Water Quality in the Albemarle-Pamlico Drainage Basin

North Carolina and Virginia, 1992–95

U.S. Department of the Interior
U.S. Geological Survey

Circular 1157

A COORDINATED EFFORT

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Information on the NAWQA Program is also available on the Internet via the World Wide Web.
Albemarle-Pamlico Drainage Study Unit's Home Page: http://sgi1dncrlg.er.usgs.gov/albe-html/ALBEpage.html
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Cover photograph: Neuse River at Cliffs of the Neuse State Park, North Carolina, during floodflow in 1996. Photographs in this report and on the front and back covers were taken by Douglas A. Harned, U.S. Geological Survey.

Water Quality in the Albemarle-Pamlico Drainage Basin, North Carolina and Virginia, 1992–95

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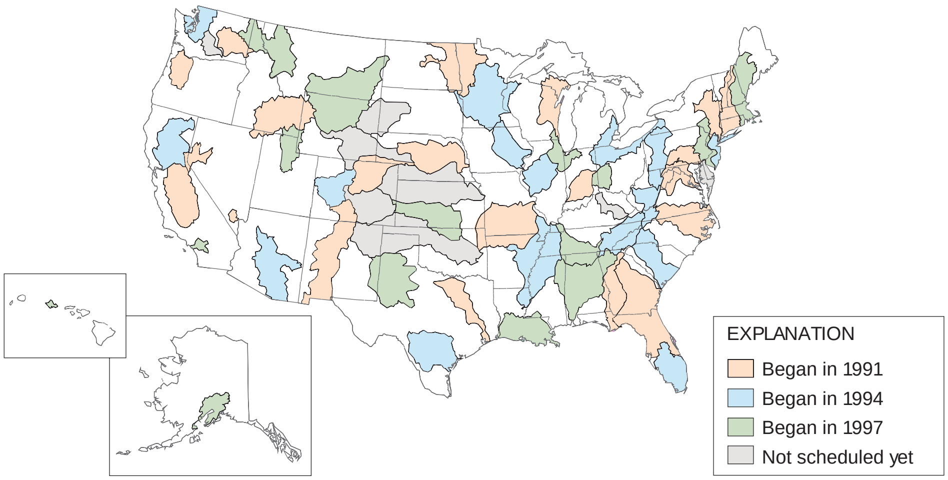
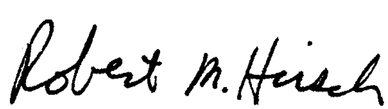


Knowledge of the quality of the Nation's streams and aquifers is important because of the implications to human and aquatic health and because of the significant costs associated with decisions involving land and water management, conservation, and regulation. In 1991, the U.S. Congress appropriated funds for the U.S. Geological Survey (USGS) to begin the National Water-Quality Assessment (NAWQA) Program to help meet the continuing need for sound, scientific information on the areal extent of the water-quality problems, how these problems are changing with time, and an understanding of the effects of human actions and natural factors on water quality conditions.

The NAWQA Program is assessing the water-quality conditions of more than 50 of the Nation's largest river basins and aquifers, known as Study Units. Collectively, these Study Units cover about one-half of the United States and include sources of drinking water used by about 70 percent of the U.S. population. Comprehensive assessments of about one-third of the Study Units are ongoing at a given time. Each Study Unit is scheduled to be revisited every decade to evaluate changes in water-quality conditions. NAWQA assessments rely heavily on existing information collected by the USGS and many other agencies as well as the use of nationally consistent study designs and methods of sampling and analysis. Such consistency simultaneously provides information about the status and trends in water-quality conditions in a particular stream or aquifer and, more importantly, provides the basis to make comparisons among watersheds and improve our understanding of the factors that affect water-quality conditions regionally and nationally.

This report is intended to summarize major findings that emerged between 1992 and 1995 from the water-quality assessment of the Albemarle-Pamlico Drainage Study Unit and to relate these findings to water-quality issues of regional and national concern. The information is primarily intended for those who are involved in water-resource management. Indeed, this report addresses many of the concerns raised by regulators, water-utility managers, industry representatives, and other scientists, engineers, public officials, and members of stakeholder groups who provided advice and input to the USGS during this NAWQA Study-Unit investigation. Yet, the information contained here may also interest those who simply wish to know more about the quality of water in the rivers and aquifers in the area where they live.



Robert M. Hirsch, Chief Hydrologist

NUTRIENTS IN STREAMS

- Of four river basins studied in the Albemarle-Pamlico Drainage Basin—the Chowan, Roanoke, Tar, and Neuse—highest nitrogen and phosphorus yields occurred in the highly agricultural and urbanized Neuse Basin; lowest nutrient yields occurred in streams of the forested Chowan Basin (p. 7).

- Suspended-sediment, suspended-solids, and dissolved-solids concentrations have decreased throughout the Albemarle-Pamlico drainage system from 1980 to 1995. Decreasing concentrations of suspended solids in the sounds and estuaries may result in clearer water and deeper light penetration which, in turn, enhance conditions for algal blooms in nutrient-enriched areas. As a result, reduction of nutrients will be even more important in controlling eutrophication (p. 15).

- A 50-percent reduction of summertime nitrogen and phosphorus concentrations in the Neuse River and a 30-percent reduction of these same constituents in the Tar River and Contentnea Creek would be required to attain literature-based guidelines to reduce the incidence of nuisance algal blooms and fishkills (p. 14).

- Permitted point sources of nitrogen and phosphorus from municipal wastewater-treatment plants and industry account for less than 6 percent of the nitrogen source inputs and 16 percent of the phosphorus source inputs in all basins. However, nutrients from these point sources go directly into streams and may constitute more than 40 percent of the instream nutrient load (p. 6).

- Based on synoptic data collected in 1995, ground water contributes significantly to instream phosphorus loads of the Neuse River, Contentnea Creek, and other streams. Natural deposits of phosphate occur in Miocene and Cretaceous sediments of the Albemarle-Pamlico Drainage Basin and produce high concentrations (median = 0.2 milligram per liter [mg/L]) of phosphorus in ground water. Because of natural geologic sources, control of phosphorus concentrations in streams in these basins may be difficult for water managers (p. 12–14).

- Phosphorus and nitrogen concentrations in streams generally have declined since 1980 in all four basins. This decrease is probably the result of improved agricultural practices, a phosphate detergent ban in North Carolina and Virginia in 1988, and enhanced wastewater-treatment practices. However, phosphorus and nitrogen concentrations are still high enough in the Tar and Neuse River Basins to cause nuisance algal growths (p. 15).

NUTRIENTS IN GROUND WATER

- Water in about 4 percent of 49 shallow monitoring wells randomly placed in agricultural areas of the Coastal Plain exceeded the 10 mg/L drinking-water standard for nitrate (U.S. Environmental Protection Agency, 1986). Nitrate-nitrogen concentrations in shallow ground water of the inner Coastal Plain are significantly higher than nitrate-nitrogen concentrations in the outer Coastal Plain (p. 8).

- Highest nitrate concentrations in shallow ground water are in well-drained, sandy soils in combination with intensive agricultural activity, such as crop or livestock production. Residents in Coastal Plain areas having high nitrate can avoid water with high nitrate concentrations by using water from deeper aquifers. Nitrate concentrations in shallow ground water can be decreased by limiting fertilizer and manure applications on crops in these areas (p. 14).

PESTICIDES

- Of 47 pesticides analyzed in stream samples, 45 were detected. Metolachlor, atrazine, alachlor, and prometon were the most commonly detected pesticides in streams. Highest incidence of pesticide detections occurred in the Tar River Basin (p. 16).

- During the 1993–95 pesticide sampling period, concentrations of atrazine, alachlor, metolachlor, and prometon in streams increased in late May and early June and decreased gradually through August until applications increased the following spring. Drinking-water standards for pesticides are most likely to be violated during May through July (p. 16–17).

- Of 47 pesticides analyzed in shallow ground-water samples, 14 were detected. Atrazine, deethylatrazine, and metalachlor were the most commonly detected pesticides. Concentrations in ground water generally were less than 0.1 mg/L and never exceeded drinking-water guidelines (U.S. Environmental Protection Agency, 1986). Breakdown products from atrazine were detected, but no drinking-water standards currently are established for these chemicals (p. 16).

OTHER ORGANIC COMPOUNDS AND TRACE ELEMENTS

- Despite the 1972 ban against the use of the organochlorine pesticide DDT in the United States, the pesticide and its metabolites DDD and DDE persist in the environment. In an examination of data from 1969 to 1990, all sites sampled for bed sediment in the Tar River Basin for DDD, DDE, and DDT had concentrations greater than the effects range established by the National Oceanic and Atmospheric Administration (Long and Morgan, 1991) as being associated with adverse biological effects on some benthic invertebrates (p. 18).

- DDD, DDE, DDT, dieldrin, *trans*-nonalachlor, polychlorinated biphenyls (PCBs), and toxaphene were detected in Asiatic clam or redbreast sunfish collected at 11 of 19 sites during 1992–93. DDE was the most common and widespread organochlorine compound detected. Except for one detection of toxaphene, pesticide concentrations were well below guidelines for the protection of fish-eating wildlife (p. 18–19).

- All 10 of the U.S. Environmental Protection Agency trace-element priority pollutants were detected in either Asiatic clam or redbreast sunfish in relatively low concentrations. Mercury concentrations were highest in heavily stained blackwater streams (p. 19).

- Mercury was widely detected, being present in 29 of 30 tissue samples, but concentrations did not exceed the Federal Food and Drug Administration (FDA) action limit (Nowell and Resek, 1994) or a risk-based screening value for the general public (Cunningham and others, 1992) (p. 19).

FISH COMMUNITIES

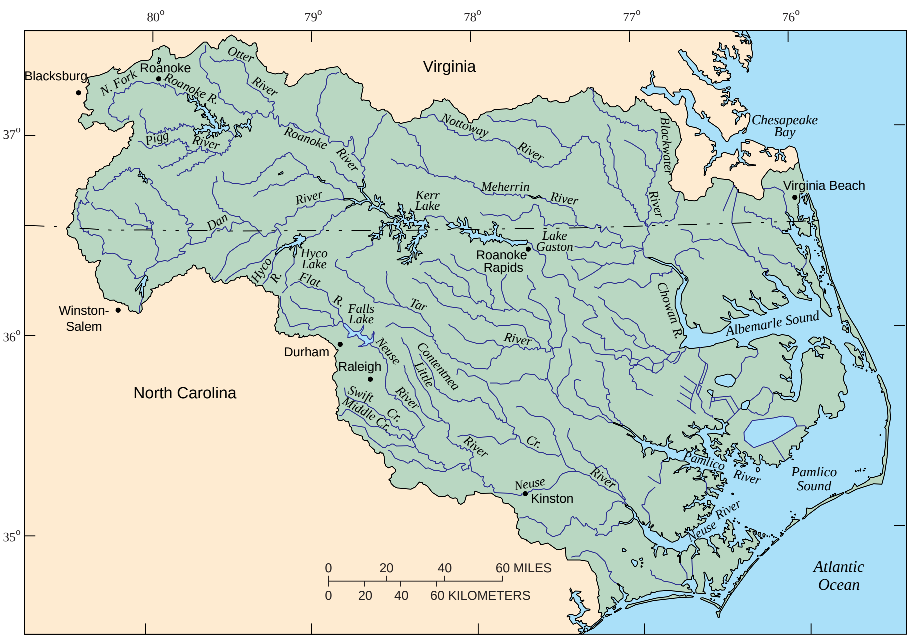
- Differences in the numbers and kinds of fish in small Coastal Plain streams were strongly related to basinwide habitat characteristics, such as soil drainage, proportion of adjacent areas of forested wetlands to streams, amount of row-crop agriculture, and channelization. Differences in fish communities were more weakly related to site-specific habitat variables, such as the amount of instream woody cover. These results indicate that mitigation and restoration strategies, which are of local focus but neglect basinwide conditions, may not be fully successful (p. 21).

- Channelized streams in agricultural areas with well-drained soils tended to have the greater numbers of fish species associated with flowing water environments than with ponded environments (p. 21).

- Agricultural land use, channelization, and destruction of floodplain buffer zones affect fish communities by altering flow regimes, decreasing the amount of organic material entering the stream, increasing nutrient concentrations, and raising pH. Fish community composition responds to these changes by shifting toward species that prefer flowing, well-oxygenated water that is moderately to weakly acidic (p. 21).

Albemarle Sound, North Carolina

The Albemarle-Pamlico Drainage Basin, located in North Carolina and Virginia, drains an area of about 28,000 square miles (mi^2) (fig. 1). Four physiographic regions—the Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain Provinces—are included within the Albemarle-Pamlico Drainage area. For this study, the Coastal Plain was further divided into the inner Coastal Plain and the outer Coastal Plain (Harned and others, 1995).



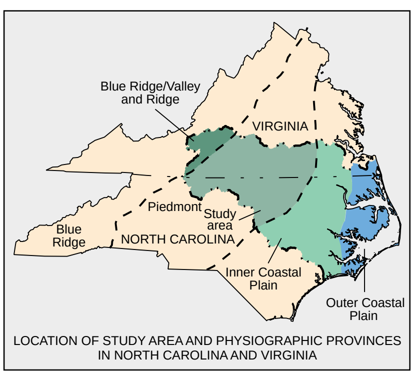


Figure 1. Four major rivers—the Chowan, Roanoke, Tar, and Neuse—drain into the Albemarle and Pamlico Sounds in North Carolina.

the mountains where slopes are steep, surface water and shallow ground water move fast and have less opportunity to dissolve rock and soil or undergo other geochemical processes, such as ion exchange or adsorption; consequently, the water generally contains very little dissolved mineral matter. In the Piedmont and Coastal Plain, slopes are gentler and water moves more slowly; consequently, surface water there generally has two to three times the mineral content of surface and ground waters in the mountains. Different rock types and the associated soils also influence the nature and amount of minerals dissolved in the waters.

Land use, population distribution, and manmade reservoirs have significant effects on water quality in the study area. In general, the study area is dominated by a patchwork of forested (50 percent of the area) and agricultural (more than 30 percent) lands, with large tracts of wetlands (about 15 percent) in the eastern Coastal Plain (fig. 2). Less than 5 percent of the overall basin area contains urban land. The principal agriculture in the basin includes corn, soybean, cotton, peanut, tobacco, grain, and potato cultivation and chicken, turkey, hog, and cattle production. Agricultural and urban land uses have the greatest potential to affect water quality because these land uses are the sources of large amounts of nutrients, sediments, and pesticides.

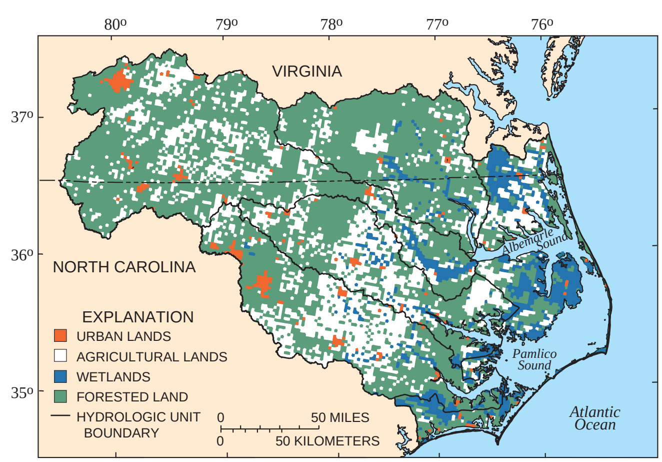


Figure 2. Forested and agricultural lands dominate the study area with extensive wetlands in the eastern part.

Water quality in the Albemarle-Pamlico Drainage area is affected by natural and cultural factors. Major factors include physiography, soils, geology, precipitation, and land use and are similar within each physiographic province.

The physiography, geology, and soils form the container over and through which surface and ground water flow. In

Average annual precipitation ranges from 36 inches in the western part of the Albemarle-Pamlico Drainage Basin to 52 inches in the eastern part of the basin (McMahon and Lloyd, 1995). This water leaves the basin by way of streams and ground water.

In general, more than one-half of the water flowing in streams discharging to the Albemarle-Pamlico Drainage Basin comes from ground water. Thus, the quality of ground water has substantial influence on surface-water quality. Major aquifers in the Valley and Ridge, Blue Ridge, and Piedmont Provinces are fractured rocks overlain by unconsolidated regolith; in the Coastal Plain Province, aquifers are primarily unconsolidated and partly consolidated sands with some limestone and sandy limestone.

Streamflow in the Roanoke River at Roanoke Rapids, N.C., was higher during the study period, 1992–95, than during the long-term period of record (1930–95) (fig. 3). Higher streamflows tend to exacerbate nonpoint surface-runoff pollution and dilute point-source pollution. Except during March, streamflow in the Neuse River at Kinston, N.C., was slightly lower during the study period than during the long-term period of record (1930–95) (fig. 3). Lower streamflows tend to exacerbate point-source pollution and diminish nonpoint surface-runoff pollution.

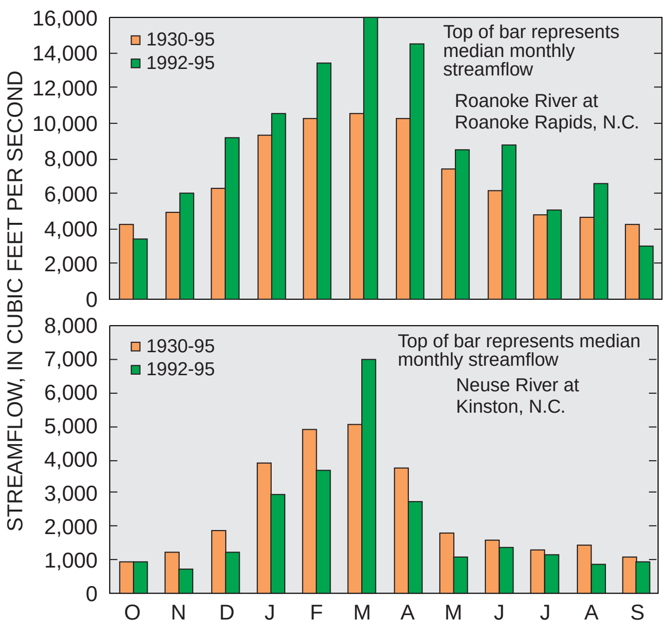


Figure 3. Streamflow was higher in the Roanoke River during the study period than during the long-term period of record, and except during March, streamflow was slightly lower in the Neuse River during the study period than during the long-term period of record.

Average water use during 1990 in the Albemarle-Pamlico Drainage Basin was about 2,800 million gallons per day (Mgal/d) (McMahon and Lloyd, 1995). Most of this water is from surface water (90 percent) with the remaining 10 percent supplied from ground water (fig. 4). About 3 million people live in the basin, and 11 percent of all water used is for public or domestic drinking water. Two-thirds of this population obtains water from public water-supply sources, most of which (75 percent) is from surface water; the remaining one-third of the population uses ground water supplied by private domestic wells (fig. 4).

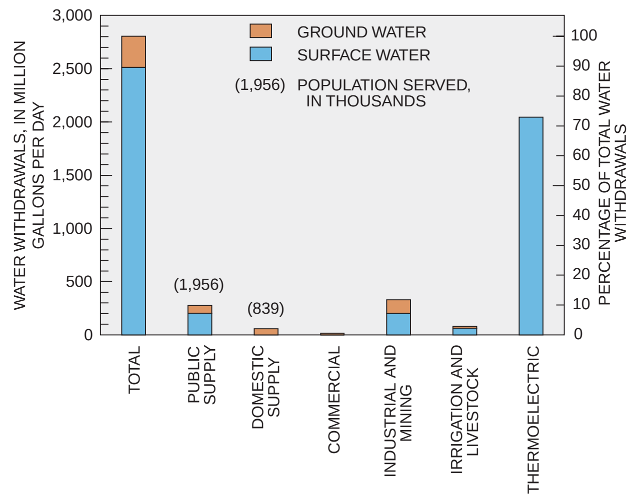


Figure 4. Surface water is used most in the study area, and the generation of thermoelectric power uses the most water.

Canoeing in Contentnea Creek, North Carolina

Major sources of nutrients in the Albemarle-Pamlico Drainage Basin are fertilizer, livestock, precipitation, and point sources.

Streams draining a basin can become contaminated from nonpoint (dispersed, both human and natural sources) and point (concentrated, such as discharge from a pipe into a river or stream) sources of nutrients. Nonpoint sources of nutrients derived from fertilizers, animal wastes, or septic fields are probably the main sources of ground-water contamination. Geologic deposits can be important nonpoint nutrient sources in some areas. Precipitation also can be a major nonpoint source of nitrogen (fig. 5). Point sources compose 6 percent or less of all nitrogen inputs and 16 percent of all phosphorus inputs.

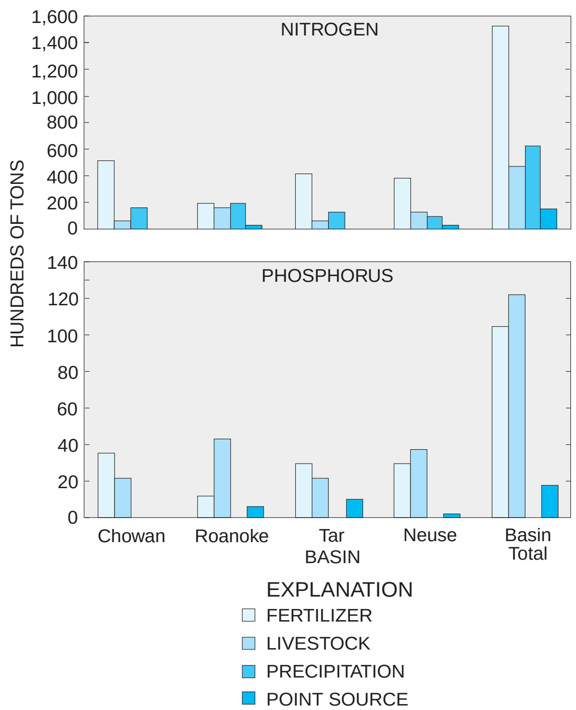


Figure 5. The major sources of nitrogen inputs to the Albemarle-Pamlico Drainage Basin, in order of importance, are fertilizer, precipitation, livestock, and point-source discharges to streams; and major sources of phosphorus inputs are livestock, fertilizer, and point sources (McMahon and Lloyd, 1995).

The Chowan River Basin had the highest nitrogen input, primarily due to fertilizer; the Neuse River Basin had the highest phosphorus input, primarily due to livestock.

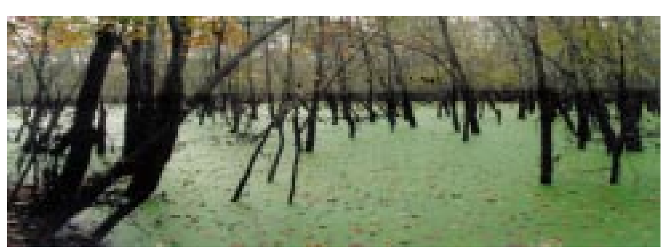
The nutrient inputs into each of the major basins can be an indication of potential stresses on water quality. The Chowan Basin received the largest inputs of nitrogen in 1990 (McMahon and Lloyd, 1995). The Roanoke Basin received the smallest inputs of nitrogen.

NUTRIENTS AND ALGAE—A POTENTIAL PROBLEM

Nutrients are elements that are necessary for the growth and nutrition of plants and animals. Nitrogen and phosphorus typically are the principal elements that limit the growth of algae. Algal cells have a nitrogen-to-phosphorus ratio of about 7 to 1; therefore, when the ratio of nitrogen to phosphorus in water is 7 to 1 or greater, growth can increase significantly. When a limiting nutrient becomes abundant, algal populations are stimulated to grow rapidly to extreme numbers until they die off. The organic load then causes fishkills, human health problems, and esthetic deterioration of the water body. The Albemarle-Pamlico estuaries are seasonally nitrogen limited. Unlike most freshwater riverine systems, the lower portions of the Tar-Pamlico and the Neuse Rivers were also nitrogen limited (Harned and Davenport, 1990), implying an unusually high source of phosphorus in these basins.

In the Neuse River, excess nitrogen is considered to be such a problem that the State of North Carolina has considered a 30-percent reduction in nitrogen loads to the river over the next 5 years, beginning in 1997 (North Carolina Division of Water Quality, written commun., 1996).

Nitrate and ammonia are the forms of nitrogen that are most important in controlling algal growth because they are available for uptake by plants. Nitrogen in either of these forms is a potential problem in regard to water quality in the estuaries because excess amounts are associated with algal blooms, fishkills, and toxicity to rooted aquatic plants.



Wetlands in the Neuse River Basin, North Carolina

Fertilizers provided more than 60 percent of the nitrogen inputs in the Chowan, Tar-Pamlico, and Neuse Basins. The main sources of nitrogen in the Roanoke Basin were precipitation and fertilizer. Precipitation provided about 20 to 30 percent of the total nitrogen inputs in all four basins. Permitted point-source inputs of nitrogen, however, were less than 6 percent in all four basins.

Phosphorus input was highest in the Neuse Basin and lowest in the Chowan Basin. Livestock contributed the greatest input of phosphorus in the Roanoke and Neuse Basins. Fertilizer was the major source of phosphorus in the Chowan and Tar-Pamlico Basins and the second highest source of phosphorus in the Roanoke and Neuse Basins. Permitted point sources were significant contributors in the Roanoke, Tar-Pamlico, and Neuse Basins, but were less than 0.5 percent of the contributors in the Chowan. Other potential nonpoint sources, such as natural geologic deposits (discussed in this report for phosphorus, p. 12), can be significant, although estimates have not been included here.

Forested portions of the Chowan Basin had the lowest nutrient yields per square mile; agricultural basins of the Neuse and upper Roanoke Rivers had the highest nutrient yields.

Not all of the nutrients that enter a basin actually enter the streams draining the watershed. The mass of nutrients that leave a watershed in streamflow over a period of time is termed “load.” The load per square mile (usually tons per square mile) is termed “yield.” In the Albemarle-Pamlico Drainage Basin, McMahon and Woodside (1997) reported that as much as 50 percent of nutrients are retained in the watershed. This is because nutrients may be tied up in nonmobile forms in soils or undergo chemical transformation. However, in general, urban and agricultural land uses would be expected to yield more nutrients and other chemicals to streams compared to other, less chemical-intensive, land uses. In the Albemarle-Pamlico Drainage area, forested basins in the Chowan Basin had the lowest nutrient yields, whereas the more urban and agricultural basins—Contentnea Creek, the Neuse River, and the Tar River in the Coastal Plain and the Dan River in the Piedmont—all had the highest yields (fig. 6).

Typical concentrations of nutrients in streams and ground water of the Albemarle-Pamlico Drainage Basin generally do not exceed drinking-water or aquatic-life standards, although concentrations are among the highest measured in 20 NAWQA Study Units.

The median concentration of nitrate as nitrogen was about 0.5 mg/L for 76 surface-water sites and 0.05 mg/L for 49 ground-water sites sampled in the Albemarle-Pamlico Drainage Basin. These median nitrate concentrations in ground and surface water are well under the U.S

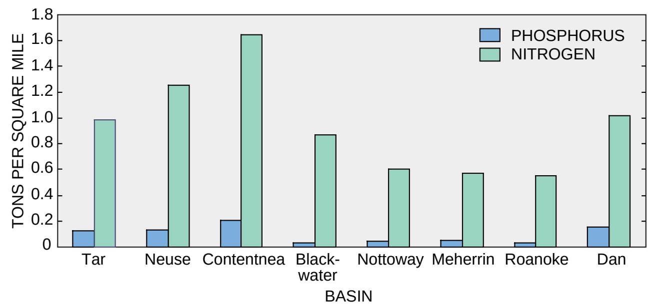


Figure 6. Highest yields of nutrients occurred in Contentnea Creek and in the Neuse, Tar, and Dan Rivers. These basins have less than 50 percent forested land and more than 35 percent agricultural land. Lowest yields were in forested areas (greater than 55 percent forest land) of the Roanoke and Chowan Basins (Blackwater, Nottoway, and Meherrin Rivers). (Data from Harned and others, 1995.)

Environmental Protection Agency (USEPA) drinking-water standard of 10 mg/L as nitrogen. Throughout the entire Coastal Plain, only about 4 percent of wells sampled had nitrate-nitrogen concentrations greater than the 10-mg/L drinking-water standard. Median ammonia concentrations in surface water were 0.06 mg/L, also less than USEPA aquatic-life standards; median ammonia concentrations in ground water were 0.13 mg/L. The median dissolved phosphorus concentration in surface water was about 0.07 mg/L and less than 0.04 mg/L in shallow ground water. Based on pre-1980 data, deep ground water in the Coastal Plain had a median dissolved phosphorus concentration of about 0.2 mg/L (Harned and others, 1995). No phosphorus standards exist for human health; however, concentrations of dissolved phosphorus above 0.05 mg/L in lakes or in streams flowing into lakes and 0.1 mg/L in streams can cause nuisance algal growths (National Technical Advisory Committee, 1968; Mackenthum, 1969).

Compared with results from 19 other NAWQA Study Units, streams in the southern portion of the Albemarle-Pamlico Drainage Basin have nutrient concentrations ranked among the highest 25 percent of nutrient concentrations measured (p. 22). Nutrient concentrations in shallow ground water were among the lowest nationally (p. 24).

Concentrations of nutrients are higher in agricultural and urban streams of the Albemarle-Pamlico Drainage Basin.

In a review of 1980–90 data, Harned and others (1995) examined total nitrogen, total ammonia plus organic nitrogen, total nitrite plus nitrate, and total ammonia basinwide. Total nitrogen concentrations at most of the larger stream sites generally are greater than 0.3 mg/L—the level cited by Vollenweider (1971) for potential nuisance algal growth. Contentnea Creek has the highest total nitrogen concentrations, followed by the Neuse, Tar, Dan, and Blackwater Rivers, the other Chowan tributaries, and the

Roanoke River. This ranking reflects the relative intensity of both urban and agricultural development in these basins. In general, the most urban basins and those with the most intensive agriculture have the highest nitrogen values. However, the Roanoke River has low total nitrogen concentrations because of upstream sedimentation and assimilation of nitrogen in algal biomass in Kerr and Gaston Lakes (fig. 1).

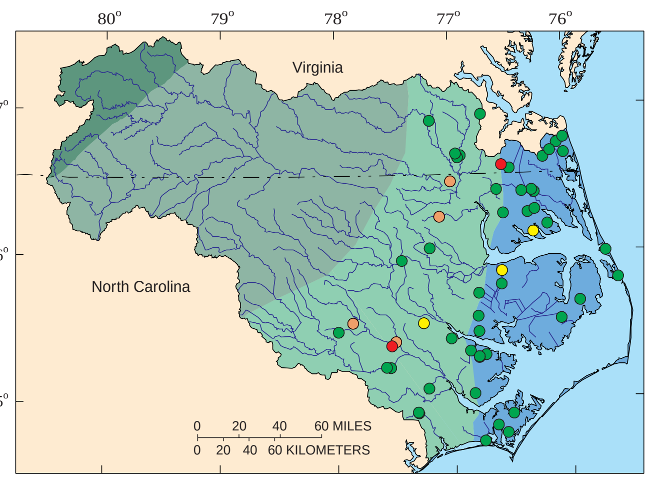
Total phosphorus concentrations are relatively uniform in the Dan River, increase downstream in the Tar River, and peak in the Neuse River near Smithfield in a manner similar to the pattern observed for nitrogen. A ranking of phosphorus concentrations in surface water (Harned and others, 1995) showed that basins with the most urban development and intensive agriculture had the highest phosphorus concentrations. Phosphorus concentrations were frequently above 0.1 mg/L in most streams, providing an ample supply of the nutrient for algal growth. Concentrations of phosphorus less than 0.1 mg/L at Roanoke Rapids are probably a result of settling of phosphorus in the sediments of Kerr and Gaston Lakes and assimilation of soluble phosphorus by algae. Concentrations of phosphorus in the Neuse River Basin are the highest values of any in the Albemarle-Pamlico Drainage Basin.

Nitrate concentrations in ground water exceed drinking-water standards in 4 percent of wells.

Nitrogen usually occurs as nitrate in oxygenated surface water or oxygenated shallow ground water. Excessive nitrate in drinking water can cause blue-baby syndrome and is associated with the occurrence of certain cancers (non-Hodgkins lymphoma) in humans (Spruill and others, 1996). About 4 percent of wells sampled throughout the Coastal Plain produced water with nitrate concentrations that exceeded the 10-mg/L drinking-water standard. The highest concentrations of nitrate in shallow ground water are associated with well-drained soils of the inner Coastal Plain in the Albemarle-Pamlico Drainage Basin (fig. 7). However, the highest nitrate-nitrogen concentration measured was 11 mg/L in an outer Coastal Plain sample. Low nitrate concentrations in shallow ground water of the outer Coastal Plain are due to denitrification or nitrate-reduction processes resulting from the large amounts of organic carbon in these poorly drained soils and sediments (Spruill and others, 1996).

Summary statistics for nitrate-nitrogen concentrations in milligrams per liter.

STATISTIC	ENTIRE STUDY UNIT	INNER COASTAL PLAIN	OUTER COASTAL PLAIN
Number of wells	49	19	30
Minimum	0.05	0.05	0.05
Median	0.05	0.38	0.05
Maximum	11	10	11
Percent >10 mg/L	4%	5%	3%



EXPLANATION

MEDIAN CONCENTRATION OF DISSOLVED NITRATE, IN MILLIGRAMS PER LITER

- GREATER THAN OR EQUAL TO 10
- GREATER THAN OR EQUAL TO 3 AND LESS THAN 10
- GREATER THAN OR EQUAL TO 0.6 AND LESS THAN 3
- LESS THAN 0.6
- BLUE RIDGE/VALLEY AND RIDGE
- PIEDMONT
- INNER COASTAL PLAIN
- OUTER COASTAL PLAIN

Figure 7. Nitrate concentrations in shallow ground water of the inner Coastal Plain are significantly higher than nitrate concentrations in shallow ground water of the outer Coastal Plain.

Neuse River at Kinston, North Carolina

Nitrate concentrations were higher in small agricultural streams than in other settings.

Nitrate concentrations in streams were highest (greater than 1 mg/L) in heavily farmed areas in the Albemarle-Pamlico Drainage Basin (fig. 8). Nitrate concentrations which exceeded 1 mg/L occurred in the Tar and Neuse Basins in small streams located in areas having at least 40 percent or more agricultural land.

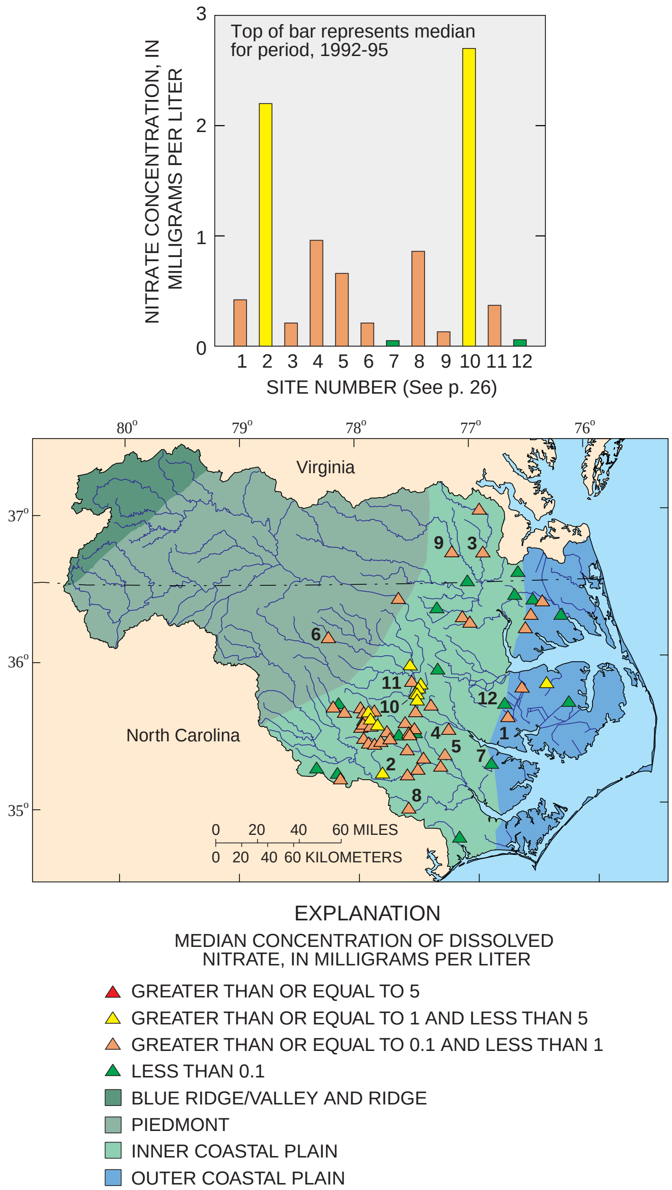
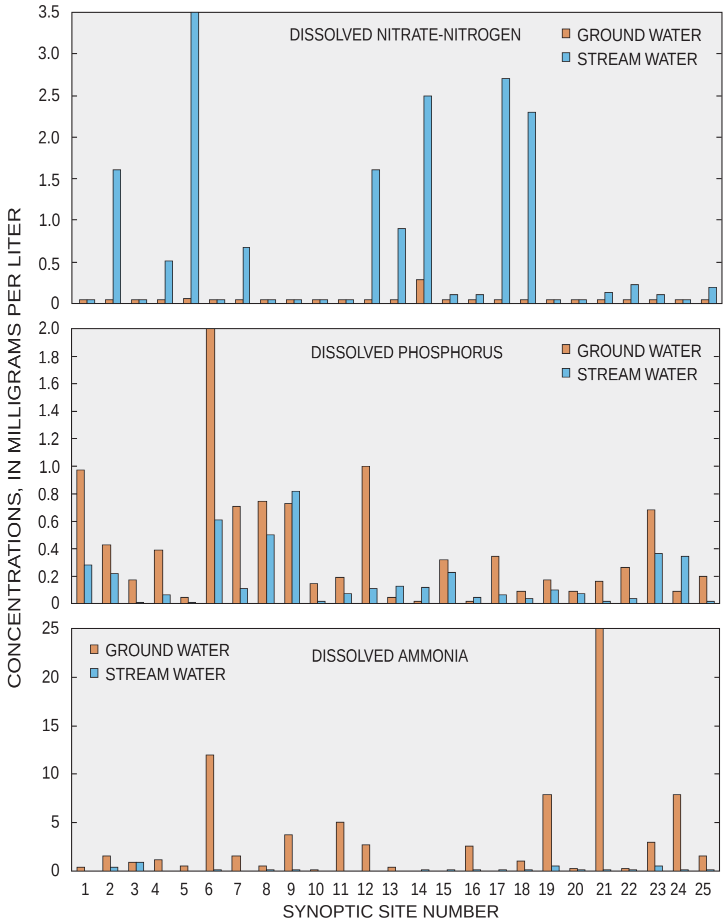


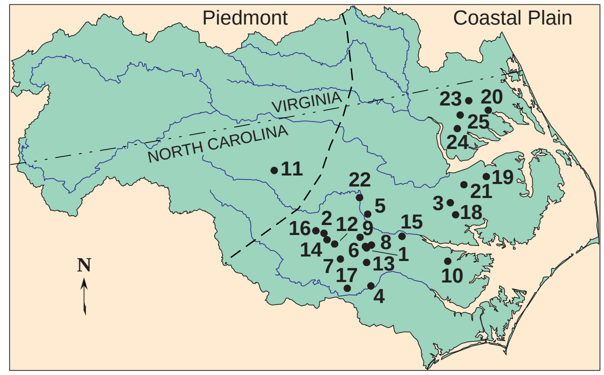
Figure 8. Small agricultural streams (sites 2 and 10) had the highest overall nitrate concentrations. Of the large streams draining more than 100 mi^2, Contentnea Creek (site 5), the Neuse River (site 8), and the Tar River (site 11) had the highest median concentrations of nitrate, although none exceeded the 10-mg/L drinking-water standard. (Numbered sites are regularly sampled sites.)

Point-source discharges are a major source of nitrate to the Tar and Neuse Rivers. Nitrate in discharging ground water is probably not a major source of nitrogen to streams.

By correlating flow and nitrate concentrations in streams, the sources of nitrate can be determined—a constant ground-water source, point source, or from surface runoff. A significant positive correlation indicates nonpoint sources in surface runoff (increase in concentration as flow increases), whereas a significant negative correlation indicates dilution at high flow—thus, a constant ground-water or point source. Negative correlations between nitrate and flow in the Tar and Neuse Rivers indicate that either ground-water base flow or point sources are responsible for most of the nitrate. However, concurrently collected samples of surface and ground water at 25 sites in the Coastal Plain during a low-flow period in September 1995 indicate that discharging ground water had very low or undetectable nitrate concentrations (fig. 9). This is probably because in a shallow ground-water system, most nitrate undergoes reduction or denitrification in the aquifer before water is discharged to the river. Deep ground water from long flow paths that discharge to these rivers also typically is low in nitrate. The organic material on stream bottoms and fine-grained organic-rich sediments of the floodplains of streams cause discharging ground water to denitrify (fig. 10). Low nitrate concentrations in discharging ground water is not a significant source of nitrate in the streams. Although naturally discharging ground water probably contributes little nitrate to streams, artificial drainage techniques, such as tile drains and ditches which intercept the water table, could contribute significantly as a nonpoint source of nitrate to stream load. Gilliam and others (1997) reported that about 28 pounds per acre of nitrogen, on average, is released from subsurface tile drains in agricultural areas of eastern North Carolina.

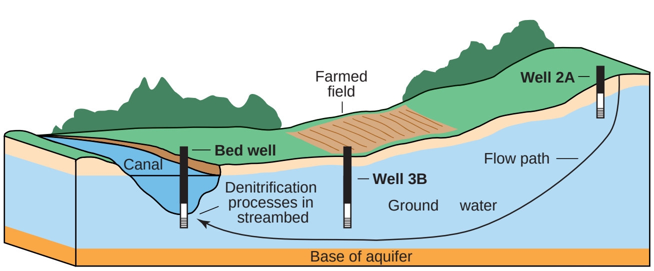
Because naturally discharging ground water is not likely the source of nitrate, the negative correlation with flow indicates that point sources are the likely primary sources of nitrate in the Neuse River and Tar River. Data presented by McMahon and Woodside (1997) indicate that point sources accounted for about 30 percent of the nitrogen load in 1990 for the Neuse River at Kinston, N.C., and about 10 percent in the Tar River at Tarboro, N.C. Forty percent or more of the phosphorus load can be from point sources in the Roanoke and Neuse Rivers. One outer Coastal Plain stream (Van Swamp), one inner Coastal Plain stream (Bear Creek), and a Piedmont stream (Devil's Cradle Creek) showed significant positive correlations of streamflow to nitrate, indicating that nitrate is derived primarily from nonpoint sources in surface runoff. Because both nitrate and ammonia are positively correlated with streamflow in Devil's Cradle and Bear Creeks, animal waste or septic systems are indicated as primary sources. A significant positive correlation between





Summary of synoptic site numbers, basin locations, and synoptic site names. Drainage basins: N, Neuse; T, Tar; A, Albemarle		
SYNOPTIC SITE NUMBER	BASIN	SYNOPTIC SITE NAMES
1	N	Sandy Run near Lizzie
2	N	Hominy Swamp at SR 1606
3	T	Van Swamp near Hoke
4	N	Neuse River at Kinston
5	T	Pete Mitchell Swamp near Penny Hill
6	N	Middle Swamp near Lizzie
7	N	Nahunta Swamp at SR 1058
8	N	Little Contentnea Creek US 264A
9	N	Little Contentnea Creek US 258
10	T	Durham Creek at Edward
11	T	Devil's Cradle Creek
12	N	Contentnea Creek at NC 222
13	N	Contentnea Creek at Hookerton
14	N	Contentnea Creek at Evansdale
15	T	Chicod Creek at SR 1760
16	N	Bloomery Swamp near Wilson
17	N	Bear Creek near Mays Store
18	T	Albemarle Canal
19	T	Scuppernong River at SR 1142
20	A	Knobs Creek near Elizabeth City
21	A	Kendrick Creek at SR 1125
22	T	Tar River at Tarboro
23	A	Newland Canal near Lynch's Corner
24	A	Goodwin Mill Creek at SR 1111
25	A	Perquimans River at SR 1204

Figure 9. Nitrate concentrations are low or barely detectable in discharging ground water compared to stream water at all sites sampled in the Coastal Plain, whereas ammonia and phosphorus concentrations tend to be higher in ground water discharging into the streams.



SAMPLING SITE	NITRATE-NITROGEN CONCENTRATION	CHLORIDE CONCENTRATION
Well 2A	<1 mg/L	15 mg/L
Well 3B	15 mg/L	22 mg/L
Bed well	18 mg/L	17 mg/L
Canal	2 mg/L	20 mg/L

Figure 10. As ground water moves along the flow path in a sandy aquifer in a small agricultural area of the Tar River Basin (flow-path study area, p. 26) from the hilltop to the canal, nitrate concentrations increase where fertilizer is applied on the farmed field and remain high until the ground water passes through organic material in the streambed, where concentrations are decreased as the ground water discharges to the canal. Bacterially mediated denitrification is primarily responsible for decreasing concentrations of nitrate from 15 mg/L in ground water before discharging to the stream to 2 mg/L in the canal. Chloride undergoes little change as it discharges to the canal, indicating dilution is not responsible for the decrease in nitrate concentrations.

flow and nitrate also indicates a surface nonpoint source of nitrate at Van Swamp, a small blackwater stream.

High ammonia-nitrogen concentrations in shallow ground water and surface water are associated with high organic carbon concentrations.

Nitrate is the main form of nitrogen in aerated waters with low organic carbon concentrations. However, nitrogen also exists in reduced form as ammonia (the ionized form of ammonia is generally termed ammonium; however, for this report, the ionized form will be referred to as ammonia) in low-oxygen waters; thus, when nitrogen occurs in water as ammonia, nitrate concentrations usually are low. Even though ammonia is not known to be toxic to humans or fish under typical concentrations or conditions, it is a biologically available form of nitrogen which can contribute to eutrophication. Ammonia can originate from decaying organic material, animal or human wastes, fertilizer, or from nitrate or nitrite that has moved into an anaerobic zone containing large concentrations of carbonaceous material (Spruill and others, 1996). Organic carbon, present in water and sediments of the Coastal Plain, allows bacteria to reduce nitrate to nitrogen gas and reduced nitrogen species. Ammonia-nitrogen concentrations in ground water ranged from less than 0.01 to 2.8 mg/L in the Albemarle-Pamlico Drainage Basin with highest concentrations in the outer Coastal Plain (fig. 11).

Stream concentrations of ammonia in the Albemarle-Pamlico Drainage Basin are relatively high compared to other parts of the United States (Mueller and others, 1995). Concentrations of ammonia in ground water discharging into streams in the Coastal Plain (fig. 9) were much higher (median = 1.2 mg/L) than concentrations in shallow ground water from randomly sampled wells throughout the Coastal Plain (median = 0.135 mg/L; fig. 11). The highest ammonia concentrations in streams occurred in Contentnea Creek and in small Coastal Plain streams. Elevated concentrations of ammonia in these streams may be due partly to discharging ground water or point-source discharges, although ammonia largely sorbs to bed material as indicated by much lower stream concentrations compared to ground water (fig. 9). In Bear Creek and Chicod Creek (fig. 12, sites 2 and 4), some ammonia may be due to animal wastes.

Summary statistics for ammonia-nitrogen concentrations in milligrams per liter.

STATISTIC	ENTIRE STUDY UNIT	INNER COASTAL PLAIN	OUTER COASTAL PLAIN
Number of wells	50	19	30
Minimum	0.010	0.010	0.030
Median	0.135	0.040	0.250
Maximum	2.80	0.700	2.80

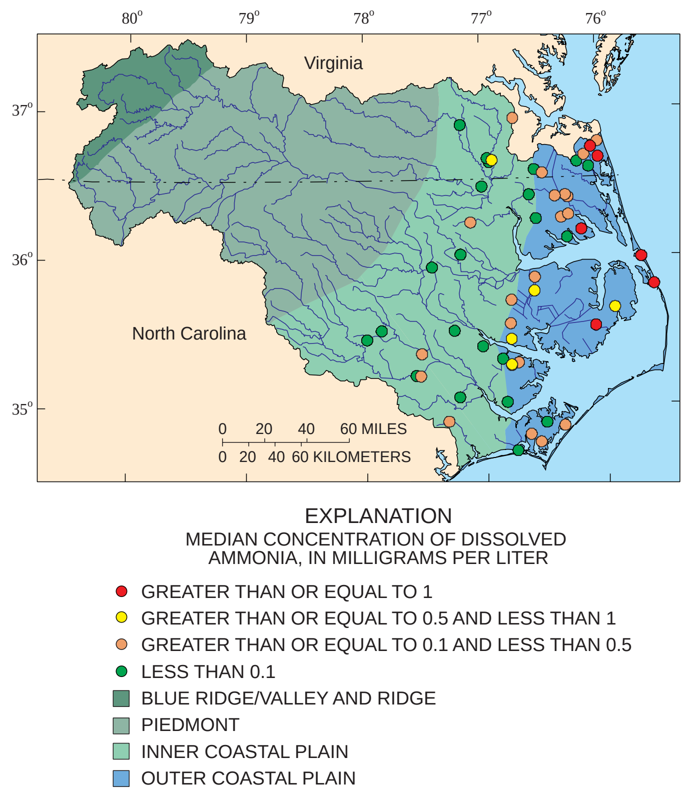
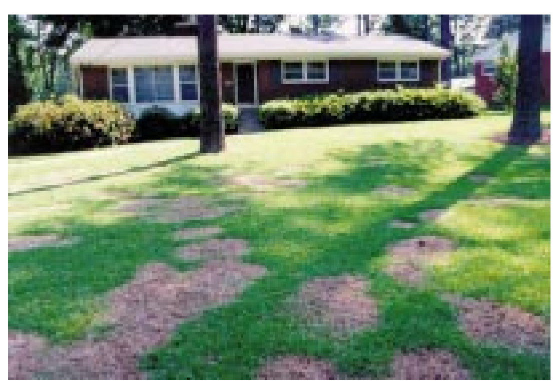


Figure 11. Ammonia-nitrogen concentrations in ground water were higher in the outer Coastal Plain (median = 0.250 mg/L) than in the inner Coastal Plain (median = 0.040 mg/L). The presence of abundant organic carbon in sediments of the outer Coastal Plain probably causes the higher concentrations of ammonia.



“Nitrogen-burned” lawn from too much fertilizer application

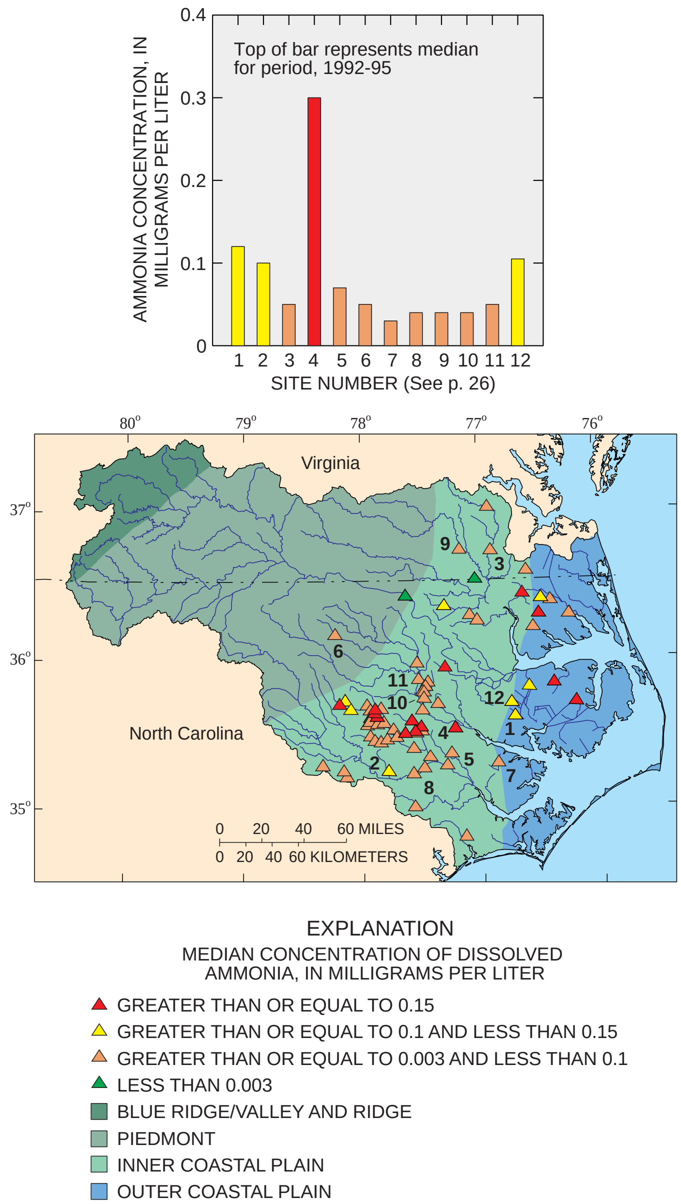


Figure 12. Concentrations of ammonia exceeding 0.1 milligram per liter occurred in streams throughout much of the study area. Much of the ammonia may be associated with discharging ground water or animal wastes.

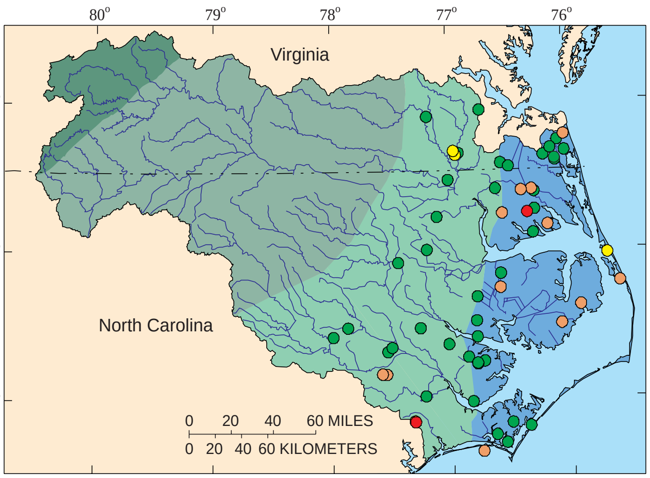
Sampling a well in the Coastal Plain, North Carolina

High phosphorus concentrations in some streams are due to high concentrations in ground water.

Phosphorus does not commonly occur in ground water at concentrations greater than a few hundredths of a milligram per liter because it tends to chemically attach, or sorb, to positively charged particles in soils and clays. In general, phosphorus concentrations in shallow ground water of the Coastal Plain of the Albemarle-Pamlico Drainage Basin reflect this in as much as the overall median phosphorus concentration was 0.035 mg/L (fig. 13). However, deep ground water in North Carolina had a median concentration of about 0.25 mg/L (Harned and others, 1995) compared to a much lower median concentration in shallow ground water. These relatively high concentrations of phosphorus are likely derived from phosphate minerals, such as fluoroapatite, in the aquifer sediments. The upward discharge of this deep ground water into shallow aquifers of the outer Coastal Plain may account for the slightly higher concentration compared to that of the inner Coastal Plain (fig. 13).

Deep ground water also affects stream-water quality. Where phosphorus-rich, deep ground water discharges to streams, it affects surface-water quality. Results from sampling 25 sites during August and September 1995 throughout the Coastal Plain indicate that phosphorus concentrations in discharging ground water generally were higher than in surface water (fig. 9).The median phosphorus concentration in discharging ground water from these 25 sites was 0.2 mg/L, about the same concentration reported by Harned and others (1995) for deep ground water from the inner Coastal Plain. The median concentration of phosphorus in surface water at these sites was 0.1 mg/L. Ground-water phosphorus concentrations affect surface-water phosphorus concentrations, as indicated by a significant correlation for all 25 sites between discharging ground-water concentrations and stream concentrations. Concentrations of phosphorus in discharging ground water were highest in Contentnea and Chicod Creeks and in the Neuse and Tar Rivers. A negative correlation between flow and instream dissolved phosphorus was found in these basins, indicating that discharging ground water and point sources are the primary sources of phosphorus.

Summary statistics for phosphorus concentrations in milligrams per liter.			
STATISTIC	ENTIRE STUDY UNIT	INNER COASTAL PLAIN	OUTER COASTAL PLAIN
Number of wells	50	19	30
Minimum	0.010	0.010	0.010
Median	0.035	0.040	0.070
Maximum	1.40	1.30	1.40

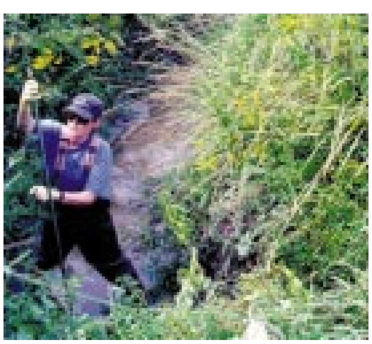


EXPLANATION

MEDIAN CONCENTRATION OF DISSOLVED PHOSPHORUS, IN MILLIGRAMS PER LITER

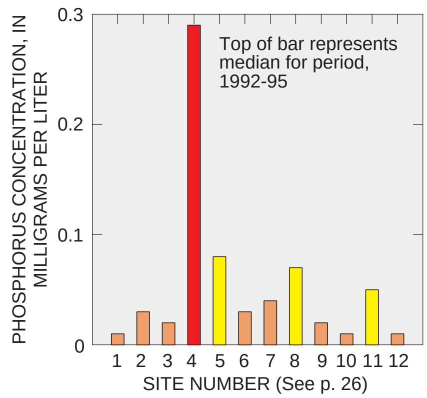
- GREATER THAN OR EQUAL TO 1
- GREATER THAN OR EQUAL TO 0.5 AND LESS THAN 1
- GREATER THAN OR EQUAL TO 0.1 AND LESS THAN 0.5
- LESS THAN 0.1
- BLUE RIDGE/VALLEY AND RIDGE
- PIEDMONT
- INNER COASTAL PLAIN
- OUTER COASTAL PLAIN

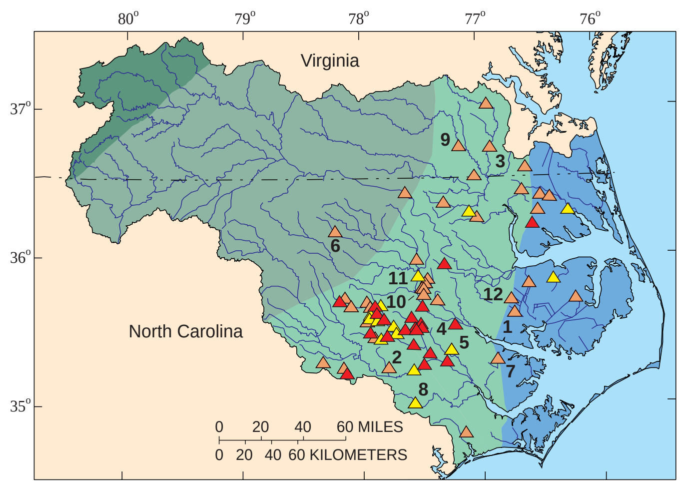
Figure 13. Shallow ground water from the outer Coastal Plain has significantly higher total phosphorus concentrations than does shallow ground water from the inner Coastal Plain. These higher concentrations, due to the presence of phosphorus minerals in the underlying aquifer sediments, may be a result of deep ground-water discharges into the surficial aquifer from long regional-flow systems in sands of Cretaceous age in the Coastal Plain.



Sampling ground water discharging to a stream

Of the 12 stream sites sampled regularly between 1992 and 1995, the highest median phosphorus concentrations were measured in samples from Chicod and Contentnea Creeks and from the Neuse and Tar Rivers (fig. 14). During the summer low-flow period when algal growth potential is highest, each of these four sites had concentrations of phosphorus greater than 0.1 mg/L, ranging from about 0.13 to 0.51 mg/L (fig. 15).





EXPLANATION

MEDIAN CONCENTRATION OF DISSOLVED PHOSPHORUS, IN MILLIGRAMS PER LITER

- GREATER THAN 0.1
- GREATER THAN OR EQUAL TO 0.05 AND LESS THAN 0.1
- GREATER THAN OR EQUAL TO 0.01 AND LESS THAN 0.05
- LESS THAN 0.01
- BLUE RIDGE/VALLEY AND RIDGE
- PIEDMONT
- OUTER COASTAL PLAIN
- INNER COASTAL PLAIN

Figure 14. The high concentrations of phosphorus measured in samples from Chicod Creek (site 4), Contentnea Creek (site 5), Neuse River (site 8), and Tar River (site 11) are probably due to ground water and(or) point-source discharges.

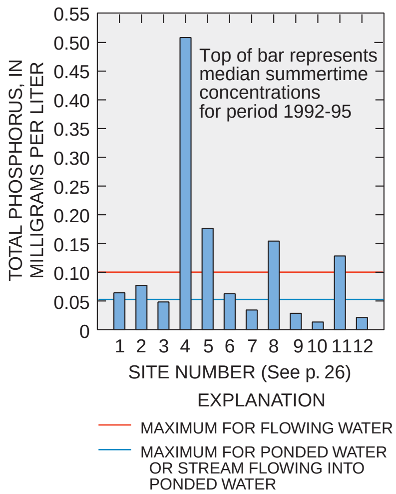


Figure 15. The highest summertime (June–August) concentrations of phosphorus were detected in Chicod Creek (site 4), probably due to animal waste, and in Contentnea Creek (site 5), the Neuse River (site 8), and the Tar River (site 11), probably due to ground-water inputs and(or) point sources.

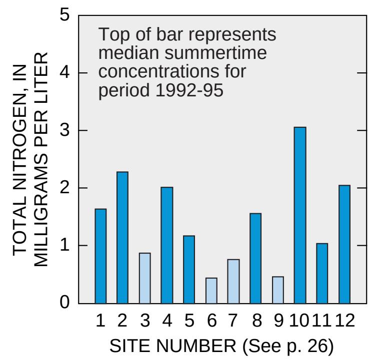


Figure 16. Highest summertime (June–August) total nitrogen concentrations were detected in Albemarle Canal (site 1), Bear Creek (site 2), Chicod Creek (site 4), Contentnea Creek (site 5), Neuse River (site 8), Pete Mitchell Swamp (site 10), Tar River (site 11), and Van Swamp (site 12). Abundant nitrogen in these streams promotes excessive algal growth.

To meet literature-based guidelines, a 30- to 50-percent reduction in nutrient concentrations is needed to reduce nuisance algal production in streams of the Tar and Neuse River Basins.

In general, summer is the time when algal growths are at their maximum and also when nutrients are most important in limiting algal growths. Summer concentrations of phosphorus (fig. 15) and nitrogen (fig. 16) are particularly high in Chicod Creek, the Neuse River, the Tar River, and Contentnea Creek. For Contentnea Creek, a 30- to 50-percent reduction in phosphorus concentration would be necessary to attain the 0.1-mg/L phosphorus guideline (Mackenthum, 1969); for the Neuse River, a 50-percent reduction in phosphorus concentration would be required to approximate the 0.05-mg/L guideline for streams flowing into lakes or quiescent water (as in the Neuse estuary). Additional sources of phosphorus from sediments, however, could reduce the effectiveness of nutrient source controls in the estuary.

Median summertime concentrations of total nitrogen are higher than 1 mg/L in several streams, including the Tar River, Contentnea Creek, and the Neuse River (fig. 16). After phosphorus reductions and assuming a 7:1 cellular growth ratio of nitrogen to phosphorus, median summer nitrogen concentrations would need to be less than 0.7 mg/L for the Tar River and Contentnea Creek and 0.3 to 0.5 mg/L for the Neuse River to reduce algal growth. The Neuse River would require about a 50-percent nitrogen reduction, and the Tar River and Contentnea Creek each would require about a 30-percent reduction in total nitrogen to reduce the incidence of nuisance algal growth, fishkills, and undesirable odors. Natural geologic sources of phosphorus in these basins may make concentration reductions difficult for water managers.

Nutrients in ground water are a problem in some areas.

Although only 4 percent of wells sampled by NAWQA across the Coastal Plain exceeded the 10 mg/L drinking-water standard, highly vulnerable areas in the inner Coastal Plain having well-drained soils and agricultural land uses are much more susceptible to nitrate concentrations. Almost 40 percent of the ground-water samples collected by the North Carolina Division of Water Quality in these areas exceeded the 10-mg/L drinking-water standard (Spruill and others, 1996). Limiting fertilizer or manure applications in such areas and developing deeper ground-water supplies that are protected from land-surface activities should minimize exposure to excessive nitrate concentrations. Although the ammonia concentration in the outer Coastal Plain is high in ground water discharged to freshwater streams, it does not appear to greatly affect concentrations of ammonia in freshwater streams (fig. 9); however, it may elevate stream ammonia concentrations. Such discharges could affect estuaries where the salt content of the estuary allows the ammonia to stay in solution. Elevated ammonia concentrations in ground water may be related to bacterial nitrate reduction or release from decay of organic material, particularly in aquifer deposits of the outer Coastal Plain, or from animal or human wastes.

Phosphorus concentrations in shallow wells generally were very low (less than 0.04 mg/L), although deeper formations of Miocene and Cretaceous age contain concentrations of phosphorus that are as high as 2 mg/L with a median of 0.2 mg/L. Discharge of this deeper ground water to streams where these formations are present increases phosphorus concentrations in streams of the Coastal Plain, particularly in the Tar and Neuse drainage basins. It is also possible that deep ground water accounts for the higher dissolved phosphorus concentrations in shallow ground water in the outer Coastal Plain. Elevated phosphorus concentrations contribute to eutrophication of streams and can stimulate growth of organisms associated with fishkills, such as *Pfiesteria piscicida* (Burkholder, 1997).

Nutrient concentrations are decreasing in streams in North Carolina, but some increases were indicated in Virginia.

Total nitrogen trends for 1980–90 (Harned and others, 1995) indicate increases in the tributaries at the upper end of Kerr Lake and decreases in the Neuse River Basin. The increases in nitrogen concentrations upstream from Kerr Lake reflect changes in atmospheric inputs of nitrogen, possibly caused by construction of powerplants near the lake. Decreases in nitrogen concentrations in the Neuse River Basin are dissimilar, suggesting differing causes for the decreases. Trends observed for total ammonia and organic nitrogen were similar to those observed for total nitrogen and nitrate nitrogen. Upward trends in nitrate also were detected for two sites in the Tar River Basin and probably are due to changes in agricultural practices. A gradual increase in nitrate concentrations in the Chowan River near Riddicksville was detected.

Total phosphorus concentrations generally showed upward trends for streams in Virginia and downward trends for streams in North Carolina. The effect of the 1988 phosphate-detergent ban in both States is evident at several streams, including the Nottoway River, Neuse River, and Contentnea Creek. Total phosphorus is strongly associated with suspended sediment; therefore, locations having high suspended-sediment concentrations, such as those in the upper Roanoke and Dan River Basins, generally have high phosphorus concentrations. Although decreases in nitrogen and phosphorus have been observed, concentrations are still high enough in the Tar and Neuse River Basins to cause nuisance algal growth.

Suspended-sediment concentrations are higher in the Piedmont than in the Coastal Plain.

Suspended-sediment concentrations for the major rivers in the Albemarle-Pamlico Drainage Basin from 1980 to 1990 generally were less than 50 mg/L with greater concentrations occurring in Piedmont streams than in Coastal Plain streams because of steeper slopes and more readily erodible soils in the Piedmont (Harned and others, 1995). Kerr and Gaston Lakes are effective traps for sediment in the upper Roanoke River Basin, as is Falls Lake in the Neuse River Basin. Substantial decreases in suspended-sediment concentrations are evident in the Neuse River as it flows from the Piedmont to the Coastal Plain. Agricultural activities, particularly highly erosive corn and tobacco farming, combined with the steep slopes of the Piedmont produce high sediment yields.

Median sediment concentrations for data collected from 1993 to 1995 during the NAWQA study were highest in the Neuse River (25 mg/L), Devil’s Cradle Creek (15.5 mg/L), and the Tar River (16.5 mg/L), probably due to the greater slopes and higher degree of erosion of the Piedmont drainage areas compared to those of the Coastal Plain. However, high median concentrations in Coastal Plain streams—Albemarle Canal (15 mg/L) and Chicod Creek (14 mg/L)—indicate that agricultural sources can have a substantial effect on sediment concentrations in streams even in areas of low slopes in the Coastal Plain.

Suspended- and dissolved-solids concentrations have decreased throughout the Albemarle-Pamlico Drainage Basin over the past 15 years (1980–95). The decrease is probably a result of (1) construction of new lakes and ponds which trap solids, (2) improved agricultural soil management, and (3) improved wastewater treatment. Decreasing concentrations of suspended solids in the sounds and estuaries may result in clearer water and deeper light penetration which, in turn, enhance conditions for algal blooms in nutrient-enriched areas.


Livestock in a stream in the Contentnea Creek Basin, North Carolina

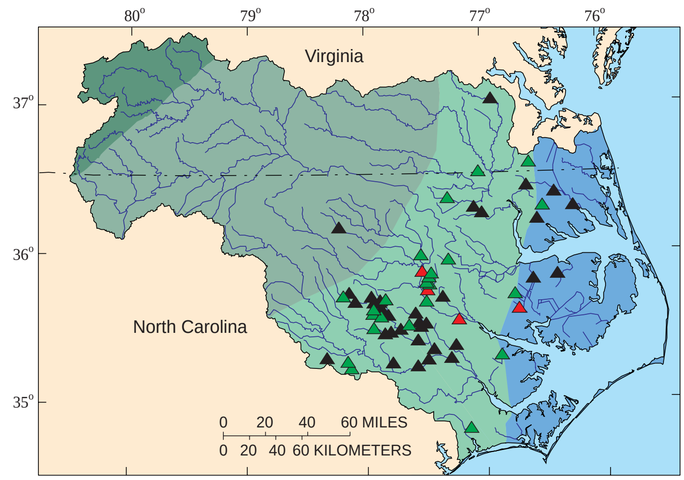
The main pesticides used in the Albemarle-Pamlico Drainage Basin include alachlor, atrazine, metolachlor, carbaryl, carbofuran, and ethoprop. Recommended application rates for most pesticides range from about 0.5 pound per acre (lb/acre) to 3 lb/acre. Alachlor, the pesticide most used in the Albemarle-Pamlico Drainage Basin, is applied at rates up to 3 lb/acre, primarily in peanut cultivation. An application rate of about 1 lb/acre of many other pesticides is used for other crops grown in the study area. Some organochlorine pesticides that have long been banned from use (such as DDT) are still present in streambed sediments (see p. 18) in the basin and provide a source of these pesticides for uptake by aquatic organisms.

Pesticides applied to crops in the study area are measured at concentrations in shallow ground water just above detection levels.

Of 47 pesticides and metabolites analyzed in ground-water samples from 49 wells less than 50 feet deep located across the Coastal Plain, 14 were detected. Atrazine and its metabolite, deethylatrazine, were the most commonly detected pesticides (each in 16 percent of wells sampled). Metolachlor and 2,6–diethylaniline (a formulation component of alachlor) were each detected in 10 percent of wells sampled. The remaining pesticides detected include the insecticides carbofuran, carbaryl, chlorpyrifos, diazinon, and dieldrin and the herbicides alachlor, prometon, simazine, terbacil, and tebuthiuron. Most pesticide concentrations were less than 0.1 microgram per liter (g/L), and no pesticide concentrations detected in water from any of the 49 wells in the study area exceeded drinking-water standards or health advisory levels (although many pesticides do not have established standards). Pesticide detection rates in ground water in the agricultural areas of the Coastal Plain were among the highest nationally (p. 25). Occurrence of specific pesticides in surface and ground water is presented in the table on pages 28–33 of this report.

Low concentrations of pesticides were commonly detected in the streams of the Albemarle-Pamlico Drainage Basin.

Of 47 pesticides analyzed in surface-water samples, 45 pesticides were detected. Four streams in the Tar River Basin had 20 or more pesticides detected, 30 streams had between 6 and 20 compounds detected, and samples from 21 streams had detectable concentrations of 1 to 5 pesticides (fig. 17). Sixteen pesticides, including four insecticides (carbaryl, carbofuran, ethoprop, and diazinon) occurred at concentrations greater than 0.1 g/L. Generally herbicides were detected in streams during the spring and summer months. Concentrations of several pesticides (atrazine, metolachlor) became elevated immediately after application in March and April, peaked in June and July, and finally dissipated to the detection limit or low concentrations for most of the year (fig. 18). Based on these data, drinking-water standards for pesticides are most likely to be violated during May through July.



EXPLANATION

NUMBER OF PESTICIDES DETECTED

- 1 TO 5
- 6 TO 20
- GREATER THAN 20
- BLUE RIDGE/VALLEY AND RIDGE
- PIEDMONT
- OUTER COASTAL PLAIN
- INNER COASTAL PLAIN

Figure 17. Twenty or more pesticides were detected at four stream sites. Streams with the greatest number of detections of pesticide concentrations greater than 0.1 microgram per liter were in agricultural areas in the Tar River Basin.

Metolachlor was detected in 80 percent, atrazine in 69 percent, prometon in 60 percent, and alachlor in 63 percent of 233 stream samples from 65 sites in the Albemarle-Pamlico Drainage Basin. Only alachlor exceeded the drinking-water standard of 2 mg/L. Standards for drinking water or aquatic life exist for about 50 percent of the compounds detected.

Pesticide application in the Contentnea Creek Basin, North Carolina

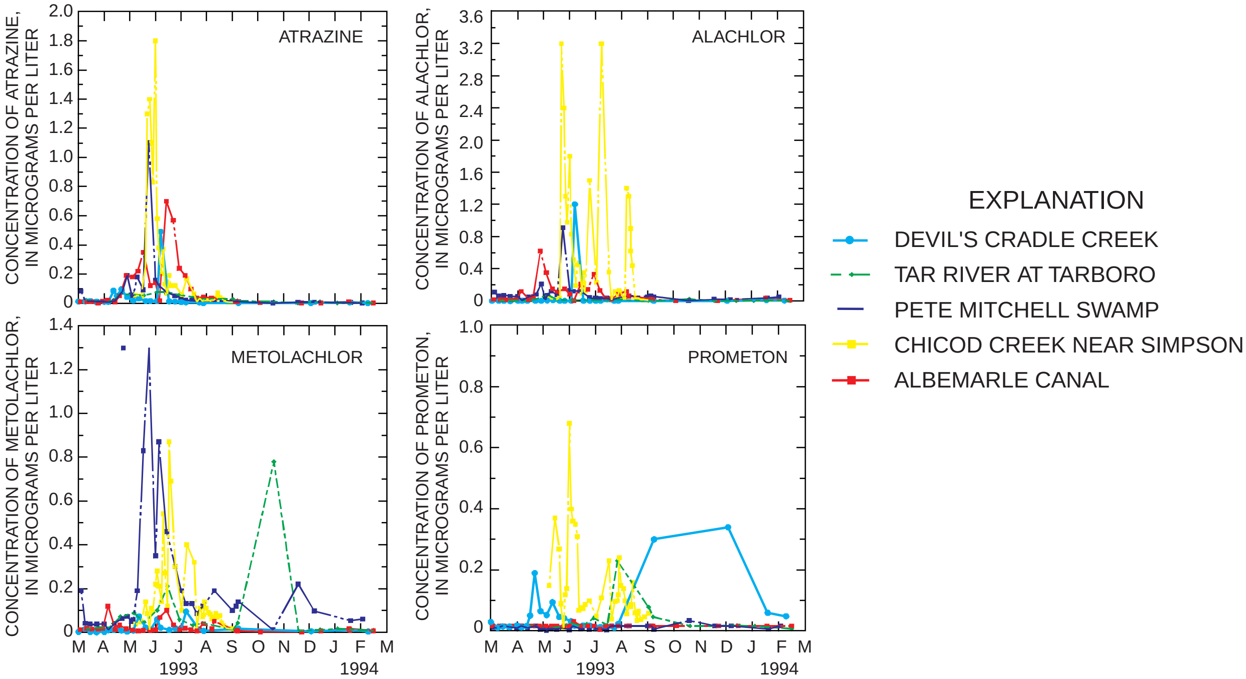


Figure 18. Atrazine, alachlor, metolachlor, and prometon concentrations in selected streams usually peaked during the principal period of herbicide application (May to June). Peaks in prometon concentration occurred in Devil's Cradle Creek from July to December.

The Albemarle-Pamlico NAWQA Study Unit team collecting and processing ground- and surface-water samples

In addition to the 47 agricultural pesticides applied to crops during the period 1992–95 and discussed in the previous section, there are many other organic compounds that can pose potential health and environmental hazards. These organic compounds (chemical compounds containing the element carbon) include organochlorine compounds (compounds with both carbon and chlorine); semivolatile organic compounds (SVOCs), which usually are the result of combustion (polyaromatic hydrocarbons [PAHs]), either natural or anthropogenic, or the product of industrial manufacturing (phenols, phthalate esters, amines, and a variety of other compounds); and volatile organic compounds (VOCs) associated with refined gasoline (benzene, toluene, xylene, methyl *tert*-butyl ether [MTBE]) or solvents, such as trichloroethene and carbon tetrachloride). Many of the organochlorine compounds were used extensively as pesticides (for example, DDT) during the 1950’s, 60’s and 70’s, but were largely banned during the late 1970’s and early 1980’s because of their carcinogenicity, toxicity, and ability to persist in the environment for many years. They are generally not very water soluble. SVOCs also do not easily evaporate into the atmosphere and are not very water soluble. VOCs, on the other hand, evaporate easily and are very water soluble. With the exception of VOCs, only results of bed-sediment sampling are discussed. Because VOCs are very soluble, they are discussed as a contaminant in ground water.

Trace elements are another class of contaminants in water and sediment that can pose environmental hazards. Trace elements, as discussed in this report, include metals and nonmetals; some elements, such as aluminum and iron, actually are very common in the environment. However, most of the elements analyzed as part of the NAWQA study typically occur at low concentrations in the environment and, thus, are termed “trace” elements. Trace elements can occur locally at elevated concentrations as a result of enrichment due to geologic processes, such as evaporite deposits, or to anthropogenic processes, such as industrial, mining, or agricultural activities. Only the occurrence of trace elements in bed sediment of streams will be discussed in this report.

DDT, SVOCs, and trace elements were detected in streambed sediment.

Many pesticides have very low solubility in water and tend to adsorb (attach) to streambed sediment. Although these compounds, mostly organochlorine pesticides, are usually not detected in the water, they persist in bed sediment and provide a source for bioaccumulation by aquatic organisms. In addition, trace elements accumulate in bed sediments and occur near urban areas as a result of runoff or waste discharges from industrial, municipal, and residential activities. Bioaccumulation of metals, such as mercury, is a concern because trace levels in bed sediment may be concentrated to harmful levels in organisms at the top of the food chain.

Streambed sediments were collected in 1992 at 22 stations and analyzed for 35 organochlorine pesticides, 63 semivolatile compounds, and 44 major, minor, and trace elements (Woodside and Simerl, 1996). DDT was detected in 27 percent, DDD in 40 percent, and DDE in 63 percent of the samples. DDD and DDE are degradation products of DDT. DDT was banned from use in the United States in 1972 yet persists in the environment. In addition, dieldrin was detected in 18 percent and chlordane was detected in 9 percent of the samples. DDT and its degradation products were detected in stations downstream from both urban and rural areas; chlordane was detected at two urban sites.

During a review of historical pesticide and trace-element data for streambed sediment in the Albemarle-Pamlico Drainage Basin for 1969–90 (Skrobialowski, 1996), results were examined from 1,049 samples collected at 301 sites. Chlordane concentrations greater than the effects range established by the National Oceanic and Atmospheric Administration (Long and Morgan, 1991) were detected in the upper Neuse River Basin, and elevated concentrations of DDT, DDD, and DDE were detected at Tar River sites and several sites in the Roanoke River Basin. DDT was detected in 18 percent, DDD in 25 percent, and DDE in 28 percent of the approximately 160 samples analyzed.

Lead concentrations during the 1992 NAWQA sampling were highest in streambed sediments from Ellerbe Creek and Crabtree Creek, both of which are urban basins in the Neuse River Basin. Mercury and cadmium concentrations in streambed sediment were highest in the Trent River—a Coastal Plain stream in the Neuse River Basin. Zinc concentrations were highest in Ellerbe Creek and the Trent River. Concentrations of chromium, lead, nickel, and zinc were higher in streams draining urban areas and near wastewater-treatment plants than in other settings.

SVOCs were most commonly detected in bed sediment of streams draining urban basins. Of 22 streams sampled throughout the Albemarle-Pamlico Basin (Woodside and Simerl, 1996), the Roanoke River downstream from Roanoke, Va., had the greatest number of SVOCs detected (36 of 63 compounds), most of which were PAHs. Of all basic sites, Devil’s Cradle Creek (site 6, p. 26) had three occurrences of phthalate esters, with one (bis 2-ethylhexyl) phthalate being the highest concentration (870 micrograms per kilogram [g/kg]) of any SVOC detected. However, phthalate esters are pervasive in the environment because the compounds are used in the manufacturing of common plastics. In general, SVOC concentrations from all other stream sites in the Albemarle-Pamlico Drainage Basin were relatively low and were few in number.

Pesticides were detected in Asiatic clam and redbreast sunfish tissue samples.

Of the 28 organochlorine compounds analyzed, seven were detected in Asiatic clam soft tissues and whole redbreast sunfish—DDD, DDE, DDT, dieldrin, *trans*-nonalachlor, PCBs, and toxaphene. Of these, DDE was the most common and widespread, being present at 11 of the 19 sites sampled. DDE is a chemically stable and persistent metabolic breakdown product of DDT and is among the most commonly detected organochlorine compounds nationwide (U.S. Environmental Protection Agency, 1992). More than one organochlorine compound was detected at 6 of the 19 sites. The only detection of toxaphene exceeded the National Academy of Sciences and National Academy of Engineering (NAS/NAE) guidelines for the protection of fish-eating wildlife (Nowell and Resek, 1994). The toxaphene exceedance occurred at Pete Mitchell Swamp—a small, intensively farmed basin in the Coastal Plain. All of the other detected compounds were present in concentrations well below the NAS/NAE guidelines (Smith and Ruhl, 1996).

Redbreast sunfish appear to be better bioindicators of organochlorine compound contamination. Asiatic clams are better bioindicators of PCB contamination.

Compared to the Asiatic clam, redbreast sunfish appear to be better bioindicators of organochlorine compound contamination in aquatic systems. Of the seven compounds detected, all but PCBs were detected in whole redbreast sunfish samples; only three compounds—DDE, *trans*-nonalachlor, and PCBs—were detected in Asiatic clam samples. Pesticides were detected at all eight sites sampled for redbreast sunfish, whereas only 3 of the 15 sites sampled for Asiatic clams had detections above the minimum reporting level. On the other hand, PCBs were only detected in Asiatic clams, lending support to other studies which have shown that Asiatic clams are good bioindicators of PCB contamination (Peterson and others, 1994).

Trace elements were detected in biological tissue samples.

Although all 10 of the USEPA trace-element priority pollutants were detected in Asiatic clam soft tissues or redbreast sunfish livers, they were present in relatively low concentrations. The sampling methods used do not permit a direct assessment of risks to human health; however, it is unlikely that widespread trace-element contamination poses a significant risk in the streams and rivers of the Albemarle-Pamlico Drainage Basin. Mercury concentrations were highest in blackwater streams and should continue to be monitored on a regular basis (Ruhl and Smith, 1996).

Trace-element concentrations detected in Asiatic clams in the study area were similar to those measured in other NAWQA Study Units in the southeastern United States (Ruhl and Smith, 1996). Mercury was widely detected, being present in 29 of 30 tissue samples, but concentrations did not exceed the FDA action limit of 1 microgram per gram (g/g) wet weight or a risk-based screening value for the general public (3.2 g/gwet weight) (Cunningham and others, 1992). Mercury concentrations in the study area ranged from 0.02 to 0.33 g/g wet weight.

The highest concentrations of mercury were detected in redbreast sunfish from the Blackwater River (0.19 to 0.33 g/g wet weight), and Contentnea Creek (0.18 g/g wet weight). Both are Coastal Plain streams where high concentrations of dissolved organic carbon also were measured. Higher mercury concentrations in fish are often associated with high concentrations of dissolved organic carbon. Studies have indicated that waters with low pH and high dissolved organic carbon concentrations, such as the Blackwater River, promote mercury uptake by aquatic organisms (Gilmore, 1995). Many Coastal Plain streams and lakes in North Carolina and Virginia have naturally low pH and high dissolved organic carbon concentrations and, thus, may be particularly susceptible to mercury bioaccumulation.

Few VOCs were detected in shallow ground water.

Volatile organic compounds (VOCs) were not commonly detected in shallow ground water. VOCs can occur in large concentrations in ground water, usually in urban environments. The most common sources of VOCs are vehicle fuel and industrial discharges of solvents. Most VOCs are known to cause cancer or are toxic; therefore, drinking-water standards have been established for these compounds.

Only three VOCs (chlorobenzene, trichlorofluoromethane, and MTBE) were detected in ground water in four separate wells in the Coastal Plain. All of the detected concentrations were below drinking-water standards. In general, VOCs do not appear to occur widely throughout the Coastal Plain and probably do not pose a concern except in local urban areas. The two highest concentrations detected occurred in industrial/commercial land-use areas. A comparison of concentrations from wells in the Albemarle-Pamlico Drainage Basin with nationwide NAWQA results indicates that VOC detections in ground water were among the lowest in the Nation.

Collecting benthic invertebrates in the Neuse River Basin, North Carolina

A fish community is a group of fish species that live in the same area and interact with one another (Meador and others, 1993). Community composition refers to the kinds of species present and their absolute and relative abundances. Fish community composition is significantly influenced by factors affecting water-quality conditions, including land use, land cover, point- and nonpoint-source pollution, channelization, and wetland destruction. In order to assess and describe these relations within the Coastal Plain of North Carolina, fish, habitat, and water-chemistry data were collected and analyzed for sites on 16 small (14- to 59-mi^2 basins) and 5 large (602- to 2,700-mi^2) Coastal Plain streams. Only results for the 16 small streams are discussed here.

The small Coastal Plain streams that were sampled had relatively diverse fish communities. Forty-five fish species from 15 different families were captured at the 16 sites. The number of species (richness) captured at each site ranged from 6 to 25 and was comparable to the number of species found in streams in other areas of the southeastern Coastal Plain (Paller, 1994).

Several species were present in nearly every stream and, thus, compose the nucleus of what might be called a typical Coastal Plain small-stream fish community. These species include pirate perch, redfin pickerel, American eel, creek chubsucker, yellow bullhead, and bluespotted sunfish. Other species that were slightly less widespread and abundant included golden shiner, eastern mosquitofish, tessellated darter, and redbreast sunfish. Nearly half of the captured species were members of either the sunfish (*Centrarchidae*) or minnow (*Cyprinidae*) families (11 species each), which together included about one-third of all the fish that were captured.

Differences in fish communities among small streams in the Coastal Plain are related to basinwide soil drainage characteristics and land use.

Although nearly every small stream site had many of the typical Coastal Plain species, there were several important characteristics of fish community composition that differed among sites. These characteristics included species richness, the relative abundances of typical Coastal Plain species, and the presence and abundances of species that are associated with particular kinds of stream habitats. In addition, the differences were strongly related to basinwide environmental characteristics, such as soil drainage, the amount of wetland buffer, and land use.

Numbers of species were significantly correlated (Spearman's rho; $p < 0.05$) with (1) the percentage of the basin having poorly drained soils (negative correlation), (2) the percentage of a 100-meter buffer zone along the entire stream classified as forested wetland (negative), and (3) the percentage of the basin used for row-crop agriculture (positive) (figs. 19, 20). Numbers of species also were correlated with several water-chemistry variables that are associated with these basinwide conditions, including (1) dissolved organic carbon (negative), (2) minimum dissolved oxygen (positive), (3) pH (negative), and (4) dissolved nitrate (positive). North Carolina Index of Biotic Integrity (NCIBI) scores, which are commonly used to indicate the ecological status of the fish community (North Carolina Department of Environment, Health, and Natural Resources, 1997), were related similarly to many of the same environmental variables (figs. 19, 20).

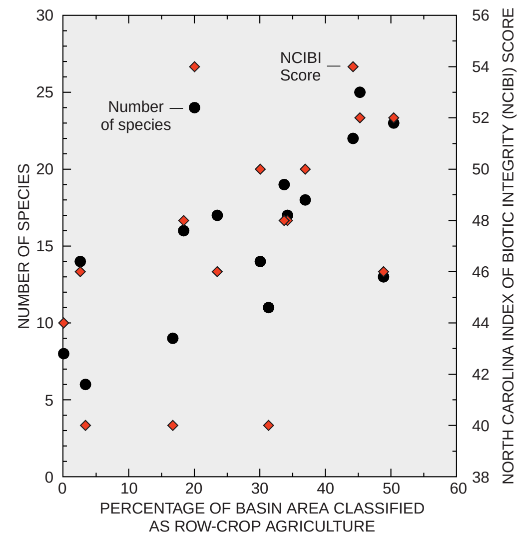


Figure 19. Numbers of species increased in basins having more row-crop agriculture.

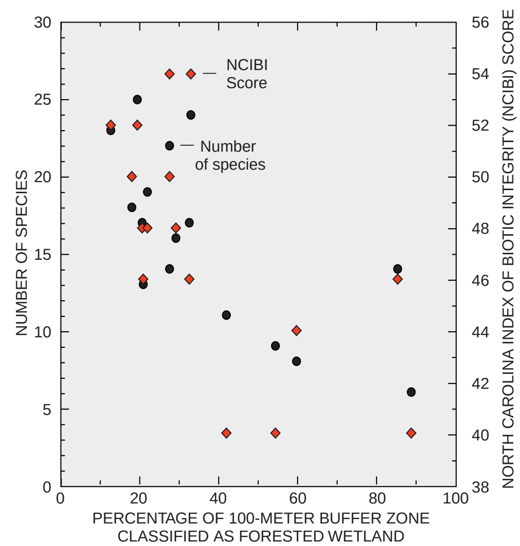


Figure 20. Areas having more forested wetlands had lower numbers of species.

Although numbers of species and NCIBI scores were correlated significantly with basinwide environmental variables, they were not correlated significantly with reach-level variables, such as the amount of instream cover and substrate particle size. This result indicates that fish community composition may be broadly determined by basinwide environmental conditions and only secondarily by local conditions. One implication of this is that mitigation and restoration strategies that focus on the local scale, while neglecting basinwide conditions, may not be fully successful.

The relations between numbers of species, NCIBI scores, and environmental characteristics indicated that, in general, more species of fish and higher NCIBI scores were found in agricultural areas with minimal wetland buffers. In fact, richer fish communities and higher NCIBI scores tended to occur in areas where human impacts have been substantial—opposite of the expectation that numbers of species, and especially NCIBI scores, should decline when streams are affected by human activities.

This unexpected pattern may reflect natural differences in fish community composition that are a consequence of soil type rather than human activities. Streams located in basins dominated by poorly drained soils generally tended to have lower numbers of species and NCIBI scores than streams in areas dominated by medium- or well-drained soils (fig. 21). Yet several of the streams in areas with poorly drained soils were among the least affected in the study area—those with natural channels, the greatest percentage of wetland buffer, and the smallest percentage of row-crop agriculture.

Many of the streams in areas where poorly drained, organic-rich soils prevail cease flowing during the summer,

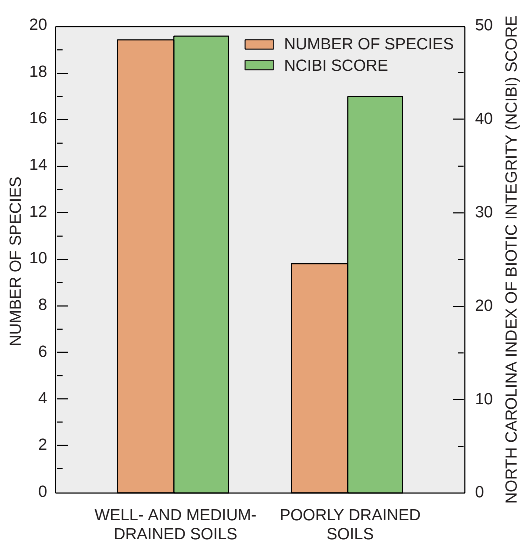


Figure 21. Streams in poorly drained basins had lower numbers of species and NCIBI scores than those basins having well- and medium-drained soils.

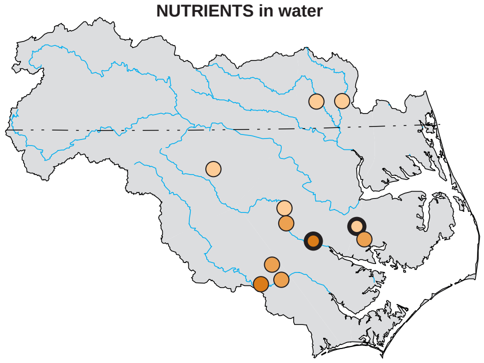
partly because the soil does not yield enough ground water to maintain streamflow. The most pristine streams have extensive floodplain forests that contribute to this condition by lowering the water table through transpiration. Floodplain swamps and organic-rich soils contribute large amounts of particulate and dissolved organic material to these streams, and when the water stops flowing, the decaying organic material reduces the concentration of dissolved oxygen. High concentrations of dissolved organic acids also lower pH. The natural combination of quiescent water, low dissolved oxygen concentration, and, in some cases, extremely low pH may limit fish communities in these areas to a relatively small number of species that can survive these difficult summer conditions. These include banded sunfish, swampfish, and mud sunfish. The harsh summer conditions may, in fact, act as a natural barrier to other species, thus resulting in a refugium for a distinct natural fish community characteristic of Coastal Plain streams in areas with poorly drained soils.

In contrast, streams in basins with well-drained, sandy soils receive more ground-water input during summer and are, therefore, less dependent on rainfall to maintain streamflow. They also tend to maintain higher concentrations of dissolved oxygen and have a pH that is neutral or only moderately acidic. As a result, these streams appear to be able to support a more diverse fish community that includes more minnow species and species that are associated with flowing water, such as satinfin shiner, dusky shiner, comely shiner, and shield darter. Fish communities of unchannelized streams in these areas also included many of the species found in the areas with poorly drained soils. Fish communities in channelized streams in well-drained soils tended to have an even greater proportion of flowing-water minnow species and often lacked the species found in streams in areas with poorly drained soils.

The current version of the NCIBI is not calibrated to account for natural differences in species richness and other aspects of fish community composition that are associated with soil drainage characteristics. One way to accomplish this might be to calibrate the NCIBI independently for the inner and outer Coastal Plain. The inner Coastal Plain typically has sandy soils that drain relatively rapidly, whereas the outer Coastal Plain has many areas with organic-rich soils that drain much more slowly (McMahon and Lloyd, 1995). Calibrating NCIBI metrics separately within each of these physiographic provinces would help water-quality assessments account for a major component of the natural variability in fish community structure. Unfortunately, the data collected for this study are not sufficient for developing and testing candidate metrics for a recalibrated biotic index. Data for additional streams in the outer Coastal Plain are needed particularly.

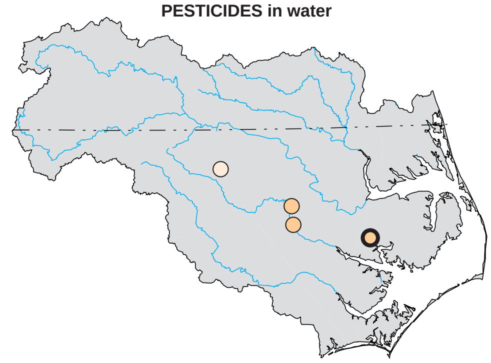
Seven major water-quality characteristics were evaluated for stream sites in each NAWQA Study Unit. Summary scores for each characteristic were computed for all sites that had adequate data. Scores for each site in the Albemarle-Pamlico Drainage Basin were compared to scores for all sites sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared to that of other NAWQA sites. Water-quality conditions at each site also are compared to established criteria for protection of aquatic life. Applicable criteria are limited to nutrients and pesticides in water and semivolatile organic compounds, organochlorine pesticides, and PCBs in sediment. (Methods used to compute rankings and evaluate aquatic-life criteria are described by Gilliom and others, in press.)

NUTRIENTS in water



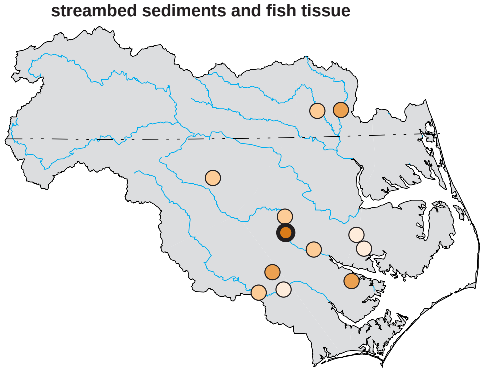
Nutrient concentrations in the southern Coastal Plain of the basin are high compared to concentrations at other NAWQA sites nationwide. Intensive agriculture in the Coastal Plain, combined with wastewater-treatment discharges and runoff from urban areas in the Piedmont, provide major sources of nutrient concentrations in the Neuse and Tar River Basins. Phosphorus concentrations are particularly high in parts of the Tar and Neuse River Basins, partly because of a geologic source.

PESTICIDES in water



Pesticides were present in low concentrations in most of the surface-water samples collected; the Tar River Basin had the highest concentrations. The herbicides metolachlor, atrazine, prometon, and alachlor were detected in over 60 percent of the stream samples. Pesticides in surface water are indicative of extensive agriculture in the Albemarle-Pamlico Drainage Basin.

PCBs and ORGANOCHLORINE COMPOUNDS in streambed sediments and fish tissue



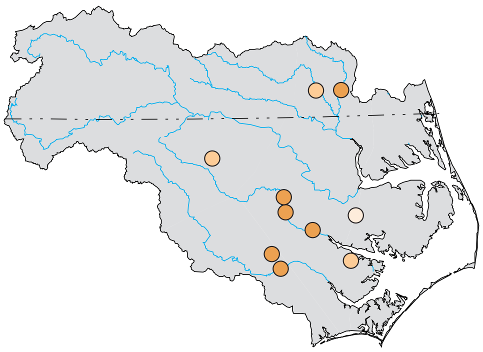
Relatively few organochlorine compounds were detected. Of those, DDE was the most common. Concentrations of the detected compounds are near or above the median at several sites when compared nationally. The highest values are associated with small basins in areas of intensive agriculture.

EXPLANATION

Ranking relative to national conditions— Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more aquatic-life criteria were exceeded.

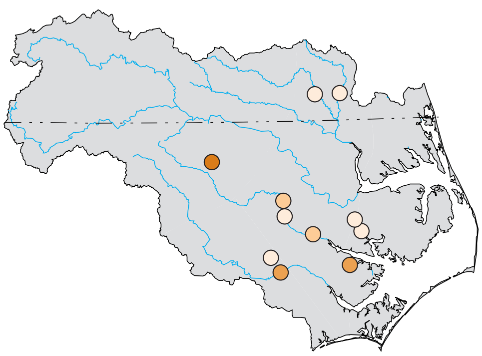
- **Greater than the 75th percentile** (Among the highest 25 percent nationally)
- **Between the median and the 75th percentile**
- **Between the 25th percentile and median**
- **Less than the 25th percentile** (Among the lowest 25 percent nationally)

TRACE ELEMENTS in streambed sediments



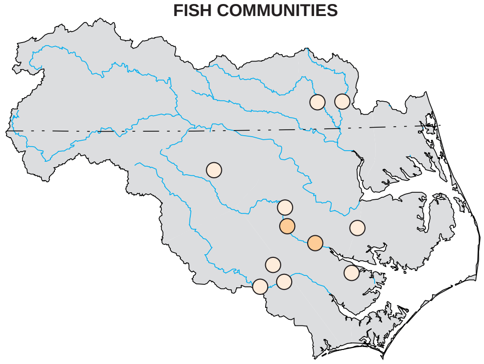
Trace element concentrations in bed sediment at 6 of the 10 sites were above the national median. Based on 1992 sampling of 22 sites, highest concentrations of trace elements in bed sediment were usually associated with urban basins.

SEMIVOLATILE ORGANIC COMPOUNDS (SVOCs) in streambed sediments



SVOCs were generally low compared to those at other NAWQA sites nationwide. The sites with elevated concentrations are generally associated with urban areas.

FISH COMMUNITIES



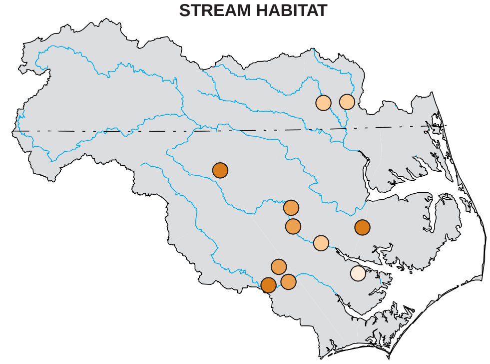
Fish communities in the Albemarle-Pamlico Drainage Basin were ranked as low to moderately degraded compared to other sites across the Nation; however, the metrics used to calculate the national rankings may not be appropriate for assessing fish community degradation in the Coastal Plain of North Carolina. The four national metrics are the percentage of individual fish belonging to species classified as (1) omnivorous, (2) non-native, (3) tolerant to human-caused stream degradation, and (4) having external physical anomalies.

CONCLUSIONS

Nutrient concentrations, organochlorine compounds, and trace elements in sediment at many of the sites in the Albemarle-Pamlico Drainage Basin were high compared to those at other NAWQA sites nationwide. The causes for the elevated concentrations are a combination of agricultural, urban, and natural sources.

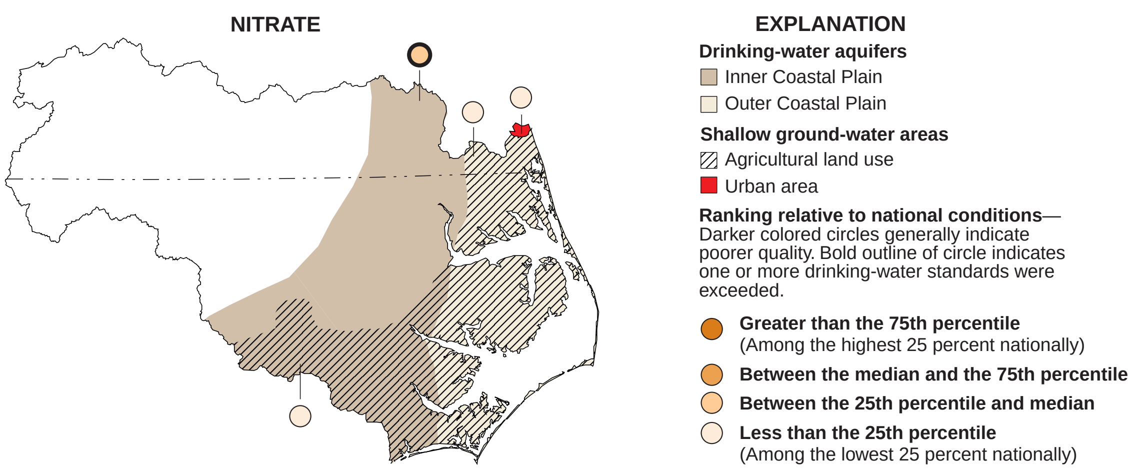
Although stream habitats tended to be more degraded than the national norm, fish communities tended to be less degraded than the national norm. This inconsistency may occur because the fish community metrics used to calculate the national index are insensitive to changes in fish community composition that occur as a result of habitat degradation in the Coastal Plain.

STREAM HABITAT



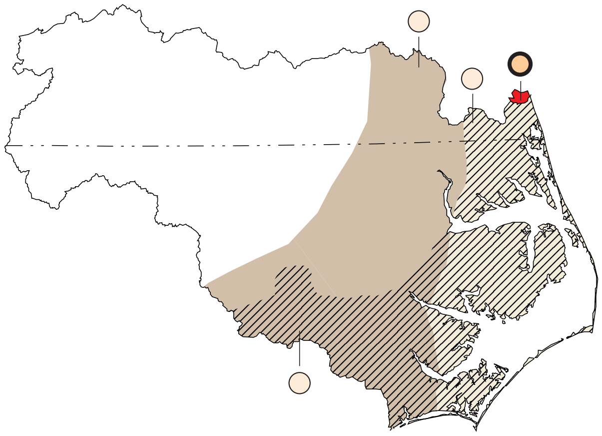
Based on stream modification, bank erosion, bank stability, and riparian vegetation density, sites in the Study Unit were moderately to highly degraded when compared to other sites in the Nation. This degradation reflects the presence of extensive and widespread channel modifications made in past decades to improve drainage and the presence of many areas susceptible to bank erosion.

Five major water-quality characteristics were evaluated for ground-water studies in each NAWQA Study Unit. Ground-water resources were divided into two categories: (1) drinking-water aquifers, and (2) shallow ground water underlying agricultural or urban areas. Summary scores were computed for each characteristic for all aquifers and shallow ground-water areas that had adequate data. Scores for each aquifer and shallow ground-water area in the Albemarle-Pamlico Drainage Basin were compared to scores for all aquifers and shallow ground-water areas sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared to that of other NAWQA ground-water studies. Water-quality conditions for each drinking-water aquifer also are compared to established drinking-water standards and criteria for protection of human health. (Methods used to compute rankings and evaluate standards and criteria are described by Gilliom and others, in press.)



Nitrate concentrations in ground water were low relative to national conditions. However, certain areas of the Albemarle-Pamlico Drainage Basin have higher concentrations than others. The highest concentrations are associated with well-drained soils of the inner Coastal Plain. About 5 percent of the wells in shallow aquifers of the inner Coastal Plain and 3 percent in the outer Coastal Plain exceeded the 10-mg/L drinking-water standard (U.S. Environmental Protection Agency, 1986).

DISSOLVED SOLIDS



Dissolved-solids concentrations in ground water were among the lowest relative to national conditions. The ground-water samples tested were from shallow, unconsolidated sedimentary units in the Coastal Plain, which contain relatively few easily dissolved minerals.

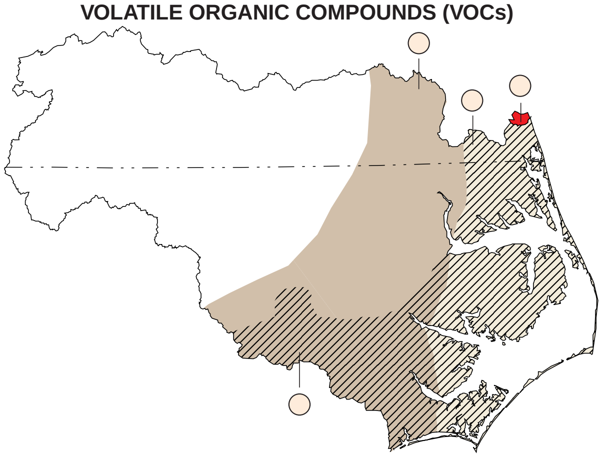
CONCLUSIONS

Nitrate concentrations in shallow ground water in the Coastal Plain of the Albemarle-Pamlico Drainage Basin were among the lowest nationally. The highest concentrations were detected in shallow aquifers of the inner Coastal Plain.

Dissolved-solids concentrations and volatile organic compound detection rates were low compared to those for the rest of the Nation.

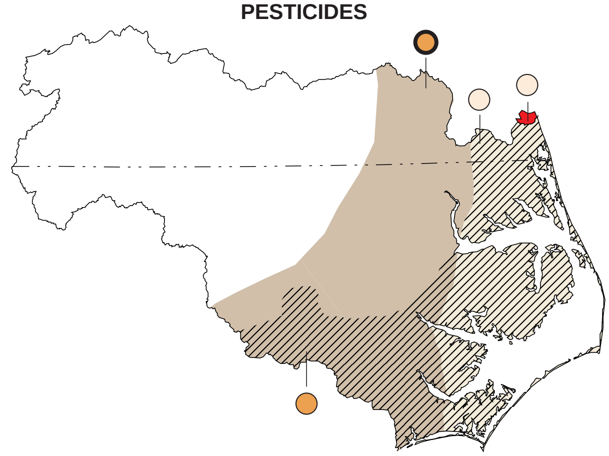
Frequency of detections of herbicides and their metabolites were among the highest nationally in agricultural areas of the outer Coastal Plain. However, the concentrations detected were less than drinking-water standards for selected herbicides.

VOLATILE ORGANIC COMPOUNDS (VOCs)



Volatile organic compound detections in ground water were among the lowest in the Nation. Only four compounds were detected in ground water in three wells in the Coastal Plain, and these concentrations were below drinking-water standards. However, these compounds may be more common in urban areas not sampled in this study.

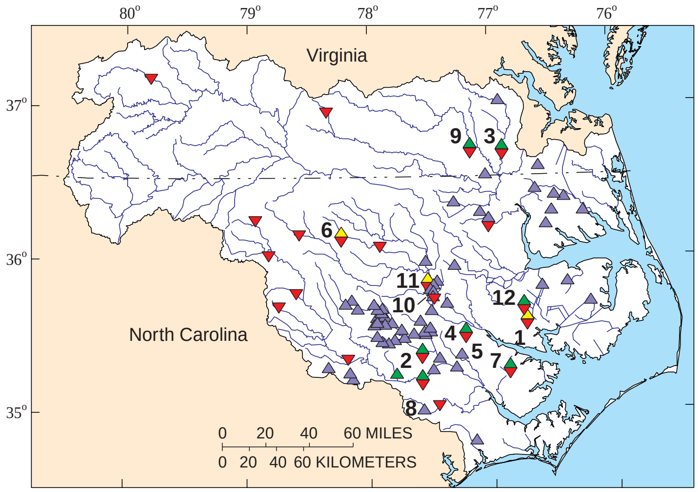
PESTICIDES



Pesticide detections in the agricultural areas of the Coastal Plain were among the highest nationally. Three herbicides or their metabolites were detected at concentrations greater than 0.1 g/Lin shallow ground water. However, in general, pesticides applied to crops appeared in shallow ground water at concentrations less than drinking-water standards.

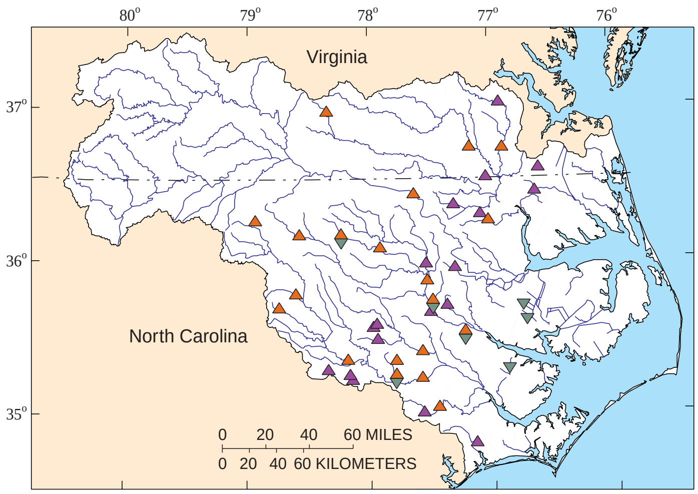
STREAM CHEMISTRY

SITE NUMBER	SITE NAME
1	Albemarle Canal at Swindell, N.C.
2	Bear Creek near Mays Store, N.C.
3	Blackwater River at Franklin, Va.
4	Chicod Creek near Simpson, N.C.
5	Contentnea Creek at Hookerton, N.C.
6	Devil's Cradle Creek near Alert, N.C.
7	Durham Creek at Edward, N.C.
8	Neuse River at Kinston, N.C.
9	Nottoway River near Sebrell, Va.
10	Pete Mitchell Swamp near Penny Hill, N.C.
11	Tar River at Tarboro, N.C.
12	Van Swamp at Hoke, N.C.



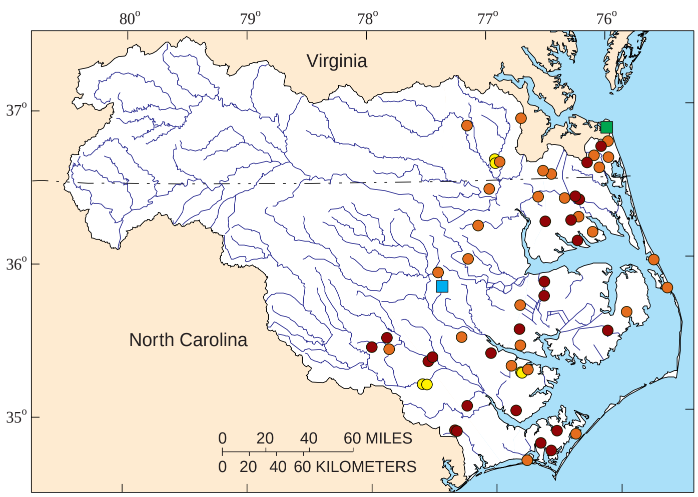
EXPLANATION
- BOTTOM SEDIMENT SURVEY
- WATER CHEMISTRY—Basic Fixed Sites
- WATER CHEMISTRY—Intensive Fixed Sites
- WATER CHEMISTRY—Synoptic Sites

STREAM ECOLOGY



EXPLANATION
- CONTAMINANTS IN TISSUES
- INTENSIVE ECOLOGICAL ASSESSMENTS
- ECOLOGICAL SYNOPTIC STUDIES

GROUND-WATER CHEMISTRY



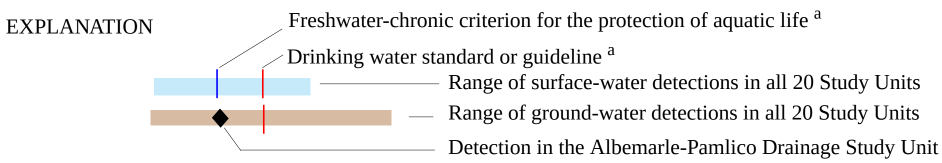
EXPLANATION
- AQUIFER SURVEY
- LAND-USE EFFECTS SURVEY
- MUNICIPAL WELLS
- FLOW-PATH STUDY AREA
- URBAN LAND-USE STUDY AREA

SUMMARY OF DATA COLLECTION IN THE ALBEMARLE-PAMLICO STUDY UNIT, 1992–95

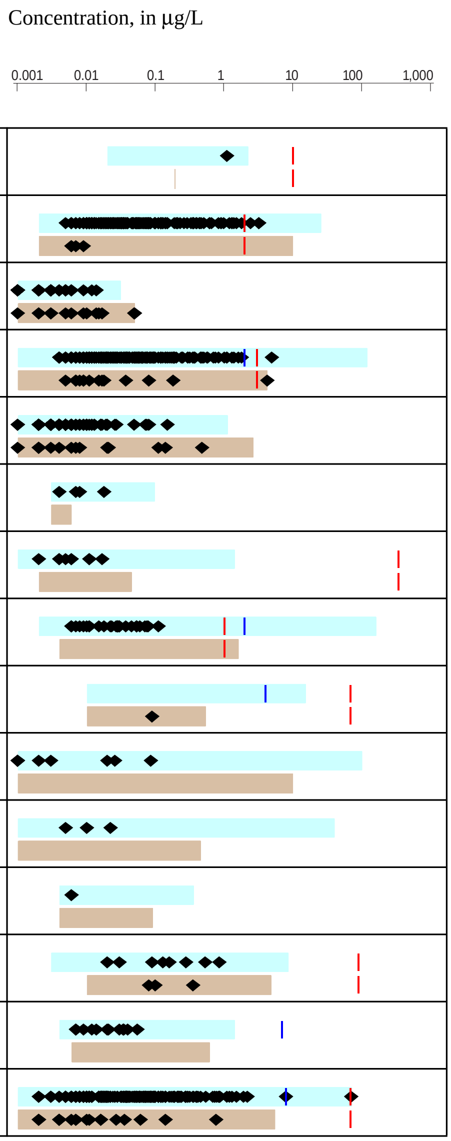
Study component	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
Stream Chemistry				
Bottom-sediment survey	Determine presence of potentially toxic compounds attached to sediments in major streams.	Sample depositional zones at selected sites basin-wide for trace elements and hydrophobic organic compounds.	22	1 (in 1992)
Water chemistry—Basic Fixed Sites	Describe concentrations and loads of chemicals, suspended sediment, and nutrients at selected sites basinwide.	Sample at or near sites where streamflow is measured continuously for major ions, organic carbon, suspended sediment, and nutrients.	12	~12 per year, 3 years
Water chemistry—Intensive Fixed Sites	Determine concentration and timing of agriculture-related compounds that run off to streams.	Subset of basinwide chemistry stations where 80 pesticides are sampled at least monthly and during selected runoff events.	4	~25 in 1993 ~ 7 in 1994
Water chemistry—Synoptic sites	Describe seasonal occurrence and spatial distribution of contamination over broad areas and how well the chemistry stations represent the entire basin.	Sample streams for pesticides and(or) nutrients, major ions, suspended sediment, organic carbon, and streamflow.	66	1–6 in 2-year period
Stream Ecology				
Contaminants in tissues	Determine occurrence and distribution of contaminants that can accumulate in tissues of aquatic organisms.	Collect and analyze Asiatic clams (*Corbicula fluminea*) and redbreast sunfish (*Lepomis auritus*) for trace elements and organochlorine compounds.	19	1 (in 1992)
Intensive ecological assessments	Assess in detail biological communities and habitat representing selected environmental settings.	Sample and quantify fish, macroinvertebrates, and algae at a subset of the water chemistry basic sites; quantitatively describe stream habitat for these organisms; replicate sampling over three stream reaches at four sites.	7	1–2 in 3-year period
Ecological synoptic studies	Determine presence and community structure of aquatic species and habitat in representative streams across the basin.	Sample and quantify fish and(or) macroinvertebrates and(or) algae, and describe habitat at selected water-chemistry sites in the Coastal Plain.	46	1–2 in 3-year period
Ground-Water Chemistry				
Aquifer survey	Describe the overall water quality and natural chemical patterns in aquifers.	Sample wells within the shallow aquifers of the Coastal Plain for major ions, nutrients, pesticides, volatile organic compounds, trace elements, and radionuclides; six deep municipal wells sampled in areas of significant drawdown.	35	1
Land-use effects	Determine the effects of specific land use on the quality of shallow ground water.	Sample shallow wells in corn and soybean areas for major ions, nutrients, pesticides, and volatile organic compounds, (some wells sampled only for nitrate, atrazine, and related compounds). Sample wells in urban area, Virginia Beach, Va., for major ions, nutrients, pesticides, and volatile organic compounds.	52	1
Flow-path study	Describe land-use effects on surficial aquifers along ground-water flow from areas of recharge beneath the land use to discharge to a stream.	Sample clusters of wells installed along an approximate line of ground-water flow and at various depths within the surficial aquifers for land-use effects of corn and soybean cultivation; analyze for major ions, nutrients, and pesticides; volatile organic compounds and age-dating constituents analyzed once at some wells.	27	~4 per year

The following tables summarize data dollected for NAWQA studies from 1992 to 1995 by showing results for the Albemarle-Pamlico Drainage Study Unit compared to the NAWQA national range for each compound detected. The data were collected at a wide variety of places and times. In order to represent the wide concentration ranges observed among Study Units, logarithmic scales are used to emphasize the general magnitude of concentrations (such as 10, 100, or 1,000), rather than the precise number. The complete dataset used to construct these tables is available upon request. The rate of detection for ground water in this table may differ from the rate reported in text because all wells sampled are included here and only 49 wells throughout the Coastal Plain are referred to in text discussion.

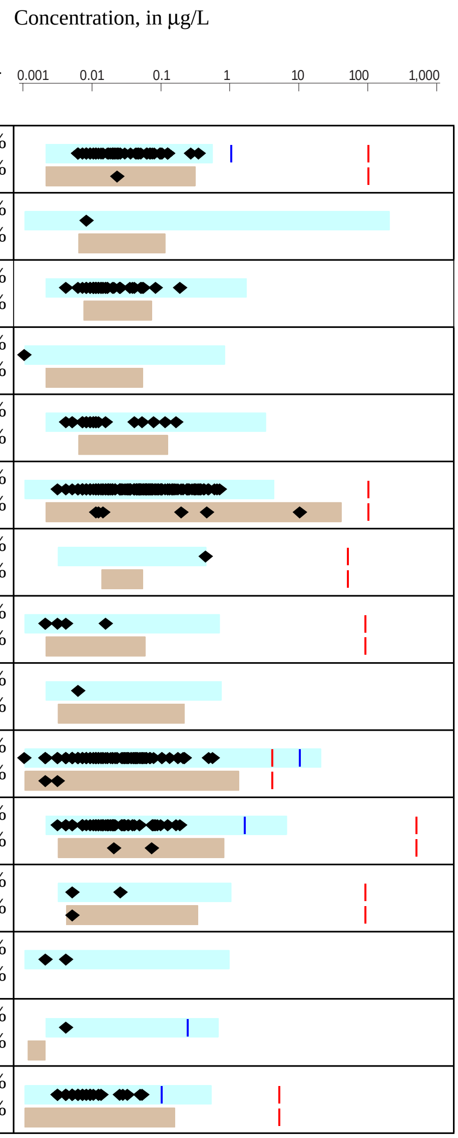
Concentrations of herbicides, insecticides, volatile organic compounds, and nutrients detected in ground and surface waters of the Albemarle-Pamlico Drainage Study Unit. [mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; %, percent; <, less than; - -, not measured; trade names may vary]



Herbicide (Trade or common name)	Rate of detection[b]
Acifluorfen (Blazer, Tackle 2S)	1% 0%
Alachlor (Lasso)	63% <1%
2,6-Diethylaniline (Alachlor metabolite)	1% 4%
Atrazine (AAtrex, Gesaprim)	70% 6%
Deethylatrazine[c] (Atrazine metabolite)	9% 4%
Benfluralin (Balan, Benefin, Bonalan)	<1% 0%
Butylate (Sutan, Genate Plus, butilate)	1% 0%
Cyanazine (Bladex, Fortrol)	10% 0%
2,4-D (2,4-PA)	0% 1%
DCPA (Dacthal, chlorthal-dimethyl)	1% 0%
EPTC (Eptam)	1% 0%
Ethalfluralin (Sonalan,Sonalen)	<1% 0%
Fluometuron (Flo-Met, Cotoran)	8% 3%
Linuron (Lorox, Linex)	4% 0%
Metolachlor (Dual, Pennant)	80% 7%



Herbicide (Trade or common name)	Rate of detection[b]
Metribuzin (Lexone, Sencor)	20% 1%
Molinate (Ordram)	<1% 0%
Napropamide (Devrinol)	16% 0%
Pebulate (Tillam)	<1% 0%
Pendimethalin (Prowl, Stomp)	5% 0%
Prometon (Gesagram, prometone)	59% 4%
Pronamide (Kerb, propyzamid)	<1% 0%
Propachlor (Ramrod, propachlore)	<1% 0%
Propanil (Stampede, Surcopur)	<1% 0%
Simazine (Aquazine, Princep, GEsatop)	32% <1%
Tebuthiuron (Spike, Perflan)	22% 1%
Terbacil[c] (Sinbar)	<1% <1%
Thiobencarb (Bolero, Saturn, benthiocarb)	<1% 0%
Triallate (Far-Go)	<1% 0%
Trifluralin (Treflan, Trinin, Elancolan)	4% 0%



Insecticide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.001 – 1,000)
Aldicarb[c] (Temik)	1% 0%	
Aldicarb sulfone[c] (Standak)	0% 2%	
Aldicarb sulfoxide[c] (Aldicarb metabolite)	0% 3%	
Azinphos-methyl[c] (Guthion, Gusathion)	<1% 0%	
Carbaryl[c] (Sevin, Savit)	19% <1%	
Carbofuran[c] (Furadan, Curaterr)	7% 2%	
Chlorpyrifos (Dursban, Lorsban)	5% <1%	
p,p'-DDE (*p,p'*-DDT metabolite)	<1% <1%	
Diazinon	8% 7%	
Dieldrin (Panoram D-31, Octalox)	1% 1%	
Ethoprop (Mocap, Prophos)	2% 0%	
Fonofos (Dyfonate)	2% 0%	
gamma-HCH	2% 0%	
Malathion (maldison, malathon, Cythion)	2% 0%	
cis-Permethrin[c] (Ambush, Pounce)	<1% 0%	
Phorate (Thimet, Rampart)	2% 0%	
Propargite (Comite, Omite, BPPS)	1% 0%	
Terbufos (Counter)	<1% 0%	

Volatile organic compound (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.01 – 1,000)
1,2,4-Trimethylbenzene (Pseudocumene)	-- 1%	
1,3,5-Trimethylbenzene (Mesitylene)	-- 1%	
Chlorobenzene (Monochlorobenzene)	-- 2%	

Volatile organic compound (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.01 – 1,000)
Chloroethene (Vinyl Chloride)	-- 1%	
Dimethylbenzenes (Xylenes (total))	-- 1%	
Ethylbenzene (Phenylethane)	-- 1%	
Isopropylbenzene (Cumene)	-- 1%	
Methylbenzene (Toluene)	-- 1%	
Naphthalene	-- 1%	
total Trihalomethanes	-- 1%	
Trichlorofluoromethane (CFC 11)	-- 1%	
n-Propylbenzene (Isocumene)	-- 1%	

Volatile organic compound (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.01 – 100,000)
Methyl *tert*-butyl[d] ether (MTBE)	-- 1%	

Nutrient (Trade or common name)	Rate of detection [b]	Concentration, in mg/L (0.01 – 100,000)
Dissolved ammonia	95% 96%	
Dissolved ammonia plus organic nitrogen as nitrogen	96% 67%	
Dissolved phosphorus as phosphorus	81% 53%	
Dissolved nitrite plus nitrate	83% 52%	

Other	Rate of detection [b]	Concentration, in pCi/L (1 – 100,000)
Radon 222	-- 80%	

Herbicides, insecticides, volatile organic compounds, and nutrients not detected in ground and surface waters of the Albemarle-Pamlico Drainage Study Unit.

Herbicides

2,4,5-T

2,4,5-TP (Silvex, Fenoprop)

2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone)

Acetochlor (Harness Plus, Surpass)

Bentazon (Basagran, Bentazone, Bendioxide)

Bromacil (Hyvar X, Urox B, Bromax)

Bromoxynil (Buctril, Brominal)

Chloramben (Amiben, Amilon-WP, Vegiben)

Clopyralid (Stinger, Lontrel, Reclaim, Transline)

Dacthal mono-acid (Dacthal metabolite)

Dicamba (Banvel, Dianat, Scotts Proturf)

Dichlorprop (2,4-DP, Seritox 50, Kildip, Lentemul)

Dinoseb (Dinosebe)

Diuron (Crisuron, Karmex, Direx, Diurex)

Fenuron (Fenulon, Fenidim)

MCPA (Rhomene, Rhonox, Chiptox)

MCPB (Thistrol)

Neburon (Neburea, Neburyl, Noruben)

Norflurazon (Evital, Predict, Solicam, Zorial)

Oryzalin (Surflan, Dirimal)

Picloram (Grazon, Tordon)

Propham (Tuberite)

Triclopyr (Garlon, Grandstand, Redeem, Remedy)

Insecticides

3-Hydroxycarbofuran (Carbofuran metabolite)

Disulfoton (Disyston, Di-Syston, Frumin AL, Solvirex, Ethylthiodemeton)

Methiocarb (Slug-Geta, Grandslam, Mesurol)

Methomyl (Lanox, Lannate, Acinate)

Methyl parathion (Penncap-M, Folidol-M, Metacide, Bladan M)

Oxamyl (Vydate L, Pratt)

Parathion (Roethyl-P, Alkron, Panthion, Phoskil)

Propoxur (Baygon, Blattanex, Unden, Proprotox)

alpha-HCH (*alpha*-BHC, *alpha*-lindane, *alpha*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

Volatile organic compounds

1,1,1,2-Tetrachloroethane (1,1,1,2-TeCA)

1,1,1-Trichloroethane (Methylchloroform)

1,1,2,2-Tetrachloroethane

1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113)

1,1,2-Trichloroethane (Vinyl trichloride)

1,1-Dichloroethane (Ethylidene dichloride)

1,1-Dichloroethene (Vinylidene chloride)

1,1-Dichloropropene

1,2,3-Trichlorobenzene (1,2,3-TCB)

1,2,3-Trichloropropane (Allyl trichloride)

1,2,4-Trichlorobenzene

1,2-Dibromo-3-chloropropane (DBCP, Nemagon)

1,2-Dibromoethane (EDB, Ethylene dibromide)

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,2-Dichloroethane (Ethylene dichloride)

1,2-Dichloropropane (Propylene dichloride)

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,3-Dichloropropane (Trimethylene dichloride)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

1-Chloro-2-methylbenzene (*o*-Chlorotoluene)

1-Chloro-4-methylbenzene (*p*-Chlorotoluene)

2,2-Dichloropropane

Benzene

Bromobenzene (Phenyl bromide)

Bromochloromethane (Methylene chlorobromide)

Bromomethane (Methyl bromide)

Chloroethane (Ethyl chloride)

Chloromethane (Methyl chloride)

Dibromomethane (Methylene dibromide)

Dichlorodifluoromethane (CFC 12, Freon 12)

Dichloromethane (Methylene chloride)

Ethenylbenzene (Styrene)

Hexachlorobutadiene

Tetrachloroethene (Perchloroethene)

Tetrachloromethane (Carbon tetrachloride)

Trichloroethene (TCE)

cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)

cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)

n-Butylbenzene (1-Phenylbutane)

p-Isopropyltoluene (*p*-Cymene)

sec-Butylbenzene

tert-Butylbenzene

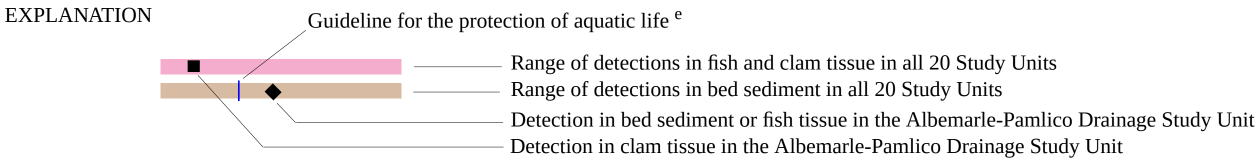
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)

trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)

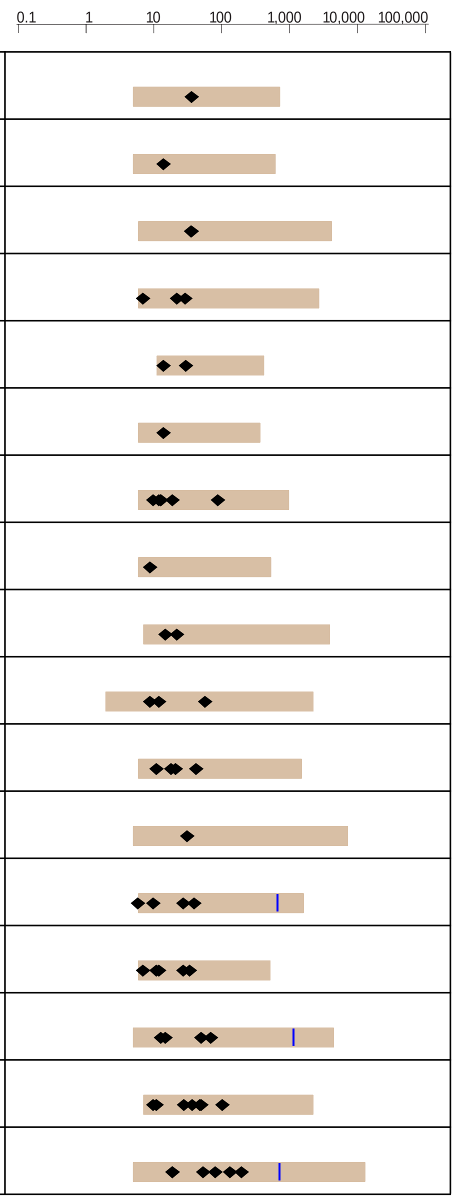
Nutrients

No non-detections

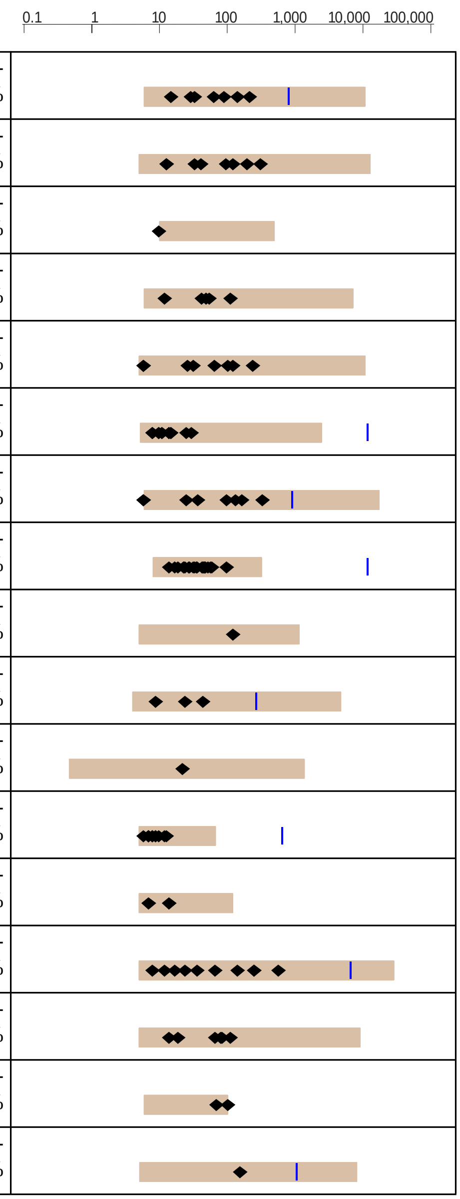
Concentrations of semivolatile organic compounds, organochlorine compounds, and trace elements detected in fish and clam tissue and bed sediment of the Albemarle-Pamlico Drainage Study Unit. [µg/g, micrograms per gram; µg/kg, micrograms per kilogram; %, percent; <, less than; - -, not measured; trade names may vary]



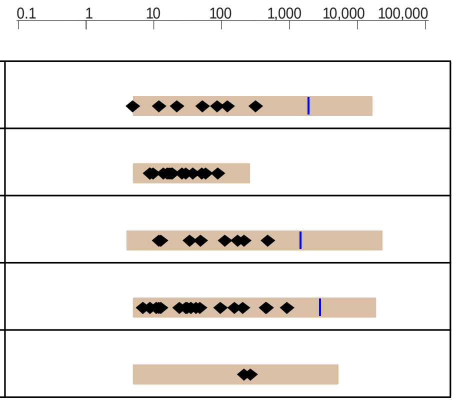
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg (0.1, 1, 10, 100, 1,000, 10,000, 100,000)
1,6-Dimethylnaphthalene	-- 5%	
1-Methyl-9H-fluorene	-- 5%	
1-Methylphenanthrene	-- 9%	
1-Methylpyrene	-- 14%	
2,2-Biquinoline	-- 9%	
2,3,6-Trimethylnaphthalene	-- 5%	
2,6-Dimethylnaphthalene	-- 27%	
2-Ethylnaphthalene	-- 5%	
2-Methylanthracene	-- 9%	
4,5-Methylenephenanthrene	-- 14%	
9H-Carbazole	-- 18%	
9H-Fluorene	-- 5%	
Acenaphthylene	-- 18%	
Acridine	-- 23%	
Anthracene	-- 18%	
Anthraquinone	-- 32%	
Benz[a]anthracene	-- 27%	



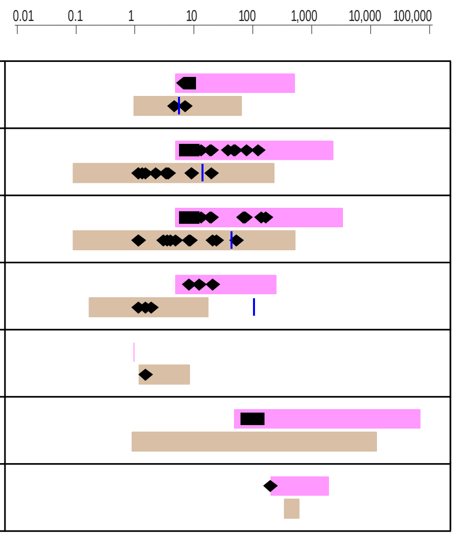
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg (0.1, 1, 10, 100, 1,000, 10,000, 100,000)
Benzo[a]pyrene	-- 32%	
Benzo[b]fluoranthene	-- 36%	
Benzo[c]cinnoline	-- 5%	
Benzo[ghi]perylene	-- 23%	
Benzo[k]fluoranthene	-- 36%	
Butylbenzylphthalate	-- 55%	
Chrysene	-- 36%	
Di- n -butylphthalate	-- 100%	
Di- n -octylphthalate	-- 5%	
Dibenz[a,h] anthracene	-- 14%	
Dibenzothiophene	-- 5%	
Diethylphthalate	-- 50%	
Dimethylphthalate	-- 18%	
Fluoranthene	-- 45%	
Indeno[1,2,3- cd] pyrene	-- 27%	
Isoquinoline	-- 9%	
Naphthalene	-- 5%	



Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
Phenanthrene	-- 32%	
Phenol	-- 68%	
Pyrene	-- 36%	
bis(2-Ethylhexyl)phthalate	-- 100%	
p-Cresol	-- 9%	



Organochlorine compound (Trade name)	Rate of detection [b]	Concentration, in µg/kg
total-Chlordane	20% 9%	
p,p'-DDE	52% 50%	
total-DDT	52% 50%	
Dieldrin (Panoram D-31, Octalox)	12% 14%	
Endosulfan I (*alpha*-endosulfan, Thiodan)	-- 5%	
PCB, total	8% 0%	
Toxaphene (camphechlor, Hercules)	4% 0%	



Trace element	Rate of detection [b]	Concentration, in µg/g
Arsenic	70% 100%	
Cadmium	93% 100%	
Chromium	100% 100%	
Copper	100% 100%	
Lead	13% 100%	
Mercury	97% 100%	
Nickel	90% 100%	
Selenium	90% 100%	
Zinc	100% 100%	

Semivolatile organic compounds, organochlorine compounds, and trace elements not detected in fish and clam tissue and bed sediment of the Albemarle-Pamlico Drainage Study Unit.

Semivolatile organic compounds

1,2,4-Trichlorobenzene

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,2-Dimethylnaphthalene

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

2,4-Dinitrotoluene

2,6-Dinitrotoluene

2-Chloronaphthalene

2-Chlorophenol

3,5-Dimethylphenol

4-Bromophenyl-phenylether

4-Chloro-3-methylphenol

4-Chlorophenyl-phenylether

Acenaphthene

Azobenzene

C8-Alkylphenol

Isophorone

N-Nitrosodi-n-propylamine

N-Nitrosodiphenylamine

Nitrobenzene

Pentachloronitrobenzene

Phenanthridine

Quinoline

bis (2-Chloroethoxy)methane

Organochlorine compounds

Aldrin (HHDN, Octalene)

Chloroneb (chloronebe, Demosan, Soil Fungicide 1823)

DCPA (Dacthal, chlorthal-dimethyl)

Endrin (Endrine)

Heptachlor epoxide (Heptachlor metabolite)

Heptachlor (Heptachlore, Velsicol 104)

Hexachlorobenzene (HCB)

Isodrin (Isodrine, Compound 711)

Mirex (Dechlorane)

Pentachloroanisole (PCA, pentachlorophenol metabolite)

alpha-HCH (*alpha*-BHC, *alpha*-lindane, *alpha*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

beta-HCH (*beta*-BHC, *beta*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

cis-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

delta-HCH (*delta*-BHC, *delta*-hexachlorocyclohexane, *delta*-benzene hexachloride)

gamma-HCH (Lindane, *gamma*-BHC, Gammexane, Gexane, Soprocide, *gamma*-hexachlorocyclohexane, *gamma*-benzene hexachloride)

o,p'-Methoxychlor

p,p'-Methoxychlor (Marlate, methoxychlore)

trans-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

Trace elements

No non-detections

[a] Selected water-quality standards and guidelines (Gilliom, Mueller, and Nowell, in press).

[b] Rates of detection are based on the number of analyses and detections in the Study Unit, not on national data. Rates of detection for herbicides and insecticides were computed by only counting detections equal to or greater than 0.01 µg/L in order to facilitate equal comparisons among compounds, which had widely varying detection limits. For herbicides and inseticides, a detection rate of "<1%" means that all detections are less than 0.01 µg/L, or the detection rate rounds to less than one percent. For other compound groups, all detections were counted and minimum detection limits for most compounds were similar to the lower end of the national ranges shown. Method detection limits for all compounds in these tables are summarized in Gilliom, Mueller, and Nowell (in press).

[c] Detections of these compounds are reliable, but concentrations are determined with greater uncertainty than for the other compounds and are reported as estimated values (Zaugg and others, 1995).

[d] The guideline for methyl *tert*-butyl ether is between 20 and 40 µg/L; if the tentative cancer classification C is accepted, the lifetime health advisory will be 20 µg/L (Gilliom, Mueller, and Nowell, in press).

[e] Selected sediment-quality guidelines (Gilliom, Mueller, and Nowell, in press).

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The terms in this glossary were compiled from numerous sources. Some definitions have been modified and may not be the only valid ones for these terms.

Algae—Chlorophyll-bearing nonvascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.

Aquatic-life criteria—Water-quality guidelines for protection of aquatic life. Often refers to U.S. Environmental Protection Agency water-quality criteria for protection of aquatic organisms. *See also* Water-quality guidelines, Water-quality criteria, and Freshwater chronic criteria.

Aquifer—A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Base flow—Sustained, low flow in a stream; ground-water discharge is the source of base flow in most places.

Basic Fixed Sites—Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of streamwater in relation to hydrologic conditions and environmental settings.

Basin—*See* Drainage basin.

Bed sediment—The material that temporarily is stationary in the bottom of a stream or other watercourse.

Bioaccumulation—The biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium. Also, the process whereby a substance enters organisms through the gills, epithelial tissues, dietary, or other sources.

Breakdown product—A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process which may result in a more toxic or a less toxic compound and a more persistent or less persistent compound.

Channelization—Modification of a stream, typically by straightening the channel, to provide more uniform flow; often done for flood control or for improved agricultural drainage or irrigation.

Community—In ecology, the species that interact in a common area.

Concentration—The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as microgram per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

Degradation products—Compounds resulting from transformation of an organic substance through chemical, photochemical, and(or) biochemical reactions.

Denitrification—A process by which oxidized forms of nitrogen such as nitrate (NO_3^-) are reduced to form nitrites, nitrogen oxides, ammonia, or free nitrogen: commonly brought about by the action of denitrifying bacteria and usually resulting in the escape of nitrogen to the air.

Discharge—Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.

Dissolved solids—Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.

Drainage basin—The portion of the surface of the Earth that contributes water to a stream through overland runoff, including tributaries and impoundments.

Fertilizer—Any of a large number of natural or synthetic materials, including manure and nitrogen, phosphorus, and potassium compounds, spread on or worked into soil to increase its fertility.

Fixed Sites—NAWQA's most comprehensive monitoring sites. *See also* Basic Fixed Sites and Intensive Fixed Sites.

Flow path—An underground route for ground-water movement, extending from a recharge (intake) zone to a discharge (output) zone such as a shallow stream.

Freshwater chronic criteria—The highest concentration of a contaminant that freshwater aquatic organisms can be exposed to for an extended period of time (4 days) without adverse effects. *See also* Water-quality criteria.

Ground water—In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat—The part of the physical environment where plants and animals live.

Herbicide—A chemical or other agent applied for the purpose of killing undesirable plants. *See also* Pesticide.

Index of Biotic Integrity (IBI)—An aggregated number, or index, based on several attributes or metrics of a fish community that provides an assessment of biological conditions.

Indicator sites—Stream sampling sites located at outlets of drainage basins with relatively homogeneous land use and physiographic conditions; most indicator-site basins have drainage areas ranging from 20 to 200 square miles.

Integrator or Mixed-use site—Stream sampling site located at an outlet of a drainage basin that contains multiple environmental settings. Most integrator sites are on major streams with relatively large drainage areas.

Intensive Fixed Sites—Basic Fixed Sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.

Load—General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Median—The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.

Metabolite—A substance produced in or by biological processes.

Micrograms per liter (g/L)—A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Milligrams per liter (mg/L)—A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Nonpoint source—A pollution source that cannot be defined as originating from discrete points such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint-source pollution.

Pesticide—A chemical applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents, or other "pests."

Point source—A source at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.

Point-source contaminant—Any substance that degrades water quality and originates from discrete locations such as discharge pipes, drainage ditches, wells, concentrated livestock operations, or floating craft.

Refugium—An area that has escaped ecological changes occurring elsewhere and so provides a suitable habitat for relict species.

Sediment—Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, and are suspended or settled in water.

Sorption—General term for the interaction (binding or association) of a solute ion or molecule with a solid.

Species diversity—An ecological concept that incorporates both the number of species in a particular sampling area and the evenness with which individuals are distributed among the various species.

Species (taxa) richness—The number of species (taxa) present in a defined area or sampling unit.

Specific conductance—A measure of the ability of a liquid to conduct an electrical current.

Study Unit—A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geographically defined by a combination of ground- and surface-water features and generally encompass more than 4,000 square miles of land area.

Study-Unit Survey—Broad assessment of the water-quality conditions of the major aquifer systems of each Study Unit. The Study-Unit Survey relies primarily on sampling existing wells and, wherever possible, on existing data collected by other agencies and programs. Typically, 20 to 30 wells are sampled in each of three to five aquifer subunits.

Synoptic sites—Sites sampled during a short-term investigation of specific water-quality conditions during selected seasonal or hydrologic conditions to provide improved spatial resolution for critical water-quality conditions.

Tolerant species—Those species that are adaptable to (tolerant of) human alterations to the environment and often increase in number when human alterations occur.

Trace element—An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Triazine herbicide—A class of herbicides containing a symmetrical triazine ring (a nitrogen-heterocyclic ring composed of three nitrogens and three carbons in an alternating sequence). Examples include atrazine, propazine, and simazine.

Volatile organic compounds (VOCs)—Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

Water-quality criteria—Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water-quality criteria established by the U.S. Environmental Protection Agency. Water-quality criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water-quality guidelines—Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.

Water-quality standards—State-adopted and U.S. Environmental Protection Agency-approved ambient standards for water bodies. Standards include the use of the water body and the water-quality criteria that must be met to protect the designated use or uses.

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