# Ground-Water Geology of Edwards County Texas

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-J

*Prepared in cooperation with the Texas Board of Water Engineers and the City of San Antonio*

Long—GROUND-WATER GEOLOGY OF EDWARDS COUNTY, TEXAS—Geological Survey Water-Supply Paper 1619-J

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*By* A. T. LONG

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

# CONTENTS



# ILLUSTRATIONS

[Plates in pocket]

# TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

# GROUND-WATER GEOLOGY OF EDWARDS COUNTY, TEXAS

By A. T. LONG


## ABSTRACT

Edwards County occupies 2,075 square miles of the southern part of the Edwards Plateau in southwest Texas. In 1950 it had a population of 2,908. Its thin limestone soil supports the characteristic flora of a semiarid region. The county is underlain by nearly flat-lying beds of limestone and a few beds of shale and marl.

The Glen Rose limestone of Cretaceous age, the oldest formation tapped by water wells in the county, yields small quantities of rather highly mineralized water. Springs in the Glen Rose discharge water that is generally less mineralized than that from wells. Nearly all the wells and springs tapping the Glen Rose are in the southeastern part of the county, where the Edwards and associated limestones have been removed by erosion or are very thin.

The Comanche Peak, Edwards, and Georgetown limestones, collectively called the Edwards and associated limestones, underlie most of the county and form the principal aquifer. Generally, the water in the Edwards is under water-table conditions, but locally it may be artesian. The Edwards and associated limestones yield small to moderate quantities of water that is hard but otherwise of good chemical quality.

The alluvium in the major stream valleys yields small to moderate quantities of hard water similar in quality to that of the Edwards and associated limestones.

The main ground-water divides in the Edwards and associated limestones follow the topographic divides. Most of the ground water flows southward and either appears as springflow in the Nueces River drainage or flows underground into Kinney or Val Verde County. The remainder flows northward and ultimately appears as springflow in the South Llano River drainage.

About 150,000 acre-feet of water is recharged annually to and discharged from the Edwards and associated limestones in Edwards County. Most of this water is available for additional development inasmuch as only about 900 acre-feet per year is currently being used; however, additional development of ground water will result in a reduction in streamflow.


## INTRODUCTION

### LOCATION AND ECONOMIC DEVELOPMENT

Edwards County in southwest Texas occupies 2,075 square miles of the southern part of the Edwards Plateau. It is bounded on the

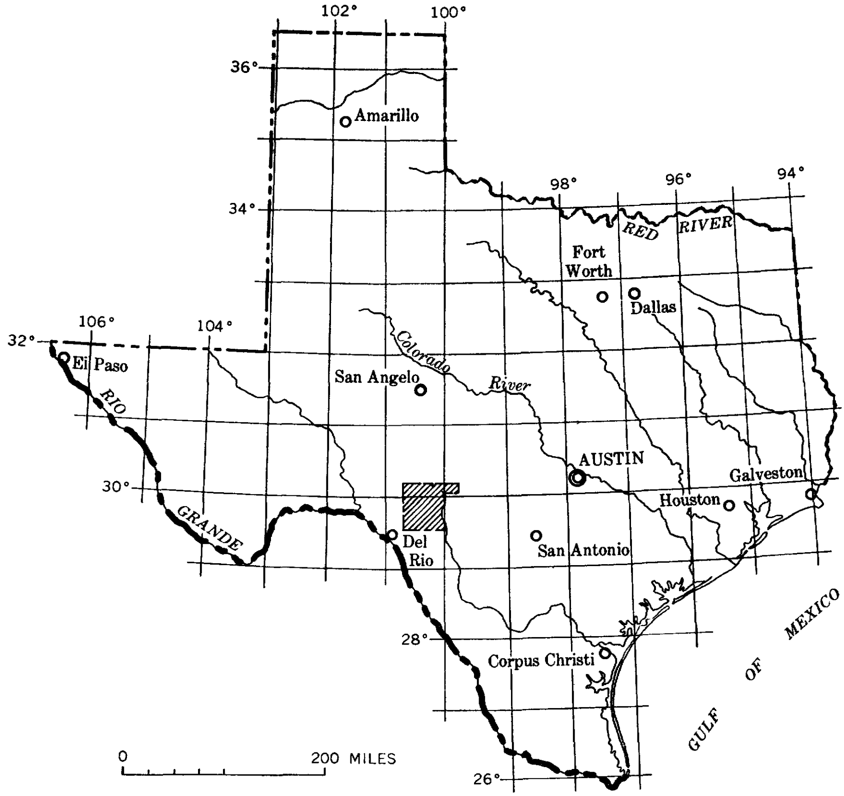


FIGURE 1.—Map of Texas showing location of Edwards County.

north by Sutton and Kimble Counties, on the south by Kinney and Uvalde Counties, on the east by Kerr and Real Counties, and on the west by Val Verde County (fig. 1).

The thin limestone soil covering most of the county supports the characteristic grass, shrubs, and small trees of a semiarid region. Cedar, live oak, red oak, and mesquite grow on the rolling uplands and cypress and pecan along the streams. Edwards County is largely ranch country; the raising of cattle, sheep, and goats is the principal occupation. Agricultural products include wool, mohair, and small quantities of pecans, feed crops, and cedar fenceposts. Oil and gas, bat guano, road metal, and building stones are produced in small quantities. The landowners in the county derive a considerable part of their income by leasing their property for deer and turkey hunting.

According to the U.S. Bureau of the Census, the population of Edwards County in 1950 was 2,908. Rocksprings, the county seat, population 1,436 in 1950, is a market for wool and mohair and a tourist center noted for rodeos. Other towns and communities in the county are Barksdale, Carta Valley, and the Texas A. & M. College Experimental Station 14.

## PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation in Edwards County was made in 1954–55 by the U.S. Geological Survey in cooperation with the Texas Board of Water Engineers and the city of San Antonio. Its purpose was to ascertain the quantity and quality of available ground water in the southern part of the Edwards Plateau. The program included inventorying wells and springs, mapping the surface geology, and contouring the water table. The data studied, which are on file in the offices of the Geological Survey in Austin, Tex., included drillers' logs of 64 wells, records of 613 wells and 46 springs, and chemical analyses of samples of water from 114 wells and 25 springs. Chemical analyses prior to 1940 were made by employees of the Works Progress Administration under the supervision of E. P. Schoch of the Bureau of Industrial Chemistry of the University of Texas and of E. W. Lohr of the U.S. Geological Survey. Although these analyses may not meet the present standards of the Geological Survey and should be used with caution, they probably are indicative of the general chemical quality of the water. Some data used in this report were obtained from an inventory of wells and springs in Edwards County made as a Works Progress Administration project in 1938–39 (Frazier, 1939).

The location of wells and springs in Edwards County is shown on plate 1, which is divided into quadrangles or grids, each measuring 10 minutes of longitude and of latitude. Each quadrangle is designated by a letter, beginning with "A" in the northwest corner of the map. Wells and springs are numbered serially according to their location within the quadrangles.

The report was prepared under the direct supervision of R. W. Sundstrom, district engineer of the U.S. Geological Survey in charge of ground-water investigations in Texas.

## ACKNOWLEDGMENTS

Appreciation is expressed for the cooperation and assistance of oil-company personnel and well drillers who furnished geologic information and well logs. Thanks are also due to landowners who allowed access to the wells and provided information concerning them.

## TOPOGRAPHY AND DRAINAGE

Edwards County is on the southern part of the Edwards Plateau, and the topography is closely related to the geologic structure of the plateau (fig. 2). The county is underlain by nearly flat-lying beds of

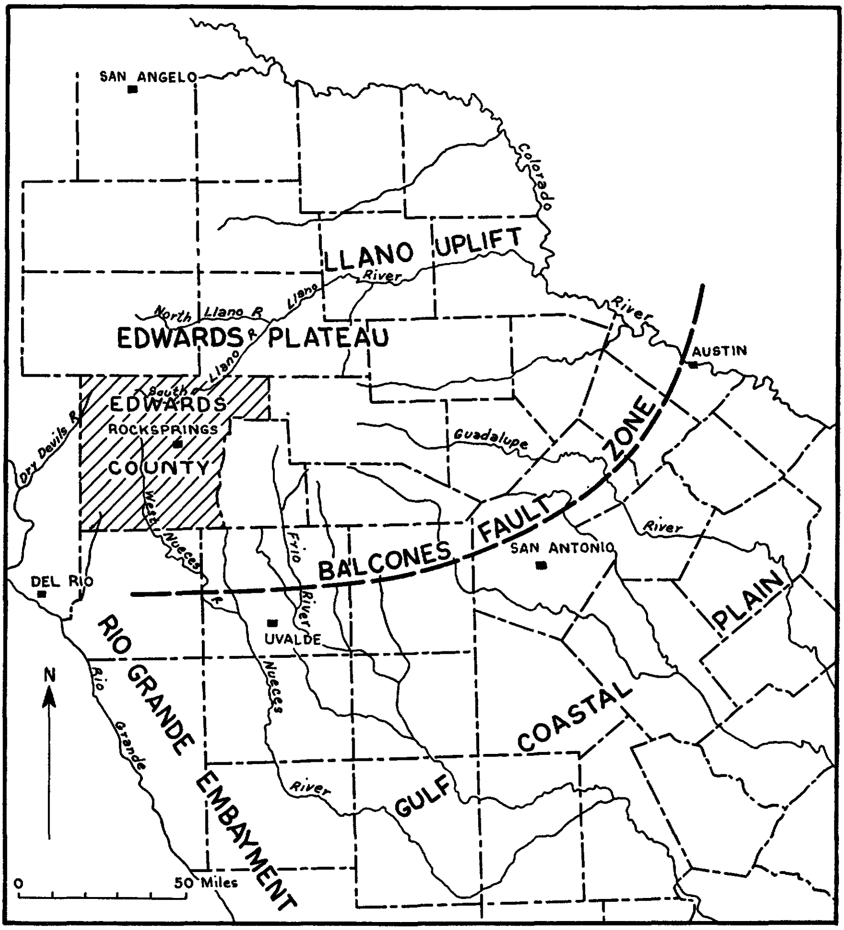


FIGURE 2.—Map of central Texas showing physiographic features.

limestone and a few beds of shale and marl; generally the surface is gently rolling, but in places erosion of resistant beds of limestone has formed steep slopes and narrow valleys. Along the southeastern border the Nueces River has cut through the resistant limestone into the underlying less resistant beds of marl and marly limestone and has formed a broad valley. Sinkholes and other features associated with limestone that has undergone extensive solution are common throughout the county. The best known of these is the Devils Sinkhole, about 6½ miles northeast of Rocksprings; its opening is 41 by 58 feet; the depth is 155 feet (Frazier, 1939, p. 10). Caves are found throughout the county, and many, particularly in the vicinity of Rocksprings, have been reported by drillers.

Edwards County is drained by tributaries of three of the major drainage systems in Texas (fig. 2). The southern part of the county is drained by the Nueces and West Nueces Rivers; the Nueces ultimately flows into the Gulf of Mexico. The South Llano River, which drains the northeastern part of the county, empties into the Colorado River. The Dry Devils River and the West Fork Sycamore Creek, both tributaries of the Rio Grande, drain the western part of the county. The Nueces and South Llano Rivers are perennial streams; the Dry Devils and the West Nueces are intermittent.

Rocksprings, the highest point on the divide between the Nueces and South Llano Rivers, is 2,410 feet above mean sea level. The lowest point in the county, 1,400 feet, is in the bed of the Nueces River just south of Barksdale.

## CLIMATE

The climate of Edwards County is typical of the semiarid regions of the Edwards Plateau. Average annual precipitation on the plateau ranges from more than 35 inches in the east to less than 20 inches in the west. The east-to-west decline may be illustrated by comparing the average annual precipitation for Real, Edwards, and Val Verde Counties. The average annual precipitation in Edwards County (about 22 inches) is about 6 inches less than in Real County and 5 inches more than in Val Verde County.

Figure 3 graphically shows the average annual precipitation, the mean monthly temperature, and the average monthly precipitation for the period 1919–55 recorded at the Texas A. & M. College Experimental Station 14. The highest annual precipitation recorded at the station was 41.51 inches in 1935; the lowest was 6.31 in 1951. The average annual precipitation was 22.17 inches during the period 1919–55 (Bloodgood, Patterson and Smith, 1954, p. 57, and Bloodgood, written communication). May and September are the wettest months of the year, having averages of 3.07 and 3.01 inches, respectively.

The mean annual temperature at the experimental station for the period 1904–53 was 65°F (Bloodgood, Patterson, and Smith, 1954, p. 23). The mean monthly temperature ranged from 47.5° in January to 80.5°F in July and August (fig. 3).

## GENERAL GEOLOGY AND STRUCTURE

The Edwards Plateau is a partially dissected remnant of an uplifted plain capped chiefly by resistant limestone. The county is underlain by Cretaceous rocks which overlie a basement of Paleozoic rocks. The Cretaceous rocks dip 10 to 12 feet per mile generally south and southwest toward the Gulf Coastal Plain and the Rio Grande Embay-

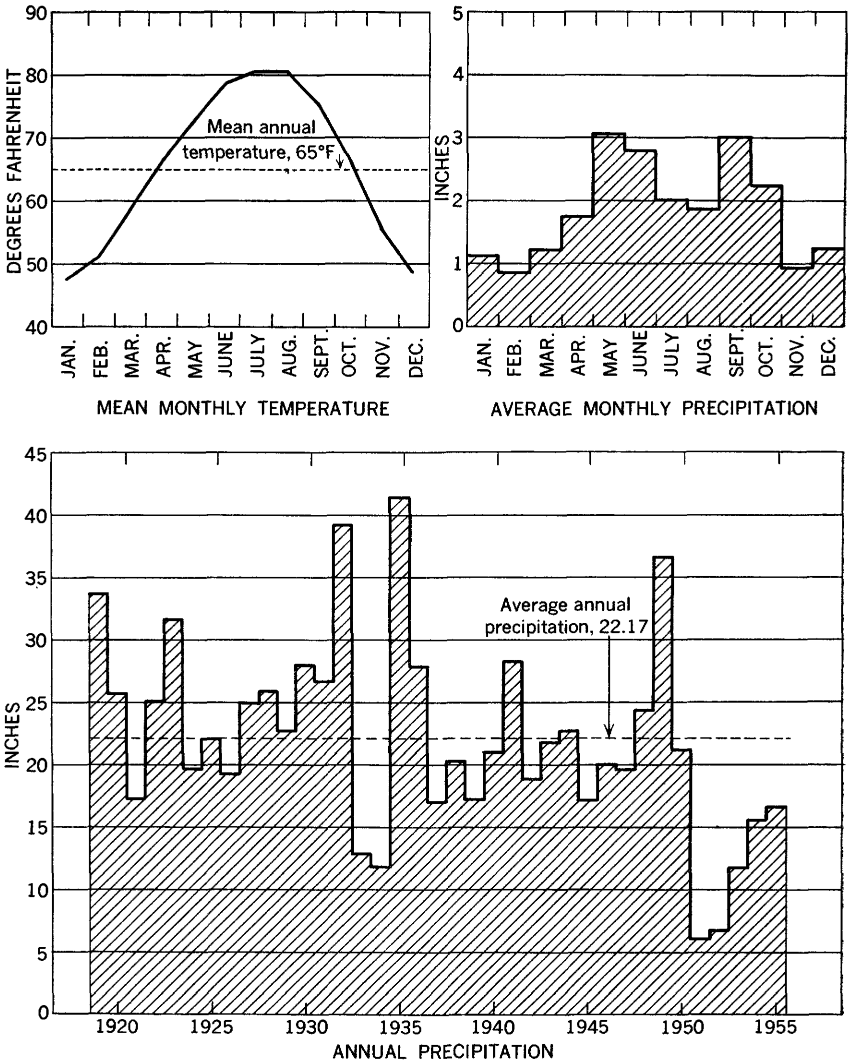


FIGURE 3.—Temperature and precipitation at Texas A. & M. College Experimental Station 14 (Records from Bloodgood, Patterson, and Smith, 1954, and from Bloodgood, written communications.)

ment (Cartwright, 1932, p. 699, pl. 4). Sellards and Baker (1934, p. 86) reported slight domes, anticlines, and synclines that interrupt the regional dip of the Cretaceous beds of the Edwards Plateau. In the northern part of the county, the beds dip northwest about 3 feet per mile. Minor faults and fractures trending northeast roughly parallel the Balcones fault zone, a major structural feature in the counties to the south and southeast. However, a few faults northeast of Rocksprings trend north to northwest. Most of the faults are down thrown to the southeast and have small displacements of 30 feet or less; however, one fault about 12 miles southeast of Rocksprings has a displacement of about 60 feet.

The Cretaceous rocks exposed in Edwards County consist from oldest to youngest of the Glen Rose limestone, Edwards and associated limestones (Comanche Peak, Edwards, and Georgetown limestones), Grayson shale, Buda limestone, and Eagle Ford shale (pl. 1). The oldest exposed formation, the Glen Rose, is found only in stream valleys where erosion has cut through the overlying formations. The Edwards and associated limestones crop out in most of the county, except on a few of the higher divides, which are capped by younger formations, and in the southeastern part of the county. Some valleys in Edwards County are underlain by alluvial deposits of Pleistocene and Recent age. These sediments are most extensive in the Nueces River valley, where they attain a maximum thickness of about 40 feet.

The composite geologic section of the formations in Edwards County is shown on plate 2. The lithologic and water bearing characteristics are summarized in table 1. The stratigraphic and structural relations of the Cretaceous units are shown on plate 3.

## ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTIES

### PRE-CRETACEOUS ROCKS

Rocks of pre-Cretaceous age are not exposed in Edwards County. However, their lithologic characteristics and age have been revealed in a few places in the process of exploration for oil and gas. The rocks consist chiefly of noncalcareous shale, sandstone, and limestone; their total thickness is not known. Different formations of probable Pennsylvanian age underlie the Cretaceous rocks in various parts of the county because of the unconformity between the Cretaceous and pre-Cretaceous rocks. The approximate altitude of the top of the pre-Cretaceous rocks is shown on plate 4.

No fresh water from the pre-Cretaceous rocks has been reported; the base of the overlying Cretaceous rocks is considered to be the base of the fresh-water-bearing beds in the county.

**Table 1.**—*Geologic formations in Edwards County and their water-supply characteristics*

| System | Series or group | Stratigraphic unit | Maximum thickness (feet) | Description of rocks | Surface expression | Water-bearing character |
|---|---|---|---|---|---|---|
| Quaternary | Pleistocene and Recent undifferentiated | Alluvium | 40 | Sand, silt, and gravel. | Terraces in stream valleys. | Yields small to moderate supplies of hard water to shallow dug wells in stream valleys. |
| Cretaceous | Gulf series | Eagle Ford shale | 10 | Sandy crystalline brown limestone. | Isolated patches capping hills. | Yields no water to wells in Edwards County. |
| Cretaceous | Comanche Series: Washita group | Buda limestone | 20 | Hard brittle light-gray porcelaneous limestone. | Fragments and boulders capping divides. | Do. |
| Cretaceous | Comanche Series: Washita group | Grayson shale | 20 | Buff-brown clay and marl; contains thin lenses of limestone. | Caps interstream divides; forms rolling topography. | Do |
| Cretaceous | Comanche Series: Washita group / Fredericksburg group | Edwards and associated limestones: Edwards and Georgetown limestones: Zone D | 240 | Massive light-gray cherty limestone: rudistids, gastropods, and brachiopods abundant. | Cliffs or steep slopes. Rolling surface in the interstream areas. | Principal water-bearing formation in Edwards County. Yields small to moderate supplies of hard water to wells. Large discharge through the springs that feed the streams. |
| Cretaceous | Comanche Series: Fredericksburg group | Edwards and associated limestones: Edwards and Georgetown limestones: Zone C | 135 | Dolomite and dolomitic limestone; secondary deposits of calcite, quartz, and siliceous limestone; chert nodules; highly leached; cavernous in places. | Gentle slopes that retain more soil than zones B or D. | Principal water-bearing formation in Edwards County. Yields small to moderate supplies of hard water to wells. Large discharge through the springs that feed the streams. |
| Cretaceous | Comanche Series: Fredericksburg group | Edwards and associated limestones: Comanche Peak limestone: Zone B | 130 | Massive cherty limestone; rudistids abundant. | Bluffs that do not retain soil. | Principal water-bearing formation in Edwards County. Yields small to moderate supplies of hard water to wells. Large discharge through the springs that feed the streams. |
| Cretaceous | Comanche Series: Fredericksburg group | Edwards and associated limestones: Comanche Peak limestone: Zone A | 60 | Nodular marly limestone: scattered *Exogyra texana;* honeycombed in places. | Gentle slopes. | Principal water-bearing formation in Edwards County. Yields small to moderate supplies of hard water to wells. Large discharge through the springs that feed the streams. |
| Cretaceous | Comanche Series: Trinity group | Glen Rose limestone | 750 | Alternating beds of hard limestone and soft marl; gray blue in subsurface; weathers brown; gypsum. | Gentle terraced slopes. | Yields small quantities of fresh to moderately saline water. |
| Cretaceous | Comanche Series: Trinity group; Pre-Comanche rocks | "Basement sand" | 400 | Well-sorted sand interbedded with marl and limestone; dolomitic limestone; interbedded varicolored marl and poorly sorted quartz sand. | Not exposed in Edwards County. | Yields no water to wells in Edwards County. |
| Pre-Cretaceous | ? | ? | ? | Shale, sandstone, and limestone. | do. | Do. |

## CRETACEOUS SYSTEM

### PRE-COMANCHE AND COMANCHE ROCKS UNDIFFERENTIATED

The oldest Cretaceous rocks reported by well drillers in Edwards County are identified in this report as "basement sand." Correlation of these beds is not certain, but they probably include the Pearsall formation of Comanche age and the Hosston and Sligo formations of Coahuila age (Imlay, 1945, p. 1426–1441). None of these rocks crop out in Edwards County.

#### "BASEMENT SAND"

In Edwards County the "basement sand" may be divided into three zones. The lowest consists of varicolored marl interbedded with poorly sorted quartz sand. The middle zone, a dolomitic limestone which is very thin or absent in the northern part of the county, reaches a maximum thickness of 50 feet in the southern part. Well-sorted sand and gravel, generally interbedded with marl and limestone, is found in the uppermost zone. The "basement sand" generally becomes more calcareous from north to south. The thickness of the "basement sand" ranges from about 150 feet in the northern part of the county to more than 400 feet in the southern part (pl. 3). The "basement sand" is not tapped by wells in Edwards County; however, it yields potable water to wells elsewhere on the Edwards Plateau, and small to moderate supplies probably could be obtained in Edwards County.

### TRINITY GROUP

#### GLEN ROSE LIMESTONE

The Glen Rose limestone overlying the "basement sand" is the oldest formation exposed in Edwards County. The Glen Rose crops out in the valleys of the tributaries of the Nueces River in the southeastern part of the county (fig. 4, grids S and T), in a small area in the valley of the West Nueces River (grid R), and in scattered small patches along Hackberry Creek (grid P). The Hackberry Creek section is given in detail on pages J13–17. The Glen Rose ranges in thickness from 450 feet in the northern part of the county to about 750 feet in the south.

George (1952, p. 17) divided the Glen Rose limestone in Comal County into a lower and upper member by designating the top of the *Salenia texana* zone as the line of separation. Only the upper member is exposed in Edwards County.

The lower member of the Glen Rose consists of massive fossiliferous limestone and limy shale, the shale predominating in the upper part. Many limestone beds are reefy and contain large rudistids in places.

The upper member of the Glen Rose consists chiefly of alternating beds of resistant limestone and soft marl which produce a typical stair-step or terraced topography. The gentle terraced slopes contrast with the steep bluffs formed by the overlying Edwards and associated limestones. The beds of the upper part of the Glen Rose are brown where exposed to weathering, but in the subsurface they are blue and are referred to by drillers as the "blue" or "blue mud." Two beds of gypsum and anhydrite, each about 20 feet thick, are generally present about 200 and 400 feet below the top of the formation.

The large foraminifer *Orbitolina texana* (Roemer) is common throughout the lower member of the Glen Rose, but is less common in the upper member. Beds containing it and *Porocystis globularis* (Giebel) are exposed in stream valleys in the vicinity of Barksdale.

The Glen Rose limestone is an aquifer in Edwards County; however, in comparison with the major aquifers in Texas it is relatively unimportant. The formation is recharged by precipitation on its outcrop, by overland runoff, and by seepage from the overlying Edwards and associated limestones. The amount of recharge to the formation and the overall potential development in Edwards County have not been estimated but are, no doubt, small.

The water in the Glen Rose occurs in cracks, crevices, and solution channels in the limestone. The upper member of the Glen Rose consists of thin beds of limestone interbedded with marl and shale; consequently, the interconnection of the cracks and channels is small and the resultant permeability is low. The thick massive limestone beds in the lower member might be expected to contain a more highly interconnected system of openings. However, the beds are deeply buried in Edwards County, and hence ground water cannot circulate extensively.

The Glen Rose limestone yields small quantities of water to domestic and stock wells in Edwards County, chiefly in the southeastern part where the more productive Edwards and associated limestones are absent. The yields of individual wells are generally not more than 10 gpm (gallons per minute), although well T–26 had a yield of 40 gpm when drilled. Most of the wells are shallow, being about 100 feet deep. A few, however, are deep; well T–33, the deepest tapping the Glen Rose, is 900 feet.

The Glen Rose yields small to moderate quantities of water to many springs in Edwards County, the largest being Taylor Springs (S–6) which had a measured flow of 430 gpm on October 15, 1953. Most of the springs are at or near the contact with the overlying Edwards and associated limestones. The similarity of the results of chemical analyses of the water and of that from the Edwards indicates a direct hydraulic connection between the two formations in the area of the springs.

### FREDERICKSBURG AND WASHITA GROUPS

The Fredericksburg group in Edwards County includes the Comanche Peak limestone and the Edwards limestone; the Walnut clay, the lowest unit, and the Kiamichi formation, the uppermost unit, have not been identified. The Washita group includes the Georgetown limestone, the Grayson shale, and the Buda limestone.

The Comanche Peak, Edwards, and Georgetown limestones form a single hydrologic unit which in the San Antonio area has been termed the "Edwards and associated limestones" (Petitt and George, 1956, p. 16). All formations between the Glen Rose limestone and the base of the Grayson shale are referred to in this report as one stratigraphic and hydrologic unit—the Edwards and associated limestones—one of the most important aquifers in Texas.

#### EDWARDS AND ASSOCIATED LIMESTONES

The Edwards and associated limestones crop out throughout Edwards County, except on the high divide where they are capped by younger formations and in the stream valleys where erosion has exposed the underlying Glen Rose limestone. The unit at Rocksprings is about 550 feet thick; its thickness elsewhere in the county has not been precisely determined.

The oldest formation in the unit, the Comanche Peak limestone which conformably overlies the Glen Rose, crops out in deep valleys. It consists chiefly of buff-to-gray nodular marly limestone and is equivalent to zone A (table 2; pl. 2). The limestone is honeycombed in places and is rather soft; it forms gentle slopes. The nodular appearance is the most distinctive characteristic of the Comanche Peak. Specimens of *Exogyra texana* (Roemer) are found throughout zone A, especially in the lower part; unidentified high-spired gastropods are common in the upper part. The Comanche Peak ranges in thickness from about 45 to 60 feet but probably averages about 50 feet in Edwards County. The Comanche Peak and the lower part of the overlying Edwards are similar in lithology, but are very different in their fauna and mode of weathering.

The upper 500 feet of the Edwards and associated limestones consists of the Edwards limestone and the Georgetown limestone. In Edwards County, the two limestones have not been differentiated as such; however, they can be divided into three zones, B, C, and D (table 2; pl. 2).

Zone B, which overlies the Comanche Peak limestone, is a light-gray to cream massive limestone, medium grained to lithographic in texture. Dark streaks of very fine texture, believed to be siliceous, probably represent a stage in the development of chert. A few dolomitic beds are present. Rudistid pelecypods, chiefly *Toucasia* sp. and *Caprina* sp., are abundant. The zone, about 130 feet thick, forms bluffs which retain very little soil and, consequently, support sparse vegetation.

Zone C, about 135 feet thick, consists of gray to dark-brown dolomite and dolomitic limestone containing chert nodules and a few chert beds. Clayey and flaggy to thin-bedded limestone is interbedded with the dolomitic limestone. The dolomite is soft and granular in places and contains many cavities ranging from a few inches to several feet in diameter. Secondary deposits of calcite, silica in the form of quartz, siliceous limestone, and chert are abundant in many beds. The upper part of the zone shows an exceptionally high degree of leaching, which has destroyed or obscured much of the bedding. A few beds contain rudistids and gastropods. The beds altered by leaching are nonfossiliferous, but some of the chert nodules and chert beds contain fossils. The gentle slopes of zone C hold more soil and support more vegetation than the limestones of zone B or zone D.

Zone D, about 240 feet thick, consists chiefly of massive, highly fossiliferous light-gray to buff limestone. Beds near the base consisting mainly of shells underlie beds containing *Pecten* sp., gastropods, and rudistids—chiefly *Caprina* sp., and *Toucasia* sp. A brachiopod, *Kingena wacoensis* (Roemer), is found near the top of the zone. In the northeastern part of the county, thin beds composed mainly of pelecypod fragments, probably *Gryphaea* sp., form a terrace in many places. Beds near the top of the zone are fine grained and thin bedded. Chert as nodules and in beds is common throughout most of the zone. In the interstream areas, zone D forms the slightly rolling surface characteristic of the Edwards Plateau; however, in the stream valleys, the massive limestone forms prominent cliffs and steep slopes which retain little soil and support sparse vegetation.

The Edwards and associated limestones unit is the principal aquifer in Edwards County. It supplies small to moderate quantities of water of good chemical quality to wells and springs in all parts of the county, except in the southeastern part, where it has been removed by erosion. Of the 568 water wells for which records are available, 524 obtain water from the unit. The yields of most of the wells are small, generally less than 10 gpm. However, generally only small quantities of water are needed and the wells are constructed accordingly. In many places much larger yields could be obtained from properly constructed wells tapping the full thickness of the aquifer. For example, well H–44 used for municipal supply at Rocksprings, had a measured yield of 280 gpm on December 7, 1953. Additional information on ground water in the Edwards and associated limestones is given in pages J18–J25.

### GRAYSON SHALE

The Grayson shale, formerly known as the Del Rio clay, which overlies the Edwards and associated limestones, crops out on the high divides in the vicinity of Rocksprings and eastward along Highway 41. The outcrops of the Grayson form a typically rolling topography which supports a considerable growth of mesquite. The Grayson and overlying Buda are not water bearing in the county and are shown as a unit on plate 1. The buff-to-brown clay and marl beds and thin limestone lenses that compose the Grayson reach a maximum thickness of 20 feet in Edwards County. A marly facies north of Rocksprings contains many echinoids, but only a few specimens of *Exogyra arietina* (Roemer), characteristically found in abundance in most places in the Grayson. The cephalopod *Turrilites brazoensis* (Roemer) is found in the lower part of the formation. The Grayson shale is nearly impermeable and is not a source of ground water in the county. Many surface reservoirs or tanks for stock use have been constructed in the outcrop area.

The following composite geologic section was measured along State Highway 55 beginning at the foot of a hill near Little Hackberry Creek and the Highway Department dynamite house, 14 miles south of Rocksprings. Tentative correlations are given. Corresponding lettered zones are shown in plate 2.

TABLE 2.—*Measured geologic sections in Edwards County*

**Edwards and associated limestones**

| Zone | Bed | Description | Thickness (feet) |
|---|---|---|---|
| D | 2 | Limestone, buff, massive; *Toucasia* sp. abundant | 1. 0 |
| | 1 | Limestone, buff, massive; *Toucasia* sp. and *Caprina* sp. abundant | 18. 1 |
| C | 37 | Covered | 10. 1 |
| | 36 | Limestone, coquinal, cream, coarse-grained, hard; large fossils | . 8 |
| | 35 | Covered | 10. 6 |
| | 34 | Limestone, coquinal, cream, medium-grained, hard; small fossils | 3. 4 |
| | 33 | Limestone, pelletal, cream, medium-grained, hard | 1. 2 |
| | 32 | Limestone, cream alternating with gray; medium-grained; lithographic at top; mostly thin-bedded; partly covered | 5. 2 |
| | 31 | Limestone, cream, red-flecked, medium-grained, thin-bedded; powdery on weathered surface | 1. 9 |
| | 30 | Covered | 3. 8 |
| | 29 | Limestone, dolomitic, brown to yellow, sugary, slightly honeycombed; scattered large brown chert nodules; *Toucasia* sp.common | 6. 0 |

TABLE 2.—*Measured geologic sections in Edwards County*—Continued

**Edwards and associated limestones—Continued**

| *Zone* | *Bed* | *Description* | *Thickness (feet)* |
|---|---|---|---|
| C | 28 | Limestone, pelletal, cream, hard; coarse grained at base, finer at top; dark flecks in lower part; inclusions of finer grained limestone; scattered gastropods | 4. 3 |
| | 27 | Limestone, dolomitic, cream, sugary; small solution caverns | 2. 7 |
| | 26 | Limestone, dolomitic, gray, sugary, massive; nodules and lenses of chert; few caverns | 2. 0 |
| | 25 | Limestone, gray to yellow, sugary, coarse-grained; leached, vuggy; may be flaggy; contains calcite | 3. 7 |
| | 24 | Limestone, dolomitic, cream, hard, thin-bedded; lenses of gray silicified limestone | 1. 8 |
| | 23 | Dolomite, gray, sugary, flaggy, medium-hard; caverns common | 2. 6 |
| | 22 | Chert, fossiliferous, purple | 0. 3 |
| | 21 | Dolomite, gray to yellow, sugary, soft; large purple-pink chert nodules; relatively large caverns common; large gastropods in upper part; *Toucasia* sp. and *Caprina* sp. common | 7. 3 |
| | 20 | Limestone, dolomitic, gray to buff, sugary; scattered brown chert; solution cavities in upper part; casts and molds | 3. 8 |
| | 19 | Limestone, dolomitic, gray, coarse-grained to powdery, highly leached; blue-purple chert nodules; small caves common | 3. 5 |
| | 18 | Limestone, dolomitic, gray, leached; caves in upper part; cavities partly filled with calcite | 3. 5 |
| | 17 | Limestone, dolomitic, gray, sugary, highly leached, thin-bedded to flaggy; brown chert nodules; much calcite replacement | 1. 8 |
| | 16 | Limestone, yellow-gray; large purple chert nodules; cavities lined with quartz and calcite; may be dolomitic; much calcite replacement | 2. 2 |
| | 15 | Limestone, gray-purple, coarse-grained; upper surface uneven; partly bedded purple chert | 1. 3 |
| | 14 | Dolomite, buff, sugary to powdery, soft; pink chert nodules; upper 2 ft consists of layered calcite deposits; geodes; bedding obscured by solution | 4. 9 |
| | 13 | Dolomite, nodular, yellow-buff, soft, highly leached; gray-purple chert nodules; bedding obscured | 5. 0 |
| | 12 | Limestone, dolomitic, yellow-brown, hard, leached; purple-pink chert nodules; contains small rounded unidentifiable objects that may be fossils; may be partly silicified | 3. 5 |
| | 11 | Dolomite, gray, sugary, soft; coquina of *Nerinea* sp. and pelecypod shells; hard layer in middle part; probably silicified | 2. 8 |
| | 10 | Limestone, yellow-gray; consists mostly of calcite crystals; probably dolomitic; small solution caverns | 3. 0 |
| | 9 | Limestone, dolomitic, coquinal, buff; *Nerinea* sp. abundant; calcite deposits | 0. 6 |

TABLE 2.—*Measured geologic sections in Edwards County*—Continued

**Edwards and associated limestones—Continued**

| *Zone* | *Bed* | *Description* | *Thickness (feet)* |
|---|---|---|---|
| C | 8 | Limestone, cream-buff, fine-grained; pink at top; upper part very fossiliferous; *Nerinea* sp. and small pelecypod shells abundant; mottled with dark patches; probably siliceous | 3.2 |
| | 7 | Limestone, white, sugary; mottled with dark patches; probably siliceous | 1.5 |
| | 6 | Limestone, dolomitic, yellow, highly leached, vuggy; calcite crystals | 1.5 |
| | 5 | Limestone, cream, fine-grained, thin-bedded, fossiliferous; lower half dolomitic; pink chert | 2.4 |
| | 4 | Dolomite, gray, sugary, soft; pink-gray chert nodules common; cavernous | 2.4 |
| | 3 | Dolomite, gray, soft; calcite deposits; small solution cavities common | 3.3 |
| | 2 | Limestone, highly leached; calcite deposits; probably dolomitic; large gray chert nodules contain fossils | 2.6 |
| | 1 | Limestone, cavernous, highly leached; secondary deposits of calcite; probably dolomitic; much of bedding destroyed or obscured by solution; large chert nodules contain fossils | 14.5 |
| | | Subtotal | 154.1 |

[Section continued on a hill near Highway 55, about half a mile north of the Highway Department dynamite house, beginning at top of hill]

| *Zone* | *Bed* | *Description* | *Thickness (feet)* |
|---|---|---|---|
| C | 1 | Limestone, dolomitic (bed 1 above) | ---- |
| B | 35 | Limestone, thin-bedded; mostly covered | 9.0 |
| | 34 | Limestone, buff, lithographic; *Caprina* sp. scattered | 3.7 |
| | 33 | Limestone, buff, fine-grained | 3.2 |
| | 32 | Limestone, light-gray, crystalline; *Caprina* sp | 5.5 |
| | 31 | Covered | 4.7 |
| | 30 | Limestone, buff, fine-grained; rosettes of milky quartz | 2.0 |
| | 29 | Limestone, light-gray, fine-grained | 1.0 |
| | 28 | Covered | 4.7 |
| | 27 | Limestone, light-gray, fine-grained | 2.0 |
| | 26 | Covered | 4.0 |
| | 25 | Limestone, fine-grained to lithographic, partly leached | 1.2 |
| | 24 | Covered | 4.8 |
| | 23 | Limestone, cream, crystalline; fossil fragments; blue chert nodules | 7.6 |
| | 22 | Covered | 3.0 |
| | 21 | Limestone, gray, fine-grained, hard | 2.0 |
| | 20 | Covered | 4.0 |
| | | Subtotal | 62.4 |

TABLE 2.—*Measured geologic sections in Edwards County*—Continued

**Edwards and associated limestones—Continued**

[Section continued from the foot of a hill at the Highway Department dynamite house on Highway 55, 15 miles south of Rocksprings]

| *Zone* | *Bed* | *Description* | *Thickness (feet)* |
|---|---|---|---|
| Fault. | | | |
| B | 19 | Limestone, buff, fine-grained, massive, hard; *Toucasia* sp. and *Caprina* sp. silicified and exposed on weathered surface; large chert nodules at top contain fossils filled with calcite | 7.5 |
| | 18 | Limestone, buff, fine-grained; lower part highly fossiliferous | 3.7 |
| | 17 | Limestone; mostly calcite and caliche | 1.8 |
| | 16 | Limestone, buff, fine-grained to lithographic, hard | 1.0 |
| | 15 | Limestone, coquinal, light-gray, hard; small gastropods abundant | 1.3 |
| | 14 | Limestone, dolomitic, gray, sugary, pelletal; medium to large chert nodules; brown-banded calcite; geodes lined with calcite | 6.6 |
| | 13 | Limestone, light-gray, fine-grained to lithographic, hard | 1.4 |
| | 12 | Limestone, dolomitic, dark-gray, medium-grained, fossiliferous; appears pelletal | 2.7 |
| | 11 | Limestone, buff, medium-grained; orange flecks; small fossils that may be fragments | 1.6 |
| | 10 | Limestone, pelletal, gray, medium-grained | 3.9 |
| | 9 | Limestone, fossiliferous, light-gray, coarse-grained; orange flecks | 2.9 |
| | 8 | Limestone, buff to brown, semilithographic; chert nodules common | 3.1 |
| | 7 | Limestone, gray, medium-grained, thin-bedded; scattered chert nodules | 4.7 |
| | 6 | Limestone, light-gray, massive, hard; *Toucasia* sp. and *Caprina* sp. abundant | 3.3 |
| | 5 | Limestone, light-gray, coarse-grained; patches of dark lithographic limestone believed to be siliceous; *Toucasia* sp. scattered | 1.8 |
| | 4 | Limestone, gray to dark-gray, coarse-grained, mottled; contains areas of lithographic siliceous limestone; scattered chert nodules; weathers nodular | 5.5 |
| | 3 | Limestone, gray to dark-gray, fine-grained; upper part contains patches of siliceous limestone; lower part contains caliche | 4.6 |
| | 2 | Limestone, buff-gray, highly bored; partly honeycombed | 6.0 |
| | 1 | Limestone, buff-gray, fine-grained, massive; bedding planes contain irregular bands of brown calcite | 6.5 |
| | | **Comanche Peak Limestone** | |
| A | 1 | Limestone, marly, nodular, buff to gray; matrix fine-grained to semilithographic; bedding obscured by solution and borings; *Exogyra texana* scattered | 43.9 |
| | | Subtotal | 113.8 |
| | | Total (composite section) | 330.3 |

The following section was measured on the south side of Little Hackberry Creek, 0.7 mile east of State Highway 55. Altitude of the creekbed is 1,760 feet. Tentative correlations are given.

| | *Thickness (feet)* |
|---|---|
| Commanche Peak Limestone: | |
| Limestone, nodular; scattered *Exogyra texana*; forms vertical bluff | |
| Glen Rose Limestone: | |
| Clay, yellow; few *Exogyra texana*; mostly covered by limestone boulders | 21. 1 |
| Marlstone, yellow | 6. 1 |
| Clay, yellow; few fossils; partly covered by boulders | 19. 4 |
| Siltstone, calcareous; some fossils | . 5 |
| Coquina of *Exogyra texana* | . 9 |
| Limestone, light-gray, fine-grained, fossiliferous | 1. 4 |
| Shale, buff; coquina of *Exogyra texana* in lower part | 1. 4 |
| Limestone, oolitic, reddish-brown, hard | . 8 |
| Limestone, light-gray; few fossil fragments | 1. 0 |
| Siltstone, dolomitic, buff, porous | 2. 0 |
| Shale, buff; *Exogyra texana* abundant | 6. 7 |
| Siltstone, dolomitic; upper part calcareous | 2. 0 |
| Shale, buff; pelecypod molds abundant; *Exogyra texana* | 3. 0 |
| Marlstone, light-gray; contains calcite crystals | . 8 |
| Shale, buff; *Exogyra texana* abundant | 10. 1 |
| Limestone, calcarenitic, hard; cream matrix with brown detrital | . 5 |
| Shale, light-brown; interbedded with limestone; fossil fragments; molds; *Exogyra texana* abundant; *Engonoceras* sp | 4. 9 |
| Shale, buff to brown; pelecypod molds abundant; fossil fragments in light-gray limestone layer in middle of bed | 5. 5 |
| Limestone, light-gray, fine-grained; abundant fossils in creekbed | |
| Total | 88. 1 |

#### BUDA LIMESTONE

The Buda limestone lies conformably upon the Grayson shale in Edwards County, but the two formations have not been differentiated on plate 1. The Buda consists of hard brittle fine-grained dense light-gray limestone. It has a porcelaneous texture and breaks with a conchoidal fracture. Erosion of the soft underlying Grayson shale generally reduces the brittle limestone to angular boulders. The presence of the Buda can generally be recognized by the heavy growth of live oak that it supports. The Buda limestone reaches a maximum thickness of 20 feet in Edwards County but it is not a source of ground water in Edwards County.

### GULF SERIES

#### EAGLE FORD SHALE

The Eagle Ford shale, the only formation of the Gulf series in Edwards County, overlies the Buda limestone, the uppermost formation of the Comanche series. Erosion has removed most of the formation; only the lower 10 feet, which consists chiefly of sandy brown crystalline limestone, is found in isolated patches capping a few hills. The Eagle Ford is not water bearing in Edwards County. Because of its limited areal extent, it is not shown on the geologic map (pl. 1), but is included in table 1 and in the composite geologic section (pl. 2).

### QUATERNARY SYSTEM

#### PLEISTOCENE AND RECENT ROCKS UNDIFFERENTIATED

##### ALLUVIUM

The alluvium in Edwards County consists of terrace deposits in stream valleys and ranges in texture from gravel to silt. The deposits reach a maximum thickness of 40 feet in the Nueces River valley where the river has cut deeply into the soft beds of the underlying Glen Rose limestone. Recent boulders and gravel in the streambeds are composed of slightly rounded chert and limestone.

The alluvium is in direct hydraulic connection with the river in many places and probably derives most of its recharge from that source. The rest of the recharge is from infiltration of precipitation, overland runoff from adjoining areas, and possibly from discharge from the underlying Glen Rose limestone.

The alluvium supplies small to moderate quantities of water to many wells in the county, particularly in the valley of the Nueces River. Most of the wells are dug wells less than 40 feet deep. The yields range from a few to as much as 400 gpm in well T–9.

Most of the wells that tap the alluvium are used for domestic and stock supply; however, well T–9 is used in part to irrigate 2 acres of land and well T–27 is used for public supply at Barksdale.

The water in the alluvium is of good chemical quality except that it is hard. In samples from five wells the dissolved-solids content ranged from 195 to 276 ppm (parts per million).

## GROUND WATER

### OCCURRENCE AND MOVEMENT

The source of all ground water in Edwards County is precipitation. Part of the water that falls as precipitation is returned to the atmosphere as evaporation or transpiration by plants; part of the water runs off as streamflow. A small part moves downward through the fractures and solution channels in the limestone and through sandy zones in the alluvium until it reaches the top of the zone of saturation. The top of this zone, the water table, is not a level surface but has irregularities which are similar to and related to the topography of the land surface.

Some of the seepage from precipitation may be held by nearly impermeable materials at some point above the main ground-water body. Ground water thus separated from an underlying body of ground water by unsaturated rock is called perched water. In Edwards County such perched-water bodies are held by extensive lenses of clay, shale, and impervious limestone. The perched-water bodies in Edwards County, though few and not extensive, may yield sufficient water for domestic and stock use as long as recharge conditions are favorable.

Plate 5 shows by contours the configuration of the water table in the Edwards and associated limestones in Edwards County. The water moves slowly along the hydraulic gradient (at right angles to the contours) until it is intercepted by wells or is discharged through springs or some other natural outlet or until it percolates into overlying or underlying beds. The contours of the water table in Edwards County indicate the presence of a ground-water divide that approximates in position the topographic divide.

The lithology, structure, thickness, and degree of weathering of a water-bearing formation determine its capacity to receive, store, and transmit water. The ground water moves from areas of recharge toward areas of discharge, the rate and direction of the movement of the water being controlled by the geologic structure and the permeability of the rock material. The permeability varies according to the size, shape, number, and degree of interconnection of the rock pores. Locally, rocks of low porosity, particularly the massive limestone in the Edwards and associated limestones, may contain fractures, fissures, and solution channels through which water moves freely.

Geologic structural features such as faults and folds affect the movement of ground water. Faults may bring a water-bearing formation into contact with less permeable clay or shale, and thus may create a barrier or impediment to the movement of ground water. Folds may upwarp beds and facilitate their exposure to recharge.

Ground water is discharged naturally from water-bearing formations by evapotranspiration in areas where the water table is near the land surface, through springs, by seepage into streams, and artificially through wells. The quantity of water discharged by wells in Edwards County is small compared to the natural discharge.

Most of the important areas of discharge through springs are shown on plate 1. Seven Hundred Springs in the upper South Llano valley is one of the largest on the interior of the Edwards Plateau. Most of the base flow of the South Llano River comes from it and other springs.

Ground water moving toward an area of discharge may pass between beds of impermeable material and thus become confined under artesian pressure. It will then rise above the bottom of the overlying confining layer in a well tapping the water-bearing formation. In some places in Edwards County, water in the Edwards and associated limestones rises above the point where it is encountered by the drill bit, and thus indicates local artesian conditions; however, in general, the water in this aquifer is probably unconfined. The water in nearly all the wells in the Glen Rose limestone is under artesian pressure. Water in the alluvium generally is unconfined.

## RELATION BETWEEN GROUND WATER AND STREAMFLOW

Streamflow can be divided into two major parts: direct runoff (water that goes directly from precipitation to the streams) and base flow (ground water that discharges from the saturated zone through seeps and springs). In Edwards County the base flow sustains the flow of the streams during periods between storms. Being sustained by ground-water discharge, the base flow is dependent on ground-water recharge. Changes in base flow are related to changes in ground-water storage. Consequently, estimates of the ground-water recharge to the Edwards and associated limestones can be made from studies of the base flow of the streams in Edwards County. Estimates of the base flow were made purposely low to eliminate the effects of bank storage and temporary storage in the alluvium in the stream valleys. Over a long period of time the average base flow is approximately equal to the average recharge to the water-bearing formations, ignoring the other forms of discharge, which in Edwards County are negligible. For a particular year or other short period of time, the two quantities will differ according to changes in storage during the period. The annual discharge, however, generally indicates whether recharge was greater or less than in the previous year because changes in storage are reflected in changes in base flow. The estimates of recharge, therefore, were made on a long-term basis rather than on an annual basis.

Recharge and discharge estimates are based chiefly on records of the four stream-gaging stations (fig. 4) shown in the following table.

| *Station* | *Drainage area (square miles)* | *Records available* |
|---|---|---|
| Llano River near Junction, Kimble County | 1,874 | September 1915–57 |
| North Llano River near Junction, Kimble County. | 914 | September 1915–57 |
| Nueces River at Laguna, Uvalde County | 764 | October 1923–57 |
| West Nueces River near Brackettville, Kinney County. | 700 | September 1939–50 and April 1956–57 |

The base flow in the South Llano and Nueces basins probably closely approximates the total ground-water discharge from those basins. The base flow at the station on the West Nueces, however,

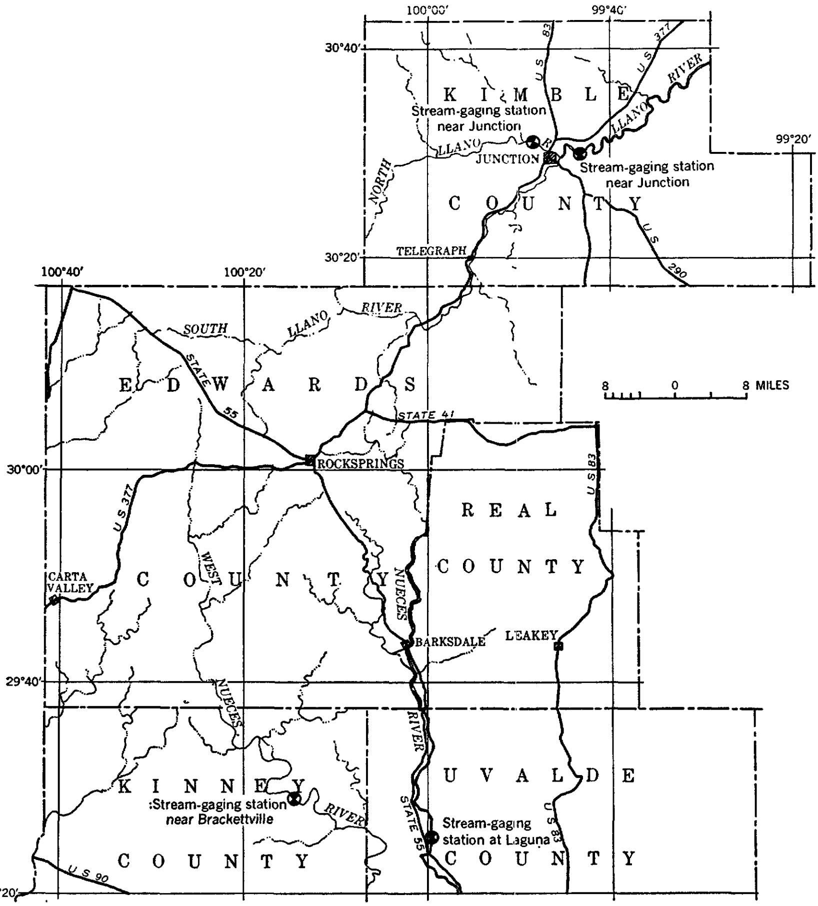


FIGURE 4.—*Location of gaging stations in the vicinity of Edwards County.*

represents only a part of the ground-water discharge. A large part of the ground-water discharge out of that basin is by underflow into Kinney County. The ground-water discharge of the West Nueces basin in Edwards County, therefore, was estimated from unit discharge figures obtained from the other two basins.

The South Llano River drains approximately 606 square miles in northeastern Edwards County. The river flows generally northeastward and joins the North Llano River at Junction in Kimble County to form the Llano River, which flows eastward into the Colorado River. The flow of the South Llano River can be computed by comparing the records of two gaging stations near Junction in Kimble County—one on the North Llano River 3 miles northwest of Junction and the other on the Llano River 3 miles east of Junction (fig. 4). The difference in discharge recorded at the two stations approximates the discharge of the South Llano River. Upstream from the crossing of U.S. Highway 377 in Edwards County the South Llano River generally is intermittent. From the crossing of the highway to the town of Telegraph in Kimble County, most of the base flow of the river comes from springs which discharge from the Edwards and associated limestones. From Telegraph to Junction, the base flow of the river does not increase appreciably. The inflow in the reach between the Kimble-Edwards County line and Junction, therefore, is approximately equal to the loss from evaporation and transpiration. Consequently, the base flow of the South Llano above its confluence with the North Llano at Junction is assumed to be equal to the base flow of the river at the Kimble-Edwards County line.

By comparing the flows at the Llano and North Llano gaging stations, hydrographs were made for the computed daily flow of the South Llano River from January 1923 through December 1954; from these graphs the base flow and the stormflow for the South Llano were estimated separately. The base flow as estimated in this manner probably is reasonably accurate, but estimates of floodflow are less accurate because of an undetermined time lag of flood peaks between gaging stations. The following table shows the computed annual runoff of the South Llano River and the estimated base flow.

| Total runoff | | | Base flow | Total runoff | | | Base flow |
|---|---|---|---|---|---|---|---|
| Year | Thousands of acre ft | Inches | Thousands of acre ft | Year | Thousands of acre ft | Inches | Thousands of acre ft |
| 1923 | 343.0 | 6.72 | 64.5 | 1939 | 99.5 | 1.95 | 50.1 |
| 1924 | 85.5 | 1.69 | 64.8 | 1940 | 54.8 | 1.06 | 50.0 |
| 1925 | 111.0 | 2.18 | 55.0 | 1941 | 57.3 | 1.11 | 49.4 |
| 1926 | 60.9 | 1.19 | 54.6 | 1942 | 71.9 | 1.41 | 52.1 |
| 1927 | 52.0 | 1.01 | 45.6 | 1943 | 71.9 | 1.40 | 54.3 |
| 1928 | 44.6 | .87 | 41.0 | 1944 | 43.7 | .85 | 43.3 |
| 1929 | 37.0 | .72 | 35.4 | 1945 | 35.1 | .69 | 33.6 |
| 1930 | 42.4 | .83 | 38.7 | 1946 | 33.4 | .65 | 29.8 |
| 1931 | 56.2 | 1.10 | 41.0 | 1947 | 32.1 | .63 | 31.6 |
| 1932 | 183.0 | 3.56 | 55.9 | 1948 | 225.6 | 4.41 | 41.8 |
| 1933 | 59.6 | 1.17 | 48.3 | 1949 | 84.6 | 1.65 | 57.5 |
| 1934 | 29.7 | .58 | 29.2 | 1950 | 42.0 | .82 | 41.5 |
| 1935 | 327.7 | 6.40 | 67.1 | 1951 | 29.1 | .57 | 29.1 |
| 1936 | 154.6 | 3.04 | 69.8 | 1952 | 20.0 | .39 | 20.0 |
| 1937 | 77.8 | 1.51 | 43.2 | 1953 | 17.9 | .35 | 17.8 |
| 1938 | 147.4 | 2.87 | 62.6 | 1954 | 22.0 | .43 | 17.9 |

The average annual precipitation in the South Llano River basin is about 24 inches. The total annual runoff ranged from 6.40 inches in 1935 to 0.35 inch in 1953 and averaged 1.71 inches during the 32-year period 1923–54. Therefore, the average annual runoff is less than 10 percent of the average annual precipitation; more than 90 percent of the water falling on the basin is discharged by evapotranspiration. About 54 percent of the total runoff is estimated to be base flow.

The computed base flow of the South Llano River at Junction (presumed to be about the same as the base flow at the Kimble-Edwards County line), suggests that the average annual recharge to and discharge from the Edwards and associated limestones in the South Llano basin in Edwards County during the 32-year period was about 45 thousand acre-feet per year, or about 40 mgd (million gallons per day). This is about 74 acre-feet per square mile or 1.4 inches.

The Nueces River, which forms part of the boundary between Edwards and Real Counties, drains 353 square miles in Edwards County and about 213 square miles in Real County. Along the county line, the Nueces is perennial; it derives its base flow from the many springs which drain the Edwards and associated limestones.

The gaging station at Laguna is about 7 miles downstream from the Edwards-Uvalde County line (fig. 4). Although springs discharge to the Nueces downstream from the county line, discharge measurements made during seepage investigations indicate that the base flow of the stream where it leaves Edwards County is about the same as that measured at Laguna; thus, the losses in this reach apparently are about equal to the gains. It is probable, therefore, that the base flow at Laguna is about equal to the discharge from the Edwards and associated limestones in the upper Nueces basin in Edwards and Real Counties. About 62 percent of the base flow is presumed to come from Edwards County, on the basis of the percentage of the drainage area in Edwards County.

The following table shows the annual runoff of the Nueces River at Laguna and the estimated base flow as estimated from hydrographs of the daily flow at the station.

| Year | Thousands of acre ft | Inches | Thousands of acre ft | Year | Thousands of acre ft | Inches | Thousands of acre ft |
|---|---|---|---|---|---|---|---|
| 1924 | 49.7 | 1.22 | 41.1 | 1940 | 52.8 | 1.30 | 44.1 |
| 1925 | 102.0 | 2.50 | 36.7 | 1941 | 86.7 | 2.13 | 53.6 |
| 1926 | 77.0 | 1.89 | 40.9 | 1942 | 96.0 | 2.36 | 48.8 |
| 1927 | 64.1 | 1.57 | 42.8 | 1943 | 43.4 | 1.07 | 37.7 |
| 1928 | 38.9 | .96 | 26.8 | 1944 | 63.7 | 1.56 | 48.9 |
| 1929 | 47.2 | 1.16 | 25.9 | 1945 | 45.5 | 1.12 | 36.2 |
| 1930 | 121.0 | 2.97 | 43.1 | 1946 | 66.8 | 1.64 | 40.0 |
| 1931 | 118.0 | 2.90 | 70.6 | 1947 | 66.0 | 1.62 | 41.9 |
| 1932 | 255.0 | 6.26 | 68.9 | 1948 | 39.5 | .97 | 25.6 |
| 1933 | 40.4 | .99 | 40.0 | 1949 | 183.4 | 4.50 | 58.7 |
| 1934 | 17.9 | .44 | 16.9 | 1950 | 47.2 | 1.16 | 41.3 |
| 1935 | 465.0 | 11.42 | 60.0 | 1951 | 19.4 | .48 | 19.1 |
| 1936 | 233.4 | 5.74 | 60.2 | 1952 | 22.0 | .54 | 14.2 |
| 1937 | 62.0 | 1.52 | 44.5 | 1953 | 22.4 | .55 | 16.9 |
| 1938 | 72.5 | 1.78 | 52.0 | 1954 | 59.2 | 1.45 | 22.6 |
| 1939 | 158.4 | 3.89 | 39.4 | 1955 | 194.5 | 4.77 | 26.6 |

The average annual precipitation in the Nueces drainage area above the gaging station at Laguna is about 24 inches. The average runoff for the 32-year period, as measured at the gaging station at

Laguna, was about 2.33 inches. About 42 percent of the total runoff for the 32-year period is estimated to be base flow.

The estimated average annual recharge into and discharge from the Edwards and associated limestones in the Nueces River basin in Edwards County for the 32-year period is 25 thousand acre-feet (about 22 mgd). This is nearly 71 acre-feet per square mile or 1.3 inches.

The average recharge into and discharge from the Edwards and associated limestones in the South Llano and Nueces River basins in Edwards County is estimated to be about 73 acre-feet per square mile per year. The geology and topography of the West Nueces basin and the remaining area in Edwards County are similar to those of the Llano and Nueces basins; therefore, the unit value probably is valid for the entire area; therefore, the average annual recharge to and discharge from the county is about 150,000 acre-feet.

## DEVELOPMENT

### PRESENT DEVELOPMENT

The average use of water from wells in Edwards County is estimated to be about 800,000 gpd (gallons per day) or about 900 acre-feet per year. The principal use of ground water is for domestic and stock purposes; small quantities are used for public supplies at Rocksprings and Barksdale. The use of water from wells for industrial and irrigation purposes in Edwards County is negligible.

Nearly all the water for domestic and stock use is obtained from privately owned and small-diameter wells, most of which range from 200 to 500 feet deep and are equipped with windmills. Most of these wells yield only a few gallons per minute.

Withdrawal rates from individual wells range from less than 1 gpm in some of the wells tapping the Glen Rose limestone to as much as 400 gpm in well T–9 tapping the alluvium. The largest yield from a well tapping the Edwards and associated limestones was 280 gpm from well H–44, a municipal well at Rocksprings. Most of the wells are designed to produce only small quantities of water; larger yields could be obtained from properly constructed, deeper wells.

### POTENTIAL DEVELOPMENT

On the basis of estimates of average annual recharge made from a study of the base flow records of the South Llano and Nueces Rivers, it is estimated than about 150,000 acre-feet of water per year (135 mgd) is available for perennial development. This is more than 150 times the present withdrawal of water from wells in Edwards County. The quantity of water available during any particular year may vary considerably from the average, depending upon changes in recharge rates and the amount of ground water in storage. The range is unpredictable because the quantity of ground water in storage is unknown. The base flow of the streams is sustained by the natural ground-water discharge which is reduced by the amount of withdrawals from wells. Thus, additional development from wells would result in reduced streamflow.

## QUALITY OF WATER

The drinking-water standards of the U.S. Public Health Service (1946, p. 13) place definite limitations on water supplies used by interstate carriers subject to Federal regulations. These standards are of general interest because they define an acceptable water that can be used as a basis for comparing water supplies. The standards pertaining to chemical characteristics, in abridged form, are:

- Iron (Fe) and Manganese (Mn) together should not exceed 0.3 ppm.
- Magnesium (Mg) should not exceed 125 ppm.
- Sulfate ($SO_4$) should not exceed 250 ppm.
- Chloride (Cl) should not exceed 250 ppm.
- Fluoride (F) must not exceed 1.5 ppm.
- Dissolved solids should not exceed 500 ppm; however, if other water is not available, a dissolved-solids content of 1,000 ppm may be permitted.

The hardness of water, defined as the property of water attributable to the presence of alkaline earths, is expressed as equivalent calcium carbonate ($CaCO_3$). An arbitrary classification of water with reference to hardness is: 60 ppm or less, soft; 61 to 120 ppm, moderately hard; 121 to 200 ppm, hard; and more than 200 ppm, very hard. Water having a hardness of more than 200 ppm should be softened for most uses.

Chemical analyses of water from 114 wells and 25 springs in Edwards County were made during the investigation; the results are on file in the office of the Geological Survey in Austin, Tex. Representative analyses of water from the three principal aquifers are shown graphically in figure 5. A bar over the well or spring number on figure 4 indicates that an analysis is available.

The analyses before 1941 were made by personnel of the Works Progress Administration and may not conform to the standards of accuracy of the Geological Survey; however, they do show the general type and approximate concentration of the mineral matter. It is likely that the values for dissolved solids in most of these analyses is low because silica and nitrate determinations were omitted and because there was probably some precipitation of $CaCO_3$ before the analyses were made.

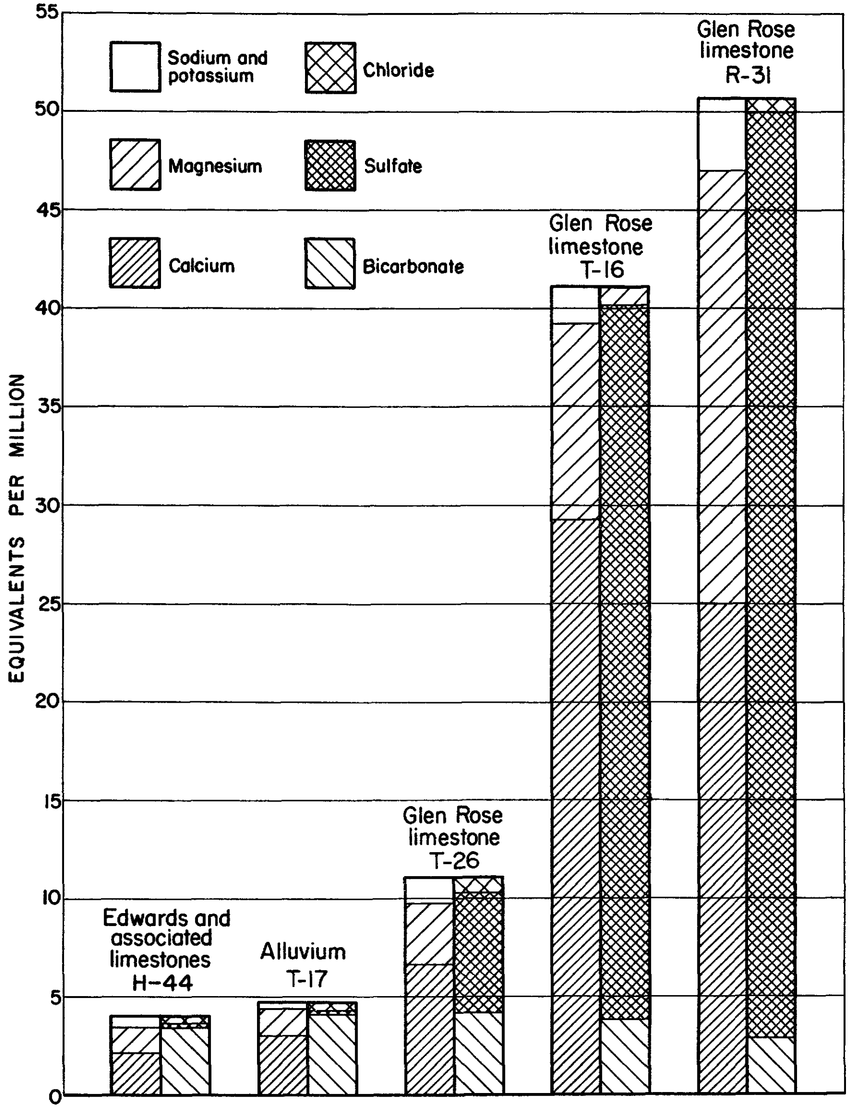


FIGURE 5.—Chemical quality of water from representative wells in Edwards County.

Water from the Glen Rose limestone in Edwards County varies widely in dissolved-solids content. Water from well T–10 had a dissolved-solids content of 259; water from well R–31 had 3,230 ppm. The high sulfate content of the Glen Rose water is probably the most objectionable feature. The sulfate content ranged from 13 ppm in well T–10 to 2,260 ppm in well R–31. The presence of sulfate is probably the result of the solution of gypsum in the Glen Rose. In general, the water from the springs in the Glen Rose is of better chemical quality than that from the wells. The spring water more nearly resembles water from the Edwards and associated limestones; this fact indicates a possible hydraulic connection between the Edwards and Glen Rose in the vicinity of the springs.

The Edwards and associated limestones yield water of a rather uniform quality which is suitable for most purposes. The dissolved-solids content of the Edwards water is low, the concentrations ranging from 171 to 386 ppm. Most of the samples contained between 200 and 300 ppm of dissolved solids. The principal objectionable feature of the Edwards water is hardness, which ranged from 152 to 305 ppm in the samples analyzed, the average being about 200 ppm.

Water from the alluvium is similar in chemical quality to water from the Edwards and associated limestones. Like the Edwards water, it is hard; otherwise, it is of good quality. The dissolved-solids content ranged from 195 ppm in well E–17 to 276 in well T–43.

## SUMMARY

The Edwards and associated limestones of Cretaceous age is the principal aquifer in Edwards County. It yields small to moderate quantities of water to wells throughout the county except in the southeastern part where the Edwards has been removed by erosion in the major stream valleys. The Glen Rose limestone underlying the Edwards yields small quantities of water to wells and springs, particularly in the southeastern part of the county where the Edwards is absent. Small supplies, principally for domestic and stock purposes, are obtained from alluvial deposits in the major stream valleys. Little is known concerning the water-bearing properties of the older Cretaceous rocks in the Edwards County, but they are at least partly sand and may be a potential source of ground water.

The source of ground water in Edwards County is precipitation. The water-bearing formations are recharged by precipitation and overland runoff. The Glen Rose limestone is recharged, at least in part, by water from the overlying Edwards and associated limestones. The water table in the Edwards and associated limestones in Edwards County is a subdued replica of the land surface and the ground-water divides follow approximately the topographic divides. Most of the ground water flows southward and either appears as springflow in the Nueces River drainage in the southeastern part of the county or flows underground into either Kinney or Val Verde County. Most of the remainder of the ground water in Edwards County flows northward and is ultimately discharged into the drainage of the South Llano River.

The base flow of the perennial streams of the county is dependent on springflow which in turn is dependent upon the rate of recharge to the Edwards and associated limestones. From a study of the base-flow records it can be shown that the average rate of recharge to the Edwards and associated limestones in the county is about 1.3 inches, or about 150,000 acre-feet annually.

The yields of wells in the county range widely from less than 1 gpm in some of the wells tapping the Glen Rose limestone to as much as 400 gpm in a well tapping the alluvium. Nearly all the wells in the county tap the Edwards and are used to supply water to ranches for domestic and stock use. These wells are designed to produce only a few gallons per minute; much larger yields could be obtained from wells tapping the complete Edwards section.

Estimates of average annual recharge in the county indicate that about 150,000 acre-feet of water per year (135 mgd) is available for perennial development. This is more than 150 times the present development of water from wells in the county. However, an increase in the development of ground water would cause a decrease in streamflow.

The Edwards and associated limestones and the alluvium contain the water of best quality in the county. Most of the water is low in dissolved solids, ranging between 200 and 300 ppm. The only objectionable feature of the water is hardness, which averages about 200 ppm.

The water from the Glen Rose limestone varies widely in quality. Some of the Glen Rose water closely resembles that of the Edwards and the alluvium. Most of the water, however, is more highly mineralized, the high sulfate content being the most objectionable constituent.

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