

# ALABAMA

## Ground-Water Quality

In Alabama, ground water is the major source for public supply—about 52 percent of the population depends on ground water (see population distribution, fig. 1). The principal area for ground-water withdrawal is the Coastal Plain of Alabama. All principal aquifers (fig. 2) generally produce water that does not exceed the U.S. Environmental Protection Agency (EPA) national primary drinking-water standards for dissolved nitrate (as nitrogen) and fluoride, and secondary drinking-water standards for dissolved solids, sulfate, and fluoride. The principal aquifers contain water that is soft to moderately hard. Dissolved solids, nitrate, fluoride, sulfate, and hardness are important indicators for the acceptability of water for public supply.

Forty-three hazardous-waste sites require monitoring of ground-water quality under the Alabama Hazardous Waste Management Act and the Federal Resource Conservation and Recovery Act (RCRA) of 1976. In addition to these RCRA sites, six sites have been placed on the National Priorities List (NPL) of hazardous-waste sites by the U.S. Environmental Protection Agency (1986c), and two other sites have been proposed for the list. These six Superfund sites require additional evaluation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. At 28 of the RCRA sites and 4 of the CERCLA sites, contamination has been detected in the shallow ground-water system (fig. 3A). An additional 475 sites are on the EPA Emergency and Remedial Response Information System (ERRIS) list. In addition, the U.S. Department of Defense has identified 89 sites at 3 facilities where contamination has warranted remedial action.

In 1981, the U.S. Geological Survey in cooperation with the Geological Survey of Alabama began a ground-water-quality monitoring program to determine background water quality in the aquifers. Initially, 50 wells were chosen; by 1985, the number had increased to 96. The analyses primarily are for the major inorganic constituents and the more common trace elements. Determinations of organic contamination in Alabama's aquifers have been limited to specific sites under projects directed by State and county agencies and private industry.

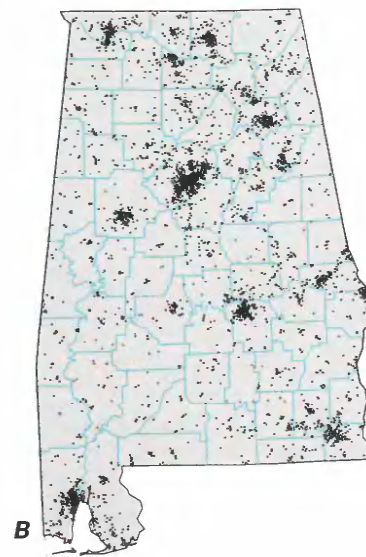


### WATER QUALITY IN PRINCIPAL AQUIFERS

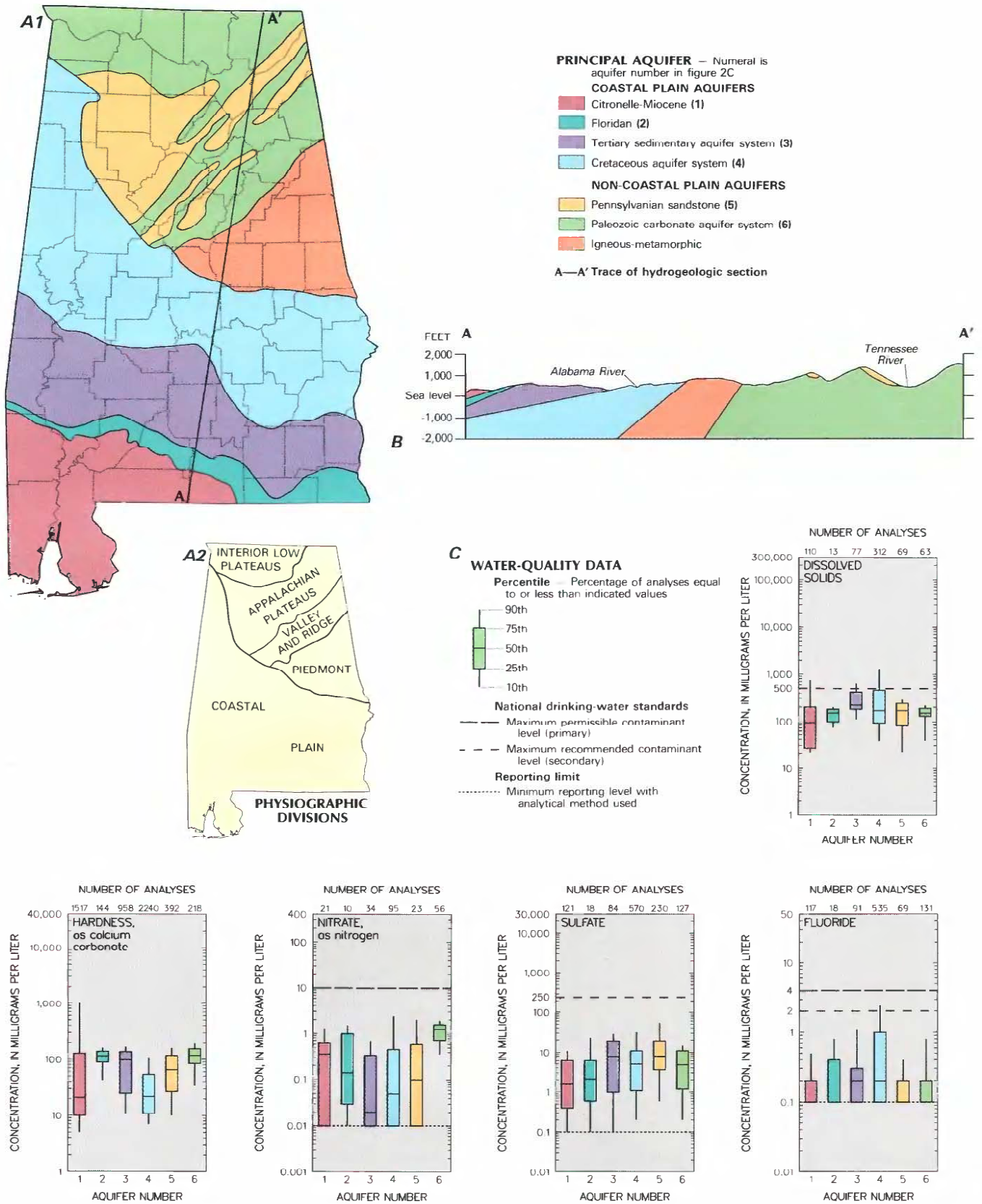
Principal aquifers in Alabama (fig. 2A1) are grouped into two types—those within the Coastal Plain and those north of the Coastal Plain (fig. 2A2). The aquifers within the Coastal Plain consist primarily of a sequence of unconsolidated sediments, whereas those outside the Coastal Plain consist of consolidated sediments, carbonate rocks, and igneous and metamorphic rocks (U.S. Geological Survey, 1985, p. 123). More than 62 percent of the State's ground-water withdrawals are from the Coastal Plain aquifers (Baker, 1983).

The freshest ground water in Alabama, commonly containing less than 100 mg/L (milligrams per liter) of dissolved solids, occurs in the recharge areas of all the principal aquifers. Down dip in Coastal Plain aquifers, the dissolved-solids concentrations become as large as 30,000 mg/L. Within the area of the non-Coastal Plain aquifers, the primary sources for public supply are surface water, spring flow, and a few deep wells. Iron concentrations larger than 300  $\mu$ g/L (micrograms per liter) and corrosive waters (pH less than 5) are the common water-quality problems in the non-Coastal Plain aquifers. Iron also is a local problem in the Coastal Plain aquifers.

Naturally impaired water quality in southwestern Alabama (fig. 3B) resulted from connate, highly mineralized water migrating upward along faults. Information is not available to determine if the water quality is continuing to change. All major aquifers in the area are affected, and the only sources of fresh ground water are discontinuous terrace deposits and alluvium along the rivers.

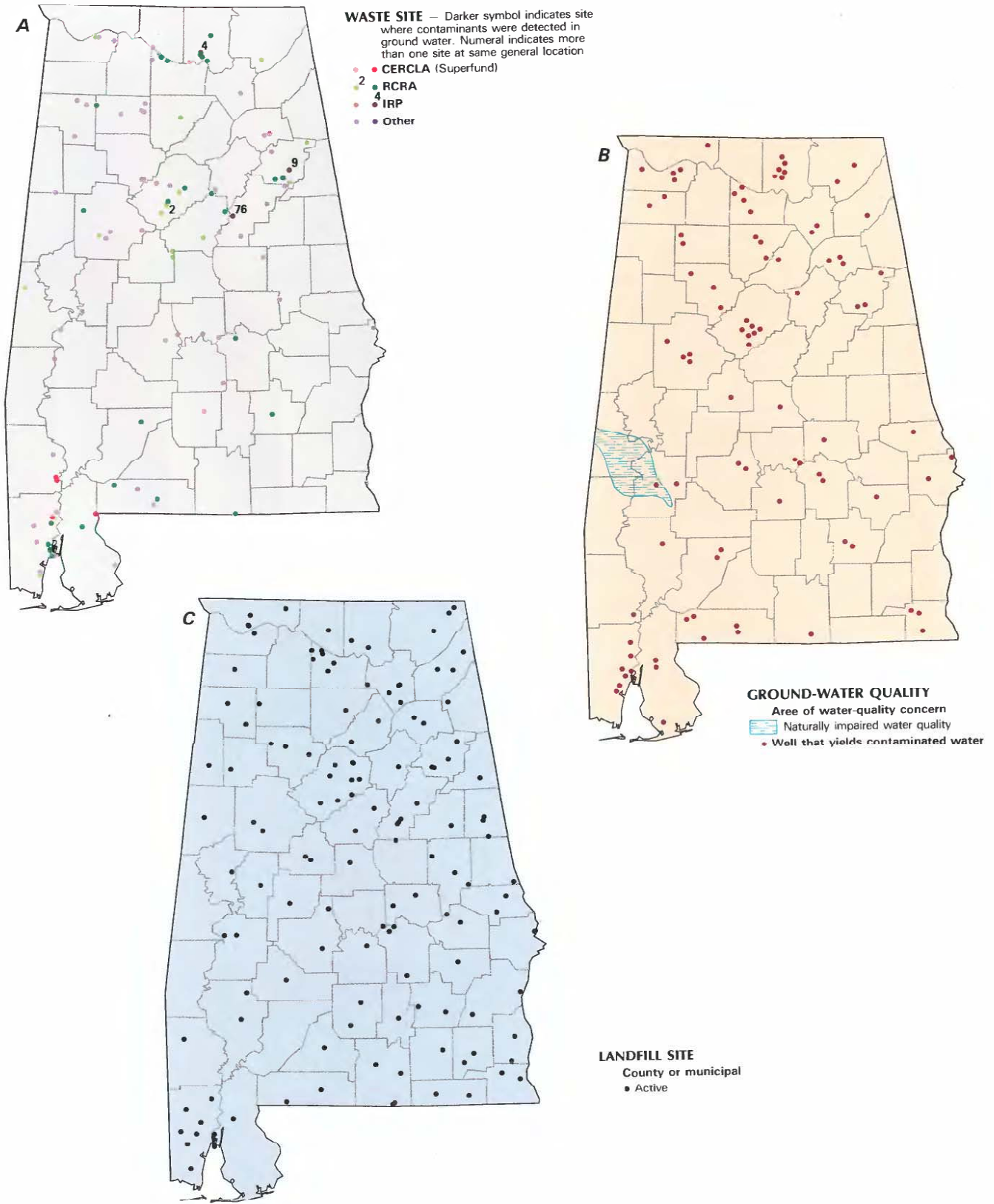


**Figure 1.** Selected geographic features and 1985 population distribution in Alabama. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted to the 1985 U.S. Bureau of the Census data for county populations.)



**Figure 2.** Principal aquifers and related water-quality data in Alabama. **A1**, Principal aquifers; **A2**, Physiographic provinces. **B**, Generalized hydrogeologic section. **C**, Selected water-quality constituents and properties, as of 1940–86 (Sources: **A1**, Johnston, 1933; Carlston, 1942. **A2**, Fenneman, 1938; Raisz, 1954. **B**, Copeland, 1968; Barksdale and Moore, 1976. **C**, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)





**Figure 3.** Selected waste sites and ground-water-quality information in Alabama. *A.* Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; Resource Conservation and Recovery Act (RCRA) sites, as of 1986; Department of Defense Installation Restoration Program (IRP) sites, as of 1986; and other selected waste sites, as of 1986. *B.* Areas of naturally impaired water quality and distribution of wells that yield contaminated water, as of 1986. *C.* County and municipal landfills, as of 1986. (Sources: *A.* Fred Mason, Alabama Department of Environmental Management, written commun., 1986, U.S. Department of Defense, 1986. *B.* *C.* Fred Mason, Alabama Department of Environmental Management, written commun., 1986.)

## BACKGROUND WATER QUALITY

A graphic summary of selected water-quality variables compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) is shown in figure 2C. The summary is based on dissolved-solids, hardness, nitrate (as nitrogen), sulfate, and fluoride analyses of water samples collected from 1940 to 1986 from the principal aquifers in Alabama. Percentiles of these variables are compared to national standards that specify the maximum concentration or level of a contaminant in drinking-water supply as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include maximum concentrations of 10 mg/L nitrate (as nitrogen) and 4.0 mg/L fluoride, and the secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids, 250 mg/L sulfate, and 2.0 mg/L fluoride.

### Coastal Plain Aquifers

The Coastal Plain aquifers consist of, from youngest to oldest, the Citronelle-Miocene aquifer, the Floridan aquifer, the Tertiary sedimentary aquifer system, and the Cretaceous aquifer system (fig. 2A1, 2B). Overall, the quality of water produced from these aquifers is very good for most uses, because most water is produced from the shallowest available aquifer. In the downdip sections of the aquifers, the water becomes progressively more mineralized. A shallow aquifer producing relatively unmineralized water usually is available for development, except in the southwestern section of the Coastal Plain in parts of Choctaw, Clarke, Marengo, Monroe, and Sumter Counties. This area contains faults, many caused by the upward migration of salt; the domes of salt have pierced the overlying sediments, providing an avenue for movement of very mineralized water from below.

The Citronelle-Miocene aquifer has the widest range for values of dissolved solids and hardness (fig. 2C) in the principal aquifers. Because it is the uppermost available of the Coastal Plain aquifers, the Citronelle-Miocene aquifer is used even when the water approaches objectionable quality. Although the range of dissolved-solids concentrations for the Citronelle-Miocene aquifer and the Cretaceous aquifer system is similar, the maximum concentration in a potential water well in the Citronelle-Miocene aquifer is about 20,000 mg/L, almost four times the maximum for water in the Cretaceous aquifer system. The values for dissolved-solids concentrations in the Cretaceous aquifer system are large, however, because the aquifer is tapped farther downdip and at a deeper interval than most of the other Coastal Plain aquifers.

Figure 2C shows that the 90th-percentile value for dissolved-solids concentration in three Coastal Plain aquifers—the Citronelle-Miocene, the Tertiary, and the Cretaceous—exceeded the national drinking-water standard of 500 mg/L. The only Coastal Plain aquifer with 90th-percentile dissolved-solids concentrations that did not exceed the standard is the Floridan aquifer system, which is tapped at relatively shallow depths near its recharge area where the mineral concentration in the water is small.

Hardness of water used for most domestic purposes is not objectionable at concentrations smaller than 100 mg/L (Hem, 1985, p. 159). Except for the Floridan aquifer, median values of hardness for Coastal Plain aquifers were smaller than 100 mg/L and all but the Citronelle-Miocene aquifer had concentrations smaller than 200 mg/L for 90 percent of the wells sampled (fig. 2C).

Large nitrate concentrations are indicators of aquifer contamination from barnyards, septic tanks, and fertilizers. Concentrations of nitrate (as nitrogen) larger than 10 mg/L are considered to be a hazard to infants less than about 1 year old. The largest median nitrate concentration for Coastal Plain aquifers (fig. 2C)

was for the Citronelle-Miocene aquifer (0.36 mg/L), possibly as a result of intense farm-related fertilization and irrigation that are common on the outcrop of this aquifer. However, the maximum nitrate concentration for a Coastal Plain aquifer in Alabama was 7.2 mg/L for a water sample from the Cretaceous aquifer system; water from the other three Coastal Plain aquifers had maximum concentrations of 2.0 mg/L or less.

Sulfate is one of the major anions occurring in natural waters. Sulfate is important in public and industrial water supplies because of its taste and laxative effects, particularly among transient and infrequent users. It is also important because waters containing appreciable amounts of sulfate form hard scales in boilers and heat exchangers. At sulfate concentrations smaller than the drinking-water standard, taste and laxative effects are rare. Because sulfate removal processes are relatively expensive, if sulfate concentrations are excessive, use of an alternate source or blending is desirable.

Sulfate concentrations exceeded drinking-water standards in 2 of 570 samples from wells completed in the Cretaceous aquifer system. The source of the large concentrations in the two samples is uncertain; however, the samples were from areas in which the Cretaceous aquifer system contains large amounts of pyrite.

Median sulfate concentrations were smaller than 10 mg/L for each of the principal aquifers. The 90th-percentile sulfate concentrations for each of the principal aquifers also were very small, ranging from 11 to 54 mg/L. Consequently, even though the secondary standards for sulfate occasionally are exceeded, most of the ground-water samples contain acceptable concentrations of sulfate.

Fluoride is a normal constituent of all diets and is an essential nutrient. At optimum levels in drinking water, fluoride has been shown to have beneficial effects in decreasing the occurrence of tooth decay and to produce no ill effects.

The primary standard for fluoride was exceeded at places in three of the Coastal Plain aquifers. The maximum fluoride concentrations ranged from 1.0 mg/L for samples from wells in the Floridan aquifer to 6.5 mg/L for samples from the Cretaceous aquifer system. However, median concentrations were 0.1 to 0.2 mg/L for each of the principal aquifers. The 90th-percentile fluoride concentrations did not exceed the primary standard for any of the principal aquifers and exceeded the secondary standard only for samples from the Cretaceous aquifer system. A few small communities and trailer parks in Alabama have abandoned their own wells because they were producing water with fluoride concentrations larger than 4.0 mg/L and have connected to larger public water systems (J.A. Power, Alabama Department of Environmental Management, oral commun., 1987).

Although several theories have been advanced as to the sources of the fluoride in ground water in Alabama, the exact sources and processes are largely unknown. LaMoreaux (1948, p. 36) noted that in the Alabama Coastal Plain deposits "there is a close relation between fluoride in ground water and sands which contain pyrite, lignite, phosphate, volcanic materials, and glauconite." Carlston (1942) theorized that the large fluoride concentrations in ground water in Cretaceous areas of Alabama (primarily Eutaw Formation) are derived from phosphate and volcanic ash deposits.

### Non-Coastal Plain Aquifers

The principal non-Coastal Plain aquifers are the Pennsylvanian sandstone aquifer and the Paleozoic carbonate aquifer system, located in the central and northern parts of the State (fig. 2A1). One other non-Coastal Plain aquifer—the igneous-metamorphic aquifer—was identified as being significant (U.S. Geological Survey, 1985, p. 124) because it is the only source of ground water in the Piedmont area of Alabama. This aquifer is not discussed in this report because too few chemical analyses are available for meaningful analysis.



The Pennsylvanian sandstone aquifer consists of sandstones containing water primarily in joints, fractures, and bedding planes. The Paleozoic carbonate aquifer system is the predominant source of ground water north and east of the Coastal Plain, and consists of cavernous limestone and dolomite that range in geologic age from Mississippian to Cambrian (Johnston, 1933; Barksdale and Moore, 1976).

The maximum dissolved-solids concentration for the non-Coastal Plain aquifers was 780 mg/L for the Pennsylvanian sandstone aquifer. However, the median concentrations for these aquifers, 170 mg/L for the Pennsylvanian and 150 mg/L for the Paleozoic, are similar to those for the Coastal Plain aquifers. The relatively small values for maximum dissolved-solids concentrations are smaller than might otherwise be expected, because wells in the non-Coastal Plain aquifers are shallow and are located in recharge areas that annually receive only slightly mineralized water from rainfall.

Hardness values are relatively small for the non-Coastal Plain aquifers (fig. 2C). The median values were 65 mg/L for the Pennsylvanian sandstone aquifer and 120 mg/L for the Paleozoic carbonate aquifer system. Hardness values for 90 percent of the sampled wells in these aquifers were smaller than 200 mg/L.

Nitrate concentrations in the non-Coastal Plain aquifers were less than the national drinking-water standard of 10 mg/L (fig. 2C). The Pennsylvanian sandstone aquifer had a maximum value of 7.0 mg/L, and the Paleozoic carbonate aquifer system had a maximum value of 3.2 mg/L. However, there is a marked difference in the 10th-percentile, 25th-percentile, and median values of nitrate between the Paleozoic carbonate aquifer system and the other aquifers in Alabama. Whereas the 10th-percentile value for the other five aquifers is less than detection limits, the Paleozoic carbonate aquifer system had a 10th-percentile concentration of 0.36 mg/L, a value that is equal to or larger than the median concentration for other aquifers. The median concentration for the Paleozoic carbonate aquifer system was 1.3 mg/L. These large increased concentrations possibly resulted from fertilization of crops within the Interior Low Plateaus area (fig. 2A2) of Alabama. Cotton and other row crops have been grown in the area since the early 1800's.

Sulfate concentrations in the non-Coastal Plain aquifers exceeded secondary standards in 13 of 230 samples from wells in the Pennsylvanian sandstone aquifer. All 13 samples of water from Pennsylvanian aquifers with large concentrations of sulfate are from wells 200 feet deep or less located in the Warrior coal field (Fayette, Tuscaloosa, and Walker Counties), which has been extensively mined for coal. Less than 10 percent of the samples from the Paleozoic carbonate aquifer system exceeded the secondary standard for fluoride.

## EFFECTS OF LAND USE ON WATER QUALITY

Water quality has deteriorated in some areas owing to migration of more mineralized water to areas of intensive pumping, leaching of minerals from spoils produced by the surface mining of coal, leaking underground storage tanks, or downward migration of leachates from surface impoundments and landfills. Long-term data are not available to document most changes in water quality in Alabama. A monitoring network of wells was established in Alabama in 1981 under a joint program between the U.S. Geological Survey and the Geological Survey of Alabama. The deterioration of ground-water quality generally is documented by the large concentrations of constituents in affected wells (fig. 3B) compared with the background water quality of unaffected wells.

### Intensive Pumping

Coastal areas are the most susceptible to migration of extremely mineralized water caused by intensive pumping. Water from a well tapping the Citronelle-Miocene aquifer, located on an off-

shore island in southern Mobile County, has had chloride concentrations increase from about 100 mg/L during 1955 to about 800 mg/L during 1976 (Chandler and Moore, 1983). Water from another well located farther inland had chloride concentrations increase from about 250 mg/L during 1967 to about 400 mg/L during 1976. Chandler and others (1985) reported that intensive pumping has caused saltwater encroachment in the Citronelle-Miocene aquifer in a small area of southern Baldwin County.

### Leaching of Mine Spoils

Several coal seams are present in the Pottsville Formation, which contains the Pennsylvanian sandstone aquifer. The Pottsville Formation contains many soluble minerals that become exposed to oxidation and precipitation and produce leachates during widespread excavation associated with surface coal mining. Leachates commonly contain increased concentrations of dissolved solids, sulfate, iron, and manganese. Contamination of the ground water generally is localized and depends upon the presence of the soluble minerals (Puente and others, 1982, p. 9).

### Leaking Underground Storage Tanks

The Alabama Department of Environmental Management has information on more than 13,000 sites, with an average of 3 underground storage tanks per site (John Poole, Alabama Department of Environmental Management, oral commun., 1986). However, the Department believes that their information is incomplete and estimates that more than 40,000 underground storage tanks are present in the State. The State has not developed a regulatory program requiring leak detection but has received 20 reports of ground-water contamination in 1986 caused by leaking tanks.

### Waste Sites

Hazardous waste is treated, stored, or disposed at 75 RCRA facilities that are at various stages of permitting or closure in Alabama. Forty-three of these facilities have ground-water monitoring systems (fig. 3A), and some level of ground-water contamination has been detected at 28 of the facilities (Fred Mason, Alabama Department of Environmental Management, oral commun., 1986). Six priority sites are related to CERCLA and four of those sites have reported ground-water contamination (fig. 3A). Also, two proposed CERCLA sites have reported ground-water contamination. An additional 475 sites are on CERCLA's ERIS list (Fred Mason, oral commun., 1986) and, of these sites, preliminary assessments have been completed at 442. Monitoring programs are designed to detect ground-water contamination, which includes increased concentrations of trace metals, acidity, volatile organic constituents, and priority pollutants. Operations that may contribute to ground-water contamination include: metal plating operations, plating wastes (metals), wood treating, solvent disposal (degreasing operations), pesticide production, battery processing and disposal (metals and acids), and industrial chemical production.

As of September 1985, 175 hazardous-waste sites at 5 facilities in Alabama had been identified by the U.S. Department of Defense (1986) as part of their Installation Restoration Program (IRP) as having potential for contamination. The IRP, established in 1976, parallels the EPA Superfund program. EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Of the 175 sites evaluated under the program, 72 sites contained contaminants but did not present a hazard to people or the environment. Eighty-nine sites at 3 facilities (fig. 3A) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. Remedial action at 63 of these sites has been completed under the program.

Waste-disposal sites not categorized as RCRA, CERCLA, or IRP sites are identified as "other" in figure 3A. These other sites in-

clude 56 disposal sites associated with manufacturing, coal mining, oil and gas production, electric power generation, and miscellaneous other industrial activities. (Some of these sites are too close to be plotted with separate symbols in fig. 3A.)

In addition to the sites described above, Alabama has 137 county and municipal landfill sites (fig. 3C). Each landfill is monitored with a minimum of three wells. One well is positioned upgradient in the natural ground-water flow pattern to establish background ground-water quality. At least two wells are positioned downgradient to evaluate potential effects from the landfill on ground-water quality. Leachate sampled from the landfills may contain increased concentrations of contaminants including iron, manganese, chromium, lead, and organic chemicals.

#### POTENTIAL FOR WATER-QUALITY CHANGES

The aquifers most susceptible to contamination are the non-Coastal Plain aquifers. In these aquifers the normal avenues for water movement are fractures, bedding planes, and solution features that collect flow and could permit relatively rapid transport of contaminants. These aquifers are recharged over their entire extent, allowing the whole aquifer to be susceptible to direct contamination from the surface. Susceptibility is also increased by the aquifers either being exposed at the land surface or being recharged through a relatively thin (usually less than 100 feet) mantle of residuum, which provides an easy avenue for downward contaminant migration.

An example of contamination to one of these aquifers is Cold-water Spring in Calhoun County, which receives water from the Paleozoic carbonate aquifer system. Concentrations of organic chemicals, which did not exceed the national drinking-water standards, were detected in 1982. The source of contamination has not been identified. Several point sources located in the area could be sources of contamination. As of 1986, no increase in the organic chemicals has been detected at the spring.

The Coastal Plain aquifers also are susceptible to contamination from the surface in their recharge areas. Wells that tap Coastal Plain aquifers in their recharge areas could become directly contaminated. However, most large-yield wells in these aquifers are farther downdip in the confined zones and, therefore, are less susceptible to direct contamination from the surface. Even in the outcrop areas of the Coastal Plain aquifers, flow through the porous unconsolidated sediments aids in faster dispersion of contaminants than would occur in the non-Coastal Plain aquifers.

#### GROUND-WATER-QUALITY MANAGEMENT

Alabama has existing and pending legislation pertaining to ground-water-quality management. All programs not under RCRA are managed under standards prescribed by the Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972) Pub. L. 92-500, as amended by Pub. L. 95-217, Pub. L. 95-576, Pub. L. 96-483 and Pub. L. 97-117, 33 U.S.C. 1251 et seq.

The Alabama Department of Environmental Management has developed a comprehensive ground-water protection law for con-

sideration by the 1988 State legislature. The law addresses the requirements of the EPA's ground-water protection strategy and underground storage-tank program. The legislation also will provide the Alabama Department of Environmental Management with the authority to protect all aquifers and recharge areas in Alabama that are extremely vulnerable to contamination and are irreplaceable because of no reasonable alternative source of drinking water. The Alabama Surface Mining Commission has regulatory powers to minimize ground-water contamination due to surface mining. The Geological Survey of Alabama has regulatory responsibility for the protection of ground-water quality related to the disposal of brines generated by the exploration and production of oil and gas. The Alabama Farm Bureau has recently proposed legislation that would regulate agricultural ground-water use.

#### SELECTED REFERENCES

- Baker, R.M., 1983, Use of water in Alabama, 1982: Geological Survey of Alabama Information Series 59C, 49 p.
- Barksdale, H.C., and Moore, J.D., eds., 1976, Water content and potential yield of significant aquifers in Alabama: Geological Survey of Alabama Open-File Report, 477 p.
- Carlston, C.W., 1942, Fluoride in the ground water of the Cretaceous area of Alabama: Geological Survey of Alabama Bulletin 52, 67 p.
- Chandler, R.V., and Moore, J.D., 1983, Fresh ground-water resources of the Dauphin Island area, Alabama: Geological Survey of Alabama Circular 109, 89 p.
- Chandler, R.V., Moore, J.D., and Gillett, Blakeney, 1985, Ground-water chemistry and saltwater encroachment, southern Baldwin County, Alabama: Geological Survey of Alabama Bulletin 126, 166 p.
- Copeland, C.W., 1968, Geology of the Alabama Coastal Plain: Geological Survey of Alabama Circular 47, 97 p.
- Fenneman, N.M., 1938, Physiography of Eastern United States: New York, McGraw-Hill Book Co., 714 p.
- Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.
- Johnston, W.D., Jr., 1933, Ground water in the Paleozoic rock of northern Alabama: Geological Survey of Alabama Special Report 16, 414 p.
- LaMoreaux, P.E., 1948, Fluoride in the ground water of the Tertiary area of Alabama: Geological Survey of Alabama Bulletin 59, 77 p.
- Puente, Celso, Newton, J.G., and Bingham, R.H., 1982, Assessment of hydrologic conditions in potential coal-lease tracts in the Warrior coal field, Alabama: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-540, 43 p.
- Raisz, Erwin, 1954, Physiographic diagram, p. 59, in U.S. Geological Survey, 1970, National atlas of the United States: Washington, D.C., U.S. Geological Survey, 417 p.
- U.S. Department of Defense, 1986, Status of the Department of Defense Installation Restoration Program—Information paper: Washington, D.C., U.S. Department of Defense, Office of the Assistant Secretary of Defense (Acquisition and Logistics), Environmental Policy Directorate, February, 35 p.
- U.S. Environmental Protection Agency, 1980, Water-quality criteria documents—Availability: Federal Register, v. 45, no. 231, p. 79318-79379.
- , 1986a, Maximum contaminant levels (subpart B of part 141, National interim primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised July 1, 1986, p. 524-528.
- , 1986b, Secondary maximum contaminant levels (section 143.3 of part 143, National secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised July 1, 1986, p. 587-590.
- , 1986c, Amendment to National Oil and Hazardous Substances Contingency Plan; national priorities list, final rule and proposed rule: Federal Register, v. 51, no. 111, June 10, 1986, p. 21053-21112.
- U.S. Geological Survey, 1985, National water summary 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, 467 p.

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