TEXAS WATER DEVELOPMENT BOARD

REPORT 299

GROUND-WATER RESOURCES OF LIMESTONE COUNTY, TEXAS

By

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U.S. Geological Survey

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FOREWORD

Effective September 1, 1985, the Texas Department of Water Resources was divided to form the Texas Water Commission and the Texas Water Development Board. A number of publications prepared under the auspices of the Department are being published by the Texas Water Development Board. To minimize delays in producing these publications, references to the Department will not be altered except on their covers and title pages.

ABSTRACT

Limestone County, located in east-central Texas, has small to plentiful ground-water supplies available, depending upon the location within the county. The Wilcox Group in the eastern part of the county has adequate supplies to meet the expected water demands in the foreseeable future. The thicker zones of the Wilcox Group can supply yields in excess of 500 gallons per minute. The Midway Group can supply yields in excess of 100 gallons per minute from the Tehuacana Member of the Kincaid Formation. This represents the largest well yields from the Midway Group in Texas. The Midway Group elsewhere in the State is mostly a poor water producer and is not considered an aquifer. The Taylor Marl and Navarro Group furnish only small quantities of ground water to wells in the western part of the county where these units crop out. The Hosston and Travis Peak Formations are present at depths in excess of 2,000 feet. These formations, which contain slightly saline water in the western part of the county, could be expected to produce water with a temperature of about 150°F that might be used for heating purposes.

About 0.9 million gallons per day of ground water was used for all purposes in 1980. This use has declined since 1955 but is expected to increase as additional public-supply and industrial wells are being developed. The Wilcox Group is capable of annually yielding at least 14,000 acre-feet or 11.6 million gallons per day of water to wells on a long-term basis.

Generally, the ground water is of acceptable quality for most uses. Relatively high dissolved-solids and iron concentrations are the major water-quality problems. Water-quality problems that may be the result of man's activities are limited to a small oilfield area near Mexia.

Lignite mining from the Wilcox Group is expected to take place in the foreseeable future. The collection of additional hydrologic data on the Wilcox would be desirable before, during, and after mining.

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INTRODUCTION

An investigation by the U.S. Geological Survey, in cooperation with the Texas Water Development Board, was conducted during 1980-83 to determine the occurrence, availability, dependability, quality, and quantity of the ground-water resources of Limestone County. Special emphasis was placed upon describing the water requirements and sources of water suitable for municipal, industrial, and irrigation use. The results of the investigation are presented in this report and will be useful in developing, protecting, and obtaining maximum benefits from the available ground-water supplies.

The scope of the investigation included determining the location and extent of major aquifers, the chemical quality of the water in the aquifers, the quantity of ground water being pumped for all uses, the hydraulic characteristics of the principal water-bearing formations, estimates of the quantities of ground water available for development from each of the major aquifers, and a discussion of the significant ground-water problems in the county.

This report includes records of 326 water wells, springs, and oil tests and chemical analysis of water from 120 wells and 10 springs. Other records and information, including drillers' logs and electric logs, are on file at the U.S. Geological Survey or Texas Water Commission. Present (1981-82) and past pumpage of ground water was inventoried. Several aquifer tests were made to obtain information on the hydraulic characteristics of various water-bearing formations. The geology is from the Geologic Atlas of Texas, which was prepared by the University of Texas, Bureau of Economic Geology. Altitude, latitude, and longitude of each well were determined from available Geological Survey 7½-minute topographic maps having a contour interval of 10 ft. Photographs used in this report were taken by the author during 1981. The technical terms used in discussing the ground-water resources of the county are defined in the section entitled "Definition of Terms" (supplemental information). The stratigraphic nomenclature used in this report was determined from several sources and may not necessarily follow usage of the Geological Survey.

Location and Extent of the Area

Limestone County is a 931-mi^2 area in the central part of northeast Texas (Figure 1) between latitudes 31°13' and 31°49'N and longitudes 96°14' and 96°56'W. Groesbeck, the county seat, is in the central part of the county, 93 mi south of Dallas.

Climate

Limestone County has a subhumid climate with precipitation less than potential evapotranspiration. The average-annual precipitation at Mexia is 37.6 in. The precipitation is fairly evenly distributed throughout the year with the months of April and May having slightly higher precipitation averages (U.S. Department of Commerce, 1980). Mexia has an average-annual temperature of 65.8°F with a growing season of about 260 days per year. The average monthly temperature extremes range from 37°F during January to 96°F during July. The average-annual gross lake-surface evaporation from Lake Mexia during 1963-70 was 51.2 in. (Dougherty, 1975).

Figure 1.—Location of Limestone County

Topography and Drainage

The topography is characterized by rolling hills and shallow valleys. The altitudes range from about 325 ft above sea level in the Navasota River bottom (now covered by Lake Limestone at the southeast border of the county) to a maximum of about 690 ft in the northwest part of the county. Most of the county is drained by the Navasota River and other tributaries of the Brazos River. The northeastern tip of the county is drained by creeks that flow into the Trinity River. The most prominent physiographic feature—a high hill—is related to the Mexia-Talco fault zone that extends in a northeast trend through the area. The fault zone forms this high hill with an altitude of 660 ft in the city of Tehuacana, and locally it is known as the highest point between Dallas and Houston. Historic springs flow from the northeast slope of this high hill. The northwest part of the county has soils of the Black Prairie Group, while the southeast part of the county has loose, sandy soil. The East Texas Timber Belt, consisting mostly of oak and cedar trees, extends into the southeast part of the county.

Population and Economy

The 1980 population of Limestone County was 18,200, with Mexia, Groesbeck, Thornton, and Kosse being the major population centers. The economy is based upon production of minerals and agriculture. Major minerals are gas and oil. Gas and oil production began in an oilfield near Mexia during 1912, making it one of the oldest oilfields in Texas. Other minerals produced are sand, limestone, and clay. The manufacture of bricks and ceramics have ceased in recent years but the raw materials are still available. Undeveloped lignite deposits in the south part of the county are expected to be mined in the near future for use in electric power generation.

When European traders entered the area in the late 18th century, the American Indian inhabitants were using springflow as a water source. Permanent Indian dwellings were in use along the Navasota River and at the springs near the present city of Tehuacana (Williams, 1969; Lorrain, 1963).

Springflow along the Navasota River near the present State Highway 14 encouraged early settlers to locate the town of Springfield there. Springfield began to decline when the railroad bypassed the town during the late 19th century (Walter, 1959) and remains as a small rural community. The water resources of the Springfield area were used by the city of Mexia from about 1900 to 1925 and are still used by the city of Groesbeck. During 1925, the city of Mexia drilled water wells in the Iley well field, 3.0 mi west of the city. The well field was used until 1962 when the city began using Lake Mexia on the Navasota River as its water supply.

The city of Tehuacana used springflow from Tehuacana Springs until about 1940 when a water-supply well was drilled near the springs. The city of Thornton has used ground water from a well field 4.0 mi west of the city since about 1940. The city of Kosse used ground water from a site 2.5 mi east of that city from 1939 until 1978. At present (1983) Kosse is being supplied ground water from outside of Limestone County.

A drought in the mid-1920's was reported by the local residents. Stock ponds and creeks went dry, and shallow pits were dug in the creek bottoms to the water table to obtain ground water for domestic and stock use.

Previous Investigations

Prior to this investigation, little detailed study had been made of the ground-water resources of Limestone County. Deussen (1914) reported on six wells and four springs in the county. In their inventory of public-water supplies of eastern Texas, Sundstrom and others (1948) included considerable information on the water sources for the municipalities in Limestone County. Bryan (1951) and Rose (1952) had separate unpublished evaluations of the ground-water resources near Mexia. Winslow and Kister (1956) mentioned the saline water supplies of this area in their Statewide report. Burnitt and others (1962) made a study of saltwater contamination of surface and ground water near an area of oilfield operations, which began during 1912. Ground-water reconnaissance studies by river basin were conducted throughout Texas beginning in 1959. Cronin and others (1963) and Peckham and others (1963) reported on the Brazos and Trinity River basins, respectively. There are data from part of Limestone County in each of these reports.

The regional geology is described in detail by Sellards and others (1932). More recently, Bammel (1979) reported on the deposition of the Simsboro Formation. The University of Texas, Bureau of Economic Geology (1970) published geologic maps of the area.

Well-Numbering System

The well-numbering system used in this report is based on the divisions of latitude and longitude and is the one adopted by the Texas Water Development Board for use throughout the State. Under this system, each 1-degree quadrangle in the State is given a number consisting of two digits, from 01 to 89. These are the first two digits of the well number. Each 1-degree quadrangle is divided into 7½-minute quadrangles, which are given two-digit numbers from 01 to 64. These are the third and fourth digits of the well number. Each 7½-minute quadrangle is subdivided into 2½-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 2½-minute quadrangle is given a two-digit number in the order in which it was inventoried, starting with 01. These are the last two digits of the well number. In addition to the seven-digit well number, a two-letter prefix is used to identify the county. The prefix for Limestone County is SD. Thus, well SD-39-20-302 (which supplies water for the city of Tehuacana; see Figure 20) is in Limestone County (SD), in 1-degree quadrangle 39, in 7½-minute quadrangle 20, in the 2½-minute quadrangle 3, and the second well (02) inventoried in that 2½-minute quadrangle (Figure 20). The Geological Survey's national site identification system uses the latitude-longitude coordinate system. Well SD-39-20-302 is located at latitude 31°44'53" and longitude 96°32'10" and with a 2-digit sequence number forms the 15-digit sequence number of 314453096321002.

Acknowledgments

The author is indebted to the well owners in Limestone County for permitting access to their property and for supplying information about their water wells, and to the local well drillers for providing logs and other information on water wells. Particular appreciation is expressed to Bobby Trantham, Water Superintendent, City of Tehuacana; Bill Neason, Water Superintendent, City of Thornton; Jim Reece, Mexia State School; John Winkler, Wallace Engineering; and Buster Chrisner, a local land owner, for their help in pumping several wells for aquifer tests.

Metric Conversions

For those readers interested in using the metric system, the inch-pound units of measurement used in this report may be converted to metric units by the following factors:

From	Multiply by	To obtain
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.189	meter per kilometer
foot squared per day (ft^2/d)	0.0929	meter squared per day
gallon per minute (gal/min)	0.06308	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
inch (in.)	25.4	millimeter
micromho per centimeter at 25° Celsius (μmho)	1.000	microsiemens per centimeter at 25° Celsius
mile (mi)	1.609	kilometer

From	Multiply by	To obtain
million gallons (Mgal)	3,785	cubic meter
million gallons per day (Mgal/d)	0.04381	cubic meter per second
	3,785	cubic meter per day
square mile (mi^2)	2.590	square kilometer
degree Fahrenheit (°F)	°C =5/9 (°F-32)	degree Celsius (°C)

GEOLOGY AS RELATED TO THE OCCURRENCE OF GROUND WATER

General Description and Structure

The principal geologic formations that contain fresh to slightly saline water (see Definition of Terms in Supplemental Information) in Limestone County are, from oldest to youngest: The Hosston Formation, Travis Peak (Pearsall) Formation, and Taylor Marl and Navarro Group of Cretaceous age; the Midway and Wilcox Groups of Tertiary age; and the alluvial deposits of Quaternary age. The Quaternary deposits are not extensive and are not known to be tapped by wells. Only the Taylor Marl and Navarro Group, undifferentiated, and younger formations are exposed in Limestone County (Figure 2). The Hosston and Travis Peak are not tapped by water wells within the county, although they contain slightly saline water, which has been mapped on the basis of projections from adjacent counties.

The areas where fresh and slightly saline water generally is available to wells are shown by geologic formation in Figure 3. Exceptions can be expected to occur in local areas, especially in the Midway Group. Areas within the Taylor Marl and Navarro Group are not designated because of the meager quantities of ground water in these units.

The subsurface position and depths of the geologic formations along a line across Limestone County are shown in Figure 4. This section also illustrates the vertical displacement of the formations as a result of faulting.

The thickness, lithologic characteristics, age, and water-bearing properties of the geologic units are summarized in Table 1. Maximum thicknesses of the geologic units given in this table were determined from interpretations of electrical and drillers' logs. Lithology as described by drillers on well logs is listed in Table 9 (supplemental information).

The major structural feature in the county is the Mexia-Talco fault system. The rock strata associated with the Mexia-Talco fault system are intricately faulted and locally folded into a deep, structural trough that trends northeastward through the central part of Limestone County (Figure 2). Graben and horst features are present and have considerable effect on the hydraulic characteristics of the ground-water flow system.

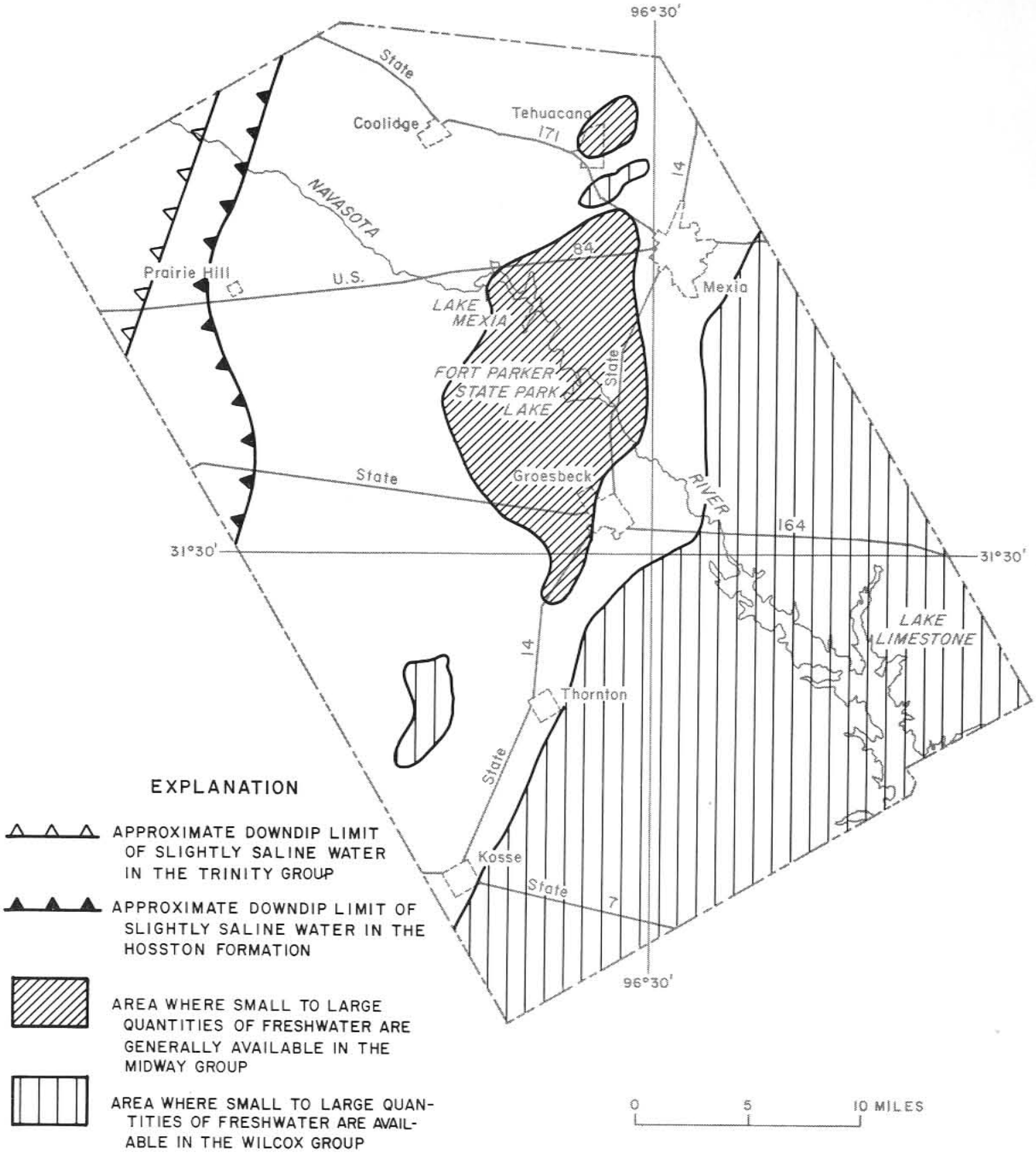

Figure 3.—Occurrence of Fresh and Slightly Saline Ground Water

Physical Description and Water-Bearing Properties of the Geologic Units

Pre-Cretaceous Rocks

The Pre-Cretaceous sedimentary rocks in the Limestone County area (Table 1) are nearly impermeable shales, quartzites, and limestones. Oil test wells have penetrated these rocks, but no water is produced from them within the county. Any water contained in them probably would be highly mineralized.

Table 1.—Geologic Units and Their Water-Bearing Properties

System	Series	Group	Geologic unit	Maximum thickness or range (feet)	Character of rocks	Water-bearing properties
Quaternary	Holocene and Pleistocene		Alluvium	0-40±	Sand, silt, clay, and gravel.	Has no known producing wells.
Tertiary	Eocene	Wilcox	Calvert Bluff Formation Simsboro Formation Hooper Formation	0-1,175	Sand, sandstone, clay, lignite, mudstone, silt, shale, gravel, and ironstone concretions.	Major aquifer in Limestone County.
Tertiary	Paleocene	Midway	Wills Point Formation	550±	Clay, silty, sandy, some limestone.	Yields small quantity of water to wells locally, usually poor quality.
Tertiary	Paleocene	Midway	Kincaid Formation: Tehuacana Member	130 (estimated)	Limestone, glauconitic, some marl.	Moderate to large well yields locally.
Tertiary	Paleocene	Midway	Kincaid Formation: Pisgah Member and Littig Glauconitic Member, undifferentiated	300 (estimated)	Sand and clay, glauconitic.	Small-yield wells on outcrop; important recharge area for some springs.
Cretaceous	Gulf	Navarro Group and Taylor Marl, undifferentiated		1,800±	Silty clay, chalk, marl; some sandstone.	A few small-yielding dug wells on outcrop; mostly non-water bearing.
Cretaceous	Gulf Comanche	Austin Chalk, Eagle Ford Shale, Woodbine Formation, and Washita and Fredericksburg Groups, undifferentiated		1,500+	Chalk, shale, gypsum, sandstone, and limestone.	Not sources of fresh to slightly saline ground water in Limestone County.
Cretaceous	Comanche	Trinity	Glen Rose Limestone	1,300±	Limestone, clay, marl, and some sandstone.	Not a source of fresh ground water in Limestone County.
Cretaceous	Comanche	Trinity	Travis Peak (Pearsall) Formation	350±	Sandstone, shale, and limestone.	Source of slightly saline water in western corner of Limestone County. No known producing wells within county.
Cretaceous	Coahuila	Nuevo Leon and Durango	Hosston Formation	2,000±	Sandstone, siltstone, shale, some limestone.	Source of slightly saline water in western corner of Limestone County. No known producing wells within county.
Pre-Cretaceous rocks				?	Shale, quartzite, and limestone.	Water-yielding ability unknown. Any water present is expected to be highly mineralized.

Cretaceous System

Hosston Formation

Although there are no known producing wells in the Hosston Formation, it is the deepest formation in Limestone County that contains slightly saline water. The Hosston Formation is about 2,750 feet (850 m) below land surface in the western corner of the county and dips to the southeast at about 100 ft/mi (Klemt and others, 1975). The eastern limits of the slightly saline water are shown in Figure 3.

Trinity Group

The Hosston Formation is overlain by the Trinity Group with only the Travis Peak Formation and Glen Rose Limestone present. The Travis Peak and the Glen Rose have a combined thickness of about 1,650 ft. The Travis Peak, which underlies the Glen Rose Limestone, was tested using well SD-39-18-802 (Figure 20). The well was produced through screened intervals near the base of the formation as well as from the Glen Rose; the quality of the produced water was not suitable for public supply (Table 10).

The Travis Peak Formation is composed of sandstone, shale, and limestone that are capable of yielding small amounts of slightly saline water to wells in the far western part of the county. The eastern limits of the slightly saline water are shown in Figure 3 and were obtained by using information from wells outside Limestone County (Cronin and others, 1963).

The upper member of this group is the Glen Rose Limestone. This formation is composed of limestone with considerable clay and marl and some sandstone. It is capable of yielding only small amounts of highly mineralized water. The Glen Rose Limestone has no producing water wells in Limestone County.

Fredericksburg and Washita Groups, Woodbine Formation, Eagle Ford Shale, and Austin Chalk, Undifferentiated

The Fredericksburg and Washita Groups, Woodbine Formation, Eagle Ford Shale, and Austin Chalk crop out in the areas west of Limestone County. Within the county, they have a combined thickness of 1,500 ft or greater and dip to the southeast (see Figure 4). These formations, which are composed of chalk, shale, gypsum, sandstone, and limestone, are not sources of fresh to slightly saline water in Limestone County.

Taylor Marl and Navarro Group, Undifferentiated

The Taylor Marl and Navarro Group are the oldest formations that crop out within Limestone County. Although these rock units may be divisible into several members, they are mostly non-water-bearing. Small quantities of water, however, could be produced in some places from these formations, but the chemical quality would be poor for domestic and livestock use. Several unused, shallow-dug water wells tap the Taylor Marl and Navarro Group on their outcrop in Limestone County. Many other wells in this formation have been filled and destroyed due to small yields and poor quality. At present, most of the residents that live on these outcrops get water by pipeline from rural water-supply systems.

Tertiary System

Midway Group

The Midway Group crops out in a north-northeastward trend across central Limestone County and has a maximum thickness of about 1,000 ft. In ascending order, the formations that compose the Midway Group are the Littig Glauconitic Member, Pisgah Member, and Tehuacana Member of the Kincaid Formation; and the Wills Point Formation. In this area of Texas, the Midway Group yields large quantities of water to wells because of the limestone layer where permeability has been enhanced by the faults and fractures associated with the Mexia-Talco fault system.

The Littig Glauconitic Member and Pisgah Member consist of clay and highly glauconitic sand. These two members, which are undifferentiated in this report, are about 300 ft thick in some places. The members are important water producers in the outcrop areas, where they furnish water to domestic wells and a few springs. The Littig Glauconitic and Pisgah Members form the recharge area for Springfield East and West Springs on the Navasota River, the largest yielding springs within the county.

The Tehuacana Member is composed mostly of hard, indurated, glauconitic limestone and some marl. The name of Limestone County was derived from the presence of this limestone, which crops out in the form of a high hill in the city of Tehuacana. This formation has an estimated maximum thickness of about 130 ft downdip (Figure 4). Large-yield water wells are located near Mexia, and several crushed limestone pits are currently in operation on the outcrop. A few of the springs along the Navasota River occur at the lower end of local, fractured, karst development in the Tehuacana limestone. This Tehuacana Member becomes less distinct and less identifiable in well logs south of Groesbeck or may be completely absent in many places.

The Wills Point Formation consists of silty, sandy clay with some limestone and yields only small quantities of ground water. A few wells and test holes, in which the water has been tested or is in limited use, are listed in Table 8.

Wilcox Group

The Wilcox Group, which crops out in the southeast part of the county (Figure 2), has a maximum thickness of about 1,175 ft in the eastern corner of the county. The base of the Wilcox Group dips to the east-southeast at about 80 ft/mi (Figure 4). It is the major aquifer in the county. The Wilcox in Limestone County is divided into three members. In ascending order, they are the Hooper, Simsboro, and Calvert Bluff Formations. These names are used by the University of Texas, Bureau of Economic Geology (1970) and will be used in this report. Other writers have used slightly different nomenclature.

The structural contours on the base of the Wilcox Group and the dip to the southeast are shown in Figure 5. This map was made from contact points of the Hooper Formation with the underlying Midway Group found on drillers' and electric logs and from the altitudes of the Hooper contact with the Midway Group where it occurs at the land surface.

Bammel (1979) describes the Simsboro and reports that the Hooper-Simsboro contact is unconformable while the Simsboro-Calvert Bluff contact generally is conformable. Inspection of drillers' and geophysical logs indicates that the contacts between these members are difficult to distinguish in wells. One electric log of a well in Freestone County, 2 mi north of the eastern corner of Limestone County, indicates that the Wilcox Group at that site has a total thickness of about 1,200 ft, with about 400 ft for each unit. However, the individual thicknesses of these units vary from place to place, and in Limestone County, the Simsboro is considerably thinner than the Hooper and Calvert Bluff along the line of section in Figure 4. Cursory analysis of well logs indicates that the Wilcox Group consists of about 40 percent sand and 60 percent sediment of low permeability, mostly clay.

The Simsboro is the principal water-producing unit of the three Wilcox formations. However, for the purpose of this report, the Wilcox is considered a hydraulic unit. There are no apparent regional barriers to water moving from one unit to another. The Simsboro has been tested with a well yield in excess of 500 gal/min. This well, SD-39-39-406, is an example of the water-producing ability of the Simsboro. Its composition is mostly sand, some mudstone, clay, and a small amount of gravel, and it crops out in a band several miles wide across the southeastern part of the county (Figure 2). A road cut on State Highway 39, 4 mi northwest of Personville, shown in Figure 6, is the same road cut shown by Bammell (1979) as locality 13. The Simsboro in this road cut contains massive lenticular sand bodies with redeposited clay ledges as thick as 1.0 ft. The sand grains have mostly rounded edges, and the face of the road cut is light buff colored.

The Hooper and Calvert Bluff form the lower and upper members of the Wilcox Group and are primarily mudstone, sand, and sandstone, with various quantities of lignite and some ironstone concretions. The Hooper yields small to large amounts of water to wells on its outcrop. The Calvert Bluff yields small amounts to wells and moderate amounts may be possible. Most wells drilled on the Calvert Bluff outcrop are drilled deep enough to tap the Simsboro below.

There are two areas of Wilcox outcrop that are not connected to the main body of the Wilcox (Figure 2) as a result of faulting and erosion. One is north of Mexia and yields water to a few domestic wells. The other is west of Thornton and yields water to several domestic wells and to public water-supply wells for the city of Thornton.

Quaternary Alluvial Deposits

Alluvial deposits overlie small areas of older formations along many of the streams. The deposits, which reach a maximum thickness of about 40 ft, are composed of sand, silt, clay, and gravel and help facilitate recharge. Lake Limestone covers a considerable area of alluvial deposits. There are no known producing water wells from these deposits in Limestone County.

Figure 6.—Outcrop of Simsboro Formation of Wilcox Group

GROUND-WATER HYDROLOGY

The following discussion concerns selected principles of ground-water hydrology that are directly applicable to Limestone County. For a more comprehensive discussion of these and other hydrologic principles, the reader is referred to Meinzer (1923a,b) and Todd (1959); for nontechnical discussions see Baldwin and McGuinness (1963).

Source and Occurrence of Ground Water

The source of ground water in Limestone County is precipitation that infiltrates the outcrop areas and, to a lesser extent, streams or lakes that lose water to underlying aquifers. Much of the water from precipitation is evaporated at the land surface, transpired by plants, or remains in the subsoil; a small part migrates downward by gravity through the zone of aeration until it reaches the zone of saturation. In the zone of saturation, water is contained in the interstices or pore spaces between the rock particles, such as sand grains.

Water-bearing rock units, or aquifers, are classified into two types; water-table (unconfined) and artesian (confined) aquifers. Unconfined water occurs where the upper surface of the zone of saturation is under atmospheric pressure only and the water is free to rise and fall in response to the changes in the volume of water in storage. The upper surface of the zone of saturation is the water table, and a well penetrating an aquifer under water-table conditions becomes filled with water to the level of the water table. Water-table conditions occur in many of the shallow wells in Limestone County.

Artesian conditions prevail where an aquifer is filled with water and is overlain by rock or materials of lower permeability, such as shales and clays, that confine the water under a pressure greater than atmospheric. In the recharge areas of an aquifer, the shallower wells usually have higher heads (Figure 7). Shale or clay lenses within an aquifer commonly create various artesian pressures in the sands. A well penetrating sands under artesian pressure becomes filled with water to a level above the base of the confining layer (wells B, C, and D). If the pressure head is large enough to cause the water in the well to rise to an altitude greater than that of the land surface, the well will flow (well D). Well A did not encounter a confining bed, and the water level in the well represents the water table. Flowing wells are more common at lower altitudes, such as stream valleys. About 90 percent of the wells in Limestone County are artesian. A few are located at lower altitudes where they can flow. The level or surface to which water will rise in artesian wells is called the potentiometric surface. The terms water table and potentiometric surface are commonly referred to as ground-water levels.

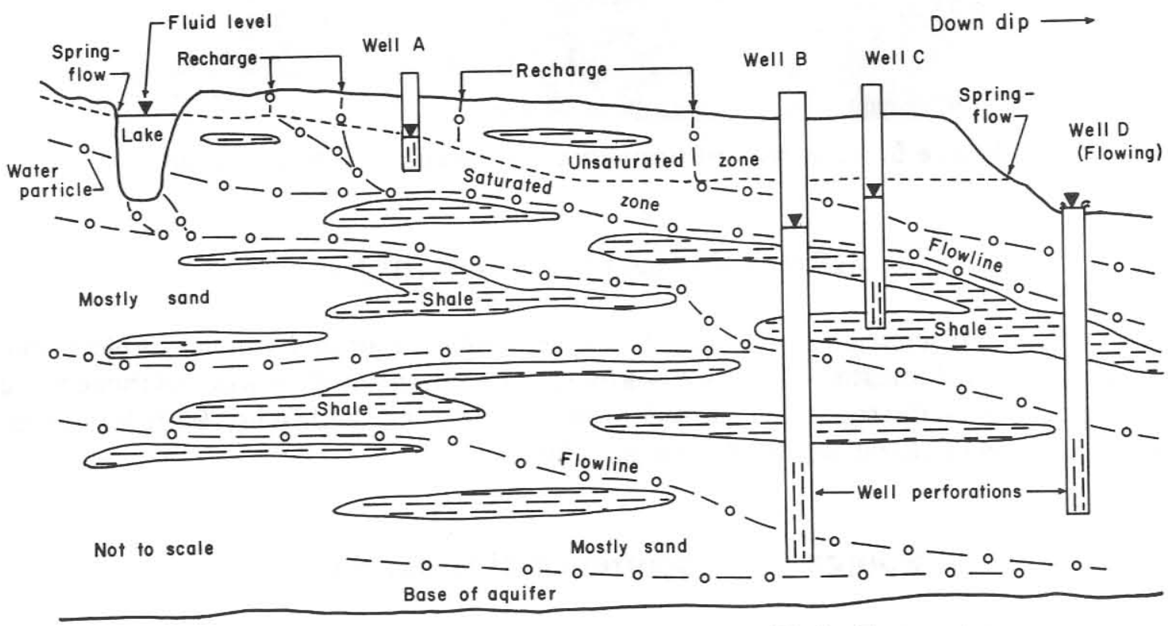

Figure 7.—Multilayered System in Which Wells Encounter Different Fluid Heads and Water Chemistry

Recharge, Movement, and Discharge of Ground Water

Aquifers may be recharged by either natural or artificial processes. Natural recharge in the outcrop of the formation results from the infiltration of precipitation by seepage losses from streams and lakes. The map of surface geology (Figure 2) shows the outcrop areas where the formations can receive direct precipitation. Some recharge by vertical leakage occurs where the aquifers are overlain by other aquifers. Artificial recharge processes include infiltration of industrial wastewater, sewage, or irrigation water. Water also can be injected into aquifers through wells. Improperly treated wastewater and sewage may contaminate the supply of fresh ground water, especially at shallow depths.

Some of the more important factors that govern the rate of natural recharge are the type of soil, the duration and intensity of precipitation, the slope of the land surface, the presence or absence of vegetation, and the depth of the water table. In general, the greater the precipitation on the outcrop area of an aquifer, the greater the recharge.

The rate of recharge also can be greater during the winter months when plant growth is at a minimum, and the evaporation rate is lower. This leads to higher water tables in winter that facilitate natural discharge to streams (Figure 8).

After ground water moves under the influence of gravity through the surface soils to the zone of saturation, much of it moves in a nearly horizontal direction toward areas of discharge. The regional direction of movement in Limestone County is to the southeast. Locally, however, the movement is rarely uniform in direction or velocity. A concept of water movement in the Wilcox Group is shown in Figure 7. The velocity of a water particle in most sand aquifers is only a few feet per year. The flow is greatest along routes of least resistance, such as in unconsolidated sand and fractured limestone. It is least in masses of sediment having low permeability, such as cemented sand or clay.

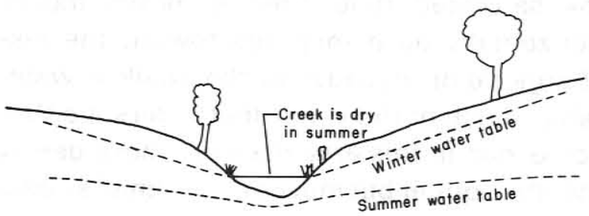

Figure 8.—Summer and Winter Conditions of Ground-Water Discharge

Recharge volumes to aquifers in this area cannot be readily calculated, but recharge to small areas of the Midway and Wilcox Groups can be estimated. The relationship of precipitation to water levels in two wells tapping the Midway Group and in one well tapping the Wilcox Group indicates that water levels rise and recharge increases as a result of precipitation (Figure 9). Well SD-39-20-801 (Figure 9) is in the northern part of the local recharge area of sand and sand dune topography on the Littig Glauconitic Member and Pisgah Member (undivided) that crop out in the vicinity of the community of Forest Glade. This area is the recharge area for some springflow along the Navasota River (Figure 10). The observed spring discharge is about 0.5 Mgal/d, and the effective area of recharge is about 6 mi^2. This would represent about 1.75 in. of water recharged per year to supply the springs. This recharge appears reasonable for a sandy area that receives about 37 in. of precipitation per year.

The Tehuacana Member of the Midway Group is moderately productive near Tehuacana. This city is located on the highest altitude of the formation, and the limestone hill is saturated with ground water up to just a few feet below land surface. Well SD-39-20-203 has a shallow water level that responds to precipitation (Figure 9). The response is greater in the winter with less precipitation than in summer, probably due to the evapotranspiration being lower. The recharge that takes place in Tehuacana furnishes water to wells and to springs which occur at or near an altitude of 550 ft in the northeast part of the town (Figure 11). The total volume of discharge down to this level comes from recharge above an altitude of 550 ft. The area enclosed by contour 550 in Figure 11 at Tehuacana is about 1.0 mi^2. The known discharge from wells and springs is about 20 Mgal per year and would not include ground water moving out of the area by underflow. This would make recharge at least 1.0 in. per year.

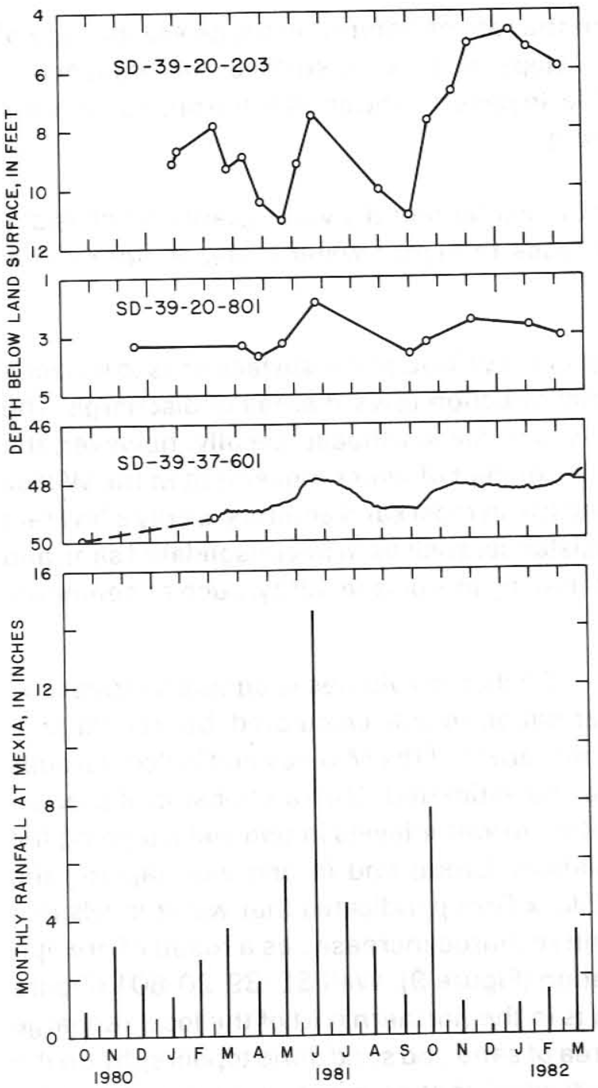

Figure 9.—Relationship of Precipitation and Water Levels in Wells

Near Mexia the Tehuacana Member occurs more deeply, in contrast to its occurrence at the town of Tehuacana, and recharge is limited. This area was moderately productive for the city of Mexia, which operated the Iley pump station at this location and for the Mexia State School nearby. The recharge to the Tehuacana possibly passes through a considerably thick overlying clay formation or more probably is recharged from the shallower part of the aquifer near the city of Tehuacana as mentioned above.

The Wilcox Group (Figure 2) has a water table within a few feet of the land surface in local areas of natural discharge along the small streams draining the area. Recharge water moves almost vertically until it reaches the saturated zone, then it moves mostly horizontally as it migrates toward the discharge point. Because of the shallow water table, much of the water that enters the Wilcox Group in this area does not move deeply into the aquifer but moves to the small stream valleys and is discharged locally as seeps. Summer and winter conditions of recharge, discharge, and streamflow on the Wilcox Group are shown in Figure 8. Water not discharged locally as seepage or not used by plants, pumped by wells, or evaporated, moves downdip to the southeast and out of the area as underflow.

Shallow water-table altitudes are depicted for the Midway and Wilcox Groups by contours in Figures 11 and 12. The water levels in shallow wells and the topography of the land surface were the major basis for the water-level control. The water levels in two rock pits in the Midway Group and in a few wells not listed in this report also were used for control. Values shown represent the top of the zone of saturation encountered in the aquifers. The contours from the Midway and Wilcox Groups (Figures 11 and 12) merge into each other and represent the hydrologic conditions in the systems. The higher heads usually are in the Midway Group at the contact of the two systems. However, movement of water from one system to the other probably is small.

The water-level depression area in the Midway Group just west of Mexia in the Iley well field (no longer used), where water levels are recovering from pumping, is shown in Figure 11. Also, just north of the Iley area at the city of Tehuacana, there is a "ground-water mound" or recharge area under the limestone hill that is saturated with water up to a few feet below the land surface. Some of the contours flex upstream along the small streams indicating discharge areas, and some of the small streams do have springs located along them.

Figure 10.—Springs That Discharge Along the Navasota River From the Midway Group

The Wilcox Group (Figure 12) gives expression of recharge under higher ground altitudes, such as east of Thornton. Large areas of ground-water discharge are expressed by the contours along the Navasota River, Steele Creek, and lesser drainage systems. An area 4.0 mi west of Thornton and one just south of Tehuacana are part of the Wilcox Group but are not connected to the main body of the Wilcox Group in the southeast part of the county. These areas have some wells with water levels, and the 500-ft contour goes through these areas.

A continuous water-level recorder at well SD-39-37-601 records the water-level fluctuations in the Wilcox Group. The water-level record reflects precipitation and therefore recharge as shown in Figure 9. As a result of infiltration of precipitation and a hydraulic gradient that slopes toward the streams, the water level in the well maintains an altitude higher than the water level of nearby Lake Limestone. These higher ground-water levels around Lake Limestone exist in the shallow parts of the Wilcox Group and cause ground water to move to the lake. However, the water level in the lake is higher than the potentiometric surfaces in the deeper members of the Wilcox Group. The lower hydraulic pressures in the deeper parts of the Wilcox result in a component of ground water that is vertically downward. This, in turn, could cause some water from the lake to move vertically downward and recharge these members. This is illustrated by the lake shown in Figure 7. The quantity of recharge by Lake Limestone was not measured, but the recharge to the Wilcox Group probably is slightly greater than the discharge from the Wilcox Group to the lake. Recharge also is indicated by the rise in water levels of as much as 40 ft in wells around Lake Limestone after the lake was filled. The water levels prior to the filling of the lake were reported by well drillers at the time of well construction.

Discharge from aquifers in Limestone County is mostly through springflow, wells, or movement downdip, although evaporation and transpiration by trees and plants whose roots reach the water table also constitute discharge. Significant volumes of discharge occur along the Navasota River where it crosses the Midway and Wilcox Groups. The impoundments on the Navasota River, such as Lake Mexia and Fort Parker Lake undoubtedly conceal some of this discharge. A considerable part of the spring discharge from the Midway Group can still be seen and measured. Water production by springs from the Midway Group is shown in Figure 10. Spring SD-39-28-205 issues at the lower end of a fracture system from a small cave created in the Tehuacana Member. Spring SD-39-28-301, the largest identifiable spring in the county, issues several feet above the river level, and its water flows directly down the bank into the river.

Estimates of the volume of spring discharge were made from a surface-water gaging station on the Navasota River (U.S. Geological Survey, 1979). The station, Navasota River near Easterly, is located about 20 river mi downstream from the Limestone-Robertson County line. The river at this point drains 968 mi^2. The period of record for this station began during 1924 and continues to the present. However, only the records during 1924 to 1978 were used because Lake Limestone began impounding water after the 1978 water year. At this station, 36 years of unregulated flow averaged 406 ft^3/s, and 18 years of regulated flow averaged 480 ft^3/s. The calendar year 1977 had an average flow of 439 ft^3/s and was chosen as a representative year to estimate springflow.

Streamflow in the Navasota River at the upper edge of the Wilcox Group near Groesbeck is predominantly overland flow with the ground-water component being relatively small. A streamflow hydrograph for the Navasota River near Easterly (Figure 13) for May through August 1977 has winter-type flow merging into summer-type flow, as an example of floodflow-springflow separation. Methods similar to those described by Busby and Armentrout (1965) were used in

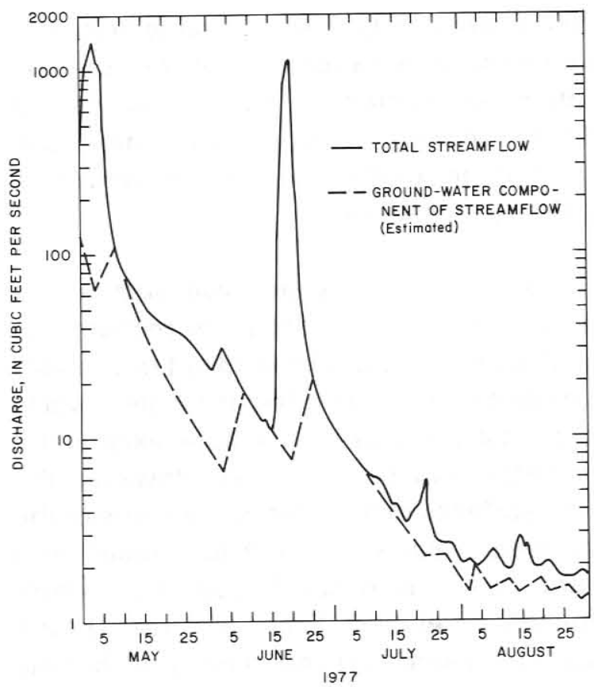

Figure 13.—Streamflow Hydrograph of Navasota River Near Easterly Showing Ground-Water Component

this separation. The method consists of using a streamflow depletion curve from the gaging station to separate ground water from surface-water flow. Inspection of the flow hydrograph indicated that overland flow was depleted about 5 days after a flood peak, when the flow became mostly springflow.

About 670 mi^2 of the total drainage area is underlain by the Wilcox Group and 30 mi^2 by similar sand-type formations. The ground-water component calculated for 1977 was 32 ft^3/s, or about 7.0 percent of the total flow. Over the 700-mi^2 area it would be 0.6 in. of runoff or about 23,000 acre-ft per year. This 0.6 in. of recharge compares with other computed recharge figures in Limestone County. To supply the springflow, the recharge must be 0.6 in., and in addition, some of the recharge moves downdip as underflow. The quantity moving downdip is unknown but probably is considerably less than 0.6 in. per year.

Changes in Water Levels

Under natural conditions, water levels in wells respond to changes in natural recharge or natural discharge. Very minor changes in water levels in aquifers are caused by changes in atmospheric pressure. Large and rapid water-level changes such as several feet in only a few minutes can be caused by the starting and stopping of pumps in wells.

Water levels in wells are an index to the quantity of water in an aquifer. A lowering of the water level in a well over a long period of time under water-table conditions represents an actual dewatering of the aquifer. This lowering may represent lower recharge, such as during drought conditions, or heavy pumping. Where artesian conditions are present, the lowering of the water level represents a decrease in artesian pressure in the aquifer, but the change in the actual quantity of water in storage may be small. A continual lowering of water levels eventually will cause an artesian aquifer to change from artesian to water-table conditions.

There are no wells with long-term records of water-level measurements in Limestone County. Table 8 (supplemental information) lists wells with recent water-level measurements and a few wells with water-level records from previous years, one as far back as 1946. Changes of water levels from about March 1961 to March 1982 are presented in Figure 14. Many of the major fluctuations in water levels may represent changes in pumpage or temporary precipitation patterns at the beginning or ending of the period of record and not a long-term trend.

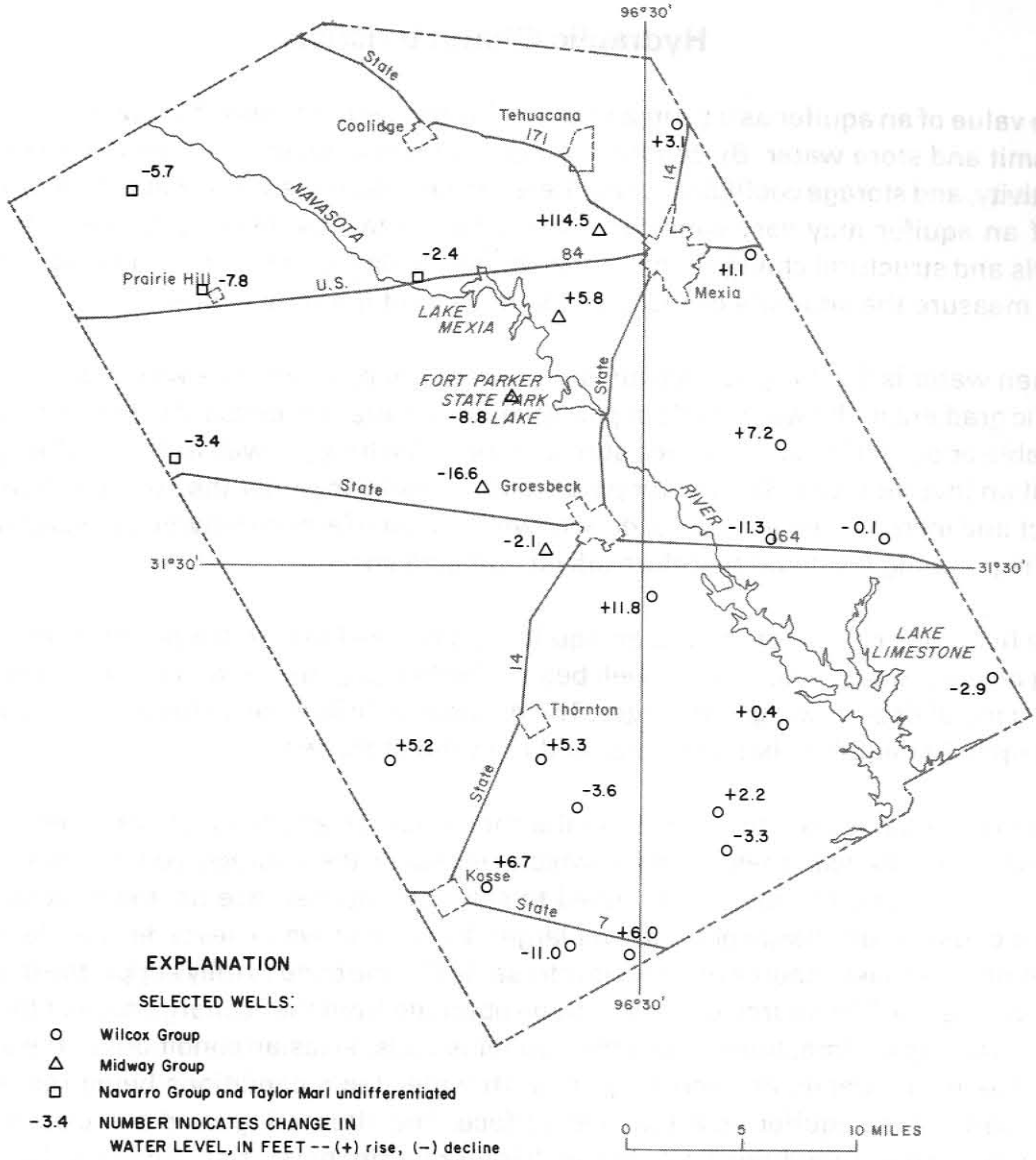

Figure 14.—Changes in Water Levels in Selected Wells, 1961 to 1982

The two wells north of Groesbeck (Figure 14), which tap the Midway Group, show declines of 16.6 and 8.8 ft; the declines were mostly during 1981-82. Neither well was in use at the time of the 1982 water-level measurement.

Well SD-39-20-603, located west of Mexia (Figure 14), shows a water-level rise of 114.5 ft. This value is based upon 1959 information from the well owner, Mexia State School. This well, along with the nearby Iley pump station, became unused during 1962. Water levels in three other wells that tap this aquifer in the area rose about 6.0 ft from 1981 to 1982, confirming the rate of water-level rise (Table 8). The substantial change in water levels in and near the Iley pump station represents a recovery of water levels and a return to levels at the time of development.

Pumpage in Limestone County is minor compared to the volume of water in storage in the aquifers. Water-level declines are negligible except at Iley pump station, where some lowering has occurred.

Hydraulic Characteristics

The value of an aquifer as a source of ground water depends upon the capacity of the aquifer to transmit and store water. By conducting aquifer tests in wells, the transmissivity, hydraulic conductivity, and storage coefficient of aquifers can be determined. The water-bearing characteristics of an aquifer may vary considerably in short distances, depending upon the formation materials and structural changes within the aquifer. A single aquifer test, therefore, can only be used to measure the aquifer's capacity in a small part of the total aquifer.

When water is discharged from an aquifer by pumping a well or a well is allowed to flow, a hydraulic gradient in the water table or potentiometric surface is established toward the well. The water table or potentiometric surface surrounding a discharging well assumes the approximate shape of an inverted cone. When pumping wells are close together the cones of depression will intersect and increase the amount of drawdown. This interference between wells causes lowering of the pumping level and therefore added pumping costs.

The hydraulic characteristics of an aquifer can be used to plan the potential of a well or the spacing of a group of wells. When a well begins discharging, the water level in the well declines and the cone of depression grows larger. The distance of influence (cone) and amount of decline depend upon the aquifer characteristics and the yield of the well.

Drawdown curves (Figure 15) show the theoretical relationship of water-level drawdown with time and distance. These curves, which represent the average conditions of the Wilcox aquifer in Limestone County, can be used to estimate interference between wells. As a cone around a constant discharge point grows larger, the rate of water-level decline decreases with time. When a sufficient source of water is intersected by the cone to fully supply the discharge, the decline will cease. The source of water can be obtained from the recharge area of the aquifer. In the Wilcox Group in Limestone County the aquifer is under artesian conditions at the depth where most of the well screens are normally set with water-table conditions being restricted to the shallow parts of the aquifer near the land surface. The alternating sand and clay lenses create these semi-confined conditions. When a well is pumped in this setting, a cone will grow until the area opposite the well screens is supplied by leakage moving downward from the shallow water-table part of the aquifer.

Tables 2 and 3 list well discharge and aquifer performance for selected sites. Assuming the well screen does not retard the flow of water from the aquifer to the well bore, some of the data form the basis of estimating certain hydraulic properties of the aquifer. A few well tests were of short duration, but still give a general knowledge of well performance in that aquifer. Wells were pumped, usually during sampling, and the drawdown and pumping time were noted. Because many wells are no longer in use and pumping equipment had been removed, a portable submersible pump with an electric motor was utilized in the tests and in the collection of samples. The procedure was to lower the portable pump into selected wells by hand and to operate the pump with a portable electric generator. The pump was run until the drawdown in the well was approaching a stable condition. If needed, the discharge was adjusted downward to produce a more stable and measurable drawdown. The specific capacity (Table 2) is expressed in gallons per minute divided by the water-level drawdown in feet. This is a good general indication of the ability of the formation to transmit water. Table 3 lists observation wells affected by nearby pumping

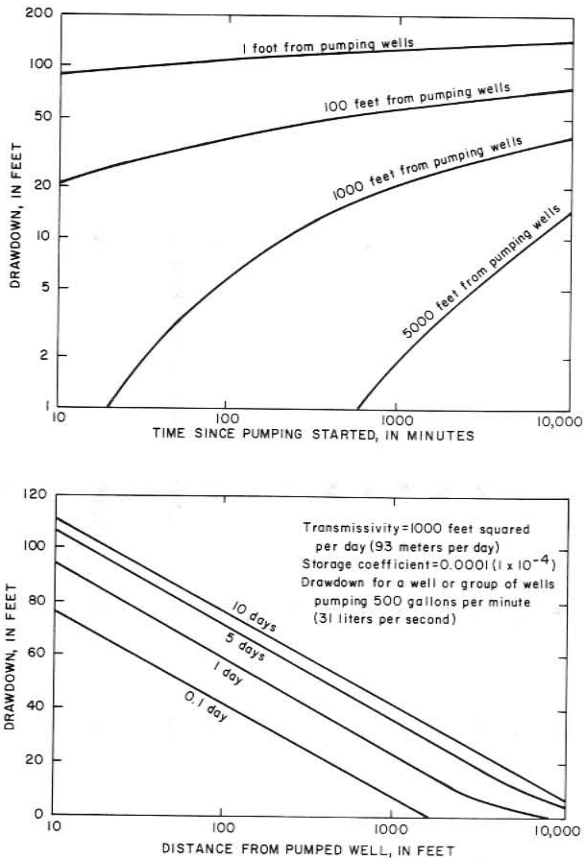

Figure 15.—Relation of Well Drawdown to Time and Distance

and wells where production was so minimal that a representative specific capacity was not practical.

A well contractor conducted aquifer tests during 1963 on the Glen Rose Limestone and Travis Peak Formation using well SD-39-18-802. Table 2 shows that this well had a specific capacity of 0.8 (gal/min)/ft. According to Meyer (1963), this is an indication of a transmissivity value of about 260 ft^2/d. This well has 44 ft of well opening.

Klemt and others (1975) reported on the Hosston and Travis Peak Formations in a part of central Texas and indicated transmissivity values may range from about 100 to 6,000 ft^2/d. These investigators used storage coefficients of 0.000025 and 0.00005.

The Taylor Marl and Navarro Group, undivided, have poor water-producing abilities. Well SD-39-18-801, a large-diameter hand-dug well, was pumped for 30 minutes (Table 3). The water pumped was mostly from storage in the well bore, as indicated by the small amount of recovery after pumping stopped. This formation is not very productive, but can yield small quantities of water.

The Midway Group yields small to large quantities of water (Tables 2 and 3). The Littig Glauconitic Member and Pisgah Member of the Kincaid Formation, undivided, yield small quantities of water to wells in the outcrop area. The largest yielding wells in the Midway Group in Texas are in Limestone County, and this large water-yielding ability is associated with the Tehuacana Member of the Kincaid Formation.

The Tehuacana Member's ability to yield water decreases south of the Navasota River, but north of the river in two areas, the Tehuacana is known to be capable of yielding moderate to large quantities of water to wells. The city of Tehuacana has wells of moderate yield in this formation. Well SD-39-20-302 produced 60 gal/min with 12.4 ft of drawdown for a specific capacity of 4.8 (gal/min)/ft (Table 2). In another test of the Tehuacana Member, well SD-39-20-609 was pumped for 10 hours, and well SD-39-20-612 was used as an observation well (Table 2). The results of this test, which were analyzed by the Theis nonequilibrium method (Theis, 1935), produced an estimated transmissivity of 6,000 ft^2/d and a storage coefficient of 0.0007. This is the area of the abandoned city of Mexia well field known as the "Iley well field".

Four aquifer tests of the Wilcox Group during this study were analyzed by using one or more of the following methods: The Theis nonequilibrium method (Theis, 1935); the Theis recovery method (Wenzel, 1942); and the step drawdown and recovery method (Harrill, 1970). The trans-

Table 2.—Summary of Aquifer Tests

[Specific capacity at the maximum pumping time]

Water-bearing unit: Knt - Navarro Group and Taylor Marl, undivided; Ktgt - Glen Rose Limestone and Travis Peak Formation; Tmkp - Pisgah Member and Littig Glauconitic Member of Kincaid Formation, undivided; Tmkt - Tehuacana Member of Kincaid Formation; Tmwp - Wills Point Formation; Twi - Wilcox Group; Twic - Calvert Bluff Formation; Twih - Hooper Formation; Twis - Simsboro Formation.

State well number	Water-bearing unit	Date tested	Diameter of well (inches)	Screen interval (feet)	Discharge (gallons/ minute)	Estimated transmissivity (feet squared/day)	Specific capacity (gallons/ minute/ foot)	Specific capacity (minutes)	Remarks
SD-39-18-802	Ktgt	8-21-63	7	3,203-3,221 3,771-3,797	100	--	0.8	1,440	Test by J. L. Myers Co.
20-302	Tmkt	6-10-81	--	--	60	--	4.8	500	--
601	Tmkt	11- 3-42	10	277-317	300	--	13.6	--	Test by Layne-Texas Co.
603	Tmkt	1-18-82	10	299-394	11	--	15.7	1,385	--
609	Tmkt	11-18-81	--	280-320	178	6,000	--	600	Transmissivity computed from a 600-minute test and drawdown data in observation well SD-39-20-612 located 655 feet distant.
704	Tmkp	3-11-81	4	--	4.1	--	.4	75	--
801	Tmkp	4-25-81	6	124-177	8.3	--	.1	96	--
902	Tmkp	3-10-81	4	43-63	8.0	--	.2	8	--
28-201	Tmkt	4- 7-81	4	10-90	5.0	--	.6	60	--
203	Tmkt	3-11-81	4	--	6.7	--	.9	60	--
204	Tmkt	3-12-81	8	--	7.9	--	.2	40	--
206	Tmkt	1-16-81	4	--	7.1	--	.2	19	--
307	Tmwp	3-11-81	4	50-86	7.0	--	.1	8	--
702	Tmkt	4-24-81	5	--	9.4	--	.2	90	--
804	Tmkt	2- 2-82	6	5-303	2.5	--	.1	45	--
901	Tmkt	3-10-81	6	--	7.0	--	.2	23	--
29-505	Twih	10-21-81	4	160-240	10	--	.2	45	--
601	Twih	4-11-81	6	--	6.6	--	.4	60	--
602	Twih	4-10-71	7	60-70 130-160 164-280	100	--	.4	2,880	Test by Smith Pump Co.
603	Twih	4-14-71	9	70-100 110-120 170-215 260-290	150	--	.6	2,880	do.
607	Twih	10- 3-81	4	280-360	8.1	--	1.5	44	--
806	Twih	5-19-82	4	160-240	9.2	--	.1	60	--

Table 2.—Summary of Aquifer Tests—Continued

State well number	Water-bearing unit	Date tested	Diameter of well (inches)	Screen interval (feet)	Discharge (gallons/ minute)	Estimated transmissivity (feet squared/day)	Specific capacity (gallons/ minute/ foot)	Specific capacity (minutes)	Remarks
SD-39-30-715	Twi	9-14-82	12	170-320 205-410	600	1,700	6.9	270	Test by Key Drilling Co.; gravel pack construction. Transmissivity computed using drawdown data in production well and observation wells SD-39-30-708 and 709, located 2,100 and 860 feet distant, respectively.
35-905	Twih	12- 5-81	6	--	160	--	2.7	50	--
907	Twih	12- 4-81	7	380-400	181	--	3.2	30	--
36-201	Tmkp	5-21-81	4	--	9.2	--	.1	40	--
37-301	Twih	6- 1-67	4	52-293	25	--	.2	180	Test by driller, R. K. Simms.
38-207	Twi	9-11-82	14	150-270 370-450	400	--	8.2	100	Test by Key Drilling Co.; gravel pack construction.
208	Twi	11- 5-82	13	250-370	310	--	1.6	140	do.
401	Twi	5-20-81	4	172-184	16.9	--	.2	43	--
403	Twi	5-19-81	4	262-287	11.7	--	1.9	33	--
602	Twi	9- 1-67	4	669-709	60	--	.8	720	Test by Frye Drilling Co.
703	Twi	10-21-81	4	225-245	17.1	--	.3	40	--
39-406	Twis	3- 4-81	18	579-735	600	1,350	4.6	2,880	Test by Layne-Texas Co.; gravel pack construction. Transmissivity is average of drawdown and recovery results, which were 1,320 and 1,380 feet squared per day, respectively.
44-401	Twih	11-29-38	10	136-157	56	--	1.1	--	Test by Layne-Texas Co.
410	Twih	4-26-81	4	160-180	8.7	--	.1	100	--
505	Twi	3-12-81	4	60-70	7.1	--	3.9	48	--
601	Twi	9- 2-70	13	110-150 175-195 240-250 270-350 410-460	451	--	2.0	1,440	Test by Layne-Texas Co.
605	Twi	12-17-63	16	285-370 380-405 435-460	422	520	2.1	1,440	Test by Layne-Texas Co. Transmissivity is average of drawdown and recovery results, which were 616 and 432 feet squared per day, respectively.
46-105	Twic	10-20-81	4	45-60	13.3	--	.2	30	--
106	Twis	10-22-81	7	552-670	69	285	1.2	100	Transmissivity is average of drawdown and recovery results, which were 280 and 290 feet squared per day, respectively.

Table 3.—Summary of Miscellaneous Aquifer-Test Data in Observation Wells

Water-bearing unit: Knt - Navarro Group and Taylor Marl, undivided; Tmkp - Pisgah Member and Littig Glauconitic Member of Kincaid Formation, undivided; Tmkt - Tehuacana Member of Kincaid Formation; Tmwp - Wills Point Formation; Twi - Wilcox Group; Twih - Hooper Formation.

Pumping well			Observation well									
State well number	Diameter of well (inches)	Screen interval (feet)	State well number	Diameter of well (inches)	Screen interval (feet)	Water-bearing unit	Date tested	Distance between wells (feet)	Time since pump started (minutes)	Discharge (gallons/ minute)	Drawdown (feet)	Remarks
SD-39-18-801	36	14-19	--	--	--	Knt	10- 1-81	--	5	12.1	0.6	
									22	12.1	3.0	
									30	12.1	3.9	Stop pump.
									60	0	3.8	
20-302	--	--	SD-39-20-301	12	--	Tmkt	6-10-81	84	5	60	0	
									60	60	.2	
									120	60	.5	
									200	60	.6	
									270	60	.9	
									415	60	1.1	
									420	0	--	Stop pump.
									430	0	.3	
									510	0	.1	
21-701	4	290-310	--	--	--	Tmwp	4-25-81	--	16	10.0	105.6	Reduce yield to 0.5 gallon/minute.
									26	.5	105.6	Stop pump.
									50	0	95.4	
									616	0	47.4	
30-715	12	170-320 205-410	SD-39-30-708	4	325-340	Twi	9-14-82	2,100	80	600	.1	
									245	600	.8	
									495	600	2.0	
									1,305	600	5.2	
									1,365	0	--	Stop pump.
									1,470	0	5.2	
									1,710	0	4.9	
									1,885	0	4.3	
									2,705	0	3.0	
30-715	12	170-320 205-410	SD-39-30-709	4	330-345	Twi	9-14-82	860	55	600	1.0	
									180	600	3.3	
									265	600	4.4	
									375	600	5.4	
									522	600	6.6	
									1,295	600	8.7	
									1,365	0	--	Stop pump.
									1,390	0	8.4	
									1,610	0	6.4	
									1,790	0	5.1	
									1,915	0	4.9	
									2,765	0	3.1	
35-905	6	--	SD-39-35-907	7	380-400	Twih	12- 5-81	204	50	160	6.4	
36-203	4	240-306	--	--	--	Tmkp	4-24-81	--	20	12.0	106.3	
									22	2.0	106.3	Reduce yield to 2.0 gallons/minute.
									70	0	106.3	Shut down pump - fine gas bubbles.
									95	0	32.1	Produced with water.

missivity values for these tests ranged from 280 to 1,700 ft^2/d and should be considered estimated values (Table 2). Hydraulic conductivities for these tests ranged from 2.4 to 8.8 ft/d. No storage coefficients were determined.

Aquifer tests of the Wilcox Group have been conducted in areas adjacent to Limestone County. William F. Guyton and Associates (1972) lists 10 test wells in the Wilcox in Freestone County. The reported transmissivity of these wells ranged from 187 to 1,270 ft^2/d. In an area of Leon County, just south of the eastern corner of Limestone County and where lignite mining is planned, seven wells were drilled and tested in the Calvert Bluff as reported by Espey, Huston and Associates (1980). The reported transmissivity of these wells ranged from 21 to 1,692 ft^2/d, and a storage coefficient of about 0.0005 was calculated for two of the wells.

Development and Use of Ground Water

About 0.9 Mgal/d of ground water was used for all purposes during 1980. Table 4, compiled from records of the Texas Department of Water Resources and field notes of the Geological Survey, shows a decline in the use of ground water in the county since 1955. Most of this decline was caused by the city of Mexia changing its source of public water supply from ground water to surface water during 1962 and by the city of Kosse obtaining its public water supply from ground water outside the county beginning in 1979. During 1955, pumpage was mostly from wells tapping formations of the Midway Group, and, by 1980, pumpage was mostly from wells tapping the Wilcox Group. Ground-water use is expected to increase as additional industrial and public-supply wells are being drilled.

Public Supply

Only about 9 percent of the total ground water used during 1980 was for public water supply. The Bistone Water District, which provides the public water supply for the city of Mexia and uses water from Lake Mexia, is developing a ground-water source from the Wilcox Group in the Personville area. Other more rural water-supply systems obtain water from surface-water or ground-water sources outside the county.

The city of Groesbeck uses water from the Navasota River. However, except during floods, very little water goes past the dam at Springfield, 4.5 mi north of Groesbeck. The city of Groesbeck is highly dependent upon springs SD-39-28-301 and 302, that issue just below this dam. This water is not included in Table 4.

Industrial Use

The principal industrial use of ground water has been to supply the Texas Industrial Minerals Sand Plant. This industry uses wells SD-39-44-601 through 605. A much smaller industrial use of water is connected with the drilling of oil and gas wells. Usually a 4-in.-diameter water well is drilled to supply water for about 3 months during the drilling of the oil or gas well, and then the water well is abandoned.

Table 4.—Use of Ground Water

[million gallons per day]

Year	Public supply	Industry	Domestic and livestock	Irrigation	Total
1955....	0.90	0.09	0.12	--	1.11
1960....	.98	.08	.15	--	1.21
1965....	.15	1.30	.23	--	1.68
1970....	.16	.58	.27	0.02	1.03
1975....	.17	.42	.30	.03	.92
1980....	.10	.45	.36	--	.91

An electric power generating plant is being constructed near the eastern corner of the county. The plant will use water from well SD-39-39-406 for all needs of the plant except cooling. Water from Lake Limestone will be used for cooling purposes.

Domestic, Livestock, and Irrigation Use

The use of ground water for domestic and livestock use is becoming increasingly important as more people build rural residences in the area. Most of the population growth is concentrated on the outcrop of the Wilcox Group where ground-water supplies are more easily obtained. Because Limestone County has an average annual precipitation of about 37 in., substantial quantities of supplemental irrigation are not needed. Wells designated for irrigation of crops are few and are seldom pumped because of the high precipitation.

Well Construction

At the beginning of this century most of the water used for domestic purposes was obtained from hand-dug wells. The wells were walled and curbed with brick; they were usually about 36 in. in diameter and 60 ft or less deep. The city of Thornton's first well (SD-39-35-901) was dug and had radial collectors. Water from the well flowed by gravity 4.0 mi to the city reservoir (Sundstrom and others, 1948). This well is still in existence, but the present source of water is from drilled wells several hundred feet deep. One of the first well-boring machines used in the area was powered by a horse and owned by R. K. Simms of Mexia. These bored wells had 8-in. tile casing installed; a few are still in use.

Most present-day wells in Limestone County are used for domestic and stock purposes (Table 8), yield small amounts of water, and are constructed at minimum costs. Drilled wells usually are constructed with 4-in. plastic casing at the land surface and 2-in. commercial well screens opposite the producing zone. A few wells in sand aquifers have no casing or screen in the production zone and are "open-hole" completions. For limestone aquifers, saw-slotted plastic or torch-slotted steel casings are often used. Most small wells are equipped with an electric motor of less than 1.0 horsepower to drive a submersible or jet pump.

The larger-yield public-supply and industrial wells have casings up to 18 in. in diameter and are equipped with turbine pumps and above-ground electric motors. Many of the wells that yield large amounts of water from the Wilcox Group are underreamed and gravel packed opposite the producing zone.

QUALITY OF GROUND WATER

General

All ground waters contain varying amounts of dissolved mineral matter. The kinds and quantities of dissolved constituents may be derived from several sources, including gases and aerosols from the atmosphere, weathering and erosion of rocks and soils, solution or precipitation reactions occurring below the land surface, and cultural effects resulting from activities of man. Some of the natural environmental factors that affect the chemical composition of ground waters include climate, types of rocks and soils through which the water passes, duration of contact, temperature and pressure, and biochemical effects associated with life cycles of plants and animals. Activities of man may modify water composition extensively through direct effects of pollution and indirect results of water development.

Results of 150 analyses for selected properties and constituents of water from 122 wells and 10 springs in Limestone County are given in Table 10 (supplemental information). Results of a few analyses for selected pesticides and minor elements are given in Tables 5 and 6.

Analyses of samples collected before January 1981 were performed by either the Geological Survey or Texas Department of Health; samples collected after January 1981 were analyzed by the Geological Survey. Values of pH, specific conductance, and alkalinity for samples collected and analyzed by the Geological Survey after January 1981 were measured in the field at the time of sample collection. Samples collected by the Geological Survey for analyses of other constituents were stabilized by preservative treatment at the time of sample collection. The concentrations or values for some of the nonconservative constituents or properties may have changed significantly in those samples not analyzed or preserved at the time of sample collection. Consequently, the results of analyses for the nonconservative constituents for samples collected before January 1981 may reflect the values at the time of analysis rather than the time of collection. Generally, however, these discrepancies in the data will not significantly affect the interpretations made in the following sections of this report.

Waters often are compared or classified on the basis of hardness and concentrations of dissolved solids. (See Table 10.) Another common classification is based on the predominant cation and anion concentrations expressed in milliequivalents per liter. In this report, for example, a water is classified as a calcium-chloride type if the calcium and chloride concentrations

Table 5.—Analyses for Selected Pesticides in Water From Wells and Springs

[µg/L - micrograms per liter]

Well number	Date	PCB, total (µg/L)	Naphthalenes, polychlor, total (µg/L)	Aldrin, total (µg/L)	Chlordane, total (µg/L)	DDD, total (µg/L)	DDE, total (µg/L)	DDT, total (µg/L)	Diazinon, total (µg/L)	Dieldrin, total (µg/L)	Endosulfan, total (µg/L)	Endrin, total (µg/L)	Ethion, total (µg/L)	Lindane, total (µg/l)
SD-39-20-302	4- 9-81	0.0	0.0	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-301	5-20-81	.0	.0	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
38-602	4- 9-81	.0	.0	.00	.0	.00	.00	.00	.00	.00	.00	.00	.00	.00

Well number	Date	Malathion, total (µg/L)	Methoxychlor, total (µg/L)	Methylparathion, total (µg/L)	Methyltrithion, total (µg/L)	Mirex, total (µg/L)	Parathion, total (µg/L)	Perthane, total (µg/L)	Toxaphene, total (µg/L)	Trithion, total (µg/L)	2,4-D, total (µg/L)	2,4,5-T, total (µg/L)	2,4-DP, total (µg/L)	Silvex, total (µg/L)
SD-39-20-302	4- 9-81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00
28-301	5-20-81	.00	.00	.00	.00	.00	.00	.00	.0	.00	.01	.00	.00	.00
38-602	4- 9-81	.00	.00	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00	.00

Table 6.—Analyses for Selected Minor Elements in Water From Wells and Springs

[µg/L - micrograms per liter]

Well number	Date	Dis-solved arsenic (µg/L as As)	Dis-solved barium (µg/L as Ba)	Dis-solved cadmium (µg/L as Cd)	Dis-solved chro-mium (µg/L as Cr)	Dis-solved copper (µg/L as Cu)	Dis-solved lead (µg/L as Pb)	Dis-solved manga-nese (µg/L as Mn)	Dis-solved mercury (µg/L as Hg)	Dis-solved sele-nium (µg/L as Se)	Dis-solved silver (µg/L as Ag)	Dis-solved zinc (µg/L as Zn)
SD-39-20-302	4- 9-81	0	100	1	18	6	0	1	0.3	0	0	10
28-301	5-20-81	1	80	<1	10	<10	22	2	.2	0	0	20
38-602	4- 9-81	0	10	<1	10	2	4	8	.5	0	0	7
44-401	11-29-38	--	--	--	--	--	--	500	--	--	--	--
46-106	10-22-81	0	130	<1	0	2	2	43	.0	<1	<1	75

constitute more than half the total of cations and anions, respectively. Most analyses by the Geological Survey after September 1980 have not differentiated bicarbonate from carbonate but have included the determination of alkalinity. The alkalinity of most waters results predominantly from the presence of bicarbonate. Consequently, a water in which alkalinity constitutes more than half the total anions is classified as a bicarbonate type.

Relation of Water Quality to Use

The significance of some of the more commonly determined water-quality parameters are included in Table 11 (supplemental information). For a more comprehensive discussion relating these and other parameters to water-quality criteria for domestic, industrial, or agricultural supplies, the reader is referred to the references listed at the end of the table.

The U.S. Environmental Protection Agency (1976, 1977a) has established regulations or criteria for drinking water that apply to public water systems. These regulations do not apply to privately-owned wells used as individual domestic supplies, but the regulations or criteria for selected properties or constituents are summarized in Table 7 as a reference. For a more comprehensive discussion of regulations or criteria for these and other properties or constituents, the reader is referred to the National Interim Primary Drinking Water Regulations and National Secondary Drinking Water Regulations set by the Environmental Protection Agency (1976, 1977a).

Several analyses in Table 6 are for samples collected from wells that are now plugged or from wells that are no longer in use. Either the mandatory maximum contaminant level or secondary maximum contaminant level recommended by the Environmental Protection Agency for one or more properties or constituents was exceeded in samples from approximately one-third of the wells still in use. Concentrations of dissolved solids and iron and the pH level of samples from some wells were the major offenders.

The concentration of dissolved solids, as determined from the sum of dissolved constituents, in samples from 95 wells and 2 springs ranged from less than 100 mg/L to more than 3,700 mg/L. The dissolved-solids concentration in samples from 16 of these wells, 15 of which are still in use, exceeded the 500 mg/L contaminant level listed in Table 7.

The concentration of dissolved iron in samples from 69 wells and 1 spring ranged from 10 to 20,000 μg/L. The dissolved-iron concentration in samples from 27 wells, 21 of which are still in use, exceeded the proposed contaminant level of 300 μg/L established by the Environmental Protection Agency. Iron in samples from many of these wells probably was derived from natural sources, but chemical or galvanic corrosion from the steel casing, drop pipe, and pump may have contributed to the iron concentrations in water from some wells. A comprehensive analysis of the sources of iron is beyond the scope of this study. For comprehensive discussions concerning the sources and chemistry of iron in ground water and the factors affecting corrosion of metallic well casings, pipes, and pumps, the reader is referred to Back and Barnes (1965) and Campbell and Lehr (1973).

The pH of samples from 122 wells and 10 springs ranged from 5.3 to 8.7 units. The pH of samples from 7 wells and 1 spring was less than 6.5 units, and the pH of samples from 5 wells was

Table 7.—Summary of Regulations for Selected Water-Quality Constituents and Properties for Public Water Systems

(µg/L - micrograms per liter; mg/L - milligrams per liter)

DEFINITIONS

Contaminant.--Any physical, chemical, biological, or radiological substance or matter in water.

Public water system.-A system for the provision of piped water to the public for human consumption, if such system has at least 15 service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

Maximum contaminant level.-The maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system. Maximum contaminant levels are those levels set by the U.S. Environmental Protection Agency (1976) in the National Interim Primary Drinking Water Regulations. These regulations deal with contaminants that may have a signicant direct impact on the health of the consumer and are enforceable by the Environmental Protection Agency.

Secondary maximum contaminant level.-The advisable maximum level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system. Secondary maximum contaminant levels are those levels proposed by the Environmental Protection Agency (1977a) in the National Secondary Drinking Water Regulations. These regulations deal with contaminants that may not have a significant direct impact on the health of the consumer, but their presence in excessive quantities may affect the esthetic qualities and discourage the use of a drinking-water supply by the public.

INORGANIC CHEMICALS AND RELATED PROPERTIES

Contaminant	Maximum contaminant level	Secondary maximum contaminant level
Arsenic (As)	50 µg/L	--
Barium (Ba)	1,000 µg/L	--
Cadmium (Cd)	10 µg/L	--
Chloride (Cl)	--	250 mg/L
Chromium (Cr)	50 µg/L	--
Copper (Cu)	--	1,000 µg/L
Iron (Fe)	--	300 µg/L
Lead (Pb)	50 µg/L	--
Manganese (Mn)	--	50 µg/L
Mercury (Hg)	2 µg/L	--
Nitrate (as N)	10 mg/l	--
pH	--	6.5 - 8.5
Selenium (Se)	10 µg/L	--
Silver (Ag)	50 µg/L	--
Sulfate (SO_4)	--	250 mg/L
Zinc (Zn)	--	5,000 µg/L
Dissolved solids	--	500 mg/L

Fluoride.--The maximum contamination level for fluoride depends on the annual average of the maximum daily air temperatures for the location in which the community water system is situated. A range of annual averages of maximum daily air temperatures and corresponding maximum contamination level for fluoride are given in the following tabulation.

Average of maximum daily air temperatures (degrees Celsius)	Maximum contaminant level for fluoride (mg/L)
12.0 and below	2.4
12.1 - 14.6	2.2
14.7 - 17.6	2.0
17.7 - 21.4	1.8
21.5 - 26.2	1.6
26.3 - 32.5	1.4

ORGANIC CHEMICALS

Chlorinated Hydrocarbons

Contaminant	Maximum contaminant level (µg/L)
Endrin	0.2
Lindane	4
Methoxychlor	100
Toxaphene	5

Chlorophenoxys

Contaminant	Maximum contaminant level (µg/L)
2,4-D	100
Silvex	10

greater than 8.5 units. Nine of these wells, in which the pH levels of water were outside the secondary maximum contaminant range of 6.5 to 8.5 shown in Table 7, are no longer in use.

Dissolved chloride and dissolved sulfate are major constituents of ground water from Limestone County. Concentrations of dissolved chloride, dissolved sulfate, and dissolved solids are shown in Figure 16 for selected wells and springs in the Midway and Wilcox Groups. Concentrations of dissolved chloride in water samples from 95 wells and 2 springs ranged from 4.7 to 2,100 mg/L. The dissolved-chloride concentration in samples from eight wells, four of which are still in use, exceeded 250 mg/L. The concentration of dissolved sulfate in water samples from 94 wells and 2 springs ranged from less than 1 mg/L to 2,110 mg/L. The dissolved-sulfate concentration in three wells, one of which is still in use, exceeded 250 mg/L.

Analyses of ground-water samples have not differentiated nitrite nitrogen (NO_2-N) from nitrate nitrogen (NO_3-N). Instead, results are reported as total nitrogen (N), which is the total of NO_2 + NO_3 nitrogen, and are given in Table 10. The total NO_2 + NO_3 concentration (as N) in samples from 53 wells and 2 springs ranged from 0.0 to 68 mg/L. The total NO_2 + NO_3 concentration (as N) of samples from only three wells exceeded 10 mg/L, which is the maximum contaminant level for nitrate (as N) set by the Environmental Protection Agency. The source of this excessive nitrate is not known but probably is wastes from livestock. Two wells producing water with excessive nitrate were shallow with depths of 28 ft or less.

On the basis of the annual average of the maximum daily air temperature for Mexia, which is 79.5°F, the maximum contaminant level set for fluoride by the Environmental Protection Agency is 1.4 mg/L. The concentration of dissolved fluoride in samples from 93 wells and 1 spring ranged from below the detection limits to 3.8 mg/L. The dissolved fluoride concentration in four wells exceeded 1.4 mg/L.

None of the other properties or constituents included in the analyses exceeded either the maximum contaminant level or secondary maximum contaminant level included in the drinking water regulation set by the Environmental Protection Agency.

The extent to which chemical quality limits the suitability of water for irrigation depends upon many factors including the following: The nature, composition, and drainage of soils and subsoils; the amount of water used and the method of application; the kinds of crops grown; and the climate of the region. Ground water is being used in Limestone County for supplemental irrigation, primarily for pastures and lawns. Water-quality criteria for these uses, which supplement precipitation, are not stringent. Generally, according to Wilcox (1955), water may be used safely for supplemental irrigation if its specific conductance is less than 2,250 μmhos and its SAR (sodium adsorption ratio) is less than 14. The specific conductance of samples collected from 115 wells and 10 springs ranged from 148 to 6,270 μmhos. The specific conductance of samples from 11 wells exceeded 2,250 μmhos. The SAR of samples from 88 wells and 2 springs ranged from 0.2 to 72. The SAR of samples from 8 wells exceeded 14. On the basis of these data for specific conductance and SAR, water from most wells in Limestone County can be used safely for supplemental irrigation.

Wells that tap the Wilcox Group often produce a black sediment, considered to be lignite, with the water, as well drillers often log coal or lignite while drilling (Table 9). Apparently, if a well produces from a lignite-bearing zone, the lignite becomes suspended in the water and can be pumped with the well water. Wells with this problem usually are abandoned.

Chemical Quality

Hosston and Travis Peak Formations

Water from the Hosston and Travis Peak Formations is used for public water supply in counties west of Limestone County. However, only in the western corner of Limestone County might water that contains less than 3,000 mg/L dissolved solids be produced from these formations. The projected eastern limits of these formations that produce water containing less than 3,000 mg/L dissolved solids are shown in Figure 3. Well SD-39-18-802, at Prairie Hill and just east of the "bad-water" line, was used to test the water quality of the Travis Peak Formation and Glen Rose Limestone, and the combined water was found to contain excessive dissolved solids and not to be suitable for public supply.

Taylor Marl and Navarro Group

The water quality of the Taylor Marl and Navarro Group usually is poor. The specific conductance of water from five shallow-dug wells ranged from 244 to 2,460 μmhos. The well producing water with a specific conductance of 244 μmhos taps a sand zone that may allow more local recharge than that of other Taylor and Navarro wells. There are no known wells in the Taylor Marl and Navarro Group being used for water supply.

Midway Group

The specific conductance of samples from wells of the Midway Group ranged from 230 to 7,390 μmhos (Table 10). Dissolved-solids concentrations were not determined for either of these two samples, but based on the respective specific conductances and complete analyses of other samples in the area, the dissolved-solids concentrations are expected to be about 140 to 4,400 mg/L, respectively. The specific conductance of 7,390 μmhos indicates that the high mineralization may be attributed to saltwater contamination, possibly from oilfield activities (Burnitt and others, 1962). This well is near the old oilfield shown in Figure 17. Available data on two wells in the Wills Point Formation of the Midway Group (Table 10) show a specific conductance of 230 and 5,150 μmhos. The Littig Glauconitic and Pisgah Members, undivided, and Tehuacana Member of the Kincaid Formation of the Midway Group generally contain water of usable quality. Analysis of water samples from these members (Table 10) shows that the concentration of dissolved solids in most wells ranges from about 350 to 600 mg/L. The water is usually a calcium-bicarbonate type and is hard to very hard. See Table 11 for classification of waters based upon hardness.

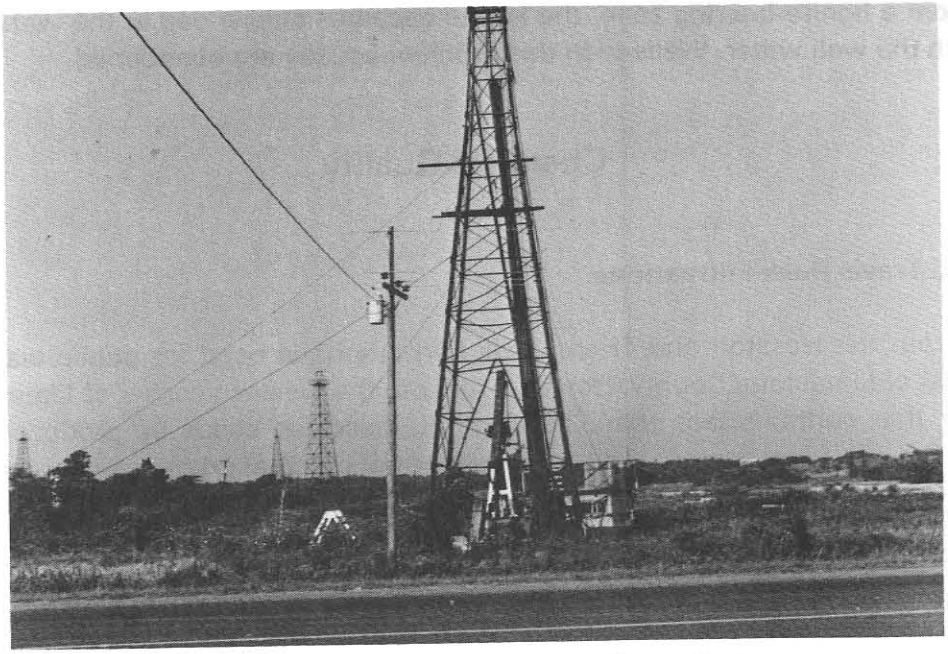

Figure 17.—Oilfield Derricks Near Mexia

Wilcox Group

The chemical quality of waters from the Wilcox Group is somewhat variable with dissolved-solids concentrations ranging from 90 to 1,530 mg/L. Eighty percent of the wells sampled produced a bicarbonate-type water, mostly sodium bicarbonate. The water ranges from soft to very hard, and the extremes in pH values were 5.3 and 8.7 units. Part of the variation in water quality probably can be attributed to the stratified deposition system of alternating layers of sand and clay. Most Wilcox wells have openings that are based upon the selected zone or zones of water production. (See Figure 7.) Some wells may be screened in sand zones that have restrictive ground-water flow, and this factor may govern the water chemistry.

Iron in water is one of the major water-quality problems, because concentrations range up to 20,000 μg/L. Iron concentrations in samples of water from the Wilcox Group, shown in Table 10, have little relationship with the depth of wells. Generally, however, water from the deeper wells has less iron. Well drillers report that they can inspect the drill cuttings and improve the opportunity to screen a well in a zone of low iron.

AVAILABILITY OF GROUND WATER

The most favorable areas for future development of ground-water resources are those areas having thick layers of saturated sand or other permeable material that readily receive natural recharge. Other hydrologic and economic factors also should be considered. Among the hydrologic factors, the most important are the ability of the aquifer to transmit water to wells, the volume of water in storage, the rate of recharge to the aquifer, and the impact of development on the aquifer. The principal economic factors are depth of wells, number of wells needed to deliver sufficient water, interference between wells, and water treatment.

Hosston and Travis Peak Formations

The Hosston and Travis Peak Formations are potential sources of slightly saline water in the western corner of the county, although they occur at depths in excess of 2,000 ft. Wells might be expected to yield up to 100 gal/min with about 200 ft of drawdown of the water level in the wells. These formations are subject to considerable lowering of the artesian heads if numerous wells are developed in the area. Both the Hosston and Travis Peak Formations are available sources of relatively hot water, with temperatures of about 150°F, that might be used for heating purposes. Water from the Hosston Formation is being used for geothermal heating of a hospital in Marlin, Falls County, 25 mi southwest of Groesbeck. The temperature of the water is reported to be 147°F.

Taylor Marl and Navarro Group

The Taylor Marl and Navarro Group contain only very small quantities of ground water. Though the quality of the water usually is poor, some small supplies are available for development by rural domestic and stock wells. Some zones of the Taylor and Navarro contain thin sand beds that would offer the best opportunity for water production. The best method of developing a small water supply would be shallow-dug wells on the outcrop of sandy zones or possibly by drilled wells within 1 mi downdip of these outcrops.

Midway Group

The Midway Group is a source of additional quantities of water. Wells of various yields may continue to be developed depending upon the specific water-bearing members. Except for the upper member, the Wills Point Formation, water quality generally is acceptable; this factor would be a constraint on the availability of water for development.

The Littig Glauconitic Member and Pisgah Member, undivided, cannot support the development of wells having large yields. However, the number of small-yield wells could be increased, because the present development is not creating serious problems such as major water-level declines.

The Tehuacana Member, which presently yields small to large quantities of water to wells, could support the development of more small-yield wells. The larger-yielding wells are confined to the fault and fracture zone at the town of Tehuacana and to a down-faulted zone west of Mexia where the "Iley well field" is located. Water production for the city of Tehuacana causes the nearby spring to stop flowing while the wells are being pumped. During 1981, this spring (SD-39-20-303) was observed to flow only during the periods of higher precipitation. In effect, the city wells are intercepting part of the springflow for public water supplies. The present source of water for the city of Tehuacana might allow for some increase of pumpage, but information is not available to determine the amount of the increase.

Wells SD-39-20-601 through 616, which produce from the Tehuacana Member, are located in the best ground-water producing zone in the immediate Mexia-Tehuacana area. Most of these wells belong to the Mexia State School or were part of the Iley well field, which is no longer used by the city of Mexia. During 1925-62, this area produced from 0.5 to 1.5 Mgal/d. Water levels declined from 125 ft below land surface during 1933 (Rose, 1952) to 294 ft below land surface (reported) during 1959. Well yields were reported to be 360 gal/min during 1933, dropping to less than 100 gal/min during 1961. The lower well yields during 1961 probably were due to the greater lift for the pumps from the lower water levels and are not a water-yielding problem of the aquifer. An aquifer test was made on well SD-39-20-609 during this investigation by producing 178 gal/min for 10 hours.

In the latter years of production in the well field, some silt was being produced with the water, which created an additional problem. In all respects, this was overproduction of the well field. In spite of the problems of declining well yields and influx of silt, the Iley area is a considerable ground-water producing asset, and, currently (1983), the area's ground-water supply is almost unused. Water levels are returning to their former levels, and, although the water quality is marginal, the water is usable for most purposes. Up to 0.5 Mgal/d of water might be available on a continuous basis without depleting the supply. Many of the former public-supply wells are still open and useable.

Ground-water supplies in the Iley area could be improved by artificial recharge. Moulder and Frazor (1957) described an experiment using lake water to recharge a sand aquifer near Amarillo, Texas. This work showed that using a natural underground storage system, such as an aquifer beneath a well field, was a practical way to store water for times of greater need. Water stored underground is protected from evaporation and atmospheric contamination. The Iley well field is located over the Tehuacana Member, which is in a down-faulted area or graben. Figure 18 shows the Tehuacana Limestone bounded by shale and clay. This "vault" type structure should limit ground water from moving away downdip. If enough water is available to recharge this area artificially, the water levels in the Tehuacana Member could be raised substantially, possibly to less than 100 ft below the land surface. A test of the recharge feasibility and recovery of the water could be done to evaluate this potential.

During the decade 1952-62, an estimated 8,000 acre-ft of water was pumped from the Iley area, and the water level was lowered an average of about 50 ft. Therefore, raising the water level 50 to 100 ft might increase the water stored in the Tehuacana aquifer by 8,000 to 16,000 acre-ft. Bryan (1951) estimated that this aquifer in the Mexia area covers about 15 mi^2.

Wilcox Group

The Wilcox Group has the most potential for additional development. Figure 19 shows that the saturated thickness increases from west to east and is at a maximum at the eastern corner of the county. It represents the difference in altitude between the water table, as shown in Figure 14, and the base of the Wilcox Group, as shown in Figure 5. Generally, the thicker parts will have the most potential for development of water supplies. Clay and other low-permeable materials make up about 60 percent of the Wilcox Group, with sand and clay not being evenly distributed. Evaluation of each test hole including drillers' and geophysical logs will be necessary to determine the maximum water-production capability at any given site.

The city of Thornton pumps water from an area of the Wilcox Group located 4.0 mi west of the city. The Wilcox Group at this location is separated by faults from the main body of the Wilcox

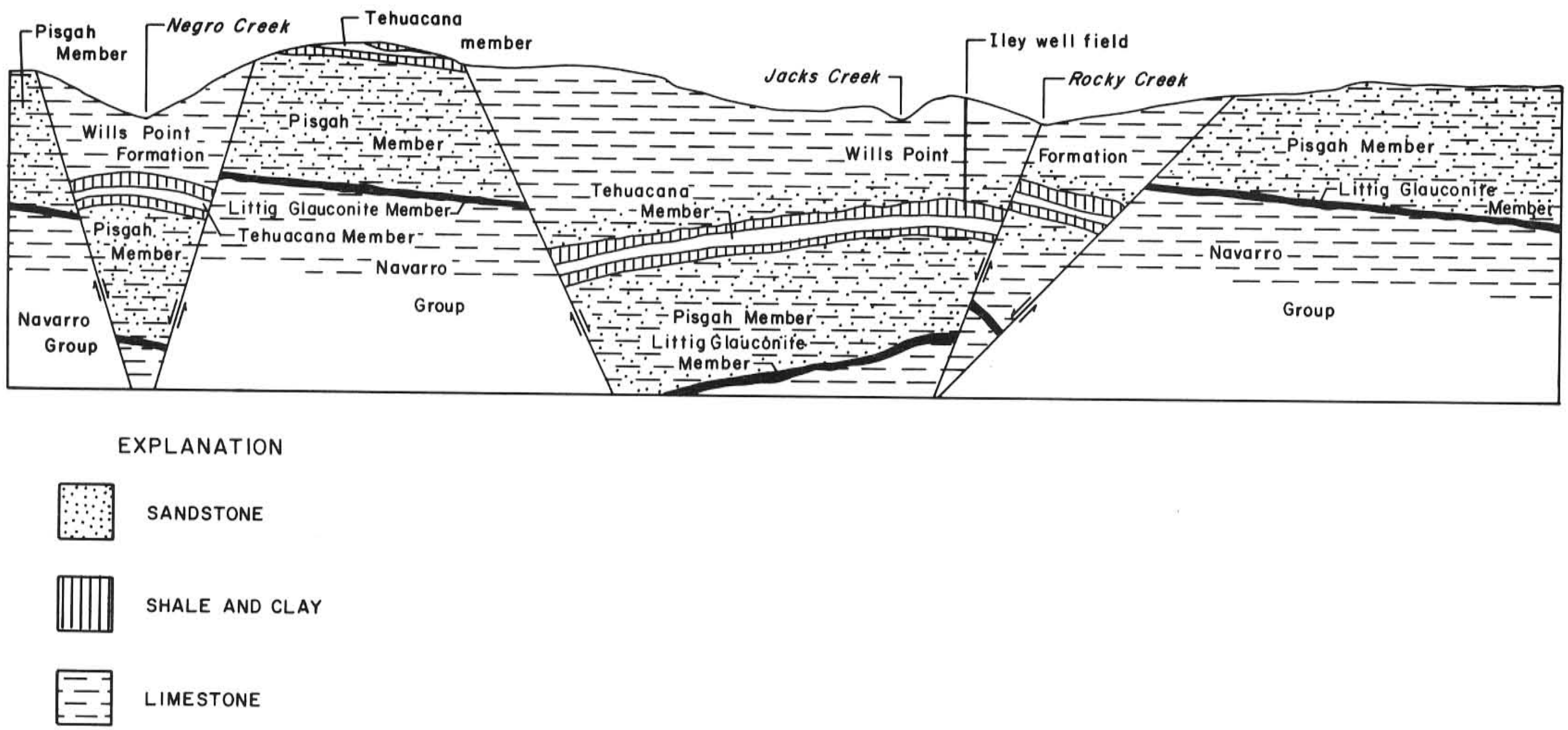

Figure 18
Generalized Section Through the Iley Well Field Area

From Burnitt and others, 1962

Group. The current source of water appears to be adequate for the city's use and might allow for some increase of pumping as the present pumping rate of 0.07 Mgal/d is not creating any serious problems such as significant water-level declines.

An index of long-term water availability from the Wilcox is the quantity of ground water salvageable by reduction of springflow and evapotranspiration. Large-scale pumping of the Wilcox Group would result in lower water levels, which could cause less ground water to move downdip to some areas and less springflow and evapotranspiration in other areas. Some, though not all, of these results are beneficial in that they may reduce the amount of natural discharge. The volume of springflow and evapotranspiration that can be intercepted is a large increment of the total volume available from the Wilcox Group on a long-term basis. To intercept most of this volume of water by wells, it would be necessary to lower the water levels many feet over a large part of the area, especially under the streams where the water table is shallow. A lowering of the water table by 25 ft (see Figure 12) might be the minimum that would capture the springflow and greatly reduce evapotranspiration.

Most water-table sand and clay aquifers have a specific yield between 0.1 and 0.2, with 0.15 often being considered average. The specific yield of the Wilcox Group of Limestone County has not been measured, but 0.15 is believed to be applicable. By lowering the water table an average of 25 ft by pumping throughout the 375-mi^2 area of the outcrop where the saturated thickness is at least 25 ft and applying 0.15 specific yield, about 900,000 acre-ft of water would be released from storage. A long period of low precipitation would also lower water levels, and not all of the 900,000 acre-ft would then be available to wells. Also, lowering water levels may cause some wells to go dry or would considerably reduce their yield.

Springflow could be greatly reduced as a result of shallow ground water being intercepted by wells. The estimate of annual springflow for the Wilcox Group is equivalent to 0.6 in., and for the total 425-mi^2 outcrop within Limestone County, this quantity represents about 14,000 acre-ft or 11.6 Mgal/d of water that would be available in an average year. This increment of springflow is a significant part of the supply of water available on a long-term basis from the Wilcox Group. In addition to the 14,000 acre-ft, an undetermined volume of water would be salvaged from reduced evapotranspiration by the lowering of water levels and be available for more beneficial use.

CONCLUSIONS

Ground-water supplies in Limestone County, depending on the location within the county, vary from plentiful to almost nonexistent. The Wilcox Group in the eastern part of the county contains an adequate supply of water to meet the expected water demands in the area in the foreseeable future. An average of about 14,000 acre-ft of water is discharged from the Wilcox Group as springflow each year and should be considered to be a quantity of water that would otherwise be available to wells on a long-term basis. Only small amounts of ground water are available in the western part of the county where the Taylor Marl and Navarro Group are the only shallow sources of ground water. However, underlying these geologic units are much deeper aquifers that contain only slightly saline water.

The major population centers are experiencing a need for greater water supplies. Additional quantities of ground water are available within the county but the supplies may be many miles away from these cities and towns.

The quality of the ground water is suitable for most uses. However, the major water-quality problems in some areas are high dissolved-solids and high dissolved-iron concentrations.

A monitoring program to observe future ground-water conditions is needed. The Texas Water Development Board has such a State-wide program to measure water levels and collect water samples periodically. A few wells in Limestone County are already included in the State's monitoring network. This program of data collection needs to be continued and possibly expanded. Also the quantities of water withdrawn from the aquifers needs to be documented for use in future water planning.

Lignite mining in the Wilcox Group is expected to take place within the county in the foreseeable future. Considerable data on ground-water quality and water levels in the Wilcox, as well as water-quality data from sampling of runoff from the Wilcox outcrop, need to be collected before, during, and after mining.

The Iley well field area near Mexia may be suitable hydrologically for artificial recharge of the Tehuacana Member of the Kincaid Formation. A pilot program to recharge and later to pump the water would help determine if this practice is feasible.

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SUPPLEMENTAL INFORMATION

Definition of Terms

In this report certain technical terms, including some that are subject to different interpretations, are used. For convenience and clarification, these terms are defined as follows:

Acre-foot—The volume of water required to cover 1 acre to a depth of 1 ft (43,560 ft^3), or 325,851 gallons.

Acre-foot per year—One acre-ft per year equals 892.13 gal/d.

Alluvial deposits—Sediments deposited by streams; includes floodplain deposits and stream-terrace deposits.

Aquifer—A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquifer test, pumping test—The test consists of the measurement at specific intervals of the discharge and water level of the well being pumped and the water levels in nearby observation wells. Formulas have been developed to show the relationships of the yield of a well, the shape and extent of the cone of depression, and the properties of the aquifer such as the specific yield, porosity, hydraulic conductivity, transmissivity, and storage coefficient.

Artesian aquifer, confined aquifer—Artesian (confined) water occurs where an aquifer is overlain by material of lower hydraulic conductivity (e.g., clay) and confines the water under pressure greater than atmospheric. The water level in an artesian well will rise above the level at which it was first encountered in the well. The well may or may not flow at the land surface.

Cone of depression—Depression of the water table or potentiometric surface surrounding a discharging well or group of wells and is more or less shaped as an inverted cone.

Confining bed—One which, because of its position and low permeability relative to that of the aquifer, keeps the water in the aquifer under artesian pressure.

Contact—The place or surface where two different kinds of rock or geologic units come together, shown on geologic maps and sections.

Dip of rocks, altitude of beds—The angle or amount of slope at which a bed is inclined from the horizontal; direction is also expressed (e.g., 1 degree southeast; or 90 ft/mi southeast).

Drawdown—The lowering of the water table or piezometric surface caused by pumping (or artesian flow). In most instances, it is the difference, in feet, between the static level and the pumping level.

Electric log—A graphic log showing the relation of the electrical properties of the rocks and their fluid contents. The electrical properties are natural potentials and resistivities to induced electrical currents, some of which are modified by the presence of the drilling mud.

Evapotranspiration—Water withdrawn by evaporation from a land area, a water surface, moist soil, or the water table, and the water consumed by transpiration of plants.

Fault—A fracture or fracture zone in rock along which there has been displacement of the two sides relative to one another parallel to the fracture.

Freshwater—Water containing less than 1,000 mg/L of dissolved solids.

Geothermal—Any heat from the earth.

Graben—A block of rock, generally long compared to its width, that has been downthrown along faults relative to the rocks on either side.

Ground water—Water in the ground that is in the zone of saturation from which wells, springs, and seeps are supplied.

Head, static—The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point.

Horst—A block of rock generally long compared to its width, that has been upthrown along faults relative to the rocks on either side.

Hydraulic gradient—The change in static head per unit of distance in a given direction.

Hydraulic conductivity—The rate of flow of a unit volume of water in unit time at the prevailing kinematic viscosity through a cross section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head over unit length of flow path. Formerly called field coefficient of permeability.

Head, or hydrostatic pressure—Artesian pressure measured at the land surface, reported in pounds per square inch or feet of water.

Hydraulic gradient—The slope of the water table or piezometric surface, usually given in feet per mile.

Karst—A type of topography that is formed over limestone, dolomite, or gypsum by solution, forms underground drainage through caves and sinkholes.

Lignite—A brownish-black coal in which the alteration of vegetal material has proceeded further than in peat, but not as far as subbituminous coal.

Lithology—The description of rocks, usually from observation of hand specimen, or outcrop.

Marl—A calcareous clay.

Micrograms per liter (μg/L)—A unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water; 1,000 μg/L is equivalent to 1 mg/L.

Milligrams per liter (mg/L)—One mg/L represents 1 mg of solute to 1 L of solution. For water containing less than 7,000 mg/L dissolved solids, 1 mg/L is equivalent to 1 part per million.

Million gallons per day (Mgal/d)—One Mgal/d equals 3.07 acre-ft per day or 1,121 acre-ft per year.

National Geodetic Vertical Datum of 1929 (NGVD of 1929)—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

Outcrop—That part of a geologic layer which appears at the land surface. On an areal geologic map a formation or other stratigraphic unit is shown as an area of outcrop where exposed and where covered by alluvial.

Potentiometric surface—A surface which represents the static head. As related to an aquifer, it is defined by the levels to which water will rise in tightly cased wells. The water table is a particular potentiometric surface.

Slightly saline water—Water containing 1,000 to 3,000 mg/L dissolved solids (Winslow and Kister, 1956, p. 5).

Specific capacity—The rate of discharge of water from a well divided by the drawdown of water level in the well. It is generally expressed in gallons per minute per foot of drawdown.

Specific yield—The quantity of water that an aquifer will yield by gravity if it is first saturated and then allowed to drain; the ratio expressed in percentage of the volume of water drained to volume of the aquifer that is drained.

Storage—The volume of water in an aquifer, usually given in acre-feet.

Storage coefficient—The volume of water an aquifer releases from or takes into storage per unit of surface area of the aquifer per unit change in the component of head normal to that surface.

Structural feature, geologic—The result of the deformation or dislocation (for example, faulting) of the rocks in the Earth's crust. In a structural basin, the rock layers dip toward the center or axis of the basin. The structural basin may or may not coincide with a topographic basin.

Surface water—Water on the surface of the Earth.

Transmissivity—The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is the product of the hydraulic conductivity and the saturated thickness of the aquifer. Formerly called coefficient of transmissibility.

Water level—Depth to water, in feet below the land surface, where the water occurs under water-table conditions (or depth to the top of the saturated zone). Under artesian conditions the water level is a measure of the pressure of the aquifer, and the water level may be at, below, or above the land surface.

Water level, pumping—The water level during pumping, measured in feet below the land surface.

Water level, static—The water level in an unpumped or nonflowing well, measured in feet above or below the land surface or sea-level datum.

Water table—The upper surface of a saturated zone except where the surface is formed by an impermeable body of rock.

Water-table aquifer (unconfined aquifer)—An aquifer in which the water is unconfined; the upper surface of the saturated zone is under atmospheric pressure only and the water is free to rise or fall in response to the changes in the volume of water in storage. A well penetrating an aquifer under water-table conditions becomes filled with water to the level of the water table.

Yield of a well—The rate of discharge commonly expressed as gallons per minute, gallons per day, or gallons per hour. In this report, yields are classified as small, less than 15 gal/min; moderate, 15-100 gal/min; and large, over 100 gal/min.

Table 8.—Records of Wells and Springs

Water-bearing unit: Knt - Navarro Group and Taylor Marl, undivided; Ktgt - Glen Rose Limestone and Travis Peak Formation; Tm - Midway Group; Tmkp - Pisgah Member and Littig Glauconite Member of Kincaid Formation, undivided; Tmkt - Tehuacana Member of Kincaid Formation; Tmwp - Wills Point Formation; Twi - Wilcox Group; Twic - Calvert Bluff Formation; Twih - Hooper Formation; Twis - Simsboro Formation.

Water level: Reported water levels given in feet; measured water levels given in feet and tenths below land surface or (+) above land surface.

Remarks: All wells are drilled unless noted. All wells are domestic or stock except: G - gas or oil test; Ind - industrial; Irr - irrigation; N - none; P - public supply; Z - destroyed well or test hole. Sp - spring; gal/min - gallons per minute.

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing		Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels		Remarks
				Diameter (inches)	Depth (feet)				Above (+) or below land surface (feet)	Date of measurement	
SD-39-10-901	--	--	15	24	15	--	Knt	582	12.3	Mar. 1, 1961	Dug well, Z.
11-501	Jerry Johnson	--	14	24	14	--	Knt	486	2.9	Mar. 1, 1961	Do.
12-601	H. H. Magness	--	7	24	7	--	Knt	500	.8	Mar. 1, 1961	Dug well, Z. 1/
901	Trotter Springs	--	Sp	--	--	--	Tmkt	551	--	--	Estimated flow 2 gal/min 6-10-81. 1/
902	George Black	1978	175	4	175	115-175	Tm	500	30	1978	1/
903	Doyle Spakes	1980	50	34	50	--	Tmwp	511	12.3	Mar. 8, 1982	N.
13-701	J. L. Boyd	--	62	36	62	--	Twih	479	27.0	Mar. 8, 1982	Dug well, N. 1/
17-902	Earnest Weiss #1	1955	1,530	--	--	--	--	609	--	--	G. 2/
18-101	Grady Crawford	1910	22	24	24	--	Knt	621	5.7 9.4 11.4	Mar. 1, 1961 June 16, 1977 Mar. 8, 1982	Dug well, N. 1/
801	Mary Whitten	--	19	36	19	--	Knt	622	2.3 18.0 10.1	Mar. 1, 1961 Jan. 1, 1981 Mar. 8, 1982	Dug well, N. 1/
802	Prairie Hill Water District	1963	3,942	7	3,832	3,203-3,221 3,771-3,797	Ktgt	595	46.5	Feb. 28, 1966	Z. 1/2/
19-601	Ruben Sunday	1947	17	33	17	--	Knt	467	7.8 11.3 10.2	Mar. 1, 1961 Jan. 13, 1981 Mar. 8, 1982	Dug well, N. 1/
20-201	T. E. Moore	1972	110	4	110	--	Twih	563	28.8 30.5 29.2	July 14, 1976 Mar. 8, 1979 Mar. 8, 1982	1/2/
202	A. G. Murphy	1971	110	4	110	90-110	Twih	558	24	1971	1/
203	Noil Vinson	1935	80	--	--	--	Tmkt	625	11.2 7.9	Jan. 30, 1981 Mar. 8, 1982	--
301	City of Tehuacana	--	73	12	73	--	Tmkt	550	--	--	P. 1/
302	do.	1953	82	--	--	--	Tmkt	550	5.0 1.1	Jan. 13, 1981 Mar. 8, 1982	P. 1/
303	Tehuacana Spring	--	Sp	--	--	--	Tmkt	548	--	--	Estimated flow 75 gal/min 6-23-81. 1/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-20-304	Hugh Gilliam	1977	85	4	85	75-85	Twih	557	23.3 20.4	Dec. 17, 1980 Mar. 8, 1982	--
601	Mexia State School	1942	322	11	322	282-322	Tmkt	505	195	1942	N. 1/3/
602	do.	1942	360	11	360	314-355	Tmkt	510	195	1942	N. 1/
603	do.	1954	394	11	394	299-390	Tmkt	508	270 294 179.5	1954 1959 Mar. 8, 1982	N. 1/
604	City of Mexia	1925	320	8	--	--	Tmkt	548	230	1943	Z. 1/
605	do.	1925	--	8	--	--	Tmkt	548	221	1943	Z. 1/
606	do.	1925	306	8	--	--	Tmkt	548	221	1943	Z.
607	do.	1925	320	8	--	--	Tmkt	548	198.6	July 16, 1942	Z. 1/
608	do.	--	--	--	--	--	Tmkt	494	--	--	N.
609	Buster Chrisner	--	--	--	--	--	Tmkt	500	--	--	Irr. 1/
610	do.	--	--	--	--	--	Tmkt	497	--	--	Irr.
611	City of Mexia	--	--	--	--	--	Tmkt	492	172.1	Jan. 13, 1981	N.
612	Buster Chrisner	1957	320	8	320	--	Tmkt	505	178.2 173.3	Jan. 28, 1981 Mar. 8, 1982	N. 2/
613	do.	1957	--	8	--	--	Tmkt	511	--	--	N.
614	Fred Brown	1949	--	12	--	--	Tmkt	509	187.2 179.4	Dec. 17, 1980 Mar. 8, 1982	N.
615	Buster Chrisner	--	336	8	--	--	Tmkt	502	180.5 173.6	Jan. 28, 1981 Mar. 8, 1981	N.
616	- Stubenrauch	1980	320	4	--	--	Tmkt	516	198.1	Mar. 25, 1981	Z. 1/
701	Bruce Reed	1969	78	4	--	--	Tmkp	512	--	--	--
702	Cecil Jacobs	1970	60	4	60	--	Tmkp	458	--	--	Z.
703	Comanche Springs	--	Sp	--	--	--	Tmkp	454	--	--	Measured flow 8.0 gal/min 6-9-81. 1/
704	E. S. Pickens	1970	40	4	40	--	Tmkp	450	3.9 1.0	Jan. 14, 1981 Mar. 8, 1982	N. 1/
705	D. Aguillard	1970	60	4	60	--	Tmkp	470	20	1970	--
706	R. Blakenship	1970	160	--	--	--	Tmkp	444	--	--	Z.

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-20-801	John Fletcher	1946	178	7	178	124-177	Tmkp	435	+2.5 12.8 3.0	Sept. 6, 1946 Apr. 27, 1949 Mar. 9, 1982	N. 1/2/3/
802	Service Pipe Line	--	103	8	--	--	Tmkp	442	6.5	Feb. 6, 1981	N.
803	George Bounds	1975	150	4	150	90-150	Tmkp	458	40	1975	--
804	J. R. Dawley	--	--	6	--	--	Tmkp	490	28.8	Mar. 8, 1982	1/
901	Guy Owens	1962	38	4	38	18-38	Tmkp	543	1.9 7.2 10.7	July 14, 1976 Mar. 11, 1980 Mar. 9, 1982	1/
902	Paul Russell	1968	63	4	63	20-63	Tmkp	537	14.8 14.9	Jan. 14, 1981 Mar. 9, 1982	1/
21-401	L. N. Robinson	1954	511	--	--	--	Tmwp	496	--	--	Z. 3/
502	C. P. Aman	1935	22	36	--	--	Twih	493	6.7 10.7 5.6	Mar. 2, 1961 Dec. 17, 1980 Mar. 8, 1982	N
503	do.	1885	60	36	--	--	Twih	493	13.1 14.2 8.2	Mar. 2, 1961 Dec. 17, 1980 Mar. 8, 1982	1/
701	Neil Beene	1980	310	4	310	290-310	Tmwp	465	11.8 12.7	Jan. 14, 1981 Mar. 9, 1982	N. 1/
801	C. R. Crider	1976	80	4	80	60-80	Twih	540	--	--	1/
903	T. Matthews	1965	142	4	142	119-142	Twih	530	48.3 48.2	Jan. 14, 1981 Mar. 9, 1982	N. 1/3/
904	E. C. Favors	1971	100	4	100	--	Twih	495	18.3 16.7	Jan. 14, 1981 Mar. 9, 1982	1/
26-501	--	--	21	38	--	--	Knt	569	3.6	Mar. 1, 1961	Z.
502	J. L. Walts	--	28	96	--	--	Knt	545	1.8 5.5 5.2	Mar. 1, 1961 June 16, 1977 Mar. 8, 1982	Dug well, N. 1/
27-301	J. G. Hudgins	--	72	4	72	--	Tmkp	600	16.1 12.8	Dec. 17, 1980 Mar. 8, 1982	1/
401	J. C. Rogers #1	1947	6,168	--	--	--	--	536	--	--	G. 2/
601	O. B. Owen	1956	200	4	200	--	Tmkp	625	8.0 11.0 16.2	Aug. 6, 1975 Mar. 8, 1979 Mar. 8, 1982	1/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-28-101	Williford Sands	--	45	20	--	--	Tmkp	522	31.9 33.8 40.7	Mar. 2, 1961 Jan. 14, 1981 Mar. 8, 1982	--
102	M. D. Hendrix	1972	108	4	73	73-108	Tmkt	521	2.4	Mar. 8, 1982	1/
201	L. Tidwell	1971	90	4	90	--	Tmkt	464	13.0 10.5	Jan. 14, 1981 Mar. 8, 1982	1/3/
202	do.	--	Sp	--	--	--	Tmkt	449	--	--	Estimated flow 25 gal/min 1-16-81. 1/
203	do.	--	65	4	--	--	Tmkt	457	12.4 9.9	Dec. 17, 1980 Mar. 8, 1982	1/
204	do.	--	141	8	--	--	Tmkt	440	13.2 12.1	Jan. 16, 1981 Mar. 8, 1982	N. 1/
205	do.	--	Sp	--	--	--	Tmkt	418	--	--	Estimated flow 10 gal/min 3-11-81. 1/
206	do.	--	165	4	--	--	Tmkt	468	24.0	Jan. 16, 1981	N. 1/
207	Burr Oak Springs	--	Sp	--	--	--	Tmkp	430	--	--	No flow 3-27-81.
301	Springfield West	--	Sp	--	--	--	Tmkt	420	--	--	Measured flow 314 gal/min 5-20-81. 1/
302	Springfield East	--	Sp	--	--	--	Tmkt	420	--	--	Estimated flow 40 gal/min 4-10-81. 1/
303	E. Robertson	1970	41	4	41	--	Tmkp	510	13.5	Mar. 9, 1982	--
304	John Lewis	1970	130	4	130	--	Tmkp	498	23.6 23.8	Jan. 16, 1981 Mar. 9, 1982	1/3/
305	A. Chandler	1976	54	7	54	30-54	Tmkt	452	14	1976	--
306	T. G. Platt	1979	36	34	36	--	Tmkt	445	31.2 31.1	Jan. 14, 1981 Mar. 9, 1982	Dug well. 1/
307	W. E. Guthrie	1974	86	4	86	50-86	Tmwp	414	16.2 16.0	Dec. 19, 1980 Mar. 9, 1982	N. 1/
401	Elmer Beene	--	167	6	--	--	Tmkt	515	5.5 4.8 22.1	Feb. 24, 1961 Jan. 17, 1981 Mar. 9, 1982	--
402	Sanders and Kelly #1	1961	3,213	--	--	--	--	537	--	--	G. 2/
501	Fort Parker Springs	--	Sp	--	--	--	Tmkp	499	--	--	Estimated flow 10 gal/min 6-24-81. 1/
502	Texas Parks and Wildlife Dept.	1972	103	4	103	70-103	Tmkp	504	--	--	P. 1/
503	Sulphur Springs	--	Sp	--	--	--	Tmkt	419	--	--	Estimated flow 2 gal/min 4-25-81. 1/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-28-504	Harold Hays	1979	164	4	164	105-164	Tmkp	535	10.8	Mar. 9, 1982	--
601	W. Crowson	1970	60	4	60	--	Tmkp	454	3.4 10.1 12.7	Mar. 24, 1977 Mar. 11, 1980 Mar. 9, 1980	1/
602	do.	1965	120	4	--	--	Tmkp	460	5.7	July 14, 1976	1/3/
603	Mary Roberts	1970	41	4	41	--	Tmkp	451	--	--	--
604	W. R. Jennings	1971	70	4	70	--	Tmkp	442	15	1971	--
605	N. W. Platt	1970	40	4	40	25-35	Tmkp	430	--	--	--
606	A. C. Cox	1971	52	4	52	32-52	Tmkp	464	24.9 24.5	Jan. 16, 1981 Mar. 9, 1982	--
701	- Telford	--	--	5	--	--	Tmkt	520	17.8 15.9	Jan. 17, 1981 Mar. 9, 1982	--
702	Elmer Beene	1920	188	5	--	--	Tmkt	493	+.5	Apr. 24, 1981	N. 1/2/
703	Nussbaum and Scharef #1	1944	5,501	--	--	--	--	476	--	--	G. 2/
801	Robert Fewell	--	20	30	--	--	Tmwp	470	4.0 9.2 6.1	Feb. 24, 1961 Jan. 17, 1981 Mar. 9, 1982	Dug well.
802	C. Daughtery	--	17	36	--	--	Tmkp	527	7.8 10.9 9.5	July 15, 1976 Mar. 7, 1979 Mar. 9, 1982	Dug. well. 1/
803	Groesbeck Springs	--	Sp	--	--	--	Tmkt	440	--	--	Estimated flow 20 gal/min 4-7-81. 1/
804	City of Groesbeck	1981	303	4	6	6-303	Tmkp	450	4.8	Mar. 9, 1982	N. 1/2/
901	Farmers Bank	--	150	6	--	--	Tmkt	480	34.7 31.9	Mar. 10, 1981 Mar. 9, 1982	N. 1/2/
29-201	Ruben Sunday	1965	112	4	112	--	Twih	511	26.2	Mar. 9, 1982	1/
202	J. G. Hawkins	1977	200	4	170	170-200	Twih	491	--	--	--
203	C. Camden	1980	44	34	44	--	Twih	514	23.2	Mar. 9, 1982	--
301	J. F. Lee	1968	122	4	122	--	Twih	479	28.67	Mar. 9, 1982	--
302	Kelley Parker	1974	266	4	266	246-266	Twih	491	--	--	1/
501	W. Sadler	1976	230	4	200	200-230	Twih	491	59.6	Jan. 15, 1981	1/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-29-502	Gary Moran	1975	226	4	226	211-226	Twih	470	55.7 55.8	Jan. 15, 1981 Mar. 9, 1982	1/
503	W. O. Blackmon	1977	300	4	80	80-300	Twih	470	23.0 22.8	Mar. 10, 1981 Mar. 9, 1982	--
504	F. Cranford	1974	148	4	148	133-148	Twih	469	15.6 15.4	Jan. 14, 1981 Mar. 9, 1982	--
505	V. E. Rodes	1978	240	4	240	160-240	Twih	496	62.8	Jan. 14, 1981	1/
506	W. Morgan	1974	700	4	700	--	--	493	62.3	Oct. 21, 1981	1/
507	T. D. Stewart	1975	163	4	163	143-163	Twih	497	--	--	--
508	John Hurst	1974	185	4	185	170-185	Twih	492	--	--	--
509	A. B. Compte	1976	60	8	59	39-60	Twih	433	34.9	Mar. 9, 1982	1/
510	A. L. Roark	1969	160	--	160	130-160	Twih	473	--	--	--
511	D. L. Prichard	1976	185	4	185	170-185	Twih	450	55.6 54.2	Jan. 15, 1981 Mar. 9, 1982	1/
601	Jack Phillips	1948	400	6	--	--	Twih	503	58.2 51.5 51.0	Mar. 2, 1961 Feb. 7, 1981 Mar. 9, 1982	1/
602	do.	1971	320	7	320	60-70 130-160 164-280	Twih	497	18	1971	Irr
603	do.	1971	300	9	--	70-100 110-120 170-215 260-290	Twih	512	55	1971	Irr
604	Bill Gathright	1971	133	4	133	25-133	Twih	480	23	1971	--
605	W. D. Hancock	1974	131	4	131	116-131	Twih	508	50.5	Jan. 15, 1981	
606	C. L. Harris	1969	143	4	143	117-143	Twih	530	63.6 64.3	Feb. 17, 1981 Mar. 9, 1981	--
607	Kelley Parker	1977	400	4	400	280-360	Twih	530	105.6 105.7	Mar. 27, 1981 Mar. 9, 1982	N. 1/
701	W. R. Allison #1	1961	6,210	--	--	--	--	444	--	--	G. 2/
801	Jeff Stevens	1973	240	4	240	225-240	Twih	461	58.2 62.5 60.1	Oct. 19, 1976 Mar. 7, 1979 Mar. 9, 1982	1/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-29-802	J. R. Coe	1975	150	4	150	135-150	Twih	458	44	1975	--
803	L. W. Abbott	1976	340	4	340	325-340	Twih	450	53.1	Jan. 15, 1981	--
804	B. E. McBay	1967	100	4	100	80-100	Twih	415	28.8	Mar. 10, 1982	1/
805	J. Montgomery	1973	265	4	265	250-265	Twih	429	53	1973	--
806	James Duke	1978	240	4	160	160-240	Twih	433	59.2	Jan. 29, 1981	1/
									51.8	Mar. 9, 1982	
807	F. Mazewski	1976	176	4	176	161-176	Twih	420	46.4	Jan. 16, 1981	--
									43.5	Mar. 9, 1982	
901	John Ivey	--	42	36	--	--	Twih	442	18.5	Mar. 2, 1961	Dug well.
									31.7	Jan. 15, 1981	
									29.8	Mar. 9, 1982	
902	R. E. Stone	1969	270	4	270	164-206	Twih	450	40	1969	N.
903	D. Schmidt	1974	328	4	328	313-328	Twih	452	62	1974	--
904	W. Ragan	1978	220	4	180	180-220	Twih	442	50	1978	1/
905	C. A. McBay	1970	216	4	216	196-216	Twih	435	44	1970	2/
30-701	Sam Perry	--	46	36	--	--	Twic	425	42.5	Mar. 2, 1961	Dug well, Z.
702	Etta Wilburn	1953	62	8	62	--	Twic	425	49.0	Mar. 2, 1961	--
									48.8	Jan. 16, 1981	
									49.1	Mar. 9, 1982	
703	J. B. Moore	1972	370	4	370	345-370	Twi	445	62.0	Jul. 12, 1976	1/
									64.4	Mar. 7, 1979	
									65.1	Mar. 9, 1982	
704	- Lomax	1979	360	4	360	240-300	Twi	495	84.3	Mar. 27, 1981	N.
									82.8	Mar. 8, 1982	
705	A. E. Ferguson	1973	435	4	435	400-415	Twi	459	72	1973	1/
706	C. T. Taylor	1977	452	4	452	417-432	Twi	453	69.7	Jan. 16, 1981	--
									69.6	Mar. 9, 1982	
707	W. W. Money	1972	290	4	290	255-280	Twi	435	55	1972	--
708	E. H. Ethridge	1977	347	4	347	325-340	Twi	424	44.8	Aug. 30, 1982	--
709	W. Smith	1976	350	4	350	330-345	Twi	442	66.6	Aug. 30, 1982	--
710	H. G. Langford	1978	410	4	410	360-410	Twi	450	85	1978	--

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date com-pleted	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bear-ing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measure-ment	Remarks
SD-39-30-711	Al Rodgers	1974	302	4	302	264-279	Twi	456	70.5 70.1	Jan. 29, 1981 Mar. 9, 1982	--
712	P. Young	1976	432	4	432	412-422	Twi	423	45.9 45.4	Jan. 16, 1981 Mar. 9, 1982	--
713	Sam Perry	1975	410	4	410	385-405	Twi	418	41.0	Jan. 16, 1981	--
714	Jack Carlson	1972	250	4	250	235-250	Twi	455	29.6	Mar. 9, 1982	1/2/
715	Bistone Water District	1982	410	12	410	170-320 205-410	Twi	438	32.9	Nov. 5, 1982	P.
716	do.	1982	400	11	400	180-210 330-400	Twi	424	--	--	P.
801	O. K. Williams	1978	280	4	215	215-280	Twis	455	80	1978	--
35-301	--	--	--	6	--	--	Tmwp	524	--	--	Z.
601	--	--	100	--	--	--	Tmkp	533	--	--	Z.
602	R. B. McNutt	1979	120	4	120	15-30	Twih	509	15.3	Mar. 10, 1982	1/
801	- Cordova	--	31	36	--	--	Twih	515	27.0 20.8 21.8	Feb. 24, 1961 Jan. 17, 1981 Mar. 11, 1981	Dug well. 1/
901	City of Thornton	--	14	96	14	--	Twih	515	1.6	Dec. 4, 1981	Dug well, N. 1/
902	do.	1944	28	--	--	--	Twih	515	--	--	Dug well, Z.
903	do.	1948	143	6	143	--	Twih	516	--	--	N.
904	do.	1948	140	6	140	--	Twih	516	--	--	N.
905	do.	1959	380	6	200	--	Twih	520	45.6	Dec. 5, 1981	P. 1/
907	do.	1973	400	7	400	380-400	Twih	520	58.0 48.4 48.2	June 17, 1977 Dec. 18, 1980 Mar. 11, 1982	P. 1/3/
908	J. B. Lown	1979	185	4	185	150-170	Twih	532	60	1979	--
909	Tom Erskin	1973	400	4	400	380-400	Twih	552	85	1973	1/
36-201	H. L. Dugan	1971	180	4	180	--	Tmkp	469	20.1 19.2	Jan. 27, 1981 Mar. 10, 1982	--
202	D. Wietzikowski	1974	177	2	177	162-177	Tmkp	456	23	1974	--

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing Diameter (inches)	Casing Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-36-203	Bob Rogers	1979	306	4	306	240-306	Tmkp	450	11.2 11.1	Jan. 28, 1981 Mar. 10, 1982	N.
301	H. Wilson	1973	152	4	152	--	Twih	461	48	1973	1/
302	J. Harris	1978	50	4	50	30-50	Twih	460	21.4 21.3	Jan. 30, 1981 Mar. 11, 1982	1/
501	Wayne North	1969	400	4	400	350-360	Tmkp	522	75.8 75.6	Jan. 27, 1981 Mar. 12, 1982	--
502	Gary Collins	1979	293	4	293	271-287	Tmkp	468	15.3	Mar. 10, 1982	3/
601	H. B. Mellina	1981	248	4	248	30-248	Tmwp	480	33.3 33.6	Apr. 25, 1981 Mar. 10, 1982	2/
602	Davis Church	1979	97	4	97	60-70	Twih	460	29.3 28.5	Jan. 27, 1981 Mar. 10, 1982	--
603	E. S. Ellis	1979	103	4	103	46-66	Twih	504	45.6	Mar. 10, 1982	1/
604	G. B. Rasco	1973	132	4	132	--	Twih	494	40	1973	1/
801	P. Loughlin	1916	67	36	--	--	Twih	479	42.1 36.5 36.8	Feb. 23, 1961 Jan. 31, 1981 Mar. 10, 1982	Dug well. 1/
802	Helen McClure	1977	200	4	200	50-110 140-180	Twih	--	40	1977	--
803	J. B. Campbell	1973	152	4	152	--	Twih	--	8	1973	1/
901	J. W. Jackson	1974	120	4	120	115-120	Twih	--	11.7 11.9	Jan. 27, 1981 Mar. 10, 1982	N. 1/
902	Texas Ranches	1976	255	4	245	235-245	Twih	452	28	1976	--
903	S. K. Reynolds	1965	320	4	320	--	Twih	463	--	--	1/
904	Jack Lewis	1980	210	4	180	180-210	Twih	481	49.2	Mar. 10, 1982	--
37-101	Bradley Ranch	1938	173	6	40	40-173	Twih	435	16.3 18.2	Jan. 28, 1981 Mar. 10, 1982	N.
102	J. T. Ferrill	1974	252	4	252	160-252	Twih	448	53.9 55.9 53.3	July 12, 1976 Mar. 9, 1979 Mar. 10, 1982	1/
103	Imagene White	1973	102	4	--	55-75	Twih	449	38.4 38.6	Feb. 6, 1981 Mar. 10, 1982	--

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-37-104	J. C. White	1979	300	4	300	140-300	Twih	450	60	1979	--
105	B. R. Copeland	1976	400	4	400	240-400	Twih	415	12	1976	--
201	L. K. Lenamon	1968	329	4	329	274-329	Twih	395	17.4	Mar. 10, 1982	N.
202	R. Lawrence	1976	265	4	265	220-265	Twih	403	26.9	May 19, 1981	N.
301	Paul Rushing	1967	293	4	293	52-293	Twih	390	17.5 19.1	July 24, 1980 Feb. 3, 1982	1/
302	Archie Simms	1981	308	4	--	--	Twi	368	+4.2	Mar. 9, 1982	1/2/
303	do.	1981	348	4	--	--	Twi	370	+	Mar. 9, 1982	2/
304	J. Merritt	1974	247	4	247	210-225	Twi	431	57	1974	--
305	J. H. McFerran	1976	354	4	354	335-350	Twi	392	28	1976	--
306	C. B. Shugart	1974	226	4	226	165-195	Twi	442	56.9	Mar. 9, 1982	--
307	Jack R. Simms	1968	400	4	400	234-295 360-400	Twi	460	65.1	Mar. 13, 1981	N.
308	J. Gibson Heirs #1	1968	13,458	--	--	--	--	418	--	--	G. 2/
401	M. J. Thurman	1976	179	4	179	164-179	Twih	472	90.0 88.6	Jan. 29, 1981 Mar. 10, 1982	--
402	R. T. Capps	1970	75	4	75	--	Twih	519	34.0	Mar. 10, 1982	1/
403	John Wilson	1976	290	4	290	265-280	Twih	518	55	1976	--
404	Ira Wilson	1976	310	4	310	285-300	Twih	515	53	1976	--
405	Ralph Spence	1979	476	4	476	430-449	Twih	550	130	1979	3/
501	Ed Armstrong	1979	49	34	49	32-49	Twis	487	30.9	Mar. 10, 1982	--
502	W. O. Webb	1979	54	34	54	34-54	Twis	480	33.8	Mar. 6, 1981	--
503	B. R. Massey	1979	51	34	51	37-51	Twis	475	37.0	Mar. 10, 1982	1/
504	J. B. Hill	1979	62	34	62	46-62	Twis	508	46	1979	--
505	James Evans	1980	451	4	451	420-441	Twih	412	36.6	Mar. 10, 1982	--
601	Texas Dept. of Water Resources	1980	770	6	353	91-343	Twi	414	50.0	Oct. 9, 1980	Automatic water stage recorder. 2/
602	David Hughes	1976	307	4	307	281-306	Twi	390	17.4 16.8	Jan. 30, 1981 Mar. 10, 1981	1/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-37-603	Z. O. Lewis	1977	440	4	440	400-440	Twih	395	25	1977	--
801	Jess White	1973	446	4	446	383-446	Twih	470	94.1 93.7 93.8	July 13, 1976 Mar. 9, 1979 Mar. 10, 1982	1/
802	Recial Cox	1980	470	4	470	400-420	Twi	459	50	1980	2/
803	Olin White	1973	424	4	424	404-424	Twih	466	90	1973	--
804	C. Robinson	1977	467	4	467	370-390 440-467	Twih	448	80	1977	--
805	Laurene Adams	1974	574	4	574	549-564	Twih	465	83	1974	--
806	D. C. Curry	1972	538	4	538	513-528	Twih	464	60	1972	--
807	R. C. Powell	1978	615	4	615	574-594	Twih	469	67.5	Mar. 10, 1982	1/
808	C. F. Couch	1977	540	4	540	500-540	Twi	467	110	1977	--
901	Eula Mason	--	--	4	--	--	Twi	443	58.0 57.6	Feb. 23, 1961 Mar. 8, 1982	--
902	G. E. Cox	1977	440	4	440	38-440	Twi	451	70	1977	--
903	O. Henderson	1978	451	4	451	410-430	Twih	450	77	1978	--
904	C. E. Duncan	1978	413	4	413	372-392	Twih	435	63	1978	--
905	A. N. Deans	1975	453	4	453	413-453	Twi	450	75	1975	--
906	Imagene White	1973	383	4	383	299-341	Twi	439	75	1973	--
907	J. Thomason	1977	430	4	430	400-430	Twi	417	47.2 47.1	Jan. 29, 1981 Mar. 10, 1982	--
908	L. O. Nettles	1978	520	4	520	480-500	Twih	462	79.0	Mar. 10, 1982	1/
909	F. R. Reeves	1978	175	4	175	139-154	Twi	410	39	1978	--
910	Nellie Shelton	1978	270	4	270	229-249	Twi	470	95.3 97.8	Jan. 30, 1981 Mar. 10, 1982	
911	Jane Yarbrough	1979	348	4	348	310-348	Twi	481	105	1979	--
38-101	Jack Simms	1975	425	4	425	362-404	Twi	412	40	1975	--
102	L. C. Simms	1977	420	4	420	380-420	Twi	430	56.7 57.1	Feb. 6, 1981 Mar. 9, 1982	1/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-38-201	O. Christie	1980	260	4	220	220-260	Twi	443	73.6 73.4	Feb. 7, 1981 Mar. 9, 1982	1/
202	W. C. Reed	1974	540	4	540	505-520	Twi	432	135	1974	1/
203	Jim Thompson	1971	273	4	273	165-273	Twi	435	78.2	Mar. 9, 1982	--
204	Jean Prichard	1969	300	4	300	240-280	Twi	438	77	1969	2/
205	Bistone Water District	1982	435	11	435	170-260 350-375	Twi	392	--	--	P.
206	do.	1982	530	12	530	180-230 250-300 400-530	Twi	420	--	--	P.
207	do.	1982	450	14	450	150-270 370-450	Twi	407	48.9	Sept. 15, 1982	P.
208	do.	1982	440	13	370	250-370	Twi	435	64.2	Nov. 5, 1982	P.
303	Gibson #1	1976	13,500	--	--	--	--	456	--	--	G. 2/
401	Hollie Reed	1978	184	4	184	172-184	Twi	391	39.0 37.3	Feb. 6, 1981 Mar. 9, 1982	1/ --
402	Tom Atkins	1970	387	4	387	367-387	Twi	389	20.6	Jan. 29, 1981	--
403	N. P. Upshaw	1978	308	4	308	262-287	Twi	385	19.5	Mar. 10, 1982	1/
404	W. T. Nutt	1980	287	4	--	--	Twi	380	70	1980	2/
501	Billy Bishop	1979	185	4	185	172-182	Twi	485	23.6 21.2	Feb. 7, 1981 Mar. 9, 1982	3/
502	Lloyd Hurst	1974	455	4	455	440-455	Twi	452	200	1974	1/
503	W. O. Thomas	1979	102	4	102	63-80	Twic	450	39.3	Feb. 7, 1981	--
601	Houston Lighting and Power	--	26	34	--	--	Twic	483	17.5 20.4	Mar. 2, 1961 Oct. 2, 1981	Dug well, Z.
602	Farrar Water Supply	1967	718	4	718	669-709	Twi	438	75	1967	P. 1/3/
603	E. H. Chandler	1978	348	4	348	180-327	Twi	471	77	1978	--
604	R. R. Gantt	1965	360	4	360	241-360	Twi	470	--	--	1/
701	R. L. Durrenberger	1977	428	4	340	340-460	Twi	368	19.3 18.2	Feb. 17, 1981 Mar. 9, 1982	--

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date com-pleted	Depth of well (feet)	Casing		Screen interval (feet)	Water bear-ing unit	Altitude of land surface (feet)	Water levels		Remarks
				Diameter (inches)	Depth (feet)				Above (+) or below land surface (feet)	Date of measure-ment	
SD-39-38-702	R. DeCordova	1979	276	4	276	240-255	Twi	375	9	1979	--
703	Guy Durham	1979	276	4	276	225-245	Twi	375	9.5	Oct. 21, 1981	1/
704	E. Abercrombie	1979	276	4	276	240-255	Twi	370	9	1979	--
705	Jim Barnes	1979	266	4	266	231-246	Twi	370	9	1979	--
706	Carl Sadler	1976	500	4	500	460-500	Twi	390	60 21.1	1976 Mar. 10, 1982	--
801	H. Goodell	1980	60	34	60	39-60	Twic	452	38.9 39.3	Feb. 6, 1981 Mar. 9, 1982	--
802	Billy Martin	1980	460	4	460	430-460	Twi	390	45.8	Mar. 9, 1982	P. 1/
901	Texas Dept. of Highways and Public Transportation	--	100	20	--	--	Twic	380	.2	Mar. 2, 1961	Z.
902	A. O. Roberts	1968	265	4	265	245-265	Twic	441	63.2 62.8 60.1	July 13, 1976 Mar. 7, 1979 Mar. 9, 1982	1/2/
903	New Hope Church	1978	246	4	246	227-246	Twic	442	50.2	Oct. 20, 1981	--
904	W. Rhodes	1979	277	4	277	226-246	Twic	453	60	1979	1/
905	J. Beddingfield	1970	460	4	460	428-450	Twi	431	70	1970	2/
906	T. J. Crane	1971	295	4	295	275-295	Twic	434	60	1971	2/
907	J. Carpenter	1978	290	4	290	260-290	Twic	428	70	1978	--
39-406	Houston Lighting and Power	1981	735	18	735	579-735	Twis	442	104.3	Mar. 2, 1981	Ind. 2/
44-201	Lullene Reagan	1974	294	4	294	117-144 164-190 274-294	Twih	431	21.3 21.1	Aug. 31, 1981 Mar. 11, 1982	N.
301	Willie Alston	--	25	30	--	--	Twih	435	16.7 21.0 20.3	Feb. 23, 1961 Jan. 31, 1981 Mar. 11, 1982	Dug well. 1/
302	Ronnie Driskell	1979	184	4	184	149-164	Twih	440	45	1979	--
303	H. N. Stacy	1979	170	4	170	120-160	Twih	409	20	1981	1/
304	C. C. White	1973	140	4	105	105-140	Twih	411	29.9 28.8	Feb. 18, 1981 Mar. 11, 1981	--

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing Diameter (inches)	Casing Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-44-401	City of Kosse	1938	155	10	--	--	Twih	500	68 45.5	1938 Feb. 8, 1981	N. 1/
402	do.	1955	160	8	160	135-154	Twih	500	31.5	Feb. 8, 1981	N.
403	do.	1960	160	8	160	135-154	Twih	500	--	--	N.
404	do.	1938	160	10	--	--	Twih	500	38.0 31.0 31.3	Feb. 23, 1961 Feb. 8, 1981 Mar. 11, 1982	N.
405	do.	1969	164	7	164	144-164	Twih	495	--	--	Z. 3/
406	W. Hicks	1973	224	4	224	204-224	Twih	508	90	1973	
407	B. Milstead	1978	260	4	200	200-260	Twih	496	65.1 64.8	Feb. 18, 1981 Mar. 11, 1982	
408	James Allen	1977	250	4	195	195-250	Twih	530	117	1977	--
409	L. B. Hunt	1977	246	4	195	195-246	Twih	525	101	1977	--
410	J. B. Davis	1974	180	4	180	160-180	Twih	525	45.8 49.4	Feb. 18, 1981 Mar. 11, 1982	N. 1/
411	P. Waddle	1978	140	6	35	35-140	Twih	540	78	1978	--
412	R. E. Poland	1977	60	6	60	50-60	Twih	560	34	1977	--
413	W. I. Johnston	1977	63	4	63	53-63	Twih	560	39	1977	--
414	A. E. Adler	1972	255	4	255	240-255	Twih	489	60	1972	--
501	H. Kerens	1978	300	4	200	200-300	Twih	507	96	1978	1/
502	W. Woley	1974	450	4	450	430-450	Twi	489	90	1974	--
503	R. L. Kyle	1974	434	4	434	414-434	Twi	489	105	1974	1/
504	Bill Parker	1974	202	4	202	182-202	Twih	518	40	1974	--
505	A. Wisdom	1979	70	4	70	60-70	Twi	552	40.3 39.8	Feb. 18, 1981 Mar. 11, 1982	N. 1/
506	D. W. Walker	1977	80	4	80	70-80	Twis	540	46	1977	--
601	Texas Industrial Minerals	1970	500	12	480	110-150 175-195 240-250 270-350 410-460	Twi	415	16.4 15.8	Feb. 18, 1981 Mar. 11, 1982	Ind. 3/

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels: Above (+) or below land surface (feet)	Water levels: Date of measurement	Remarks
SD-39-44-602	Texas Industrial Minerals	1975	500	10	500	460-500	Twi	415	70	1975	Ind.
603	do.	1980	500	10	500	330-350 430-450	Twi	430	--	--	Ind. 1/
604	do.	1978	470	4	470	450-470	Twi	440	106	1978	Ind.
605	do.	1963	475	16	475	285-370 380-405 435-460	Twi	438	45	1963	Ind. 2/
701	B. O. Lloyd	1969	300	4	300	--	Twih	508	51.2 62.1	Apr. 26, 1981 Mar. 11, 1982	N. 1/
801	P. Robertson	1979	100	4	100	80-100	Twis	550	51.7 51.9	Feb. 1, 1981 Mar. 11, 1982	1/
802	J. W. Robinson	1975	282	4	282	219-282	Twi	530	100	1975	--
803	D. Johnson	1970	210	4	210	168-210	Twi	561	65	1970	--
901	Boyd Tillman	1920	56	30	--	--	Twic	488	47.8	Feb. 23, 1961	Dug well, Z. 1/
902	Levi Truett	--	137	5	--	--	Twi	460	38.1 33.6 32.1	Feb. 23, 1961 Jan. 31, 1981 Mar. 11, 1982	N.
903	Bayne Truett	1973	339	4	339	297-339	Twi	475	34.9 30.3 32.1	Mar. 24, 1977 Mar. 11, 1980 Mar. 11, 1982	N.
905	Boyd Tillman	1925	66	27	--	--	Twic	500	21.4 29.0 32.4	Feb. 23, 1961 Jan. 31, 1981 Mar. 11, 1982	Dug well, N.
45-101	Clayton Archer	1956	120	5	--	--	Twi	461	41.5	Mar. 10, 1982	1/
102	E. E. Dunn	1976	420	4	420	410-420	Twi	452	65.7	Mar. 10, 1982	--
201	C. D. Jones	1960	143	4	--	--	Twi	431	39.3 37.2 37.1	Feb. 23, 1961 Jan. 30, 1981 Mar. 10, 1982	N.
202	Marvin Stinson	1974	539	4	539	509-524	Twi	454	74.6 75.4 76.4	July 13, 1976 Mar. 9, 1979 Mar. 10, 1982	1/
203	W. Hodge	1974	532	4	532	507-522	Twi	463	55	1974	--
204	Jane Yarbrough	1979	533	4	533	508-523	Twi	444	63	1979	--

See footnotes at end of table.

Table 8.—Records of Wells and Springs—Continued

Well number	Owner or spring	Date completed	Depth of well (feet)	Casing		Screen interval (feet)	Water bearing unit	Altitude of land surface (feet)	Water levels		Remarks
				Diameter (inches)	Depth (feet)				Above (+) or below land surface (feet)	Date of measurement	
SD-39-45-205	Jack Jones	1972	393	4	393	351-393	Twi	450	63	1972	--
206	Aaron Shields	1978	348	4	348	323-338	Twi	441	40	1978	--
207	J. A. Van Dyke	1974	410	4	410	375-390	Twi	440	67.4 67.6	Feb. 19, 1981 Mar. 10, 1982	1/
208	Frank Connell	1960	320	4	--	--	Twi	411	34.9 38.7 38.2	Feb. 23, 1961 Jan. 30, 1981 Mar. 10, 1982	N.
209	do.	1978	520	4	520	500-520	Twi	423	48	1978	1/3/
301	Oletha Grocery	--	40	30	--	--	Twic	470	5	1961	Dug well, Z.
302	Jack Thompson	1977	620	4	620	500-540 580-620	Twic	462	90	1977	--
303	C. F. Goldman	1973	303	4	303	292-302	Twi	459	88	1973	1/
304	John Murphy	1976	438	4	438	378-438	Twi	440	75	1976	--
305	Brooks Peel	1972	347	4	347	336-347	Twi	420	55	1972	--
46-101	H. Longenbaugh	1978	500	4	500	480-500	Twi	422	60.7	Mar. 10, 1982	1/
102	W. C. Grymes	1980	395	4	395	363-386	Twi	375	8.1	Mar. 10, 1982	P.
103	Tom Kelly	1979	100	4	100	60-80	Twic	370	12	1979	--
104	C. Neason	1979	100	4	100	78-100	Twic	370	5.7	Feb. 19, 1981	--
105	Jim Flynn	1979	100	4	100	45-60	Twic	372	11.2	Oct. 20, 1981	--
106	Limestone Coves	1980	670	7	670	552-670	Twis	410	51.4	Oct. 20, 1981	P. 1/
52-101	George Douglas	1979	264	4	196	196-264	Twih	550	127.7	Mar. 11, 1982	--
102	F. E. Scott	1969	115	4	115	105-115	Twi	534	78.4 78.6	Feb. 20, 1981 Mar. 11, 1982	1/
103	N. W. Tryer	1975	318	4	318	270-316	Twi	500	76	1975	--

1/ For chemical analyses of water from wells, see Table 10.
2/ Electric log in files of U.S. Geological Survey or Texas Water Commission, Austin, Texas.
3/ For drillers' logs of wells, see Table 9.

Table 9.—Selected Drillers' Logs of Water Wells

Well SD-39-20-201

Owner: T. E. Moore
Driller: R. K. Sims

	Thickness (feet)	Depth (feet)
Clay, yellow	5	5
Shale, blue	20	25
Shale, sandy	30	55
Rock	1	56
Rock, sand and clay	17	73
Sand and gravel	36	109
Shale, blue	1	110

Well SD-39-20-601

Owner: Mexia State School
Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, yellow	22	23
Shale, blue	84	107
Shale, sandy	28	135
Shale, hard	16	151
Shale, sandy	9	160
Shale	49	209
Shale, hard	37	246
Rock, soft	1	247
Shale, soft	13	260
Rock, hard	21	281
Sand and boulders	7	288
Rock, hard	11	299
Sand, soft	1	300
Rock, hard	3	303
Sand, soft	1	304
Rock, hard	2	306
Rock, broken	1	307
Rock, hard	2	309

Well SD-39-20-601--Continued

	Thickness (feet)	Depth (feet
Sand, soft	1	310
Rock, hard	12	322

Well SD-39-20-801

Owner: John Fletcher
Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)
Soil, surface	6	6
Clay, blue	7	13
Clay, yellow	8	21
Clay, sandy	4	25
Limestone, hard, crevices	23	48
Sand, fine	2	50
Rock, hard, crevices	16	66
Sand, blue, fine	2	68
Rock	2	70
Sand, blue, fine	2	72
Limestone, hard, crevices	12	84
Rock, hard	4	88
Sand, hard	7	95
Sand, layers, hard	7	102
Rock, hard	3	105
Rock	2	107
Sand, good	6	113
Rock	1	114
Sand, good	6	120
Limestone, hard	2	122
Sand, fine	45	167
Rock	2	169
Shale, blue, sandy	92	261
Clay, black, sticky	153	414

Table 9.—Selected Drillers' Logs of Water Wells—Continued

Well SD-39-21-401

Owner: L. N. Robinson
Driller: Crockett Drilling Co.

	Thickness (feet)	Depth (feet)
Surface	44	44
Shale	84	128
Rock and shale	20	148
Shale	60	208
Rock and shale	20	228
Shale	20	248
Shale and rock	21	269
Shale, sandy	101	370
Shale	141	511

Well SD-39-21-903

Owner: T. Matthews
Driller: R. K. Sims

	Thickness (feet)	Depth (feet)
Clay, red	3	3
Clay, yellow	1	4
Clay, sandy	8	12
Shale, blue	24	36
Shale and coal streaks	9	45
Shale, soft and coal	30	75
Sand and coal streaks	5	80
Sand	20	100
Shale, sandy	42	142

Well SD-39-28-201

Owner: L. Tidwell
Driller: R. K. Sims

	Thickness (feet)	Depth (feet)
Clay, white	5	5
Rock	7	12
Sand	3	15
Rock	5	20

Well SD-39-28-201--Continued

	Thickness (feet)	Depth (feet)
Sand	3	23
Rock	2	25
Sand and caliche	10	35
Rock	3	38
Sand	1	39
Rock	3	42
Caliche, sandy	1	43
Rock	1	44
Rock, soft and sand	6	50
Rock, hard	7	57
Sand	1	58
Rock	11	69
Sand	1	70
Rock	5	75
Sand	4	79
Rock	2	81
Rock, hard	9	90

Well SD-39-28-304

Owner: John Lewis
Driller: J. M. Adams

	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, yellow	6	8
Clay, sandy	8	16
Boulders, hard	3	19
Sand, dry	8	27
Limestone, hard	2	29
Sand, hard, streaks	9	38
Shale, blue	12	50
Shale, blue, hard	5	55
Clay, blue, hard, sandy	15	70
Limestone, very hard	3	73
Shale, blue, soft	57	130

Well SD-39-29-602

Owner: Jack Phillips
Driller: R. A. McClinton

	Thickness (feet)	Depth (feet)
Sand and soil	6	6
Clay, grey	24	30
Coal	3	33
Clay	25	58
Coal	3	61
Sand	9	70
Shale, sandy	60	130
Sand	30	160
Shale	9	169
Sand	3	172
Shale	48	220
Sand	13	233
Shale	17	250
Sand	30	280
Shale	40	320

Well SD-39-35-907

Owner: City of Thornton
Driller: G. P. Brien

	Thickness (feet)	Depth (feet)
Sand	3	3
Clay	7	10
Sand	45	55
Coal	4	59
Shale	34	93
Coal	2	95
Rock	1	96
Shale	29	125
Rock	3	128
Shale	7	135
Sand	8	143

Well SD-39-35-907--Continued

	Thickness (feet)	Depth (feet)
Shale	27	170
Sand	83	253
Sand and shale	12	265
Sand	15	280
Sand and shale	25	305
Sand	16	321
Rock	4	325
Sand and sandy shale	45	370
Sand and shale	30	400

Well SD-39-36-502

Owner: Gary Collins
Driller: J. Mauldin

	Thickness (feet)	Depth (feet)
Clay, blue	5	5
Clay, yellow	15	20
Shale, blue	195	215
Rock	31	246
Sand	7	253
Rock	1	254
Sand	3	257
Rock	1	258
Sand	1	259
Rock	8	267
Sand	4	271
Rock	1	272
Sand	4	276
Rock	1	277
Sand	10	287
Rock	6	293

Well SD-39-37-405

Owner: Ralph Spence
Driller: J. Mauldin

	Thickness (feet)	Depth (feet)
Sand	110	110
Sand, streaks of coal	33	143
Shale, blue	82	225
Sand	35	260
Shale	90	350
Sand	60	410
Shale	20	43
Sand	19	449
Shale	27	476

Well SD-39-38-501

Owner: Billy Bishop
Driller: J. Mauldin

	Thickness (feet)	Depth (feet)
Clay, red	5	5
Clay, white	5	10
Sand	10	20
Shale, blue	30	50
Coal	9	59
Shale, blue and coal streaks	23	82
Shale, blue	20	102
Coal	6	108
Shale, blue	10	118
Sand	5	123
Coal	1	124
Sand	5	129
Shale, blue	15	144
Shale, sandy	25	169
Shale, blue	3	172
Sand	13	185

Well SD-39-38-602

Owner: Farrar Water Supply
Driller: John A. Frye

	Thickness (feet)	Depth (feet)
Topsoil, clay and sand	22	22
Clay, sandy and lignite	17	39
Shale and sand	20	59
Clay, sandy with rock	22	81
Sand and clay	42	123
Shale and rock	83	206
Shale, hard with sandstone stringers	41	247
Shale with sandstone stringers	41	288
Sandstone	82	370
Shale, medium hard	20	390
Shale, soft	21	411
Shale with fine sand	41	452
Shale, sandy	82	534
Shale, medium hard	20	554
Rock and very hard shale	41	595
Shale, medium hard	21	616
Shale, very hard with hard sand	20	636
Sand, hard with shale and sand	21	657
Shale and sand	20	677
Sand, thin consolidated rock	21	698
Sand and shale	20	718

Well SD-39-44-405

Owner: City of Kosse
Driller: H. Meadows

	Thickness (feet)	Depth (feet)
Soil, black	2	2
Clay, sandy	5	7
Clay, white, sandy	12	19
Shale, green	6	25
Clay, yellow, sandy	9	34
Shale, gray	10	44
Shale, blue	15	59
Sand, white	14	73
Shale, blue, sandy	70	143
Sand, gray	17	160
Shale, blue	4	164

Well SD-39-44-601

Owner: Texas Industrial Minerals
Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)
Clay	20	20
Sand	25	45
Clay, sandy and sand	39	84
Sand and gravel	50	134
Clay	36	170
Sand and lignite	12	182
Shale and sand streaks	69	251
Shale	27	278
Shale, sandy	22	300
Sand	42	342
Sand and shale streaks	32	374
Shale and sand streaks	16	390
Shale, sandy	29	419
Sand	22	441

Well SD-39-44-601--Continued

	Thickness (feet)	Depth (feet)
Shale	21	462
Sand	12	474
Shale, sandy and sand streaks	26	500

Well SD-39-45-209

Owner: Frank Connell
Driller: P. Brien

	Thickness (feet)	Depth (feet)
Clay	10	10
Sand	10	20
Clay	10	30
Coal	3	33
Rock	5	38
Shale	9	47
Coal	8	55
Sand and shale	12	67
Coal	4	71
Shale	24	95
Sand	195	290
Coal	5	295
Shale	55	350
Sand	10	360
Shale	32	392
Coal	2	394
Sand	13	407
Shale	33	440
Sand	55	495
Rock	1	496
Sand and shale	24	520

Table 10.—Water-Quality Data for Wells and Springs

Well	Owner or spring	Depth (feet)	Water-bearing unit	Date	Specific conductance (micromhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Dissolved calcium (mg/L as Ca)	Dissolved magnesium (mg/L as Mg)	Dissolved sodium (mg/L as Na)	Sodium adsorption ratio (SAR)	Dissolved potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Dissolved sulfate (mg/L as SO_4)	Dissolved chloride (mg/L as Cl)	Dissolved fluoride (mg/L as F)	Dissolved silica (mg/L as SiO^2)	Dissolved solids (sum of constituents) (mg/L)	Total nitrogen NO_2+NO_3 (mg/L as N)	Total nitrogen ammonia (mg/L as N)	Total organic nitrogen (mg/L as N)	Total phosphorus, (mg/L as P)	Dissolved iron (µg/L as Fe)
SD-39-12-601	H. H. Magness	7	Knt	3- 1-61	1,060	7.4	--	263	66	24	148	4.0	1/	330	166	50	3.8	21	678	0.1	--	--	--	40
901	Trotter Spring	springs	Tmkt	6-10-81	720	7.1	19.0	--	--	--	--	--	--	290	--	--	--	--	--	--	--	--	--	--
902	George Black	175	Tm	9- 1-81	1,150	6.8	23.0	680	97	16	130	3.4	3.8	370	22	150	.3	26	680	.17	0.06	0.59	0.06	10
13-701	J. L. Boyd	62	Twih	3- 1-61	929	7.6	--	181	46	16	147	4.7	1/	380	34	58	.4	26	560	1.7	--	--	--	10
18-101	G. Crawford	22	Knt	6-16-77[2/]	2,460	7.7	--	650	196	39	351	6.0	--	410	328	437	.8	20	1,620	.1	--	--	--	--
801	M. Whitten	19	Knt	10- 1-81	1,020	7.1	20.0	--	--	--	--	--	--	350	--	--	--	--	--	--	--	--	--	--
802	Prairie Hill Water District	3,942	Ktph	9- 3-64[2/]	6,273	7.4	--	--	229	35	850	13.8	--	180	2,110	119	2.8	--	3,459	.8	--	--	--	60
19-601	R. Sunday	17	Knt	10- 1-81	244	8.0	21.5	--	--	--	--	--	--	110	--	--	--	--	--	--	--	--	--	--
20-201	T. E. Moore	110	Twih	7-14-76[2/]	665	7.6	--	212	74	6	68	2.0	--	270	13	56	.4	27	404	.1	--	--	--	--
				3-11-80[2/]	598	7.7	--	202	63	11	64	1.9	--	260	16	46	.4	30	387	.02	--	--	--	--
202	A. G. Murphy	80	Twih	4-10-81	758	7.3	21.0	220	72	9.2	66	1.9	1.9	260	18	71	.2	30	425	--	--	--	--	640
301	City of Tehuacana	50	Tmkt	6- -38[2/]	--	7.1	--	332	124	5.2	11	--	--	280	17	21	.2	29	440	7.9	--	--	--	200
				4- -43	--	7.9	--	282	108	3.1	34	--	2.2	280	17	23	.2	4.6	397	8.8	--	--	--	150
				6-23-81	728	7.2	19.5	360	140	2.0	14	.3	2.0	330	45	18	.1	11	431	3.8	.01	.84	.1	150
302	do.	82	Tmkt	4- 9-81	614	6.9	19.0	310	120	1.8	14	.3	2.0	280	28	18	.1	11	363	4.6	.9	.87	.08	30
303	Tehuacana Spring	springs	Tmkt	6-10-81	664	6.7	19.0	--	--	--	--	--	--	290	--	--	--	--	--	--	--	--	--	--
601	Mexia State School	322	Tmkt	5-23-44	--	7.4	--	224	72	11	197	--	1/	300	7.8	248	0	18	733	.3	--	--	--	150
602	do.	360	Tmkt	5-23-44	--	7.4	--	230	74	11	95	--	1/	290	7.9	99	--	18	481	--	--	--	--	150
603	do.	394	Tmkt	1-19-82	1,060	7.4	24.0	240	76	11	140	4.1	1.9	320	94	96	.3	21	632	.09	.40	.24	.01	610
604	City of Mexia	320	Tmkt	4-21-43	--	7.7	--	137	41	8.4	205	--	4.8	320	4.9	184	.4	22	659	.2	--	--	--	20
605	do.	291	Tmkt	4-21-43	--	7.7	--	108	30	8.0	126	--	1/	280	7.7	67	.4	21	442	.1	--	--	--	80
607	do.	230	Tmkt	4-21-43	--	7.9	--	108	31	7.4	128	--	6.2	280	13	69	.4	19	466	.2	--	--	--	100
609	Buster Chrisner	--	Tmkt	9- -54[2/]	--	8.0	--	135	34	12	122	--	--	310	18	50	.3	--	440	.1	--	--	--	130
				11-18-81	720	7.4	24.0	200	57	13	93	3.1	2.9	320	55	31	.3	17	462	.1	.78	.18	.01	720
616	Steubenrauch	320	Tmkt	1-13-81	7,390	6.9	24.5	--	--	--	--	--	--	260	--	--	--	--	--	--	--	--	--	--
703	Comanche Springs	springs	Tmkp	6- 9-81	480	6.8	20.0	--	--	--	--	--	--	240	--	--	--	--	--	--	--	--	--	--
704	E. S. Pickens	40	Tmkp	3-11-81	750	6.9	18.0	--	--	--	--	--	--	370	--	--	--	--	--	--	--	--	--	--

See footnotes at end of table.

Table 10.—Water-Quality Data for Wells and Springs—Continued

Well	Owner or spring	Depth (feet)	Water-bearing unit	Date	Specific conductance (micromhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Dissolved calcium (mg/L as Ca)	Dissolved magnesium (mg/L as Mg)	Dissolved sodium (mg/L as Na)	Sodium adsorption ratio (SAR)	Dissolved potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Dissolved sulfate (mg/L as SO_4)	Dissolved chloride (mg/L as Cl)	Dissolved fluoride (mg/L as F)	Dissolved silica (mg/L as SiO_2)	Dissolved solids (sum of constituents) (mg/L)	Total nitrogen NO_2+NO_3 (mg/L as N)	Total nitrogen ammonia (mg/L as N)	Total organic nitrogen (mg/L as N)	Total phosphorus (mg/L as P)	Dissolved iron (µg/L as Fe)
SD-39-20-801	J. Fletcher	414	Tmkp	4-25-81	701	7.1	21.0	180	55	11	98	3.2	2.9	350	0.8	30	0.3	25	434	--	--	--	--	570
804	J. R. Dawley	--	Tmkp	3- 9-62 2/	845	7.5	--	410	152	7	17	--	1/	330	14	42	--	--	391	0.8	--	--	--	--
				5-18-81	765	6.7	20.0	360	140	3.4	12	.3	.9	330	15	20	.2	18	408	--	--	--	--	--
901	Guy Owens	38	Tmkp	7-14-76 2/	741	7.5	21.0	363	139	4	25	.6	--	320	18	49	.2	18	450	.6	--	--	--	--
				3-11-80 2/	691	7.5	18.5	350	138	1	26	.6	--	310	22	53	.2	17	445	.9	--	--	--	--
902	P. Russell	63	Tmkp	3-10-80	550	7.0	21.0	--	--	--	--	--	--	250	--	--	--	--	--	--	--	--	--	--
21-503	C. P. Aman	60	Twih	10- 1-81	4,070	7.1	20.5	--	--	--	--	--	--	310	--	--	--	--	--	--	--	--	--	--
701	N. Beene	310	Tmwp	4-25-81	5,150	7.8	22.5	--	--	--	--	--	--	250	--	--	--	--	--	--	--	--	--	--
801	C. R. Crider	80	Twih	9- 1-81	591	6.6	21.5	160	51	8.1	48	1.7	2.2	150	17	81	.2	53	351	1.4	0.5	.61	1.5	10
903	T. Matthews	142	Twih	3-10-81	336	8.2	21.0	--	--	--	--	--	--	48	--	--	--	--	--	--	--	--	--	--
904	E. C. Favors	100	Twih	6-11-81	1,360	6.5	20.5	400	110	30	100	2.2	4.8	150	42	320	.1	53	750	--	--	--	--	60
26-502	J. Walts	28	Knt	3- 1-61	1,400	7.6	--	490	180	10	92	1.8	1/	230	104	75	1.5	23	924	68	--	--	--	30
27-301	J. Hudgins	72	Tmkp	5-18-81	984	6.8	22.5	400	150	6.3	31	.7	41	310	94	69	.1	13	591	--	--	--	--	20
601	O. B. Owen	200	Tmkp	3-10-80 2/	636	7.6	--	360	139	3.0	9.0	.2	--	320	27	12	.1	12	418	5.6	--	--	--	--
28-102	M. D. Hendrix	108	Tmkt	5-18-81	648	7.4	24.0	--	--	--	--	--	--	380	--	--	--	--	--	--	--	--	--	--
201	L. Tidwell	90	Tmkt	4- 7-81	651	6.5	20.0	290	110	4.4	25	.6	.5	310	12	21	.3	19	379	--	--	--	--	--
202	do.	springs	Tmkt	4- 7-81	570	6.7	19.5	--	--	--	--	--	--	270	--	--	--	--	--	--	--	--	--	--
203	do.	65	Tmkt	3-11-81	780	7.0	21.5	--	--	--	--	--	--	330	--	--	--	--	--	--	--	--	--	--
204	do.	141	Tmkt	3-12-81	655	7.3	20.0	--	--	--	--	--	--	330	--	--	--	--	--	--	--	--	--	--
205	do.	springs	Tmkt	3-11-81	886	7.1	16.0	--	--	--	--	--	--	360	--	--	--	--	--	--	--	--	--	--
206	do.	165	Tmkt	3-12-81	970	7.4	21.5	--	--	--	--	--	--	310	--	--	--	--	--	--	--	--	--	--
301	Springfield West	springs	Tmkt	5-20-81	559	7.4	24.0	290	110	4.0	20	.5	1.2	280	15	19	.1	23	361	.26	.19	1.1	.13	10
302	Springfield East	springs	Tmkt	3- 8-62 2/	675	7.0	--	305	112	6	8	--	1/	270	14	18	--	--	343	.2	--	--	--	--
				4-10-81	672	7.1	18.0	310	120	2.8	9.8	.2	1.2	300	19	13	.2	20	366	2.7	.05	.85	.07	--
304	John Lewis	130	Tmkp	4-10-81	538	6.7	20.0	240	92	2.7	19	.5	.8	250	12	17	.1	32	326	--	--	--	--	--
306	T. G. Platt	36	Tmkt	4-10-81	936	6.7	20.0	380	140	8.1	55	1.2	1.1	400	20	55	.2	23	543	--	--	--	--	--
307	W. E. Guthrie	86	Tmwp	3-11-81	230	7.1	20.0	--	--	--	--	--	--	92	--	--	--	--	--	--	--	--	--	--

See footnotes at end of table.

Table 10.—Water-Quality Data for Wells and Springs—Continued

Well	Owner or spring	Depth (feet)	Water-bearing unit	Date	Specific conductance (micromhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Dissolved calcium (mg/L as Ca)	Dissolved magnesium (mg/L as Mg)	Dissolved sodium (mg/L as Na)	Sodium adsorption ratio (SAR)	Dissolved potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Dissolved sulfate (mg/L as SO_4)	Dissolved chloride (mg/L as Cl)	Dissolved fluoride (mg/L as F)	Dissolved silica (mg/L as SiO_2)	Dissolved solids (sum of constituents) (mg/L)	Total nitrogen NO_2+NO_3 (mg/L as N)	Total nitrogen ammonia (mg/L as N)	Total organic nitrogen (mg/L as N)	Total phosphorus (mg/L as P)	Dissolved iron (µg/L as Fe)
SD-39-28-501	Ft. Parker Springs	springs	Tmkp	5-24-80	510	6.0	23.0	--	--	--	--	--	--	80	--	--	--	--	--	--	--	--	--	--
502	Texas Parks and Wildlife Dept.	103	Tmkp	9- 2-81	706	6.8	22.0	260	96	5.7	43	1.2	0.1	300	6.0	42	0.7	21	395	0.66	0.07	0.54	0.06	40
503	Sulphur Springs	springs	Tmkt	1-21-82	640	7.6	18.5	--	--	--	--	--	--	330	--	--	--	--	--	--	--	--	--	--
601	W. Crowson	60	Tmkp	3-24-77 2/	591	7.5	--	310	117	4	9	.2	--	250	20	31	.2	16	364	4.1	--	--	--	--
				3-11-80 2/	504	7.6	18.0	257	100	1	9	.2	--	200	18	22	.2	13	320	8.8	--	--	--	--
602	do.	120	Tmkp	7-14-76 2/	525	7.6	24.0	266	101	3	8	.2	--	200	19	12	.3	15	337	13	--	--	--	--
702	E. Beene	188	Tmkt	4-24-81	831	7.7	22.0	69	18	5.8	170	8.9	2.4	340	16	67	.2	19	503	--	--	--	--	--
802	C. Daughtery	17	Tmkp	7-15-76 2/	1,079	7.5	24.0	428	152	12	59	1.2	--	220	42	130	.2	19	700	34	--	--	--	--
				3-11-80 2/	1,116	7.4	15.5	494	183	9	63	1.2	--	200	46	161	.2	18	782	41	--	--	--	--
803	Groesbeck Springs	springs	Tmkt	4- 7-81	627	6.9	19.0	--	--	--	--	--	--	300	--	--	--	--	--	--	--	--	--	--
804	City of Groesbeck	303	Tmkp	2- 2-82	540	7.4	20.5	--	--	--	--	--	--	290	--	--	--	--	--	--	--	--	--	--
901	Farmers Bank	150	Tmkt	3-10-81	4,640	7.1	22.5	--	--	--	--	--	--	440	--	--	--	--	--	--	--	--	--	--
29-201	R. Sunday	112	Twih	10-20-81	437	6.7	21.0	130	34	12	38	1.5	2.0	130	42	48	.4	55	317	.09	.12	.18	.30	7,500
302	Kelley Parker	266	Twih	10- 3-81	843	7.5	22.0	240	59	22	74	2.3	4.5	200	14	130	.3	21	445	.17	.61	.21	.06	170
501	Weaver Sadler	230	Twih	4- 9-81	742	8.0	22.0	51	13	4.6	150	9.1	2.6	240	58	62	.2	13	448	--	--	--	--	10
502	Gary Moran	248	Twih	4-11-81	667	7.7	21.0	57	15	4.8	120	6.9	2.6	220	32	58	.2	14	379	--	--	--	--	40
505	V. E. Rhodes	240	Twih	10-21-81	763	7.4	22.0	170	42	16	100	3.6	4.1	230	70	59	.2	29	459	.09	.68	.18	.15	350
506	Wade Morgan	715	--	10-21-81	1,040	8.2	22.0	--	--	--	--	--	--	250	--	--	--	--	--	--	--	--	--	--
509	A. B. Compte	60	Twih	10-21-81	2,110	5.6	21.5	440	120	34	260	5.4	2.8	290	77	470	.4	37	1,180	--	--	--	--	--
511	D. L. Prichard	195	Twih	10- 3-81	681	8.2	22.0	34	8.8	2.9	140	11	2.1	190	54	64	.3	14	400	.15	.30	1.0	.13	15
601	Jack Phillips	400	Twih	4-11-81	982	6.7	22.0	360	88	33	58	1.3	3.5	180	75	170	.3	45	587	--	--	--	--	6,200
607	Kelley Parker	400	Twih	10- 3-81	730	7.1	21.0	--	--	--	--	--	--	240	--	--	--	--	--	--	--	--	--	--
801	Jeff Stevens	250	Twih	7-12-76 2/	556	8.4	--	16	5.0	1.0	124	13	--	200	44	37	.3	13	344	.52	--	--	--	--
				3-11-80 2/	542	8.2	--	15	5.0	1.0	125	13	2.0	200	45	37	.3	11	345	.06	--	--	--	--
804	B. E. McBay	100	Twih	5-19-81	2,950	6.3	21.0	930	220	93	250	3.6	3.8	270	210	730	.1	27	1,700	--	--	--	--	830
806	James Duke	240	Twih	5-19-81	553	8.4	22.0	26	6.3	2.5	130	11	1.5	230	16	34	.2	19	354	--	--	--	--	6,600
901	John Ivey	36	Twih	4-10-81	800	6.7	19.0	--	--	--	--	--	--	120	--	--	--	--	--	--	--	--	--	--

See footnotes at end of table.

Table 10.—Water-Quality Data for Wells and Springs—Continued

Well	Owner or spring	Depth (feet)	Water-bearing unit	Date	Specific conductance (micromhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Dissolved calcium (mg/L as Ca)	Dissolved magnesium (mg/L as Mg)	Dissolved sodium (mg/L as Na)	Sodium adsorption ratio (SAR)	Dissolved potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Dissolved sulfate (mg/L as SO_4)	Dissolved chloride (mg/L as Cl)	Dissolved fluoride (mg/L as F)	Dissolved silica (mg/L as SiO^2)	Dissolved solids (sum of constituents) (mg/L)	Total nitrogen NO_2+NO_3 (mg/L as N)	Total nitrogen ammonia (mg/L as N)	Total organic nitrogen (mg/L as N)	Total phosphorus, (mg/L as P)	Dissolved iron (μg/L as Fe)
SD-39-29-904	W. Ragan	220	Twih	5-21-81	628	8.1	21.0	43	12	3.2	130	8.6	2.1	200	49	51	0.2	15	383	--	--	--	--	490
30-703	J. B. Moore	370	Twi	7-12-76 2/ 3-11-80 2/	316 315	7.8 7.4	24.0 --	28 25	10 8.0	1.0 1.0	62 64	5.1 5.6	-- 3.0	140 140	8.0 10	12 14	.1 .1	16 15	195 200	0.36 .02	-- --	-- --	-- --	-- --
705	A. E. Ferguson	435	Twi	1-19-82	428	7.8	20.0	71	19	5.7	66	3.7	3.1	160	18	33	.1	21	262	--	--	--	--	20
714	J. Carlson	250	Twi	6-23-81	402	7.9	24.5	--	--	--	--	--	--	120	--	--	--	--	--	--	--	--	--	--
35-602	R. McNutt	120	Twih	4-25-81	2,010	6.9	22.0	--	--	--	--	--	--	520	--	--	--	--	--	--	--	--	--	--
801	- Cordova	31	Twih	10- 2-81	1,080	7.0	20.5	--	--	--	--	--	--	540	--	--	--	--	--	--	--	--	--	--
901	City of Thornton	14	Twih	4- -43	--	7.8	--	58	18	3.3	13	--	3.8	60	7.4	13	.2	29	145	--	--	--	--	--
905	do.	380	Twih	8-31-81	549	7.0	23.0	160	46	11	50	1.8	2.9	180	21	51	.5	40	331	.02	0.27	0.56	0.12	370
907	do.	400	Twih	6-17-77 2/ 7-16-80 2/	460 445	7.6 7.9	23.5 24.5	155 147	50 46	7.0 8.0	36 42	1.2 1.5	3.0 --	150 156	19 18	47 48	.4 .4	42 41	294 297	.09 .02	-- --	-- --	-- --	-- --
909	T. Erskin	400	Twih	4-27-81	609	7.4	22.5	150	45	9.9	67	2.4	2.3	190	22	69	.4	35	365	--	--	--	--	420
36-201	H. L. Dugan	180	Tmkp	5-21-81	984	7.5	22.0	120	26	14	170	6.7	2.6	340	81	59	.3	19	576	--	--	--	--	--
203	B. Rogers	306	Tmkp	4-24-81	6,560	7.8	23.5	72	19	6.0	1,400	72	5.3	310	7.0	2,100	1.5	11	3,740	--	--	--	--	--
301	H. Wilson	152	Twih	10-21-81	1,760	7.3	22.0	120	27	13	350	15	3.3	450	110	250	.2	15	1,040	--	--	--	--	10
302	J. Harris	70	Twih	12- 5-81	2,250	6.5	20.5	570	150	47	290	5.3	2.9	270	490	330	.4	34	1,510	--	--	--	--	2,200
603	E. S. Ellis	103	Twih	4-25-81	764	6.6	21.0	--	--	--	--	--	--	150	--	--	--	--	--	--	--	--	--	--
604	G. B. Rasco	132	Twih	12- 4-81	600	6.6	20.5	130	32	13	70	2.9	2.4	110	78	76	.3	46	387	.10	.28	.25	.01	2,700
801	P. Laughlin	67	Twih	2-23-61	938	7.0	--	242	54	26	122	3.4	1/	370	39	65	.6	21	552	.0	--	--	--	--
803	J. B. Campbell	152	Twih	12- 5-81	725	7.1	21.0	150	44	9.2	98	3.7	2.7	150	81	95	.2	45	465	--	--	--	--	10
901	J. W. Jackson	120	Twih	4-24-81	2,360	8.6	22.0	--	--	--	--	--	--	30	--	--	--	--	--	--	--	--	--	--
903	S. K. Reynolds	320	Twih	4-27-81	390	6.8	22.0	50	13	4.2	47	2.9	2.1	120	23	31	.3	57	261	--	--	--	--	11,000
37-102	J. T. Ferrill	252	Twih	7-12-76 2/ 3-11-80 2/	1,360 1,175	7.5 7.7	24.0 --	260 203	67 49	23 20	197 221	5.2 6.7	4.0 --	206 220	170 174	216 206	.4 .4	25 23	826 829	.09 .02	-- --	-- --	-- --	-- --
301	P. Rushing	293	Twih	4-10-81	941	8.3	22.5	41	11	3.2	190	13	2.1	270	66	98	.2	12	545	--	--	--	--	10
302	A. Sims	308	Twi	3- 9-82	803	8.4	20.5	--	--	--	--	--	--	270	--	--	--	--	--	--	--	--	--	--
402	R. T. Capps	75	Twih	12- 5-81	260	6.9	20.5	60	23	.5	20	1.1	1.3	90	7.0	4.7	.5	60	171	--	--	--	--	29
503	B. Massey	51	Twis	10- 4-81	244	6.2	19.5	80	29	1.8	21	1.0	1.3	75	5.0	35	.1	25	163	.47	.10	.20	.01	10

See footnotes at end of table.

Table 10.—Water-Quality Data for Wells and Springs—Continued

Well	Owner or spring	Depth (feet)	Water-bearing unit	Date	Specific conductance (micromhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Dissolved calcium (mg/L as Ca)	Dissolved magnesium (mg/L as Mg)	Dissolved sodium (mg/L as Na)	Sodium adsorption ratio (SAR)	Dissolved potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Dissolved sulfate (mg/L as SO_4)	Dissolved chloride (mg/L as Cl)	Dissolved fluoride (mg/L as F)	Dissolved silica (mg/L as SiO^2)	Dissolved solids (sum of constituents) (mg/L)	Total nitrogen NO_2+NO_3 (mg/L as N)	Total nitrogen ammonia (mg/L as N)	Total organic nitrogen (mg/L as N)	Total phosphorus, (mg/L as P)	Dissolved iron (µg/L as Fe)
SD-39-37-602	D. Hughes	307	Twi	1-20-82	451	8.3	22.0	35	10	2.5	92	7.2	2.2	210	23	12	0.2	14	282	0.09	0.82	0.03	0.06	10
801	J. White	446	Twih	7-13-76 2/ 3-11-80 2/	430 427	7.9 7.6	24.5 25.0	49 52	14 16	3.0 3.0	82 88	5.1 5.2	-- --	190 200	16 20	14 15	.2 .2	17 16	264 278	.27 .02	-- --	-- --	-- --	-- --
807	R. C. Powell	615	Twih	1-20-82	480	8.7	24.0	7	2.2	.3	120	21	.9	230	6.0	25	.2	15	308	--	--	--	--	15
908	L. D. Nettles	520	Twih	1-20-82	633	8.7	23.0	6	2.1	.1	150	28	1.0	290	5.0	39	.3	13	393	--	--	--	--	10
38-102	L. C. Simms	420	Twi	10- 3-81	318	7.1	22.0	55	16	3.6	45	2.8	1.7	120	5.0	21	.2	44	191	.13	.32	.07	.21	1,400
201	O. J. Christie	260	Twi	10-20-81	601	7.3	22.0	140	41	9.5	65	2.5	4.5	160	59	53	.1	24	353	.09	.54	.19	.06	800
202	W. C. Reed	540	Twi	1-19-82	389	8.3	21.0	8	2.1	.6	93	16	.9	200	7.0	7.0	.1	16	247	--	--	--	--	10
401	H. Reed	205	Twi	5-20-81	360	8.6	21.5	20	5.9	1.3	76	7.4	1.0	160	8.4	10	.1	13	212	--	--	--	--	20
403	N. P. Upshaw	308	Twi	5-19-81	308	8.2	21.0	--	--	--	--	--	--	230	--	--	--	--	--	--	--	--	--	--
502	L. Hurst	455	Twi	10-20-81	483	8.3	23.0	9	2.7	.5	120	18	.9	220	19	11	.2	11	298	.15	.09	.25	.18	10
602	Farrar Water District	718	Twi	4- 9-81	643	8.6	26.0	3	1	.1	130	33	.7	280	9.3	8.3	.1	15	333	.01	.10	.80	.39	50
604	R. Gantt	360	Twi	10-20-81	645	8.3	22.5	42	13	2.4	140	9.8	1.7	230	29	5.4	.2	14	393	.09	.44	.19	.06	32
703	G. Durham	276	Twi	10-21-81	325	7.5	21.0	60	17	4.2	43	2.6	4.9	140	8.0	13	.1	25	200	.09	.39	.15	.03	130
802	B. Martin	460	Twi	10- 3-81	360	8.0	23.5	56	16	4.0	57	3.5	2.9	160	14	12	.1	17	219	.13	.60	.15	.01	18
902	A. D. Roberts	268	Twic	7-12-76 2/ 3-11-80 2/	510 530	7.7 7.9	24.0 --	173 175	51 53	11 10	45 56	1.4 1.8	-- --	210 220	22 26	32 40	.2 .2	23 28	309 346	.11 .43	-- --	-- --	-- --	-- --
904	W. Rhodes	277	Twic	5-20-81	570	7.1	21.5	200	55	14	43	1.3	3.4	190	29	61	.1	37	357	--	--	--	--	690
44-301	W. Alston	25	Twih	4-27-81	451	6.9	20.0	--	--	--	--	--	--	160	--	--	--	--	--	--	--	--	--	--
303	H. N. Stacy	170	Twih	4-27-81	516	7.1	22.0	160	44	11	40	1.4	4.1	130	16	75	.1	31	300	--	--	--	--	640
401	City of Kosse	155	Twih	11-29-38 2/ 6-24-42 4- -43	-- -- --	6.2 7.3 7.7	-- -- --	428 437 476	107 106 120	39 42 43	94 100 109	2.1 1.5 1.6	1/ 1/ 1/	180 190 270	141 170 155	220 207 203	.8 -- --	55 42 28	859 832 869	.1 0 .05	-- -- --	-- -- --	-- -- --	18,000 10,000 20,000
410	J. B. Davis	180	Twih	4-26-81	1,010	6.8	22.0	460	140	26	54	1.1	3.9	200	89	200	.1	40	676	--	--	--	--	2,700
501	H. Kerens	300	Twih	12- 5-81	743	7.8	22.5	97	28	6.6	130	6.1	2.6	220	67	76	.4	18	461	.1	.57	.23	.05	140
503	R. L. Kyle	434	Twi	6-11-81	1,360	8.5	22.0	32	8.6	2.5	320	25	--	310	1.4	320	.4	11	853	--	--	--	--	60
505	A. Wisdom	70	Twi	3-12-81	200	6.6	19.0	--	--	--	--	--	--	90	--	--	--	--	--	--	--	--	--	--

See footnotes at end of table.

Table 10.—Water-Quality Data for Wells and Springs—Continued

Well	Owner or spring	Depth (feet)	Water-bearing unit	Date	Specific conductance (micromhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Dissolved calcium (mg/L as Ca)	Dissolved magnesium (mg/L as Mg)	Dissolved sodium (mg/L as Na)	Sodium adsorption ratio (SAR)	Dissolved potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Dissolved sulfate (mg/L as SO_4)	Dissolved chloride (mg/L as Cl)	Dissolved fluoride (mg/L as F)	Dissolved silica (mg/L as SiO_2)	Dissolved solids (sum of constituents) (mg/L)	Total nitrogen NO_2+NO_3 (mg/L as N)	Total nitrogen ammonia (mg/L as N)	Total organic nitrogen (mg/L as N)	Total phosphorus (mg/L as P)	Dissolved iron (µg/L as Fe)
SD-39-44-603	Texas Industrial Minerals	500	Twi	10- 2-81	372	6.9	23.0	45	12	3.7	59	4.1	2.4	140	5.0	33	0.2	43	247	0.13	0.24	0.15	0.07	4,200
701	B. O. Lloyd	300	Twih	4-26-81	698	6.3	22.5	--	--	--	--	--	--	120	--	--	--	--	--	--	--	--	--	--
801	P. Robertson	100	Twis	1-20-82	439	6.3	21.0	110	32	6.2	38	1.7	5.5	57	11	92	.0	30	249	--	--	--	--	10
901	B. Tillman	56	Twic	2-23-61	2,730	7.3	--	969	235	93	197	2.8	1/	350	71	680	--	25	1,530	3.39	--	--	--	--
45-101	A. Clayton	120	Twi	8-31-81	300	5.3	22.0	65	19	4.2	20	1.1	5.0	40	5.0	49	.1	26	180	.09	.06	.68	.20	3,000
202	M. Stinson	539	Twi	7-13-76 2/	480	7.7	25.0	58	18	3.0	82	5.1	2.0	140	51	33	.2	23	299	.16	--	--	--	--
				3-11-80 2/	457	8.0	--	56	18	3.0	83	4.7	3.0	140	53	33	.2	24	305	.45	--	--	--	--
207	J. A. Van Dyke	410	Twi	1-20-82	411	8.1	23.0	56	14	5.1	72	4.5	2.1	180	24	14	.1	17	257	--	--	--	--	22
209	F. Connell	520	Twi	4-24-81	482	8.4	24.5	11	3.0	.8	110	15	1.2	210	11	21	.2	13	286	--	--	--	--	20
303	C. Goldman	303	Twi	10-20-81	303	6.6	22.0	72	19	5.9	25	1.4	5.8	100	8.0	23	.1	14	164	.09	.15	.47	.04	3,100
46-101	Longenbaugh	500	Twi	6- 9-81	377	6.8	23.0	63	18	4.4	53	2.9	4.7	130	16	22	.1	16	213	--	--	--	--	630
102	W. C. Grymes	395	Twi	4-24-81	293	6.7	22.0	66	17	5.8	33	1.8	6.1	120	11	17	.1	31	195	--	--	--	--	1,800
106	Limestone Coves	746	Twis	10-22-81	333	7.5	25.0	66	18	5.2	44	2.5	5.0	140	7.0	23	.1	21	208	.09	.32	.18	.05	280
52-102	F. Scott	122	Twi	4-26-81	148	5.6	20.5	23	5.6	2.1	15	1.4	3.2	23	2.2	23	.0	23	90	--	--	--	--	1,900

1/ Included with Na.
2/ Analysis by Texas Department of Health.

Table 11.—Source and Significance of Selected Constituents and Properties Commonly Reported in Water Analyses 1/

(mg/L, milligrams per liter; µg/L, micrograms per liter; micromhos, micromhos per centimeter at 25° Celsius)

Constituent or property	Source or cause	Significance
Silica (SiO_2)	Silicon ranks second only to oxygen in abundance in the Earth's crust. Contact of natural waters with silica-bearing rocks and soils usually results in a concentration range of about 1 to 30 mg/L; but concentrations as large as 100 mg/L are common in waters in some areas.	Although silica in some domestic and industrial water supplies may inhibit corrosion of iron pipes by forming protective coatings, it generally is objectionable in industrial supplies, particularly in boiler feedwater, because it may form hard scale in boilers and pipes or deposit in the tubes of heaters and on steam-turbine blades.
Iron (Fe)	Iron is an abundant and widespread constituent of many rocks and soils. Iron concentrations in natural waters are dependent upon several chemical equilibria processes including oxidation and reduction; precipitation and solution of hydroxides, carbonates, and sulfides; complex formation especially with organic material; and the metabolism of plants and animals. Dissolved-iron concentrations in oxygenated surface waters seldom are as much as 1 mg/L. Some ground waters, unoxygenated surface waters such as deep waters of stratified lakes and reservoirs, and acidic waters resulting from discharge of industrial wastes or drainage from mines may contain considerably more iron. Corrosion of iron casings, pumps, and pipes may add iron to water pumped from wells.	Iron is an objectionable constituent in water supplies for domestic use because it may adversely affect the taste of water and beverages and stain laundered clothes and plumbing fixtures. According to the National Secondary Drinking Water Regulations proposed by the U.S. Environmental Protection Agency (1977a), the secondary maximum contamination level of iron for public water systems is 300 µg/L. Iron also is undesirable in some industrial water supplies, particularly in waters used in high-pressure boilers and those used for food processing, production of paper and chemicals, and bleaching or dyeing of textiles.
Calcium (Ca)	Calcium is widely distributed in the common minerals of rocks and soils and is the principal cation in many natural freshwaters, especially those that contact deposits or soils originating from limestone, dolomite, gypsum, and gypsiferous shale. Calcium concentrations in freshwaters usually range from zero to several hundred milligrams per liter. Larger concentrations are not uncommon in waters in arid regions, especially in areas where some of the more soluble rock types are present.	Calcium contributes to the total hardness of water. Small concentrations of calcium carbonate combat corrosion of metallic pipes by forming protective coatings. Calcium in domestic water supplies is objectionable because it tends to cause incrustations on cooking utensils and water heaters and increases soap or detergent consumption in waters used for washing, bathing, and laundering. Calcium also is undesirable in some industrial water supplies, particularly in waters used by electroplating, textile, pulp and paper, and brewing industries and in water used in high-pressure boilers.
Magnesium (Mg)	Magnesium ranks eight among the elements in order of abundance in the Earth's crust and is a common constituent in natural water. Ferromagnesian minerals in igneous rock and magnesium carbonate in carbonate rocks are two of the more important sources of magnesium in natural waters. Magnesium concentrations in freshwaters usually range from zero to several hundred milligrams per liter; but larger concentrations are not uncommon in waters associated with limestone or dolomite.	Magnesium contributes to the total hardness of water. Large concentrations of magnesium are objectionable in domestic water supplies because they can exert a cathartic and diuretic action upon unacclimated users and increase soap or detergent consumption in waters used for washing, bathing, and laundering. Magnesium also is undesirable in some industrial supplies, particularly in waters used by textile, pulp and paper, and brewing industries and in water used in high-pressure boilers.
Sodium (Na)	Sodium is an abundant and widespread constituent of many soils and rocks and is the principal cation in many natural waters associated with argillaceous sediments, marine shales, and evaporites and in sea water. Sodium salts are very soluble and once in solution tend to stay in solution. Sodium concentrations in natural waters vary from less than 1 mg/L in stream runoff from areas of high rainfall to more than 100,000 mg/L in ground and surface waters associated with halite deposits in arid areas. In addition to natural sources of sodium, sewage, industrial effluents, oilfield brines, and deicing salts may contribute sodium to surface and ground waters.	Sodium in drinking water may impart a salty taste and may be harmful to persons suffering from cardiac, renal, and circulatory diseases and to women with toxemias of pregnancy. Sodium is objectionable in boiler feedwaters because it may cause foaming. Large sodium concentrations are toxic to most plants; and a large ratio of sodium to total cations in irrigation waters may decrease the permeability of the soil, increase the pH of the soil solution, and impair drainage.

Table 11.—Source and Significance of Selected Constituents and Properties Commonly Reported in Water Analyses—Continued

Constituent or property	Source or cause	Significance
Potassium (K)	Although potassium is only slightly less common than sodium in igneous rocks and is more abundant in sedimentary rocks, the concentration of potassium in most natural waters is much smaller than the concentration of sodium. Potassium is liberated from silicate minerals with greater difficulty than sodium and is more easily adsorbed by clay minerals and reincorporated into solid weathering products. Concentrations of potassium more than 20 mg/L are unusual in natural freshwaters, but much larger concentrations are not uncommon in brines or in water from hot springs.	Large concentrations of potassium in drinking water may impart a salty taste and act as a cathartic, but the range of potassium concentrations in most domestic supplies seldom cause these problems. Potassium is objectionable in boiler feedwaters because it may cause foaming. In irrigation water, potassium and sodium act similarly upon the soil, although potassium generally is considered less harmful than sodium.
Alkalinity	Alkalinity is a measure of the capacity of a water to neutralize a strong acid, usually to pH of 4.5, and is expressed in terms of an equivalent concentration of calcium carbonate ($CaCO_3$). Alkalinity in natural waters usually is caused by the presence ob bicarbonate and carbonate ions and to a lesser extent by hydroxide and minor acid radicals such as borates, phosphates, and silicates. Carbonates and bicarbonates are common to most natural waters because of the abundance of carbon dioxide and carbonate minerals in nature. Direct contribution to alkalinity in natural waters by hydroxide is rare and usually can be attributed to contamination. The alkalinity of natural waters varies widely but rarely exceeds 400 to 500 mg/L as $CaCO_3$.	Alkaline waters may have a distinctive unpleasant taste. Alkalinity is detrimental in several industrial processes, especially those involving the production of food and carbonated or acid-fruit beverages. The alkalinity in irrigation waters in excess of alkaline earth concentrations may increase the pH of the soil solution, leach organic material and decrease permeability of the soil, and impair plant growth.
Sulfate (SO_4)	Sulfur is a minor constituent of the Earth's crust but is widely distributed as metallic sulfides in igneous and sedimentary rocks. Weathering of metallic sulfides such as pyrite by oxygenated water yields sulfate ions to the water. Sulfate is dissolved also from soils and evaporite sediments containing gypsum or anhydrite. The sulfate concentration in natural freshwaters may range from zero to several thousand milligrams per liter. Drainage from mines may add sulfate to waters by virtue of pyrite oxidation.	Sulfate in drinking water may impart a bitter taste and act as a laxative on unacclimated users. According to the National Secondary Drinking Water Regulations proposed by the Environmental Protection Agency (1977a) the secondary maximum contaminant level of sulfate for public water systems is 250 mg/L. Sulfate also is undesirable in some industrial supplies, particularly in waters used for the production of concrete, ice, sugar, and carbonated beverages and in waters used in high-pressure boilers.
Chloride (Cl)	Chloride is relatively scarce in the Earth's crust but is the predominant anion in sea water, most petroleum-associated brines, and in many natural freshwaters, particularly those associated with marine shales and evaporites. Chloride salts are very soluble and once in solution tend to stay in solution. Chloride concentrations in natural waters vary from less than 1 mg/L in stream runoff from humid areas to more than 100,000 mg/L in ground and surface waters associated with evaporites in arid areas. The discharge of human, animal, or industrial wastes and irrigation return flows may add significant quantities of chloride to surface and ground waters.	Chloride may impart a salty taste to drinking water and may accelerate the corrosion of metals used in water-supply systems. According to the National Secondary Drinking Water Reguations proposed by the Environmental Protection Agency (1977a), the secondary maximum contaminant level of chloride for public water systems is 250 mg/L. Chloride also is objectionable in some industrial supplies, particularly those used for brewing and food processing, paper and steel production, and textile processing. Chloride in irrigation waters generally is not toxic to most crops but may be injurious to citrus and stone fruits.
Fluoride (F)	Fluoride is a minor constituent of the Earth's crust. The calcium fluoride mineral fluorite is a widespread constituent of resistate sediments and igneous rocks, but its solubility in water is negligible. Fluoride commonly is associated with volcanic gases, and volcanic emanations may be important sources of fluoride in some areas. The	Fluoride in drinking water decreases the incidence of tooth decay when the water is consumed during the period of enamel calcification. Excessive quantities in drinking water consumed by children during the period of enamel calcification may cause a characteristic discoloration (mottling) of the teeth. According to the

Table 11.—Source and Significance of Selected Constituents and Properties Commonly Reported in Water Analyses—Continued

Constituent or property	Source or cause	Significance
Fluoride--Cont.	fluoride concentration in fresh surface waters usually is less than 1 mg/L; but larger concentrations are not uncommon in saline water from oil wells, ground water from a wide variety of geologic terranes, and water from areas affected by volcanism.	National Interim Primary Drinking Water Regulations established by the Environmental Protection Agency (1976) the maximum contaminant level of fluoride in drinking water varies from 1.4 to 2.4 mg/L, depending upon the annual average of the maximum daily air temperature for the area in which the water system is located. Excessive fluoride is also objectionable in water supplies for some industries, particularly in the production of food, beverages, and pharmaceutical items.
Nitrogen (N)	A considerable part of the total nitrogen of the Earth is present as nitrogen gas in the atmosphere. Small amounts of nitrogen are present in rocks, but the element is concentrated to a greater extent in soils or biological material. Nitrogen is a cyclic element and may occur in water in several forms. The forms of greatest interest in water in order of increasing oxidation state, include organic nitrogen, ammonia nitrogen (NH_4-N), nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N). These forms of nitrogen in water may be derived naturally from the leaching of rocks, soils, and decaying vegetation; from rainfall; or from biochemical conversion of one form to another. Other important sources of nitrogen in water include effluent from wastewater treatment plants, septic tanks, and cesspools and drainage from barnyards, feed lots, and fertilized fields. Nitrate is the most stable form of nitrogen in an oxidizing environment and is usually the dominant form of nitrogen in natural waters and in polluted waters that have undergone self-purification or aerobic treatment processes. Significant quantities of reduced nitrogen often are present in some ground waters, deep unoxygenated waters of stratified lakes and reservoirs, and waters containing partially stabilized sewage or animal wastes.	Concentrations of any of the forms of nitrogen in water significantly greater than the local average may suggest pollution. Nitrate and nitrite are objectionable in drinking water because of the potential risk to bottle-fed infants for methemoglobinemia, a sometimes fatal illness related to the impairment of the oxygen-carrying ability of the blood. According to the National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1976), the maximum contaminant level of nitrate (as N) in drinking water is 10 mg/L. Although a maximum contaminant level for nitrite is not specified in the drinking water regulations, Appendix A to the regulations (U.S. Environmental Protection Agency, 1976) indicates that waters with nitrite concentrations (as N) greater than 1 mg/L should not be used for infant feeding. Excessive nitrate and nitrite concentrations are also objectionable in water supplies for some industries, particularly in waters used for the dyeing of wool and silk fabrics and for brewing.
Dissolved solids	Theoretically, dissolved solids are anhydrous residues of the dissolved substance in water. In reality, the term "dissolved solids" is defined by the method used in the determination. In most waters, the dissolved solids consist predominantly of silica, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, and sulfate with minor or trace amounts of other inorganic and organic constituents. In regions of high rainfall and relatively insoluble rocks, waters may contain dissolved-solids concentrations of less than 25 mg/L; but saturated sodium chloride brines in other areas may contain more than 300,000 mg/L.	Dissolved-solids values are used widely in evaluating water quality and in comparing waters. The following classification based on the concentrations of dissolved solids commonly is used by the Geological Survey (Winslow and Kister, 1956). Classification — Dissolved-solids concentration (mg/L) Fresh — <1,000 Slightly saline — 1,000 - 3,000 Moderately saline — 3,000 - 10,000 Very saline — 10,000 - 35,000 Brine — >35,000 The National Secondary Drinking Regulations (U.S. Environmental Protection Agency, 1977a) set a dissolved-solids concentration of 500 mg/L as the secondary maximum contaminant level for public water systems. This level was set primarily on the basis of taste thresholds and potential physiological effects, particularly the laxative effect on unacclimated users. Although drinking waters containing more than 500 mg/L are undesirable, such waters are used in many areas where less mineralized supplies are not available without any obvious ill effects. Dissolved solids in industrial water

Table 11.—Source and Significance of Selected Constituents and Properties Commonly Reported in Water Analyses—Continued

Constituent or property	Source or cause	Significance
Dissolved solids--Cont.		supplies can cause foaming in boilers; interfere with clearness, color, or taste of many finished products; and accelerate corrosion. Uses of water for irrigation also are limited by excessive dissolved-solids concentrations. Dissolved solids in irrigation water may adversely affect plants directly by the development of high osmotic conditions in the soil solution and the presence of phytoxins in the water or indirectly by their effect on soils.
Specific conductance	Specific conductance is a measure of the ability of water to transmit an electrical current and depends on the concentrations of ionized constituents dissolved in the water. Many natural waters in contact only with granite, well-leached soil, or other sparingly soluble material have a conductance of less than 50 micromhos. The specific conductance of some brines exceed several hundred thousand micromhos.	The specific conductance is an indication of the degree of mineralization of a water and may be used to estimate the concentration of dissolved solids in the water.
Hardness as $CaCO_3$	Hardness of water is attributable to all polyvalent metals but principally to calcium and magnesium ions expressed as $CaCO_3$ (calcium carbonate). Water hardness results naturally from the solution of calcium and magnesium, both of which are widely distributed in common minerals of rocks and soils. Hardness of waters in contact with limestone commonly exceeds 200 mg/L. In waters from gypsiferous formations, a hardness of 1,000 mg/L is not uncommon.	Hardness values are used in evaluating water quality and in comparing waters. The following classification is commonly used by the Geological Survey. Hardness (mg/L as $CaCO_3$) — Classification 0 - 60 — Soft 61 - 120 — Moderately hard 121 - 180 — Hard >180 — Very hard Excessive hardness of water for domestic use is objectionable because it causes incrustations on cooking utensils and water heaters and increased soap or detergent consumption. Excessive hardness is undesirable also in many industrial supplies. (See discussions concerning calcium and magnesium.)
pH	The pH of a solution is a measure of its hydrogen ion activity. By definition, the pH of pure water at a temperature of 25°C is 7.00. Natural waters contain dissolved gases and minerals, and the pH may deviate significantly from that of pure water. Rainwater not affected significantly by atmospheric pollution generally has a pH of 5.6 due to the solution of carbon dioxide from the atmosphere. The pH range of most natural surface and ground waters is about 6.0 to 8.5. Many natural waters are slightly basic (pH >7.0) because of the prevalence of carbonates and bicarbonates, which tend to increase the pH.	The pH of a domestic or industrial water supply is significant because it may affect taste, corrosion potential, and water-treatment processes. Acidic waters may have a sour taste and cause corrosion of metals and concrete. The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977a) set a pH range of 6.5 to 8.5 as the secondary maximum contaminant level for public water systems.

1/ Most of the material in this table has been summarized from several references. For a more thorough discussion of the source and significance of these and other water-quality properties and constituents, the reader is referred to the following additional references: American Public Health Association and others (1975); Hem (1970); McKee and Wolf (1963); National Academy of Sciences, National Academy of Engineering (1973); National Technical Advisory Committee to the Secretary of the Interior (1968); and U.S. Environmental Protection Agency (1977b).