TEXAS
WATER
DEVELOPMENT
BOARD

REPORT 79

GROUND-WATER RESOURCES OF WOOD COUNTY, TEXAS

AUGUST 1968

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GROUND-WATER RESOURCES OF WOOD COUNTY, TEXAS

By

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United States Geological Survey

Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board

August 1968

Published and distributed
by the
Texas Water Development Board
Post Office Box 12386
Austin, Texas 78711

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLES

TABLE OF CONTENTS (Cont'd.)

GROUND-WATER RESOURCES OF WOOD COUNTY, TEXAS

ABSTRACT

Nearly all the water used in Wood County, in northeast Texas, is supplied from ground-water sources. The principal aquifers are the Carrizo-Wilcox and the Sparta-Queen City.

At the 1965 rate of pumping, 3 million gallons per day or 3,500 acre-feet per year, the ground-water supplies in Wood County are practically untapped. At least 53,000 acre-feet of water per year is perennially available for development, of which 50,000 acre-feet is in the Sparta-Queen City aquifer. In addition, the aquifers contain as much as 34 million acre-feet of fresh water in the upper 400 feet of the aquifers. The low pH and high iron content of the water and the low permeability of the sand in the aquifers may limit large-scale development of ground water in the county.

The water in the aquifers generally is fresh; the most general chemical problem is an excessive concentration of iron. However, the occurrence of excessive iron follows a somewhat predictable pattern, so that with discriminate well construction and pumping rates, water relatively free of iron can be recovered from both aquifers.

GROUND-WATER RESOURCES OF WOOD COUNTY, TEXAS

INTRODUCTION

Location and Extent of the Area

Wood County, in northeast Texas (Figure 1), encompasses 723 square miles, bounded on the north by Hopkins and Franklin Counties, on the south by the Sabine River and Smith County, on the west by Rains County, and on the east by Upshur County. The city of Quitman, county seat and approximate center of the report area, is about 75 miles east of Dallas, Texas, and 100 miles west of Shreveport, Louisiana.

Purpose and Scope

Ground water provides nearly all the water used in Wood County. Although the present water use is small, annual ground-water withdrawals over the past few years have increased significantly, mainly in response to industrial and urban development. In regard to present trends, an appraisal of the ground-water resources is important for future planning and development within the county.

A detailed ground-water investigation of Wood County was conducted in 1965 under a cooperative agreement between the Texas Water Development Board and the U.S. Geological Survey. The purpose of this report is to provide a guide for the optimum development of the available ground-water supplies in the county.

Data are presented to show the vertical and lateral extent of the water-bearing formations or aquifers, the hydrologic properties of the aquifers, and the chemical quality of the water. The report gives the quantities and uses of the ground water being withdrawn and the effects of these withdrawals on water levels. Problems associated with ground-water development are discussed, and estimates are given of ground water that is available for development.

Methods of Investigation

The report data were collected during the period May-October, 1965. Basic information, including depths of wells, water levels, methods of construction and water lift, yield characteristics, and use of water, was collected on 302 wells. Well information previously collected by the Texas Water Commission and the U.S. Geological Survey was updated. Well records are shown in Table 8 and well locations are shown on Figure 18.

The static water levels in most wells and all water levels used for control points for the piezometric surface map (Figure 6) were measured with a steel tape. The altitudes of the land surface at the wells were interpolated from U.S. Geological Survey 7½-minute quadrangle topographic maps (contour interval, 10 feet).

Water samples were collected for chemical analysis from 133 wells and 5 springs. Seventy-one surface-water samples were collected for partial chemical analyses. The records of analyses are shown in Tables 10 and 11. Table 10 also includes the results of analyses of water from 52 wells sampled in 1942.

Ground-water pumpage (Table 3) for public and industrial use was obtained from available records. Pumpage for domestic and livestock use was estimated by the number of users and rate of use.

The geologic map (Figure 2) is taken largely from the Geologic Atlas of Texas, Tyler Sheet, 1964.

Subsurface control for the geologic sections (Figures 19 and 20), and for maps showing the altitudes of and depths to the top or base of the aquifers (Figures 3, 4, and 5) and the saturated sand thickness (Figures 16 and 17), were determined from electrical logs of oil and gas tests and water wells. Additional subsurface information was provided by drillers' logs of wells, a representative number of which are given in Table 9.

Aquifer tests (Table 2) were analyzed by the Theis non-equilibrium method as modified by Cooper and Jacob (1946) and the Theis recovery method (Wenzel, 1942).

Previous Investigations

The geology of Wood County is described in a report by Sellards and others (1932) on the regional geology of Texas. The first investigation of the

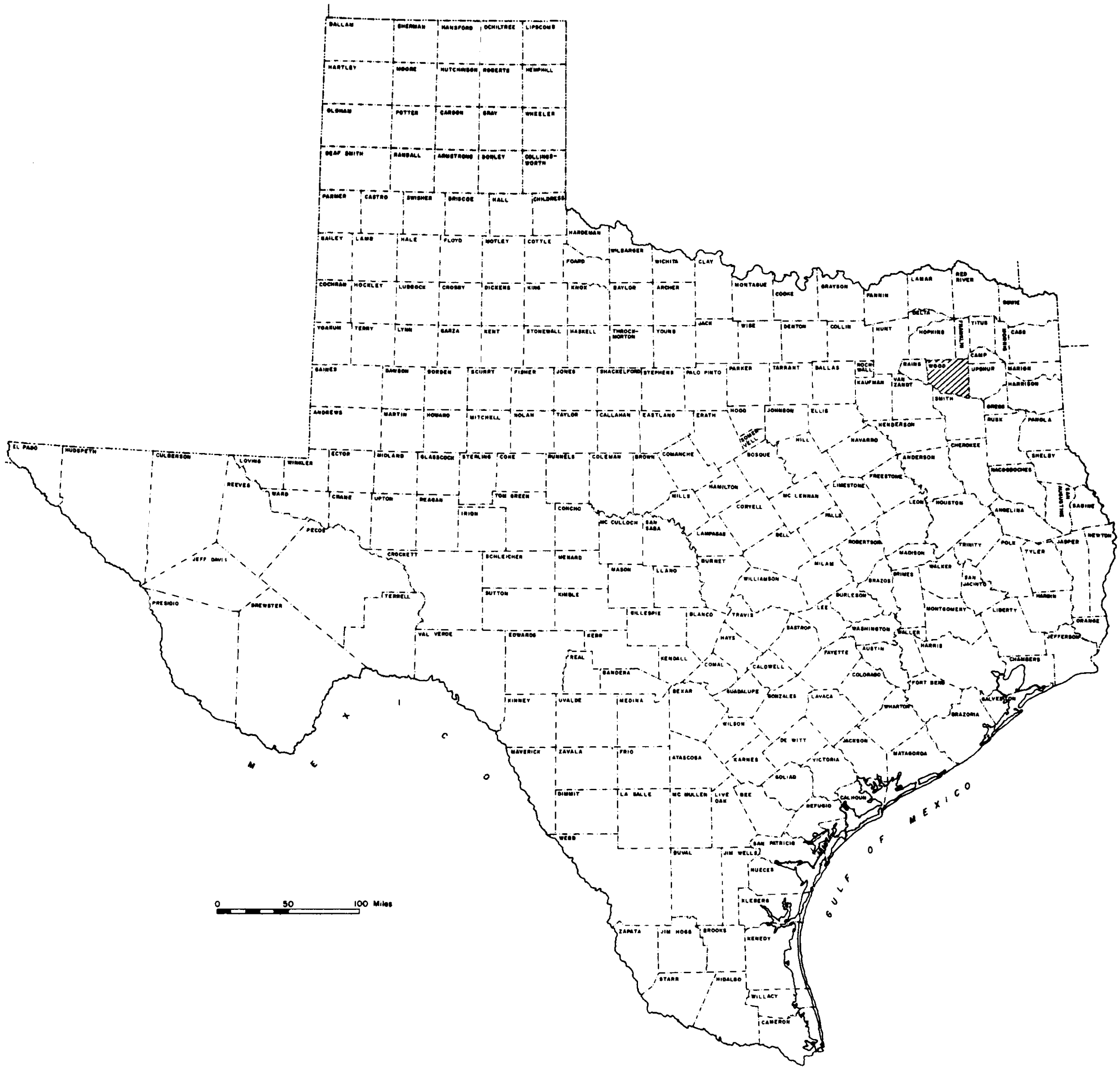

Figure 1

Location of Wood County

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

ground-water resources of the county was by Follett (1942) who included in his study an inventory of wells and springs, records of wells, drillers' logs, water analyses, and a map showing the location of wells and springs. Sundstrom and others (1948), in a study of the public water supplies of East Texas, included information on wells at Alba, Hawkins, Mineola, Quitman, and Winnsboro. Burnitt (1962) investigated ground-water contamination at Hawkins. Baker and others (1963) in a report of reconnaissance of the ground-water resources of the Sabine River basin included a discussion of the aquifers in Wood County. A report on a reconnaissance of the ground-water resources of the Red River, Sulphur River, and Cypress Creek basins (Baker and others, 1963) included information on the ground-water resources for a small segment of Wood County that lies within the Cypress Creek basin. Detailed ground-water investigations in adjacent areas have been made in Smith County (Dillard, 1963) and in Camp, Franklin, Morris, and Titus Counties (Broom and others, 1965). Hughes and Leifeste (1965) in a reconnaissance of the chemical quality of surface waters of the sabine River basin discussed brine pollution in the Lake Fork subbasin of Wood County.

The discharge at two gaging stations reflecting the runoff from Wood County, Lake Fork Creek near Quitman and Big Sandy Creek near Big Sandy (Upshur County), has been measured by the U.S. Geological Survey continuously since 1939.

Climate

The climate of Wood County is moist subhumid (Thornthwaite, 1952). The records of the U.S. Weather Bureau at Gilmer in Upshur County, 25 miles east of Quitman, provide almost complete climatological data since 1933. The normal annual precipitation at Gilmer is 44.09 inches, and the normal monthly precipitation, in inches, is as follows:

January	3.78	May	4.96	September	2.67
February	3.32	June	3.29	October	3.16
March	3.60	July	3.46	November	3.82
April	5.04	August	2.60	December	4.39

The normal January temperature is 45.8°F, and the normal July temperature is 83.2°F. The average date of the first killing frost is November 9, and the last is March 12. The mean annual growing season is 242 days.

Physiography and Drainage

Wood County, situated mostly in the Sabine River basin, is in the West Gulf Coastal Plain (Fenneman, 1938) of eastern Texas.

The land surface is gently rolling to hilly, with local relief ranging from about 50 to 200 feet. The only flat areas of any extent are the flood plains of the major streams. Altitudes above mean sea level range from 630 feet along the Cypress Creek-Sabine River basin divide in the northeastern part of the county to 270 feet along the Sabine River in the southeastern part of the county.

Except for a small area in the northeastern part of the county which is in the upper reaches of the Cypress Creek basin, all drainage is southeastward to the Sabine River. Lake Fork and Big Sandy Creeks are the main tributaries of the Sabine River in Wood County.

Population and Economic Development

The population of Wood County in 1960 was 17,653. The cities and towns with populations of 200 or more are: Alba, 470; Golden, 125; Hawkins, 868; Mineola, 3,800; Quitman, 1,225; Winnsboro (partly in Franklin County), 2,690; and Yantis, 287.

The economy of Wood County is based on agriculture and industry. Beef cattle production has increased in recent years to where it accounted for a large percentage of the total farm income in 1965. Emphasis on beef has caused the conversion of much row-crop land to hay meadow and pasture. Other livestock include dairy cattle, poultry, swine, and sheep. Row crops of importance include sweet potatoes, watermelons, nursery plants, and strawberries. The principal orchard products are peaches and pecans. About 44 percent of the land area supports a substantial growth of pine and hardwood timber.

The principal industry of Wood County is the production, processing, and distribution of petroleum products. Oil production in 1965 was approximately 15,000,000 barrels, and cumulative production since 1941 was more than 400,000,000 barrels.

Well-Numbering System

The numbers assigned to wells and springs conform to the statewide system used by the Texas Water Development Board. The system is based on the division of Texas into 1-degree quadrangles bounded by lines of latitude and longitude. Each 1-degree quadrangle is divided into 64 smaller quadrangles, 7½ minutes on a side, each of which is further divided into 9 quadrangles, 2½ minutes on a side. Each of the 89 1-degree quadrangles in the State has been assigned a 2-digit number for identification; the area of this report is entirely within the 1-degree quadrangle number 34. The 7½-minute quadrangles are numbered with 2-digit numbers consecutively from left to right beginning in the upper left-hand corner of the 1-degree quadrangle (Figure 18). The 2½-minute quadrangles within each 7½-minute quadrangle are numbered with a 1-digit number. Each well inventoried in each 2½-minute quadrangle is assigned a 2-digit number. The well number is determined as follows: The first two numbers identify the 1-degree quadrangle, the next two numbers identify the 7½-minute quadrangle, the fifth number identifies the 2½-minute quadrangle, and the last two numbers designate the well in the 2½-minute quadrangle.

In addition to the 7-digit well number, a 2-letter prefix is used to identify the county. The letter prefix for Wood County is ZS. All wells in the report carry the letter ZS except for wells in Franklin County which carry the letter prefix JZ.

Thus, well ZS-34-13-503 (a well for the city of Quitman) is in Wood County (ZS), in the 1-degree quadrangle (34), in the 7½-minute quadrangle (13), in the 2½-minute quadrangle (5), and was the third (03) well inventoried in that 2½-minute quadrangle (Figure 18).

Acknowledgments

The investigation was achieved largely through the cooperation of well owners and county, city, and industrial officials who allowed access to their property and permitted examination of pertinent records.

Definition of Terms

Many of the following definitions have been taken or adapted from Meinzer (1923), American Geological Institute (1960), Langbein and Iseri (1960), and Ferris and others (1962).

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

Aquiclude.—A formation, group of formations, or part of a formation that is non-water bearing, or is sufficiently impermeable to severely restrict the transmission of water.

Aquifer.—A formation, group of formations, or part of a formation that is water bearing, or is sufficiently permeable to allow transmission of considerable quantities of water.

Aquifer test.—A test from which the essential hydrologic properties of an aquifer may be determined, such as the coefficients of permeability, transmissibility, and storage.

Artesian aquifer.—An aquifer that is confined both above and below by a relatively impermeable formation (aquiclude), and in which water is under pressure greater than atmospheric pressure. Consequently, the water rises in artesian wells to levels above the top of the aquifer and sometimes rises to levels above land surface (flows).

Cone of depression.—Depression of the water table or piezometric surface caused by a discharging well; more or less the shape of an inverted cone.

Drawdown.—The difference between the static water level and the pumping water level in a well.

Equivalents per million (epm).—The concentration of chemical substances in terms of the reacting values of electrically charged particles or ions in solution.

Evapotranspiration.—A combined term for evaporation and transpiration; the amount of water withdrawn from surface and ground storage by evaporation and plants.

Fresh water and saline water.—The terms as applied in the report are taken from a general classification based on dissolved-solids content by Winslow and Kister (1956): fresh, 0 to 1,000 ppm (parts per million); slightly saline, 1,000 to 3,000 ppm; moderately saline, 3,000 to 10,000 ppm; very saline, 10,000 to 35,000 ppm; and brine, more than 35,000 ppm.

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

Parts per million (ppm).—One part per million represents 1 milligram of solute in 1 kilogram of solution. As commonly measured and used, parts per million is numerically equivalent to milligrams of a substance per liter of water.

Permeability, coefficient of.—A measure of the capacity of an aquifer to transmit water. The rate of flow in gallons per day through a cross section of 1 square foot under a hydraulic gradient of 1 foot per foot and at a temperature of 60°F.

Piezometric surface.—An imaginary surface that everywhere coincides with the static level of the water in an aquifer. The surface to which the water from a given aquifer will rise under its hydrostatic pressure or head.

Specific capacity.—The rate of yield of a well per unit of drawdown, usually expressed as gallons per minute per foot of drawdown.

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

Transmissibility, coefficient of.—The rate of flow of ground water in gallons per day through a vertical strip of the aquifer 1 foot wide extending through the vertical thickness of the aquifer at a hydraulic gradient of 1 foot per foot and at the prevailing temperature of the water.

Transmission capacity of an aquifer.—The quantity of water that can be transmitted through a given width of an aquifer at a given hydraulic gradient, usually expressed in acre-feet per year or million gallons per day.

Water-table aquifer.—An aquifer that is unconfined; the upper surface of the zone of saturation 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. The depth to the static water level in a water-table well coincides with the depth to the water table.

Water table. —The upper surface of the zone of saturation.

Yield of a well.—The rate of discharge, usually expressed in gallons per minute. In this report, yields are classified as small, less than 50 gpm; moderate, 50 to 500 gpm; and large, more than 500 gpm.

GEOLOGY

Stratigraphy and Structure

Geologic units of Eocene age are the principal sources of ground water in Wood County. Rocks of Recent and Pleistocene age yield only small amounts of ground water. The geologic units and their water-bearing characteristics are summarized in Table 1.

Except for the alluvium, the units crop out in belts that trend northeastward across the county (Figure 2). The units dip generally southeastward at about 30 to 40 feet per mile, and each unit is successively overlain by a

Table 1.--Geologic Units and Their Water-Bearing Characteristics, Wood County

SYSTEM	SERIES	GROUP	UNIT	APPROXIMATE MAXIMUM THICKNESS (FT)	CHARACTER OF ROCKS	WATER-BEARING PROPERTIES
Quaternary	Recent and Pleistocene		Alluvium	60	Sand, silt, clay, and some gravel.	Not known to yield water to wells in Wood County; probably would yield small quantities.
Tertiary	Eocene	Claiborne	Sparta Sand	250	Sand, silt, and clay.	Known to yield only small quantities in Wood County, but probably would yield moderate quantities locally.
			Weches Greensand	75	Glauconite, and glauconitic clay, and sand; secondary deposits of limonite common in outcrop area.	Not known to yield water to wells in Wood County.
			Queen City Sand	400	Sand, silt, clay, and some lignite.	Yields small to moderate quantities of water in Wood County.
			Reklaw Formation	70	Glauconitic clay, and some sand and lignite; limonite is common in outcrop areas.	Yields only small quantities of water to wells in outcrop area; elsewhere in the county it is not a source of water supply.
			Carrizo Sand	200	Sand, silt, and clay.	Yields moderate to large quantities of water in Wood County.
		Wilcox		900	Sand, silt, clay, lignite, and limonite sand beds; generally thin bedded and discontinuous.	Yields moderate quantities of water.
	Paleocene	Midway			Calcareous clay, and minor amounts of limestone, silt, and glauconitic sand.	Yields no water.

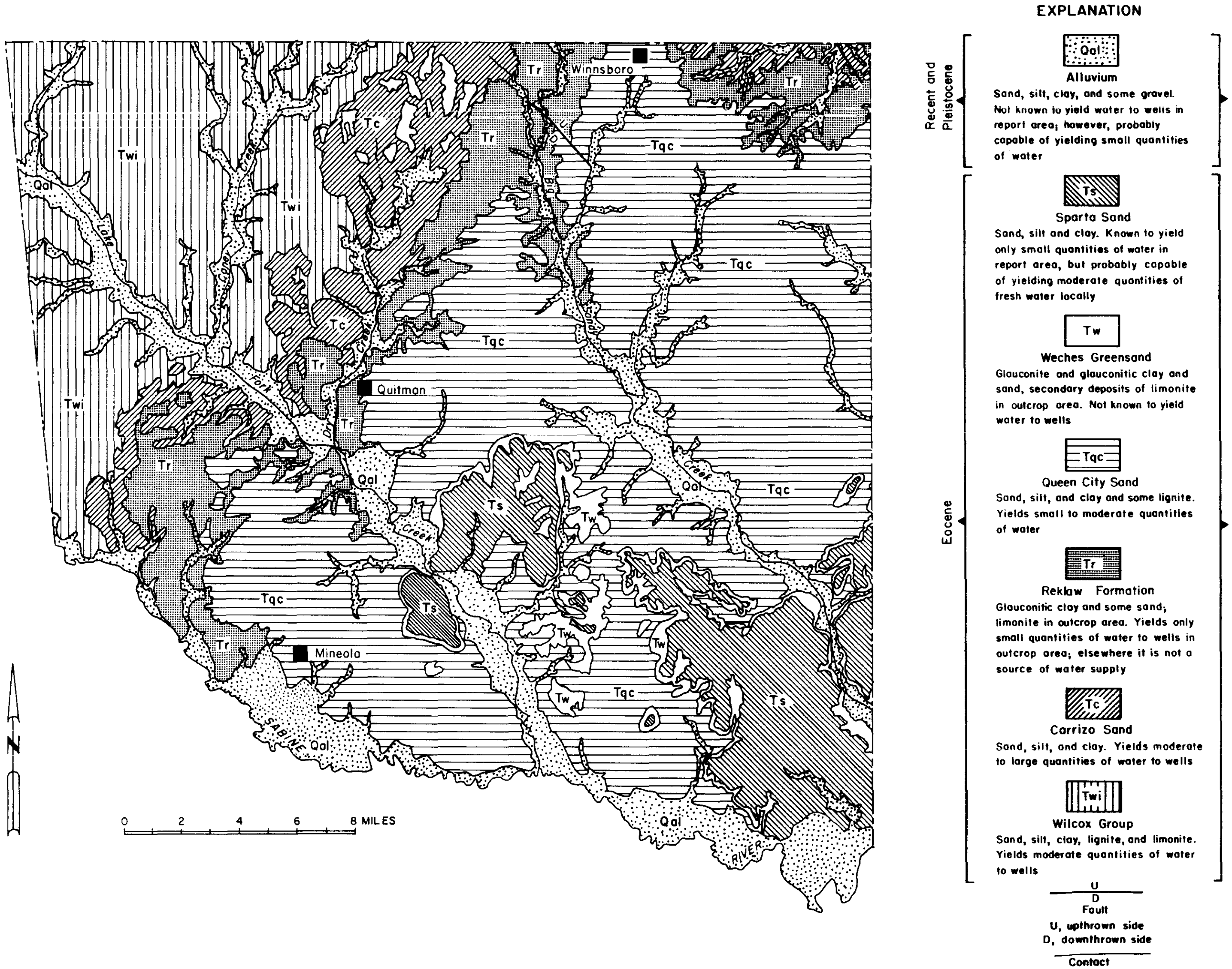

Figure 2

Geologic Map of Wood County

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

Geology modified from Geologic Atlas of Texas, Tyler Sheet (1964) younger unit in the dip direction. The units form a wedge-shaped body of sediments, mostly water-bearing, that thicken from about 200 feet in the northwest corner to about 1,500 feet in the southeast corner of the county.

The geologic sections (Figures 19 and 20) show the stratigraphic relationship between the units in the subsurface. The contacts between the geologic units often are difficult to determine on drillers' and electric logs; consequently, the contacts shown on the geologic sections and the thickness of the units shown on Table 1 are only approximate. The top of the Midway Group defines the approximate base of fresh to slightly saline water in Wood County. The altitude of and depth to the top of the Midway are shown on Figure 3. The Wilcox Group, the lowermost fresh water-bearing unit, generally comprises more than half the available water-bearing sediments. The sediments above the Wilcox Group, except the alluvium, are assigned to the Claiborne Group which is, in ascending order, divided into the Carrizo Sand, Reklaw Formation, Queen City Sand, Weches Greensand, and Sparta Sand.

The general southeast dip of the units is the result of an extensive structural down-warping which in its entirety froms the East Texas Embayment. The embayment is a trough-like geologic basin whose long axis trends northeastward across the southeast corner of Wood County.

The faults and folds of the area account for the entrapment of abundant quantities of oil and gas. The amount of displacement along the faults and the steepness of the folds generally decrease upward. Few, if any, of the faults extend upward to the water-bearing units, but locally, folds are reflected at the surface. The most prominent folds are in the southeastern part of the county where irregular dips are reflected by contours on the top of the Midway Group (Figure 3).

Physical Characteristics and Water-Bearing Properties of the Geologic Formations

Midway Group

The Midway Group crops out in the counties adjacent to Wood County on the north and west and underlies all of Wood County at progressively greater depths southeastward. The unit, mostly marine in origin, is composed chiefly of calcareous clay which locally may contain thin stringers of limestone and glauconitic sand. The unit tends to become silty and slightly sandy in the upper part of the section.

Altitudes on the top of the Midway (Figure 3) range from about 150 feet above sea level (280 feet below land surface) in the northwestern corner to at least 1,340 feet below sea level (1,660 feet below land surface) in the southeastern corner of Wood County.

The Midway is not known to yield any water to wells in Wood County. Nevertheless, it is hydrologically significant in that it forms the basal confining layer for the overlying Wilcox Group.

Wilcox Group

The Wilcox Group, conformably overlying the Midway Group, crops out in the northwestern part of the county (Figure 2). The outcrop area of the Wilcox generally is characterized by a nearly level to gently rolling land surface mantled by clayey to sandy textured soils.

The Wilcox Group, 250 to 900 feet thick, is composed of interbedded sand, silt, clay, and some lignite, with secondary deposits of limonite which occur locally at or near the surface in the form of seams and concretions. Medium to very fine quartz sand generally constitutes one-third to one-half of the Wilcox. Individual beds of sand generally are thin bedded and discontinuous although some (well ZS-34-20-505, Figure 20) may attain a thickness of as much as 100 feet. The geologic sections (Figures 19 and 20) clearly show that few beds of sand can be correlated from well to well.

Because of the lenticularity of the sand beds in the Wilcox, the yields of wells can be expected to range over fairly wide limits. Wells that tap the Wilcox in the outcrop area yield from 50 to 200 gpm (gallons per minute); elsewhere in the county, the yields range from 100 to 350 gpm. Doubtlessly, larger yields—possibly more than 500 gpm—can be obtained from wells in the southern and southeastern parts of the county that screen all the available fresh to slightly saline water sands.

Claiborne Group

Carrizo Sand

The Carrizo Sand, which unconformably overlies the Wilcox Group, crops out in a narrow (less than 2 miles wide) northeastward-trending belt in the northwestern part of the county (Figure 2) and in a small area in the northeast corner of the county. The outcrop of the Carrizo generally is expressed by a ridge of gentle to moderate relief mantled by a light-gray sandy soil.

The full thickness of the Carrizo Sand in Wood County ranges from about 100 to 200 feet. Typically, the unit is composed of massive to cross-bedded, coarse to fine sand. In places, however, the Carrizo is interbedded with silt and clay, so that it is not easily distinguishable from the underlying Wilcox Group.

Yields of wells tapping the Carrizo in Wood County generally range from about 400 to 700 gpm; locally, smaller yields of less than 200 gpm may be obtained.

Reklaw Formation

The Reklaw Formation conformably overlies the Carrizo Sand and crops out in a belt about 1 mile wide in the northwestern part of the county (Figure 2). The outcrop of the Reklaw is easily recognized because of its red clayey soil which is in sharp contrast to the gray sandy soil of the underlying Carrizo Sand. Also, characteristics of the Reklaw is the common occurrence of limonitic seams and concretions at or near the land surface. The limonite forms an effective caprock and sustains a gentle to moderate relief in the outcrop areas. The Reklaw is composed largely of glauconitic clay with lesser amounts of sand and lignite. Locally, however, the Reklaw may contain more than 50 percent sand. The thickness of the formation is fairly uniform, ranging from slightly less than 50 feet to a maximum of 70 feet.

The Reklaw yields only small quantities of water to large-diameter dug wells in the outcrop, but elsewhere in the county, it is not a source of water supply. It is significant hydrologically as a confining bed above the underlying Carrizo Sand.

Queen City Sand

The Queen City conformably overlies the Reklaw Formation and crops out over a large part of the southeastern half of the county (Figure 2). In contrast to the red clayey soil and more gentle relief of the underlying Reklaw, the outcrop of the Queen City is characteristically a loose, gray, sandy soil topographically expressed as a moderately rolling to hilly land surface. The outcrop of the Queen City roughly defines the westward extent of the pine-timber belt and the perennial streams in Wood County.

The Queen City Sand consists largely of massive to cross-bedded fluvial sediments, locally stratified. It is composed generally of about 80 percent medium- to fine-grained quartz sand and about 20 percent silt and clay with minor amounts of lignite. The maximum thickness of the Queen City is approximately 400 feet, and the formation supplies small to moderate quantities of water to wells in the county.

Weches Greensand

The Weches Greensand crops out in a narrow, irregular belt in the southeastern part of the county (Figure 2). The formation consists principally of interbedded glauconite, glauconitic clay, and sand; secondary deposits of limonite are common in the area of outcrop. In the subsurface, the Weches maintains a fairly uniform thickness, ranging from 50 to 75 feet. The formation is not known to supply water to wells in the county, although in adjoining counties to the north—Camp, Franklin, Morris, and Titus Counties—(Broom and others, 1965, p. 23), the Weches supplies small quantities of fresh water to domestic and livestock wells. Southward, in Smith County, Dillard (1963, p. 24) reported that the Weches is relatively impermeable and yields no water to wells.

Sparta Sand

The Sparta Sand overlies the Weches Greensand on the high northwestward-trending ridge between the lower reaches of Lake Fork and Big Sandy Creeks (Figure 2). The Sparta sand generally lacks the compaction of the older geologic units, and in the outcrop area it generally weathers to a deep, very loose, light-gray sandy soil. The Sparta, which attains a maximum thickness of about 250 feet in the report area, consists of about 70 percent medium- to fine-grained quartz sand and 30 percent sandy clay.

The Sparta Sand is known to be tapped only by small-capacity wells in Wood County, but locally the unit would probably yield moderate (at least 100 gpm) quantities of water to wells.

Alluvium

Alluvial sediments occur in and near the flood plains of the Sabine River and its larger tributaries (Figure 2). The sediments, generally consisting of clay, silt, fine sand, and minor amounts of gravel, reach a maximum thickness of at least 60 feet in the Sabine River flood plain south of Mineola. The alluvium is not known to yield water to wells in the county; doubtlessly, it is capable of yielding at least small quantities of water.

Hydrologic Units

The Wilcox Group, Carrizo Sand, Queen City Sand, and the Sparta Sand are the principal sources of fresh ground water in Wood County. The first two formations have similar hydrologic properties and are in hydraulic continuity. Consequently, they function as a single aquifer, which for the purposes of this report is referred to as the Carrizo-Wilcox aquifer. The other two formations—Queen City Sand and Sparta Sand—are ineffectively separated by the Weches Greensand. Thus, they also are considered in this report as a single aquifer—the Sparta-Queen City aquifer.

The outcrop of the Carrizo-Wilcox aquifer is in the northwestern half of the county. In the subsurface, the top of the aquifer slopes generally southeastward at about 40 feet per mile and is encountered in wells at depths ranging from a few tens of feet near its contact with the Reklaw Formation to as much as 650 feet in the southeastern part of the county and in the trough that trends northeasterly through the south-central part of the county (Figure 4). The aquifer thickens from about 250 feet in the northeast corner of the county to slightly more than 1,000 feet a few miles east of Quitman.

The Sparta-Queen City aquifer crops out over an area of about 430 square miles in the southeastern half of the county. The base of the aquifer slopes generally south and southeastward (Figure 5). In detail, however, the map shows a northeastward-trending trough in the east-central part of the county. The thickness of the aquifer, which is nearly equivalent to the depth to the base of the aquifer shown on Figure 5, ranges from a few feet to more than 600 feet.

GROUND-WATER HYDROLOGY

Occurrence and Movement of Ground Water

Ground water in Wood County occurs under water-table and artesian conditions. Under water-table conditions, the water is unconfined and does not rise above the level at which water is first encountered. Under artesian conditions, the water is confined under hydrostatic pressure and where the elevation of the land surface is considerably below the general level of the area of outcrop, the pressure may be sufficient to cause the water to rise above the level at which it is first encountered in the well.

In the Carrizo-Wilcox aquifer, the water in the outcrop area generally is under water-table conditions, although locally, artesian pressure may exist where the water is confined beneath lenticular bodies of clay of limited areal extent. In general, the water table is shallow, about 50 feet, and commonly is at or near the base of the streams that cross the outcrop. Artesian conditions prevail downdip from the outcrop. The piezometric surface (the water surface under artesian conditions) slopes generally southward at about 5 feet per mile (Figure 6). In the north-central part of the county, the piezometric surface is at an altitude of more than 425 feet; in the southern and southeastern parts of the county, the piezometric surface is above the level of the flood plain of the larger streams, consequently, wells in these low areas flow.

Water in the Sparta-Queen City aquifer generally is unconfined, although artesian conditions exist locally in the deeper parts of the Queen City Sand. Where the Queen City is overlain by the Weches Greensand, the water is, for all practical purposes, unconfined, indicating the ineffectiveness of the Weches as a confining layer. At most, the Weches functions only to retard the exchange of water between the two units. The water table in the Sparta-Queen City aquifer ranges in depth from a few feet to nearly 100 feet below land surface. The configuration of the water table generally is irregular, conforming largely to local topography. As determined from water levels in selected wells, the water table slopes southeastward at about 5 feet per mile.

Ground water in the two aquifers moves steadily from areas of recharge to areas of discharge under the influence of gravity. The movement generally is toward the southeast in the direction of the dip of the beds; in some places, particularly in the Sparta-Queen City aquifer, ground water moves toward the larger streams. Because of the low hydraulic gradient, 5 feet per mile, the rate of movement is slow, perhaps only a few hundred feet per year.

Recharge and Discharge

Ground water in the aquifers in Wood County is derived from the infiltration of precipitation, either where it falls or from runoff en route to a watercourse; from the infiltration of water from streams or lakes; and from the movement of ground water into the county from surrounding areas. The rate at which the aquifers are recharged ranges widely, depending on the type of soil in the outcrop areas of the aquifers, the duration and intensity of rainfall, the slope of the land surface, the presence or absence of a cover of vegetation, and the depth of the water table.

Recharge to the Carrizo-Wilcox aquifer is small, considerably less than that to the Sparta-Queen City aquifer. The soil on the outcrop of the Carrizo-Wilcox aquifer is less sandy and has a lower permeability than that of the Sparta-Queen City aquifer. Consequently, a substantial part of the annual rainfall—45 inches—runs off to the streams. The small recharge to the Carrizo-Wilcox can be illustrated by computing the quantity of water that the aquifer is capable of transmitting under a hydraulic gradient that has not been influenced significantly by pumping. On the basis of a permeability of 50 gpd (gallons per day) per square foot and a hydraulic gradient of 5 feet per mile, approximately 3,000 acre-feet per year, or 2.6 mdg (million gallons per day) passes through a vertical section of the aquifer 26 miles long. In this vertical section, the water-bearing sands have an aggregate thickness of about 400 feet and a coefficient of transmissibility of about 20,000 gpd per foot. The 3,000 acre-feet per year of water moving downdip is equivalent to about half an inch of rainfall effectively recharging the aquifer, or only about 1 percent of the average annual precipitation (45 inches).

Recharge to the Sparta-Queen City aquifer is considerably greater than recharge to the Carrizo-Wilcox. Although data are insufficient to determine the volume of water being transmitted by the aquifer, an estimate of the recharge can be made from the low flow of Big Sandy Creek and Lake Fork Creek, which is sustained by the discharge of ground water through springs and seeps. Although this is actually a form of discharge, it commonly is referred to as "rejected recharge" because the water does not reach the parts of the aquifer below the level of the streams. Nearly all the rejected recharge in Wood County is from the Sparta-Queen City aquifer. There is practically no rejected recharge from the Carrizo-Wilcox. On the basis of the average winter low flow for the 4-year period 1961-64 in Big Sandy Creek, which drains an area of 231 square miles of the outcrop of the Sparta-Queen City aquifer, the volume of flow contributed to the creek by rejected recharge is about 39,000 acre-feet per year (nearly 35 mgd) or 169 acre-feet per year per square mile. Assuming an equal amount of ground water is lost per square mile throughout the rest of the outcrop area in Wood County, the average volume of rejected recharge for the 430 square miles in Wood County is about 70,000 acre-feet per year. This figure includes water that normally is consumed by evapotranspiration during the summer months. The average base flow for the same 4-year period (1961-64) is approximately 50,000 acre-feet per year; thus the loss due to evapotranspiration, assuming that all the loss occurs before the water is discharged to the stream, is about 20,000 acre-feet per year. The 50,000 acre-feet per year of rejected recharge is equivalent to slightly more than 2 inches of rainfall entering the aquifer as replenishment. This amount of recharge, less than 5 percent of annual precipitation, compares favorably with calculations of recharge elsewhere in the State. The figure 50,000 acre-feet per year of recharge is minimal because an additional part, perhaps as much as 5 percent, of the rainfall enters the aquifer and moves downdip beyond the influence of streams and lakes and continues downgradient to areas of pumping or natural discharge.

The water in the two aquifers is discharged both naturally and artificially. The natural discharge is the flow of springs and seeps, evaporation from the water table, and transpiration by trees and plants whose roots reach the water table. The quantity of water discharged by each method is difficult to determine, but it is several times that by wells. In 1965, about 3,500 acre-feet, or 3.0 mgd, was discharged through wells for municipal, industrial, domestic, and livestock purposes.

Hydraulic Properties of the Aquifers

Knowledge of the hydraulic properties of an aquifer is essential to an evaluation of the ground-water resources of an area. The more important hydraulic properties of an aquifer, which determine its capacity to transmit and store water, are expressed as the coefficient of transmissibility and the coefficient storage. (See list of definitions, p. 6.)

Pumping tests were made in eight wells tapping the Carrizo-Wilcox aquifer. Most of the wells were screened in sands of the Wilcox Group, which constitutes more than 50 percent of the total sand thickness in the aquifer; only two wells were screened in sands of both the Wilcox Group and Carrizo Sand. The coefficients of transmissibility determined from these tests ranged from 600 to 19,000 gpd per foot; discharge rates ranged from 50 to 490 gpm; and specific capacities ranged from 0.8 to 9.7 gpm per foot of drawdown (Table 2). The wide range in transmissibility is due to variations in the permeability and thickness of the sands. None of the wells fully penetrated the aquifer; consequently, the results of the tests generally gave values that are less than those that would have been obtained from wells that penetrated the entire aquifer. The coefficients of permeability, which were estimated from the total amount of sand believed to be contributing to the well (in most of the tests it was equivalent to the amount of screen or perforation in the well), ranged from about 4 to 700 gpd per square foot. The average permeability of the Carrizo-Wilcox aquifer probably is on the order of 50 gpd per square foot This value compares favorably with that determined for the Wilcox in Smith County (Dillard, 1963, p. 16). Thus, where as much as 600 feet of sand is available (for example near Mineola), the coefficient of transmissibility might be as much as 30,000 gpd per foot. Coefficients of storage from aquifer tests in two wells were 0.00046 and 0.00034. These values are within the range generally attributable to artesian conditions.

Little is known about the hydraulic properties of the Sparta-Queen City aquifer in Wood County. In Smith County, Dillard (1963, p. 24) reported that coefficients of transmissibility and permeability of 3,200 gpd per foot and 10 to 30 gpd per square foot, respectively, probably are representative of the Queen City Sand. Dillard (1963, p. 29) also reported a coefficient of transmissibility of 12,400 gpd per foot and a coefficient of storage of 0.00017 for the Sparta Sand. The permeability determined from the tests in the Sparta averaged about 250 gpd per square foot, considerably higher than in any of the older water-bearing units. Assuming an average coefficient of permeability of only 30 gpd per square foot for the sands in Sparta-Queen City aquifers, the coefficient of transmissibility would be at least 12,000 gpd per foot. The transmissibility is probably higher where the Sparta Sand constitutes a substantial part of the aquifer.

Table 2.--Results of Aquifer Tests in the Carrizo-Wilcox Aquifer, Wood County

WELL	SCREENED INTERVAL (FT)	AVERAGE DISCHARGE DURING TEST (GPM)	COEFFICIENT OF TRANS-MISSIBILITY (GPD/FT)	SPECIFIC CAPACITY	COEFFICIENT OF STORAGE	REMARKS
ZS-34-03-601	201-251	50	1,300	0.8	--	Drawdown of pumped well.
ZS-34-03-601	201-251	--	8,600	--	4.6×10^{-4}	Well ZS-34-03-602 pumping.
ZS-34-03-602	240-290	150	3,700	1.8	--	Drawdown of pumped well.
ZS-34-04-401	104-114 122-154 204-274 288-318 332-348	85	800	1.04	--	Do.
ZS-34-13-502	345-365	322	14,000	9.7	--	Recovery of pumped well; specific capacity computed from drawdown test.
ZS-34-20-202	360-380 400-430	100	2,500	1.7	--	Drawdown of pumped well.
ZS-34-21-701	310-332 350-400 421-465	490	19,000	6	--	Recovery of pumped well; specific capacity computed from drawdown test.
ZS-34-31-103	449-479 500-579 589-599	--	700	--	3.4×10^{-4}	Recovery of observation well 75 feet from ZS-34-31-107.
ZS-34-31-104	505-645	---	600	--	--	Recovery in well after pumping 13 months at an average discharge of 81 gpm.

The coefficients of transmissibility and storage may be used to predict future drawdowns of water levels by pumping. Figure 7 shows the relation of drawdown to distance and time as a result of pumping from a water-table aquifer of infinite areal extent. If the coefficients of transmissibility and storage are 5,000 gpd per foot and 0.10, respectively, as is common in the outcrop area of the Carrizo-Wilcox aquifer, the decline in water level would be 1 foot at a distance of 1,000 feet from a well pumping 300 gpm for 30 days, about 12 feet after 1 year, and about 27 feet after 10 years. In a well having a lower coefficient of transmissibility than assumed, the drawdown would be greater. Figure 8 shows a similar relation as a result of pumping from an artesian aquifer of infinite areal extent. Downdip from the outcrop of the Carrizo-Wilcox aquifer, where the coefficient of storage (0.0003) is considerably less, the decline in water level would be 34 feet at a distance of 1,000 feet after 30 days pumping, about 51 feet after 1 year, and about 67 feet after 10 years. Figure 7 also may be used to estimate the water-level decline in a well tapping the Sparta-Queen City aquifer. In general, the decline in a well screened only in the Queen City Sand probably will be greater than that shown; whereas, the decline in a well in the Sparta Sand may be less than shown, and the decline in a well tapping all the sands in the Sparta-Queen City aquifer would be considerably less.

Pumping from wells too closely spaced may cause intersecting cones of depression which will cause additional lowering of the water levels and serious declines in the yields of the wells. Figures 7 and 8 should serve as a general guide for optimum spacing of wells that tap the Carrizo-Wilcox aquifer in Wood County.

Influence of Ground-Water Storage on the Flow of Lake Fork and Big Sandy Creeks

Ground-water storage influences not only the yield of a drainage basin, but also the flow characteristics of a stream. Where the stream bed is incised below the water table, ground-water effluent—chiefly springs—sustains the low flow of the stream; where the streambed is above the water table, the flow in the stream consists entirely of surface runoff.

The effect of ground-water storage on the flow characteristics of a stream can be seen by comparing the hydrographs of daily streamflow for Lake Fork Creek near Quitman for Big Sandy Creek near Big Sandy for the 1964 water year. The locations of the gaging stations and the outcrops of the geologic units crossed by these streams are shown in Figure 9.

The Lake Fork stream-gaging station measures the runoff from 585 square miles, most of which is the outcrop of the Carrizo-Wilcox aquifer; the station on Big

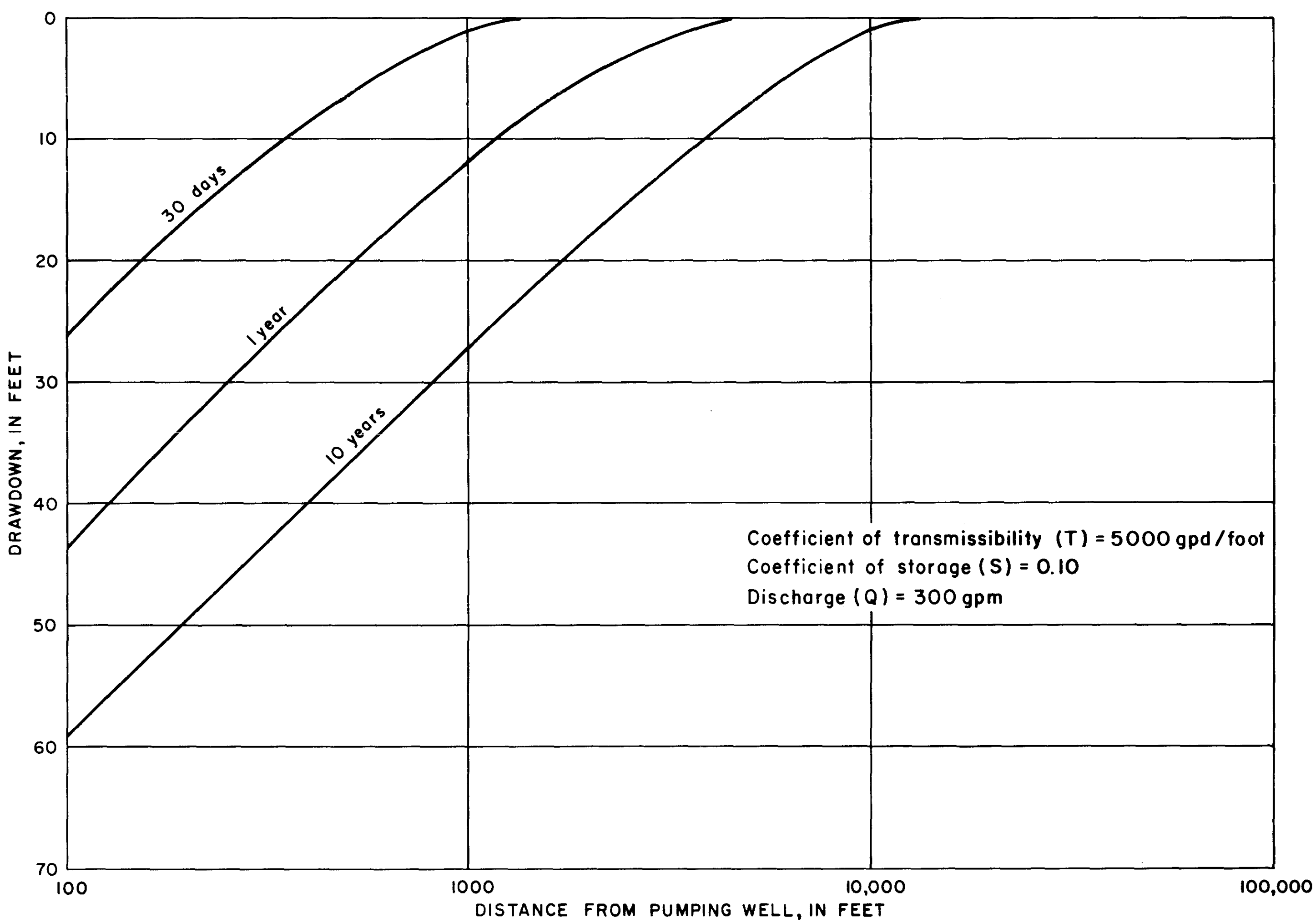

Figure 7

Relation of Drawdown to Distance and Time, Water-Table Conditions

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

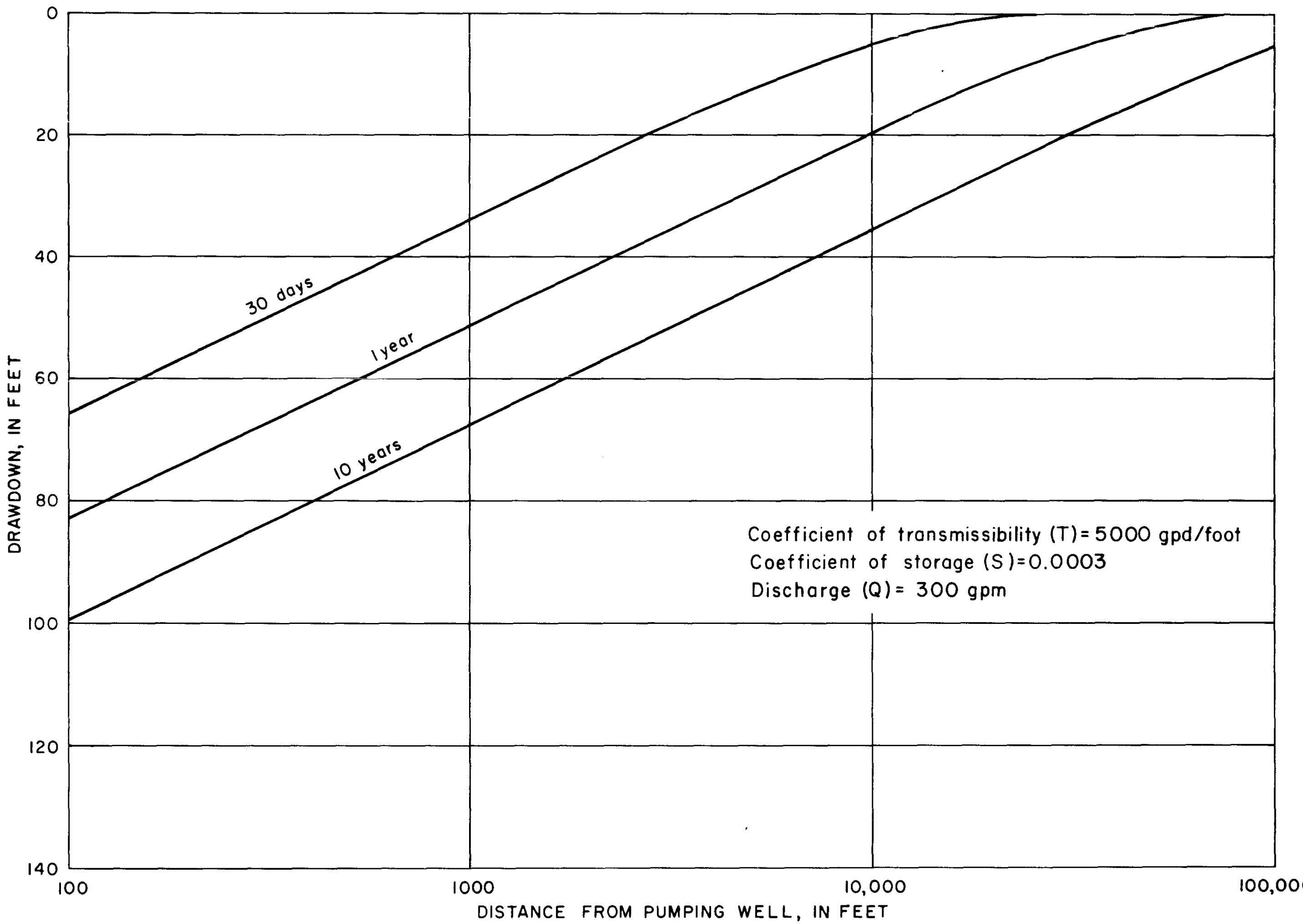

Figure 8

Relation of Drawdown to Distance and Time, Artesian Conditions

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

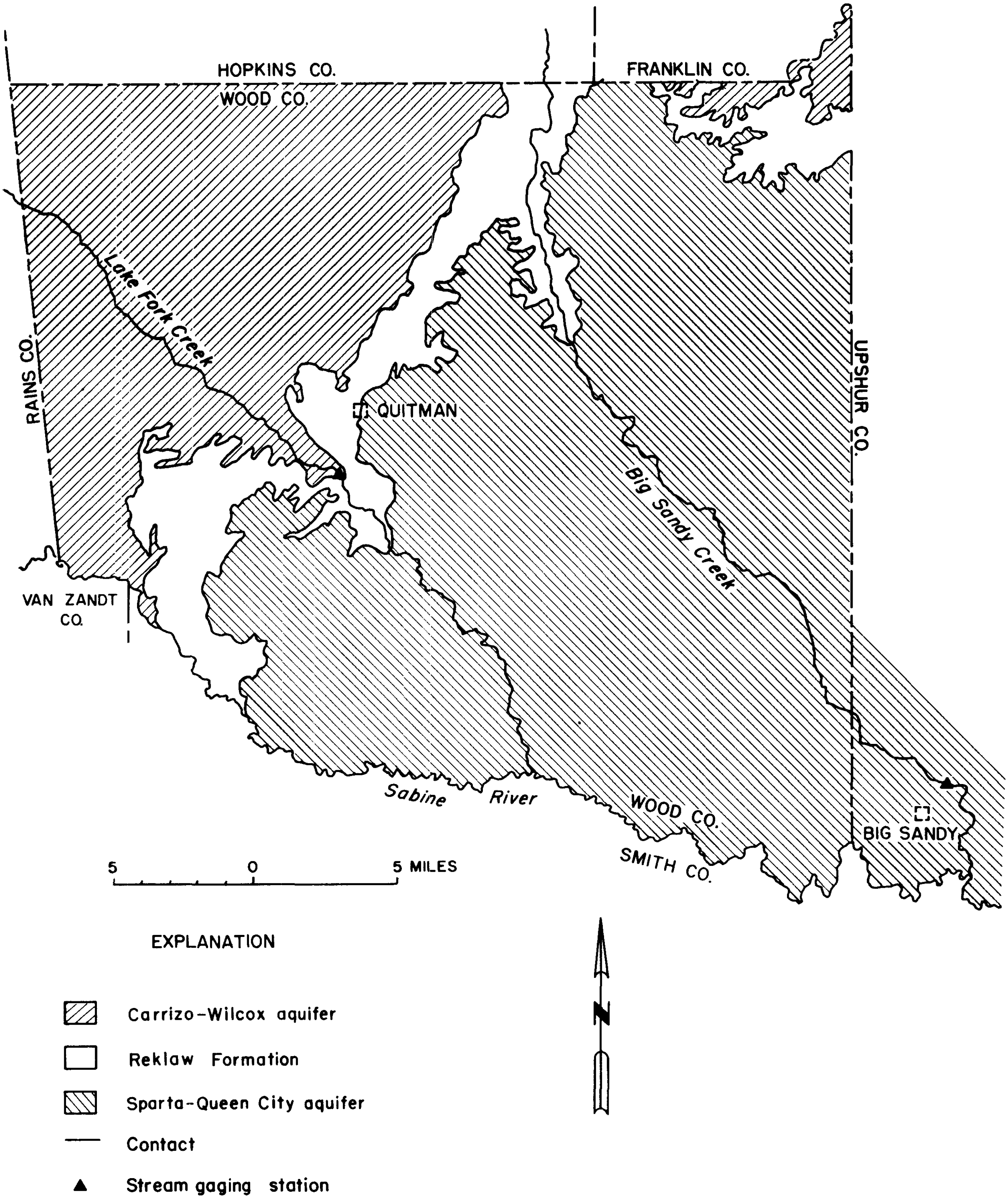

Figure 9

Locations of Stream-Gaging Stations and Outcrop Areas of the Carrizo-Wilcox and Sparta-Queen City Aquifers

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

Sandy Creek measures the runoff from 231 square miles, most of which is the outcrop of the Sparta-Queen City aquifer.

A comparison of the hydrographs (Figure 10) shows a striking contrast in the flow recession characteristics of the two stations. Except for small flash flows, no flow was measured at the Lake Fork station from October to December 1963 or from July to September 1964. During the same periods, a minimum flow of 8 cfs (cubic feet per second) was measured at the station on Big Sandy Creek.

The influence of ground-water storage on the flow characteristics of the two streams is also demonstrated by the flow-duration curve shown in Figure 11. A flow-duration curve is a cumulative frequency curve that shows the frequency of time in which specified discharges were equalled or exceeded (Searcy, 1959, p. 1). The effect of ground-water effluent on the flow of the two streams is shown by a change in the slope of the curve. Where the flow-duration curve shows a flattening of the lower part or low-flow end of the curve, the flow of the stream consists largely of ground-water effluent; where the slope of the curve is uniformly steep, ground-water effluent is negligible. The flow-duration curve for Big Sandy Creek shows a flattening on the low-flow end of the curve; that for Lake Fork is uniformly steep throughout, indicating that rejected recharge from the Carrizo-Wilcox aquifer is negligible. Big Sandy Creek actually functions as a drain for the Sparta-Queen City aquifer.

Use and Development of Ground Water

Pumpage and use of ground water in Wood County in 1965 are summarized in Table 3. Approximately 3 mgd or 3,500 acre-feet was pumped from the Carrizo-Wilcox and Sparta-Queen City aquifers. This amount includes practically all the water used in Wood County for municipal, industrial, and domestic purposes. It includes a comparatively small part of the amount used for livestock as most water supplies for livestock were derived from surface-water sources. No ground water was pumped for irrigation in 1965, but small quantities have been pumped during unusually dry seasons and a few irrigation wells are kept operable on a standby basis.

Municipal

Municipal pumpage in 1965, including Jarvis Christian College, was 1.4 mgd or 1.500 acre-feet (Table 3). Except for Hawkins and Jarvis Christian, all municipal pumpage was from the Carrizo-Wilcox aquifer. Hawkins pumped nearly equal amounts from both aquifers in 1965. Jarvis Christian pumped only from the Sparta-Queen City aquifer.

Records of municipal pumpage from 1955 to 1965 are shown in Table 4. Each city or user shows a significant increase in pumpage since 1955. The increases are attributed largely to increased population growth, and increased water use per capita. Pumpage at Hawkins in 1965 was nearly triple that of 1964, probably because of reduction in summer price rates.

Data on the municipal well facilities are given in Table 8. The table also includes wells for Jarvis Christian College and the unincorporated town of Golden. The well at Golden was developed by the Golden Water Supply Corporation in 1965 and planned for operation in 1966. The well will supply water to 115 or more homes and farmsteads in and around Golden. Similar water supply corporation wells are planned for the communities of Forest Hill and New Hope.

Industrial

Industrial pumpage in 1965 was 0.78 mgd or 880 acre-feet (Table 3), chiefly for cooling and oil-field repressurization. Of the water used for cooling, 0.33 mgd or 370 acre-feet was pumped from the Carrizo-Wilcox aquifers, and 0.2 mgd or 230 acre-feet from the Sparta-Queen City aquifer for the year. Of the water used for repressurization, 0.25 mgd or 280 acre-feet was from the Carrizo-Wilcox; none was derived from the Sparta-Queen City in 1965.

The chief users of cooling water in Wood County are the Pan American Petroleum Company, the Casko Corporation, and the Humble Oil and Refining Company. Pan American, with plant facilities near Yantis in the northwest corner of the county, taps the Carrizo-Wilcox aquifer with four wells ranging in depth from 308 to 450 feet. Yields range from 50 to 200 gpm and

Table 3.--Pumpage and Use of Ground Water in Wood County, 1965

AQUIFER	MUNICIPAL MGD	MUNICIPAL AC-FT	INDUSTRIAL MGD	INDUSTRIAL AC-FT	DOMESTIC MGD	DOMESTIC AC-FT	LIVESTOCK MGD	LIVESTOCK AC-FT	TOTAL MGD	TOTAL AC-FT
Carrizo-Wilcox	1.1	1,228	0.58	654	0.20	224	0.08	92	2.0	2,300
Sparta-Queen City	.28	314	.20	225	.40	448	.16	184	1.04	1,200
Totals	1.4	1,500	.78	880	.60	670	.24	280	3.0	3,500

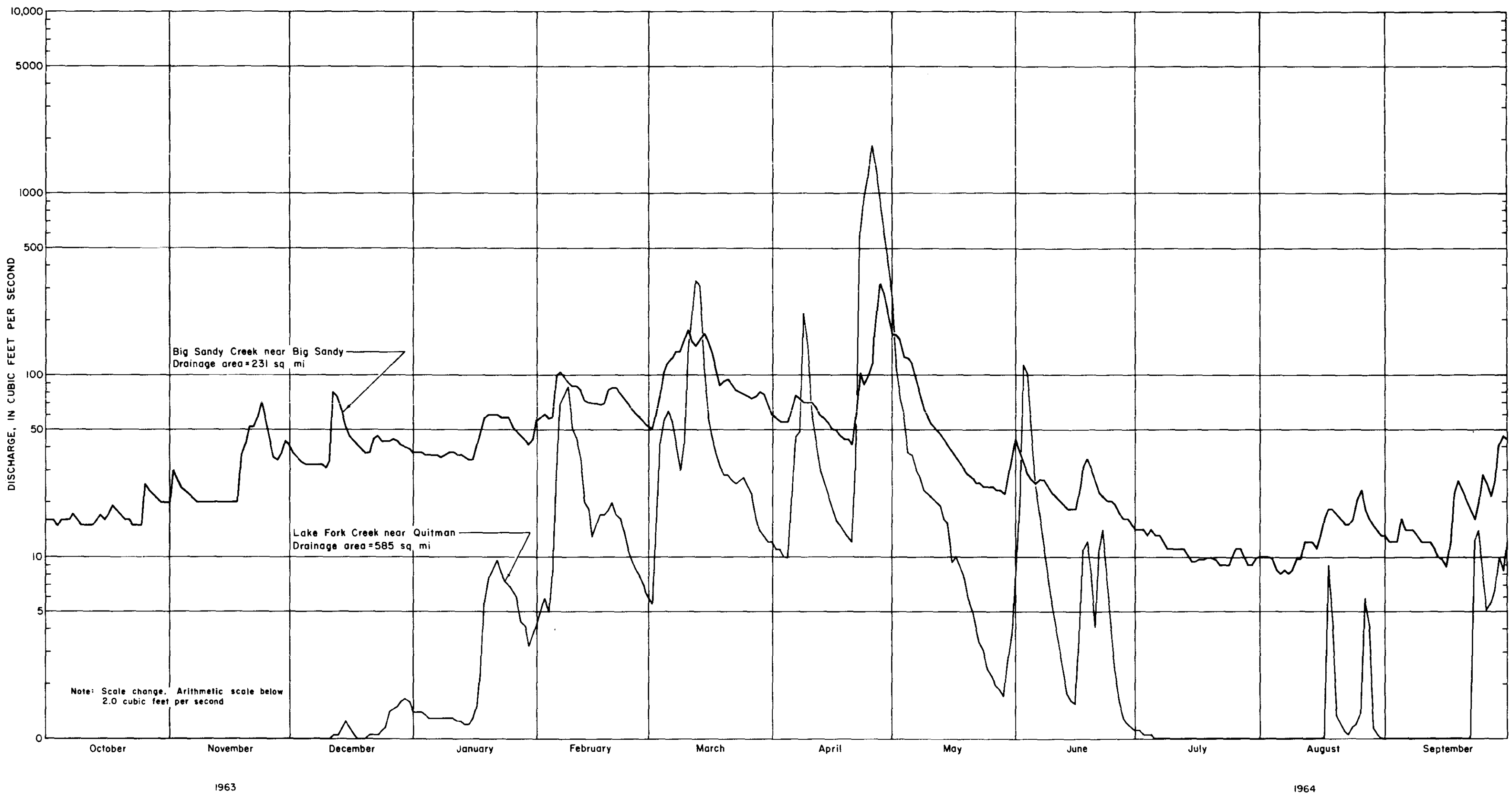

Figure 10

Hydrographs for Stream-Gaging Stations, Lake Fork Creek near Quitman and Big Sandy Creek near Big Sandy, Water Year 1964

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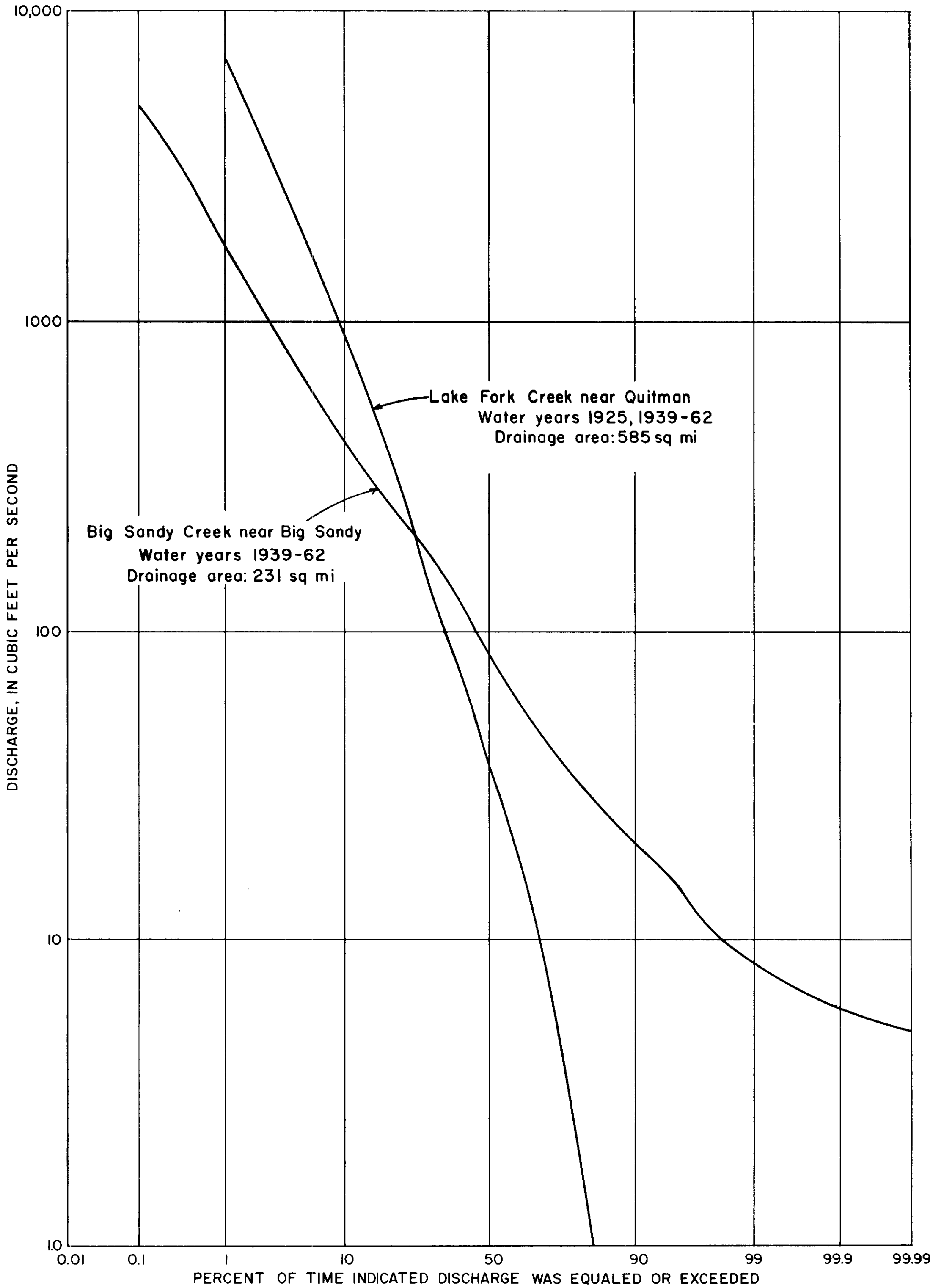

Figure 11

Duration Curves of Daily Discharge

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

Table 4.--Record of Municipal Pumpage, Wood County

YEAR	ALBA		HAWKINS		JARVIS CHRISTIAN COLLEGE		MINEOLA		QUITMAN		WINNSBORO	
	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT	MGD	AC-FT
1955	0.01	15	0.07	74	--	--	0.33	374	0.10	116	0.21	232
1956	.05	55	.08	87	--	--	.43	479	.3	262	.28	312
1957	.04	43	.08	88	--	--	.35	395	.14	152	.22	244
1958	.05	56	.08	93	--	--	--	--	.10	108	.16	178
1959	.05	56	.10	111	--	--	.35	395	.20	224	.21	238
1960	.02	27	.10	117	0.11	126	.40	452	.16	176	.23	256
1961	.03	33	.10	112	.10	111	.41	455	.20	221	.24	274
1962	.04	42	--	--	.11	120	.45	503	.15	169	.27	302
1963	.04	47	--	--	.12	130	.53	592	.21	238	--	--
1964	.04	47	.12	135	.14	161	.55	612	.22	246	.31	350
1965	.04	45	.35	388	.05	55	.50	565	.22	242	.27	307

water lifts range from 140 to 200 feet. Casko, with plant facilities about 3 miles northwest of Quitman, taps the Carrizo-Wilcox with two wells about 540 feet deep. Yields are about 125 gpm, and water lifts are about 150 feet. Humble, with plant facilities about 1 mile northeast of Hawkins, taps the Sparta-Queen City aquifer with two wells, 428 and 429 feet deep. Yields are about 300 gpm, and water lifts are about 150 feet.

Waterflooding (repressurization) was conducted in 1965 by the Bryan Hanks Operating Company in the Merigale-Paul oil field, a few miles east of Quitman; by Cities Service Petroleum Company in the Forest Hill and Midway Lake oil fields, a few miles northeast of Quitman; and by the Bracken Oil Company in the Nolan-Edwards oil field, a few miles northwest of Mineola. Two wells, 735 and 977 feet deep, drilled by Bryan Hanks tap the Carrizo-Wilcox aquifer and yield about 175 and 350 gpm from depths of 180 and 340 feet. Two wells owned by Cities Service, 275 and 280 feet deep, tap the Carrizo-Wilcox and yield about 150 gpm each from a depth of about 100 feet. The Bracken Oil Company's two wells, 400 and 450 feet deep, tap the Carrizo-Wilcox and yield, because of small capacity pumps, about 50 gpm each.

Domestic and Livestock

Domestic pumpage in 1965 was 0.60 mgd or 670 acre-feet (Table 3), of which 0.2 mgd or 224 acre-feet was from the Carrizo-Wilcox aquifer and 0.4 mgd or 448 acre-feet was from the Sparta-Queen City aquifer.

Pumpage for livestock in 1965 was 0.25 mgd or 280 acre-feet (Table 3). Of this, 0.08 mgd or 92 acre-feet was from the Carrizo-Wilcox and 0.16 or 184 acre-feet was from the Sparta-Queen City aquifer. The water for livestock consisted chiefly of supplies for dairy cattle, dairy barn facilities, and poultry. Comparatively small amounts were used for beef cattle.

Many of the approximately 3,000 domestic and livestock wells in the county are dual purpose wells. Most of these wells are drilled to only a few feet below the water table, which is seldom greater than 30 feet. The shallow wells generally are capable of pumping only a few gallons per minute and only for short periods. During extended dry spells, many fail to provide an adequate water supply to modern homes. Consequently, a number of these wells are being replaced by wells about 300 feet deep. In the deeper wells, water lifts range from a few feet to about 150 feet. Those that tap the Carrizo-Wilcox aquifer beneath the flood plains of the Sabine River and Lake Fork and Big Sandy Creeks generally flow.

Changes in Water Levels

Records of water levels in wells tapping the Carrizo-Wilcox and Sparta-Queen City aquifers are included in Table 8. Many of the shallow domestic and livestock wells inventoried by Follett (1942) were still in use in 1965. A comparison of the 1942 and 1965 water levels in these wells indicate no significant change in water levels. Well owners, however, report considerable seasonal fluctuation in the shallow wells. As reported, summer levels are generally 10 feet or more below the winter levels.

Although declines have not been general, many well owners reportedly have had to deepen their old wells or drill deeper wells to sustain a sufficient home water supply. This lowering of water levels in the vicinity of the wells is due to two factors: (1) low permeability of the sand causing large drawdowns, and (2) a general increase in the per capita demand for water. The typical domestic well drilled in the 1940's was equipped with hand-lift facilities and was capable of supplying on the order of 100 gpd. On the other hand, recently drilled wells are equipped with an electric pump which is capable of yielding on the order of 400 gpd.

Records showing changes in water levels in municipal and industrial wells in Wood County are few and short-ranged. Table 5 shows the change in water levels in 3 municipal, 2 industrial, and 1 observation well, all of which tap the Carrizo-Wilcox aquifer. The observation well is 75 feet from a continuously pumped municipal well at Hawkins. Nearly continuous pumping and low permeabilities account for the large declines.

Well Construction

The yield from wells tapping the Carrizo-Wilcox and Sparta-Queen City aquifers depends on the well location, well spacing, and the method and type of well construction. Improperly spaced wells will cause unnecessary water lift and pumping costs. Because of the non-uniform water-bearing characteristics of the aquifers, it is advisable to choose a well site based on sand sampling, electric logging, and pumping tests of one or more test holes.

Well ZS-34-13-503 (city of Quitman) is typical of the construction of wells for municipal and industrial uses in Wood County. The well-site location was based on data from sand analyses, electric logs, and pumping tests of two test holes. Briefly, the construction details of the well are as follows: (1) The well was drilled by the hydraulic-rotary method to 204 feet and cased with 16-inch surface casing; (2) cement was pumped between the hole wall and surface casing, providing a seal against vertical leakage of water along the casing to the producing zone and also providing a deterrent to corrosion on the outer surface of the casing; (3) after the surface casing was cemented, the well was deepened to 270 feet, penetrating approximately 45 feet of the Carrizo-Wilcox aquifer; (4) the well was underreamed to 30 inches in diameter in the water-producing horizon; (5) a total length of 270 feet of 10-3/4-inch blank steel liner and screen, with set nipple and back pressure valve on bottom, was lowered in the well—the screen being opposite the water-bearing sand when the set nipple reached the bottom of the well; (6) using the space between the 16-inch surface casing and the 10-3/4-inch liner as a conduit, small-size gravel was poured into the well so that the underreamed portion of the hole around the screen was filled with gravel, forming what is termed a "gravel-pack"; the gravel pack tends to reduce the velocity of the water near the well intake and thereby reduces the amount of fine sand that would enter the well; and (7) drilling mud was washed from the well and the well was tested for production. The well, which was equipped with a vertical turbine pump and 50-horsepower electric motor, was tested on July 16, 1962. The static water level was 79.6 feet below land surface. After pumping an average of 355 gpm for 24 hours, the pumping level was 183.2 feet below land surface with a drawdown of 103.6 feet, a specific capacity of 3.4 gpm per foot of drawdown.

Most of the domestic and livestock wells are very shallow, tapping the Carrizo-Wilcox and the Sparta-Queen City aquifers only a few feet below the water table. Nearly all the shallow wells completed before 1940 were hand dug and curbed with brick or rock; the diameters generally ranged from 3 to 4 feet. Most were originally equipped with hand-lift pumps which have since been replaced by water-jet, cylinder, or centrifugal pumps powered by ¼- to ½-horsepower electrical motors. Recently completed shallow wells are drilled by bucket-type power augers whose operating depths generally are limited to about 50 feet. The augered wells usually are curbed with 30-inch diameter cement tile. Lift facilities are about the same as for the dug wells.

Table 5.--Water Levels in Wells That Tap the Carrizo-Wilcox Aquifer in Wood and Franklin Counties

WELL	OWNER	DEPTH (FT)	YIELD (GPM)	WATER LEVEL (FEET BELOW LAND SURFACE) 1956	1960	1961	1965	DECLINE	PERIOD OF RECORD (YEARS)	DECLINE PER YEAR
JZ-34-06-302	City of Winnsboro (Franklin County)	277	457	112.8	--	114.4	--	1.6	5	0.3
ZS-34-13-502	City of Quitman	365	322	--	75.0	--	83.8	8.8	5	1.8
ZS-34-13-601	Bryan Hanks	977	351	--	88.0	--	136.1	48.1	5	9.6
ZS-34-14-401	do	735	175	--	73.8	--	82.7	8.9	5	1.8
ZS-34-21-701	City of Mineola	469	490	--	85.6	--	89.2	3.6	5	.7
ZS-34-31-103	City of Hawkins	672	a	--	84.5	--	240.3	155.8	5	31.2

[a] Observation well.

A few domestic wells in Wood County have been constructed by methods similar to those used in municipal and industrial well construction. These wells use a cemented steel surface casing about 4 inches in diameter to the top of the water-bearing sand. A 2- to 3-inch diameter screen or perforated liner is set opposite the sand. A gravel-pack may or may not be used.

The drilled domestic and livestock wells are equipped generally with either water-jet or submersible turbine pumps, powered by electrical motors of 1/2 to 1 horsepower.

CHEMICAL QUALITY OF WATER

The suitability of a water supply is controlled largely by the restrictions imposed by the contemplated use of the water. Various standards have been established for dissolved mineral content, bacterial content, and physical properties such as temperature, odor, color, and turbidity. Bacterial content and undesirable physical properties may warrant concern, but generally the water can be treated by simple and inexpensive processes. The removal of dissolved mineral constituents, however, may be difficult and expensive.

The source and significance of dissolved-mineral constituents summarized in Table 6 were adapted from Doll and others (1963). Chemical analyses of ground water from 22 wells tapping the Carrizo-Wilcox aquifer and 41 wells and 2 springs tapping the Sparta-Queen City aquifer are shown in Table 10. Chemical analyses of surface water from 38 collection sites are shown in Table 11.

The U.S. Public Health Service has established and periodically revises standards of drinking water to be used on common carriers engaged in interstate commerce. The standards are designed to protect the traveling public and may be used to evaluate domestic and public water supplies. According to the U.S. Public Health Service (1962), dissolved mineral constituents should not be present in a public water supply in excess of concentrations shown for the following selected constituents, except where more suitable water is not available or cannot be made available at reasonable cost.

CONSTITUENT	CONCENTRATION IN PPM (PARTS PER MILLION)
Iron (Fe)	0.3
Sulfate (SO_4)	250
Chloride (Cl)	250
Nitrate (NO_3)	45
Dissolved solids	500

Iron in concentrations of more than 0.3 ppm will cause unsightly reddish-brown stains on clothes and porcelain fixtures and encrustations or scale in pipes or other water conduits and containers. Sulfate in excess of 250 ppm may produce a laxative effect. Chloride in excess of 250 ppm in combination with sodium will give a salty taste and will increase corrosion. Nitrate in excess of 45 ppm may be pathologically detrimental. Where excessive concentrations of nitrate occur locally, it may be the result of organic pollution from sewage facilities. Dissolved solids is a measure of the total mineral constituents in water, and water containing more than 500 ppm is undesirable for public supply if less mineralized water can be made available.

Excessive iron concentration is the most general chemical problem in water from both the Carrizo-Wilcox and the Sparta-Queen City aquifers in Wood County. However, the occurrence of excessive iron follows a somewhat predictable pattern, so that with discriminate well construction and pumping rates, water relatively free of iron can be recovered from both aquifers (see "Chemical Zones in the Aquifers," p. 34). Excessive concentrations of sulfate, chloride, nitrate, and dissolved solids occur only rarely and generally are confined to relatively shallow depths, suggesting local contamination from sewage or brine disposal facilities. As an example, changes in concentrations of constituents from two wells are shown below.

WELL	DEPTH (FEET)	DATE OF SAMPLE	CONCENTRATIONS, IN PPM			
			SULFATE (SO_4)	CHLORIDE (CL)	NITRATE (NO_3)	DISSOLVED SOLIDS
ZS-34-03-503	123	Feb. 13, 1942	26	28	a	273
		June 21, 1965	307	345	88	1,460
ZS-34-05-505	97	Feb. 11, 1942	75	90	a	600
		Aug. 3, 1965	944	1,550	1.5	3,820

[a] less than 20 ppm

Both wells tap the Carrizo-Wilcox aquifer and are constructed so that both probably draw water from near the land surface to the bottom of the wells. The 123-foot well is in the vicinity of one or more home septic tanks. The 97-foot well is located in an oil field in the vicinity of brine disposal pits. Changes in the concentration of constituents as a result of contamination appears conclusive in both cases.

Calcium and magnesium are the principal constituents in water that cause hardness. Excessive hardness causes increased consumption of soap and induces the formation of scale in hot water heaters and water pipes. The commonly accepted standards and classifications of water hardness are shown in the following table.

Table 6. -Source and Significance of Dissolved-Mineral Constituents and Properties of Water

CONSTITUENT OR PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of iron in surface waters generally indicates acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 ppm stains laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. U.S. Public Health Service (1962) drinking-water standards state that iron should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. U.S. Public Health Service (1962) drinking-water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. U.S. Public Health Service (1962) drinking-water standards recommend that the chloride content should not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptbility of the individual. (Maier, 1950)
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. U.S. Public Health Service (1962) drinking-water standards suggest a limit of 45 ppm. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes some water of crystallization.	U.S. Public Health Service (1962) drinking-water standards recommend that waters containing more than 500 ppm dissolved solids not be used if other less mineralized supplies are available. Waters containing more than 1000 ppm dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness as much as 60 ppm are considered soft; 61 to 120 ppm, moderately hard; 121 to 180 ppm, hard; more than 180 ppm, very hard.
Specific conductance (micromhos at 25°C)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
Hydrogen ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.

HARDNESS RANGE (PPM)	CLASSIFICATION
60 or less	Soft
61 to 120	Moderately hard
121 to 180	Hard
More than 180	Very hard

Water from both the Carrizo-Wilcox and Sparta-Queen City aquifers is generally soft. Only 4 of 50 samples collected in 1965 from wells in the Carrizo-Wilcox aquifer exceeded 60 ppm hardness; only 12 of 38 samples collected in 1965 from wells in the Sparta-Queen City aquifer exceeded 60 ppm. Of the 12 exceeding 60 ppm hardness, 3 exceeded 100 ppm hardness.

The quality of water for industry does not depend necessarily on potability—that is, it may or may not be acceptable for human consumption. Water used for industry may be classified in three principal categories—cooling, process, and boiler. For cooling, the natural temperature of the water may be significant. Temperatures of water from the Carrizo-Wilcox and the Sparta-Queen City aquifers, given in Table 8, range from 65 to 70°F, generally increasing with depth. For cooling, any characteristic that may adversely affect heat-exchange surfaces is undesirable. Calcium, magnesium, aluminum, iron, and silica may cause scale or encrustation in both cooling and boiler facilities. Of these constituents, iron and silica warrant some concern with water from the two aquifers. The scale-forming tendency of silica in boiler water generally increases with pressure. The following table shows the maximum suggested concentration of silica for water used in boiler (Moore, 1940, p. 264):

CONCENTRATION OF SILICA (PPM)	BOILER PRESSURE (LBS/IN.^{2})
40	Less than 150
20	150 to 250
5	251 to 400
I	More than 400

Of 44 samples from the Carrizo-Wilcox aquifer, silica concentrations ranged from 9.6 to 59 ppm, but only 5 of the samples exceeded 20 ppm. Generally, the silica concentration decreased with depth. The highest concentration (59 ppm) was obtained from a well only 23 feet deep. Of 39 samples from the Sparta-Queen City aquifer, silica concentrations ranged from 3.8 to 90 ppm, and averaged 29.4 ppm. Generally, the silica concentration decreased with depth. The highest concentration (90 ppm) was obtained from a well only 35 feet deep, and the lowest concentration (3.8 ppm) was obtained from a well 386 feet deep.

Process water is subject to a wide range of quality requirements. Usually rigidly controlled, these requirements commonly involve physical, chemical, and biological factors. In general, water used in the manufacture of textiles must be low in dissolved-solids content and free of iron and manganese. Here again, iron appears to be the main concern with water from the two aquifers. Manganese in 9 samples from the Carrizo-Wilcox ranged from 0.01 to 0.40 ppm, but only 2 of the samples exceeded 0.3 ppm. Manganese in 2 samples from the Sparta-Queen City was 0.02 and 0.03 ppm. Water free of iron, manganese, and organic substances normally is required by beverage industries. Unlike cooling and boiler water, much of the process water is consumed or undergoes a change in quality in the manufacturing process and is not generally available for reuse.

Corrosiveness is an objectionable property in water for nearly any use. The hydrogen ion concentration (pH) of some waters in the Carrizo-Wilcox and the Sparta-Queen City aquifers warrant general concern. (See significance of pH in Table 6.) The pH in the water in the two aquifers range from about 4.0 to 8.0. The pH values are closely related to the occurrence of dissolved iron in the water. (See "Chemical Zones in the Aquifers," p. 34.)

The suitability of water for irrigation generally cannot be evaluated on chemical content alone, but must be evaluated along with type of soil, adequacy of drainage, tolerance of crops, and frequency of rainfall. Total dissolved constituents (salinity) is significant, but permissible limits will vary with local conditions controlling the rate of accumulation of the constituents in the soil from the applied water. If the rate of accumulation tends to be great, a lower permissible limit for salinity, or a less mineralized water, would be required. Sodium in large amounts in irrigation water is significant in that it tends to break down soil structure, causing the soil to become plastic or less tillable.

A system for classifying irrigation water based on the salinity hazard (as measured by the specific conductance of the water, Table 6) and the sodium hazard (as measured by the SAR—sodium-adsorption ratio) was proposed by the U.S. Salinity Laboratory Staff (1954, p. 69-82). Figure 12 shows how representative samples of water from the Carrizo-Wilcox and the Sparta-Queen City aquifers fit this classification. Water from the Carrizo-Wilcox ranges from a low to a very high sodium hazard and a low to a high salinity hazard. Water from the Sparta-Queen City is low in sodium hazard, and ranges from low to medium in salinity hazard. On the basis of this system of classification, the water from the Sparta-Queen City is more suitable for irrigation than

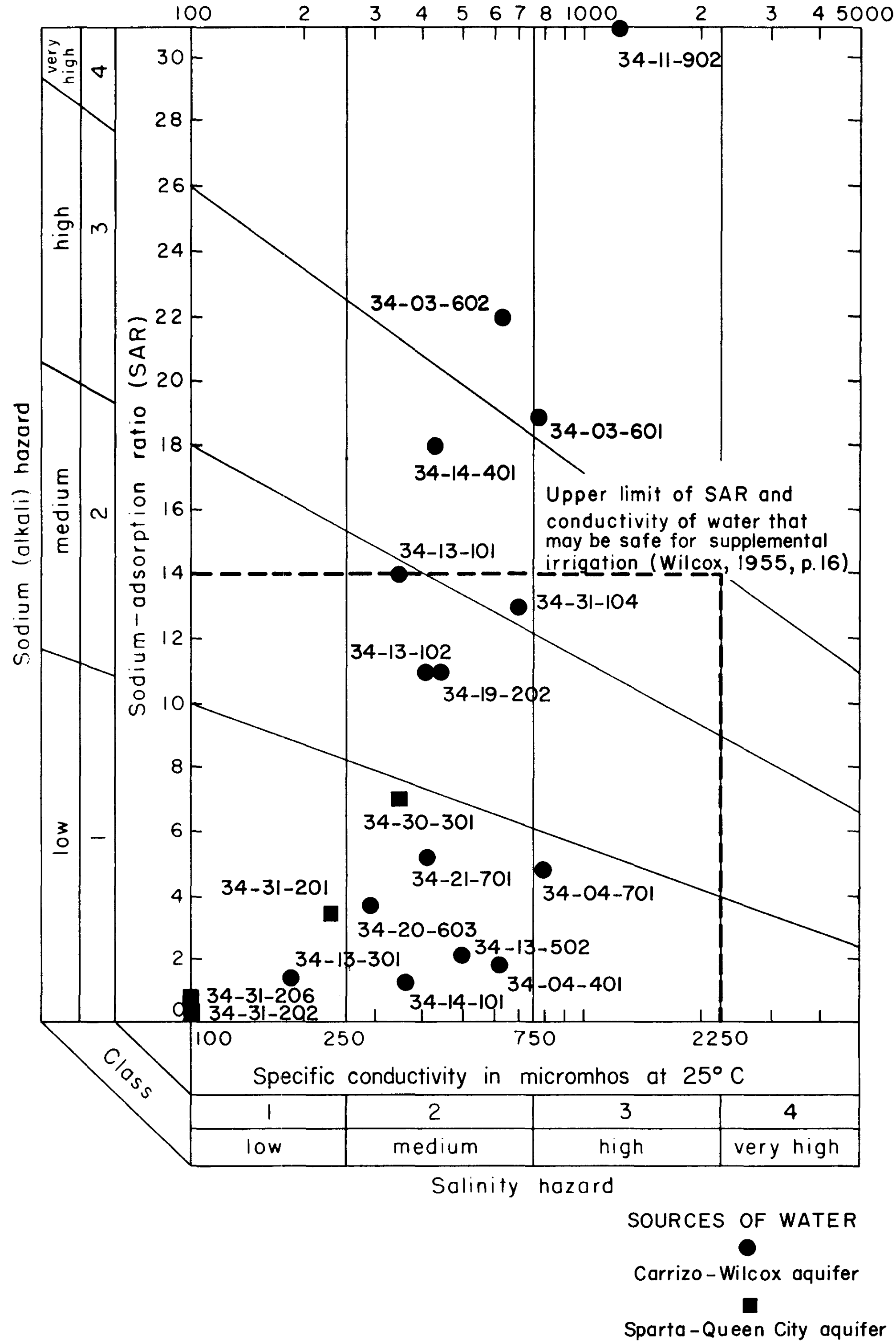

Figure 12

Classification of Irrigation Waters

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that from the Carrizo-Wilcox. However, either aquifer probably would be a suitable source for supplemental irrigation. Wilcox (1955, p. 15) stated this system of classification "...is not directly applicable to supplemental waters used in areas of relatively high rainfall." Thus, in Wood County with a rainfall of 45 inches, permissible limits for the sodium and salinity hazards probably could be raised for supplemental irrigation. Also, the generally sandy soil and character of drainage in the county would tend to raise permissible limits.

Another factor used in evaluating the suitability of water for irrigation is the RSC (residual sodium carbonate). Excessive RSC will react with the organic content of the soil and tend to develop a "black alkali" soil. Wilcox (1955, p. 11) concludes from laboratory and field studies that water containing more than 2.5 epm (equivalents per million) RSC is not suitable for irrigation; water containing 1.25 to 2.5 epm is marginal; and water containing less than 1.25 epm probably is safe. However, it is believed that good irrigation practices and proper use of amendments might make it possible to use the marginal water successfully for irrigation. The RSC in 48 samples from the Carrizo-Wilcox aquifer ranged from 0.0 to 5.7 epm. Fourteen contained more than 2.5 epm (not suitable); 16 contained from 1.25 to 2.5 epm (marginal); and 18 contained less than 1.5 epm (safe). The RSC in 39 samples from the Sparta-Queen City aquifer ranged from 0.0 to 2.26 epm (safe to marginal); only 2 of the samples contained more than 1.5 epm (marginal).

An excessive concentration of boron causes water to be unsuitable for irrigation. Scofield (1936, p. 286) indicated that boron concentrations of 1 ppm are permissible for irrigating most boron-sensitive crops, and concentrations of 3 ppm are permissible for the more boron-tolerent crops. In 14 samples from the Carrizo-Wilcox aquifer and 3 samples from the Sparta-Queen City aquifer, boron concentrations were less than 0.5 ppm. Thus, boron is not a problem in Wood County.

Chemical Zones in the Aquifers

Selective sampling of water from various depths in the Carrizo-Wilcox and Sparta-Queen City aquifers indicates three zones of water, common to both aquifers, and sufficiently different in chemical constituents and properties to warrant delineation. The zones are of particular significance because they have a direct bearing on the general extent of dissolved iron in the aquifers.

Figure 13 illustrates the zones in a diagrammatic section. Zone B generally contains excessive dissolved iron (more than 0.3 ppm) and zones A and C are relatively free of iron. Figure 13 also shows a typical compositional pattern of constituents in water from each zone. Samples of water from wells tapping more than one zone show no regular compositional pattern except that they almost invariably contain excessive amounts of dissolved iron.

Zone A (Figure 13) generally extends from the land surface to an altitude slightly below the base of the larger stream valleys. Thus, the vertical extent of zone A varies predominantly with local surface relief which may range from less than 50 feet at the outcrop of the Carrizo-Wilcox aquifer to 200 feet or more at the outcrop of the Sparta-Queen City aquifer. Typically, the water in zone A is very low in all constituents. The most objectionable feature of water in zone A is the low pH, which generally ranges from about 5.0 to 6.5, and locally 4.0 or less. Consequently, the water tends to be corrosive to iron and other metal components in wells and plumbing systems. Because of the comparatively shallowextent of zone A, the zone generally yields only small quantities of water to wells, usually considerably less than 50 gpm. Also, wells tapping only zone A may be subject to considerable seasonal fluctuation of water levels, and if not sufficiently deep, may go dry during extended drought periods.

Zone B (Figure 13) extends to a depth of approximately 100 to 200 feet below the base of zone A in the outcrop of the Carrizo-Wilcox. In the outcrop of the Sparta-Queen City, the base of zone B generally will extend below the base of the Sparta-Queen City until the base of the aquifer attains a depth of at least 200 feet below the base of zone A. At greater depths, the base of the Sparta-Queen City and the base of zone B are about coincident; only locally does any part of the Sparta-Queen City dip below zone B. The water in Zone B shows a slight overall increase in dissolved constituents, but still would be considered a very dilute water, rarely containing any excessive concentrations of constituents, except dissolved iron. Typically, the water in zone B contains excessive concentrations of dissolved iron, or more than 0.3 ppm. Although zone B is vertically more extensive in the Sparta-Queen City aquifer, the highest concentrations of dissolved iron were found in samples of water from the Carrizo-Wilcox aquifer (up to 31 ppm). The highest concentration of dissolved iron found in the Sparta-Queen City was 4.1 ppm, but the Sparta-Queen City was less extensively sampled. Dillard (1963, p. 24, 29) reported concentrations of as much as 65 and 71 ppm iron in water from the Sparta Sand and Queen City Sand in Smith County, which adjoins Wood County on the south. The pH of water in zone B, as in zone A, typically is low. The pH values generally ranged from 5.0 to 7.0 and locally were 4.0 or less. Moderate quantities of water, up to about 150 gpm in the Carrizo-Wilcox and up to about 300 gpm in the Sparta-Queen City, can be recovered from zone B. Of course, most of the recoverable water in the Sparta-Queen City exists in zone B. On the other hand, water in zone B in the Carrizo-Wilcox makes up only a small portion of the recoverable water in the Carrizo-Wilcox.

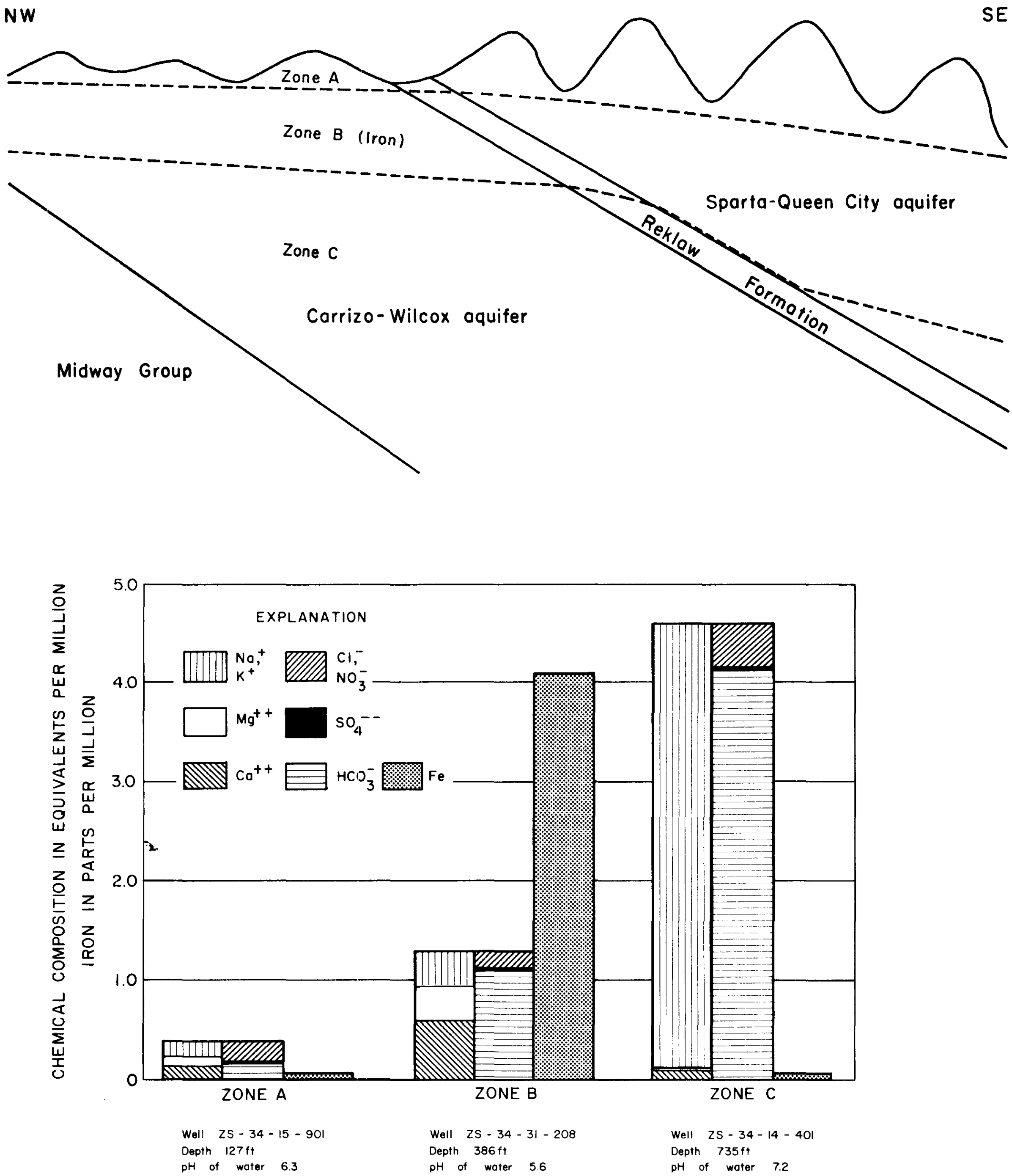

Figure 13

Diagrammatic Section Showing Position of the Iron-Water-Bearing Zone in the Carrizo-Wilcox and Sparta-Queen City Aquifers, and Graph Showing Chemical Composition of Water from Wells Tapping Each Zone

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Zone C (Figure 13) extends from the base of zone B to the top of the Midway Group. Because the slope of the boundary between zone B and zone C is less than the slope of the aquifers, zone C becomes vertically more extensive in the downdip direction or toward the southeast. The Carrizo-Wilcox dips completely below zone B in most of the southeast half of Wood County. Consequently, all recoverable water in the Carrizo-Wilcox underlying Quitman, Mineola, Hawkins, and most points in between is typical of water found in zone C (Figure 13). Water in zone C shows a striking increase in sodium and bicarbonate ions in comparison to the other zones, and contains only a trace of dissolved iron. The water rarely contains excessive concentrations of any constituents. Unlike zones A and B, zone C contains an alkaline water, generally ranging in pH values from about 7.1 to 8.0. Most water recoverable from the Carrizo-Wilcox is representative of water in zone C. Available yields from this zone in the Carrizo-Wilcox will range from about 50 to 700 gpm, generally increasing downdip.

The chemical zonation in the aquifers in Wood County appears similar to that described elsewhere in northeast Texas (Broom and others, 1965). The phenomenon of zonation is for the most part supported by established chemical principles of ground water and are particularly consistent with equilibrium chemistry of iron in ground water (Hem, 1959, 1960a, and 1960b; Hem and Cropper, 1959; and Hem, 1966).

Generally the chemical zones in Wood County occur in aquifers largely of similar rock composition, and chiefly as a result of variations in (1) the extent of oxidation and reduction, (2) the pH of the waters, and (3) the amount of bicarbonate ions. Relatively abundant quantities of iron-source minerals may be assumed constant, but in varying states of oxidation and reduction in the aquifers.

Zone A is an oxidized zone, containing freely circulating, low pH water charged with dissolved oxygen and carbon dioxide. Iron minerals in zone A are in a completely oxidized state, mostly in the form of limonite. This form of iron would be mostly insoluble in zone A, which probably explains the general absence of dissolved iron in zone A.

Zone C is a reduced zone, containing water mostly under confined conditions, deficient of dissolved gases, high in bicarbonate, and alkaline. Iron minerals in this zone are in the reduced state, and mostly in the form of pyrite, siderite, and glauconite. The reduced iron minerals would be mostly insoluble in zone C, which probably explains the general absence of dissolved iron in zone C.

Zone B is a transitional zone of oxidation and reduction, containing water partly under atmospheric and confined conditions, which is generally low to neutral in pH, and contains small amounts of bicarbonate and some dissolved gases. The iron minerals in zone B are partly oxidized and partly reduced. Reduced iron minerals in contact with low pH waters tend to be soluble and capable of releasing large amounts of iron to solution, and this probably explains the presence of relatively large amounts of iron in zone B.

Excessive iron in solution in ground water is mostly localized to that part of the aquifer in which oxidizing zones are in contact with reducing zones, in the presence of iron-source minerals. This essentially is what occurs in zone B. It is entirely a result of natural processes and nothing is likely to alter the situation for some time. The well owners and drillers in Wood County have a few choices with respect to zone B. They may choose to tap zone B for the available water, because with treatment for dissolved iron and low pH, which usually involves only aeration and filtration, the water would be very suitable for most uses. In zone A they would be limited to small quantities, but with treatment for low pH, the water would be very suitable. In zone C, water can be obtained that generally would be sufficient in quantity and acceptable in quality, but because the well bore provides a conduit through which waters from different zones may become mixed, the well must be constructed so that no water but that from zone C enters the well bore. This construction does not involve any methods unfamiliar to reputable and experienced well drillers. The methods of constructing and pumping wells in zone C should include: (1) Surface casing below zone B to a clay bed sufficiently impermeable to retard the downward movement of low pH water through natural interconnections from the upper zones; (2) surface casing cemented for its entire length, not only to prevent the downward movement of low pH water between the hole wall and casing, but also to retard corrosion in the zones of low pH water; (3) screens set opposite sands in zone C; and (4) pumping at rates that allow pumping levels to stay well above the screens. If the pumping levels drop near or below the top of the screens, reduced iron minerals in zone C will tend to be oxidized and, consequently, release iron to solution. Also, the water will tend to change from an alkaline solution to an acid solution.

Contamination by Oil-Field Brine

Brine is produced from 17 oil fields in Wood County, and according to a report of the Texas Water Commission and Texas Water Pollution Control Board (1963), total brine production in 1961 was 13,003,162 barrels (about 2,000 acre-feet). Table 7 shows the amount of brine production in each field in 1961 and the methods of disposal. Without adequate disposal methods, brine may contaminate potable water sources. Methods of brine disposal are regulated by the Texas Railroad Commission.

Table 7.--Oil-Field Brine Production and Disposal, 1961

(From Texas Water Commission and Texas Water Pollution Control Board, 1963)

FIELD NAME	BRINE PRODUCTION (BARRELS)	BRINE DISPOSAL			
		INJECTION WELL		OPEN-SURFACE PITS	
		BARRELS	PERCENT	BARRELS	PERCENT
Alba	112,361	0	0.0	112,361	100
Coke	1,185,218	1,184,568	99.95	650	0.05
Deupree	14,600	14,600	100	0	.0
Earl-Lee	1,208	1,208	100	0	.0
Forest Hill	5,897	5,897	100	0	.0
Hawkins	4,190,298	3,985,522	95.1	204,467	4.9*
Manziel	794,405	542,460	68.2	251,947	31.8
McCrary	472,990	0	.0	472,990	100
Merigale-Paul	1,829,353	1,622,853	98.87	206,500	1.13
Midway Lake	44,774	0	.0	44,774	100
Nolan Edward	387,135	387,135	100	0	.0
Pine Mills	770,937	596,040	79.1	174,897	20.9
Quitman	2,882,111	2,789,120	99.67	92,991	.33
Shirley-Barbara	55,100	55,100	100	0	.0
Trice	41,975	0	.0	41,975	100
Winnsboro	7,418	0	.0	5,600	100
Yantis	48,132	0	.0	48,132	100
County Totals	13,003,162	11,320,065	87.1	1,682,788	12.9

* 309 barrels unaccounted for.

Brine has been disposed of in Wood County by both injection and open-pit methods. The Texas Railroad Commission issued an order November 3, 1966, ending disposal of brine in open pits in Wood County not later than November 1, 1967. The most common method of disposal is the injection method by which the brine is pumped back down to the oil-bearing strata or some other deep strata designated by the Commission. The injection method, if properly and fully employed, greatly reduces the incidence of brine contamination. This method was employed in disposing of 87.1 percent of the brine produced in Wood County in 1961 (Table 7).

Another potential source of contamination is the upward movement of brine from deep strata through inadequately cased or plugged oil and gas tests and wells. This contamination hazard has been for the most part minimized by regulations of the Railroad Commission, which specifies casing and plugging requirements. In the absence of field rules, the oil operators are required by the Railroad Commission to obtain approval on completion methods for individual wells or leases. Published oil-field rules generally are based on ground-water data compiled by or in cooperation with the Texas Water Development Board. As additional data become available in some areas, it is found that potable water may sometimes extend below the specified surface casing depths in the published field rules. In these cases, the field rules do not adequately protect the water. Data collected during this investigation indicate that fresh water in Wood County generally extends to the base of the Wilcox Group or to the top of the Midway Group. By the intended purpose of the field rules, cemented surface casing or alternative fresh-water protection devices should extend to a depth at least to the top of the Midway Group in Wood County.

Figure 14 illustrates the approximate depth to the top of the Midway Group or the base of fresh water in the various oil fields in the county and the depth to which cemented casing is required in accordance with the published field rules. No cases have been recorded in Wood County in which brine contamination has resulted from inadequate casing. However, an investigation by the Texas Water Development Board (Burnitt, 1962) established that two of the city of Hawkins' wells were contaminated with gas; no contamination by brine was noted. He also reported the existence of one or more nearby gas wells in which the surface casing did not

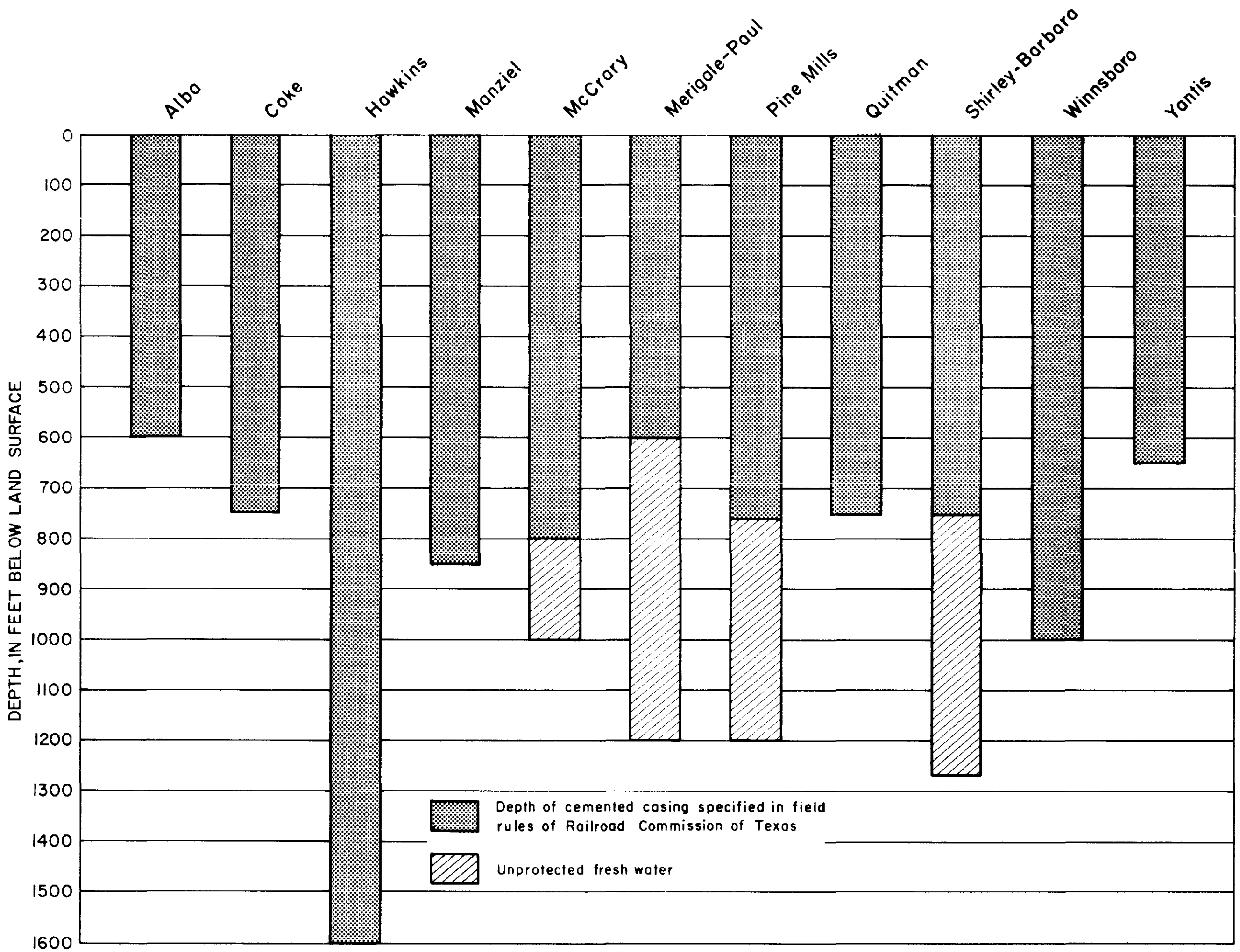

Figure 14

Comparison Between Depth to the Base of the Fresh Water Sands and Amount of Surface Casing Required in Oil Fields

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extend to the top of the Midway Group. Since the investigation, remedial action has been taken and the city wells reportedly are usable, although currently they are pumped only occasionally.

The composition of oil-field brine varies, but the principal constituents, in the order of highest concentrations, are generally chloride, sodium, calcium, and sulfate. Abnormal concentrations of chloride in ground and surface water in brine-producing areas are therefore indicative of brine pollution, but not necessarily conclusive evidence of pollution. Hughes and Leifeste (1965) reported brine pollution of streams in the Lake Fork Creek subbasin in Wood County. Subsequent studies indicate that brine pollution of streams is also occurring in the Big Sandy Creek subbasin in Wood County.

Ground water in both the Carrizo-Wilcox and Sparta-Queen City aquifers generally contains less than 250 ppm chloride, and seldom contains concentrations in excess of 50 ppm. Where higher concentrations of chloride occurred, the wells were shallow and near oil field or brine-producing areas.

Table 11 gives the results of the chemical analyses of surface-water samples collected at 37 sites in Wood County, and 1 site in Upshur County at the gaging station 6 miles east of Hawkins. The analyses range from partial to complete. The chloride concentrations in surface-water samples collected in areas distant from the oil-field areas seldom exceeded 10 ppm. The chloride concentrations in water from wells near oil fields ranged from less than 10 to more than 3,000 ppm.

Figure 15 shows the chloride content in all surface- and ground-water samples collected in 1965. Most of the surface-water samples were collected during June and July when streamflow consisted principally of ground-water effluent. Figure 15 also shows the relative locations of oil fields and the water-sampling sites. The relation between the occurrence of high-chloride concentrations in the water samples and the locations of the oil fields strongly indicates that contamination is due to oil-field operations.

AVAILABILITY OF GROUND WATER FOR FUTURE DEVELOPMENT

At the 1965 rate of pumping (3,500 acre-feet per year or 3 mgd), the ground-water resources of Wood County are practically untapped. The amount of water that is available for future development from the two aquifers—Carrizo-Wilcox and Sparta-Queen City—is dependent upon the rate of recharge to these aquifers and their ability to transmit and store water.

Carrizo-Wilcox Aquifer

The quantity of water available for future development from the Carrizo-Wilcox aquifer is limited chiefly by the low rate at which the aquifer transmits water. The transmission capacity of the aquifer at the present hydraulic gradient is only about 3,000 acre-feet per year, or about 700 acre-feet more than was pumped from the aquifer in 1965. Obviously, additional pumpage of ground water in excess of the 3,000 acre-feet per year would result in removing water from storage.

In contrast to the small amount of water that is perennially available (3,000 acre-feet), an immense quantity of ground water is in transient storage. On the basis of a 30-percent porosity, slightly more than 50 million acre-feet of ground water in stored in the Carrizo-Wilcox aquifer. Of this amount, 18 million acre-feet of water is in storage within a depth of 400 feet, but most of this water is not available to wells because of the low permeability of the aquifer.

The isopachous map (Figure 16), which shows the actual thickness of sand containing fresh water, may be used to show the areas that are most favorable for the development of ground water from the Carrizo-Wilcox aquifer. According to the map, the thickness of the sand ranges from less than 100 feet to slightly more than 300 feet in the outcrop area; downdip, in the artesian part of the aquifer, the sand thickens to a maximum of slightly more than 600 feet in two widely separated areas—one near Mineola and the other south of Winnsboro. Yields probably greater than 700 gpm can be expected from properly constructed and adequately spaced wells in the area of maximum sand thickness that trends northeasterly through Mineola. The map (Figure 16) shows that the sands in this area have a thickness of about 500 feet.

Sparta-Queen City Aquifer

The Sparta-Queen City aquifer has at least 50,000 acre-feet of water per year available for development. This is the amount discharged to the streams as rejected recharge. An additional, but unknown, amount escapes discharge to the streams and moves downdip to the deeper part of the aquifer. The aquifer also has a large quantity of fresh water in transient storage; the upper 400 feet of the aquifer contains an estimated 16 million acre-feet of water.

The isopachous map (Figure 17) shows that the area most favorable for the development of ground water from the Sparta-Queen City aquifer is that encompassed by the 300-feet isopach. Properly constructed and adequately spaced wells drilled in this area probably would be capable of yielding at least 300 gpm, possibly as much as 500 gpm.

Factors that may limit large-scale development of the ground-water supplies in the two aquifers are the low pH and high iron content of the water and the low permeability of the sands in the aquifers. The first factor can be controlled by proper construction and operation of the wells or treatment of the water. Where iron-free water is required, wells should be drilled more than 200 feet deep, below the zones that produce the high iron-bearing water or acid water. The second factor, that of low permeability, requires that wells be properly constructed, adequately spaced, and regulated to prevent excessive drawdowns.

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Table 9.--Drillers' Logs of Wells in Wood County and Adjacent Areas

Well ZS-34-03-601

Owner: Pan American Petroleum Corp.
Driller: Edington Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	22	22
Shale	73	95
Sand	23	118
Shale	16	134
Sand	21	155
Shale	41	196
Sand	62	258
Shale, sandy	10	268
Sand	20	288
Shale	20	308

Well ZS-34-03-602

Owner: Pan American Petroleum Corp.
Driller: Edington Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface	3	3
Clay, yellow	15	18
Sand	6	24
Shale	12	36
Lignite	2	38
Shale	7	45
Shale and lignite	31	76
Sand	6	82
Shale	16	98
Sand	17	115
Shale	21	136
Lignite	1	137
Sand	15	152
Shale	33	185
Sand and shale	13	198
Sand	48	246
Shale	7	253
Rock	1	254
Sand	34	288
Shale	61	349

Well JZ-34-06-304
(In Franklin County)

Owner: City of Winnsboro.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Soil, sandy	3	3
Clay, yellow	33	36
Sand	60	96
Clay, sandy	4	100
Sand and sandy clay	65	165
Clay, sandy	6	171
Sand	9	180
Clay, sandy	6	186
Sand	12	198
Clay, sandy	12	210
Sand	30	240
Clay, sandy	6	246
Clay, blue, stiff	9	255

Well ZS-34-11-903

Owner: M. E. Jones.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	10	10
Sand, fine-grained	5	15
Clay	16	31
Lignite	8	39
Clay	19	58
Sand, fine-grained	5	63
Shale	27	90
Shale and soapstone	8	98
Shale	30	128
Sand	5	133
Shale	15	148
Lignite	20	168
Shale	8	176
Lignite	30	206
Shale	44	250
Sand, black	2	252
Shale	2	254
Sand	31	285
Shale	14	299
Sand	10	309
Shale	15	324

Well ZS-34-13-102

Owner: Casko Corp.
Driller: White Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay, red	30	30
Lignite	5	35
Shale, blue	21	56
Shale, lignitic	34	90
Shale, gray, and sandy shale	16	106
Lignite	3	109
Shale, gray	5	114
Shale, sandy, and fine sand	9	123
Shale, gray and broken	48	171
Shale, gray, and sandy shale	36	207
Sand, gray, and some shale and lignite	10	217
Shale, hard	13	230
Shale, sandy, and fine sand	90	320
Sand	19	339
Shale, brown	11	350
Shale, sandy, and some streaks of lignite	60	410
Shale, gray	48	458
Shale, sandy	4	462
Rock, hard	2	464
Shale, sandy	6	470
Sand, fine, and sandy shale	22	492
Sand, gray, good	43	535
Sand, fine, and some sandy shale	7	542

Well ZS-34-31-101

Owner: Humble Oil & Refining Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	10	10
Clay with layers of rock	22	32
Clay with layers of lignite	48	80
Sand with thin layers of shale	30	110
Sand, fine-grained	52	162
Lignite	2	164
Sand, coarse-grained	56	220
Sand with layers of lignite	21	241
Shale	6	247

Well ZS-34-31-102

Owner: Humble Oil & Refining Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	4	4
Surface soil and sand	12	16
Clay with layers of rock	33	49
Clay	38	87
Clay and gravel	12	99
Clay	15	114
Sand	52	166
Shale	10	176
Sand	67	243
Shale and lignite	7	250
Shale and sand	26	276
Sand with thin layers of sand	124	400
Sand with layers of sand	58	458
Rock	2	460
Shale	35	495
Shale with layers of sand	29	524
Sand, hard	7	531
Sand with hard streaks	90	621
Shale	5	626

Well ZS-34-31-201

Owner: City of Hawkins.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil, sandy	3	3
Clay, brown and sandy, with thin layers of iron ore	7	10
Clay, sandy, brown, hard	15	25
Clay and lignite, brown, hard	2	27
Rock, hard	1	28
Shale, sandy, and lignite, hard, brown	16	44
Rock	2	46
Shale and rock, hard layers	2	48
Shale and lignite, gray, hard	14	62
Sand, fine-grained, hard, gray	8	70
Shale, gray	5	75
Sand, fine-grained, gray	33	108
Shale, sand, and lignite	6	114
Sand, fine-grained, gray	5	119

(Continued on next page)

Table 9.--Drillers' Logs of Wells in Wood County and Adjacent Areas--Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well ZS-34-31-201--(Cont'd.)		
Shale	2	121
Sand, fine-grained, gray	10	131
Sand, fine-grained, gray, with thin layers of shale	16	147
Sand, gray, with little lignite	38	185
Sand, broken, shale and lignite	13	198
Sand, coarse-grained, gray	21	219
Lignite	7	226
Shale and lignite	6	232
Sand, fine-grained, hard, gray, with layers of shale	9	241
Shale, gray	12	253