NEW JERSEY 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 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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New Jersey (fig. 1*A*) historically has had and continues to have a sufficient supply of ground water for much of the State that is suitable for most uses. In fact, about 50 percent of the 7.56 million people in New Jersey (fig. 1*B*) obtain their drinking water from ground-water supplies—about 39 percent from public-supply wells and 11 percent from domestic-supply wells.

Of the 622 public water-supply systems in the State, which include more than 1,900 wells, 90 percent obtain all or part of their supplies from ground-water sources (fig. 2). An additional 16,000 self-supply irrigation, industrial and commercial wells and about 400,000 rural domestic-supply wells are used in the State (Robinson, 1986). In 1985, about 442 Mgal/d (million gallons per day) of ground water was pumped for public-supply use, 157 Mgal/d for self-supplied industrial/commercial use, 97 Mgal/d for irrigation use, and 64 Mgal/d for rural domestic-supply use (Charles Qualls, U.S. Geological Survey, written commun., 1986).

The scientific literature before 1970 indicated that New Jersey's ground water was regionally suitable for most uses, although locally saltwater intrusion, toxic metal or other inorganic contamination, objectionable odor and taste, and excessive iron content were problems. These studies had focused only on inorganic quality because an awareness of organic ground-water contamination was not realized until the advent of improved organic analytical capability in the 1970's. By 1977, reports on incidents of organic contamination resulting from chemical-waste storage, production, disposal, or spills were reaching the New Jersey Department of Environmental Protection with some regularity.

In 1986, New Jersey had 1,224 known or suspected hazardous-waste sites (fig. 3*A*) at which at least a site inspection or preliminary assessment had been made in response to suspected ground-water contamination (Robert Kunze, New Jersey Department of Environmental Protection, written commun., 1986). More than 650 of these sites are known to need some remedial measures, and about 60 of the sites have been cleaned (Robinson, 1986). As of May 1986, 91 sites were on the "Superfund" or National Priorities List for cleanup (U.S. Environmental Protection Agency, 1986c), as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, and another 6 sites were proposed for inclusion. Also, 196 sites require monitoring under the Federal Resource Conservation and Recovery Act of 1976 (RCRA) program (Robert Kunze, New Jersey Department of Environmental Protection, written commun., 1986). A total of 205 county and municipal landfills (fig. 3*C*) are known to exist in New Jersey as of July 1986 (John Castner, New Jersey Department of Environmental Protection, written commun., 1986), most of which are not included in the 1,224 sites noted above.

WATER QUALITY IN PRINCIPAL AQUIFERS

New Jersey's principal aquifers (fig. 2*A*1) are classified into two groups—Coastal Plain aquifers south of the Fall Line and non-Coastal Plain aquifers north of the Fall Line (U.S. Geological Survey, 1985 p. 309). Depending on location, these aquifers are recharged by precipitation, soil-moisture drainage, seepage from surface-water systems, or leakage through confining beds. Three major areas of the State (fig. 2*A*2) have special State regulations protecting ground water. The Pinelands Region has stringent controls on development and removal of ground water from the region in order to protect the ecology of it's wetlands. The two Water Supply Critical Areas have controls (reductions) on pumpage to allow water levels to recover and to reduce the potential for saltwater intrusion and other water-quality problems.

The five principal Coastal Plain aquifers or aquifer systems (from youngest to oldest) are the Kirkwood-Cohansey aquifer system, the Atlantic City 800-foot sand aquifer of the Kirkwood Formation, the Wenonah–Mount Laurel aquifer, the Englishtown aquifer, and the Potomac-Raritan-Magothy aquifer system (fig. 2*A*1). In general, extremely permeable beds of unconsolidated sand and gravel form the aquifers and slightly permeable interbeds of silt and clay form the confining beds. These interbedded, unconsolidated sediments differ in areal extent and thickness, but the entire Coastal Plain system dips to the southeast and thickens seaward (fig. 2*B*). All the aquifers except the Kirkwood-Cohansey aquifer system are confined except where they crop out. These aquifers supply more than 70 percent of the freshwater used in the 4,400-mi^2 (square mile) Coastal Plain area.

North of the Fall Line, the principal aquifers are associated with the glacial valley-fill deposits (narrow, beltlike deposits scattered throughout northern New Jersey and too small in areal extent to be shown in figure 2*A*1), the fractured shale and sandstone units of the Newark Group, the Valley and Ridge sedimentary units, and the weathered and fractured zones of the Highlands crystalline units. These aquifers are important locally and commonly are interconnected with surface-water sources in most northern New Jersey public water-supply systems. Ground water provides about 20 percent of the freshwater supply north of the Fall Line, an area of 3,080 mi^2.

The New Jersey Geological Survey and U.S. Geological Survey have investigated ground-water conditions in the Coastal Plain since the late 1800's. In cooperation with the State, the U.S. Geological Survey formally began a saltwater-intrusion monitoring program in 1923. Nearly 9,000 chloride analyses were performed on water samples from 884 wells between 1923 and 1961 (Seaber, 1963). Since 1961, about 225 wells of a network of about 500 wells have been sampled each year for chloride, specific conductance, temperature, and, more recently, sodium and pH. Thirteen areas of the Coastal Plain (fig. 3*B*) have well-defined occurrences of saltwater intrusion (Schaefer, 1983).

In 1961, the cooperative program began "network" coverage of inorganic ground-water quality by sampling 15 to 50 different wells per year, largely in the Coastal Plain. By 1982, the sampling had been expanded to include trace metals and various organics, and the sampling network had been redirected toward 20 different wells in the water-level observation-well network each year. The water-quality and water-level networks are being further expanded into the less-studied non-Coastal Plain aquifers in northern New Jersey. The water-quality network will sample about 30 wells annually and the intensive basin-assessment program will sample another 20 wells.

U.S. Geological Survey cooperative studies with the State that assess the quantity and inorganic quality o f New Jersey's water-supply sources also started in 1923 (Seaber, 1963). Since 1980, the New Jersey and U.S. Geological Surveys have undertaken many ground-water-quality studies around the State, emphasizing trace-metal and organic analyses. More than 1,750 wells have been sampled for major ions since 1980; about 55 percent (977 wells) also have been analyzed for trace metals and organic constituents. Of the 1,750 wells, 90 percent were sampled in regional studies and 10 percent were sampled as part of a network.

Background Water Quality

The inorganic water quality of the nine major aquifer systems in New Jersey is summarized by graphs (fig. 2*C*) compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE). The graphs show dissolved-solids, hardness, iron, nitrate plus nitrite (as nitrogen), and sulfate of water samples collected from 1923 to 1986. 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, which are health related and are legally enforceable, include a maximum concentration of 10 mg/L (milligrams per liter) nitrate (as nitrogen). The secondary maximum contaminant level standards, which apply to esthetic qualities and are recommended guidelines, include maximum concentrations of 500 mg/L dissolved solids, 300 μg/L (micrograms per liter) iron, and 250 mg/L sulfate. The data in figure 2*C* are presented without distinction as to sample depth or whether the aquifer is confined or unconfined. Where more than one sample was analyzed per site, the median value of the constituent was used.

Median dissolved-solids concentrations (fig. 2*C*) ranged from 32 to 219 mg/L, which did not exceed the national drinking-water standard. In the Coastal Plain the dissolved-solids concentrations for aquifers 2, 3, and 4 reflect the longer residence time of water expected under predominantly confined conditions and show less variation than aquifers 1 and 5, which are under predominantly unconfined conditions.

The predominant ions in most New Jersey ground waters are calcium, magnesium, and bicarbonate. A gradual change to sodium bicarbonate dominance is observed about 30 to 40 miles downdip in the confined Coastal Plain aquifer systems as a result of cation-exchange mechanisms (Leroy Knobel, U.S. Geological Survey, written commun., 1986). The Atlantic City 800-foot sand aquifer is a sodium bicarbonate dominated system except where it is salty south of the tip of Cape May County (fig. 3*B*). The Potomac-Raritan-Mogothy aquifer system is salty in the southern part of the Coastal Plain (fig. 3*B*).

The soils overlying the Kirkwood-Cohansey aquifer system are very sandy and permeable, leaving little time and potential for mineralization of recharge water. Consequently, dissolved-solids concentrations near that of rainfall occur in ground water of this system. Water in this aquifer system also is poorly buffered (median alkalinity is 3 mg/L) and naturally acidic (median pH is 5.2). Ion dominance in this aquifer system is variable, depending on depth and location relative to wetlands (Rhodehamel, 1979).

The Potomac-Raritan-Magothy, the glacial valley-fill, and the Newark Group aquifer systems have median chloride concentrations of 11.6, 30.5, and 16.0 mg/L, respectively. All other aquifers have median chloride concentrations smaller than 7.0 mg/L. Chloride is a problem only in some coastal areas (fig. 3*B*) where extensive ground-water withdrawals have induced saltwater intrusion (Schaefer, 1983).

Using Hem's (1985, p. 159) classification ranges for hardness, the Kirkwood-Cohansey, Atlantic City 800-foot sand, Potomac-Raritan-Magothy, and Highlands crystalline aquifer systems have "soft" ground water (0–60 mg/L as calcium carbonate); the Wenonah-Mount Laurel, Englishtown, and Valley and Ridge aquifer systems have "moderately hard" ground water (61–120 mg/L); and the glacial valley-fill and Newark Group aquifers have "hard" ground water (121–180 mg/L) (fig. 2*C*). Hardness is easily treatable for those ground waters with concentrations larger than 100 mg/L.

Median iron concentrations (fig. 2*C*) commonly exceed the national drinking-water standard of 300 μg/L in all aquifers except the glacial valley-fill deposits, the Newark Group, and the Highlands crystalline systems. Iron concentrations are extremely variable within each aquifer system because of large variations in local conditions controlling the dissolution of iron minerals. Iron is a local or subregional problem and usually is treatable.

Sulfate (fig. 2*C*) follows a pattern similar to dissolved solids, as does chloride. Sulfate is not perceived to be a water-quality problem in New Jersey ground water. However, certain soils in the Coastal Plain appear to be saturated with respect to sulfate and present research indicates that sulfate mobility through soils to shallow ground-water and surface-water systems may be increasing the mobilization of aluminum (Paul Schuster, U.S. Geological Survey, written commun., 1986). Increased aluminum, if in the ionic form, can be toxic to some plants (Ulrich and others, 1980) and fish (Driscoll and others, 1980).

Median concentrations of nitrate plus nitrite (fig. 2*C*) in the confined Coastal Plain aquifer systems are consistently 0.11 mg/L or less, which is considerably smaller than the national drinking-water standard of 10 mg/L. Although median concentrations in the Kirkwood-Cohansey and Potomac-Raritan-Magothy aquifer systems are small, 0.1 mg/L, the data set is extremely variable because of the large number of samples from unconfined wells, which are more susceptible than confined wells to the effects of different land uses. The glacial valley-fill and Newark Group aquifer systems generally are water-table systems overlain by soils more fertile than soils overlying the other New Jersey aquifer systems; therefore, the median concentrations of nitrate plus nitrite are larger than in the other systems.

Several dozen rural-domestic wells have been closed statewide because of increased nitrate levels resulting from the intensity of agricultural practices or septic systems in some areas (Haig Kasabach, New Jersey State Geologist, oral commun., 1986). Furthermore, the New Jersey Department of Environmental Protection recently has received loan requests from six Coastal Plain communities to correct nitrate-contamination problems in their water supplies (Joseph Miri, New Jersey Department of Environmental Protection, written commun., 1986).

Effects of Land Use on Water Quality

Ground-water quality in some areas of New Jersey has been degraded, in some instances severely, owing to the effects of urbanization, transportation, industrialization, agriculture, land disposal of wastes, ground-water pumpage, and perhaps atmospheric deposition. New Jersey has between 10,000 and 15,000 firms engaged in the manufacture of chemical and petrochemical products. New Jersey also generates about 8 percent of the Nation's hazardous waste—more than 40 million pounds annually, which is the largest of any State (Stevenson and others, 1986). The use, transport, and storage of organic and other hazardous chemicals is pervasive throughout much of the State. Consequently, aquifers have been contaminated in many locations through poor industrial housekeeping, spills and accidents of all types, deliberate dumping, illegal discharges, leaks from subsurface storage tanks, landfills, and other factors.

In retrospect, the permitting process of the 1970's and before did not consider ground water to be so vulnerable, and, consequently, ground-water protection did not receive sufficient consideration. In fact, State and Federal laws passed in the 1970's concentrated on "fishable and swimmable" goals for surface waters and, lacking comprehensiveness with respect to ground water, inadvertently increased ground-water contaminant discharges. Many surface-water discharges were replaced by lagoons, spray irrigation, and landfills that accepted chemical wastes (Kasabach and Althoff, 1983), thereby increasing contaminant movement to ground water. Later, the seriousness of ground-water contamination was brought into focus and, important steps in the late 1970's led to development of comprehensive legislation in the early 1980's to both identify and deal with existing problems and to greatly aid prevention of further ground-water degradation.

Roux and Althoff (1980) described the hydrogeologic complexity associated with ground-water supplies that became contaminated by multiple industrial sources of volatile organic compounds (voc's). This study, which indicates how industrial-plant procedures of the 1970's contributed to the degradation of ground-water quality, is an example of how a detailed hydrogeologic analysis was used to define sources of contamination and to provide solutions for abatement.

In two regional ground-water studies of toxic contaminants (metals, pesticides, and voc's), researchers found that voc's present the most serious and pervasive contamination threat to New Jersey's ground water (Tucker, 1981; Fusillo and Hochreiter, 1982). Testing for 22 organic compounds, Tucker (1981) found one or more of eight voc's with a concentration larger than 10 $\mu g/L$ in 16.6 percent of the 670 wells sampled statewide. The most common compounds were 1,1,1-trichloroethane, trichloroethylene, and trichloromethane (chloroform). Fusillo and others (1985) found one or more of 27 voc's with a concentration larger than 1 $\mu g/L$ in about 20 percent of the 315 Coastal Plain wells sampled. The three most common contaminants were trichloroethylene, tetrachloroethylene, and benzene.

An overview report on the State's ground-water-quality program (Kasabach and Althoff, 1983) reported nearly 70 percent of the ground-water-contamination cases involved industrial solvents. The principal contaminants were trichloromethane, 1,1,1-trichloroethane, tetrachloroethylene, trichloroethylene, carbon tetrachloride, and methylene chloride. Where gasoline discharges had occurred, dissolved benzene, toluene, and xylene were common ground-water contaminants.

Results of the State Safe Drinking Water Testing Program (A-280) for the spring of 1985 indicate that about 18 percent of the New Jersey public water supplies ("finished water") had detectable concentrations (more than 1 $\mu g/L$) of one or more organic contaminants (New Jersey Department of Environmental Protection, 1986a). Interestingly, all public-water systems where samples contained detectable levels of organic contaminants use ground water as either the sole or partial source of supply. The most frequently detected contaminants were trichloroethylene, 1,1,1-trichloroethane, and tetrachloroethylene. More importantly, though, only 1 percent of the suppliers had contamination levels large enough that they were required to take some remedial action within 1 year or face closure. At least 17 wells that yield contaminated water have been closed as a result of this Safe Drinking Water Testing Program.

Since 1970, about 200 wells in the State have been closed because of chloride, arsenic, nitrate, mercury, lead, hexavalent chromium, biological, or radiological (both natural and human-caused) contamination (John Preczewski, New Jersey Department of Environmental Protection, oral commun., 1986). Also, since 1970, nearly 1,200 wells have been closed because of contamination from organic compounds. Most of these closures, 80 to 90 percent, were private wells.

The New Jersey experiences with ground-water contamination indicate that wells located in unconsolidated, water-table aquifers near population and industrial centers are most likely to have contamination problems. Organic compounds, especially volatile organic compounds, are the most common and pose the most serious human-induced contamination threats to ground-water supplies. Furthermore, as indicated by Kish and others (1987), an association exists between specific groups of contaminants and land uses, at least for the outcrop of the Potomac-Raritan-Magothy aquifer system.

POTENTIAL FOR WATER-QUALITY CHANGES

In response to severe water-level declines (about 90 feet) and continued development, two major areas of the Potomac-Raritan-Magothy aquifer system are being delineated as water-supply critical areas (fig. 2*A2*). Decreases in pumpage from 35 to 50 percent of 1983 pumpage will be required of all critical area ground-water users by 1990. This mandate is forcing most users to rigorously search for alternative sources such as importation of water; increased surface-water use, such as high-flow skimming and increased surface-water storage; or use of shallower, generally water-table ground-water systems. It follows from past experiences that a potential increase in the identification of water-quality problems, especially organic contamination, is to be expected where usage of shallow ground water increases.

Furthermore, ground-water-contamination problems with respect to nonpoint sources in New Jersey are not delineated or well understood. For example, the effects of agricultural practices, especially the use of pesticides, and the effects of atmospheric deposition on ground-water quality are not well documented. Also, natural radioactivity in ground water may be a problem in some non-Coastal Plain aquifers (Otto Zapecza, U.S. Geological Survey, written commun., 1986). Increasing sampling and use of ground water will uncover more existing problems. Undoubtedly, expected growth outward from populous areas shown in figure 1*B* will cause additional problems. However, New Jersey appears not to be growing in chemical or heavy manufacturing industries, but rather is growing in the lighter industrial, commercial corporate, and research and development activities, and also in suburban residential development. This trend, along with the more active implementation of comprehensive and stringent State and Federal protective and cleanup legislation, likely will minimize New Jersey's future ground-water-contamination problems.

GROUND-WATER-QUALITY MANAGEMENT

New Jersey considers ground-water protection and pollution control to be extremely important and, by legislative guides and mandates, has made major commitments towards progressive, often innovative, approaches to ground-water management. The New Jersey Department of Environmental Protection (NJDEP) is the agency delegated with primary responsibility for ground-water management and regulation in New Jersey. The State has taken a comprehensive resource management approach to ground-water protection. Virtually every State law dealing with ground-water protection requires certain groups of facilities or users to self-monitor, for State review, all uses of the resource and all activities suspected or known to be a contamination source. New Jersey's laws and regulations are broad based in that they control potential, as well as actual, discharges to ground water.

The Delaware River Basin Commission also has an active ground-water management program for the part of New Jersey in the basin. Included in the program's 27 recommendations are a comprehensive ground-water data base and computer management system, and new well registration and metering regulations.

On the resource assessment side, the thorough evaluation of the State's ground-water resources, both in quantity and quality, has been established to be critical to effective management. Identification of significant resource problems during the last 10 years has further stimulated resource assessment. Increased activities include major ongoing and planned regional ground-water studies in problem areas, a statewide aquifer-mapping project, redirection of the statewide monitoring networks, development of county/State cooperative ground-water monitoring, "A-280" mandated monitoring of public water supplies (see later in this section), revision of State ground-water-quality standards, improved coordination between data-collection agencies, a growing and better informed enforcement program, and development of an aquifer classification system based on the evaluation of potability, hydraulic properties, use, and susceptibility to contamination. The New Jersey Geological Survey and the U.S. Geological Survey are providing technical support to the ground-water regulatory programs, particularly through development of the resource data bases, interpretive resource and modeling studies, and studies of ground-water contamination processes.

On the regulatory side, New Jersey Law 1947, further strengthened by the Water Supply Management Act of 1981, requires all ground-water users to obtain NJDEP certification for irrigation withdrawals or diversion permits for all other withdrawals of 0.1 Mgal/d or more, and well permits for all public or private water-supply well installations before drilling a well. More than 1,000 diversion permits have been granted and about 10,000 well permit applications are processed annually (Robinson, 1986). New Jersey also requires that all water-well drillers be licensed.

The 1981 Act also provides for the designation of water-supply critical areas if severe water-supply problems exist, thereby empowering the State to exercise regional water-management controls not otherwise applicable. The NJDEP responded to severe ground-water-level declines as a result of pumpage and increased development in the Coastal Plain by establishing the first water-supply critical area in 1985 and a second in 1986 (fig. 2*A2*).

The direction and activities of water-quality management programs are outlined in the Statewide Water Quality Management Plan (New Jersey Department of Environmental Protection, 1986b). One direction is through the New Jersey Pollutant Discharge Elimination System (NJPDES) program, proposed as a State program in 1975 and officially approved for State primacy by the U.S. Environmental Protection Agency in 1981, whereby both surface- and ground-water dischargers are issued permits. Ground-water discharges include surface impoundments or lagoons, injection wells, spray irrigation, land application of residuals, and landfills for both hazardous and nonhazardous materials. An important requirement is that all ground-water permitted facilities must perform routine discharge and aquifer water-quality monitoring (Robinson, 1986).

The State had issued 618 final NJPDES ground-water discharge permits through July 1986—314 for land application of wastewaters and 304 for landfills (Robert Berg, New Jersey Department of Environmental Protection, written commun., 1986). Another 762 draft NJPDES permits had been issued and several hundred more permits are expected to be issued over the next few years.

Pursuant to the New Jersey Solid Waste Management Act of 1970, the State is revising the standards for installation and construction of onsite disposal systems, and transferring to the local health agencies some onsite system review and control of sludge/septage disposal.

Under the NJPDES permit program and the provisions of the Federal RCRA, the State has taken an active role in registration and identification of underground storage tanks (UST) in excess of 1,100 gallons. About 14,000 UST facilities have registered so far. On September 3, 1986, the Governor signed into law the New Jersey Underground Storage Tank legislation to provide for the registration, annual certification, systematic testing, and monitoring of UST's. The State UST law will increase the number of facilities to be registered by an estimated 50,000 to 70,000 owing to the broader scope of the State law (Robert Nugent, New Jersey Department of Environmental Protection, written commun., 1986).

In addition to Federal RCRA and Superfund cleanup activities, the State has initiated private (that is, at the cost of the violator) remedial cleanup actions pursuant to the New Jersey Water Pollution Control Act of 1981. The State is currently handling nearly 500 private contamination cases and is supervising more than 100 on-going private cleanup projects (William Althoff, New Jersey Department of Environmental Protection, written commun., 1986). As efforts on these private cases continue, millions of dollars of private funds have already been spent, thereby saving millions of public dollars for private parties not able to address their contamination cleanup. Other State cleanup funding and authority is provided by the New Jersey Spill Commission and Control Act of 1977 and the New Jersey Hazardous Discharge Bond Act of 1981.

New Jersey's Environmental Cleanup Responsibility Act (ECRA) of 1983 imposes preconditions on the sale, transfer, or closure of industrial establishments or property involved in the generation, manufacture, refining, transportation, treatment, storage, or disposal of either hazardous substances or wastes. Analagous to home buyer protection programs, this environmental audit determines potential and existing contamination problems, and establishes where and to what extent cleanup is required "before" sale, transfer, or closure can be legally completed. ECRA provides preventative legislation that will benefit New Jersey's environment and economy. From January 1984 through September 1986, a total of 1,990 ECRA cases had been received and 928 cases are closed (Lance Miller, New Jersey Department of Environmental Protection, written commun., 1986).

In 1984, amendments to the New Jersey Safe Drinking Water Act, commonly called "A-280", were signed into law establishing New Jersey as a national leader in assessing drinking-water quality. The law requires all public community water supplies to report to the State the test results on their finished water for 22 hazardous organic contaminants twice a year. Metals and other inorganic constituents are required on a less frequent basis as mandated by the national interim primary drinking-water standards. The law also requires that a 15-member Drinking Water Quality Institute be established to determine additions to the water-quality constituents list, to develop maximum contaminant levels, and to determine appropriate sampling and analytical protocol. The NJDEP administers the "A-280" program and is extending considerable effort in quality assurance of the data collected, in planning financial aid programs for systems with problems, and in bringing problem systems within compliance quickly.

New Jersey has more than 900,000 acres of wetlands (Tiner, 1985), which serve as important components of ground-water surface-water systems. The New Jersey Pinelands Protection Act of 1979 substantially protects the integrity of some 278,000 acres of freshwater wetlands in the Coastal Plain. Another 243,000 acres of coastal area salt and freshwater (mostly saltwater) wetlands are afforded protection under the New Jersey Wetlands Act of 1970. The remaining freshwater wetlands, more than 380,000 acres, are only partly protected through five State and one U.S. Army Corps of Engineers permit programs (Robinson, 1986).

To emphasize the importance of New Jersey's ground water to its citizens and industries, the NJDEP petitioned the U.S. Environmental Protection Agency in 1985 to declare practically the entire State as a sole-source aquifer. The added protection provided by this unprecendented sole-source aquifer petition for the entire State goes hand in hand with the active ground-water discharge permit program and aggressive implementation of Federal and State ground-water-quality legislation.

Despite the fact that ground-water contamination, especially from organic compounds, is locally a very serious problem, New Jersey continues to have a sufficient supply of good quality ground water for most users throughout the State. Furthermore, in-place management practices of the State indicate a comprehensive approach to ground-water protection, whereby all known and potential sources of contamination are subject to controls. Clearly, the future of New Jersey's ground-water resources lies in the continued ability to implement and strengthen these controls as new and unforeseen water-quality problems arise.

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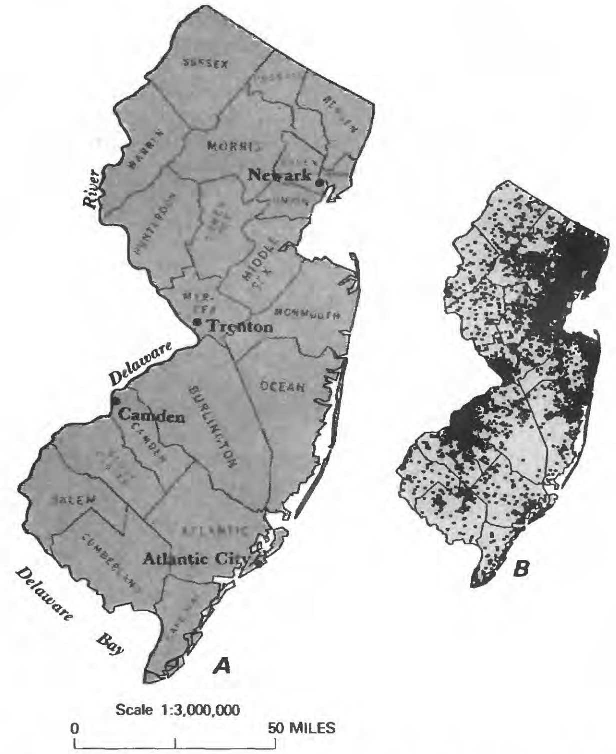

Figure 1. Selected geographic features and 1985 population distribution in New Jersey. *A,* Counties, selected cities, and major drainages. *B,* Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted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

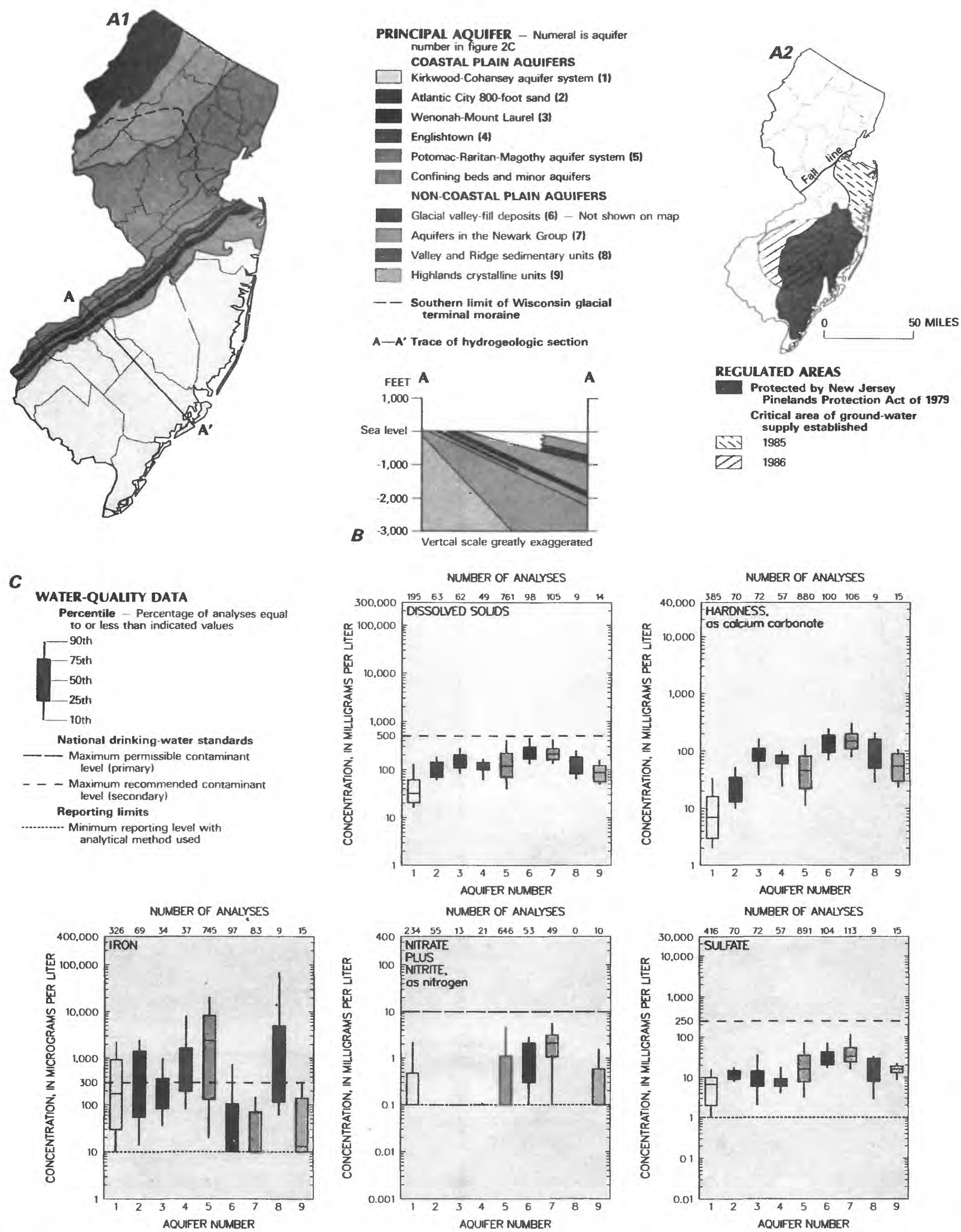

Figure 2. Principal aquifers and related water-quality data in New Jersey. *A*1, Principal aquifers; *A*2, Pinelands region and water-supply critical areas. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1923-86. (Sources: *A*1, Compiled by O.S. Zapecza from U.S. Geological Survey files; *A*2, Unpublished documents of the New Jersey Department of Environmental Protection and the New Jersey Pineland Commission. *B*, Compiled by O.S. Zapecza from U.S. Geological Survey files. *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S Environmental Protection Agency, 1986a,b)

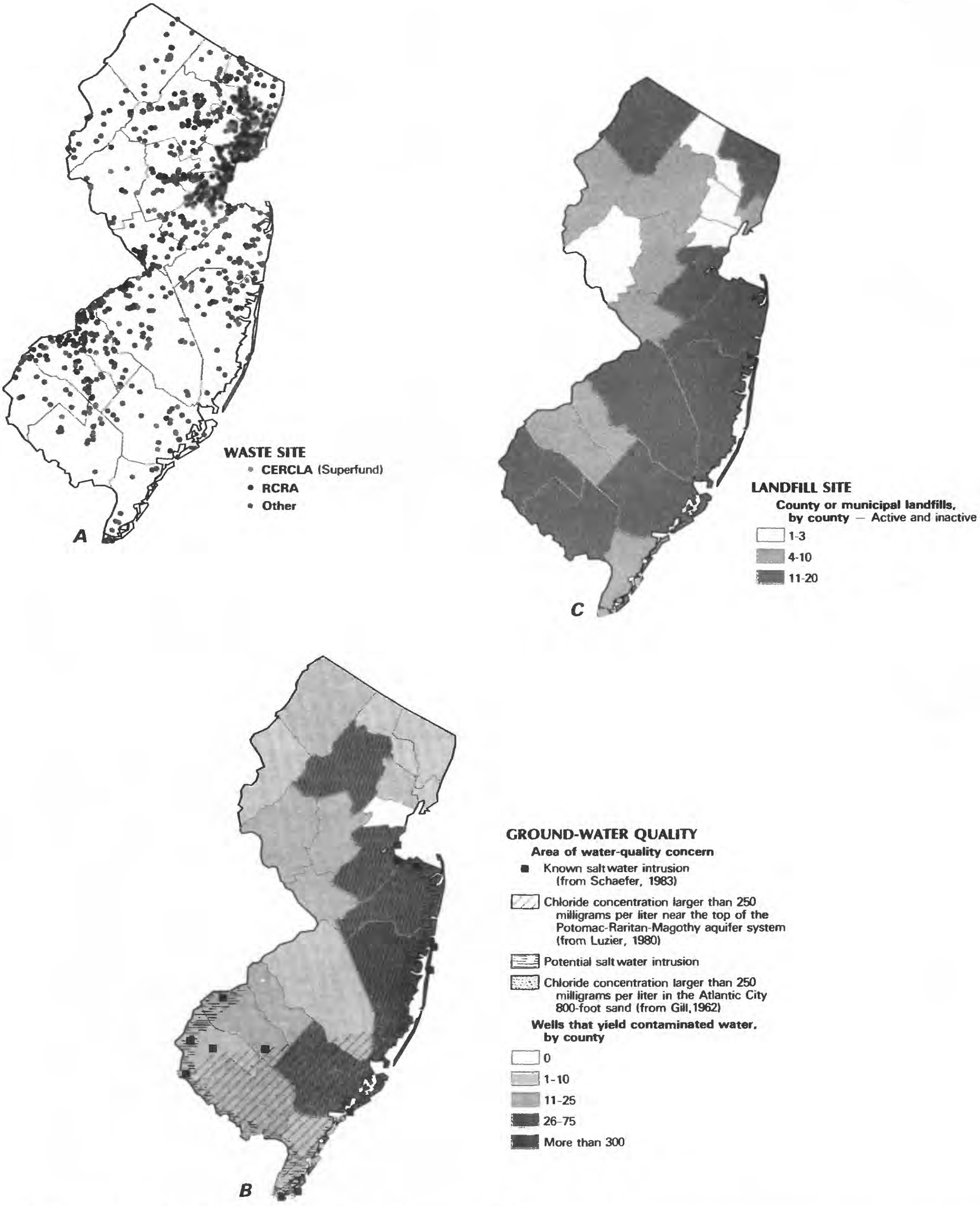

Figure 3. Selected waste sites and ground-water-quality information in New Jersey. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; and other selected waste sites, as of August 1986. *B*, Areas of human-induced and potential saltwater contamination, and distribution of wells that yield contaminated water, as of 1985. *C*, County and municipal landfills, as of July 1986. (Sources: *A*, Robert Kunze, New Jersey Department of Environmental Protection. *B*, Compiled from Association of State and Interstate Water Pollution Control Administrators, 1985; Gill, 1962; Luzier, 1980; Schaefer, 1983. *C*, John Castner, New Jersey Department of Environmental Protection.)