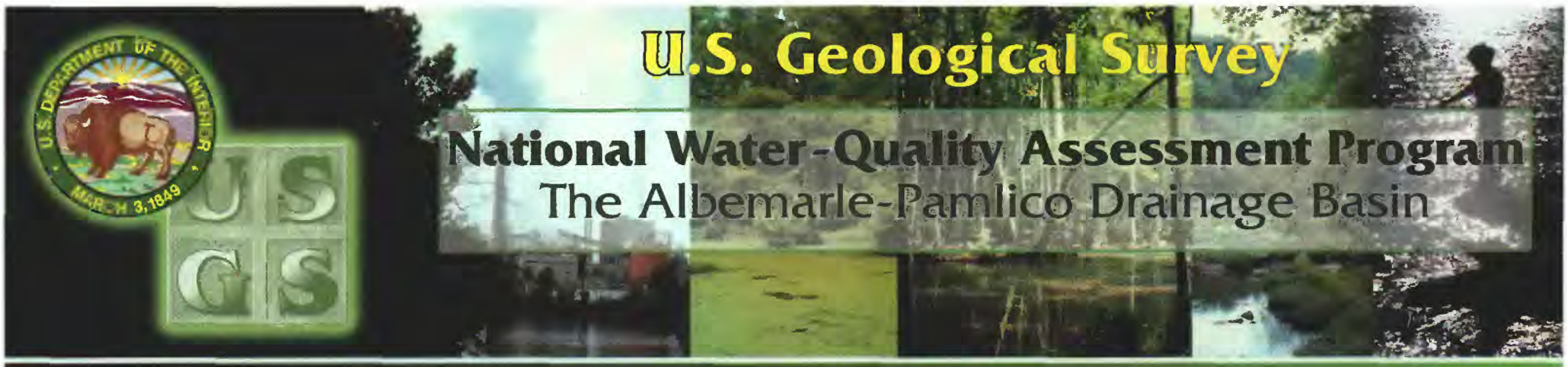

U.S. Geological Survey

National Water-Quality Assessment Program

The Albemarle-Pamlico Drainage Basin

Land Use and Nutrient Concentrations and Yields in Selected Streams in the Albemarle-Pamlico Drainage Basin, North Carolina and Virginia

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Open File Report 95-457

Introduction

Because nutrients can cause water-quality degradation, a major focus of NAWQA is to investigate effects of nutrients on surface- and ground-water quality (Spruill and others, 1995). This report summarizes surface-water quality study design and land uses in the NAWQA Albemarle-Pamlico Drainage Basin study unit, one of 60 study units nationwide, and shows how nutrient concentrations are related to land uses at selected basins in the study unit. The study area encompasses about 28,000 square miles (mi^2) in central and eastern North Carolina and southern Virginia. The major river basins in the Albemarle-Pamlico Drainage Basin are the Chowan, Roanoke, Tar, and Neuse. The barrier islands, estuaries, and the Albemarle, Pamlico, and associated sounds are not included in the study-unit area. The Albemarle-Pamlico Drainage Basin covers four physiographic provinces: Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain. About 50 percent of the land in the study area is forested, 30 percent is cropland, 15 percent is wetland, and 5 percent is developed. The population of the study unit is about 3 million people.

Fecal coliform measurement by Kelly Smith, USGS

Study Design

Seven streams in the Albemarle-Pamlico Drainage Basin study unit were selected to evaluate water quality in relation to cropland, forest land, and wetlands—Van Swamp, Albemarle Canal, Chicod Creek, Durham Creek, Devil's Cradle Creek, Pete Mitchell Swamp, and Bear Creek (fig. 1). The water-quality sampling stations in these basins are referred to as "indicator stations" because the water quality at these stations is an indicator or an example of inputs from one or two major land uses. The basin areas upstream from the indicator stations range in size from 13 to 74 mi^2. All of the indicator stations are located in the Coastal Plain Physiographic Province, except for Devil's Cradle Creek which is in the Piedmont Physiographic Province.

National Water-Quality Assessment Program (NAWQA)

National NAWQA Study units

(Shown in green, Albemarle-Pamlico study unit shown in white)

The U.S. Geological Survey's NAWQA Program is designed to assess historical, current, and future water-quality conditions in a large, representative part of the Nation's surface- and ground-water resources, and to examine the natural and human factors that affect the quality of these water resources (Leahy and others, 1990). Understanding the major factors that affect water quality at local, regional, and national levels can provide a scientific basis for water-management decisions.

Significant Findings:

- ***The highest median concentrations of dissolved nitrate were in two streams draining basins which contained more than 45-percent cropland.***
- ***The lowest median concentrations of dissolved nitrate were in two streams draining basins which contained more than 90-percent forest land.***
- ***High fecal coliform counts suggest that elevated nutrient concentrations in Chicod Creek are related to swine and poultry operations.***
- ***The highest annual yields of total nitrogen and total phosphorus were in Contentnea Creek, which contains more than 50-percent cropland.***

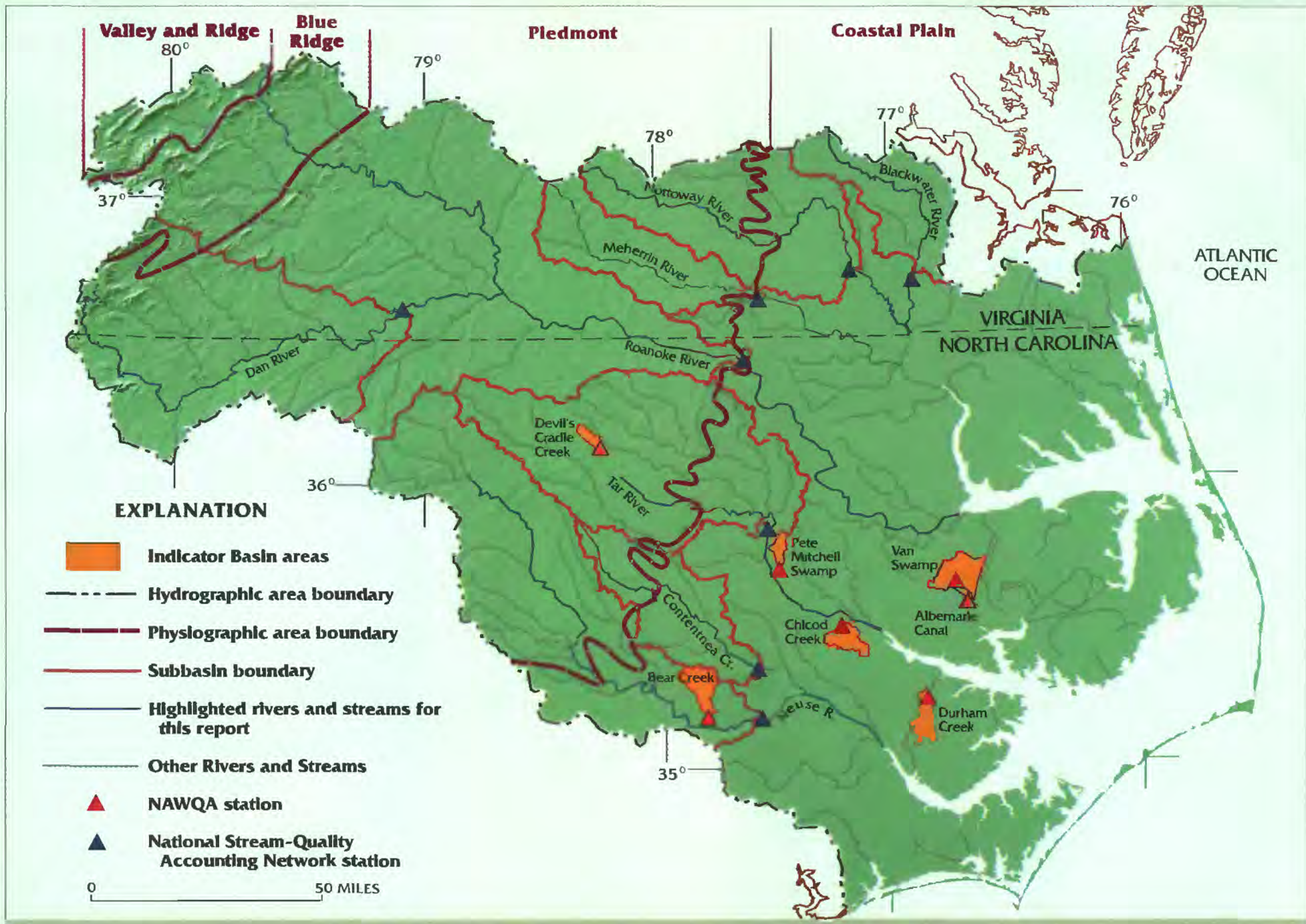


Figure 1. Location of water-quality sampling stations in the Albemarle-Pamlico Drainage Basin.

Water-quality samples were usually collected monthly at the indicator stations from March 1993 through February 1995.

The Dan, Roanoke, Meherrin, Nottoway, Blackwater, Tar, and Neuse Rivers and Contentnea Creek are the major streams in the Albemarle-Pamlico Drainage Basin (fig. 1). Stations along major streams are referred to as "integrator stations" because the water quality at these stations is an integration of discharges from wastewater-treatment plants, runoff from urban areas and cropland, atmospheric deposition, ground-water inputs, and numerous inputs from other natural and manmade sources. Water-quality samples were collected at a station near a downstream, nontidal section of most of these rivers during 1980-94 as part of the National Stream-Quality Accounting Network. No water-quality samples were collected during 1994 at the Dan and Meherrin River stations. Water-quality samples were collected as part of the Albemarle-Pamlico Drainage Basin study from March 1993 through February 1995 at the Nottoway, Blackwater, Tar, and Neuse River stations and the Contentnea Creek station. Basin areas upstream from the integrator stations in the Albemarle-Pamlico Drainage Basin study area range in size from 602 to 8,384 mi^2 and drain about 70 percent of the study unit area.

Ammonia application in the Chicod Basin.

Land Use

Geology, soils, climate, and physiography are natural characteristics that influence surface-water quality and quantity. Water quality and quantity also can be affected by human activities in a basin, thus basin land-use information can be useful for interpreting differences in streamwater quality. For instance, fertilizers applied in urban areas and on cropland can be transported into streams during periods of heavy rainfall.

Land-use data were compiled for the indicator basins from aerial photographs taken during the 1970's (fig. 2). Additional cropland data for 1994 were obtained from unpublished records from the United States Department of Agriculture. Land use listed as "other" includes open water and differences between the cropland data compiled in 1994 and during the 1970's. The largest difference in cropland data between these periods occurred in the Devil's Cradle Basin. Conversion of cropland to forest land or identification errors associated with the 1970's data are possible explanations for differences in land uses in the Devil's Cradle Basin.

The Pete Mitchell, Bear, and Albemarle Basins contain at least 45-percent cropland. In contrast, the Van and Durham Basins contain more than 90-percent forest land or forested wetland.

In 1994, estimates for poultry and swine populations in the indicator basins were obtained from county officials from the United States Department of Agriculture (table 1). The numbers of poultry in the Chicod, Bear, and Devil's Cradle Basins ranges from 225,000 to 1,410,420. There were no poultry reported in the Pete Mitchell, Albemarle, Van, or Durham Basins. The swine population in the Albemarle, Pete Mitchell, Bear, and Chicod Basins ranges from 500 to 44,300. No swine were reported in the Durham, Van, or Devil's Cradle Basins.

Nutrient Concentrations

Water-quality management programs are generally designed to control nutrient inputs to surface waters. Nitrogen, in the form of nitrate and ammonia, and phosphorus in the dissolved form are usually the primary nutrients that control plant growth in most surface waters. When present in excessive amounts, these nutrients can promote nuisance growths or "blooms" of algae, which can shade out desirable aquatic vegetation or cause fish kills. An understanding of the sources and transport of nutrients in surface water can facilitate the design of basin water-quality management programs.

Figure 2. Major land uses in indicator basins.

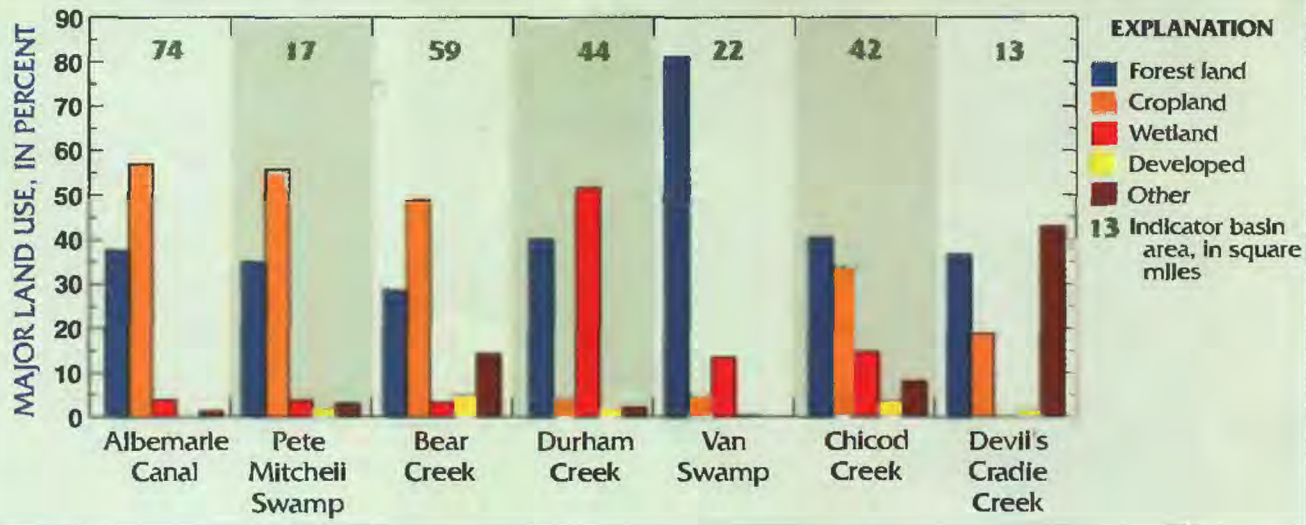
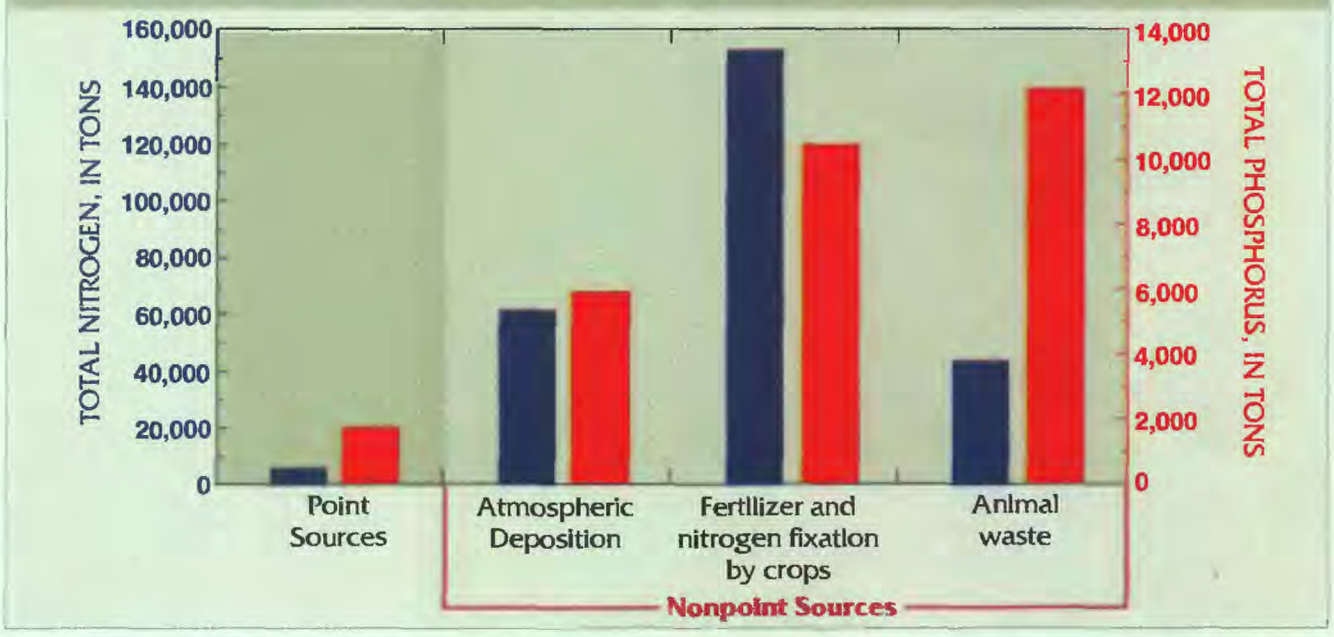


Table 1. Animal populations in indicator basins, 1994.

Indicator Basin	Cattle	Poultry	Swine
Albemarle Canal	200	0	500
Pete Mitchell Swamp	70	0	850
Bear Creek	115	1,410,420	25,380
Durham Creek	0	0	0
Van Swamp	0	0	0
Chicod Creek	200	470,400	44,300
Devil's Cradle Creek	0	225,000	0

Figure 3. Estimated total nitrogen and total phoshorus inputs.

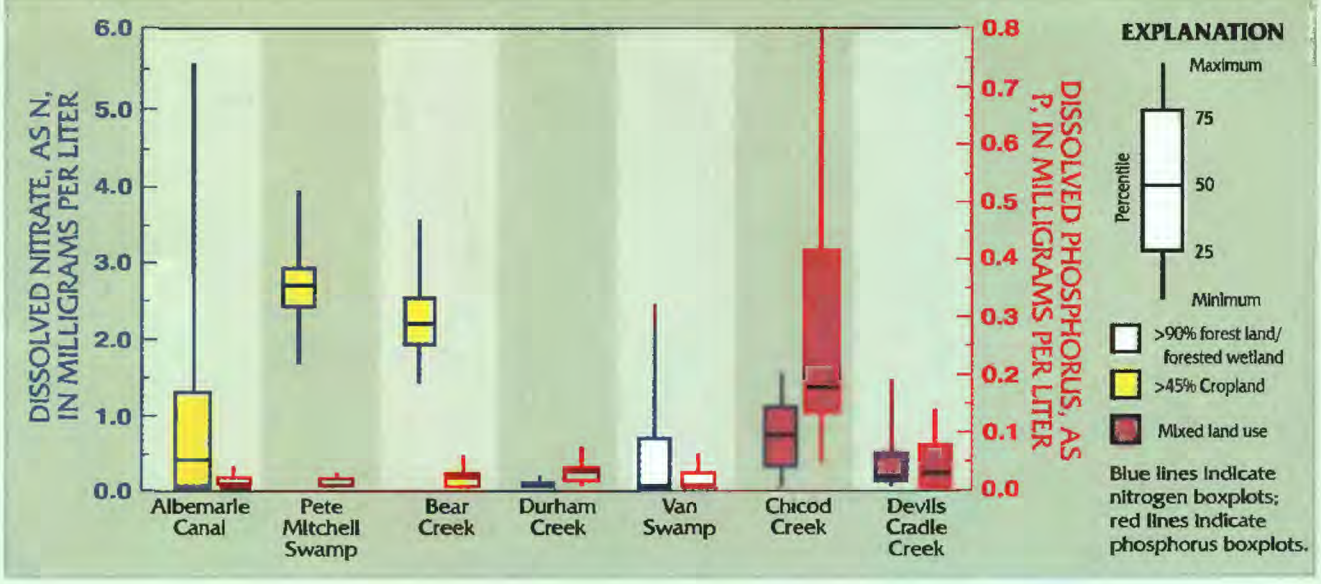


Permitted point sources and nonpoint sources contribute to the total amount of nutrients that are generated in the Albemarle-Pamlico Drainage Basin (fig. 3). Permitted point sources include discharges from wastewater-treatment plants and industrial processes. Atmospheric deposition, fertilizer applications, and animal wastes are examples of nonpoint nutrient sources. McMahon and Lloyd (1995) used permitted point source data, atmospheric nutrient data, fertilizer data from 1990, and animal data from 1987 to estimate the amount of nitrogen and phosphorus generated in the Albemarle-Pamlico Drainage Basin. Permitted point sources contributed an estimated 2 percent of the total nitrogen and 6 percent of the total phosphorus input to the basin. Atmospheric sources contributed 23 percent of the total nitrogen and 20 percent of the total phosphorus. Animal wastes produced 17 percent of the total nitrogen and 40 percent of the total phosphorus. Fertilizers and biologically fixed nitrogen from soybeans and peanuts accounted for 58 percent of the total nitrogen and 34 percent of the total phosphorus. Not all of these nutrients are transported to surface waters in the Albemarle-Pamlico Drainage Basin. Natural processes such as nutrient uptake by crops, bacterial denitrification, and sedimentation transform or reduce the amounts of these nutrients.

Basin land-use characteristics were used to describe differences in streamwater quality among indicator stations because there are generally one or two major land uses in indicator basins. Median concentrations of nitrate were less than 0.05 milligrams per liter (mg/L) at the Durham Creek and Van Swamp indicator stations, which contain greater than 90-percent forest land/forested wetland (fig.4). Pete Mitchell and Bear Basins contain greater than 45-percent cropland and have the highest median concentrations of nitrate as nitrogen (2.7 and 2.2 mg/L, respectively) among the indicator basins. Although the Albemarle Basin contains greater than 45-percent cropland, the median concentration of nitrate was lower than at the Pete Mitchell Swamp and Bear Creek stations; however, nitrate concentrations among the indicator stations varied the most at the Albemarle Canal station, ranging from less than 0.05 to 5.6 mg/L. Low nitrate concentrations at the Albemarle Canal station may be related to flow patterns in the canal. Wind-blown tides often retard flow in the canal and its feeder ditches, causing the water to become stagnant and anoxic. These conditions promote the bacterial conversion of nitrate into gaseous forms of nitrogen.

Among the indicator stations, the Chicod Creek station has the highest median concentration of dissolved phosphorus (0.18 mg/L) (fig. 4). The Chicod Creek Basin also contains the largest population of swine among the indicator basins. A maximum fecal coliform count of 22,000 colonies per 100 milliliters, and a maximum concentration of ammonia nitrogen of 23 mg/L indicate that animal wastes affected the water quality at the Chicod Creek station during the study period. The median concentrations of total phosphorus at the other indicator stations were less than 0.04 mg/L.

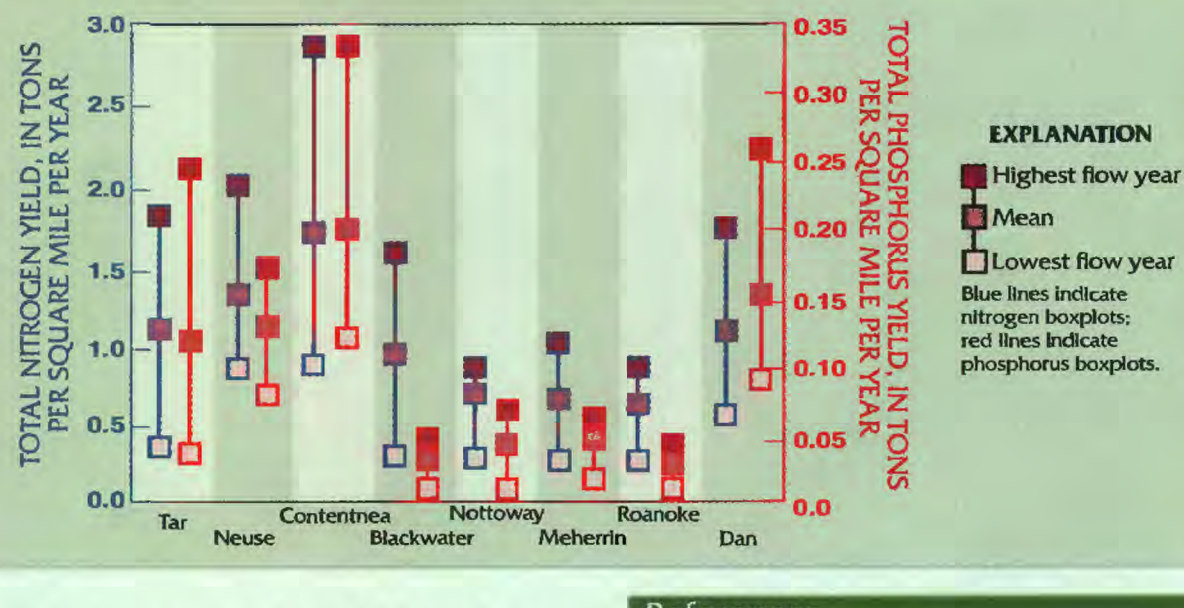
Figure 4. Dissolved nitrate and dissolved phoshorus at indicator stations.



Nutrient Yields

Nutrient yields for river basins are often estimated to evaluate the effectiveness of water-quality management programs. A comparison of nutrient yields among river basins can be useful to water-resource managers in prioritizing basins for water-quality improvement measures. The discussion of nutrient yields is primarily limited to basin comparisons because all the integrator stations, except Contentnea Creek which contains 50-percent cropland, contain similar land-use patterns (McMahon and Lloyd, 1995).

Figure 5. Total nitrogen and total phoshorus yields at integrator stations, 1980-94.



Annual yields of total nitrogen and total phosphorus were estimated at integrator basins for 1980-94, except for the Dan and Meherrin Basins where nutrient yields were estimated for 1980-93 (fig. 5). Yields were not estimated at indicator stations because of insufficient streamflow data.

The lowest yields of total nitrogen were from the Nottoway, Meherrin, and Roanoke Basins. These total nitrogen yields were also the least variable. The mean annual yields of total nitrogen were highest in the Contentnea and Neuse Basins.

Yields of total phosphorus were lowest in the Blackwater, Nottoway, Meherrin, and Roanoke Basins and highest in the Tar, Neuse, Contentnea, and Dan Basins. Yields of total phosphorus are small in the Blackwater Basin because phosphorus bound to sediment particles is deposited in the broad floodplains adjacent to the Blackwater River. Sedimentation in three large reservoirs upstream from the Roanoke River station reduces downstream total phosphorus yields. The yields of total nitrogen and total phosphorus are higher at the Dan River station which is located upstream from these reservoirs.

From 1980 through 1994, the Contentnea Basin had the highest mean annual yields of total nitrogen and total phosphorus. This basin also had the highest yields of total nitrogen and total phosphorus during the lowest and highest annual mean streamflow years recorded from 1980 through 1994. In 1990, permitted point-source discharges accounted for less than 13 percent (150 tons) of the total nitrogen load transported at the Contentnea Creek station. The remaining 87 percent (1,020 tons) of the total nitrogen load was related to nonpoint sources, such as atmospheric deposition and runoff from cropland and urban areas. The Contentnea Basin also had the highest estimated yields of total nitrogen and total phosphorus from fertilizer applications and animal wastes.

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