PENNSYLVANIA

GROUND-WATER QUALITY

By J.L. Barker

U.S. Geological Survey Open-File Report 87-0748

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

For sale by:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center
Box 25425
Denver, Colorado 80225

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.

Contents

Illustrations

PENNSYLVANIA
Ground-Water Quality

Since Colonial times, ground water in Pennsylvania has become increasingly important for domestic, commercial, and industrial use. The largest withdrawals have always been concentrated in the industrial areas of Pittsburgh and Philadelphia (fig. 1). Whereas ground-water withdrawals today comprise only about six percent of the total water use in Pennsylvania, more than one-third of the population depends on nearly one billion gallons of high quality uncontaminated ground water for its daily needs (Solley and others, 1983). Twenty one of the 67 counties obtain more than one-half their total supply from ground water, and two rural counties obtain as much as 98 percent (Becher, 1970). Although there has been only minimal population growth during the past two decades, the sustained migration of people and industry from the cities to a more rural setting has been responsible for the development of ground-water resources at a rate three times that of surface water (fig. 1).

Ground water in the principal aquifers is generally acceptable for drinking with little or no treatment. Excess iron, sulfate, and dissolved-solids concentrations near mining and oil and gas production activities in western Pennsylvania contribute to quality problems. Hardness and nitrate problems are generally limited to the carbonate aquifers in the central and southeastern part of the State.

Ground-water contamination is a serious problem in some urban and agricultural areas. Important coastal-plain aquifers in the extreme southeastern part of Pennsylvania have been severely contaminated by industrial waste including such persistent organic compounds as trichloroethylene (TCE) and tetrachloroethylene [Perchloroethylene (PCE)]. Leaking underground gasoline storage tanks have contributed to local ground-water problems statewide. Major water-quality concerns are related to contamination from malfunctioning septic systems, landfills, illegal dumping of waste, overfertilization with nutrients, organic chemicals, and road salts.

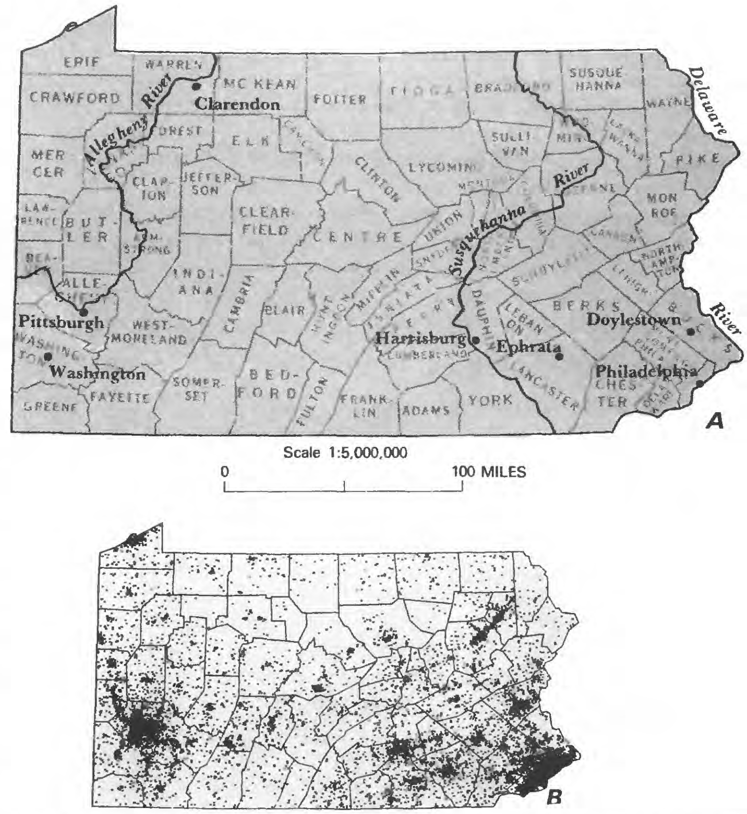

Figure 1. Selected geographic features and 1985 population distribution in Pennsylvania. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files,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

Approximately 70 land-disposal facilities require monitoring under the Federal Resource Conservation and Recovery Act (RCRA) of 1976, and 47 sites have been included in the National Priorities List (NPL) of hazardous-waste sites by the U.S. Environmental Protection Agency (1986c). The 47 Superfund sites require additional evaluation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Contamination has been detected at 26 of the CERCLA sites.

WATER QUALITY IN PRINCIPAL AQUIFERS

Natural ground-water quality in Pennsylvania is extremely diverse due to the large number of rock formations and their lithologic and chemical differences. Because of Pennsylvania's complex geologic history, ground-water basins are limited in areal extent and bedrock aquifers are regionally less significant. Four principal types of aquifers exist in Pennsylvania (fig. 2): (1) Unconsolidated sand-and-gravel aquifers; (2) sandstone and shale aquifers; (3) carbonate aquifers; and (4) crystalline aquifers. Physical descriptions of the aquifer groups along with water-well characteristics are discussed in the U.S. Geological Survey (1985) and in Barker (1984).

The constituents of water that generally determine its suitability for most purposes are dissolved solids, calcium carbonate, and iron. Concentrations of chloride and nitrate may also restrict the use of water. A water supply with a dissolved-solids content of less than 500 mg/L (milligrams per liter), a hardness (as calcium carbonate) of less than 150 mg/L, and an iron content of less than 300 μg/L (micrograms per liter) is satisfactory for domestic purposes. For industrial purposes, acceptable concentrations depend on the intended use.

A recent statewide analysis of ground-water-quality data (Barker, 1984) indicates that about 93 percent of the nearly 4,700 water samples examined contained less than 500 mg/L of dissolved solids. In general, natural ground-water quality in Pennsylvania is within the U.S. Environmental Protection Agency (EPA) national primary and secondary drinking-water standards. Except in isolated cases, such as excess iron and sulfate in some sedimentary rocks, the major aquifers do not contain significant amounts of poor-quality ground water. Areas of naturally impaired ground water are not well defined nor cause apparent serious problems.

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, nitrate (as nitrogen), chloride, and iron analyses of water samples collected from 1925 to 1985 from the principal aquifers in Pennsylvania. The summary is limited to selected representative geologic units where the data base for chemical quality is adequate for statistical summaries. Water-quality analyses with obvious natural or man-made contamination were not included. 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 legally enforceable. The secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids, 250 mg/L chloride, and 300 μg/L iron.

Unconsolidated Sand-and-Gravel Aquifers

The unconsolidated sand-and-gravel aquifers consist of the coastal-plain sediments and glacial fluvial and alluvial deposits. The coastal-plain sediments are along the Delaware River estuary from north of Philadelphia to the Delaware state line. The sediments consist of a wedge of sand, silt, clay, and gravel deposited in a marine and non-marine environment that thickens from a few feet at the Fall Line to more than 6,000 ft at the shore of the Atlantic Ocean. The glacial outwash and alluvial deposits occupy most major stream valleys affected by glaciers that covered the northern part of the State. These deposits range from a few feet to more than 200 ft thick.

The unconsolidated sand-and-gravel aquifers contain the Commonwealth's most important and productive water-bearing formations. Yields of 1,000 gal/min (gallons per minute) or more are common and occasionally 2,000 gal/min or more are obtained from a single well. The ground water in most areas is of good to excellent quality. However, ground-water contamination is a serious problem near Philadelphia where overdevelopment has resulted in saltwater intrusion and down-dip migration of contaminants. Contamination by trace metals and synthetic organic compounds from industrial waste and landfill leachate is also a threat to water supplies.

Water from the aquifers in the unconsolidated sand-and-gravel are chemically highly diverse but dominated by ions of calcium and bicarbonate. The dissolved-solids concentrations range from 20 to more than 4,000 mg/L. About 20 percent of the well water tested exceed the national secondary drinking-water standard of 500 mg/L.

Hardness, mainly as calcium and magnesium, ranges from about 60 to 1,900 mg/L. The median value of 128 mg/L indicates that almost half of the water tested exceeds the suggested State criteria of 150 mg/L for domestic use.

Nitrate (as nitrogen) is an end product of the bacterial oxidation of organic material. Problems with nitrate pollution are present in many local areas due to the ease with which wastes from leaky sewers, septic tank drain-field systems, and barnyards infiltrate the unconsolidated aquifers. Concentrations are as large as 39 mg/L. The median value for the aquifer group is 0.8 mg/L, and less than 10 percent of the water supplies exceed the national primary drinking-water standards of 10 mg/L as nitrogen.

Chloride is present in all natural waters but is rarely the dominant ion. The median value of 16 mg/L (fig. 2*C*) for the unconsolidated sand-and-gravel aquifers is considerably above the State median of 10 mg/L due to the large number of wells in the coastal-plain sediments that are affected by saltwater intrusion caused by over-development. The national secondary drinking-water standard of 250 mg/L is exceeded in only four percent of the more than 300 samples tested. Salt used for deicing highways and industrial waste may be a factor in chloride concentrations.

Iron is an abundant and widespread constituent of water in the coastal-plain aquifers. Concentrations of iron range upward to more than 400,000 μg/L. The median value is 765 μg/L (fig. 2*C*), exceeding the EPA national secondary drinking-water standard of 300 μg/L.

Sandstone and Shale Aquifers

The sandstone and shale aquifers are an extremely diverse group of interbedded sandstones, siltstones, and shales that dominate the lithology of much of Pennsylvania's bedrock. Their combined thickness can be from 16,000 to 20,000 ft. Most water-bearing units are confined. The water is contained in fractures that may permit vertical flow, and yields are commonly from 5 to 60 gal/min; yields of 500 gal/min are possible. The State's complex geology has resulted in ground-water supplies that commonly obtain water from more than one water-bearing zone and, therefore, have a chemical character that is the product of diverse lithology. Where sandstones predominate, the water is soft; where shales predominate, the water is usually hard.

Ground water in the sandstones and shales in southeastern, central, and northern Pennsylvania predominantly contains calcium and bicarbonate ions where the dissolved-solids concentration is less than 300 mg/L and contains calcium and sulfate ions where the dissolved-solids concentration is greater than 300 mg/L (Durfor and Anderson, 1963).

Less than 10 percent of the water samples tested exceeded the national drinking-water standard of 500 mg/L for dissolved solids, whereas nearly half the samples tested contained water that exceeded 150 mg/L hardness (fig. 2*C*). Nitrate (as nitrogen) contamination is rarely a problem and chloride is only a problem in a few deep wells that intercept saline water. Iron is a common problem in some units, particularly those associated with Pennsylvanian Age coal-bearing formations.

Carbonate Aquifers

The carbonate aquifers containing limestone and dolomite, chiefly of Cambrian and Ordovician Age, are in the valleys in the central and southeastern parts of the State. Carbonate aquifers are among the most important water-bearing formations in Pennsylvania. Solution channels, fractures, and partings between rock layers yield moderate to large supplies of water to wells. These characteristics also make the shallow carbonate aquifers susceptible to contamination from agricultural chemicals, landfills, and spills.

Water quality in the carbonate aquifers is also highly diverse. The major ions are calcium and bicarbonate, which account for the group's median hardness of 260 mg/L and dissolved-solids concentration of 325 mg/L. About 10 percent of the samples tested exceeded the secondary drinking-water standard of 500 mg/L for dissolved solids.

Nitrate contamination, primarily from agricultural waste, exceeds the national primary drinking-water standard of 10 mg/L as nitrogen in almost 25 percent of the samples tested. Most of this water is within the drinking water criteria for chloride and iron.

Crystalline Bedrock Aquifers

Crystalline bedrock aquifers, consisting of Precambrian, Cambrian, and Silurian Age igneous and metamorphic rocks, occupy a large part of southeastern Pennsylvania (fig. 2). Because of their crystalline nature, these rocks store only small to moderate amounts of water, and commonly yield about 5 to 25 gal/min—sufficient for domestic needs. Water-bearing zones that yield significant quantities of water are found only near the surface in fractures and crevices of weathered rock. The median well depth is only about 100 feet.

The quality of water from the crystalline bedrock aquifers is suitable for most uses, and is among the freshest in the state;

the median dissolved-solids concentration is less than 200 mg/L. The water is soft, with a median hardness of less than 80 mg/L (fig. 2*C*). The predominant ions are calcium, sulfate, and bicarbonate, and the water is generally slightly acidic. Nitrate (as nitrogen) exceeds the 10 mg/L national primary drinking-water standard in about 12 percent of the samples tested. Chloride is not a common contaminant but iron and manganese exceed the recommended standard in about 35 percent of the samples tested. Iron and manganese generally increase with depth. Contamination with metals and volatile organics from storage tank leakage, industrial waste discharge, and landfill leachate is a local problem.

EFFECTS OF LAND USE ON WATER QUALITY

As the fourth most populated state and the second-ranking industrial state, Pennsylvania's cultural activities are severely affecting the ground-water resources in many areas. Ground-water quality is particularly susceptible to the effects of urbanization, effluent from mining, gas and oil wells, agriculture, and industrial wastes. In 1985, for example, the Pennsylvania Department of Environmental Resources (PADER) investigated more than 400 ground-water pollution incidents. The most commonly investigated incidents were related to underground storage tanks, oil and gas brine pits, road salting, septic tank, and agricultural activities in that order (Commonwealth of Pennsylvania, 1986). Sewage-treatment facilities that apply sludge directly to the land, waste-disposal sites, liquid-storage lagoons, and landfills that use natural or artificial depressions over highly permeable formations are high risks.

Waste Disposal

Human activities are a primary cause of ground-water-quality problems in all aquifer groups. A recent study by R.E. Wright Associates, Inc. (1982), concluded that 84 percent of documented ground-water contamination cases in the Middle Delaware River Basin were related to contamination by hydrocarbons or organic chemicals. They also found that the volatile organic chemicals (VOC's), TCE and PCE accounted for nearly one-third of the reported cases. The losses to public water supplies in the region due to TCE and PCE contamination range between 3.0 and 3.5 million gallons per day.

The PADER has identified approximately 70 hazardous-waste land-disposal facilities or RCRA sites in the Commonwealth. Forty-seven hazardous waste CERCLA sites have met the requirements of the EPA (U.S. Environmental Protection Agency, 1986c) for remedial action under Superfund because it has been determined that a "hazardous substance" was released into the environment or that there is a substantial threat of such release. Many of the sites (fig. 3*A*) are in the densely populated areas of southeastern Pennsylvania and are a potential health threat.

As of September 1985, 80 hazardous-waste sites at facilities in Pennsylvania 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 80 sites in the program, 9 sites contained contaminants but did not present a hazard to the environment. Fifteen sites at three facilities (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. Remedial action at four of these sites has been completed under the program. The remaining sites were scheduled for contamination studies to determine if remedial action is required.

Mining

Deep and surface mining of coal in northeastern and western Pennsylvania, and oil and gas drilling activities in the northwestern part of the Commonwealth have caused some ground-water supplies to have increased acidity and elevated concentrations of sulfate, hardness, dissolved solids, and methane gas (fig. 3*B*, area 1). Some aquifers in the northeastern anthracite fields (fig. 3*B*, area 2) can no longer be used as potable water supplies as the result of contaminated mine water.

State and U.S. Geological Survey studies have documented such impacts throughout much of the coal, oil, and gas region. Authorities and citizens in Washington County are concerned about the effects large-scale mining of coal will have on water resources including the reduction of ground-water storage in shallow aquifers and municipal reservoirs which serve about 69 percent of the county residents. A recently completed U.S. Geological Survey study (D.R. Williams, U.S. Geological Survey, written commun., 1986) indicates that underground mining resulted in lowered water levels in wells, and increased concentrations of iron, manganese, sulfate, and dissolved solids. Well owners reported an objectionable sulfur odor and an iron taste in their water during and after mining.

In Warren County, near Clarendon, and in Erie County, several private wells were investigated for the presence of natural gas following complaints by residents. An investigation by PADER showed concentrations of methane, as much as 70 parts per million, to be a safety hazard. The methane gas was traced to local gas wells that had a build-up of pressure causing migration into the private water wells (Robert H. Gleason, Pennsylvania Department of Environmental Resources, written common., 1986).

Agricultural Practices

Contamination of ground water from excessive application of manure and agricultural chemicals has led to the deterioration of ground-water quality in many intensively farmed areas, particularly those underlain by carbonate bedrock (fig. 3*B*, area 3). A study by Fishel and Lietman (1986) has shown that in an area near Ephrata, Lancaster County, nitrate (as nitrogen) concentrations reached 40 mg/L and the median concentration was about 10 mg/L. Following spring fertilizer applications, the ground water from one 55-acre field contained nitrate (as nitrogen) concentrations that ranged from 7.4 to 130 mg/L. This is about three times that which is required by corn crop.

Median concentrations of nitrate were generally three times higher in water from carbonate aquifers than noncarbonate aquifers. Forty percent of the ground-water supplies that were both in a carbonate aquifer and an agricultural area had nitrate (as nitrogen) concentrations that exceeded the 10-mg/L criterion established by the EPA as excessive for drinking water. Atrazene, simizine, alachlor, and metolachlor are commonly used herbicides that were found almost exclusively in the ground water of the agricultural carbonate areas. Concentrations in ground water often reached 3 to 4 μg/L following application.

Urbanization

Human activity has a cumulative effect on ground-water resources during the progressive stages of urbanization. The effects may include diversion of recharge, aquifer overdevelopment, and contamination from industry, sewage-treatment plants, and municipal landfill sites. The largest number of municipal landfill sites are in counties adjacent to areas of high population densities (fig. 3*C*).

Overdevelopment of the aquifers in the urbanized and industrial areas of the coastal plain has resulted in large cones of depression that have created a number of water-quantity and quality problems as a result of induced infiltration of contaminants and saltwater intrusion (fig. 3*B*, area 4). Identified problems include increased concentrations of iron, manganese, sulfate, chloride, and nitrate. The effects of induced infiltration and aquifer contamination are illustrated with the fifteen-year documentation of changing water quality in a well in the Coastal Plain (fig. 4). Possibly as much as 43 percent of the total flow to the Potomac-Raritan-Magothy aquifer, in 1973, was induced from the Delaware River (Delaware River Basin Commission, 1982). VOC's have been detected in 39 percent of the samples from wells in the industrial and commercial areas of the coastal plain, and in 28 percent of the ground-water supplies from the Potomac-Raritan-Magothy aquifer (Delaware River Basin Commission, 1982).

A 65-mi^2 area in southeastern Pennsylvania just south of Doylestown (fig. 1) that sustained rapid suburban development and industrial growth following World War II, increased in population by more than 1,700 percent between 1940 and 1970. Ground-water pumpage in 1980 of 2.7 billion gallons has resulted in significant aquifer drawdown as far as 2,500 feet away, thereby reducing the quantity of streamflow. Reduced streamflow has resulted in degradation of surface-water quality due to higher concentrations of sewage-plant effluent. Seven wells, sampled in the mid-1950's and again in 1979, had an average of 22 percent increase in the median concentration of most dissolved constituents. Contamination by VOCs has made water from some wells unsuitable for public supply. Reported concentrations of two of the most common VOCs, Trichloroethylene (TCE) and Tetrachloroethylene (PCE), were as high as 87,000 µg/L, and 26,000 µg/L, respectively (Sloto and Davis, 1983).

POTENTIAL FOR WATER-QUALITY CHANGES

Future demands upon available ground-water resources may require planned development as the needs reach the maximum sustained yield of a region or aquifer. Development of the ground-water resources will likely follow patterns similar to those of the past. Industry and suburban expansion near to existing population centers will continue to require ground water to supply its growth needs. The agricultural industry and the domestic needs of a growing number of rural dwellers will also need to be satisfied. According to the 1980 census, the Commonwealth's population has nearly stabilized at just under 12 million with a growth of only 0.5 percent since 1970. It is significant that between 1950 and 1970, the urban population decreased by 2.6 percent while the rural population increased by 8.4 percent. This trend toward to a more rural environment has been at least partly responsible for a 35-percent increase in ground-water use between 1960 and 1966, a rate three times that of surface water (Becher, 1970).

Known sources of ground-water contamination in Pennsylvania are many and varied. A recent (1986) tally by PaDER shows there are approximately 4,000 surface mines, 300 deep mines, 420 coal-refuse disposal sites, 1,000 community on-lot disposal systems greater than 10,000 gal/d, 7,250 industrial and mining waste impoundments, 159 hazardous-waste-management facilities, 1,700 municipal and residual waste-management facilities, 60 open dumps, 11 hazardous-injection wells and industrial disposal wells, and 85 spray irrigation sites. In addition, there have been at least 560 hydrocarbon spills since 1968.

Whereas Pennsylvania has relatively large ground-water supplies in the developed and undeveloped areas of both the unconsolidated sand-and-gravel aquifers and the carbonate aquifers, these aquifer groups also are the most susceptible to contamination. Projected industrial expansion, population trends, and agricultural trends are expected to stimulate ground-water development in these areas. Primary future concerns will be related to ground-water depletion due to overdevelopment, contamination from malfunctioning on-lot septic systems, landfills, illegal dumping of toxic substances, the excessive use of nutrients, organic chemicals, and road salts (U.S. Department of Commerce, 1984).

GROUND-WATER QUALITY MANAGEMENT

The PaDER is the State agency primarily responsible for the protection and management of Pennsylvania's ground-water resources. Several bureaus within the PaDER Offices of Environmental Protection and Resources Management implement ground-water programs within the Commonwealth. The majority of these ground-water management programs rely upon the development and implementation of regulations, siting criteria, and permits to prevent and abate pollution from all major sources. As examples, PaDER is developing siting criteria and regulations governing the development and operation of solid-waste and hazardous-waste facilities. State mining regulations require evaluation of mine impacts on the hydrologic balance and water quality of affected aquifers and watersheds before permitting, and mandate reclamation of disturbed lands concurrent with mining. Proposed oil and gas regulations adopted in 1985 address significant potential pollution problems through standards for casing, brine disposal, and closure of abandoned wells.

In addition to State regulatory control, certain activities are also governed by federal agencies and basin commissions. A dual program exists with the Federal Government in regard to the Underground Injection Control (UIC) Program. Both the Susquehanna and Delaware River Basin Commissions have adopted programs regulating significant withdrawals of ground water throughout their respective basins. In addition, an intensive program instituted by the Delaware River Basin Commission (DRBC) in the five county Southeastern Pennsylvania Ground Water Protected Area (near Philadelphia) is aimed at protecting stressed ground-water resources within the predominantly Triassic aquifers. This DRBC program requires permits for withdrawals of ground water that exceed 10,000 gal/d within the Protected Area, and imposes strict pump-test, environmental-review and conservation criteria.

IMPLEMENTATION OF FEDERAL WATER-QUALITY LEGISLATION

Current program areas under federal legislation include primacy under the Safe Drinking Water Act, RCRA, CERCLA, Clean Water Act, Toxic Substance Control Act, and the Surface Mining Control and Reclamation Act.

The Bureau of Community Environmental Control has the prime responsibility for the implementation of the Pennsylvania Safe Drinking Water Act and the development of State maximum contaminant levels (MCLs) for drinking-water supplies, on a case by case basis, where MCLs have not been established by the EPA. In addition to drinking-water supplies, the Safe Drinking Water Act has various other programs associated with it—the UIC Program, Well Head Protection Program, and the Sole Source Aquifer Designation Program.

The Bureau of Waste Management is responsible for the program areas of RCRA and CERCLA. The RCRA regulations govern the control, usage, and disposal of hazardous wastes requiring cradle to grave manifests for regulatory purposes. The CERCLA or Superfund investigation and clean-up activities are also carried out in the State at many sites. To date, two sites have been cleaned up to levels acceptable to EPA.

Several activities were carried out recently under Section 208 of the Clean Water Act. One of the projects was titled "The Evaluation of Soil Dependent Treatment Systems." This project examined sites with marginal soil cover to determine the sites' renovative capabilities for treating sewage effluent. Other section 208 activities included the development of a proposed ground-water management protection strategy and a proposed ground-water monitoring strategy. These strategies are currently being revised internally within PaDER.

STATE POLICIES AND STRATEGIES

As stated, the development of a ground-water-management program was initiated under Section 208. It is being continued under

Section 106 grants. The proposed ground-water-management program consists of two strategies: 1) a proposed ground-water-quality protection strategy; and 2) a proposed ground-water-quality monitoring strategy. The ground-water quality-protection strategy is designed to protect ground water for two designated statewide uses: 1) potable-water supply; and 2) surface-water-quality maintenance. In addition, the protection strategy also proposed the delineation of special protection in areas where no ground-water degradation would be permitted by waste sources regulated by the Department. The protection strategy also provides for delineation of mixing and buffer zones for all major land treatment/disposal systems.

The proposed ground-water-quality monitoring strategy will provide for a greater utilization of the ground-water data currently collected by the compliance monitoring activities of the bureaus in the Department. To supplement this effort, a fixed-station monitoring network has been proposed for high-priority ground-water basins. In addition, special in-house surveys would be used in areas where ground-water data gathering efforts are limited or more detailed data are needed because of a suspected pollution problem.

ADEQUACY OF GROUND-WATER INFORMATION

An assessment of existing data indicates that data are available, but they are not readily accessible. Collection is accomplished as part of the compliance and monitoring activities routinely carried out by the various bureaus and through specific activities such as the pilot project monitoring ground-water quality in ground-water basins. Most of the data are stored in paper form or on various computer systems with limited compatibility and accessibility. Adequate information exists on maps and geological documentation to provide support for any type of ground-water protection program. The proposed monitoring strategy recommends that most ground-water monitoring data be placed in a computer data base which is accessible by both State and federal agencies.

SELECTED REFERENCES

Barker, J. L., 1984, Compilation of ground-water quality data in Pennsylvania: U.S. Geological Survey Open-File Report 84-706, 102 p.

Becher, A.E., 1970, Ground water in Pennsylvania: Pennsylvania Geological Survey Educational Service Report No. 3, 42 p.

Commonwealth of Pennsylvania, 1986, 1986 Water Quality Assessment: Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, 206 p.

Delaware River Basin Commission, 1982, Special ground water study: Basin-wide Report and Executive Summary, 148 p.

Durfor, C.N., and Anderson, P.W., 1963, Chemical quality of surface water in Pennsylvania: U.S. Geological Survey Water-Supply Paper 1619-W, 50 p.

Fishel, D.K., and Lietman, P.L., 1986, Occurrence of nitrate and herbicides in ground water in the upper Conestoga River Basin, Pennsylvania: U.S. Geological Survey Water Resources Investigations Report 85-4202, [in press].

Greenman, D.W., Rima, D.R., Lockwood, W.N., and Meisler, Harold, 1961, Ground-water resources of the coastal plain area of Southeastern Pennsylvania: Pennsylvania Geological Survey Bulletin W13, 375 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3rd ed.): U.S. Geological Survey Water Supply Paper 2254, 264 p.

Lohman, S.L., 1941, Ground-water resources of Pennsylvania: Pennsylvania Topographic and Geologic Survey Bulletin W7, 32 p.

Sloto, R.A. and Davis, D.K., 1983, Effects of urbanization on the water resources of Warminster Township, Bucks County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations 82-4020, 72 p.

Solley, W.B. , Chase, E.B., and Mann, W.B. IV, 1983, Estimated use of water in the United States in 1980: U. S. Geological Survey Circular 1001, 56 p.

U.S. Bureau of the Census, 1982, Census of the population, characteristics of the population, number of inhabitants—1980: Published separately by states, Puerto Rico and outlying areas: PC 80-1-A1 to A57a, and A57b.

U.S. Department of Commerce, Bureau of Census, 1984: 1982 Census of Agriculture, v. 1, part 38, Pennsylvania State and County Data, 364 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, 1985, National Water Quality Inventory, 1984 Report to Congress: EPA 440/4-85-029, 77 p.

_____ 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 as of 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 as of 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.

Wright, R.E. and Associates, Inc., 1982, Special Ground Water Study of the Middle Delaware River Basin, Study Area II:Vol. 1: Middletown, Pa., R.E. Wright Associates, 85 p.

Prepared by James L. Barker, U.S. Geological Survey; "Ground-Water-Quality Management" section by Nicholas Molina, Pennsylvania Department of Environmental Resources.

FOR ADDITIONAL INFORMATION: District Chief, U.S. Geological Survey, P. O. Box 1107, Harrisburg, Pennsylvania 17108-1107

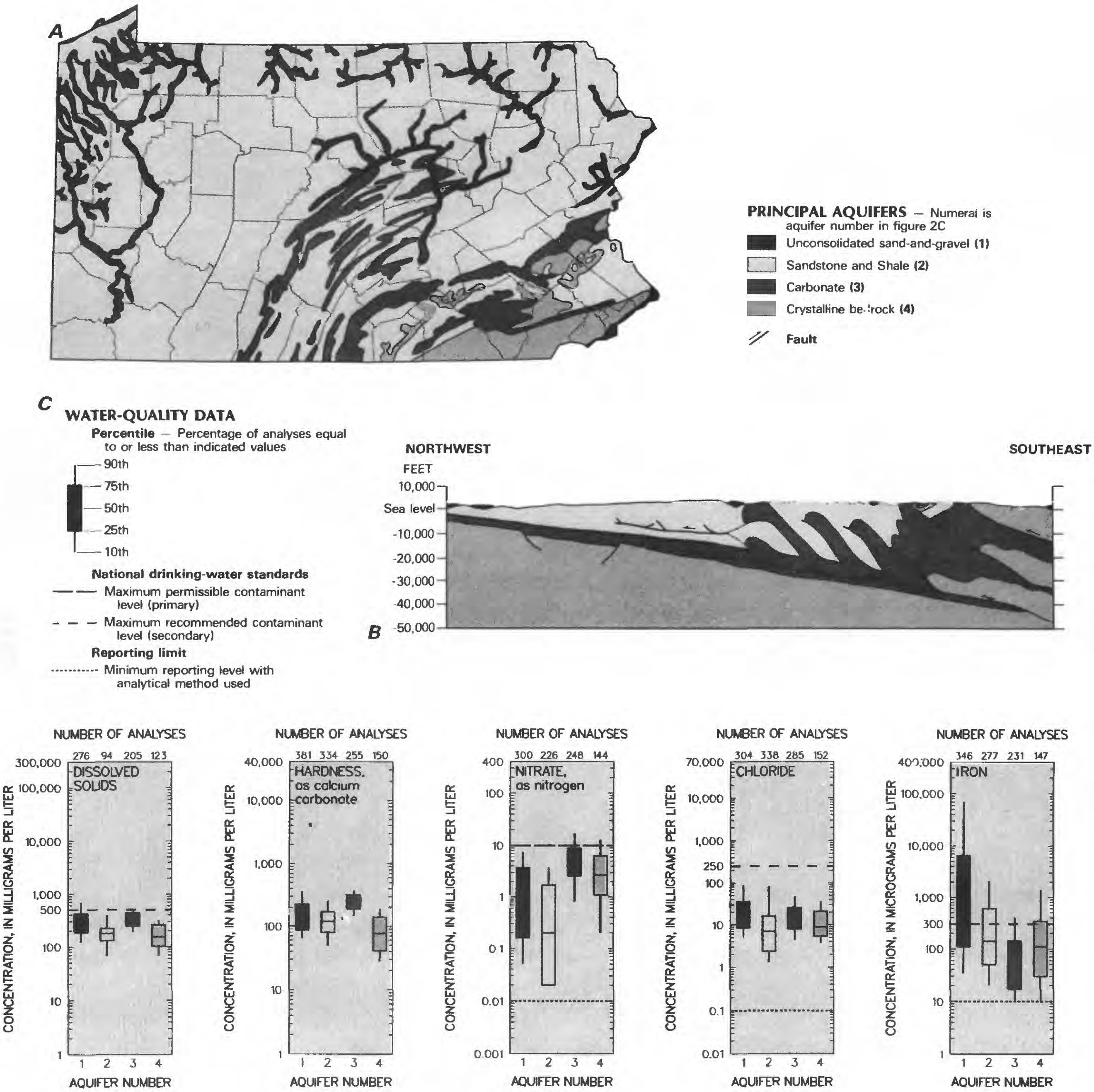

Figure 2. Principal aquifers and related water-quality data in Pennsylvania. *A*, Principal aquifers. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, 1925 to 1985. (Sources: *A*, *B*, Pennsylvania Topographic and Geologic Survey. *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)

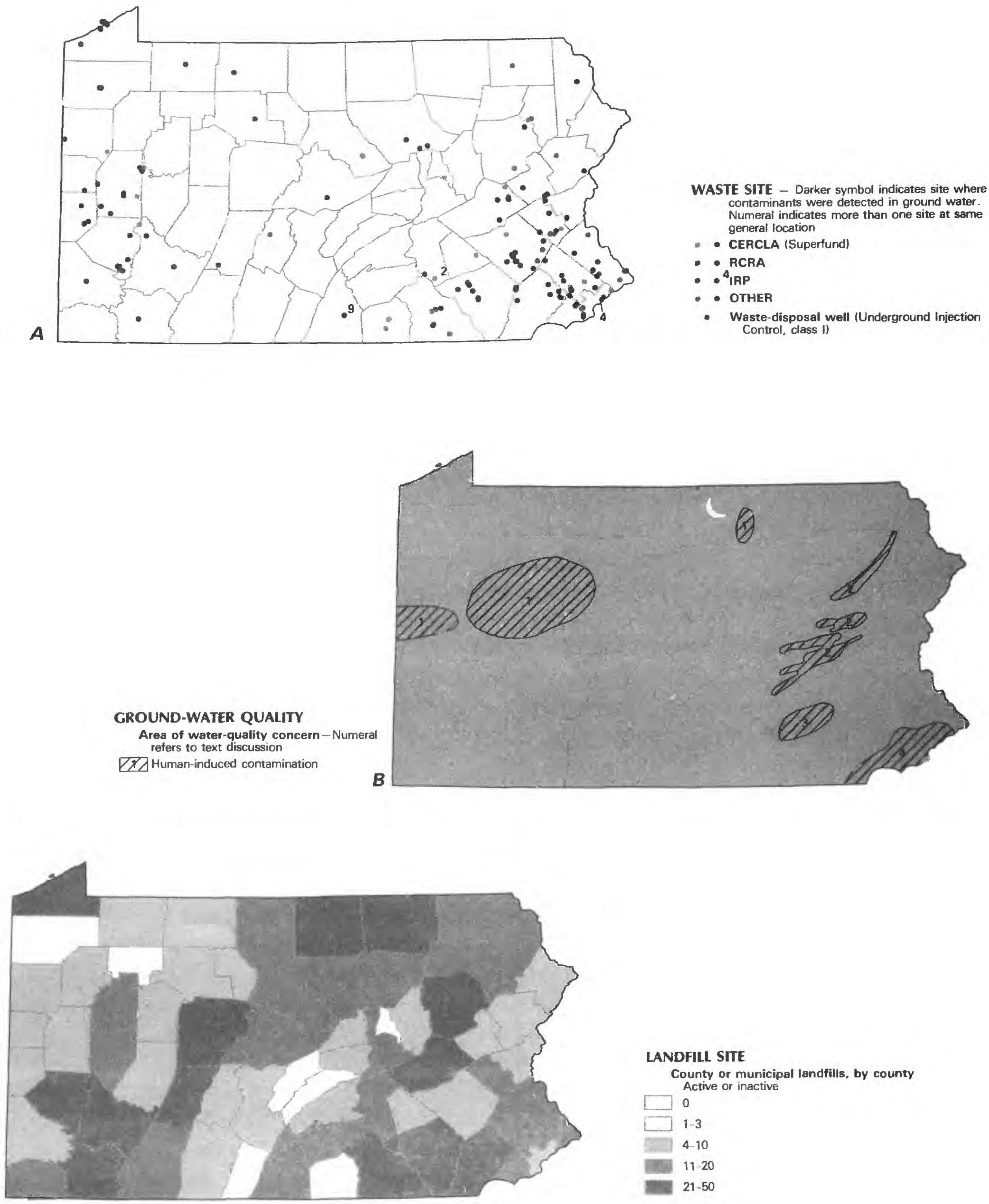

Figure 3. Selected waste sites and ground-water-quality information in Pennsylvania. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; Resource Conservation and Recovery Act (RCRA) sites, as of 1986; Department of Defense Installation Restoration Program (IRP) sites, as of 1985; and other selected waste sites, as of 1986. *B*, Areas of human-induced contamination, as of 1986. *C*, Municipal landfills, as of 1986. (Sources: *A*, Commonwealth of Pennsylvania 1986; U.S. Department of Defense 1986; U.S. Environmental Protection Agency, 1986c. *B*, Delaware River Basin Commission, 1982; Durfor and Anderson, 1963; Fishel and Lietman, 1986. *C*, Commonwealth of Pennsylvania 1986.)

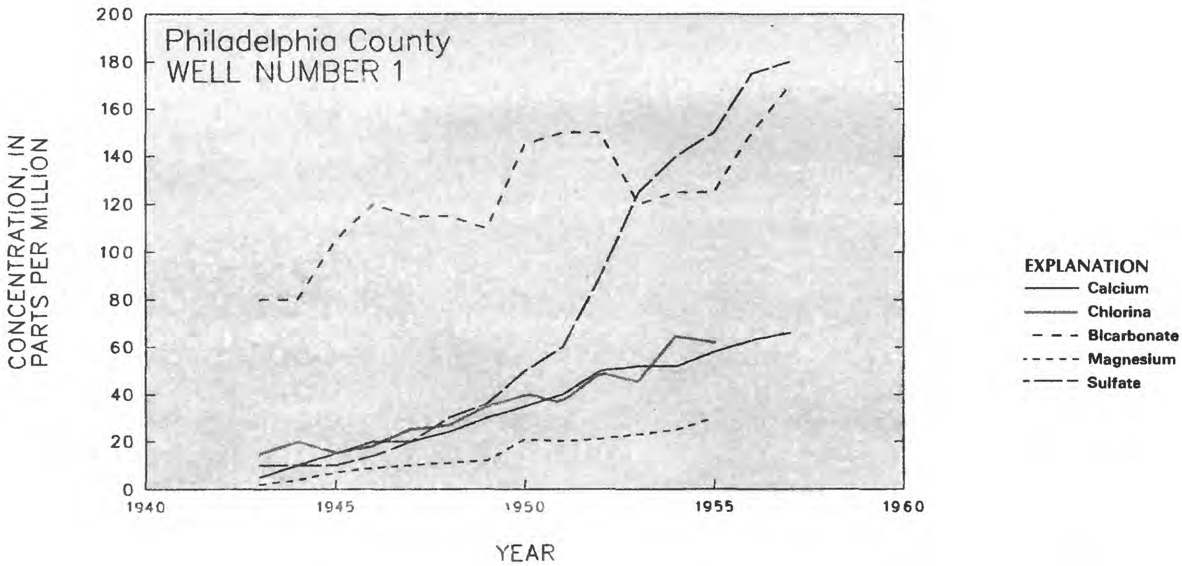

Figure 4. **Changes in selected chemical constituent concentrations in well PH-1 from 1943 to 1957.** (Sources: Greenman and others, 1961.)