33	Tybee River, 0.2 mile southward of Northern entrance to Shad River (32°01′ .1 N.; 80°56′.4 W.).	May 24-June 2	3	Pole	7	1.03	−2.60	327	1.09	5.99	0.92	−3.60	151	1.56	6.43	10.20
				Meter	5	1.03	−2.50	------	1.14	5.89	0.82	−3.72	------	1.62	6.53	10.17
				do	12	0.97	−2.52	------	1.16	6.16	1.03	−3.62	------	1.54	6.26	10.23
				do	19	0.45	−2.55	------	1.14	6.72	1.07	−3.73	------	1.49	5.70	10.07
H 34	Wilmington River, 0.5 mile northwestward of Skidaway River mouth (32° 01′.0 N.; 81°01′.2 W.).	Apr. 23-26	3	Pole	7	0.75	−2.37	317	1.05	6.17	0.82	−3.67	147	1.01	6.25	10.14
				Meter	3	0.92	−2.33	------	1.05	5.86	0.68	−3.57	------	1.01	6.56	10.19
				do	13	0.22	−2.37	------	1.06	6.66	0.78	−3.72	------	1.06	5.76	9.99
H 35	Mouth of Skidaway River (32°00′ .5 N.; 81°01′.0 W.).	do	3	Pole	3½	0.88	−2.48	204	1.12	5.79	0.57	−3.93	16	1.46	6.63	10.02
				Meter	3	0.64	−2.27	------	1.19	5.83	0.37	−3.98	------	1.56	6.59	9.95
				do	12	0.10	−2.05	------	1.09	6.63	0.63	−3.72	------	1.18	5.79	10.00
H 36	Wilmington River, 0.3 mile southward of Turners Creek entrance (32°00′.3 N.; 81°00′.2 W.).	Apr. 26-June 13	3	Pole	6¾, 7	0.77	−2.47	344	1.09	6.05	0.72	−3.58	154	1.42	6.37	10.12
				Meter	7, 8	0.82	−2.35	------	1.01	6.03	0.75	−3.52	------	1.36	6.39	10.19
				do	18, 20	0.83	−2.17	------	1.02	6.09	0.82	−3.42	------	1.23	6.33	10.28
				do	29, 32	0.44	−2.02	------	0.92	6.49	0.83	−3.42	------	0.92	5.93	10.22

[1] 1 foot below surface.
[2] Midway between surface and bottom.
[3] 2 feet above bottom.
[4] Stations in each section are numbered from north to south.
[5] For stations by Hicks not included in this table, see table 4.
[6] The observed times of current at station H 18 are somewhat inconsistent with those for other stations in the vicinity.
[7] Current did not flood at station H 24. Values refer to the minimum velocity of the current in an ebb direction.
[8] A persistent irregularity in the observational curve tends to make the times of slack before flood indefinite.

For reference to above table, see p. 33.

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TABLE 4.—*Data for Irregular Currents, Savannah River Vicinity*

[Referred to times of high water and low water at Tybee Light, Ga.]

Station no.	Location and date	Observations			Slack	Flood									Slack	Ebb strength		
						First strength			Minimum flood			Second strength						
		Period	Method	Depth		Time	True direction	Velocity	Time	True direction	Velocity	Time	True direction	Velocity		Time	True direction	Velocity
		Days		*Feet*	*Hours after low water*	*Hours after low water*	*Degrees*	*Knots*	*Hours after high water*	*Degrees*	*Knots*	*Hours after high water*	*Degrees*	*Knots*	*Hours after high water*	*Hours after low water*	*Degrees*	*Knots*
H 9	Southwestern end of Fields Cut (32°04'.5 N; 80°57'.6 W.), Apr. 16-19, 1934.	3	Pole	3½	−1.32	−0.37	211	0.53	−4.48	34	−0.90	−2.28	214	0.54	−0.87	−3.58	35	1.42
			Meter	2	−1.22	−0.43		0.50	−4.53		−1.02	−2.26		0.61	−0.87	−3.50		1.68
			do	8	−1.56	−0.55		0.70	−4.38		−0.80	−1.82		1.02	0.22	−3.80		1.00
H 32	South Channel entrance to Wilmington River (32°04'.6 N.; 81°00'.1 W.), Apr. 10-13, 1934.	3	Pole	3½	2.00	3.23	32	0.99	−0.22		−0.04	1.84	53	1.27	2.72	−0.30	206	1.55
			Meter	2	2.00	3.22		1.08	−0.12		0.02	1.72		1.25	2.86	−0.07		1.57
			do	8	2.02	3.32		1.04	−0.17		0.01	1.72		1.33	2.86	−0.47		1.54

At stations H 9 and H 32, the currents exhibit persistent irregularities which prevent the presentation of the results in the usual form. At each of these stations a double flood occurs. Starting at the slack before flood, the velocity in the flood direction increases to a maximum which is designated "first strength of flood." It then decreases to a minimum value called minimum flood, after which it increases to a second maximum designated "second strength of flood." At the time of minimum flood, the current may be flowing in either a flood or an ebb direction. The latter condition is indicated by a minus sign preceding the tabulated minimum flood velocity.

TABLE 5.—*Current Harmonic Constants, Between Jetties, Savannah River Entrance*

[May 1-15, 1934, 15 days]

Constituent	Velocity	Epoch		Constituent	Velocity	Epoch	
	H	Local (κ)	Greenwich		H	Local (κ)	Greenwich
	Knots	*Degrees*	*Degrees*		*Knots*	*Degrees*	*Degrees*
K_1	0.146	50	131	M_8	0.022	258	185
M_2	1.932	167	328	N_2	0.406	147	309
M_4	0.156	224	187	O_1	0.079	46	127
M_6	0.062	79	204	S_2	0.288	202	4

Epochs apply to the westward strengths of the several constituents.
The local epochs refer to the local meridian, Greenwich epochs to the Greenwich meridian.
For reference to above table, see p. 34.