

THE UNIVERSITY OF NORTH CAROLINA  
WATER RESOURCES RESEARCH INSTITUTE

NORTH CAROLINA STATE UNIVERSITY  
at RALEIGH

THE UNIVERSITY OF NORTH CAROLINA  
at CHAPEL HILL

David H. Howells, Director  
124 Riddick Building  
North Carolina State University  
Raleigh, North Carolina, 27607

April 2, 1970

MEMO: To Whom It May Concern

FROM: David H. Howells, Director

SUBJECT: Institute Report No. 33 -- "Phosphorus Concentrations  
in the Pamlico River Estuary of North Carolina"

The attached report is the first of a series covering work completed under Project B-004-NC, "Changes During Eutrophication of an Estuary," Matching Grants Program, Office of Water Resources Research, U. S. Department of the Interior. The study was initiated by Dr. Donald Horton and brought to conclusion by Dr. John E. Hobbie, Department of Zoology, N. C. State University at Raleigh.

This report on the phosphorus concentrations in a North Carolina estuary summarizes data collected bi-weekly since 1967. The conclusions are:

1. The Texas Gulf Sulphur Company is adding large amounts of phosphorus to the waters of the Pamlico River. This phosphorus is entering from the plant site and not from the decant water of the slimes-settling basin.
2. The phosphorus added by the phosphate mining and fertilizer manufacturing operation does not appear to be changing the ecology of the River because more than enough phosphorus for normal algal photosynthesis is already present.
3. Phosphorus concentrations in the Tar River entering the upper estuary have tripled since 1967. This is likely due to sewage and indicates that nitrogen compounds are also increasing (unpublished evidence bears this out).
4. Phosphorus concentrations are already above the 0.04 mg P/l (2.8 ug-at P/l) level that marks the limit between polluted and unpolluted waters. If sufficient nitrogen compounds become available from sewage or farm land drainage, then intense eutrophication and eventually pollution of this estuary will result within the next two decades.

DHH:k

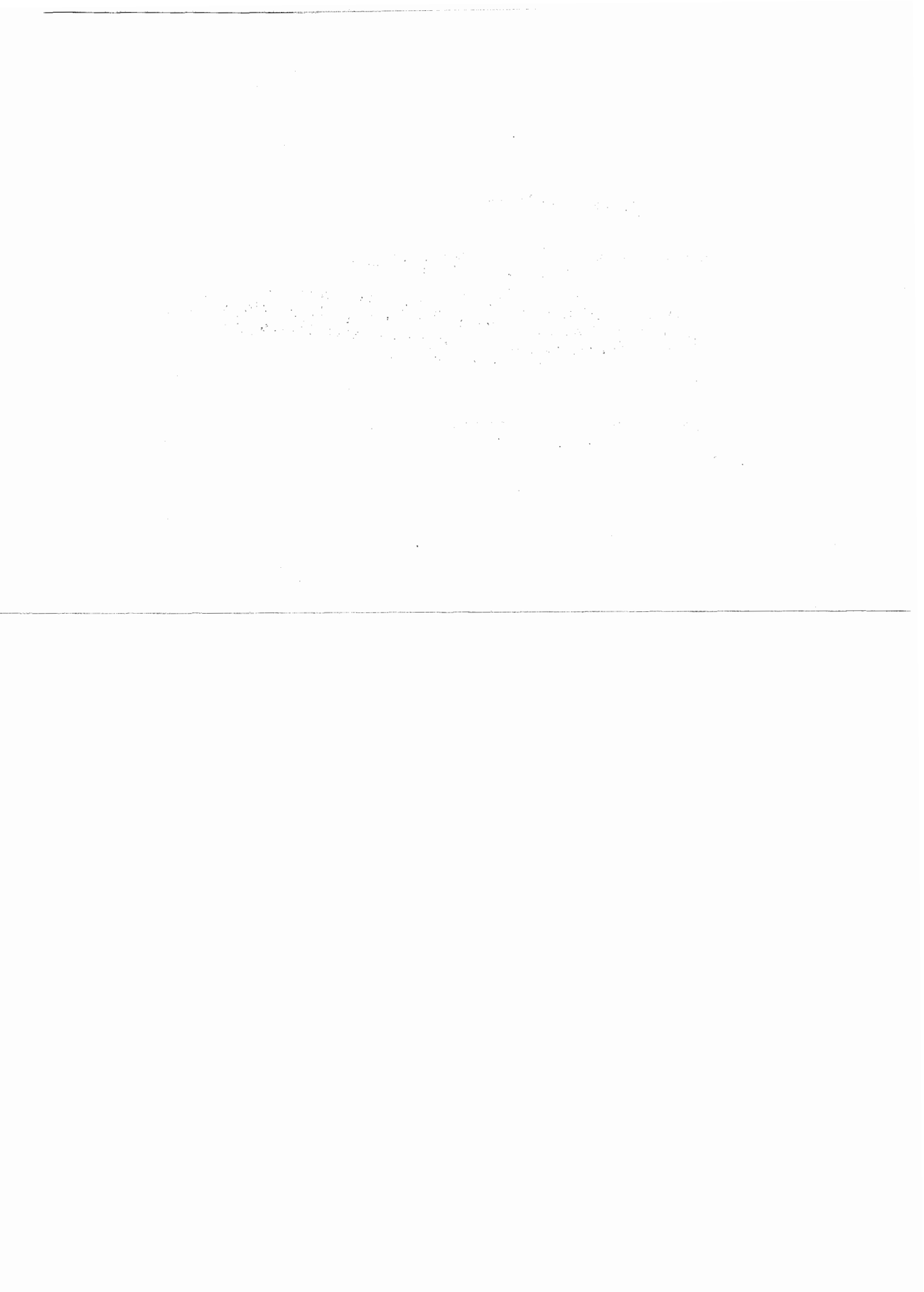


ADDENDA -- WRRI REPORT NO. 33

Page 7, second paragraph under River Flow, add:

A short-term flow study of the Pamlico River in 1967 using rhodamine B dye by Horton, et al, provided additional insight into the flushing characteristics of the estuary. (See WRRI Report No. 6.)

Page 44 should be labeled page 47.



PHOSPHORUS CONCENTRATIONS  
IN THE PAMLICO RIVER ESTUARY OF NORTH CAROLINA

by

John E. Hobbie

Associate Professor of Zoology

N. C. State University

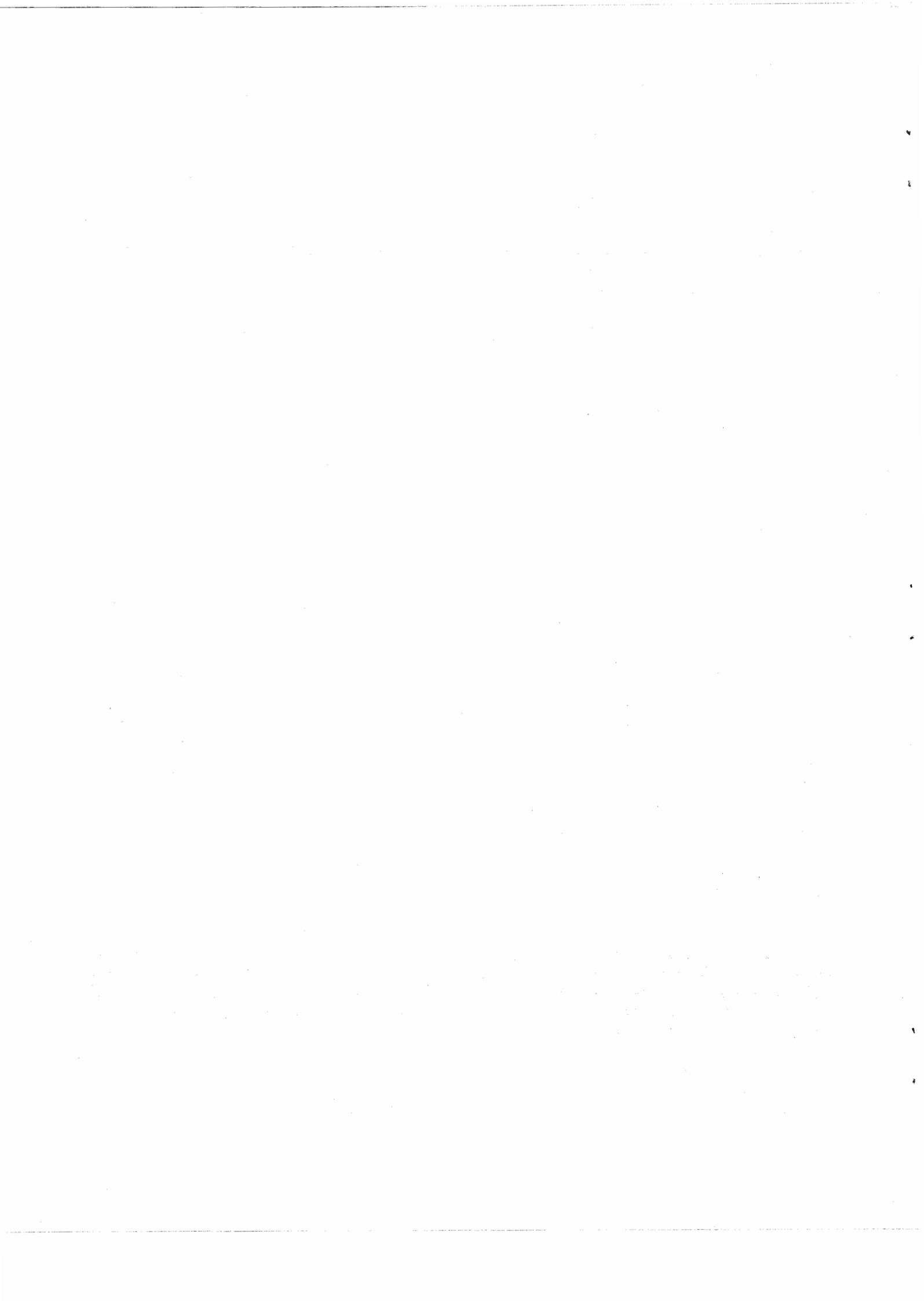
Raleigh, N. C.

March 16, 1970

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## ABSTRACT

The Pamlico River is a naturally rich estuary that extends from Washington, North Carolina some 35 miles to enter the west side of Pamlico Sound. It is shallow (average depth 10.5 feet), and has only a six inch lunar tide.

The natural levels of phosphorus in the estuary are, for total phosphorus, 1 - 2 ug-at P/l (0.031 - 0.062 mg P/l). As a result of phosphate mining activities, phosphate levels as high as 93 ug-at P/l (2.9 mg P/l) have been measured in the estuary, however, release is intermittent and the high phosphorus water is found as patches that move seaward along the south shore of the estuary. Because this estuary appears to have more than enough phosphorus for normal algal photosynthesis, it is believed that the phosphorus added by the phosphate mining and fertilizer manufacturing operation has little effect on the biology of the river at the present time.

Even more serious is a rise in the concentration of phosphorus entering the upper estuary from the Tar River. This added phosphorus has tripled over the past three years. Because this phosphorus appears to come from sewage, it is likely that the nitrogen is also increasing and that eutrophication of the river could take place within 10 - 20 years.



## INTRODUCTION

The estuaries of the United States are important to the nation as a whole as a place for recreation, as a nursery ground for many of the commercial fish, and as water available to industry for cooling waters and transportation. For most of these uses it is important that the estuaries remain as unpolluted as possible. Yet, with the increasing growth of population and industry in North Carolina, increasing amounts of nutrients are entering the rivers and eventually the estuaries. Given time, these nutrients will change the estuaries through enrichment of the phytoplankton and other plants. For this reason, it is important to monitor the concentration and effects of the various nutrient chemicals entering the North Carolina estuaries. This information is important not only for its value as an indicator of the changes in North Carolina estuaries, but also will give important information for regulatory bodies and other appropriate state agencies.

Under the impetus of the establishment of phosphate mining industry on the estuaries of North Carolina, an estuarine laboratory was set up near Aurora, North Carolina under the direction of The Department of Zoology, North Carolina State University. Since 1965 this laboratory has carried a series of sampling projects and experimental work. These projects have covered such diverse topics as phosphate concentration, nitrogen concentration, fish abundance and distribution, phytoplankton abundance, the reasons for zooplankton abundance at various times of the year, and the distribution and abundance of benthic (bottom dwelling) animals. The report here, which covers the phosphate concentrations in the Pamlico River, is the first of a series of reports which will deal with the monitoring data gathered over the past four years. It is expected that they will cover salinity, temperature, dissolved oxygen, nitrogen, algal concentrations, and benthic animals.

Not only will these data present a base-line study for comparison in future changes, but also will evaluate and delineate changes that have already occurred in these estuaries.

Phosphate is a vital part of every living organism, yet is found in nature at a very low concentration. For example, the use of carbon, nitrogen, and phosphorus by organisms in nature has the approximate ratio of 106:16:1 (C:N:P:) (Redfield, Ketchum and Richards, 1963). Estuaries usually contain around 1-ug-at P/liter (equal to 31 ug P/liter). Ketchum (1969) states that the maximum concentration of phosphate found in unpolluted waters is about 2.8 ug-at P/liter for coastal waters. This implies that if more than this amount were found, eutrophication or the speed up of biological activity and the resultant changes in the biological population will begin. This also implies that the necessary nitrogen and other nutrients are present. In fact, in many coastal aquatic ecosystems there is not enough nitrogen present and it is said that the nitrogen is the limiting factor.

In spite of the importance of phosphorus in estuaries, the annual cycles of phosphorus have not been well studied on the east coast estuaries. In one extremely polluted situation, Morriches Bay on Long Island, the total phosphorus reached 80 ug-at P/liter in the river entering the bay (Barlow, Lorenzen and Myren, 1963). At the other extreme, the open ocean has around 1 ug-at P/liter. In a recent study, Carpenter, Pritchard, and Whaley (1969) reported that most of Chesapeake Bay had between 1 and 2 ug-at P/liter.

#### Pamlico River Estuary

The river enters Pamlico Sound directly to the west of Cape Hatteras. The estuary extends from Washington, N. C. on the west, some 35 miles to Pamlico Point where the river enters the sound. The maximum width is about 8 miles (Fig. 1). The average depth is only 10.5 feet and the outer banks damp out the lunar tide effect

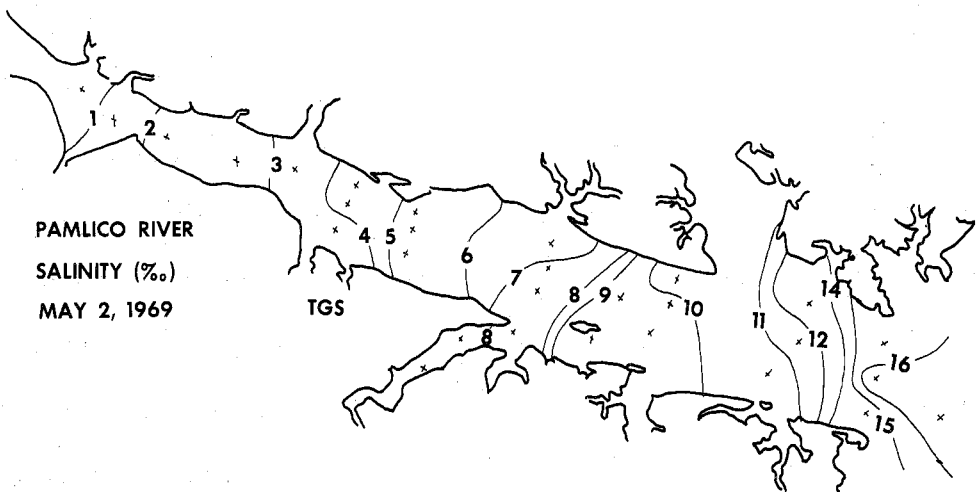
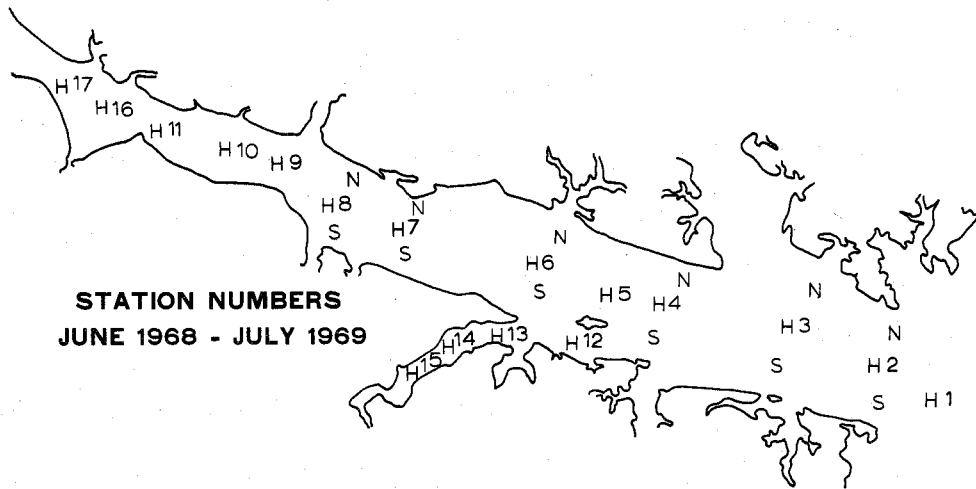
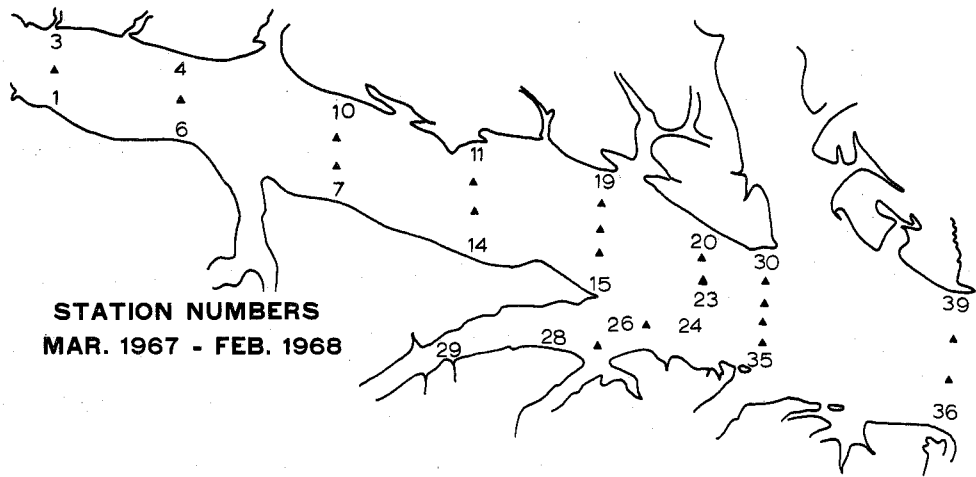


Figure 1. Top--Station numbers for samples taken in the Pamlico River between March, 1967 and February, 1968.  
Middle--Same, June, 1968 to July, 1969.  
Bottom--Salinity (parts per thousand) in the Pamlico River, N. C.

so that the tide is only 6 inches. Most of the change in water level, up to 3 to 4 feet, is caused by wind tides.

This type of estuary, in which a river spreads out into a slowly moving broad body of water and becomes mixed with sea water, has been called an oligohaline estuary. In a recent report to FWPCA, data from the Pamlico River were used as an example of this type of estuary (Copeland, Horton, and Tenore, published report in preparation). The material that follows is taken from this report as well as from unpublished reports and theses by graduate students in the Department of Zoology, North Carolina State University.

The estuary is characteristically shallow with low salinity (Fig. 1) and high turbidity. Large amounts of fresh water runoff can shift these salinity isochlors as much as 10 miles to the west (to the right in Fig. 1), and it is this fluctuating salinity that may be most important in deciding the distribution of plankton and benthic organisms.

The plankton is dominated by a tremendous algal bloom which reached red tide proportion in the numbers of Peridinium triquetrum in January, February and March of every year. After the bloom, the algae remain at low population levels for the rest of the year. The zooplankton is dominated by the common estuarine copepod, Acartia tonsa. Most of the fish found are salt water fish, although fresh water forms do occur close to Washington, N.C. The permanent resident fish include mummichog, the rainwater killifish, the naked goby, white perch, the striped anchovy, American eel, and the hogchoker. Another group of fish is present year round except in the winter. These include the tide water silverside, the rough silverside, the common silverside, spot, atlantic croker, pinfish, atlantic menhaden, summer flounder, and the northern pipe fish. Other fish are found only during their migrations through the estuary. These include hickory shad, the alewife, glut herring, American shad, gizzard, shad, striped bass, and the common sturgeon.

The deeper waters of the estuary are frequently very low in dissolved oxygen during the summer which appears to limit the benthic invertebrates to the sandy sediments found in the shallow waters. The clam, Rangia cuneata, dominates the oligohaline portion of the estuary whereas the bivalve Macoma Balthica is important throughout the estuary. Also occurring in the shallow zones are extensive stands of rooted aquatic plants, Ruppia, and Potamogeton, which furnish food for wintering ducks and geese.

The blue crab and shrimp as well as the clam (Rangia), and the oyster are harvested from this river in sizable quantities.

Texas Gulf Sulphur Company began mining phosphate ore on the south side of the estuary in 1965. This company now has a large mine and a fertilizer plant near Aurora, N. C., and exports both the ore and the finished fertilizer. The mining operation is an open, dry pit mine and the ore is first concentrated and separated from the accompanying clay and sand. This waste material resulting from this separation and concentration, called slime, is pumped some 8 miles into a large, 750 acre settling basin from which the water runs off into the estuary. It was initially expected that most of the phosphorus added to the river would come from this runoff from the large settling basin. However, it soon became apparent that Lee Creek, which runs through the plant itself, is adding much more phosphorus than the settling pond runoff.

Many people participated in the planning, data collecting, and data reducing phases of this project. Among those who should be given credit are Edward Carpenter, James Berry, David Gossett, Nat Smith, Jan Lee, Nita Scobie and Nancy Hall. Dr. Donald Horton directed the early data collection and was coinvestigator.

## METHODS

At least four different series of stations have been used in the past. Only the last two are reported here (Fig. 1).

At two week intervals, surface samples were taken at each station and returned to the laboratory for analysis. Analysis methods followed in general those proposed by Strickland and Parsons (1965). Part of the sample was filtered through Gelman type A Glass Fiber Filters prior to analysis and part of the unfiltered and part of the filtered sample was digested by the potassium persulfate oxidation method of Menzel and Corwin (1965) using an autoclave. All three samples were then analyzed by the mixed reagent method of adding molybdic acid, ascorbic acid, and trivalent antimony.

	not filtered	---	digested	---	analyzed	=	Total unfiltered P
Sample	filtered	---	digested	---	analyzed	=	Total Filtered P
	not filtered	---	not digested	---	analyzed	=	Reactive P

The color development was read in a Beckman DU II spectrophotometer and calibrated against standards. These standards proved to be constant and a factor of 5.0 multiplied by this spectrophotometer reading gave the concentration. However, it was noted in 1969 that the calibration curve was not linear above 10 ug-at P/liter and that the previous readings obtained were underestimates. Therefore, the concentrations measured prior to October 14, 1969, are low and can be corrected by multiplying by a factor of 1.0 at 10 ug-at P/liter and 1.6 at 20 ug-at P/liter. Because this correction makes no difference to the conclusions of this paper, it was not applied to the data. It was also found that the curves for total (digested) and reactive (undigested) phosphate concentrations versus extinction had different slopes. Again the differences are slight, but this

correction and the correction for the differing factors at high concentrations of phosphorus will clear up most of the discrepancies of the data where the reactive phosphorus is higher than the total phosphorus.

Phosphorus in the sediment was measured in a manner similar to the total unfiltered phosphorus. A measured amount of sediment was placed in a beaker and the persulfate oxidation carried out in an autoclave before analyzing with mixed reagent. The dry weight of the sediment was determined after two or three hours of drying in a 100°C oven.

## RESULTS

### River Flow

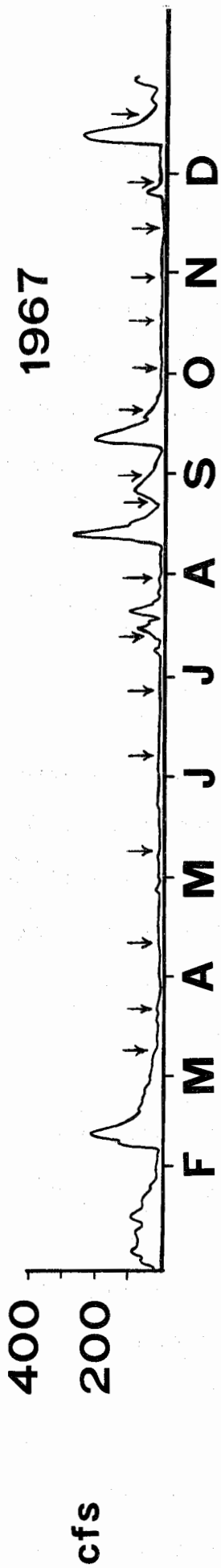
The only water flow data available from the study area is that of the U. S. Geological Survey (reports for 1966, 1967, and 1968 were obtained from the Water Resources Division, U. S. Geological Survey, Raleigh). One station reported in Figure 2 is on the Tar River at Tarboro, North Carolina, 49.2 miles upstream from Washington, N. C. The other station is on Durham Creek near Edward, N. C., about 6.7 miles upstream (south) from the estuary (Durham Creek is the large creek entering the south side of the Pamlico River just to the west of Texas Gulf Sulphur (see Fig. 1)).

The great differences in station location are reflected in the periods of high water (Fig. 2). Some of the high flow occurring at one station did not appear at the other (for example the high flow in June, 1967 in the Tar River), probably because of the local character of that particular storm. The high flow in the Tar River lagged that of Durham Creek by 6 to 15 days, reflecting the more immediate response of the small Durham Creek watershed (21 square miles) versus the 2,140 square miles of the Tar River.

The water flow was irregular at both stations but there was more flow during the winter. High flow periods in the Tar River were: 1967 in early March, end of

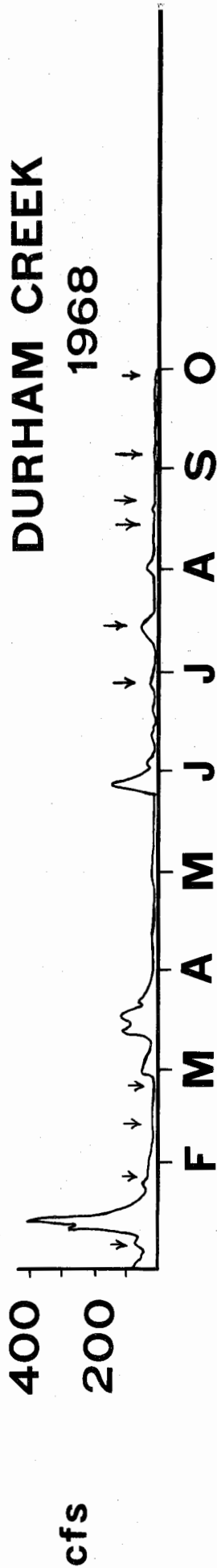
# DURHAM CREEK

1967



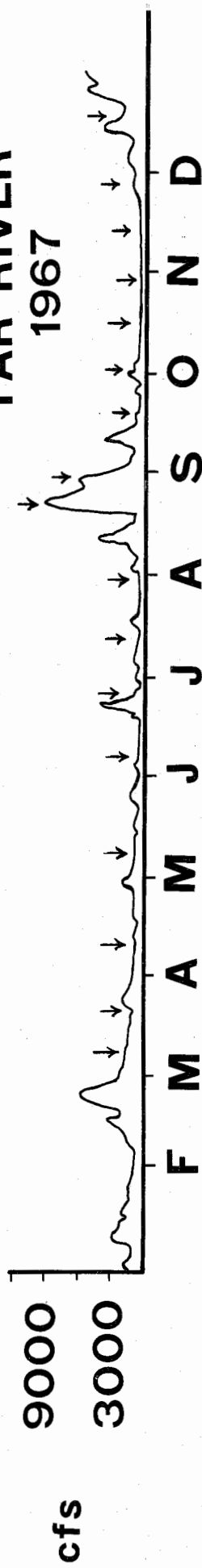
# DURHAM CREEK

1968



# TAR RIVER

1967



# TAR RIVER

1968

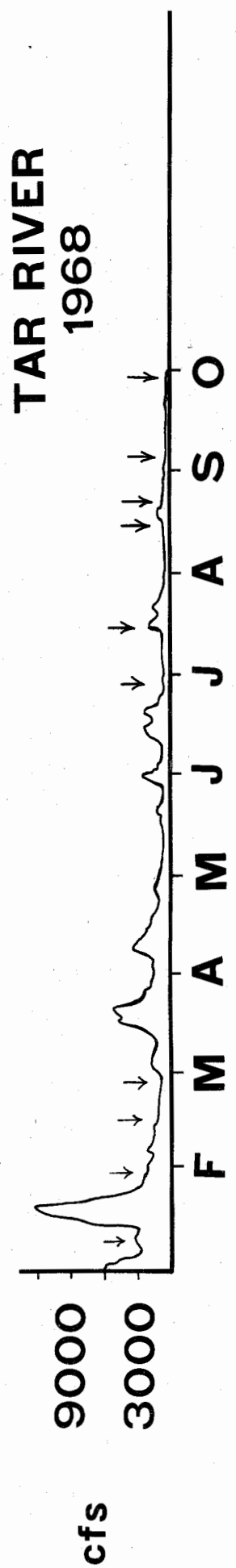


Figure 2. Water flow (cubic feet per second) in the Tar River at Tarboro, N. C. and in Durham Creek near Edward, N. C.

August, early September, December; and in 1968 in January and at the end of March. For Durham Creek high flow occurred in: 1967 in mid February, July, August, September, and December; and in 1968 in January, mid March, and the beginning of June.

### Phosphorus Concentrations

Measurements began in 1965 at five stations which were located at about H1, H4, H6, H8, and H11 (Fig. 1). These early results, which measured only reactive phosphorus, were almost always below 1 ug-at P/liter (Table 1). Sampling dates were June 29, August 4, August 19, September 23, November 12, and December 16.

Station		H1	H4	H6	H8	H11
29 June	Surface	0.15	0.00	0.25	0.25	0.50
	Bottom	0.15	0.15	0.25	0.25	0.40
19 August	Surface	0.85	0.70	0.05	0.40	1.25
	Bottom	1.25	1.45	1.00	1.15	0.18
12 December	Surface	0.00	0.02	0.02	0.01	0.03
	Bottom	0.00	0.01	0.02	0.04	0.04

Table 1. Some samples from 1965 data of the concentration of reactive phosphorus (ug-at P/liter) in the Pamlico River (See Fig. 1 for location of stations).

Although these few data are not enough for definite conclusions, it appears that the upstream stations are higher in reactive phosphorus and that low amounts reach Pamlico Sound. Another interesting result is the higher concentrations in some of the bottom water samples during the summer. This is due to the phosphate-iron relationship at low oxygen concentrations. When the  $E_h$  sinks, the insoluble ferric phosphate changes to the soluble ferrous phosphate which then enters the water from the sediment.

Regular sampling began in 1967 and the data are presented in Tables, and for the total unfiltered phosphorus, in Figures. For the purpose of this paper, the total unfiltered phosphorus was chosen because the other two measurements are subfractions of this. The distribution and especially the sources of the phosphorus was adequately illustrated by these concentration data and little additional

information could be gained by presentation of all the data.

The phosphorus concentration data are presented in Tables 2 through 8. In these Tables, the upper river, that which is unaffected by Texas Gulf Sulphur, is represented by stations 1 - 6 and H9, H10, H11, H16, and H17. The middle stations, where higher phosphorus concentrations can often be attributed to Texas Gulf Sulphur operations, are represented by stations 11 - 35, and H4 - H7. The lower river water that enters Pamlico Sound is given by stations 36 - 39 and H1 - H3.

The same data for total unfiltered phosphorus are also presented in Figures 3 through 14. The following discussion centers around the figures as they summarize the data well.

The samples from early 1967 (Fig. 3) indicate a generally low amount of total phosphorus in the river with values lying between 1 and 3 ug-at P/liter (0.031-0.093 mg P/liter). The sample from May 9, however, does have a value of 6.04 a little downstream from the Texas Gulf Sulphur plant. Studies of the river currents (Horton, Kuenzler, and Wood, 1967) indicated that the water from Texas Gulf Sulphur would flow towards Pamlico Sound along the south shore of the river, so this concentration can probably be attributed to outflow from the plant. Slightly higher than normal values of total unfiltered phosphorus are also seen along the same bank of the river on June 27 and July 13 (Fig.4) and a very high value of 7.32 is noted 31 July. During this same series, there is no sign of high phosphorus concentrations due to the outfall from the slimes settling pond (area to the southwest of Indian Island). The peninsula that extends toward Indian Island (Hickory Point) formerly reached the island so the water there is extremely shallow and the current flow is again along the south shore.

The first very high concentrations of phosphorus was seen on August 23 (Fig.5) when 23.1 ug-at P/liter was noted (0.32 mg P/liter). By August 30 this area of high concentration had moved downstream and was off Hickory Point (high of 8.0). Three weeks later (Sept.20) the whole of the river was again very low in phosphorus.

Table 2. Phosphorous Concentration (ug-at P/l) in the Pamlico river expressed as Total Unfiltered (TU), Total Filtered (TF), and Reactive (R). Mar. 10 - Aug. 23, 1967

Stations:		1	2	3	4	5	6	7	8	9	10	11	12	13
Mar. 10 1967 (No Data)														
Mar. 23 1967	TU	0.44	0.39	2.84	3.86	0.80	0.89	1.87	2.12	1.91	2.18	2.05	1.16	0.27
	TF	0.43	0.27	0.62	0.56	0.58	0.67	0.75	0.66	0.69	0.74	0.41	0.68	0.34
	R	0.26	0.12	0.14	0.14	0.11	0.07	0.44	0.29	0.11	0.09	0.11	0.30	0.19
Apr. 11 1967	TU	2.92	2.69	2.64	2.65	2.81	3.44	3.17	3.25	3.28	3.41	2.82	3.13	2.67
	TF	1.50	1.36	1.12	1.24	1.24	1.13	1.88	1.84	1.81	1.64	1.53	1.44	1.59
	R	0.28	0.42	0.27	0.50	0.61	0.47	1.37	1.40	1.30	0.94	0.99	0.95	0.53
May 9 1967	TU	2.07	2.93	2.67	3.06	3.19	2.28	2.61	3.10	3.48	2.87	2.54	3.28	3.34
	TF	0.79	1.14	1.11	0.45	1.09	1.09	0.84	1.09	1.14	1.01	0.60	1.50	1.22
	R	2.07	2.93	2.67	3.06	3.19	2.28	2.61	3.10	3.48	2.87	2.54	3.28	3.34
June 7 1967 (No Data)														
June 28 1967	TU	1.93	1.09	0.97	1.20	1.21	1.23	4.63	4.48	2.33	1.63	3.26	3.14	1.92
	TF	1.07	0.67	0.67	0.72	--	0.67	3.64	2.69	1.05	0.65	2.02	1.79	1.11
	R	0.07	0.17	0.12	0.12	--	0.10	3.38	2.18	0.61	0.13	1.48	1.17	0.55
July 13 1967	TU	1.71	1.35	1.55	1.44	1.39	1.56	2.36	1.93	1.54	1.99	1.86	2.30	1.99
	TF	0.89	0.76	0.80	0.84	1.01	1.04	1.58	1.32	0.91	1.40	1.14	2.88	1.45
	R	0.09	0.09	0.09	0.08	0.10	0.16	0.73	0.45	0.20	0.35	0.55	0.86	0.76
July 31 1967	TU	2.02	1.98	1.90	1.78	1.76	2.12	5.23	4.12	2.69	2.03	2.66	3.10	3.57
	TF	0.88	0.99	1.00	0.95	0.91	1.03	--	3.29	0.96	1.11	1.76	1.94	--
	R	0.31	0.38	0.24	0.47	0.20	0.40	3.96	2.74	0.34	0.51	1.26	1.42	2.51
Aug. 23 1967	TU	1.40	1.80	1.80	1.60	1.52	1.56	1.51	1.56	1.81	1.65	2.89	1.77	2.35
No Data on	TF													
	R	0.21	0.38	0.36	0.56	0.28	0.21	0.17	0.73	0.26	--	0.86	0.50	1.29

Table 2. Continued (Mar. 10 - Aug. 23, 1967)

Stations:		14	15	16	17	18	19	20	21	22	23	24	25	26
Mar. 10 1967 (No Data)														
Mar. 23 1967														
	TU	--	--	0.41	0.84	0.96	0.81	0.82	0.84	0.76	1.01	1.13	1.27	1.34
	TF	--	--	0.37	0.50	0.59	0.52	0.62	1.22	0.75	0.72	0.65	0.70	0.78
	R	--	--	0.16	0.40	0.49	0.37	0.35	0.83	0.37	0.32	0.26	0.28	0.38
Apr. 11 1967														
	TU	2.40	2.17	2.16	1.96	1.98	2.47	2.06	1.91	1.66	1.68	1.82	--	--
	TF	1.49	1.39	--	1.05	1.01	1.16	0.44	1.00	0.85	0.81	1.03	--	--
	R	0.48	0.57	--	0.38	0.36	0.38	0.29	0.28	0.28	0.22	0.31	--	--
May 9 1967														
	TU	6.04	3.27	3.01	3.24	3.22	3.14	3.38	2.78	3.24	3.43	3.86	3.59	3.15
	TF	2.78	1.64	1.37	1.20	1.17	1.07	0.90	0.99	1.33	0.91	1.15	1.24	1.40
	R	6.04	3.27	3.01	3.24	3.22	3.14	3.38	2.78	3.24	3.43	3.86	3.59	3.15
June 7 1967 (No Data)														
June 28 1967														
	TU	3.63	2.43	2.25	1.67	2.18	2.06	1.89	1.89	1.64	1.64	2.23	--	2.52
	TF	2.69	1.66	1.56	0.95	1.29	1.21	1.02	1.02	1.18	1.18	1.35	--	2.63
	R	2.29	1.13	0.80	0.26	0.76	0.20	0.40	0.40	0.28	0.28	0.66	--	0.54
July 13 1967														
	TU	4.34	3.34	2.38	1.95	2.15	2.43	--	--	--	--	2.16	--	--
	TF	3.33	2.51	1.80	1.48	1.41	1.62	--	--	--	--	1.51	--	--
	R	2.71	1.79	1.28	0.84	0.85	0.81	--	--	--	--	0.93	--	--
July 31 1967														
	TU	4.51	7.32	6.57	3.00	2.36	2.40	3.06	2.44	2.62	3.26	3.63	3.17	4.11
	TF	3.51	6.34	5.55	2.41	2.19	--	1.99	1.72	2.13	2.35	2.84	1.98	3.14
	R	3.00	6.19	5.33	1.92	1.70	--	1.60	1.28	1.62	1.97	2.32	1.58	2.77
Aug. 23 1967														
No Data on	TU	23.11	4.09	--	3.50	3.29	--	2.73	3.17	3.37	--	2.24	4.59	--
	TF													
	R	27.26	2.39	1.89	2.26	2.09	0.86	1.47	2.01	2.15	1.84	1.14	1.94	3.11

Table 2. Continued (Mar. 10 - Aug. 23, 1967)

Stations:	27	28	29	30	31	32	33	34	35	36	37	38	39
Mar. 10 1967 (No Data)													
Mar. 23 1967		0.77	2.31	1.30									
		TU											
		0.87	1.34	1.09									
		TF											
		0.50	0.97	0.49									
		R											
Apr. 11 1967													
No Data on													
TU													
No Data on													
TF													
No Data on													
R													
May 9 1967		2.82	2.56										
		TU											
		1.12	1.29										
		TF											
		2.82	2.56										
		R											
June 7 1967 (No Data)													
June 28 1967			1.71										
		TU											
			0.77										
		TF											
			0.40										
		R											
July 13 1967		4.01	2.86		1.83	2.36	2.42	2.11	2.09	2.43			
		TU											
No Data on			1.47	1.03	1.34	1.76	1.56	1.74	--	1.76			
TF			0.88	0.44	0.36	1.31	1.02	1.26	0.85	1.11			
No Data on													
R													
July 31 1967													
		4.01	2.86		1.83	2.36	2.42	2.11	2.09	2.43			
		TU											
			1.47	1.03	1.34	1.76	1.56	1.74	--	1.76			
		TF											
			0.88	0.44	0.36	1.31	1.02	1.26	0.85	1.11			
		R											
Aug. 23 1967													
No Data on													
TU			2.87	2.53	3.24	--	4.13	3.75	3.15	--			
TF			0.21	1.14	1.77	2.05	2.48	2.37	1.48	--			
No Data on			0.40										
R													

Table 3. Phosphorous Concentration (ug-at P/l) in the Pamlico river expressed as Total Unfiltered (TU), Total Filtered (TF), and Reactive (R). Aug. 30 - Dec. 19, 1967

Stations:		1	2	3	4	5	6	7	8	9	10	11	12	13
Aug. 30 1967	TU	5.37	4.78	3.87	4.87	7.43	2.53	4.91	1.03	2.93	6.27	2.97	--	5.01
No Data on	TF													
	R	1.62	7.62	1.20	5.32	5.33	0.07	1.14	--	--	7.64	0.87	0.58	2.75
Sept. 20 1967	TU	0.87	0.45	0.60	0.62	0.75	1.25	0.78	--	0.67	0.82	1.30	0.37	0.69
	TF	0.46	1.20	0.64	1.40	1.36	0.49	1.81	0.52	0.94	1.89	1.79	1.12	1.15
	R	2.21	2.25	--	1.92	3.01	2.32	2.23	2.00	2.05	1.92	1.77	1.87	1.72
Oct. 4 1967	TU	2.00	1.48	1.67	2.14	2.61	1.99	2.28	2.01	2.08	1.89	2.37	--	2.97
	TF	1.72	1.13	1.31	1.91	1.75	1.28	2.20	2.09	1.49	--	2.47	--	3.10
	R	0.76	0.33	0.59	0.63	1.02	0.59	1.00	0.75	0.99	0.91	1.42	1.49	1.89
Oct. 17 1967	TU	1.72	1.39	1.41	1.64	1.73	1.65	3.17	3.27	3.15	2.65	2.17	2.57	2.85
	TF	1.12	0.91	0.97	1.08	1.26	1.02	2.71	2.78	2.56	2.25	1.65	2.04	2.35
	R	0.57	0.42	0.64	0.58	0.88	0.64	2.52	2.54	2.55	1.88	1.32	1.70	2.19
Oct. 30 1967	TU	1.31	1.20	1.21	1.64	1.56	1.79	4.03	2.04	2.02	1.64	2.24	2.41	2.58
	TF	1.34	1.21	1.21	1.85	1.69	1.45	4.89	2.58	2.08	2.05	2.55	2.67	2.81
	R	0.70	0.63	0.52	1.38	1.15	0.93	4.98	2.21	1.64	1.73	2.13	2.18	2.24
Nov. 14 1967	TU	1.71	2.16	1.94	1.26	2.11	1.58	1.67	1.31	2.75	1.15	1.27	2.22	2.45
	TF	1.21	1.60	1.61	2.07	1.21	1.88	1.36	1.41	1.53	1.64	1.55	3.14	3.02
	R	0.65	0.78	0.62	1.26	0.68	0.79	0.79	0.77	0.81	0.92	1.11	1.07	1.12
Nov. 28 1967	TU	1.59	1.13	1.39	1.14	1.24	1.13	1.36	1.09	4.88	2.79	4.37	2.84	5.41
	TF	1.49	1.60	1.53	1.71	1.70	1.24	1.53	2.27	5.03	4.30	4.72	5.83	4.73
	R	0.90	0.88	0.92	1.65	0.94	0.83	0.99	1.69	4.66	3.75	4.47	5.44	4.59
Dec. 19 1967	TU	2.53	1.79	2.02	2.20	2.18	1.90	3.17	2.23	3.26	2.64	7.07	3.70	4.95
	TF	2.94	4.28	1.71	1.84	2.20	1.74	3.82	3.23	3.66	2.52	6.30	4.39	6.75
	R	2.20	1.61	1.40	1.34	1.76	1.40	2.34	2.64	2.07	2.12	3.74	3.01	6.56

Table 3. Continued (Aug. 30 - Dec. 19, 1967)

Stations:		14	15	16	17	18	19	20	21	22	23	24	25	26
Aug. 30														
1967	TU	3.52	7.95	2.41	3.49	3.31	3.42	4.10	2.27	2.38	1.95	2.62	0.62	2.62
No Data on	TF													
	R	0.95	4.56	0.38	1.10	0.77	0.90	0.21	0.56	0.38	0.69	0.85	0.79	0.55
Sept. 20														
1967	TU	0.77	1.37	0.65	1.14	0.91	--	1.51	1.50	0.84	1.39	2.52	0.99	0.87
	TF	1.92	1.70	1.62	1.42	1.20	2.29	2.64	1.99	2.09	4.57	2.30	2.30	2.19
	R	1.84	1.96	1.73	1.74	1.53	1.67	--	3.09	2.65	3.38	15.79	4.13	2.30
Oct. 4														
1967	TU	2.87	3.11	2.53	2.32	1.98	1.98	0.99	1.72	1.48	1.52	0.62	1.78	1.02
	TF	2.96	2.32	1.87	2.22	1.39	2.21	0.53	0.62	0.59	0.31	0.45	0.55	0.45
	R	2.94	1.41	1.71	1.55	1.11	1.30	1.15	1.22	1.14	1.08	1.23	1.08	1.17
Oct. 17														
1967	TU	13.83	1.95	1.69	1.98	1.83	1.99	2.24	1.88	1.76	1.72	1.60	1.57	1.59
	TF	14.39	1.27	1.36	1.53	1.52	1.80	1.33	1.56	1.40	1.24	1.25	1.22	1.17
	R	19.19	1.01	0.95	1.21	1.16	1.62	0.96	1.12	1.02	1.02	0.95	0.93	0.88
Oct. 30														
1967	TU	2.65	3.15	2.57	2.13	2.20	2.20	1.84	1.87	1.79	1.94	3.19	3.27	3.14
	TF	3.34	3.15	2.99	2.87	2.47	2.52	1.48	2.07	1.92	2.20	2.83	2.78	2.77
	R	3.03	2.93	2.68	2.53	2.12	2.32	0.90	1.70	1.67	1.85	2.37	2.35	2.29
Nov. 14														
1967	TU	25.97	5.77	3.11	2.62	1.04	1.73	1.13	1.07	1.92	2.44	2.48	2.69	3.36
	TF	21.48	4.48	3.08	2.98	1.38	2.29	1.38	1.64	1.67	3.08	1.86	1.80	2.98
	R	20.38	2.75	1.30	1.19	0.90	1.33	0.99	1.12	1.24	1.44	1.42	1.35	1.49
Nov. 28														
1967	TU	1.87	8.45	4.25	3.70	1.87	2.61	12.00	1.51	1.65	2.49	8.07	3.71	4.86
	TF	2.18	7.23	4.68	3.48	2.59	2.48	2.27	2.59	2.52	5.38	7.93	7.42	8.43
	R	1.63	6.93	4.46	2.98	2.18	2.00	2.08	2.20	2.61	5.03	7.93	7.38	8.93
Dec. 19														
1967	TU	2.43	3.98	3.30	1.81	2.64	1.77	1.56	1.80	2.10	2.09	1.42	1.83	2.21
	TF	2.56	2.98	2.98	2.60	2.34	2.34	2.10	2.06	2.41	2.38	2.12	2.62	3.96
	R	2.05	2.26	2.23	2.15	2.00	1.87	1.86	1.58	1.85	1.84	1.72	2.18	2.93

Table 3. Continued (Aug. 30 - Dec. 19, 1967)

Stations:		27	28	29	30	31	32	33	34	35	36	37	38	39
Aug. 30 1967	TU	2.91	2.35	2.50	5.04	2.01	0.76	1.22	2.65	2.37	--	--	--	--
No Data on	TF													
	R	0.72	0.46	0.76	0.54	0.77	0.50	0.80	0.75	0.47	--	--	--	--
Sept. 20 1967	TU	2.31	--	1.38	1.40	1.22	0.53	1.12	1.89	1.39	2.34	1.24	1.59	1.38
	TF	3.01	2.76	3.07	2.02	2.72	2.55	5.89	6.24	5.69	3.52	2.76	2.01	1.67
	R	8.59	4.69	5.19	2.17	4.03	4.04	9.64	9.54	9.99	4.71	4.27	2.78	2.54
Oct. 4 1967	TU	0.45	0.16	0.44	0.94	1.51	0.76	1.60	1.52	0.73	0.27	1.49	1.59	0.74
	TF	0.57	0.30	0.23	0.70	0.73	0.45	0.71	0.47	0.57	0.41	0.34	0.80	0.58
	R	0.79	0.58	0.39	1.05	0.99	0.99	1.16	1.09	1.27	0.77	0.89	1.14	1.02
Oct. 17 1967	TU	1.29	1.25	1.18	1.73	1.59	1.67	1.60	1.49	1.42	1.44	1.51	1.36	1.32
	TF	0.92	0.78	0.77	1.29	1.32	1.53	1.28	1.21	1.14	1.05	1.10	1.09	1.07
	R	0.49	0.32	0.29	0.90	0.88	1.05	0.91	0.76	0.78	0.75	0.72	0.78	0.56
Oct. 30 1967	TU	2.77	1.93	1.02	1.68	1.28	1.41	1.31	1.61	1.20	1.50	1.33	0.79	1.06
	TF	2.23	1.58	1.11	1.26	1.46	1.56	1.44	1.25	1.21	1.01	0.95	0.95	0.69
	R	1.82	1.04	0.61	0.85	1.09	1.15	1.11	0.76	0.80	0.58	0.51	0.60	0.29
Nov. 14 1967	TU	3.23	2.84	3.17	1.53	1.24	1.11	0.90	1.40	1.79	1.46	1.28	0.66	--
	TF	2.72	3.15	2.58	1.19	1.50	1.98	1.73	2.33	1.70	1.44	2.24	1.23	--
	R	2.09	1.13	0.76	0.74	1.08	1.39	1.35	1.95	1.14	0.93	0.94	0.71	--
Nov. 28 1967	TU	2.18	4.27	2.12	1.71	4.56	5.60	3.82	7.84	2.04	2.07	0.96	0.88	--
	TF	4.23	7.58	3.27	1.89	4.58	5.33	6.68	7.93	3.27	2.25	1.49	1.38	--
	R	4.08	7.39	2.70	1.61	4.19	5.18	6.78	7.98	3.03	1.83	1.04	1.11	--
Dec. 19 1967	TU	1.72	3.98	1.90	1.42	2.58	1.52	1.86	1.47	1.78	1.58	1.21	0.73	--
	TF	2.32	3.66	2.48	1.67	2.30	2.15	2.33	3.17	2.23	2.06	1.19	0.86	--
	R	1.54	2.68	2.42	1.38	1.92	1.75	2.10	2.55	1.98	1.74	0.76	0.54	--

Table 4. Phosphorous Concentration (ug-at P/l) in the Pamlico river expressed as Total Unfiltered (TU), Total Filtered (TF), and Reactive (R) Jan. 8 - April 2, 1968

Stations:		1	2	3	4	5	6	7	8	9	10	11	12	13
Jan. 8														
1968	TU	1.50	0.82	1.66	1.91	1.93	1.33	33.70	11.93	4.65	2.74	2.18	4.14	24.16
	TF	1.13	5.18	1.30	2.25	1.87	1.35	26.48	7.38	5.73	5.28	2.07	6.22	31.20
	R	1.00	3.85	1.11	2.04	1.20	1.00	49.23	5.88	3.04	3.42	1.57	5.23	35.47
Jan. 29														
1968	TU	5.48	2.44	2.89	2.49	2.28	2.69	3.11	3.65	4.89	4.15	6.27	5.41	4.96
	TF	2.30	5.31	2.58	6.36	2.06	7.11	3.48	4.19	6.86	4.16	5.91	4.70	4.38
	R	2.17	2.26	2.51	2.01	2.08	2.63	3.66	4.20	4.11	3.97	6.02	4.87	4.27
Feb. 14														
1968	TU	6.29	5.81	5.49	5.33	6.85	6.93	3.47	1.92	2.37	2.75	2.67	2.49	2.34
	TF	6.81	4.09	3.77	6.05	4.61	3.74	4.58	3.32	8.46	5.80	5.34	4.39	5.28
	R	9.12	7.92	7.43	7.13	7.98	7.43	4.34	3.22	3.24	4.25	4.10	3.41	4.08
Feb. 26														
1968	TU	6.73	5.04	5.64	3.76	2.53	2.32	2.58	3.86	4.70	7.21	6.24	6.13	3.46
	TF	3.79	4.50	5.24	3.76	2.69	2.20	3.97	3.97	4.40	6.80	4.64	5.94	6.14
	R	2.14	2.57	3.29	2.95	2.30	1.62	3.33	4.04	2.14	6.54	3.92	5.69	5.29
Mar. 11														
1968		No Data												
April 2														
1968		No Data												

Table 4. Continued (Jan. 8 - April 2, 1968)

Stations:		14	15	16	17	18	19	20	21	22	23	24	25	26
Jan. 8 1968	TU	26.73	43.10	19.87	4.11	2.72	1.61	1.08	1.30	2.51	3.39	7.55	8.39	7.56
	TF	33.90	36.30	29.90	4.90	4.10	4.08	8.20	2.80	5.60	7.20	13.50	10.24	10.48
	R	59.48	53.98	38.78	5.48	3.91	2.84	5.83	2.17	4.65	5.78	12.68	10.98	11.58
Jan. 29 1968	TU	15.14	15.33	9.03	7.68	3.75	5.74	5.78	5.88	5.56	5.53	11.81	8.88	12.19
	TF	14.16	17.06	6.76	4.10	6.21	6.06	9.01	5.36	5.16	12.04	11.26	17.06	15.96
	R	17.47	15.97	7.47	7.02	4.33	6.62	6.17	5.12	5.62	5.42	12.48	9.97	16.87
Feb. 14 1968	TU	13.24	6.07	3.50	2.91	3.18	2.85	2.23	2.27	3.94	4.13	4.95	3.49	4.20
	TF	3.63	4.61	4.66	4.64	6.66	6.56	5.95	6.46	5.81	7.11	--	--	--
	R	5.05	7.35	5.50	5.44	4.45	3.97	3.35	4.57	3.81	4.37	6.70	6.70	6.00
Feb. 26 1968	TU	3.43	19.62	8.11	5.21	3.72	4.78	4.70	4.26	5.06	3.90	3.15	4.18	5.39
	TF	5.10	3.36	7.44	4.84	5.20	5.04	5.80	5.30	5.20	3.80	8.70	7.70	11.64
	R	4.24	23.57	7.44	4.65	4.94	4.43	5.59	4.69	4.62	3.75	9.94	7.94	11.54
March 11 1968	No Data													
April 2 1968	No Data													

Table 4. Continued (Jan. 8 - April 2, 1968)

Stations:	27	28	29	30	31	32	33	34	35	36	37	38	39
Jan. 8 1968													
TU	12.84	17.45	2.52	1.29	1.66	2.27	5.12	9.72	0.91	1.09	0.59	0.71	--
TF	16.28	16.03	3.58	1.73	1.87	2.44	4.28	5.08	2.15	1.84	0.87	0.71	--
R	26.43	18.48	2.80	1.44	1.76	2.18	3.53	3.94	1.69	1.55	0.56	0.51	--
Jan. 29 1968													
TU	9.93	9.94	9.83	4.53	6.04	8.03	9.68	8.58	6.60	6.15	8.91	4.53	--
TF	14.86	9.26	5.36	5.96	8.41	9.46	12.26	5.91	6.86	12.46	5.26	--	--
R	16.47	15.97	9.72	5.77	6.22	8.57	9.97	12.28	6.27	7.28	9.97	5.57	--
Feb. 14 1968													
TU	3.86	3.47	3.27	--	--	--	--	--	--	--	--	--	--
TF													
R	6.20	5.55	6.75	--	--	--	--	--	--	--	--	--	--
Feb. 26 1968													
TU	3.86	2.91	2.84	0.54	14.94	4.24	5.58	4.06	4.62	4.22	3.48	3.19	--
TF	9.04	5.83	5.84	12.95	5.79	4.50	5.40	6.20	6.79	3.94	3.71	3.00	--
R	9.44	5.38	5.44	4.04	4.37	4.49	4.37	6.49	4.28	3.32	3.15	2.96	--
Mar. 11 1968	No Data												
April 2 1968	No Data												

Table 5. Phosphorous Concentration (ug-at P/l) in the Pamlico river expressed as Total Unfiltered (TU), Total Filtered (TF), and Reactive (R). June 29 - NOV. 21, 1968

Stations:		H1	H2N	H2	H2S	H3N	H3	H3S	H4N	H4	H4S	H5	H6N	H6	H6S	H7N
June 29																
1968	No Data															
	TU															
	No Data on															
	TF															
	R	9.95	8.90	10.25	7.95	10.00	10.70	10.45	9.95	10.55	11.20	10.05	11.20	10.55	10.70	9.94
July 16																
1968	TU	2.10	2.04	1.55	2.39	2.10	2.31	5.70	4.87	5.69	4.56	5.61	5.14	6.09	6.34	5.23
	TF	1.73	1.82	1.23	1.71	1.15	1.40	6.06	3.91	5.06	1.94	4.73	4.41	5.11	5.56	4.21
	R	.96	1.39	1.75	4.13	.64	4.49	3.70	3.93	4.78	2.59	3.29	4.38	5.02	5.33	3.78
Aug. 6																
1968	TU	1.77	1.94	2.22	2.22	2.25	2.03	5.01	2.80	4.48	5.84	5.65	3.83	5.11	13.09	5.14
	TF	1.49	1.48	1.83	2.01	1.98	1.73	4.48	2.23	3.76	4.61	4.54	3.21	4.26	10.83	4.09
	R	1.05	1.10	1.38	1.63	1.67	1.37	4.07	1.90	2.03	1.77	4.51	3.01	1.83	5.36	4.19
Aug. 23																
1968	TU	2.33	2.09	2.63	2.65	1.88	2.83	3.08	5.03	6.20	5.13	4.65	7.39	5.75	5.67	4.53
	TF	2.04	1.94	2.26	2.22	1.72	2.19	2.71	4.02	5.67	4.76	4.06	7.47	4.77	5.12	3.97
	R	1.56	1.75	1.81	1.94	1.29	1.97	2.33	3.73	5.18	2.20	3.97	4.90	4.75	4.70	3.80
Sept. 6																
1968	TU	1.56	1.82	1.82	2.32	3.60	2.70	2.48	4.69	4.37	3.52	5.29	5.58	4.94	3.10	--
	TF	1.29	1.34	1.38	1.81	3.13	2.28	2.17	4.07	3.55	3.08	4.68	5.08	4.26	2.68	--
	R	1.10	1.01	1.01	1.56	2.56	2.07	1.83	3.37	3.31	2.61	4.45	4.71	4.03	2.21	--
Sept. 30																
1968	TU	2.29	1.84	2.43	2.11	2.42	1.87	2.03	2.19	2.48	2.79	3.33	4.72	3.67	5.69	5.32
	TF	--	2.20	2.10	1.91	2.62	1.47	1.69	2.40	2.95	2.94	2.34	4.23	3.11	5.27	4.38
	R	1.77	1.70	1.79	1.58	2.32	1.17	1.40	2.06	2.47	2.67	2.01	3.74	2.63	4.98	3.90
Oct. 11																
1968	TU	1.72	1.26	1.39	1.63	1.73	1.88	1.76	2.54	2.71	2.49	2.70	4.24	4.62	3.97	3.80
	TF	1.43	1.38	1.36	1.11	1.50	1.77	1.43	1.37	2.14	1.96	2.43	4.17	5.87	5.87	5.07
	R	1.19	.80	1.11	1.09	1.17	1.47	.98	1.11	1.93	1.67	2.18	4.49	3.91	3.39	3.14
Nov. 21																
1968	TU	1.09	1.25	1.26	2.18	1.56	1.58	2.10	2.36	2.02	2.06	2.97	2.74	2.44	2.71	2.62
	TF	0.78	1.26	0.66	1.85	1.52	1.25	1.59	2.19	1.78	1.72	2.68	1.99	1.82	2.20	2.23
	R	.46	.84	.42	1.48	1.08	.92	1.18	1.57	1.44	1.76	2.17	1.71	1.46	1.97	1.87

Table 5. Continued June 29 - Nov. 21, 1968

Stations:		H7	H7S	H8N	H8	H8S	H9	H10	H11	H12	H13	H14	H15	H16	H17
June 29 1968	No Data on TU														
	No Data on TF														
	R	10.20	10.34	10.95	10.30	11.15	10.45	10.45	9.45	10.15	11.45	--	--	--	--
July 16 1968	TU	4.08	4.83	2.56	2.88	3.29	3.28	3.01	2.44	6.13	6.54	2.68	2.56	2.01	3.90
	TF	3.45	4.17	1.80	2.20	2.64	2.49	2.16	1.76	5.26	4.60	1.88	1.39	1.41	1.63
	R	3.08	3.91	2.08	1.44	2.23	1.53	1.81	1.37	5.18	5.48	1.01	.61	.94	1.96
Aug. 6 1968	TU	4.55	5.14	5.28	4.07	5.03	4.05	3.64	3.92	9.85	5.44	2.18	2.96	4.02	2.51
	TF	3.84	4.61	6.46	4.58	4.33	3.43	3.44	2.62	5.36	5.08	2.04	2.62	2.83	7.62
	R	3.76	4.28	3.50	3.25	4.16	3.36	3.24	2.41	6.14	2.83	1.64	1.26	2.19	2.25
Aug. 23 1968	TU	5.18	5.48	4.77	4.74	4.59	3.42	5.58	4.65	5.26	5.03	4.31	3.39	3.17	3.38
	TF	4.47	4.78	4.16	4.18	3.87	2.59	4.97	3.79	4.87	4.27	3.40	2.63	2.37	2.22
	R	4.24	6.14	3.68	3.87	3.59	2.19	4.87	3.35	4.60	4.02	2.93	2.11	2.03	1.82
Sept. 6 1968	TU	--	--	--	--	--	--	--	--	3.51	--	--	--	--	--
	TF	--	--	--	--	--	--	--	--	2.95	--	--	--	--	--
	R	--	--	--	--	--	--	--	--	2.72	--	--	--	--	--
Sept. 30 1968	TU	5.18	5.62	6.38	5.21	5.11	4.71	4.60	3.08	3.32	2.68	3.34	3.13	2.18	2.74
	TF	4.67	4.75	5.62	4.38	4.43	3.85	3.95	2.18	2.64	2.38	2.84	2.17	1.60	1.97
	R	4.49	4.58	5.29	3.96	3.89	3.23	3.29	1.49	2.42	2.01	2.04	1.38	1.18	1.39
Oct. 11 1968	TU	5.08	4.93	--	4.00	4.74	2.48	2.71	2.78	2.56	3.47	3.53	5.22	4.00	3.51
	TF	3.87	3.61	4.54	3.63	--	2.28	2.06	2.62	2.59	2.94	2.72	3.07	1.17	9.97
	R	3.70	4.42	--	3.44	3.93	1.99	1.42	1.69	2.27	2.55	2.28	2.63	1.88	7.54
Nov. 21 1968	TU	2.64	2.11	2.31	1.40	2.71	3.35	2.45	1.94	2.97	3.18	2.14	2.66	1.77	1.54
	TF	2.26	1.40	2.03	--	2.37	1.52	1.96	1.74	2.72	2.44	1.67	2.27	1.30	1.00
	R	1.88	1.25	1.69	.77	1.79	1.12	1.50	1.16	2.33	--	1.36	1.72	1.20	.80

Table 6. Phosphorous Concentration (ug-at P/l) in the Pamlico river expressed as Total Unfiltered (TU), Total Filtered (TF), and Reactive (R). (Dec. 13, 1968 - June 19, 1969)

Stations:	H1	H2N	H2	H2S	H3N	H3	H3S	H4N	H4	H4S	H5	H6N	H6	H6S	H7N
Dec. 13 1968															
TU	.77	.63	.93	1.31	.58	.85	--	.82	1.37	1.44	2.16	2.34	3.43	2.58	2.86
TF	0.50	0.49	0.51	1.09	0.51	0.67	1.91	0.59	1.13	1.50	1.92	2.02	3.04	2.05	2.46
R	.33	.31	.38	.81	.38	.43	1.53	.44	.93	1.16	1.70	1.60	2.42	1.71	2.00
Feb. 6 1969															
TU	1.06	1.01	1.29	1.26	.92	1.53	1.53	1.91	2.49	3.33	2.22	2.46	2.69	2.67	2.26
TF	0.84	0.64	0.86	1.07	0.74	1.00	1.06	1.18	1.45	1.97	1.85	1.68	1.55	1.83	1.52
R	.49	.37	.50	.64	.40	.62	.57	.83	1.10	1.56	1.36	1.00	.98	1.14	.68
Feb. 26 1969															
TU	1.56	--	.93	1.32	1.39	1.26	2.21	1.25	1.29	2.71	1.31	1.47	2.30	1.86	1.50
TF	1.39	--	0.74	1.01	0.81	0.85	1.44	0.89	1.01	2.10	0.63	0.84	1.72	1.06	0.96
R	.68	--	.25	.44	.33	.27	.82	.23	.23	1.38	.15	.29	1.21	.47	.27
Apr. 1 1969															
TU	--	1.05	1.19	1.26	1.21	1.05	1.87	1.46	1.95	1.69	2.59	3.08	1.80	2.43	3.59
TF	1.01	0.90	0.88	0.92	0.83	1.30	1.05	1.38	1.17	1.39	2.05	1.32	1.62	2.28	1.41
R	--	.53	.41	.41	.44	.42	.44	.55	.66	.77	.75	1.33	.78	1.17	1.18
April 15 1969															
TU	1.27	.66	1.34	.96	1.58	1.08	--	1.16	--	2.14	2.84	2.11	3.02	3.67	5.13
TF	0.84	0.56	1.09	0.59	1.17	0.64	--	0.81	--	1.49	1.68	1.57	1.85	3.03	3.79
R	.48	.25	.54	.33	.65	.43	--	.44	--	1.04	1.33	.85	1.21	2.44	3.24
May 2 1969															
TU	.97	.69	.87	1.13	1.13	1.27	1.47	--	1.48	1.72	1.62	2.70	1.84	1.98	2.41
TF	0.68	0.61	0.76	0.64	0.72	1.10	1.35	--	0.98	1.31	1.59	1.60	1.27	1.39	1.59
R	.38	.37	.34	.42	.41	.68	.87	--	.66	1.06	.74	1.24	1.05	1.14	1.17
June 3 1969															
TU	.70	1.18	1.19	.86	2.19	1.36	1.23	1.93	2.15	1.73	1.86	3.05	3.05	2.11	3.33
TF	0.58	0.99	0.87	0.50	2.00	0.98	0.84	1.20	1.60	0.84	1.39	1.47	2.15	1.68	2.16
R	.27	.57	.67	.21	.73	.63	.47	.84	1.03	.41	.84	1.19	1.83	1.18	1.99
June 19 1969															
TU	1.25	.99	1.11	2.12	1.44	1.38	1.77	2.77	1.81	2.59	2.80	4.62	3.15	4.66	3.39
TF	0.96	0.70	0.74	1.03	0.81	0.98	1.15	1.52	1.21	1.48	2.13	3.40	2.37	3.50	2.36
R	.58	.46	.53	.73	.63	.71	.87	1.06	1.00	1.24	2.03	3.23	2.13	3.16	2.24

Table 6. Continued Dec. 13, 1968 - June 19, 1969

Stations:		H7	H7S	H8N	H8	H8S	H9	H10	H11	H12	H13	H14	H15	H16	H17
Dec. 13															
1968	TU	2.74	5.33	2.39	--	2.67	1.34	1.56	2.74	1.39	1.89	3.67	1.58	--	3.34
	TF	2.45	--	2.02	--	2.28	1.06	1.17	2.27	1.03	1.13	3.11	1.31	--	2.67
	R	1.83	11.47	1.50	--	1.70	.82	.89	1.80	.80	.89	2.61	1.16	--	2.23
Feb. 6															
1969	TU	2.24	2.00	4.33	3.58	3.46	5.53	6.35	6.95	3.86	3.11	2.19	3.14	4.04	3.72
	TF	1.52	1.23	2.31	2.06	2.24	3.27	3.74	3.81	2.42	1.82	1.43	1.88	2.10	1.39
	R	.82	.60	1.18	1.13	1.22	1.72	1.73	3.54	1.92	1.19	.70	.90	1.60	1.26
Feb. 26															
1969	TU	1.51	1.65	1.22	1.35	1.72	2.47	2.79	3.95	2.03	4.08	5.40	4.02	3.75	4.82
	TF	0.99	1.04	0.78	0.68	0.78	1.28	1.29	1.82	1.13	3.15	4.15	2.18	2.34	2.02
	R	.30	.30	.32	.23	.29	.54	.55	.83	.57	2.04	2.78	1.44	1.13	1.06
Apr. 1															
1969	TU	2.61	3.99	3.51	2.65	3.10	2.98	3.86	3.22	3.20	3.22	2.73	3.01	3.54	3.26
	TF	2.32	2.10	1.70	1.99	1.35	1.64	1.64	1.45	2.51	1.81	1.90	2.10	1.78	--
	R	.61	1.87	1.16	1.12	1.12	.90	1.27	1.36	1.17	1.82	1.31	1.32	1.80	1.63
Apr. 15															
1969	TU	2.69	2.85	--	3.47	5.39	3.39	4.37	5.89	1.65	1.80	2.87	2.14	4.74	4.71
	TF	1.98	1.94	7.02	2.92	4.02	2.03	2.44	2.64	1.29	1.32	2.14	1.44	2.73	2.69
	R	1.35	1.32	5.69	2.43	3.64	1.54	2.04	2.42	.89	.89	1.58	1.03	2.48	2.57
May 2															
1969	TU	2.29	2.51	2.39	2.75	10.91	2.58	2.90	3.10	1.90	1.57	1.78	1.57	3.12	3.85
	TF	1.71	2.24	1.49	1.86	9.49	1.56	1.51	1.33	1.50	1.00	1.01	1.29	2.25	1.89
	R	1.20	1.76	.83	1.06	8.74	.94	1.02	1.03	1.08	.71	.70	.75	1.85	1.68
June 3															
1969	TU	3.12	2.95	2.97	2.36	2.60	2.22	2.49	3.42	2.27	2.62	2.32	1.68	4.82	4.74
	TF	2.43	2.09	2.27	1.69	2.01	1.51	1.90	2.15	1.33	1.35	1.24	1.11	2.40	2.62
	R	2.21	1.84	1.83	1.52	1.73	1.16	1.30	1.74	.96	.96	.87	.67	2.06	2.33
June 19															
1969	TU	3.61	3.86	3.02	3.09	2.89	3.01	3.91	2.51	2.85	3.29	2.81	2.00	5.10	6.24
	TF	2.26	2.46	1.66	1.74	1.44	1.75	2.96	1.11	1.83	1.92	1.48	1.09	2.73	3.48
	R	1.96	2.24	1.38	1.46	1.26	1.29	1.53	.78	1.66	1.34	1.04	.49	2.41	3.29

Table 7. Phosphorous Concentration (ug-at P/l) in the Pamlico river expressed as Total Unfiltered (TU), Total Filtered (TF), and Reactive (R). Jul. 4 - Oct. 29, 1969

Stations:		H1	H2N	H2	H2S	H3N	H3	H3S	H4N	H4	H4S	H5	H6N	H6	H6S	H7N
Jul. 4																
1969	TU	.95	--	1.69	--	1.70	1.74	3.18	3.18	3.20	3.88	3.91	4.11	3.04	4.03	4.37
	TF	0.62	1.56	1.15	--	1.29	1.00	1.42	1.64	1.66	1.95	2.82	3.26	2.29	3.39	2.61
	R	.39	.87	.66	--	.77	.64	1.19	1.32	1.30	1.68	2.65	2.51	1.89	2.20	2.37
Aug. 6																
1969	TU	--	--	--	--	2.72	4.55	6.04	5.89	5.14	8.90	9.44	8.93	8.43	10.99	8.98
	TF	--	--	--	--	1.57	3.49	4.79	4.58	4.36	2.94	7.90	6.38	7.98	8.86	8.39
	R	--	--	--	--	1.19	3.23	4.68	4.34	3.94	5.92	7.99	5.94	7.39	8.24	8.22
Aug. 21																
1969	TU	4.36	4.16	3.82	5.22	4.56	4.79	6.21	2.96	6.98	7.42	7.17	6.10	7.75	6.94	7.48
	TF	3.61	3.09	3.33	4.77	2.83	3.31	4.16	1.87	4.36	5.18	4.67	4.07	6.94	4.97	6.64
	R	2.79	2.59	2.96	3.24	2.42	--	3.94	1.49	4.34	4.97	4.54	3.89	5.94	4.81	6.29
Sept. 3																
1969	TU	4.35	3.83	4.94	5.22	6.99	5.33	5.98	6.37	6.61	6.93	7.29	--	8.41	10.34	8.41
	TF	7.08	1.98	9.58	3.73	5.13	3.48	5.08	2.83	4.73	4.23	3.33	5.43	4.63	13.23	4.63
	R	7.06	1.93	7.26	3.25	3.99	2.96	3.86	2.66	4.34	3.36	2.55	5.16	3.89	13.71	3.89
Sept. 17																
1969	TU	4.74	4.87	4.40	5.06	4.59	5.07	5.70	6.23	--	9.44	6.74	10.98	11.74	10.08	10.53
	TF	2.10	2.45	4.05	2.55	2.35	2.75	2.50	3.50	--	3.85	5.40	6.80	5.80	6.45	4.95
	R	1.53	1.51	2.72	1.76	1.73	2.27	1.88	2.75	5.43	3.73	4.67	--	5.68	6.18	4.58
Oct. 1																
1969	TU	2.29	3.22	2.65	3.39	3.82	3.62	5.28	5.83	6.41	8.20	5.30	7.22	7.59	7.94	8.96
	TF	1.14	2.03	1.65	1.89	2.15	2.07	3.24	2.98	4.16	4.45	3.15	3.07	2.99	3.59	2.63
	R	0.72	1.32	1.10	1.65	2.00	1.47	2.86	2.72	3.99	3.93	2.27	2.61	2.72	3.51	2.39
Oct. 17																
1969	TU	4.13	2.97	3.23	5.35	3.03	4.08	5.89	4.37	4.52	5.60	5.95	5.30	4.83	16.84	5.60
	TF	4.29	2.55	2.31	3.75	2.77	3.00	4.27	2.98	2.87	4.75	5.48	3.70	5.26	11.17	4.10
	R	2.66	1.30	1.29	2.33	1.59	2.08	2.98	1.67	1.50	3.27	4.00	2.34	3.75	10.40	3.51
Oct. 29																
1969	TU	1.79	2.29	2.00	3.08	2.18	2.08	3.47	2.39	2.65	3.35	3.30	3.13	2.96	3.73	3.78
	TF	1.50	1.70	1.60	2.13	1.78	2.35	2.40	2.19	2.15	2.70	2.58	2.48	2.55	2.67	2.90
	R	1.05	1.18	1.10	1.65	1.21	1.80	1.85	1.65	1.69	2.14	2.00	1.88	1.68	2.14	2.15

Table 7. Continued (Jul 4 - Oct. 29, 1969)

Stations:	H7	H7S	H8N	H8	H8S	H9	H10	H11	H12	H13	H14	H15	H16	H17
Jul. 4 1969	TU 6.31	6.73	3.58	4.28	6.78	3.83	2.24	3.61	3.21	3.86	2.75	2.88	3.77	4.67
	TF 3.65	5.66	2.30	3.46	6.21	2.98	1.86	1.82	1.70	2.78	1.78	1.31	2.00	2.24
	R 3.48	5.37	1.92	3.13	2.96	2.68	1.57	1.25	1.38	2.53	1.26	.81	1.46	1.64
Aug. 6 1969	TU 9.41	7.73	5.89	6.53	5.45	6.10	5.85	5.45	8.47	10.42	4.70	6.10	7.19	5.46
	TF 8.38	6.74	3.55	5.24	2.26	4.39	3.74	3.11	6.34	9.49	2.13	3.71	3.38	2.55
	R 7.99	6.67	3.35	4.76	2.17	4.01	3.53	2.98	6.22	8.99	1.73	2.84	3.21	2.43
Aug. 21 1969	TU 10.61	29.13	10.37	8.81	8.64	6.79	7.09	6.03	8.00	12.58	8.53	6.25	5.61	6.32
	TF 6.67	27.62	7.19	7.69	6.84	3.27	3.54	3.22	5.27	7.54	4.12	3.42	3.07	2.45
	R 5.43	27.38	5.54	6.19	5.79	3.13	3.05	3.03	5.03	6.19	3.86	3.09	2.61	2.18
Sept. 3 1969	TU 8.16	19.50	13.35	14.28	11.20	8.70	5.11	6.00	--	10.25	8.61	7.91	0.46	--
	TF 6.48	19.48	5.98	6.33	6.28	5.08	2.43	2.58	--	6.93	2.78	3.68	1.83	2.53
	R 5.61	23.01	4.95	6.66	6.01	4.17	1.96	2.16	--	6.31	2.07	3.36	1.26	1.60
Sept. 17 1969	TU 10.52	14.88	8.75	8.55	9.76	7.67	6.23	6.57	7.67	9.68	6.09	7.47	6.29	6.69
	TF 7.10	13.55	4.05	6.45	4.50	4.30	2.80	2.50	4.00	5.55	2.75	3.65	1.95	2.10
	R 6.23	19.88	3.88	5.98	4.37	3.83	2.44	1.98	3.44	6.03	2.45	2.68	1.53	1.91
Oct. 1 1969	TU 6.38	11.08	7.96	8.99	8.32	6.14	4.87	4.64	6.98	6.67	5.09	6.40	5.19	4.75
	TF 3.13	6.78	4.21	3.49	2.97	3.24	2.15	2.14	2.98	4.37	3.14	2.85	1.94	1.70
	R 2.84	6.57	4.39	2.95	2.55	2.81	1.83	1.59	2.82	3.91	3.92	2.28	1.63	1.47
Oct. 17 1969	TU 6.26	93.33	5.75	5.58	19.65	5.33	9.37	7.00	6.56	7.85	6.27	6.32	6.47	6.34
	TF 4.29	72.00	8.07	3.83	10.40	4.29	4.93	4.65	5.46	7.23	5.73	5.10	4.53	3.56
	R 2.90	91.40	7.11	2.70	9.70	2.93	3.44	2.49	3.88	5.80	4.28	3.68	2.85	2.28
Oct. 29 1969	TU 4.05	7.90	3.62	3.78	4.55	3.10	3.40	3.78	3.15	3.45	3.70	3.25	4.60	2.85
	TF 3.33	7.40	2.62	3.02	2.46	2.16	2.12	2.42	2.38	2.50	2.48	2.25	2.90	1.55
	R 2.60	5.90	1.96	2.48	1.78	1.40	1.40	1.39	1.40	1.90	1.97	1.45	1.64	0.75

Table 8. Phosphorous Concentration (ug-at P/l) in the Pamlico river expressed as Total Unfiltered (TU), Total Filtered (TF), and Reactive (R) Nov. 12, 1969 - Jan. 2, 1970

Stations:		H1	H2N	H2	H2S	H3N	H3	H3S	H4N	H4	H4S	H5	H6N	H6	H6S	H7N
Nov. 12 1969	TU	5.20	5.00	4.18	5.05	3.30	5.00	6.15	5.00	6.10	5.65	6.15	4.75	7.50	8.85	3.28
	TF	4.60	4.00	4.00	3.85	3.00	5.05	6.38	4.30	5.53	4.90	6.28	4.20	6.69	6.28	2.78
	R	4.06	3.50	3.05	3.40	2.44	3.60	5.50	3.83	4.83	4.19	4.88	3.58	5.73	5.20	2.28
Dec. 3 1969	TU	2.56	2.42	2.92	2.22	2.91	2.65	2.45	3.78	3.40	4.25	5.45	4.30	3.78	8.00	3.78
	TF	1.88	2.08	2.09	2.15	2.60	2.55	2.35	--	3.08	3.82	4.58	2.60	3.40	4.63	2.10
	R	1.21	1.42	1.45	1.45	1.70	2.10	1.80	2.75	2.48	2.53	3.79	1.95	2.90	4.05	1.55
Dec. 15 1969	TU	2.65	2.35	2.32	3.38	2.52	3.13	4.12	3.10	3.85	4.14	5.40	3.52	3.98	3.99	3.73
	TF	1.85	1.61	1.53	1.98	1.88	2.60	2.82	2.50	3.13	3.35	3.68	2.90	3.05	3.19	2.45
	R	1.38	1.35	1.35	1.82	1.75	2.20	2.38	2.00	2.63	2.95	3.22	2.35	2.53	2.63	1.79
Jan. 2 1970	TU	1.50	1.68	1.38	2.68	1.45	1.57	2.58	1.75	1.82	3.37	2.62	2.21	2.68	5.55	1.35
	TF	1.35	1.33	1.55	2.80	1.65	2.11	2.45	1.83	1.80	2.36	2.11	2.25	2.26	4.72	1.23
	R	0.45	0.33	0.40	0.80	0.50	0.67	0.85	0.63	0.63	0.78	0.67	0.75	0.79	1.95	0.33

Table 8. Continued (Nov. 12, 1969 - Jan. 2, 1970)

Stations:		H7	H7S	H8N	H8	H8S	H9	H10	H11	H12	H13	H14	H15	H16	H17
Nov. 12 1969	TU	4.48	19.40	2.95	4.00	4.19	3.60	3.38	5.02	5.60	10.50	11.58	11.00	7.15	5.00
	TF	4.40	19.60	2.69	2.15	2.83	2.94	3.23	3.68	5.79	8.70	11.42	10.25	4.10	2.35
	R	2.18	15.48	1.92	1.97	2.08	2.07	1.72	1.82	4.25	7.20	10.72	9.95	4.92	1.85
Dec. 3 1969	TU	2.95	14.53	4.06	3.20	5.72	5.30	2.70	10.20	5.00	3.92	4.42	4.07	9.58	3.65
	TF	2.17	13.75	3.20	2.80	3.65	4.28	2.10	5.58	2.88	3.28	3.40	3.19	3.48	1.68
	R	1.56	15.55	2.50	2.20	3.14	2.90	1.38	2.78	2.44	2.87	2.86	2.53	2.08	1.00
Dec. 15 1969	TU	3.10	6.80	3.48	2.89	3.38	6.08	4.53	5.50	4.35	5.10	4.10	4.07	4.07	3.31
	TF	2.55	2.62	2.30	2.10	2.22	2.67	2.05	2.25	3.60	4.00	3.24	3.19	2.08	2.45
	R	1.85	2.35	1.57	1.62	1.70	1.62	1.32	1.55	3.20	3.37	2.67	2.52	1.25	1.72
Jan. 2 1970	TU	3.38	12.09	3.00	2.35	5.40	2.42	3.45	2.35	3.17	4.35	1.93	3.35	2.02	1.55
	TF	1.87	8.95	2.47	1.85	3.00	1.48	1.47	1.80	2.53	3.21	1.96	3.27	1.48	1.20
	R	0.54	8.35	0.75	0.50	0.98	0.37	0.50	0.67	0.87	2.72	0.67	1.20	0.51	0.40

Stations:		Runyan	Washington
Jan. 2 1970	TU	1.55	1.55
	TF	0.95	0.98
	R	0.20	0.32

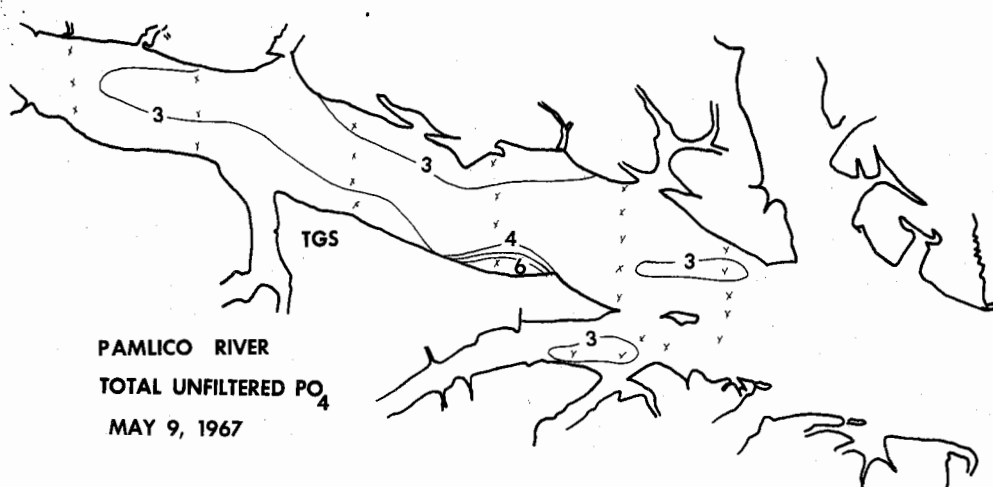
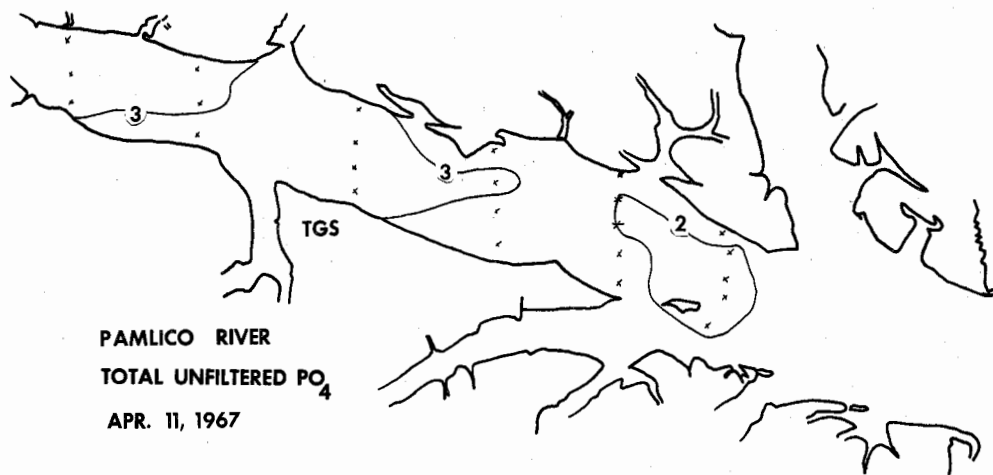
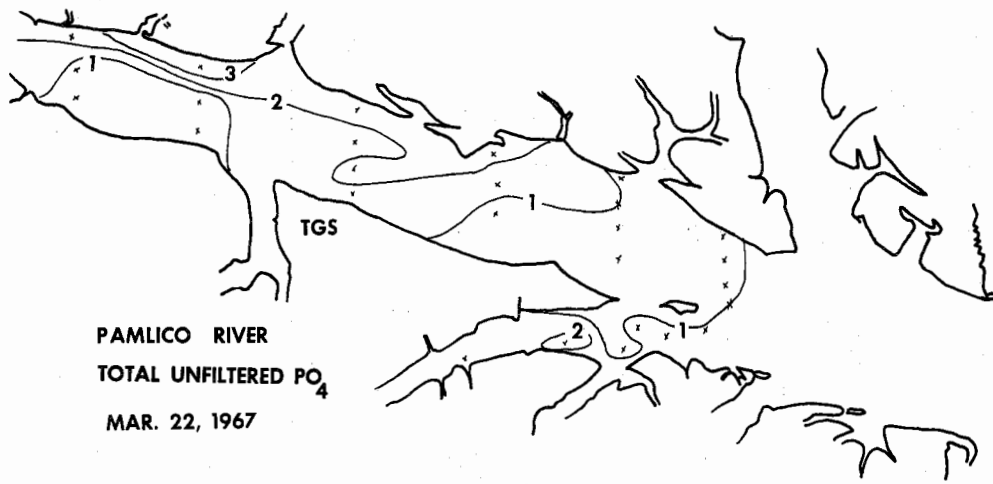
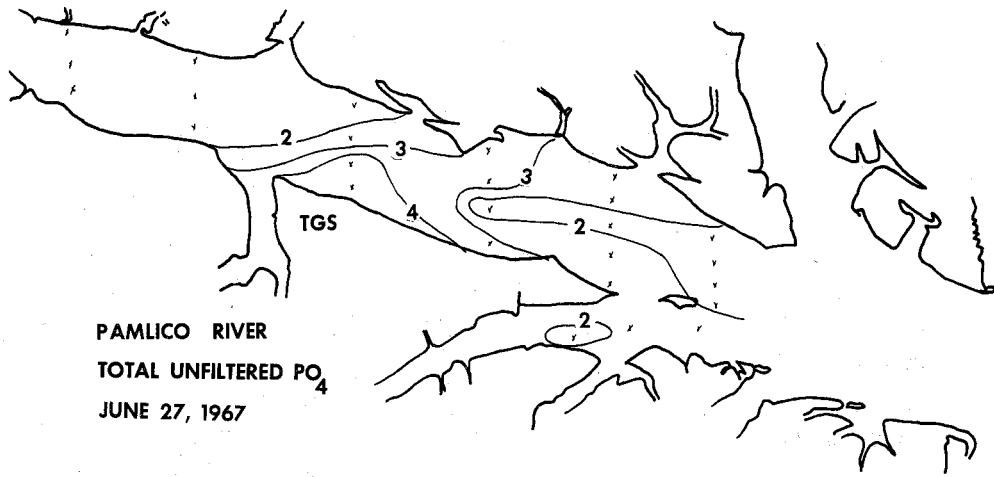
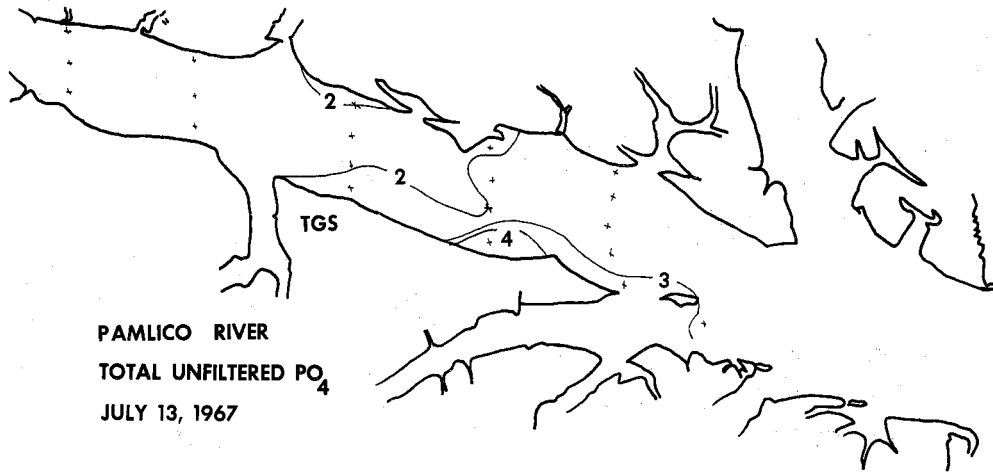


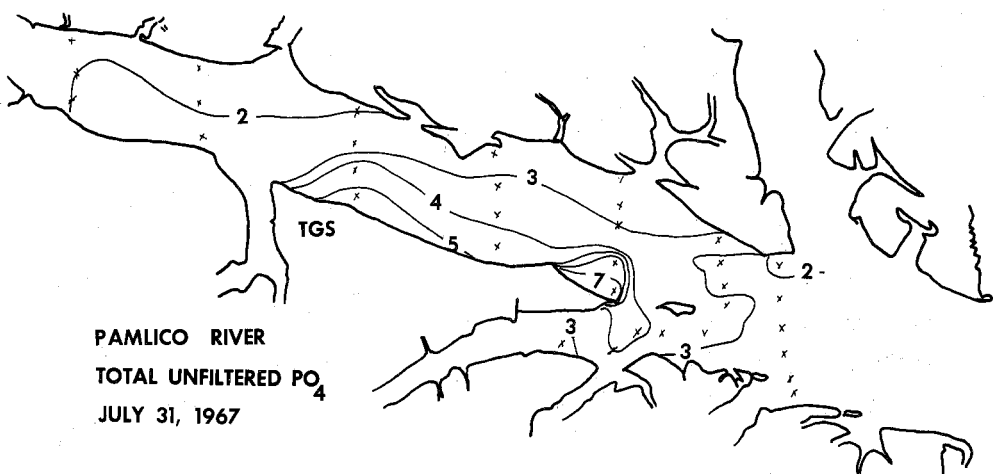
Figure 3. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 22 March, 11 April and 7 May, 1967.



PAMLICO RIVER  
TOTAL UNFILTERED PO<sub>4</sub>  
JUNE 27, 1967



PAMLICO RIVER  
TOTAL UNFILTERED PO<sub>4</sub>  
JULY 13, 1967



PAMLICO RIVER  
TOTAL UNFILTERED PO<sub>4</sub>  
JULY 31, 1967

Figure 4. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 27 June, 13 July, and 31 July, 1967.

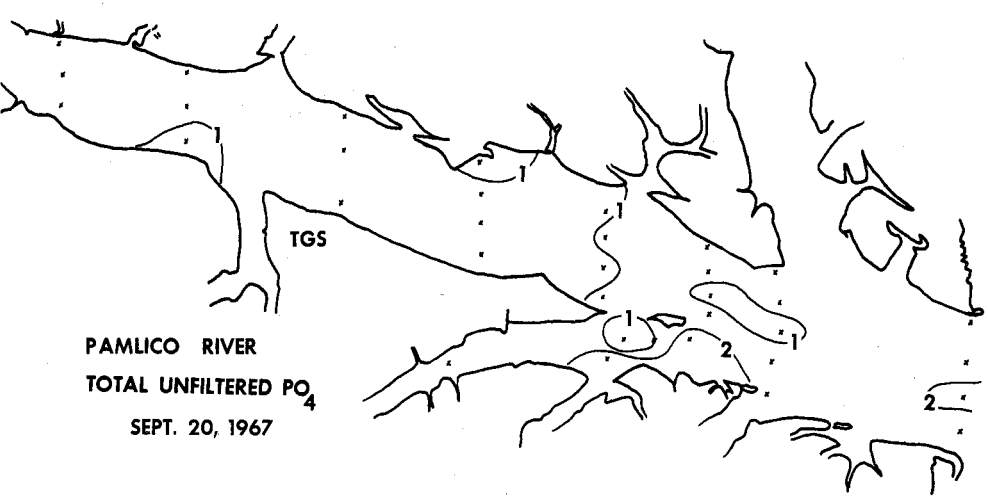
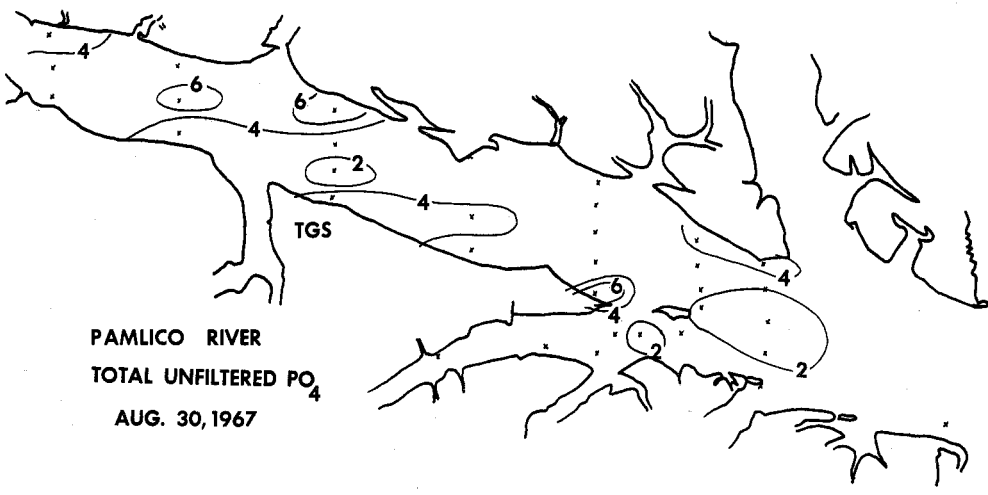
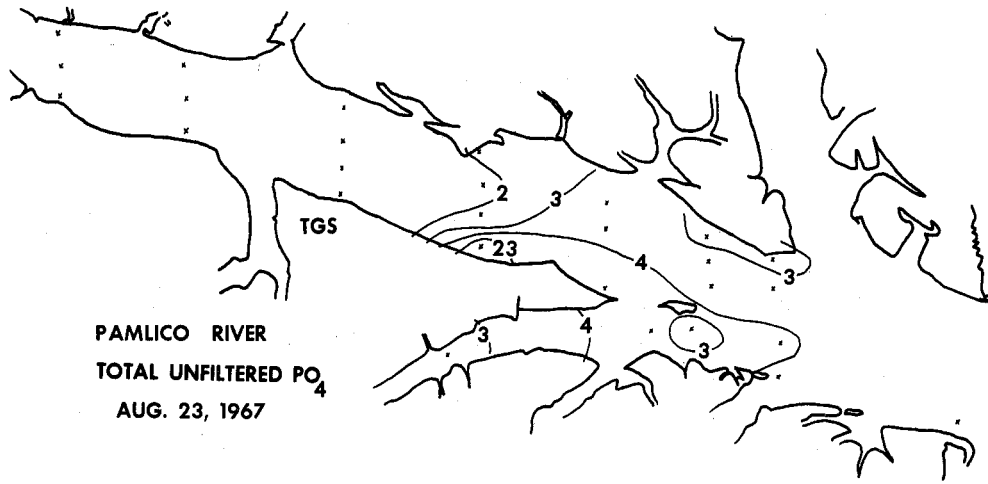


Figure 5. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 23 August, 30 August, and September 20, 1967.

The results from October through August 6 sampling (Fig. 4, 5, 6, and 7) followed much the same pattern with some patches of high phosphorus water entering the river from the Texas Gulf Sulphur plant area and passing downstream. Of particular interest is a value of 25.97 (0.80 ug-at P/liter) on 14 November (Fig.7). For some reason, a patch of high phosphorus water (12.00 ug-at P/liter) is found across the river against the north shore on 28 November (Fig.5). This is the only time that high phosphorus water was found along this shore and it is possible that a windstorm moved the water in this direction.

Another slug of high phosphorus water evidently reached the river shortly after December 19. By January 8 (Fig. 8) the very high phosphorus water (40 ug-at or 1.24 mg P/liter) had moved down to Hickory Point. By January 29, high phosphorus water was even farther towards Pamlico Sound and only residual amounts were left by February 13 (Fig. 8 and 9). This confirms the general current flow map presented by Horton, Kuenzler, and Woods (1967), but indicates a much slower flow than the one mile per day they estimated.

Beginning on August 23, 1968 (Fig. 10) and lasting until July 4, 1969 (Fig. 14), there were no high phosphorus patches of water found in the river. There were, however, concentrations that reached 5 ug-at P/liter (Fig. 11) that showed that the phosphorus was still reaching the river from Texas Gulf Sulphur.

It may be seen in Figure 12 that relatively high amounts of phosphorus were coming down the Pamlico River, presumably from Washington, N. C. (the exact source is unknown). For example, on February 6 there was greater than 6 ug-at P/liter upstream and as low as 1 ug-at P/liter downstream. Another clear reduction in phosphorus is seen February 26 with high (4 ug-at P/liter) values upstream and low values downstream. The same general pattern is also seen on 19 June (Fig.14).

The data plotted in the figures ends on 4 July, 1969, and leaves the impression that the high phosphorus additions to the river by Texas Gulf Sulphur had stopped. However, as seen in Table 7 and 8 and in Figure 15, there were high

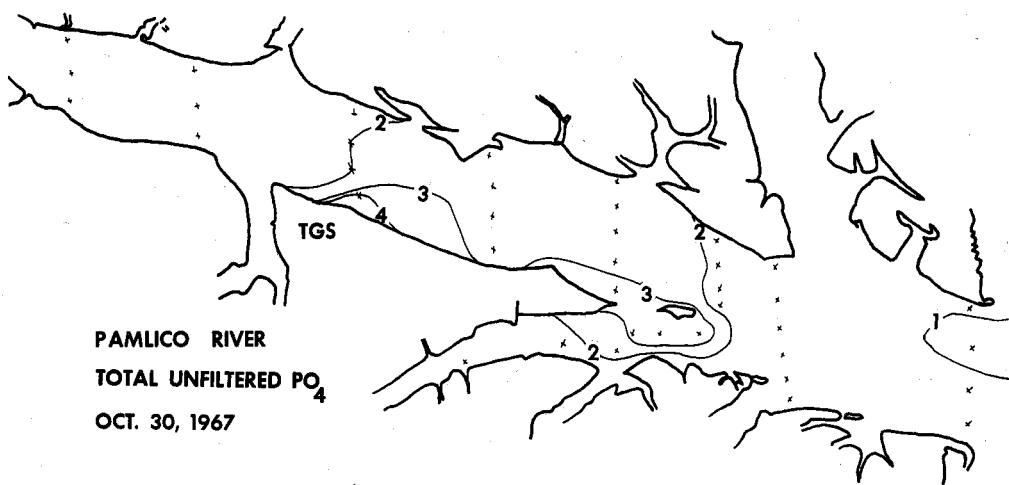
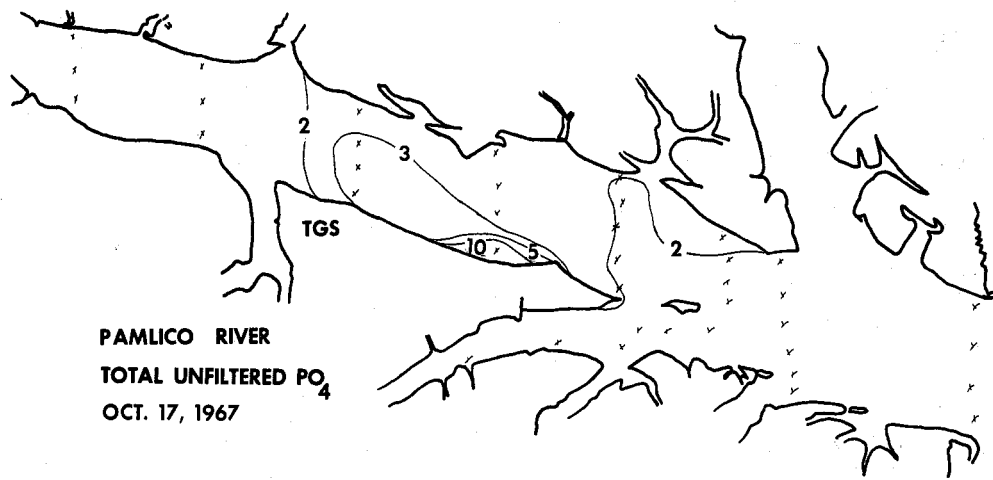
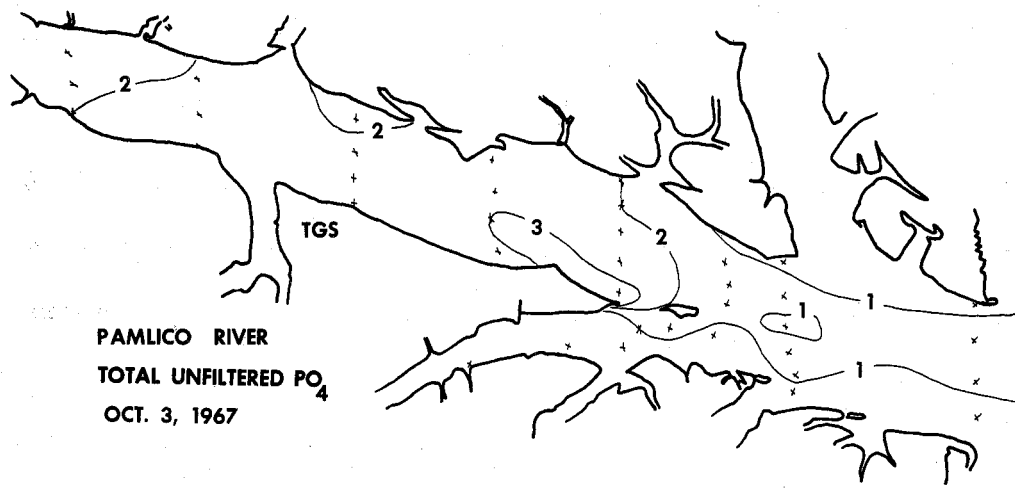


Figure 6. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 3 October, 17 October, and 30 October, 1967.

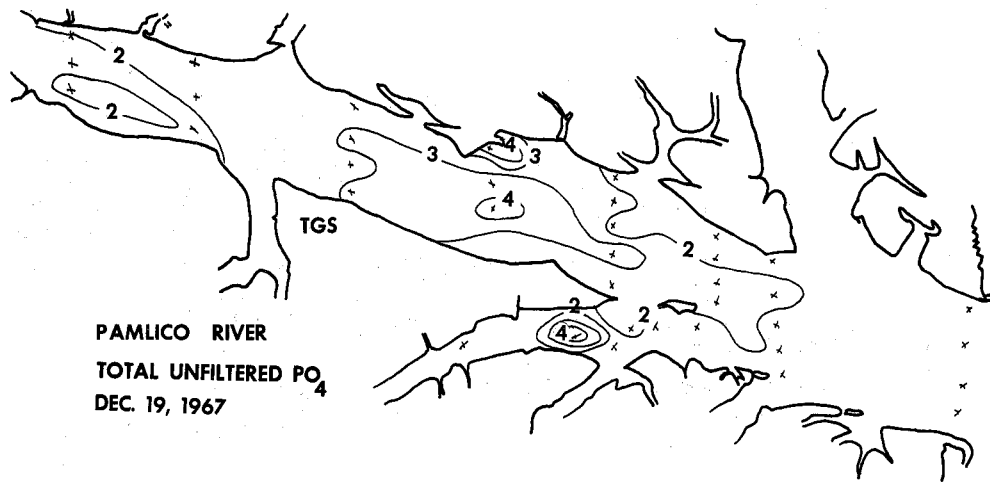
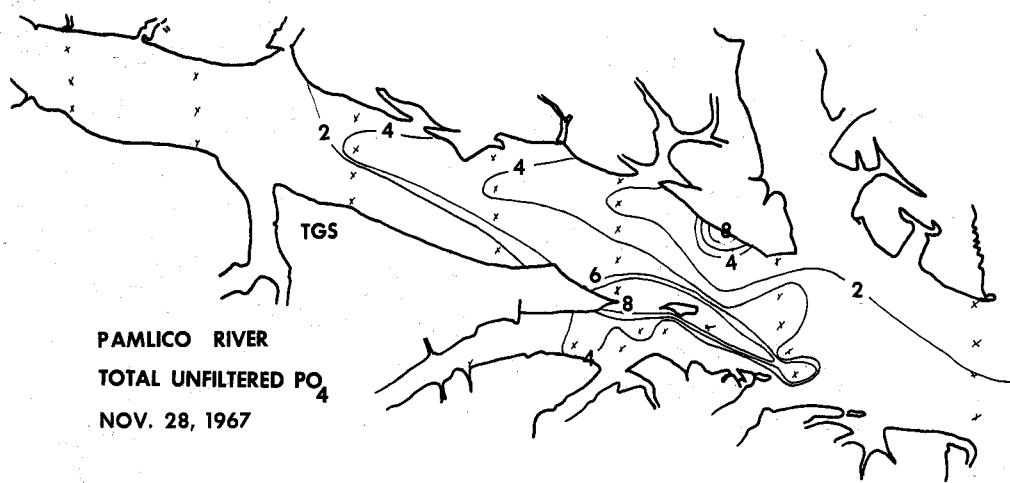
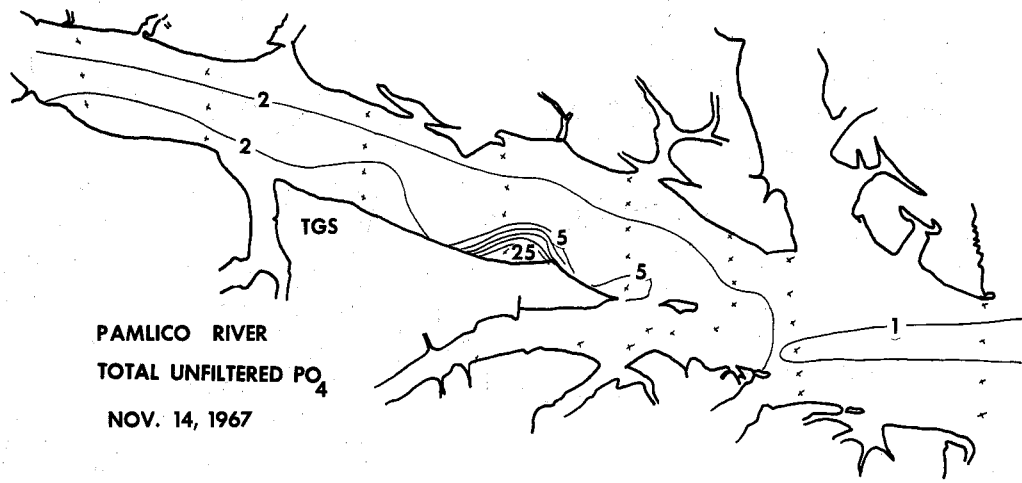


Figure 7. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 14 November, 28 November and 19 December, 1967.

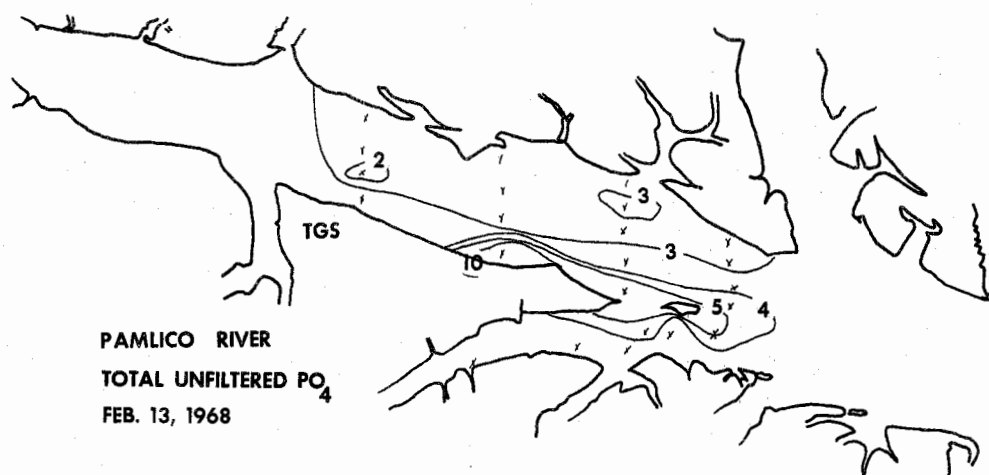
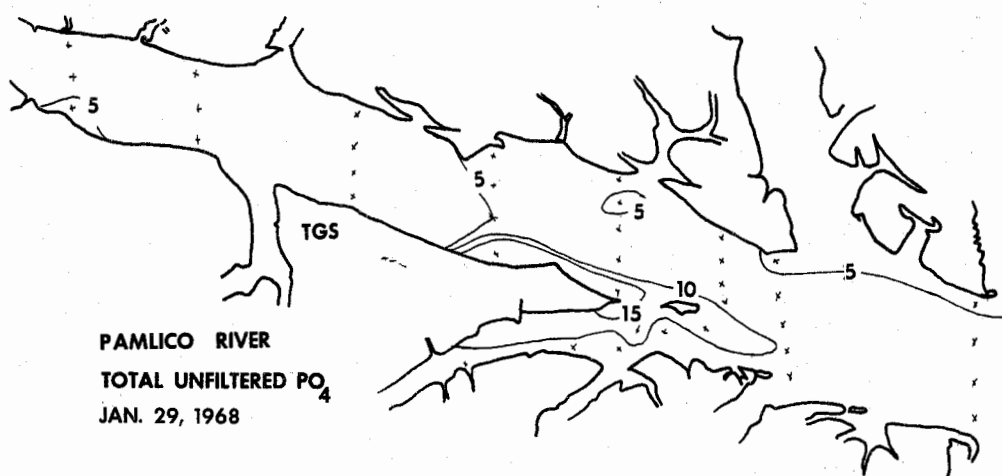
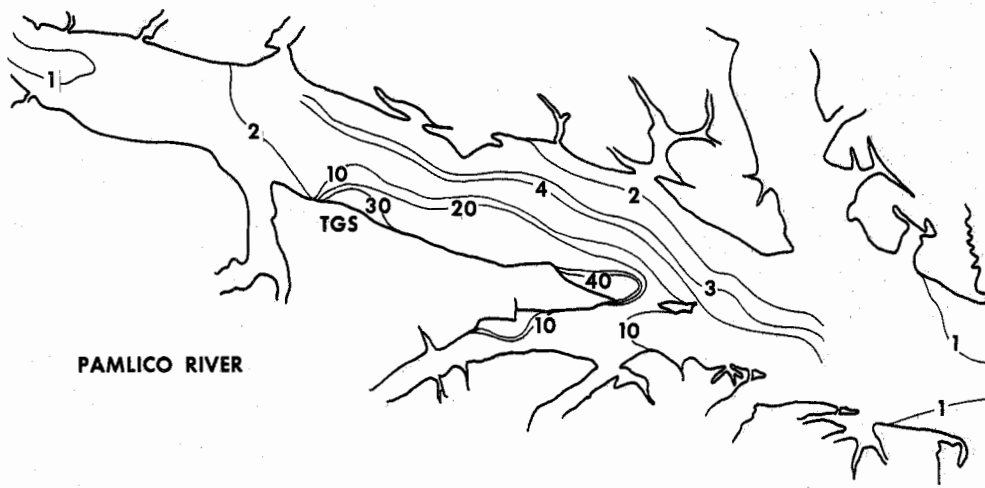


Figure 8. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 8 January, 29 January, and 13 February, 1968.

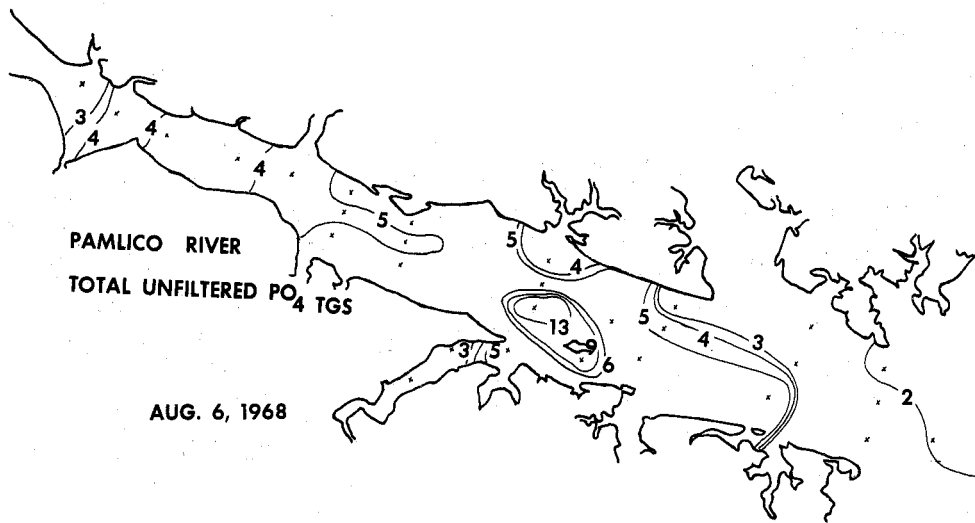
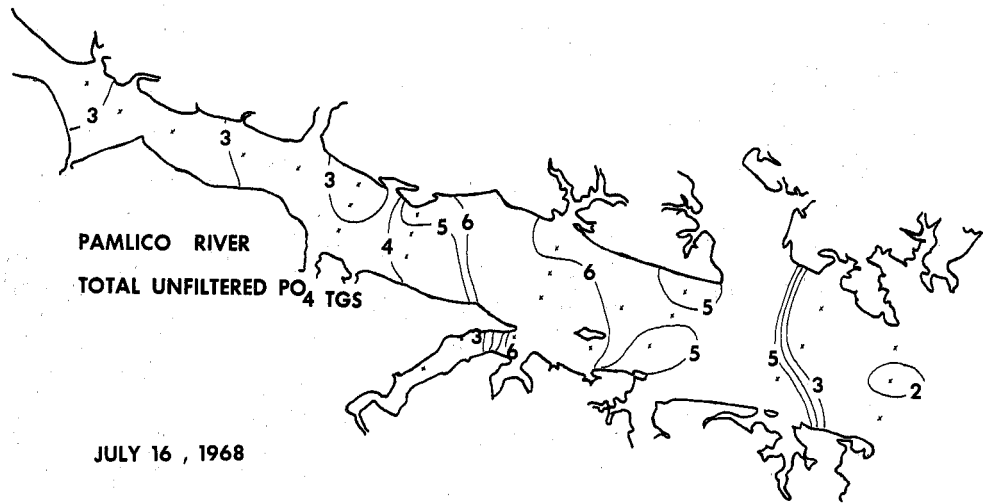
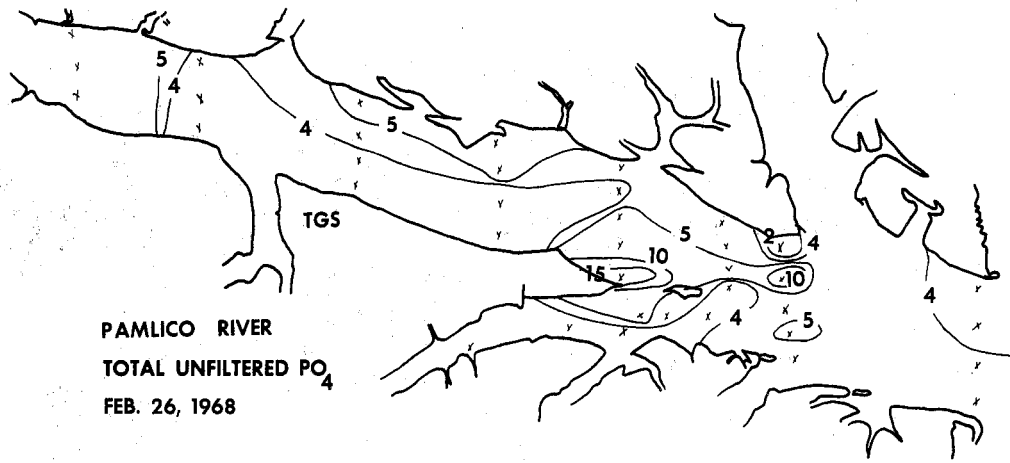


Figure 9. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 26 February, 16 July, and 6 August, 1968.

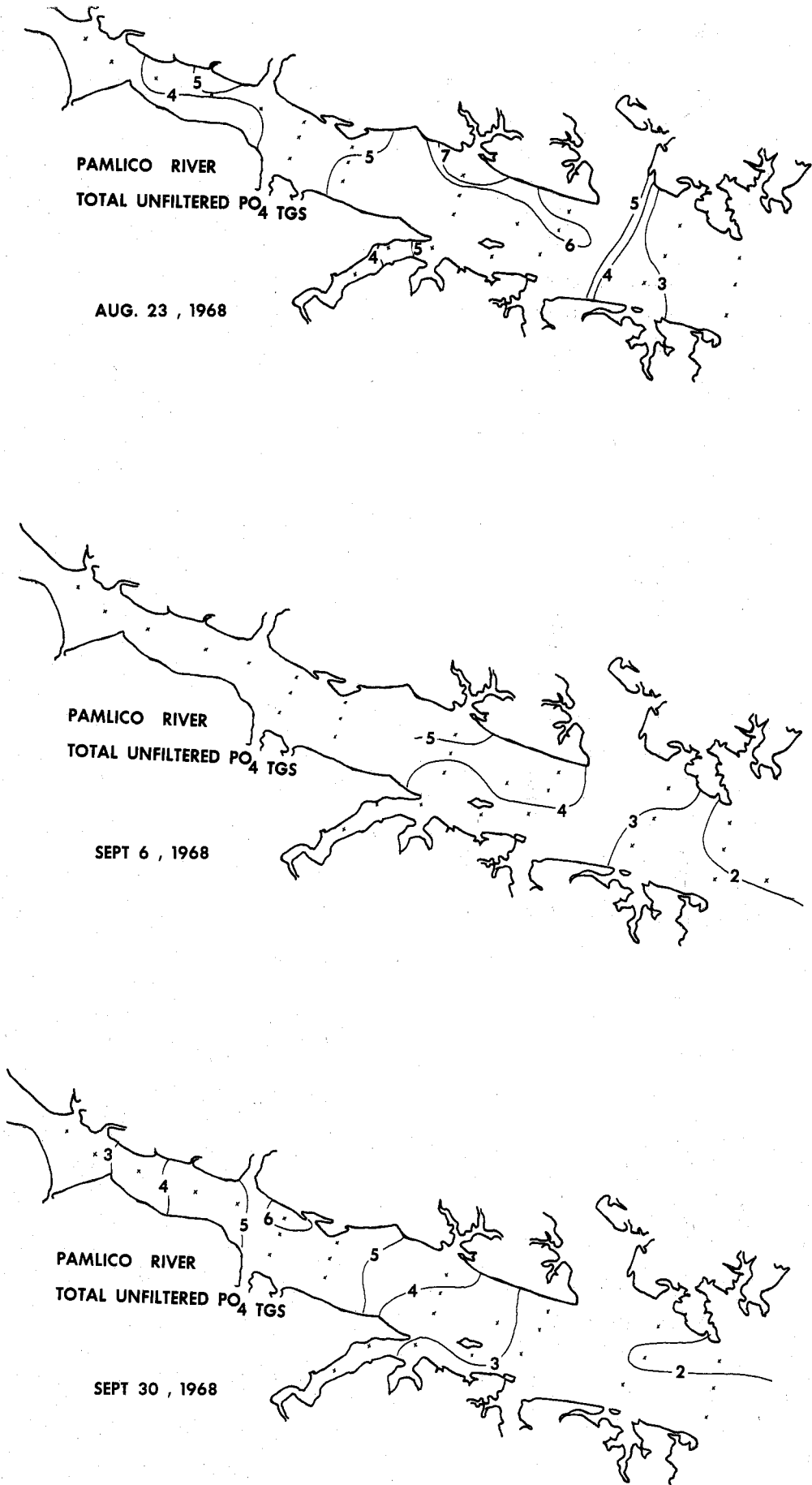


Figure 10. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 23 August, 6 September, and 30 September, 1968.

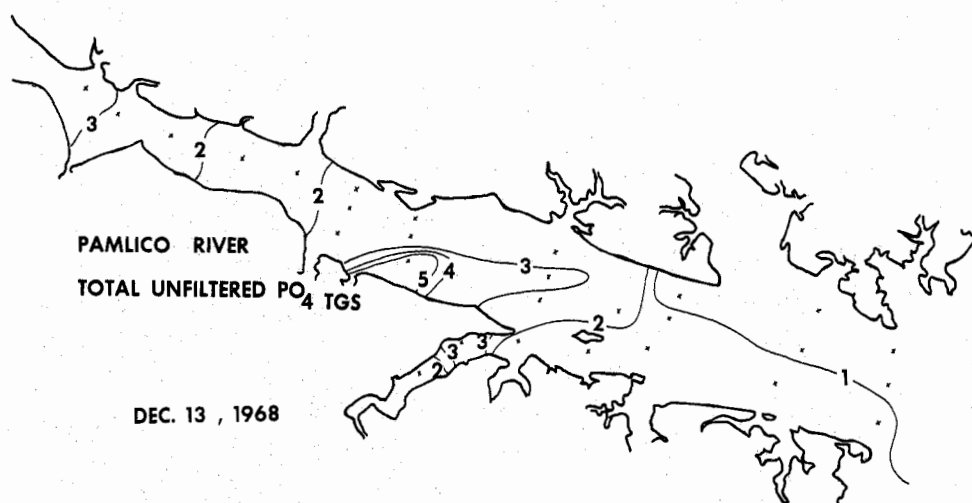
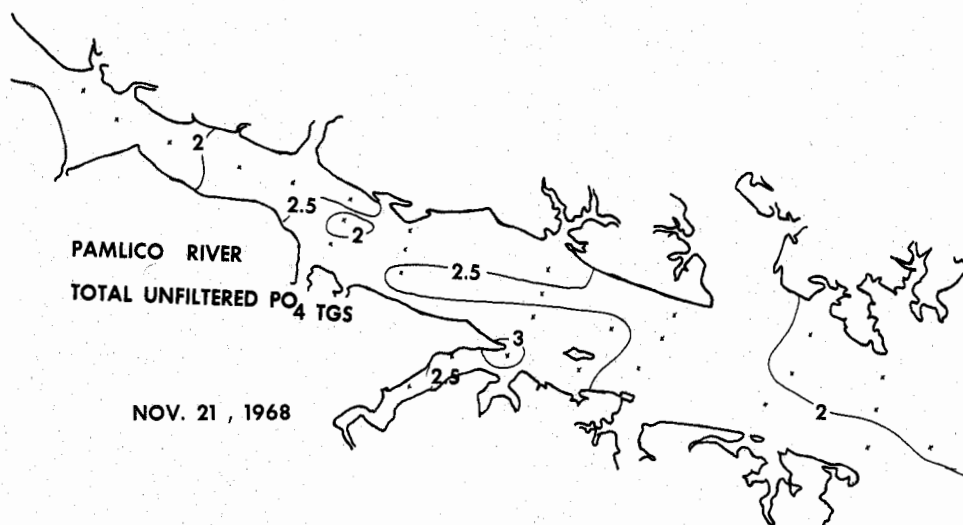
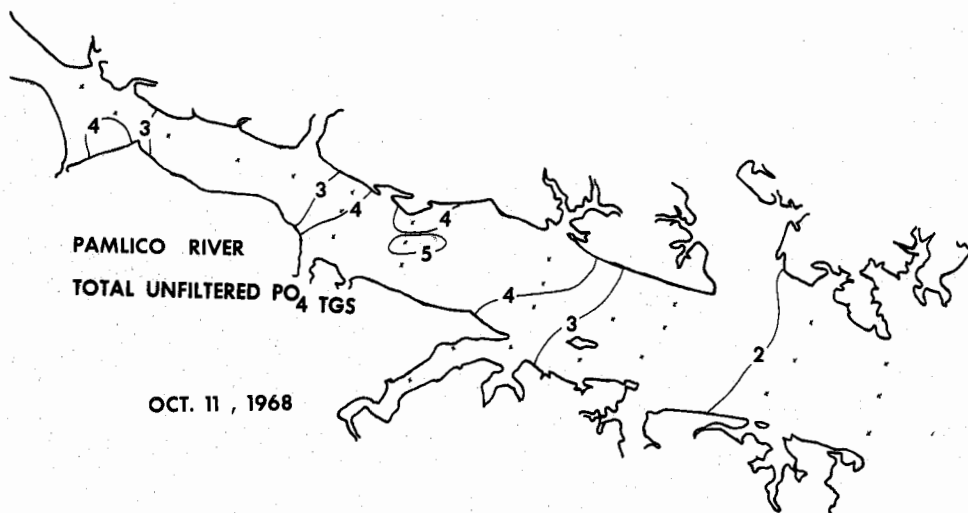


Figure 11. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 11 October, 21 November, and 31 December, 1968.

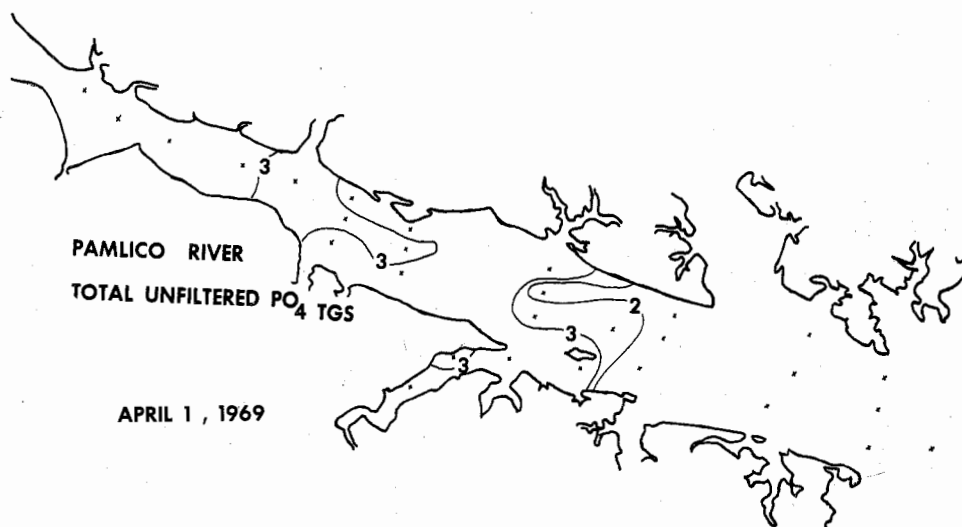
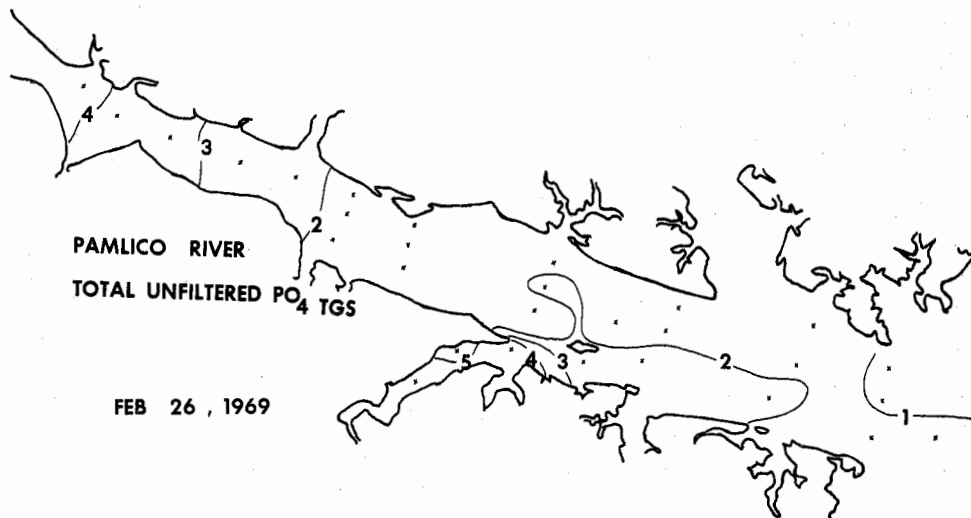
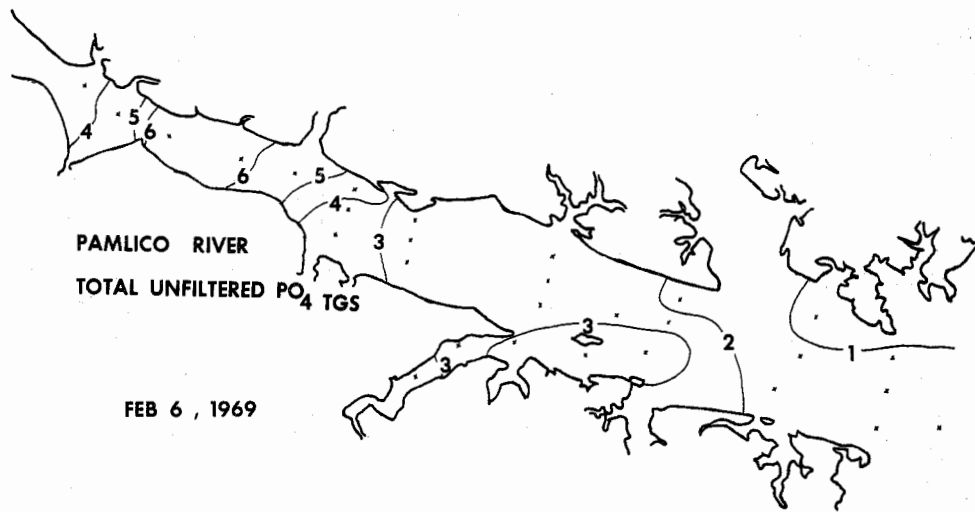


Figure 12. Total unfiltered phosphorus (in ug-at P/liter) in the Pamlico River on 6 February, 26 February, and 1 August, 1969.

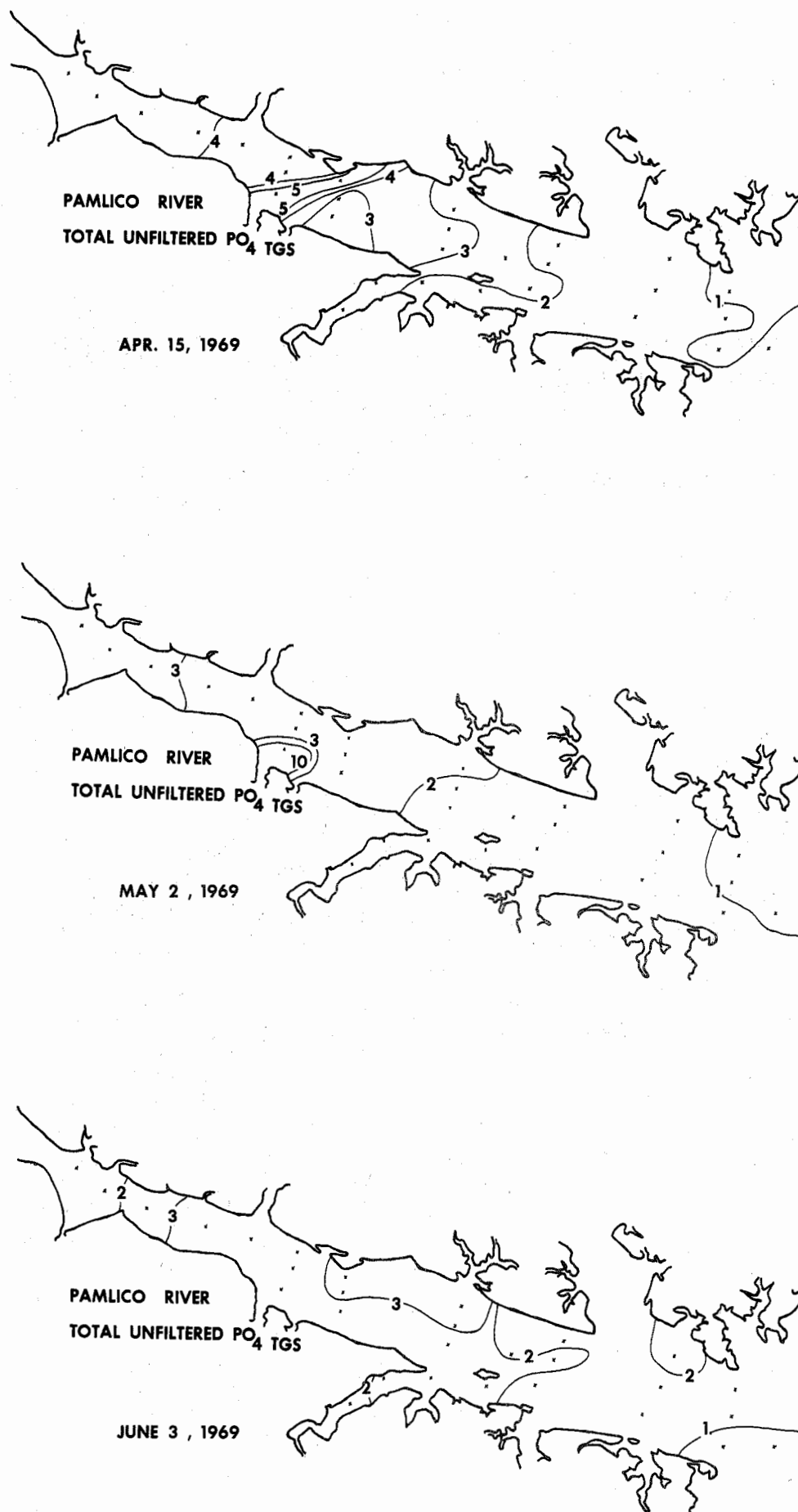


Figure 13. Total unfiltered phosphorus (in  $\mu\text{g-at P/liter}$ ) in the Pamlico River on 15 April, 2 May, and 3 June, 1969.

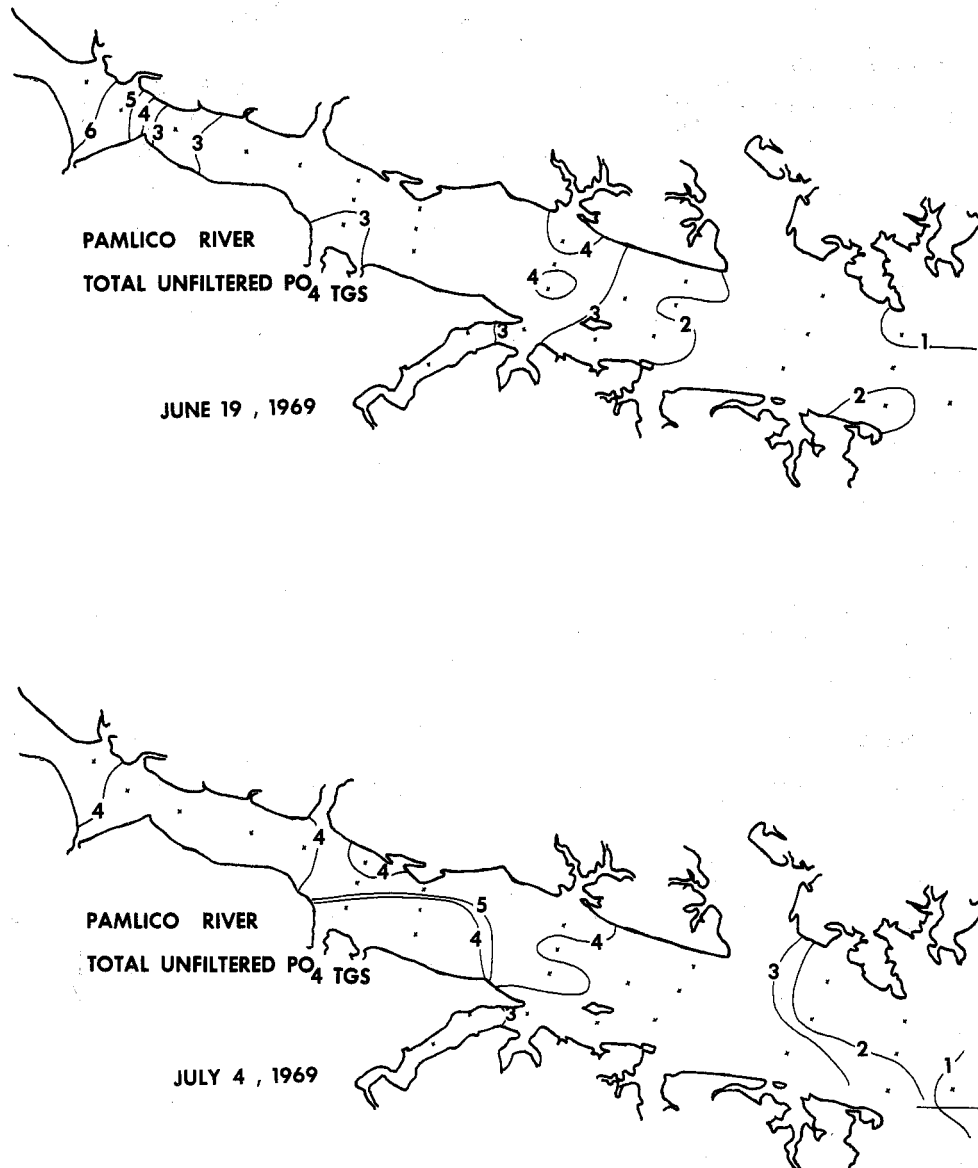


Figure 14. Total unfiltered phosphorus (in  $\mu\text{g-at P/liter}$ ) in the Pamlico River on 19 June and 4 July, 1969.

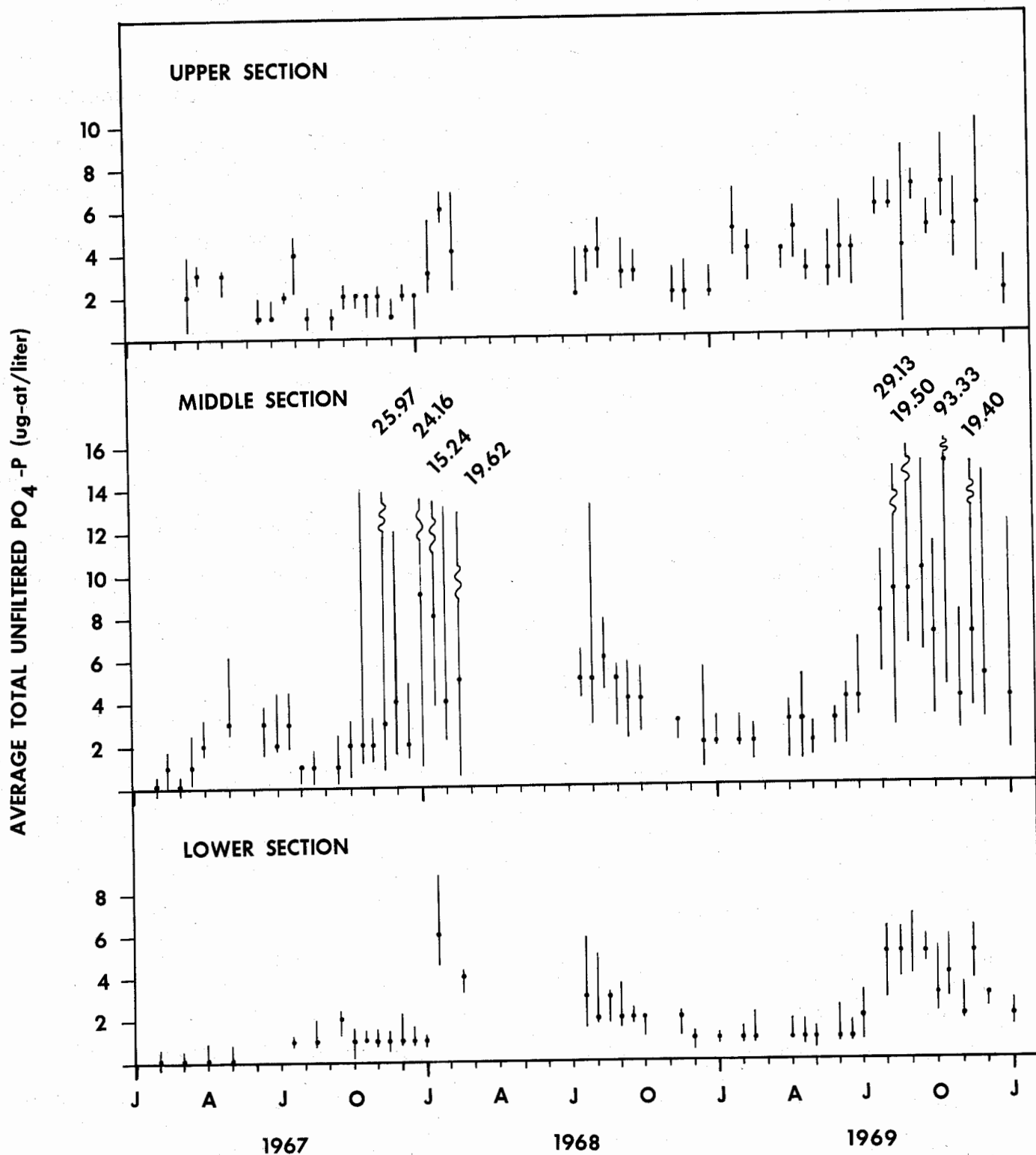


Figure 15. The means and ranges for the total unfiltered phosphorus (ug-at P/liter) in three strata of the Pamlico River, 1967-1969. The upper section (closest to Washington, N. C.) contains Stations 1-6 (1967-1968) and H9, 10, 11, 16, 17, (1968-1969). The middle stratum contain stations 11-35 (1967-1968) and H4-7 (1968-1969). The lower stratum contain stations 36-39 (1967-1968) and H1-3 (1968-1969).

phosphorus patches of water in the river after August, 1969. One concentration reached 93.33 ug-at P/liter (2.9 mg P/liter).

When the total unfiltered phosphorus data are summarized for the upper, middle, and lower river (Fig. 15) it becomes obvious that there has been a general increase in the concentration of phosphorus in the upper river over three years of sampling. In this graph, the means and ranges are plotted and not all stations have been included. For example, stations 7 - 9 fell into an intermediate region between the upper and the middle river and were omitted. In spite of the scatter of values and the seasonal changes, there was a tripling in the phosphorus concentration in the upper river.

The middle river (middle section of Fig. 15) was greatly affected by the high concentration of phosphorus entering from Texas Gulf Sulphur. These high concentrations started in August, 1967 (a data point is missing in the graph but one value reached 23 ug-at P/liter) and ended the next August (1968), but did start again a year later (August of 1969).

The lower section of the river has fewer stations but also seems to be strongly affected by Texas Gulf Sulphur's activities. The periods of relatively high phosphorus concentrations correlate well with the high values in the middle section closer to Texas Gulf Sulphur. While it is difficult to say whether or not the amount of phosphorus reaching Pamlico Sound is increasing, most of the time only low levels reach the sound.

#### Phosphorus in Sediment

A total of 48 samples were taken in the river itself for analysis of the phosphorus in the surface sediment. The river was divided into six strata and 8 random samples were taken in each strata (Tenore, in preparation).

Another set of 25 samples were taken in a series of transects off the Texas Gulf Sulphur plant and yet another of 44 samples were taken off the slimes settling pond. All samples were classed as either sand or mud.

The series is difficult to interpret as one set was taken in July (river) and the others in October. There might have been changes due to season but these are as yet unknown. However, there were no measurable differences between the strata even though Texas Gulf Sulphur added phosphorus would affect only 3 strata. Besides the great differences between the sand and the mud, there were also differences that were correlated with different oxygen conditions (Table 9). As already noted, when the oxygen is very low, the phosphorus is transformed into a soluble form and leaves the sediment.

Some very high values, for example 112.4 and 85.6 for sand were found off Texas Gulf Sulphur plant and the average for the mud is also very high. Increased mud levels were noticed off the slimes basin, with one value reaching 191.7 and another 194.4. Despite these high values, it is difficult to say definitely that the phosphate mining has raised the phosphorus level in the sediment. This difficulty arises from the great variability from sample to sample and the lack of an adequate number of samples.

Table 9. Phosphorus concentrations in surface sediments of the Pamlico River, July (River Samples) and October off Texas Gulf Sulphur (off slimes pond), 1968. Concentrations are reported as ug-at P/mg dry weight of sediment.

	<u>Mean</u>	<u>No. of Samples</u>	<u>S. D.</u>	<u>S. E.</u>
<b>SAND:</b>				
River	13.2	25	7.60	1.51
Off TGS	44.6	8	40.87	14.45
Off Slimes	30.8	21	27.60	6.02
<b>MUD:</b>				
River, high O <sub>2</sub>	43.8	15	13.32	3.44
River, low O <sub>2</sub>	24.2	8	3.58	1.26
Total River (low + high)	37.0	23	14.43	3.00
Off TGS	113.1	17	29.57	7.17
Off Slimes Pond	121.8	23	44.76	9.33

is set up and if water low in phosphorus passes over these sediments, some phosphorus will go into the water. This exchange effect has been shown in laboratory experiments at the Pamlico Marine Lab by H. L. Davis (Davis, 1967).

Perhaps the finding with the most impact for the future of the estuary is the tripling of the phosphorus in the Tar River inflow over three years. It is likely that this phosphorus is accompanied by nitrogen and that it comes from sewage as farm land usually holds very tightly to added phosphorus. Thus, sewage fertilization is rapidly increasing in the river basin and if the rate of increase continues, can only harm the estuary within the next few decades.

## DISCUSSION AND CONCLUSIONS

It must be pointed out again that this is only the first of a series of reports on the Pamlico River. Only when the data on the salinity, temperature, other nutrients, oxygen and algae cycles are complete can the complete and the total effects of the phosphate mining industry on the ecology of the river be evaluated. Unlike some pollutants, phosphate is not harmful by itself, at least not at the concentrations found in this river or even those found in Tampa Bay where thousands of pounds of phosphorus are being dumped every day (Hobbie, report in preparation for FWPCA). However, when other nutrients, such as nitrogen compounds are available to work in concert with the phosphorus, then the algae will take advantage of the improved conditions, grow faster, change in species, and eventually produce harmful blooms. Ultimately, this speed-up of the algal growth will produce an eutrophication, or enrichment of the whole biological system and lead to a rapid change in the whole biota. For example, if the type of algae change, then the oyster and the clam larvae may not survive as well and eventually be eliminated from the river. The same could happen to shrimp and fish larvae. The rich environment will produce so much algae that decay and odor problems will eventually reduce the recreational opportunities.

The first conclusion that can be reached from these data is that the Pamlico River is naturally rich in phosphate. Relatively high concentrations are present in the Tar River waters entering the estuary but these have probably tripled in the past three years. These concentrations alone equal and surpass the 2.8 ug-at P/liter suggested by Ketchum (1969) as a likely upper level for unpolluted coastal waters. The considerable amounts of phosphorus added from the plant wastes of Texas Gulf Sulphur are, therefore, added to a river already very rich in phosphate.

Some biological data from this river have already been presented (Hobbie, in preparation for publication as an FWPCA Document) that indicate that little biological effect of the added phosphorus from Texas Gulf Sulphur can be measured. For example, there was no discernable additional algal quantities or photosynthesis in the areas of the river where there was high phosphorus concentrations. Experiments with added nutrients revealed that nitrate stimulated photosynthesis while phosphate did not. Finally, large scale experiments in one-half acre artificial estuaries revealed no effect of added slime pond decant water on periphyton (Sherk, 1969) and phytoplankton (Carpenter, 1969). Of course this is only a preliminary conclusion but it appears that nitrogen is limiting in this estuary and that the polluting effects of the Texas Gulf Sulphur phosphate are slight at this time.

If these high amounts of phosphorus were added to a lake there would be a strong pollution effect. Luckily, there are several differences between a lake and an estuary. First of all, the estuary is a flow-through system and much of the phosphorus is removed from the estuary within a number of weeks. A lake, in contrast, would hold almost all the phosphorus in its waters and sediment where it could be recycled several times. A second difference lies in the slight amount of stratification in the estuary. Once phosphorus does reach the sediments, it is held by chemical precipitation from returning to the water column. A stratified lake, on the other hand, has active recycling of soluble phosphorus because of the reducing nature of the lower water and the top of the sediments. In this estuary, significantly lower amounts of sediment phosphorus were found in those areas of low oxygen content (Table 9).

The sediment, however, is also a dynamic exchange system for phosphorus, not merely a receptacle for sedimented material. Much of the phosphorus lost from the water goes into the sediment as the water moves downstream. An equilibrium

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