GROUND WATER IN THE GRAND (NEOSHO) RIVER BASIN, KANSAS AND OKLAHOMA

By

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ABSTRACT

Ground water in the Grand (Neosho) River basin occurs in both consolidated rocks and unconsolidated deposits. Water for domestic and stock supplies generally can be obtained from wells in either of the above deposits. Water for municipal, industrial, and irrigation supplies generally can be obtained in limited quantities from the unconsolidated deposits of sand and gravel and in adequate quantities from the consolidated rocks in the southeastern part of the area.

The unconsolidated deposits in the basin receive about 226,000 acre-feet of recharge annually, and about 775,000 acre-feet of water is in storage in the deposits. An additional 77 million acre-feet is in storage in the consolidated aquifers. In 1968 about 7,500 acre-feet of ground water was withdrawn for all purposes. About 6,300 acre-feet of surface water and 1,400 acre-feet of ground water was withdrawn for irrigation of 7,600 acres of cropland. The total annual ground-water withdrawal for irrigation may be as much as 20,000 acre-feet by year 2000.

INTRODUCTION

This report, which describes ground water in the Grand River (Oklahoma) and Neosho River (Kansas) basin (fig. 1), was prepared by the U.S. Geological Survey at the request of the U.S. Corps of Engineers, Tulsa District, for inclusion in the Corps' overall planning report on the water resources of the basin. The report is a compilation of available data from previous reports (see Selected References) and from the files of the U.S. Geological Survey and cooperating State agencies. The data generally were collected during water-resources investigations made by the U.S. Geological Survey in cooperation with various State and local agencies and with other Federal agencies. Few additional data were collected for this investigation.

The information contained herein consists primarily of maps showing areal geology, configuration of the potentiometric surface, saturated thickness of unconsolidated deposits, potential yield of wells, and location of selected wells within the basin. Also included is information about the current and projected use of ground water, the amount of ground water in storage, the chemical quality of the ground water, the geologic and hydrologic properties of rocks, and the costs of developing ground-water supplies in the individual counties.

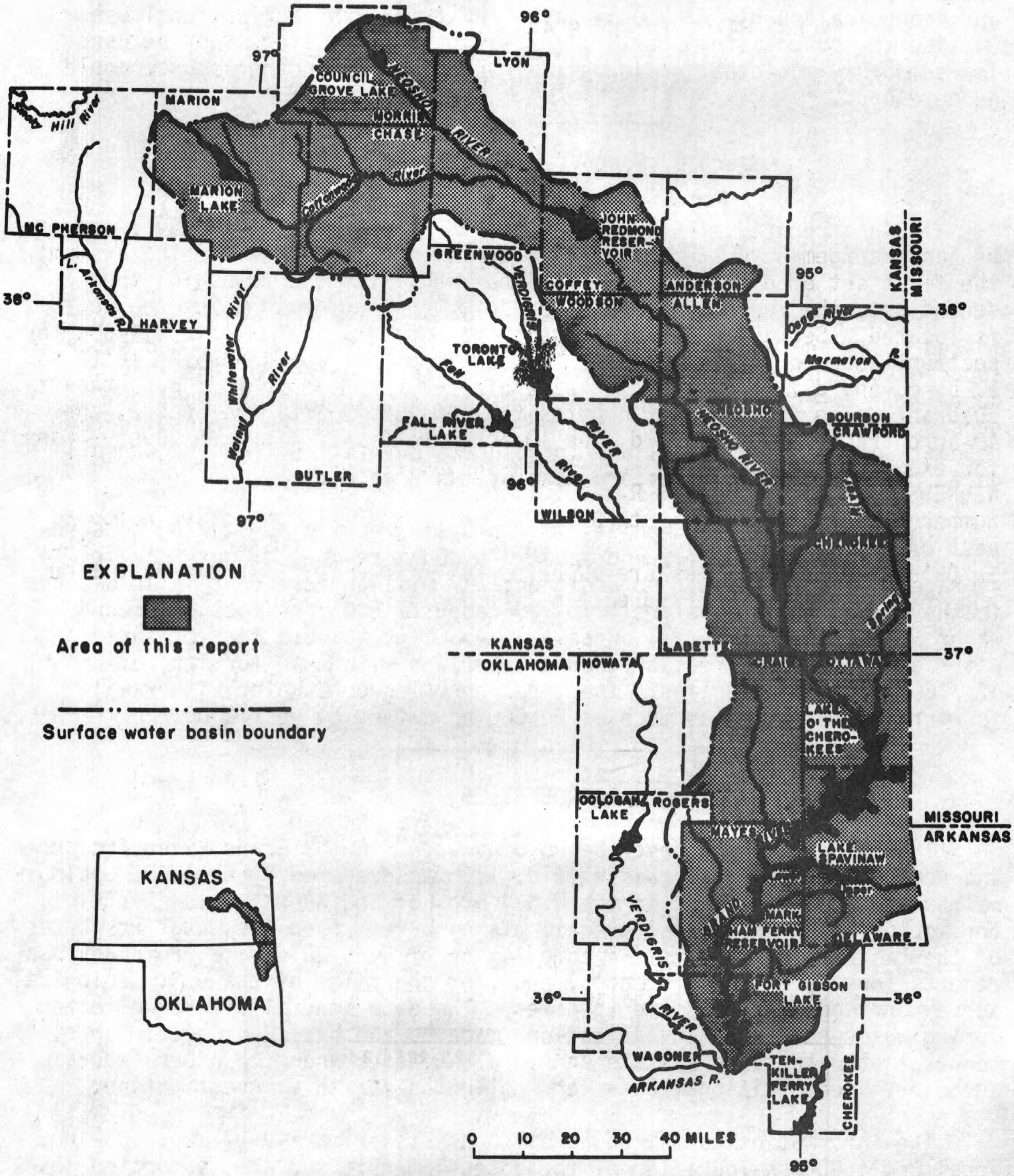

Figure 1.--Location of study area.

The availability of ground water is an important consideration in planning the development of water resources in the Grand River basin. In general, only small supplies are available, but in the southeastern part of the basin large-capacity wells can furnish a dependable and economical supply for municipal, industrial, and agricultural use. Outside the southeastern part of the basin, ground water might be used for temporary municipal or industrial supply until another source could be developed.

WELL-NUMBERING SYSTEM

In this report all wells are numbered according to the U.S. Bureau of Land Management system of land subdivision. In this numbering system, the first set of digits of a well number indicates the township; the second set, the range; and the third set, the section in which the well is located. Sections are subdivided into quarter section, quarter-quarter section, and quarter-quarter-quarter section. The quadrants are lettered a, b, c, and d in a counterclockwise direction beginning in the northeast quadrant. The first letter denotes the 160-acre tract; the second, the 40-acre tract; and the third, the 10-acre tract. In Cherokee County, Kans., for example, the number 32S-22E-12daa indicates that the well is in the NE¼NE¼SE¼ sec.12, T.32 S., R.22 E. (fig. 2). In Kansas the townships are numbered south from the north State boundary and the ranges are numbered east of the sixth principal meridian for the area discussed in this report. In Oklahoma the townships are numbered north from the Oklahoma base line and the ranges are numbered east of the Indian meridian.

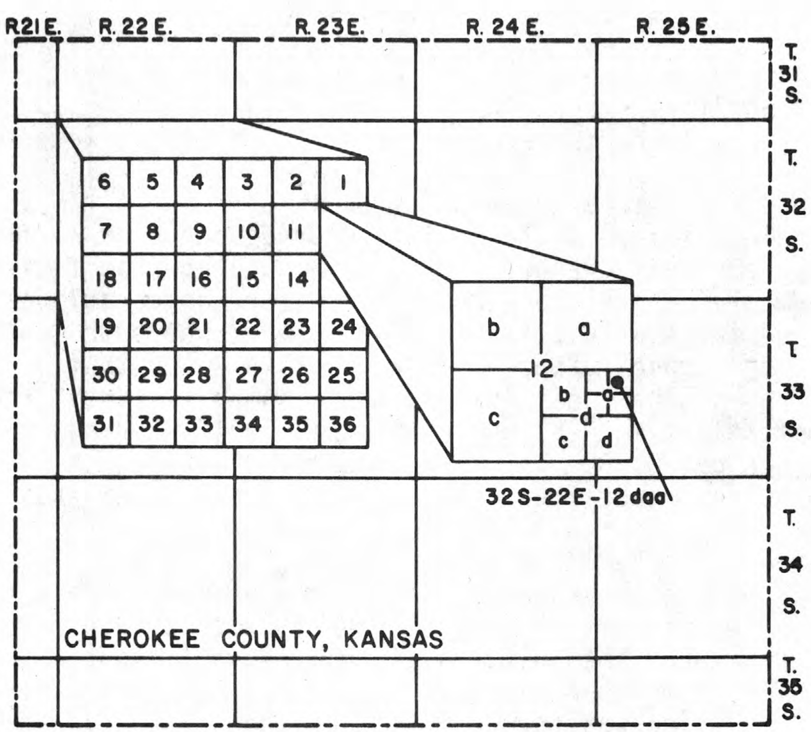

Figure 2.--Well-numbering system.

GEOLOGIC SETTING

The rocks that crop out or that are aquifers in the Grand (Neosho) River basin are grouped, for this report, in two general categories--consolidated and unconsolidated deposits. The consolidated deposits (bedrock), which include formations of Ordovician to Cretaceous age, consist mainly of shale, limestone, sandstone, siltstone, dolomite, and some gypsum. Rocks of Ordovician, Silurian, Devonian, and Mississippian age crop out in the southern part of the basin and are overlain by rocks of Pennsylvanian, Permian, and Cretaceous age northward and westward. The bedrock units generally dip gently westward and northwestward. A series of northeast-trending faults occurs in the southeastern part of the area.

The unconsolidated deposits, which include younger surficial sediments, consist mainly of silt, clay, sand, and gravel of Quaternary age. The thickness of the unconsolidated deposits ranges from less than 10 to more than 60 feet near Emporia (Lyon County), Kans. Unconsolidated deposits overlie the consolidated rocks in the stream valleys and occur as terrace deposits adjacent to the stream valleys and on the uplands.

The principal geologic units in the Grand (Neosho) River basin are listed in table 1, and the areas of outcrop are shown on the geologic maps (pls. 1, 2). Additional information about the geologic units is given in the generalized sections for the individual counties.

GROUND WATER

Aquifer Characteristics

The availability of ground water in an area depends primarily on the ability of the aquifers (rocks that will yield significant quantities of water to wells) underlying the area to store and transmit water.

The storage coefficient (S) of an aquifer is defined as the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The storage coefficient is a dimensionless number. The storage coefficient for the consolidated aquifers might be as large as 0.2 in areas of outcrop where the water is unconfined. Where the consolidated aquifers contain water that is semi-confined or artesian, storage coefficients are assumed to range from 0.0001 to 0.005. The coefficient for the unconsolidated aquifers ranges from 0.01 to 0.2 and averages about 0.15. The lower storage coefficients of the unconsolidated deposits are related to the semiconfined water that occurs locally.

Transmissivity (T) is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. The units for transmissivity are square feet (sq ft) per day. The term "transmissivity" replaces the term "coefficient of transmissibility," which was formerly used by the U.S. Geological Survey and which was reported in the inconsistent units of gallons per day per foot. To convert a value for coefficient of transmissibility to the equivalent value of transmissivity, multiply by 0.134; to convert from

Table 1.--Generalized columnar section of geologic units for the Grand (Neosho) River basin, Kansas and Oklahoma. The stratigraphic nomenclature and correlations used were determined from several sources and may not necessarily follow usage of the U.S. Geological Survey.

System	Kansas			Oklahoma		
	Series	Group	Geologic unit	Series	Group	Geologic unit
Quaternary	Holocene and Pleistocene		Alluvium	Holocene and Pleistocene		Alluvium
			Silt			
			Undifferentiated Pleistocene deposits			Terrace deposits
Cretaceous	Lower Cretaceous		Dakota Sandstone			
			Kiowa Shale			
			Cheyenne Sandstone			
Cretaceous(?)			Igneous rocks			
Permian	Lower Permian	Sumner	Wellington Formation			
		Chase				
		Council Grove				
		Admire				
Pennsylvanian	Upper Pennsylvanian	Wabaunsee				
		Shawnee				
		Douglas				
		Lansing				
		Kansas City				
		Pleasanton				
	Middle Pennsylvanian	Marmaton		Des Moines	Marmaton	
		Cherokee			Cabaniss	
					Krebs	
				Atoka		Atoka Formation
	Lower Pennsylvanian			Morrow		
Mississippian	Upper Mississippian		Warsaw Limestone	Chester		
				Meramec		
	Lower Mississippian		Keokuk Limestone	Osage		Boone Formation
			Burlington Limestone			
				Kinderhook		
Devonian						Chattanooga Shale
Silurian				Niagara	Clinton	St. Clair Limestone
Ordovician	Upper Ordovician			Champlainian	Chazy	Burgen Sandstone
	Lower Ordovician	Arbuckle	Cotter and Jefferson City Dolomites undifferentiated	Canadian	Arbuckle	Cotter Dolomite
						Jefferson City Dolomite
			Roubidoux Formation			Roubidoux Formation
			Gasconade Dolomite			Gasconade Dolomite

transmissivity to coefficient of transmissibility, multiply by 7.48. The transmissivity is equal to the product of aquifer saturated thickness and hydraulic conductivity. Aquifer tests have shown that the transmissivity of the consolidated aquifers ranges from 670 to 33,000 sq ft per day, and of the unconsolidated aquifers ranges from 500 to 3,300 sq ft per day.

The hydraulic conductivity (K) of a water-bearing material is the volume of water at the prevailing kinematic viscosity that will move through a unit cross section of the material in unit time under a unit hydraulic gradient. The units for hydraulic conductivity are feet per day. The term "hydraulic conductivity" replaces the term "field coefficient of permeability," which was formerly used by the U.S. Geological Survey and which was reported in the inconsistent units of gallons per day per square foot. To convert a value for field coefficient of permeability to the equivalent value of hydraulic conductivity, multiply by 0.134; to convert from hydraulic conductivity to coefficient of permeability, multiply by 7.48.

The values for hydraulic conductivity and saturated thickness presented later in this report can be used to estimate the drawdown at various distances from a well discharging at a constant rate. In eastern Crawford County, Kans., for example, the maximum thickness of the Arbuckle Group (see table, p. 42) is 630 feet, which is equal to the saturated thickness (b), and the hydraulic conductivity (K) ranges from 5 to 60 feet per day. The hydraulic conductivity in the Pittsburg area is about 50 feet per day. This figure was used to compute transmissivity as follows:

$$T = bK = (630)\ (50) = 31{,}500 \text{ sq ft per day}$$

The storage coefficient (S) for this aquifer is 0.0007 (Stramel, 1957). These transmissivity and storage values were used to construct the lines on figure 3. The theory, mathematical equations, and assumptions for constructing such graphs are described by Theis (1935), Wenzel (1942), and Jacob (1950). The graphs as shown on figure 3 can be used to compute the mutual interference of wells as defined in most text books on ground-water hydrology. Examples of the use of these curves are given by Fader (1957, 1967).

Availability

The yield of a well depends on the thickness and hydraulic conductivity of the water-bearing materials, the amount of penetration of these materials by the well, the diameter of the well, the efficiency of the well screen, the efficiency of the pump, and other factors. Because of the wide range in these factors, well yields cannot be predicted accurately. However, an estimate of yield is possible if the following assumptions are made: (1) sites for the wells are selected after proper test drilling, (2) wells are constructed to specifications used by successful drillers in the area, (3) properly designed pumping equipment is used, (4) the wells penetrate the entire thickness of the aquifer, and (5) hydraulic conductivity of the water-bearing materials is uniform. In practice, the hydraulic conductivity of the materials differs considerably owing to the heterogeneous distribution of the materials in the aquifer. Thus, a well screened in coarse gravel in an area where

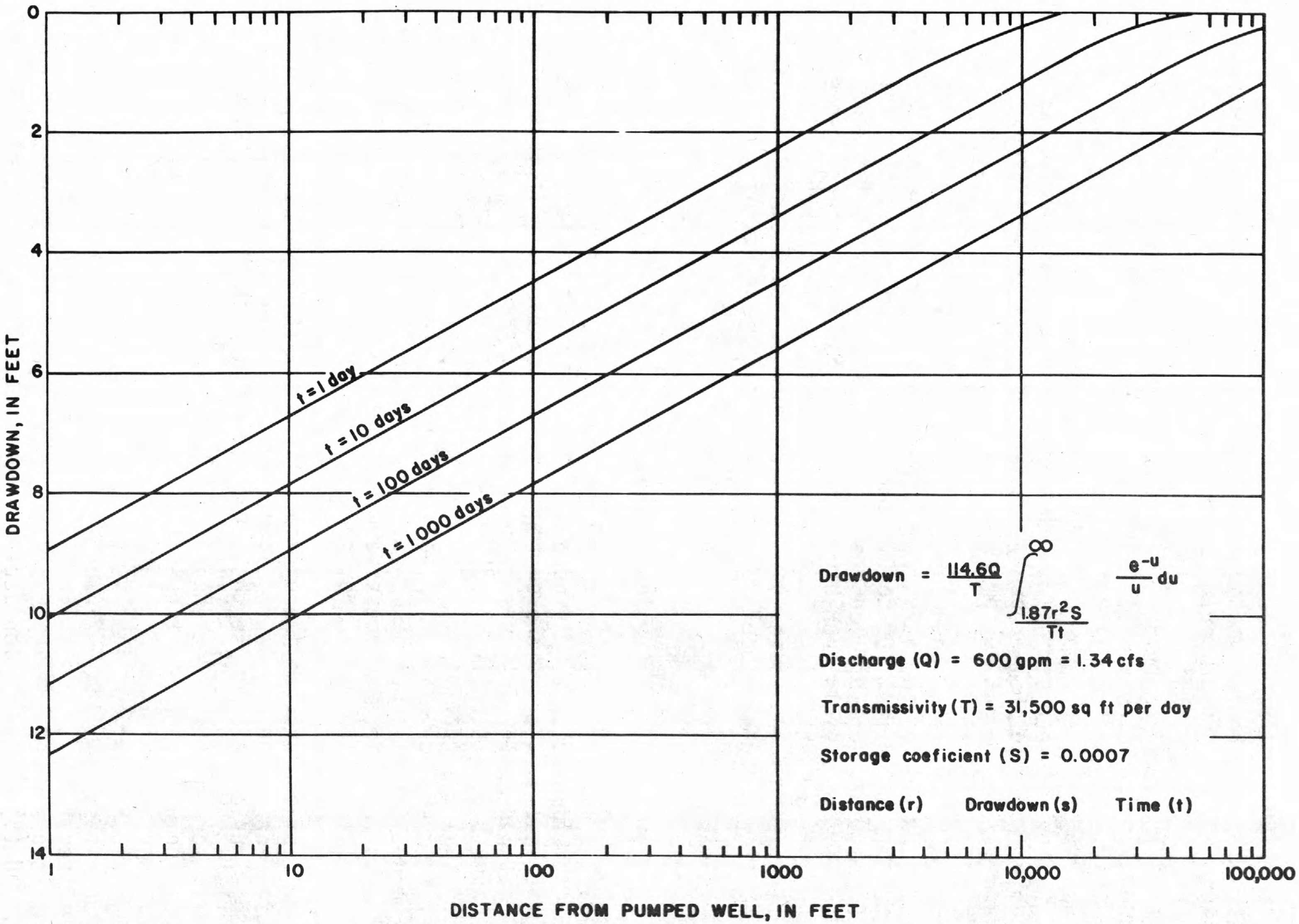

Figure 3.--Theoretical drawdown of water level at various distances from a well discharging at a constant rate.

the saturated thickness is less than 10 feet may yield more water than a well screened in fine-grained material having a much greater saturated thickness.

Plates 3 and 4 show estimated well yields, which indicate the general availability of water to properly constructed wells.

Sufficient saturated thickness of unconsolidated deposits to yield water to wells occurs only in the stream valleys or the adjacent terraces in the Grand (Neosho) River basin. Yields to wells screened in these deposits have been reported to be 100 gpm (gallons per minute), or 0.22 cfs (cubic feet per second). Although yields of 150 gpm (0.33 cfs) are probably available from properly constructed wells in some areas, the average yield is about 30 gpm (0.07 cfs).

In general, yields of good quality water from shallow wells in areas of outcrop of consolidated rocks range from 0 to 100 gpm in the northwestern part of the basin and from 100 to 500 gpm (1.10 cfs) in the southeastern part. If the wells were drilled deeper to penetrate a larger thickness of aquifer, the well yield probably would be greater, but water in some areas might be so highly mineralized that it would be unusable. In the southeastern part of the basin, yields of as much as 1,000 gpm (2.23 cfs) of good quality water have been reported from wells penetrating Ordovician rocks.

Chemical Quality

Chemical analyses of water from selected wells are given in tables for each individual county. In general, water from Ordovician rocks is of good chemical quality in the eastern part of the basin. Except for the areas of outcrop, water from the consolidated aquifers of Mississippian age and younger is generally of poor chemical quality. In the outcrop areas, the aquifers receive small amounts of fresh water from precipitation and water from shallow wells is probably of good chemical quality, but the water from deeper wells may be of poor chemical quality. Little or no precipitation for several successive years may cause deterioration in the chemical quality of the water from shallow wells.

Water from the unconsolidated deposits is generally of good chemical quality for irrigation and of fair chemical quality for most other uses. Some municipalities use the water without treatment (other than chlorination). Water from the alluvium generally is very hard.

Extent of Development

Annual Withdrawals

In 1968 about 7,500 acre-feet of ground water was withdrawn for all uses in the Grand (Neosho) River basin. About 2,500 acre-feet of this amount was from the unconsolidated aquifers and 5,000 acre-feet was from the consolidated aquifers of Ordovician age. Of the approximately 7,700 acre-feet of water used to irrigate 7,600 acres of cropland, about 1,400 acre-feet was ground water. Withdrawals from the Ordovician aquifers have increased considerably since 1965, probably as a result of the increased number of rural water districts.

Water-Level Changes

Representative changes in water level in the Grand (Neosho) River basin are shown by hydrographs (fig. 4). Hydrographs for wells 20S-7E-13cb and 32S-24E-19c, which are outside the areas of extensive pumping, generally show water-level fluctuations in the bedrock aquifers. The hydrograph for well 20S-17E-13cb represents water-level changes in wells in the outcrop areas of the bedrock aquifers, and it reflects water-level fluctuations due to changes in climate. The hydrograph for well 32S-24E-19c represents water-level fluctuations in wells screened in the deeper Ordovician rocks. The general downward trend is due to pumping throughout the area, mostly for public supplies, and to the almost negligible rate of recharge.

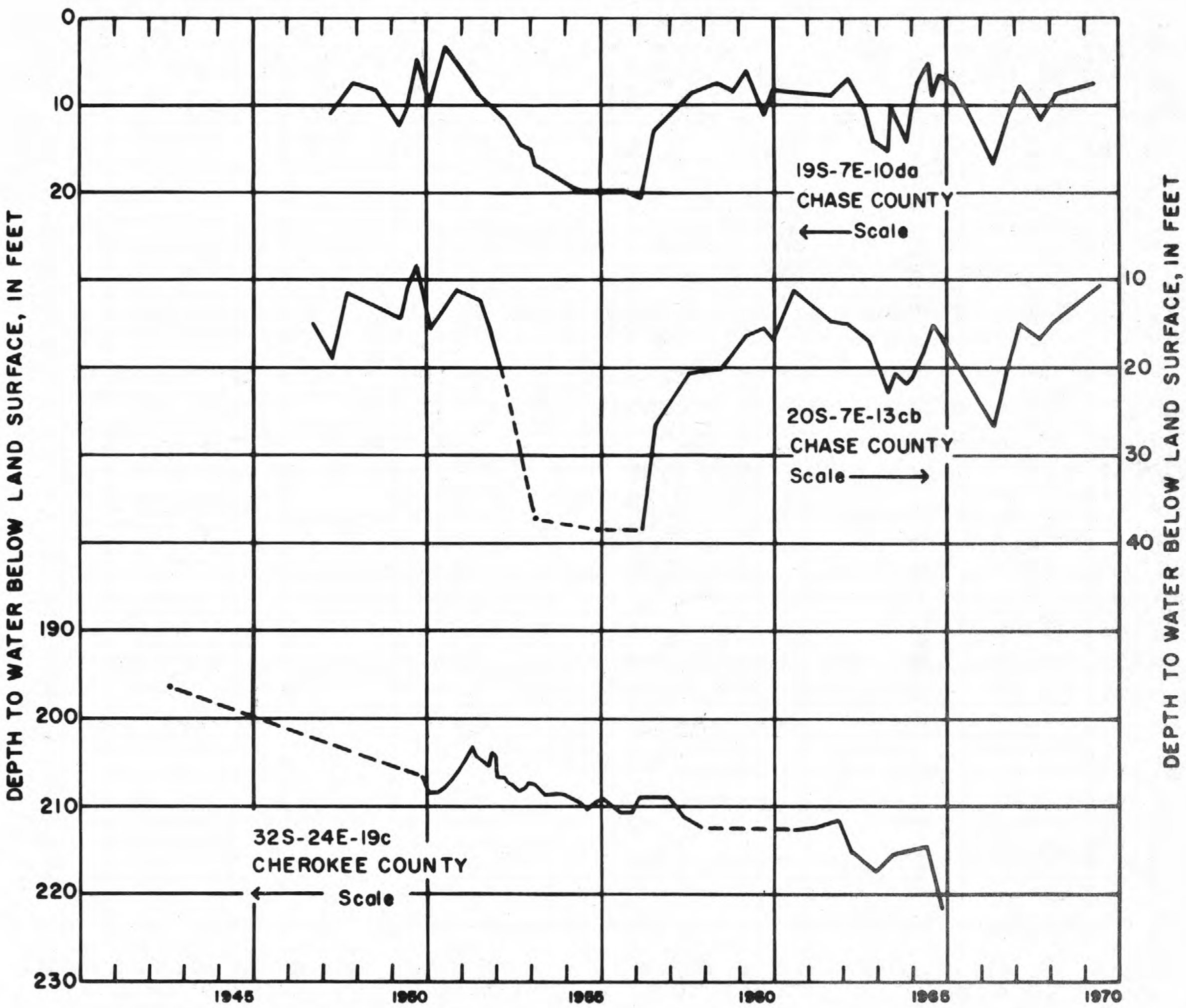

Figure 4.--Hydrographs for three selected wells.

The fluctuations shown by the hydrograph for well 19S-7E-10da are typical for wells screened in the alluvial aquifers of the Grand (Neosho) River and its tributaries. The water-levels, which are not influenced by nearby pumping, indicate changes in climate. The 10-foot decline of water level for several years during the 1950's is approximately 50 percent of the saturated thickness of the aquifer and, consequently, created a significant reduction in transmissivity.

Potential for Development

Ground-Water Storage

The amount of ground water in storage in the Grand (Neosho) River basin is larger in the consolidated aquifers than in the unconsolidated aquifers. Most of the usable water is stored in the upper 300 feet or less of the aquifers in the outcrop area. The more mineralized water below 300 feet generally is not usable for most purposes. However, a large amount of usable water is stored in the deeper Ordovician and Mississippian aquifers in the eastern part of the area and in the Chase Group in the western part of the area. The distribution of the 77 million acre-feet of water stored in the consolidated aquifers is as follows: 8 million acre-feet of water of fair to poor chemical quality in the outcrop areas, 5 million acre-feet of water of poor to fair chemical quality in the Chase Group, 20 million acre-feet of water of fair to poor chemical quality in the Mississippian rocks, and 44 million acre-feet of water of fair to good chemical quality in the Ordovician aquifers.

The amount of ground water in storage in the unconsolidated aquifers is about 775,000 acre-feet, most of which is in stream valleys. This estimate was determined by multiplying the volume of saturated unconsolidated deposits in the basin by a storage coefficient of 0.15. However, this volume of water does not represent the amount that can be pumped; drilling enough wells to drain all the water from the aquifer is not economically feasible. As water levels are lowered by pumping, the saturated thickness decreases, well yields decrease, and pumping lifts increase; thus, pumping becomes impractical or uneconomical for most users before the aquifer is completely dewatered. Due to the natural drainage of the aquifers, the estimated ground water in storage may be reduced considerably during periods of drought (negligible recharge) and would not be available for use when most needed.

Annual Recharge

The unconsolidated aquifers are recharged at an average rate of about 226,000 acre-feet annually. This figure is the sum of the estimates given in the second page of the individual county discussions. Recharge to the consolidated aquifers was not estimated but is believed to be less than one-fourth inch per year.

Projected Development

The unconsolidated aquifers have not been extensively developed in the area, mainly because surface water is generally available and is commonly of better chemical quality. Small well fields, capable of producing as much as 200,000 gallons per day, generally can be developed in the alluvial valleys, but owing to the thin aquifers and low storage capabilities, yields may be less during a year of drought.

The withdrawals of ground water from the alluvial valleys could be increased considerably at a cost of installing large numbers of low-yielding wells and connecting pipe lines. If this were done, the unconsolidated aquifers would be seriously depleted in the areas of the wells, and flows would be reduced in the nearby streams. However, recharge is rapid in the stream valleys and the aquifers probably would be refilled during the first period of adequate rainfall.

The consolidated aquifers have not been extensively developed throughout most of the area, mainly because of the generally poor quality of the water. However, water of fair to good chemical quality is pumped for municipal and industrial use from the Mississippian and Ordovician rocks in the southeastern part of the area. Recharge to these aquifers is probably less than one-fourth inch per year; thus, almost any water pumped is permanently removed from the estimated 69 million acre-feet in storage in the consolidated aquifers in the basin.

The annual withdrawals of ground water for irrigation may be as much as 20,000 acre-feet in the year 2000.

Large withdrawals of ground water would cause significant lowering of water levels and could eventually reduce or deplete the flow in the streams of the area. The extent and rate of withdrawals of ground water eventually will become a management decision. A digital-computer or electrical analog model to estimate the effects of withdrawals on ground-water levels and on streamflow would aid in making these decisions and should be planned for future projects. Although models are available, a model study was beyond the scope of this project.

GROUND WATER BY COUNTIES

Sources of Data and Methods of Estimation

The first part of each county discussion contains a generalized columnar section of the geologic formations that are in the subsurface or are shown on plates 1 and 2, and estimates of the water-bearing properties of the formations. The information given is from existing ground-water reports for the county described or is estimated from information in reports on adjacent counties and from information in the files. Estimates of yields to wells are based on information given in existing county reports, on maps by Bayne and Ward (1967) and Schoff (1955), and on information in the files of the Oklahoma Water Resources Board. The ranges of yield shown are generalized from very limited data and the reader is cautioned that the upper limit of the ranges shown may not be available at any given site. The values for hydraulic conductivity are based on aquifer tests or are estimates by the authors.

The comments about chemical quality of water shown in the remarks column of the generalized section were compiled from previous reports or from information in the files. In general, the chemical quality of water for municipal and domestic use was described as good if the water contained concentrations of less than 500 mg/l (milligrams per liter) dissolved solids or less than 250 mg/l chloride and sulfate, fair if it contained between 500 and 1,000 mg/l dissolved solids or between 250 and 500 mg/l chloride and sulfate, and poor if it contained more than 1,000 mg/l dissolved solids or more than 500 mg/l chloride and sulfate. However, because the suitability of the water was not defined by previous authors, the evaluations shown for each county should be used only as guidelines.

The second part of each county discussion contains related hydrologic information. The estimated irrigated area for Kansas is from R. L. Herpich (written commun., 1970) and for Oklahoma is from data provided by the Oklahoma Water Resources Board, or the Oklahoma State University Irrigation Specialist. The value for acre-feet of water applied in Kansas was determined from the 1966 rate of application computed from the report by the Kansas Water Resources Board (1967), and in Oklahoma was estimated by the authors. The estimated volume of ground water pumped by municipal and industrial users is from data in the files compiled for the report by Murray (1968) and from data reported to the Oklahoma Water Resources Board. The projected irrigated area in the year 2000 for Kansas is from the Kansas Water Resources Board (1967) (modified by the authors' estimate of water available in a few instances), and for Oklahoma was estimated by the authors.

The estimated annual recharge to the unconsolidated aquifers in Kansas was modified from a report by the Kansas Water Resources Board (1967). The annual recharge in Oklahoma was estimated by the authors from data published in previous ground-water reports and from the base flow in the streams in the area as shown by the U.S. Geological Survey (1968, 1969). The annual recharge to the consolidated aquifers was not estimated.

The amount of ground water in storage in the unconsolidated deposits was estimated from data published by the Kansas Water Resources Board (1967), a map by Bayne and Ward (1969), and from data compiled by the authors.

The estimated cost per 1,000 gallons of water from a well field capable of producing a minimum of 1 million gallons per day includes the following: cost of construction of one or more wells allocated on the basis that large-capacity wells are used one-fourth of the year, cost of pumping equipment connected to the power and water lines at the well site, interest cost at 6½ percent for a period of 25 years, and cost of power for pumping. The estimated cost does not include the cost of water lines from the well field to the consumer or the cost of electrical power lines to the pumps. The cost data in this report are principally for municipal systems. The cost per 1,000 gallons for an irrigation system may be one-third to two-thirds that shown in this report.

In some counties the only source of ground water is the thin alluvial aquifers in the valleys or the upper parts of the consolidated aquifers. One or more low-yielding wells may produce sufficient water from these aquifers for small communities, but a well field capable of producing 1 million gallons per day may not be economically feasible, owing to the number of wells required and the necessarily large distance between wells to reduce interference. In these counties, the cost estimate for producing 1 million gallons per day is omitted or restated for 100,000 gallons per day.

The third part of each county discussion contains a table of chemical analyses of water from selected wells. The concentrations for the chemical constituents and hardness are from previous reports or from the files of the U.S. Geological Survey. In Kansas most of the water samples were analyzed by the Division of Environmental Health of the Kansas State Department of Health. In Oklahoma the samples were analyzed by the U.S. Geological Survey.

Plates 1 and 2 are geologic maps showing potentiometric contours; the maps were modified from existing State Geological Survey of Kansas reports and State geologic maps. Where no previous report showed potentiometric contours, the contours were inferred from reported water levels and from points where land-surface contours crossed perennial streams. Few additional data were collected for this report; therefore, most of the potentiometric contours represent data collected during a period of about 20 years. In general the potentiometric contours were mapped as water-table contours in the previous reports. However, the authors of this report are of the opinion that water in parts of the area is semiconfined, and the term "potentiometric contour" is more appropriate.

Plates 3 and 4 are maps showing generalized potential well yield, saturated thickness of unconsolidated deposits, and location of selected wells. The data for the maps showing yield and saturated thickness were modified from the same sources as those used to estimate the water in storage. In some areas shown as unconsolidated deposits on the geologic maps, the saturated thickness is not known or is less than the interval shown in the explanation. These areas are outlined by zero-saturated-thickness lines on the saturated thickness map. In areas where the saturated thickness of unconsolidated deposits is small for the well yields shown, the yields are from one or more consolidated aquifers or from both consolidated and unconsolidated aquifers. The ranges of yield shown are generalized from very limited data and the reader is cautioned that the maximum yields of the ranges shown may not be available at any given site. The locations of the wells were obtained from previous ground-water reports, from applications for water rights as shown by the Kansas Water Resources Board (1967), from the files of the Oklahoma Water Resources Board, and from the files of the U.S. Geological Survey. None of the locations were field checked; therefore, some duplication can be expected from the two sources of information. Also, a number of the applications are never completed (the wells are never drilled); consequently, more wells may be shown than actually existed in 1966.

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	35	Silt, clay, fine sand, and gravel. Gravel generally in the lower 4 feet.	0-100	70-700	Water probably highly mineralized. Yields may decrease considerably during drought years.
			Undifferentiated Pleistocene deposits	35	Silt, clay, fine sand, and gravel.	0-100	10-200	Water probably highly mineralized. Yields may decrease considerably during drought years.
Pennsylvanian	Upper Pennsylvanian	Douglas		30	Bluish-gray clayey to sandy shale.	0-10	--	Water may be of poor chemical quality.
		Lansing		80	Predominately limestone with shale and sandy shale.	0-10	--	Water may be of poor chemical quality.
		Kansas City		320	Limestone and sandy-silty shale beds, with some sandstone.	0-10	--	Water may be of poor chemical quality.

The irrigated area in 1968 was 480 acres and 450 acre-feet of surface water was applied. No ground water was pumped for irrigation, municipal, or industrial supply. The irrigated area in year 2000 may be about 1,100 acres. The unconsolidated deposits receive 15,000 acre-feet of recharge annually, and 50,000 acre-feet of water is in storage. The depth to water is generally less than 20 feet in the major stream valleys and ranges from 5 to 90 feet in the uplands. The estimated cost of water from a well field capable of producing 100,000 gallons per day from the alluvium is $0.20 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
23S-20E-33aad	190	3- 5-65	Kansas City Group	1,960	1,000	170	1,100
24S-18E-17aad	17	3- 5-65	Alluvium	347	32	21	340
24S-20E-31ccd	200	3- 5-65	Kansas City Group	378	120	53	170
25S-21E-32aab	70	6-30-65	Kansas City Group	434	73	22	380
26S-18E-13cbc	120	6-28-65	Kansas City Group	911	88	130	590
26S-19E-27bbc	130	3-26-65	Kansas City Group	824	210	91	180

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	30	Silt, clay, sand, and some cherty gravel in lower parts.	0-30	40-130	Water probably highly mineralized. Yields may decrease considerably in drought years.
Pennsylvanian	Upper Pennsylvanian	Shawnee		70	Limestone and shale with some silty shale.	0-10	--	Water may be of poor chemical quality.
		Douglas		200	Sandstone, shale, and sandy shale with few thin limestone beds.	0-50	--	Water may be of poor chemical quality.
		Lansing		80	Predominately limestone with shale and sandy shale.	0-10	--	Water may be of poor chemical quality.
		Kansas City		320	Limestone and sandy-silty shale with some sandstone.	0-10	--	Water may be of poor chemical quality.

The irrigated area in 1968 was 500 acres and a total of 500 acre-feet of water was applied. Of this total, about 125 acre-feet was ground water. No ground water was pumped for municipal or industrial supply. The irrigated area in year 2000 may be about 1,000 acres. The unconsolidated deposits receive about 12,000 acre-feet of recharge annually and 30,000 acre-feet of water is in storage. The depth to water is generally less than 20 feet in the major stream valleys and ranges from 10 to 65 feet in the uplands. The estimated cost of water from a well field capable of producing 100,000 gallons per day from the alluvium is $0.50 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collec-tion	Geologic source	Dis-solved solids	Sul-fate (SO_4)	Chlo-ride (Cl)	Total hard-ness as $CaCO_3$
19S-21E-19aab	42	4- 4-67	Alluvium	425	46	28	310
20S-19E-26bcd	95	12-13-67	Lansing Group	644	52	46	480
21S-19E-14bba	155	12-18-67	Kansas City Group	453	32	22	220
22S-18E-19aaa	21	12-18-67	Douglas Group	129	12	5.0	92
23S-18E- 6ddd	32	12-19-67	Alluvium	306	58	23	180
23S-21E- 5abb	100	12-19-67	Kansas City Group	1,540	150	470	64

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	60	Gravel, sand, silt, and clay. Finer materials in the smaller stream valleys.	0-150	10-200	Water probably highly mineralized. Yields may decrease considerably during drought years.
Quaternary	Pleistocene and Holocene		Undifferentiated Pleistocene deposits	40	Chert gravel, quartz sand, silt, and clay.	0-40	70-270	Water probably highly mineralized. Yields may decrease considerably during drought years.
Permian	Lower Permian	Sumner		40	Red, green, and blue shale; few thin limestone beds.	0-10	--	Water may be of poor chemical quality.
Permian	Lower Permian	Chase		300	Limestone, shale, and sandy shale. Some dolomite.	0-100	10-70	Wells yielding 500 gpm may be available in the western part of the county. Water may be of poor chemical quality.
Permian	Lower Permian	Council Grove		300	Limestone, shale, and sandy shale. Some dolomite and gypsum.	0-10	--	Water may be of poor chemical quality.
Permian	Lower Permian	Admire		75	Shale and sandy shale. Some limestone and sandstone.	0-10	--	Water may be of poor chemical quality.

The irrigated area in 1968 was 250 acres and 250 acre-feet of surface water was applied. About 150 acre-feet of ground water was pumped for municipal supply. The irrigated area in year 2000 may be about 1,000 acres. The unconsolidated deposits receive 18,000 acre-feet of recharge annually, and 100,000 acre-feet of water is in storage. In addition, about 1 million acre-feet of water is stored in rocks in the Chase Group. The depth to water generally is less than 20 feet in the major stream valleys and ranges from 20 to 85 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the alluvium is $0.07 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
18S- 6E-12da	34	4-16-48	Council Grove Group	414	32	27	360
19S- 7E-22ac	51	4-16-48	Council Grove Group	1,220	64	490	380
19S- 8E- 5ba	39	6-24-48	Alluvium	310	15	5.5	280
19S- 9E-16ad	30	12- 9-68	Alluvium	940	180	150	580
20S- 7E-27da	112	4-14-48	Chase Group	357	14	8.5	330
21S- 8E-15ba	64	3-19-69	Council Grove Group	1,090	110	87	690
22S- 6E-18dc	56	4-14-48	Chase Group	375	18	8.8	400

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	35	Silt, clay, sand, and gravel. Generally 4 or 5 feet of chert gravel at the base.	0-100	70-700	Yields may decrease considerably during drought years.
			Undifferentiated Pleistocene deposits	40	Silt and clay in the upper part with some sand and gravel at the base.	0-50	10-200	Yields may decrease considerably during drought years.
Pennsylvanian	Middle Pennsylvanian	Marmaton		80	Shale, sandy shale, limestone, and sandstone.	0-5	--	Water probably of poor chemical quality.
		Cherokee		250	Gray shale with some pyrite and few thin coal beds.	0-5	--	Water probably of poor chemical quality.
Mississippian	Upper Mississippian		Warsaw Limestone	90	Cherty limestone and dolomite.	0-5	--	Water probably of poor chemical quality.
	Lower Mississippian		Keokuk and Burlington Limestones	175	Gray and dark-brown cherty limestone and dolomite with some siltstone.	100-500	10-50	Water probably highly mineralized, but used for some purposes.
Ordovician	Lower Ordovician	Arbuckle	Cotter and Jefferson City Dolomites undifferentiated	430	Gray cherty dolomite with some limonite.	100-1,000	1-10	Subsurface unit. Water of good chemical quality generally available. May be highly mineralized in northwestern part of county.
			Roubidoux Formation	160	Gray cherty sandstone and dolomite with some shale.			
			Gasconade Dolomite	65	Gray cherty dolomite.			

The irrigated area in 1968 was 220 acres and 200 acre-feet of surface water was applied. About 1,300 acre-feet of ground water was pumped for municipal and industrial supplies. The irrigated area in year 2000 may be about 300 acres. The unconsolidated deposits receive about 20,000 acre-feet of recharge annually, and 60,000 acre-feet of water is in storage. In addition, about 1 million acre-feet of water is stored in the Mississippian rocks and about 22 million acre-feet of water is stored in the Ordovician rocks. The depth to water is generally less than 20 feet in the major stream valleys, from 5 to 300 feet in the Pennsylvanian and Mississippian aquifers, and from 82 to 370 feet in the Ordovician aquifers. The estimated cost of water from a well field capable of producing 1 million gallons per day from the consolidated rocks ranges from $0.07 to $0.37 per 1,000 gallons and averages $0.18.

Water of poor to fair chemical quality may be obtained from the Mississippian aquifers and water of fair to good chemical quality may be obtained from the Ordovician aquifers. Typical depth intervals for rocks of various ages are as follows: Pennsylvanian from land surface to 215 feet, Mississippian from 215 to 530 feet, and Ordovician from 530 to 1,110 feet. The Roubidoux Formation, from 880 to 1,015 feet below land surface, is the principal water-bearing unit of the deep aquifers. Water in the deeper aquifers is generally confined.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
32S-22E- 7aac	12	6-13-63	Alluvium	1,660	1,000	7.0	890
32S-22E-12daa	100	8-27-64	Cherokee Group	874	80	37	90
33S-23E-13baa	1,026	8- 2-67	Roubidoux Formation	488	80	63	260
33S-25E-34ccc	14	6-27-63	Alluvium	668	210	34	460
34S-25E-19b	18	3-23-63	Undifferentiated Pleistocene deposits	642	310	57	320
34S-25E-23ada	1,177	4- 4-66	Roubidoux Formation	217	35	7.0	190

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	30	Dark-gray and brown silt and silty clay, clay, and fine sand. Silty sand, sand, and gravel in basal part. Some chert gravel.	0-50	10-200	Yields may decrease considerably during drought years.
			Undifferen-tiated Pleistocene deposits	40	Clay, silt, sand, and gravel.	0-50	10-200	Yields may decrease considerably during drought years.
Pennsylvanian	Upper Pennsylvanian	Wabaunsee		180	Limestone and shale beds with a few sandstone and sandy shale zones. Also a thin coal bed.	0-10	--	Water may be of poor chemical quality. Yields from shallow wells may decrease considerably during drought years.
		Shawnee		350	Predominately limestone and shale with thin sandstone and sandy shale zones.	0-10	--	Water may be of poor chemical quality. Yields from shallow wells may decrease considerably during drought years.
		Douglas		300	Sandstone, shale, and sandy shale with a few thin limestone beds.	0-50	--	Water may be of poor chemical quality.

The irrigated area in 1968 was 150 acres and 120 acre-feet of surface water was applied. About 22 acre-feet of ground water was pumped for municipal supply. The irrigated area in year 2000 may be about 700 acres. The unconsolidated deposits receive about 20,000 acre-feet of recharge annually, and 100,000 acre-feet of water is in storage. The depth to water is generally less than 20 feet in the major stream valleys and ranges from 5 to 185 feet in the uplands. The estimated cost of water from a well field capable of producing 100,000 gallons per day from the alluvium is $0.32 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collec-tion	Geologic source	Dis-solved solids	Sul-fate (SO_4)	Chlo-ride (Cl)	Total hard-ness as $CaCO_3$
19S-14E-10c	75	8-10-54	Wabaunsee Group	689	220	13	450
19S-16E-24cbc	268	11- 8-66	Shawnee Group	535	73	36	68
21S-15E-10ddd	20	4-15-68	Alluvium	439	32	11	390
21S-17E- 4baa	20	7-10-68	Douglas Group	794	190	39	440
22S-17E-33cdd	30	7-10-68	Douglas Group	333	23	43	140
23S-16E-11dbb	41	7-10-68	Alluvium	377	48	14	260

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	25	Silt, clay, and silty sand with thin bed of sand or gravel in basal part.	0-20	10-20	Water probably highly mineralized.
Pennsylvanian	Upper Pennsylvanian	Kansas City		50	Limestone and shale.	0-10	--	Water probably highly mineralized.
		Pleasanton		90	Shale, limestone, and sandstone.	0-10	--	Water probably highly mineralized.
	Middle Pennsylvanian	Marmaton		300	Shale, sandy shale, limestone, and sandstone.	0-5	--	Water probably highly mineralized.
		Cherokee		250	Gray shale and limestone with some pyrite and few thin coal beds.	0-5	--	Water probably highly mineralized.
Mississippian	Lower Mississippian			350	Gray cherty shale, cherty limestone, and dolomite with some pyrite and and glauconite.	100-500	10-50	Subsurface unit. Water probably highly mineralized, but used for some purposes.
Ordovician	Lower Ordovician	Arbuckle	Cotter and Jefferson City Dolomites undifferentiated	375	Gray cherty dolomite with some limonite.	100-1,000	5-60	Subsurface unit. Water of good chemical quality obtainable in eastern part of county.
			Roubidoux Formation	75	Gray sandy dolomite and sandstone with some shale.			
			Gasconade Dolomite	180	Gray cherty dolomite.			

The irrigated area in 1968 was 20 acres and 15 acre-feet of surface water was applied. About 3,500 acre-feet of ground water was pumped for municipal and industrial supplies. The irrigated area in year 2000 may be 1,000 acres. The unconsolidated deposits receive about 8,000 acre-feet of recharge annually. About 10,000 acre-feet of water is stored in the unconsolidated deposits, about 630,000 acre-feet of water is stored in the Mississippian rocks, and 1.1 million acre-feet of water is stored in the Ordovician rocks in the eastern half of the county. The depth to water is generally less than 20 feet in the major stream valleys, from 20 to 50 feet in the shallow aquifers in the uplands, and from 150 to 250 feet in the deeper aquifers. The estimated cost of water from a well field capable of producing 1 million gallons per day from the consolidated rocks ranges from \$0.09 to \$0.53 per 1,000 gallons and averages about \$0.29.

Water of poor to fair chemical quality can be obtained from the Pennsylvanian and Mississippian rocks and water of fair to good chemical quality may be obtained from the Ordovician rocks in the eastern part of the county. Typical depth intervals for rocks of various ages are as follows: Pennsylvanian from land surface to 240 feet, Mississippian from 240 to 600 feet, and Ordovician from 600 to 1,250 feet. The Roubidoux Formation of Ordovician age, from 975 to 1,050 feet below land surface, is the principal water-bearing unit of the deeper aquifers. Water in the deeper aquifers generally is confined.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
27S-23E-25ddd	42	5-21-70	Marmaton Group	778	130	100	550
28S-22E-20cc	1,015	10- 4-67	Roubidoux Formation	1,540	93	680	300
28S-22E-20ccd	50	1- 7-54	Alluvium	496	40	29	260
28S-25E- 3aaa	11	5-21-70	Cherokee Group	1,440	740	85	550
29S-22E-14dcc	128	5-21-70	Marmaton Group	570	150	74	410
30S-25E-19ccc	1,420	2-16-59	Roubidoux Formation	543	84	97	320

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	35	Clay, silt, sand, and chert gravel. Chert gravel generally in the basal 10 feet beneath flood plains and terraces adjacent to the present stream channels.	0-100	20-70	Yields may decrease considerably during drought years.
			Undifferentiated Pleistocene deposits	20		0-20	10-40	Yields may decrease considerably during drought years.
Pennsylvanian	Upper Pennsylvanian	Kansas City		300	Shale, sandy shale, sandstone, and limestone.	0-10	--	Water may be of poor chemical quality.
		Pleasanton		250	Limestone and shale.	0-5	--	Water probably of poor chemical quality.
	Middle Pennsylvanian	Marmaton		250	Shale, sandy shale, sandstone, limestone, and siltstone.	0-40	--	Water may be of poor chemical quality.
		Cherokee		140	Shale, sandy shale, sandstone, limestone, and some thin coal beds.	0-10	--	Water of poor chemical quality from upper part; may be highly mineralized in eastern part of county.
Mississippian				360	Gray and blue shale with limestone and sandy shale beds.	0-10	--	Subsurface unit. Water may be of poor chemical quality. Generally high in sulfate concentration.
Ordovician	Lower Ordovician	Arbuckle	Cotter and Jefferson City Dolomites undifferentiated	245	White and gray limestone and dolomite with chert and sandstone.	10-100	1-10	Subsurface unit. Water of good chemical quality may be available in southeastern part of county.
			Roubidoux Formation	350	White and gray loose sandstone and cherty limestone.			
			Gasconade Dolomite	150	Cherty limestone and sandstone.			

The irrigated area in 1968 was 200 acres and 180 acre-feet of surface water was applied. No ground water was pumped for municipal or industrial supply. The irrigated area in year 2000 may be 800 acres. The unconsolidated deposits receive about 20,000 acre-feet of recharge annually, and 50,000 acre-feet of water is in storage. The depth to water generally is less than 15 feet in the major stream valleys and ranges from 5 to 60 feet in the uplands. Depth to water in the deeper Ordovician aquifers ranges from 90 to 240 feet in the southeast corner of the county, and the water generally is confined. The estimated cost of water from a well field capable of producing 100,000 gallons per day from the alluvium is $0.20 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
31S-17E-11da	190	2-18-65	Kansas City Group	617	120	67	220
31S-19E-28bb	74	6-18-64	Pleasanton Group	1,300	210	83	270
31S-21E- 7bb	88	6-19-64	Marmaton Group	2,870	250	1,200	590
31S-21E- 9cc	28	6-22-64	Undifferentiated Pleistocene deposits	439	20	7.0	400
31S-21E-22aa	33	2-18-65	Undifferentiated Pleistocene deposits	1,710	920	44	970
33S-18E-33cb	23	2-18-65	Marmaton Group	1,120	89	76	650
34S-21E-29cd	102	7- 9-65	Cherokee Group	1,670	660	100	180

LYON COUNTY, KANSAS

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	50	Silt, clay, sand, and chert gravel. Gravel in basal part.	0-100	30-130	Yields may decrease considerably during drought years.
			Undifferentiated Pleistocene deposits	45	Silt, clay, sand, and chert gravel. Gravel in basal part.	0-100	30-100	Yields may decrease considerably during drought years.
Permian	Lower Permian	Chase		125	Shale and limestone.	0-10	--	Water may be of poor chemical quality at depth.
		Council Grove		320	Shale, limestone, and some cavernous limestone.	0-10	--	Water may be of poor chemical quality at depth.
		Admire		125	Shale, sandy shale, and sandstone.	0-10	--	Water of questionable chemical quality.
Pennsylvanian	Upper Pennsylvanian	Wabaunsee		450	Shale, sandy shale, limestone, and lenses of sandstone.	0-10	--	Water of questionable chemical quality.
		Shawnee		50+	Limestone, shale, and sandy shale.	0-10	--	Water in outcrop area is of fair chemical quality.

The irrigated area in 1968 was 700 acres and 1,000 acre-feet of surface water was applied. Thirty acre-feet of ground water was pumped for municipal supply. The irrigated area in year 2000 may be 5,000 acres. The unconsolidated deposits receive about 25,000 acre-feet of recharge annually, and 150,000 acre-feet of water is in storage. The depth to water is generally less than 20 feet in the major stream valleys and ranges from 10 to 70 feet in the uplands. The estimated cost of water from a well field capable of producing 100,000 gallons per day from the alluvium is $0.10 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
15S-10E-23dc	18	9-13-51	Chase Group	1,030	140	71	600
15S-13E-19ca	16	9-13-51	Admire Group	656	180	20	530
16S-11E-21da	40	9-12-51	Council Grove Group	556	140	33	390
17S-13E-34aaa	40?	4-24-68	Alluvium	409	32	17	310
18S-10E-12cb	18	9-12-51	Undifferentiated Pleistocene deposits	1,180	110	140	660
18S-11E-1cc	31	9-12-51	Undifferentiated Pleistocene deposits	998	270	63	590
20S-10E-17dc	13	9-11-51	Council Grove Group	625	170	17	480
21S-13E-27aa	26	9-11-51	Wabaunsee Group	511	200	9.0	340

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	60	Gravel, sand, silt, and clay. Finer materials in the smaller stream valleys. Contains both chert and arkosic gravels.	10-100	10-200	Water probably of poor chemical quality. Yields may decrease considerably during drought years.
			Silt	50	Brownish-gray clay and silt containing lenses of sand and gravel.	0-50	70-270	Water probably of poor chemical quality. Yields may decrease considerably during drought years.
Cretaceous	Lower Cretaceous		Dakota Sandstone	45	Red, brown, and light-gray silt and clay containing lenses of buff to orange fine to medium quartz sand and thin lenses of gravel.	10-50	1-70	Water may be of poor chemical quality.
			Kiowa Shale	130	Dark-gray to black and gray to buff sandy shale; some plant fossils, thin layers of bentonite and gypsum, and abundant concretions of limonite and hematite.	10-50	1-40	Water may be of poor chemical quality.
Permian	Lower Permian	Sumner	Wellington Formation	450	Red, gray, green, and tan shale with limestone beds. Some dolomite, gypsum, and anhydrite.	10-500	--	Water may be of poor chemical quality.
		Chase		330	Limestone, shale, sandy shale, and some dolomite. Nodules and lenses of chert in the lower part.	10-100	10-70	Water may be of poor chemical quality.

The irrigated area in 1968 was 2,100 acres and a total of 2,500 acre-feet of water was applied. Of this total, about 800 acre-feet of water was pumped for municipal supply. The irrigated area in year 2000 may be 2,500 acres. The unconsolidated deposits receive about 10,000 acre-feet of recharge annually, and 30,000 acre-feet of water is in storage. In addition, about 2 million acre-feet of water is stored in rocks in the Chase Group. The depth to water is generally less than 20 feet in the major stream valleys and ranges from 20 to 90 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the alluvium is $0.10 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dis-solved solids	Sul-fate (SO_4)	Chlo-ride (Cl)	Total hard-ness as $CaCO_3$
17S- 1E-18add	39	5-28-68	Kiowa Shale	306	5.3	8.0	270
19S- 1E- 4ac	67	3-17-68	Kiowa Shale	189	27	10	100
19S- 2E-25cdd	80	10-10-57	Sumner Group	2,090	1,200	74	1,500
19S- 4E-10aaa	80	5- 9-62	Chase Group	1,460	820	38	1,100
21S- 5E- 7bb	spring	3-16-67	Chase Group	400	41	10	340
22S- 3E- 4bca	70	7- 4-65	Sumner Group	925	410	30	680
22S- 5E-33dcc	150	2-26-68	Chase Group	413	66	29	390

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	50	Grayish-brown silt, clay, and lime-stone and chert gravel.	0-50	10-200	Water probably highly mineralized. Yields may decrease considerably during drought years.
Permian	Lower Permian	Sumner	Wellington Formation	30	Tan, gray, and green silty shale with thin limestone beds.	0-10	--	Water probably highly mineralized.
		Chase		330	Limestone, shale, sandy shale, and silty calcareous shale. Some dolomite and fossiliferous shale. Lower part contains nodules and bands of chert.	0-500	10-70	Water may be of poor chemical quality.
		Council Grove		270	Limestone, shale, and silty shale. Some calcareous shale and fossilifer-ous shale and limestone.	0-10	--	Water may be of poor chemical quality.

The irrigated area in 1968 was 320 acres and 350 acre-feet of surface water was applied. Fifty-five acre-feet of ground water was pumped for municipal supply. The irrigated area in year 2000 may be about 10,000 acres. The unconsolidated deposits receive about 4,000 acre-feet of recharge annually and 25,000 acre-feet of water is in storage. In addition, about 2 million acre-feet of water is stored in rocks in the Chase Group. The depth to water generally is less than 20 feet in the major stream valleys and ranges from 20 to 90 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the alluvium is $0.10 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collec-tion	Geologic source	Dis-solved solids	Sul-fate (SO_4)	Chlo-ride (Cl)	Total hard-ness as $CaCO_3$
14S- 5E-23ccc	135	5-18-70	Chase Group	422	37	17	360
14S- 6E-34aaa	125	11- 7-66	Chase Group	577	80	41	410
14S- 8E-29ddd	75	5-18-70	Chase Group	676	10	70	480
14S- 9E-31ddc	28	5-18-70	Alluvium	454	54	9.0	360
17S- 6E-19bbb	63	5-22-70	Chase Group	450	33	19	310

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	35	Silt, fine to coarse sand, and very coarse chert pebbles. Chert pebbles generally occur in the basal 3 feet.	0-100	70-800	Yields may decrease considerably in drought years.
			Undifferentiated Pleistocene deposits	30	Silt and clay in the upper part with some fine to coarse sand at the base.	0-50	10-200	Yields may decrease considerably in drought years.
Pennsylvanian	Upper Pennsylvanian	Lansing		75	Shale and limestone.	0-10	--	Water probably highly mineralized.
		Kansas City		630	Shale, limestone, sandstone, and some coal.	0-15	--	Water from sandstone and limestone probably highly mineralized but usable for some purposes.
		Pleasanton		95	Shale, limestone, and sandstone.	0-1	--	Water probably highly mineralized.
	Middle Pennsylvanian	Marmaton		290	Shale, sandy shale, limestone, and sandstone.	0-5	--	Water probably highly mineralized.

The irrigated area in 1968 was 800 acres and 700 acre-feet of surface water was applied. No ground water was pumped for irrigation, municipal, or industrial supply. The irrigated area in year 2000 may be 1,000 acres. The unconsolidated deposits receive about 20,000 acre-feet of recharge annually and 90,000 acre-feet of water is in storage. The depth to water is less than 20 feet in the major stream valleys and ranges from 0 to 180 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the alluvium is $0.30 per 1,000 gallons.
Water of poor to fair chemical quality may be available from the Mississippian and Ordovician rocks at depths ranging from 250 to 1,233 feet below the land surface in the eastern part of the county. Water in the deeper aquifers generally is confined.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
27S-17E-11ad	47	10-10-61	Kansas City Group	900	98	160	490
27S-18E- 9da	20?	7-22-64	Alluvium	380	54	11	250
28S-19E- 1ba	123	10- 9-61	Kansas City Group	381	19	18	250
28S-19E-14cd	48	10- 9-61	Alluvium	421	24	14	350
28S-20E-24ad	35	12-28-60	Pleasanton Group	1,020	210	110	690
29S-17E-13cc	29	10-10-61	Kansas City Group	1,410	750	10	910
29S-21E-32dd	20	8-29-62	Alluvium	338	46	7.0	260
30S-20E-22dd	22	8-30-62	Marmaton Group	997	240	90	610

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	35	Silt, clay, fine sand, and gravel. Gravel generally in lower 4 feet.	0-100	70-700	Water probably highly mineralized. Yields may decrease considerably during drought years.
Creta-ceous(?)					Igneous rocks.	0	--	
Pennsylvanian	Upper Pennsylvanian	Wabaun-see		80	Shale and sandy shale.	0-10	--	Water probably of poor chemical quality.
		Shawnee		350	Predominately limestone and shale with thin sandstone and sandy shale zones.	0-10	--	Water probably of poor chemical quality.
		Douglas		300	Sandstone, shale, and sandy shale with few thin limestone beds.	0-50	--	Water probably of poor chemical quality.
		Lansing		80	Predominately limestone with shale and sandy shale.	0-10	--	Water probably of poor chemical quality.

The irrigated area in 1968 was 500 acres and 500 acre-feet of surface water was applied. No ground water was pumped for irrigation, municipal, or industrial supply. The irrigated area in year 2000 may be 1,000 acres. The unconsolidated deposits receive about 3,000 acre-feet of recharge annually, and 10,000 acre-feet of water is in storage. The depth to water is generally less than 20 feet in the major stream valleys and ranges from 5 to 85 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the alluvium is $0.30 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collec-tion	Geologic source	Dis-solved solids	Sul-fate (SO_4)	Chlo-ride (Cl)	Total hard-ness as $CaCO_3$
24S-14E- 3aaa	15	7-10-68	Shawnee Group	5,170	1,600	1,700	3,500
24S-16E- 6ddd	23	7-10-68	Douglas Group	896	390	83	500
24S-16E-34abb	19	7-10-68	Alluvium	354	66	23	140
25S-14E-16ccb	30	7-10-68	Douglas Group	402	36	12	330
26S-14E- 5ddd	82	7-10-68	Douglas Group	1,350	180	350	900
26S-16E-25bbc	20	7-10-68	Alluvium	1,430	800	8.0	870

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	20	Gravel, sand, silt, and clay.	10-100	130-260	Water generally of good chemical quality, but hard.
Pennsylvanian	Atoka		Atoka Formation	350	Thin conglomerate at base, sandy limestone, crystalline oolitic fossiliferous limestone, sandstone, siltstone, and shale.	0-10	--	Water generally of good chemical quality.
	Morrow							
Mississippian	Chester			300	Fossiliferous limestone and shale interbedded; some fine-grained sandstone and siltstone.	0-10	--	Water probably of good chemical quality.
	Meramec							
	Osage		Boone Formation	360	Commonly massive bedded limestone, chert, and cherty limestone; fossiliferous, fractured, locally dolomitic and oolitic. Small amount of shale.	10-50	1-6	Water generally of good chemical quality, but hard. Yield may be higher locally.
	Kinderhook		Chattanooga Shale	70	Black fissile carbonaceous shale.	--	--	
Devonian								
Silurian	Niagara	Clinton	St. Clair Limestone	200+	Bluish-gray finely crystalline cherty limestone becoming oolitic near base. Grades upward into grayish-white to pink crinoidal limestone.	0-10	--	Water probably of fair to good chemical quality.
Ordovician	Champlainian	Chazy	Burgen Sandstone	75	Predominately fine- to medium-grained sandstone with some shale, limestone, and dolomite.	5-25	1-3	Water probably of fair to good chemical quality.
	Canadian	Arbuckle	Cotter Dolomite	150	Mostly dolomite with minor amounts of sandstone, shale, and chert.	10-50	1-6	Water generally of good chemical quality, but hard.
			Jefferson City Dolomite	350	Cherty dolomite.	10-50	1-5	
			Roubidoux Formation	200	Dolomite with a few sandstone layers.	10-1,000	13-40	

The irrigated area in 1969 was 800 acres and a total of 540 acre-feet of water was applied. Of this total, less than 500 acre-feet was ground water. No ground water was pumped for industrial or municipal supplies. The irrigated area in year 2000 may be 800 acres. The unconsolidated deposits, outside inundated areas, receive about 19,000 acre-feet of recharge annually and a negligible amount of water is in storage. However, 6 million acre-feet of water is stored in the Mississippian aquifers and 3.5 million acre-feet is stored in the Ordovician aquifers. Depth to water ranges from less than 20 feet in the major stream valleys to 140 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the Boone Formation is $0.10 per 1,000 gallons, and from the Roubidoux Formation is $0.12 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
16N-22E- 3ccb	90	11-20-46	Boone Formation	224	7.2	9.0	180
17N-21E-29c	124	5-27-50	Boone Formation	925	40	22	53
17N-23E-27ab	36	11-20-46	Boone Formation	274	15	26	140
18N-20E-22bcb	--	10-14-68	Boone Formation	107	.5	5.6	80
18N-21E-17ba	98	11-20-46	Boone Formation	243	18	29	130
18N-22E-15aba	242	1- 7-69	Pre-Mississippian rocks	118	2.7	2.4	98
19N-21E-32add	--	10-14-68	Boone Formation	125	1	4.2	100
19N-22E-11dbd	202	1- 3-69	Pre-Mississippian rocks	184	.0	3.6	120
19N-23E-26dca	82	1- 7-69	Pre-Mississippian rocks	270	35	5.2	240

CRAIG COUNTY, OKLAHOMA

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	30	Clay and silt in upper part grading downward to sand and gravel near base.	0-50	3-8	Water generally of good chemical quality, but may be hard.
Pennsylvanian	Des Moines	Marmaton		350	Mostly shale with thick fossiliferous limestone. Lesser amounts of sandstone and coal.	0-10	--	Water of poor to good chemical quality, but hard. Chloride and sulfate ion concentration may be high.
Pennsylvanian	Des Moines	Cabaniss		300	Generally thick cross-bedded sandstone in bottom half, overlain by alternating series of shale, sandstone, limestone, and thin coal beds.	0-10	--	Water of poor to good chemical quality, but may be hard. Sulfate concentration may be high.
Pennsylvanian	Des Moines	Krebs		400	Mostly shale interbedded with thinner units of sandstone and limestone. Thin coal beds common.	0-10	--	Water of poor to fair chemical quality, but may be hard. Sulfate concentration may be high.
Pennsylvanian	Atoka		Atoka Formation	40	Brown fine to medium grained cross-bedded bituminous sandstone occurring as channel fill.	--	--	
Pennsylvanian	Morrow							
Mississippian	Chester			100	Fossiliferous limestone and shale, interbedded. Some fine-grained sandstone.	0-10	--	Water probably of good chemical quality.
Mississippian	Meramec, Osage		Boone Formation	200	Commonly massive bedded limestone, chert, and cherty limestone; fossiliferous, fractured, locally dolomitic and oolitic. Small amount of shale.	10-50	1-9	Water of good chemical quality, but hard. Yield may be much higher locally.
Mississippian, Devonian	Kinderhook		Chattanooga Shale	70	Black, fissile, carbonaceous shale.	--	--	
Ordovician	Canadian	Arbuckle	Cotter Dolomite	185	Mostly dolomite and magnesium limestone. Cherty with lesser amounts of shale and oolites.	10-50	1-5	Water probably of fair chemical quality and probably hard.
Ordovician	Canadian	Arbuckle	Jefferson City Dolomite	350	Cherty dolomite.	10-50	1-5	Water probably of acceptable chemical quality for most uses.
Ordovician	Canadian	Arbuckle	Roubidoux Formation	200	Sandy cherty oolitic dolomite.	10-1,000	13-40	Water generally of fair chemical quality, but may be hard. Chloride concentration may be high.

None of the area was irrigated in 1969 and no ground water was pumped for municipal or industrial supply. The irrigated area in year 2000 probably will be negligible. The unconsolidated deposits, outside the inundated areas, receive about 2,000 acre-feet of recharge annually and a negligible amount of water is in storage. However, 2.2 million acre-feet of water is stored in the Mississippian aquifers and 1.8 million acre-feet is stored in the Ordovician aquifers. The depth to water ranges from less than 20 feet in the major stream valleys to 300 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the Boone Formation is $0.10 per 1,000 gallons, and from the Roubidoux Formation is $0.12 per 1,000 gallons.

Typical depth intervals for the consolidated rocks in T.28 N., R.20 E., are as follows: Pennsylvanian from land surface to 400 feet, Mississippian and Devonian from 400 to 750 feet, and Ordovician from 750 to more than 800 feet. Water in the deeper aquifers generally is confined.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
24N-19E-14abb	51	10-30-68	Krebs Group	1,320	820	72	150
24N-20E-20ccd	73	10-31-68	Krebs Group	1,420	530	7.2	780
25N-18E- 1cbb	82	10-29-58	Cabaniss Group	2,040	1,300	19	860
25N-18E-28aab	32	10-30-68	Cabaniss Group	372	170	5.2	212
25N-20E-12	1,139	3-10-50	Roubidoux Formation	1,210	28	620	190
25N-21E-25ddd	48	10-30-68	Boone Formation	209	8.1	2	180
26N-18E-18add	26	10-31-68	Marmaton Group	1,890	11	720	54
26N-19E-13cbc	30	10-31-68	Krebs Group	940	350	25	500
27N-19E-15ccc	29	10-29-68	Marmaton Group	275	39	1.8	250
27N-20E-12bdd	688	1-14-69	Roubidoux Formation	872	3.2	400	120
27N-21E-28dcc	155	10-30-68	Krebs Group	3,210	2,100	11	1,300
28N-18E- 5aaa	35	11- 8-68	Marmaton Group	394	27	6.4	330
28N-19E-17abb	54	11-13-68	Marmaton Group	1,070	390	70	630
28N-20E- 7ddd	52	11- 8-68	Cabaniss Group	450	130	12	60
28N-20E-25bbc	90	11- 8-68	Krebs Group	552	120	50	350
29N-20E-23cdd	43	11-12-68	Cabaniss Group	2,120	1,700	5.4	1,100

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thickness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conductivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Terrace deposits	10	Gravel, sand, and clay.	0-10	--	Probably above potentiometric surface.
Mississippian	Chester			50	Fossiliferous limestone and shale.	0-10	--	Locally, basal part may be below potentiometric surface.
	Meramec, Osage		Boone Formation	300	Commonly massive bedded limestone, chert, and cherty limestone; fossiliferous, fractured, locally dolomitic and oolitic. Small amounts of shale.	10-100	1-9	Water of good chemical quality, but hard. Yields may be much higher locally.
Mississippian, Devonian	Kinderhook		Chattanooga Shale	70	Black thin bedded carbonaceous shale.	--	--	
Ordovician	Champlainian	Chazy	Burgen Sandstone	80	Predominately fine- to medium-grained sandstone with some beds of shale, limestone, and dolomite.	5-25	1-3	Water probably of fair to good chemical quality.
	Canadian	Arbuckle	Cotter Dolomite	165	Mostly dolomite and magnesium limestone. Cherty with lesser amounts of shale and oolites.	10-50	1-5	Water probably of fair to good chemical quality.
			Jefferson City Dolomite	340	Cherty dolomite.	10-50	1-5	Water probably of fair to good chemical quality.
			Roubidoux Formation	180	Dolomite with a few sandstone layers.	10-1,000	13-40	Water of good chemical quality, but hard.
			Gasconade Dolomite	250	Dolomite, limestone, and chert with 60 feet of sandstone at base.	10-50	1-5	Water probably of fair to good chemical quality.

The irrigated area in 1969 was 250 acres and 200 acre-feet of surface water was applied. Seventeen acre-feet of ground water was pumped for municipal supply. The irrigated area in year 2000 probably will be negligible. The unconsolidated deposits, outside inundated areas, receive about 17,000 acre-feet of recharge annually, and a negligible amount of water is in storage. However, 4.9 million acre-feet of water is stored in the Mississippian aquifers and 8.4 million acre-feet is stored in the Ordovician aquifers. The depth to water ranges from less than 20 feet in the major stream valleys to 225 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the Boone Formation is $0.08 per 1,000 gallons and from the Roubidoux Formation is $0.09 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
20N-23E-33dcc	--	10-14-68	Boone Formation	140	2.2	13	110
20N-24E-19aa	48	11-21-46	Boone Formation	230	26	42	26
20N-25E- 4cdc	100	11-19-68	Boone Formation	106	.2	.2	92
21N-22E- 7adc	125	1- 3-69	Pre-Mississippian rocks	240	9.8	3	9
21N-23E-24bba	200	1- 3-69	Pre-Mississippian rocks	212	17	11	86
22N-22E-15acd	200	1- 2-69	Pre-Mississippian rocks	510	170	6.7	400
22N-23E-14cbd	200	1- 2-69	Pre-Mississippian rocks	160	31	3.2	120
22N-24E-26abb	82	11-19-68	Boone Formation	336	8.2	2.4	330
22N-25E-23dbd	37	11-19-68	Boone Formation	403	44	28	220
23N-22E-32dd	65	11-19-46	Boone Formation	153	3.6	10	120
23N-24E-29aab	56	11-19-68	Boone Formation	417	73	9.2	84
23N-25E-33ddc	1,160	12-18-68	Roubidoux Formation	167	.3	1.6	160
24N-22E-35dad	91	11-20-68	Boone Formation	296	11	16	240
24N-24E-19dd	70	11-19-46	Boone Formation	187	3	7	160
24N-25E-17ada	92	11-20-68	Boone Formation	317	13	22	220
25N-22E-29ada	78	11-20-68	Boone Formation	194	10	2	180
25N-23E-11cad	97	11-20-68	Boone Formation	410	24	18	280
25N-24E-28bbb	1,600	12-15-68	Roubidoux Formation	350	7.9	90	140
25N-25E-17ccd	110	11-21-68	Boone Formation	219	4.2	3.7	180

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	30	Lenses of gravel, sand, silt, and clay.	0-10	1-5	
			Terrace deposits	20	Gravel, sand, silt, and clay slightly indurated.	0-10	--	Most terrace deposits probably above potentiometric surface.
Pennsylvanian	Des Moines	Cabaniss						
		Krebs						
	Atoka		Atoka Formation	600	Shale, siltstone, sandstone, limestone, and some coal and conglomerate.	0-10	--	Water of fair to good chemical quality, but may be hard.
	Morrow							
Mississippian	Chester			150	Fossiliferous limestone and shale interbedded; some fine-grained sandstone and siltstone.	0-10	--	Water of fair to good chemical quality, but may be hard.
	Meramec							
	Osage		Boone Formation	225	Commonly massive-bedded limestone, chert, and cherty limestone; fossiliferous, fractured, locally dolomitic and oolitic. Small amount of shale.	10-50	1-9	Water generally of good chemical quality, but hard. Yields locally may exceed 50 gpm.
	Kinderhook		Chattanooga Shale	70	Black fissile carbonaceous shale.	--	--	
Devonian								
Ordovician	Champlainian	Chazy	Burgen Sandstone	40	Predominately sandstone with minor amounts of shale and thin dolomitic limestone.	5-25	1-3	Water probably of fair to good chemical quality.
	Canadian	Arbuckle	Cotter Dolomite	125	Mostly white to gray dolomite with minor amounts of sandstone, shale, chert, and intraformational conglomerate.	10-50	1-5	Water generally of good chemical quality, but hard.
			Jefferson City Dolomite	350	Cherty dolomite.	10-50	1-5	
			Roubidoux Formation		Sandy cherty oolitic dolomite.	10-100	13-40	

The irrigated area in 1969 was 90 acres and 90 acre-feet of surface water was applied. No ground water was pumped for irrigation, municipal, or industrial supplies. The irrigated area in year 2000 may be 100 acres. The unconsolidated deposits, outside inundated areas, receive about 8,000 acre-feet of recharge annually, and 10,000 acre-feet of water is stored in the Mississippian aquifers and 1.2 million acre-feet is stored in the Ordovician aquifers. The depth to water ranges from less than 20 feet in the major stream valleys to 300 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the Boone Formation is $0.10 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
19N-19E-15adb	25	12- 4-68	Alluvium	228	12	8.1	180
19N-20E-24ccd	54	12-11-68	Boone Formation	210	.2	.8	190
20N-19E-24ddd	45	4-20-57	Boone Formation	--	--	24	320
20N-19E-27ccc	51	12-11-68	Chester and Meramec Series, undifferentiated	241	8.6	3.9	210
20N-19E-27dcd	--	4-22-57	Alluvium	--	--	70	340
20N-21E-17bbb	52	12-11-68	Boone Formation	207	4.5	5.1	180
21N-18E- 5dda	57	12- 4-68	Krebs Group	970	270	150	120
21N-19E-20dcd	28	4-20-57	Atoka Formation	--	--	26	100
21N-19E-26add	25	12-11-68	Chester and Meramec Series, undifferentiated	935	160	180	470
21N-19E-30bcb	--	4-20-57	Alluvium	--	--	280	850
21N-19E-31add	--	4-20-57	Atoka Formation	--	--	8	140
21N-21E-12dda	--	10-15-68	Boone Formation	145	5.3	3.4	120
22N-19E-23cdd	20	11-12-68	Chester and Meramec Series, undifferentiated	771	310	6.6	480
22N-21E-15cac	--	10-15-68	Cotter Dolomite	114	.6	6	98
23N-18E-28ccc	39	11-12-68	Krebs Group	117	51	4.6	56
23N-20E-29cdc	46	11-12-68	Chester and Meramec Series, undifferentiated	678	1.8	220	200
23N-21E- 6ddd	60	11-12-68	Boone Formation	153	5.4	.8	130

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	35	Gravel, sand, and clay	0-50	3-8	Water generally of good chemical quality, but hard.
Pennsyl-vanian	Des Moines	Krebs		200	Mostly dark-gray to black shale with lesser amounts of fine- to medium-grained sandstone, limestone, and coal.	0-10	--	
Mississippian	Chester			100	Fossiliferous limestone and shale.	0-10	--	Water probably of good chemical quality.
Mississippian	Mera-mec; Osage; Kin-der-hook		Boone Formation	380	Commonly massive-bedded limestone, chert, and cherty limestone; fossiliferous, fractured, locally dolomitic and oolitic. Small amounts of shale.	10-100	1-9	Water generally of good chemical quality, but hard. Yields may be greater locally.
Mississippian; De-von-ian	Kin-der-hook		Chattanooga Shale	30	Black thin-bedded carbonaceous shale.	0-10	--	
Ordovician	Canadian	Arbuckle	Cotter Dolomite	165	Mostly dolomite and magnesium limestone. Cherty with lesser amounts of shale and oolites.	10-1,000	1-40	Water probably of good chemical quality.
			Jefferson City Dolomite	340	Cherty dolomite.			Water probably of good chemical quality.
			Roubidoux Formation	180	Dolomite with a few sandstone layers.			Water of good chemical quality, but hard.
			Gasconade Dolomite	300	Dolomite, limestone, and chert with 60 feet of sandstone at base.			Water probably of fair to good chemical quality.

The irrigated area in 1969 was 240 acres and a total of 64 acre-feet of water was applied. Of this total, 30 acre-feet was ground water. An additional 370 acre-feet was pumped for municipal and industrial supplies. The irrigated area in year 2000 may be 250 acres. The unconsolidated deposits, outside inundated areas, receive about 4,000 acre-feet of recharge annually and 50,000 acre-feet of water is in storage. In addition, 4.8 million acre-feet of water is stored in the Mississippian aquifers, and 5.8 million acre-feet in the Ordovician aquifers. The depth to water ranges from less than 20 feet in the major stream valleys to 370 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the unconsolidated deposits is $0.04 per 1,000 gallons, from the Roubidoux Formation is $0.12 per 1,000 gallons, and from the Boone Formation is $0.10 per 1,000 gallons.

In the Miami area, typical depth intervals for the consolidated rocks are as follows: Pennsylvanian from land surface to 80 feet, Mississippian and Devonian from 80 to 470 feet, and Ordovician from 470 to 1,400 feet. The Roubidoux Formation, from 940 to 1,100 feet below land surface, is the principal water-bearing unit of the deeper aquifers. Water in the deeper aquifers generally is confined.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collec-tion	Geologic source	Dis-solved solids	Sul-fate (SO_4)	Chlo-ride (Cl)	Total hard-ness as $CaCO_3$
25N-24E- 2abd	--	10-15-68	Boone Formation	180	5.6	7.8	160
26N-23E- 8bb	1,100	7-25-46	Roubidoux Formation	374	16	130	180
27N-23E- 4cdd	1,033	5- 1-48	Roubidoux Formation	287	15	94	140
27N-24E-21cd	1,040	7-24-46	Roubidoux Formation	162	17	10	140
27N-24E-32aac	90	11-21-68	Boone Formation	242	11	16	180
27N-25E-29ddd	--	10-15-68	Boone Formation	150	1.8	7.4	110
28N-22E-24aab	1,235	8- 5-44	Roubidoux Formation	201	15	32	150
28N-22E-35dc	1,130	7-26-46	Roubidoux Formation	189	16	17	130
28N-24E-15	--	10-15-68	Boone Formation	167	6.8	4.1	150
29N-21E-23bcd	12	4-28-48	Alluvium	335	68	14	210
29N-23E-18baa	1,080	4-29-48	Roubidoux Formation	583	21	260	210
29N-23E-21bbc	1,125	4-28-48	Roubidoux Formation	178	18	23	140
29N-24E-25bbc	--	10-15-68	Boone Formation	214	15	2.8	190

Generalized section of geologic units and their water-bearing properties.

System	Series	Group	Geologic unit	Maximum thick-ness (feet)	Physical character	Estimated yield to wells (gpm)	Estimated hydraulic conduc-tivity (ft per day)	Remarks
Quaternary	Pleistocene and Holocene		Alluvium	35	Generally silt and fine sand in upper part grading downward to coarse sand and fine gravel.	100-500	130-260	Water generally of good chemical quality, but very hard.
			Terrace deposits	30	Clayey silt in upper part grading downward to fine sand and then to coarse sand and fine gravel.	10-100	1-4	Water generally of good chemical quality.
Pennsylvanian	Des Moines	Marmaton	—	100	Mostly shale with lesser amounts of limestone and some sandstone.	0-10	--	Water of fair to good chemical quality, but generally very hard.
		Cabaniss		300	Predominately dark-gray to black shale interbedded with lesser amounts of sandstone and limestone, and a slight amount of coal.	0-10	--	Water generally of good chemical quality, but generally hard.
		Krebs		400	Mostly shale interbedded with thinner units of sandstone and limestone. Thin coal beds common.	0-10	--	Water of fair to good chemical quality.
	Atoka		Atoka Formation	300	Thin conglomerate at base, sandy limestone, crystalline oolitic fossiliferous limestone, sandstone, siltstone, and shale.	0-10	--	Water generally of good chemical quality.
	Morrow							
Mississippian	Chester			180	Fossiliferous limestone and shale interbedded. Some fine-grained sandstone and siltstone.	0-10	--	Water of fair to good chemical quality, but may be hard.
	Meramec							
	Osage		Boone Formation	250	Commonly massive-bedded limestone, chert, and cherty limestone; fossiliferous, fractured, locally dolomitic and oolitic. Small amount of shale.	10-50	1-6	Water of good chemical quality, but hard.
	Kinderhook							

No ground water was pumped in the Grand (Neosho) River basin for municipal, irrigation, or industrial supply. The irrigated area in year 2000 may be about 100 acres. The unconsolidated deposits in the drainage of the Grand River, outside inundated areas, receive about 1,500 acre-feet of recharge annually and 20,000 acre-feet of water is in storage. The depth to water ranges from less than 20 feet in the major stream valleys to 100 feet in the uplands. The estimated cost of water from a well field capable of producing 1 million gallons per day from the unconsolidated deposits is $0.010 per 1,000 gallons.

Chemical analyses of water from selected wells. Dissolved constituents and hardness in milligrams per liter.

Well number	Depth (feet)	Date of collection	Geologic source	Dissolved solids	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
16N-15E-11add	55	11-15-66	Krebs Group	[1] 822	42	60	28
16N-16E-19aaa	20	12-14-66	Alluvium	658	20	95	440
16N-16E-20	22	--	Alluvium	518	19	48	480
16N-17E-11bbc	29	11-15-66	Krebs Group	297	11	6	160
16N-18E-27cdd	67	10-18-66	Terrace deposits	231	6	6.3	66
16N-19E-32dc	38	6- 5-46	Alluvium	400	7.7	21	--
16N-19E-34c	31	6- 5-46	Alluvium	264	25	28	--
17N-16E- 9daa	47	10-18-66	Krebs Group	728	36	100	100
17N-18E- 3bad	31	10-18-66	Krebs Group	[1] 382	5	39	38
17N-19E-33dcc	225	8- 4-65	Atoka Formation and Morrow(?) Series, undifferentiated	3,380	110	[2]1,700	320
18N-15E-14ada	32	12- 9-68	Cabaniss Group	222	25	41	140
18N-15E-18abb	375	10-19-65	Cabaniss Group(?)	840	42	200	20
18N-16E-26daa	46	12- 9-68	Krebs Group	296	96	43	82
18N-18E-13aac	54	12- 4-68	Atoka Formation and Morrow Series, undifferentiated	324	50	4.9	250
18N-18E-19ada	72	12- 4-68	Krebs Group	978	250	190	110
19N-15E-14dcd	73	12- 9-68	Cabaniss Group	614	99	39	360

[1]Estimated.
[2]Well apparently producing below the fresh-salt water interface or contamination has occurred.

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