VIRGINIA GROUND-WATER QUALITY

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FOREWORD

This report contains summary information on ground-water quality in one of the 50 States, Puerto Rico, the Virgin Islands, or the Trust Territories of the Pacific Islànds, Saipan, Guam, and American Samoa. The material is extracted from the manuscript of the *1986 National Water Summary*, and with the exception of the illustrations, which will be reproduced in multi-color in the *1986 National Water Summary*, the format and content of this report is identical to the State ground-water-quality descriptions to be published in the *1986 National Water Summary*. Release of this information before formal publication in the *1986 National Water Summary* permits the earliest access by the public.

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VIRGINIA
Ground-Water Quality

The quality of ground water in Virginia (fig. 1*A*) is generally good and suitable for most purposes, and the supply is generally adequate to meet current (1986) needs. Current usage (1986) is about 400 million gallons per day and continues to increase (39 percent increase from 1970 to 1980). In Virginia, 41 percent of the population (fig. 1*B*) partly or entirely depends on ground water for their water supply (T.K. Kull, U.S. Geological Survey, oral commun., 1986); for 1.5 million Virginians, ground water is the only source of water for drinking and domestic purposes (Kull, 1983).

Ground-water-quality problems can originate from natural and human-induced sources. Natural problems include radiation (particularly within the Piedmont province, fig. 2), the presence of saltwater, low pH, and increased concentrations of chemical constituents, such as dissolved solids, iron, manganese, sulfate, fluoride, and hardness. Human-induced sources of contamination, such as landfills and hazardous materials spills, may have a significant effect on the quality of ground water.

According to the Virginia Water Control Board, about 1 percent of Virginia's ground water is contaminated, primarily near intensely populated areas. A 1983 Virginia State Health Department study in 14 south-central counties found chemical or bacterial contamination in 75 percent of 200 randomly sampled wells (Robert Taylor, Virginia State Health Department, oral commun., 1986). Most contamination was caused by improper well design or maintenance. Agricultural fertilizers and pesticides, along with the application of road salts, may constitute a major source of contamination. Leaking surface impoundments, septic tanks, wood preserving operations, inadequately designed landfills, and leaking underground storage tanks also have caused ground-water contamination. The Virginia Surface Impoundment Assessment identified more than 2,000 active or abandoned waste impoundments. Waste-lagoon seepage near Danville, Virginia, may have been responsible for the presence of trichloroethylene and 1,1,1-trichloroethane in the ground water. Selenium, vanadium, and arsenic have contaminated the ground water near Chisman Creek in York County. Sulfide minerals in a waste site in Nelson County contaminated ground water and caused several fishkills. An electroplating facility in Roanoke County caused chromium contamination of the ground-water supplies of 30 families in the area. Tetrachloroethylene was found in ground water that supplied 20,000 Prince William County residents (Howard Freeland, Virginia Department of Waste Management, oral commun., 1986).

Seven facilities in Virginia (fig. 3*A*) have been included by the U.S. Environmental Protection Agency (1986c) on the National Priorities List (NPL) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, known as the Superfund act. Six sites are currently proposed for possible inclusion on the NPL. The contents of about 400 active and inactive municipal landfill sites are unknown. In addition, the U.S. Department of Defense (DOD) has identified 23 sites at 7 facilities where contamination has warranted remedial action. All these locations serve as a potential source of additional contamination that might be detected in future ground-water sampling programs.

WATER QUALITY IN PRINCIPAL AQUIFERS

Virginia has two principal aquifer types (fig. 2*A*)—unconsolidated Coastal Plain aquifers, and sedimentary and crystalline bedrock aquifers (U.S. Geological Survey, 1985, p. 429). Each of the principal aquifers has its attendant water-quality problems. The unconsolidated Coastal Plain aquifers include the Columbia aquifer, Yorktown-Eastover aquifer, Chickahominy-Piney Point aquifer, Aquia aquifer, Brightseat aquifer, and the Potomac aquifer (fig. 2*A*,*B*). The sedimentary and crystalline bedrock aquifers (fig. 2*A*) include the Piedmont Mesozoic basin aquifers, the Piedmont and Blue Ridge crystalline aquifers, the Valley and Ridge aquifers, and the Appalachian Plateau aquifers.

The unconsolidated Coastal Plain aquifers are composed of combinations of clay, silt, sand, and gravel. The uppermost aquifers in the Coastal Plain province are used primarily for domestic supply; the deeper confined aquifers are used for municipal supply.

Naturally occurring chemical constituents in Virginia's aquifers sometimes exceed the drinking-water standards set by the U.S. Environmental Protection Agency (1986a,b). Constituents most commonly containing excessive concentrations are dissolved solids, iron, fluoride, chloride, and sulfate.

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 presented in figure 2*C*. The summary is based on dissolved-solids, hardness (as calcuim carbonate), nitrate (as nitrogen), iron, and fluoride analyses of water samples collected from 1965 to 1985 from the principal aquifers in Virginia. 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 a maximum concentration of 10 mg/L (milligrams per liter) nitrate (as nitrogen) and 4 mg/L fluoride. The secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids, 300 μg/L (micrograms per liter) iron, and 2 mg/L fluoride.

Unconsolidated Coastal Plain Aquifers

COLUMBIA AQUIFER

The Columbia aquifer, a water-table aquifer, is used primarily for domestic and irrigation supply. It is extremely vulnerable to contamination by bacteria, fertilizers, and pesticides because it is near the surface. The water is moderately hard, with a median concentration of hardness of 96 mg/L (fig. 2*C*). The largest concentrations of nitrate in Virginia are found in this aquifer; at least 10 percent of the wells sampled (fig. 2*C*) exceeded the primary drinking-water standard of 10 mg/L nitrate (as nitrogen). The median iron concentration (390 μg/L) exceeded the secondary drinking-water standard of 300 μg/L).

YORKTOWN-EASTOVER AQUIFER

The Yorktown-Eastover aquifer is a water-table aquifer in the western Coastal Plain where it crops out (fig. 2*A*). The aquifer is confined where it underlies the Columbia aquifer and the intervening confining unit in the eastern Coastal Plain. Yields of water from wells are largest in the east, where the aquifer is used primarily for domestic and light-industrial supply. Water is hard with a median concentration of 122 mg/L. Iron exceeded the secondary drinking water standard of 300 μg/L in at least 10 percent of the wells sampled (fig. 2*C*).

CHICKAHOMINY-PINEY POINT AQUIFER

The Chickahominy-Piney Point aquifer is confined except in the western Coastal Plain where it crops out in very small areas and becomes unconfined. It is an important source of water for domestic, industrial, and public water supplies in the central Coastal Plain. Concentrations of dissolved solids larger than 500 mg/L are present in at least 10 percent of the wells sampled (fig. 2*C*). Water is generally soft, with a median hardness concentration of 42 mg/L. Concentrations of fluoride larger than 2.0 mg/L are present in at least 10 percent of the wells sampled.

AQUIA AQUIFER

The Aquia aquifer is confined except in a small outcrop area in the northwestern Coastal Plain where it is unconfined (fig. 2*B*). It is principal source of water for large industrial and public water supplies. Concentrations of dissolved solids larger than 500 mg/L are present in at least 10 percent of the wells sampled (fig. 2*C*). The water is soft, with a median hardness concentration of 32 mg/L (fig. 2*C*). Concentrations of chloride larger than 250 mg/L are present in at least 10 percent of the wells sampled. Concentrations of fluoride larger than 2.0 mg/L are found throughout the aquifer. Water in at least 25 percent of the wells sampled exceeded the secondary drinking-water standard for fluoride (fig. 2*C*).

BRIGHTSEAT AQUIFER

The Brightseat aquifer is a confined, multiaquifer unit in the north-central part of the Coastal Plain (fig. 2*B*). It is a principal source of water for industries. Available water-quality data are insufficient to characterize the quality of water in this aquifer.

POTOMAC AQUIFER

The Potomac aquifer is a confined, multiaquifer unit. It has a small outcrop area in the northwestern part of the Coastal Plain (fig. 2*B*), and it is the principal source of water for large industrial and public water-supply uses. Concentrations of dissolved solids exceeded the drinking-water standard of 500 mg/L in at least 25 percent of the wells sampled (fig. 2*C*). The water is soft, with a median hardness concentration of 14 mg/L. Concentrations of iron larger than 300 μg/L are present in more than 10 percent of the wells sampled (fig. 2*C*). Concentrations of chloride larger than 250 mg/L are present in more than 10 percent of the wells sampled. The largest concentrations of fluoride in Virginia are present in this aquifer (fig. 2*C*). Fluoride exceeding 2.0 mg/L in at least 25 percent of the wells sampled (fig. 2*C*).

Sedimentary and Crystalline Bedrock Aquifers

PIEDMONT MESOZOIC BASIN AQUIFER

The Piedmont Mesozoic basin aquifers, which are composed of sandstone, siltstone, limestone, and igneous intrusive rocks, are used for industrial, public, and domestic supply. Water from at least 20 percent of the wells sampled exceeded the secondary drinking-water standards of 500 mg/L for dissolved solids and and 250 mg/L sulfate (fig. 2*C*). The water is very hard (median concentration was 190 mg/L), and the largest concentrations of hardness in Virginia are found in these aquifers. Water from deep wells completed in this aquifer contains the largest concentrations of dissolved solids and sulfate of any Virginia aquifers.

PIEDMONT AND BLUE RIDGE CRYSTALLINE AQUIFERS

The Piedmont and Blue Ridge crystalline aquifers, which are composed of intrusive igneous and metamorphic rocks, are used primarily for domestic supply. Although water in the Piedmont and Blue Ridge crystalline aquifers is generally acidic and can leach copper and lead from pipes and plumbing connections, water from this aquifer generally had the smallest concentrations of dissolved solids of the principal aquifers of the State (fig. 2*C*). The water is generally suitable for most purposes, with differing concentrations of hardness and iron depending on the mineral composition of the host rock. The crystalline igneous and metamorphic rocks of the Piedmont and Valley and Ridge provinces have large levels of natural radiation in the ground water.

VALLEY AND RIDGE AQUIFERS

The Valley and Ridge aquifers, which are composed mainly of carbonate rocks (limestone and dolomite), are used for industrial and public water supply as well as for domestic supply. Water in the carbonate aquifers tends to be very hard (median concentration was 254 mg/L; fig. 2*C*) and large concentrations (greater than 10 mg/L) of nitrate (as nitrogen) are a concern in the Valley and Ridge aquifers.

APPALACHIAN PLATEAU AQUIFERS

The Appalachian Plateau aquifers, which are composed mainly of sandstone, siltstone, and coal, are used predominantly for domestic supply. Water in the Appalachian Plateau aquifer was moderately hard (median concentration of 72 mg/L). Appalachian Plateau aquifers tend to have large concentrations of iron (fig. 2*C*). The median iron concentration (220 μg/L) was near the secondary drinking-water standard of 300 μg/L. Concentrations exceeding the secondary drinking-water standard were found in at least 25 percent of the wells sampled.

EFFECTS OF LAND USE ON WATER QUALITY

The most widespread sources of contamination of ground water, in Virginia, are probably septic systems (nitrates and bacteria), agricultural practices (nitrates and pesticides), and improperly designed and maintained wells (bacteria). Contamination of ground water by hydrocarbon compounds and trace metals occurs primarily at wood treatment plants, textile plants, leaking underground storage tanks, and inadequately designed and maintained landfills. Hydrocarbon compounds, because of their carcinogenic nature, are of great concern, although contamination by these compounds is generally local.

In Virginia, 912 sites require permitting according to the Resource Conservation and Recovery Act (RCRA) of 1976, which regulates the generation, transport, storage, treatment, or disposal of hazardous materials. Seventy-eight of these RCRA sites (fig. 3*A*) are locations where hazardous materials are stored, treated, or disposed. These facilities are widely distributed throughout Virginia and have potential to affect ground water. Nineteen of the RCRA sites are undergoing assessment monitoring and are shown as contaminated sites in figure 3*A*.

Seven locations where ground-water contamination has been detected have been included by the U.S. Environmental Protection Agency (EPA) on the NPL of CERCLA known as "Superfund" (fig. 3*A*). Three sites are located in the Valley and Ridge aquifers (Frederick, Roanoke, and Smyth Counties) where wastes have contaminated the ground water with hydrocarbons, dissolved chromium, and mercury, respectively. Two sites are located in the Piedmont and Blue Ridge crystalline aquifers (Nelson and Warren Counties) where sulfide minerals in a waste site have contaminated the ground water and caused several fishkills at the former, and synthetic organic compounds have contaminated the ground water at the latter. Two sites are located in an unconsolidated Coastal Plain aquifer where vanadium, selenium, and arsenic have leaked into the ground water from landfills along Chisman Creek (York County) and organic compounds have contaminated the ground water in Spotsylvania County.

Human-induced sources of potential ground-water contamination exist throughout Virginia; however, only 10 wells to date (1986) have been condemned by the Virginia Health Department (R. Taylor, Virginia Health Department, oral commun., 1986). These wells, which are located in the Piedmont and Blue Ridge crystalline aquifers (fig. 3*B*) near Danville, Virginia, were contaminated by trichloroethylene and 1,1,1 trichloroethane. Many additional wells in Virginia may have been affected by contamination, but wells commonly are abandoned by the owner without notifying the Health Department.

As of September 1985, 112 hazardous-waste sites at 17 facilities in Virginia had been identified by the DOD as part of their Installation Restoration Program (IRP) as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the EPA Superfund program under CERCLA. The EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Of the 112 sites in the program, 16 sites contained contaminants but did not present a hazard to the environment. Twenty-three sites at 7 facilities (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. Remedial action at five of these sites has been completed under the program. The remaining sites were schedule for confirmation studies to determine if remedial action is required.

POTENTIAL FOR WATER-QUALITY CHANGES

Degradation of ground water in Virginia has been associated with leaking underground petroleum storage tanks; surface impoundments used to store, treat, and recycle waste products; septic tanks and associated drainfields; poorly constructed wells; improper use and inadequate design of landfills; and agricultural use of fertilizers and pesticides. According to Virginia Water Control Board data, complaints about ground water related to gasoline or petroleum contamination from leaking underground storage tanks, increased from about 13 in 1979 to more than 120 in 1985. The actual number and locations of all such contamination sites are unknown, and collectively, these may be one of the greatest threats to ground-water quality in Virginia.

Surface impoundments containing hazardous materials also pose a contamination threat to ground water. Surface impoundments have caused ground-water-quality problems near wood-treatment and textile-manufacturing plants. Inadequate design and use of landfills have resulted in the presence of metals and organic compounds in ground water. About 400 active and inactive landfill sites are distributed throughout the State; each site is a potential source of contamination to Virginia's ground water. The approximate locations of active municipal landfills are shown in figure 3*C*.

Effluent from domestic septic systems, along with improperly designed wells, is thought to be a major threat to the local ground-water quality in rural areas. Nitrate contamination, derived from feedlots, fertilization practices, or animal waste disposal, continues to threaten the quality of the shallow ground-water system, particularly in the Coastal Plain and Valley and Ridge provinces. Although there is an effort in Virginia to prevent further contamination of ground water, many instances of contamination resulting from past practices probably remain to be discovered.

The potential for ground-water contamination differs with local geology. Of particular concern are the carbonate aquifers of the Valley and Ridge province, which are very susceptible to contamination. In this area, thin soil coverings are insufficient to filter infiltrating water, and sinkholes facilitate rapid recharge of surface water to ground water. Recharge areas of major aquifers of the Coastal Plain (fig. 2*B*), which occur along the Fall Line near major metropolitan areas, are vulnerable to contamination caused by the handling and disposal of hazardous materials associated with industry.

In some instances, the continued withdrawal of ground water has apparently resulted in lateral and vertical movement of poor-quality water into potable water suplies. There is a large potential for encroachment of salty ground water into the shallow freshwater system near coastal communities in this manner.

GROUND-WATER-QUALITY MANAGEMENT

The Virginia Constitution states that it is the policy of the Commonwealth of Virginia to protect Virginia's water resources from pollution, impairment, or destruction, for the benefit, enjoyment, and general welfare of the people. To accomplish this goal, the General Assembly of Virginia passed the State Water Control Law of 1946, which established the Virginia Water Control Board (VWCB). The VWCB has the responsibility to supervise and control the quality of Virginia's surface water and ground water and to enforce and administer the State Water Control Law. The Ground-water Act of 1973, amended in 1986, authorized the VWCB to establish ground-water management areas to more closely regulate ground-water withdrawal in large areas where ground water is a major water-supply source. Ground-water withdrawals in excess of 300,000 gallons per month require a permit. The two management areas established to date are located in southeastern Virginia and on the eastern shore of Virginia. The 1973 Act also authorized the Virginia Department of Health to protect the State's ground-water resources from contamination by hazardous and solid waste. The responsibility for this mission was moved to the Virginia Department of Waste Management on July 1, 1986. This agency works in close cooperation with the VWCB and the EPA.

Federal statutes involved in protecting Virginia's ground-water resources include the Safe Drinking Water Act of 1974, CERCLA of 1980, the RCRA of 1976, the Toxic Substance Control Act of 1976, the Clean Water Act of 1977, the Federal Insecticide, Fungicide and Rodenticide Act of 1972, the Underground Storage Tank Act of 1984, and Surface Mining Control and Reclamation Act of 1977.

Virginia's ground-water protection policy is based on a philosophy of non-degradation. The VWCB maintains a statewide ground-water-monitoring network of wells sampled each month. In addition, wells along the lower Chesapeake Bay and Atlantic Ocean are monitored for intrusion of saltwater into Coastal Plain aquifers. The U.S. Geological Survey contributes to the water-quality data base through various regional hydrologic studies within Virginia.

SELECTED REFERENCES

Breeding, N.K., Jr., and Dawson, J.W., 1976, Roanoke County ground water, present conditions and prospects: Virginia Water Control Board Planning Bulletin 301, 72 p.

_____ 1976, Botetourt County ground water, present conditions and prospects: Virginia Water Control Board Planning Bulletin 304, 66 p.

Dawson, J.W., and Davidson, C.B., 1979, Ground water resources of Henry County, Virginia: Virginia Water Control Board Planning Bulletin 312, 69 p.

Fennema, R.J., and Newton, V.P., 1982, Ground water resources of the eastern shore of Virginia, present conditions and prospects: Virginia Water Control Board Planning Bulletin 332, 74 p.

Hinkle, K.R., and Sterrett, R.M., 1976, Rockingham County ground water, present conditions and prospects: Virginia Water Control Board Planning Bulletin 300, 88 p.

_____ 1977, Shenandoah County ground water, present conditions and prospects: Virginia Water Control Board Planning Bulletin 306, 67 p.

_____ 1978, Ground water resources of Augusta County, Virginia: Virginia Water Control Board Planning Bulletin 310, 119 p.

Kahn, J.H., 1984, Virginia's ground water—Proceedings of a symposium organized by the Environmental Defense Fund, November 9–10, 1983:

Virginia Water Resources Research Center, Virginia Polytechnical Institute and State University, 101 p.
Kull, T.K., 1983, Water use in Virginia, 1980: Virginia State Water Control Board Basic Data Bulletin 59 [map].
Posner, Alex, and Zenone, Chester, 1983, Chemical quality of ground water in the Culpeper Basin, Virginia and Maryland: U.S. Geological Survey Miscellaneous Investigations Series Map I-1313-D.
Rogers, S.M., and Powell, J.D., 1983, Quality of ground water in southern Buchanan County, Virginia: U.S. Geological Survey Water-Resources Investigations Report 82-4022, 36 p.
Sevebeck, K.P., Kahn, J.H., and Chapman, N.L., 1986, Virginia's waters: Virginia Water Resources Research Center, Virginia Polytechnical Institute and State University, 40 p.
Siudyla, E.A., Berglund, T.D., and Newton, V.P., 1977, Ground water of the middle peninsula, Virginia: Virginia Water Control Board Planning Bulletin 305, 90 p.
Sterrett, R.M., and Hinkle, K.R., 1975, Ground water conditions in the eastern shore of Virginia: Virginia Water Control Board Planning Bulletin 45, 59 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, 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. Geolgical Survey Water Supply Paper 2275, 467 p.
Virginia State Water Control Board, K.R., 1974, Ground water conditions of southeastern Virginia (supplement to Planning Bulletin 261): Virginia Water Control Board Planning Bulletin 261-A, 33 p.

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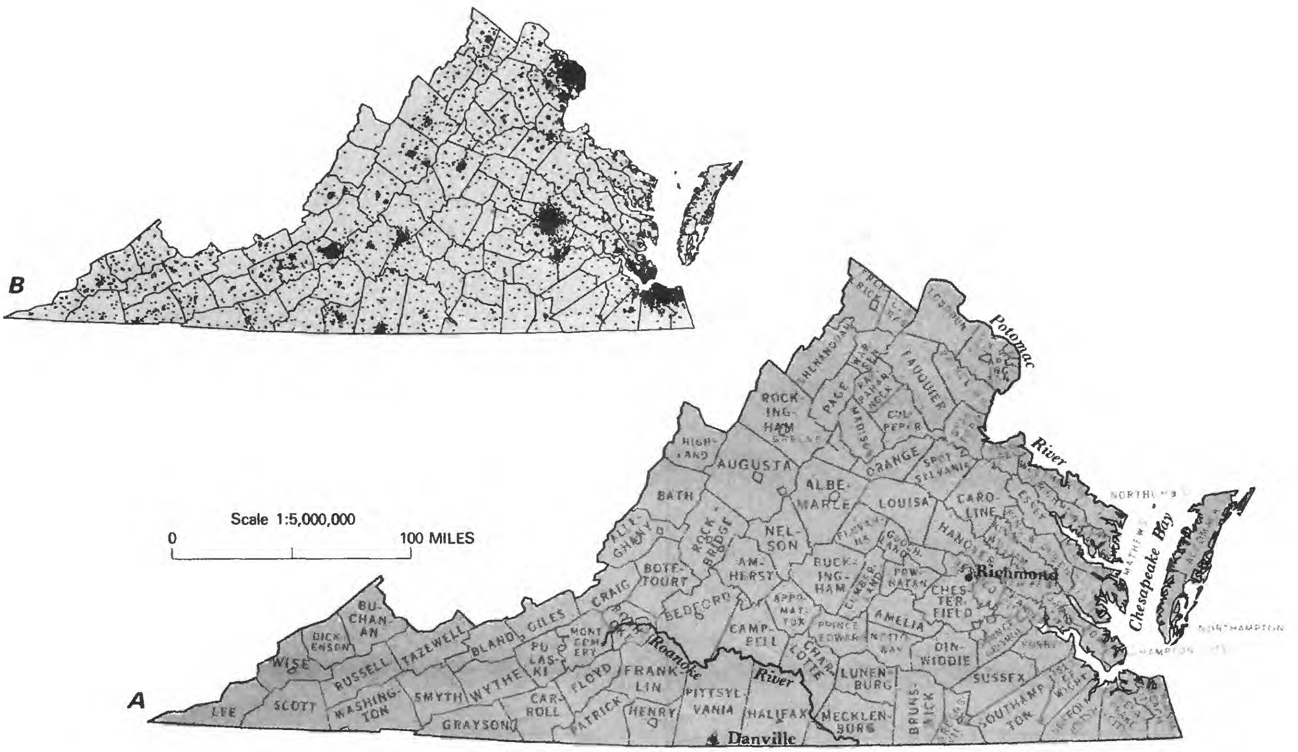

Figure 1. Selected geographic features and 1985 population distribution in Virginia. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted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

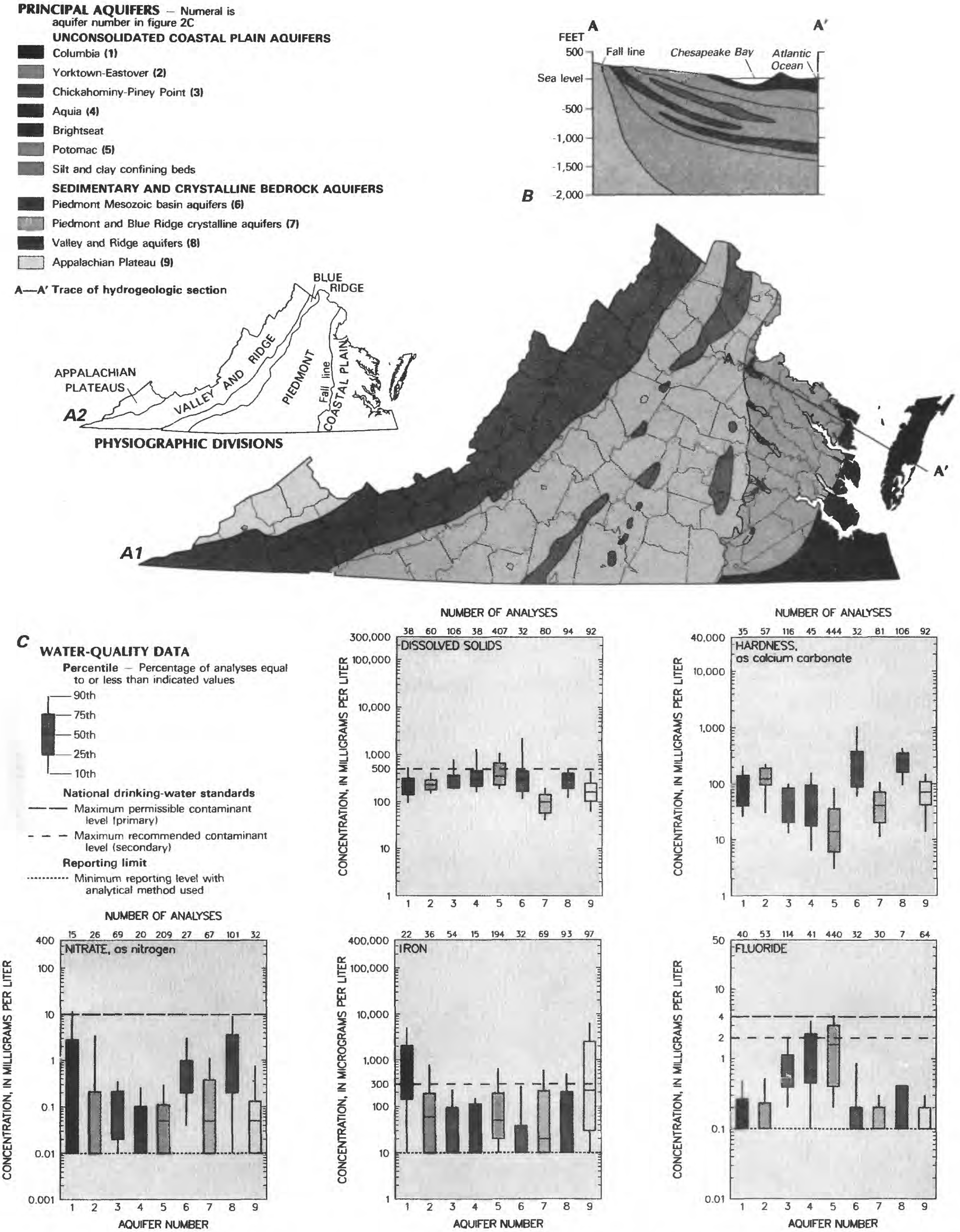

Figure 2. Principal aquifers and related water-quality data in Virginia. *A1*, Principal aquifers; *A2*, Physiographic provinces. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1965–1985. (Sources: *A*, *B*, U.S. Geological Survey, 1985. *C*, Data from Virginia Water Control Board and U.S. Geological Survey files; national drinking water standards from U.S. Environmental Protection Agency, 1986a,b.)

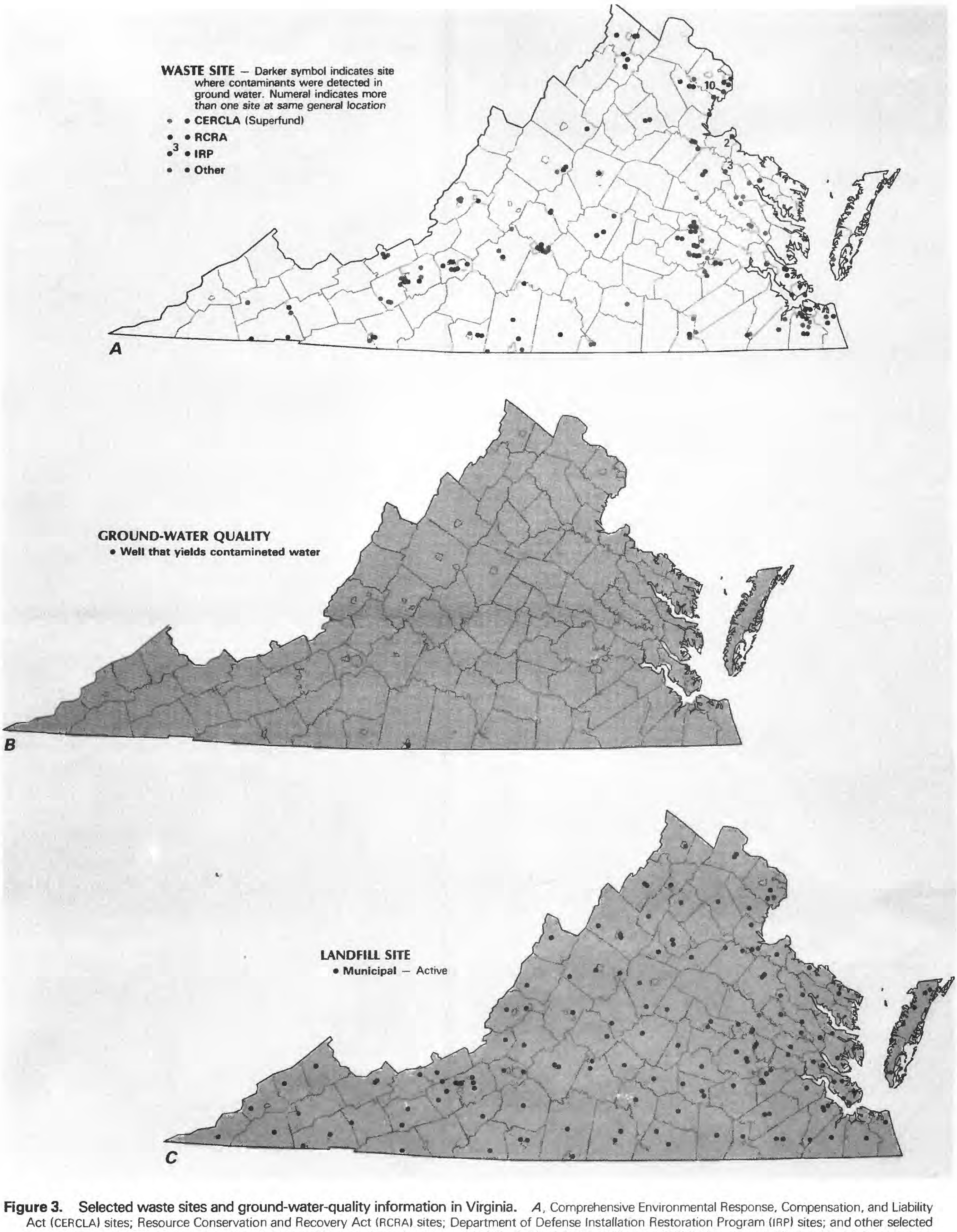

Figure 3. Selected waste sites and ground-water-quality information in Virginia. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; Department of Defense Installation Restoration Program (IRP) sites; and other selected waste sites, as of 1986. *B*, Location of wells that yield contaminated water, as of 1986. *C*, Municipal landfills, as of 1986. (Sources: *A*, Virginia Health Department, Virginia Water Control Board, and U.S. Geological Survey files; U.S. Department of Defense, 1986. *B*, *C*, Virginia Health Department, Virginia Water Control Board, and U.S. Geological Survey files.)