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REPORT 60

GROUND-WATER RESOURCES OF KENDALL COUNTY, TEXAS

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REPORT 60

GROUND-WATER RESOURCES OF

KENDALL COUNTY, TEXAS

By

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Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board
Guadalupe-Blanco River Authority
Kendall County Commissioners' Court
Kendall County Water Control and Improvement District No. 1
and the
City of Boerne

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ABSTRACT

Kendall County, an area of 670 square miles on the southern edge of the Edwards Plateau, had an estimated population of 5,900 in 1965. The economy depends chiefly on farming, raising of livestock, and tourist trade. Nearly all water used in the county is obtained from ground-water sources.

The principal water-bearing units, which supply most of the water to wells in the county, are from oldest to youngest, the Hosston and Sligo Formations, the Cow Creek Limestone and Hensell Members of the Pearsall Formation, and the lower member of the Glen Rose Limestone. The yields of the wells range from a few gallons per minute to as much as 425 gallons per minute. Because few wells produce from all of the water-bearing units at any one location, most of the wells yield considerably less than their potential.

Ground water in Kendall County is used principally for rural domestic, livestock, and municipal supplies. In 1965, about 1,000 acre-feet or 0.9 million gallons per day was pumped, of which about 500 acre-feet was used for rural domestic and livestock purposes, 415 acre-feet for municipal supply, and the remainder for irrigation and industrial purposes.

The quantity of water perennially available for development in the county is estimated to be about 50,000 acre-feet per year, or about 50 times the quantity pumped in 1965. A substantial large-scale development of the ground-water supply, however, might reduce the streamflow; but, because the aquifers generally have low transmissibilities and because the well yields are low, much of the ground water discharged into streams by seepage and springflow would be only slowly intercepted by wells.

The ground water in the county, although mostly very hard, has good chemical quality. Much of the water is suitable for public supplies and industrial uses and is excellent for irrigation.

GROUND-WATER RESOURCES OF KENDALL COUNTY, TEXAS

INTRODUCTION

Purpose and Scope of Investigation

The investigation of the ground-water resources of Kendall County, begun in 1964, was a cooperative project of the U.S. Geological Survey, the Texas Water Development Board, the Guadalupe-Blanco River Authority, Kendall County Commissioners' Court, Kendall County Water Control and Improvement District No. 1, and the city of Boerne. The purpose of the study was to determine the occurrence, quality, availability, and dependability of the ground-water resources of Kendall County.

The scope of the project required mapping the surface geology so that the recharge areas of the water-bearing units could be delineated. In addition, measurements of the depth of water in wells were made during the inventory of wells and springs, and data on water use and well pumpage were collected. Maps containing geologic and hydrologic information of the subsurface were prepared.

This report contains records of 352 wells and springs (Table 4), drillers' logs of 22 wells (Table 5), periodic water-level measurements in 13 wells (Table 6), and 140 chemical analyses of ground-water samples (Table 7). The locations of wells and springs are shown on Figure 9.

Appreciation is expressed to the many landowners, drillers, and city and county officials who willingly supplied much of the information on which this report is based.

Location and Economic Development of the Area

Kendall County, an area of 670 square miles, is in central Texas on the southern edge of the Edwards Plateau (Figure 1). Boerne, the county seat, is 30 miles northwest of San Antonio.

The predominantly rough and rolling land is used primarily for the raising of livestock, the principal economic product. Wool and mohair are also important to the economy of the county. Farming is limited to the cultivation of grain crops in the stream valleys. Most of the land is dry farmed. Supplementary income is derived from tourist trade, leasing of hunting acreage, sale of cedar posts, and quarrying of building stone.

The population of the county in 1965 was estimated at 5,900. Boerne and Comfort, the two largest towns, had 2,200 and about 1,200, respectively. In

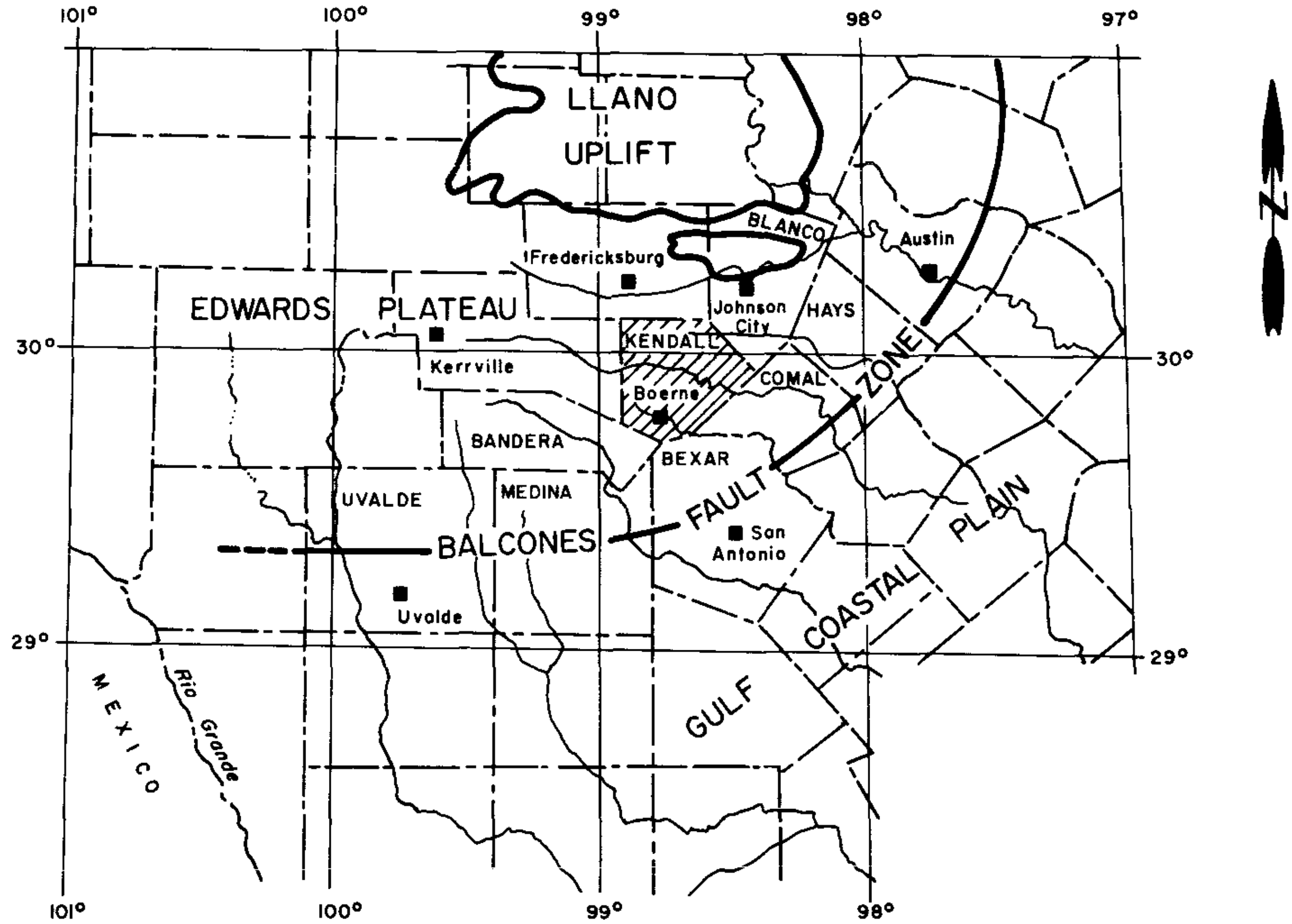

Figure 1

Map of Central Texas Showing Physiographic Features and Location of Kendall County

U. S. Geological Survey in cooperation with the Texas Water Development Board and others

general, the population of the county has shown a slow but steady increase. Because of its scenic beauty and proximity to the city of San Antonio, the county has drawn many of its residents from the San Antonio area.

Previous Investigations

Prior to this study, little detailed information was available concerning the ground-water resources and geology of Kendall County. A report by Frazier (1940) contained records of wells and springs, drillers' logs, chemical analyses of water, and a map showing the well and spring locations; the well numbers used by Frazier and the corresponding numbers in this report are shown in Table 1. The public water supply of Boerne was described by Broadhurst, Sundstrom, and Rowley (1950, p. 79). An investigation of ground-water conditions in a small area in the county was made by George and Doyel (1952). The geology of parts of the county has been mapped and described by Barnes (1952a, b, c; and 1965). The ground-water resources of the Guadalupe, San Antonio, and Nueces River basins, including most of Kendall County, were discussed by Alexander, Myers, and Dale (1964).

Well-Numbering System

The well-numbering system in this report is one adopted by the Texas Water Development Board for use throughout the State and is based on latitude and longitude.

Under this system, each 1-degree quadrangle in the State is given a number consisting of two digits. These are the first two digits appearing in the well number--large open-block numerals 57 and 68 as shown in Figure 9. Each 1-degree quadrangle is divided into 7-1/2 minute quadrangles, which are given two-digit numbers from 01 to 64. These are the third and fourth digits of the well number and are shown generally in the upper left-hand corner of each 7-1/2 minute quadrangle in Figure 9. Each 7-1/2 minute quadrangle is subdivided into 2-1/2 minute quadrangles and given a single digit number from 1 to 9. This is the fifth digit of the well number. Finally, each well within a 2-1/2 minute quadrangle is given a two-digit number, starting with 01. These are the last two digits of the well number. The last three digits are given at the well location on Figure 9. In addition to the seven-digit well number, a two-letter prefix is used to identify the county. The prefix for Kendall County is RB.

Topography and Drainage

The topography of Kendall County is predominantly rough and rolling. The stream-dissected Edwards Plateau is characterized by limestone-capped hills separated by valleys which are incised into materials less resistant than those forming the caprock. The altitude of the land surface ranges from about 1,100 feet in the bed of the Guadalupe River at the southeastern edge of the county to about 2,100 feet in the north-central part. The county is well drained. Most of the northern and central parts of the county are drained by the Guadalupe River and its tributaries. Cibolo Creek and its tributaries drain the southern part of the county; the Blanco River and tributaries of the Medina and Pedernales Rivers drain the rest.

Table 1.--Well numbers used in this report and corresponding numbers in Frazier's (1940) report

New number	Old number	New number	Old number	New number	Old number
RB-57-49-901	381	RB-68-01-604	342	RB-68-03-107	318
50-702	379	01-904	184	03-301	310
50-801	377	02-103	363	03-405	322
51-701	300	02-104	362	03-501	323
51-801	298	02-105	360	03-702	212
57-303	384	02-109	335	03-901	227
57-903	391	02-201	367	03-903	225
57-906	394	02-203	365	04-101	279
58-201	375	02-301	328	04-103	282
58-502	371	02-401	337	04-302	285
58-703	390	02-502	332	04-503	274
58-704	369	02-505	330	04-504	275
58-801	370	02-601	326	04-601	262
59-302	297	02-605	325	04-602	258
59-401	303	02-701	192	04-606	261
59-402	304	02-801	194	04-701	229
59-701	306	02-902	210	04-801	247
60-101	294	02-905	206	04-901	256
60-601	291	02-906	207	04-902	252
60-603	289	02-907	208	04-903	253
60-801	288	02-908	204	04-904	254
60-907	287	02-909	205	04-905	255
68-01-305	393	03-101	314	04-908	246

(Continued on next page)

Table 1.--Well numbers used in this report and corresponding numbers in Frazier's (1940) report--Continued

New number	Old number	New number	Old number	New number	Old number
RB-68-05-104	266	RB-68-11-208	220	RB-68-12-209	243
05-105	265	11-411	148	12-401	139
09-301	183	11-609	142	12-409	138
10-301	154	11-610	141	12-410	137
10-401	181	11-701	77	12-501	240
10-501	173	11-703	103	12-502	241
10-603	158	11-704	105	12-503	242
10-803	168	11-705	69	19-101	114
10-904	160	11-709	129	19-102	112
10-905	163	11-710	105	19-103	115
10-906	164	11-714	127	19-205	120
11-205	224	12-101	238		
11-207	222	12-201	237		

The U.S. Geological Survey has maintained gaging stations on the Guadalupe River 1 mile east of Spring Branch in northern Comal County, at Comfort, and on Cibolo Creek near Boerne since 1922, 1939, and 1962, respectively. Records of runoff at these stations and miscellaneous measurements of streamflow at other points in the county have been published by the U.S. Geological Survey in annual Water-Supply Papers, Part 8, "Western Gulf of Mexico Basins" through 1960, and since then in the annual series "Surface Water Records of Texas."

Climate

Kendall County has a subhumid climate. The average annual precipitation at Boerne from 1932 to 1964 was 30.69 inches; however, the average annual precipitation during the 1947-56 drought was 23.11 inches. Although distribution of rainfall generally is fairly uniform throughout the year, the heaviest rainfall occurs in May, June, September, and October. The maximum recorded precipitation for 1 year was 62.47 inches in 1919; the minimum was 10.29 inches in 1954.

At Boerne, the average annual temperature is 68.5°F; the average monthly temperature in January is 48.7°F, and in July is 80.7°F. The average annual gross lake-surface evaporation from 1940 to 1957 was about 67 inches (Lowry, 1960), or more than twice the average annual precipitation.

GEOLOGIC STRUCTURE

The principal geologic structures in Kendall County are a broad, low syncline and associated anticline. These structures trend generally northwestward across most of the county; the crest and trough of the structures plunge gently southward nearly at right angles to the Balcones fault zone, a major structural feature in the counties to the south and southeast of the report area (Figures 1 and 4). The syncline and anticline are crossed by several discontinuous northeastward-trending faults. Because the displacement along the faults is small and because the faults apparently have little or no effect on the occurrence of ground water, they are not shown in the geologic map (Figure 9).

STRATIGRAPHIC UNITS AND THEIR WATER-BEARING PROPERTIES

The rocks exposed in Kendall County range in age from Early Cretaceous to Recent. Several small bodies of intrusive basalt are exposed in the southeastern part of the county; but because they have small areal extent and little hydrologic significance, these exposures are not included on the geologic map (Figure 9).

The principal water-bearing units in Kendall County are, from oldest to youngest, the Hosston, Sligo, and Pearsall Formations and the Glen Rose Limestone, all of Cretaceous age. Other units, such as the Comanche Peak and Edwards Limestone (collectively referred to as the Edwards and associated limestones) of Cretaceous age and the alluvial deposits of Pleistocene and Recent age are not important sources of ground water, although they yield water to a few wells. The lithologic and water-bearing properties of all the units in the county are summarized in Table 2.

For general discussions of the relative well yields, the following ratings will be used:

Description	Yield (gallons per minute)
Very small	Less than 5
Small	5 to 20
Moderate	20 to 100
Large	More than 100

Pre-Cretaceous Rocks

Pre-Cretaceous rocks are not exposed in Kendall County, but underlie rocks of Cretaceous age at increasingly greater depths southward (Figure 2). Their nearest exposure is along the Pedernales River in Gillespie County, which adjoins the report area on the north. Logs of oil tests and water wells indicate that these rocks consist of black, red, and green non-calcareous shale, limestone, sandstone, and slate.

Although pre-Cretaceous rocks are not known to yield water to wells in the county, small quantities of fresh and slightly saline water might possibly be obtained from them in the northern part of the county.

Cretaceous System

Pre-Comanche Rocks

Imlay (1945, p. 1425) divided the Cretaceous rocks of south Texas into the Coahuila (in Mexico), Comanche, and Gulf Series. The oldest rocks of Cretaceous age in the county have been classified as the Hosston and Sligo Formations and correlated with the Durango and Nuevo León Groups of the Coahuila Series of Mexico.

Hosston and Sligo Formations

The Hosston and Sligo Formations do not crop out in Kendall County, but equivalent rocks may be exposed along the Pedernales River in Gillespie County, north of the report area.

In the southern part of Kendall County, the Hosston Formation consists of conglomerate, sandstone, and dolomite interbedded with shale. The Hosston grades upward into sandy dolomite and dolomitic limestone of the Sligo Formation. In the northern part of the county, the Hosston consists chiefly of conglomerate, sandstone, and shale; the Sligo is represented by a series of sand and sandy dolomite and limestone beds.

Table 2.--Stratigraphic units and their water-bearing properties

System	Series	Group	Stratigraphic unit		Approximate maximum thickness (ft)	Character of rocks	Water-bearing properties
Tertiary(?) and Quaternary	Pliocene(?), Pleistocene, and Recent		Alluvium		50	Clay, silt, sand, and gravel.	Yields very small quantities of fresh water to a few domestic and livestock wells along the major streams.
Cretaceous	Comanche	Fredericksburg	Edwards and associated limestones	Edwards Limestone	250	Hard, massive and thin-bedded limestone; few beds of argillaceous or siliceous limestone and calcareous shale; limestone is commonly dolomitic, contains beds and nodules of chert or flint, and is honeycombed and cavernous.	Yields very small quantities of fresh water to a few domestic and livestock wells.
				Comanche Peak Limestone	60	Marly nodular fossiliferous limestone.	
			Walnut Clay		15	Marly shell aggregate.	Not known to yield water to wells in Kendall County.
		Trinity	Glen Rose Limestone	Upper member	430	Shale and nodular marl alternating with thin beds of impure limestone; dolomitic beds common; massive fossiliferous limestone about 120 feet above base of member; member also contains two distinctive evaporite beds.	Yields very small quantities of water; much of the water is slightly saline.
				Lower member	300	Massive fossiliferous limestone and thin beds of limestone, marl, and shale in basal part; thin beds of fossiliferous marl, shale, and limestone in upper part.	Yields small to large quantities of fresh to slightly saline water.
			Pearsall Formation	Hensell Member	140	Conglomerate, sand, fine-grained sandstone, glauconitic shale, marl, and dolomite.	Yields small to large quantities of fresh to slightly saline water to municipal, irrigation, domestic, and livestock wells in northern part of county.

(Continued on next page)

Table 2.--Stratigraphic units and their water-bearing properties--Continued

System	Series	Group	Stratigraphic unit		Approximate maximum thickness (ft)	Character of rocks	Water-bearing properties
Cretaceous	Comanche	Trinity	Pearsall Formation	Cow Creek Limestone Member	55	Massive fossiliferous limestone, shale, sand, and lignite.	Yields small to moderate quantities of water in southern and western parts of county. Yields very small quantities of water in northern and eastern parts of county.
				Pine Island Shale Member	75	Sandy, fossiliferous, dark-blue to gray shale containing thin interbedded layers of dolomitic limestone.	Does not yield water to wells in Kendall County.
	Coahuila of Mexico	Nuevo León and Durango of Mexico	Hosston and Sligo Formations		330	Limestone, dolomite, shale, sandstone, and conglomerate.	Yields small to moderate quantities of fresh to slightly saline water to irrigation, rural domestic, and livestock wells.
Pre-Cretaceous	?	?	?		?	Black, red, and green non-calcareous shale, limestone, sandstone, and slate.	Not known to yield water to wells.

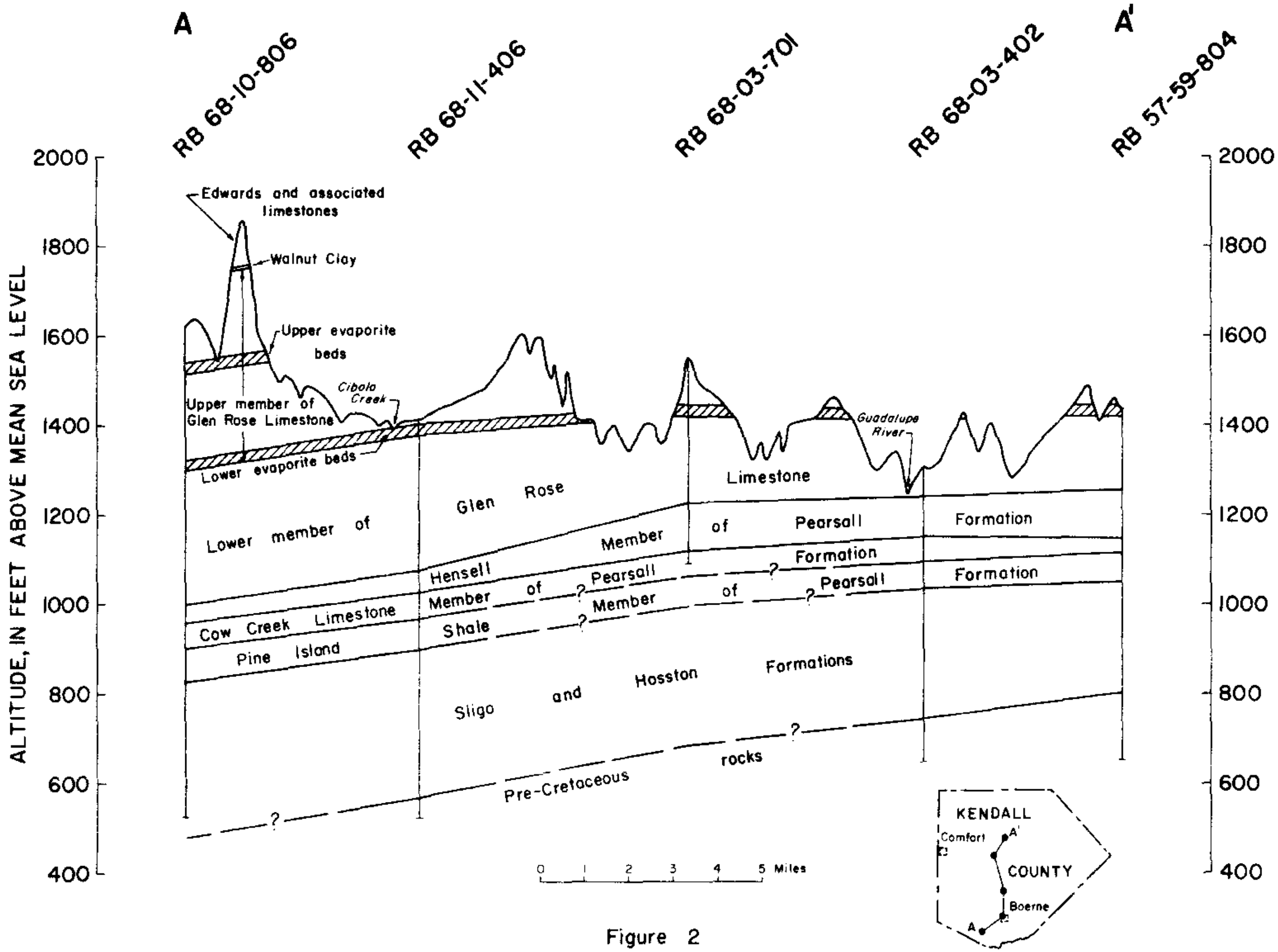

Figure 2

Geologic Section A–A'

U.S. Geological Survey in cooperation with the Texas Water Development Board and others

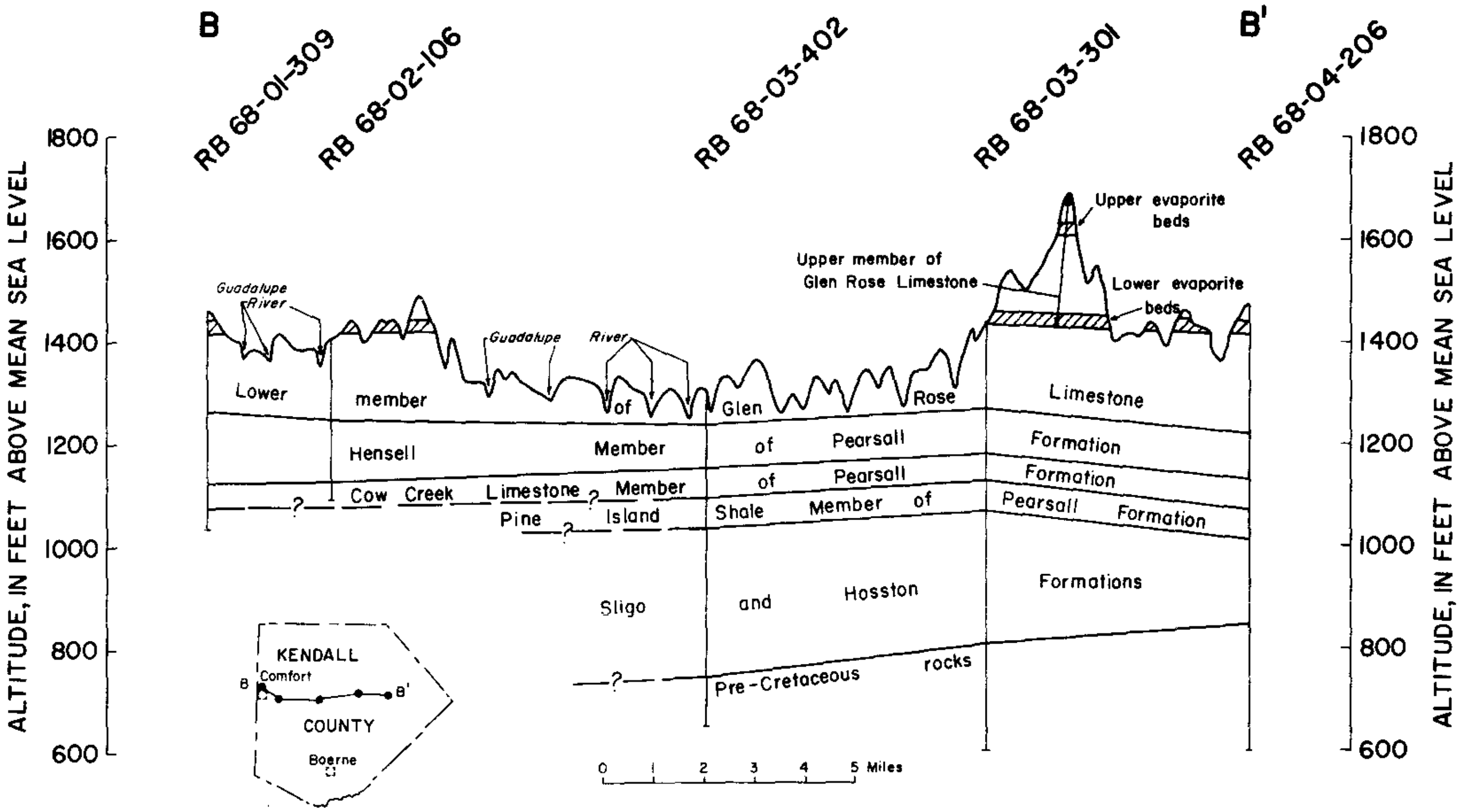

Figure 3

Geologic Section B-B'

U.S. Geological Survey in cooperation with the Texas Water Development Board and others

The formations form a wedge that irregularly thins northward from about 330 feet in well RB-68-11-406 to 235 feet in well RB-57-804 (Figure 2). However, the rate of thinning is not uniform because of the relief on the surface of the pre-Cretaceous rocks.

The Hosston and Sligo Formations have been tapped by only 13 water wells in Kendall County. The wells were used for irrigation and rural domestic and livestock needs. Yields of these wells ranged from 8 gpm (gallons per minute) in well RB-68-03-607 to 92 gpm in well RB-57-59-801; the yield of 92 gpm was obtained after the well was acidized to increase its production. The average yield of the 13 wells was about 20 gpm.

The Hosston and Sligo Formations probably can be expected to yield only small to moderate quantities of fresh to slightly saline water to wells in Kendall County.

Comanche Series

The Comanche Series in the county consists of the Trinity and Fredericksburg Groups. The oldest water-bearing unit exposed in the county consists of rocks of equivalent age to the Pearsall Formation.

Trinity Group

The Trinity Group in Kendall County includes the Pearsall Formation and the Glen Rose Limestone.

Pearsall Formation

The Pearsall Formation is the oldest formation of the Trinity Group. Imlay (1945, p. 1441), who stated that the Pearsall Formation is the sursurface equivalent of the Travis Peak, suggests that the term Travis Peak be restricted to the formation where it is exposed at the surface. On this basis, therefore, the Pearsall Formation everywhere underlies the county except in the southeastern part where rocks of equivalent age are exposed in the valley of the Guadalupe River. According to Imlay's terminology, these exposed rocks should be referred to as Travis Peak; however, because they are lithologically similar to those in the Pearsall and because they are relatively distant from the principal outcrop area, these rocks are included in the Pearsall Formation in this report. As described by Imlay, the Pearsall includes, in ascending order, the Pine Island Shale, Cow Creek Limestone, and the Hensell Shale Members. In this report, the term "Hensell Member" is used because the member is predominantly sandy in the northern and northwestern part of the county and shaly or marly in the southern and southeastern part.

Pine Island Shale Member.--The Pine Island Shale Member consists of sandy, fossiliferous, dark-blue to gray shale containing thin interbedded layers of dolomitic limestone in the southern part of the county. The member, which thins northward and becomes increasingly sandy, ranges in thickness from 65 to 75 feet (Figure 2). It does not crop out in Kendall County.

The Pine Island Shale Member does not yield water to wells. Instead, the member confines the water in the underlying Sligo Formation.

Cow Creek Limestone Member.--The oldest geologic unit exposed in Kendall County, the Cow Creek Limestone Member, crops out in the southeastern part of the county where the Guadalupe River has cut through the overlying strata. The Cow Creek is predominantly a massive, white, fossiliferous limestone. Locally, beds of sand, shale, and lignite are in the lower and middle part of the member. At places on the outcrop the thick limestone beds are honeycombed. The Cow Creek ranges in thickness from 55 feet in the subsurface to 25 feet in the outcrop.

The Cow Creek yields small to moderate quantities of fresh to slightly saline water to wells in the southern and western parts of the county where the unit has a maximum thickness. At Boerne in southern Kendall County, well RB-68-11-406 had a reported yield of 75 gpm after having been treated with 10,000 gallons of acid. In the northern and eastern parts of the county, where the member is thin, the yield generally is less than 5 gpm. The average yield of the wells tapping the Cow Creek was about 10 gpm.

Hensell Member.--In the northern and northwestern part of the county, the Hensell Member consists of loosely cemented conglomerate and sand, sandstone, shale, and marl; in the southern and southeastern part, the member consists principally of shale and marl and interbedded layers of sandstone and dolomite.

The Hensell is exposed only along the Guadalupe River in the southeastern part of the county; elsewhere in the county, the member occurs in the subsurface at increasingly greater depths southeastward. The Hensell, thickest in the western part of the county (140 feet in well RB-68-01-309, Figure 3), thins southeastward by interfingering with beds in the overlying Glen Rose Limestone.

The Hensell is an important aquifer only in the northern and northwestern half of the county. Moderate to large yields can be expected from Hensell wells north of the line shown in Figure 7. Few of these wells yield more than 100 gpm; the average yield probably is about 20 gpm. South and southeast of the line in Figure 7, local sand lenses in the Hensell yield only small quantities of water to a few wells. Most wells in the southern and southeastern parts of the county are drilled to the underlying more permeable limestone beds of the Cow Creek Limestone Member or to the overlying Glen Rose Limestone. Most of the wells that draw from the Hensell yield water that is suitable for many purposes. The water, though, is hard.

Glen Rose Limestone

In Comal County, George (1952, p. 17-18) divided the Glen Rose Limestone into lower and upper members. A thin limestone bed at the top of a prominent fossiliferous zone (*Salenia texana* zone) was arbitrarily selected as the boundary between the members. The limestone bed, capped by a layer of shells of the fossil *Corbula texana* Whitney, is immediately overlain by a porous evaporite bed of anhydrite at the base of the upper member. A second evaporite zone, which has almost identical characteristics as the underlying one, is approximately in the middle of the upper member. In this report, these anhydrite zones are referred to as the lower and the upper evaporite beds. The thin limestone bed at the boundary of the members and the overlying evaporite beds form easily mappable units. The evaporite beds, which are recognizable in well cuttings and are indicated by a strong resistivity peak on electric logs, are useful in subsurface correlation.

In the report area, the contact between the Pearsall Formation and the Glen Rose Limestone is placed arbitrarily at the base of the lowest well-developed limestone beds of the Glen Rose.

Lower Member.--The lower member of the Glen Rose Limestone crops out in the central part of the county along the Guadalupe River and along Cibolo and Balcones Creeks southeast of Boerne.

The basal part of the lower member consists of massive rudistid limestone and thin beds of shale or marl which grade upward into thin beds of limestone, marl, and shale. The upper 15 feet of the member, the *Salenia texana* zone, is fossiliferous shale and nodular marl containing many fossils. A flaggy limestone bed having an abundance of the small clam *Corbula texana* Whitney at the top of the *Salenia texana* zone marks the upper limit of the lower member of the Glen Rose. The lower member thins northward, from 300 feet in well RB-68-10-806 to 165 feet in well RB-57-59-804 (Figure 2). Figure 4 shows that the lower member of the Glen Rose dips mostly south and southwestward from about 5 to 20 feet per mile in the southwestern and eastern parts of the county.

The lower member of the Glen Rose is an important aquifer only in the southern half of the county. The massive basal limestone, which contains solution channels that carry significant quantities of water, is the most prolific water-bearing zone in the lower member. Generally, small to large quantities of fresh water can be obtained from wells tapping the lower member. In the extreme southwestern part of the county, the lower member yields small quantities of slightly saline water; most of the wells in this area produce from the overlying upper member.

Upper Member.--The upper member of the Glen Rose Limestone consists predominantly of blue shale that weathers to yellowish-brown in surface exposures and of nodular marl alternating with thin beds of impure limestone. Dolomitic beds are common throughout the member, and a massive rudistid- and oyster-bearing limestone is about 120 feet above the base of the member. The upper member ranges in thickness from about 430 feet in the southern part of the county to about 360 feet in the northern part.

Two evaporite beds are important marker horizons, which are indentifiable in both the outcrop and in the subsurface (Figures 2 and 3). The lower bed, directly overlying the *Corbula texana* Whitney bed, marks the base of the upper member. Where exposed, the evaporite beds consist mostly of 20 to 30 feet of yellow marl and dolomite interbedded with white chalky limestone; most of the anhydrite has been removed from the beds by solution. Distorted bedding, seeps, and springs are characteristic features of the outcropping evaporite beds. In the subsurface, where they are not weathered, the evaporite beds are easily identified by one or more of the following characteristics: caving tendencies during drilling; the presence of anhydrite in well cuttings; and a pronounced high resistivity peak on electric logs.

The upper member of the Glen Rose Limestone generally yields only very small quantities of water to wells, much of the water being slightly saline. Slow circulation of water in the thin limestone is a contributing factor to the relatively high mineralization of the ground water. Water from the evaporite beds has a high sulfate content, which makes the water unfit for most purposes; therefore, particular care should be taken to case off the evaporite beds properly when drilling through the upper member of the Glen Rose.

Fredericksburg Group

The Fredericksburg Group in Kendall County includes, in ascending order, the Walnut Clay, the Comanche Peak Limestone, and the Edwards Limestone. The Kiamichi Formation, the uppermost formation of the Fredericksburg Group, was not recognized in the county. The Comanche Peak and Edwards Limestones, which form a single hydrologic unit, are referred to in this report as the Edwards and associated limestones.

Walnut Clay

The Walnut Clay, the oldest formation of the Fredericksburg Group in Kendall County, consists of marl containing a profusion of *Exogyra texana* (Roemer). Because the Walnut ranges in thickness from only 3 to 15 feet, it is not shown on the geologic map (Figure 9).

The Walnut is not known to yield water to wells in Kendall County.

Edwards and Associated Limestones

The Edwards and associated limestones comprise the Comanche Peak and Edwards Limestones. The Comanche Peak consists of light-gray, marly, nodular, fossiliferous limestone ranging in thickness from 20 to 60 feet. Many springs and seeps issue from the base of the formation. The Edwards Limestone consists principally of light-gray to white, hard, dense, crystalline limestone. It is commonly dolomitic and contains a few beds of argillaceous or siliceous limestone and calcareous shale. Most of the limestone is massive but some is thin bedded. The limestone, which is honeycombed and cavernous, is characterized by nodular and bedded chert or flint. The Edwards reaches a maximum thickness of about 250 feet in the northern part of the county.

The Edwards and associated limestones yield very small quantities of fresh water to a few domestic and livestock wells in Kendall County. The Edwards and associated limestones are not important as an aquifer, because of their topographic position on hilltops and small areal extent.

Tertiary(?) and Quaternary Systems

Pliocene(?), Pleistocene, and Recent Alluvial Deposits

Alluvial deposits, consisting of clay, silt, sand, and gravel, occur as small remnants on hilltops, as fillings of old meander channels of streams, and as terrace and flood-plain deposits along present streams. The maximum observed thickness of the alluvium was about 50 feet in the Guadalupe River valley.

The alluvial deposits, because of their thinness and small areal extent, are not important aquifers. The deposits yield only very small quantities of fresh water to a few domestic and livestock wells along the major streams.

GROUND WATER

Source and Occurrence of Ground Water

The principal source of ground water in the report area is rainfall on the surface of Kendall and adjacent counties. Most of the rainfall is evaporated from the land surface, is transpired by plants, or runs off as streamflow. Only a small part of the water reaches the water table and recharges the aquifers.

Ground water in Kendall County occurs in aquifers composed of two types of rocks: (1) gravel and coarse- to fine-grained sandstone, in which the water is contained in the spaces between the grains of sand and gravel; and (2) limestone and dolomite, in which the water is contained in joints, fractures, and solution channels. In both kinds of aquifers, in Kendall County, the water is under water-table conditions or artesian conditions. Under water-table conditions the water is unconfined and will not rise in wells above the level at which it was first found. Under artesian conditions the water is confined between relatively impermeable layers, and the water will rise in a well above the base of the confining layer.

Most of the water in the Glen Rose Limestone occurs under artesian pressure because of the presence of shale beds which act as confining layers for the water-bearing limestone beds. In the upper member of the Glen Rose, the solution channels, which contain the water, are tubular and developed parallel with the bedding planes of the thin-bedded limestone. In the thick-bedded limestone of the lower member, vertical connection of solution channels is greater, which allows more water to be stored in the rocks. Along the main streams, where the lower member crops out, several large caverns have developed largely because of good vertical connection of channels; however, in the interstream areas, where the thick-bedded limestones are protected by overlying shale beds, solution channels are small and have developed primarily along the bedding planes of the limestone.

Recharge, Movement, and Discharge of Ground Water

Recharge to the Hosston and Sligo Formations and to the Cow Creek Limestone and Hensell Members of the Pearsall Formation is chiefly from rainfall and streamflow on the outcrop of these rocks north of Kendall County. Some recharge to the Hensell and Cow Creek takes place also in the extreme southeastern part of the county where these formations are exposed.

The Glen Rose Limestone is recharged largely by direct infiltration of rainfall, and to a smaller extent by seepage from overlying alluvial deposits and streamflow on the outcrop. Part of this recharge from streamflow is contributed by seepage and springflow from the Edwards and associated limestones.

The Edwards and associated limestones are recharged principally by precipitation on the outcrop. The outcrop, which is extensively honeycombed and contains solution-enlarged fractures, readily permits infiltration of ground water.

The alluvium is hydraulically connected with the streams in many places but probably derives most of its recharge from direct infiltration of precipitation.

Ground water moves slowly under the influence of gravity from areas of recharge to areas of discharge. The movement is seldom uniform in direction or velocity. The rate of movement of ground water is a direct function not only of the size of the open spaces and interconnecting passages in rocks, but also of the existing hydraulic gradient. In most sand and gravel aquifers, the movement of water is very slow and ranges from tenths of a foot per day to many feet per year; whereas in limestone aquifers, movement is more rapid.

Data are not available to determine accurately the direction of ground-water movement in the Sligo and Hosston Formations and in the Cow Creek Limestone Member of the Pearsall Formation in Kendall County; however, the general direction of movement is probably down the dip of the formations toward the south and southeast.

The direction of movement of water in the Hensell Member of Pearsall Formation and lower member of Glen Rose Limestone is indicated by Figure 7. Although the lack of adequate water-level control prevents a detailed analysis of the movement of water, the map shows that the water moves down the hydraulic gradient (at right angles to the contours) toward the Guadalupe River.

Water is discharged naturally and artificially from the aquifers in the county. Natural discharge is by springs and seeps in the outcrop, by evapotranspiration where the water table is near the surface, by vertical seepage through semiconfining beds (interformational leakage), and by subsurface movement out of the county toward the south. Artificial discharge of ground water is pumping from wells. The quantity of water discharged by wells is relatively small compared to that discharged naturally.

Relation Between Ground Water and Streamflow

The base flow of streams in Kendall County is sustained by ground-water discharge, and changes in base flow are related to changes in ground-water storage. Base flow is the total streamflow that is contributed entirely by springflow or seepage of ground water from aquifers.

The quantity of base flow of the streams represents a significant loss of ground water. Figure 5 shows the average annual base flow of the Guadalupe River in Kendall County and the average annual precipitation at Boerne. The average annual base flow of the Guadalupe River in Kendall County between the points where the river enters and leaves the county (376 square miles of drainage area) is 29,000 acre-feet, or about 77 acre-feet per square mile. Assuming that an equal amount of ground water is lost per square mile throughout the remainder of Kendall County not drained by the Guadalupe River, the average base flow for the 670 square miles in Kendall County is about 50,000 acre-feet

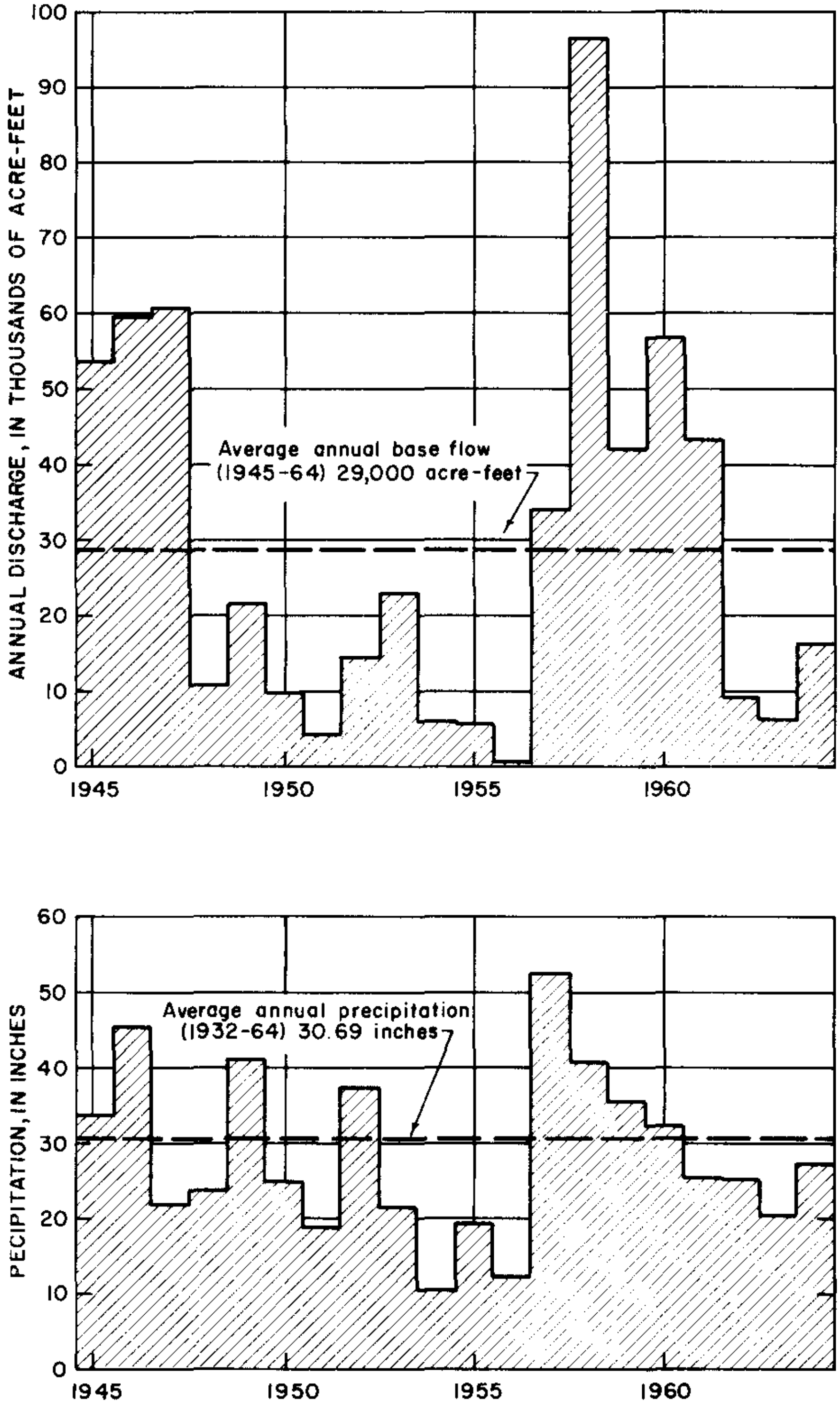

Figure 5

Comparison of Base Flow Contributed to Guadalupe River from Aquifers in Kendall County and Precipitation at Boerne

U. S. Geological Survey in cooperation with the Texas Water Development Board and others

per year. The base flow of about 50,000 acre-feet per year represents approximately 1-1/2 inches of precipitation that enters the aquifers as recharge.

Water Levels

Water levels in wells in Kendall County fluctuate mainly in response to changes in ground-water storage. A rise in water levels indicates an increase in storage, whereas a decline in water levels indicates a decrease in storage. Because the discharge of water from wells is only a fraction of the discharge from springs, the fluctuations in water levels in wells tapping the water-bearing formations in Kendall County reflect mostly the adjustments between the natural recharge, chiefly as a result of rainfall, and natural discharge from the aquifers.

The fluctuations of water levels in three wells are illustrated by hydrographs shown in Figure 6; the locations of the wells are shown in Figure 9. The hydrographs of these wells and the water levels in a large number of other wells (Tables 4 and 6) show that, in general, water levels reach their highest level in late spring and early summer, when rainfall is fairly high, and are lowest in late summer, when rainfall is low and evapotranspiration rates are near maximum.

A comparison of water-level measurements in wells in 1940 with measurements in 1964 or 1965 in the same wells shows a rise of water levels in some wells and a decline in others (Table 4). In 16 wells, the rise in levels ranged from 0.4 foot to 18.0 feet, and in 10 wells, the decline ranged from 0.1 foot to 22.4 feet. However, little significance can be attributed to the changes in water levels over the 25-year period, as no water-level trend can be inferred from only two sets of measurements per well.

Records are not available to show the effect of the 1947-56 drought on water levels in the county. A few well owners, however, reported that, because of declining water levels during the drought, pumps had to be lowered in some wells and that other wells required deepening. Several shallow wells that could not be deepened were abandoned because of insufficient yield. The decline in water levels during the drought was not restricted to any particular aquifer or part of the county.

Figure 7 shows the altitude of water levels in 1964-65 in wells tapping the Hensell Member of the Pearsall Formation and lower member of the Glen Rose Limestone. The map also indicates by contours the configuration of the water-level surface. This surface, which dips toward the Guadalupe River at an average of about 30 feet per mile, represents the level to which water would rise in wells tapping the two aquifers.

Well Construction

Methods of developing and completing water wells are becoming more important with the ever-increasing demand for large-capacity wells. The discussion that follows treats some of the more significant methods.

Hydrochloric acid is used in developing most large-capacity wells in Kendall County. Where the reservoir rock is limestone or calcareous sandstone

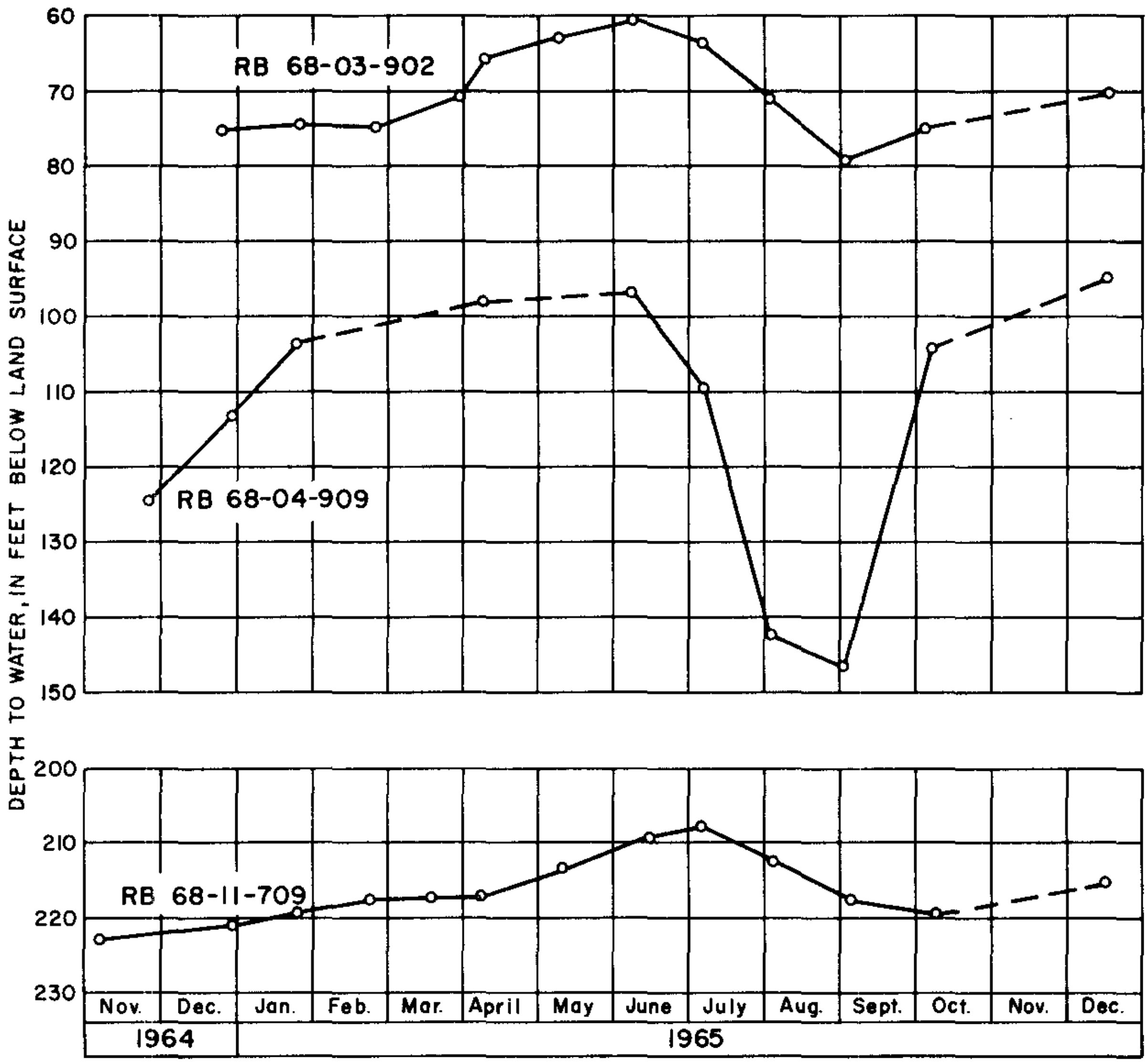

Figure 6

Hydrographs of Selected Wells

U. S. Geological Survey in cooperation with the Texas Water Development Board and others

the yields of wells tapping these rocks may be increased by the use of acid. The acid increases the permeability of the reservoir rock by enlarging the joints or solution channels in the immediate vicinity of the well. This process increases the effective well diameter, thereby increasing the yield of the well per unit of drawdown.

The major problems of well construction are related to the caving tendencies of shale beds, and to the occurrence of highly mineralized water in the evaporite zones of the upper member of the Glen Rose Limestone. If a shale bed is soft and it has a tendency to cave when penetrated by the drill bit, the bed should be cased off so that the shale will not collapse and shut off production from underlying water-bearing strata. When drilling through the upper member of the Glen Rose Limestone, the two evaporite zones, which are sources of highly mineralized water, should be cased and cemented to prevent contamination of better quality water in the deeper aquifers.

Development of Ground Water

Nearly all water used in Kendall County is obtained from ground-water sources. During 1965, about 1,000 acre-feet or 0.9 mgd (million gallons per day) of ground water was withdrawn for all purposes. The water is used principally for rural domestic, livestock, and municipal supplies; irrigation and industrial pumpage is relatively insignificant. Most of the withdrawals were from the Hensell Member of the Pearsall Formation and from the lower member of the Glen Rose Limestone.

The use of ground water for municipal supply increased 20 percent over the past decade (Table 3). From 1955 to 1965, municipal use increased from 346 acre-feet (0.31 mgd) in 1955 to 415 acre-feet (0.37 mgd) in 1965. The largest quantity of water used for municipal supply was in 1963 when 596 acre-feet (0.53 mgd) was pumped. This large usage was due largely to the below-normal rainfall in 1963. The increase in population of Boerne and Comfort and the modernization of homes have created the need for additional supplies of municipal water. Nearly all municipal wells now in use in the county were drilled within the past 15 years.

Most of the ground water pumped in Kendall County is for rural domestic and livestock purposes. In 1965, an estimated 500 acre-feet (0.4 mgd) was pumped for these purposes. Although the rural domestic and livestock wells generally yield only a few gallons per minute, larger yields could be obtained from larger diameter wells that tap all available aquifers and that are equipped with high-capacity pumps.

Ground water for supplemental irrigation in 1965 amounted to about 50 acre-feet (0.04 mgd). Most of this pumpage was from four wells, each capable of pumping more than 100 gpm. In 1964 almost 80 acre-feet of ground water was used to irrigate 117 acres (Gillett and Janca, 1965).

Aquifer Tests

The ability of aquifers to transmit and yield water is usually expressed as the coefficient of transmissibility. The coefficient of transmissibility is defined as the rate of flow of water in gallons per day, at the prevailing

Table 3.--Ground-water pumpage for municipal supplies, 1955-65

Year	Municipal Supply				Totals	
	Boerne		Comfort			
	mgd	ac-ft/yr	mgd	ac-ft/yr	mgd	ac-ft/yr
1955	0.25	280	0.06	66	0.31	346
1956	.24	274	.07	79	.31	353
1957	.25	282	.07	80	.32	362
1958	.20	225	.06	63	.26	288
1959	.21	233	.07	76	.28	309
1960	.22	252	.07	79	.29	331
1961	.28	309	.07	84	.35	393
1962	.36	399	.08	95	.44	494
1963	.43	488	.10	108	.53	596
1964	.39	439	.09	96	.48	535
1965	.28	316	.09	99	.37	415

Figures are shown to the nearest 0.01 mgd and to the nearest acre-foot.

water temperature, through a vertical strip of the aquifer 1 foot wide extending the full height of the aquifer under a hydraulic gradient of 1 foot per foot.

The coefficients of transmissibility determined from two aquifer tests were 1,130 gpd (gallons per day) per foot for well RB-68-01-301, which taps the Hensell Member of the Pearsall Formation, and 7,100 gpd per foot for well RB-68-11-412, which draws from the lower member of the Glen Rose Limestone (Table 4). The results of these two tests should not be considered as representative of the full extent of the aquifers tested. In fact, the ability of the Glen Rose to transmit water is widely variable within short distances because of the irregular distribution of the fracture and solution openings in the limestone. For example, one of the two wells tested--well RB-68-11-412, which taps the lower member of the Glen Rose--had a reported yield of 350 gpm on a previous test, whereas a nearby well of similar depth and construction yielded insufficient water for municipal supply and the well was abandoned.

The specific capacity of a well is the yield in gallons per minute per foot of drawdown and is related to the transmissibility of the water-bearing units tapped. Various factors such as well construction and development, the time the well has been pumped, and the size of the well affect the specific capacity. The specific capacities of six large-capacity wells ranged from 0.5 to 11.6 gpm per foot of drawdown. Most of these values, however, are not representative of any single aquifer because all but two of the wells tested, RB-68-01-301 and RB-68-11-412, produce from more than one aquifer. Furthermore, all wells tested, except RB-57-59-802, have been acidized to increase the specific capacity. The high specific capacity (11.6) of well RB-68-11-412, which taps the lower member of the Glen Rose Limestone, is largely attributed to the fact that this well penetrated more permeable zones than did the other wells.

Availability of Ground Water

The quantity of water available for perennial development, estimated from base-flow records of the Guadalupe River, is at least about 50,000 acre-feet per year. This volume is about 50 times the ground-water withdrawals in the county in 1965. To intercept the 50,000 acre-feet per year of ground water by wells may be impractical, because the low transmissibility of the aquifers would necessitate the drilling of a large number of wells. Any large development of ground-water supplies would probably result in a reduction of the base flow of the Guadalupe River or the tributaries that drain the county.

The present yields of wells in the county range from a few gallons per minute to 425 gpm, but because few of the wells screen all available water-bearing material, most of the yields are less than the potential. The potential yields of properly constructed and developed wells in the county were estimated on the basis of the specific capacities and present yields obtained during the investigation. If all the fresh water-bearing units were tapped by a well, then, in general, potential yields ranging from 10 to 100 gpm would be possible from a well in the eastern half of the county; yields of from 50 to 500 gpm would be possible from the western half.

Chemical Quality of Ground Water

The amount and kind of minerals in solution in ground water depend on the solubility and mineral composition of the rocks through which the water has moved. Other factors that influence the mineralization of water are the length of time the water has been in contact with the rocks and the effects of temperature and pressure.

The results of chemical analyses of water from 121 wells and 17 springs are given in Table 7. A line above the well or spring numbers in Figure 9 indicates that an analysis is included in Table 7.

The suitability of water depends on its quality as judged by the requirements imposed by the contemplated use. Various criteria have been developed for water-quality requirements including bacterial content, physical characteristics, and chemical constituents. Usually, water-quality problems of the first two categories can be alleviated economically, but the removal or neutralization of undesirable chemical constituents can be difficult and expensive.

For many purposes, the dissolved-solids content is a major limitation on the use of water. A general classification of water based on dissolved-solids content follows (Winslow and Kister, 1956, p. 5).

Description	Dissolved-solids content (parts per million)
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000

The U.S. Public Health Service has established and periodically revises standards of drinking water to be used on common carriers engaged in interstate commerce. The standards are designed to protect the traveling public and may be used to evaluate public water supplies. According to the standards, chemical constituents should not be present in a water supply in excess of the listed concentrations shown in the following table, except where more suitable supplies are not available or cannot be made available at reasonable cost. Some of the standards adopted by the U.S. Public Health Service (1962, p. 7-8) are as follows.

Substance	Concentration (parts per million)
Chloride (Cl)	250
Fluoride (F)	1.0*
Iron (Fe)	.3
Manganese (Mn)	.05
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Dissolved solids	500

*Upper limit for Kendall County based on an annual average of maximum daily air temperature between 70.7 and 79.2°F.

Concentration of mineral constituents in excess of the suggested standards can be tolerated, and water that does not meet the suggested standards is being used in many places in Kendall County.

Water having a chloride content exceeding 250 ppm (parts per million) may have a salty taste. The chloride content in 140 samples analyzed ranged from 4 to 460 ppm, exceeding 250 ppm in 6 samples. The samples having a high chloride content were from wells tapping the Sligo and Hosston Formations and the basal sands of the Hensell Member of the Pearsall Formation.

The optimum fluoride level for a given community depends on climatic conditions because the amount of water (and consequently the amount of fluoride) consumed is influenced principally by air temperature. The presence of fluoride in water in Kendall County in average concentrations greater than 1.6 ppm would constitute grounds for rejection of the supply (U.S. Public Health Service, 1962, p. 8). Optimum fluoride concentrations of 0.8 ppm may reduce the incidence of tooth decay, especially in children, when the water is used during the period of enamel calcification. However, in excessive concentrations, it may cause mottling of the teeth (Maier, 1950, p. 1120-1132). The fluoride content in 73 samples in Kendall County ranged from 0 to 5.2 ppm, exceeding 1.0 ppm in 41 wells; it exceeded 1.6 ppm, which is twice the optimum value, in 24 samples. The high fluoride content is not confined to any part of the county or to any one aquifer.

Water containing iron in excess of 0.3 ppm and manganese in excess of 0.05 ppm may cause reddish-brown or dark gray stains on clothes, plumbing fixtures, and utensils. In 41 samples, the iron content ranged from 0 to 14 ppm and exceeded 0.3 ppm in 20 samples. In 4 samples analyzed for manganese, all samples had concentrations of manganese that were less than the established limit of 0.05 ppm; the range in concentration was from 0.00 to 0.04 ppm. Although many wells in Kendall County yield water having a high iron content, the iron usually can be removed from most waters by aeration (oxidation) and filtration. The high iron content is not associated with waters from any one aquifer.

Water having a nitrate content in excess of 45 ppm is dangerous for infant feeding and has been related to infant cyanosis or "blue baby" disease (Maxcy, 1950, p. 271). Nitrate is considered a final oxidation product of nitrogenous matter, and its presence in water in concentrations of more than several parts per million may indicate contamination by sewage or other organic matter (Lohr and Love, 1954, p. 10). The nitrate content in 52 samples collected after 1940 ranged from 0 to 148 ppm, exceeding 45 ppm in only 1 sample. Usually water having a high nitrate content is found in shallow wells or in wells having shallow casing, and is not associated with waters from any one aquifer.

Water containing sulfate in excess of 250 ppm may produce a laxative effect. The sulfate content in 139 samples in Kendall County ranged from 7 to 1,830 ppm, and exceeded the established limit of 250 ppm in 21 samples. Water having a high sulfate content is obtained from: the Sligo and Hosston Formations in the eastern part of the county; the lower member of the Glen Rose Limestone in the extreme southwestern part; and the upper member of the Glen Rose Limestone everywhere in the county. Of the 21 samples that had a high sulfate content, 12 were from wells tapping the upper member of the Glen Rose Limestone at widely scattered points throughout the county. The source of the sulfate is probably the evaporite beds in the aquifer.

The dissolved-solids content in the 140 samples of ground water analyzed ranged from 254 to 2,780 ppm and exceeded 500 ppm in 68 samples. In 15 samples, the dissolved-solids content exceeded 1,000 ppm.

The dissolved-solids, chloride, and sulfate content of water from wells and springs throughout Kendall County is shown on a map of the county (Figure 8.) The map is useful in indicating areas of good or poor quality water. High sulfate or dissolved-solids content in water in some areas, however, may be due to improper well construction, such as not casing off a highly mineralized water zone. Good quality water may, thus, be available in some of the areas where poor quality water is indicated.

Hardness is one of the most important chemical properties affecting the use of ground water for domestic and industrial use. Calcium and magnesium are the principal constituents in water that cause hardness. Excessive hardness causes increased consumption of soap and induces the formation of scale in hot-water heaters and water pipes. Commonly accepted standards and classifications of water hardness are shown in the following table.

Hardness range		Classification
Parts per million	Grains per gallon	
60 or less	3.5 or less	Soft
61 to 120	3.6 to 7.0	Moderately hard
121 to 180	7.1 to 10.5	Hard
More than 180	More than 10.5	Very Hard

The water in Kendall County is mostly very hard, a situation which generally prevails throughout the hill country. The hardness in 145 samples ranged from 145 ppm in a spring in the lower member of the Glen Rose Limestone to 2,120 ppm in a well tapping three aquifers--the upper and lower members of the Glen Rose Limestone and the Hensell Member of the Pearsall Formation. The hardness exceeded 180 ppm in all but three samples.

Ground water used by industry may be classified into three principal categories--cooling, process, and boiler.

Cooling water usually is selected for its temperature and source of supply, although its chemical quality also is significant. Any characteristic that may adversely affect heat-exchange surfaces is undesirable. Calcium, magnesium, aluminum, iron, and silica may cause scale. Corrosiveness is another objectionable feature. Calcium and magnesium chloride, sodium chloride in the presence of magnesium, acids, oxygen, and carbon dioxide are among the substances that make water corrosive.

Process water, that is incorporated into the manufactured product, usually is subject to rigid quality requirements. Quality approaching that of distilled water is required for processes such as the manufacture of textiles, high-grade paper, beverages, and pharmaceuticals, where impurities in the water would seriously affect the quality of the product. Water that is low in dissolved solids and contains little or no iron and manganese which cause staining is highly desirable for use as process water.

The quality of boiler water for the production of steam must meet rigid requirements. Here the problems of corrosion and encrustation are paramount. The calcium and magnesium content, which causes hardness, greatly affects the industrial value of the water by contributing to the formation of boiler scale. Silica in boiler water is undesirable because it also forms a hard scale, the scale-forming tendency increasing with pressure in the boiler.

According to Moore (1940, p. 263), 20 ppm of silica in water is the maximum suggested concentration when the boiler pressure is no more than 250 psi (pounds per square inch). Of the 53 samples analyzed for silica, no sample exceeded 20 ppm. The range in silica was from 9.2 ppm in a well tapping the Sligo and Hosston Formations to 18 ppm in a well tapping the lower member of the Glen Rose Limestone and the Cow Creek Limestone Member of the Pearsall Formation.

The suitability of water for irrigation depends on the chemical quality of the water and other factors such as soil texture and composition, type of crops, irrigation practices, and climate. The principal factors in classifying water for irrigation are: the concentration of dissolved solids, an index of the salinity hazard; the relative proportion of sodium to other cations, an index of the sodium hazard; the residual sodium carbonate; and the concentration of boron or other elements that may be toxic.

A system for judging the quality of water for irrigation was proposed in 1954 by the U.S. Salinity Laboratory Staff (1954, p. 69-82). The system is based primarily on the salinity hazard as measured by the specific conductance of the water and on the sodium hazard as measured by the SAR (sodium-adsorption ratio). Wilcox (1955, p. 16) indicated that water generally may be used safely for supplemental irrigation if the specific conductance of the water is less than 2,250 micromhos per centimeter at 25°C, its SAR is less than 14, and soil-drainage conditions are good. Therefore, in Kendall County, care should be taken when supplemental irrigation water approaches these limits. The SAR of 45 samples ranged from 0.1 to 11, all well below the limit of 14. Water having the higher ratios of SAR was from the Sligo and Hosston Formations. The specific conductance of 55 samples ranged from 73 to 3,000 and exceeded 2,250 in only three samples. The high conductance in these three samples was attributed largely to a high sulfate content.

Another factor in assessing the quality of water for irrigation is the RSC (residual sodium carbonate) in the water. Excessive RSC causes the water to be alkaline, and the organic content of the soil tends to dissolve. Wilcox (1955, p. 11) states that laboratory and field studies have led to the conclusion that water containing more than 2.5 epm (equivalents per million) RSC is not suitable for irrigation; from 1.25 to 2.5 epm is marginal; and less than 1.25 epm RSC probably is safe. The RSC in 41 samples ranged from 0.00 to 1.64 epm. In 39 of the 41 samples the RSC was 0.00 epm. The two samples having a RSC value were from the Sligo and Hosston Formations.

An excess concentration of boron renders water unsuitable for irrigation. Scofield (1936, p. 286) indicated that boron concentrations of as much as 1 ppm are permissible for irrigating most boron-sensitive crops, and concentrations of as much as 3.0 ppm are permissible for the more boron-tolerant crops. The boron content in 15 samples ranged from 0.8 to 4.2 ppm and exceeded 1.0 ppm in only three samples. The three samples having a boron content in excess of 1.0 ppm were from the Hosston and Sligo Formations. Boron is not a problem in most of the aquifers in Kendall County.

CONCLUSIONS

Additional ground water is available for development in Kendall County. In 1965, almost 1,000 acre-feet (0.9 mgd) of ground water was pumped for all purposes. About 50,000 acre-feet per year is discharged from the aquifers through springs and seeps, which sustain the base flow of the Guadalupe River and other streams in the county. This 50,000 acre-feet per year of ground water is perennially available for development without depleting the aquifers in the county. However, because of the low transmissibility of the aquifers many wells would be required to intercept this quantity of water. For this reason a development of 50,000 acre-feet per year, although possible, may be impractical.

The effects of droughts on the availability of ground water may seriously limit the amount of water available in places during the dry periods. Water levels in wells may drop significantly during these periods and some wells may go dry. Because the duration of a drought cannot be predicted, water-conservation practices should always be considered in an effort to conserve the supply.

The yields of most wells would be larger if all of the available aquifers were tapped. Acidizing of wells generally increases yields, but the increase varies widely.

Because of the low transmissibility of the aquifers, close spacing of large-capacity wells should be avoided to reduce interference. When closely spaced wells are pumped, their cones of depression overlap, resulting in an increase in pumping lifts.

Most of the water pumped in Kendall County has good chemical quality except that it is very hard. Much of the ground water available for development is satisfactory for public supply and industrial use, and is excellent for irrigation.

Periodic collection of basic data such as inventory of pumpage, observation of water levels, and collection of water samples for quality studies should be started in Kendall County as ground-water development increases. Long-term records of basic data are essential in developing and utilizing the ground water for optimum efficiency.

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Table 5.--Drillers' logs of wells

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well RB-57-57-601

Owner: R. Willmann. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	3	3	Rock, hard, light-gray	25	245
Topsoil and gravel	7	10	Shale, medium soft, gray-blue, with rock layers	15	260
Caliche and gravel	25	35	Rock, hard, gray	25	285
Shale, medium, soft blue	5	40	Rock, medium hard, gray	25	310
Rock, hard, gray	27	67	Shale, sandy, medium hard, green	8	318
Shale, soft, light blue	5	72	Sand and shale, soft, lots of very fine crystals, no water	2	320
Honeycomb, yellow, seep	2	74	Shale, sandy, medium soft, green	10	330
Shale, hard, blue-gray, with rock layers	43	117	Shale, sandy, soft, green	12	342
Shale, soft, blue, with thin rock layers	13	130	Sandstone, medium hard, green	5	347
Rock, hard, grayish-white	19	149	Sand and shale, fine	1	348
Shale, soft, gray, slightly sticky	7	156	Rock, medium hard, gray	7	355
Shale, medium hard, gray	9	165	Sand, gray, lots of crystals and red sand	5	360
Shale, soft, blue-gray, slightly sticky	10	175	Shale, medium soft, gray	2	362
Rock, medium hard, yellowish-light gray	13	188	Rock, medium hard, white	6	368
Shale, medium soft, brown and blue, sandy (trace of "gyp")	2	190	Shale, medium soft, green	7	375
Shale, hard, greenish-blue	30	220			

Well RB-57-58-503

Owner: M. Davis. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)
Limestone, hard, light-yellow	30	30
Clay, soft, dark-yellow, with thin layers of rock	36	66
Limestone, medium hard, light-yellow	9	75
Clay, soft, red	5	80
Clay, soft, dark-yellow	15	95
Shale, soft, light-blue	5	100
Limestone, hard, light-yellow	38	138
Limestone, hard, yellow, porous, dry	4	142
Shale, soft, sticky, blue	37	179
Rock, hard, blue-gray	10	189
Limestone, hard, dark-yellow	23	212
Limestone, hard, gray-white	12	224
Limestone, medium hard, dark-yellow	4	228
Limestone, hard, dark-yellow	4	232
Limestone, extremely hard, abrasive, white white	10	242
Limestone, hard, white, abrasive	3	245
Limestone, extra hard, white	1	246
Limestone, medium hard, white	19	265
Limestone, hard, and medium-hard layers, white	10	275
Limestone, medium hard, white	31	306
Limestone, extra hard, white	15	321
Limestone, hard, yellow	23	344
Limestone, very hard, yellow	4	348
Shale, medium soft, blue	3	351
Honeycomb, very hard, abrasive, yellow, with rough red clay	5	356
Limestone, very hard, abrasive, gray-yellow	10	366
Limestone, porous, blue-gray	9	375
Limestone, hard, probably porous; red, yellow, and gray	19	394

(Continued on next page)

Table 5.--Drillers' logs of wells--Continued

Well RB-57-58-503--Continued

	Thickness (feet)	Depth (feet)
Limestone, medium soft, porous; red, yellow, and gray	9	403
Honeycomb, medium soft, yellow, water	4	407
Limestone, hard, yellow	3	410
Limestone, very porous, good water supply	8	418
Limestone, hard, white	5	423
Rock, very porous, white, blue and gray, red clay	5	428
Limestone, hard, white	23	451

Well RB-57-58-702

Owner: Mrs. P. Dreiss. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)
Caliche and broken rock	47	47
Shale, medium soft, gray	5	52
Shale, medium hard, gray	9	61
Shale, medium soft, blue-gray, sticky and caving	10	71
Limestone, medium hard, cream-colored, water	7	78
Shale, medium hard, gray	47	125
Shale, medium hard, gray and blue	15	140
Rock, medium soft, gray	16	156
Shale, very soft, sticky, blue	4	160
Shale, medium hard, blue	5	165
Rock, hard, light-yellow	131	296
Rock, very hard, gray	64	360
Shale, soft, sticky, dark-blue	5	365
Shale, medium soft, blue	7	372
Sandstone, medium hard, blue	7	379
Shale, very soft, green, sandy, lots of granite sand	3	382
Shale, sandy, medium soft, green	2	384
Sand, granite, soft, coarse	5	389
Rock, very hard, gray, blue, pink and white	9	398

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Well RB-57-58-702--Continued

	Thickness (feet)	Depth (feet)
Shale, medium soft, pink	3	401
Sand, fine, brown	4	405
Rock, medium hard, gray	7	412
Clay, medium soft, red	8	420

Well RB-57-59-403

Owner: B. Oelkers. Driller: H. W. Schwope.

	Thickness (feet)	Depth (feet)
Caliche	20	20
Shale, blue and limerock	25	45
Shale, blue (sandy) and limerock	15	60
Rock, honeycomb (seep)	5	65
Limerock and shale, sandy	65	130
Limestone, white	20	150
Limerock and gray shale, sandy	40	190
Lime, porous, and hard shale	6	196
Limerock and shale	19	215
Sand, water	5	220
Rock, hard	2	222
Sand, coarse, and quicksand, granite sand	10	232

Well RB-57-59-804

Owner: W. M. Kothrum. Driller: J. Edmonds.

	Thickness (feet)	Depth (feet)
Soil, caliche, and rock	15	15
Shale, gray, and lime shells	165	180
Shale, gray, and sand	10	190
Sand, gray	12	202
Lime and sand	76	278
Sand	10	288
Sand, lime, and shale	110	298
Lime, gray	12	310
Shale and lime, gray	10	320
Shale, gray and brown	58	378
Shale, gray and brown with some white	6	384
Lime	34	418
Lime and shale breaks	25	443
Shale, red, and lime shells	20	463
Lime	26	489

(Continued on next page)

Table 5.--Drillers' logs of wells--Continued

Well RB-57-60-906--Continued

	Thickness (feet)	Depth (feet)
Sandstone, medium hard, few pink grains	7	275
Rock and shells, hard, grayish-white	18	293
Rock layers, medium hard, brown to gray, with white shale	119	412
Rock, medium hard, gray, with shale layers	11	423
Shale, medium soft, dark blue or black, with small rocks, lots of shells	6	429
Rock, medium hard, gray	11	440
Sandstone, medium soft, or very porous rock	3	443
Shell and rock, hard, gray	12	455
Rock, hard, grayish-blue, slightly abrasive	11	466
Rock, medium hard, gray	10	476
Rock, hard, gray	11	487
Limestone, medium hard, brownish-white	2	489
Limestone, very hard; brown, green, and white	7	496
Limestone, hard, white	17	513
Rock, medium hard, blue-gray	9	522
Sandstone, hard, blue	6	528
Rock, medium hard, blue-gray, very porous	7	535
Rock, medium hard, blue-gray, very hard layers, all colors	9	544
Shale, medium soft, sticky blue-green (oily)	16	560

Well RB-68-01-309

Owner: City of Comfort. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)
Topsoil	1	1
Gravel, cemented	17	18
Caliche and broken rock	29	47
Shale, soft blue, oily and sticky	13	60
Shale, medium hard, blue	15	75
Shale, very soft, blue	10	85
Rock, medium hard, greenish-yellow	20	105
Shale, soft, blue-gray	10	115
Rock, medium hard, light-gray, and blue shale layers	43	158

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well RB-68-01-309--Continued					
Rock, medium hard, blue-	12	170	Shale, soft, dark blue, lots of sand----------	7	287
Rock, medium hard, light-gray-----------	18	188	Shell and rock, medium hard, gray-----------	19	306
Rock, medium soft, brown----------------	7	195	Sand, coarse, granite, water----------------	4	310
Sandstone, medium soft, blue-gray------------	15	210	Shale, medium soft, blue-green-----------	5	315
Shale, medium soft, green, sandy---------	3	213	Clay and rocks, medium soft, red------------	19	334
Lime, medium soft, gray-green, sandy---------	5	218	Rock, very soft, gray and green, lots of white sand-----------	4	338
Shale, medium soft, green----------------	9	227	Rock, medium hard; gray, green, and white------	6	344
Rock, medium soft, gray-	7	234	Rock, medium soft; gray, green, and white------	11	355
Sand, medium coarse-----	6	240	Lime, medium hard, light gray, sandy----------	20	375
Rock, medium hard, brown----------------	12	252	Rock, hard, dark gray---	10	385
Sand, medium fine, granite, water--------	3	255	Shale, very soft, green, very sticky----------	30	415
Clay, soft, brownish-red------------------	18	273			
Shale, hard, blue-green-	7	280			

Well RB-68-01-902

Owner: Q. Lee. Driller: L. Bergmann & Sons.

Caliche----------------	40	40	Limestone--------------	3	53
Shale, sticky, blue-----	4	44	Rock, light-blue--------	17	70
Rock, blue-------------	6	50	Shale, hard, light-blue-	20	90

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well RB-68-01-902--Continued					
Shale, soft, blue-------	35	125	Rock, light-gray-brown--	25	370
Shale, hard, light-gray-	5	130	Sandstone, dark-blue-brown-----------------	11	381
Shale, soft, light-blue-	33	163	Rock, light-gray--------	4	385
Rock and clay, yellow---	27	190	Shale, blue, and glassy sand-----------------	7	392
Shale, soft, sticky, blue------------------	20	210	Clay, blue-green, sandy-	2	394
Rock, blue--------------	1	211	Rock, light-gray--------	18	412
Shale, hard, blue-------	24	235	Sand and shale, fine, glassy, (water)-------	5	417
Shale, hard, gray-------	5	240	Sandstone, blue---------	12	429
Rock and shell, light-gray-----------------	12	252	Rock, very hard, brown--	3	432
Shale, sticky, blue-----	8	260	Rock, brown-------------	8	440
Rock, light-blue--------	50	310	Rock, blue--------------	10	450
Shale, light-blue-gray--	25	335			
Rock, light-gray--------	10	345			

Well RB-68-02-106

Owner: W. G. Sprawls. Driller: L. Bergmann & Sons

Topsoil-----------------	7	7	Rock, hard, light-gray, seep------------------	15	60
Caliche and gravel------	11	18	Mud layers, hard, gray--	25	85
Rock, dark-yellow-------	6	24	Rock, light-gray, oily--	10	95
Caliche and broken rock-	11	35	Shale, medium hard, blue------------------	5	100
Shale, hard, blue-------	10	45			

(Continued on next page)

Table 5.--Drillers' logs of wells--Continued

Well RB-68-02-106--Continued

	Thickness (feet)	Depth (feet)
Rock, soft, light-gray, water----------	14	114
Rock, medium soft, yellowish------------	21	135
Rock, medium hard, gray--	10	145
Shale, soft, blue-------	4	149
Rock, medium hard, gray-	7	156
Rock, hard, light-gray--	5	161
Sand, coarse granite, water----------------	12	173
Sandstone, hard, gray---	5	178
Sand, medium coarse, light-red------------	5	183
Sandstone, medium hard, light-gray-----------	4	187
Sand, dark-red---------	3	190
Clay, sandy, green and yellow---------------	15	205
Sand, fine, red, with green shale-----------	5	210
Rock, light-gray--------	13	223
Shell and rock, hard, blue-----------------	10	233
Shale, soft, blue-black-	4	237
Sandstone, medium hard, light-blue-----------	5	242
Sand, medium-coarse, gray, trace of red mud-----------------	5	247

Well RB-68-02-501

Owner: Mrs. P. R. Samuels. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)
Silt, sand, and gravel--	38	38
Rock, light-blue--------	27	65
Sandstone, blue---------	8	73
Shale, sandy, blue------	12	85
Rock, blue--------------	7	92
Clay, sticky, blue------	15	107
Sandstone, blue---------	4	111
Sand, coarse, gray and glassy, water---------	8	119
Rock, hard, gray--------	3	122
Rock, light-gray, and shell----------------	11	133
Rock, hard, gray, and shell----------------	9	142
Sandstone, dark-blue----	18	160
Sand, fine, gray, and glassy---------------	4	164
Rock, and sand, light-gray-----------------	5	169

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Well RB-68-02-501--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay and sand, red------	4	173	Sand and granite--------	4	194
Clay, red---------------	10	183	Rock, hard, white-------	2	196
Clay, blue-green, and light-green rock------	4	187	Rock, green and white---	7	203
Shale, green and white--	3	190			

Well RB-68-02-805

Owner: J. J. Martinez. Driller: H. W. Schwope.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Caliche ---------------	15	15	Lime, gray, some shale -	50	370
Rock, yellow ----------	5	20	Lime, white, porous ----	60	430
Shale, blue, and lime-rock ----------------	35	55	Shale, blue-black ------	10	440
Lime, cream-colored, porous --------------	5	60	Limerock, white --------	10	450
Shale, gray, sticky ----	22	82	Shale, limy, hard, gray ----------------	45	495
Rock, yellow, sedimentary ----------------	18	100	Limerock, white --------	5	500
Shale, blue, layers of lime, sticky ---------	75	175	Shale, gray, hard ------	45	545
Shale, hard, gray ------	15	190	Rock, light-gray, sedimentary ----------	15	560
Shale, gray, and lime-rock ----------------	60	250	Limerock, white --------	35	595
Shale, blue, and lime layers --------------	40	290	Shale, hard, brown, and limerock-------------	10	605
Limerock, some water ---	15	305	Shale, light-gray, and limerock-------------	7	612
Shale, gray -----------	15	320	Shale, muddy------------	13	625

Well RB-68-03-102

Owner: B. O. Timberlake. Driller: H. W. Schwope.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Caliche and gravel, water	30	30	Shale, streaks of green	1	126
Rock, white	5	35	Sandrock	4	130
Rock, soft, yellow	10	45	Sand and shell, coarse	5	135
Shale, blue	5	50	Lime, hard, white	15	150
Limerock and shale	10	60	Rock, white, chalky	15	165
Sandrock, brown	5	65	Shale and limerock	13	178
Limerock and shale	50	115	Shale, green	12	190
Limerock and sandy shale	10	125			

Well RB-68-03-402

Owner: H. Atherton. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	2	2	Shale, hard, gray-white	24	107
Clay, brown, some gravel	37	39	Rock with clay, medium hard, grayish-white	9	116
Gravel, clean	9	48	Shale, medium hard, blue-gray	8	124
Shale, medium hard, light-blue	5	53	Rock, medium hard, blue-gray	5	129
Rock, very hard, blue-gray	13	66	Shale, medium soft, light-blue	6	135
Rock, medium hard, blue-gray, with clay layers	8	74	Shale, medium soft, light-red (pink mud)	11	146
Shale, medium hard, gray	5	79	Shale, hard, light-gray	5	151
Rock, medium hard, gray	4	83			

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Table 5.--Drillers' logs of wells--Continued

Well RB-68-03-402--Continued

	Thickness (feet)	Depth (feet)
Rock, very hard, light-gray	16	167
Shale, medium hard, gray	3	170
Rock, very hard, dark-gray, with layers of pink and gray rock and medium hard gray sandstone, porous	6	176
Sandstone, medium hard, dark-gray	8	184
Sandstone, hard, light-gray to green, pink, and brown	13	197
Shale, hard, light-gray	11	208
Shale, medium hard, blue-green, very sticky	47	255
Shale, medium soft, dark-blue, very sticky	7	262
Clay, medium soft, dirty brown, very sticky	10	272
Shale, medium hard, gray	80	352
Rock, medium hard, gray	18	370
Shale, medium hard, pink with pink rock layers	28	398
Rock, hard, light-gray	17	415
Rock, hard, brownish-gray, with pink shale	34	449
Rock, medium hard, abrasive (all colors)	26	475
Shale, medium soft, green-brown to black, with floating rock	15	490
Shale, medium soft, green	11	501
Shale, medium hard, green	5	506
Rock, very hard, gray and green	5	511
Shale, medium hard, gray-blue	11	522
Shale, medium soft, blue (sticky)	38	560
Rock, medium hard, blue	27	587
Sandstone, very hard, black and green, abrasive	8	595
Rock, medium hard, dark, blue-black	6	601
Sandstone, very hard, blue and green, abrasive	21	622
Rock, hard; black, brown, white, and green	6	628
Shale, medium soft, black, trace of oil	7	635
Rock, very hard, black, yellow mineral	20	655

Well RB-68-03-701

Owner: H. E. West. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Rock, broken	1	1	Rock and shell, light-gray	77	295
Rock, medium and soft	13	14	Rock, hard, light-gray	27	322
Clay, yellow	8	22	Clay, blue, sticky	8	330
Shale, blue	6	28	Sandstone, dark-gray	3	333
Shale, blue, sticky	22	50	Rock, blue	10	343
Rock and shale, blue	30	80	Shale, hard, gray	12	355
Shale, blue, sticky	20	100	Rock, blue	30	385
Clay, blue, sticky	9	109	Rock, white, and coal particles	8	393
Rock, blue	2	111	Rock, dark-blue, and shale	21	414
Shale, soft, blue	7	118	Sandstone, light-brown	12	426
Clay and rock, yellow (seep)	6	124	Shale, blue	4	430
Shale, blue	8	132	Sand, granite, and gravel	3	433
Rock, blue, porous	1	133	Limestone, white	2	435
Shale, blue, sticky	12	145	Limestone, white, porous	13	448
Rock, blue, hard	2	147	Limestone, white, hard	11	459
Shale, blue, soft	5	152	Rock, brown, porous	1	460
Shale, blue	13	165			
Shale, light-blue, hard	35	200			
Rock, soft, blue-white	12	212			
Putty, gray	6	218			

Well RB-68-04-505

Owner: -- Hagelstein. Driller: C. G. Newton.

	Thickness (feet)	Depth (feet)
No record	15	15
Limestone, white, oölitic, soft; shell fragments	30	45
Limestone, earthy, nodular	30	75
No record	10	85
Limestone, light-gray, dolomitic, finely nodular; _Orbitolina texana_ (Romer) rare	10	95
Limestone, light-gray, oölitic	20	115
Dolomite, light-gray, finely crystalline	10	125
Dolomite, light-gray, and sandy limestone	10	135
Dolomite, light-gray, finely crystalline	20	155
Dolomite, light-gray, nodular	20	175
Limestone, light-gray, oölitic, nodular	20	195
Dolomite, medium-grained, sandy, nodular, glauconitic	10	205
Dolomite, light-gray, finely crystalline	20	225
Limestone, white, oölitic	40	265
Dolomite, medium-grained to finely crystalline	30	295
Shale, calcareous, sandy; oyster fragments frequent	50	345
Limestone, dolomitic, porous with pink oölites; oyster fragments abundant	30	375
Shale, tan and gray, and oölitic limestone; oyster fragments frequent	10	385
Limestone, white, oölitic, and gray fine-grained dolomite	20	405
Dolomite, light-tan, finely crystalline	10	415
Shale, medium-grained, with trace of sandstone and dolomite	10	425

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-04-505--Continued		
Dolomite, light-tan, finely crystalline, nodular	10	435
Dolomite, light-tan, finely crystalline, nodular	10	445
Dolomite, tan, and oölitic limestone	30	475
Limestone, pink, dolomitic, with white nodular limestone and gray sandy shale	10	485
Shale, pink and white, mottled and medium-grained sandy shale	30	515
Sandstone, tan to pink, medium-grained, porous	10	525
Sandstone and shale with abundant chert and limestone fragments	20	545
Limestone, pink, and medium-grained crystalline dolimite with vericolored chert fragments	10	555
Shale, red, sandy, and nodular white limestone	10	565
Shale, varicolored, with white limestone and gray dolomite	10	575
Limestone fragments and shale	10	585
Limestone, white, nodular, and black shale	20	605
Shale, chocolate colored, contorted	240	845
Shale, chocolate and olive green	455	1,300
No record	1,042	2,342
Well RB-68-10-201		
Owner: F. Offenhauser. Driller: L. Bergmann & Sons.		
Dirt, black	2	2
Rock, soft, white	6	8
Rock, medium hard, light-yellow	47	55
Rock, medium hard, dark-yellow	20	75
Shale, medium hard, blue	22	97

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-10-201--Continued		
Shale, medium soft, gray	28	125
Rock, soft, light-yellow, very small seep	7	132
Shale, medium hard, blue-gray	65	197
Shale, medium soft, blue	8	205
Shale, medium hard, gray	50	255
Shale, medium soft, gray, sticky	10	265
Shale, medium hard, gray, with thin layers of soft sticky blue shale	52	317
Shale, soft, blue, sticky, very oily	8	325
Shale, medium hard, blue-gray	25	350
Shale, medium soft, blue, sticky	18	368
Rock, medium soft, light-gray, seep	29	397
Shale, medium soft, blue-gray	18	415
Shale, medium hard, gray	35	450
Shale, medium soft, gray, slightly sticky	22	472
Rock, medium hard, dark-gray, water	25	497
Rock, hard, dark-gray, water	18	515
Shale, medium soft, gray	40	555
Rock, medium soft, grayish-white	13	568
Rock, hard, brown	7	575
Rock and shell, medium soft, white, water	40	615
Rock, medium hard, white	30	645
Rock and shells, soft, white	15	660
Rock, medium hard, grayish-white	20	680

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-10-201--Continued		
Rock, medium soft, very porous	12	692
Rock, medium hard, gray	16	708
Shale, medium soft, blue-gray	7	715
Shale, medium hard, green	15	730
Sandstone, medium soft, blue-gray	10	740
Rock, medium hard, gray, with layers of soft shale	20	760
Rock, medium hard, gray	24	784
Sand, soft, glassy, some water	1	785
Rock and shells, medium hard; blue, gray, and white	35	820
Shale, sandy, medium soft, gray, caves badly	20	840

Well RB-68-10-801

Owner: J. Less. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)
Caliche	20	20
Shale and rock, blue	20	40
Shale, light-blue	106	146
Rock and gypsum, hard, porous, blue, water	4	150
Shale, soft, blue	15	165
Rock, soft, light-gray	6	171
Shale, hard, blue-gray	16	187
Shale, soft, light-blue	13	200
Shale, light-blue	10	210
Shale, hard, light-gray	22	232
Shale, soft, blue	38	270

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-10-801--Continued		
Shale, hard, blue	3	273
Shale, soft, blue	12	285
Shale, light-gray	11	296
Shale, light-blue	41	337
Rock and gypsum, blue	28	365
Shale and rock, hard, blue	45	410
Rock, blue-white	20	430
Shale, hard, light-gray	20	450
Limestone, soft, light-gray, porous	40	490
Shale, hard, light blue-gray	35	525
Shale, sandy, hard, gray	35	560
Shale, hard, gray, and oyster shells	5	565
Sandstone, gray	13	578
Shale, blue	10	588
Rock, light-blue	12	600

Well RB-68-10-806

Owner: T. N. Smith. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)
Rock layers and gravel	24	24
Shale, medium hard, light-blue	57	81
Shale, light-gray	20	101
Rock, porous, blue-gray, strong supply of water	4	105
No record	2	107
Shale and rock, gray	78	185

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	Thickness (feet)	Depth (feet)
Well RB-68-10-806--Continued		
Shale, medium soft, light-blue	11	196
Shale, soft, sticky, blue-gray	4	200
Shale, blue-gray	38	238
Shale and rock, gray	24	262
Shale, soft, sticky, blue	19	281
Shale, medium hard, gray	11	292
Shale, medium soft, light-blue	7	299
Rock and gypsum, hard, light-blue	20	319
Rock, hard, light-brown	2	321
Rock, dark-blue	3	324
Shale, medium soft, sticky, light-blue	21	345
Rock, hard, gray	11	356
Shale, soft, light-blue	5	361
Shale, medium hard, light-gray	5	366
Limestone, very hard, yellow	11	377
Shale, hard, gray	15	392
Shale, medium hard, yellow	4	396
Rock and shale, hard and medium hard, gray	51	447
Limestone, hard and very hard, gray	88	535
Shale, hard, light-blue	6	541
Limestone, hard, gray	34	575
Limestone, medium hard, blue-gray	16	591
Limestone, very hard, white	15	606
Limestone, hard, gray	12	618

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	Thickness (feet)	Depth (feet)
Well RB-68-10-806--Continued		
Sandstone, hard, light-blue, trace of granite sand	23	641
Shale, medium soft, dark-blue, abundant shells	20	661
Limestone, sandy, gray	24	685
Lime, hard, light-brown	11	696
Shell rock, hard, gray	24	720
Shale, medium hard, oily, gray	26	746
Gumbo, soft, sticky, blue oyster shells	49	795
Shell rock, blue-gray	43	838
Sandstone, medium soft, brown, possibly porous	14	852
Rock, medium hard, blue	6	858
Rock, soft brown, and white putty	5	863
Rock, medium hard, dark-blue	17	880
Shale, soft and hard, gray	12	892
Shale and lime, hard and soft layers, blue	24	916
Sandstone, medium hard, red	10	926
Rock, hard, gray	10	936
Shale, soft, gray	6	942
Shale, red	3	945
Lime, sandy, white	7	952
Limestone, sandy, red	18	970
Lime, sandy, white, white and yellow grains of sand	13	983
Shale, medium hard; red, gray, and light-blue	23	1,006
Sand formation, porous, water sand; tan, white, and pink	6	1,012
Sandstone, very hard, red	18	1,030

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	Thickness (feet)	Depth (feet)
Well RB-68-10-806--Continued		
Sandstone, very hard, tan and brown	8	1,038
Limestone, hard, pink, brown, and white	12	1,050
Limestone, hard, white	35	1,085
Limestone, medium hard, white and dark-yellow	13	1,098

Well RB-68-11-404

Owner: City of Boerne, well 4. Driller: L. Bergmann & Sons.

	Thickness (feet)	Depth (feet)
Rock, blue and yellow	3	3
Adobe	10	13
Rock, light yellow	3	16
Adobe, yellow, soft	2	18
Shale, blue	25	43
Clay, blue, sticky	13	56
Shale, blue, hard	3	59
Clay, blue, sticky	12	71
Shale, light-blue	18	89
Limestone, yellow, hard, honeycomb	1	90
Limestone, honeycomb, and yellow clay	6	96
Clay, yellow, hard	1	97
Shale, blue	4	101
Rock, blue	3	104
Shale, blue, sticky	7	111
Shale, blue, hard, and shells	4	115
Rock, blue	2	117

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-11-404--Continued		
Shale, blue, hard	7	124
Rock, blue	7	131
Shale, blue	9	140
Clay, blue, sticky	2	142
Rock, light-blue	6	148
Shale, light-gray, hard	10	158
Rock, light-gray	6	164
Limestone, cream-colored	30	194
Shale, light to blue-gray, hard	31	225
Rock, light-gray	20	245
Shale, light to blue-gray, and shells	15	260
Rock, light-gray, and shell	60	320
Rock, blue	12	332
Rock, light-gray, sandy, and shell	11	343
Shale, dark-blue	5	348
Rock, blue	7	355
Rock, dark-blue, hard	5	360
Limestone, light-gray, and shell	14	374
Clay, light-blue	6	380
Rock, blue, with few pink sand grains	5	385
Rock, gray, with few pink sand grains	7	392
Sandstone, blue, with shale and white crystals	15	407
Shale, blue, soft	2	409
Rock, blue, and shell	1	410

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-11-404--Continued		
Shale, blue, soft	11	421
Rock, blue, and shell	2	423
Shale, blue-green, sticky	3	426
Sandstone and chert fragments	2	428
Sandstone, blue-gray	4	432
Shale, blue, soft	3	435
Shale, blue, and granite sand	6	441
Limestone and sand	1	442
Rock, dark-blue, porous	3	445
Limestone, white, hard	19	464
Rock, light-blue, hard	2	466
Shale, light-blue, hard	11	477
Rock, blue, porous limestone	7	484
Limestone, white, porous	3	487
Rock, gray-green, oily	4	491
Limestone, gray-green, sandy, and rock	7	498
Shale, gray-green, sandy	2	500
Shale, light-blue, sandy	5	505
Clay, bright-blue, sticky	2	507
Clay, blue, sticky, and dark shells	8	515
Clay, blue, sticky	7	522

	Thickness (feet)	Depth (feet)
Well RB-68-11-702		
Owner: L. Marchak. Driller: L. Bergmann & Sons.		
Caliche and rock ledges	33	33
Clay, sticky, blue	7	40
Rock ledge	2	42
Clay, sticky, blue	10	52
Rock, light-blue	14	66
Shale, light-blue	59	125
Clay, soft, blue	11	136
Rock, medium hard, blue, and gyp particles	22	158
Shale, blue	2	160
Rock, medium hard, blue	10	170
Shale, dark-blue (soft sticky)	11	181
Shale, blue	11	192
Shale, light-blue	12	204
Rock, gray	6	210
Shale, blue	5	215
Shale, light-gray	14	229
Rock, light-gray and white	7	236
Shale, light blue-gray	19	255
Shale, light-gray, hard	51	306
Rock, light-gray	82	388
Clay, blue-green	3	391
Shale, light-gray, porous	10	401
Sandstone, gray, light and soft	12	413

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-11-702--Continued		
Rock and shell, light-gray	15	428
Shale and shell, blue	4	432
Rock slate, blue	4	436
Rock, light-brown	14	450
Rock, dark-blue	11	461
Sandstone, brown, containing glassy sand	9	470
Sandstone, blue, containing glassy sand	10	480
Rock, blue, and shale	27	507
Rock, blue, and shell beds	3	510
Clay, dark blue-green, sticky	2	512
Rock, hard, dark gray-green	3	515
Rock, hard, cream-color	2	517
Limestone, white, porous, water	24	541
Rock, light-blue	7	548
Shale, light-gray, sandy	12	560
Well RB-68-12-405		
Owner: A. E. Coveney. Driller: L. Bergmann & Sons.		
Caliche and white rock layers	19	19
Shale, soft blue	5	24
Rock, medium hard, blue	18	42
Rock, hard	1	43
Rock and clay, porous, yellow, dry	17	60
Rock, hard, light-blue	7	67

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Table 5.--Drillers logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-12-405--Continued		
Shale, medium soft, blue	2	69
Shale, medium hard, blue	28	97
Shale, soft, blue	2	99
Shale, hard, gray-blue	17	116
Rock and limestone, medium hard, light-yellow	6	122
Limestone, medium hard, cream-colored, dry, porous	28	150
Lime, hard, gray-white, some porous layers	18	168
Limestone, hard, gray	12	180
Limestone, soft, white, very porous	9	189
Rock, hard, gray-blue	27	216
Rock, hard, gray-white	5	221
Rock, very hard, gray-white	3	224
Rock, medium hard, gray	34	258
Rock, medium soft, gray	3	261
Rock, medium hard, gray	16	277
Rock, soft or porous	1	278
Rock, medium hard, gray	2	280
Rock, medium hard, blue, some abrasive sand	11	291
Shale, medium soft, blue	2	293
Rock, medium hard, blue	6	299
Shale, medium soft, blue	1	300
Rock, medium hard, light-gray and brown glassy parts	5	305
Sandstone, medium hard, gray and brown	9	314
Rock, medium hard, light-gray, sandy	27	341

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Table 5.--Drillers' logs of wells--Continued

	Thickness (feet)	Depth (feet)
Well RB-68-12-405--Continued		
Shell, and rock, medium hard, light-blue	5	346
Rock, medium hard, blue	3	349
Rock, medium hard, blue-gray, soft or porous	17	366
Shale, medium hard, blue, oily trace, some soft sticky	3	369
Rock, medium hard, blue-gray, with brown shell rock	9	378
Shale, shell, and rock, medium hard, blue	8	386
Rock, very hard, light-gray, very abrasive	14	400
Limestone, soft or porous, sandy, white, probably water	26	426
Rock, medium hard, gray and brown, possibly porous	11	437
Rock, medium hard, light-gray	5	442
Shale, soft, gray	3	445
Shell and rock, medium hard, gray-blue	16	461
Shale, medium soft, blue-green, oily, some clay	5	466
Shells and shale, hard, blue	1	467
Gumbo, very soft, sticky, dark blue-green, caving	13	480