TEXAS 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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In Texas, aquifers provide about 60 percent of the freshwater used. More than 80 percent of this water is used for irrigation, and about 9 percent is used for public supply. About 46 percent of all water used for public supply (see population distribution in fig. 1) comes from ground water (Bill Moltz, Texas Water Development Board, written commun., 1986). Ground-water supplies occur primarily in 7 principal (fig. 2*A*) and 17 minor aquifers that underlie more than 75 percent of the State.

Most ground water in all the principal withdrawal areas of each principal and minor aquifer does not exceed the drinking-water standards established by the Texas Department of Health (1985) for dissolved solids, nitrate, and fluoride, which are important for evaluating the suitability of water for public use. The freshwater that is present in the outcrop and shallow subcrop areas of these aquifers progressively changes to saline water in the deeper, downdip areas of most of the aquifers.

Most of the principal and minor aquifers, however, have had water-quality problems affecting limited areas. The problems generally have resulted from natural excessive salinity or salinity that has been induced by excessive withdrawals of ground water. The excessive withdrawals can cause an intrusion of more mineralized water from nearby locations in the same producing strata or from adjacent strata. These problems have been associated mostly with agricultural and public ground-water withdrawals in parts of the alluvium and bolson deposits, the Gulf Coast aquifer system, the High Plains (Ogallala) aquifer, and the Trinity Group aquifer.

Twenty-one hazardous-waste sites in Texas (fig. 3*A*) have been listed in the National Priorities List (NPL) of hazardous-waste sites by the U.S. Environmental Protection Agency (1986c). These Superfund sites require additional evaluation as established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Six of the CERCLA sites have been documented to have shallow ground-water contamination (Texas Water Commission, 1986), but none have caused widespread contamination of drinking-water supplies in the deeper aquifers. Additionally, about 180 other hazardous-waste sites (fig. 3*A*) require monitoring of ground-water quality as established by the Federal Resource Conservation and Recovery Act (RCRA) of 1976. At most of the RCRA sites, ground-water contamination has been minimal and at shallow depths. Many of the waste-disposal sites are located in a part of the Gulf Coast area where clay of the Beaumont Formation occurs at the land surface; this clay is relative impermeable (Gabrysch, 1977) and probably has helped to prevent contaminants from entering deeper aquifers used for public supply. In addition, the U.S. Department of Defense (DOD) has identified 31 sites at 7 facilities where contamination has warranted remedial action.

There are 118 Class-I underground injection control (UIC) wells (U.S. Environmental Protection Agency, 1984) in the State that are operated under permits issued by the Texas Water Commission (fig. 3*A*). These wells are used to inject industrial waste into aquifers containing moderately saline to briny water; the aquifers are located at great depths below the base of slightly saline ground water containing dissolved-solids concentrations of more than 3,000 mg/L (milligrams per liter) (Winslow and Kister, 1956, p. 5). Thus far, ground-water contamination has not been associated with the underground injection wells (Knape, 1984, p. 3-12).

Projections for the next 20 years indicate that about 4,500 new wells will be needed to supply water for public supply needs. Many of these projected wells will be located in areas where extensive ground-water use has yet to occur (Texas Department of Water Resources, 1984a, p. 37). The greatest number of these wells will be located in the High Plains and along the Gulf Coast. Past experience indicates that salinity increases induced by ground-water withdrawals can be one of the primary ground-water-quality problems in some parts of these areas.

WATER QUALITY IN PRINCIPAL AQUIFERS

Most of the ground water used in Texas comes from seven principal aquifers (fig. 2*A*). These aquifers are: alluvium and bolson deposits, the Gulf Coast aquifer system, High Plains (Ogallala), Carrizo-Wilcox, Edwards (Balcones fault zone), Edwards-Trinity (Plateau), and Trinity Group (U.S. Geological Survey, 1985, p. 398). With the exception of the alluvium and bolson deposits and the High Plains (Ogallala), the aquifers dip to the south and east towards the Gulf of Mexico (fig. 2*B*). All these aquifers supply water for public, industrial, and irrigation uses. The High Plains (Ogallala) aquifer, the most intensively developed, is used primarily for supplying water for irrigation. The Gulf Coast aquifer system, Carrizo-Wilcox, Edwards (Balcones fault zone), and Trinity Group aquifers are the next most intensively developed; most of the water is used for public supply in areas of dense population (fig. 1*B*), although each aquifer also supplies a substantial volume of water for irrigation. There are 17 minor aquifers delineated in Texas (Muller and Price, 1979, p. 49). Each minor aquifer is important locally and, in some places, constitutes the only source of freshwater supply in the area.

BACKGROUND WATER QUALITY

Ranges in concentrations of five water-quality variables from each of the principal aquifers were complied from about 30,000 water analyses available from the Texas Water Development Board, based on samples collected from 1900 to 1986 (fig. 2*C*). Percentiles of these water-quality variables are compared to national standards that specify the maximum concentration or level of a contaminant in drinking-water supply as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include a maximum concentration of 10 mg/L nitrate (as nitrogen), and 4 mg/L fluoride. The secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids and 2 mg/L flouride.

Comparison of the analyses to drinking-water standards established by the Texas Department of Health (1985) indicated that water from 32 percent of the wells sampled contained one or more of the following constituents in excess of the State drinking-water standard (indicated in parentheses): dissolved solids (1,000 mg/L), chloride (300 mg/L), nitrate (10 mg/L as nitrogen), or fluoride (2.4 mg/L). Records from the Texas Department of Health were used to estimate that between 1 and 2 percent of the total population had used at some time drinking water that contained one or more of these constituents in excess of Texas drinking-water standards.

Alluvium and Bolson Deposits

Water from the alluvium and bolson deposits is used mainly for irrigation and public supply. Alluvial deposits (fig. 2*A*) are found locally in extensive areas in far western and north-central Texas (Alvarez and Buckner, 1980; Muller and Price, 1979). The chemical quality of the water ranges considerably. Dissolved-solids concentrations ranged from 100 to about 35,000 mg/L in the far west (Gates and others, 1980) and from 500 to 2,500 mg/L in north-central

Texas. The median concentration was 771 mg/L (fig. 2*C*), and nearly 45 percent of the samples had dissolved-solids concentrations exceeding 1,000 mg/L. The water had a median hardness (as calcium carbonate) concentration of 378 mg/L; more than 75 percent of the samples were classified as very hard. About 40 percent of the samples had nitrate concentrations that exceeded 10 mg/L.

Gulf Coast Aquifer System

Ground water in the Gulf Coast area is used mainly for public supply in densely populated areas and for irrigation and public supply elsewhere. The Gulf Coast aquifer system generally yields water containing from 500 to 1,000 mg/L dissolved solids. In much of the eastern part of the aquifer, the water contains about 300 to 500 mg/L dissolved solids. In the southern part of the aquifer, water generally is more saline. Along the Rio Grande valley in southern Texas, ground water generally contains between 1,000 and 1,500 mg/L dissolved solids. The median concentration of dissolved solids for the Gulf Coast aquifer system was 420 mg/L (fig. 2*C*). About 19 percent of the samples analyzed had dissolved-solids concentrations that exceeded 1,000 mg/L. The water was moderately hard, with a median hardness of 80 mg/L. At shallow depths, the water was hard; but below about 500 feet it softened, with sodium replacing calcium. Slightly more than 10 percent of the samples had nitrate concentrations that exceeded 10 mg/L. In 1985, about 40 water samples from the Gulf Coast aquifer system near Houston were analyzed for 15 trace-elements (J. L. Strause, U.S. Geological Survey, written commun., 1986). With the exception of barium and strontium, trace-element concentrations in most samples were less than 10 μg/L (micrograms per liter) for each of 15 elements. Barium had a median concentration of 220 μg/L, and strontium had a median concentration of 110 μg/L. Additionally, large concentrations of radionuclides have been detected in samples from several locations in this aquifer. Samples from several wells have gross alpha concentrations of more than 100 picocuries per liter (Texas Department of Health, written commun., 1985). The source of these radionuclides has not been defined, and no changes in ambient concentrations due to human activities have been identified.

High Plains (Ogallala) Aquifer

Although most of the water withdrawn from the High Plains (Ogallala) aquifer is used for irrigation, the water withdrawn for public supply provides the only source of drinking water for many towns and cities. Excessive ground-water withdrawals coupled with natural and human-induced salinity, natural fluoride concentrations, or increased nitrate concentrations due to human activities have threatened or decreased ground-water use in local areas. Dissolved-solids concentrations ranged from about 200 to 9,000 mg/L (Knowles and others, 1984), with a median concentration of 419 mg/L (fig. 2*C*). About 18 percent of the samples analyzed had dissolved-solids concentrations that exceeded 1,000 mg/L. The water was very hard, with a median hardness of 254 mg/L. Small and randomly distributed areas of saline water occur in the southeastern part of the aquifer in association with saline playa lakes. There, the water table is shallow, and salt deposits and evaporation cause an increase in ground-water salinity. In 25 percent of the analyses, the nitrate (as nitrogen) concentration exceeded 10 mg/L. Fluoride also can limit the aquifer as a source of public supply; almost 20 percent of the analyses had fluoride concentrations that exceeded 4.0 mg/L (fig. 2*C*).

Carrizo-Wilcox Aquifer

This aquifer provides irrigation and public supplies throughout much of east-central and southern Texas. The Carrizo-Wilcox yields fresh to slightly saline water that had dissolved-solids concentrations ranging from about 100 to 3,100 mg/L, with a median concentration of 369 mg/L (fig. 2*C*). Dissolved-solids concentrations in a farming area southwest of San Antonio ranged from about 100 to 3,100 mg/L (Klemt and others, 1976). About 10 percent of the samples had dissolved-solids concentrations that exceeded 1,000 mg/L. The water was moderately hard, with a median hardness of 72 mg/L. The exchange of calcium for sodium occurs with depth, and results in a decreasing hardness as in the Gulf Coast aquifer system (Foster, 1950). Nitrate and fluoride concentrations did not exceed State standards in any of the samples, but iron concentrations limit the use of water from the Carrizo-Wilcox aquifer in parts of east Texas (Texas Department of Water Resources, 1984b). Intensive withdrawals for irrigation in the farming area southwest of San Antonio have caused some leakage of saline water into the aquifer from overlying formations (Texas Department of Water Resources, 1984b, p. II–12).

Edwards (Balcones Fault Zone) Aquifer

The Edwards aquifer in the area of the Balcones fault zone provides water primarily for public supply, although some water is used for irrigation. The aquifer yields water through springflow that sustains not only a viable tourist economy but also downstream water rights. In the San Antonio area, the Edwards aquifer has been designated as a sole source aquifer by the U.S. Environmental Protection Agency (EPA). The dissolved-solids concentrations in the water ranged from about 200 to 3,000 mg/L (Baker and others, 1986), with a median concentration of 371 mg/L (fig. 2*C*). The water was very hard, with a median hardness of 270 mg/L. About 15 percent of the samples had nitrate concentrations that exceeded 10 mg/L. Between 1976 and 1985, about 50 water samples were analyzed for 14 trace elements (P.M. Buszka, U.S. Geological Survey, written commun., 1986). With the exception of barium and strontium, trace-element concentrations in most of the samples were smaller than 10 μg/L. Barium had a median concentration ranging from 110 to 140 μg/L in four classes of samples based on the depth of the water-yielding strata. Strontium had a median concentration ranging from 370 to 545 μg/L in three of the classes and 17,000 μg/L in the fourth class defined as the deeper confined zone.

Edwards-Trinity (Plateau) Aquifer

The Edwards-Trinity (Plateau) aquifer in the area of the Edwards Plateau yields water that is used primarily for irrigation but also for public supply. Dissolved-solids concentrations in the water ranged from about 200 to 3,500 mg/L (Walker, 1979), with a median concentration of 773 mg/L (fig. 2*C*) ; about 45 percent of the samples contained dissolved solids in excess of 1,000 mg/L. The water generally becomes more mineralized towards the western part of the area (Texas Department of Water Resources, 1984b; Walker, 1979). The water was very hard, with a median hardness of 407 mg/L. About 35 percent of the samples had nitrate concentrations that exceeded 10 mg/L.

Trinity Group aquifer

The Trinity Group aquifer provides public supplies in densely populated parts of northern Texas and irrigation supply throughout much of northern and central Texas. However, its use is becoming limited in some areas because of major declines in water levels. The dissolved-solids concentration of water ranged from about 70 to 3,500 mg/L (Nordstrom, 1982), with a median concentration of 619 mg/L (fig. 2*C*). About 25 percent of the samples had dissolved-solids concentrations that exceeded 1,000 mg/L. The water was very hard, with a median hardness of 258 mg/L. About 30 percent of the samples had nitrate concentrations that exceeded 10 mg/L.

Effects of Land Use on Water Quality

Water quality in the principal aquifers has been degraded in localized areas by the effects of ground-water withdrawals, urbanization, agricultural practices, industrial activity, and waste disposal.

Ground-Water Withdrawals

The most commonly documented type of ground-water degradation has been the increase in salinity caused by intensive ground-water withdrawal and migration of saline water toward centers of pumping. This degradation is a result of public, irrigation, and industrial ground-water withdrawals. Fewer instances of ground-water degradation involving nitrate, trace elements, and organic substances have been documented. Very few analyses are available for trace elements and organic substances in deep ground water. Records of individual well contamination are maintained by State agencies, but the records are not sufficiently consolidated to allow a statewide appraisal or general description of contamination (Association of State and Interstate Water Pollution Control Administrators, 1985, p. 29).

Urbanization

Increases in ground-water salinity due to public and industrial pumpage have occurred near several population centers in the Gulf Coast area, in northern Texas, and near El Paso. Isolated incidents of the introduction of synthetic organic substances into the ground water have been documented in San Antonio and Austin where the permeable Edwards (Balcones fault zone) aquifer is at land surface (Andrews and others, 1984; P.M. Buszka, U.S. Geological Survey, written commun., 1986).

Agricultural Practices

Nitrate in ground water occurs in several parts of Texas, predominantly within the Edwards-Trinity (Plateau) and the High Plains (Ogallala) aquifers and the alluvial and bolson deposits. The relative differences between human-induced contamination and naturally large concentrations of nitrate in water from these aquifers have not been well defined. Arsenic from cotton-gin waste has contaminated a limited part of the High Plains (Ogallala) aquifer (C. E. Nemir, Texas Department of Water Resources, written commun., 1984). The effects of widespread pesticide and fertilizer use throughout much of the State have not been determined.

The percentage of samples, by county, that contained nitrate concentrations in excess of Federal drinking-water standards (U.S. Environmental Protection Agency, 1986a) are shown in figure 4*A*; similar data for fluoride are shown in figure 4*B*. The greatest percentage of samples containing excessive nitrate are from counties in west Texas where the Edwards-Trinity (Plateau) and the High Plains (Ogallala) aquifers are the predominant water sources. The specific causes of these excessive concentrations have not been identified but probably result from a combination of naturally excessive concentrations and agricultural practices. The greatest percentage of samples containing excessive fluoride also is from counties in west Texas (High Plains aquifer) and probably are natural in origin (Gutentag and others, 1984).

Industrial Activity

The primary effects of industrial ground-water use have been the salinity increase resulting from excessive withdrawals, commonly occurring in combination with public-supply use. Most of the Class-I injection wells shown in figure 3*A* are used for the disposal of industrial waste. A majority of the industrial waste-disposal wells in Texas are located along the Gulf Coast and are used to inject chemical-petrochemical industrial effluent (fig. 3*A*). Only two of the Class-I injection wells have had to be plugged and abandoned as a result of leakage; aquifers containing freshwater were not endangered because of the leaks (W. B. Klemt, Texas Water Commission, oral commun., 1986). Nearly all the CERCLA sites are located within major urban centers and about 6 of the 21 have some type of shallow ground-water contamination involving minor elements or organic substances or both (Texas Water Commission, 1986). There are about 180 RCRA sites, and some type of shallow ground water contamination has occurred at more than one-half of them. Widespread degradation of drinking-water supplies has not been detected. However, the Texas Water Commission is in the midst of a multiyear effort to evaluate ground-water quality at these sites (P.S. Lewis, Texas Water Commission, oral commun., 1986).

In addition to the Class-I injection wells shown in figure 3*A*, the Railroad Commission of Texas has authorized, by permit, slightly more than 15,000 saltwater disposal wells and slightly more than 33,000 secondary-recovery injection wells used throughout the State for oil and gas production (Knape, 1984). Both types of wells range in depth from a few hundred feet to about 10,000 feet and have a basic requirement that the injection zone be below the base of moderately saline ground water (dissolved-solids concentration more than 10,000 mg/L). About 40,000 solution-mining wells also exist in the State (Texas Water Resources Institute, 1986). Most of these wells are used for mining sulfur in southeastern Texas and uranium in southern Texas. Extensive State regulations cover the operations of these wells.

Prior to the last 20 years, when unlined surface pits were used for disposing brines produced with oil, ground-water contamination by salts near oil- and gas-well operations was common. Although numerous instances of ground-water contamination from oil and gas activities have been reported (Shamburger, 1959; R.W. Harden and Associates, 1978; Sandeen, 1985;), their overall effects have not been evaluated thoroughly on a statewide basis.

Waste Disposal

Locations of waste-disposal sites regulated under RCRA, CERCLA, and UIC regulations are shown in figure 3*A*, and sites regulated as municipal landfills are shown in figure 3*B*. As of September 1985, 168 hazardous-waste sites at 19 facilities in Texas 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 the CERCLA. The EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Of the 168 sites in the program, 52 sites contained contaminants but did not present a hazard to the environment. Thirty-one sites at 7 facilities (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. Remedial action at three of these sites has been completed under the program. The remaining sites were scheduled for confirmation studies to determine if remedial action is required.

POTENTIAL FOR WATER-QUALITY CHANGES

Several major aquifers in Texas are susceptible to ground-water contamination because of hydrogeologic setting, projected ground-water withdrawals, or current and projected land use. The following is a brief list of some activities and their possible effects:

(1) Continued and accelerated intrusion of saline water is possible in most of the major aquifers in Texas but most likely will occur—under current ground-water withdrawal patterns—along the Gulf Coast, in the Trinity Group aquifer in northern Texas, and in the alluvium and bolson deposits near El Paso. Introduction of synthetic organic compounds and trace elements is a primary concern in the San Antonio and Austin areas where the Edwards (Balcones fault zone) aquifer allows rapid recharge of surface water into the ground-water system. In parts of the Gulf Coast aquifer system, radioactive ions from deposits containing radium are present in water wells. Continued development of ground-water supplies near Houston could result in individual wells producing water

with radionuclide concentrations at or near the limits established by national drinking-water standards.

(2) Degradation from the return flow of irrigation is possible in the High Plains (Ogallala) and Edwards-Trinity (Plateau) aquifers. The introduction of irrigation return flow containing excessive nitrate (as nitrogen) and pesticide concentrations to shallow, unconfined aquifers is most likely where the water table is shallow and where water-application rates are large.

(3) The potential effects of industry parallel those of urbanization, being greatest in the San Antonio and Austin areas where the permeable Edwards (Balcones fault zone) aquifer is at the surface. Degradation from the largest concentration of industrial waste-disposal sites in the Gulf Coast probably will continue to be ameliorated by the poorly permeable Beaumont clay at the surface. However, the danger of intrusion of contaminants through vertical avenues, such as abandoned well casings, will continue. Many of these industrial waste-disposal sites also are near the major population centers along the Gulf Coast. Similar types of degradation from oil and gas activities, past and present, are a continuing possibility throughout the State in all the major aquifers.

GROUND-WATER-QUALITY MANAGEMENT

State legislation to regulate ground-water quality is contained primarily in the Texas Water Code, Chapters 16, 26, 27, 28, 29, and 52. Ground-water-protection programs in Texas are administered by six agencies: the Texas Water Commission, the Texas Water Development Board, the Texas Water Well Drillers Board, the Railroad Commission of Texas, the Texas Department of Health, and the Texas Department of Agriculture.

The Water Commission, as the lead agency for water resources, has the responsibility to coordinate the State's efforts to develop a comprehensive ground-water-protection strategy. The Water Commission's ground-water policy is to help ensure maintenance of the State's ground-water quality through planning and education, and cooperation with other State agencies and the public and private sectors. Four Federal laws administered in some degree by the Commission include: the Safe Drinking Water Act; the Resource Conservation and Recovery Act; the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund); and the Clean Water Act. State legislation administered by the Commission includes the Texas Water Code, the Texas Solid Waste Disposal Act, and the Texas Water Well Drillers Act. The Commission, in response to State and Federal mandates, has promulgated rules that establish waste-disposal regulatory programs and that outline technical and administrative requirements for meeting goals of the individual programs. A State-funded Superfund program recently has identified 14 sites for consideration from a list of more than 100 sites judged to be potential threats but which did not meet criteria for the Federal program (Kidd, 1986). Deep-well waste injection has been regulated since the passage of the Texas Disposal Well Act in 1962, and the current program contains technical elements more restrictive than Federal requirements. A feature of this program in Texas is a mandatory "area of review" requirement of a 2.5-mile radius from the well for Class-I injection wells.

The purposes and policies of the Texas Water Development Board are to collect and analyze ground-water data and to assist users of this information. The Board's activities include investigations of the occurrence, quantity, quality, and availability of ground-water resources; operation of ground-water level and quality-monitoring networks; estimation of future water supplies; determination of current water use and projections of future water demands; and development of plans to meet future water demands. A ground-water-quality monitoring program operated by the Board includes the collection of about 700 samples per year from a network of 5,700 wells for analysis of several inorganic constituents.

The Texas Water Well Drillers Board was created and charged by the Legislature to help ensure the quality of the State's ground water through the licensing of water-well drillers. Staff and assistance are provided to the Board by the Texas Water Commission.

The Oil and [redacted] protects ground water [redacted] associated with the exploration, development, and production of oil, gas, and geothermal resources through several provisions of the Texas Natural Resources Code and the Texas Water Code. The EPA delegated authority to the Railroad Commission to administer an underground-injection control program through the Safe Drinking Water Act to regulate injection wells associated with oil and gas operations (Class-II wells). The Surface Mining and Reclamation Division of the Railroad Commission protects ground water from pollution by surface-mining activities through the Texas Surface Mining and Reclamation Act.

The Texas Department of Health is involved in ground-water protection through activities and functions administered by three separate sections—Division of Water Hygiene, Bureau of Solid Waste Management, and Bureau of Radiation Control. Federal (Safe Drinking Water Act, Resource Conservation and Recovery Act, Atomic Energy Act, Uranium Mill Tailings Radiation Control Act) and State (Texas Sanitation and Health Protection Law, Texas Solid Waste Disposal Act, and Texas Radiation Control Act) legislation establishes authority and specifies functions to be administered by these three sections.

The Texas Department of Agriculture's role in the protection of ground water is to ensure compliance with Federal and State laws and with regulations relating to pesticide distribution and use. Under the Federal Insecticide, Fungicide, and Rodenticide Act, the Department has primary enforcement responsibility for pesticide-use violations.

Additionally, 17 underground water conservation districts have been created in Texas through specific administrative and electoral procedures (Chapter 52 of the Texas Water Code) or by the Legislature to monitor, protect, and conserve ground water in particular geographic areas. Special regulations are imposed on certain activities in the recharge zone of the Edwards (Balcones fault zone) aquifer in the San Antonio area. Some of the regulations are enforced locally and others are enforced by State and Federal agencies.

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A

Figure 1. Selected geographic features and 1985 population distribution in Texas. *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.)

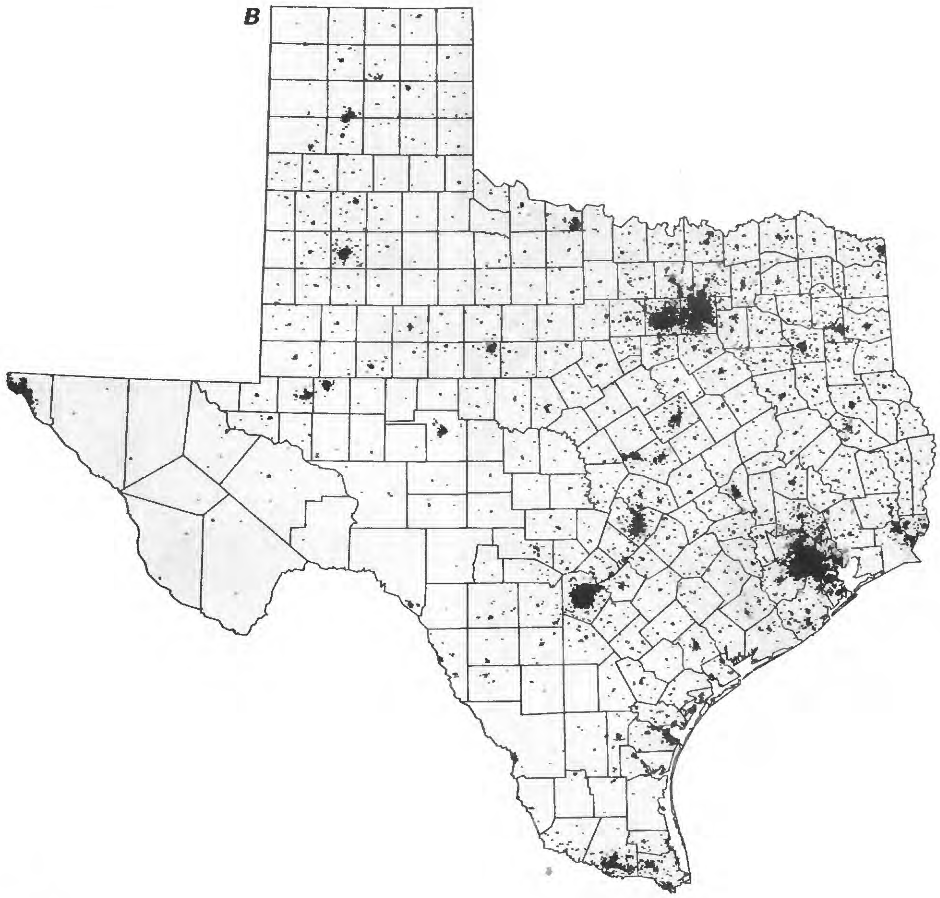


Figure 1. —Continued.

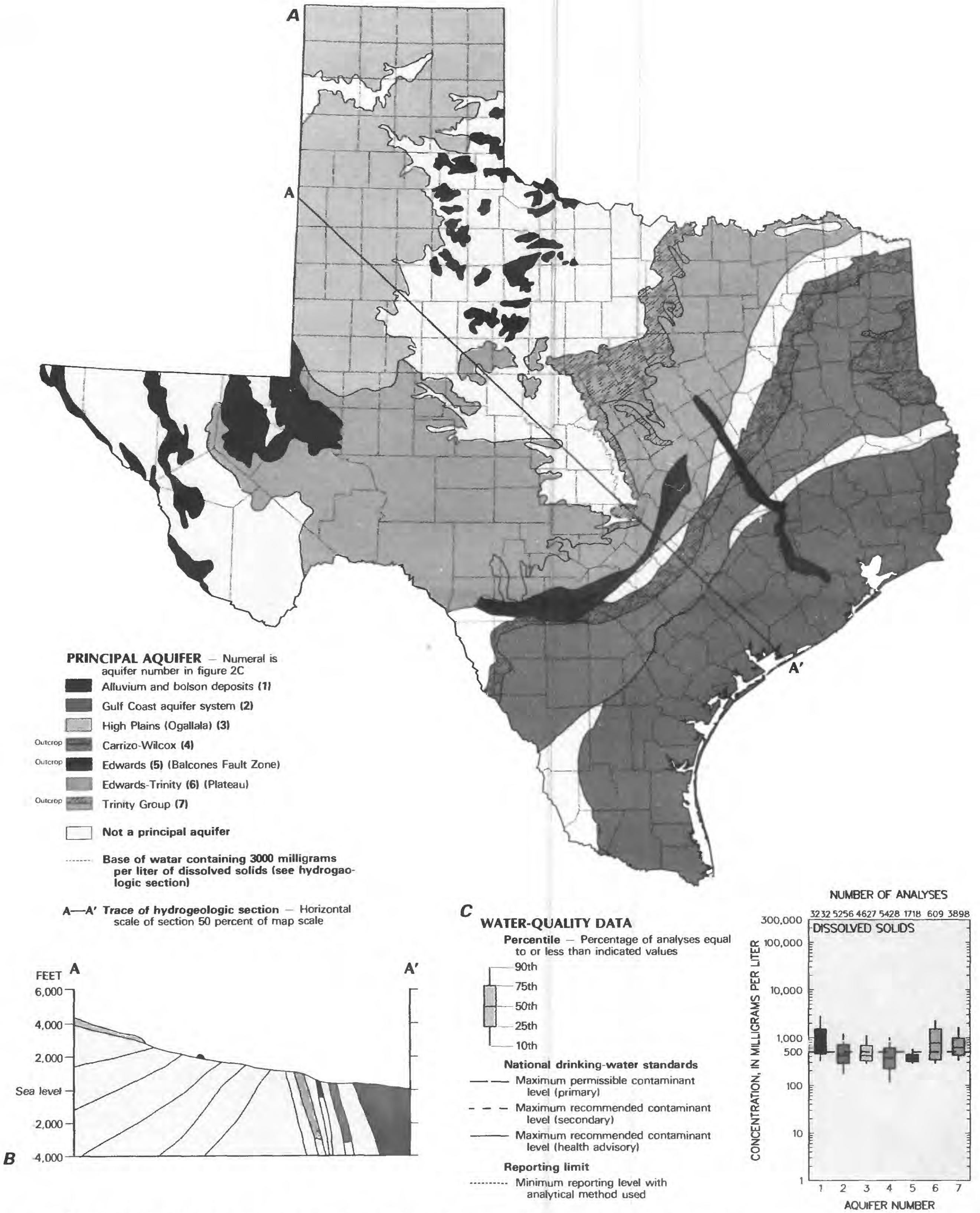
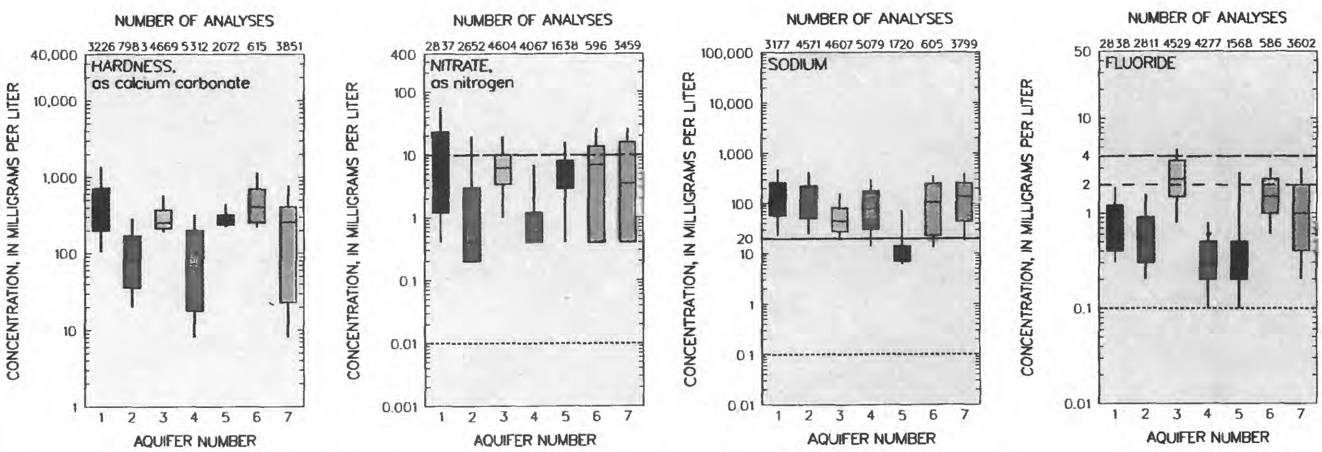


Figure 2. **Principal aquifers and related water-quality data in Texas.** *A*, Principal aquifers; *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1900-86. (Sources: *A*, Modified from Texas Department of Water Resources, 1984b. *B*, Compiled by E.T. Baker, Jr., from U.S. Geological Survey files. *C*, Analyses compiled from Texas Water Board files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)



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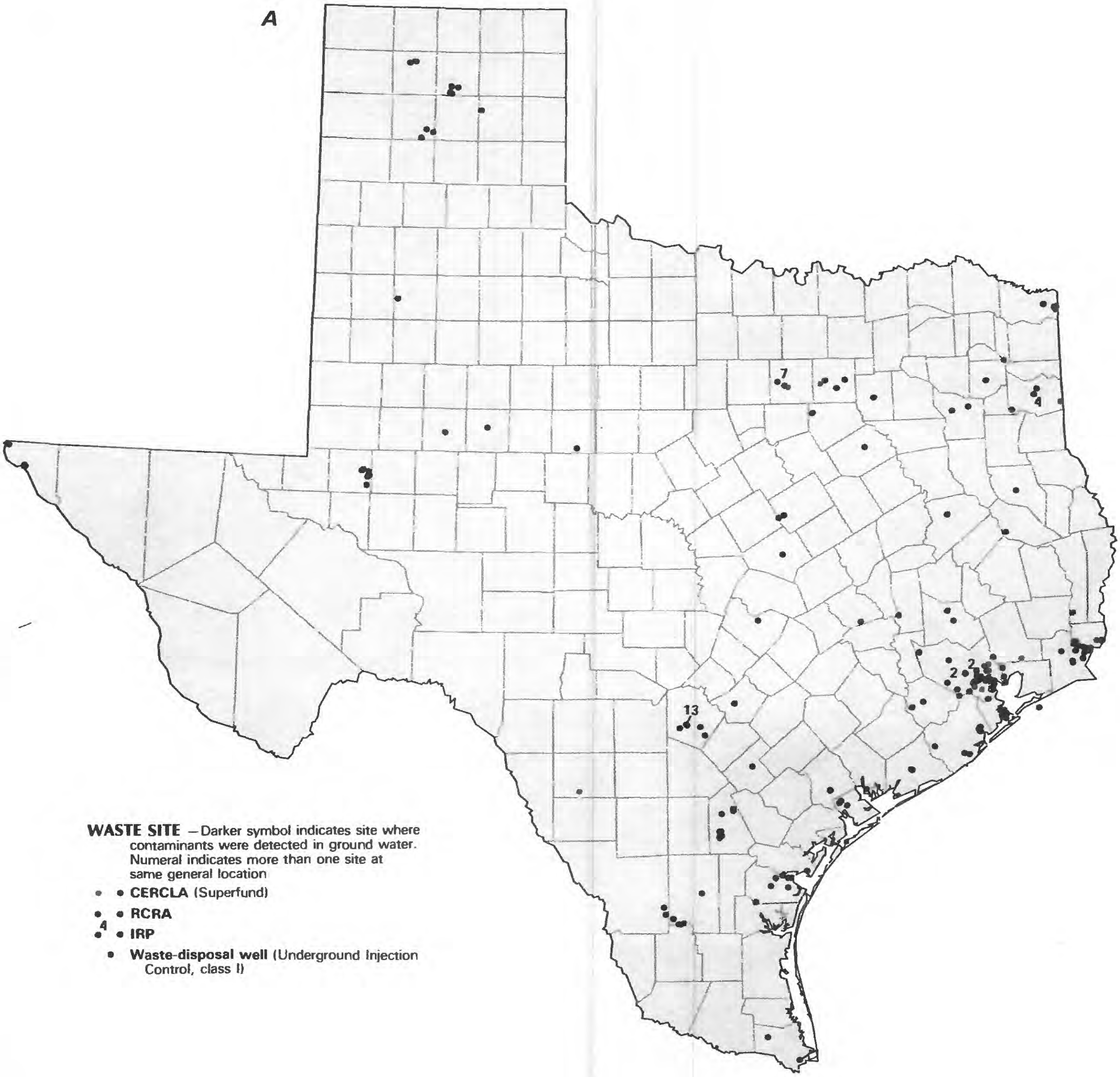
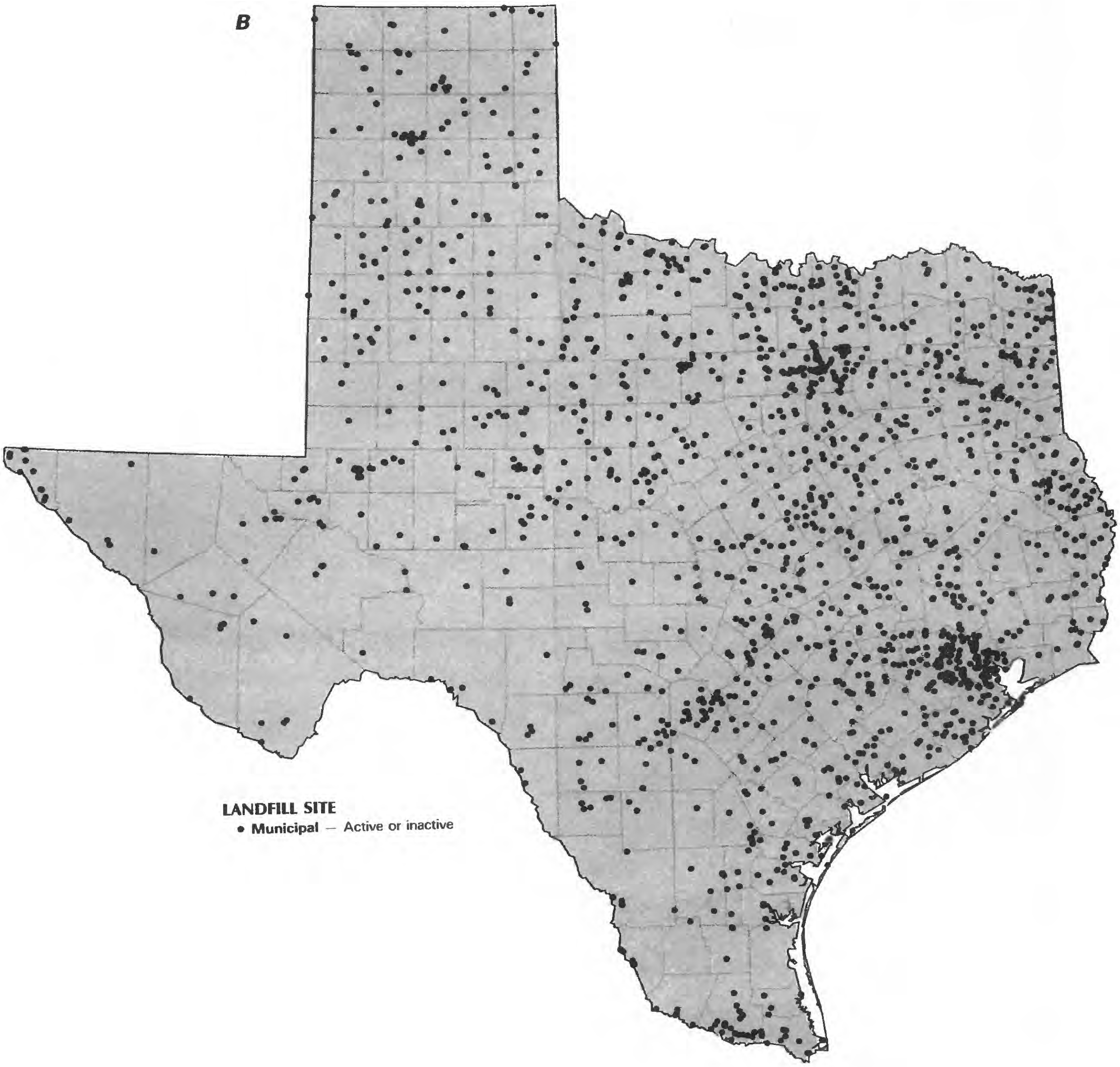


Figure 3. Selected waste sites and ground-water-quality information in Texas. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; Resource Conservation and Recovery Act (RCRA) sites, as of 1986; Department of Defense Installation Restoration Program (IRP) sites, as of 1985; and other selected waste sites, as of 1986. *B*, Municipal landfills, as of 1986. (Sources: *A*, CERCLA, RCRA, and other waste-disposal sites, Texas Water Commission files; IRP sites, U.S. Department of Defense, 1986. *B*, Texas Department of Health files.)



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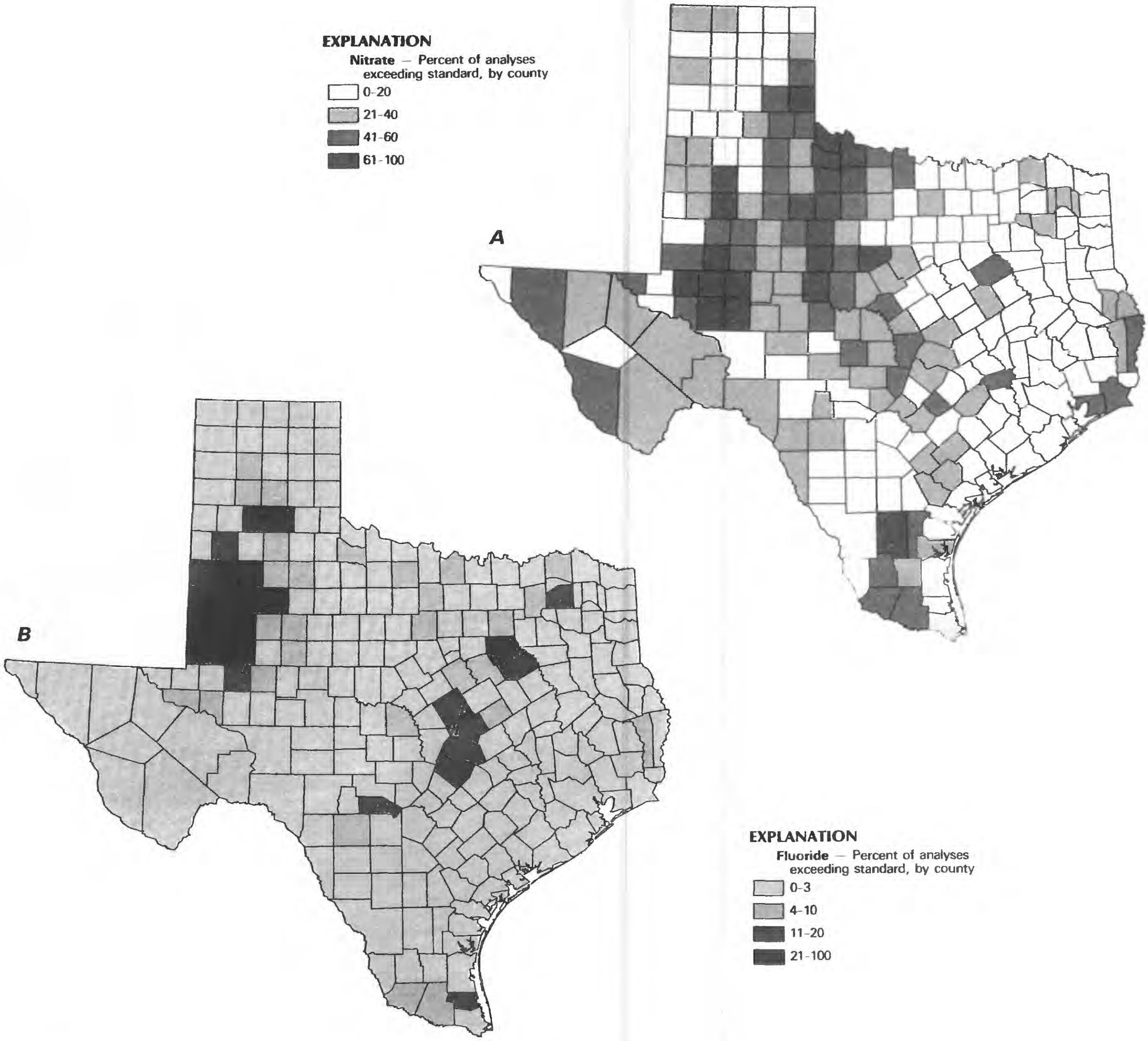

Figure 4. Percentage of water-quality analyses that exceed U.S. Environmental Protection Agency national drinking-water standards for (*A*) nitrate and (*B*) fluoride, by county. (Source: Texas Water Commission files).