# MARYLAND AND
# THE DISTRICT OF COLUMBIA
# GROUND-WATER QUALITY

*By* Judith C. Wheeler and Lillian B. Maclin

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DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, *Secretary*

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, *Director*

For additional information:

Chief Hydrologist
U.S. Geological Survey
407 National Center
Reston, VA 22092

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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 Islands, 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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# Maryland and the District of Columbia
## Ground-Water Quality

Maryland and the District of Columbia (fig. 1) lie in five distinct physiographic provinces—the Coastal Plain, the Piedmont, the Blue Ridge, the Valley and Ridge, and the Appalachian Plateaus (fig. 2). Differences in physiography affect the State's climate, soils, land use, and water use. Ground water is an abundant natural resource in Maryland. Although it constitutes only 13 percent of total water used in the State, it is of substantial socioeconomic significance. Most freshwater withdrawals are from the Coastal Plain, and the area east of Chesapeake Bay depends almost entirely on ground water for supply. The District of Columbia depends almost entirely on surface-water supplies, although ground water is used for some industries and for emergency backup for several hospitals, government facilities, and embassies (U.S. Geological Survey, 1985, p. 243).

Maryland's aquifers provide water for about 30 percent of the State's population—13 percent from public supplies and 17 percent from rural self-supplied systems. (See population distribution in fig. 1*B*.) Population growth has increased the demand for potable ground water. The resulting need to dispose of increasing quantities of wastewater, sewage sludge, refuse, and many other wastes has increased the potential threat to ground-water quality.

The ground water used in Maryland generally is suitable for most purposes. With few exceptions, ground water used by public-supply systems meets U.S. Environmental Protection Agency (EPA) drinking-water standards (1986a,b). Natural water-quality problems, however, do occur; the most common are iron and manganese concentrations that exceed national drinking-water standards, excessive hardness as calcium carbonate, naturally occurring saltwater (sodium chloride), and low pH (less than 5.0 units in some places).

Human activities that contribute to present or potential sources of contamination include septic systems, landfills and open dumps, underground oil and gasoline storage tanks, saltwater intrusion due to pumping, agriculture, mining, surface impoundments, road salting, chemical spills, and improper storage and disposal of hazardous substances. The contaminants from these activities include nitrates, chloride, toxic organic and inorganic compounds, petroleum, and bacteria. Some of these contaminants have the potential to threaten human health and ecological systems; others are merely nuisances. Most ground-water contamination in Maryland occurs in widely scattered but localized areas around specific sources (fig. 3). However, some larger "clusters" of wells that yield contaminated water occur where hydrogeologic conditions can promote expansion of ground-water contamination or where potential ground-water-polluting activities are concentrated (Maryland Office of Environmental Programs, 1984a, p. 41).

The Maryland Department of the Environment, Hazardous and Solid Waste Management Administration, through its Maryland Superfund Program has identified 168 sites where hazardous substances may affect public health and the environment. Seventy-four of these sites are regulated also by the Federal Resource Conservation and Recovery Act (RCRA) of 1976 and six sites are included in the National Priorities List (NPL) of hazardous waste sites (U.S. Environmental Protection Agency, 1986c) (fig. 3*A*). These six sites require additional evaluation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Within the District of Columbia, the Department of Consumer and Regulatory Affairs has identified one RCRA site; no CERCLA sites have been designated. In addition, the U.S. Department of Defense has identified three sites at two facilities where contamination has warranted remedial action.

Maryland and the District of Columbia do not have statewide or district-wide routine ground-water-quality monitoring programs. However, such a program is now being considered by Maryland's Ground-Water Steering Committee.

### WATER QUALITY IN PRINCIPAL AQUIFERS

The aquifers in Maryland and the District of Columbia generally are of two distinct types—unconsolidated aquifers of the Coastal Plain and consolidated sedimentary and crystalline aquifers of the other physiographic provinces, termed non-Coastal Plain aquifers. The principal aquifers, their geographic distribution, physiographic divisions, and a generalized hydrogeologic section (A–A') are shown in figure 2. A description of the aquifers is given by the U.S. Geological Survey (1985, p. 243-248). More than 90 percent of the State's total ground-water withdrawals are from Coastal Plain aquifers (Herring, 1983, p. 39).

Natural water quality in freshwater aquifers of the Coastal Plain is suitable for most uses, although quality varies with the composition of the rocks through which the water moves. Water that has been drawn from limey (calcareous) formations may have a greater carbonate content and will be harder than water from other formations. Most public water supplies with hardness that exceeds 150 mg/L (milligrams per liter) are treated to soften the water. Water of Coastal Plain aquifers ranges from soft to very hard, with the average being in the moderately hard range (61 to 120 mg/L as calcium carbonate). The concentration of dissolved solids in the Coastal Plain aquifers varies greatly; largest concentrations (median of more than 200 mg/L) are in the Chesapeake Group and Piney Point aquifers. Dissolved iron concentrations also vary greatly; generally, they are smaller than 200 $\mu$g/L (micrograms per liter); however, locally they may be larger than 300 $\mu$g/L.

One of the most common problems in Coastal Plain aquifers is saltwater intrusion. The position of the freshwater–saltwater boundary depends not only on the amount of inflow to the aquifer but also the amount of freshwater discharging from the aquifer. Any change in freshwater discharge can change the location of the boundary. Minor variations occur naturally as a result of tidal action and seasonal and annual changes in freshwater discharge.

In the non-Coastal Plain aquifers, natural water quality is satisfactory for most uses, but may vary greatly depending on the type of rock with which the water comes into contact. Water is relatively soft (median of 40 mg/L as calcium carbonate) in most of the Piedmont and Blue Ridge crystalline aquifers. Water in the Carbonate aquifer may be harder—in some areas in excess of 400 mg/L as calcium carbonate. In most non-Coastal Plain aquifers the pH ranges from 6.0 to 8.0, although in some areas the water may be acidic, with pH values smaller than 5.0. Iron concentrations larger than 300 $\mu$g/L also are a common problem.

#### BACKGROUND WATER QUALITY

A graphic summary of water-quality analyses for dissolved solids, hardness as calcium carbonate, nitrate plus nitrite (as nitrogen), chloride, and sodium is shown in figure 2*C* to characterize the variability of the background chemical quality of water in the principal aquifers in Maryland. The data were interpreted without distinction as to either the date of sample collection or the depth within the aquifer from which the sample was collected.

The summary (fig. 2*C*) is based on selected chemical data available in the U.S. Geological Survey's National Water Data

Storage and Retrieval System (WATSTORE). Percentiles of the variables are compared to national standards established by the U.S. Environmental Protection Agency (1986a,b) that specify the maximum concentration or level of a contaminant in a drinking-water supply. 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.

## Coastal Plain Aquifers

### COLUMBIA AQUIFER

The Columbia aquifer crops out over much of the Maryland Eastern Shore (fig. 2*A*1). This aquifer primarily is a water-table aquifer that is recharged by infiltration of precipitation; however, in eastern Worcester County, the aquifer is semiconfined. Natural water quality of the Columbia aquifer generally is suitable for most purposes. Dissolved-solids concentration, a secondary drinking-water standard, commonly is small (median of 70 mg/L). The water usually is soft, with hardness commonly less than 35 mg/L. Nitrate plus nitrite concentration, a primary drinking-water standard, has a median value of 1.6 mg/L. Although chloride concentration, a secondary drinking-water standard, is small (median of 8.7 mg/L), saltwater intrusion is a potential problem, particularly in coastal areas along the Chesapeake Bay and Atlantic Ocean. Sodium concentrations generally are smaller than 10 mg/L.

### CHESAPEAKE GROUP AQUIFERS

The aquifers of the Chesapeake Group are major sources of water for several counties of the Eastern Shore of Maryland (fig. 2*A*1). Overall water quality is sufficient for most uses. Salinity, however, generally increases downdip and toward the Chesapeake Bay. Dissolved-solids concentrations generally range from 100 to about 690 mg/L, with the median being 259 mg/L. The average hardness is about 92 mg/L, which is moderately hard. Median chloride and sodium concentrations are 52 and 36 mg/L, respectively.

### PINEY POINT AQUIFER

The Piney Point aquifer is a major source of water for public supply, rural-domestic, and small self-supplied commercial uses in Calvert, St. Marys, Queen Annes, Caroline, Talbot, and Dorchester Counties. This aquifer does not crop out (fig. 2*B*); therefore, recharge to the aquifer is by leakage from overlying and underlying aquifers. Quality of water is suitable for most uses and is relatively uniform. In most areas of the aquifer, dissolved-solids concentrations are smaller than 250 mg/L, but they are commonly larger east of the Chesapeake Bay. The water naturally becomes increasingly brackish downdip (toward the southern edge of Dorchester County). Hardness ranges greatly throughout the aquifer, generally from 23 to 140 mg/L (soft to hard). Chloride and sodium concentrations have median values of 2.7 and 17 mg/L, respectively.

### AQUIA AQUIFER

The natural water quality of the Aquia aquifer is suitable for most public supply and rural-domestic uses without treatment. The median dissolved-solids concentration is 194 mg/L. In the outcrop area, water usually is soft because much of the fossil shell material and calcite cement commonly found in the aquifer material has been removed by leaching. However, in the rest of the aquifer, water hardness generally ranges from 10 to 190 mg/L (soft to very hard) with the median at 73 mg/L. The median concentrations for chloride and sodium are 2.5 and 40 mg/L, respectively.

### MAGOTHY AQUIFER

The Magothy aquifer is one of the most extensive aquifers beneath the Maryland Coastal Plain. Its natural water quality is acceptable for most uses, but in some updip areas the water is excessively acidic and contains undesirably large concentrations of iron (more than 300 μg/L). To the southeast, in parts of Caroline and Somerset Counties, water becomes brackish and is unsuitable for most uses. Median dissolved-solids concentration is 151 mg/L, which is considerably smaller than the drinking-water standard of 500 mg/L. Hardness averages about 70 mg/L (moderately hard) and median chloride and sodium concentrations are small—2.0 and 3.6 mg/L, respectively.

### POTOMAC GROUP AQUIFERS

The Potomac Group aquifers supply the largest quantity of ground water for public supplies. Overall, the natural water quality is satisfactory for most uses. The median concentration of dissolved solids (61 mg/L) is considerably smaller than the drinking-water standard. However, iron content may exceed the standard (300 μg/L) in updip areas of the aquifers. Median hardness is about 14 mg/L (soft). Chloride concentrations generally are small (less than 10 mg/L) in the updip areas, and sodium concentrations average 4.1 mg/L. Farther downdip, the water tends to become harder and more alkaline, and contain less iron, more chloride (greater than 250 mg/L), and more dissolved solids until the water becomes too brackish for potable use.

All the principal Coastal Plain aquifers have median values of nitrate plus nitrite (as nitrogen) that are considerably smaller than the drinking-water standard (10 mg/L). The majority of the samples from the Piney Point, Magothy, and Aquia aquifers have nitrate plus nitrite concentrations smaller than 0.1 mg/L.

## Non-Coastal Plain Aquifers

Non-Coastal Plain aquifers, which are west of the Fall Line (fig. 2*A*2), usually have natural water quality that is suitable for most uses, although problems of hardness and large iron concentrations are evident. Dissolved-solids concentrations may vary depending on the rock type with which the water comes into contact; concentrations generally range from 38 to about 600 mg/L for the different non-Coastal Plain aquifers. Water hardness also varies widely, generally from about 12 to 390 mg/L (soft to very hard). Brine underlies freshwater in the Appalachian sedimentary aquifers.

The median concentrations of nitrate plus nitrite (as nitrogen) for the principal non-Coastal Plain aquifers are considerably smaller than the drinking-water standard of 10 mg/L. Median chloride and sodium concentrations for the aquifers average about 10 mg/L.

### EFFECTS OF LAND USE ON WATER QUALITY

In some areas of Maryland, ground-water quality has deteriorated because of the effects of malfunctioning septic systems, landfills and open dumps, military facilities, leaking underground oil and gasoline storage tanks, saltwater intrusion due to pumping, agricultural practices, surface impoundments, and mining. Locations of documented areas or points of known ground-water contamination, as well as hazardous-waste sites and municipal landfills, are shown in figure 3.

## Septic Tank Systems

Approximately 20 percent of the State's population is dependent on individual septic systems for waste disposal. A properly installed and operated septic system is not a threat to ground water; however, a system that malfunctions because of improper installation or maintenance, poor soil conditions (either relatively impermeable or poorly drained), or a high water table may pollute ground water with nitrate, chloride, and bacteria. Septic systems are the most commonly reported source of ground-water contamination in the State. Malfunctioning systems occur in all physiographic areas but are more prevalent in many low-lying shoreline communities where soils are poorly drained and the water table is near the land surface.

Ground-water contamination from septic-system failure usually is localized around communities with numerous failing systems. Many of the existing malfunctioning septic systems were installed before present State Department of the Environment regulatory procedures were in effect, and, in most problem areas, remedies currently are being sought through the EPA Construction Grant Program under the national Clean Water Act (Maryland Department of Natural Resources and Maryland Department of Health and Mental Hygiene, 1983a, p. 209).

### Landfills and Open Dumps

Landfilling is the most commonly used method of solid-waste disposal in Maryland. Water that leaches solid wastes at a landfill may contain large concentrations of organic-carbon compounds, chloride, iron, lead, copper, and sodium. Formation of leachate can continue for years after closure of a landfill. As of 1986, new landfills are sited well above maximum ground-water levels and are required to have a liner, an underdrain system to collect leachate for treatment, and monitoring wells to detect and to minimize the potential for contamination of ground water (Maryland Office of Environmental Programs, 1986a). With no such protection at older landfills, the potential for leachate to travel through the soil to ground water is much greater. As of July 1986, 46 municipal land and rubble fills are permitted to operate in the State. However, more than 100 closed or abandoned landfills and open dumps pose potential hazards to ground-water quality; forty two of these sites are on the Maryland Superfund list. (See fig. 3*C* for location of active and inactive landfills.) Ground-water contamination has been detected at several of these landfills (fig. 3*C*, sites 1–4), but monitoring wells have been installed and remedial action to prevent further contamination has been taken (Maryland Office of Environmental Programs, 1986b, p. 1059–1089).

In the District of Columbia, no landfills are in operation, but about 80 sites were used in the past as landfills or open dumps. Several of the abandoned sites are shown in figure 3*C*.

### Military Facilities

As of September 1985, 62 hazardous-waste sites at 8 facilities in Maryland had been identified by the U.S. Department of Defense 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 62 sites in the program, 30 contained contaminants but did not present a hazard to the environment. Three sites at two facilities (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. The remaining sites were scheduled for confirmation studies to determine if remedial action is required.

### Underground Oil and Gasoline Storage Tanks

Petroleum products can enter ground water in two ways—as surface spills that percolate through the soil or as leaks from underground tanks and pipes. Once in the ground water, hydrocarbons may remain for a long time because they can be very resistant to degradation. Small concentrations of hydrocarbons generally are not acutely toxic, but even slight concentrations can render water unpotable because of unpleasant taste or odor (Maryland Department of Natural Resources and Maryland Department of Health and Mental Hygiene, 1983a, p. 237).

The magnitude of ground-water pollution caused by leaking oil and gasoline storage tanks is difficult to assess. Although the incidents of contamination usually are localized, many instances are reported—250 in fiscal year 1986 (Maryland Water Resources Administration, 1986). Most counties report one or more instances each year. The areal extent of the ground-water contamination from a leaky buried storage tank may not be large, but the impact is severe for those directly affected. One site in Baltimore County (fig. 3*B*, site 1) is typical of many instances of petroleum contamination. At this site, one family and five businesses were forced to abandon use of their wells and have water delivered. However, the problem of underground storage tanks is being addressed by the Maryland Department of the Environment. Prevention and detection of underground spills were addressed in regulations promulgated in 1985 for controlling the installation, testing, lining, and abandonment of underground storage tanks. Current efforts are directed toward an evaluation of the feasibility and necessity of complete restoration of contaminated ground water.

### Saltwater Intrusion

Saltwater occurs naturally in downdip areas of most Coastal Plain aquifers. Under certain hydrogeologic conditions, saltwater also can be drawn into freshwater aquifers from the Chesapeake Bay or the Atlantic Ocean. (See section on "Background Water Quality.") The problem of saltwater intrusion into freshwater aquifers is associated most commonly with excessive withdrawals of water from aquifers. When saltwater is drawn in, the affected part of the aquifer is no longer suitable for water supply. A public water supply in Harford County experienced saltwater intrusion in the late 1960's when excessive withdrawals from one of the Potomac Group aquifers drew in brackish water from a nearby tidal river that is tributary to Chesapeake Bay. Withdrawal levels were decreased until the hydraulic gradient in the aquifer reversed and the chloride concentrations decreased to acceptable levels (Maryland Department of Natural Resources and Maryland Department of Health and Mental Hygiene, 1983a).

The northwestern corner of Kent Island in Queen Annes County (fig. 3*B*, area 2) is experiencing a saltwater-intrusion problem in the Aquia aquifer. Since 1983, the U.S. Geological Survey and the Maryland Geological Survey, in cooperation with Queen Annes County and the Maryland Water Resources Administration, have been conducting a comprehensive evaluation of the problem. In the meantime, the Maryland Water Resources Administration has prohibited increased pumpage from the affected part of the Aquia aquifer.

The Potomac Group aquifers under south-central Baltimore city (fig. 3*B*, area 3) became contaminated with saltwater as a result of large withdrawals of ground water for industrial use in the first half of this century. Most industries in the city now use the public supply, which is a surface-water reservoir system. A recently completed investigation of the status of ground water in the Baltimore city area concluded water quality was unlikely to improve significantly even if all ground-water pumpage in the Baltimore area were stopped; and significant pumping stress in the northeastern corner of Anne Arundel County could cause the chloride plume to migrate toward that pumping center (Chapelle, 1985).

Saltwater intrusion in the Indian Head area of Charles County (fig. 3*B*, area 4) has been recognized as a potential threat to local water supplies for many years, but until recently, little indication of saltwater intrusion had been found. The town of Indian Head has experienced increased concentrations of dissolved solids in the drinking water drawn from Potomac Group aquifers. Before 1964, dissolved-solids concentrations in the town's water supply typically ranged from 200 to 250 mg/L; however, by 1982, the concentrations had increased to about 424 mg/L. In 1983, brominated compounds, which may be associated with brackish water, also were detected. A preliminary investigation by the Water Resources Administration indicates the possibility of intrusion of brackish water from the Potomac River (Maryland Water Resources Administration, 1984, p. 211–235).

Increased withdrawals of ground water by Maryland's largest coastal resort town, Ocean City, Worcester County (fig. 3*B*, area 5), have caused the development of large cones of depression in the aquifers pumped. In addition, Ocean City is located on an island surrounded by the ocean, thus increasing the potential for saltwater intrusion. Since 1974, chloride concentrations in some supply wells of the 44th Street cluster have increased from 75 mg/L during November 1974 to 197 mg/L during February 1986 (fig. 4).

Two major ground-water studies currently are underway in the Ocean City area. One study by the U.S. Geological Survey, in cooperation with Maryland and Delaware agencies, is investigating water levels, chloride concentrations, and water use in coastal Maryland and Delaware. The other study is a multistate management planning effort between Maryland and Delaware, which is expected to result in the formation of a State water-supply strategy for resolving several issues in the region, including the saltwater-intrusion problem in the Ocean City area.

### Agricultural Practices

Agriculture affects the State's ground-water quality primarily by the misapplication of pesticides and fertilizers. Some classes of pesticides, including organic botanicals such as rotenone and pyrethrin, are biodegradable and in most situations present little threat to ground water. However, other classes, including organometallic compounds, have toxic and (or) heavy metals as part of their structure and present a real threat to ground water. Of greatest concern are the metallic arsenates, which contain extremely toxic arsenic. Under ideal circumstances, arsenic reacts with iron, aluminum, and calcium present in soils and forms compounds that are insoluble in water. Areas most vulnerable to ground-water contamination by arsenic compounds are those where the soil layer is thin or excessively permeable.

In 1983, the Maryland Office of Environmental Programs conducted a statewide study of selected wells to evaluate whether increased use of pesticides had affected ground-water quality. For most of the wells tested (at 28 agricultural sites), pesticides were not detected in the water, and in the few samples in which pesticides were present, concentrations were considerably smaller than established "alert" levels (Maryland Office of Environmental Programs, 1986a, p. 101).

Agricultural fertilizers usually contain one or more of the three major nutrients required for plant growth—nitrogen, phosphorus, and potassium. The most significant of these, from a drinking-water standpoint, is nitrogen. Excessive use of nitrogen fertilizers is suspected to be a factor in increased levels of nitrate in ground water in several areas of the State. A statewide study evaluated nitrate levels in 1,521 wells (Maryland Office of Environmental Programs, 1986a). Nearly 7 percent of the wells tested had nitrate concentrations that exceeded the national drinking-water standard of 10 mg/L as nitrogen. Twenty-two percent of the wells had concentrations ranging from 3 to 10 mg/L, whereas the remaining 71 percent had less than 0.3 mg/L.

A study completed in 1983 (Bachman, 1984) focused on describing the factors that affect nitrate variability in the Columbia aquifer in Maryland. A major finding of that report was that of 604 water-quality samples analyzed from randomly selected wells, 25 percent had nitrate concentrations that ranged from 0 to about 0.42 mg/L as nitrogen and that more than half had concentrations greater than 3 mg/L, which is larger than the median concentrations of 144 analyses shown here in figure 2*C*. In that study about 15 percent of the samples had nitrate concentrations that exceeded the drinking-water standard. The overall median concentration was about 3.5 mg/L. Concentration of nitrate tended to be larger at sites with urban and agricultural land uses and moderately well drained soils.

### Surface Impoundments

Pits, ponds, and lagoons are surface impoundments widely used in Maryland for the treatment, disposal, or storage of wastes. In 1978–79, the Maryland Surface Impoundment Assessment Group identified 855 impoundments throughout the State. Approximately 75 percent of all sites were unlined and were possible sources of ground-water contamination. However, very little ground-water-quality monitoring had been done at the sites to determine the extent and severity of contamination (McGlincy and others, 1980).

About 82 percent of the surface impoundments were used for waste treatment rather than storage or disposal. Municipal impoundments were mostly sewage-treatment lagoons designed to discharge to surface water. Agricultural impoundments typically were used for storage or treatment of swine or dairy wastes. Mining ponds commonly were unlined basins used to settle and neutralize acid water with lime. Industries primarily used impoundments for waste treatment by settling or seepage. Of the 132 industrial impoundments assessed by the Surface Impoundment Assessment Group, 40 contained hazardous wastes as defined by State regulations. Leaking industrial impoundments are the most well-known sources of severe ground-water contamination in the State. Many of the RCRA sites shown in figure 3*A* are surface impoundments, and several have documented ground-water contamination, including a CERCLA site located in St. Marys County.

### Mining

Acid mine drainage from abandoned coal mines is western Maryland's most critical water-contamination problem. The large number of abandoned mines, the method of mining commonly employed, and the extent of many underground workings render acid mine drainage difficult to decrease. Coal-bearing sedimentary rocks usually contain sulfide minerals. When rocks are exposed to surface conditions, as in mining, weathering begins. Sulfides, water, and atmospheric oxygen react to produce large quantities of sulfuric acid-bearing water. This acid water, in turn, can dissolve considerable amounts of metals from surrounding rocks. The result is ground water that may exceed national standards for pH, sulfate, iron, and trace metals.

Several areas in western Maryland are known to have degraded ground-water quality that may be attributed to mine drainage. Water from several springs in western Allegany County (fig. 3*B*, area 6) contains excessive hardness, acidity, large concentrations of iron (more than 300 $\mu$g/L), and bacterial contamination. Similar water-quality problems occur in the coal mining areas of Garrett County. Information is insufficient to determine the degree to which mining has contributed to the problem.

## POTENTIAL FOR WATER-QUALITY CHANGES

Some aquifers or geographic regions are more susceptible than others or are particularly at risk of becoming contaminated because they are more exposed to potential surface sources of contamination. Unconfined aquifers typically have greater potential for contamination than confined aquifers for these reasons. The effect of land-use activities on these vulnerable areas may be substantial. Deeper confined aquifers may also become contaminated by infiltration of contaminated water from unconfined aquifers or by direct access through wells.

Aquifers that underlie coastal areas are susceptible to saltwater intrusion as a result of excessive withdrawals of water from the aquifer. A few locations where such problems already exist are shown in figure 3*B* (areas 2–5). A particular area of concern is the Broadneck Peninsula in Anne Arundel County (fig. 1*A*), where a decline in the potentiometric surface of the Magothy aquifer is creating a potential for salt-water intrusion. In this area, the potentiometric surface is below sea level about a mile from the aquifer's outcrop/subcrop, which is under the salt-water tidal zone of the Magothy River. If the hydraulic gradient at the saltwater source is landward toward the aquifer, the possibility for salt-water intrusion is present. Since 1983, the Maryland Water Resources Administration has placed restrictions on further increases in withdrawals from the Magothy aquifer in the Broadneck Peninsula, as well as the upper sand zone of the hydrologically connected Potomac Group aquifers. Despite these actions, the potentiometric surface continues to decline, although at a slower rate. As a result, the Water Resources Administration has encouraged the Anne Arundel County Department of Utilities to drill into the lower zones of the Potomac Group aquifers to meet future public-supply demands.

The large region of Maryland underlain by carbonate aquifers (fig. 2*A*1) has distinct problems regarding waste disposal and ground-water quality. Like other bedrock types found west of the Fall Line (fig. 2*A*2), the carbonate rocks may contain cavernous passages through which large volumes of ground water can move. The Hagerstown Valley in Washington County is representative of this phenomenon and is the largest area underlain by carbonate aquifers in the State (fig. 3*B*, area 7). Although some of the carbonate aquifers of the Hagerstown Valley are capable of yielding large quantities of water to wells, any contaminant introduced into the ground water can spread quickly and over great distances. In some areas, the subterranean passages intersect with the land surface as sinkholes, giving contamination direct access to ground water. Long-standing concern about ground-water quality in the Valley has increased as residential development with individual wells and septic systems has accelerated. Ground-water quality has already deteriorated in some locations. Conclusions of studies by the State and Washington County indicated that this contamination was the result of constructing numerous septic systems on sites where soil thickness was insufficient to attenuate the effluent before it reached the carbonate aquifer. These problems may increase, because thousands of such systems are already in place and hundreds more are proposed each year. The county responded to the problem by formulating a comprehensive quality management plan, which, in part, addresses and regulates point and nonpoint sources of contamination, as well as requiring appropriate well siting and construction standards (Maryland Department of Natural Resources and Maryland Department of Health and Mental Hygiene, 1983a, p. 245).

The Columbia aquifer also is extremely susceptible to ground-water contamination. This unconfined aquifer underlies much of the Eastern Shore area of Maryland (fig. 2*A*1) where it is a major source of potable water. The aquifer is vulnerable to contamination because water occurs close to the land surface under unconfined conditions and because the aquifer consists largely of permeable sand and gravel, and lacks sufficient clay and organic matter to provide effective filtration. Because land use is mostly agricultural, risk of contamination from industrial sources is small. However, problems can occur because this aquifer serves as a potable water supply and also receives potential contaminants from septic systems and agricultural activities. Although this risk is present in all areas of the State underlain by unconfined aquifers, it is especially significant on the Eastern Shore because of the weak attenuating capacity of the soil/sediment material.

The use of infiltration techniques to manage storm water may affect ground-water quality. In 1985, the U.S. Geological Survey, in cooperation with the Maryland Geological Survey and the Water Resources Administration, began a 5-year study to evaluate effects of infiltration structures on ground-water quality. Depending on results of the study, the State may incorporate additional design specifications or restrict the use of infiltration structures in vulnerable areas (Maryland Water Resources Administration, 1986).

## GROUND-WATER-QUALITY MANAGEMENT

The strategy of Maryland State and local regulatory agencies is to prevent ground-water contamination by concentrating on the potential sources of the contamination. This prevention-based approach allows each regulatory group to develop expertise in dealing with the source of contamination for which it is responsible and to establish programs that are compatible with Federal laws. Currently, the U.S. Environmental Protection Agency is emphasizing the development of a comprehensive ground-water-protection program. In response, the State legislature assigned the primary responsibility to develop, coordinate, and plan ground-water-protection policies, programs, and strategies for the State to the Ground-water Steering Committee, composed of representatives from the Maryland Department of the Environment (lead agency), the Department of Natural Resources, and the Department of Agriculture.

The Department of the Environment, through a number of different divisions, is the primary regulatory agency responsible for ground-water-quality protection:

- Division of Planning reviews and approves county water and sewerage plans.
- Division of Residential Sanitation issues ground-water-discharge permits for land treatment systems that apply municipal wastewater; issues well construction permits for rural-domestic and public-water systems, and dairy farm wells; and assists local health departments with regulation of septic systems.
- Division of Water Supply implements provisions of the Federal Safe Drinking Water Act of 1974 and activities related to the quality of "finished" potable water (treated and delivered water) rather than quality of "raw" water within the aquifer, including monitoring community water systems and sampling treated water for bacteriological, radiological, physical, and chemical analysis.
- Hazardous and Solid Waste Management Administration, in addition to administering RCRA and CERCLA, issues permits for and monitors ground-water discharges; landfills; sewage sludge; and the treatment, transport, and disposal of hazardous and nonhazardous industrial wastes. The administration also regulates oil operations, vehicle operators, anbd terminal facilities, and responds to spill emergencies for both surface spills and leaking underground storage tanks; administers State regulations pertaining to the installation, testing, lining, and abandonment of underground storage tanks.
- Stormwater Management Administration directs the State Erosion and Sediment Control Program through enforcement and monitoring of sediment control plans and a statewide program to decrease stream-channel erosion, pollution, siltation, and sedimentation.

The Department of Natural Resources, through the Water Resources Administration, is responsible for the protection, management, and development of the State's water resources. These goals are accomplished primarily through the Water Management and Resource Protection Programs and Bureau of Mines:

- Water Management Program directs the development, management, and conservation of the State's water-supply resources by regulating water withdrawals through the issuance of appropriation permits and by analyzing areawide effects of collective water appropriation in view of future supply and demand needs.
- Resource Protection Program is responsible for assuring compliance with environmental safeguards in the operation and reclamation of non-fossil fuel surface mines.
- Bureau of Mines ensures adherence of environmental safeguards and proper reclamation of coal mines in western Maryland.

The Hazardous Waste Facilities Siting Board is an independent board created in 1980 to ensure that the State has a means of locating new hazardous-waste management facilities. The Board's program includes maintaining the statutory authority to locate needed facilities for hazardous and low-level radioactive waste; conducting studies as needed at proposed sites; establishing and maintaining a level of awareness by citizens, government, and commerce that will permit informed response to a proposed facility; and conducting periodic reviews of the State's hazardous-waste treatment and disposal needs. An important aspect of the State's experience since 1980 is that facilities have not been developed as expected.

In addition to State-level agencies concerned with ground-water quality, local health departments are responsible for overseeing the proper siting and installation of private wells and septic systems, verifying quantity and quality of well water for new dwellings or before reconveyance of already developed property, reviewing subdivision plans with respect to their effect on ground water, sampling monitoring wells at landfills, sampling private rural-domestic wells on request for bacterial and chemical quality, and requiring septic system repairs or maintenance when failures become evident.

The State has a continuing commitment to improve programs that address ground-water quality with greater emphasis on inspection, compliance, and enforcement and with better quality control to ensure their effectiveness. However, more information is needed on other sources of ground-water contamination including agricultural and residential uses of fertilizers, herbicides, and pesticides and uses of unregulated toxic chemicals including domestic cleaners and other household chemical products (Maryland Office of Environmental Programs, 1984a). Evaluation of the effects of these sources may indicate a need for additional regulations to minimize contamination problems.

The District of Columbia relies mainly on surface water and has no specific legislation directed at ground-water management. However, the Environmental Control Division of the Department of Consumer and Regulatory Affairs is responsible for ground-water-quality protection through two branches. The Water Hygiene Branch manages the ground- and surface-water needs of the District, and the Hazardous Wastes and Pesticides Branch is responsible for regulations that pertain to pesticides; leaking underground storage tanks; and the treatment, storage, and disposal of hazardous wastes, as well as administering RCRA and CERCLA.

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*Prepared by* Judith C. Wheeler and Lillian B. Maclin

FOR ADDITIONAL INFORMATION: District Chief, U.S. Geological Survey, 208 Carroll Building, 8600 LaSalle Road, Towson, MD 21204

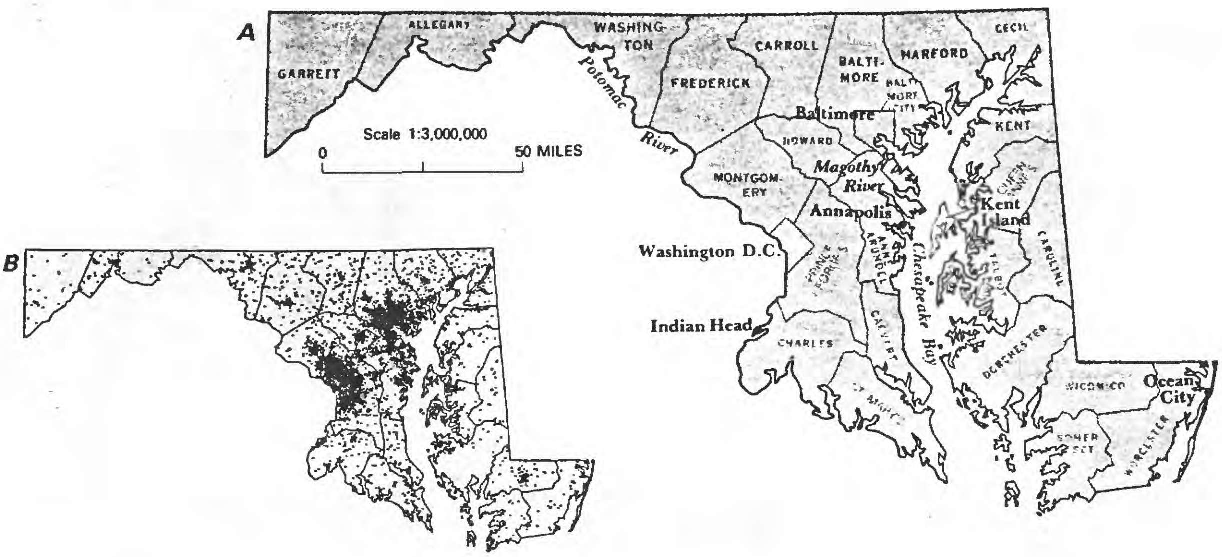


**Figure 1. Selected geographic features and 1985 population distribution in Maryland.** *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files,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

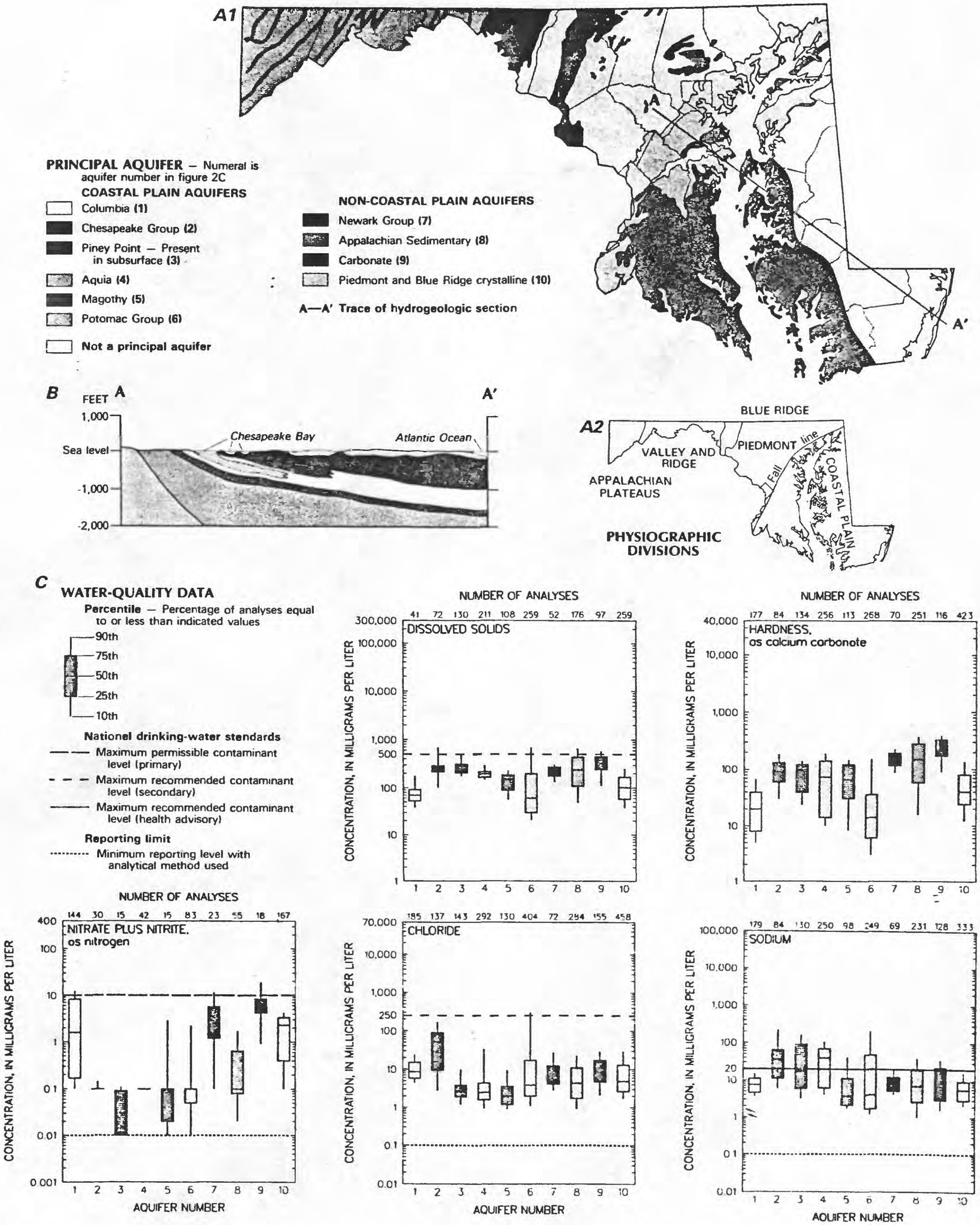


**Figure 2.** Principal aquifers and related water-quality data in Maryland. *A1*, Principal aquifers; *A2*, Physiographic provinces. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1938-86. (Sources: *A1*, Otton and Richardson, 1958; Maryland Geological Survey, 1967; Cleaves and others, 1968; Hansen, 1972. *A2*, Fenneman, 1946. *B*, U.S. Geological Survey, 1985. *C*, Analyses compiled by L.B. Maclin from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)

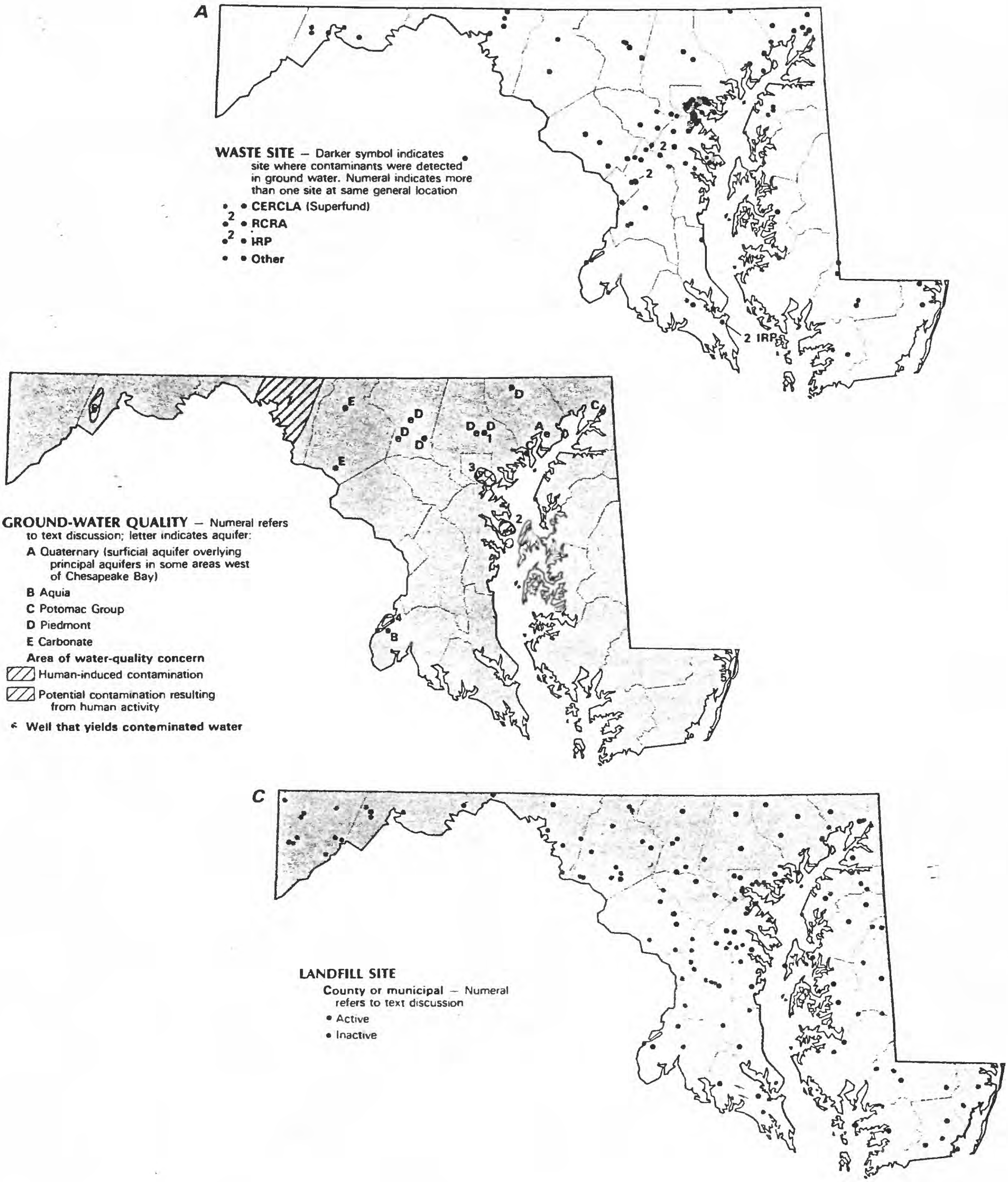


**Figure 3.** Selected waste sites and ground-water-quality information in Maryland. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; Department of Defense Installation Restoration Program (IRP) sites; and other selected waste sites, as of July 1986. *B*, Areas of human-induced and potential contamination, and distribution of wells that yield contaminated water, as of July 1986. *C*, County and municipal landfills, as of July 1986. (Sources: *A*, Maryland Office of Environmental Programs, 1984a,b; 1985; 1986a,b; U.S. Department of Defense, 1986. *B*, Maryland Department of Natural Resources and Maryland Department of Health and Mental Hygiene, 1983a; Maryland Water Resources Administration, 1984; Maryland Department of Natural Resources files. *C*, Maryland Office of Environmental Programs, 1984a; Maryland Office of Environmental Programs files.)

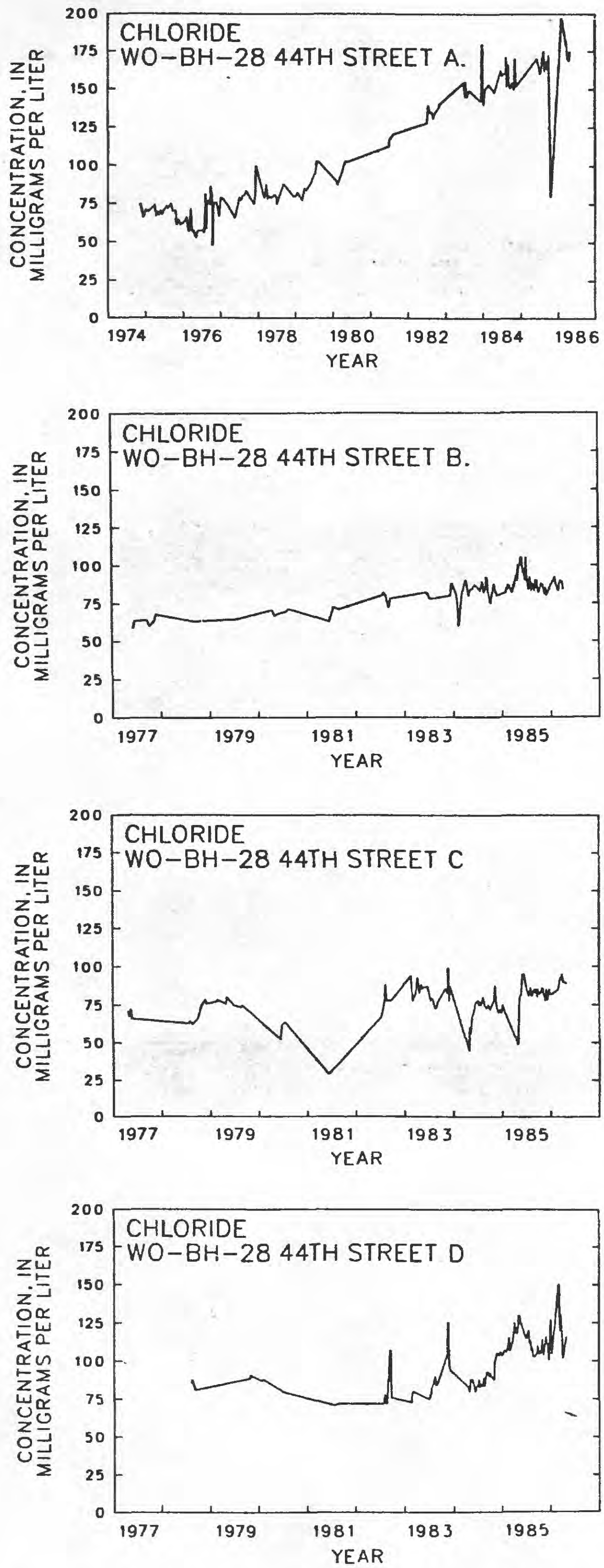


**Figure 4.** Chloride concentrations in samples from four wells, 44th Street, Ocean City, Md., November 1974 through February 1986. (Source: Worcester County Sanitary Commission files, July 1986.)