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Water Quality in the Mobile River Basin

Alabama, Georgia, Mississippi, and Tennessee, 1999–2001

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

Circular 1231

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The Quality of Our Nation's Waters—Nutrients and Pesticides (Circular 1225)

Front cover: The Cahaba River lillies are native to the Cahaba River Basin, a tributary in the Mobile River Basin (photograph by Beth Maynor Young and used by permission).
Back cover: Left, processing water-quality samples for analysis (photograph by Douglas A. Harned); middle, invertebrate sampling, Cahaba Valley Creek, Alabama (photograph by J. Brian Atkins); right, surface-water sampling, Cahaba Valley Creek, Alabama (photograph by J. Brian Atkins).

Water Quality in the Mobile River Basin, Alabama, Georgia, Mississippi, and Tennessee, 1999–2001

By J. Brian Atkins, Humbert Zappia, James L. Robinson, Ann K. McPherson, Richard S. Moreland, Douglas A. Harned, Brett F. Johnston, and John S. Harvill

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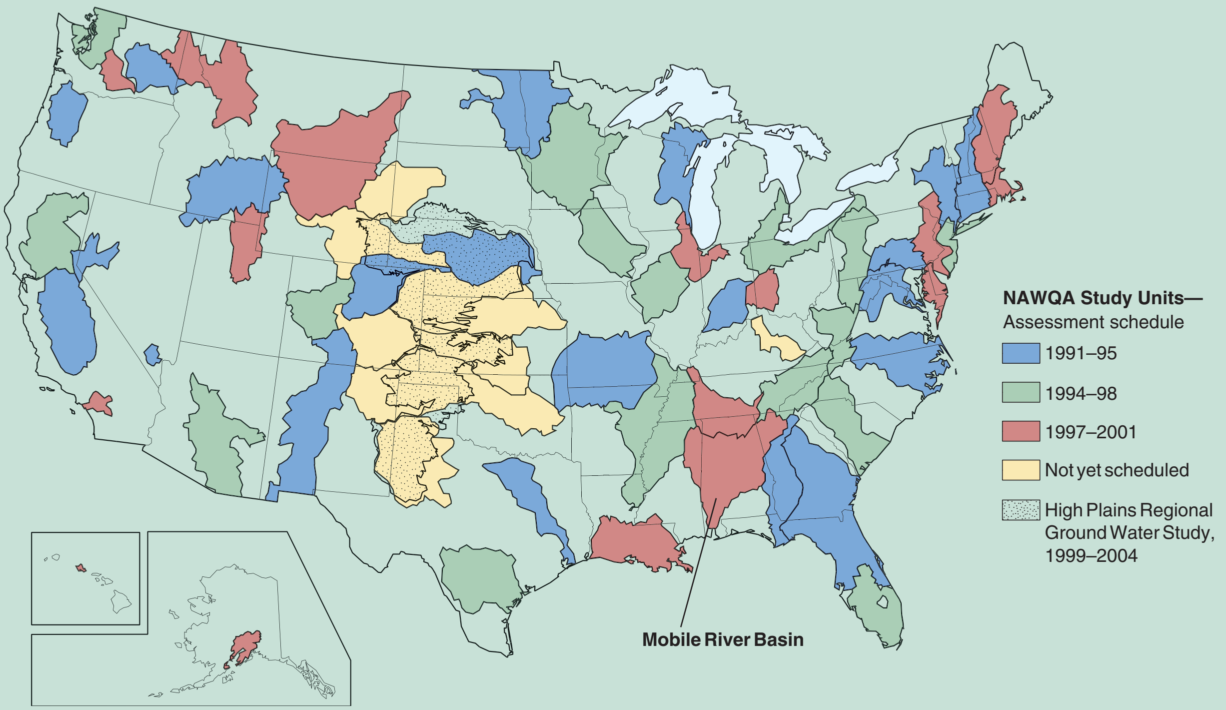
Contents

National Water-Quality Assessment Program

The quality of the Nation's water resources is integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and also suitable for industry, irrigation, and habitat for fish and wildlife. Recognizing the need for long-term, nationwide assessments of water resources, the U.S. Congress has appropriated funds since 1991 for the USGS to conduct the **National Water-Quality Assessment (NAWQA) Program**. Scientists in the NAWQA Program work with partners in government, research, and public interest groups to assess the spatial extent of water-quality conditions, how water quality changes with time, and how human activities and natural factors affect water quality. This information is useful for guiding water-management and protection strategies, research, and monitoring in different hydrologic and land-use settings across the Nation.



The Mobile River Basin is one of 51 water-quality assessments initiated since 1991. Together, the 51 major river basins and aquifer systems, referred to as "Study Units," include water resources used by more than 60 percent of the population in watersheds that cover about half of the land areas of the conterminous United States. Timing of the assessments varies because of the Program's rotational design, in which one-third of all Study Units are intensively investigated for 3 to 4 years, with trends assessed every 10 years. As indicated on the map, the Mobile River Basin is part of the third set of intensive investigations, which began in 1997.

What kind of water-quality information does the NAWQA Program provide?

Water-quality assessments by a single program cannot possibly address all of the Nation's water-resources needs and issues. Therefore, it is necessary to define the context within which NAWQA information is most useful.

- Total resource assessment—NAWQA assessments are long-term and interdisciplinary, and include information on water chemistry, hydrology, land use, stream habitat, and aquatic life. Assessments are not limited to a specific geographic area or water-resource problem at a specific time. Therefore, the findings describe the general health of the total water resource, as well as emerging water issues, thereby helping managers and decision makers to set priorities.

- Source-water characterization—Assessments focus on the quality of the available, untreated resource and thereby complement (rather than duplicate) Federal, State, and local programs that monitor drinking water. Findings are compared to drinking-water standards and health advisories as a way to characterize the resource.

- Compounds studied—Assessments focus on chemical compounds that have well-established methods of investigation. It is not financially or technically feasible to assess all the contaminants in our Nation's waters. In general, the NAWQA Program investigates those pesticides, nutrients, volatile organic compounds, and metals that have been or are currently used commonly in agricultural and urban areas across the Nation. A complete list of compounds studied is on the NAWQA Web site at *water.usgs.gov/nawqa*.

- Detection compared to risk—Compounds are measured at very low concentrations, often 10 to 100 times lower than Federal or State standards and health advisories. Detection of compounds, therefore, does not necessarily translate to risks to human health or aquatic life. However, these analyses are useful for identifying and evaluating emerging issues, as well as for tracking contaminant levels over time.

- Multiple scales—Assessments are guided by a nationally consistent study design and uniform methods of sampling and analysis. Findings thereby pertain not only to water quality of a particular stream or aquifer, but also contribute to the larger picture of how and why water quality varies regionally and nationally. This consistent, multi-scale approach helps to determine if a water-quality issue is isolated or pervasive. It also allows direct comparisons of how human activities and natural processes affect water quality in the Nation's diverse environmental settings.

Introduction to this Report

This report contains the major findings of a 1999–2001 assessment of water quality in the Mobile River Basin. It is one of a series of reports by the National Water-Quality Assessment (NAWQA) Program that present major findings in 51 major river basins and aquifer systems across the Nation.

In these reports, water quality is discussed in terms of local, State, and regional issues. Conditions in a particular basin or aquifer system are compared to conditions found elsewhere and to selected national benchmarks, such as those for drinking-water quality and the protection of aquatic organisms.

This report is intended for individuals working with water-resource issues in Federal, State, or local agencies, universities, public interest groups, or in the private sector. The information will be useful in addressing a number of current issues, such as the effects of agricultural and urban land use on water quality, human health, drinking water, source-water protection, hypoxia and excessive growth of algae and plants, pesticide registration, and monitoring and sampling strategies. This report is also for individuals who wish to know more about the quality of streams and ground water in areas near where they live, and how that water quality compares to the quality of water in other areas across the Nation.

The water-quality conditions in the Mobile River Basin summarized in this report are discussed in detail in other reports that can be accessed from the Mobile River Basin Web site (*http://al.water.usgs.gov/pubs/mobl/mobl.html*). Detailed technical information, data and analyses, collection and analytical methodology, models, graphs, and maps that support the findings presented in this report in addition to reports in this series from other basins can be accessed from the national NAWQA Web site (*http://water.usgs.gov/nawqa*).

The Cahaba River east of Centreville, Alabama.

Photo courtesy of Dan Brothers, Alabama Department of Conservation and Natural Resources

"The NAWQA Program has filled a tremendous void in the pesticide data the State of Alabama must acquire in the development of the USEPA-mandated State Pesticide Management Plan. The scope of the data collected has made the decision-making process of writing the plan simpler because actual NAWQA data are used to make important determinations and the plan can target the areas of greatest importance."

Tony Cofer,
Program Director
Pesticide Division
Alabama Department of Agriculture and Industries

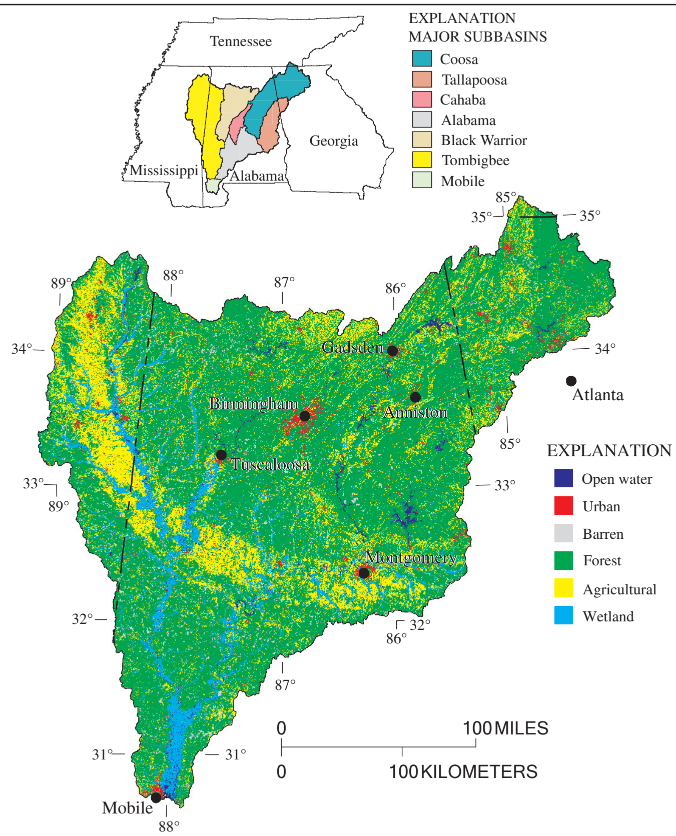
"Properly balancing competing water-resources demands while conserving our significant fish and wildlife resources for future generations is one of the most critical environmental management issues facing the Service today. The NAWQA Program provides an objective scientific foundation to assist resource agencies charged with making difficult management decisions. It synthesizes surface-water, ground-water, and biological data in an accessible and understandable way for a wide range of readers. We find the NAWQA Program to be a valuable resource to our agency."

Larry E. Goldman,
Field Supervisor
U.S. Fish and Wildlife Service
Daphne, Alabama

Summary of Major Findings

Stream and River Highlights

Surface water sampled in the Mobile River Basin generally meets Federal and State drinking-water standards and guidelines for the protection of aquatic life. However, water-quality conditions are adversely affected by urban and agricultural activities, as indicated by elevated concentrations of nutrients, pesticides, and other organic compounds, and biological communities commonly exhibit signs of environmental stress. Nonpoint sources of nutrients—primarily animal wastes and commercial fertilizer—account for about 98 percent of the nitrogen and 96 percent of the phosphorus in streams. Nonpoint sources of pesticides, including applications on farmland and in residential areas, have resulted in a widespread occurrence of pesticides in streams, with detections of three or more pesticides in more than 90 percent of the stream samples.



The Mobile River Basin encompasses 44,000 square miles in parts of Alabama, Georgia, Mississippi, and Tennessee. Approximately 70 percent of the basin is forested and 26 percent is agricultural. Pasture land for hay and cattle is the most common agricultural land use, although row crops are grown primarily in the Mississippi part of the basin and in the flood plains along major rivers. Urban land accounts for only 3 percent of the basin, where nearly 4 million people live. Surface water supplies more than 75 percent of the total water used in the basin.

- Concentrations of nitrogen generally were highest in streams or rivers draining urban areas; however, total nitrogen concentrations in the agricultural Bogue Chitto Creek ranked among the upper 20 percent of 479 streams and rivers monitored nationwide by the NAWQA Program. Phosphorus concentrations in 33 percent of samples collected from urban and agricultural streams exceeded the U.S. Environmental Protection Agency (USEPA) goal of 0.1 milligram per liter of phosphorus to minimize nuisance plant and algal growth (p. 7).
- Herbicides were detected more frequently and usually at higher concentrations in the agricultural Bogue Chitto Creek than in the urbanized Threemile Branch and Cahaba Valley Creek. About one-third of the samples from Bogue Chitto Creek had herbicide concentrations that exceeded aquatic-life guidelines or drinking-water standards. The herbicide atrazine was detected in all streams and in nearly 100 percent of water samples, regardless of land-use setting (p. 11).
- Insecticides were detected more frequently and usually at higher concentrations in the two urban streams (Threemile Branch and Cahaba Valley Creek) than in the agricultural stream (Bogue Chitto Creek) and in rivers draining areas of mixed land uses (Alabama, Black Warrior, Cahaba, and Tombigbee Rivers). Although concentrations generally were low, chlorpyrifos, diazinon, malathion, and carbaryl concentrations exceeded aquatic-life guidelines in about 14 percent of the urban stream samples (p. 11).
- Organochlorine compounds, such as PCBs, DDT, and dieldrin, commonly occur in streambed sediment and fish tissue, even though their uses were discontinued 15 to 30 years ago. The most commonly detected organochlorine compounds in sediment were PCBs and the pesticides chlordane, DDT, and their breakdown products. Concentrations of chlordane and DDT in whole fish exceeded guidelines for the protection of fish-eating wildlife at 13 of 19 sites. Concentrations of chlordane and heptachlor epoxide in fish tissue increased with increasing amounts of urban land use; however, concentrations of DDT in fish tissue increased with increasing amounts of agricultural land use (p. 15).
- Volatile organic compounds (VOCs) were detected frequently in urban streams at low concentrations. One or more VOCs were detected in 98 percent of the water samples from Threemile Branch and Cahaba Valley Creek (p. 16).

- Increases in urbanization in a basin correspond to decreases in invertebrate and fish diversity, abundance, numbers, and types of pollution-sensitive species. Degradation of fish and invertebrate communities is related to physical and chemical factors associated with increasing residential development, density of roads, commercial industrial land use, and population (p. 18).

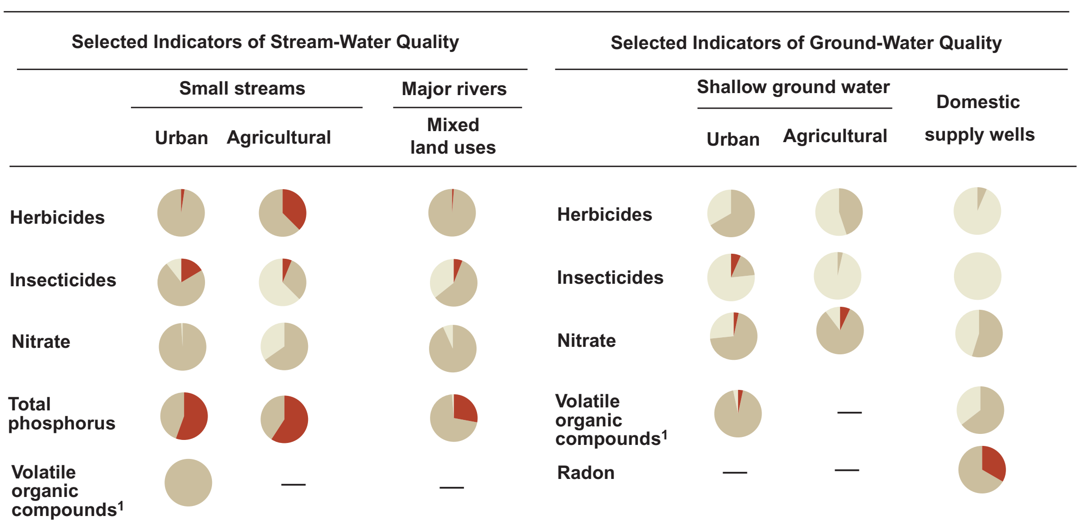
Major Influences on Stream Quality

- Increased urban development and population density
- Runoff from urban and agricultural areas

Ground-Water Highlights

More than 50 percent of the ground water used for public and domestic supply in the Mobile River Basin comes from the Black Warrior River aquifer. Water samples from shallow monitoring wells (median depth about 25 feet) and deeper wells used for domestic supply (median depth about 120 feet) generally meet Federal and State standards and guidelines for drinking-water quality. Water-quality conditions in the shallow parts of the Black Warrior River aquifer, however, are affected by urban and agricultural land uses, as indicated by elevated concentrations of nutrients, pesticides, and VOCs related to industry, households, and motor vehicles. In addition, deeper, domestic wells in areas of mixed land uses contained low concentrations of numerous synthetic chemical compounds.

- Nitrate concentrations generally were highest in shallow monitoring wells in urban and agricultural areas and exceeded the USEPA drinking-water standard in three wells. Dissolved phosphorus concentrations generally were highest in deeper domestic wells in forested and mixed land use areas where phosphorus occurs naturally in calcium phosphate deposits in the deeper parts of the Black Warrior River aquifer (p. 8).
- Pesticides were detected in 50 of 59 shallow monitoring wells in agricultural and urban areas, but none of the pesticide concentrations exceeded USEPA drinking-water standards. Herbicides commonly were detected in ground water both in agricultural and urban areas. Dieldrin was the only insecticide detected in the Mobile River Basin, and only in urban wells (p. 11).
- VOCs were detected in 20 of 30 shallow monitoring wells in the city of Montgomery, Ala. Concentrations generally were low except for one compound, tetrachloroethylene (PCE), which exceeded the USEPA drinking-water standard in one well. VOCs also were detected in 19 of 30 deeper domestic wells in mixed land use areas. Chloroform, the most frequently detected VOC, was found in 11 of 30 wells (p. 16).
- Radon occurs naturally in the clays of the Black Warrior River aquifer, and radon was detected in every water sample collected from the deeper domestic wells completed in the aquifer in mixed land-use areas. Ten of 30 ground-water wells had radon concentrations greater than the USEPA proposed drinking-water standard of 300 picocuries per liter (p. 22).



Proportion of samples with detected concentrations **greater than or equal to** health-related national guidelines for drinking water, protection of aquatic life, or the desired goal for preventing nuisance plant growth.

Proportion of samples with detected concentrations **less than** health-related national guidelines for drinking water, protection of aquatic life, or the desired goal for preventing nuisance plant growth.

Proportion of samples with **no detections**.

— Not assessed.

[1] Solvents, refrigerants, fumigants, and gasoline compounds in water.

Major Influences on Ground-Water Quality

- Urban and agricultural land-use practices
- Depth to water from land surface
- Aquifer properties

Introduction to the Mobile River Basin

The Mobile River Basin is the sixth largest river basin in the Nation (Lamb, 1979) and encompasses 44,000 square miles (mi^2) in parts of Alabama, Georgia, Mississippi, and Tennessee. The Mobile River, formed by the Alabama and Tombigbee Rivers, flows south into Mobile Bay, which discharges into the Gulf of Mexico (fig. 1). Landforms in the Mobile River Basin range from rugged mountains to coastal lowlands and are included in five physiographic provinces—the Blue Ridge in the northeast, the Piedmont in the east, the Valley and Ridge and Appalachian Plateaus in the north-central part of the basin, and the Coastal Plain (fig. 1).

Land use affects water quality and aquatic biology

Approximately 70 percent of the Mobile River Basin is covered by forests. Consequently, silviculture is the largest industry. Logging and other silviculture activities can significantly affect the quality of streams because of increased sediment from erosion and runoff.

Nearly 4 million people live in the Mobile River Basin (Johnson and others, 2002). The largest population centers (greater than 100,000) include Birmingham, Mobile, Montgomery, and Tuscaloosa (fig. 1). Although urban areas account for only 3 percent of the land use in the basin, their effect on water quality and aquatic life can still be substantial. Contaminant sources associated with urban areas include septic systems and wastewater effluent; fertilizers and pesticides used on lawns, gardens, parks, rights-of-way, and golf courses; and runoff containing oil, solvents, metals, and other contaminants from streets and parking lots.

About one-fourth of the land in the Mobile River Basin is used for agriculture. Contaminants associated with agricultural areas, which can affect streams and ground water, include fertilizers and pesticides used in crop production and manure from livestock animal production. Pasture for hay and cattle grazing is the most common type of agricultural land use throughout the basin. Row crops, primarily corn, soybeans, cotton, wheat, and sorghum, are common in the Mississippi part of the basin and in the alluvial flood plains along parts of the Coosa, Tallapoosa, Alabama, and Black Warrior Rivers. Other agricultural activities include aquaculture and poultry and cattle production.

Birmingham is the largest city in the basin. Increasing urbanization, marked by increases in population, roads, and other impervious areas, stresses the biological health of suburban streams.

Streamflow in the Mobile River Basin is highly regulated by upstream reservoirs for water supplies, flood-control and navigational locks and dams, and hydroelectric plants (fig. 2). As a result, natural seasonal flow patterns in these tributaries have been altered, with moderated peaks and low flows downstream from the reservoirs. In addition, stream habitat has been altered by reduced streamflow velocities, causing changes in populations of fish and other aquatic organisms. For example, fish species such as largemouth bass that thrive in pooled environments with slow currents are more numerous than fish species such as darters, which require swift water for spawning and feeding. Aquatic organisms also are affected by increases in stream temperature and reduced oxygen levels that often occur in pooled or slow-moving river reaches.

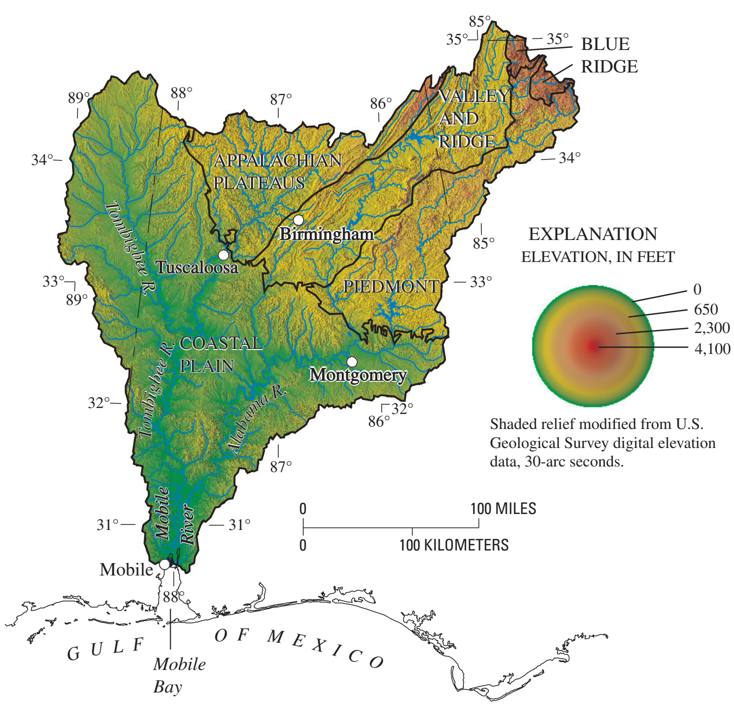


Figure 1. Topography in the Mobile River Basin ranges from steep mountains and plateaus in the northeast to broad, flat plains and rolling hills in the south and west. The physiographic provinces are related to natural changes in geology and hydrology in the basin.

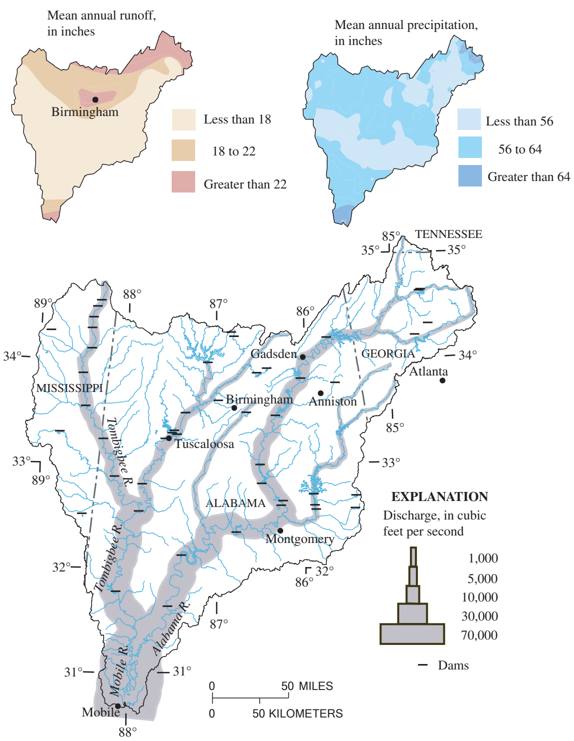


Figure 2. The Alabama River contributes slightly more inflow to the Mobile River than the Tombigbee River. Flow in the Alabama and Tombigbee River Basins is regulated by upstream reservoirs, flood-control and navigational locks and dams, and hydroelectric plants. Mean annual runoff in the Mobile River Basin ranges from 18 to 30 inches per year. The mean annual runoff in the Birmingham area is influenced partly by increasing urbanization and impervious areas.

Water quality is affected by sediment and nutrients that are trapped in the reservoirs and contribute to eutrophication, algal blooms, low-oxygen levels, and fish kills.

Water Availability

The mean annual flow in the Mobile River is about 62,100 cubic feet per second (ft^3/s) (U.S. Army Corps of Engineers, written commun., 1974), which ranks fourth in the Nation and is exceeded only by flows in the Mississippi, Columbia, and Yukon Rivers (Wilson and Iseri, 1969). The Alabama and Tombigbee Rivers contribute about 52 and 48 percent of the flow, respectively (fig. 2). Mean annual runoff and precipitation generally are uniform throughout the Mobile River Basin; the highest precipitation amounts (about 64 inches per year) typically occur in the northeastern part and southern tip of the basin.

The Blue Ridge and Piedmont are underlain by a fractured, crystalline-rock aquifer characterized by little or no pore spaces or openings and overlying unconsolidated, weathered rock remnants and soil. The Valley and Ridge and Appalachian Plateaus are underlain by fractured-rock aquifer systems in well-consolidated sandstones and by interconnected fractured-rock systems in cavernous limestone and dolomite; openings in these latter rocks become enlarged as water flows through them. Caves and sinkholes in the limestone and dolomite increase the susceptibility of ground water to contamination from inflowing surface water. The Coastal Plain is underlain primarily by sand and gravel aquifer systems, which are important sources of drinking water. Water supplies in the Coastal Plain are produced from shallow ground water and from deep ground water that is confined by impermeable layers of chalk and clay.

Approximately 1.3 billion gallons of water is used each day in the basin for public supplies, commercial and industrial uses, mining, and agricultural uses, such as irrigation for crops and water for livestock (fig. 3). Surface water supplies more than 75 percent of the total water used. More than 300 million gallons of ground water is withdrawn per day, most of which is used for public and domestic drinking-water supplies. The use of surface water and ground water varies geographically within the basin. In the Coastal Plain, for example, nearly 60 percent of the water used comes from ground water; in the other physiographic provinces, however, more than 80 percent comes from surface water.

Hydrologic Conditions

Water quality in streams, rivers, and shallow aquifers commonly varies in response to hydrologic conditions; thus, information on streamflow is critical for assessing water-quality conditions. Water samples collected during 1999 through 2001 in the Mobile River Basin generally represented drought conditions within the basin and in the Southeastern United States. Typically, rainfall amounts are higher during the winter and spring months than what fell in those months during the 3-year sampling period (National Weather Service, 2003; fig. 4). As a result, streamflow was below average (fig. 5). During dry conditions, streamflow consists primarily of base flow (ground water discharging to the stream). Water quality in the streams,

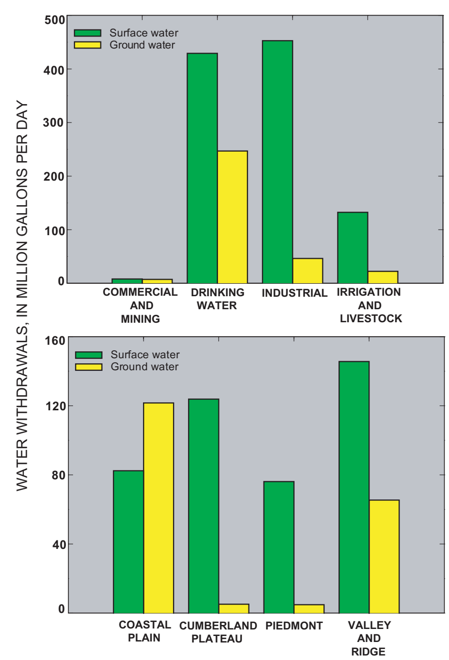


Figure 3. Surface water is the major source of water supply in most areas of the Mobile River Basin (more than 75 percent), except for the Coastal Plain, where ground water is the predominant source of drinking water.

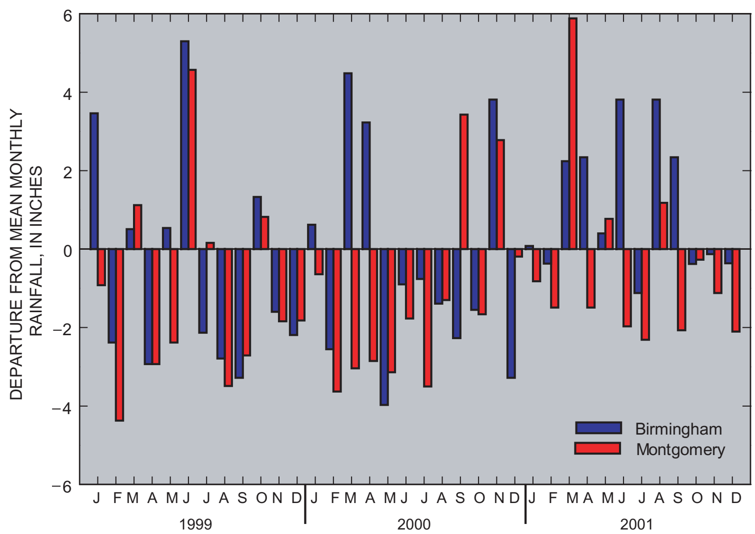


Figure 4. Departures from mean monthly rainfall at two stations in the Mobile River Basin indicate drought conditions during the 1999–2001 sampling period. The mean monthly rainfall amounts are based on the 30-year period, 1971–2000.

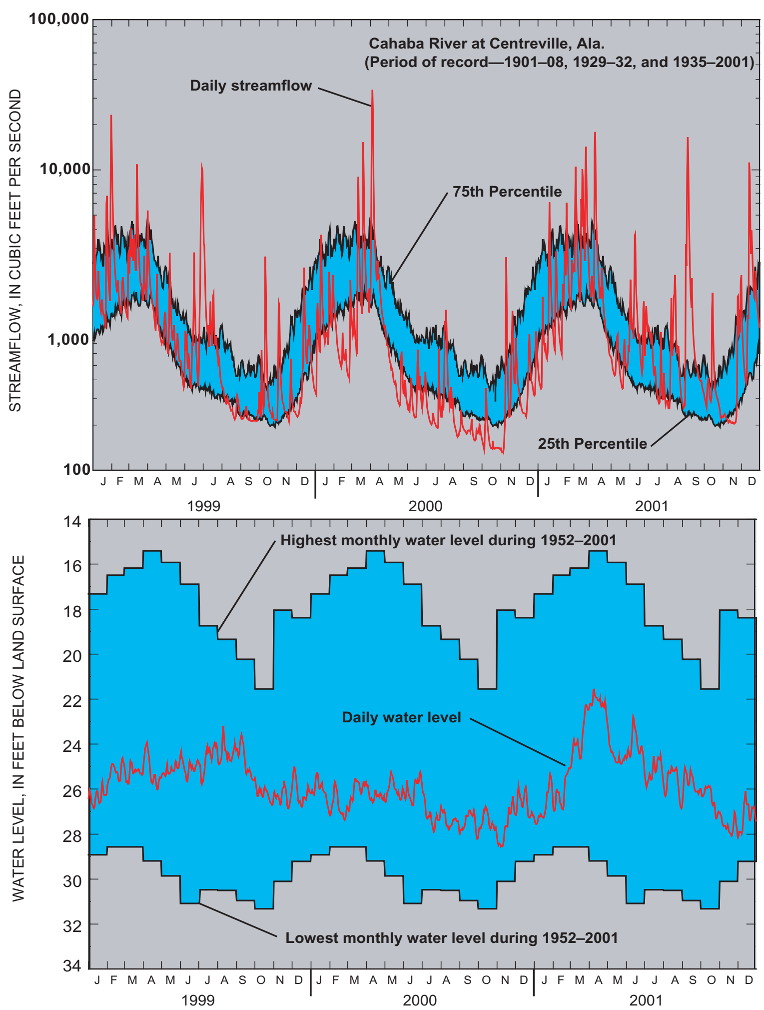


Figure 5. Streams and rivers, such as the Cahaba River at Centreville, Ala., were sampled during 1999–2001, when flows generally were below the long-term average flow. Ground-water levels in the Black Warrior River aquifer in Montgomery, Ala., generally were below normal during 1999–2001.

therefore, is influenced predominantly by the quality of ground water and by point-source discharges to the streams.

Study design focused on effects of land use on water quality

Chemical and biological samples were collected from selected streams and rivers in urban, agricultural, and mixed land-use areas to assess overall quality and the effects of specific land-use practices. At some sites, water samples were collected monthly and during storms to assess the effects of storm runoff on water quality in the streams. Other sites were sampled only once or twice during periods of base flow.

Ground water was sampled from shallow and deep wells in the Black Warrior River aquifer in the Coastal Plain. The aquifer contributes 51 percent of the ground water used for public water supply in the Mobile River Basin. Monitoring wells were installed in unconsolidated alluvial deposits overlying the Black Warrior River aquifer to assess the quality of water in agricultural and urban land-use areas. Ground water moves downward from the alluvial deposits to the deeper parts of the Black Warrior River aquifer. Domestic wells in the recharge area for the aquifer were sampled to assess general water quality. (See page 23 for details on the study design.)

Additional Information

More information on the natural and human factors affecting water quality in the Mobile River Basin can be found in Johnson and others (2002).

The report is available at

http://pubs.water.usgs.gov/wri024162

Major Findings

Nutrients

Human activities in the Mobile River Basin—including agricultural and urban uses of fertilizer, agricultural use of manure, and discharge of municipal wastewater—have contributed to increases in nitrogen and phosphorus in streams and nitrate in ground water. Although nitrogen and phosphorus are essential to the growth and health of plants and animals, elevated concentrations of these nutrients are a potential concern for human health and aquatic life. Excessive concentrations can contribute to the overgrowth of algae and other nuisance plants, whose death and subsequent decay can cause oxygen levels in streams to decrease substantially during warm weather and at night. Some sensitive aquatic organisms cannot live in low-oxygen environments. Infants who ingest water containing elevated concentrations of nitrate can develop a condition known as "blue-baby syndrome" in which blood oxygen levels become dangerously low. Because of these health concerns, the USEPA set the drinking-water standard for nitrate at 10 milligrams per liter (mg/L) as nitrogen (N).

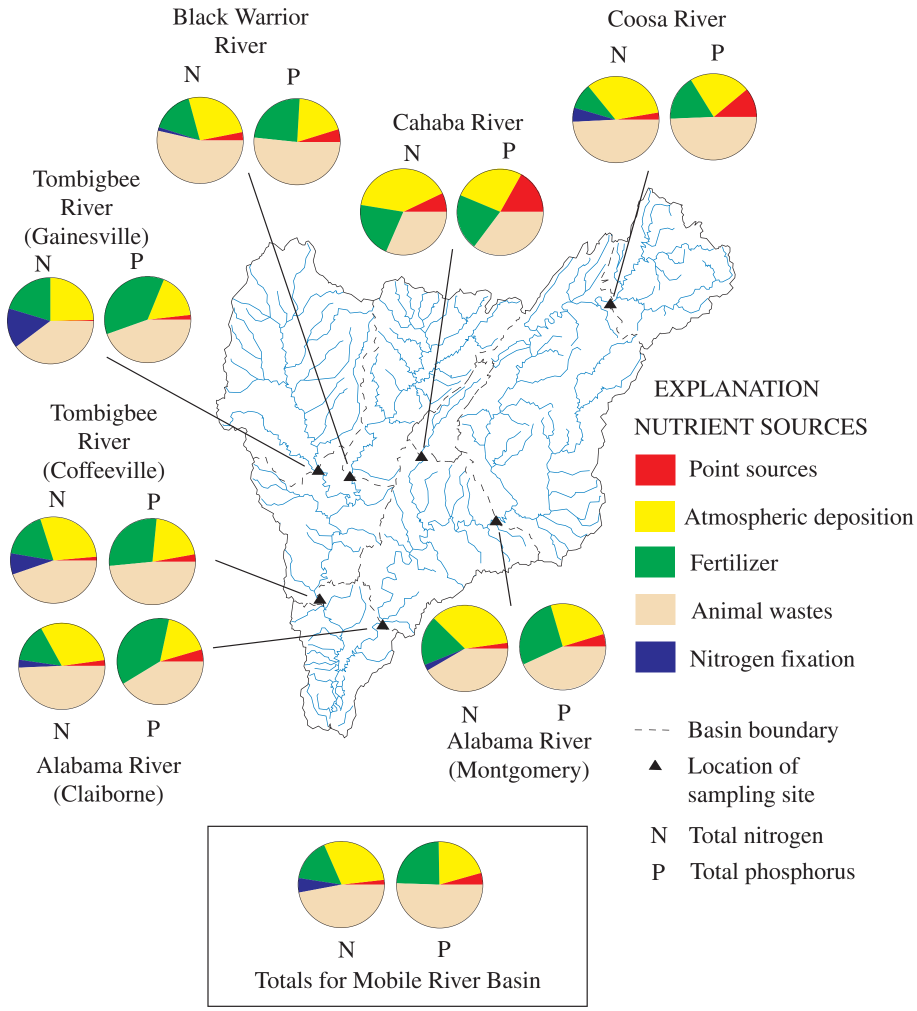


Figure 6. Nonpoint sources account for 98 percent of the nitrogen and 96 percent of the phosphorus in the Mobile River Basin. Animal wastes contribute approximately 50 percent of the nitrogen and phosphorus, row-crop agricultural practices contribute 20 and 25 percent, atmospheric sources contribute 30 and 20 percent, and point sources contribute less than 5 percent of the nitrogen and phosphorus.

Nonpoint sources are the primary sources of nutrients

About 98 percent of the nitrogen and 96 percent of the phosphorus in the Mobile River Basin are from nonpoint sources (fig. 6). Commercial fertilizer and animal wastes are the major nonpoint sources of nitrogen and phosphorus for most of the basin (contributing about 60 and 77 percent, respectively). Agricultural nonpoint sources are especially high in the upper Tombigbee River Basin, where large amounts of row-crop agriculture, specifically soybeans, result in the highest amounts of nitrogen fixation in the basin (see "Glossary"). Atmospheric contributions are another significant nonpoint source, accounting for about 30 and 20 percent of the nitrogen and phosphorus, respectively. Although point sources, such as municipal wastewater-treatment plants, contribute less than 5 percent of the nitrogen and phosphorus to the basin overall, these sources are locally important in watersheds draining urban and industrial areas, such as the Cahaba, Coosa, and Black Warrior Rivers. These point sources also can have significant effects on water quality during periods of low flow (Mueller and Helsel, 1996).

Soybeans are the largest crop, grown primarily in the upper Tombigbee River Basin in Mississippi.

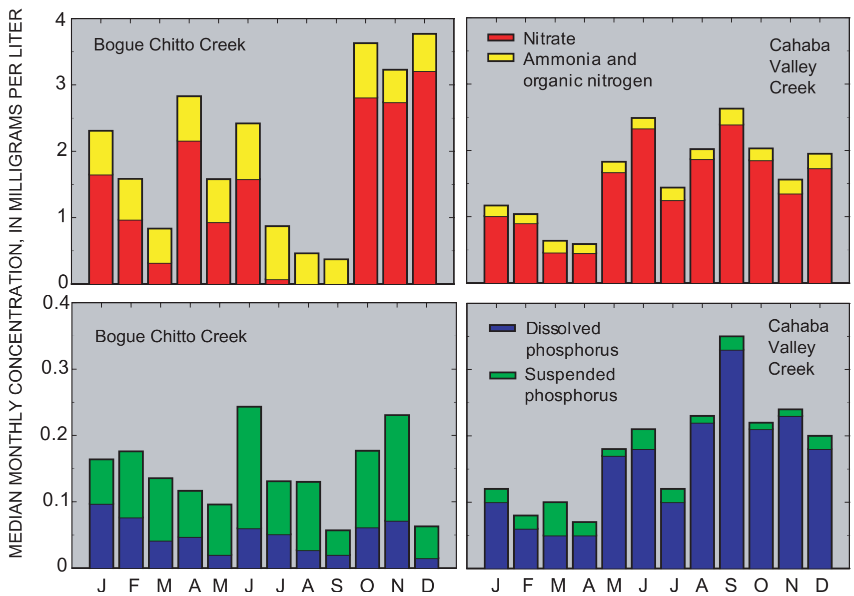


Figure 7. Nitrogen concentrations in Bogue Chitto Creek, an agricultural watershed, generally were lowest in late summer when plant uptake is at its maximum, but concentrations of phosphorus varied in response to runoff events. In the urban Cahaba Valley Creek, concentrations of nitrogen and phosphorus generally were stable except for relatively low values from January through April when streamflow was diluted by rainfall runoff.

Nutrients were detected frequently in agricultural and urban streams

Streams draining basins with large areas of agricultural or urban land, or with mixed land uses, commonly carry complex mixtures of nutrients. The variation can be explained in large part by land use, sources of nutrients, including the types and amounts of fertilizer used in the basins and the presence of waste-treatment discharges, and natural features, including soil type and hydrologic setting. Variations are noted both at the basin scale and within smaller watersheds. For example, average flow-weighted concentrations of nitrogen and phosphorus in the Tombigbee River, which drains much of the western half of the basin, were higher (0.85 and 0.14 milligram per liter [mg/L], respectively) than in the Alabama River, which drains much of the eastern half (0.63 and 0.09 mg/L, respectively). The higher concentrations of nutrients in the Tombigbee are attributed to the application of relatively large amounts of fertilizer to intensive row-crop agriculture in the upper part of the Tombigbee River Basin (fig. 6). Variations at the watershed scale are demonstrated by higher average flow-weighted concentrations of nitrogen and phosphorus in the intensively farmed Bogue Chitto Creek watershed (3.90 and 1.20 mg/L, respectively) than in the urbanized Cahaba Valley Creek (1.30 and 0.15 mg/L, respectively). Nutrients in Bogue Chitto Creek are primarily from farmland applications of fertilizer and manure from cattle operations, whereas nutrients in Cahaba Valley Creek are derived primarily from waste-treatment discharges and applications of fertilizers on residential land.

Overall, nitrate was the most frequently detected form of nitrogen in 343 samples collected from nine streams (detected in about 89 percent of the samples), although the relative occurrence of nitrate varied by land use. For example, nitrate concentrations, which were generally highest in urban streams, accounted for more than 80 percent of the total in the urbanized Cahaba Valley Creek (fig. 7), whereas only about half of the total nitrogen in the agricultural Bogue Chitto Creek was in the nitrate form.

Ammonia also was dominant in Bogue Chitto Creek, where it accounted for about 37 percent of the total nitrogen concentration (versus only 13 percent in Cahaba Valley Creek). Ammonia, which is soluble in water, generally is not stable in stream environments and is readily transformed to nitrate in waters that contain oxygen. Environmental factors, including soil type, presence of organic carbon, and hydrologic setting, however, can contribute to increased stability and occurrence of ammonia, such as that found in Bogue Chitto Creek.

Concentrations of ammonia in Bogue Chitto Creek reached a maximum of 1.63 mg/L. The average flow-weighted concentration of ammonia in Bogue Chitto Creek (0.27 mg/L), was among the upper 6 percent of the concentrations in all NAWQA studies across the Nation. Although elevated, ammonia concentrations in Bogue Chitto Creek generally were below USEPA criteria for maximum ammonia concentrations in surface water based on toxicity to aquatic organisms such as fish. These criteria vary with acidity and water temperature, which affect both the toxicity of ammonia and the form in which it occurs. In most natural surface waters, total ammonia concentrations greater than 2 mg/L would exceed the chronic exposure criteria for fish.

Phosphorus was elevated in Mobile River Basin streams. In fact, average flow-weighted concentrations of total phosphorus in seven of nine streams exceeded the USEPA recommended goal of 0.1 mg/L established to minimize nuisance plant and algal growth in streams (U.S. Geological Survey, 1999) (fig. 8). The average flow-weighted concentration of total phosphorus in Bogue Chitto Creek (1.25 mg/L) was among the highest (upper 5 percent) in the Nation. Total phosphorus concentrations consisted primarily of suspended phosphorus, which is attached to suspended sediment or incorporated into algal cells and other organic matter (fig. 7). This reflects the chemical nature of many forms of phosphorus, which attach to soil particles rather than dissolve. A large amount of phosphorus, thereby, is

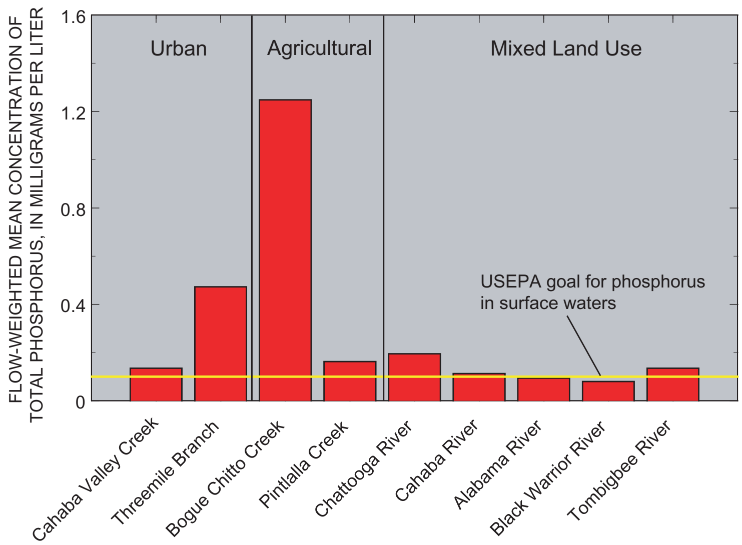


Figure 8. Seven streams in the Mobile River Basin exceeded the USEPA goal for phosphorus in surface water. Concentrations generally were higher in urban and agricultural streams than in mixed land-use rivers (see "Study Unit Design" on p. 23 for sampling site locations).

transported to streams with eroded soils, particularly during times of high runoff from irrigation or precipitation. Total phosphorus concentrations at the urban Threemile Branch were in the upper 12 percent relative to other NAWQA sites nationally.

Nutrient concentrations varied seasonally in streams

Concentrations of nitrogen were lowest (less than 1.0 mg/L) in Bogue Chitto Creek in late summer, when plant uptake is at its maximum (fig. 7). Seasonal variations in phosphorus were not as pronounced as that of nitrogen. Concentrations of phosphorus typically are event-controlled, with highest values coinciding with increased runoff from rainfall and irrigation, during which soil and sediment-bound phosphorus are transported to streams.

Seasonal patterns in nutrients in the urban Cahaba Valley Creek were different than those in the agricultural Bogue Chitto Creek (fig. 7). The concentrations of nitrogen and phosphorus generally were stable in Cahaba Valley Creek during most of the year, which in large part reflects the relatively constant inputs from wastewater-treatment discharge. From January through April, however, nutrient concentrations tend to be at their lowest because of dilution of streamflow by runoff from increased rainfall.

Concentrations of nitrate and ammonia are elevated in shallow ground water underlying agricultural land

Nitrate, ammonia, and orthophosphate are the most common forms of nutrients detected in ground water. Most other forms attach to soil particles or organic matter and do not easily dissolve or move readily in water. Ground water typically is not vulnerable to contamination by compounds that attach to soils. Ground water is most vulnerable to contamination in well-drained areas with rapid infiltration and highly permeable subsurface materials, which minimize the degree to which nutrients are taken up by plants, consumed by bacteria in the soil, or transformed to other forms.

NAWQA findings show that concentrations of nitrate are elevated in shallow ground water (about 20 feet below land surface) beneath farmland. Specifically, the median concentration was 3.05 mg/L in 29 wells in agricultural areas, with a maximum of 17.6 mg/L (fig. 9). Concentrations in two wells exceeded the drinking-water standard of 10 mg/L. This shallow water is not commonly used for drinking supplies, but contaminated shallow ground water can move vertically into the aquifer over time and affect the deeper water that is used for drinking. In addition, shallow ground water that is used for domestic supply in rural areas is of particular concern because many homeowners are not aware of possible risks. Privately owned wells are not monitored regularly, as is required by the Safe Drinking Water Act for public-supply wells. Many homeowners in recently established residential areas that rely on

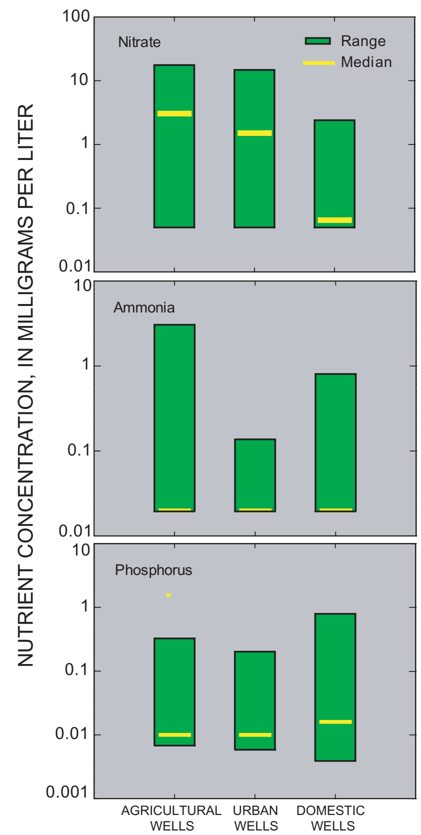
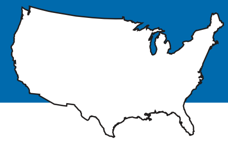
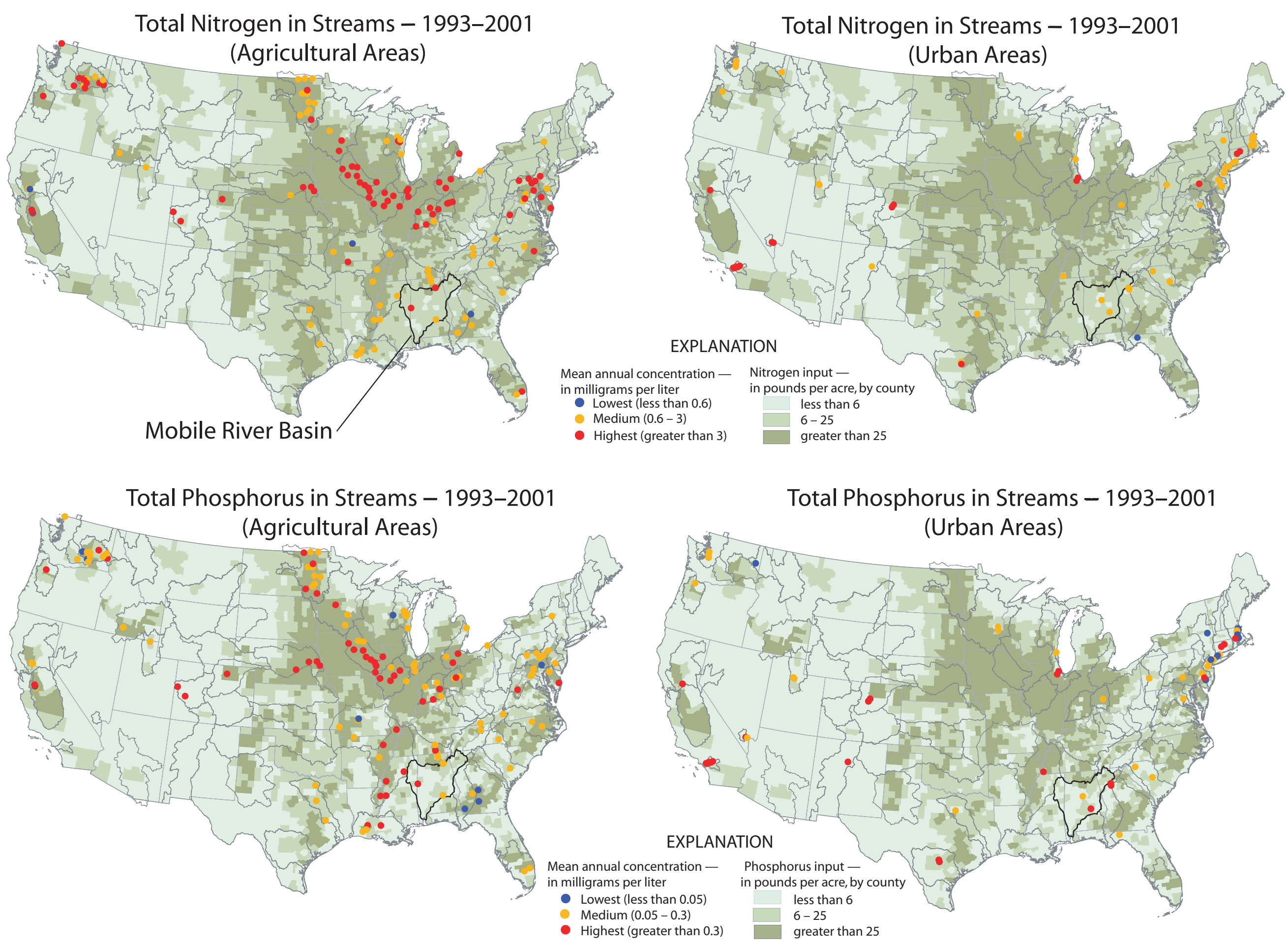


Figure 9. Concentrations of nitrate were generally higher in agricultural and urban wells than in domestic wells. Ammonia concentrations also were higher in agricultural wells than in urban and domestic wells. Concentrations of dissolved phosphorus were generally higher in deep domestic wells completed in the Black Warrior River aquifer than in shallower agricultural and urban wells completed in unconsolidated alluvial deposits overlying the aquifer.



Nutrient Concentrations In Some Mobile River Basin Streams Are Among The Highest In The Nation

Intensive use of fertilizers associated with row-crop agriculture in the Bogue Chitto Creek watershed resulted in average flow-weighted concentrations of ammonia and total phosphorus that ranked among the upper 5 percent of 479 streams sampled across the Nation by the NAWQA Program. Bogue Chitto Creek was the only agricultural stream sampled by NAWQA in the Southeastern United States with total nitrogen and total phosphorus concentrations in the high range. Phosphorus concentrations in the urbanized Threemile Branch in Montgomery, Ala., also were elevated compared to other streams sampled nationally, ranking among the upper 10 percent. Generally, concentrations of nutrients in the other streams in the Mobile River Basin, including the urban Cahaba Valley Creek and agricultural Pintlalla Creek, were in the medium range (0.6 - 3 mg/L for total nitrogen and 0.05 - 3 mg/L for total phosphorus).



privately owned wells are not aware that chemicals leached from previous agricultural or other activities can remain in shallow ground water for decades.

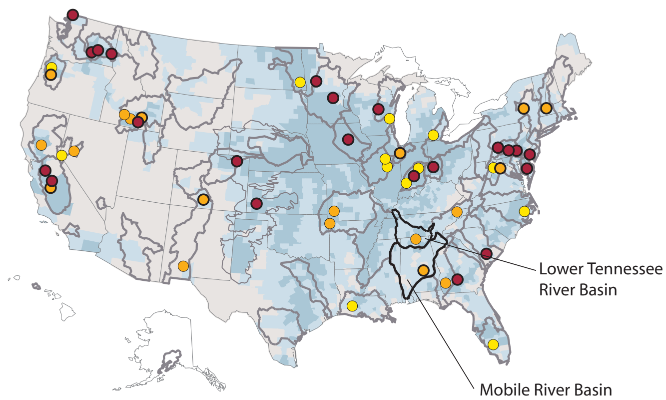
Concentrations of nitrate were generally lower in shallow ground water underlying the urban area of Montgomery, Ala., than in shallow water underlying farmland, with a median of 1.51 mg/L and a maximum of 14.8 mg/L (fig. 9). The concentration in only one urban well exceeded the drinking-water standard. Nitrate concentrations also were relatively low (median of about 0.1 mg/L) in the deeper, domestic wells completed in the Black Warrior River aquifer. In fact, nitrate was detected in only 55 percent of these wells, compared to 73 percent and 93 percent of the urban and agricultural wells, respectively. Nitrate concentrations typically decrease with depth below land surface and age of the ground water. In addition, deeper and older ground water typically has relatively low dissolved oxygen, which can contribute to denitrification and reduce nitrate concentrations.

Concentrations of other nutrient forms in ground water, such as ammonia and phosphorus, generally are lower than concentrations of nitrate (fig. 9). Specifically, most concentrations of ammonia in samples were lower than the

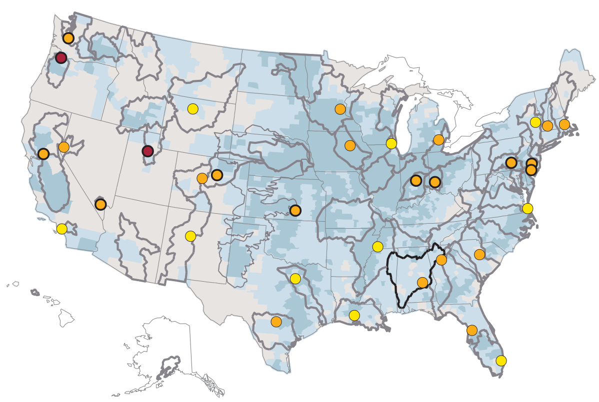
Nitrate Concentrations In Shallow Ground Water In The Mobile River Basin Are Similar To National Results

Median concentrations of nitrate in the shallow ground water underlying urban and agricultural lands in the Mobile River Basin were in the medium range (0.4–5 mg/L) of other shallow wells in urban (890 wells) and agricultural (1,421 wells) areas sampled across the Nation by the NAWQA Program. The median concentration of nitrate in shallow ground water underlying agricultural land was nearly twice the background concentration of 2 mg/L. Median concentrations of nitrate for agricultural wells in the Mobile River Basin (about 3.05 mg/L) were three times greater than the median concentrations in agricultural wells sampled in northern Alabama by NAWQA in the Lower Tennessee River Basin, despite similar chemical use, probably because of differences in geology. Specifically, agricultural wells in the Lower Tennessee River Basin were completed in predominantly fine-grained soils and weathered rock that slow the downward movement of water. This allows time for removal of dissolved oxygen, then denitrification, and decreases in nitrate concentrations (Kingsbury, 2003). Agricultural wells in the Mobile River Basin were completed in loosely consolidated deposits, which allow relatively oxygen-rich water to readily infiltrate and recharge the aquifers (Scott and others, 1987) and minimizes the opportunity for denitrification to occur.

Agricultural areas



Urban areas



EXPLANATION

Median concentration of nitrate, in milligrams per liter
Each circle represents a ground-water study

- Highest (greater than 5)
- Medium (0.4 to 5)
- Lowest (less than 0.4)
- Bold outline indicates median values greater than background concentration (2 milligrams per liter)

Average annual total nitrogen input—
in pounds per acre, by county, for 1995–98.
Inputs are from fertilizer, manure, and the atmosphere

- Greater than 25
- 6 to 25
- Less than 6
- No data available

naturally occurring (or "background") ammonia concentration of 0.1 mg/L; concentrations in samples from only five agricultural and three urban wells exceeded this level. Several samples from wells tapping shallow ground water underlying farmland contained elevated concentrations of ammonia (maximum of 3.06 mg/L), which is most likely related to reducing and low-oxygen conditions in the aquifer, favoring the stability of the ammonia form. Concentrations of dissolved phosphorus also were low in shallow ground water,

Additional Information

For addition information on nutrients in surface waters of the Mobile River Basin, refer to McPherson and others (2003). For additional information on nutrients in the shallow ground water in Montgomery, Ala., and in agricultural areas, refer to Robinson (2002, 2003, respectively). These reports are available at

http://pubs.water.usgs.gov/wri034203,

http://pubs.water.usgs.gov/wri024052, and

http://pubs.water.usgs.gov/wri034182

rarely exceeding 0.1 mg/L. This is, in large part, because phosphorus does not readily dissolve and move with ground water but rather attaches to soils and sediments. Despite the natural chemical properties of phosphorus, however, concentrations were elevated in deeper ground water found in the Black Warrior River aquifer. In fact, dissolved phosphorus was detected in 14 wells, with a maximum concentration of 0.79 mg/L. These relatively high concentrations most likely result from natural deposits of calcium phosphate in marine clays in this part of the aquifer.

Pesticides

Pesticides, which are used to control weeds, insects, and fungi, can have unintended effects on the health of humans and aquatic communities. Concentrations of pesticides generally are low in streams and ground water in the Mobile River Basin—almost always below 0.05 microgram per liter (µg/L)—but they are widespread. Specifically, at least one pesticide was detected in 228 of 230 water samples collected at seven stream sites. In all, 69 different pesticides, including 51 herbicides, 15 insecticides, and 3 fungicides, were detected out of the 104 compounds for which the samples were analyzed. A relatively small number of heavily used herbicides accounted for most of the detections. These include atrazine (and its breakdown products or degradates, deethylatrazine, hydroxyatrazine, and deisopropylatrazine), simazine, metolachlor, tebuthiuron, and 2,4-D. Atrazine, a pre-emergent herbicide used on corn in agricultural areas and on lawns and golf courses, was detected at all seven sites in 99 percent of the water samples.

Pesticides were detected in water samples collected from 50 of 59 wells in agricultural and urban areas (about 85 percent). More than 30 different pesticide compounds were detected in ground water, including the frequently detected herbicides atrazine and fluometuron and the atrazine breakdown product, deethylatrazine.

Pesticide contamination varies with land use

The type and amount of pesticide contamination in streams and ground water are closely linked to land use and to the chemicals used in each setting. Insecticides, including diazinon, chlorpyrifos, and carbaryl, occurred more frequently and usually at higher concentrations in urban streams than in the agricultural or mixed land-use sites. Although concentrations generally were low, 13 of 91 water samples (about 14 percent) from the two urban streams—Threemile Branch and Cahaba Valley Creek—had concentrations of chlorpyrifos, diazinon, malathion, and carbaryl that exceeded aquatic-life guidelines. Only 5 of 52 samples (about 10 percent) from the agricultural site—Bogue Chitto Creek—had insecticide concentrations (all chlorpyrifos) that exceeded aquatic-life guidelines.

The herbicides atrazine, simazine, and prometon (used in lawn care and in the maintenance of rights-of-way) also were detected in urban streams. Concentrations generally were low; only three samples from the urban Threemile Branch site had concentrations that exceeded aquatic-life guidelines or drinking-water standards or guidelines for herbicides (one each for atrazine, 2,4-D, and simazine). Overall, herbicides were detected more frequently and usually at higher concentrations in the agricultural stream than in the urban streams. For example, atrazine concentrations in 18 water samples (about 35 percent) from Bogue Chitto Creek exceeded the aquatic-life guidelines, whereas only 1 sample (about 4 percent) from Threemile Branch exceeded aquatic-life guidelines for atrazine.

The type and concentration of pesticides varied in ground water underlying agricultural and urban land, reflecting the chemicals used in the vicinity of the wells. Specifically, herbicides commonly detected in shallow urban wells included deethylatrazine, atrazine, simazine, terbacil, and hydroxyatrazine, with atrazine accounting for the highest concentration, 0.55 µg/L. Dieldrin was the only insecticide detected in urban wells (7 of 30 wells). The herbicides atrazine, deethylatrazine, fluometuron, aldicarb, aldicarb sulfoxide, norflurazon, and aldicarb sulfone were commonly detected in agricultural wells.

Pesticides vary seasonally in streams

Concentrations of pesticides varied seasonally in streams in response to seasonal chemical use and the frequency and magnitude of runoff from precipitation and irrigation. For example, elevated concentrations of atrazine (reaching a maximum of 201 µg/L) generally occurred in agricultural areas in April and May, which corresponds to applications of atrazine prior to the planting and emergence of corn (fig. 10). Cyanazine concentrations generally peaked during July and August after cotton crops emerged. Seasonal patterns in concentrations of herbicides and insecticides were not as evident in urban streams; one exception was elevated concentrations of simazine—a turf-grass herbicide—during November through March. Simazine is applied in the fall to control winter weeds and in late winter to control annual summer weeds (Alabama Cooperative Extension System, 1997).

Hydrology affects pesticide contamination in major rivers

In addition to land use, hydrology and basin characteristics influence the occurrence and concentrations of pesticides in major rivers. For example, pesticides detected in the Cahaba River, an urban setting, were similar to those in its tributary, Cahaba Valley Creek. Similarly, pesticides detected in the Tombigbee River, an agricultural setting, were similar to those in its tributary, Bogue Chitto Creek. Concentrations generally were much lower, however, in rivers than in tributaries because of dilution by water contributed from undeveloped and other land-use areas within the larger, more integrated basins. For example,

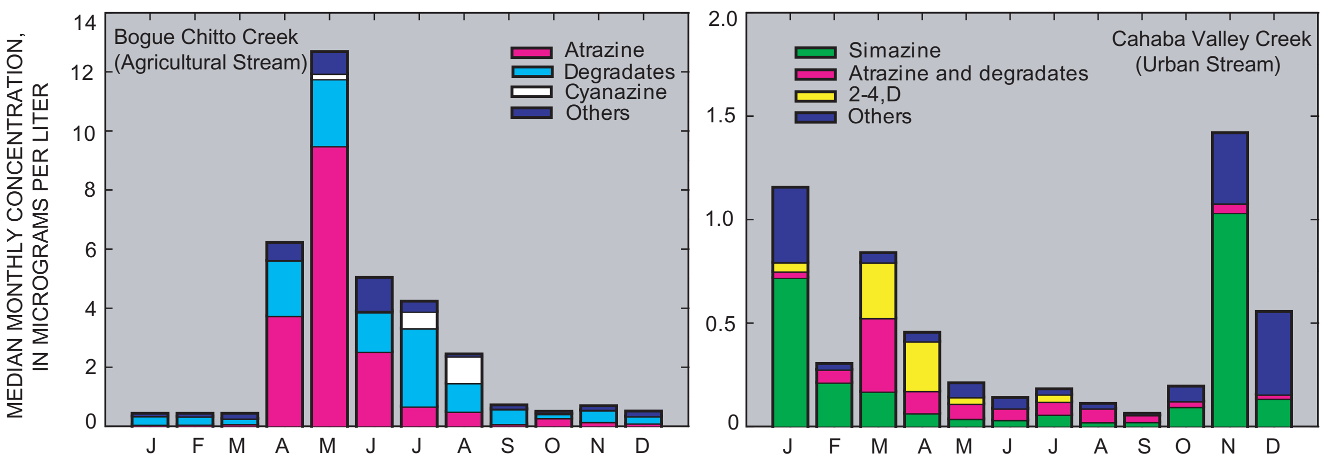


Figure 10. Herbicide concentrations in agricultural streams in the Mobile River Basin, such as Bogue Chitto Creek, were more seasonal and varied and were detected in higher concentrations than concentrations in urban streams, such as Cahaba Valley Creek. In urban areas, concentrations of simazine varied the most throughout the year.

the median concentration of atrazine in Bogue Chitto Creek was 0.54 µg/L, whereas the median concentration in the Tombigbee River was 0.10 µg/L.

Hydrologic characteristics also control the exchange of water and pesticides between streams and the ground-water system. Ground-water contributions to streams are most important in geologic settings that readily allow exchange between the ground-water and surface-water systems, such as in the loosely consolidated deposits underlying the urban stream, Threemile Branch. Such exchanges, for example, may explain the frequent detection of dieldrin—in 17 of 25 stream samples—in Threemile Branch, which is close to wells with elevated concentrations of dieldrin (Robinson, 2002; fig. 11). Although the USEPA cancelled use of dieldrin in 1987 (Frick, 1997), concentrations of dieldrin were detected in streambed-sediment and fish-tissue samples in Threemile Branch (Zappia, 2002). In contrast, dieldrin was not detected in samples of water, streambed sediment, or fish tissue from a comparable urban stream, Cahaba Valley Creek. Although carbonate-rock streams in the Valley and Ridge Physiographic Province, such as Cahaba Valley Creek, may receive ground-water discharge during base flows, the ground water

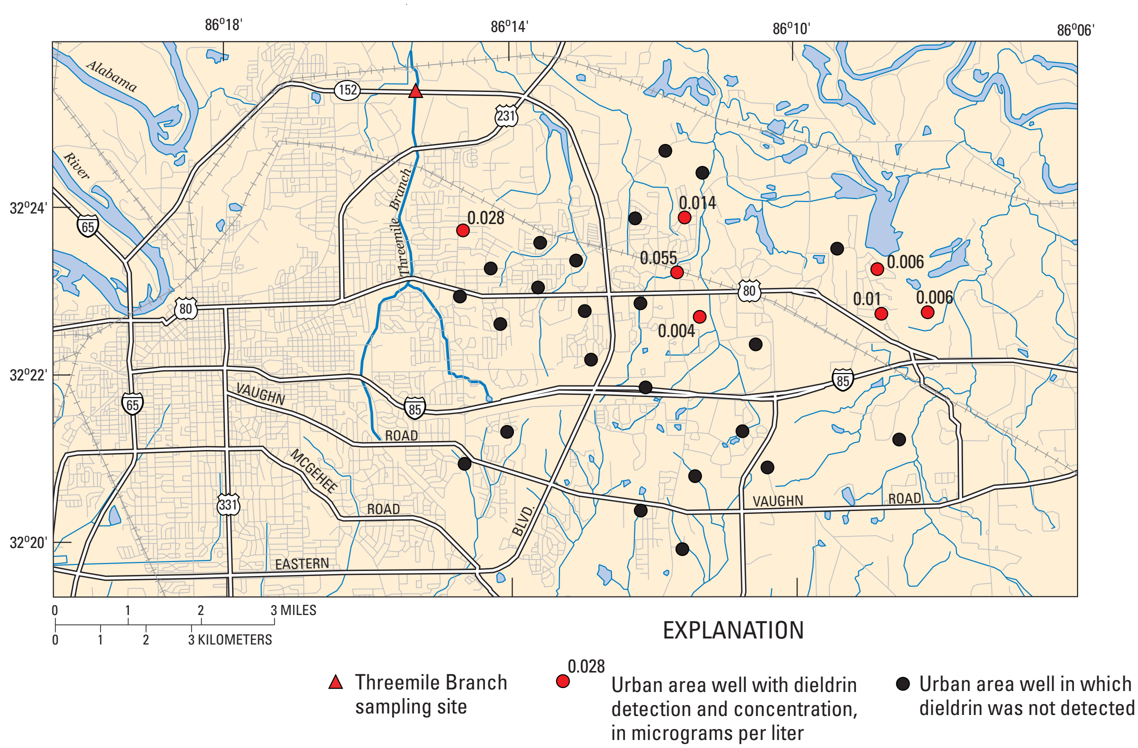
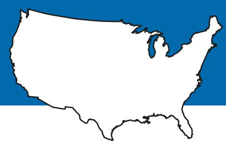


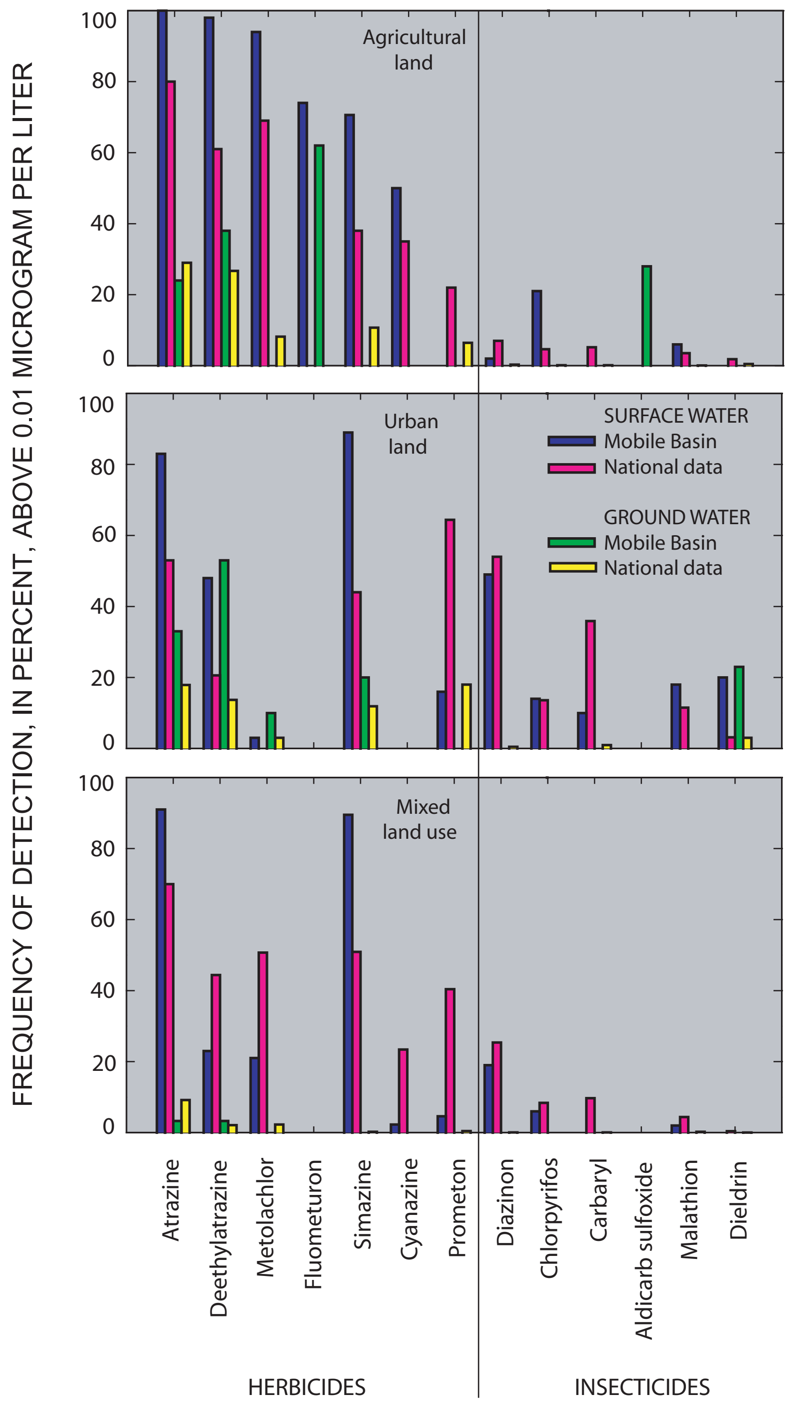
Figure 11. The insecticide dieldrin was detected in Threemile Branch and in 7 of 30 shallow wells sampled in residential and commercial areas in Montgomery, Ala. Dieldrin most likely moves with ground-water discharge to Threemile Branch through the loosely consolidated alluvial deposits underlying parts of Montgomery.



Occurrence Of Pesticides In The Mobile River Basin Is Both Similar To And Different From National Patterns

The occurrence of pesticides in the Mobile River Basin is both similar and different to patterns around the Nation. Dieldrin, for example, is the only insecticide that was detected in urban wells in the Mobile River Basin, and it also has been the most commonly detected insecticide in urban ground water nationally (U.S. Geological Survey, 1999). Several pesticides, however, were detected more frequently in the Mobile River Basin than nationwide. For example, atrazine and simazine were detected more frequently in streams in the Mobile River Basin (86 percent) than in 155 streams sampled nationwide (57 percent). Aldicarb sulfoxide, a breakdown product of aldicarb, was detected more frequently in agricultural wells in the Mobile River Basin (28 percent) than in other NAWQA Study Units nationwide. Fluometuron, a herbicide used for cotton crops throughout much of the Southeast, was detected more frequently in agricultural settings in the Mobile River Basin (74 percent), in the Lower Tennessee River Basin (about 65 percent; Hoos and others, 2002), and in the Mississippi Embayment (about 65 percent; Kleiss and others, 2000) than in other parts of the Nation. Fluometuron has not been detected as much in other NAWQA studies nationwide because it has not been used extensively in other agricultural areas.

Seasonal patterns in concentrations of several pesticides in the Mobile River Basin were similar to those in other parts of the Southeast. For example, concentrations of atrazine in Bogue Chitto Creek (fig. 10) peaked in April and May, reaching a maximum of 201 µg/L, which was similar to seasonal concentration patterns of atrazine in agricultural streams in the Mississippi Embayment (Kleiss and others, 2000). Concentrations of simazine, which peaked in November through March in the urban Cahaba Valley Creek (fig. 10), were also seasonally similar in the Apalachicola-Chattahoochee-Flint River Basin (Frick and others, 1998) and in the Mississippi Embayment.



flows quickly through limestone features, typically with much less residence time than in a sand and gravel aquifer, thereby allowing dieldrin and other potential contaminants to be flushed out soon after infiltrating the ground-water system. For example, the median age of the water samples collected from the shallow aquifer underlying Threemile Branch and eastern Montgomery, Ala., is approximately 12 years (Robinson, 2002), whereas the median age of the water in the shallow carbonate-rock aquifer underlying Cahaba Valley Creek is typically much less than 12 years because the carbonate rocks transmit large volumes of water rapidly (Johnson and others, 2002).

Pesticides occur in mixtures and as breakdown products

Pesticides seldom occurred alone in streams and ground water. More than 90 percent of stream samples in the Mobile River Basin contained three or more pesticides; more than 50 percent of stream samples contained nine or more. Pesticide mixtures were less common in ground water. Two or more compounds were detected in about 20 percent of the ground-water samples, and at least eight compounds were detected in about 7 percent of the samples.

Chemical breakdown products, which can have similar or even greater toxicities than parent compounds, are often as common in the water as parent compounds (U.S. Geological Survey, 1999). Atrazine was detected in 99 percent of all stream samples in the Mobile River Basin; deethylatrazine, a breakdown product of atrazine or other triazine herbicides, was detected in every sample in Bogue Chitto Creek and in nearly 90 percent of the urban and mixed land-use stream samples. Other triazine breakdown products that were detected in stream samples, regardless of land use, were hydroxyatrazine, deisopropylatrazine, and desethyl deisopropyl atrazine, all of which were detected in more than 50 percent of all stream samples. Deethylatrazine also was detected in 53 percent and 34 percent of ground-water samples from urban and agricultural wells, respectively. Hydroxyatrazine was detected eight times each in urban and agricultural wells, and deisopropyl atrazine was detected in four agricultural wells. Hydroxyatrazine also was detected in stream samples at various times of the year and at higher concentrations than atrazine. Aldicarb was not detected in any stream or ground-water samples in the Mobile River Basin, although one of its breakdown products, aldicarb sulfoxide, was detected in 24 percent of the agricultural wells.

Pesticide risks to humans and aquatic life remain unclear

Although pesticides were detected frequently, concentrations were usually lower than current standards and guidelines for drinking water and aquatic life. The risk to humans and aquatic life from present-day levels of pesticide exposure remains unclear. Pesticide information gathered in the Mobile River Basin indicated that exposure is complicated by lengthy periods of low concentrations that are often punctuated by seasonal spikes of much higher concentrations in addition to complex mixtures of compounds and breakdown products.

Additional Information

For additional information on pesticides in surface waters in the Mobile River Basin, refer to McPherson and others (2003). For additional information on pesticides in the shallow ground water in Montgomery, Ala., and in agricultural areas, refer to Robinson (2002, 2003, respectively). These reports are available at

http://pubs.water.usgs.gov/wri034203,

http://pubs.water.usgs.gov/wri024052, and

http://pubs.water.usgs.gov/wri034182

Ground-water samples are pumped directly into a mobile laboratory for processing and analysis.

Insecticides, which exceeded aquatic-life guidelines in 10–14 percent of samples from urban and agricultural streams, may affect aquatic life, particularly if seasonal conditions result in sustained periods of elevated concentrations of multiple compounds. Possible risks from these patterns of exposure have not been fully evaluated. Moreover, many of the contaminants and their breakdown products do not have drinking-water standards or aquatic-life guidelines; the current (2003) standards and guidelines do not address exposure to mixtures or to brief spikes of high concentrations. Finally, possible pesticide effects on aquatic life, such as hormonally mediated effects of responses in sensitive species, have not yet been assessed.

Whole-fish and fish-tissue samples were analyzed for organochlorine compounds and trace elements.

Organochlorine Compounds and Trace Elements

Most organochlorine pesticides, such as DDT, chlordane and dieldrin, and polychlorinated biphenyls (PCBs) have not been manufactured or used in the United States for at least 10 to 25 years. Because of their chemical stability and persistence, however, they are widespread in streambed sediment and fish tissue in the Mobile River Basin. Many of these compounds are classified as endocrine disruptors and are known to cause liver and kidney lesions in fish. The compounds can pose a threat to fish-eating wildlife, and some are a concern for human consumption because of possible carcinogenic toxicity.

At least one of the 32 organochlorine compounds for which samples were analyzed was detected in streambed sediment at 11 of 21 stream sites (about 52 percent) in the Mobile River Basin. Multiple compounds were detected at five of the sites. The most commonly detected compounds in sediment were PCBs and the organochlorine pesticides chlordane, DDT, and their breakdown products. In fact, *p,p´*-DDE, a breakdown product of DDT, was the most commonly detected compound at seven sites. The highest concentration of any organochlorine compound analyzed in streambed sediment in the Mobile River Basin was 160 micrograms per kilogram (μg/kg) of PCBs, detected at Valley Creek near Bessemer, Ala. (Zappia, 2002), although this concentration did not exceed any aquatic-life guidelines. Concentrations of chlordane in streambed-sediment samples exceeded probable-effects concentrations (PECs) for the protection of aquatic life at 1 of 21 stream sites (fig. 12). The PECs represent concentrations above which adverse effects to aquatic organisms would be expected to occur (MacDonald and others, 2000).

Organochlorine compounds were reported more frequently in whole-fish tissue samples than in streambed-sediment samples in the Mobile River Basin. Specifically, at least one organochlorine compound was detected in fish-tissue samples collected at 16 of 19 sites (84 percent), and multiple compounds were detected in fish tissue at 12 sites. Similar to findings on streambed sediment, *p,p´*-DDE was the most frequently detected compound in fish tissue at 15 sites. Other commonly detected compounds were chlordane, DDT, dieldrin, heptachlor epoxide, nonaclor, PCBs and breakdown products.

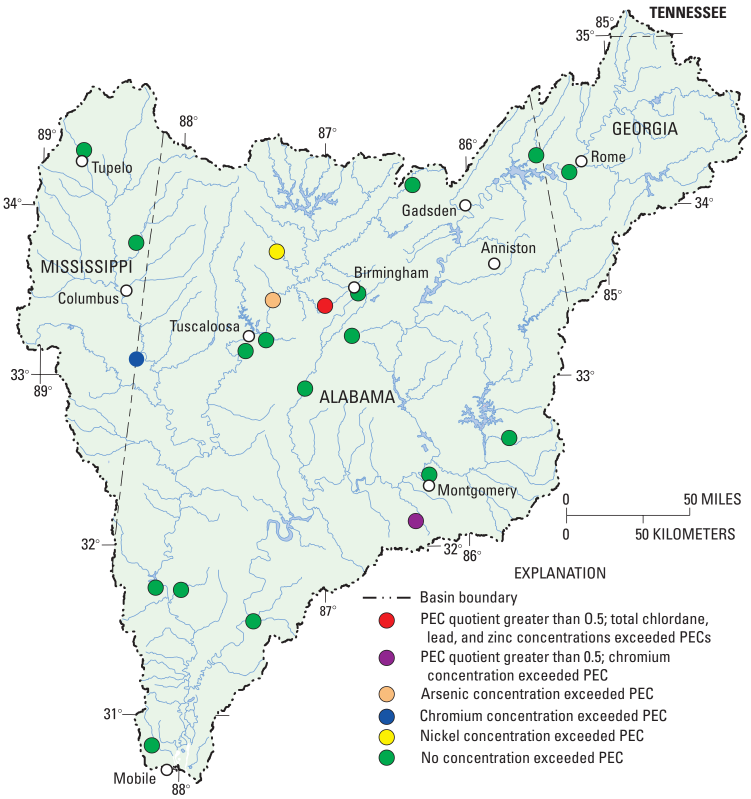


Figure 12. Concentrations of organochlorine compounds and trace elements exceeded probable-effects concentrations (PECs) in streambed-sediment samples at five sites in the Mobile River Basin.

Concentrations of organochlorine compounds commonly were higher in fish tissue than in streambed sediment because of bioaccumulation. The highest concentration in whole-fish tissue (900 μg/kg of PCBs) was measured in a sample from the Coosa River near Rome, Ga. Concentrations of chlordane and DDT in whole-fish tissue samples exceeded Canadian tissue-residue guidelines (TRGs) for the protection of fish-eating wildlife (Canadian Council of Ministers of the Environment, 1999) at 13 of the 19 sampling sites (fig. 13).

Concentrations of organochlorine compounds in fish are related to land use. For example, concentrations of chlordane and heptachlor epoxide in whole-fish tissue samples increased with increasing amounts of urban land. Concentrations of DDT in whole-fish tissue samples, however, increased with increasing amounts of agricultural land use.

Trace elements, similar to organochlorine compounds, are persistent and widely detected in streambed sediment and fish tissue throughout the Mobile River Basin. At least one trace element was detected at each of the 21 sites. A total of 36 of 44 (82 percent) trace elements were detected at least once in streambed-sediment samples and 19 of 22 (86 percent) trace elements were detected in fish-liver samples at least once. Aluminum, copper, iron, manganese, selenium, strontium, and zinc were the most frequently detected trace elements in fish and streambed sediment. Established PECs for the protec-

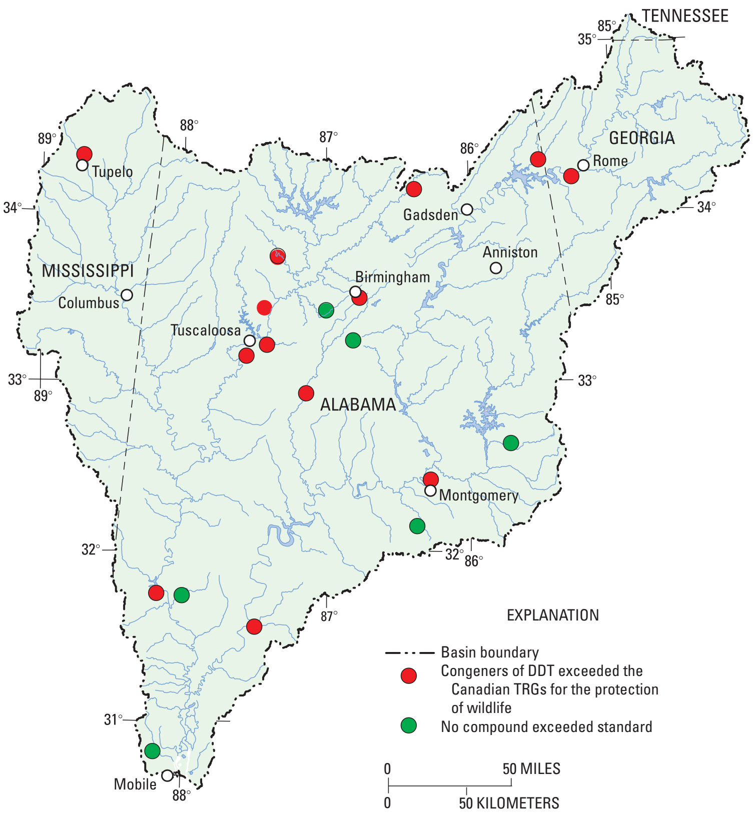


Figure 13. Concentrations of organochlorine compounds in whole-fish tissue exceeded Canadian tissue-residue guidelines (TRGs) for the protection of wildlife at 13 sites in the Mobile River Basin.

tion of aquatic life were exceeded by the concentrations of at least one of the elements (arsenic, chromium, lead, nickel, or zinc) in streambed sediment at 5 of 21 stream sites (fig. 12).

Most trace elements are naturally occurring, originating from geologic formations and minerals in the basin.

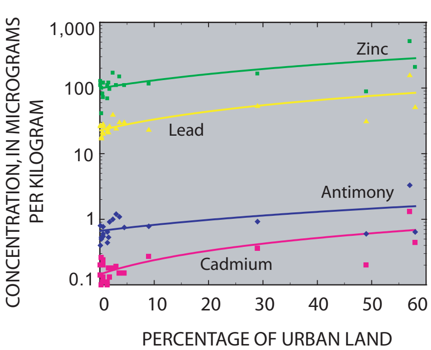


Figure 14. Although most trace elements are naturally occurring, concentrations of antimony, cadmium, lead, and zinc increased in streambed sediment with increasing amounts of urban land within a watershed.

Exceptions include antimony, cadmium, lead, and zinc in streambed-sediment samples, which also can be affected by land-use activities. These compounds increased in concentration with increasing amounts of urban land (fig. 14). Cadmium, lead, and zinc are known to be associated with the steel industry, which has had a long history in the Birmingham, Ala. area. Antimony is a common impurity in ores. In addition, these trace elements are common in urban runoff, contributed by nonpoint sources such as batteries, ceramics, wear of automobile parts, pigments, and fuel combustion (Zappia, 2002).

The frequency of detection and the concentrations of most trace elements and organochlorine compounds in samples from the Mobile River Basin are similar or less than those in other NAWQA study areas nationwide (see Appendix). An exception is the slightly higher median concentrations of arsenic in streambed-sediment samples in the Mobile River Basin that originate from naturally occurring arsenic in the sediments of north Alabama (Goldhaber and others, 2001).

Additional Information

Additional information on organochlorine compounds and trace elements in streambed sediment and fish tissue in the Mobile River Basin can be found in Zappia (2002). The report is available at

http://pubs.water.usgs.gov/wri024160

Volatile Organic Compounds

One or more VOCs were detected in 98 percent of 59 stream samples collected in the urban streams in the Mobile River Basin—Cahaba Valley Creek near Birmingham, Ala., and Threemile Branch in Montgomery, Ala. Of the 86 measured VOCs, 27 (about 31 percent) were detected in one or more samples. The most frequently detected VOCs include trichloromethane (chloroform), which is a by-product of the chlorination of water; tetrachloroethylene (PCE) and trichloroethylene (TCE), which are used extensively in commercial and industrial solvents and degreasers; the solvent cis-1,2-dichloroethene, which is also a breakdown product of TCE; the gasoline oxygenate methyl *tert*-butyl ether (MTBE); and the hydrocarbons benzene, and toluene.

VOCs were prevalent but detected less frequently in shallow ground water than in streams. Specifically, one or more VOCs were detected in 20 of 30 wells (67 percent) in a residential and commercial area in Montgomery, Ala. (Robinson, 2002). Of the 86 measured VOCs, 29 (about 34 percent) were detected in one or more samples. The most frequently detected VOCs include chloroform and toluene; carbon disulfide, which has been used historically as an insecticide and fumigant (Stackelberg and others, 2001); PCE; benzene; and

Volatile Organic Compounds (VOCs)

VOCs are a class of organic compounds that are produced in large quantities for many uses. Products containing VOCS are used extensively in industry, commerce, and households. VOCs are present in fuels and are a by-product of their combustion. VOCs are in many manufactured products including paint, adhesives, cleaning agents, deodorants, and polishing products. VOCs also are used widely in commercial and industrial applications as solvent degreasers and refrigerants, in the dry-cleaning industry, in the manufacture of pharmaceutical products and plastics, and in agricultural applications as active and inactive components of pesticides and fumigants. Many VOCs have properties that make them likely to be mobile and persistent in the environment. Many VOCs also are known to be carcinogenic and otherwise toxic to humans and aquatic organisms; therefore, their use, disposal, and concentration in drinking-water supplies are regulated (Ayers and others, 2000).

1,1,1 trichloroethane (TCA), which also has been used in commercial and industrial solvents and degreasers (fig. 15).

The frequency and types of VOCs detected in ground water varied among the different types of urban land use, including residential, commercial, and industrial. For example, as the percentage of residential land use increased, the total number of VOCs detected increased because VOCs are used in household chemicals, solvents, and fuels. Also, the total number of VOCs detected in ground-water samples increased as concentrations of nickel increased. Nickel is widely used in industry as a constituent of stainless steel and other alloys and is a common environmental contaminant (Childress and Treece, 1996).

Although VOCs were detected frequently in ground water in urban areas, concentrations generally were low. Only one compound—PCE—exceeded drinking-water standards in the surface- and ground-water samples. The highest detected PCE concentration (45.5 µg/L) occurred in a shallow monitoring well; all other detections of PCE in surface- and ground-water samples were below water-quality standards or guidelines.

VOCs were detected less frequently in deep domestic wells completed in the Black Warrior aquifer in mixed land-use areas (predominantly forested and rural land) in the Coastal Plain. At least one VOC was detected in 19 of 30 wells (about 63 percent); however, only seven different VOCs were detected. Chloroform, the most frequently detected VOC, was detected in 11 of 30 wells. The source of the chloroform is not known, but possible sources may be septic tanks or disinfection of wells with household bleach (Moran and others, 2002).

When compared to a national reporting level of 0.2 µg/L, detection frequencies of chloroform, PCE, and 1,1,1-trichloroethane in the Mobile River Basin were slightly higher than those in other NAWQA Study Units (fig. 15). Chloroform was detected in nine urban wells; PCE was detected in

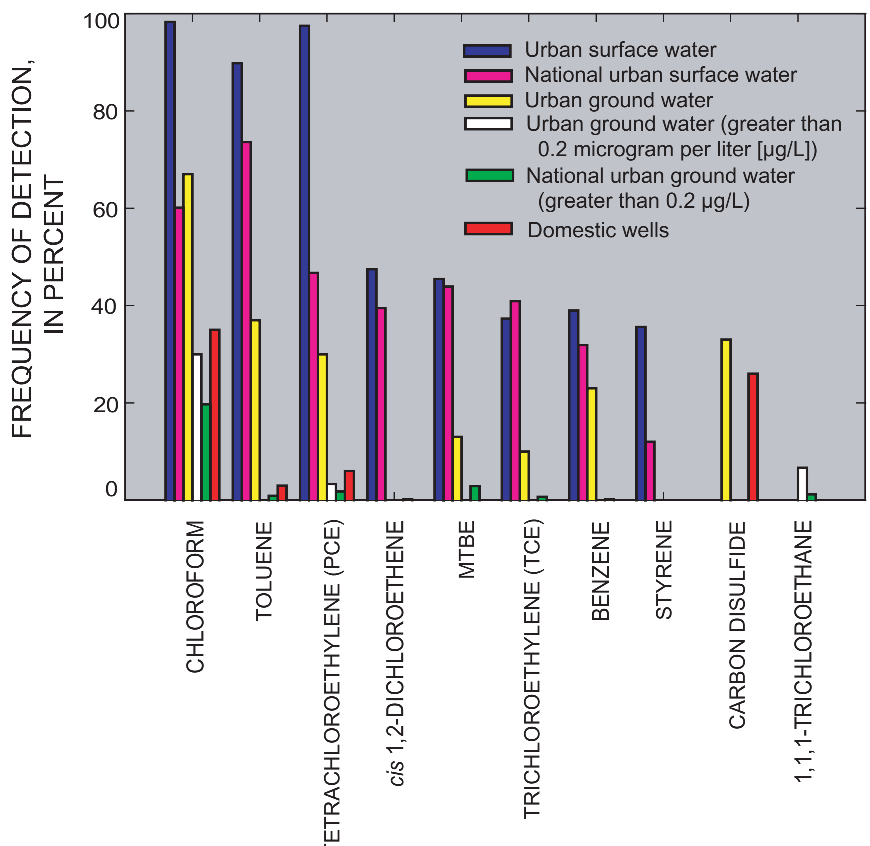


Figure 15. Chloroform, toluene, and PCE were the most frequently detected VOCs in the Mobile River Basin, particularly in urban settings. VOCs generally were detected more frequently in urban areas of the Mobile River Basin than in urban areas in other NAWQA Study Units nationwide. VOCs were detected less frequently in deep domestic wells in mixed land-use areas than in shallow urban wells.

Additional Information

For additional information on VOCs in the shallow ground water in Montgomery, Ala., refer to Robinson (2002). The report is available at

http://pubs.water.usgs.gov/wri024052

one urban well; and 1,1,1-trichloroethane was detected in two urban wells. (Note: 0.2 µg/L was used for national comparisons to include early NAWQA studies in which the higher reporting level was used.)

Biological Communities

Natural conditions and human activities affect water quality and stream habitat, which influence fish, invertebrates, and algal communities. Human activities related to agriculture, urbanization, and silviculture can result in increased levels of nutrients, organic chemicals, and sediment in streams and changes in temperature regime, flow characteristics, and stream-channel morphology. Degraded stream quality and habitat conditions can result in reduced abundance of individuals and numbers of pollution-sensitive aquatic species and increases in the numbers and types of species tolerant to altered or degraded water-quality conditions. Changes in biological communities and other measures of community composition often are used as indicators of environmental stress and are referred to as "biological metrics."

Biological metrics from nine sites throughout the Mobile River Basin indicated various degrees of environmental stress. Highly tolerant macroinvertebrate taxa, such as midges (Chironomidae) and aquatic worms (Oligochaetae), dominated biological communities at seven sites, including streams draining agricultural (Bogue Chitto Creek) and urban areas (Cahaba Valley Creek and Threemile Branch) and in the large rivers (Alabama, Black Warrior, Cahaba, and Tombigbee Rivers, fig. 16).

Pintlalla Creek and the Chattooga River were the only sites not dominated by midges and worms; however, signs of stress were observed within the invertebrate communities. Specifically, communities in Pintlalla Creek and the Chattooga River were dominated by insect groups typically considered sensitive to degraded stream quality—mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), or EPT taxa—but the tolerant species of these groups were most abundant. For example, species from the family Hydropsychidae dominated the caddisflies. Many Hydropsychidae species commonly are found in degraded waters and are adapted to feed on fine particulate organic matter, which is commonly associated with agriculture and urbanization.

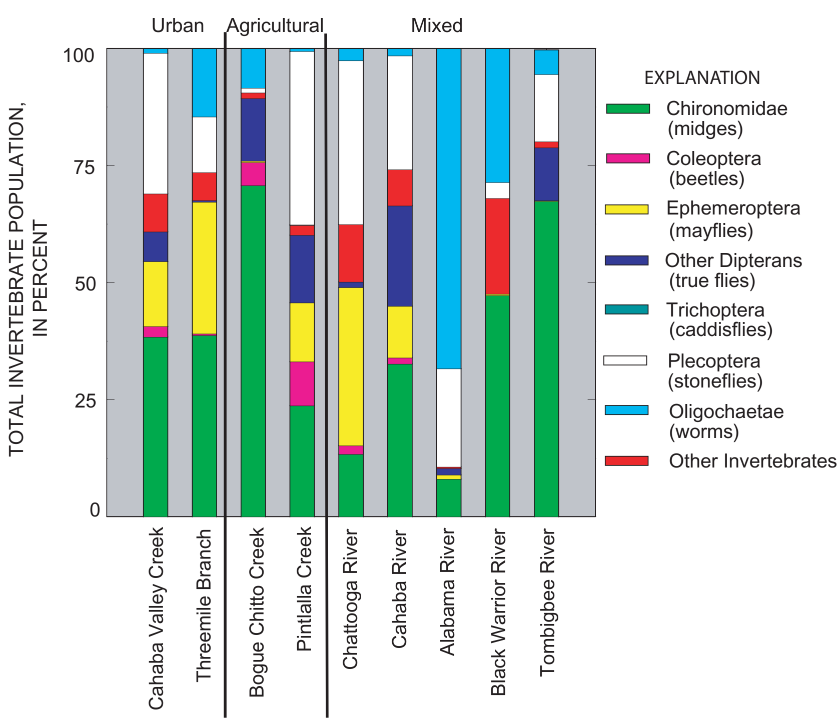


Figure 16. Pollution-tolerant macroinvertebrate taxa, such as midges and worms, dominated the invertebrate communities at seven sites in the Mobile River Basin, 1999–2001.

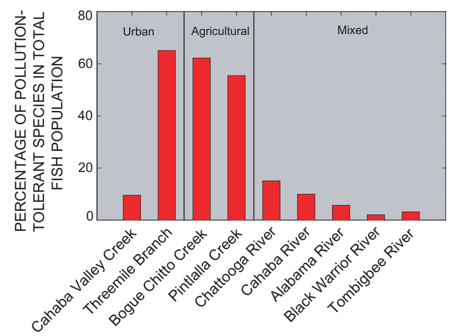


Figure 17. Certain fish species, such as green sunfish, mosquito fish, and yellow bullhead, are more tolerant of degraded water quality and habitat conditions, and thereby dominated the fish communities in the agricultural Bogue Chitto and Pintalla Creeks and in the urban Threemile Branch.

Fish species tolerant of degraded streams, such as green sunfish, mosquito fish, and yellow bullhead, dominated communities at three sites—Pintlalla Creek, Bogue Chitto Creek, and Threemile Branch (fig. 17). The fish communities at the remaining six sites were composed mainly of sensitive species, such as darters (Percidae) and minnows (Cyprinidae), and relatively few tolerant fish species.

Aquatic biological communities are affected by urban development

Physical, chemical, and biological characteristics in 30 similar-sized streams that varied in degree of watershed development were assessed in the Ridge and Valley ecoregion (Omernik, 1987) within the Mobile River Basin (fig. 18). The watersheds ranged in size from 5 to 50 mi^2. An integrated index of "urban intensity" was used to define urban effects on aquatic ecosystems. Each stream was ranked by urban intensity (ranging from 1 to 100) on the basis of 24

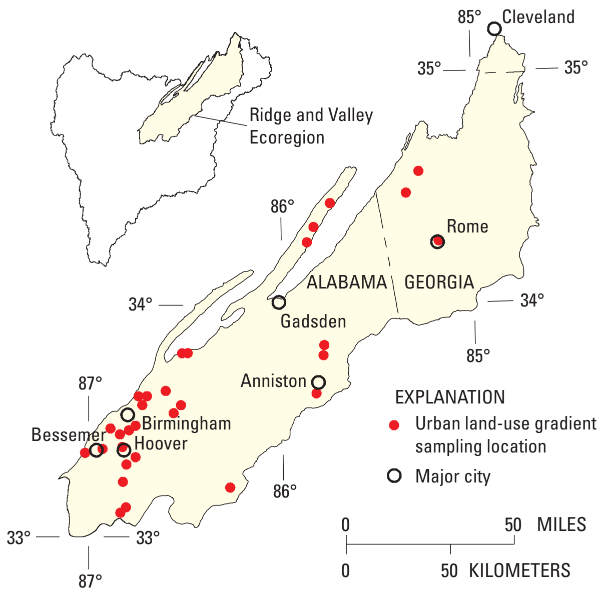


Figure 18. Urban land-use gradient sites in the Ridge and Valley ecoregion (modified from Omernik, 1987).

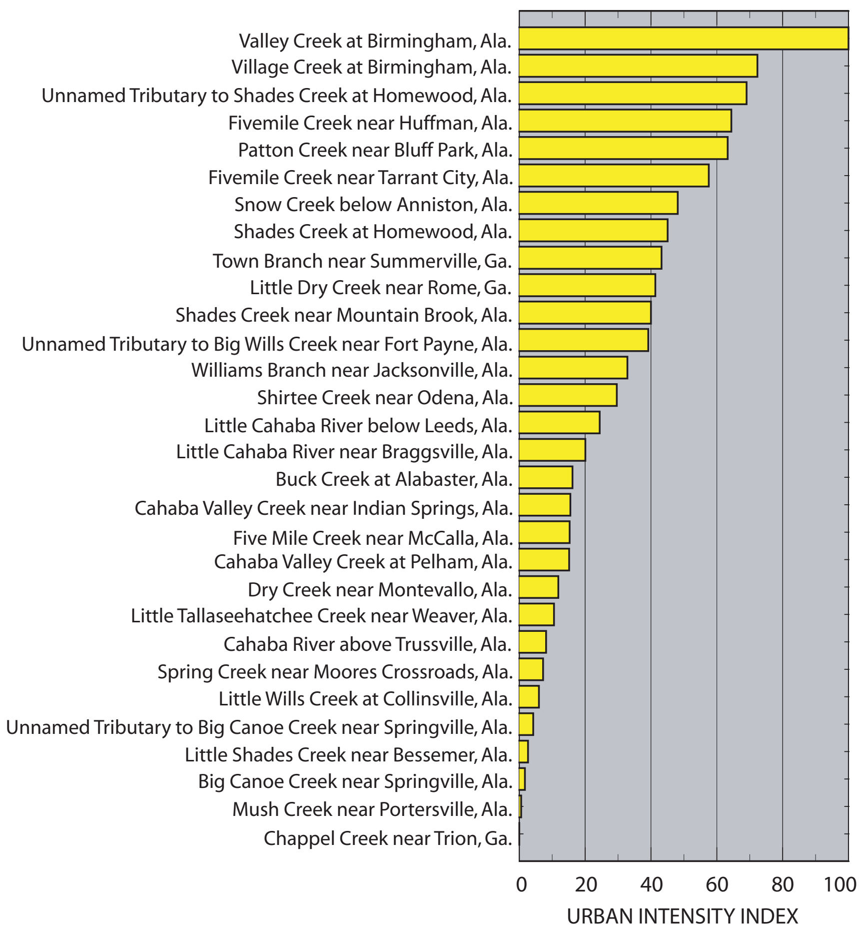


Figure 19. Intensity of urban land varies among the 30 urban gradient sampling sites because of varying levels of population, amount of urban land, urban infrastructure, and socioeconomic factors.

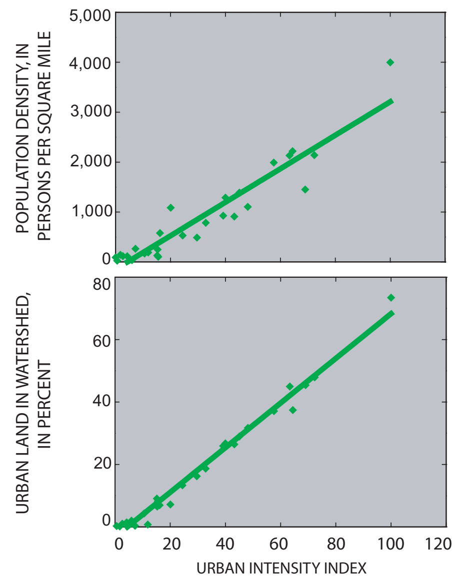


Figure 20. Increases in the urban intensity index were strongly related to increases in population density and the percentage of urban land in a watershed.

measures of urbanization, including amounts of residential development within a watershed and land used for commercial and industrial enterprises and transportation services, numbers of roads, and various socioeconomic factors related to housing, income, and population characteristics (fig. 19). Population densities in the 30 drainage basins ranged from 26 to nearly 4,000 people per square mile; urban land covered from 0 to 73 percent. An urban index of 60 is closely associated with a population density of about 1,870 persons per square mile and about 40 percent urban land cover (fig. 20). An urban intensity score of zero represents forested watersheds, such as Chappel Creek near Trion, Ga., and a score of 100 represents the most urbanized watersheds in Birmingham (fig. 19).

The ecosystem assessment showed that invertebrate and fish communities change as watersheds become increasingly urbanized. For example, the number of invertebrate species sensitive to pollution, such as mayflies, caddisflies, and stoneflies (EPT taxa), decreased with increasing urban intensity (fig. 21A). Specifically, the number of EPT taxa ranged from 21 species per stream in a drainage

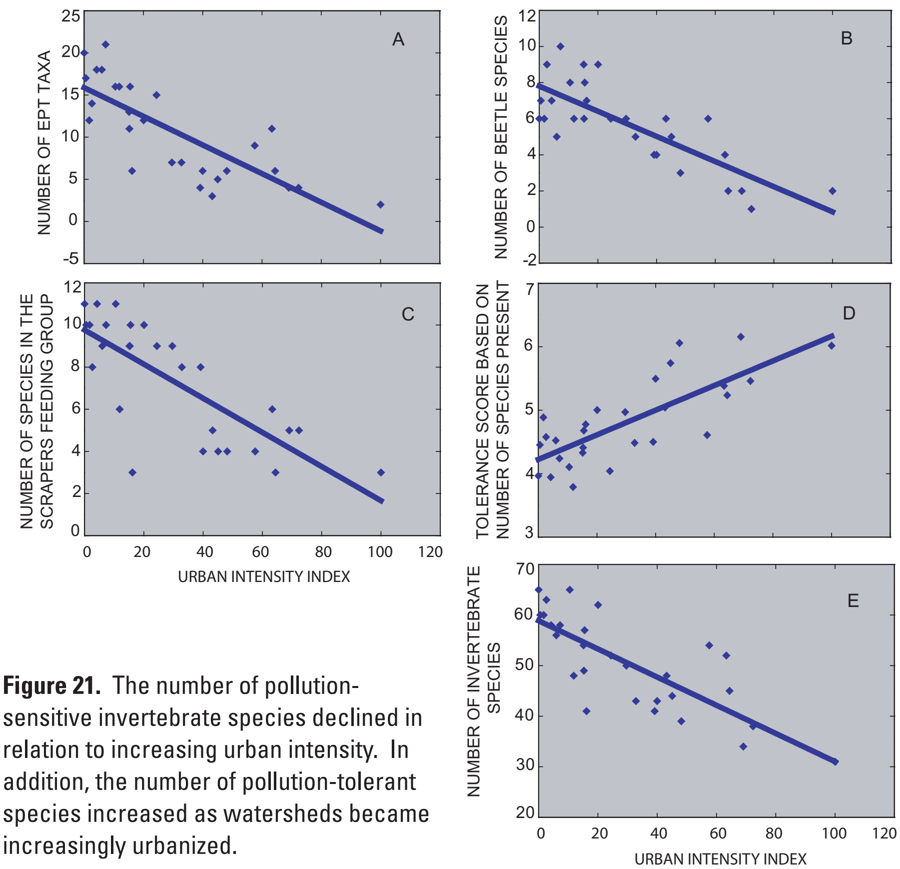


Figure 21. The number of pollution-sensitive invertebrate species declined in relation to increasing urban intensity. In addition, the number of pollution-tolerant species increased as watersheds became increasingly urbanized.

basin with 7 percent urban intensity (associated with less than 1 percent urban land), such as Spring Creek near Moores Crossroads, Ala., to 2 species in the highly urbanized Valley Creek at Birmingham (draining about 73 percent urban land). The numbers and types of beetles (also sensitive to pollution) and the types of organisms within the scrapers functional feeding group decreased as urban intensity increased (figs. 21B and 21C, respectively). Scrapers are insect grazers that scrape algae and other microorganisms from rocks and plant surfaces. They are a vital link between the primary producers (or algae) and the higher food chains (insects and fish) in stream ecosystems. Scraper abundance in the least urbanized watersheds was about 11 species, whereas the most urbanized streams in Birmingham had only about 3 species. The percentage of noninsects, such as midges and worms (a relatively pollution-tolerant group), increased from about four to six as watersheds increased in urban intensity from 0 to 100, which reflects deteriorating conditions (fig. 21D). Overall, the number of invertebrate species decreased by about half, from about 65 species in the least urbanized watersheds to about 30 in the most urbanized (fig. 21E).

Similarly, the number of different fish species (or diversity) decreased, from about 20 different species to about 5 (fig. 22A). The decreases mostly reflected those sensitive to pollution, including black bass, minnow, and herbivore (plant-eating) fish species (figs. 22B–E). More tolerant species, including green sunfish, blue gill, yellow bullhead, and creek cub, dominated the most urbanized streams (up to about 70 percent of the fish community, fig. 22F).

The ecosystem assessment showed that the invertebrate and fish communities were degraded with increasing urban intensity in a constant or linear fashion, and that degradation of aquatic communities in and around Birmingham begins early in the process of watershed urbanization. Specifically, the kinds and amounts of invertebrate and fish communities began to show declines in drainage basins with an urban intensity index of 10, which correlates to only about 4 percent urban land cover and a population density less than 200 people per square mile. Degradation in invertebrate and fish communities continues in drainage basins up to an urban intensity index of about 100 and does not show a leveling off or "threshold" at which point degradation peaks.

No response patterns were detected in algal communities in relation to urbanization. The lack of a strong relation could be the result of the lack of sensitivity of algal communities to urban intensity, or sampling and analysis methods that may not be as effective for evaluating urban effects on algal communities as those for invertebrate and fish communities.

Relations among invertebrate, fish, and algal communities are useful in better understanding where water-quality management actions are likely to have the greatest effects. Specifically, this information is helpful to water managers in resource prioritization by highlighting those streams that have passed a certain point at which resources used for restoration may not be a viable option, but rather applied to protection of less urbanized and less degraded streams. Such relations should be used with caution, however, and should not necessarily be applied to all streams or for all biological characteristics and species within or outside the geographic region. Response may vary by specific species of fish, for example, and for individual streams with unique environmental features.

Invertebrate samples were collected in the Mobile River Basin by scraping organisms from submerged rocks in the streams.

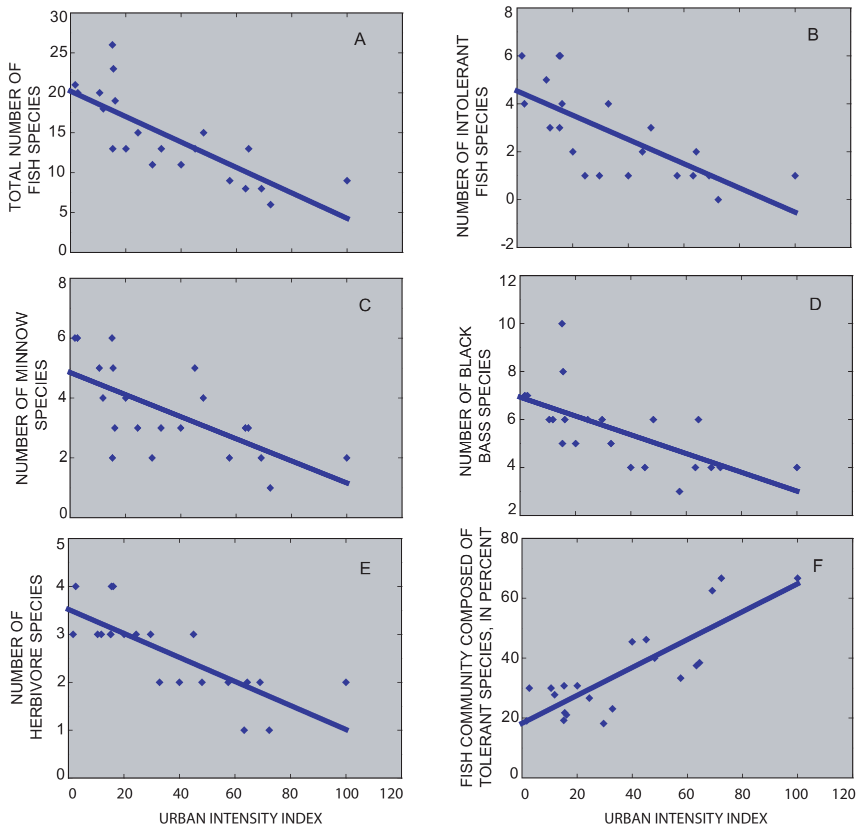


Figure 22. The number of pollution-sensitive fish species declined in relation to increasing urban intensity. Conversely, the number of pollution-tolerant species increased as watersheds became increasingly urbanized.

Increasing development and urbanization is associated with both physical and chemical factors that may affect biological communities. For example, increased residential development, road density, and commercial, industrial, and transportation areas all result in increased impervious surfaces, urban runoff, and streams controlled by storm drains and artificial controls—all of which greatly alter streamflow and habitat. Specifically, streams in more urbanized areas demonstrate increases in peak discharge and flashiness of flow, as measured by the magnitude of changes in stage over 1-hour periods (fig. 23). Increased stream flashiness can result in increased water velocities, which can destroy fish-spawning beds, remove debris and other stream habitat for invertebrates and fish, transport large amounts of sediment, scour instream habitats, and remove firm substrates. These physical characteristics are not well tolerated by biological communities, which require a firm substrate and ample natural habitat to thrive.

Generally, increases in impervious areas within a watershed result in warmer stream temperatures because of higher temperatures associated with runoff over warm surfaces. However, no relations between stream temperature and urban intensity were detected in the Mobile River Basin. This lack of relation or correlation could be attributed to the influence of ground water, which remains relatively consistent in temperature as it discharges to the carbonate-rock streams in the Ridge and Valley ecoregion. Such ground-water contributions may help to lower warmer temperatures associated with urban runoff.

In addition to physical conditions, chemical factors associated with increased urban intensity may play a part in the degradation of biological communities. The number of contaminants, such as herbicides and insecticides used in residential and commercial areas, increases with increasing urban intensity (figs. 24A,B). Concentrations of the herbicide prometon, which is used along roadside rights-of-way, increased with increasing urban intensity, most likely reflecting increasing numbers of roads within a watershed (fig. 24C).

These findings indicate that physical and chemical conditions associated with increasing urbanization affect biological communities by decreasing diversity, increasing tolerant species, and contributing to the loss of sensitive species.

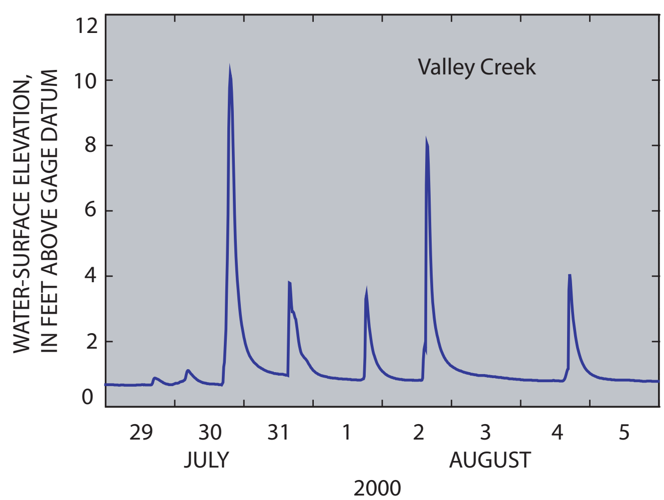


Figure 23. Streams in the most urbanized areas of the Mobile River Basin show rapid increases and decreases in peak discharges and water-surface elevations during short periods of time. Stream flashiness can result in increased water velocities, which adversely affect invertebrate and fish communities.

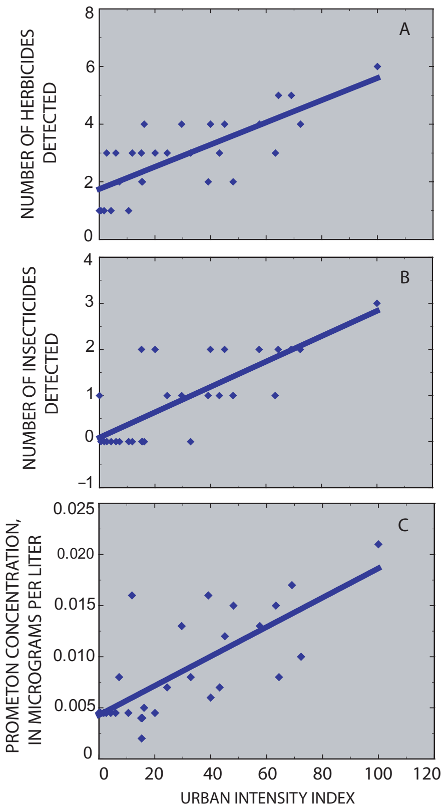


Figure 24. Herbicides and insecticides were detected more frequently in more urbanized watersheds. Concentrations of prometon, a herbicide used on urban lawns and roadside rights-of-way, increased in relation to increasing urbanization.

Such findings may help in the development of useful key ecological or other indicators of the effects of urbanization on stream ecosystems, such as EPT taxa, pesticides, and streamflow, which could improve the cost-effectiveness of monitoring programs. In addition, these findings may also help in developing and prioritizing optimal management strategies for a particular ecosystem, such as focusing resources on chemical-use tracking, controlling storm runoff, or restoring physical habitat.

Radon

Radon is a colorless, odorless, radioactive gas that occurs naturally in rocks and soils as an intermediate product in the decay of uranium-238. The gas, which can cause cancer in humans, can enter homes directly from the soil or in drinking water supplied by wells. Radon can be a health risk through direct inhalation of the gas and from drinking water contaminated with radon.

Many rocks contain uranium, especially light-colored volcanic rocks, granites, dark shales, phosphatic sedimentary rocks, and the metamorphic equivalents of any of these rocks. Phosphate nodules occur in marine clays of the Black Warrior River aquifer; sediments eroded from the shales of the Appalachian Plateau and granitic rocks of the Piedmont and Blue Ridge Physiographic Provinces may have been deposited in the Black Warrior River aquifer.

Radon exceeded proposed standards in several wells

Radon was present in every water sample collected from the mixed land-use domestic wells in the recharge area of the Black Warrior River aquifer (see “Study Unit Design”). Of the 30 ground-water samples analyzed for radon, 33 percent had concentrations greater than 300 picocuries per liter (pCi/L), the USEPA (1999) proposed standard or maximum contaminant level (MCL) for drinking water. The maximum concentration was 623 pCi/L. No sample had concentrations that exceeded the USEPA-proposed alternative maximum contaminant level (AMCL) for radon of 4,000 pCi/L. The MCL is proposed for drinking water when there is no other indoor air radon-reduction program. The AMCL is proposed for drinking water when an indoor air radon-reduction program is used to reduce radon exposure. The median concentration of radon in ground water in rural areas of the Mobile River Basin was 215 pCi/L, which was near the 25th percentile of radon concentrations reported by all NAWQA Study Units nationwide.

Ground- and surface-water samples are filtered and processed in a mobile laboratory immediately after sample collection.

Shallow monitoring wells were installed for the urban and agricultural studies in the Mobile River Basin.

Additional Information on Effects of Urbanization on Stream Ecosystem

The NAWQA Program is investigating the effects of urbanization on stream ecosystems in 15 metropolitan areas across the Nation. For more information, refer to Couch and Hamilton (2002) (http://pubs.water.usgs.gov/fs04202/) and McMahon and Cuffney (2000). Internet access to supporting NAWQA technical and program information also can be found at http://water.usgs.gov/nawqa/

Study Unit Design

Physical, chemical, and biological characteristics of surface water and ground water were assessed in the Mobile River Basin. Water-quality information was collected on stream- and ground-water chemistry and ecology using nationally consistent protocols and methods (Gilliom and others, 1995). As a result, local water-quality conditions in the Mobile River Basin can be compared with those in other basins locally and placed in a regional and national context.

Stream Chemistry and Ecology

Assessment of stream chemistry focused on how water quality varies in large rivers and streams in relation to land use and the natural setting, which represents a combination of physiography, geology, and soils. The quality of water in the Chattooga, Cahaba, Alabama, Black Warrior, and Tombigbee Rivers reflects an integration of multiple land uses and natural settings. The quality of water in the Pintlalla and Bogue Chitto Creeks generally represents effects from agricultural activities, and the quality of water in Cahaba Valley Creek and Threemile Branch represents effects from watershed development and urbanization.

Ecological assessments were conducted at sites on the large rivers and small streams and creeks to describe fish, algal, and invertebrate communities and instream habitat in relation to water-quality conditions and land use.

A special study was conducted, referred to as the "urban gradient" study, that focused on stream chemistry and ecology at 29 sites that ranged from relatively undeveloped, forested, and pristine to heavily urbanized (Birmingham). This gradient study allowed assessment of changes that occur in water chemistry, streamflow, biological communities, and stream habitat in relation to watershed development.

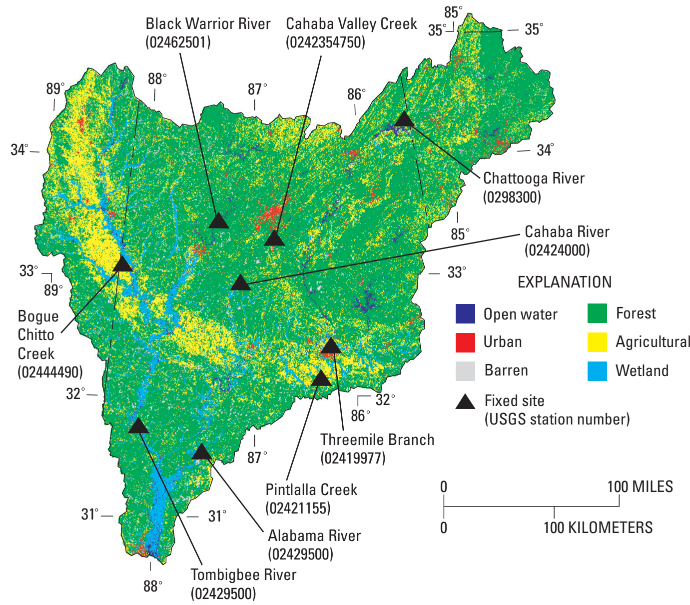
Ground-Water Chemistry

Ground-water quality was assessed in the recharge area of the Black Warrior River aquifer in the Coastal Plain by sampling and analyzing water from domestic wells in the aquifer. The quality of shallow ground water in unconsolidated, alluvial deposits underlying agricultural and urban land use also was assessed. Alluvial deposits overlie the Black Warrior River aquifer and are present in the alluvial flood plains of the Tallapoosa, Coosa, Alabama, and Black Warrior Rivers.

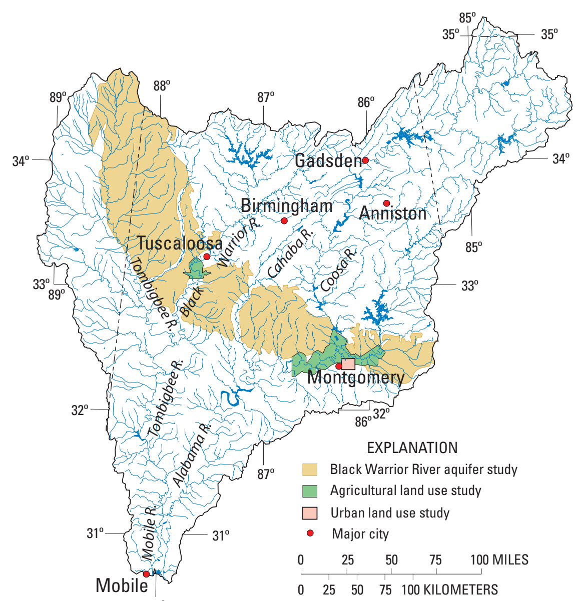
Additional Information

Additional information on water-quality conditions in the Mobile River Basin is available at

http://al.water.usgs.gov/pubs/mobl/mobl.html



STREAM CHEMISTRY AND ECOLOGY



GROUND-WATER CHEMISTRY

Study component	What data were collected and why	Types of sites sampled	Number of sites sampled	Sampling frequency and period
Stream Chemistry				
Large rivers	Streamflow, nutrients, pesticides (at 3 sites), major ions, suspended sediment, water temperature, specific conductance, organic carbon, dissolved oxygen, alkalinity, and pH were measured to describe seasonal variations of concentrations and loads in major tributaries in and from the Mobile River Basin.	Sites on the Chattooga, Black Warrior, Alabama, and Tombigbee Rivers, draining 366 to 21,967 mi^2, integrate the effects of multiple land uses and physiographic regions.	4	Monthly and during storm events, 1999–2001.
Streams	Streamflow, nutrients, pesticides (at 1 site), major ions, suspended sediment, VOCs (at 1 site), water temperature, specific conductance, organic carbon, dissolved oxygen, alkalinity, and pH were measured to examine the effects of land use on water quality.	Streams draining 8.79 to 59.3 mi^2 that represent urban (Threemile Branch) and agricultural (Pintlalla Creek) uses. Pesticides and VOCs were measured at Threemile Branch.	2	Monthly and during storm events, 1999–2001.
Intensively sampled streams and large rivers	Streamflow, nutrients, pesticides, major ions, suspended sediment, water temperature, specific conductance, organic carbon, dissolved oxygen, alkalinity and pH were measured to define short-term temporal variability. In addition, VOC samples were collected at the urban site.	Streams draining 25.6 to 52.6 mi^2 that represent urban (Cahaba Valley Creek) and agricultural (Bogue Chitto Creek) uses and the Cahaba River, which drains 1,027 mi^2.	3	Biweekly, 1999; monthly, 2000–2001.
Urban gradient	Nutrients, pesticides, major ions, organic carbon, bacteria, and suspended sediment were sampled to assess water-quality variability in relation to urban land use.	Sites over a full range (gradient) of urban land use (0–100 percent) and drainage areas ranging from 2 to 25.6 mi^2.	30	Twice during base-flow conditions, May 2000 and May 2001.
Stream Ecology				
Large rivers and streams	Algal, benthic-invertebrate, and fish communities and the condition of stream habitat were sampled to assess the variability of the communities in relation to land use, location, and time.	Basic and intensive stream-chemistry sites.	9	Annually, 1999–2001.
Streambed sediment	Trace elements and organic compounds were measured to determine the occurrence and distribution in streambed sediment.	Depositional zones of all basic and intensive stream-chemistry sites plus additional sites.	21	August–September 1998.
Fish tissue	Trace elements and organic compounds in the tissues of whole fish were measured to determine the occurrence and distribution in fish tissue.	Same sites from which streambed sediment samples were collected.	21	August–December 1998.
Urban gradient	Algal, benthic-invertebrate, and fish communities and the condition of stream habitat were sampled to assess the biological responses in relation to water quality and urban land use.	Same sites as stream chemistry urban gradient study.	30	Once, 2000–2001.
Ground-Water Chemistry				
Black Warrior River aquifer	Nutrients, pesticides, major ions, VOCs, organic carbon, trace elements, radon, and radium were measured to assess quality in the recharge area of aquifers used for drinking water in the Coastal Plain.	Existing domestic wells completed in the Black Warrior River aquifer (62–465 feet deep).	30	May–August 1999.
Shallow ground water underlying agricultural and urban areas	Nutrients, pesticides, major ions, VOCs (in urban study), organic carbon, trace elements (in urban study), chlorofluorocarbons (CFCs), and sulfur hexafluoride (SF6) were analyzed to examine the effects of specific land uses (urban and agricultural) on the quality of shallow ground water.	Monitoring wells were completed in unconsolidated alluvial deposits.	30 wells in the urban study; 29 wells in the agricultural study	October 1999–January 2000; June–September 2001.

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Glossary

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.

Alluvial aquifer—A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.

Ammonia—A compound of nitrogen and hydrogen (NH_3) that is a common by-product of animal waste. Ammonia readily converts to nitrate in soils and streams.

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.

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

Atmospheric deposition—The transfer of substances from the air to the surface of the Earth, either in wet form (rain, fog, snow, dew, frost, hail) or in dry form (gases, aerosols, particles).

Average flow-weighted concentration—A concentration calculated by first multiplying each sample concentration by its asssociated streamflow value, then dividing the sum of these products by the sum of the streamflows. The resultant average, or mean value, accounts for the effects of variable streamflow on concentrations.

Background concentration—A concentration of a substance in a particular environment that is indicative of minimal influence by human (anthropogenic) sources.

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.

Benthic invertebrates—Insects, mollusks, crustaceans, worms, and other organisms without a backbone that live in, on, or near the bottom of lakes, streams, or oceans.

Bioaccumulation—The net accumulation of a substance by an organism as a result of uptake from all environmental sources, including gills, epithelial tissues, and dietary sources.

Bioavailability—The capacity of a chemical constituent to be taken up by living organisms either through physical contact or by ingestion.

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.

Carbonate rocks—Rocks (such as limestone or dolomite) that are composed primarily of minerals (such as calcite and dolomite) containing the carbonate ion (CO_3^{2-}).

Chlordane—Octachloro-4,7-methanotetrahydroindane. An organochlorine insecticide no longer registered for use in the United States. Technical chlordane is a mixture in which the primary components are cis- and trans-chlordane, cis- and trans-nonachlor, and heptachlor.

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

Detect—To determine the presence of a compound.

p-p'**-DDE** (dichloro-diphenyldichloroethylene)—A breakdown product of DDT.

DDT (dichloro-diphenyl-trichloroethane)—An organochlorine insecticide that is no longer used in the United States. It was used heavily in agriculture and for mosquito control.

Dieldrin—An organochlorine insecticide that is no longer registered for use in the United States. It is also a breakdown product of the insecticide aldrin. Dieldrin was used in agriculture and also for termite control.

Drinking-water standard or guideline—A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Ecoregion—An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

Effluent—Outflow from a particular source, such as a stream that flows from a lake or liquid waste that flows from a factory or sewage-treatment plant.

EPT richness index—An index based on the sum of the number of taxa in three insect orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), that are composed primarily of species considered to be relatively intolerant to environmental alterations.

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.

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.

Heptachlor epoxide—A breakdown product of the organochlorine insecticide heptachlor. It was used in the United States until the 1970s in agriculture and also for termite control.

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

Insecticide—A substance or mixture of substances intended to destroy or repel insects.

Intolerant organisms—Organisms that are not adaptable to human alterations to the environment and thus decline in numbers where human alterations occur. See also Tolerant species.

Invertebrate—An animal having no backbone or spinal column. See also Benthic invertebrates.

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.

Mean—The average of a set of observations, unless otherwise specified.

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.

Midge—A small fly in the family Chironomidae. The larval (juvenile) life stages are aquatic.

Nitrate—An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a plant nutrient and is very mobile in soils.

Nitrogen fixation—The amount of biologically fixed nitrogen produced by legume crops, such as soybeans and peanuts.

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.

Nutrient—Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Organochlorine compounds—Synthetic organic compounds that contain chlorine. The term generally refers to compounds that contain predominantly carbon, hydrogen, and chlorine. Examples include organochlorine pesticides, polychlorinated biphenyls, and some solvents containing chlorine.

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

Phosphorus—A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Physiography—A description of the surface features of the Earth, with an emphasis on the origin of landforms.

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

Polychlorinated biphenyls (PCBs)—a mixture of chlorinated derivatives of biphenyl, marketed under the trade name Arochlor with a number designating the chlorine content (such as Arochlor 1260). PCBs were used in transformers and capacitors for insulating purposes and in gas pipeline systems as a lubricant. Further sale for new use was banned by law in 1979.

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

Species—Populations of organisms that may interbreed and produce fertile offspring having similar structure, habits, and functions.

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.

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

Taxon (plural taxa)—Any identifiable group of taxonomically related organisms.

Taxa richness—See Species richness.

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.

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

Appendix—Water-Quality Data from the Mobile River Basin in a National Context

Concentrations and detection frequencies of the most commonly detected constituents, constituents that exceed a drinking-water standard or aquatic-life guideline, or constituents that are of regulatory or scientific importance are presented below. Plots of other pesticides, nutrients, VOCs, and trace elements assessed in the Mobile River Basin are available at our Web site at:

http://water.usgs.gov/nawqa/graphs

These summaries of chemical concentrations and detection frequencies from the Mobile River Basin are compared to findings from 51 NAWQA Study Units investigated from 1991 to 2001 and to water-quality benchmarks for human health, aquatic life, fish-eating wildlife, or prevention of nuisance plant growth. These graphical summaries provide a comparison of chemical concentrations and detection frequencies between (1) surface- and ground-water resources, (2) agricultural, urban, and mixed land uses, and (3) shallow ground water and aquifers commonly used as a source of drinking water.

For example, the graph for atrazine shows that detections and concentrations in the Mobile River Basin generally are (1) higher than national findings in agricultural streams; (2) greater in streams draining agricultural areas than in those draining urban areas or areas of mixed land use, resulting in some violations of the USEPA drinking-water standards in both streams and ground water; and (3) greater in streams than in ground water.

NOTE to users:

- The analytical detection limit varies among the monitored chemicals; thus, frequencies of detections are not comparable among chemicals.
- It is important to consider the frequency of detection along with concentration. For example, deethylatrazine was detected more frequently in mixed land-use streams in the Mobile River Basin than in mixed land-use streams nationwide (95 percent compared to 78 percent) but generally was detected at lower concentrations.

CHEMICALS IN WATER

Concentrations and detection frequencies, Mobile River Basin, 1999–2001

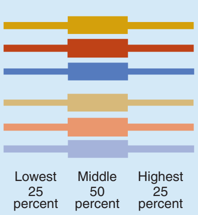
◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size. For ground water, the number of samples is equal to the number of wells sampled

National ranges of detected concentrations, by land use, in 51 NAWQA Study Units, 1991–2001—Ranges include only samples in which a chemical was detected



National water-quality benchmarks

National benchmarks include standards and guidelines related to drinking-water quality, criteria for protecting the health of aquatic life, and the desired goal for preventing nuisance plant growth due to phosphorus. Sources include the U.S. Environmental Protection Agency and the Canadian Council of Ministers of the Environment

| Drinking-water quality (applies to ground water and surface water)

| Protection of aquatic life (applies to surface water only)

| Prevention of nuisance plant growth in streams

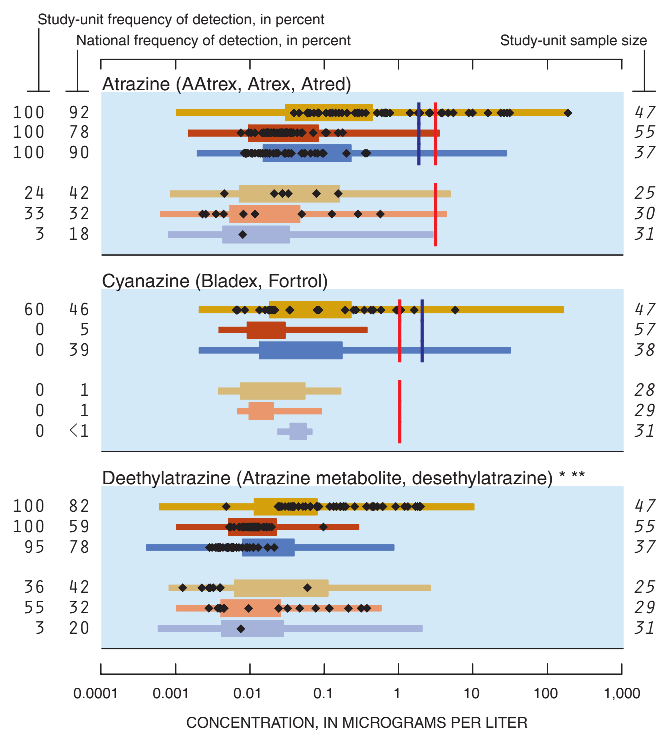
* No benchmark for drinking-water quality

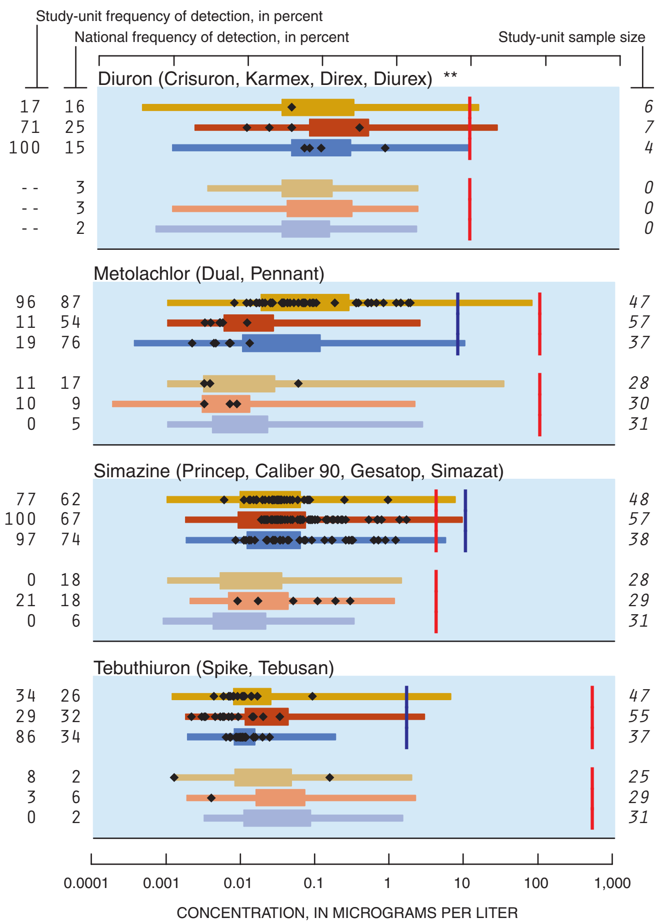
** No benchmark for protection of aquatic life

Quality-control data for these analytes indicate relatively frequent low-level contamination of samples during sample processing for analysis. Results for these analytes cannot, therefore, be presented using the generalized methods that were applied to other analytes in this Appendix. Analysis of results for analytes potentially affected by contamination requires special statistical treatment beyond the scope of this report. For more information about these analytes and how to interpret data on their occurrence and concentrations, please contact the appropriate NAWQA Study Unit.

Trace elements in ground water: aluminum, barium, boron, cadmium, chromium, cobalt, copper, lithium, nickel, strontium, zinc
SVOCs in bed sediment: phenol, bis(2-ethylhexyl)phthalate, butylbenzylphthalate, di-*n*-butylphthalate, diethylphthalate
Insecticides in water: *p,p'*-DDE

Pesticides in water—Herbicides





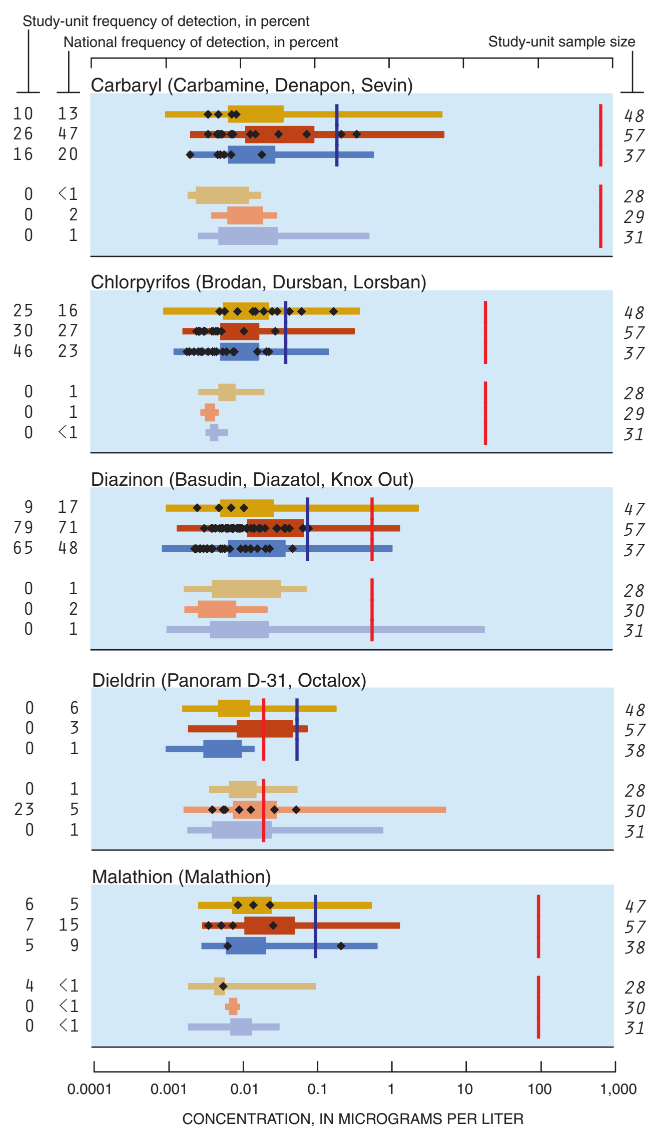
Other herbicides detected

Alachlor (Lasso, Bronco, Lariat, Bullet) **
Benfluralin (Balan, Benefin, Bonalan, Benefex) * **
2,4-D (Aqua-Kleen, Lawn-Keep, Weed-B-Gone)
DCPA (Dacthal, chlorthal-dimethyl) **
EPTC (Eptam, Farmarox, Alirox) * **
Fluometuron (Flo-Met, Cotoran, Cottonex, Meturon) **
MCPA (Rhomene, Rhonox, Chiptox)
Metribuzin (Lexone, Sencor)
Molinate (Ordram) * **
Norflurazon (Evital, Predict, Solicam) * **
Pendimethalin (Pre-M, Prowl, Weedgrass Control, Stomp, Herbadox) * **
Prometon (Pramitol, Princep, Gesagram 50, Ontracic 80) **
Pronamide (Kerb, Propyzamid) **
Propanil (Stam, Stampede, Wham, Surcopur, Prop-Job) * **
Terbacil (Sinbar) **
Triclopyr (Garlon, Grandstand, Redeem) * **
Trifluralin (Treflan, Gowan, Tri-4, Trific, Trilin)

Herbicides not detected

Chloramben, methyl ester (Amiben methyl ester) * **
Acetochlor (Harness Plus, Surpass) * **
Acifluorfen (Blazer, Tackle 2S) **
Bentazon (Basagran, Bentazone, Bendioxide) **
Bromacil (Hyvar X, Urox B, Bromax)
Bromoxynil (Buctril, Brominal) *
Butylate (Sutan +, Genate Plus, Butilate) **
Clopyralid (Stinger, Lontrel, Reclaim) * **
2,4-DB (Butyrac, Butoxone, Embutox Plus) *
Dacthal mono-acid (Dacthal metabolite) * **
Dicamba (Banvel, Dianat, Scotts Proturf)
Dichlorprop (2,4-DP, Seritox 50, Kildip) * **
2,6-Diethylaniline (metabolite of Alachlor) * **
Dinoseb (Dinosebe)
Ethalfluralin (Sonalan, Curbit) * **
Fenuron (Fenulon, Fenidim) * **
Linuron (Lorox, Linex, Sarclex, Linurex, Afalon) *
MCPB (Thistrol) * **
Napropamide (Devrinol) * **
Neburon (Neburea, Neburyl, Noruben) * **
Oryzalin (Surflan, Dirimal) * **
Pebulate (Tillam, PEBC) * **
Picloram (Grazon, Tordon)
Propachlor (Ramrod, Satecid) **
Propham (Tuberite) **
2,4,5-T
2,4,5-TP (Silvex, Fenoprop)
Thiobencarb (Bolero, Saturn, Benthiocarb, Abolish) * **
Triallate (Far-Go, Avadex BW, Tri-allate) *

Pesticides in water—Insecticides



Other insecticides detected

Aldicarb sulfone (Standak, aldoxycarb)
Aldicarb sulfoxide (Aldicarb metabolite)

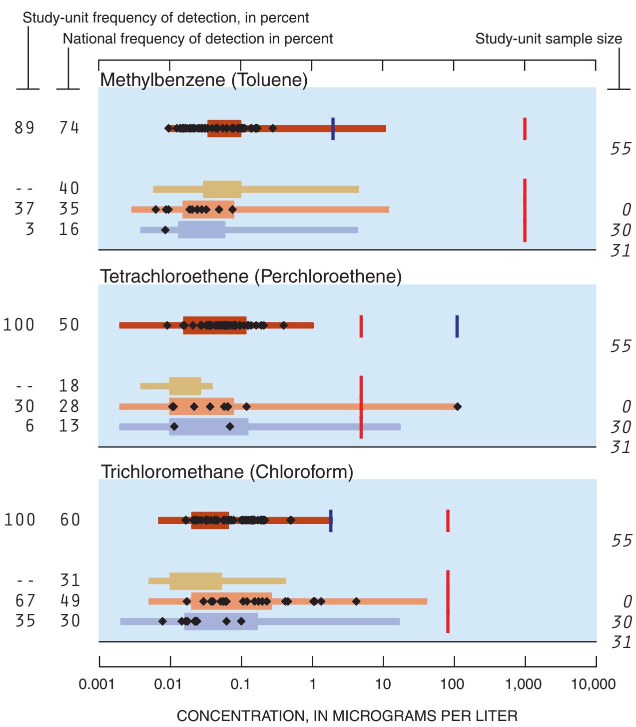
Ethoprop (Mocap, Ethoprophos) * **
Phorate (Thimet, Granutox, Geomet, Rampart) * **

Insecticides not detected

Aldicarb (Temik, Ambush, Pounce)
Azinphos-methyl (Guthion, Gusathion M) *
Carbofuran (Furadan, Curaterr, Yaltox)
Disulfoton (Disyston, Di-Syston, Frumin AL, Solvirex, Ethylthiodemeton) **
Fonofos (Dyfonate, Capfos, Cudgel, Tycap) **
alpha-HCH (alpha-BHC, alpha-lindane) **
gamma-HCH (Lindane, gamma-BHC, Gammexane)
3-Hydroxycarbofuran (Carbofuran metabolite) * **
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) *
cis-Permethrin (Ambush, Astro, Pounce) * **
Propargite (Comite, Omite, Ornamite) * **
Propoxur (Baygon, Blattanex, Unden, Proprotox) * **
Terbufos (Contraven, Counter, Pilarfox) **

Volatile organic compounds (VOCs) in water

These graphs represent data from 32 Study Units, sampled from 1994 to 2001



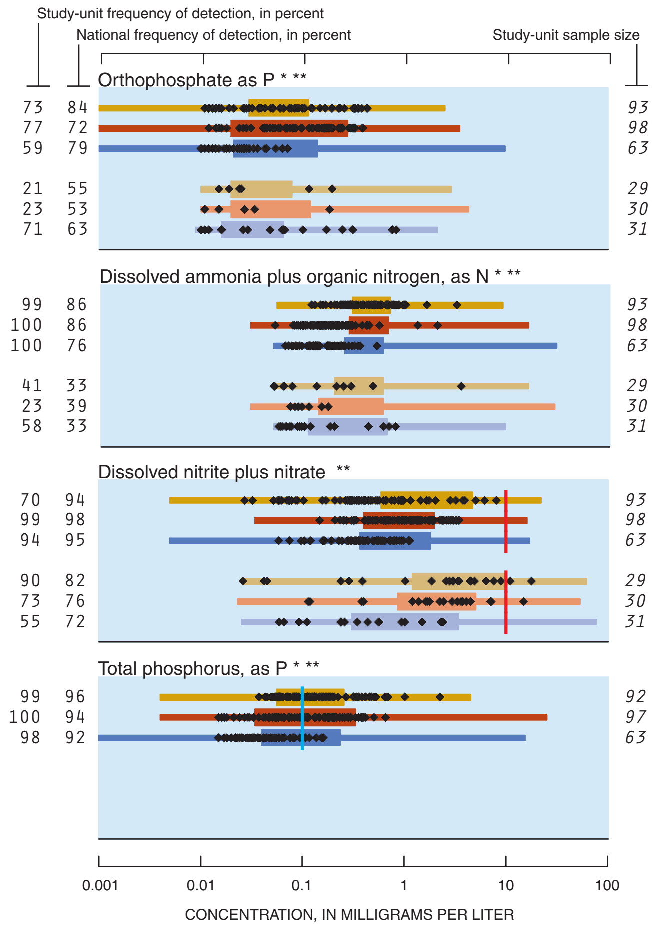
Other VOCs detected

Acetone (Acetone) * **
Benzene
Bromodichloromethane (Dichlorobromomethane) **
2-Butanone (Methyl ethyl ketone (MEK)) **
Carbon disulfide * **
1-Chloro-2-methylbenzene (*o*-Chlorotoluene) **
Chloromethane (Methyl chloride) **
Dibromochloromethane (Chlorodibromomethane) **
1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)
1,1-Dichloroethane (Ethylidene dichloride) * **
1,1-Dichloroethene (Vinylidene chloride) **
cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene) **
Dichloromethane (Methylene chloride)
Diisopropyl ether (Diisopropylether (DIPE)) * **
1,2-Dimethylbenzene (*o*-Xylene) **
1,3 & 1,4-Dimethylbenzene (*m*-&*p*-Xylene) **
Ethenylbenzene (Styrene) **
Ethylbenzene (Phenylethane)
2-Ethyltoluene (*o*-Ethyltoluene) * **
p-Isopropyltoluene (*p*-Cymene, 1-Isopropyl-4-methylbenzene) * **
Methyl *tert*-butyl ether (MTBE) **
4-Methyl-2-pentanone (Methyl isobutyl ketone (MIBK)) * **
Naphthalene
n-Propylbenzene (Isocumene) * **
Tetrachloromethane (Carbon tetrachloride)
Tetrahydrofuran (Diethylene oxide) * **
1,2,3,5-Tetramethylbenzene (Isodurene) * **
1,1,1-Trichloroethane (Methylchloroform) **
Trichloroethene (TCE)
Trichlorofluoromethane (CFC 11, Freon 11) **
1,2,3-Trimethylbenzene (Hemimellitene) * **
1,2,4-Trimethylbenzene (Pseudocumene) * **
1,3,5-Trimethylbenzene (Mesitylene) * **
tert-Amyl methyl ether (TAME) * **

VOCs not detected

Bromobenzene (Phenyl bromide) * **
Bromochloromethane (Methylene chlorobromide) **
Bromoethene (Vinyl bromide) * **
Bromomethane (Methyl bromide) **
n-Butylbenzene (1-Phenylbutane) * **
sec-Butylbenzene ((1-Methylpropyl)benzene) * **
tert-Butylbenzene ((1,1-Dimethylethyl)benzene) * **
3-Chloro-1-propene (3-Chloropropene) * **
1-Chloro-4-methylbenzene (*p*-Chlorotoluene) **
Chlorobenzene (Monochlorobenzene)
Chloroethane (Ethyl chloride) * **
Chloroethene (Vinyl chloride) **
1,2-Dibromo-3-chloropropane (DBCP, Nemagon) **
1,2-Dibromoethane (Ethylene dibromide, EDB) **
Dibromomethane (Methylene dibromide) * **
trans-1,4-Dichloro-2-butene ((Z)-1,4-Dichloro-2-butene) * **
1,3-Dichlorobenzene (*m*-Dichlorobenzene)
Dichlorodifluoromethane (CFC 12, Freon 12) **
1,2-Dichloroethane (Ethylene dichloride)
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene) **
1,2-Dichloropropane (Propylene dichloride) **
2,2-Dichloropropane * **
1,3-Dichloropropane (Trimethylene dichloride) * **
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene) **
cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene) **
1,1-Dichloropropene * **
Diethyl ether (Ethyl ether) * **
Ethyl methacrylate (Ethyl methacrylate) * **
Ethyl *tert*-butyl ether (Ethyl-t-butyl ether (ETBE)) * **
1,1,2,3,4,4-Hexachloro-1,3-butadiene (Hexachlorobutadiene)
1,1,1,2,2,2-Hexachloroethane (Hexachloroethane) **
2-Hexanone (Methyl butyl ketone (MBK)) * **
Iodomethane (Methyl iodide) * **
Isopropylbenzene (Cumene) * **
Methyl acrylonitrile (Methacrylonitrile) * **
Methyl methacrylate (Methyl-2-methacrylate) * **
Methyl-2-propenoate (Methyl Acrylate) * **
2-Propenenitrile (Acrylonitrile) **
1,1,2,2-Tetrachloroethane **
1,1,1,2-Tetrachloroethane (1,1,1,2-TeCA) **
1,2,3,4-Tetramethylbenzene (Prehnitene) * **
Tribromomethane (Bromoform) **
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113) * **
1,2,4-Trichlorobenzene
1,2,3-Trichlorobenzene (1,2,3-TCB) *
1,1,2-Trichloroethane (Vinyl trichloride) **
1,2,3-Trichloropropane (Allyl trichloride) **

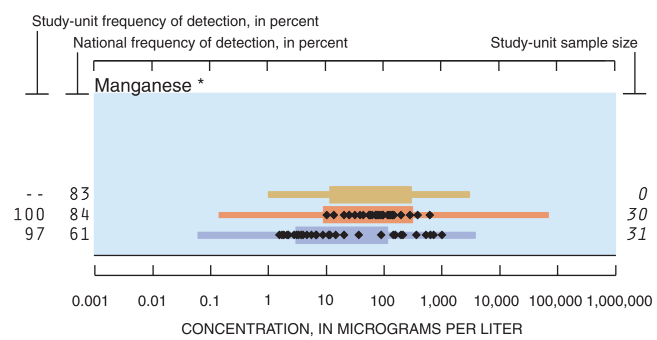
Nutrients in water

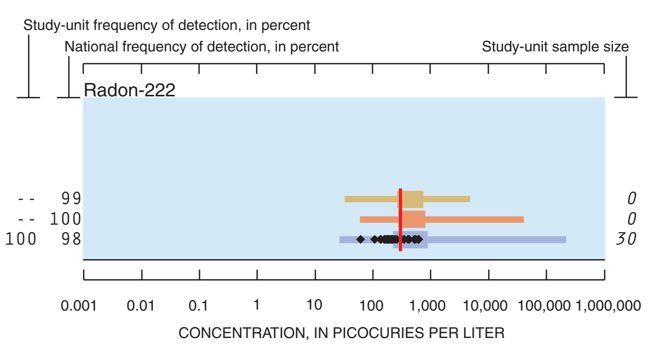


Other nutrient detected

Ammonia **

Trace elements in ground water





Other trace elements detected

Arsenic
Lead
Molybdenum
Selenium
Uranium

CHEMICALS IN FISH TISSUE AND BED SEDIMENT

Concentrations and detection frequencies, Mobile River Basin 1999–2001—Study-unit frequencies of detection are based on small sample sizes; the applicable sample size is specified in each graph

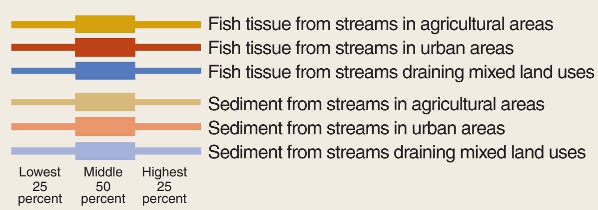
◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size

National ranges of concentrations detected, by land use, in 51 NAWQA Study Units, 1991–2001—Ranges include only samples in which a chemical was detected



National benchmarks for fish tissue and bed sediment

National benchmarks include standards and guidelines related to criteria for protection of the health of fish-eating wildlife and aquatic organisms. Sources include the U.S. Environmental Protection Agency, other Federal and State agencies, and the Canadian Council of Ministers of the Environment.

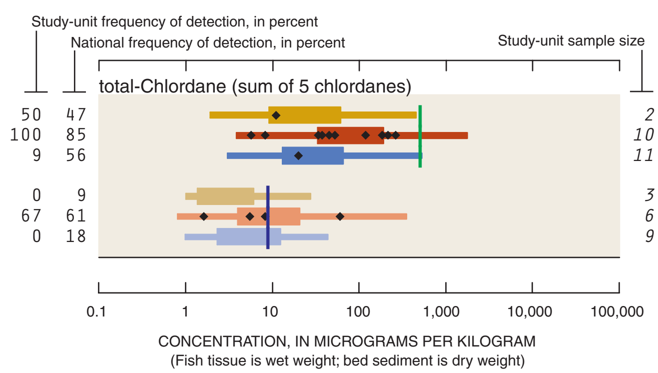
| Protection of fish-eating wildlife (applies to fish tissue)

| Protection of aquatic life (applies to bed sediment)

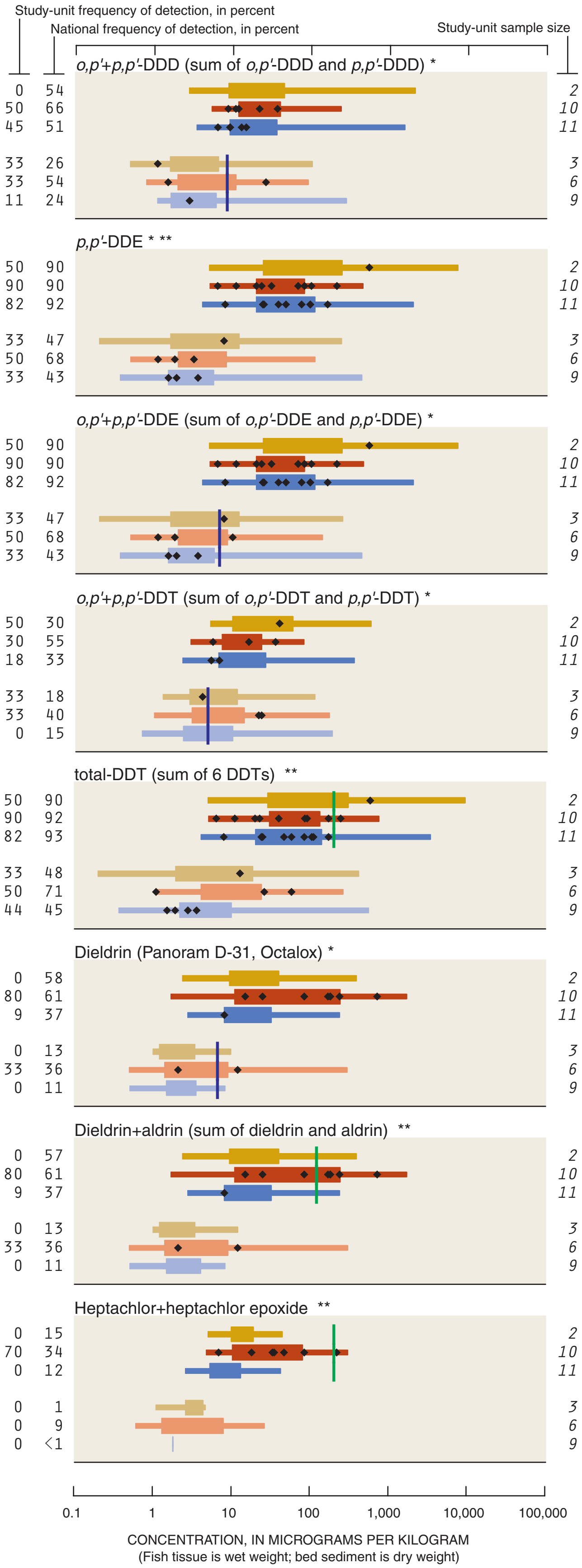
* No benchmark for protection of fish-eating wildlife

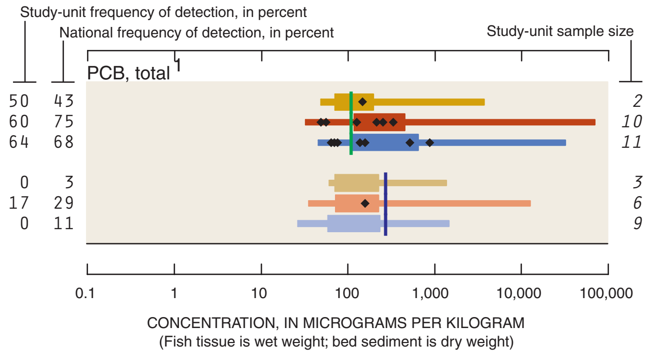
** No benchmark for protection of aquatic life

Organochlorines in fish tissue (whole body) and bed sediment



Organochlorines in fish tissue (whole body) and bed sediment





[1] The national detection frequencies for total PCB in sediment are biased low because about 30 percent of the samples nationally had elevated detection limits compared to this Study Unit. See http://water.usgs.gov/nawqa/ for additional information.

Other organochlorines detected

Endrin (Endrine)
Heptachlor epoxide (Heptachlor metabolite) *
Hexachlorobenzene (HCB) **
p,p'-Methoxychlor (Marlate, methoxychlore) * **
Mirex (Dechlorane) **
Pentachloroanisole (PCA, pentachlorophenol metabolite) * **

Organochlorines not detected

Chloroneb (chloronebe, Demosan) * **
DCPA (Dacthal, chlorthal-dimethyl) * **
Endosulfan I (alpha-Endosulfan, Thiodan) * **
gamma-HCH (Lindane, gamma-BHC, Gammexane) *
Total HCH (sum of alpha, beta, gamma, and delta-HCH) **
Isodrin (Isodrine, Compound 711) * **
o,p'-Methoxychlor * **
cis-Permethrin (Ambush, Astro, Pounce) * **
trans-Permethrin (Ambush, Astro, Pounce) * **
Toxaphene (Camphechlor, Hercules 3956) * **

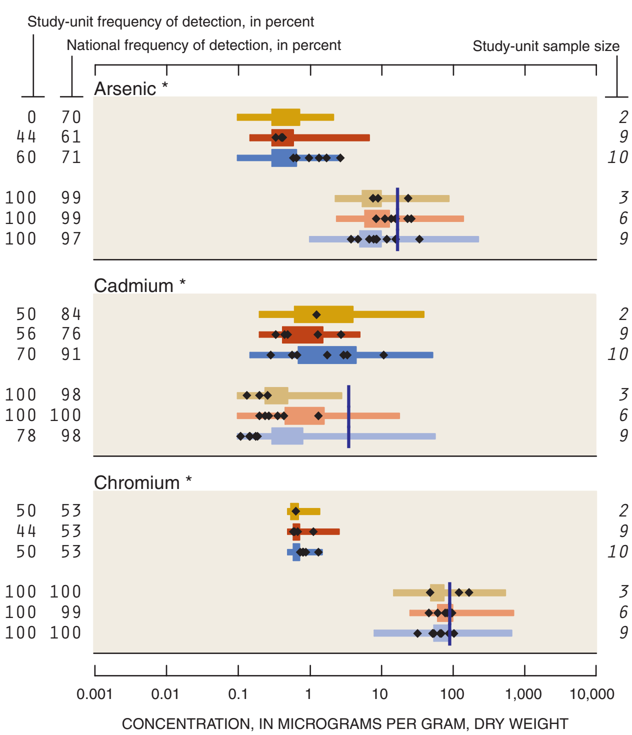
Semivolatile organic compounds (SVOCs) in bed sediment

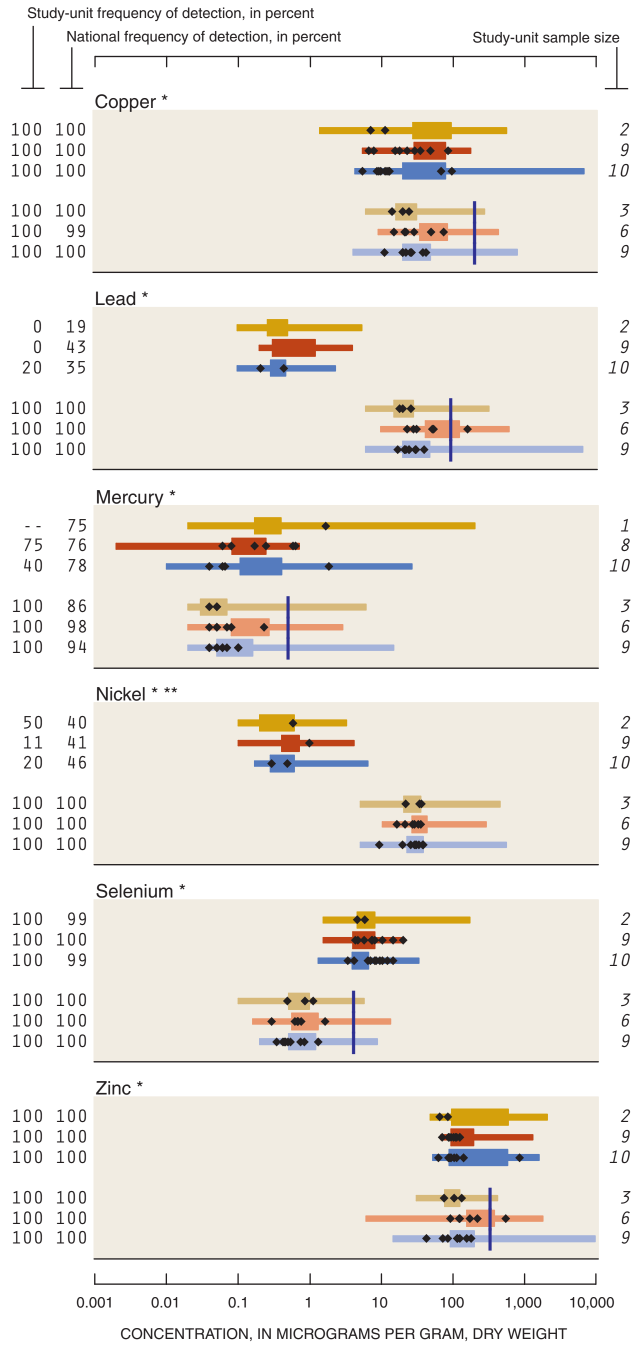
SVOCs not detected

Acenaphthene
Acenaphthylene
Acridine **
C8-Alkylphenol **
Anthracene
Anthraquinone **
Azobenzene **
Benz[*a*]anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene **
Benzo[*c*]cinnoline **
Benzo[*g,h,i*]perylene **
Benzo[*k*]fluoranthene **
2,2-Biquinoline **
4-Bromophenyl-phenylether **
9*H*-Carbazole **
4-Chloro-3-methylphenol **
bis (2-Chloroethoxy)methane **
bis (2-Chloroethyl)ether **
2-Chloronaphthalene **
2-Chlorophenol **
4-Chlorophenyl-phenylether **
Chrysene

Di-*n*-octylphthalate **
Dibenz[*a,h*]anthracene
Dibenzothiophene **
1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB) **
1,3-Dichlorobenzene (*m*-Dichlorobenzene) **
1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB) **
1,2-Dimethylnaphthalene **
3,5-Dimethylphenol **
Dimethylphthalate **
2,4-Dinitrotoluene **
Fluoranthene
9*H*-Fluorene (Fluorene)
Indeno[1,2,3-*c,d*]pyrene **
Isophorone **
Isoquinoline **
1-Methyl-9*H*-fluorene **
2-Methylanthracene **
4,5-Methylenephenanthrene **
1-Methylphenanthrene **
1-Methylpyrene **
Naphthalene
Nitrobenzene **
N-Nitrosodi-*n*-propylamine **
N-Nitrosodiphenylamine **
Pentachloronitrobenzene **
Phenanthrene
Phenanthridine **
Pyrene
Quinoline **
1,2,4-Trichlorobenzene **
2,3,6-Trimethylnaphthalene **

Trace elements in fish tissue (livers) and bed sediment





Trace elements not detected
Antimony
Beryllium
Silver

Coordination with agencies and organizations in the Mobile River Basin was integral to the success of this water-quality assessment. We thank those who served as members of our liaison committee.

Federal Agencies
Natural Resources Conservation Service
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Department of Agriculture—Forest Service

State Agencies
Alabama Cooperative Extension System
Alabama Department of Agriculture and Industries
Alabama Department of Conservation and Natural Resources
Alabama Department of Corrections
Alabama Department of Environmental Management
Alabama Department of Industrial Relations
Alabama Department of Public Health
Alabama Forestry Commission
Alabama Soil and Water Conservation Committee
Geological Survey of Alabama
Georgia Department of Natural Resources

Local Agencies
Autauga County Soil and Water Conservation District
City of Montgomery
Elmore County Soil and Water Conservation District
Jefferson County
Montgomery County Soil and Water Conservation District
Montgomery Water Works and Sanitary Sewer Board

Universities
Auburn University
Auburn University at Montgomery
University of Alabama
University of Alabama at Birmingham
Troy State University
Samford University

Other public and private organizations
Alabama Clean Water Partnership
Alabama Power Company
Alabama Pulp and Paper Council
Alabama Water Resources Research Institute
Alabama Water Watch
Mobile River Basin Coalition
The Cahaba River Society

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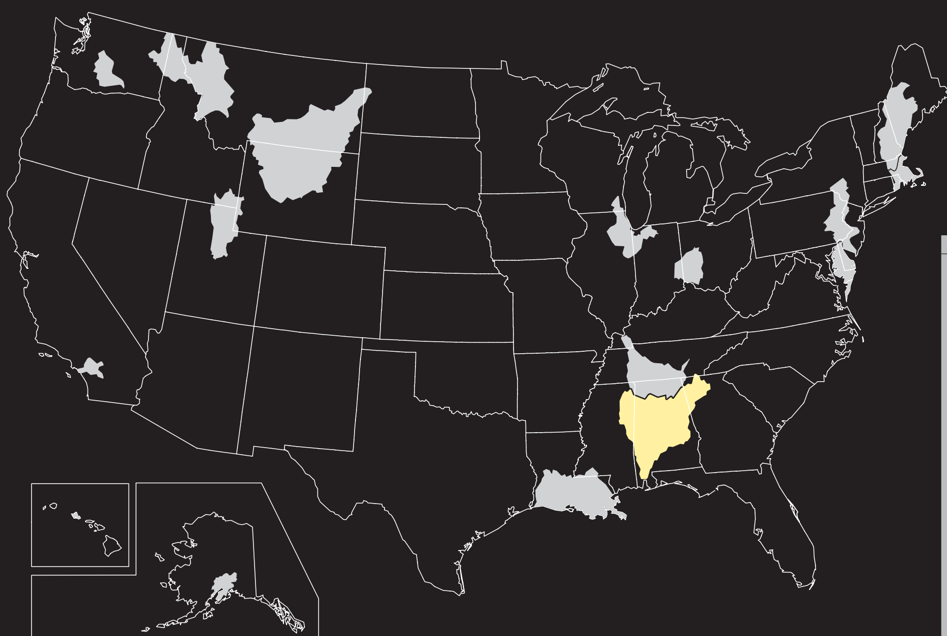
NAWQA

National Water-Quality Assessment (NAWQA) Program
Mobile River Basin



Atkins and others—Water Quality in the Mobile River Basin
U.S. Geological Survey Circular 1231

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