Pesticides Commonly Were Detected in Santee Basin Streams

Thirty pesticides, including 22 herbicides and 8 insecticides, were detected in streams in the Santee Basin (Maluk and Kelley, 1998). Of the 161 surface-water samples collected, 141 contained at least one pesticide. At least one pesticide was detected at all of the sites, including forested sites that have little influence from humans.

Although detections were frequent, concentrations tended to be low, with no herbicides and only four insecticides and one metabolite exceeding aquatic-life criteria. None of the pesticide concentrations exceeded drinking-water standards. Thirteen of the 30 pesticides detected do not have aquatic criteria and 7 do not have drinking-water standards (U.S. Environmental Protection Agency, 1996).

Herbicides were the most commonly detected pesticides in streams. Atrazine, an herbicide used on corn as well as turfgrasses and golf courses, was detected at the most sites, occurring at 11 of the 13 sampling sites. Other frequently detected herbicides were simazine, metolachlor, and prometon.Tebuthiuron, an herbicide that generally is used to control weeds on highway and railroad rights-of-way, also was detected frequently.

Insecticides were detected much less frequently than herbicides, accounting for less than one-third of the pesticides detected. Most insecticides detected are used on agricultural and ornamental crops, lawns, livestock, and in homes and gardens. Those most commonly detected included chlorpyrifos, diazinon, malathion, and carbaryl.

Insecticides were detected most frequently in urban streams, such as Gills Creek in Columbia, S.C.

Urban Streams Contain More Pesticides than Other Streams

Pesticides were detected more frequently in urban streams than in agricultural streams (fig. 5). The most commonly detected herbicides—simazine, prometon, atrazine, and tebuthiuron—were detected nearly twice as frequently in water samples collected at urban sites than at agricultural sites. Conversely, some herbicides such as metolachlor and alachlor were detected almost exclusively at agricultural sites.

Insecticides were detected about four times more frequently at urban stream sites than at agricultural stream sites, and aquatic-life criteria were exceeded in nine samples collected at urban sites and in three samples collected at agricultural sites. The insecticide diazinon was detected only in urban streams, whereas chlorpyrifos was detected frequently in both urban and agricultural streams. This agrees with national findings in which insecticides were detected more frequently in urban than in

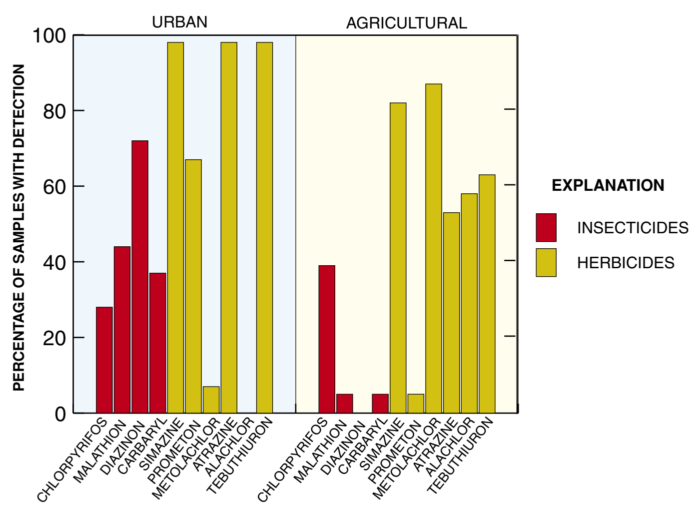


Figure 5. Pesticides, particularly insecticides, were detected more frequently in urban streams than in agricultural streams.

agricultural streams (U.S. Geological Survey, 1999).

These findings indicate that while agricultural activities contribute pesticides to surface water, concentrations are rarely high enough to affect aquatic life. The consequences of urban and suburban use of pesticides is much more significant, with concentrations of insecticides frequently at levels that can affect aquatic life.

Pesticides Showed Seasonal Patterns in Streams

Some herbicides showed patterns of occurrence that can be related to seasonal applications and weather patterns. At Gills Creek, an urban stream, concentrations of herbicides, such as atrazine, simazine, and tebuthiuron, peaked in the spring following application and gradually decreased over the summer (fig. 6). Atrazine and simazine followed a similar pattern at Cow Castle Creek, an agricultural stream, with the addition of a second peak in early fall. The highest concentrations at all sites were observed during storms that followed applications.

Understanding these patterns of occurrence is important because sampling programs need to be designed so that critical periods of high pesticide concentrations are monitored. This information also can be used by environmental managers to assess risk associated with agricultural chemical use.

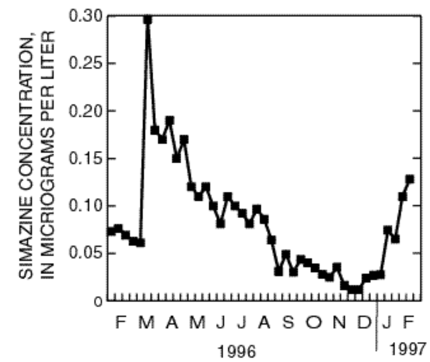


Figure 6. Herbicide concentrations generally peaked following spring applications in Gills Creek, an urban stream.

Few Pesticides Were Detected in Drinking-Water Supply Aquifers

Of the 90 drinking-water, industrial, and irrigation supply wells sampled in the Floridan, Piedmont, and Sandhills aquifers, 17 had detectable concentrations of pesticides; of those, only two wells had pesticide concentrations that exceeded USEPA drinking-water standards (U.S. Environmental Protection Agency, 1996). Eleven of the 34 pesticides detected in drinking-water supply aquifers did not have water-quality standards.

The Sandhills aquifers are more susceptible to contamination than the other aquifers, as is illustrated by the larger number of pesticides detected and the higher detection frequency in the Sandhills aquifers than in the Piedmont and Floridan aquifers (fig.7). In addition, the two wells that had pesticide concentrations exceeding USEPA drinking-water standards were located in the Sandhills aquifers. Drinking water obtained from the Piedmont and Floridan aquifers is probably unlikely to contain pesticides at harmful levels; however, the high rate of detection and large number of pesticides detected in the Sandhills aquifers are a cause for concern.

Ground-water samples are pumped directly into a mobile laboratory for processing samples and conducting field analyses.

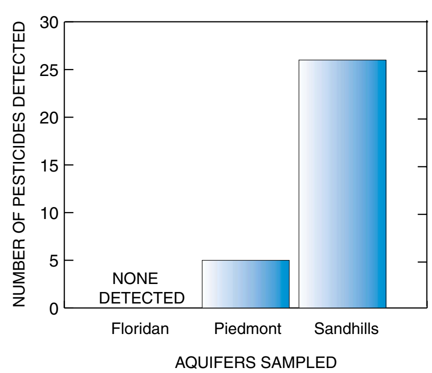


Figure 7. The large number of pesticides detected in the Sandhills aquifers illustrates its relatively high susceptibility to contamination.

The differences in the rate and number of detections in the aquifers may be related to differences in aquifer properties. The Sandhills are largely composed of layers of coarse and fine sand with various quantities of clay. No continuous confining unit or soil layer overlies the aquifer to impede the movement of contaminants into ground water. At the other extreme, the Floridan aquifer has an overlying clay confining layer that impedes vertical movement of contaminants throughout much of its extent (Aucott and others, 1987). The Piedmont aquifer has an overlying layer of weathered bedrock that contains abundant clay. The thickness of this unit is highly variable, but generally it impedes rapid vertical movement of contaminants from land surface to ground water.

Pesticides Were Common in Shallow Ground Water in Urban and Agricultural Areas

Pesticides were detected in 24 of 30 shallow wells in urban areas and in 22 of 30 wells in agricultural areas (Reuber, 1999). Dieldrin concentrations exceeded drinking-water standards in four urban wells; however, the wells sampled were installed for monitoring purposes only and are not drinking-water supply wells. Dieldrin also exceeded aquatic-life standards in these four urban wells, and tebuthiuron concentrations exceeded aquatic-life standards in one agricultural well. Generally, ground-water concentrations are not compared to aquatic-life standards; however, these concentrations can be of concern because shallow ground water can discharge to streams, elevating the pesticide concentrations in surface water.

Pesticides were detected in ground water in urban areas about twice as frequently as in agricultural areas (fig. 8). Some pesticides detected in urban and agricultural ground water were the same, although insecticides were detected more frequently in urban ground water. This was similar to national NAWQA findings. The insecticide most frequently detected at urban sites was dieldrin. Although its agricultural use was canceled in the mid-1970s, dieldrin (and aldrin, which breaks down to dieldrin) was used for termite control until the mid-1980s and is a persistent compound (Barbash and Resek, 1996). Dieldrin was also the most commonly detected pesticide in urban ground water nationally (U.S. Geological Survey, 1999).

Shallow wells for the urban ground-water study were installed by the U.S. Geological Survey with assistance from the South Carolina Geological Survey.

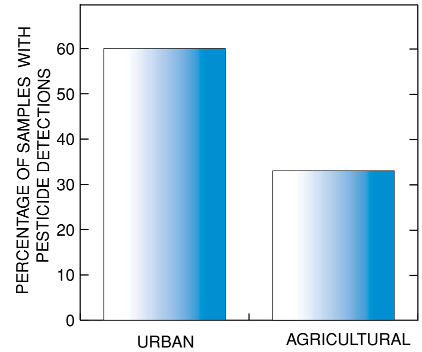


Figure 8. Pesticides were detected more frequently at urban ground-water sites than at agricultural sites.

Organochlorine Pesticides Were Detected in Bed Sediment and Tissues

Fourteen pesticides were detected in streambed-sediment samples, and 21 of 24 sites sampled had at least one detectable pesticide. All of the pesticides detected in sediment were organochlorine insecticides, such as chlordane, dieldrin, mirex, and DDT and its derivatives. Many of these compounds had their agricultural uses cancelled more than 20 years ago, yet they still appear in sediment samples. The reason for this is because the compounds are persistent, or are highly resistant to chemical breakdown.

Of the compounds detected, only DDE, a breakdown product of DDT, exceeded guidelines for the protection of aquatic life. The guidelines were exceeded at three sites, all of which are in basins with a high percentage of agricultural land. In addition, DDT concentrations were only slightly below the aquatic guidelines at several sites. Comparisons of land use to concentrations of organochlorine pesticides generally did not show strong relations, primarily because these insecticides were used in both urban and agricultural settings (fig. 9). The only prominent rela-

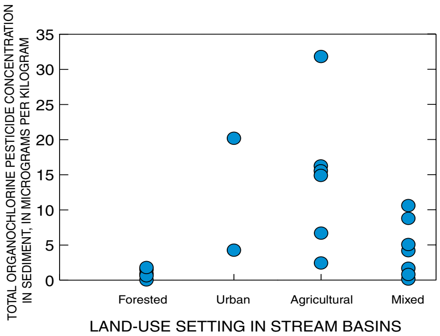


Figure 9. Bed sediment in forested settings has significantly lower total organochlorine pesticide concentrations than bed sediment in other land-use settings.

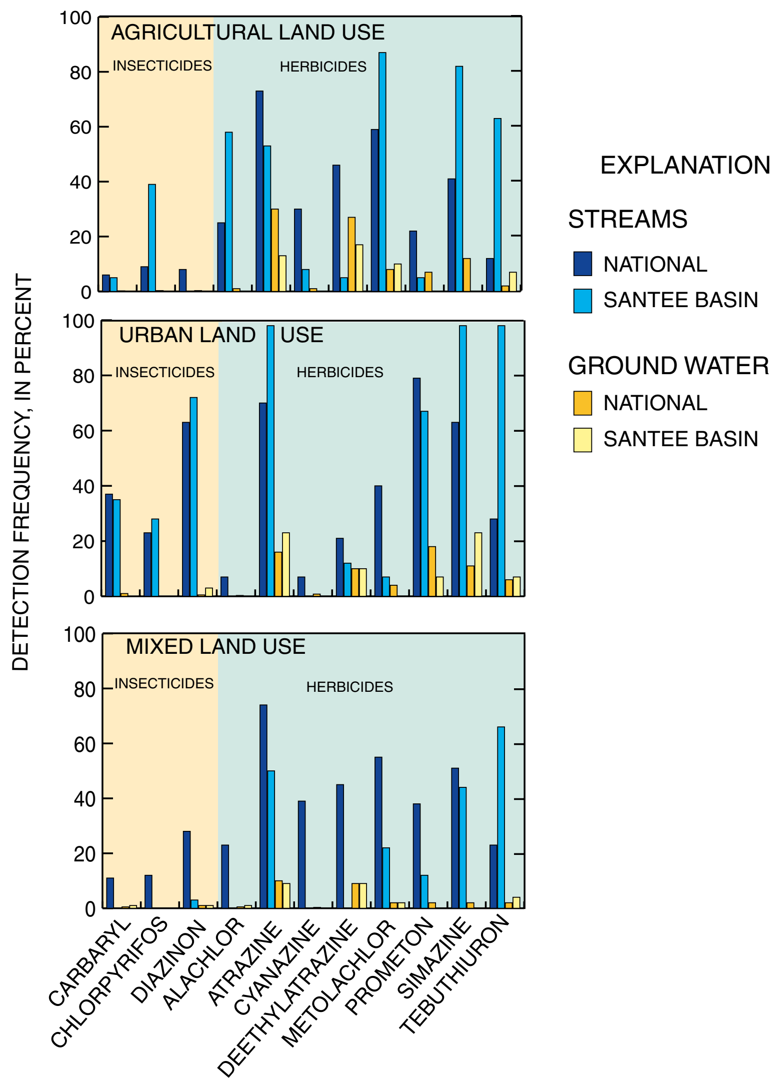
tion is the uniformly low levels of these pesticides detected at forested sites where these chemicals were less likely to be used.

The same pesticides detected in sediments were also in clam and fish tissues. Concentrations measured were generally much higher in tissue than in sediment; however, a direct comparison of these concentrations may not be valid because of potential differences in exposure rates of sediment and fish, differences in uptake by sediment organic carbon and tissue, and partitioning in fish tissue.

Organochlorine pesticides, such as DDT, can be found in streambed sediment and can accumulate in tissues of fish, such as this carp.

SANTEE BASIN PESTICIDE FINDINGS WERE SIMILAR TO NATIONAL FINDINGS

The most common pesticides detected in the Santee Basin included atrazine, simazine, tebuthiuron, prometon, and metolachlor. These pesticides were among the top 11 pesticides detected nationally. Consistent with national findings, herbicides were the most common type of pesticide detected in streams and aquifers in agricultural areas in the Santee Basin, whereas insecticides were more prevalent in urban areas. Overall, streams and aquifers that integrate different land uses had lower concentrations of pesticides than those that are dominated by either agricultural or urban land uses. Detections of pesticides in mixed land-use streams in the Santee Basin overall were much less frequent than national detections. The most striking differences between national and Santee Basin findings are the more frequent detections of alachlor, diazinon, and metolachlor in agricultural streams, simazine in agricultural and urban streams, and tebuthiuron in all land-use settings in the Santee Basin. The greater detection frequency does not appear to result from higher use of these compounds in the Santee Basin.



Phosphorus Concentrations in Streams Frequently Exceeded USEPA Goals

Nutrients measured in streams in the Santee Basin, such as ammonia, nitrite, nitrate, phosphate, and orthophosphate, were elevated above background concentrations in areas affected by agricultural and urban runoff. Of these nutrients, the only one governed by a drinking-water standard is nitrite-plus-nitrate nitrogen (hereinafter referred to as nitrate) because it is the only nutrient that directly affects human health. None of the surface-water samples had concentrations of nitrate that were above the drinking-water standard of 10 milligrams per liter (mg/L) (U.S. Environmental Protection Agency, 1996).

Phosphorus concentrations were above the USEPA goal in several rivers in the Santee Basin. For example, the flow-weighted mean annual concentration of total phosphorus in the South Fork Catawba River is about four times higher than the USEPA goal for streams entering a reservoir (U.S. Environmental Protection Agency, 1986) (fig. 10). This is important because many of the reservoirs in the Santee Basin are eutrophic; that is, they have high levels of nutrients that can result in excessive growth of algae (Stecker and Crocker, 1991). Much of the phosphorus and nitrogen that feeds the algae is carried into the reservoirs by major rivers. The South Fork Catawba River flows into Lake Wylie directly downstream of the sampling site and is the only stream sampled that enters directly into a reservoir.

The USEPA also has a goal of 0.1 mg/L total phosphorus for streams that do not directly discharge to reservoirs (U.S. Environmental Protection Agency, 1986). The purpose of this goal is to prevent excessive plant growth in streams. Indian Creek, N.C., Congaree River, and Brushy Creek do not meet this goal based on mean annual concentrations (fig. 10). Only two of the streams sampled did not have at least one sample above the goal. These were Jacob Fork River and McTier Creek, both of which drain forested watersheds. The remaining streams had percentages of individual samples that exceeded the goal, ranging from 4 to 96 percent.

An analysis of nutrient data collected by State monitoring agencies during 1973–93 (Maluk and others, 1998) showed that all but 3 of 90 stream and lake sites exceeded the applicable phosphorus goal at least once, and 23 sites had median concentrations that exceeded the goal.

The Congaree River is one of several rivers in the Santee Basin that exceeded the U.S. Environmental Protection Agency goal for phosphorus.

Although 34 of the 90 sites showed decreasing trends in phosphorus concentrations, 53 showed no trend, and 3 had increasing trends.

Agricultural Runoff and Industrial Discharges are Sources of Nutrients in Surface Water

For all the streams in the study unit, except in the South Fork Catawba River, there is a strong relation between orthophosphate

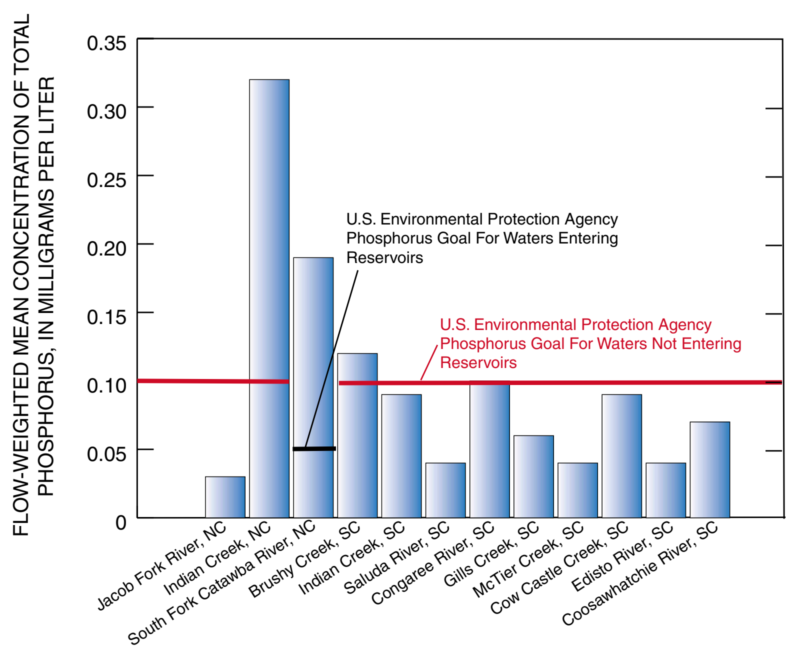


Figure 10. Three streams in the Santee Basin frequently exceeded the U.S. Environmental Protection Agency goal for phosphorus in surface waters not entering reservoirs, and one exceeded the goal for waters entering reservoirs.

(the predominant form of dissolved phosphorus in streams) concentrations and the percentage of agricultural land in the basins sampled (fig. 12). This relation most likely results from the runoff of phosphate-containing chemical fertilizer and manure from agricultural lands. The relation generally is not influenced by municipal waste-water discharges because phosphate-containing detergents have been banned for domestic use in the Santee Basin since the late 1990s (Litke, 1999).

The South Fork Catawba River has much higher concentrations of orthophosphate than would be predicted from the amount of agricultural land in the basin (fig. 11). This may result from a lack of a phosphorus ban on industrial users. The South Fork Catawba River Basin contains a large concentration of industries that use phosphate detergents, which are a potential source for the high orthophosphate levels in the South Fork Catawba River (Lindsey and Lewis, 1994).

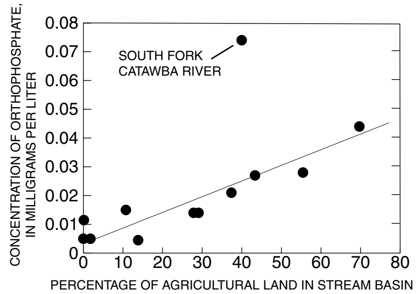


Figure 11. The concentration of orthophosphate in streams is directly related to the percentage of agricultural land in the stream basin except for the South Fork Catawba River.

Water-Supply Aquifers Rarely Exceeded Drinking-Water Standards for Nitrate

With the exceptions of nitrate, most nutrient concentrations in ground water in the Santee Basin were low. This is fairly typical of ground water in which most forms of nitrogen and phosphorus are negligible (Nolan and Stoner, 2000).

Nitrate concentrations exceeded the USEPA (1996) drinking-water standard of 10 mg/L in 14 of the 150 wells sampled. Drinking water containing concentrations of nitrate above the standard can result in methemoglobinemia, a life-threatening illness. All but two of the wells that exceeded the standard were located in the shallow aquifer beneath agricultural land in the Coastal Plain. In fact, wells in the agricultural land-use study had the highest concentrations of nitrate overall, with concentrations up to 23 mg/L and a median concentration about double the national NAWQA median for agricultural land use (fig.12). Although the shallow aquifer generally is not used for drinking-water supplies, the potential for movement of nitrate-enriched water to deeper aquifers used for water supply is a cause for concern. Wells beneath urban land had lower median concentrations of nitrate than wells in agricultural lands and were lower than the national NAWQA median for urban land use.

Nitrate concentrations measured in the three drinking-water supply aquifers sampled in the Santee Basin were variable. The Piedmont had the highest nitrate concentrations, followed by the Sandhills and Floridan aquifers (fig. 13). Only two wells exceeded the drinking-water standard for nitrate, one each in the Piedmont and Sandhills aquifers. With the exception of these two wells, most concentrations measured were well within the standard. One of the wells with a concentration above the standard was an irrigation well located in the middle of a corn and soybean field; the other was adjacent to a golf course. These results suggest that most wells in these three aquifers are safe from high levels of nitrate, but some concern is justified for wells located near areas with high fertilizer use.

The higher nitrate concentrations in the Piedmont and Sandhills aquifers are related to the lack of con-

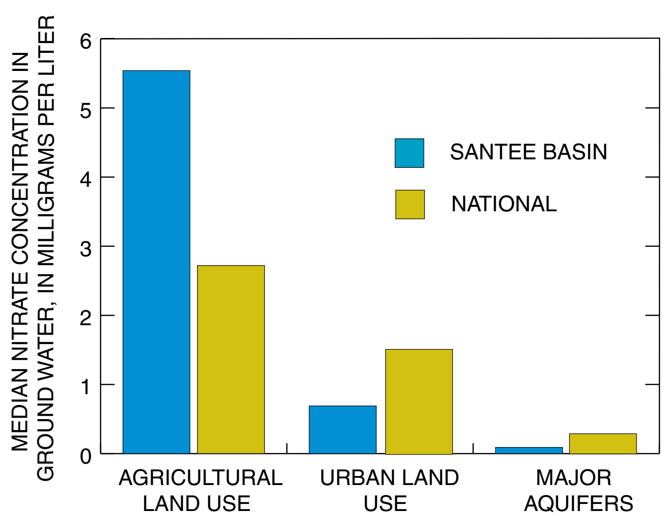


Figure 12. Nitrate concentrations in shallow ground water in agricultural areas were higher than those in urban areas and in major aquifers.

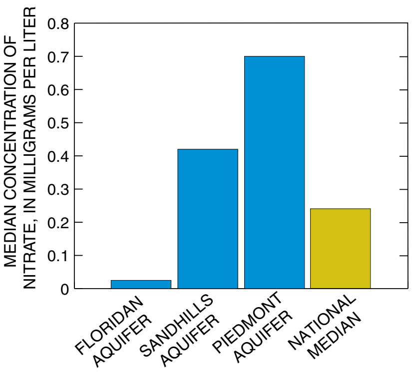


Figure 13. The Piedmont and Sandhills aquifers had higher median nitrate concentrations than the Floridan aquifer.

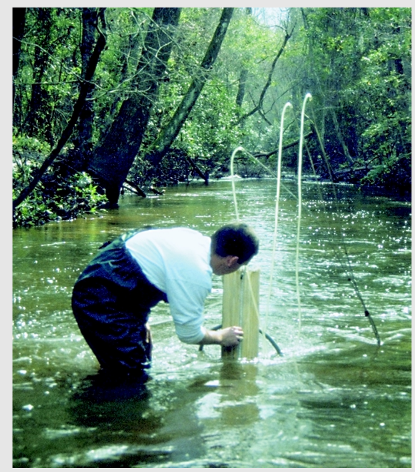
finement for these aquifers, which readily allows the downward movement of surficial contaminants. Water in these aquifers often has high dissolved oxygen concentrations, which prevents denitrification (the removal of nitrate by conversion to nitrogen gas). By comparison, the Floridan aquifer has the lowest nitrate concentrations because it is confined, meaning little water moves vertically into the aquifer, and it has little dissolved oxygen, a condition which can promote denitrification.

Nitrate in Ground Water Can Affect Nitrate Concentrations in Streams

Local conditions can strongly affect the nitrogen concentrations in ground water and how much nitrate discharges from ground water to surface water. A study of the transport of nitrate in ground water was conducted at an agricultural site adjacent to Cow Castle Creek, S.C. (fig. 14). At this site, ground water beneath a corn field had concentrations of nitrate more than 28 mg/L, nearly three times the drinking-water standard. Along the ground-water flow path, nitrate concentrations decreased to less than 5 mg/L.

Directly below the streambed, nitrate concentrations were above 4 mg/L. However, as ground water moves upward to the stream, it passes through an organic-rich zone containing little dissolved oxygen. Denitrification occurring in this zone results in water with a nitrate concentration of only 0.4 mg/L.

Denitrification may not always be effective in removing nitrate at all locations where ground water discharges to Cow Castle Creek. This is evidenced by the high concentrations of nitrate measured in Cow Castle Creek during low flow when most streamflow is attributed to ground-water discharge.



Water levels were measured simultaneously in Cow Castle Creek and at multiple depths in the aquifer below the creek. Under most streamflow conditions, water from the aquifer was moving upward into the creek.

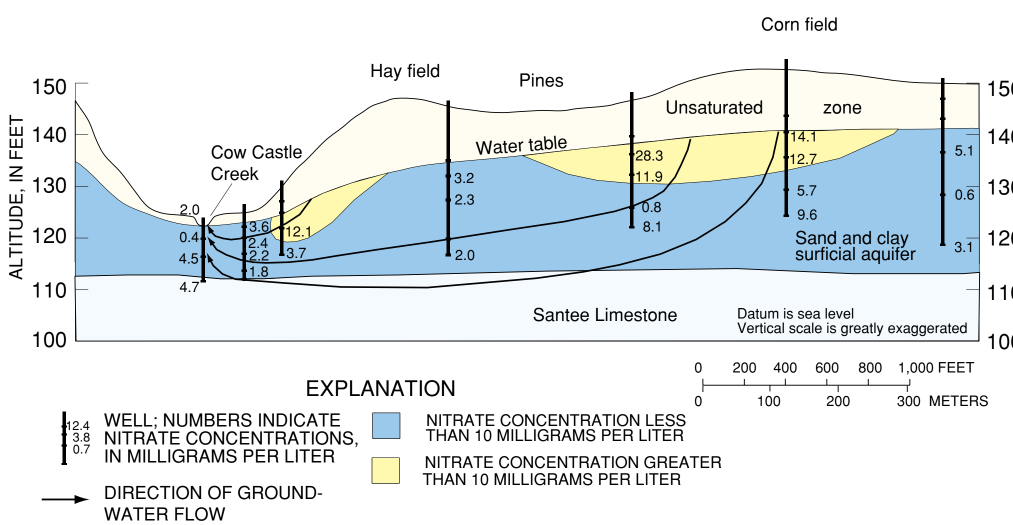
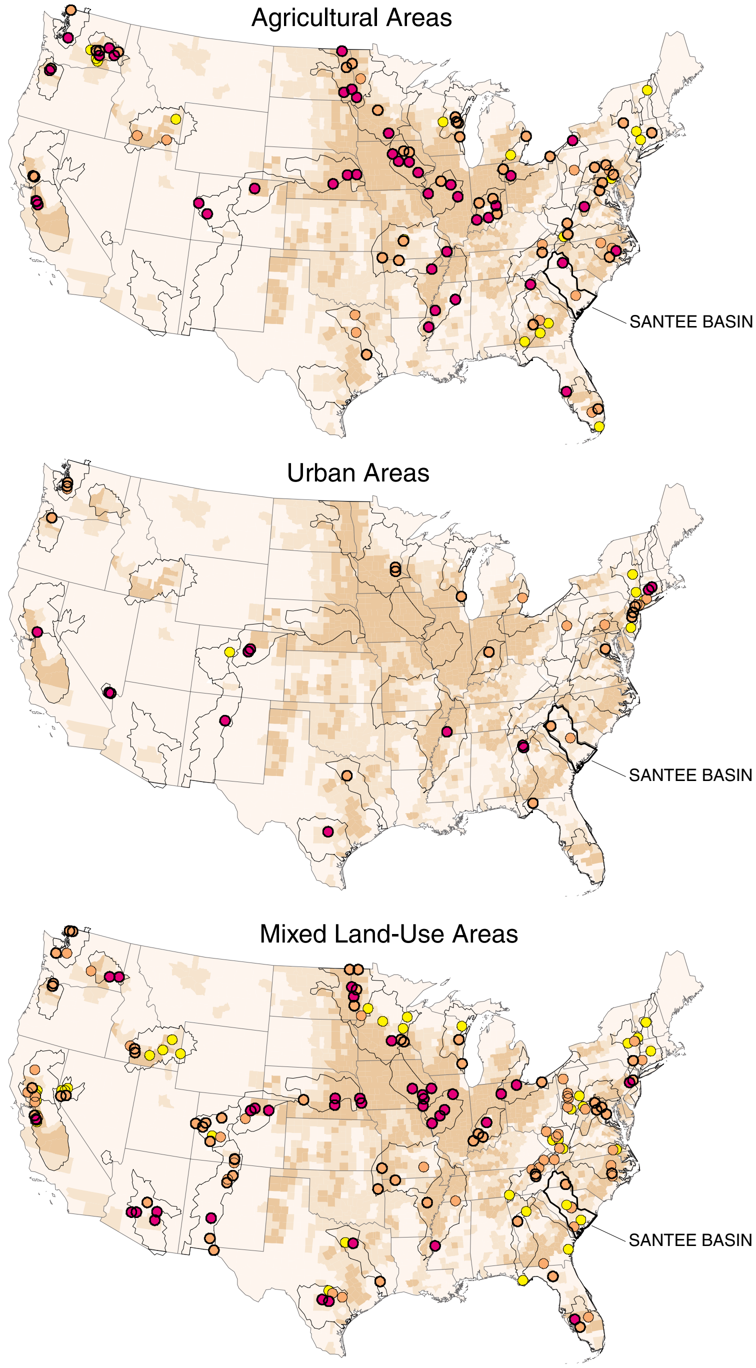


Figure 14. Concentrations of nitrate are reduced through denitrification as ground water flows to Cow Castle Creek. Typical wells used for water supply in this area are greater than 100 feet deep. Nitrate concentrations at that depth generally are not above drinking-water standards.

PHOSPHORUS CONCENTRATIONS IN THE SANTEE BASIN WERE IN THE MIDDLE RANGE OF NATIONAL RESULTS

Six of the 12 streams sampled in the Santee Basin had average concentrations of total phosphorus that were within the medium concentration range of all streams sampled in the NAWQA Program. The exceptions were an agricultural area drained by Indian Creek in North Carolina, which ranked high nationally, and two mixed land-use streams, which were in the lowest category for phosphorus. Nationally, higher concentrations of phosphorus corresponded to areas of the Midwest that also had high inputs of phosphorus from fertilizer and manure that were applied to agricultural lands. Phosphorus inputs from agriculture in the Santee Basin were typically in the low to middle range. The two mixed land-use sites that had the lowest phosphorus concentrations compared to national results were located on the Saluda and Edisto Rivers. The Saluda River site is located downstream from a major reservoir that traps much of the phosphorus carried into the system. The Edisto River is located in the Coastal Plain and mostly drains forested and agricultural lands. Extensive wetlands border the Edisto River and may act as local traps for phosphorus attached to sediment.

TOTAL PHOSPHORUS IN STREAMS



EXPLANATION

AVERAGE ANNUAL CONCENTRATION OF TOTAL PHOSPHORUS--IN MILLIGRAMS PER LITER

- Highest (greater than 0.27)
- Medium (0.05 to 0.27)
- Lowest (less than 0.05)

BACKGROUND CONCENTRATIONS

- Bold outline indicates median values greater than USEPA desired goal of 0.1 milligrams per liter for prevention of nuisance plant growth in flowing waters not discharging directly to lakes and impoundments

AVERAGE ANNUAL TOTAL PHOSPHORUS INPUT--IN POUNDS PER ACRE, BY COUNTY, FOR 1995-98. INPUTS ARE FROM FERTILIZER AND MANURE

- Greater than 5 pounds per acre
- 2 to 5 pounds per acre
- Less than 2 pounds per acre

Bed Sediment Had Low Concentrations of Trace Elements

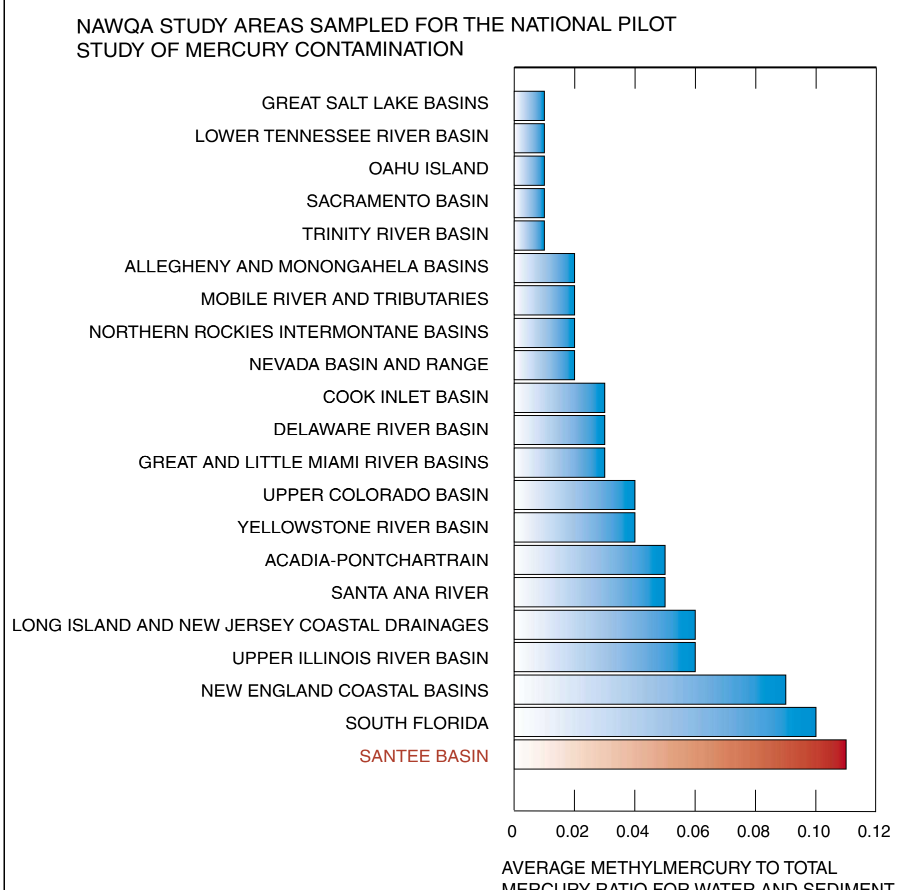
Trace elements in bed sediment were detected frequently but mostly at concentrations below those expected to affect aquatic life (Canadian Council of Ministers of the Environment, 1995). Arsenic and lead exceeded aquatic standards in one sample each, and chromium exceeded standards in four samples. The samples with elevated chromium concentrations were not associated with any particular land use; however, most of these samples were collected at sites in the Piedmont. This suggests that the elevated concentrations may be naturally occurring as a result of geologic conditions in the Piedmont.

Regional differences in bed sediment trace-metal concentrations were observed in the study area. In general, a decrease in the bed-sediment concentrations of arsenic, chromium, copper, nickel, and zinc occurs from the Blue Ridge southeastward across the Piedmont to the Coastal Plain. In the same direction, an increase in the bed-sediment concentrations of lead, mercury, and selenium occurs. These differences are likely a result of geologic differences among the areas (Abrahamsen, 1999).

A comparison of land use with bed sediment trace-element concentrations indicates that lead is significantly higher in sediment from urban streams than in sediment from forested streams. Neither agricultural nor mixed land-use streams had significantly higher concentrations of lead than forested streams (Abrahamsen, 1999).

MERCURY CONTAMINATION POTENTIAL IN SANTEE BASIN WAS HIGHEST IN NATION

Mercury is a widespread and extremely toxic contaminant that affects the Nation's aquatic ecosystems. Approximately 80 percent of the fish consumption advisories in the Nation were issued as a result of contamination by mercury (U.S. Environmental Protection Agency, 1998). Methylmercury is the form of mercury that is easily accumulated in the tissues of organisms. As part of the NAWQA Program, a nationwide investigation of methylmercury in water, sediment, and fish tissues was conducted (Krabbenhoft and others, 1999). Analysis of samples collected in the Santee Basin indicated that they had the greatest methylation efficiency (the ratio of methylmercury to total mercury) in the Nation. In other words, conditions at the sites sampled in the Santee Basin are such that a relatively small amount of elemental mercury in water can result in high concentrations of methylmercury being available for accumulation in fish tissue. The types of sites sampled were primarily blackwater streams, which typically have large amounts of dissolved organic carbon and low dissolved oxygen concentrations. The bacteria that convert elemental mercury to methylmercury thrive under these conditions. Many of the streams that are covered by State fish-consumption advisories are blackwater streams.



Trace Elements Accumulated in Clam Tissue and Fish Livers

Trace metals are naturally occurring and were detected in all fish liver and clam tissue samples collected. Nine trace elements (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc) have been classified as priority pollutants because they are toxic to aquatic organisms in low concentrations (Code of Federal Regulations, 1996). Of these nine metals, concentrations of cadmium, copper, selenium, and zinc were higher in clams and fish liver tissue than those measured in sediment. Carp liver tissue contained significantly higher concentrations of these metals than those in clams and bed sediment, indicating that the metals accumulate in fish livers. Concentrations of arsenic, chromium, lead, and nickel were significantly lower in tissues than in sediment, suggesting that these metals do not accumulate in tissues (fig. 15). Concentrations of mercury were higher in clam tissue than in sediment and fish livers. Although data suggest that some metals accumulate in tissues, most metals do not have criteria for assessing risk to human health or aquatic wildlife associated with fish consumption.

Concentrations of mercury in clams and fish liver tissue from the Edisto River were 24 and 8 times greater, respectively, than the South Carolina action level for issuance of a fish-consumption advisory. Data collected in the NAWQA Program cannot be used to assess potential risk to human health because fish livers were used for analyses, whereas fish fillets are needed to assess human-health risk. Consumption advisories generally are not applied to clams because few humans consume them. The South Carolina Department of Health and Environmental Control (2000) has issued fish-consumption advisories because of high levels of mercury in 49 rivers and reservoirs in the Santee Basin, including the Edisto River.

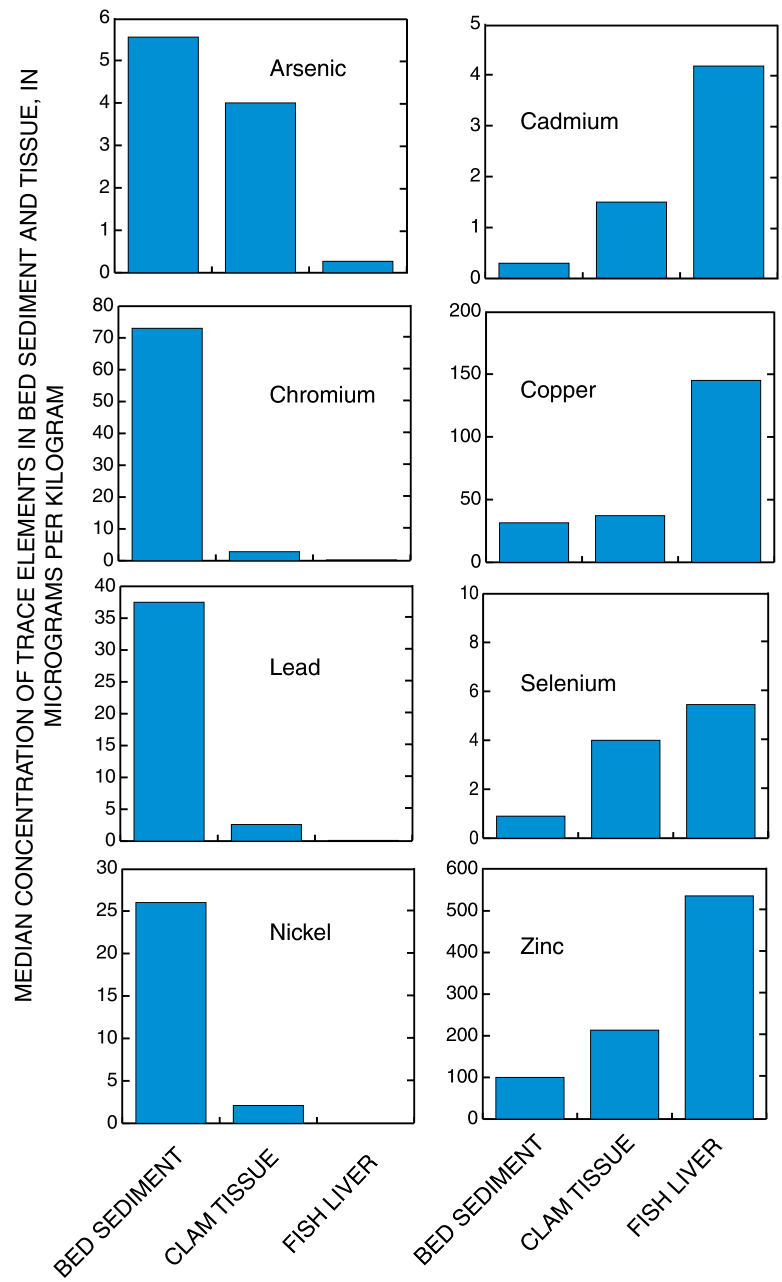


Figure 15. Cadmium, copper, selenium, and zinc were detected at higher concentrations in clam and fish tissue than in sediment, suggesting that they accumulate in the tissues. Conversely, arsenic, chromium, lead, and nickel were detected in lower concentrations in tissues than in sediment, indicating that these metals do not accumulate in the tissues.

Radon Exceeded Proposed Standards in Many Wells

Ninety-six percent of the 90 wells sampled in drinking-water supply aquifers of the Santee Basin contained measurable quantities of radon, a colorless, odorless gas that can cause cancer in humans. The gas results from the radioactive decay of uranium in rocks and soil and can enter homes directly from the soil or in drinking water supplied by wells. Radon is a health risk through direct inhalation of the gas and from drinking water contaminated with radon.

Of the 90 wells sampled, radon exceeded the USEPA's (1999) proposed maximum contaminant level (MCL) of 300 picocuries per liter (pCi/L) in 100, 47, and 17 percent of the wells in the Piedmont, Sandhills, and Floridan aquifers, respectively (fig. 16). For wells not meeting the MCL, the USEPA has proposed an Alternative Maximum Contaminant Level (AMCL) of 4,000 pCi/L. To comply with the AMCL, the State or local water utility must develop indoor air radon-reduction programs and reduce radon levels in drinking water to 4,000 pCi/L. Of the wells that were sampled in the Piedmont, Sandhills, and Floridan aquifers, 20 percent, zero percent, and less than 1 percent, respectively, exceeded the proposed AMCL.

Wells in the Piedmont had much higher concentrations of radon, on average, than wells sampled in the Sandhills and Floridan aquifers (fig. 16). This results from the greater relative abundance of minerals containing uranium in the metamorphic rocks that compose the Piedmont aquifer. The same bedrock underlies the Sandhills and Floridan aquifers, but generally at depths ranging from several hundred to several thousand feet.

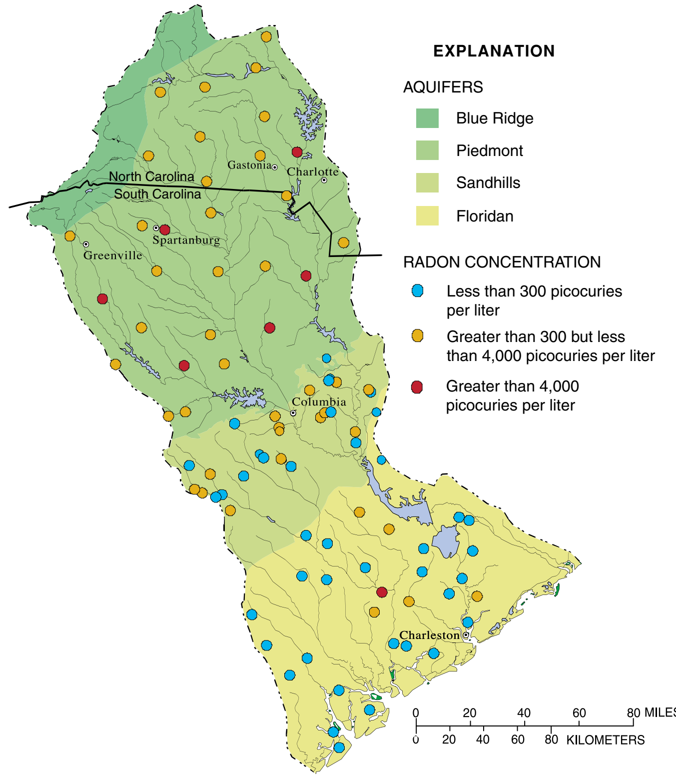
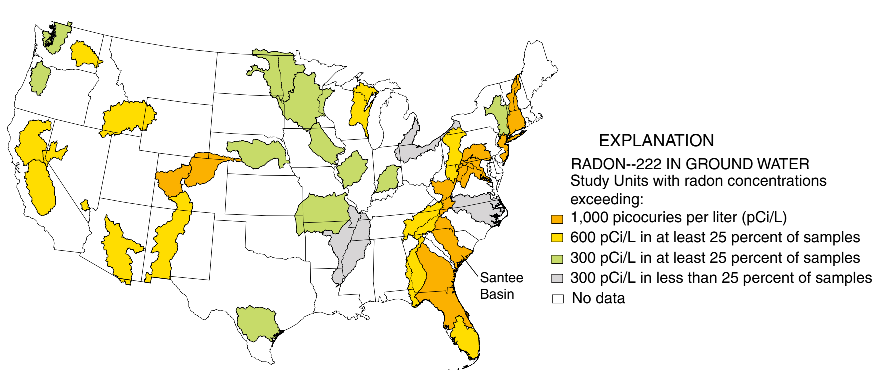


Figure 16. Radon concentrations were highest in the Piedmont and Sandhills aquifers, resulting from naturally high levels of uranium in near-surface rocks and sediment.

RADON CONCENTRATIONS WERE HIGH IN THE SANTEE BASIN

Radon concentrations in the Santee Basin were among the highest measured in the Nation. These high concentrations result from radioactive decay of naturally occurring minerals in the soil and rock that underlie the study area and compose the aquifer in the Piedmont part of the study area. The Piedmont metamorphic rocks are present in many eastern coastal States and probably account for the high radon concentrations observed in Study Units located in those States.



Volatile Organic Compounds Were Common in Urban Ground Water

All but 3 of 30 monitoring wells installed in commercial and residential areas of Columbia, S.C., contained a variety of volatile organic compounds (VOCs), a group of chemicals that includes gasoline additives, solvents, and disinfection by-products (Reuber, 1999). Thirty-five such compounds were detected. Most wells contained three or more VOCs, and one well contained 15 different VOCs.

Most of the VOC detections were at extremely low levels. The five VOCs detected with the highest concentrations were methyl *tert*-butyl ether (MTBE), trichloroethene (TCE), acetone, *tert*-amyl methyl ether (TAME), and trichloromethane. Of the 35 detected VOCs, 14 have established drinking-water standards; of these, only TCE exceeded the standard. Currently there is no standard for MTBE, but the MTBE concentration in one well exceeded a drinking-water advisory.

Some of the most frequently detected compounds included trichloromethane, chloromethane, and bromodichloromethane. These compounds can result from the chlorination of drinking water and can enter ground water by infiltration from irrigation systems or from leaky water-supply lines. Other VOCs that were detected were solvents, such as TCE, tetrachloroethene, and acetone. These compounds have commercial and industrial uses as degreasers and dry-cleaning solvents, but they are often used in households for similar purposes. The gasoline additives MTBE and TAME and the gasoline component benzene also were detected in Columbia's ground water. These compounds can enter ground water from leaking gasoline storage tanks, spills, and potentially through atmospheric deposition (Lopes, 1998).

The diffuse, nonpoint nature of sources of VOCs in ground water makes it difficult to attribute detected compounds to particular homes or businesses, posing a problem for scientists who seek to establish the relative importance of these sources and for regulators who seek to educate the public or control the release of toxic substances.

Shallow ground water in the Columbia, S.C., metropolitan area contains a variety of volatile organic compounds, but mostly at low concentrations.

Volatile Organic Compounds in Streams Can Result from Ground-Water Discharge and Urban Runoff

Ten VOCs were detected in seven monthly stream-water samples that were collected from Gills Creek, an urban stream in the Columbia metropolitan area. MTBE, chloromethane, methylbenzene, chlorobenzene, and acetone were detected most frequently. None of the VOCs detected in Gills Creek were at concentrations exceeding drinking-water or aquatic-life standards. Six of the VOCs detected do not have standards.

VOCs have many sources, including contaminated precipitation, surface-water runoff, and ground-water discharge. Though the sources are diffuse and hard to measure directly, inferences can be made about the likely sources. For example, samples collected in Gills Creek while the water level was rising during a rainstorm indicate that as streamflow increased, the concentration of acetone increased. This suggests that the source of acetone in the samples was from contaminated precipitation or stormwater runoff (Lopes and others, 2000). If the acetone resulted from continuously discharging ground water, the concentration would be expected to decrease as dilution by rainfall and runoff increased.

Stormwater samples for volatile organic compounds were collected by using special samplers developed for the NAWQA Program.

During the summer of 1996, 20 different VOCs were detected at low concentrations in individual samples collected at 16 surface-water sites scattered throughout the Gills Creek Basin. The compounds detected in the highest concentrations included MTBE, 1,1-dichloroethene, trichloroethene, methylbenzene, and 1,2-dibromo-3-chloropropane—all solvents except for MTBE, which is a gasoline additive. Fifteen of the compounds detected in surface water also were present in the Columbia ground-water samples. This result is not surprising because the samples were collected during low streamflow conditions when the ground-water contribution to Gills Creek is greatest; consequently, VOCs from contaminated ground water most likely would be detected in stream samples.

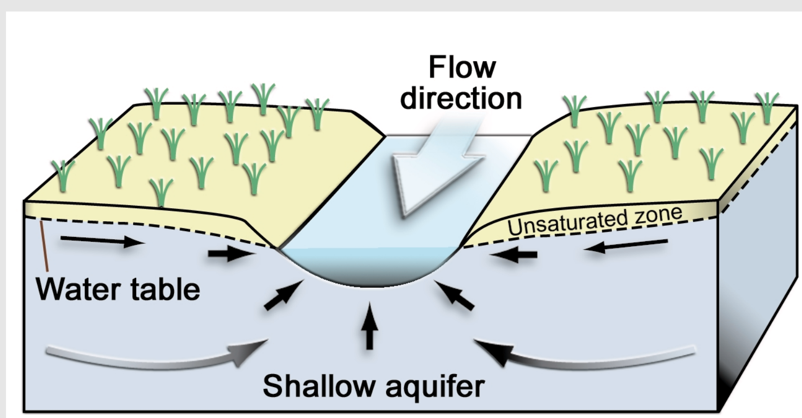
Drinking-Water Aquifers Had Low Concentrations of Volatile Organic Compounds

Of the 90 wells sampled in the Piedmont, Sandhills, and Floridan aquifers, 62 contained detectable concentrations of VOCs. All of the 28 compounds detected met USEPA drinking-water standards; however, 19 of the compounds did not have standards. The VOCs measured had widely ranging detection limits, making comparisons among compounds and aquifers difficult. A subset of the compounds having detection limits of 0.05 microgram per liter (µg/L) or lower was used to make comparisons. This comparison shows that about twice as many wells in the Sandhills aquifers contain VOCs as those in the Floridan and Piedmont aquifers. The more frequent occurrence of VOCs in the Sandhills aquifers probably relates to their greater susceptibility to contamination.

Data on VOCs in drinking-water aquifers indicate that although these compounds are widespread, concentrations are sufficiently low that human health is not immediately at risk. However, the fact that detections were so frequent suggests that aquifers are susceptible to contamination and should be carefully monitored.

Ground water affects the quality of surface water

Presently, surface water is used for most public water supplies in the Columbia metropolitan area. However, the quality of these supplies is largely controlled by ground-water quality, especially during summer months. In areas of the basin with sandy soils, such as the Sandhills, flow in streams is contributed mostly by discharge from ground water. Discharging ground water transports contaminants, including VOCs, that can result in water-quality problems in streams and lakes. Consequently, the health of aquatic organisms and surface-water drinking supplies can be affected by the chemical quality of shallow ground water discharged to streams and reservoirs. Several streams in the metropolitan area, including Penn Branch and Jackson Creek, have high concentrations of nutrients and pesticides that evidence suggests result from ground-water discharge (Maluk, 1999).



Urban and Agricultural Streams Had High Concentrations of Bacteria

Thirteen of 17 streams sampled for fecal coliform bacteria had at least one sample that exceeded the South Carolina single-sample standard of 400 colonies per 100 milliliters (cols/100 mL; South Carolina Department of Health and Environmental Control, 1992). This standard was implemented to reduce the risk of gastrointestinal disorders that are associated with recreational contact with water containing elevated levels of bacteria. All concentrations measured in this report were compared to South Carolina standards for consistency; North Carolina does not recognize a single-sample standard.

Urban and agricultural streams had more concentrations of bacteria that exceeded standards than forested and mixed land-use streams (fig. 17). Several creeks repeatedly had high concentrations of bacteria. For example, one of the urban streams sampled, Brushy Creek, exceeded the standard in 60 percent of the samples collected.

The highest bacterial concentrations measured were at agricultural sites, such as Cow Castle Creek and Indian Creek, N.C., which had concentrations of 21,600 and 12,000 col/100 mL, respectively. The highest concentrations observed in urban streams were much lower—around 2,000 col/100 mL. Forested streams generally had the lowest peak concentrations, ranging from about 500 to 1,000 col/100 mL. Samples were collected under all flow conditions, and higher concentrations as well as standard exceedances tended to occur at higher streamflows.

Stream Size is Important

All of the regularly monitored small streams exceeded the South Carolina single-sample standard for bacteria. Most large rivers did not exceed the standard during the period sampled, including the Wateree, Saluda, Congaree, and Edisto Rivers. The median bacterial concentrations in streams with drainage areas larger than 100 square miles (mi^2) were significantly lower than those in streams with drainage areas less than 100 mi^2. Because major rivers and small streams have similar sources of bacteria, the most likely reason for the differences in bacterial levels is dilution by the larger flows in the major rivers.

Bacterial cultures were prepared and counted in a mobile field laboratory and in the USGS South Carolina District laboratory.

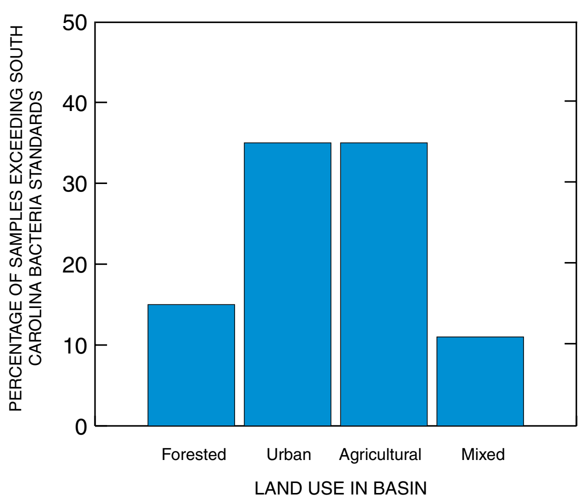


Figure 17. Urban and agricultural streams had more concentrations of bacteria that exceeded South Carolina State standards than forested and mixed land-use streams.

Sources of Bacteria

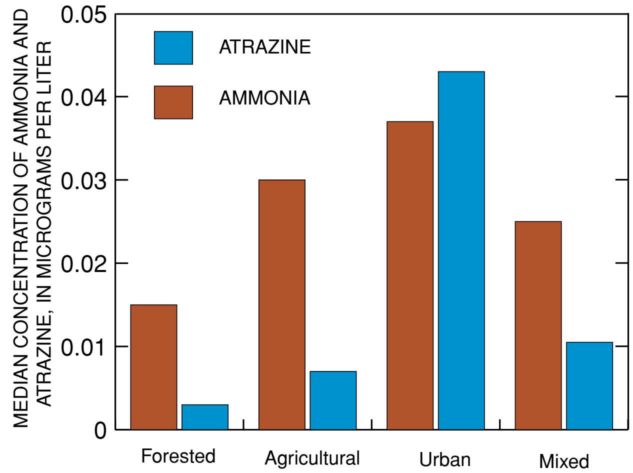
A comparison of bacterial concentrations to the physical and chemical parameters of the water indicate that surface-water runoff accounts for much of the elevated fecal coliform concentrations (Wilhelm and Maluk, 1998). Bacterial concentrations increased as streamflow, organic nitrogen, organic carbon, phosphorus, and suspended-sediment concentrations increased. Because increases in these parameters usually result from surface-water runoff, the implication is that the increase in bacteria also resulted from runoff.

In agricultural areas, bacteria in runoff may result from applications of manure to fields and from animal holding and feeding areas. Urban sources include runoff from lawns containing pet wastes, leaking or failed septic tanks and sewer lines, and municipal or industrial discharges. Bacterial contamination in forested areas most likely results from fecal contamination by wildlife.

Biological Communities Reflected Land-Use Differences

Biological communities that inhabit streams in Santee Basin agricultural and urban areas were indicative of degraded water quality compared to those that inhabit streams that drain forested areas. Fish that have a low tolerance for contamination make up a smaller percentage of the fish community at agricultural and urban sites than at forested sites (fig. 18). This can result because fish such as darters and shiners that are sensitive to contaminants do not thrive at degraded sites. Other species such as catfish, redbreast sunfish, and some minnows that are relatively unaffected by contaminants will take the place of the more sensitive fish.

Urban and agricultural streams also had lower numbers of invertebrate species that are intolerant of contaminants than forested and mixed land-use streams. This is evidenced by the lower numbers of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, a group of aquatic insects that are relatively intolerant of contamination, at urban and agricultural sites. The USEPA (Plafkin and others, 1989) uses the presence or absence of EPT taxa as an indicator of aquatic community health.



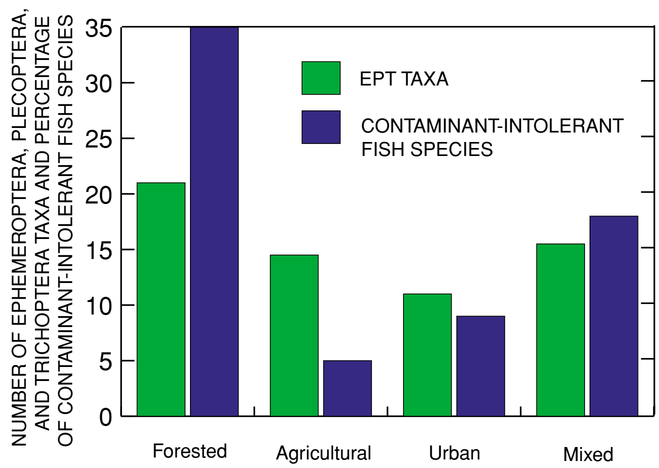
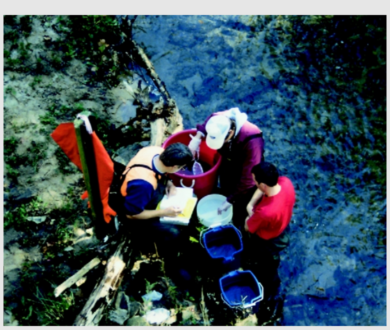


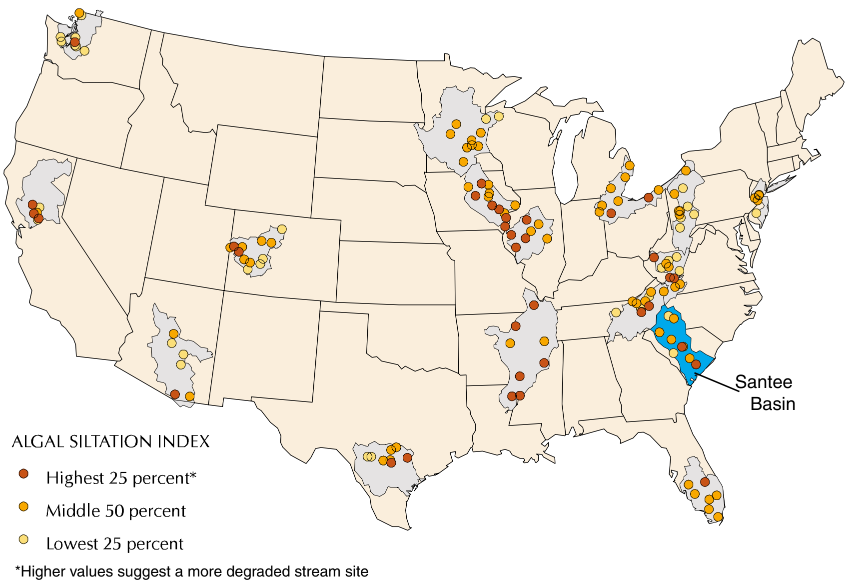
Figure 18. Compared to forested sites, urban and agricultural sites have higher concentrations of atrazine and ammonia as well as lower numbers of fish and invertebrates that are intolerant of contamination.

Water-quality constituents and contaminant-intolerant species are related (fig.18). Median concentrations of ammonia, a nutrient associated with wastewater discharges, and atrazine, an agricultural and turfgrass herbicide, are highest at urban and agricultural sites, corresponding to low numbers of contaminant-intolerant fish and invertebrate species. This suggests that these water-quality constituents have an effect on the aquatic community; however, other factors, primarily those associated with aquatic habitats, can affect aquatic community health in ways that are similar to those that result from changes in water quality. In addition, sample sites were located in several different physiographic provinces, including the Blue Ridge, Piedmont, and Coastal Plain. Differences in species distributions and habitat in these different settings can make comparisons difficult to interpret. Most likely, a combination of water quality and habitat disturbance associated with agricultural and urban land uses results in the observed differences in biological communities.



Over 85 fish species were identified during ecological sampling in the Santee Basin.

SANTEE BASIN STREAMS WERE IN THE MIDDLE OF NATIONAL BIOLOGICAL RANKINGS



Algal Siltation Index

Algal data collected in each of the NAWQA Study Units were combined and compared to show differences in the percentage of species that are able to avoid burial by sediment (Bahls and others, 1992). High percentages of these mobile algae are indicative of siltation of benthic habitats. Two sites in the Santee Basin were in the highest 25-percent category. One of these sites is the Edisto River, a blackwater river that has low light penetration.The high ranking at this site may result from low-light conditions that favor mobile algal species. Other variables that can lower light levels in streams can affect this index, including turbidity and forest canopy closure.

Invertebrate Status Index

A multimetric index was developed to compare invertebrate populations nationally. The index is an average of 11 metrics that summarize changes in richness, tolerance, trophic condition, and dominance associated with water-quality degradation. Only one site in the Santee Basin, an urban stream, was placed in the highest 25-percent category. The remaining Santee Basin sites were in the middle category, except for Jacob Fork River and McTier Creek, which were in the lowest category. Both of these sites represent the least degraded water quality in the study area and were located in areas with the least effects of human activity. Nationally, urban and agricultural sites tended to have the most degraded invertebrate communities according to this index.