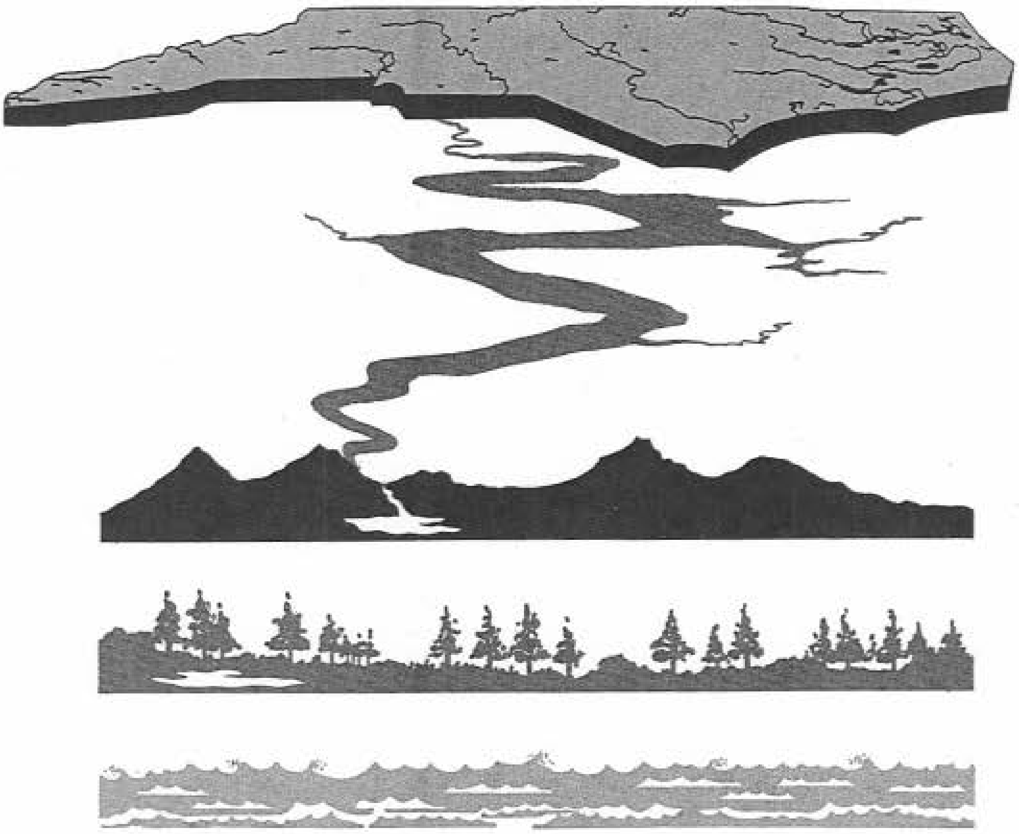
ALBEMARLE-PAMLICO BASELINE WATER QUALITY MONITORING DATA SUMMARY 1991-1992



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North Carolina Department of Environment, Health, and Natural Resources
Division of Environmental Management
Water Quality Section

ALBEMARLE-PAMLICO BASELINE WATER QUALITY MONITORING DATA SUMMARY 1991-1992

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HEALTH, AND NATURAL RESOURCES
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BASELINE WATER QUALITY
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Water Quality Section

This report has been approved for release ____________

Steve W. Tedder, Chief
Water Quality Section

Date: December 30th, 1992

EXECUTIVE SUMMARY

In 1988 the Division of Environmental Management (DEM) expanded its ambient water quality monitoring program in the Albemarle-Pamlico estuary area. Baseline physical, chemical and biological information obtained through this expanded monitoring program will be useful for researchers and water quality managers. This report summarizes water quality information for the Tar-Pamlico, Neuse, Roanoke, Chowan and Pasquotank River basins collected between October 1991 and July 1992. It serves as an addendum to the data collected between 1988 and September 1991 which are summarized and presented in Albemarle-Pamlico Baseline Water Quality Monitoring Summary 1988-1991 (NC DEHNR 1992). Since this report conveys water quality data for a ten month period it provides only a concise summary of essential points and facts.

Low flows were prevalent throughout the study area for most of this sampling period. This resulted in low dissolved oxygen (DO) concentrations at some of the upper basin stations during the warmer months, particluarly at sites adjacent to swamps.

In the Tar-Pamlico River basin high total nitrogen occurred at Pantego Creek at Belhaven during this and the previous study. The range of nutrients were within the ranges established between 1988-1991. Six metals exceeded state standards.

Stratification occurred intermittently in the Neuse River below New Bern and in the deeper tributaries. Elevated nutrient concentrations were found throughout the upper and mid-portions of the study area. The majority of algal blooms occurred in the upper estuary of the Neuse River below New Bern.

Stratified DO conditions were measured only once in the Roanoke River basin in conjunction with a salt wedge in Batchelor Bay. The Cashie River had the lowest pH and the highest nutrient values in the basin, probably due to swamp conditions. Density and biovolume concentrations of phytoplankton were low throughout the Roanoke River basin.

In the Pasquotank River basin, dissolved oxygen stratification occurred at several Albemarle Sound sites and near Edenton. High nutrient concentrations were found in the upstream portions of most of the rivers in the basin. Algal blooms were present in November 1991 and February 1992 in the Albemarle and Currituck Sounds.

Below average flows in the Chowan basin allowed a salt wedge to form in the Chowan River in early winter. The highest upper river conductivity and salinity values occurred in conjunction with Union Camp's discharge at downstream monitoring stations. The highest nutrient values also occurred at these stations during the discharge. Phytoplankton biovolume and density, and chlorophyll *a* values were low.

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INTRODUCTION

History

The Albemarle-Pamlico Estuary Study (APES) is one of the Environmental Protection Agency's (EPA) 17 nationwide estuary programs. The goal of the APES is to provide scientific knowledge to water resource managers so that the Albemarle-Pamlico (A/P) estuary can continue to supply citizens with natural resources and recreational opportunities. In order to meet this goal, a five year study of the A/P waters was conducted between 1988-1992 by the North Carolina Division of Environmental Management (NC DEM) in conjunction with the U.S. Geological Survey (USGS).

Human use of the A/P system includes tourism, recreation, resort development and fishing; forestry and agriculture are the primary land uses. The demand for these uses has increased resulting in several significant environmental changes: losses of shellfish and submerged macrophyte beds, losses of wetlands, declines in fisheries, outbreaks of fish disease and algal blooms. These changes have increased concerns related to water quality and potential relationships. Thus, the foci of this study include: 1) characterizing water quality parameters, 2) evaluating temporal and spatial trends once sufficient data are available, 3) characterizing events of low dissolved oxygen, and 4) providing baseline data for water resource managers and researchers.

This report summarizes the water quality information for the Tar-Pamlico, Neuse, Roanoke, Chowan and Pasquotank River basins collected between October 1991 and July 1992. Since this report conveys water quality data for a ten month period it provides only a concise summary of essential points and facts. It serves as an addendum to the data collected between 1988 and September 1991 which are summarized and presented in Albemarle-Pamlico Baseline Water Quality Monitoring Summary 1988-1991 (NC DEHNR 1992).

Site Locations and Parametric Coverage

Figure 1 depicts the locations of the sample sites in the ambient water quality network; Table 1 identifies the parameters sampled at these stations. The study design considers spatial and temporal variation and is as dense as feasible given fiscal limitations.

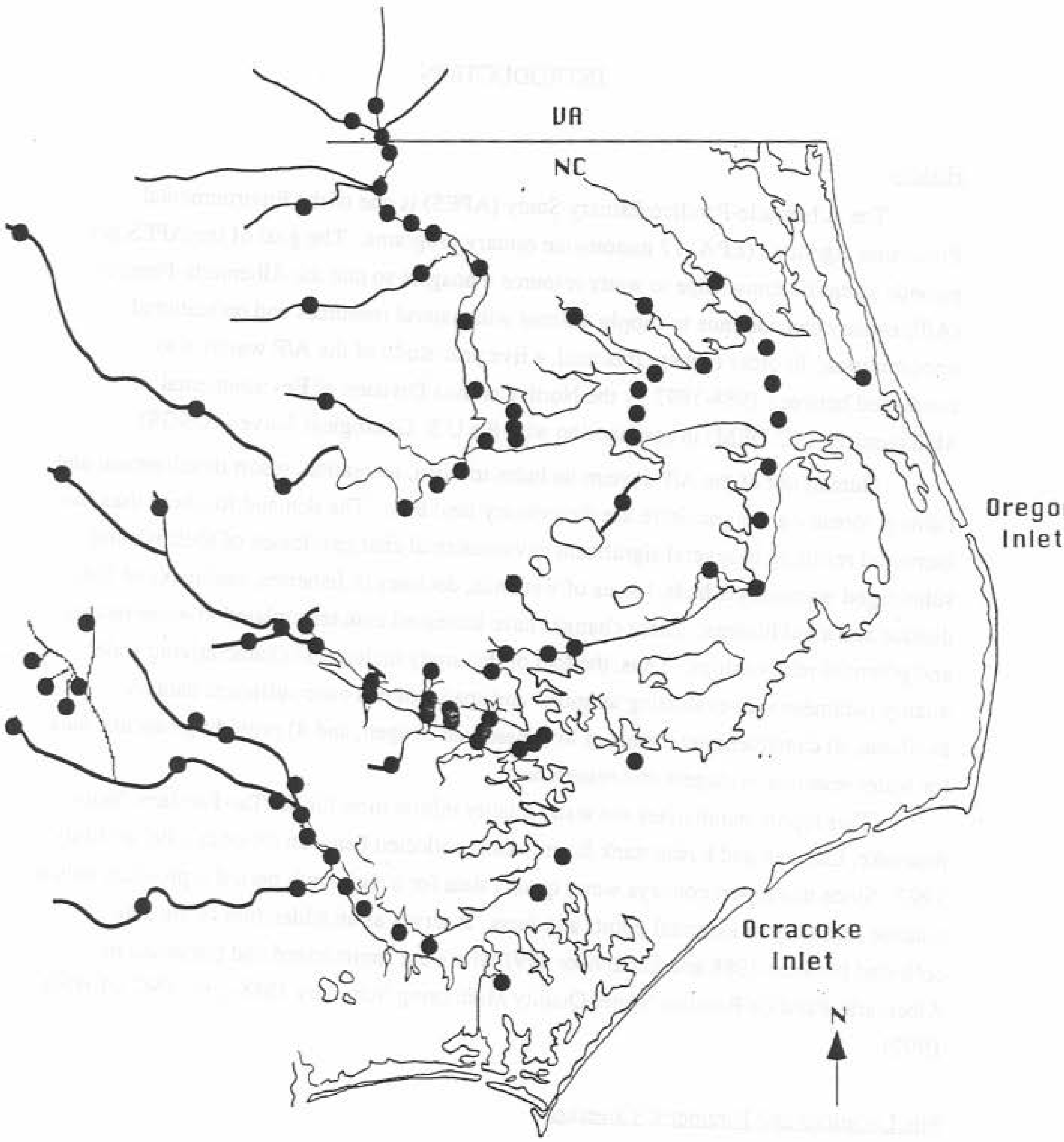

FIGURE 1. AMBIENT WATER QUALITY STATIONS
ALBEMARLE-PAMLICO STUDY AREA

Table 1. Parameters measured within the A/P study area.

PHYSICAL	CHEMICAL	BIOLOGICAL	METALS
Dissolved Oxygen	NH_3-N	Chlorophyll *a* - Corrected[1]	Aluminum
Temperature	TKN	Phytoplankton	Arsenic
pH	NO_2+NO_3	Fecal coliform bacteria[1]	Beryllium
Conductivity	Total N		Cadmium
Salinity	PO_4		Copper
Turbidity			Cyanide
Secchi Depth			Iron
			Lead
			Manganese
			Mercury
			Nickel
			Selenium
			Silver
			Zinc

[1]Parameter is listed in the Chemical Data appendices for each river basin.

Parameters were measured monthly for most stations with slight deviations from this schedule. The North Carolina Administrative Code (15A NCAC 2B .0100 and 5A NCAC 2B .0200) specifies water quality standards or action levels for certain parameters. These standards were used as guidelines when interpreting the data and are not considered in violation when values outside the normal range are caused by natural conditions (e.g. low dissolved oxygen in swamp waters).

Dissolved Oxygen. The water quality standard for dissolved oxygen (DO) is a daily average of 5.0 mg/l or greater for all surface waters, and not less than a minimum instantaneous value of 4.0 mg/l for fresh waters. Sites, such as swamps, coves and bottom waters, may have lower values if caused by natural conditions. When dissolved oxygen is depleted to near zero levels the waters are said to be hypoxic. When dissolved oxygen is at zero in the water column the condition is called anoxia. Hypoxia and anoxia commonly occur in estuaries throughout the world. Monthly sampling may not be frequent enough to determine short term events of hypoxia and anoxia; therefore, care must be taken when interpreting monthly dissolved oxygen sampling results. The USGS has established several continuous monitoring stations in the A/P estuarine area to provide information on the frequency and duration of hypoxic and anoxic events. A summary of stratification and hypoxia in the Pamlico River estuary using a 15 year set of biweekly measurements is provided by Stanley and Nixon (1992).

pH. pH is the measure of the concentration of hydrogen ions in solution. The standard for pH is 6.0 to 9.0 standard units (s.u.) for freshwater and 6.8 to 8.5 s.u. for tidal saltwaters.

Conductivity and Salinity. Conductivity, or specific conductance, measures the ease in which an electrical current can pass through water. It is related to the concentration of dissolved solids in fresh water or the salinity of sea water.

Secchi Depth and Turbidity. Secchi depth and turbidity measurements give an indication of light penetration within a water body. This information is useful in determining the depth to which light can penetrate for growth of phytoplankton and submersed aquatic vegetation (SAV). Sedimentation and an increase in phytoplankton concentrations could decrease secchi depth.

Turbidity depends on the amount of suspended materials, the production of organic matter, and the tidal currents and storms which can resuspend sediments (Gulicher 1967). Turbidity in estuaries is variable and higher than in neighboring marine waters (Darnell 1967). High turbidity limits the growth of most phytoplankton and rooted vegetation (Day 1952) and promotes the growth of surface algae such as Anabaena and Microcystis (Darnell 1967). Turbidity standards for both freshwater (50 Nephlometric Turbidity Units - NTU) and tidal saltwater (25 NTU) were used for assessing turbidity values.

Nitrogen and Phosphorus. The nutrients nitrogen and phosphorus can occur in different forms or species. Nitrogen species include nitrate/nitrite (NO_2+NO_3), ammonia as nitrogen (NH_3-N) and total kjeldahl nitrogen (TKN). Total nitrogen (TN) is defined as the sum of TKN and NO_2+NO_3. Total phosphorus (TP) and orthophosphate (PO_4) were also measured.

Research has shown that overenrichment of a water body by nutrients (nitrogen and phosphorus) is the major cause of accelerated eutrophication. Phosphorus has been identified as the limiting nutrient for most lake and river systems but in an estuarine system nitrogen usually appears to be the controlling factor. The most graphic examples of eutrophication are the green and blue-green scums seen on ponds and slow moving rivers and estuaries. In recognition of the role that nutrients play in the eutrophication process, DEM is continuing to evaluate the feasibility of criteria for freshwater systems. Estuarine waters are more complex and evaluation of nitrogen and phosphorus concentrations relative to growth response needs to be conducted for specific zones.

Biochemical Oxygen Demand. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen used in the biological process of degradation and decomposition of organic matter. Effluent from wastewater treatment plants, degradation of dead algae or vegetation, or direct delivery of organic matter from adjacent tributaries could result in elevated values of BOD. This parameter is considered high when values exceed 5.0 mg/l; a high BOD value may indicate the presence of a source of organic matter. Although BOD samples were collected at the monitoring sites, results of the analyses for this monitoring period are not yet available.

Phytoplankton and Chlorophyll a. Phytoplankton biovolume and density concentrations provide information about the primary production or trophic status of a waterbody. Bloom conditions exist when phytoplankton biovolume estimates exceed 5,000 mm^3/m^3 or density estimates exceed 10,000 units/ml. Increasing concentrations of phytoplankton are reflected in a concomitant increase in chlorophyll *a*. Chlorophyll *a* values approaching or exceeding the state water quality standard of 40 µg/l also are indicative of algal blooms. During blooms or periods of increased algal activity, elevations in surface dissolved oxygen and pH values often occur as a result of photosynthesis.

Fecal Coliform Bacteria. Fecal coliforms are important indicators of bacteria which may be detrimental to human health. The state standard for fecal coliforms for freshwaters and all tidal salt waters states that fecal coliforms are not to exceed geometric mean of 200 membrane filter fecal coliform colonies (MFFCC) per 100 ml based upon at least five consecutive samples examined during any 30-day period; and are not to exceed 400/100 ml in more than 20 percent of the samples examined during such period. For shellfishing (SA) waters the fecal coliform group cannot exceed a median MF of 14/100 ml and no more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions (15A NCAC 2B .0200).

Metals. Some metals, such as copper, iron, molybdenum, and zinc are essential micronutrients; however all metals may have detrimental effects on aquatic fauna when concentrations exceed threshold values. Metals are measured, and may be present, in small concentrations, usually micrograms per liter (µg/l). Progressive bioaccumulation of an element may occur until it reaches a toxic concentration. Toxic effects vary depending on the life history stage of an organism.

METHODS

Temperature, dissolved oxygen, pH, salinity, and conductivity were measured with a Hydrolab Surveyor II at 0.15 meter below the surface at all stations. In addition, measurements were taken at one meter increments until the bottom of the water column was reached to determine if temperature, DO and salinity stratifications were present. The Chemical Physical Standard Operations Manual (NC DEHNR 1989) quality control procedures were followed.

Nitrogen and phosphorus, turbidity, BOD, chlorophyll *a*, and phytoplankton samples were taken using a Labline sampler pulled slowly through the photic zone. The photic zone was defined as twice the secchi depth. The average of the depths obtained by lowering a secchi disc from the shaded side of the boat until it disappeared and then raising it until it reappeared was considered the secchi depth. Samples were preserved, placed on ice, and transported to the laboratory.

Laboratory analyses of the chemical samples were performed at DEM's Chemistry Laboratory and Washington Regional Laboratory using EPA approved standard methods (American Public Health Association 1989). Phytoplankton samples were analyzed by the Biological Assessment Group in accordance with DEM's Standard Operating Procedures Biological Monitoring Manual (NC DEHNR 1992) using a modification of Utermohl's inverted microscope technique (Utermohl 1958). Data collected were stored in EPA's STORET database.

RESULTS AND DISCUSSION

Data will be discussed by the Tar-Pamlico, Neuse, Roanoke, Chowan, and Pasquotank basins. Each section provides a watershed description, a figure showing sampling locations and discussion of physical, chemical, biological and metal data. Raw data are included in appendices by watershed.

TAR-PAMLICO RIVER BASIN

The Tar and Pamlico Rivers are two segments of the same river system. The Tar River begins near Roxboro in the eastern Piedmont of NC and runs for about 225 km (140 mi) until it reaches Washington. At Washington the Tar River becomes the Pamlico River which continues for another 60 km (37 mi) until it enters the Pamlico Sound. The major difference between the rivers is that most of the Pamlico River is saline. This results in a biological distinction between the Tar and Pamlico Rivers.

The Tar-Pamlico watershed is the fourth largest in North Carolina covering about 13,990 km^2 (5400 mi^2). The watershed is almost divided in half near Rocky Mount by the fall line, the division between the Piedmont and the Coastal Plain. Below the fall line the river has a flat mucky or sandy bottom with numerous tupelo and cypress swamps along its border.

Water quality concerns in the Tar-Pamlico River basin include point and nonpoint pollution, fish kills and algal blooms. Many of these problems may stem from nutrient (nitrogen and phosphorus) loading resulting in eutrophication. The state of North Carolina recognized the problems associated with nutrient loading by designating the Tar-Pamlico River as Nutrient Sensitive Waters in 1989.

Point and nonpoint discharges are present within the watershed. There are 111 permitted dischargers within the Tar-Pamlico basin, 12 with discharges greater than 0.5 MGD (NPDES Permitting Database). Nonpoint pollution sources include cropland in the Piedmont and agriculture and forestry in the coastal plain.

Table TP1 describes the 18 sample stations in the Tar-Pamlico River basin. No data were available during this study period for Chicod Creek near Bethel (# 02083800) and Durham Creek at Edwards (# 02084540). Sample sites are depicted in Figure TP1. Data are provided in Appendix 1.

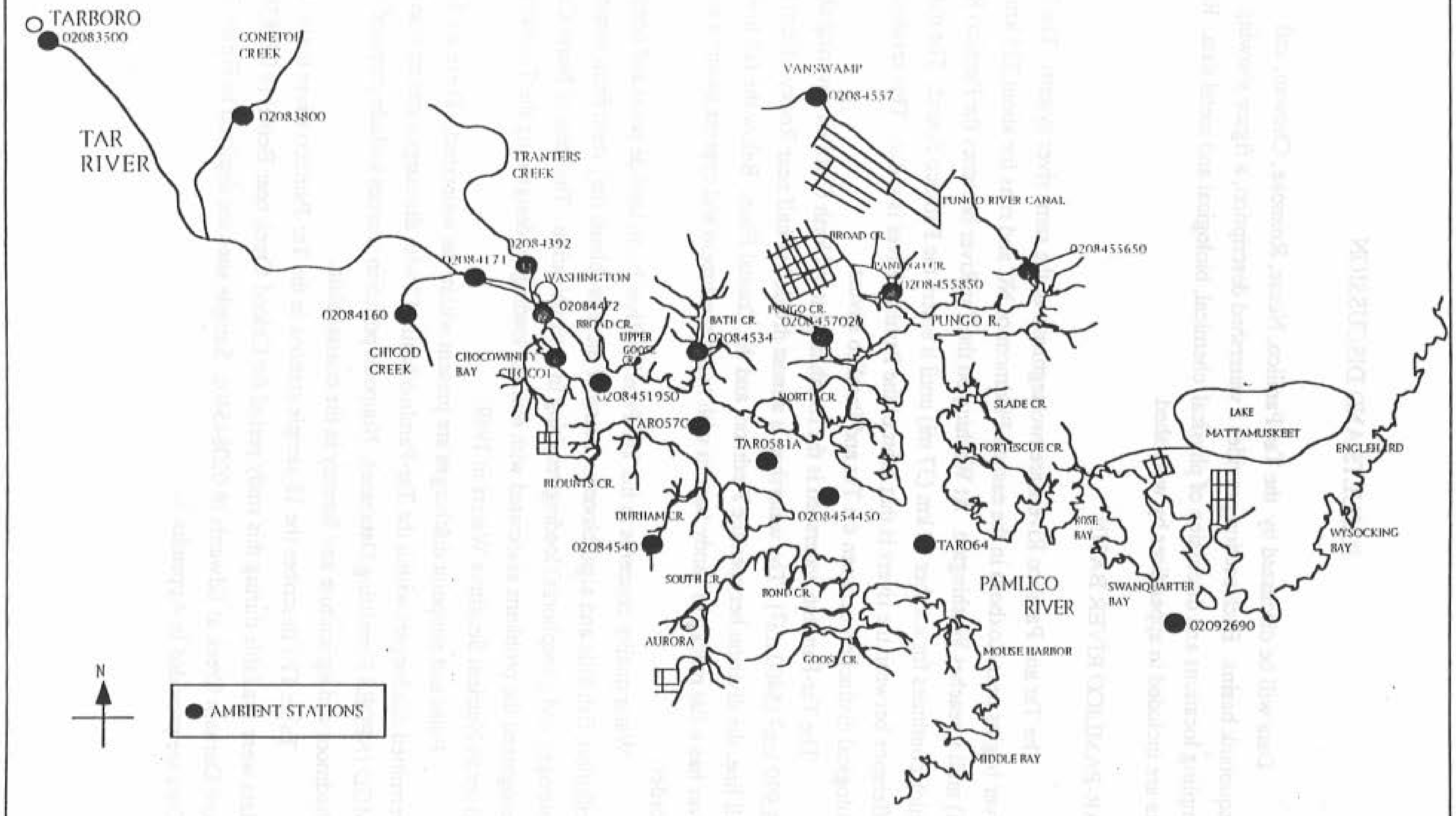

FIGURE TP1. AMBIENT STATIONS IN THE TAR-PAMLICO RIVER BASIN

Table TP1. Sample stations and parameters measured in the Tar-Pamlico River Basin.

STATION #	DESCRIPTION	PARAMETERS
02083500	Tar R @ Tarboro	P,T,N
02083800	Conetoe Cr nr Bethel	P,T,N,M,F
02084160	Chicod Cr nr Simpson	P,T,B
02084171	Tar R nr Grimesland	P,T,N,M,BP,F
02084392	Tranters Cr nr Washington	P,T,N,M,BP,F
02084472	Pamlico R @ Washington	P,T,N,M,BP,F *
0208451950	Pamlico R @ mouth of Broad Cr	P,T,N,M,BP,F *
02084534	Bath Cr nr Bath (Hwy 92)	P,T,N,M,BP,F
TAR057G	Pamlico R @ Light 5 nr Cove Pt	P,T,N,M,BP,F *
02084540	Durham Cr @ Edwards	P,T,N
TAR0581A	Pamlico R @ Light 4 nr Gum Pt	P,T,N,M,BP,F *
0208454450	Pamlico R @ Hickory Pt	P,T,N,M,BP,F *
0208457020	Pungo Cr @ Hwy 92 @ Sidney Crossroads	P,T,N,M,F
0208455850	Pantego Cr @ Belhaven	P,T,N,M,F
02084557	Van Swamp @ Hwy 32 nr Hoke	P,T,N,M,F
0208455650	Pungo R @ Hwy 264 nr Ponzer	P,T,N,M,BP,F
TAR064	Pamlico R @ Pungo	P,T,N,M,BP,F *
02092690	Pamlico Sound @ Great Island	P,T,N,M,BP,F *

P (Physical parameters - DO, pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll *a*), B (BOD), F (fecals), * (secchi depth)

Physical Data

Flow. During the 1991-1992 water year (Oct.-Sept.), monthly flow measured at Tarboro (# 02083500) was below the mean monthly flow except for January 1991 and July 1992. During these two above average months, flow was up 54% and 23% respectively.

Temperature and Dissolved Oxygen The range of surface temperatures (6 to 30° C) from October 1991 to July, 1992 were within the range (0 to 31° C) established during the period between 1988 and September 1991 (NC DEHNR 1992.). Vertical temperature and dissolved oxygen (DO) profiles were only measured from Washington to the Pamlico Sound. The temperature difference between surface and bottom water never exceeded 3° C.

Dissolved oxygen measurements ranged from hypoxic conditions (DO saturation ≤ 20%), to supersaturation (DO saturation ≥ 110%). Hypoxic conditions may be detrimental to aquatic life and are mostly found in subsurface and bottom water. The one incident of surface water hypoxia occurred at Tranters Creek (# 02084392) on December 4,

1991. However, Tranters Creek is classified as Swamp Waters and may have lower DO concentrations caused by natural conditions.

Photosynthesis by algae and other primary producers can increase DO and pH. Thus, water may become supersaturated with oxygen when algal densities are high. Supersaturation is often associated with a high concentration of chlorophyll *a*. Supersaturated water occurred during July 1992 in the Pamlico River at the mouth of Broad Creek (# 0208451950), at Light 4 near Gum Point (# TAR0581A), at Hickory Point (# 0208454450) and at Pungo (# TAR064). Chlorophyll *a* analyses have not been completed for these stations. During 1988-1991 most algal activity resulting in supersaturation occurred in the Pamlico River from Washington to Light 4 near Gum Point (NC DEHNR 1992).

Violations of the water quality standard for surface waters occurred in the Pamlico River at Washington (# 02084472) in October 1991 (DO=4.7 mg/l), and in the Pungo River at Highway 264 near Ponzer in June 1992 (DO=4.9 mg/l). Other incidences of surface water DO less than or equal to 5.0 mg/l occurred at Tranters Creek in October (DO=4.9 mg/l), November (DO=3.1 mg/l), December 1991 (DO=1.8 mg/l) and in May (DO=3.8 mg/l) and June, 1992 (DO=3.9 mg/l). However, swamp waters may have lower DO values caused by natural conditions.

pH. The pH values ranged from 2.9 to 8.9 s.u. during the 1991-1992 monitoring period. This range compares with the one established during the 1988-1991 monitoring period (NC DEHNR 1992). Van Swamp (# 02084557) had pH values less than 4.2 s.u. for all measurements taken between October 1991 and May 1992. This site has water with high concentration of organic acids commonly associated with tannic waters. This site has a history of low pH water (NC DEHNR 1992).

Other freshwater sites with low pH values (5.0<pH<6.0) are Conetoe Creek (# 02083800), Tranters Creek (# 02084392) and the Tar River near Grimesland (# 02084171). Tranters Creek is classified as Swamp Water which may have natural conditions resulting in low pH.

Two tidal saltwater stations, Pantego Creek at Belhaven (# 0208455850) and Pungo River at Highway 264 near Ponzer (# 0208455650), had pH values ranging from 6.2 to 6.7 s.u. for some samples measured during 1991-1992. These values are slightly below the range (6.8<pH<8.5) commonly found in tidal salt waters.

Conductivity and Salinity The measurements for the 1991-1992 monitoring period were within the ranges found during the 1988-1991 monitoring period (NC

DEHNR 1992). Salinity was present upstream as far as Tranters Creek (# 02084392) during November and December 1991. At Washington (# 02084472), salt waters were present mostly as a salt wedge for the entire 1991-1992 monitoring period except for July 1992 during which no salinity was present.

Secchi Depth and Turbidity. Turbidity values ranged from 2 to 44 NTU with the maximum value occurring in the Tar River near Grimesland (# 02084171), in January 1992. River flow during January was very high, and turbidity values at many of the monitoring stations peaked during this month. No turbidity values exceeded the standard of 50 NTU. During the 1988-1991 monitoring period turbidity values ranged from 1 to 240 NTU (NC DEHNR 1992).

Chemical Data

Nitrogen and Phosphorus Total nitrogen values ranged from 0.21 to 4.60 mg/l with a median of 0.65 mg/l. The high value occurred in Pantego Creek at Belhaven (# 0208455850) in January 1992. This sample site also had the highest concentration for total nitrogen during the 1988-1991 monitoring period (NC DEHNR 1992). The highest values of nitrogen occurred during the late fall and winter months. The range for TN during the previous study was 0.24 to 5.0 mg/l; high values also occurred during the late fall and winter months. (NC DEHNR 1992).

Total phosphorus values ranged from 0.01 to 0.43 mg/l with a median of 0.08 mg/l. The high value occurred in the Pamlico River at Hickory Point in May 1992. Lowest phosphorus values occurred during the spring season, which is consistent with the trend established during the 1988-1991 monitoring.

Biological Data

Phytoplankton and Chlorophyll a. Only one phytoplankton sample has been evaluated for the 1991-1992 period, and this was for the Pamlico River at Washington (# 02084472). The paucity of data precludes an assessment of phytoplankton during the monitoring period and a comparison with 1988-1991 monitoring period.

Chlorophyll *a* values ranged from 1 to 180 µg/l. The high value occurred in the Pamlico River at Washington during December 1991. A concentration of 74 µg/l was measured for November 1991 at this site. No values were greater than or equal to 40 µg/l for any other site.

Fecal Coliform Bacteria. Fecal coliform bacteria concentrations greater than 200 colonies/100ml occurred eight times. The high value of 1600 colonies/100 ml occurred in the Pamlico River at Washington (# 02084472). Only 11 measurements exceeded 200 colonies/100ml during the 1988-1991 monitoring period (NC DEHNR 1992).

Metal Data

Concentrations of cadmium, copper, iron, lead, nickel and zinc exceeded state standards or action levels at several monitoring stations. Cadmium exceeded the state standard for salt water (5 µg/l) at six different monitoring stations during April 1992, all with values of 10 µg/l. Copper exceeded the state standard of 7 µg/l for fresh water twice. Concentrations of 480 µg/l and 440 µg/l were measured at Tranters Creek near Washington (# 02084392) and Van Swamp (# 02084557) respectively. These concentrations exceeded the highest value (31 µg/l) measured during the 1988-1991 monitoring period. Copper exceeded the state standard of 3 µg/l for tidal salt waters (NC DEHNR 1992) six times; all violations were 4 µg/l.

There are many occurrences of iron exceeding the state action level of 1000 µg/l. However, iron is present as a element in the piedmont and coastal plain of North Carolina and commonly exceeds the state action level.

Eleven lead measurements exceeded the state action level of 25 µg/l. The highest concentration was 50 µg/l and this concentration occurred nine times at various locations. Only one measurement (33 µg/l) exceeded the state action level during the 1988-1991 measurement period (NC DEHNR 1992). Nickel exceeded the state action limit of 88 µg/l once for fresh water at Tranters Creek (# 02084392; 240 µg/l). Two values (39 µg/l at # TAR057G and 13 µg/l at # 0208455850) exceeded the state action level for salt water (8.3 µg/l). Zinc exceeded the state standard of 50 µg/l for fresh water at Van Swamp (# 02084557; 1000 µg/l) and at Tranters Creek (# 02084392; 2500 µg/l). Zinc concentrations did not exceed the state action levels during the 1988-1991 monitoring period.

NEUSE RIVER BASIN

The Neuse River basin encompasses 16,037 km^2 (6,192 mi^2) in the lower piedmont and coastal plain, contains 133,019 hectares (328,700 acres) of saltwater and is the third largest river basin in North Carolina. Major tributaries to the Neuse River in the coastal plain are the Little River, Swift Creek, Contentnea Creek and the Trent River. The Neuse River basin currently contains 290 permitted surface water dischargers, with 33 of these dischargers exceeding 0.5 MGD.

Land use in the lower Neuse basin consists mainly of forest, wetlands and agriculture. Above New Bern, the Neuse River is fairly narrow and winding with an average depth of approximately 2 m. Below New Bern the river widens to 10 km and has a mean depth of 5 m at its mouth near Maw Point (Geise et al. 1979). Tidal effects are observed as far upstream as Fort Barnwell (approximately 110 km from Maw Point). In May 1988 the entire Neuse River basin was reclassified as Nutrient Sensitive Waters. Figure N1 shows the locations of the 25 ambient water quality stations in the Neuse River basin. A description of the stations and the parameters sampled for each of these stations are provided in Table N1; data available for the current sampling period are given in Appendix 2.

Physical Data

Flow. Flow in the Neuse River was measured at Kinston (# 02089500). Daily mean flow data from October 1991 through May 1992 were compared to the past ten years (1983-1992) to obtain normal flow conditions. With the exception of October and January, the Neuse River flow was below normal.

Temperature and Dissolved Oxygen. During the study period, monthly surface temperatures in the mainstem Neuse River ranged from 7 to 29°C. Surface temperatures at tributary stations ranged from 7 to 30°C. These maximum temperature values are comparable to data from 1988 - 1991 since data from the potentially warmest months (August and September) are not included. Seasonally, the 1991-1992 winter was milder than normal, therefore minimum water temperatures were not as low as in previous years.

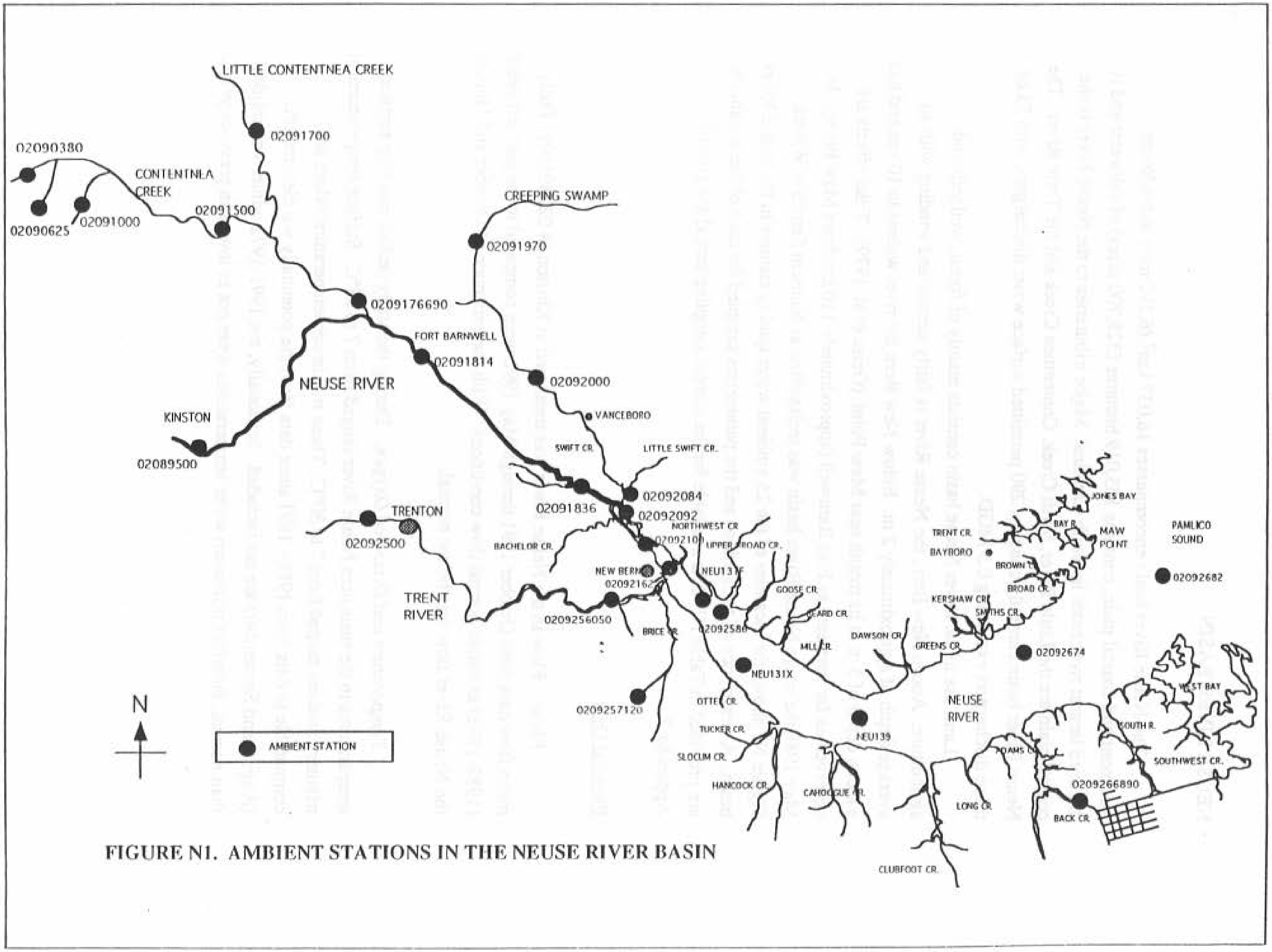

FIGURE N1. AMBIENT STATIONS IN THE NEUSE RIVER BASIN

Highest concentrations of DO were generally found from November through February corresponding with lower water temperatures. Effects of stratification were most evident spatially at four stations from New Bern (# 02092162) through Riverdale (# NEU131X) and sometimes extending to Minnesott Beach (# NEU139).

Table N1. Sample stations and parameters measured in the Neuse River Basin.

STATION #	DESCRIPTION	PARAMETERS
02089500	Neuse R @ Kinston	P,T,N,M,B,BP
02090380	Contentnea Cr nr Lucama	P,T,N,M,B
02090625	Turner Swamp nr Eureka	P,T,N,M,B
02091000	Nahunta Swamp nr Shine	P,T,N,M,B
02091500	Contentnea Cr @ Hookerton	P,T,N,M,B
02091700	Little Contentnea Cr nr Farmville	P,T,N,M,B
0209176690	Contentnea Cr @ Grifton	P,T,N,M,B
02091814	Neuse R nr Fort Barnwell	P,T,N,M,BP
02091836	Neuse R @ Streets Ferry	P,T,N,M,B,BP *
02091970	Creeping Swamp nr Vanceboro	P,T,N,M,B
02092000	Swift Cr nr Vanceboro	P,T,N,M,B
02092084	Swift Cr @ mouth nr Askin	P,T,N,M,BP,F *
02092092	Neuse R below Swift Cr nr Askin	P,T,N,M,BP,F *
02092109	Neuse R @ Narrows	P,T,N,M,BP,F *
02092162	Neuse R @ New Bern	P,T,N,M,BP *
02092500	Trent R nr Trenton	P,T,N,M
0209256050	Trent R above Reedy Br nr Rhems	P,T,N,M,BP,F *
0209257120	West Prong Brice Cr nr Riverdale	P,T,N,M,B
02092586	Neuse R @ mouth of Broad Cr nr Thurman	P,T,N,M,BP *
NEU131F	Neuse R @ Light #22 nr Fairfield Harbor	P,T,N,BP
NEU131X	Neuse R @ Light #11 nr Riverdale	P,T,N,BP *
NEU139	Neuse R nr Minnesott Beach	P,T,N,M,BP *
0209266890	Back Cr nr Merrimon	P,T,N,M
02092674	Neuse R nr Oriental	P,T,N,M,BP,F *
02092682	Neuse R @ mouth nr Pamlico	P,T,N,M,BP,F *

P (Physical parameters - D.O., pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll a), B (BOD), F (fecals), * (secchi depth)

Stratification of DO in the water column was intermittent from December through July. Mild stratification was apparent in the deeper tributaries, Swift Creek and the Trent River on May 18, 1992. Thermal stratification (greater than 5°C) was infrequent and only occurred twice during a pronounced salt wedge on May 18th. Salt wedges are common during periods of low flow, when dense hypolimnetic saline waters resist mixing with less dense fresh waters. Bottom water becomes hypoxic due to natural oxygen comsuming processes and poor mixing.

In mid-May (14^{th} and 18^{th}) a strong salt wedge was detected at five stations from the Neuse River at Narrows (# 02092109) downstream to Riverdale. During the same period, three instances of supersaturation accompanied by elevations in pH values occurred. The Neuse River at New Bern, Fairfield Harbor (# NEU131F) and Riverdale contained surface saturation levels of 139, 177 and 141% saturation respectively, indicating rapid algal growth. Algal bloom conditions were documented at two stations in this river reach.

pH. Surface values for pH ranged from 6.0 to 9.3 s.u. in the mainstem Neuse River. The tributaries, many of which drain swamplands, exhibited much lower pH values ranging from 3.2 to 7.6 s.u. In agreement with the last four years of data, the West Prong of Brice Creek (# 0209257120) contained the minimum pH value of 3.2 s.u. probably due to natural causes as acidic soils are characteristic of this region. Values of pH were elevated in the lower Neuse River because of increased algal activity.

Conductivity and Salinity. Conductivity values ranged from 50 to 768 µhmos at freshwater stations and peaked at 31,350 µhmos at the most downstream station (# 02092682) where salinity reached a maximum value of 20 ppt throughout the water column. During the drier months of November and December, salinity reached near the mouth of Swift Creek so the maximum conductivity value of 768 µmhos was probably attributable to salinity which was not measured. In May a salt wedge reached as far upstream as Neuse River at Narrows. The Neuse River typically becomes brackish near New Bern.

Secchi Depth and Turbidity. Turbidity values were generally low and all were below the state standard of 50 NTU for freshwater and 25 NTU for tidal saltwater. Mean turbidity values decreased in a downstream progression and secchi values increased inversely to turbidity.

Chemical Data

Nitrogen and Phosphorus. Values for NO_2+NO_3 and TN were generally elevated in the Neuse River from Kinston (# 02089500) through New Bern. Values for TN ranged from 0.31 mg/l at several tributary and mainstem stations to 2.3 mg/l at the Neuse River at Kinston. Below New Bern, settling and assimilation by phytoplankton may have caused decreases in the levels of NO_2+NO_3. Figure N2 depicts mean concentrations of NO_2+NO_3 and TN in the Neuse River moving downstream. Slight pulses in these nutrient concentrations are shown below Swift Creek (# 02092092) and are more pronounced near Fairfield Harbour (# NEU131F).

Mean concentrations of NH_3-N, PO_4 and TP generally decreased moving downstream (Figure N3). These nutrient concentrations exhibited peaks near Fairfield Harbor (# NEU131F) suggesting nutrient inputs from this area. The Neuse River at Fort Barnwell (# 02091814) and Narrows also showed slight increases in mean values for NH_3-N and TP.

Mean values for TP ranged from 0.01 mg/l at Brice Creek and the Pamlico Sound (# 02092682) to 0.52 mg/l at Little Contentnea Creek near Farmville (# 02091700), similar to previous years findings. Elevated levels of TP and TN were measured in many tributaries of the Neuse including Nahunta Swamp (# 02091000), Little Contentnea Creek, Contentnea Creek at Hookerton (# 02091500) and at Grifton (# 0209176690), Swift Creek near Vanceboro (# 02092000) and near Askin (# 02092084), Trent River near Trenton (# 02092500) and Back Creek near Merrimon (# 0209266890).

Biological Data

Phytoplankton and Chlorophyll a. Phytoplankton biovolume and density estimates and corresponding chlorophyll *a* concentrations were low in the upper Neuse River at Streets Ferry (# 02091836) and Narrows. Elevated algal growth occurred from New Bern to Minnesott Beach as the Neuse River widens and slows down. Figure N4 depicts mean chlorophyll *a* concentrations in the Neuse River . As with past years, the majority of algal blooms occurred from New Bern to Minnesott Beach.

The winter phytoplankton samples were generally dominated by cool weather dinoflagellates (Dinophyceae) such as Heterocapsa triquetra and Prorocentrum minimum. Spring and summer algal populations were most often dominated by various dinoflagellates (Gymnodinium spp, Gyrodinium spp, and Peridinium spp.), small centric diatoms, Cyclotella sp. (Bacillariophyceae) and chain-forming diatoms such as Skelotonema, Melosira, and Leptocylindrus spp.

Fecal Coliform Bacteria. Fecal coliform samples were collected at eight stations in the Neuse River Basin. Fecal coliforms measured greater than 200 colonies/100ml, the state standard for this parameter, during routine monitoring on three occasions, once in the Trent River (# 0209256050) and and twice in samples collected from Back Creek near Merrimon.

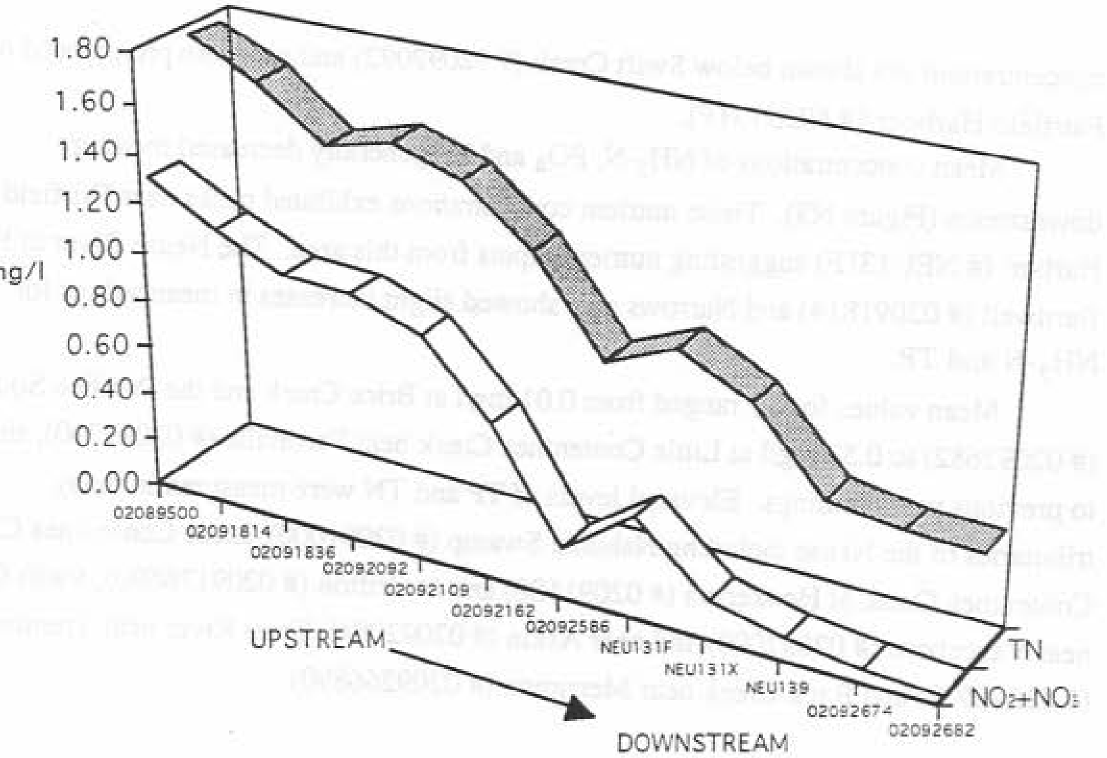

FIGURE N2. MEAN NITRATE/NITRITE (NO_2+NO_3) AND TOTAL NITROGEN (TN) VALUES FOR THE NEUSE RIVER, OCTOBER 1991 - JUNE 1992

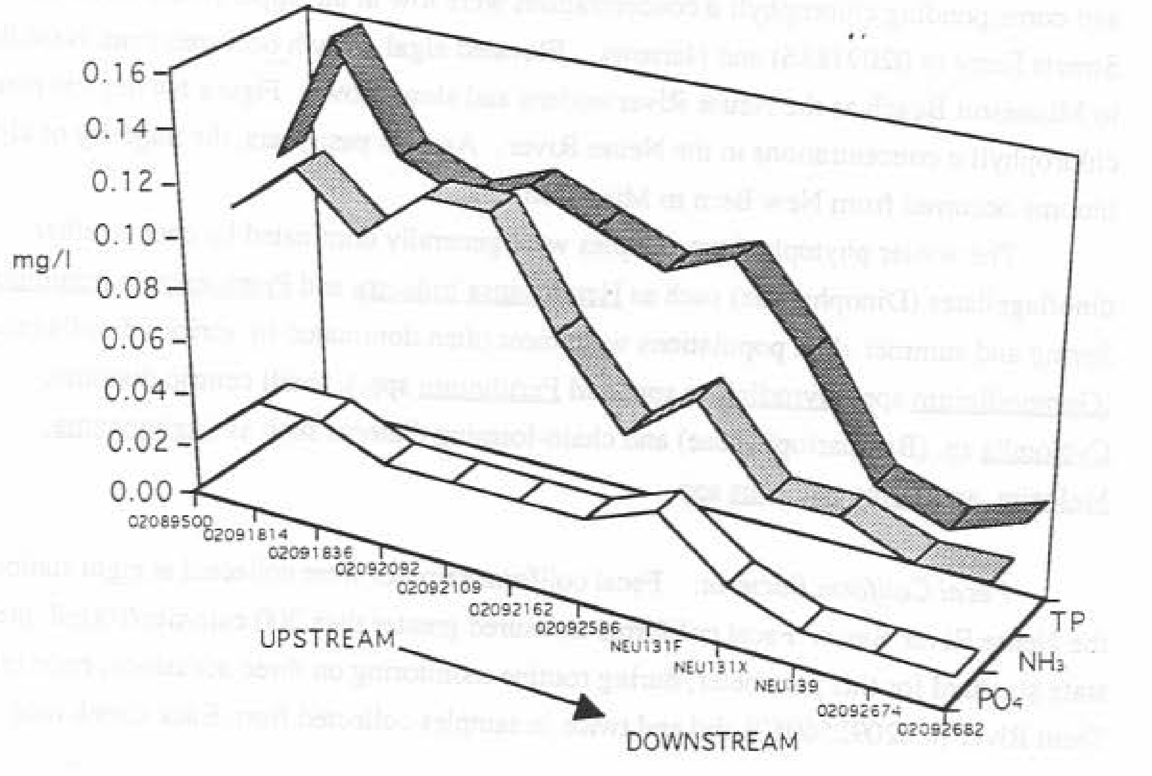

FIGURE N3. MEAN TOTAL PHOSPHORUS (TP), ORTHOPHOSPHATE (PO_4) AND AMMONIA (NH_3) VALUES FOR THE NEUSE RIVER, OCTOBER 1991 - JUNE 1992

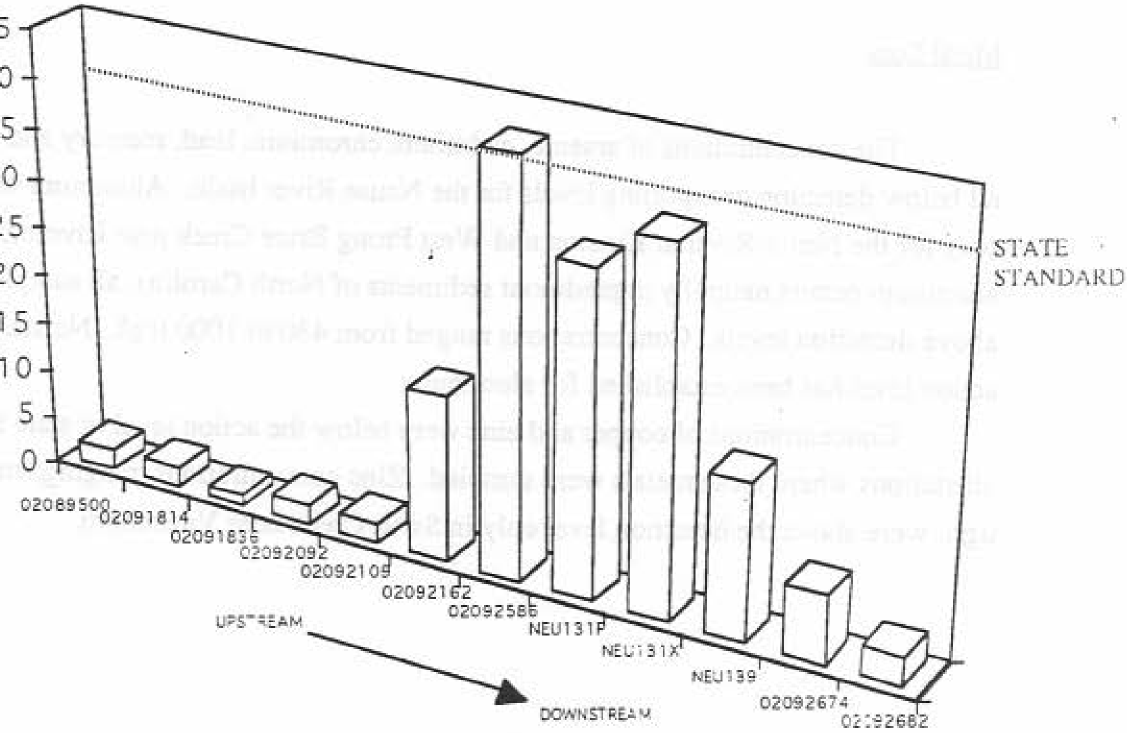

FIGURE N4. MEAN CHLOROPHYLL *a* CONCENTRATIONS IN THE NEUSE RIVER, OCTOBER 1991- JUNE 1992

Metal Data

The concentrations of arsenic, cadmium, chromium, lead, mercury and nickel were all below detection or reporting levels for the Neuse River basin. Aluminum was sampled only for the Neuse River at Kinston and West Prong Brice Creek near Riverdale. Because aluminum occurs naturally in piedmont sediments of North Carolina, all samples were above detection levels. Concentrations ranged from 430 to 1000 µg/l. No standard or action level has been established for aluminum.

Concentrations of copper and zinc were below the action level or state standards for all stations where these metals were sampled. Zinc concentrations, ranging from 24 to 26 µg/l, were above the detection level only in Swift Creek near Vanceboro.

ROANOKE RIVER BASIN

The Roanoke River and its tributaries encompass 9,332 km^2 (3,603 mi^2) in 17 counties located in the piedmont and inner coastal plain regions of North Carolina as well as an additional 12,388 km^2 (4,783 mi^2) of mountain and piedmont regions in Virginia. Below Roanoke Rapids, N.C., the Roanoke River is characterized by variable water levels and flow rates due to changes in discharge rates from an upstream dam at Roanoke Rapids Lake. There are 238 active dischargers in the basin, with 18 having permitted flows greater than 0.5 MGD. Figure R1 shows the locations of the eight ambient water quality stations in the Roanoke River basin. A description of each of these eight stations and the parameters measured in each are listed in Table R1; available data are given in Appendix 3.

Table R1. Sample stations and parameters measured in the Roanoke River basin.

STATION #	DESCRIPTION	PARAMETERS
02080500	Roanoke R @ Roanoke Rapids	P,T,M,B
02081000	Roanoke R nr Scotland Neck	P,T,N,M
02081022	Roanoke R nr Lewiston	P,T,M,B,F
02081054	Roanoke R @ Williamston	P,T,N,M,B
02081101	Cashie R nr Lewiston	P,T,N,M,B,F
02081135	Roanoke R nr Plymouth	P,T,N,M,BP,B *
02081141	Roanoke R @ Sans Souci	P,T,N,M,BP,B *
0208114330	Albemarle Sound (Batchelor Bay)	P,T,N,F *

P (Physical parameters - D.O., pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll a), B (BOD), F (fecals), * (secchi depth)

Physical Data

Flow. During the October 1991 to July 1992 study period, flow rates for the Roanoke River at Roanoke Rapids were generally below the mean flow for the water years 1964 - 1980. Only January and May 1991 had flow rates above the mean monthly values. February 1991 was below the historical minimum value set in 1977 for that month.

Temperature and Dissolved Oxygen. Surface temperatures in the Roanoke River ranged from 6 to 31°C for the nine month period from October 1991 through July 1992. The highest surface temperatures for this period were recorded at Sans Souci (# 02081141) and in the Albemarle Sound at Batchelor Bay (# 0208114330) on July 20, 1992. Surface temperatures for the Cashie River near Lewiston (# 02081101) were similar

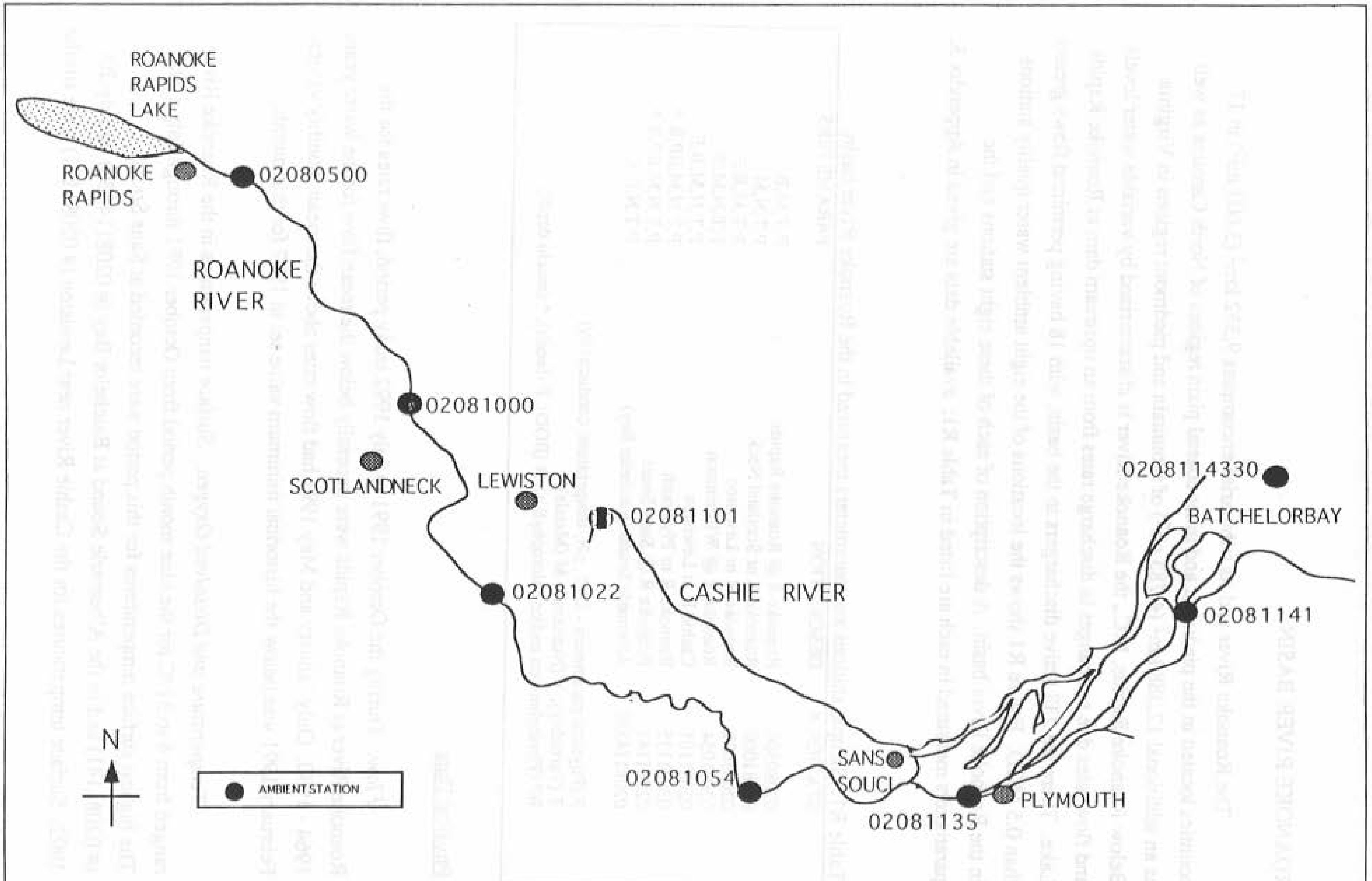

FIGURE R1. AMBIENT STATIONS IN THE ROANOKE RIVER BASIN to the Roanoke River with a range from 5 to 24ºC. July temperature data are not available for this station, therefore potentially higher temperatures for that month are not represented in this range.

Surface DO ranged from 4.3 to 11.8 mg/l in the Roanoke River, with the highest values recorded at Roanoke Rapids near the Roanoke Rapids Lake dam (# 02080500). This is consistent with data from the past four years and may be a result of aeration associated with release of water from Roanoke Rapids Lake (NC DEHNR 1992).

Dissolved oxygen concentrations of less than 5 mg/l occurred most often in the Cashie River and in the Roanoke River at Sans Souci. These stations are classified as swamp waters where DO values of less than 5 mg/l are considered natural occurrences. In the Cashie River, DO ranged from 1.1 to 8.4 mg/l with the lowest value occurring on May 28, 1992. Data from the past four years indicate that DO levels below 5 mg/l also occurred in the Roanoke River near Plymouth (# 02081135; NC DEHNR 1992), however values did not drop below 5 mg/l in the nine months included in this report.

Depth profiles indicate that stratification of the water column within the Roanoke River basin was measured only on November 25, 1991 in Batchelor Bay. Although temperatures did not differ with depth, DO levels decreased from 8.2 mg/l at the surface to 2.2 mg/l at 3 m. This decrease in dissolved oxygen occurred in conjunction with a salt wedge that increased the salinity from 1 ppt at the surface to 8 ppt at 3 m at this station.

pH. Surface pH in the Roanoke River was circumneutral with a range of 6.2 to 7.8 s.u. These values are within the limits considered by the state as normal for fresh water. Values within the surface waters of the Cashie River near Lewiston ranged from 5.4 to 6.5 s.u. These lower pH values may occur for rivers associated with swamp waters and are due to natural conditions.

Conductivity and Salinity. Fresh water conductivity data in the Roanoke River ranged from 63 µmhos near Lewiston (# 02081022) to 205 µmhos at Sans Souci. Conductivity values varied between 1440 µmhos to 12,400 µmhos in Batchelor Bay in conjunction with salt water intrusion on November 25, 1991 and July 20, 1992. Salinity at all other stations remained at 0 ppt during this study, except for one occasion at Sans Souci on December 30, 1991 when salinity reached 1 ppt at 5 m depth.

Secchi Depth and Turbidity. Turbidity values for the Roanoke River ranged from 2 NTU at Roanoke Rapids to 27 NTU in Batchelor Bay. Turbidity values ranged between

4 NTU and 11 NTU in the Cashie River. All turbidity values in both the Roanoke and Cashie Rivers were below the state standard of 50 NTU.

Secchi depths ranged from 0.4 to 1.7 m for the Roanoke River basin, with the lowest value found near Plymouth and in Batchelor Bay. The highest value was also found in Batchelor Bay during a period of salt water intrusion on July 20, 1992.

Chemical Data

Nitrogen and Phosphorus. Average NH_3-N levels remained constant across all stations (Figure R2). Individual values ranged from 0.01 to 0.31 µg/l, with the highest concentration found in the Cashie River on May 28, 1992. Roanoke River NO_2+NO_3 and TN values were variable near Scotland Neck, with mean concentrations exceeding 1 mg/l at that station (Figure R2). Data are not available for the upstream station near the Roanoke Rapids Lake dam, but the Scotland Neck data are consistent with the past four years. Mean concentrations at all other stations were relatively low, with NO_2+NO_3 ranging from 0.01 to 0.35 mg/l and TN values between 0.31 and 1.11 mg/l. The highest concentrations of NO_2+NO_3 were found in the Cashie River on May 28 and June 9, 1992.

Mean values of two species of phosphorus analyzed in the study, orthophosphate (PO_4) and total phosphorus (TP), are given in Figure R3. On an upstream to downstream transect, TP differed from TN in that the lowest concentration of TP was measured for the Roanoke River near Scotland Neck, whereas this station had the highest concentration of TN. Data from the previous four years indicate that the station near Sans Souci had the highest concentrations of TP, yet 1991-1992 data indicate a decrease in TP at this station. Because insufficient data are available at this time, these differences in phosphorus concentrations may not indicate significant changes in loading rates, but may instead be temporal fluctuations due to flow rates and other physical variables. Consistent with previous data, TP was significantly higher on the Cashie River than at any other station in the Roanoke River Basin, although concentrations did not reach previously reported values. For the eight month period in the current study, TP concentrations ranged from 0.03 to 0.28 mg/l on the Cashie River. Mean PO_4 values were comparable across all stations, with a slightly higher mean concentration found near Sans Souci on the Roanoke River. Values for both the Roanoke and Cashie Rivers ranged from 0.01 to 0.03 mg/l.

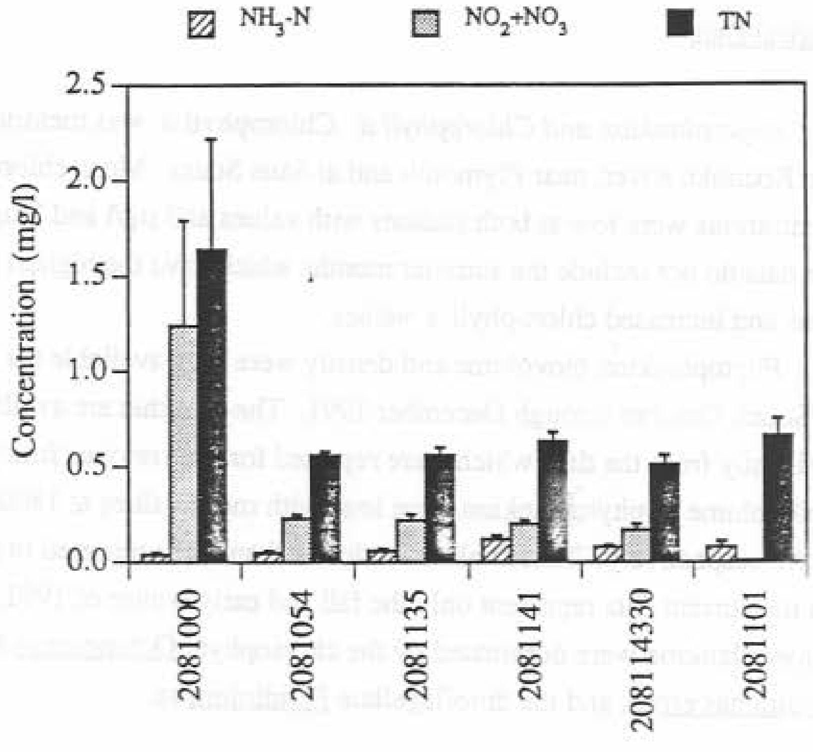

Figure R2. Mean ammonia, nitrate/nitrite and total nitrogen concentrations for the Roanoke River basin, October 1991 - June 1992. Error bars represent + 1 standard error.

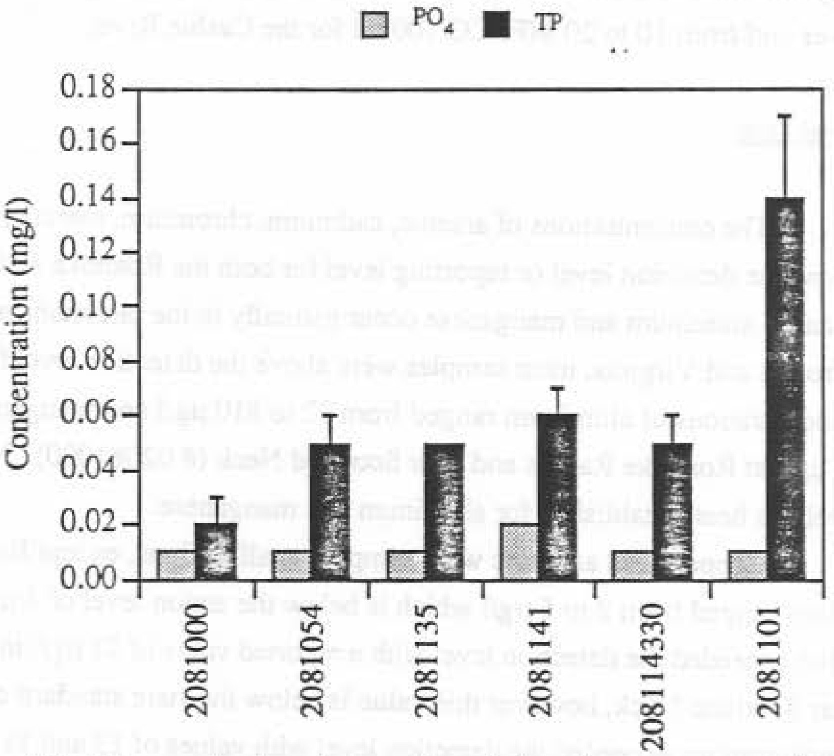

Figure R3. Mean orthophosphate and total phosphorus concentrations for the Roanoke River basin, October 1991 - June 1992. Error bars represent +1 standard error.

Biological Data

Phytoplankton and Chlorophyll a. Chlorophyll *a* was measured for two stations on the Roanoke River, near Plymouth and at Sans Souci. Mean chlorophyll *a* concentrations were low at both stations with values at 3 µg/l and 2 µg/l, respectively. These data do not include the summer months which have the highest potential for algal blooms and increased chlorophyll *a* values.

Phytoplankton biovolume and density were only available for the Roanoke River at Sans Souci, October through December 1991. The data that are available do not vary significantly from the data which were reported for the previous four years. Both density and biovolume of phytoplankton were low, with mean values at 1300 units/ml and 100 mm^3/m^3 respectively. These values are lower than those reported in previous studies, but again the current data represent only the fall and early winter of 1991. During this period the phytoplankton were dominated by the chrysophyte Ochromonas sp., the cryptophyte Cryptomonas erosa, and the dinoflagellate Peridinium sp.

Fecal Coliform Bacteria. Fecal coliform bacteria counts were analyzed for the Roanoke River near Lewiston, Batchelor Bay and the Cashie River. Values which exceeded 200 MFFCC/100 ml were found only on the Roanoke River near Lewiston in May and June of 1992. Counts ranged from 10 to 375 MFFCC/100 ml for the Roanoke River and from 10 to 20 MFFCC/100 ml for the Cashie River.

Metal Data

The concentrations of arsenic, cadmium, chromium, mercury and nickel were all below the detection level or reporting level for both the Roanoke and Cashie Rivers. Because aluminum and manganese occur naturally in the piedmont sediments of North Carolina and Virginia, most samples were above the detection level for these metals. Concentrations of aluminum ranged from 92 to 810 µg/l and manganese ranged from 17 to 91 µg/l at Roanoke Rapids and near Scotland Neck (# 02081000). No standard or action level has been established for aluminum and manganese.

Copper, lead and zinc were sampled at all stations, except Batchelor Bay. Copper values ranged from 2 to 5 µg/l which is below the action level of 7 µg/l. Only one lead value exceeded the detection level with a reported value of 21 µg/l in the Roanoke River near Scotland Neck, however this value is below the state standard of 25 µg/l. Two zinc concentrations exceeded the detection level with values of 13 and 11 µg/l in the Roanoke

River near Scotland Neck and in the Cashie River near Lewiston respectively. These values are well below the state action level of 50 µg/l.

Iron samples from the Roanoke River at Roanoke Rapids and near Scotland Neck, had values which fell below the action level and ranged from 55 to 500 µg/l. However, two values of 1100 µg/l were reported for the station near Scotland Neck, which are above the action level of 1000 µg/l. Like aluminum and manganese, iron occurs naturally in sediments of the piedmont of North Carolina and Virginia.

CHOWAN RIVER BASIN

The Chowan River basin encompasses 3400 km^2 (1,315 mi^2) in five counties in the coastal plain of North Carolina and also includes 9260 km^2 (3,575 mi^2) in Virginia. Major rivers in the basin include the Chowan, the Meherrin and the Wiccacon Rivers. There are 73 active surface water dischargers in the Pasquotank and Chowan basins combined, with 2 having permitted flows greater than 0.5 MGD. All North Carolina stream segments in the basin have been designated as Nutrient Sensitive Waters. This classification provides regulatory authority to limit nutrient inputs (NC DEHNR 1990a). The locations of the monitoring stations are depicted in Figure C1; a description of these stations and a list of the parameters measured are provided in Table C1.

Table C1. Sample stations and parameters measured in the Chowan River basin.

STATION #	DESCRIPTION	PARAMETERS
02047370	Nottaway R nr Riverdale	P,T,N,F *
02050065	Blackwater R @ Horseshoe Bend	P,T,N,BP,F *
0205007750	Blackwater R nr Wyanoke	P,T,N,BP,F *
02050079	Chowan R nr Riddicksville	P,T,N,BP,F *
02053200	Potecasi Cr nr Union	P,T,N,BP
0205321790	Meherrin R (Parkers Ferry) nr Como	P,T,N,M,B,F *
02053244	Chowan R @ Winton	P,T,N,B,BP,F *
0205325510	Chowan R @ Channel Marker # 27	P,T,N,B,BP,F *
02053500	Ahoskie Cr @ Ahoskie	P,T,N,M,B,BP
02053574	Chowan R nr Gatesville (Marker # 16)	P,T,N,BP,F *
0205360615	Chowan R below Holiday Island	P,T,N,M,BP,F *
02053569	Wiccacon R nr Harrelsville	P,T,N,BP
02053632	Chowan R @ Colerain	P,T,N,BP,F *
02053652	Chowan R @ Edenhouse	P,T,N,M,BP *

P (Physical parameters - D.O., pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll a), B (BOD), F (fecals), * (secchi depth)

Physical Data

Flow. Flows in the Chowan basin were below average from October 1991 through May 1992 and average during June and July. Much less than average flows were followed by an occurrence of salt water intrusion during the early winter months.

Temperature and Dissolved Oxygen. Surface temperatures from October 1991 through July 1992 ranged from 4 to 31° C, being coldest in January and warmest in July. No thermal stratification was measured during this period.

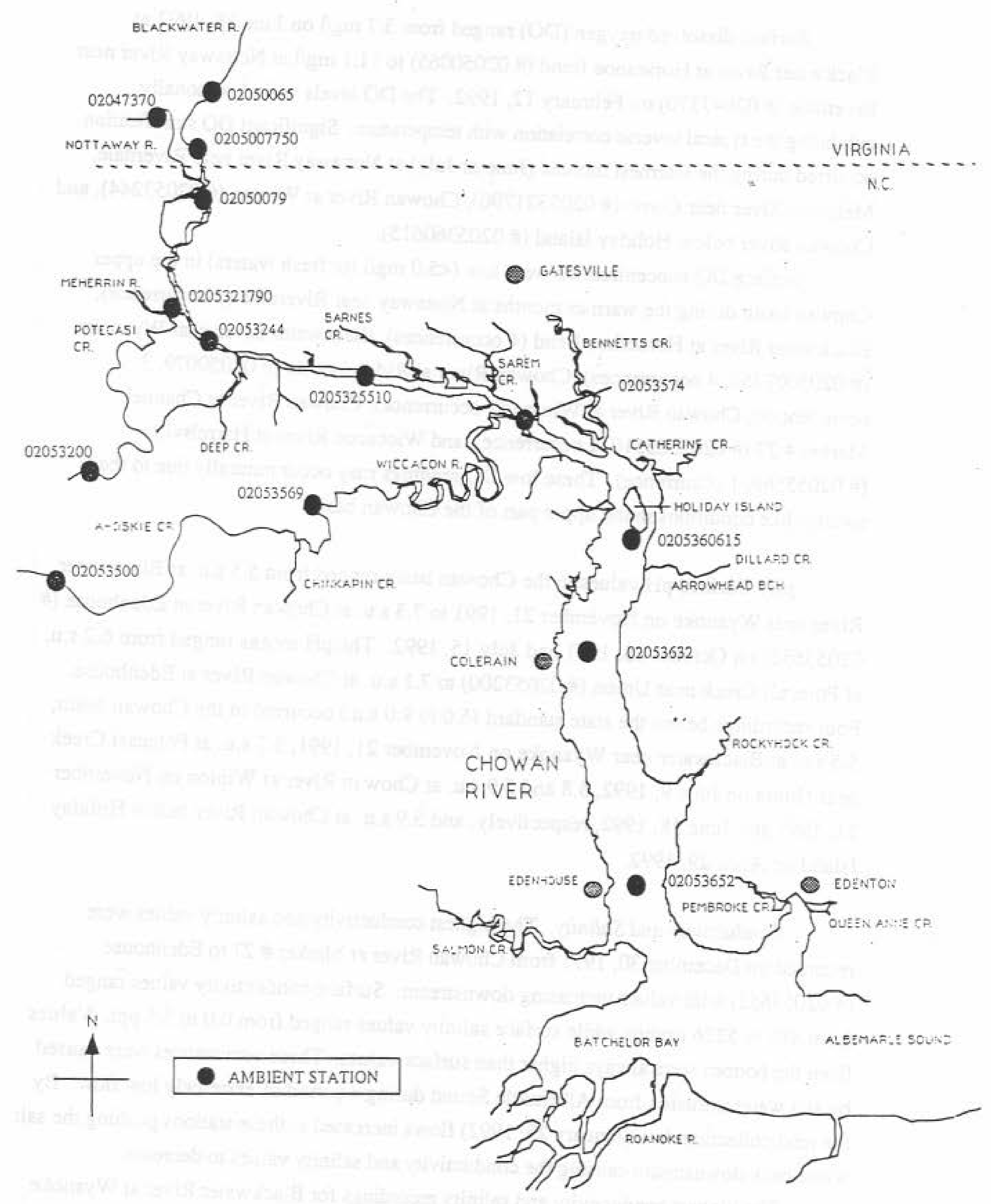

FIGURE C1. AMBIENT STATIONS IN THE CHOWAN RIVER BASIN

Surface dissolved oxygen (DO) ranged from 3.7 mg/l on June 18, 1992 at Blackwater River at Horseshoe Bend (# 02050065) to 11.1 mg/l at Nottaway River near Riverdale (# 02047370) on February 12, 1992. The DO levels varied seasonally, exhibiting the typical inverse correlation with temperature. Significant DO stratification occurred during the warmest months (June or July) at Nottaway River near Riverdale, Meherrin River near Como (# 0205321790), Chowan River at Winton (# 02053244), and Chowan River below Holiday Island (# 0205360615).

Surface DO concentrations were low (<5.0 mg/l for fresh waters) in the upper Chowan basin during the warmer months at Nottaway near Riverdale (1 occurrence), Blackwater River at Horseshoe Bend (4 occurrences), Blackwater River near Wyanoke (# 0205007750, 4 occurrences), Chowan River at Riddicksville (# 02050079, 3 occurrences), Chowan River at Winton (1 occurrence), Chowan River at Channel Marker # 27 (# 0205325510, 1 occurrence), and Wiccacon River at Harrelsville (# 02053569, 1 occurrence). These low DO readings may occur naturally due to the swamp-like conditions in the upper part of the Chowan basin.

pH. Surface pH values in the Chowan basin ranged from 5.5 s.u. at Blackwater River near Wyanoke on November 21, 1991 to 7.3 s.u. at Chowan River at Edenhouse (# 02053652) on October 15, 1991 and July 15, 1992. The pH means ranged from 6.2 s.u. at Potecasi Creek near Union (# 02053200) to 7.1 s.u. at Chowan River at Edenhouse. Four recordings below the state standard (6.0 to 9.0 s.u.) occurred in the Chowan basin; 5.5 s.u. at Blackwater near Wyanoke on November 21, 1991, 5.7 s.u. at Potecasi Creek near Union on June 9, 1992, 5.8 and 5.9 s.u. at Chowan River at Winton on November 21, 1991 and June 18, 1992, respectively, and 5.9 s.u. at Chowan River below Holiday Island on April 29, 1992.

Conductivity and Salinity. The highest conductivity and salinity values were recorded on December 30, 1991 from Chowan River at Marker # 27 to Edenhouse (# 02053652) with values increasing downstream. Surface conductivity values ranged from 488 to 5226 µmhos while surface salinity values ranged from 0.0 to 3.5 ppt. Values from the bottom were always higher than surface values. These occurrences were caused by salt water intrusion from Albemarle Sound during a period of extremely low flow. By the next collection date (January 29, 1992) flows increased at these stations pushing the salt water back downstream causing the conductivity and salinity values to decrease.

The highest conductivity and salinity recordings for Blackwater River at Wyanoke (# 0205007750) down to Chowan River at Winton (# 02053244) occurred on January 21, 1992 with values decreasing downstream. Bottom conductivity values ranged from 414 to 1890 µmhos while bottom salinity values ranged from 0.0 to 1.0 ppt. The values were slightly lower but still high on the next collection date (February 12, 1992) for the same stations. These elevated conductivies are due to Union Camp's discharge, located upstream of Blackwater at Wyanoke. Union Camp's effluent, which contains high amounts of salts and conductivity, is discharged during high flow periods, generally from December through March.

Secchi Depth and Turbidity. The turbidity levels were below the state standard of 50 NTU (fresh water) for all the stations on all collecting dates. The highest readings occurred during the high flow periods (January - March). Secchi depths were generally inversely related to the turbidity values. The lowest secchi depth recordings along with the higher turbidity levels at some stations in the upper Chowan River were associated with the Union Camp discharge.

Chemical Data

Nitrogen and Phosphorus Most of the stations experienced the highest nutrient levels during the winter and early spring. The levels may be attributed to nonpoint source inputs during high flow and/or from point source inputs such as the Union Camp discharge. The highest NH_3-N and TKN levels along with PO_4 levels were recorded on January 21, 1992 at Blackwater near Wyanoke (# 0205007750) with values of 0.60 mg/l, 1.10 mg/l, and 0.21 mg/l respectively. The TP level (0.30 mg/l) at this station was slightly less than the highest level (0.32 mg/l) recorded at Chowan River near Riddicksville (# 02050079) on the same date. The Blackwater near Wyanoke station is located below the discharge canal from Union Camp, and on January 21, 1992 much lower nutrient concentrations were measured upstream of the discharge on the Blackwater River at Horsebend (# 02050065). The highest NH_3-N, TP, and PO_4 levels for the Chowan River stations down to Winton also occurred on this date, decreasing as distance from the Union Camp's discharge increased.

Biological Data

Phytoplankton and Chlorophyll a. Chlorophyll *a* levels from October 1991 through June 1992 remained low at all the stations, reaching 14 µg/l on June 15, 1992 at Chowan River below Holiday Island (# 0205360615). Phytoplankton data, collected from the Chowan River at Winton, Colerain, and Edenhouse, revealed generally low biovolume and density levels reflecting the low chlorophyll *a* measurements on the same dates. Both the chlorophyll *a* and phytoplankton data do not include the late summer months which have the highest potential for increased algal biomass and subsequent increased chlorophyll *a* values. The phytoplankton data were available from October through December 1991 and March 1992 for the Chowan River at Winton station; October 1991 through January 1992 and March 1992 for Chowan River at Colerain; November 1991 for Chowan River at Edenhouse.

The phytoplankton community was predominantly composed of chrysophytes and cryptophytes in Chowan River at Winton from October through December 1991. The algal species dominant were Ochromonas sp. (chrysophyte) and Cryptomonas erosa (crytophyte). Chroomonas minuta, a cryptophyte, and Rhizosolenia sp., a diatom (bacillariophyte), dominated the community in March 1992.

The community in Chowan River at Colerain was dominated by Vacuolaria virescens (chloromonadophyte) from October through November, along with Ochromonas sp. in November. A cryptophyte community was prevalent in December dominated by Chroomonas caudata. The community changed in composition in January and March with chrysophytes Bicoeca planctonica and Ochromonas spp. dominating. The phytoplankton community in Chowan River at Edenhouse was similar to Chowan River at Colerain during the same period, dominated by Vacuolaria virescens (biovolume) and Ochromonas sp. (density).

Fecal Coliform Bacteria. Fecal coliform samples were collected at all but three stations, (Potecasi Creek near Union, Ahoskie Creek at Ahoskie, and Wiccacon River near Harrelsville). All samples from November 1991 to June 1992 exhibited low counts, much less than the 200 MFFCC/100ml state standard for freshwaters.

Metal Data

Analyses for arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc were conducted for samples from three stations (Meherrin River near Como, Ahoskie

Creek at Ahoskie, Chowan River at Edenhouse) in the Chowan basin. No concentrations exceeded the state standards, but copper levels were above detection in some instances at all the stations tested, most likely due to the natural abundance of copper within the sediment.

PASQUOTANK RIVER BASIN

The Pasquotank River and its tributaries encompass an area of 9,575 km^2 (3,697 mi^2) in nine counties in the outer coastal plain region of North Carolina, including 213,640 ha (527,900 acres) of salt and brackish water. The Pasquotank River arises from the Great Dismal Swamp in northeastern North Carolina and empties into the Albemarle Sound, along with the other rivers which make up the Pasquotank River basin including the Perquimans, Scuppernong and Alligator Rivers. There are 73 active surface water dischargers in the Pasquotank and Chowan basins combined, with 2 having permitted flows greater than 0.5 MGD. Figure P1 shows the locations of the 25 ambient water quality stations in the Pasquotank River basin. Station descriptions and the sampled parameters are given in Table P1; available data are given in Appendix 5.

Table P1. Sample stations and parameters measured in the Pasquotank River Basin.

STATION #	DESCRIPTION	PARAMETERS
02042955	Currituck Sound @ Point Harbor	P,T,N,BP *
02043859	Pasquotank R @ RR Bridge nr Elizabeth City	P,T,N,M *
02043862	Pasquotank R @ Elizabeth City	P,T,N,M,F *
02043878	Pasquotank R @ Buoy FL"5"Sec nr Old Trap	P,T *
02043882	Little R @ Woodville	P,T,N
02043884	Little R nr Weeksville (Buoy # 4)	P,T *
02081179	Albemarle Sound nr Frog Island	P,T,N,BP *
02043892	Perquimans R @ Hertford	P,T,N
0208455655	Intracoastal Waterway @ US Hwy 264	P,T *
02043906	Perquimans R @ Harvey Point	P,T,N,F *
02081172	Albemarle Sound btwn Harvey Pt & Mill Pt	P,T,N,BP,F *
02081145	Albemarle Sound nr Edenton (Buoy #R"4")	P,T,N,BP,F *
02081185	Kendricks Cr @ Mackeys	P,T,N,M
02081166	Scuppernong R nr Columbia	P,T,N,BP
0208117810	Alligator R us Cherry Ridge Landing	P,T,N,BP *
0208117820	Alligator R @ Newport News Pt	P,T,N,BP *
0208117830	Alligator R 3 miles us Catfish Pt	P,T,N,BP *
0208117840	Alligator R @ US Hwy 6	P,T,N,BP *

P (Physical parameters - D.O., pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll a), B (BOD), F (fecals), * (secchi depth)

Physical Data

Temperature and Dissolved Oxygen. Surface temperatures in the Pasquotank River basin ranged from 4 to 31°C for the nine month period beginning October 1991 - July 1992. The lowest surface temperature was recorded on January 16, 1992 in the Little River at Woodville (# 02043882); the highest temperature was measured in the Pasquotank

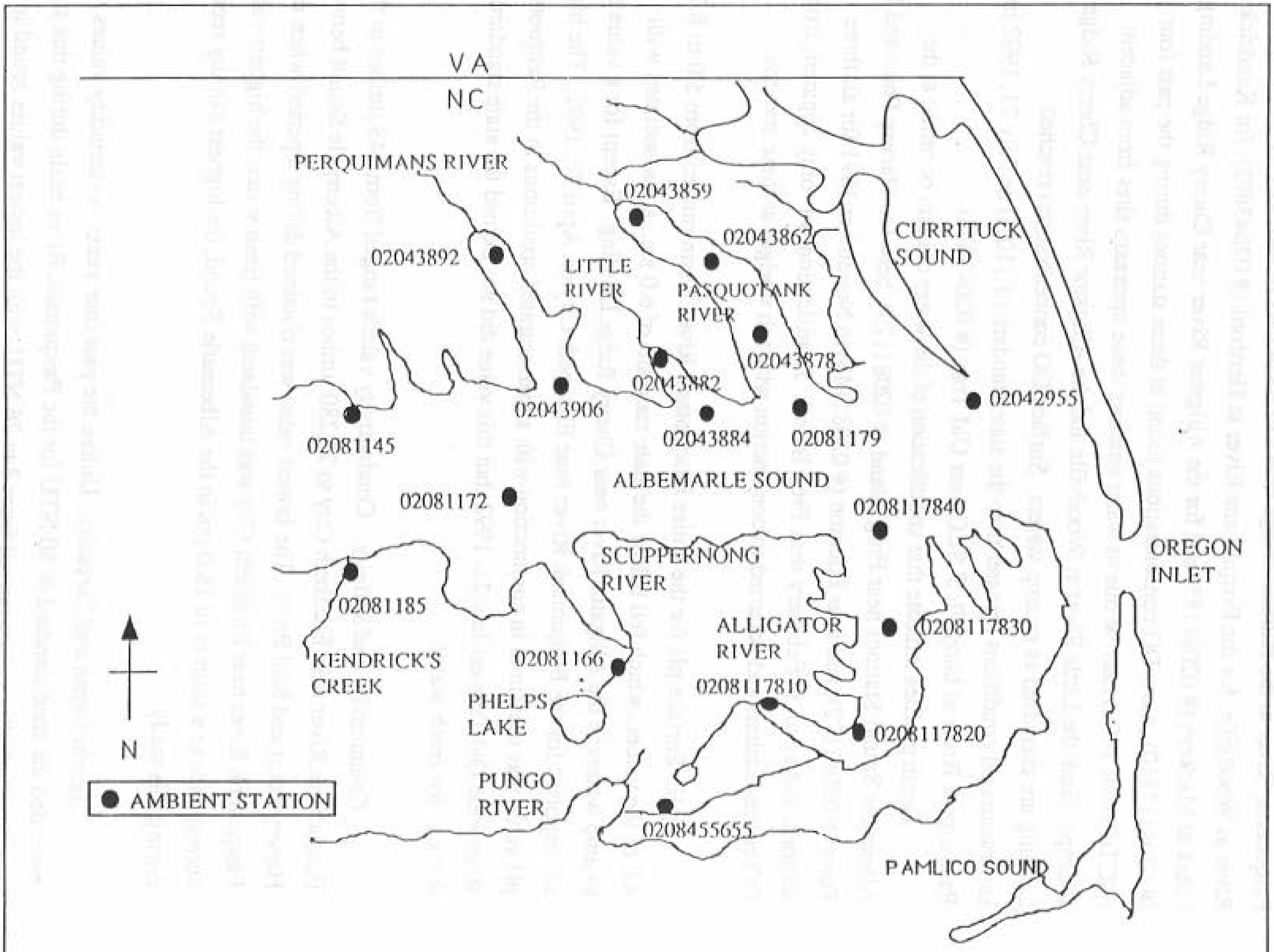

FIGURE P1. AMBIENT STATIONS IN THE PASQUOTANK RIVER BASIN

River at Elizabeth City (# 02043862) on July 21, 1992.

Surface values for DO ranged from 1.6 to 12.2 mg/l in the Pasquotank basin. Surface DO values less than 5 mg/l, the state DO standard, were measured for the Pasquotank River at the railroad bridge near Elizabeth City (# 02043859), for the Little River at Woodville, for the Perquimans River at Hertford (# 02043892), for Kendrick's Creek at Mackeys (# 02081185) and for the Alligator River near Cherry Ridge Landing (# 0208117810). Low DO concentrations found at these stations during the past four years (NC DEHNR 1992) may be due to water entering these upstream sites from adjacent swamps. Both the Little River at Woodville and the Alligator River near Cherry Ridge Landing are classified as swamp waters. Surface DO concentrations reached supersaturated conditions (greater than the state standard of 110%) on July 21, 1992 in the Pasquotank River at buoy FL'5' SEC near Old Trap (# 02043878).

Depth profiles indicate that stratification of the water column occurred at the Albemarle Sound Stations near Frog Island (# 02081179), between Harvey Point and Mill Point (# 02081172), and near Edenton (# 02081145) in November 1991 for all three stations, and again in February near Frog Island. Stratification was only apparent from the DO concentrations and occurred in conjunction with salt wedges at these stations.

pH. Surface pH for the entire Pasquotank River Basin ranged from 5.0 to 8.7 s.u. All of the values, which fell below the state standard of 6.0 s.u., are associated with swamp waters in the Alligator River near Cherry Ridge Landing. Except for a value of 5.7 s.u. reported for the Pasquotank River near Elizabeth City on April 27, 1992. The highest pH value was measured in conjunction with supersaturated conditions in the Pasquotank River near Old Trap on July 21, 1992, but this value did not exceed the state standard of 9.0 s.u. for fresh water.

Conductivity and Salinity. Conductivity values ranged from 143 µmhos in the Pasquotank River near Elizabeth City to 27,280 µmhos in the Albemarle Sound between Harvey Point and Mill Point. The lowest value was obtained during a period when the Pasquotank River near Elizabeth City was inundated with fresh water; the highest value corresponds to a salinity of 18.0 ppt in the Albemarle Sound, the highest salinity recorded during this study.

Secchi Depth and Turbidity. Unlike the past four years, no turbidity values exceeded the state standard of 50 NTU for the Pasquotank River basin during this study period. Turbidity values ranged from 3 to 26 NTU, with the lowest values found in the

Albemarle Sound near Frog Island, between Harvey Point and Mill Point, and near Edenton, and in the Alligator River near Cherry Ridge Landing. The highest turbidity was reported for the Intracoastal Waterway at US Highway 264 (# 0208455655).

Secchi depths ranged from 0.2 to 2.5 m for the basin, with the lowest secchi found in the Alligator River near Cherry Ridge Landing, which is classified as swamp water and would be expected to have low secchi depths. The highest value was recorded during a fresh water spate in the Albemarle Sound near Edenton on July 27, 1992.

Chemical Data

Nitrogen and Phosphorus. Ammonia-N (NH_3-N), nitrate/nitrite (NO_2+NO_3), and total Kjeldahl nitrogen (TKN) were sampled for the Pasquotank River Basin (Figure P2). Mean NH_3-N values were consistent among all stations except Kendrick's Creek at Mackeys where concentrations ranged from 0.23 to 0.69 mg/l. Concentrations for all other stations ranged from a low of 0.01 mg/l for the Pasquotank River at Elizabeth City and the Perquimans River at Harvey Point (# 02043906) to a high of 0.17 mg/l for the Perquimans River at Hertford. Nitrate/nitrite values followed the same trends as NH_3-N values with the highest concentrations present in Kendrick's Creek which ranged from 0.08 to 2.10 mg/l. Concentrations for all other stations ranged from a low of 0.01 mg/l for several of the downstream and Albemarle Sound stations to a high of 0.84 mg/l for the Perquimans River at Hertford. Mean TN concentrations indicate elevated values of nitrogen at upstream stations in the Perquimans River, Pasquotank River, Little River, Kendrick's Creek and Alligator River. Values for these stations range from 0.87 to 2.90 mg/l and are consistent with data from the previous four years. The Alligator River near Cherry Ridge Landing receives tannic waters from adjacent swamps which lowers water transparency limiting phytoplankton growth. Elevated nitrogen values at this station may be due to limited uptake of available nutrients from the water column by phytoplankton (NC DEHNR 1992).

Mean values of the two species of phosphorus analyzed in this study, orthophosphate (PO_4) and total phosphorus (TP), are given in Figure P3. Mean PO_4 concentrations are uniformly low among all stations sampled in the Pasquotank River basin, with individual values ranging from 0.01 to 0.03 mg/l. TP values were highest at the same stations where elevated TN values occurred, with the exception of the upstream station of the Alligator River which only reached 0.03 mg/l. Upstream stations of Kendrick's Creek, the Perquimans River, the Little River and the Pasquotank River had TP

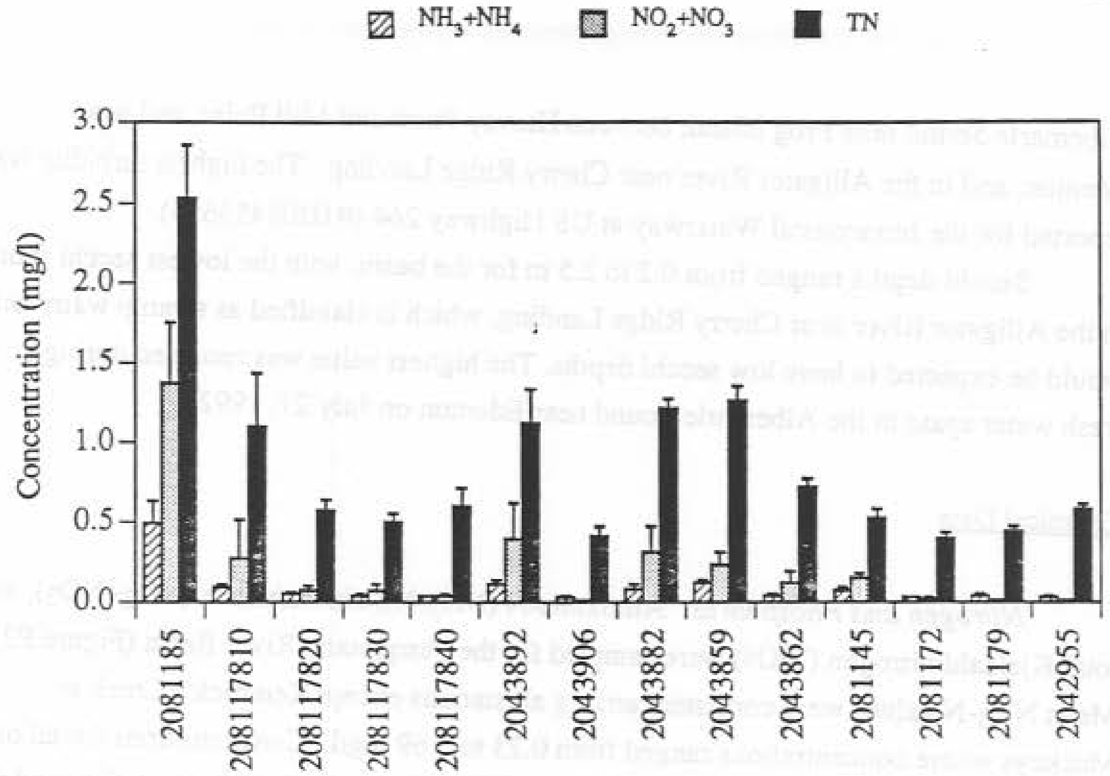

Figure P2. Mean ammonia, nitrate/nitrite and total nitrogen concentrations for the Pasquotank River basin, October 1991 - July 1992. Error bars represent + 1 standard error.

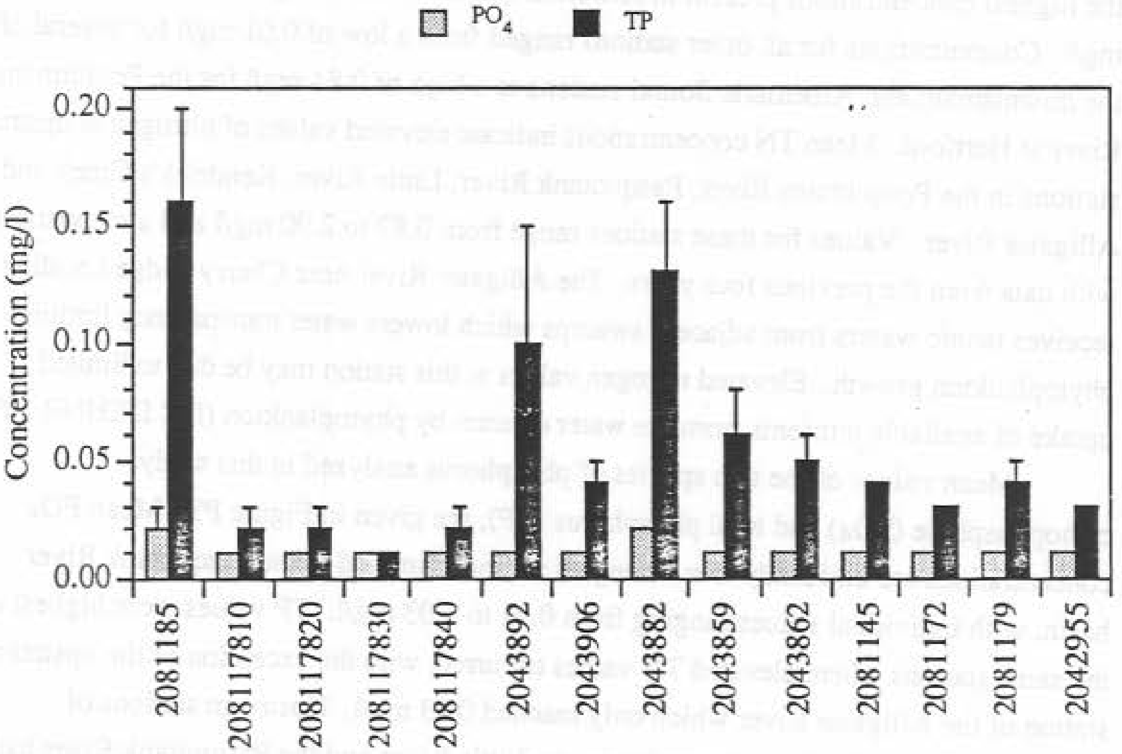

Figure P3. Mean orthophosphate and total phosphorus concentrations for the Pasquotank River basin, October 1991 - June 1992. Error bars represent + 1 standard error.

concentrations in the range of 0.04 to 0.23 mg/l. All other stations had TP concentrations between 0.01 to 0.06 mg/l.

Biological Data

Phytoplankton and Chlorophyll a. Chlorophyll *a* was measured for the stations on the Albemarle and Currituck Sounds and for the Alligator River. Concentrations ranged from 1 µg/l in the most upstream portions of the Albemarle Sound and the Alligator River to 19 µg/l in the Currituck Sound at Point Harbor (Station # 02042955). These data do not include the late summer months which have the highest potential for increased algal biomass and subsequent increased chlorophyll *a* values.

Phytoplankton biovolume and density estimates available for the Albemarle and Currituck Sounds in November 1991 and February 1992 corresponded to the reported chlorophyll *a* values for these dates. Phytoplankton data are not available for the Alligator River during the period of this study. In November 1991, phytoplankton density increased from 6,500 units/ml at the station farthest upstream in the Albemarle Sound to 55,800 units/ml at the most downstream station. Although the chlorophyll *a* values do not indicate bloom concentrations, blooms were present in terms of density both between Harvey Point and Mill Point and near Frog Island in the Albemarle Sound, and in the Currituck Sound. The dominant algal species present in bloom concentrations in November were Rhizosolenia eriensis, Lyngbya sp., Achnanthes sp., Phormidium angustissimum, and Dactylococcopsis sp. Most of these species are relatively small and are better represented in density estimates than as significant contributors to total biovolume.

February 1992 data indicate similar trends although relative densities are not as high as in November. Phytoplankton density estimates for this date range from 1,100 units/ml to 23,100 units/ml for the Albemarle Sound, and 25,100 units/ml for the Currituck Sound, with bloom concentrations present at the same stations as in November. Biovolume estimates for the same stations in February range from 900 to 3500 mm^3/m^2 which is below normal bloom concentrations. Most of the algal blooms during this time were dominated by Dictyosphaerium pulchellum, Chroomonas amphioxeia, and Achnanthes sp. The small size and high numbers of these species account for the high density/low biovolume ratio apparent above.

Fecal Coliform Bacteria. Fecal coliform bacteria counts were performed for the Perquimans River at Harvey Point, the Pasquotank River at Elizabeth City, the Albemarle Sound near Edenton and the Albemarle Sound between Harvey Point and Mill Point. No values exceeded the state standard of 200 MFFCC/100 ml, with the highest value of 20 MFFCC/100 ml found in the Pasquotank River.

Metal Data

Metal data for this study is limited to four sites within the Pasquotank River Basin: the Pasquotank River near Elizabeth City and at Elizabeth City, the Intracoastal Waterway at US Highway 264, and Kendrick's Creek at Mackeys. Concentrations of arsenic, cadmium, chromium, mercury and nickel were all below the detection level or reporting level for the entire basin. Iron and aluminum were evaluated only in the Intracoastal Waterway on October 10, 1991, where they were each above the detection level. Both were present at 410 µg/l which is below the state standard of 1000 µg/l for iron; no standard or action level has been established for aluminum.

Copper, lead and zinc were sampled at all four stations mentioned above. Copper values ranged from below detection level to 3 µg/l, lead from below detection level to 12 µg/l and zinc from below detection level to 13 µg/l. All of the reported values fall below the state standards or action levels for these metals.

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