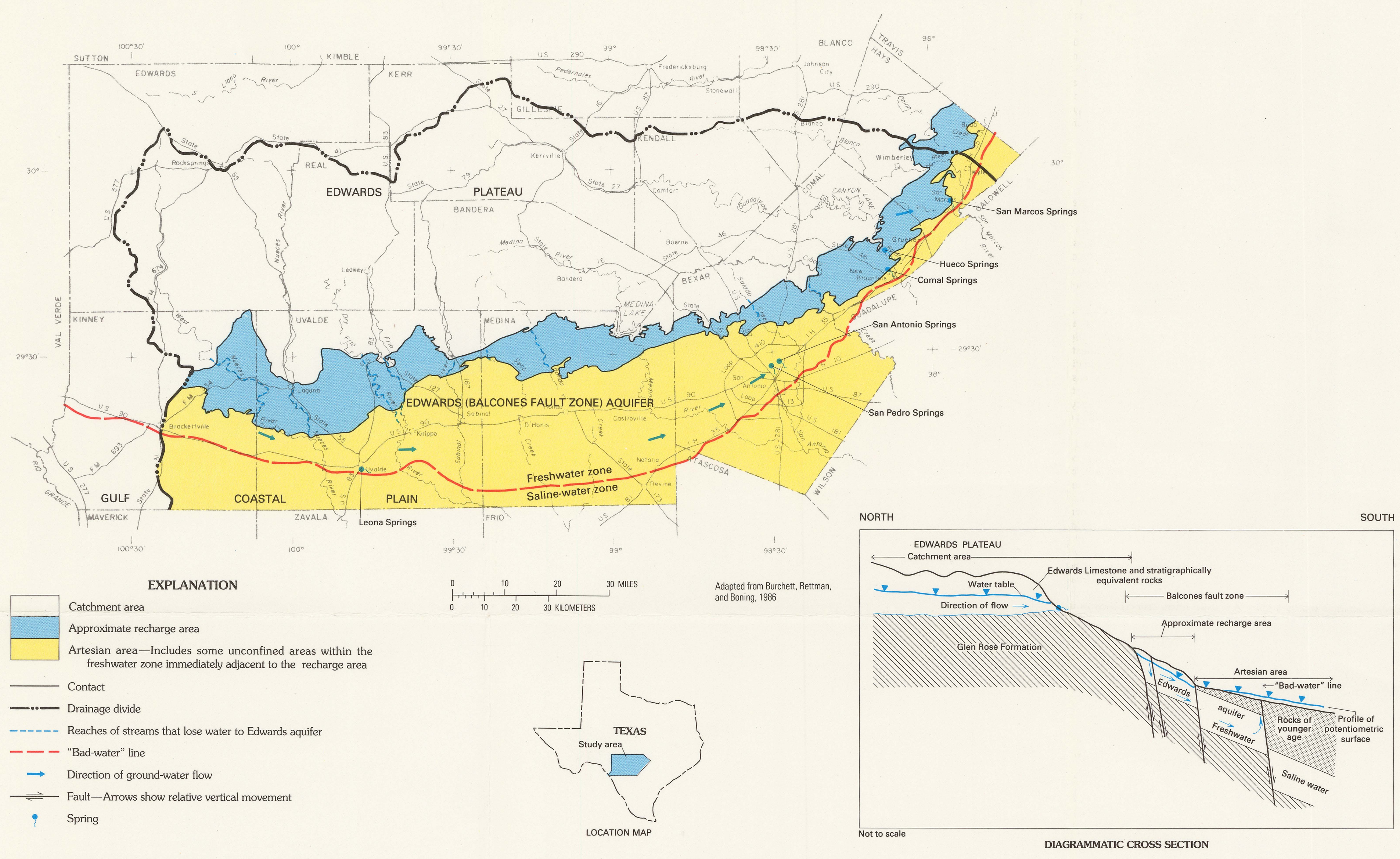


Figure 1. Hydrologic setting.

INTRODUCTION

The Edwards aquifer in south-central Texas is one of the most productive and most important aquifers in the State, with an average annual discharge of about 608,000 acre-ft of water during 1932–82 (Reeves and Ozuna, 1985). The Edwards aquifer is the principal source of water for municipal, industrial, and irrigation use in all or parts of five counties—Bexar, Comal, Hays, Medina, and Uvalde—and is the only source of water for San Antonio, the tenth-largest city in the United States (1980 population, 786,000) (A.H. Belo Corporation, 1985).

Since 1930, the U.S. Geological Survey has conducted many investigations of the Edwards aquifer and of streams that contribute recharge to the aquifer (Arnow, 1959; DeCook, 1963; George, 1952). Early investigations showed that the Edwards aquifer consisted of freshwater and saline-water zones separated by a narrow transitional zone, locally called the "bad-water" line (fig. 1).

Dissolved-solids concentrations are about 1,000 mg/L (milligrams per liter) along the "bad-water" line. To the south and southeast of the "bad-water" line, dissolved-solids concentrations increase sharply in the saline-water zone, whereas to the north and northwest of this line, dissolved-solids concentrations range only from about 200 to 400 mg/L in the freshwater zone. Within the freshwater zone, several areas with differing water-quality characteristics have been delineated, on the basis of differences in ion concentrations (Maclay, Rettman, and Small, 1980; Pearson and Rettman, 1976).

Hydrogeologic investigations have determined that the Edwards aquifer is extremely permeable, porous, and productive (Maclay and Rettman, 1973; Maclay and Small, 1984; Maclay, Small, and Rettman, 1980; Puente, 1976). These investigations and a tritium investigation by Pearson and others (1975) also determined that the aquifer has a complex flow pattern and that water moves into and through the aquifer at a relatively fast rate.

Although there were relatively few sources of water pollution until the middle 1900's, the hydrologic characteristics of the aquifer—rapid recharge, extremely large permeability and porosity, and relatively rapid movement of water—indicated that the aquifer could be contaminated relatively quickly. During the past few decades, agricultural operations and urbanization have intensified, and the public is concerned that some areas of the Edwards aquifer might contain contaminants—nutrients, trace elements, pesticides, and bacteria. The analysis for these possible contaminants was beyond the scope of the earlier investigations.

In response to these concerns and because of the importance of the Edwards aquifer to the San Antonio region, the U.S. Environmental Protection Agency (EPA) designated the Edwards aquifer as one of the few "sole-source aquifers" in the Nation, and development projects in the area for which Federal funding is sought are reviewed by the EPA for potential effects on the aquifer. Additionally, the Geological Survey began investigations, in cooperation with the Texas Water Development Board (TWDB), the Edwards Underground Water District (EUWD), and the San Antonio City Water Board, to detect contaminants in the aquifer or in streams which recharge the aquifer.

In 1968, an intensive ground-water-quality investigation, in cooperation with the TWDB and EUWD, began with the annual sampling of about 100 wells. The results of these water analyses are described in Reeves (1976, 1978), Reeves and Blakey (1970), Reeves and others (1972, 1980, 1981, 1982, and 1984), and Reeves and Ozuna (1985). Also in 1968, a surface-water-quality investigation began, in cooperation with the TWDB and the City of San Antonio, to determine the quality of urban runoff in San Antonio. Four of the creeks involved in this study—Olmos Creek tributary, Lorence Creek, West Elm Creek, and East Elm Creek—contribute recharge to the Edwards aquifer. The annual results of this investigation are described in Gonzalez (1976), Harmsen (1977, 1978), Land (1971, 1972), Perez (1981, 1982, 1983), Perez and Harmsen (1980), and Steger (1973, 1974, 1975).

In 1974, another surface-water-quality investigation began, in cooperation with the TWDB and EUWD, that focused on the eight streams which supply nearly all of the recharge to the Edwards aquifer in the San Antonio region. Streams in this study included, from west to east, the Nueces River, Dry Frio River, Frio River, Sabinal River, Seco Creek, Hondo Creek, Medina River, and Blanco River. Analytical results of this investigation were published in a series of annual Geological Survey reports entitled "Water Resources Data for Texas" (U.S. Geological Survey, 1968–84). Additionally, the EUWD published a summary and an update of the ground-water-quality data and some of the surface-water-quality data for 1968–72 (Reeves and others, 1972) and for 1968–75 (Reeves, 1976).

This report provides statistical summaries of selected data from the three most recent investigations and is based on analyses of samples collected from 1968 to 1983. In addition, the aquifer is divided and streams are grouped into subareas, which differ with respect to dissolved solids and likelihood of water quality being affected by urbanization or agricultural practices. Water-quality differences among these subareas are summarized and compared to primary and secondary drinking-water regulations established by the EPA (U.S. Environmental Protection Agency, 1986a,b).

HYDROLOGIC SETTING

The study area encompasses about 7,500 mi² and includes both the Edwards aquifer and the watersheds that supply recharge to the aquifer (fig. 1). The study area, commonly referred to as the San Antonio region, is bounded by a locally ill-defined ground-water divide in part of Kinney County on the west, by the watershed divides on the north and west, and by the county boundaries of Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties on the south and east. The study area is composed of three smaller divisions—the catchment area, the approximate recharge area, and the artesian area (fig. 1).

The catchment area comprises about one-half of the study area and encompasses the watersheds of streams that flow across the recharge area. The catchment area is located along the southern and southeastern edge of the Edwards Plateau physiographic province. The Edwards Limestone and stratigraphically equivalent rocks, shown in diagrammatic cross section (fig. 1), cap the high plateau in the western part of the catchment area. In the eastern part, erosion of the cap has exposed the older, underlying Glen Rose Formation. The eroded part of the plateau is known locally as the "Hill Country" and is characterized by stair-step topography (Maclay and Small, 1984). Land use in the area is predominantly ranching.

The recharge area comprises about one-sixth of the study area and is located south of the catchment area where the aquifer either crops out or is covered by porous and permeable alluvium. The recharge area is located in the Balcones fault zone, an arc of geological faults in the middle of the study area. The recharge area marks the northwest edge of the Gulf Coastal Plain physiographic province. Land use in the area is mostly ranching, except for notable limestone mining areas and residential development near San Antonio, San Marcos, and New Braunfels.

The artesian area comprises about one-third of the study area and is located south of the recharge area where the Edwards aquifer is overlain by confining layers of middle and upper Cretaceous marl, clay, and limestone. The artesian area lies within the Gulf Coastal Plain physiographic province and is characterized by flat or rolling topography. Land use in the artesian area of Kinney, Uvalde, and Medina Counties is mostly farming and small urban districts such as the city of Uvalde, whereas land use in the artesian area of Bexar, Comal, and Hays Counties is mostly mixed-use urban.

RECHARGE AND DISCHARGE

From 1932 to 1982, the recharge to the Edwards aquifer has approximately equalled the discharge, annually about 608,000 acre-ft. Published records (Reeves and others, 1985) indicate that about 65 percent of the total recharge enters the aquifer in Uvalde and Medina Counties, about 33 percent enters in Bexar, Comal, and Hays Counties, and about 2 percent enters in Kinney County. Although some water is withdrawn from wells in Uvalde and Medina Counties, most of the discharge occurs in Bexar, Comal, and Hays Counties by pumpage through numerous large-yield municipal wells in the vicinity of San Antonio, and by springflow from Comal and San Marcos Springs.

Precipitation within the study area accounts for nearly all of the recharge to the aquifer, and precipitation within the catchment area accounts for most of this recharge (Puente, 1975, 1976). Precipitation ranges from about 21 in/yr in the western part of the study area to about 34 in/yr in the northeastern part (Reeves and Ozuna, 1985).

A significant amount of the precipitation in the catchment area rapidly infiltrates the limestone cap and eventually emerges through springs and seeps at many points along the contact of the base of the Edwards Limestone and the underlying, less permeable Glen Rose Formation. These springs and seeps are the major sources of water which sustain the base flows of streams that originate in the catchment area. Except for the Guadalupe River, nearly all of these base flows become recharge to the Edwards aquifer where the streams cross the recharge area. Large volumes of extremely variable stormflows from these streams also recharge the aquifer. Direct infiltration of precipitation in the recharge area contributes a relatively small percentage of recharge, and stormflows on creeks which head in the recharge area, including creeks in the San Antonio urban area, contribute very small volumes of recharge. The ground-water inflow from the Glen Rose and other formations is very small relative to recharge from surface-water sources.

GROUND-WATER-FLOW PATTERNS AND HYDROLOGIC PROPERTIES

Ground-water-flow patterns within the Edwards aquifer depend on the volume of recharge and discharge and location of recharge and discharge areas and on the aquifer's transmissivity, a measure of the quantity of water that can travel through the full vertical extent of the aquifer. Transmissivity values are extremely variable for the Edwards aquifer (Maclay and others, 1986; Maclay and Small, 1984). The aquifer lies within the Balcones fault zone, and many of the faults have throws that completely displace the entire thickness of the aquifer. Hence, the transmissivity across these fault barriers is extremely small. Transmissivity values in areas not associated with the fault barriers depend on the variable permeabilities of the limestone layers and commonly range from 200,000 to 2 million ft²/d in the freshwater zone. Within the freshwater zone, transmissivities generally are about 500,000 ft²/d in most of Medina and Bexar Counties and may be as large as 2 million ft²/d near major springs. Transmissivities are much smaller in the saline-water zone.

Most water which recharges the aquifer moves rapidly through the unsaturated zone. Ground water in the recharge area generally flows toward the south and southeast into the artesian area. In Kinney, Uvalde, and Medina Counties, ground water within the unconfined zone generally moves southward to the confined zone, but locally the movement is diverted by barriers occurring along major faults. Within the confined zone, water regionally moves eastward through the permeable limestones, but again is diverted locally by fault barriers. One such hydraulic barrier is located between the towns of Uvalde and Knippa and is a major restriction of flow between southern Uvalde County and the downfaulted parts of the aquifer in Medina and Bexar Counties. In Bexar, Comal, and Hays Counties, part of the recharged water moves downdip to the confined zone and then toward the northeast, whereas the rest of the water moves to the northeast within the unconfined zone. In all of these counties, much less flow occurs in the saline-water zone.

CONVERSION FACTORS

Some values in this report are given in inch-pound units. Conversion factors for metric (International System) units are listed below:

Multiply inch-pound units	By	To obtain metric units
acre-foot (acre-ft)	0.001233	cubic hectometer
foot (ft)	0.3048	meter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
square foot per day (ft²/d)	0.09290	square meter per day
square mile (mi²)	2.590	square kilometer

GROUND-WATER-QUALITY SITES

In the ground-water data-collection program, 274 sites in the Edwards aquifer and 5 sites in the Glen Rose Formation were sampled (fig. 2). This reconnaissance network was designed to detect regional contamination within the aquifer and included 276 wells, 2 springs, and Woodard Cave. Nearly two-thirds of the sites were sampled only once or twice during 1968–83, but a few sites were sampled many more times. Many of the wells that were sampled more than twice were not sampled on a regular basis. For example, one well was sampled for nutrients 3 times in 1970, 13 times in 1971, 1 time in 1972, and 1 time in 1974. Another well was sampled 57 times for bacteria during 1972–73, including 18 times in 1 day, but was not sampled at all before or after this 2-year period. Samples usually were analyzed for specific conductance, pH, water temperature, dissolved solids, nutrients, and bacteria. At three wells, only samples for specific conductance and bacteria were collected. Some samples were also analyzed for trace elements and pesticides, and at seven wells, samples were collected only for pesticide analysis.

SURFACE-WATER-QUALITY SITES

Nine sites (fig. 2) on eight rivers and major creeks—Nueces River, Dry Frio River, Frio River, Sabinal River, Seco Creek, Hondo Creek, Medina River, and Blanco River—have been sampled in the catchment area since 1974. Bimonthly samples were collected from 1974 to 1979, and three samples per year—winter, spring, and summer—were collected during 1980-83. The Blanco River site was sampled from 1974 to 1979; the lower Medina River site was sampled from 1974 to 1982; and the upper Medina River site was sampled in 1983. The rest of the sites were sampled from 1974 to 1983. In general, all samples were analyzed for specific conductance, pH, water temperature, dissolved solids, nutrients, and bacteria.

Four sites (fig. 2) on creeks with watersheds located entirely in the recharge area were sampled since 1968 as part of an urban runoff study. None of these four creeks were sampled every year, either because the creek was not in the investigation during that year or because samples were not collected during some dry years. During years when there were frequent stormflows, each of these creeks was sampled from 5 to 10 times, and up to 5 samples were collected per storm. The periods of record for the sampling of these creeks are: Olmos Creek tributary, 1968–81; West Elm Creek, 1976–83; East Elm Creek, 1976–83; and Lorence Creek 1980–83.

STATISTICAL METHODS

Because of the irregular distribution of available data, and the differing characteristics of the sites, standard statistical compilations of means are not used. Instead, time-nested-average concentrations and other statistics are used to summarize the data by site; hydrologic differences are used to categorize the sites for comparison of subareas. Time-nested-average concentrations are computed for dissolved solids, nutrients, dissolved metals, and bacteria at each site by successively averaging concentrations for individual days, months, years, and during the period of record. For example, the time-nested-average concentrations at a site with three samples collected on March 1, one sample on March 15, two samples in June of a given year, and one sample in each of the 2 successive years would be calculated by first averaging the concentrations of the three samples collected March 1, averaging that result with the concentration of the March 15 sample, averaging that value with the average of the two June samples, and finally, averaging that result with the values of the samples collected in the 2 successive years. This final value would be considered the time-nested-average concentration for the period of record at this site.

For ammonia, phosphorus, dissolved metals, pesticides, and bacteria, concentrations often are very small, and for these constituents, the number of sites with detected concentrations is determined. Results are compiled in tables 2–6. For selected constituents, time-nested-average concentrations at each site are shown in maps to illustrate distributional patterns in the aquifer and the surface-water sites. Comparisons of neighboring wells should be made with caution, however, because samples may have been collected at times when flow patterns, water levels, seasons, or antecedent conditions were different. Samples from adjacent wells may not be comparable because (1) the wells may penetrate different layers containing water of different quality; (2) more than half of the wells were sampled only once or twice; or (3) errors in collection, preservation, or laboratory analysis may have occurred. Maximum and minimum concentrations and sample numbers for each constituent are compiled by subareas. For most constituents, frequency distributions of time-nested averages are compiled by subarea, with each site having equal weight within the subarea. Additionally, for ammonia, phosphorus, dissolved metals, pesticides, and bacteria, the "percent of sites with detectable concentrations" is compiled by subarea.

HYDROLOGIC SUBAREAS

Sampling sites are divided into hydrologic subareas, on the basis of data from previous studies and the three phases of this study. Ground-water sites are grouped into eight subareas, and surface-water sites are divided into two subareas (table 1).

The Edwards aquifer is divided into seven subareas on the basis of flowpaths, results of past and present water-quality studies, and the likelihood of anthropogenic impacts (table 1). Wells in the freshwater zone with time-nested-average dissolved-solids concentrations less than 600 mg/L are grouped into five subareas. Differences in concentrations in water between neighboring wells among these five subareas often are not pronounced, and subarea boundaries arbitrarily parallel county lines or latitude/longitude lines for simplicity. Wells just north of the "bad-water" line with dissolved-solids concentrations ranging between 600 and 1,000 mg/L are grouped in the transition subarea, and the wells in the saline-water zone are grouped in the saline-water subarea. With the exception of the Uvalde subarea, the ground-water subareas divide the freshwater part of the aquifer into segments along regional flowpaths.

As shown in table 1, the effects of urbanization, which include increased concentrations of metals and pesticides and bacteria densities, are most likely to be detected in the north Bexar subarea. The effects of agricultural practices, which include increased concentrations of nutrients and pesticides and increased fecal streptococci densities, are most likely to be detected in the Uvalde subarea. These effects are least likely to be detected in the artesian area of the Medina-Bexar subarea.

The remaining ground-water sites are in the Glen Rose Formation. These sites are included as a subarea, because there may be some cross-formational flow between the Glen Rose Formation and the Edwards aquifer.

Although samples were collected at three sites in Woodard Cave, the cave is not considered representative of any subarea. Time-nested-average concentrations for selected constituents for all sampling sites are shown in figure 3. Statistical results, however, are given by hydrologic subarea in tables 2–6 for only the samples collected from wells, springs, and surface-water sites.

The nine surface-water sites on the spring-fed rivers and major streams that contribute almost all of the recharge to the aquifer are in the rural subarea. The four surface-water sites on creeks in the urban area in north Bexar County are in the urban subarea. Nearly all of the samples from sites in the rural area were collected during periods of base flow from ranchland areas. At these times, the flow is composed mostly of springwater which has emerged from the Edwards Limestone in the rural catchment area, and dissolved-solids concentrations are about 250 mg/L. In contrast, nearly all of the samples from the sites in the urban area were collected during periods of stormflow from urban areas. At these times, the flow is composed mostly of rainwater that has collected large quantities of suspended material containing pollutants washed from streets, parking lots, lawns, and other urban areas. Dissolved-solids concentrations of samples from these sites usually are less than 100 mg/L, but the water may contain large concentrations of trace elements such as lead and organic compounds such as oil and gasoline.

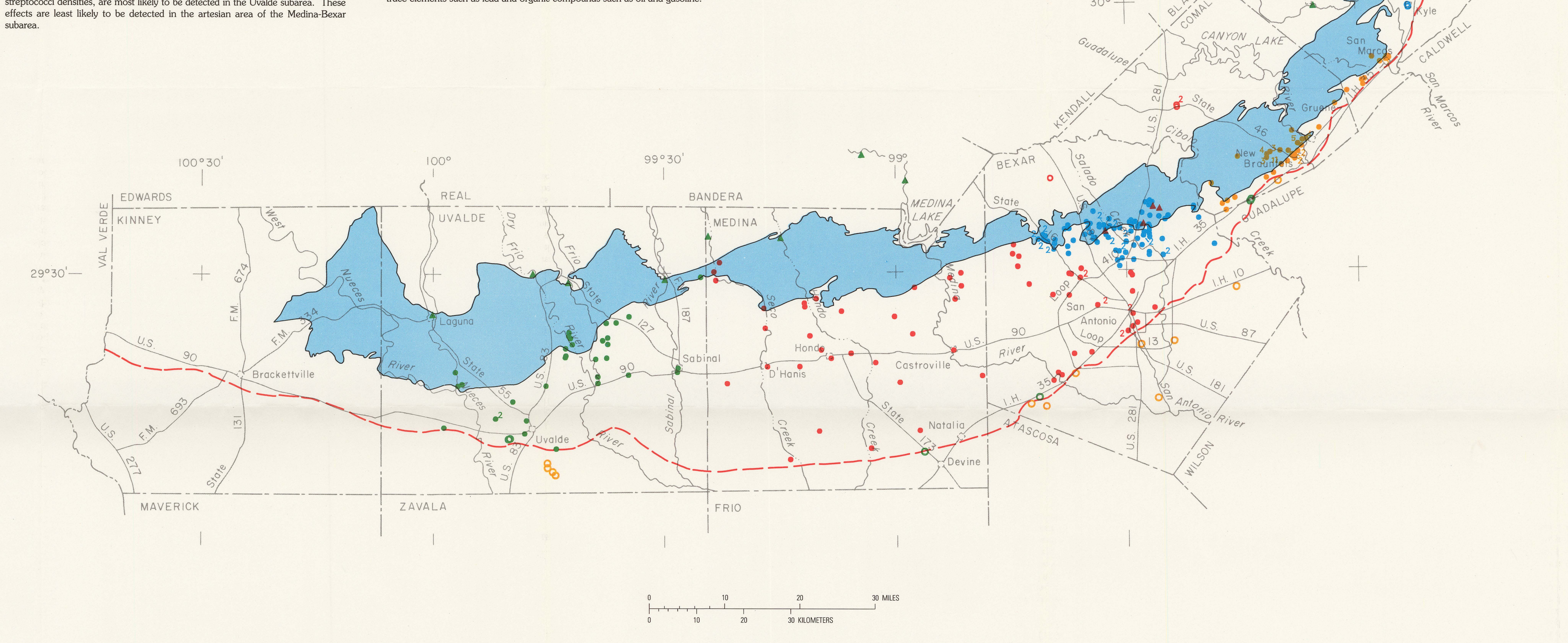


Figure 2. Locations of water-quality data-collection sites and hydrologic subareas.

EXPLANATION

Approximate recharge area (adapted from Burchett, Rettman, and Boning, 1986)

"Bad-water" line

Sites in hydrologic subareas—Number indicates the number of wells at location

- Urban
- Rural
- Medina-Bexar
- Uvalde
- North Bexar
- Comal-Hays
- North Hays
- Transition
- Saline water
- Glen Rose

Table 1. *Summary of characteristics of hydrologic subareas*

[mg/L, milligrams per liter; ft, feet; >, more than; <, less than]

Hydrologic subarea	Typical range of dissolved-solids concentration (mg/L)	Major source of ground water	Depth to ground water below land surface (ft)	Potential sources of degraded ground-water quality[1]
		Ground-water subareas		
Edwards aquifer subarea				
Medina-Bexar	200-300	Surface recharge and inflow from northern Uvalde County	50-400	Ranchland
Uvalde	250-400	Surface recharge	50-200	Farmland and ranchland
North Bexar	250-400	Surface recharge and inflow from northern Medina County	50-100	Urban
Comal-Hays	300-400	Inflow from Bexar County and some surface recharge	50-100	Urban
North Hays	300-400	Surface recharge	50-75	Ranchland
Transition	600-1,000	--	200-600	Geology
Saline water	>1,000	--	400-800	Geology
Glen Rose Formation subarea				
Glen Rose	250-500	Surface recharge	100-200	Ranchland

Hydrologic subarea	Typical range of dissolved-solids concentration (mg/L)	Source of flow for most samples	Location of watershed	Potential sources of degraded ground-water quality[1]
		Surface-water subareas		
Rural	200-400	Base flow	Catchment area	No appreciable sources
Urban	<100	Stormflow	Recharge area	Urban

[1] Urban sources can contribute increased concentrations of some nutrients, metals, and pesticides and densities of bacteria. Farmland sources can contribute increased concentrations of some nutrients and pesticides. Ranchland sources can contribute increased concentrations of some nutrients and densities of fecal streptococci. Geological formations can contribute increased concentrations of dissolved solids and decreased concentrations of dissolved oxygen.

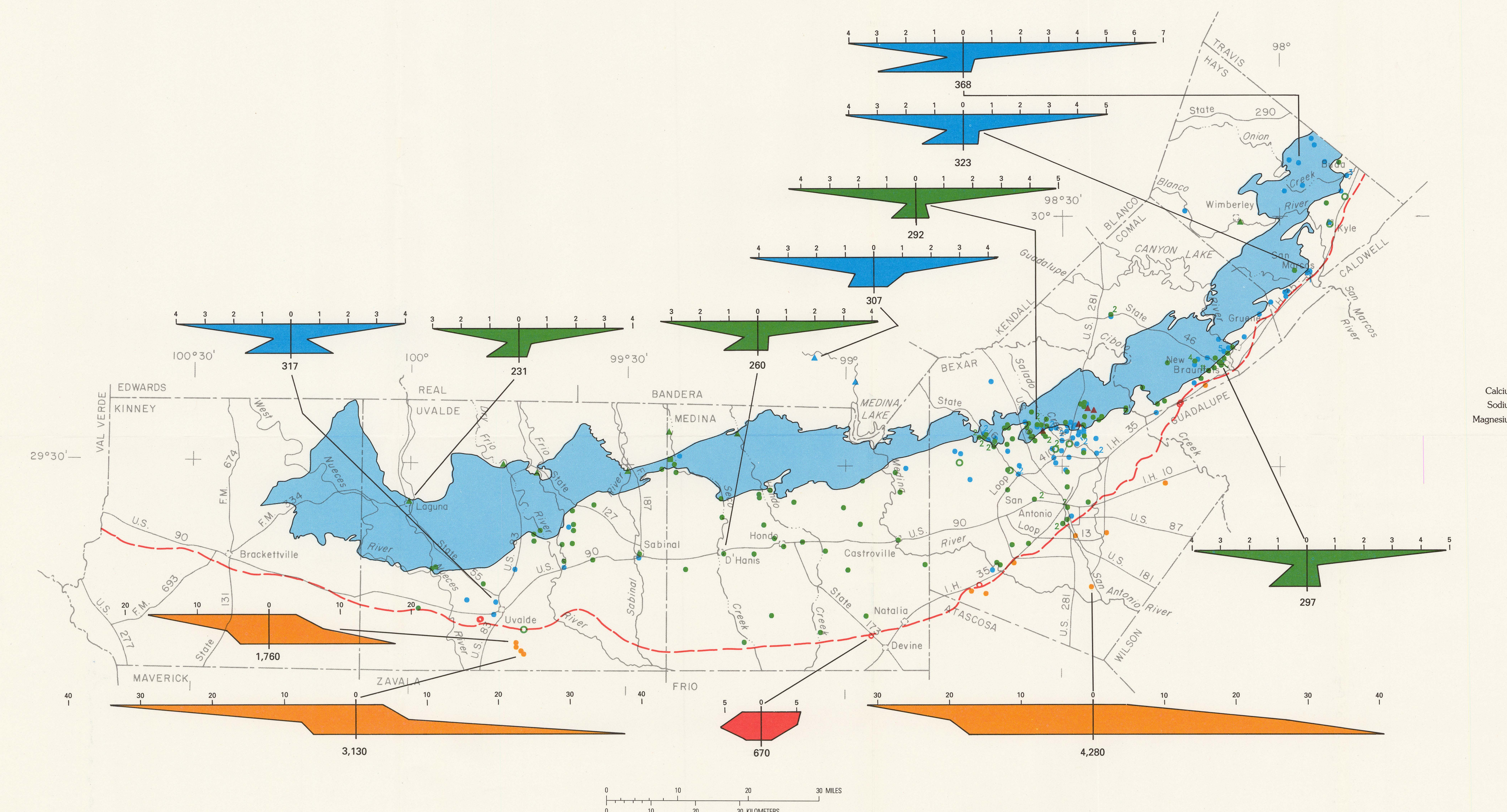


Figure 3. Areal distribution of dissolved-solids concentrations and water types.

EXPLANATION

Approximate recharge area (adapted from Burchett, Rettman, and Boning, 1986)

"Bad-water" line

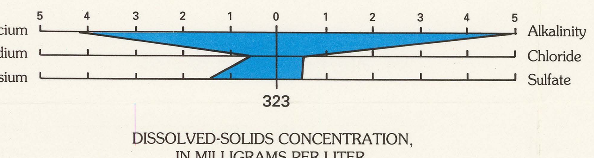
DISSOLVED SOLIDS

Map symbol	Range of time-nested-average concentration, in milligrams per liter	Number and type of site in range
▲ (red)	66–128	4 stream gages in urban area
▲ (green)	201–300	7 stream gages in rural area
● (green)	201–300	133 wells
spring (green)	201–300	1 spring
▲ (blue)	301–400	2 stream gages in rural area
● (blue)	301–400	89 wells
spring (blue)	301–400	1 spring
○ (green)	401–600	8 wells
■ (green)	401–600	1 cave
○ (red)	601–1,000	6 wells
● (orange)	1,001–5,400	12 wells

2 Number indicates the number of wells at location

STIFF DIAGRAM

Pattern is based on water analyses from indicated well, spring or gage. Concentrations are plotted for six constituents, in milliequivalents per liter



DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER

Table 2. *Results of analyses for dissolved solids by hydrologic subarea*

[mg/L, milligrams per liter]

Hydrologic subarea	Number of sites	Number of samples	Dissolved-solids concentration (mg/L): Minimum	Maximum	Percentile, based on time-nested averages[1]: 25th	50th	75th
Urban	4	76	37	128	70	79	89
Rural	9	363	147	385	230	246	288
Medina-Bexar	57	162	171	470	255	263	282
Uvalde	25	74	229	569	246	271	316
North Bexar	80	354	226	594	289	301	317
Comal-Hays	49	164	220	397	282	297	317
North Hays	16	71	228	467	318	324	371
Transition	6	13	568	957	626	671	825
Saline water	12	14	1,230	5,400	1,930	2,870	4,260
Glen Rose	5	10	269	321	297	310	317

[1] A time-nested average was computed for each site by successively averaging concentrations by day, month, year, and period of record. Thus for dissolved solids, 75 percent of the wells in the Medina-Bexar subarea had time-nested averages of 282 mg/L or less.

DISSOLVED SOLIDS AND WATER TYPES

Dissolved solids are defined as the inorganic minerals and colloidal material in a water sample which will pass through a 0.45–µm (micrometer) filter. Generally, water with dissolved-solids concentrations less than 1,000 mg/L is classified as fresh; water with concentrations ranging from 1,000 to 3,000 mg/L is classified as slightly saline; and water with concentrations greater than 3,000 mg/L is classified as saline. Water with dissolved-solids concentrations greater than about 1,000 mg/L generally is unsuitable for many domestic, irrigation, or industrial uses. In this report, the concentration of dissolved solids is the sum of the concentrations of the major dissolved inorganic constituents.

The major dissolved inorganic constituents in water from the Edwards aquifer are three cations (calcium, magnesium, and sodium) and three anions (bicarbonate, sulfate, and chloride). Concentrations of bicarbonate often were not determined; therefore, alkalinity (as $CaCO_3$) has been substituted for bicarbonate in this report. Concentrations of other dissolved constituents such as fluoride, potassium, and silica are included in the calculated sum of dissolved solids, but these ions are not discussed because of their generally small and insignificant concentrations.

Of 1,305 samples analyzed for dissolved solids, 830 were taken from 249 wells, 18 from Comal Springs, 14 from San Marcos Springs, 4 from Woodard Cave, and 439 from 13 surface-water sites (fig. 3). About one-third of the wells were sampled only once; another one-third were sampled twice; and 19 were sampled 10 or more times. The remaining sites were sampled from three to nine times each. A summary of the dissolved-solids concentrations for samples from wells, springs, and surface-water sites is given by hydrologic subareas in table 2.

DISTRIBUTION OF DISSOLVED-SOLIDS CONCENTRATIONS

Time-nested-average dissolved-solids concentrations typically ranged between 200 and 400 mg/L in the freshwater subareas of the Edwards aquifer and between 600 and 950 mg/L in the transition subarea (table 2 and fig. 3). In the saline-water subarea, concentrations ranged from about 1,000 mg/L to more than 5,000 mg/L. In the Glen Rose Formation concentrations were about 300 mg/L, and in Woodard Cave concentrations were about 415 mg/L.

Except for the Medina River sites, dissolved-solids concentrations at sites on the rivers and major creeks in the rural area were nearly identical to the concentrations from wells in the Medina-Bexar subarea because these rivers are fed by springs issuing from the Edwards Limestone in the rural area. Concentrations at the two sites on the Medina River were slightly greater than at the other surface-water sites in the rural area because the source of water for the baseflow of this river primarily is from the Glen Rose Formation, and the larger concentrations may be the result of dissolution of more soluble minerals present in the Glen Rose Formation. Four sampling sites on creeks in the urban area had dissolved-solids concentrations less than 128 mg/L.

AREAL DISTRIBUTION OF WATER TYPES

Water from diagenetically similar parts of the Edwards aquifer that are connected hydraulically is of similar type and contains ions in similar concentrations. Within a diagenetically similar part of the aquifer, dissolved-solids concentrations in water usually increase in the downgradient flow direction because the water has had a longer residence time to dissolve constituents from the limestone.

The type of water in the freshwater zone was calcium bicarbonate (fig. 3). Most of the water in the aquifer was similar; however, because of different parent material or dissolution and flushing processes, several subareas were distinguishable. Wells in the Medina-Bexar subarea are located in the most productive part of the aquifer on the main flowpaths, and the types of water from these wells were virtually the same as the type of recharge water contributed by streams in the rural subarea. Water types of wells in the Uvalde subarea were varied. Concentrations of ions in water samples from a well near Uvalde, upgradient of the major flow-restricting fault barrier of the aquifer, were similar to concentrations in water samples from the Medina-Bexar subarea, but magnesium and sulfate concentrations in the Uvalde subarea were much larger. Compared to the Medina-Bexar subarea, concentrations of ions were larger in samples from wells in north Bexar County and from Comal Springs, which is near the major regional discharge point of the aquifer, and concentrations of ions in water samples from San Marcos Springs were even larger. Concentrations of magnesium and alkalinity were larger in water samples from wells near the ground-water divide in Hays County than from San Marcos Springs.

Concentrations of all six ions, calcium, magnesium, sodium, alkalinity as calcium carbonate, sulfate, and chloride, increased sharply within the saline-water subarea. In Uvalde County, the concentrations of sodium, sulfate, and chloride were largest. In Bexar County, the concentrations of magnesium, sodium, sulfate, and chloride were largest.

Except for the Medina River, the streams in the rural subarea had virtually the same water type because of the springflow from the Edwards Limestone cap (fig. 3). The water type of these streams also was very similar to that for water from typical wells in the freshwater zone of the aquifer. The water in the Medina River, which has a longer contact with the Glen Rose Formation than the other streams, contained comparatively larger concentrations of sodium and chloride and was similar to the water in downgradient wells in northwest Bexar County.

Differences in ion concentrations between sites on rivers in Uvalde County and water from wells in the southern parts of the county indicated a complex ground-water circulation pattern in these areas. Restricted circulation in the lower layers of the aquifer in southern Uvalde County has increased the residence time of ground water, and has retarded the dissolution of highly soluble minerals. Under normal conditions, ground water tends to pool in the southern part of the county as the main regional flow occurs higher and farther to the north because of the constriction near Knippa. During high water-level conditions, water in the southern part of the county probably flows in the upper layers to be discharged upward to the Nueces River through Leona Springs near the town of Uvalde.

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1992

Base from U.S. Geological Survey Texas State base map, 1:500,000

WATER QUALITY OF THE EDWARDS AQUIFER AND STREAMS RECHARGING THE AQUIFER IN THE SAN ANTONIO REGION, TEXAS

By
W. R. Roddy

1992

For sale by the U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225