CURRENT STUDY IN THE NEUSE RIVER

AND

ESTUARY OF NORTH CAROLINA

by

William J. Woods
Institute of Marine Sciences
University of North Carolina
at Chapel Hill

Project A-020-NC
Agreement No. 14-01-0001-1401

The work upon which this publication is based was supported in part by funds provided by the Office of Water Resources Research, Department of the Interior, through the Water Resources Research Institute of the University of North Carolina as authorized under the Water Resources Research Act of 1964.

WATER RESOURCES RESEARCH INSTITUTE
UNIVERSITY OF NORTH CAROLINA
124 RIDDICK BUILDING
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NORTH CAROLINA

ABSTRACT

Two Rhodamine B dye insertions were made in the lower 59 km of the Neuse River Estuary during the summer of 1967. Movement of the dye was followed with Turner Model 111 Fluorometers. Time-of-travel estimates of the dye patch were made for the two insertions.

Under meteorological conditions existing at the time of the study a mean flushing time of six days and a maximum flushing time of 7.4 days is estimated for the lower 28.2 km of the Neuse River Estuary. A mean flushing time of 12.3 days and a maximum flushing time of 19.25 days is estimated for the 30.8 km of the river immediately below New Bern, North Carolina.

A maximum flushing time of 26 to 27 days is estimated for the lower 59 km of the Neuse River Estuary for conditions existing during the summer of 1967. Further measurements are suggested.

Acknowledgments

Financial assistance has been acknowledged on the title page. Several people assisted in carrying out the field work. C. T. Kellum operated R.V. Machapunga during the pumping and some parts of the tracing phases. R. A. Hyle, S. M. Adams and P. J. Buhan worked long hours, sometimes under conditions that were unfavorable for small boat operation. The United States Marine Corps Air Station at Cherry Point, North Carolina made available meteorological observations and permitted access to personnel and equipment during boat launch and retrieval operations.

INTRODUCTION

The study reported in this paper was conducted on the Neuse River during the summer of 1967. The purpose of the study was to contribute to some understanding of the flushing rate and circulation patterns in this estuary. It is part of an overall effort to determine circulation patterns in the Pamlico Sound complex. A study similar to this one was conducted during the summer of 1966 on the Pamlico River (Horton, et al, 1967). It is hoped that information of this kind can be developed in the future for Pamlico Sound proper. As a preliminary effort several present and past members of the faculty at the Institute of Marine Sciences of the University of North Carolina at Chapel Hill have prepared a salinity-temperature atlas of North Carolina estuarine waters (Williams, et al, 1967).

The Neuse River drains an area of over 15,000 km^2 and is approximately 320 km long. However, only the lower 59 kilometers (from New Bern, N. C. to Pamlico Sound) of the Neuse River Estuary are under consideration in this study (Figure 1). Because of the length of the study area it is presented on two charts (Figures 2 and 3), which were prepared from United States Coast and Geodetic Survey charts No. 538 and 1231. Although the charts are published in different scales, the reproductions have been modified so that the scales agree. The estuary is typical of North Carolina coastal waters in that it is shallow; average depth for most of the study area is approximately 3 meters while in the lower portions the

Figure 1. Map of coastal North Carolina locating the study portion of the Neuse River and Estuary.

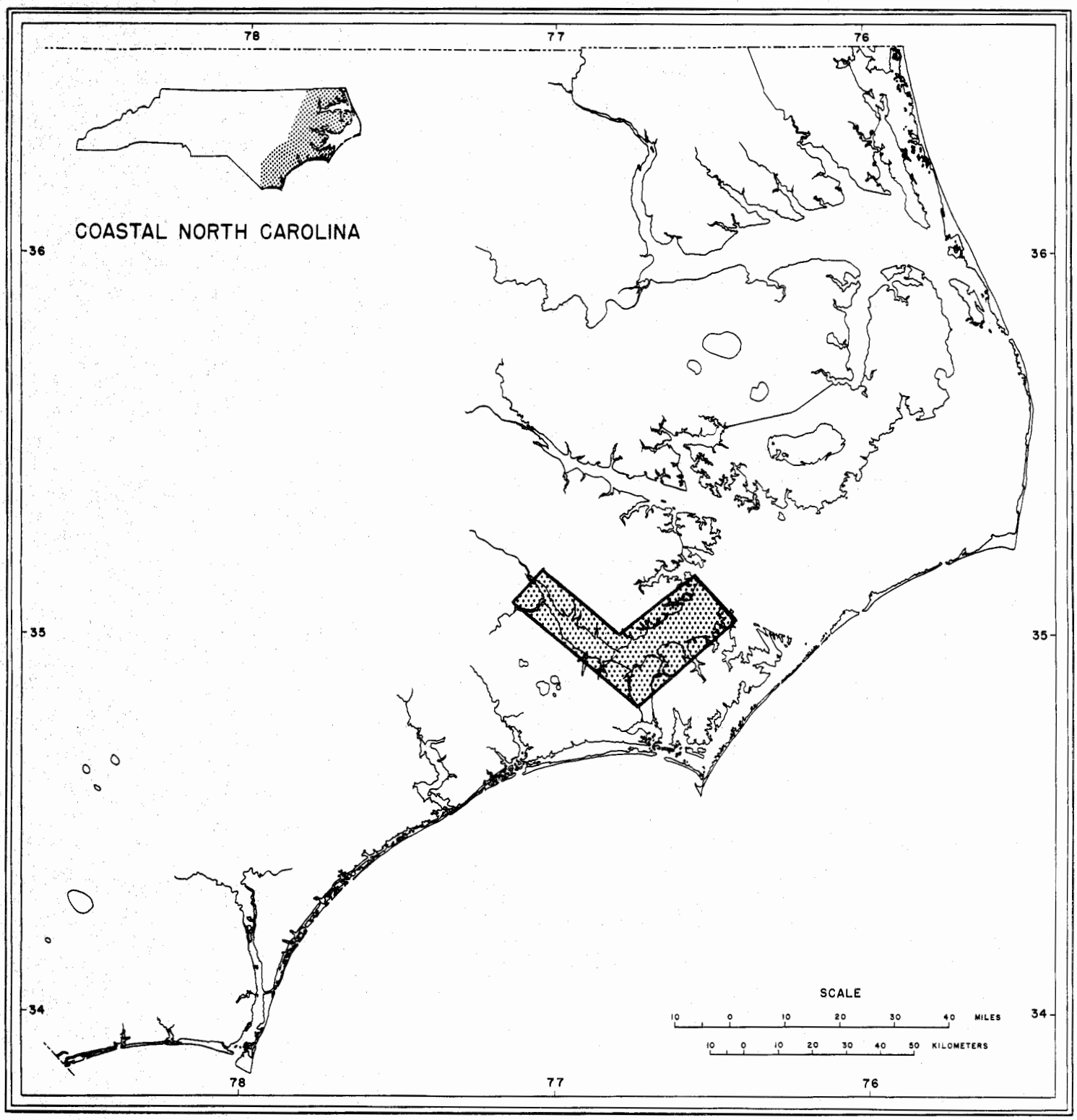

78
77
76
COASTAL NORTH CAROLINA
36
35
34
SCALE
10 0 10 20 30 40 MILES
10 0 10 20 30 40 50 KILOMETERS

Figure 2. Map of the lower part of the Neuse Estuary. The closed/open circle shows the location of R.V. Machapunga during the July, 1967, dye insertion.

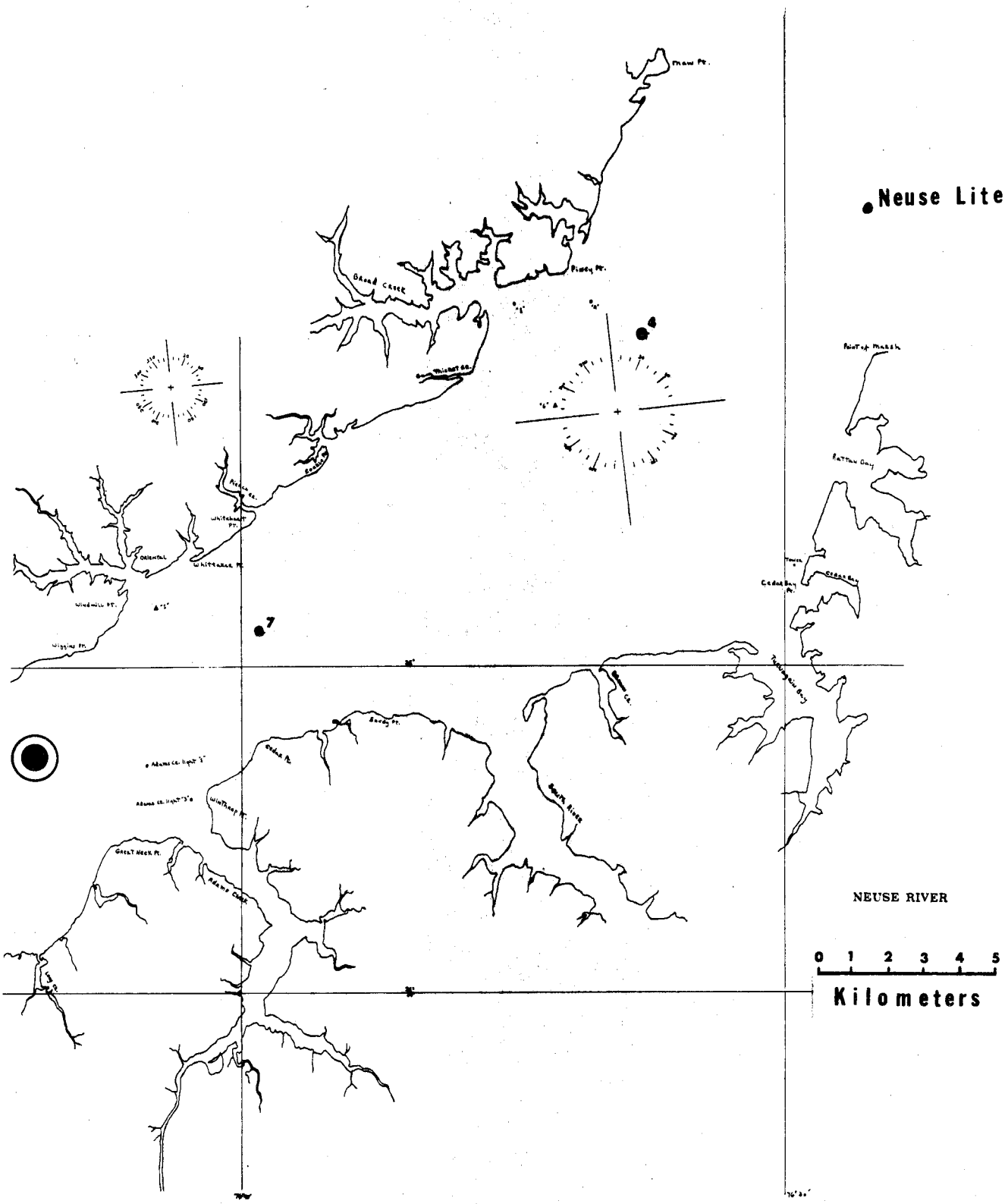
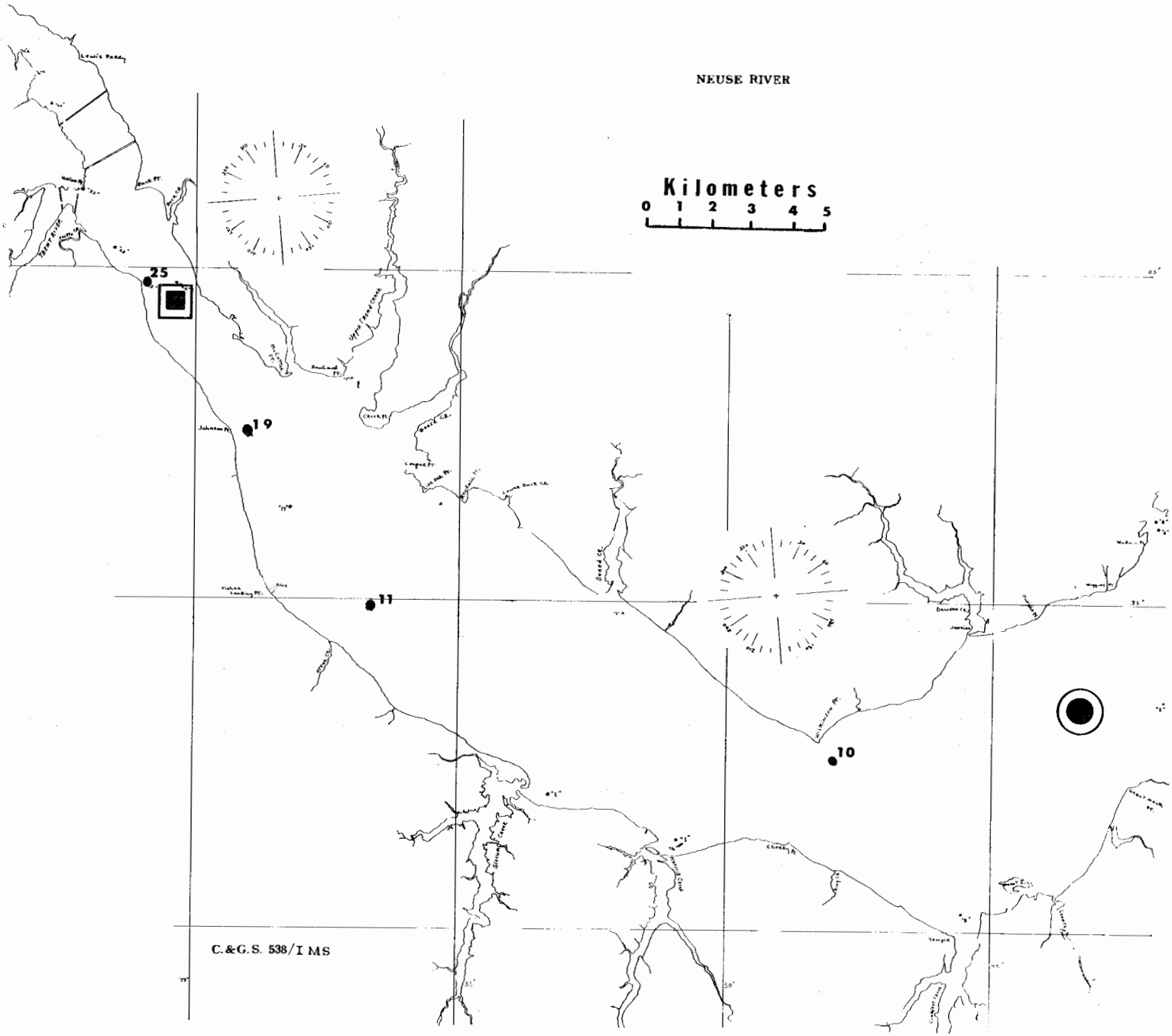

Neuse Lite
NEUSE RIVER
0 1 2 3 4 5
Kilometers

Figure 3. Map of the upper part of the Neuse Estuary. The closed/open square shows the location of R.V. Machapunga during the August, 1967, dye insertion. The closed/open circle is repeated from Figure 2. The other circles represent navigation markers.


NEUSE RIVER
Kilometers
0 1 2 3 4 5
25
19
11
10
C.&G.S. 538/I MS

average is about 6 meters. Notations on the Coast and Geodetic Survey charts report that the main tidal fluctuation is "less than one half foot" but note further that there can be a variation in depth as great as four feet at New Bern and as great as two feet at the mouth of the estuary depending on meteorological conditions. The estuary is oriented northwest-southeast from New Bern to Wilkinson's Point (Beacon 10, Figure 3) from which it is oriented southwest-northeast to Pamlico Sound (Neuse Light, Figure 2).

METHODS

Movement of water was followed using the fluorescent dye technique developed by Pritchard and Carpenter (1960). The dye of choice was Rhodamine B which was mixed in 50-gallon drums and pumped continuously from the deck of R.V. Machapunga through an outlet which was one meter below the surface of the water. The dye was mixed on station as it was needed with water which was drawn from a depth of approximately 1 meter. The dye was traced by pumping from one-meter depth to a Turner Model 111 Fluorometer equipped for continuous flow operation. A continuous record was made of the instrument's readings. Most of the tracing was done with an instrument mounted in an open 20-foot skiff while for limited periods, R.V. Machapunga was also available for tracing. During these times an identical instrument borrowed from the North Carolina State University Pamlico Marine Laboratory

was also used. Both instruments were calibrated with the same standards. High background problems which plagued the 1966 Pamlico River Estuary study were traced to improper primary and secondary filters (see Horton, et al, 1967). New filters with narrower band passes were obtained for both instruments for the 1967 study. Natural background fluorescence for the Neuse River Estuary was established by a series of reconnaissance cruises in June and early July, 1967.

The study was initiated July 10, 1967 with a dye insertion made in the Neuse River. During the insertion period R.V. Machapunga was anchored approximately mid-river at 34°28'23"N, 76°43'39"W, 2743 meters due west of Beacon No. 1, Adams Creek (Figures 2 and 3). In thirty-six hours of continuous pumping a total of 120 pounds of Rhodamine dye was added to the river; insertion was completed July 12 at 0315. Tracing was begun at 1650 on July 10 and continued each day, except July 13, until July 15.

A second dye insertion was made August 7 and 8, 1967. During a twenty hour period of continuous pumping a total of 120 pounds of Rhodamine B dye was added to the river. During this period R.V. Machapunga was anchored at 35°04'24"N, 77°0'33"W, about 4200 meters down-river from the New Bern-Bridgeton Bridge (US Highway 17) (Figure 3). Tracing was started on August 8 at 0900 and, except August 13 and 17, was continued until August 19.

RESULTS

The movement of the dye patch during the downstream phase of the study is shown in Figures 4 through 8. Eight and three-quarter hours after dye insertion was begun, the head of the dye patch was found to be 5575 meters downstream from the point of insertion. On successive days, July 11-12, the head of the dye patch was located 9.6 km and 16.9 km respectively downstream. During this time the wind blew consistently from 220°-230° at velocities from 8 to 22 knots (Table 1). It should probably be noted here that the weather station at the nearby Cherry Point Marine Corps Air Station (MACS) recorded 6.57 inches of rain in the three days (July 7, 8 and 9) immediately preceding the dye insertion. In addition a guaging station maintained (until October, 1967) by the USGS (on the New Bern-Bridgeton Bridge) recorded a peak height on July 6, 1967 followed by a gradual decrease in mean height (1.64 feet) to a low on July 11 (Table 2). These observations indicate a period of high flow for the part of the estuary under study at this time. Mechanical problems and weather (another 2.84 inches of rain) precluded tracing on July 13.

On July 14, the head of the dye patch was found 20.6 km from the point of insertion. Poor weather (1.73 inches of rain) caused termination of field work in early afternoon on July 15. At that time the head of the dye patch was 26.9 km and the tail of the patch was 19.8 km from the insertion point. Continued poor weather prevented field work on July 16 and when

Figure 4. Dye patch on July 10, 1967.

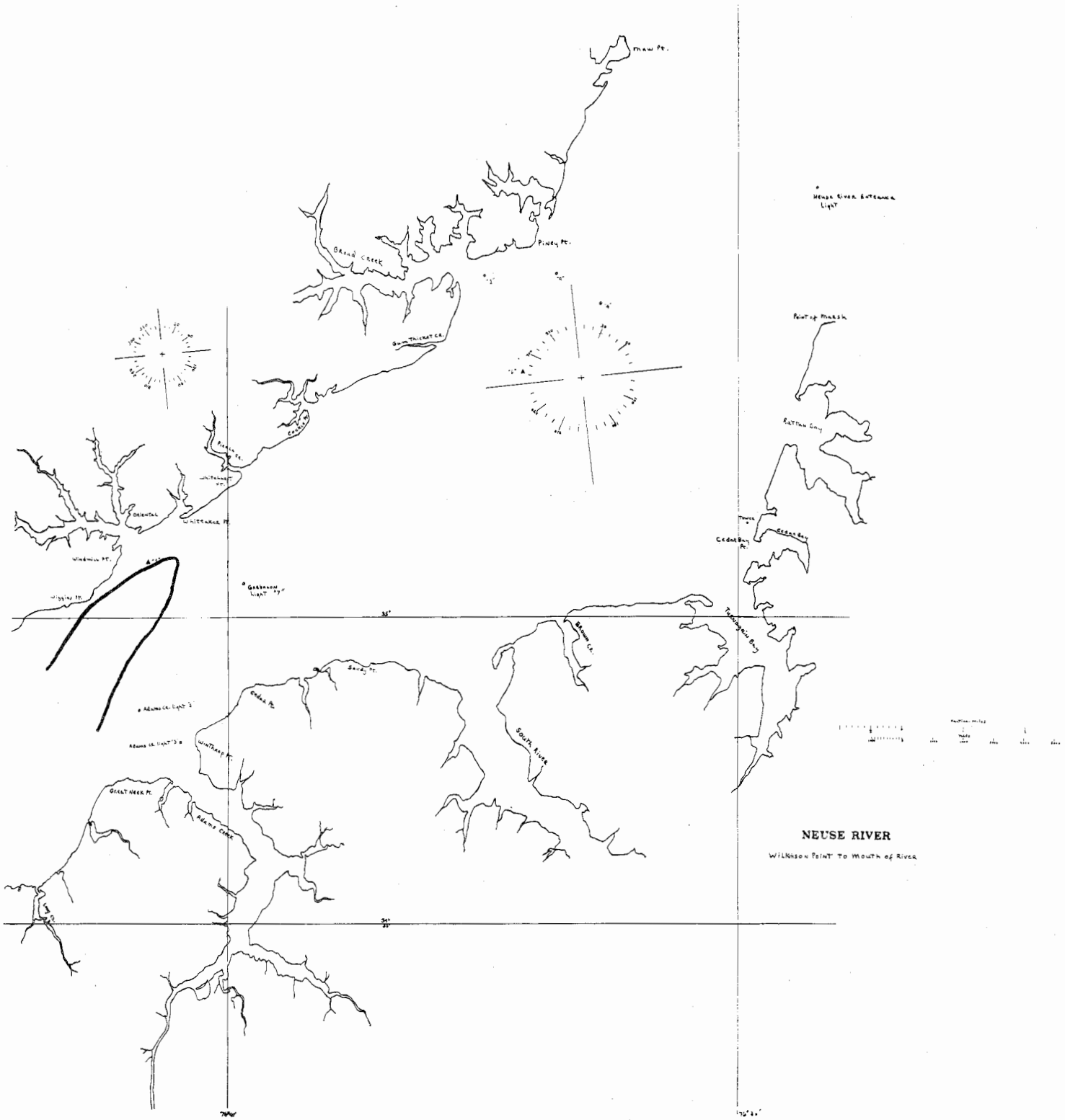

Maw Pt.
Broad Creek
Piney Pt.
Point of Marsh
Rattan Bay
Cedar Bay
Oriental
Whitehurst Pt.
Higgins Pt.
Adams Creek Light "3"
Adams Creek
Great Neck Pt.
Winthrop Pt.
Sandy Pt.
South River
Brown Cr.
Thursday Gut Bay
NEUSE RIVER
Wilkinson Point to Mouth of River

Figure 5. Dye patch on July 11, 1967.

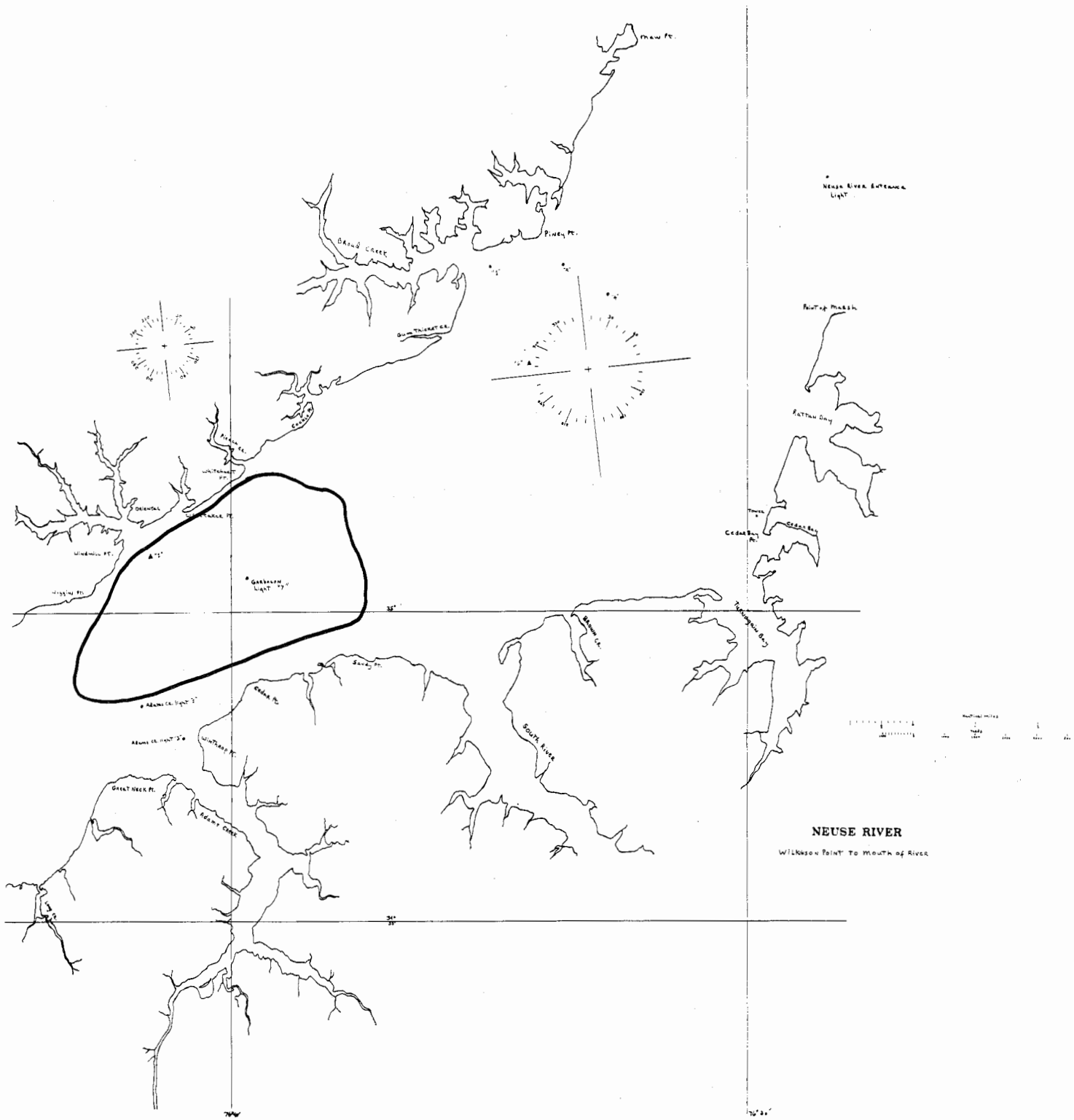

Maw Pt.
Piney Pt.
Broad Creek
Gum Thicket Cr.
Neuse River Entrance Light
Point of Marsh
Rattan Bay
Cedar Bay
Cedar Bay Pt.
Tuscarora Bay
Brown Cr.
South River
Sandy Pt.
Cedar Pt.
Winthrop Pt.
Great Neck Pt.
Adams Creek
Adams Cr. light "3"
Adams Cr. light "3"
Whitehurst Pt.
Oriental
Whitaker Pt.
Windmill Pt.
Higgins Pt.
Garbalon Light "7"
35°
76°30'
NEUSE RIVER
Wilkinson Point to Mouth of River

Figure 6. Dye patch on July 12, 1967.

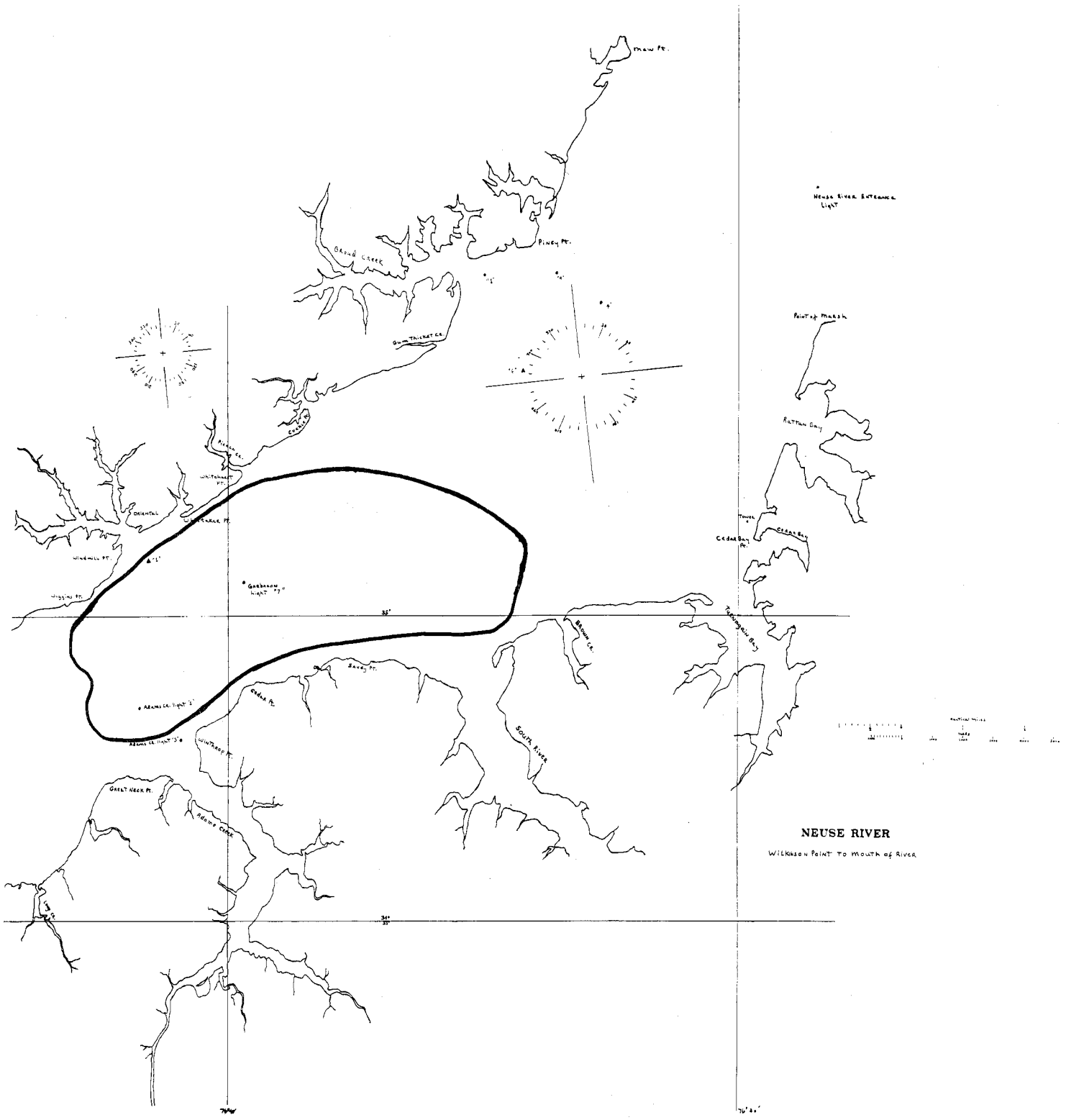

Maw Pt.
Piney Pt.
Neuse River Entrance Light
Point of Marsh
Rattan Bay
Cedar Bay
Cedar Bay Pt.
Tower
Gum Thicket Cr.
Whitehurst Pt.
Oriental
Windmill Pt.
Wiggins Pt.
Garbarron Light "7"
35'
Brown Cr.
Tuckahoe Bay
Savey Pt.
Cedar Pt.
Adams Cr. light "3"
Winthrop Pt.
South River
Great Neck Pt.
Adams Creek
34°
33'
76°30'
NEUSE RIVER
Wilkinson Point to Mouth of River

Figure 7. Dye patch on July 14, 1967.

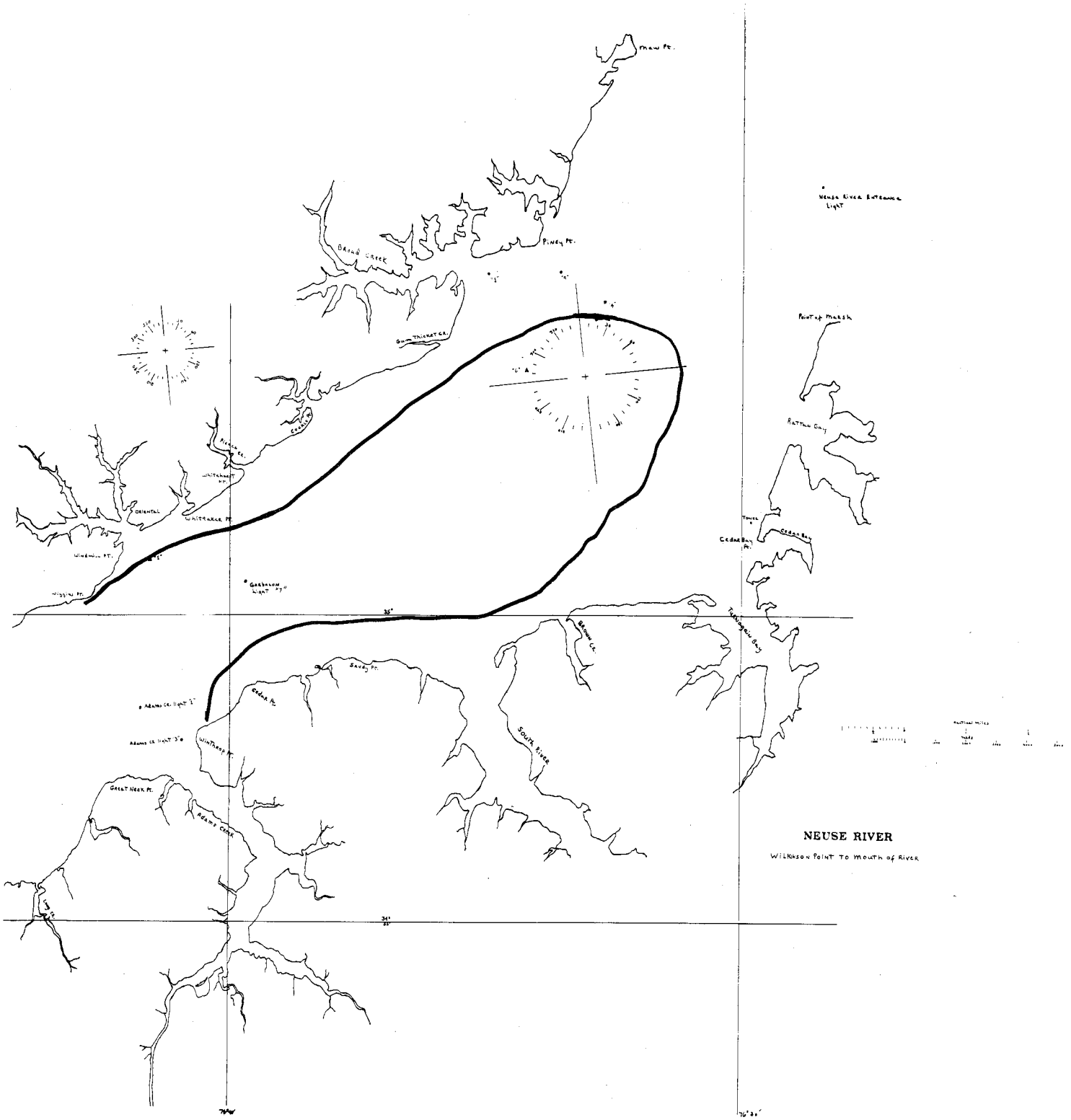
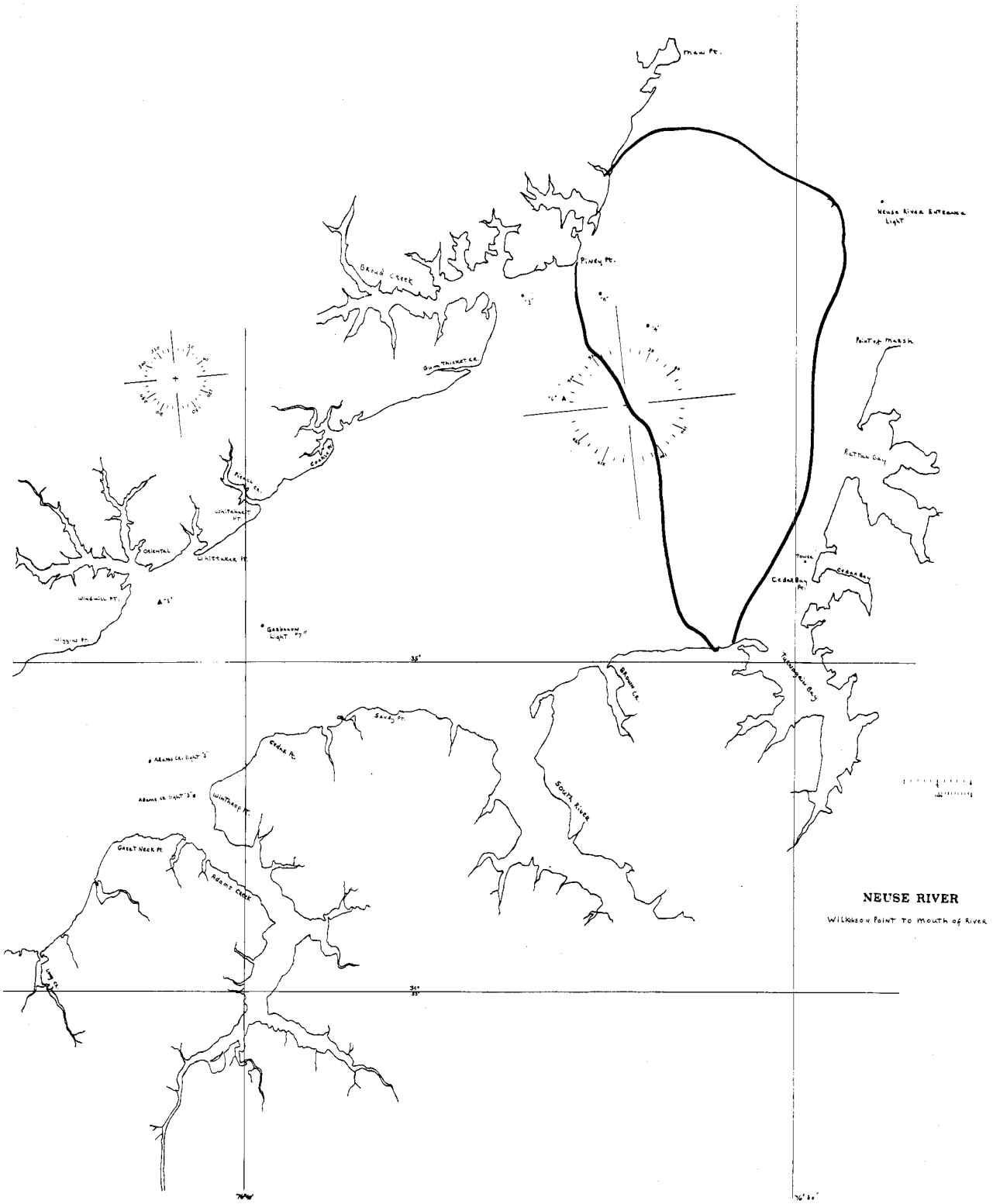

Maw Pt.
Neuse River Entrance Light
Piney Pt.
Broad Creek
Gum Thicket Cr.
Point of Marsh
Rattan Bay
Tower
Cedar Bay Pt.
Cedar Bay
Whitehurst Pt.
Oriental
Whittaker Pt.
Windmill Pt.
Wiggins Pt.
Garbalon Light "7"
35°
Brown Cr.
Tuckahoe Bay
Savey Pt.
Cedar Pt.
Adams Cr. light "2"
Adams Cr. light "3"
Winthrop Pt.
South River
Great Neck Pt.
Adams Creek
34°
76°30'
NEUSE RIVER
Wilkinson Point to Mouth of River

Figure 8. Dye patch on July 15, 1967.



NEUSE RIVER

Wilkinson Point to mouth of River

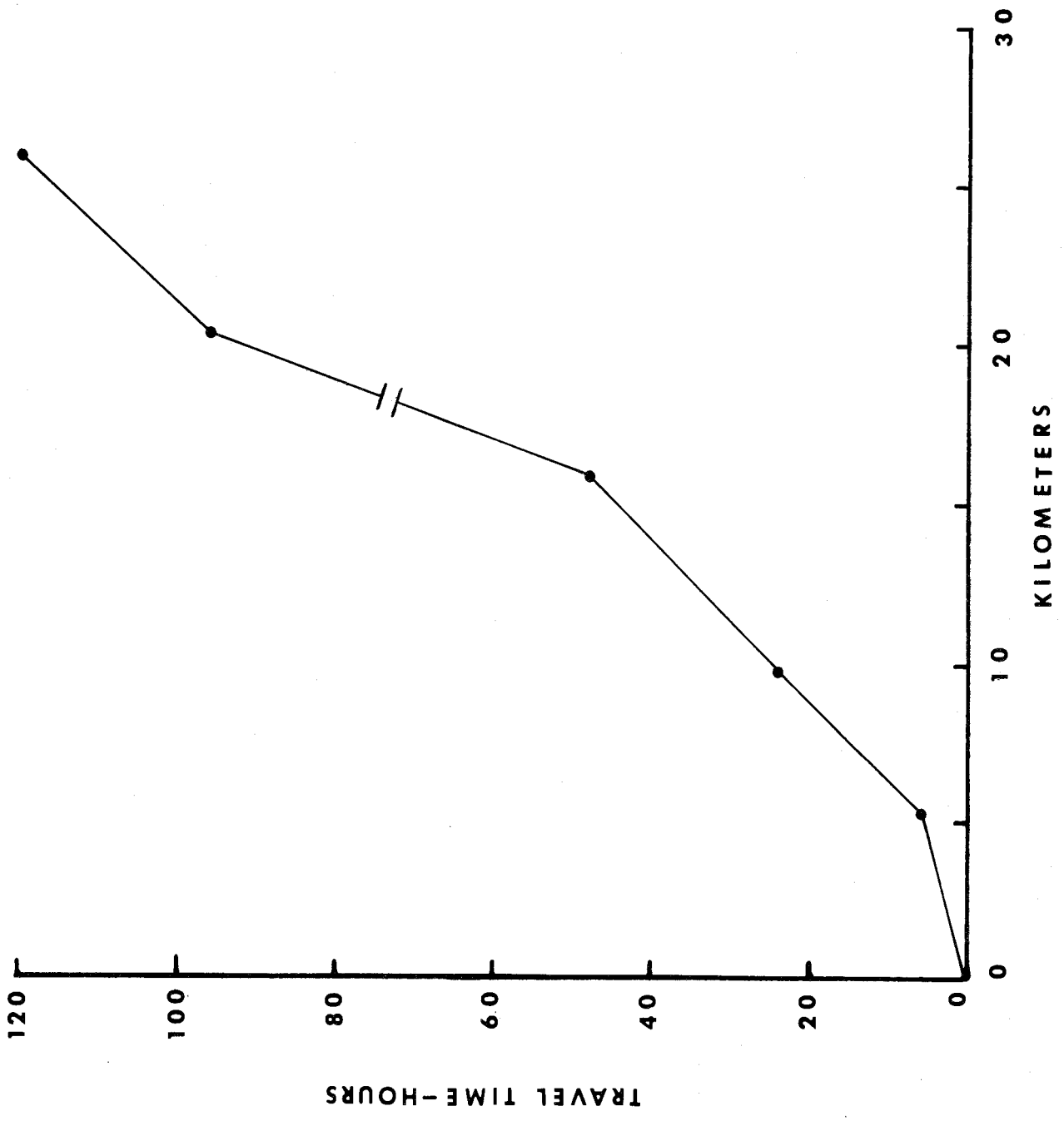
TIME	WIND DIRECTION	WIND VELOCITY (KNOTS)	DYE PLUME DIRECTION
July 10, 1967			
1043	260°	16	80°
1108	245°	12	65°
1330	220°	15	50°
1435	220°	15	50°
2020	220°	18	50-55°
2132	215°	18	50°
2300	215°	18	50°
July 11, 1967			
0015	220°	22	50°
0250	230°	20	50°
0455	230°	14	50°
0650	230°	12-14	50°
0840	240°	16-18	50°
1020	240°	15	50°
1215	345°	10	120°
1245	300°	10	120°
1315	275°	10	90°
1515	165°	16	300°
2015	335°	15	135°
2215	335°	15	130°

Table 1. Wind direction and velocity measurements and dye plume observations made during first dye insertion, July 10-11, 1967.

DATE	MEAN GAUGE HEIGHT	DATE	MEAN GAUGE HEIGHT(FT)
July 6, 1967	7.18	August 6, 1967	6.35
		August 7, 1967	6.83
July 7, 1967	6.96	August 8, 1967	6.64
July 8, 1967	6.37	August 9, 1967	6.55
July 9, 1967	6.23	August 10, 1967	5.63
July 10, 1967	5.91	August 11, 1967	6.24
July 11, 1967	5.54	August 12, 1967	7.38
July 12, 1967	6.06	August 13, 1967	7.44
July 13, 1967	5.99	August 14, 1967	7.37
July 14, 1967	5.83	August 15, 1967	7.43
July 15, 1967	6.41	August 16, 1967	7.13
July 16, 1967	6.46		

Table 2. Gauge height readings at New Bern, North Carolina during dye study periods, July and August, 1967. Data were supplied by the Raleigh, North Carolina office of United States Geological Survey.

Figure 9. Time-of-travel graph for the July, 1967 dye insertion.


TRAVEL TIME-HOURS
120
100
80
60
40
20
0
KILOMETERS
0
10
20
30

tracing was recommenced on July 17, no trace of the dye could be found. A total of 11.35 inches of rain was recorded for the area between July 7 and July 15, 1967, not unusual during summer months. The head of the dye patch moved 26.9 km during the five days it was traced.

Movement of the dye patch during the upstream phase of the study is shown in Figures 10 through 16. Pumping was begun at 1130 on August 7 and attempts to trace the dye on that date were unsuccessful. During the night, ca 2330, August 7, a squall struck during which the ship's anemometer was observed while indicating 40 m.p.h. (ca 35 knots); it is not known if that was the maximum. A set of Pritchard Vanes (Pritchard and Burt, 1951), in a configuration suitable for measuring water velocities as high as 0.68 knot was in the water at the time and was observed planing during the storm and noted to be back in the water at 0045, August 8. Wind direction, which had been 140° (velocities 3 to 16 knots), shifted to 320° and remained at or near that heading for the remainder of the dye insertion (Table 3). Wind heading was reflected in the direction of the dye plume as it moved away from the vessel.

Tracing was started on August 8, 1967 and the tail of the dye patch was located (at 0950) almost 2.5 km upstream of the point of insertion. The head of the patch was located (at 1430) 9.7 km downstream of the point of insertion. On August 9 tracing with two boats was begun; the dye was found in an area that extended from 0.73 km upstream to 14.4 km downstream

Figure 10. Dye patch on August 8, 1967.

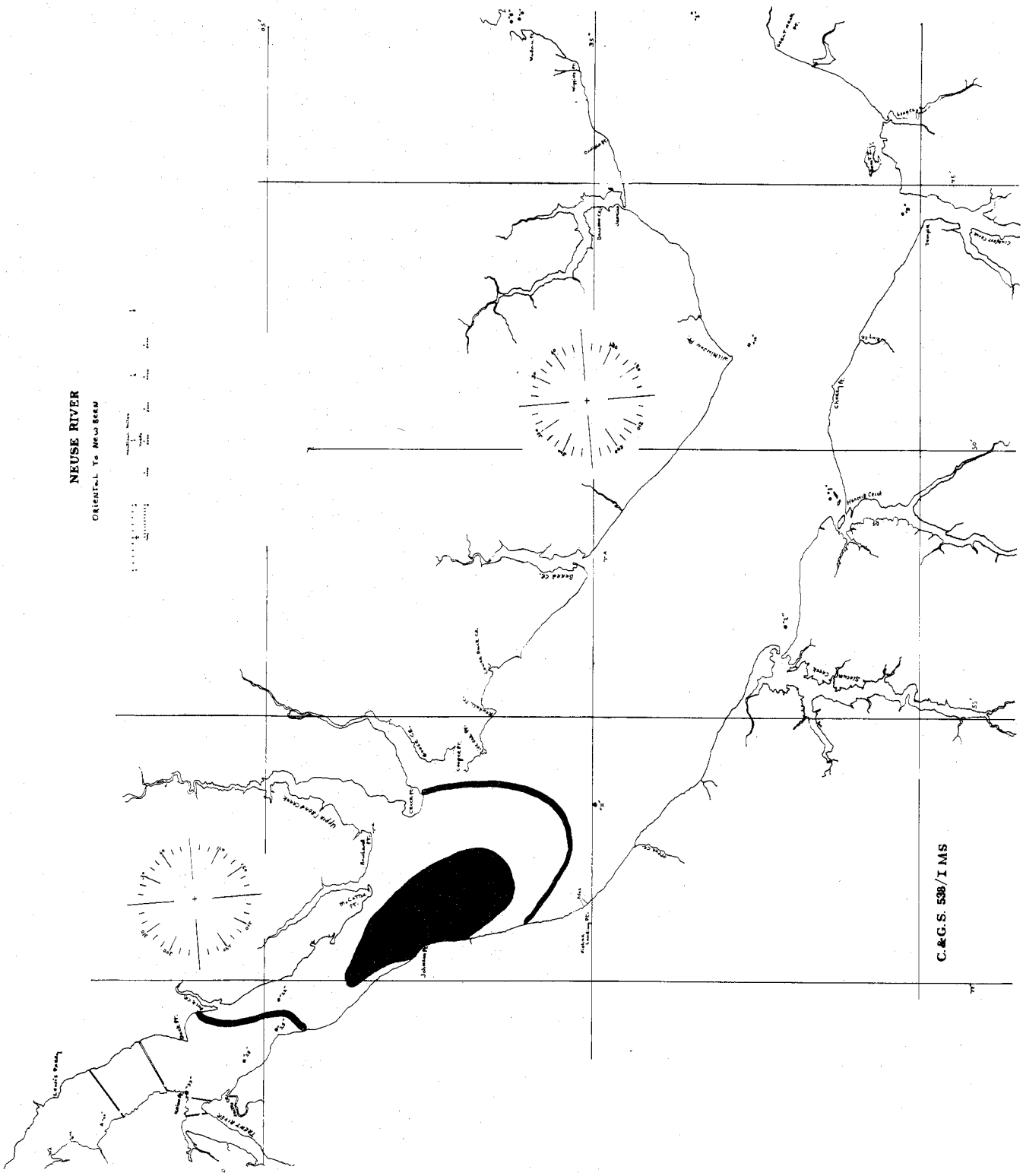

NEUSE RIVER
ORIENTAL TO NEW BERN
C.&G.S. 538/I MS

Figure 11. Dye patch on August 9, 1967.

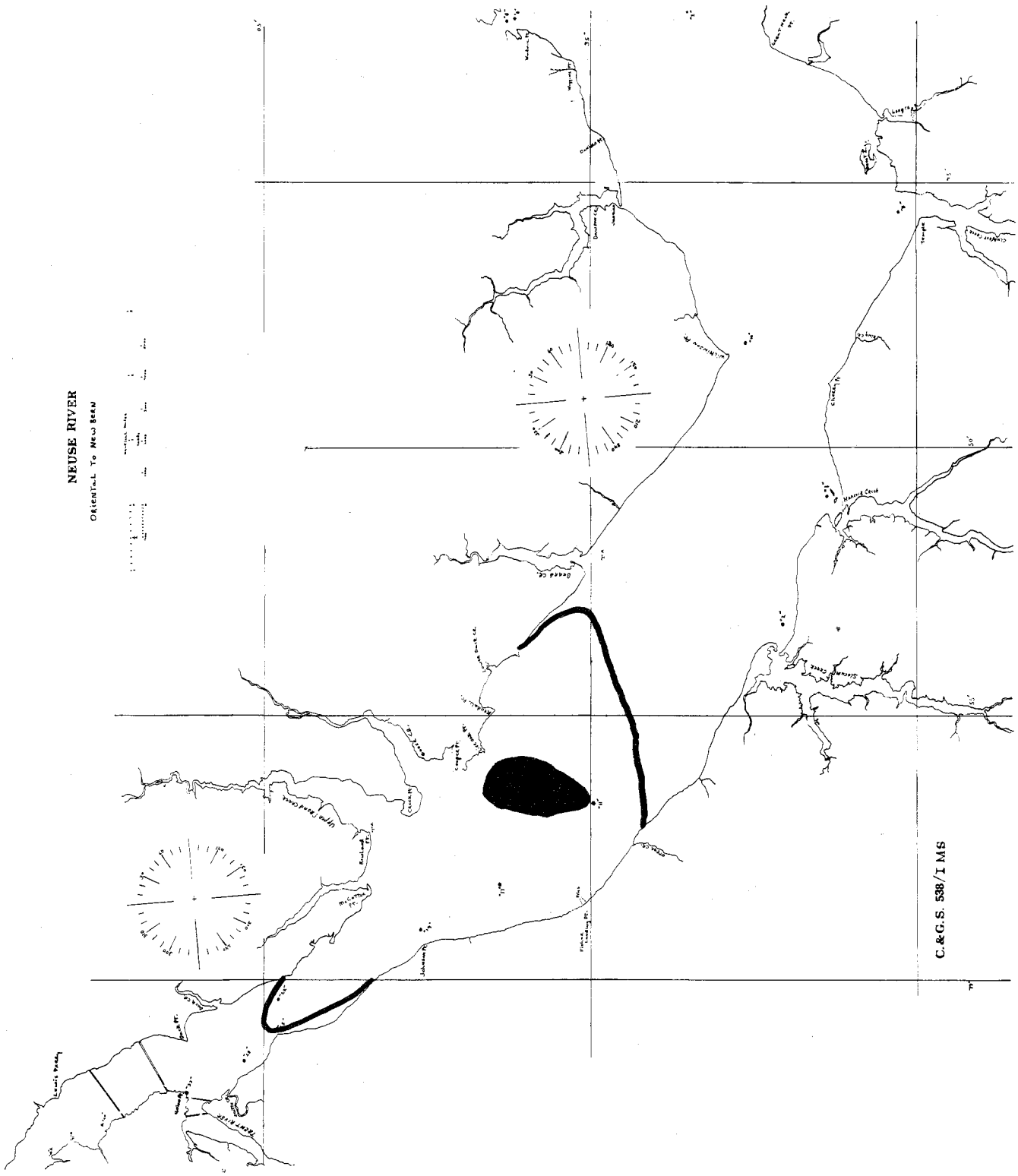

NEUSE RIVER
ORIENTAL TO NEW BERN
C.&G.S. 538/1 MS

Figure 12. Dye patch on August 10, 1967.

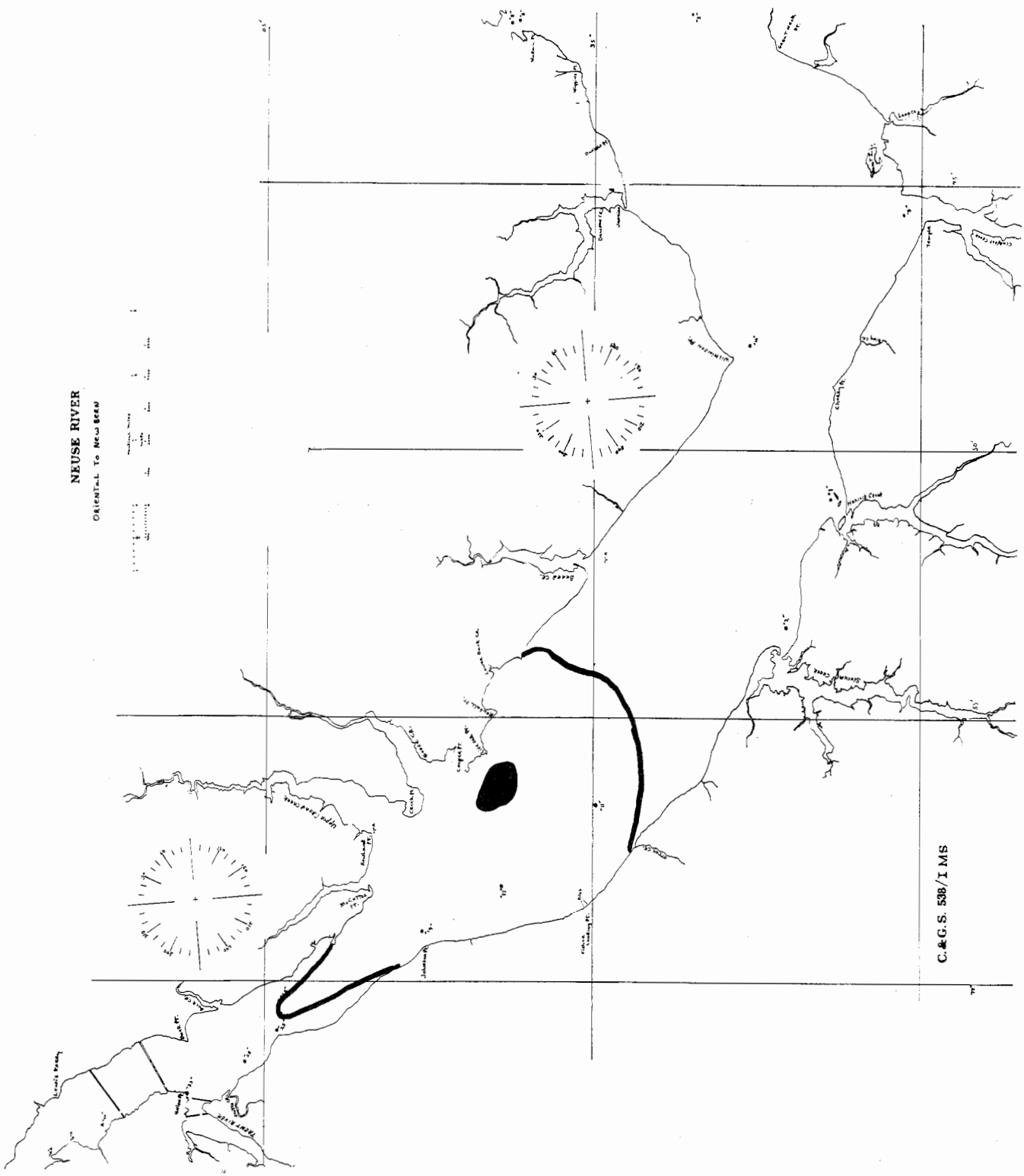

NEUSE RIVER
ORIENTAL To NEW BERN
C.&G.S. 538/1 MS

Figure 13. Dye patch on August 11, 1967.

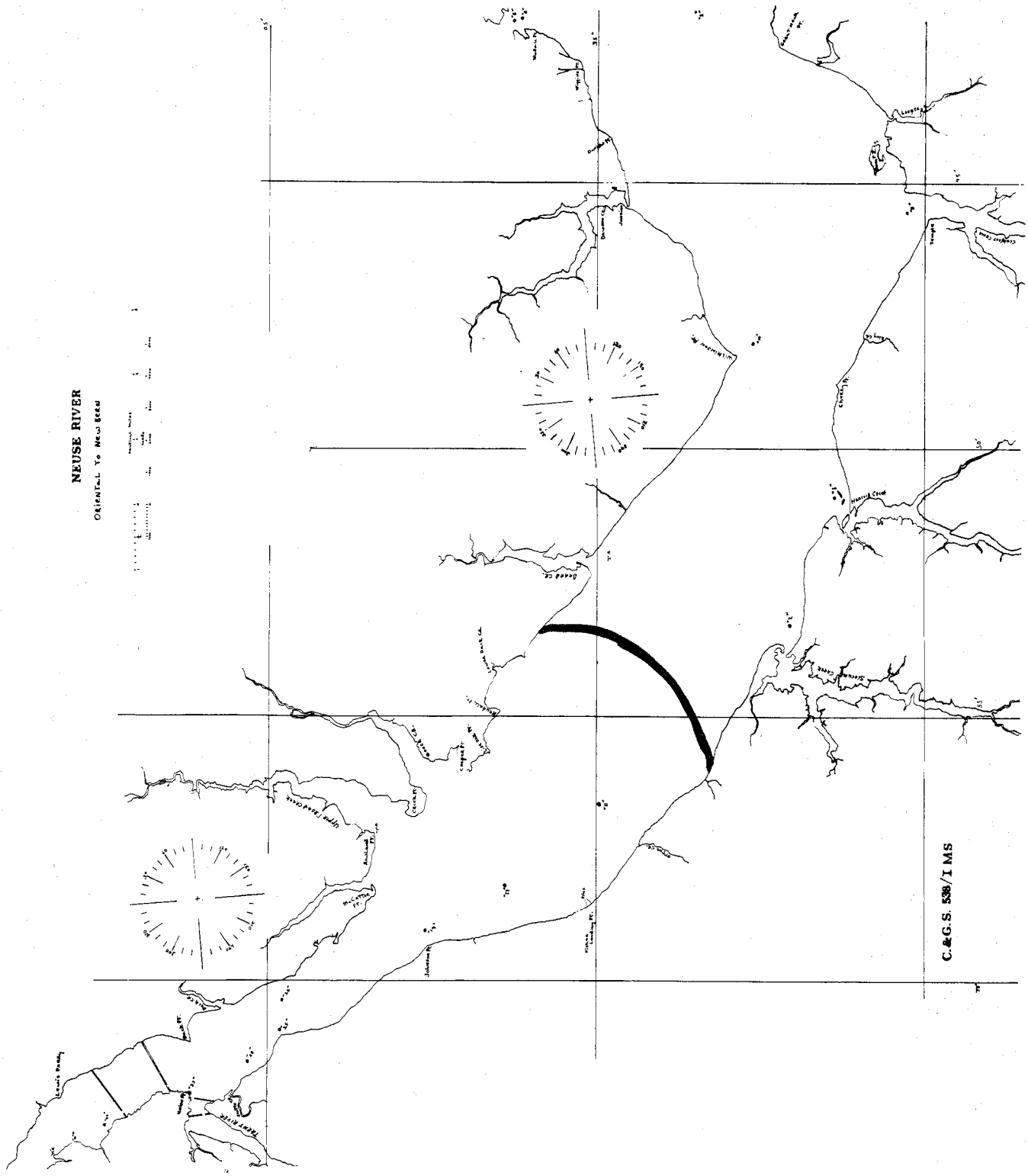

NEUSE RIVER
ORIENTAL TO NEW BERN
C.&G.S. 538/1 MS

Figure 14. Dye patch on August 12, 1967.

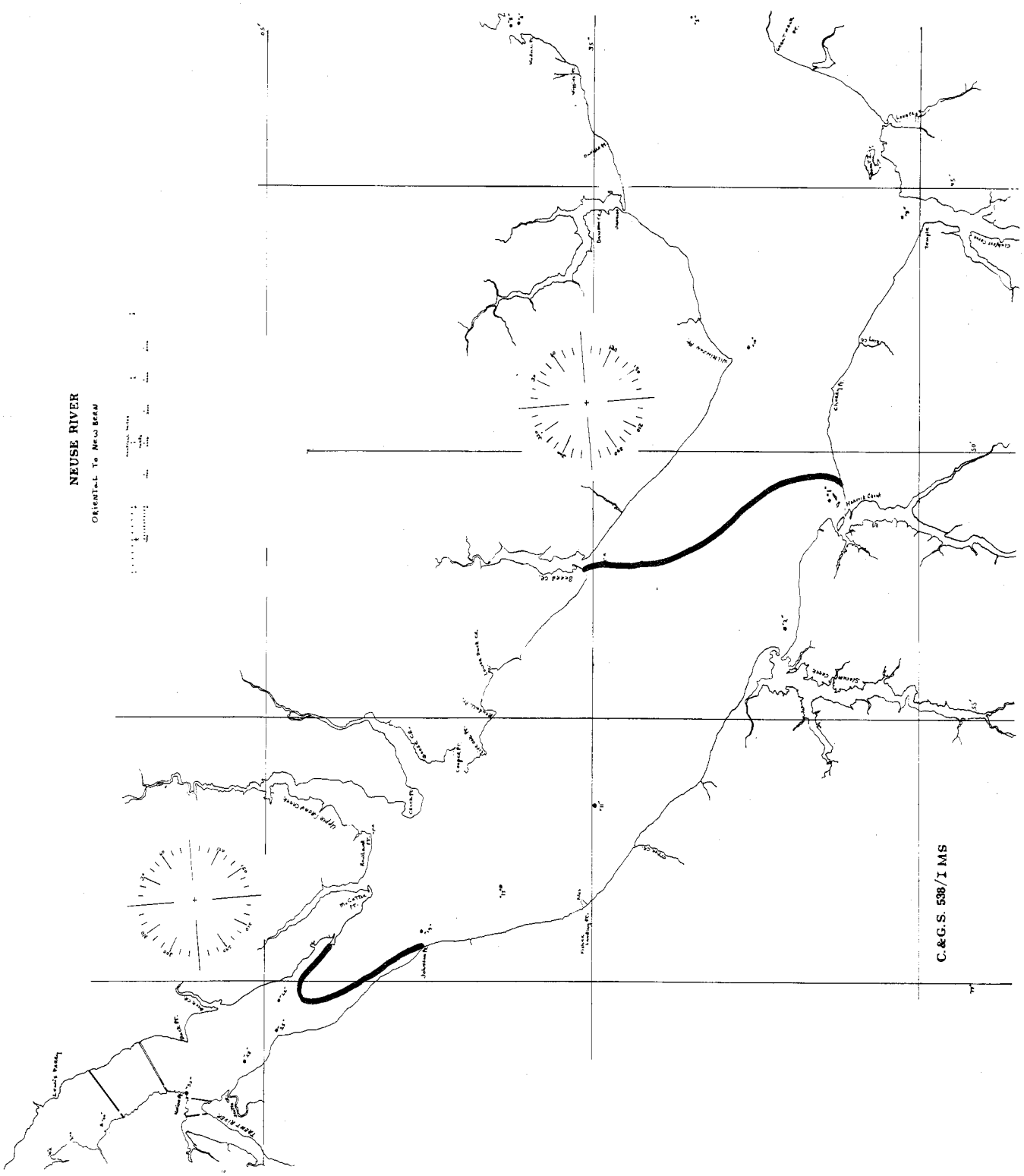

NEUSE RIVER
Orientation To New Bern
C.&G.S. 538/1 MS

Figure 15. Dye patch on August 14, 1967.

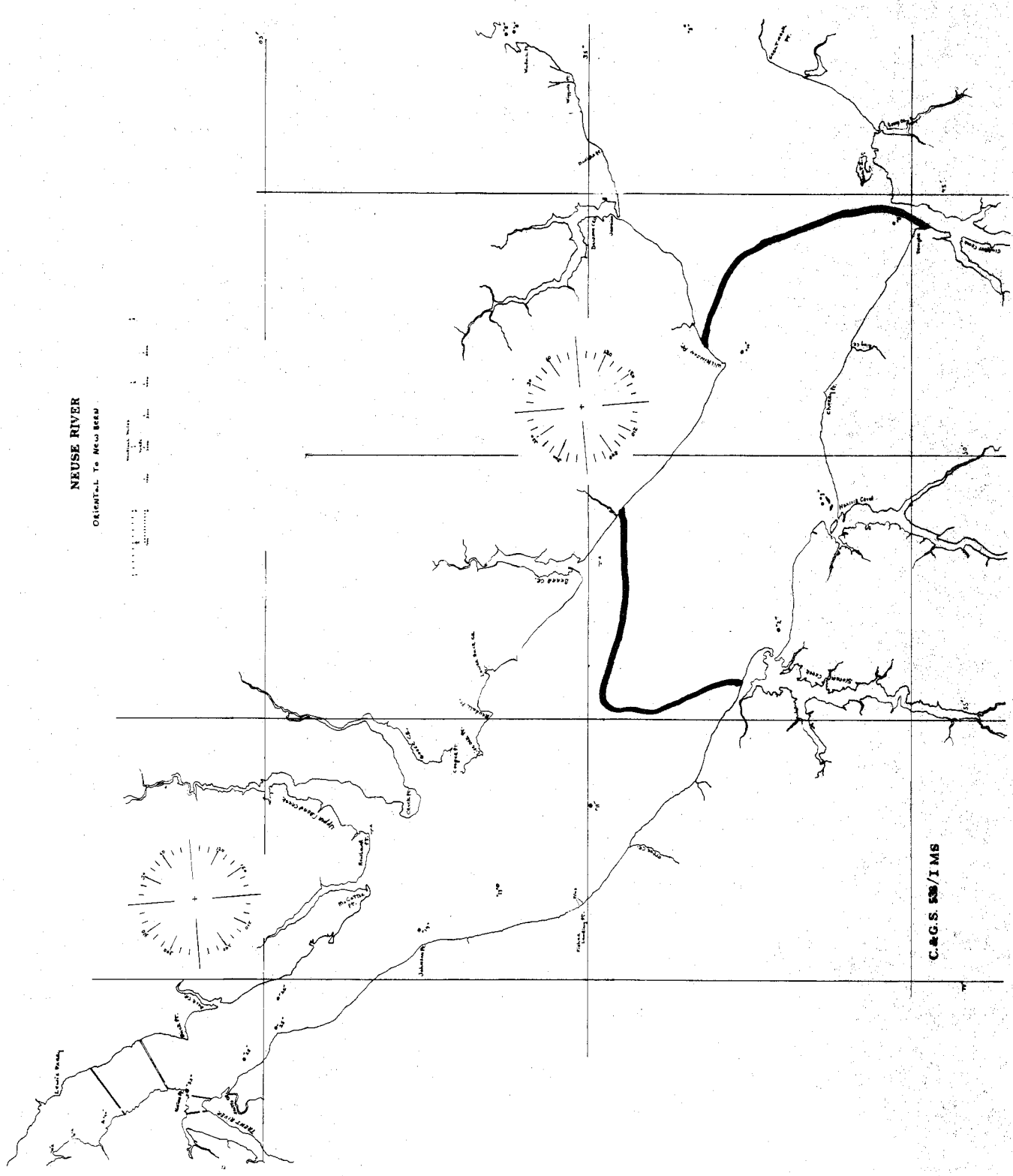
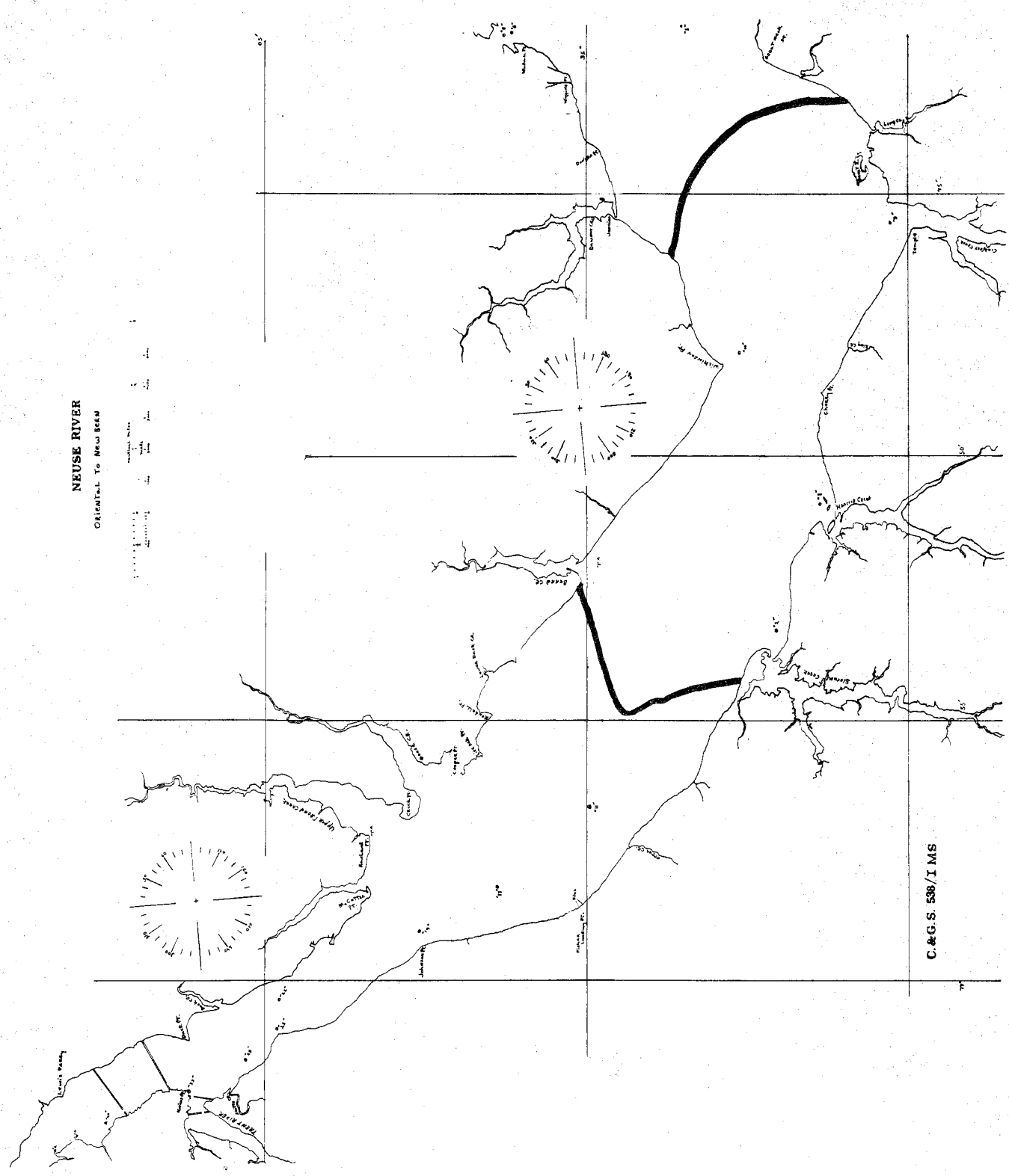

NEUSE RIVER
Oriental To New Bern
C.&G.S. 538/1 MS

Figure 16. Dye patch on August 16, 1967.


NEUSE RIVER
Oriental To New Bern
C.&G.S. 538/1 MS

TIME	WIND DIRECTION	WIND VELOCITY (KNOTS)	DYE PLUME DIRECTION
August 8, 1967			
1130	350°	3	150°
1215	350°	3	150°
1255	350°	3	150°
1354	340°	2	163°
1440	140°	8	160°
1535	140°	5	10°
1631	140°	20	350°
1725	140°	10	350°
1820	140°	10	350°
1920	160°	10	350°
2020	160°	10	350°
2120	160°	7	350°
2220	160°	7	350°
2320	140°	8	320°
2330	320°	35	
August 9, 1967			
0020	320°	17	160°
0120	45°	2	160°
0220	45°	2	250°
0320	45°	2	180°
0420	255°	4	140°
0525	330°	4	140°
0625	335°	1	160°

Table 3. Wind direction and velocity measurements and dye plume observations made during second dye insertion, August 8-9, 1967.

of the point of origin. The distances were approximately the same on August 10. Mechanical problems eliminated one boat on August 11 and the entire dye patch was not sampled; however, the head was located in approximately the same area as on August 9 and 10. The trailing edge of the dye patch remained in approximately the same area on August 12 when it was found to be 0.82 km upstream of the insertion point, however, the head of the dye was located at 20 km downstream.

Weather conditions were not suitable for small boat operation on August 13 (a total of 4.64 inches of rain fell on August 11, 12 and 13). When tracing was resumed on August 14 the dye was found in an area between 13.4 km and 28.5 km downstream. Data collected on August 15 are not considered reliable but the dye patch was located between 14.6 km and 30.5 km downstream on August 16. Mechanical difficulties prevented tracing on August 17. Tracing was resumed on August 18 and continued on August 19 but the dye could no longer be detected. The dye head of the patch moved 30.5 km in nine days, an average of 3.4 km per day.

MCAS recorded 7.45 inches of rain from August 6 to August 13. Wind records at that station and at Cape Hatteras Weather Station (HWS) indicate that the southwesterly winds which started late in the day on August 8 persisted until early afternoon of August 11. North or north north-east winds held from then until late in the day on August 16. Mean river level at New Bern rose 1.81 feet between August 10 and 13 and fell 0.34 feet between August 13 and 18 (Table 2).

CONCLUSIONS

In reporting on a similar study conducted in the Pamlico River in 1966, Horton et al (1967) attempted to compare observed travel-time with estimated travel-time calculated using a volume-displacement method (Ketchum, 1951). Calculated flushing time was 587 days whereas the observed time based on dye patch movement was 65 days. Wilson (1968) also reports studies in which there was poor agreement between estimated and observed travel-times and comments on some factors which he feels contribute to the situation. The models which permit estimating flushing rates assume steady state conditions which seldom exist.

Figure 9 is a graph showing time of travel for the downstream phase of the study. The relatively constant slope reflects the consistently high river flow and prevailing winds during the study period. If one examines USGS NC, 1967, one notes an increase in river flow from 581 cfs on June 20 to 1820 cfs on June 21 at the Kinston station. The increase continued to a high flow of 6180 cfs on June 28 and, while there was some fluctuation, river flow at Kinston did not fall below 1000 cfs until July 28. Total flow in the lower Neuse Estuary was increased by additions from that portion of the watershed that is located below the Kinston station and by the 11.35 inches of rain that fell in the area during the study period.

Wind direction and velocities during the dye insertion periods have been noted (Table 1) and wind records at MCAS show that the generally south-

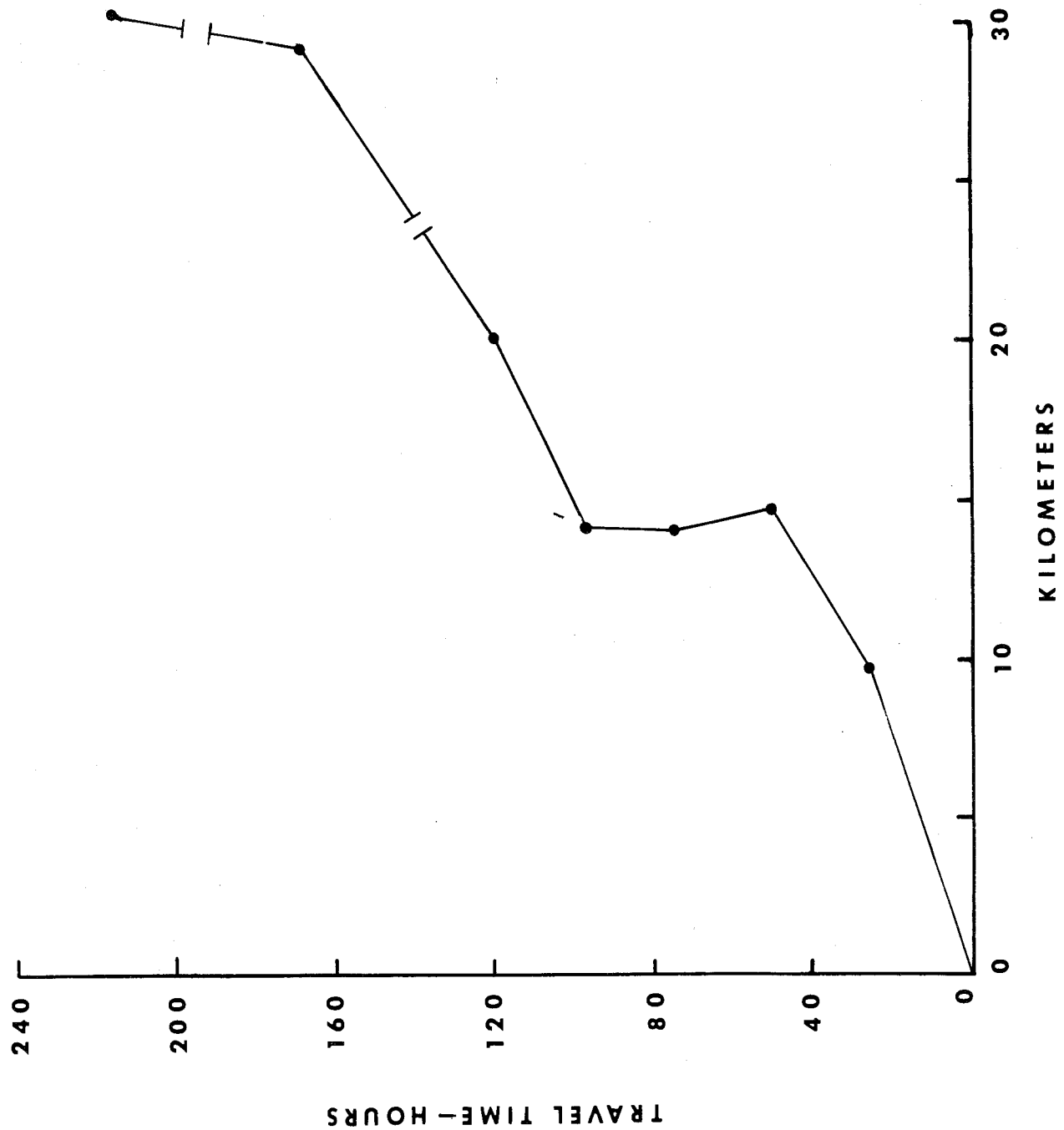
west winds persisted except for a few hours on July 13. The effect of wind on the Pamlico Sound complex has been noted previously (Seiwell, 1927; Roelofs and Bumpus, 1953; Woods, 1967).

While the head of the dye patch moved 26.9 km in 5 days, the trailing edge moved only 19.8 km, a mean dye patch movement of 23.4 km or 4.7 km/day. If the mean is used a flushing time of six days is estimated for the lower 28.2 km of the Neuse River Estuary under the conditions noted. If the movement of the trailing edge of the dye patch is considered the estimated flushing time is increased to 7.4 days.

Figure 17 is a graph showing time of travel for the upstream phase of the study. Rapid movement of the dye patch early in the tracing period no doubt was influenced by the squall described above, the configuration of the river and river flow. The river is narrow at the point of dye insertion, a segment one meter wide has a volume of 4374 m^3 while a similar segment at 5 km (Light 19, Figure 3) has a volume of 15856 m^3 and at 15 km (Light 11, Figure 3) a volume of 18099 m^3.

Apparently the dye patch did not move significantly on August 10 and 11 (Figures 12 and 13) despite the southwest winds that should have moved water out of the lower estuary. Gauge height at New Bern decreased on August 9, 10 and 11 (Table 2). This decrease coincides with a decrease in river flow at Kinston 12-13 days earlier (USGS, North Carolina, 1967). The increase in gauge height at New Bern starting August 11 is reflected in dye patch movement between August 11 and August 14 (Figures 14 and 15) when the head

Figure 17. Time-of-travel graph for the August, 1967 dye insertion.


TRAVEL TIME— HOURS
240
200
160
120
80
40
0
KILOMETERS
0
10
20
30

of the patch moved approximately 15 km in 60 hours. This occurred despite the wind shift noted above. However, although a northerly wind would ordinarily move water into the estuary, high discharge rates were recorded at Kinston for almost the entire month of August (USGS NC, 1967).

Mean dye patch movement for the nine days it was traced was 22.5 km or 2.5 km/day. Using this figure an estimated flushing time of 12.3 days is obtained for the section of estuary between the two dye insertion points. If movement of the trailing edge of the dye patch is considered, estimated flushing time is increased to 19.25 days.

Flushing time for the Neuse River Estuary during the summer of 1967 is estimated to have been a maximum of 26 to 27 days. However, river flow varies considerably (Table 4). It is obvious that further measurements will be needed before a mean flushing time can be estimated or before flushing times can be estimated for any given river discharge. Wilson (1968) outlines a method based on several measurements made under minimum and maximum conditions.

	1965	1966	1967	1968
JULY	225,720	19,583	60,537	32,642
AUGUST	178,530	33,993	97,942	12,219

Table 4. Total monthly discharge (cfs) for the Neuse River at Kinston, North Carolina in four successive years. Data are from USGS, NC, 1965, 1966, 1967 and 1968.

LITERATURE CITED

Horton, D. B., E. J. Kuenzler and W. J. Woods. 1967. Current studies in the Pamlico River and Estuary of North Carolina. Report No. 6. Water Resources Research Institute, University of North Carolina.

Ketchum, B. H. 1951. The exchange of fresh and salt waters in tidal estuaries. J. Mar. Res., 10(1):18-38.

Pritchard, D. W. and W. V. Burt. 1951. An inexpensive and rapid technique for obtaining current profiles in estuarine waters. J. Mar. Res., 10(2):180-189.

Pritchard, D. W. and J. H. Carpenter. 1960. Measurements of turbulent diffusion in estuarine and inshore waters. Proc. XII Gen. Assembly, International Un. Geodesy and Geophysics 51(36).

Roelofs, E. W. and D. F. Bumpus. 1953. The hydrography of Pamlico Sound. Bull. Mar. Sci. Gulf Caribbean, 3:181-205.

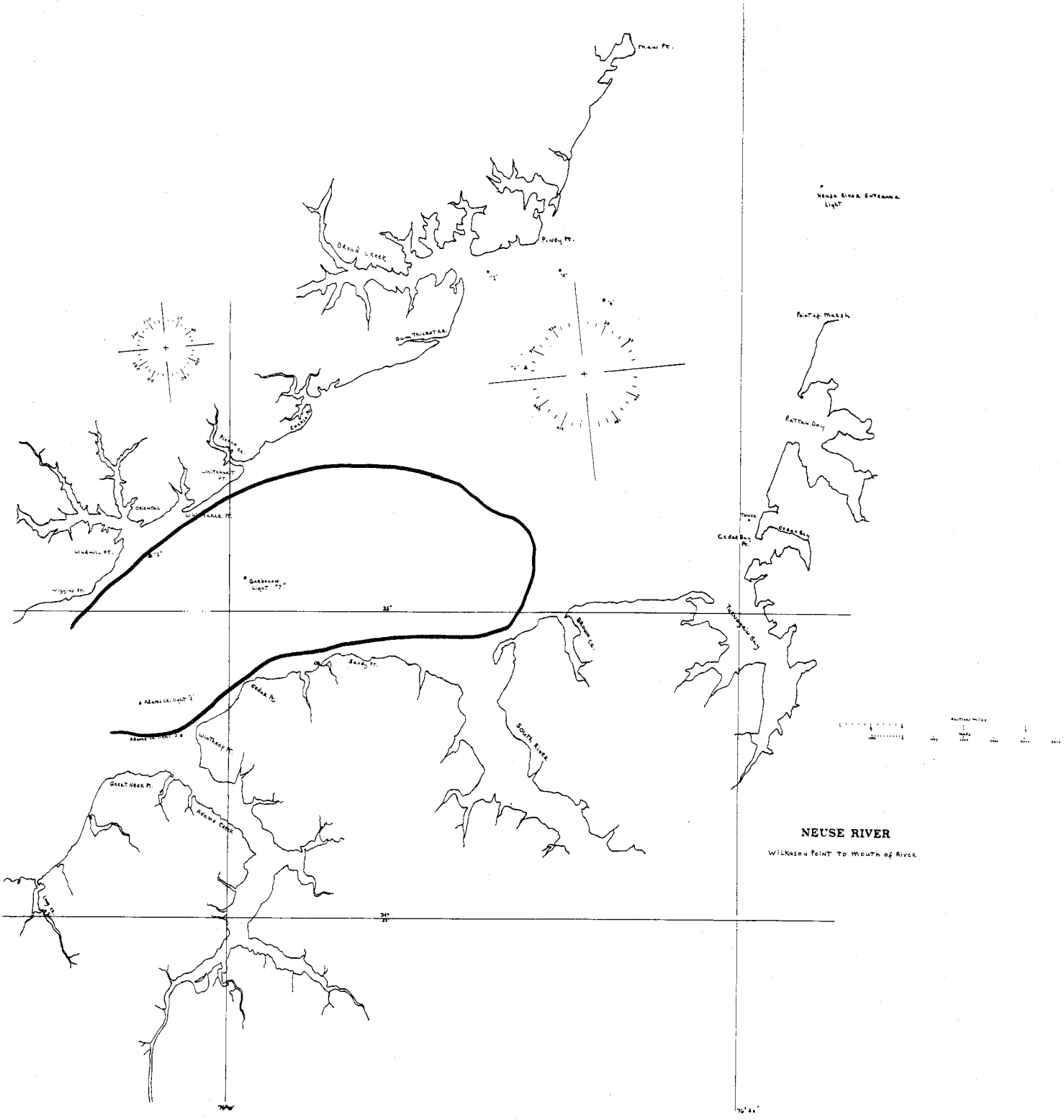
Seiwell, H. R. 1927. A brief report on the physical hydrography of Pamlico Sound and its tributaries. Typed report to the Department of Geology, University of North Carolina and the U. S. Bureau of Fisheries. Unpublished.

USGS NC. 1965, 1966, 1967 and 1968. Water resources data for North Carolina. Part 1. Surface water records. Published annually by United States Geological Survey.

Williams, A. B., G. S. Posner, W. J. Woods and E. E. Deubler. 1967. A hydrographic atlas of larger North Carolina Sounds. United States Fish and Wildlife Service. Data Report 20.

Wilson, J. F. 1968. Time-of-travel measurements and other applications of dye tracing. Internat. Assoc. Sci. Hydrol. Pub. No. 76.

Woods, W. J. 1967. Hydrographic studies in Pamlico Sound. In Proc. Symposium: Hydrology of the coastal waters of North Carolina. Water Resources Research Institute, University of North Carolina, Raleigh, N. C.



NEUSE RIVER

WILKINSON POINT TO MOUTH OF RIVER