IOWA 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.

Contents

Illustrations

IOWA
Ground-Water Quality

The population served by ground-water supplies in Iowa (fig. 1*A*) is estimated to be about 2,392,000, or 82 percent of the total population (U.S. Geological Survey, 1985, p. 211). The population of Iowa is distributed fairly uniformly throughout the State (fig. 1*B*), with 59 percent residing in rural areas or towns of less than 10,000 (U.S. Bureau of the Census, 1982). Surficial aquifers, the Jordan aquifer, and aquifers that form the uppermost bedrock aquifer in a particular area are most commonly used for drinking-water supplies and usually provide ample amounts of good quality water. However, naturally occurring properties or substances such as hardness, dissolved solids, and radioactivity limit the use of water for drinking purposes in some areas of each of the five principal aquifers (fig. 2*A*). Median concentrations of nitrate in all aquifers and radium-226 in all aquifers except the Jordan are within the primary drinking-water standards established by the U.S. Environmental Protection Agency (1986a). Median concentrations for dissolved solids in the surficial, Dakota, and Jordan aquifers exceed secondary drinking-water standards established by the U.S. Environmental Protection Agency (1986b).

Ground water in Iowa, however, has been affected by human-induced contamination. Water from some wells in surficial and the uppermost bedrock aquifers contains nitrate concentrations exceeding the primary drinking-water standard of 10 mg/L (milligrams per liter) as nitrogen. Surficial aquifers also contain detectable concentrations of pesticides and other organic substances. Standards have not been established for many of the organic substances detected, and water supplies containing these substances may continue to be used. The long-term health consequences of exposure to these substances are not known; however, the estimated number of people in Iowa exposed to pesticide contaminants is believed to exceed 750,000 or 25 percent of the population (Kelley and others, 1986.)

Land-use and waste-disposal practices are believed to be responsible for most human-induced contamination in Iowa. About 33 million acres, or nearly 93 percent of the land area of Iowa, is farmed (Skow and Halley, 1986). About 56 million pounds of herbicides was used for agriculture during 1979 (Becker and Stockdale, 1980) and about 2.7 million tons of fertilizer products was used during 1985 (Skow and Halley, 1986). Additionally, 30 hazardous-waste sites are under authority of the Federal Resource Conservation and Recovery Act (RCRA) of 1976; six other sites have been listed in the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (U.S. Environmental Protection Agency, 1986c). As of September 1985, two Federal sites at one facility under the U.S. Department of Defense Installation Restoration Program (IRP) were designated for remedial response in accordance with CERCLA. In addition to the above sites, Iowa has 90 active municipal landfills (fig. 3*C*).

The U.S. Geological Survey, in cooperation with the University of Iowa Hygienic Laboratory, the Iowa Department of Natural Resources, and several counties in Iowa, currently (1986) is monitoring about 1,500 public and private wells for inorganic and organic constituents. The principal objective of this program, begun in 1982, is to collect water-quality data that will describe the long-term chemical quality of the surficial and major bedrock aquifer systems in Iowa (Detroy, 1985).

WATER QUALITY IN PRINCIPAL AQUIFERS

Five principal aquifers are used in Iowa—surficial aquifers, the Dakota aquifer, the Mississippian aquifer, the Silurian-Devonian aquifer, and the Jordan aquifer (fig. 2*A*). All aquifers except the surficial aquifers are bedrock. The surficial aquifers are present throughout Iowa but are limited to the valleys of major streams in extreme northeastern Iowa because of thin or nonexistant unconsolidated glacial material in this area. The bedrock aquifers beneath the Dakota aquifer dip gently to the south and southwest (fig. 2*B*). In most areas of Iowa, more than one aquifer is available as a potential water supply. The population served by each aquifer has not been determined because many of the municipal wells derive water from more than one aquifer or several wells may tap different aquifers.

In Iowa, the concentration of dissolved solids in ground water typically increases with depth and with the distance from recharge areas. Shallow aquifers usually are preferred for drinking-water supplies, especially in areas where alternative aquifers are deeply buried and contain more mineralized water. However, shallow aquifers are more susceptible to human-induced contamination than more deeply buried aquifers that are protected from activities on the land surface by relatively thick overlying deposits. This susceptibility of the surficial aquifers is demonstrated by the number of water samples from wells completed in shallow aquifers that contain detectable concentrations of synthetic organic chemicals and pesticides and substantial concentrations of nitrate.

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), radium-226, and atrazine analyses of water samples collected from 1975 to 1985 from the principal aquifers in Iowa. 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). Primary maximum contaminant level standards are health related and are legally enforceable. Secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary standards for the variables shown in figure 2*C* are 10.0 mg/L nitrate (as nitrogen) and 5.0 pCi/L (picocuries per liter) radium-226 plus radium-228. Primary drinking-water standards require that samples having concentrations of radium-226 in excess of 3.0 pCi/L be analyzed additionally for radium-228. The secondary standard for dissolved solids is 500 mg/L. At present (1986), no primary or secondary standard has been established for atrazine in drinking water.

Surficial Aquifers

The surficial aquifers in Iowa (fig. 2*A*) are the water-yielding strata within the unconsolidated deposits overlying the bedrock surface. The three general types of surficial aquifers in Iowa are buried-channel aquifers, glacial-drift aquifers, and alluvial aquifers.

Preglacial depressions and valleys in the buried bedrock surface that contain sand and gravel compose the buried-channel aquifers. Glacial-drift aquifers consist of lenses of sand and gravel distributed within the silt and clay deposited by Pleistocene glaciers. Alluvial aquifers consist of sand and gravel deposits along present-day streams.

The naturally occurring quality of water within surficial aquifers generally is suitable for most uses. Buried-channel aquifers that occur beneath a substantial thickness of glacial drift or that fill valleys deeply incised into the bedrock may have water-quality characteristics similar to those of water in the bedrock aquifers, particularly if the buried channel is in hydraulic contact with the bedrock aquifer. Glacial-drift aquifers generally yield a limited quantity of water because of their limited hydraulic connection to other sources of water and their limited areal extent. Glacial-drift aquifers usually are considered to be unreliable for public or industrial water supplies. Alluvial aquifers typically yield large quantities of water and may have water-quality characteristics similar to those of adjacent streams.

The median dissolved-solids concentration approximately equaled the drinking-water standard (fig. 2*C*); concentrations in 10 percent of the samples were larger than 870 mg/L. Nearly all water sampled was very hard. The median for hardness was 390 mg/L and the hardness was larger than 230 mg/L as calcium carbonate ($CaCO_3$) in 90 percent of the samples. The median nitrate concentration was 0.6 mg/L as nitrogen, but the concentration in nearly 10 percent of the samples exceeded the drinking-water standard. Radium-226 was present in concentrations smaller than 3.0 pCi/L in 90 percent of the samples. Atrazine, a herbicide used in the production of corn, was detected in about 10 percent of the samples.

Dakota Aquifer

The Dakota aquifer consists of sandstone of Cretaceous age and occurs mainly in the western one-half of Iowa (fig. 2*A*). This aquifer lies unconformably on the other bedrock aquifers and is overlain throughout its extent by unconsolidated deposits that contain surficial aquifers. The Dakota aquifer is important in northwestern Iowa as a source of public, industrial, irrigation, and rural-domestic water. In some areas, large concentrations of dissolved solids limit the use of the water for some purposes. Water in some areas of the aquifer also contains naturally occurring radium-226 and radium-228 in concentrations that may limit the use of the water. The areal extent of naturally occurring contaminants such as radium has not been determined.

The median dissolved-solids concentration of 824 mg/L exceeded the drinking-water standard (fig. 2*C*). The median dissolved-solids and hardness concentrations were among the largest in water from the five principal aquifers. Nitrate does not occur in significant concentrations in water from the Dakota aquifer. Radium-226 exceeded 3.0 pCi/L in about 25 percent of the samples. Water samples from wells more than 150 feet deep commonly are not tested for atrazine because there probably is little likelihood of atrazine percolating below that depth. Because most wells completed in the Dakota aquifer exceed this depth, few analyses of atrazine are available for this aquifer and other deep aquifers.

Mississippian Aquifer

The Mississippian aquifer, which consists of limestone and dolomite, is the uppermost bedrock aquifer in parts of central Iowa (fig. 2*A*), although in parts of western Iowa it is overlain by the Dakota aquifer. In much of southwestern and south-central Iowa, the Mississippian aquifer is overlain by rocks of Pennsylvanian age, which usually are not considered to be aquifer materials. Large concentrations of naturally occurring dissolved solids limit the use of water from the Mississippian aquifer in many areas. Furthermore, because of the large concentrations of dissolved solids and small yields from the the Mississippian aquifer, the aquifer usually is neglected as a drinking-water source in areas where it is the uppermost bedrock aquifer. Instead, supplies are obtained from surface water, surficial aquifers, or the deeper Jordan aquifer.

Data for the Mississippian aquifer (fig. 2*C*) indicate that the water had a median dissolved-solids concentration of 470 mg/L and was very hard. Concentrations of nitrate were not significant in this aquifer, based on 73 samples. Radium-226 concentrations exceeded 3.0 pCi/L in more than 25 percent of the samples analyzed.

Silurian-Devonian Aquifer

The Silurian-Devonian aquifer, consisting of limestone and dolomite, is the uppermost bedrock aquifer in most of north-central and eastern Iowa (fig. 2*A*). Where it forms the bedrock surface, the Silurian-Devonian aquifer provides a readily available source of water for most uses. Where overlain by younger bedrock units, water from the aquifer may not be suitable for drinking because of undesirable concentrations of naturally occurring sulfate and dissolved solids. As a result, these parts of the aquifer usually are bypassed as a source of water supply in the same manner as the Mississippian aquifer. The aquifer is near or at the land surface in much of northeastern Iowa and, because of solution-enlarged fractures and thin soil cover, is particularly susceptible to surface contamination.

Water from this aquifer contains the smallest median concentrations of dissolved solids and hardness of the five principal aquifers (fig. 2*C*). Nitrate and atrazine are known to be contaminants in parts of Iowa where the Silurian-Devonian aquifer is susceptible to surface-water contamination or to the leaching of contaminants from shallow ground water (Hallberg and others, 1984). However, data from those areas are not contained in the data base used to prepare this report. Nitrate and atrazine, in analyses of 18 samples from other areas of the Silurian-Devonian aquifer, do not appear to be significant problems at the present time. Radium-226 concentrations exceeded 3.0 pCi/L in more than 25 percent of the samples tested.

Jordan Aquifer

The Jordan aquifer consists of sandstone and dolomite of Ordovician and Cambrian age. It is the most extensively used aquifer in Iowa and is present throughout the State except for an area in northwestern Iowa. This aquifer is a source for many large-capacity water systems in Iowa because of its large yields and the suitability of the water for most uses. Large concentrations of naturally occurring dissolved solids and the greater depth to the aquifer limit the use of the Jordan aquifer in southwestern Iowa; however, in many areas of southwestern Iowa the Jordan aquifer is the best source of drinking water despite large dissolved-solids concentrations. Radium also is a naturally occurring constituent in water from parts of the Jordan aquifer, but the extent of this problem has not been determined.

Median concentrations of dissolved solids and radium-226 in water from the Jordan aquifer exceeded drinking-water standards (fig. 2*C*). More than 90 percent of the samples had a hardness exceeding 260 mg/L, which is very hard. In the samples analyzed, no nitrate concentrations exceeded the drinking-water standard. Analysis for atrazine in water from Jordan wells was uncommon because the depth to the Jordan in most parts of Iowa was considered to be a significant barrier to pesticide contamination. About 75 percent of the samples analyzed for radium-226 had concentrations larger than 3.0 pCi/L and required additional analysis for radium-228. Concentrations in about 50 percent of the samples exceeded the drinking-water standard for radium without consideration of radium-228.

An additional deeper, and possibly separate, aquifer exists in eastern Iowa below the Jordan aquifer (not shown in fig. 2). This aquifer, locally known as the Dresbach aquifer, is composed of a Cambrian sandstone that has not been extensively mapped; detailed information on the hydraulic and water-quality characteristics of the aquifer is not available. The Dresbach aquifer is used by several public water systems and industries along the eastern border of Iowa; however, many of these wells also are open to the Jordan aquifer and obtain some water from that source.

EFFECTS OF LAND USE ON WATER QUALITY

The monitoring of ground-water quality within Iowa has been conducted mainly by Federal and State agencies as part of the Safe Drinking Water Act (Public Law 93-523) and as part of the environmental responsibilities of public-health agencies. Four types of human-induced ground-water contamination routinely occur in Iowa—nitrate, bacteria, pesticides, and synthetic organic compounds other than pesticides. Agricultural and waste-disposal activities currently (1986) are receiving the most attention as potential sources of these contaminants. The location of the CERCLA, RCRA, IRP, and other waste-disposal sites in Iowa is shown in figure 3*A*. The latter category consists primarily of privately owned landfills and disposal sites.

As of September 1985, 28 hazardous-waste sites at 2 facilities in Iowa had been identified by the U.S. Department of Defense (DOD) as part of their IRP as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the U.S. Environmental Protection Agency (EPA) Superfund program under CERCLA. EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Two sites at one facility (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.

The locations of 104 public water-well systems in Iowa that consistently contain nitrate concentrations in excess of the drinking-water standard or have been determined to contain detectable concentrations of pesticides or synthetic organic substances other than pesticides are shown in figure 3*B*. Many of the 104 systems shown contain more than 1 contaminant. The estimated population potentially served by these systems is 739,000 or about 25 percent of the total State population. The number of private wells that are contaminated and the population served by them are not known.

The location of municipal landfills in Iowa is shown in figure 3*C*. The effect of many of these landfills on local ground-water quality has not been determined.

Nitrate

In Iowa, large nitrate concentrations in shallow ground water were detected as early as the 1940's (McDonald and Splinter, 1982). From 1978 to 1981, the University of Iowa Hygienic Laboratory analyzed 13,625 water samples from private wells less than 100 feet deep. Twenty-eight percent of these samples exceeded the drinking-water standard of 10 mg/L nitrate as nitrogen (Hallberg, 1985).

The correlation of increasing nitrate with decreasing well depth has been apparent for some time. However, Detroy (1986) has more specifically defined the vertical distribution of nitrate in an alluvial aquifer in Iowa County, Iowa. Nitrate concentrations in shallow aquifers also typically have a seasonal fluctuation, with the concentrations being largest during the early part of the growing season. As a result, the concentrations of nitrate in water from many wells do not consistently exceed the drinking-water standard throughout the year. Complexities of the shallow ground-water-flow system, as well as chemical transformation occuring within the aquifer, may affect the quantity and form of nitrogen present at any particular location and time.

Bacteria

Most of the water-quality data available are for public water supplies that are required to be free of bacteria. However, bacteria have been relatively common contaminants in shallow private wells. Many times this problem is caused by faulty well construction, which has allowed surface runoff and bacterial contaminants to enter the well. Remedial measures, such as chlorination, may decontaminate a well; however, additional measures would be needed to prevent renewed contamination. Conditions within the aquifer may prevent a total decontamination of affected wells.

Pesticides

Agricultural pesticides have been detected in water from both public and private wells in Iowa (Hallberg and others, 1984; Kelley, 1985; Kelley and Wnuk, 1986; and data from U.S. Geological Survey files). Pesticides usually are detected in water that also contains substantial concentrations of nitrate. Recent investigations by the U.S. Geological Survey have detected commonly used pesticides in public water-supply wells; however, samples are not routinely analyzed for every pesticide used in Iowa. Atrazine is the most commonly detected pesticide in ground water.

Pesticide occurrence in ground water is similar to nitrate occurrence in that it commonly is detected shortly after application. Modern agricultural pesticides are not as persistent as the early chlorinated pesticides like DDT. This condition may help explain why in many wells, pesticides are detected in the water only during the growing season. Recent investigations, however, have found detectable quantities of atrazine throughout the year in ground water (Hallberg and others, 1984). There is also an uncertainty concerning the prevalence and health effects of the pesticide degradation products. The chemistry of the degradation of these pesticides is complex and water samples from monitoring activities have not been analyzed for the degradation products.

Synthetic Organic Substances

Synthetic organic substances other than pesticides have been detected in water from public and private wells in Iowa (Kelley, 1985; Kelley and Wnuk, 1986). These substances commonly are associated with commercial or industrial uses, or chemical storage and disposal areas. Many of the detected substances such as trichloroethylene (TCE) are among those identified as potential carcinogens, although drinking-water standards have not yet been established for them (U.S. Environmental Protection Agency, 1979; 1986a).

POTENTIAL FOR WATER-QUALITY CHANGES

Iowa predominantly is an agricultural State and most land use is related to agriculture. Iowa ranks first in the Nation in the production of corn and second in the production of soybeans (Skow and Halley, 1986). This national leadership in row-crop production has been bolstered by the use of modern agricultural practices and chemicals. The correlation between increases in agricultural-chemical use and ground-water contamination has been apparent for some time (McDonald and Splinter, 1982). In 1982, the U.S. Geological Survey in cooperation with the University of Iowa Hygienic Laboratory and the Iowa Geological Survey began a program of long-term monitoring of wells in Iowa. The network currently (1986) contains about 1,500 wells. The location of each well and the aquifers monitored at each well site are shown in figure 4. About 300 of the network wells are sampled each year for a variety of water-quality properties and constituents, including nitrate, trace metals, pesticides, and synthetic organic substances.

Shallow wells are monitored more frequently because of the vulnerability of shallow aquifers to point and nonpoint source contamination.

Data collected thus far indicate that pesticide residues in ground water probably are increasing (Kelley and others, 1986, p. 2). Contaminants entering shallow aquifers likely will continue unless land-use or agricultural practices are changed significantly. Deeper aquifers also may begin to be affected as water from shallow aquifers moves downward within the recharge areas to the deeper aquifers. Increased efforts are needed to define the extent and magnitude of detected or suspected contamination; to determine the physical, chemical, and biological mechanisms that affect the movement and degradation of contaminants; and to determine alternatives to decrease or eliminate the cause of contamination.

Waste-disposal sites in Iowa (figs. 3*A* and 3*C*) also may present a long-term threat to ground-water quality. Not included in the sites shown in figures 3*A* and 3*C* are the location of wells used for the gravity draining of agricultural lands or the areas within Iowa where municipal sewage sludge is being applied to the land. Agricultural-drainage wells transport surface water and shallow ground water and their associated contaminants into deeper aquifers in north-central Iowa (Baker and Austin, 1982). The extent and potential of this contamination are not known.

GROUND-WATER-QUALITY MANAGEMENT

The Iowa Department of Natural Resources has primary responsibility for managing ground-water quality in Iowa. Regulatory functions related to ground-water quality are conducted by the Department's Environmental Protection Division. These functions include implementing the Federal Safe Drinking Water Act, managing a water allocation permit system, and regulating solid-waste disposal. For the most part the RCRA program is administered by the EPA; however, EPA is involved with certain hazardous-waste programs. It administers the State Superfund program, which primarily is a registry of uncontrolled or abandoned waste sites in the State. The State also has an established administrative procedure for obtaining State and local approval of sites for any hazardous-waste disposal facility. In addition, the Iowa Department of Natural Resources provides technical assistance for control of hazardous spills and participates with the EPA in CERCLA investigations and cleanups.

Various divisions of the Iowa Department of Natural Resources become involved in ground-water studies, commonly supported by grants from the EPA. The Geological Survey Bureau of the Department's Energy and Geological Resources Division performs ground-water investigations, research, and service work. Ground-water-monitoring programs and special studies commonly are cooperative efforts between the Geological Survey Bureau, the University of Iowa Hygienic Laboratory, and the U.S. Geological Survey. Such studies have included surveys of the occurrence of synthetic organic compounds, including commonly used pesticides, in public water supplies.

The Iowa Department of Agriculture and Land Stewardship administers rules for pesticide handling and storage facilities, which attempt to prevent ground-water contamination. The Department also administers the Federal Insecticide, Fungicide, and Rodenticide Act in Iowa. This act involves the registration and use of pesticides.

The Planning Bureau of the Iowa Department of Natural Resources' Coordination and Information Division prepared a legislatively mandated ground-water-protection plan for presentation to the 1987 Iowa Legislature. The plan was to identify sources of ground-water pollution, provide policy options, and recommend legal and program changes. In addition, the plan was to be reviewed and a status report provided to the Legislature every 5 years. The plan resulted in the passage of a ground-water protection act that emphasizes a nondegradation policy.

The State has passed numerous items of legislation related to the protection of ground-water quality in the past few years in addition to the ground-water-protection plan mandate. This recent legislation can be divided into three general catagories: hazardous waste, landfills, and preventive measures.

Legislation has required the development of a State hazardous-waste-management plan. This development will be followed by a more specific plan for the establishment of a State-owned facility for the long-term, above-ground storage of hazardous waste. New legislation requires registration of underground tanks used for the storage of petroleum products or other hazardous chemicals with the Iowa Department of Natural Resources. The Department also was directed to establish rules regarding detection, prevention, and correction of leaking tanks. There is a hazardous-waste fee and remedial fund (State Superfund) that has been recently established. "Toxic cleanup days" demonstration projects are created to promote the proper disposal of household and farm-generated hazardous wastes.

A fee was established for solid-waste disposal in landfills, with the revenue to be used to develop alternative waste-disposal methods and methods for preventing ground-water contamination. Rules also were developed for improved monitoring of ground water at landfills. Other new legislation requires that alternative means of waste disposal, other than landfills, be considered and given preference if determined to be economically feasible. This legislation attempts to phase out landfills by 1997.

Legislation that may aid in the prevention of water-quality problems includes the establishment of an Agricultural Energy Management Fund to be used for education and demonstration projects which result in management practices that, among other things, decrease the potential for ground-water contamination. Municipal water suppliers have been mandated to conduct a one-time sampling for certain synthetic organic compounds including commonly used pesticides. A provision was passed enabling the designation of protected water sources and restriction of water use from such sources to protect the long-term quantity and quality of ground water. Also, the registration of well drillers is now required.

The recent legislation listed above primarily has addressed ground-water quality with respect to potential point-sources of contaminants. However, studies have identified degradation of ground-water quality from nonpoint agricultural chemicals. Thirty-three percent of the samples from water-supply wells, sampled in various environments, contained pesticide residues (Kelley and others, 1986, p. 1). These nonpoint sources may constitute the major ground-water-quality problem in Iowa. Research in this regard is being done by the Iowa Geological Survey Bureau of the Energy and Geological Resources Division, in cooperation with numerous Federal and other State, local, and private agencies.

Past efforts involving ground-water data collection in Iowa focused on regional, deep bedrock aquifers and naturally occurring constituents that affect water quality. As a result, these aquifers have been well characterized. Recently, emphasis has shifted to shallow aquifers and the effects of human activities on water quality. However, the data base for such information is still small and continued efforts to expand it are needed. For effective management of ground-water quality, information also is needed on the hydraulic and chemical factors affecting contaminant movement, effective means for preventing ground-water contamination, and the effects of various contaminants on human health.

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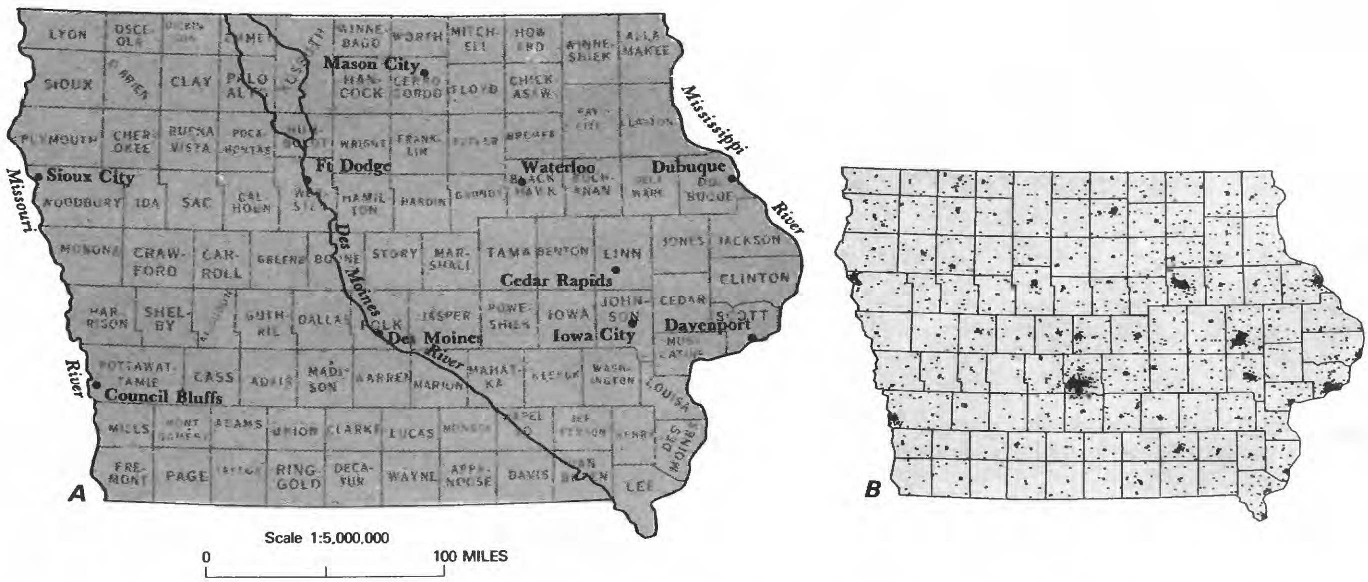

Figure 1. **Selected geographic features and 1985 population distribution in Iowa.** *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted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

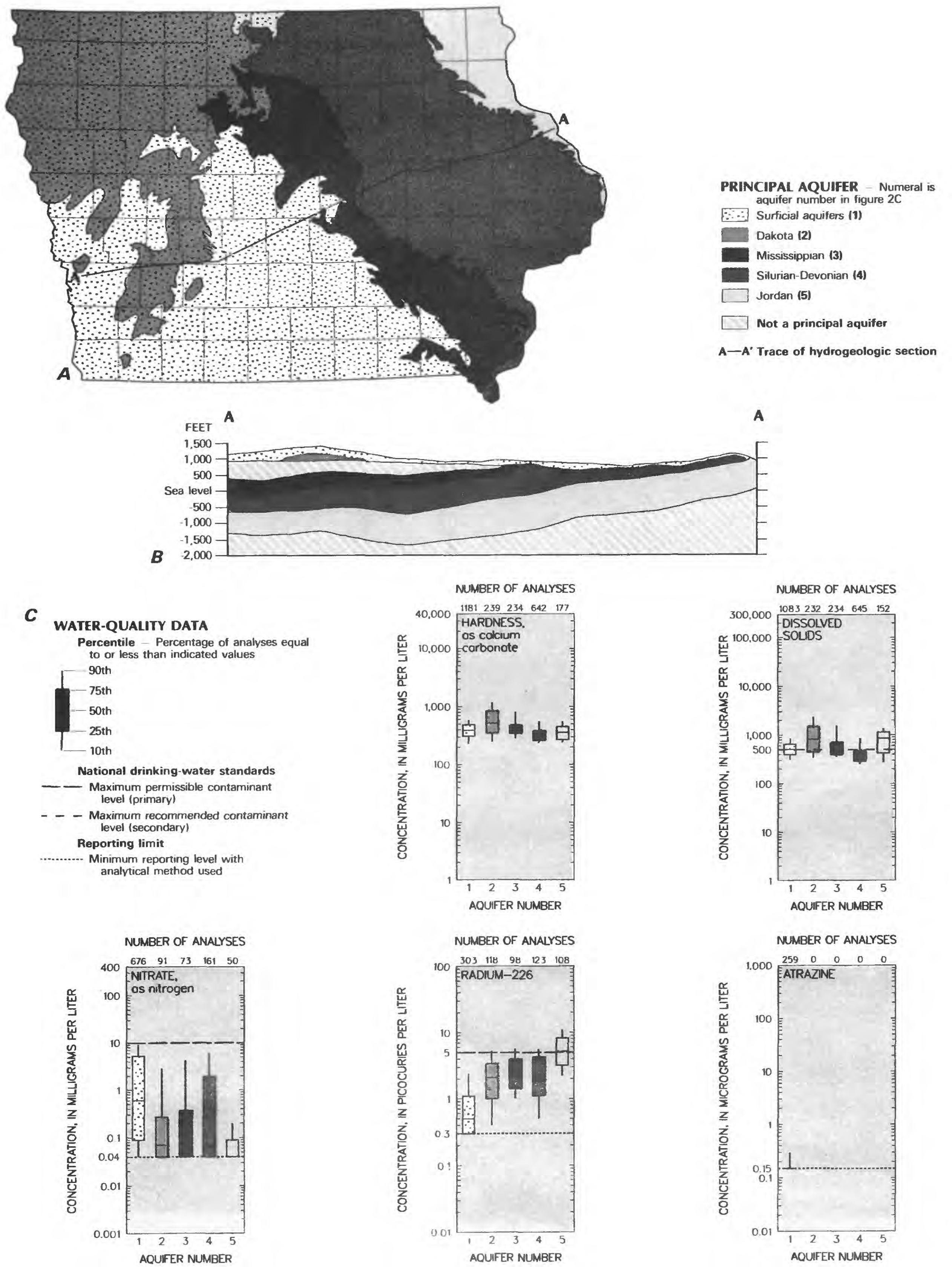

Figure 2. **Principal aquifers and related water-quality data in Iowa.** *A*, Principal aquifers. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1975-85. (Sources: *A*, Modified from Hershey, 1969, and Horick and Steinhilber, 1978. *B*, Modified from Horick and Steinhilber, 1978. *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a, b.)

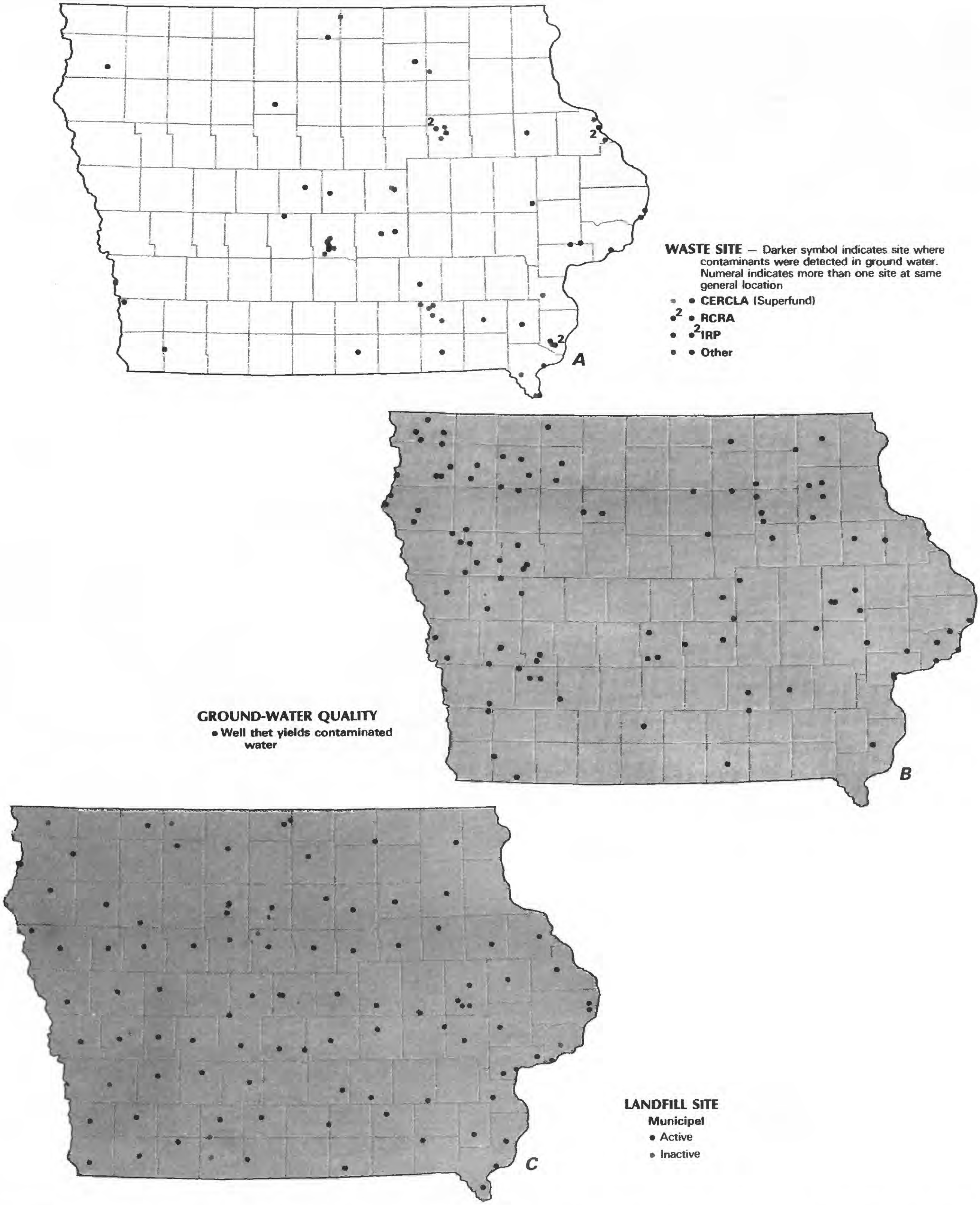

Figure 3. Selected waste sites and ground-water-quality information in Iowa. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; Resource Conservation and Recovery Act (RCRA) sites, as of 1986; Department of Defense Installation Restoration Program (IRP) sites, as of 1985; and other selected waste sites, as of 1986. *B*, Distribution of wells that yield contaminated water, as of 1986. *C*, County and municipal landfills, as of 1986. (Sources: *A*, Bruce Henning, Iowa Department of Water, Air and Waste Management, written commun., 1986; Peter Culver and David Doyle, U.S. Environmental Protection Agency, written commun., 1986; U.S. Environmental Protection Agency, 1986c. *B*, Kelley, 1985; Kelley and Wnuk, 1986; G.R. Hallberg, Iowa Geological Survey, written commun., 1986. *C*, Bruce Henning, Iowa Department of Water, Air and Waste Management, written commun., 1986.)

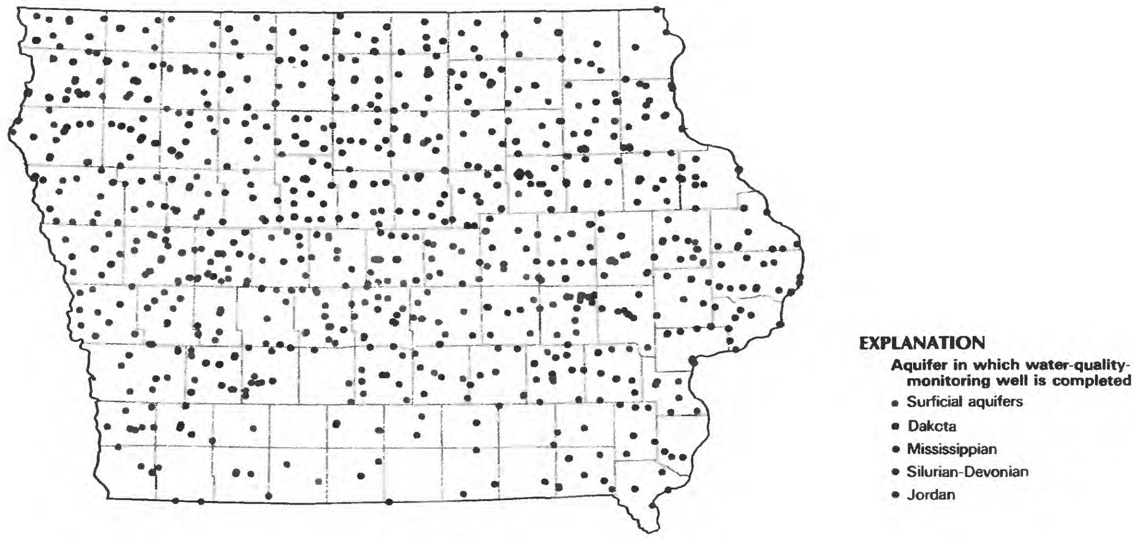

Figure 4. Location of ground-water-monitoring network wells in Iowa, 1986. (Source: U.S. Geological Survey files; Detroy, 1985.)