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GEOHYDROLOGY AND WATER QUALITY OF THE ROUBIDOUX AQUIFER, NORTHEASTERN OKLAHOMA

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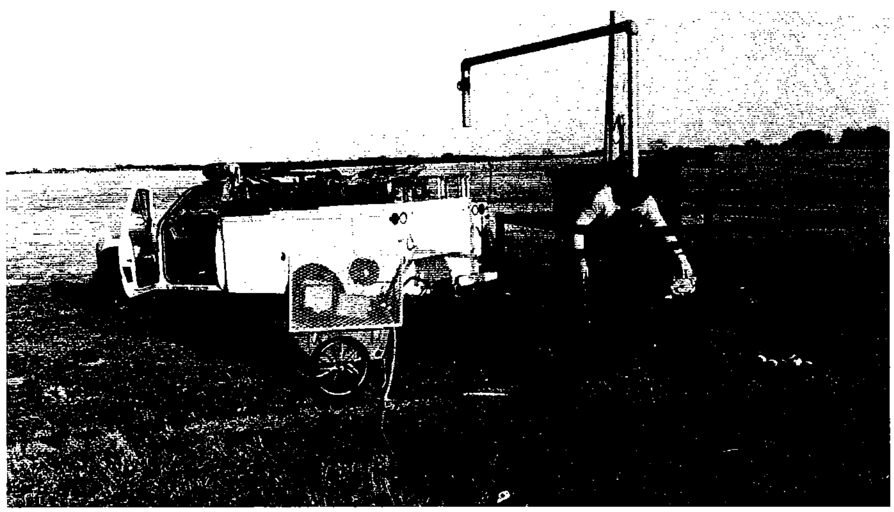
Prepared by the United States Geological Survey
in cooperation with the Oklahoma Geological Survey



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Title-Page Illustration

Collecting water samples from the Ogeechee Farms well completed in the Roubidoux aquifer in northeastern Oklahoma.

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Geohydrology and Water Quality of the Roubidoux Aquifer, Northeastern Oklahoma

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ABSTRACT.—The Roubidoux aquifer is an important source of fresh water for public supplies, commerce, industry, and rural water districts in northeastern Oklahoma. Ground-water withdrawals from the aquifer in 1981 were estimated to be 4.8 million gal/day, of which ~90% was withdrawn in Ottawa County. Wells drilled at the beginning of the 20th century originally flowed at the land surface, but in 1981 water levels ranged 22–471 ft below land surface. A large cone of depression has formed as a result of ground-water withdrawals near Miami. Wells completed in the Roubidoux aquifer have yields that range from ~100 to >1,000 gal/min.

An aquifer test and a digital ground-water flow model were used to estimate aquifer and confining-layer hydraulic characteristics. Using these methods, the transmissivity of the aquifer was estimated to be within a range of 400–700 ft^2/day. The leakance of the confining layer was determined to be within a range of 0–0.13 per day, with a best-estimate value in a range from 4.3×10^{-8} to 7.7×10^{-8} per day.

Analyses of water samples collected between 1980 and 1983 as part of this study and of water-quality data from earlier work indicate that a large areal change in major-ion chemistry occurs in ground water in the Roubidoux aquifer in northeastern Oklahoma. The ground water in the easternmost part of the study unit has relatively small dissolved-solids concentrations (<200 mg/L), with calcium, magnesium, and bicarbonate as the major ions. Ground water in the westernmost part of the study unit has relatively large dissolved-solids concentrations (>800 mg/L), with sodium and chloride as the major ions. A transition zone of intermediate sodium, chloride, and dissolved-solids concentrations exists between the easternmost and westernmost parts of the study unit.

Three water-quality problems are apparent in the Roubidoux aquifer in northeastern Oklahoma: (1) contamination by mine water, (2) large concentrations of sodium and chloride, and (3) large radium-226 concentrations.

Many wells in the mining area have been affected by mine-water contamination. At present (1990), all instances of ground-water contamination by mine water can be explained by faulty seals or leaky casings in wells that pass through the zone of mine workings and down to the Roubidoux aquifer. None of the data available in 1990 demonstrate that mine water has migrated from the Boone Formation through the pores and fractures of the intervening geologic units to the Roubidoux aquifer, although the available data do not preclude that possibility.

Ground water with large concentrations of sodium and chloride occurs at some depth throughout the study unit. Large concentrations of sodium and chloride make ground water in the Roubidoux aquifer unsuitable as a water supply in the northwestern part of the study unit. In the eastern part of the study unit, chloride concentrations >250 mg/L are found at depths greater than approximately 1,200–1,500 ft. Data are too few to determine the depth to ground water with large concentrations of sodium and chloride in the southern and southwestern parts of the study unit.

Large concentrations of gross-alpha radioactivity in ground water occur near the western edge of the transition zone. Generally, ground water with large concentrations of gross-alpha radioactivity was found to exceed the maximum contaminant level for radium-226.

INTRODUCTION

The Roubidoux aquifer in northeastern Oklahoma is used extensively as a source of water for public supplies, commerce, industry, and rural water districts. Recognizing a need for additional information, the Oklahoma Geological Survey initiated a hydrologic study of the Roubidoux aquifer in cooperation with the U.S. Geological Survey.

The term "Roubidoux aquifer" is used in this report to describe those geologic units, including the Roubidoux Formation, in northeastern Oklahoma in which deep wells are completed. The Roubidoux Formation is a distinct geologic unit recognized in the subsurface in Arkansas, Missouri, Kansas, and Oklahoma, and on the surface in Missouri. Wells that are completed in the Roubidoux Formation generally are left open to the overlying Cotter and Jefferson City Dolomites. In addition, in order to increase yield, wells that are drilled to the Roubidoux Formation are sometimes drilled into the underlying Gasconade Dolomite. Because the wells with the greatest yield are completed in the Roubidoux Formation, it is inferred that the Roubidoux Formation contributes most of the water.

Purpose and Scope

This report presents the results of a study of the water resources of the Roubidoux aquifer in northeastern Oklahoma which was conducted between 1980 and 1983. The main objective of the study was to refine and extend knowledge of the geology, hydrology, and water quality of the aquifer. The scope of work included: obtaining and interpreting geophysical, geological, and drilling logs to define stratigraphic relations; measuring water levels to define the potentiometric surface; analyzing an aquifer test as well as developing and using a digital model to determine aquifer and confining-layer hydraulic characteristics; and sampling wells for chemical analysis to assess the water quality of the aquifer.

Previous Investigations

Several investigations of all or parts of the study unit have been made in the past. (Because depth as well as areal extent must be considered in any discussion of the Roubidoux aquifer, the term "study unit" is used throughout this report instead of the more conventional "study area.") The focus of many of these studies has been the extensive lead and zinc mining in Ottawa County. In the early part of the 20th century, Siebenthal (1908,1915), in describing the mineral resources of northeastern Oklahoma, referred to some of the wells extracting water from the Roubidoux Formation and described the hydrogeology of the area. Reed and others (1955) conducted an extensive investigation of the ground-water resources of Ottawa County. Marcher and Bingham (1971) described the water resources of much of northeastern Oklahoma as part of the Hydrologic Atlas series of investigations done cooperatively by the Oklahoma Geological Survey and the U.S. Geological Survey. Playton and others (1980) conducted a study of the water within the abandoned lead and zinc mines in the region. Recently, with recognition of its potential to contaminate the Roubidoux aquifer, this water in abandoned mines has come under intense study. Parkhurst (1987) published chemical analyses of water samples from the Picher mining area.

Site-Numbering System

The location of data-collection sites in this report is illustrated in Figure 1. This method of locating sites is referred to as the "local identifier." The local identifier replaces the standard legal method of locating sites by fractional section, section, township, and range. By the standard legal method, the location of the site indicated by the "•" in Figure 1 is described as SW¼SE¼ NW¼ sec. 18, T. 18 N., R. 26 E. The local identifier reverses the order and indicates quarter subdivisions of the section by letters. By this method, the location of the site is given as 18N–26E–18 BDC 1. A sequence number ("1" in this example) is added to provide a unique identifier for each site.

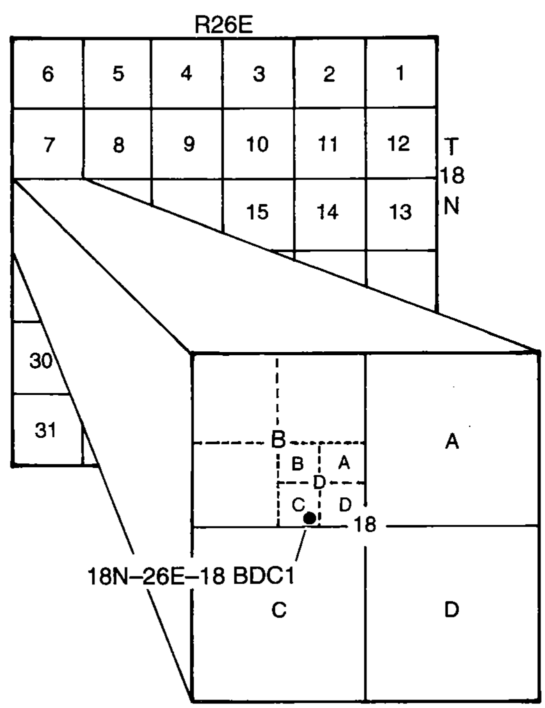

Figure 1. "Local identifier" method for locating data-collection sites.

Acknowledgments

The authors are indebted to many people throughout the study unit for their cooperation and assistance in obtaining information concerning wells, ground-water withdrawals, use of water, and other pertinent data. Many individuals from municipal water departments, operators of rural water districts, well drillers, and individual well owners provided information.

The cooperation and assistance extended by members of the Oklahoma Geological Survey and the Oklahoma Water Resources Board are especially appreciated. Both agencies were helpful in supplying information and providing many helpful suggestions.

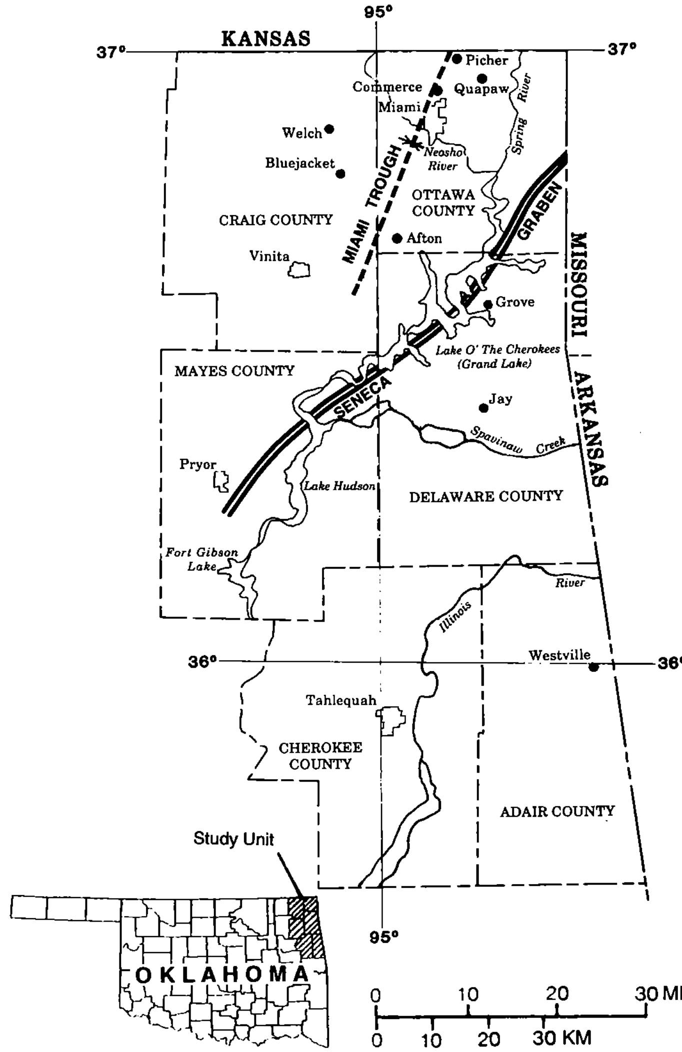

Figure 2. Location of study unit.

DESCRIPTION OF THE STUDY UNIT

The study unit is defined by those counties in northeastern Oklahoma that have wells completed in the Roubidoux aquifer. Those counties are Adair, Cherokee, Craig, Delaware, Mayes, and Ottawa Counties (Fig. 2). The surface area of the study unit is ~4,500 mi^2. (See Appendix 1 for metric conversion factors.)

Physiography and Drainage

The study unit lies along the western flanks of the Ozark uplift and is part of two physiographic provinces. The eastern part of the study unit is within the Ozark Plateaus province, and the western part of the study unit is within the Osage Plains section of the Central Lowland province (Fenneman, 1946). The Ozark Plateaus province is characterized by rugged topography with deep V-shaped valleys separated by narrow flat-topped ridges. The Osage Plains section of the Central Lowland province is a gently eastward-sloping plain interrupted by low east-facing escarpments and isolated buttes capped by resistant limestone and sandstone.

The highest altitude, ~1,450 ft, is in the southeastern part of the study unit in Adair County. The lowest altitudes, ~700 ft, are in the southern and western parts of the study unit.

The area is drained by several large streams including the Illinois River, the Neosho River, Spavinaw Creek, and the Spring River. Streams flow westward and southwestward. The drainage is dendritic and, in places, modified trellis.

Climate

The study unit is in a humid climatic zone. Annual precipitation averages ~42 in., with most precipitation occurring in the spring and early fall. The driest part of the year is November through February. Average annual temperature is ~60°F. January is the coolest month of the year, and July is the warmest. Graphs showing average monthly temperature and precipitation at Miami, Pryor, Tahlequah, and Vinita, 1941–70, are shown in Figure 3.

GEOLOGY

The thickness, lithology, and water-bearing characteristics of the major geologic units in the study unit are listed in Table 1. The 110 wells completed in the Roubidoux aquifer that were used as control points in

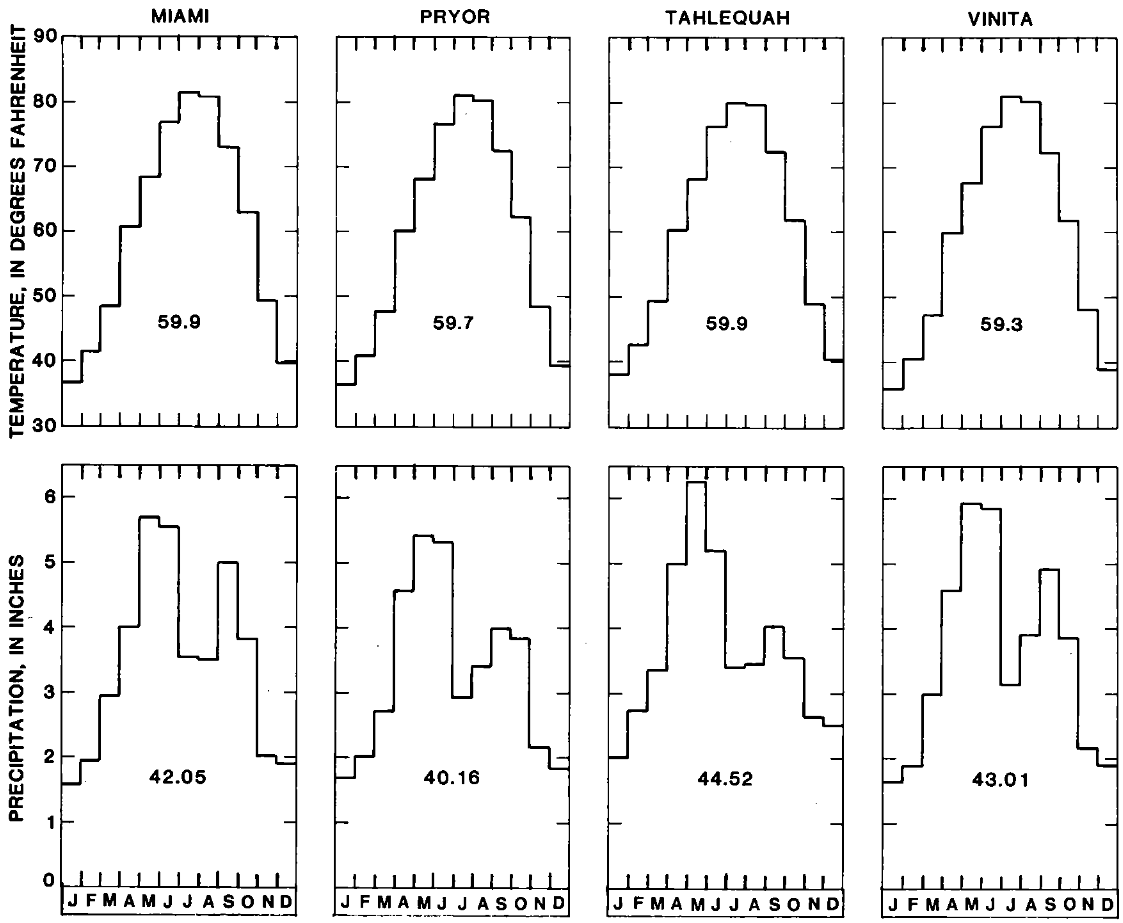

Figure 3. Average monthly temperature and precipitation at Miami, Pryor, Tahlequah, and Vinita, 1941–70. Number in center of each graph is the average annual temperature or the average annual precipitation at the station (U.S. Department of Commerce, 1973).

this study are shown in Figure 4. The stratigraphic nomenclature used in this report was compiled from both the Oklahoma Geological Survey and the U.S. Geological Survey.

Stratigraphy

The study unit is underlain by Precambrian-age igneous rocks that can be divided into two different units. The Washington volcanic group (Denison, 1981) is dominantly a rhyolite, but andesite is present in some areas. The Spavinaw Granite Group (Denison, 1981) is a granite porphyry. These two units underlie approximately equal areas within the study unit. Small outcrops of Spavinaw Granite are found in Mayes County. In southern Delaware County, granitic rocks are ~3,000 ft below the land surface. These widely ranging depths to Precambrian rocks within small lateral distances indicate that the Precambrian surface is very irregular.

Although Cambrian-age rocks are not present at the surface in the study unit, they have been identified in wells. The lowermost formation of Cambrian age is the Lamotte Sandstone. Based on data from the few wells in the study unit that penetrate the Lamotte Sandstone, it is a poorly sorted mixture of sandstone, shale, and siltstone, 0–80 ft thick. Because the Precambrian-age Spavinaw Granite Group crops out in Mayes County, the thickness of all younger geologic units in the study unit is 0 at that location. Stratigraphically above the Lamotte Sandstone is the Bonneterre Dolomite. In the study unit, the Bonneterre Dolomite ranges 0–180 ft thick. The Bonneterre Dolomite is predominantly dolomite but also contains chert, pyrite, oolites, glauconite, and sand. The percentage of sand decreases upward from the base of the formation. Overlying the Bonneterre Dolomite are the Eminence and Potosi Dolomites, undivided in this study. The Eminence and Potosi Dolomites are cherty dolomites, 0–370 ft thick.

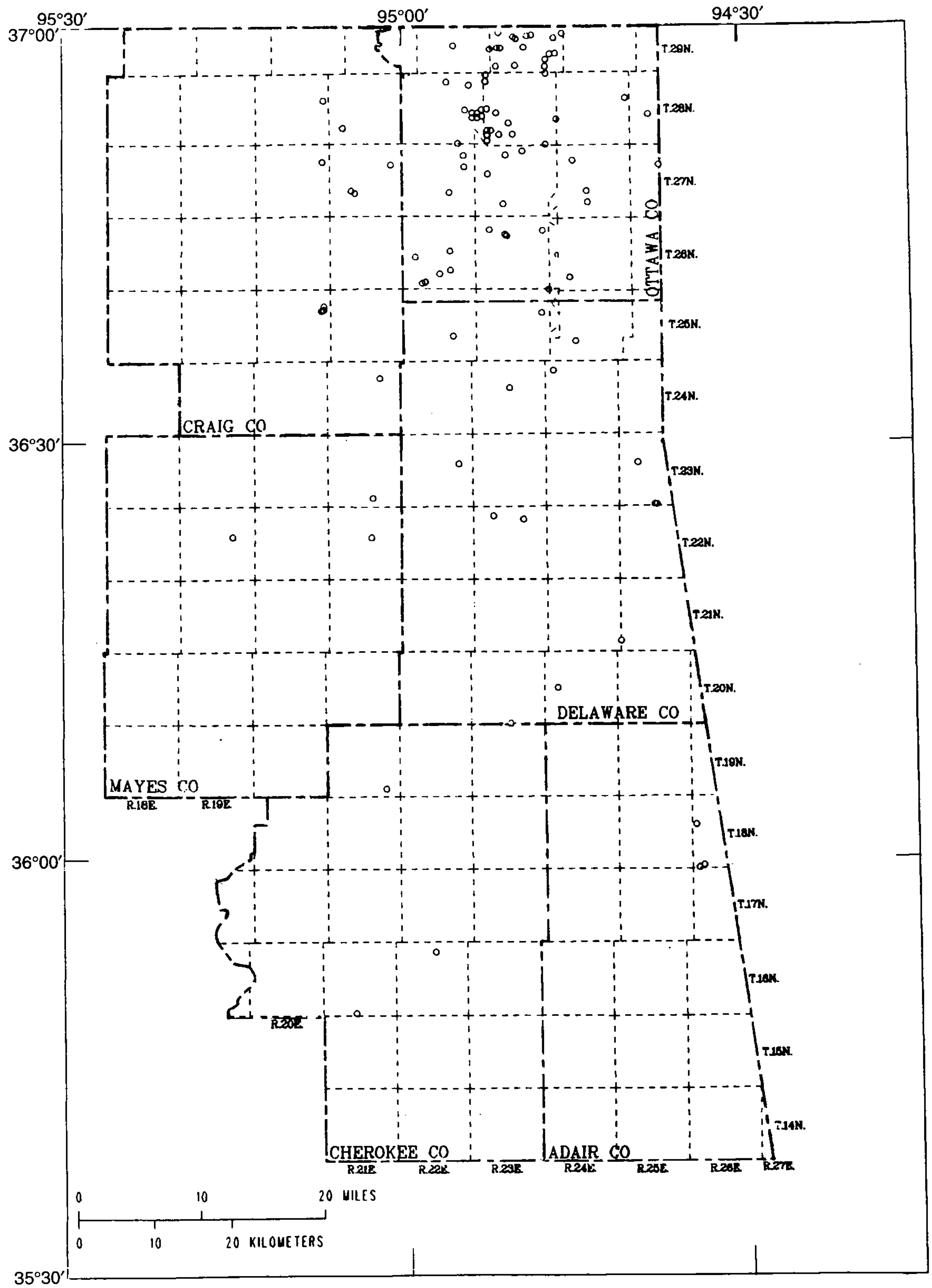

Figure 4. Locations of 110 wells penetrating the Roubidoux aquifer in northeastern Oklahoma that were used as control points.

TABLE 1.—GENERALIZED GEOLOGIC NOMENCLATURE AND WATER-YIELDING CHARACTERISTICS OF ROCKS IN NORTHEASTERN OKLAHOMA

System	Geologic unit	Thickness (ft)	Lithologic description	Water-yielding characteristics
Pennsylvanian	Pennsylvanian rocks, undivided	0–230	Shale, siltstone, sandstone, limestone, and a few thin coal seams.	Wells yield from <1 to >50 gal/min.
Mississippian	Mississippian rocks, undivided	0–175	Limestone, shale, siltstone, and sandstone.	Wells yield from <1 to 20 gal/min.
	Boone Formation	0–370	Chert and fine- to coarse-grained gray, light gray, and bluish limestone.	Wells generally yield <10 gal/min but may yield as much as 750 gal/min.
	Northview Shale	0–30	Greenish-black or dull-blue shale.	Not water bearing.
	Compton Limestone		Gray, nodular, shaly limestone.	Not water bearing.
Devonian and Mississippian	Chattanooga Shale	0–80	Black, carbonaceous, fissile shale.	Not water bearing.
Ordovician	Ordovician rocks, undivided	0–550	Finely crystalline dolomite, with some thin shale beds and some sand stringers; found in a few wells in the southern part of the study unit.	Water-yielding characteristics not known.
	Cotter Dolomite	0–840	Light buff to brown cherty dolomite with several sandy and argillaceous zones; Swan Creek sandstone identified at base of Cotter in some wells is sandstone or sandy dolomite.	Wells generally yield <10 gal/min but may yield as much as 380 gal/min.
	Swan Creek sandstone			
	Jefferson City Dolomite		Light buff, gray and dark brown very cherty dolomite.	Water-yielding characteristics not known.
	Roubidoux Formation	0–300	Light-colored, cherty dolomite with 2 or 3 layers of sandstone, each about 15–20 ft thick.	Principal aquifer in northeastern Oklahoma. Wells yield from 100 to >1,000 gal/min.
	Gasconade Dolomite	0–350	Light-colored, medium to coarsely crystalline, cherty dolomite; at the base, the Gunter Sandstone Member is sandstone or sandy dolomite.	Not known to yield significant amount of water from beds above Gunter Sandstone Member. Gunter yields moderate amount of water.
	Gunter Sandstone Mbr.			
Cambrian	Eminence and Potosi Dolomites	0–370	Dark brown and light-colored cherty dolomite.	Water-yielding characteristics not known.
	Bonneterre Dolomite	0–180	Dolomite with chert, pyrite, oolites, and glauconite; percentage of sand decreases progressively upward from the base of the formation.	Water-yielding characteristics not known.
	Lamotte Sandstone	0–80	Medium- to coarse-grained sandstone, shale, and siltstone.	Not known to yield water to wells in the study unit.
Precambrian	Precambrian basement rocks, undivided	Unknown	Volcanic rocks and granite.	Not water bearing.

Rocks of Ordovician age overlie the Cambrian rocks. The lowermost Ordovician unit is the Gasconade Dolomite. The Gasconade Dolomite consists of cherty dolomite, sandstone, and sandy dolomite. A basal sandstone, the Gunter Sandstone Member, is composed of ~20 ft of sandstone and sandy dolomite. Many wells in Missouri and Arkansas are completed with the Gunter Sandstone Member as the primary water-contributing geologic unit. The overall thickness of the Gasconade Dolomite in the study unit ranges 0–350 ft; average thickness is 230 ft.

The Roubidoux Formation overlies the Gasconade Dolomite. The Roubidoux Formation consists of cherty dolomite ranging 0–300 ft thick and averaging ~175 ft thick (Fig. 5). The top of the Roubidoux Formation ranges from ~80 ft above to nearly 600 ft below sea level in wells in the study unit (Fig. 6), which corresponds to depths 770–1,300 ft below land surface. The Roubidoux Formation contains two or three layers of sandstone, each about 15–20 ft thick.

The Cotter and Jefferson City Dolomites, undivided in this study, overlie the Roubidoux Formation. The Cotter and Jefferson City Dolomites are mainly cherty dolomites with sandstone lenses. The combined thickness of the two formations is 0–840 ft (Fig. 7). The Cotter Dolomite is at the surface in Mayes County, but in wells in other parts of the study unit it can be as much as 670 ft below land surface. The Swan Creek sandstone is identified in some wells at the base of the Cotter Dolomite. The Swan Creek sandstone is a sandstone or sandy dolomite, as much as 30 ft thick.

Other geologic units of Ordovician age are identified in a few wells in the southern part of the study unit. These formations, stratigraphically above the Cotter Dolomite, are undivided in this report. These geologic units are identified as the Powell Dolomite, Everton Formation equivalent, Burgen Sandstone, or Tyner Formation in the few wells in which they are found. All four units were not identified in any single well. Combined thickness is 0–550 ft. These units are predominantly a finely crystalline dolomite, with some thin shale beds and some sand stringers.

The Chattanooga Shale, of Devonian and Mississippian age, overlies the Ordovician-age geologic units. It is a black, carbonaceous, fissile shale, 0–80 ft thick (Fig. 8).

In a few locations, the Northview Shale and the Compton Limestone of Mississippian age overlie the Chattanooga Shale. The Northview Shale is a greenish-black or dull-blue shale, and the Compton Limestone is a gray, nodular, shaly limestone. The combined thickness of these two formations is ≤30 ft.

Overlying the Northview Shale is the Boone Formation, a sequence of cherty limestone strata of Mississippian age that crops out in the eastern half of the study unit. The Boone Formation is 0–370 ft thick. The Boone Formation contains lead and zinc ores that were mined extensively in northeastern Oklahoma, southeastern Kansas, and southwestern Missouri from about 1890 to 1970. Overlying the Boone Formation are other Mississippian formations, undivided for this study. These undivided formations consist of limestone, shale, siltstone, and fine-grained sandstone that range 0–175 ft thick in the study unit.

Stratigraphically above the Mississippian-age formations are rocks of Pennsylvanian age, also undivided for this study. These rocks are mostly shales, siltstones, sandstones, limestones, and a few thin coal seams. These formations are ≤230 ft thick and crop out in the western part of the study unit.

Structure

The study unit is located on the western flank of the Ozark uplift. The regional dip in the western Ozarks generally is westward and averages ~25 ft/mi. Folding and faulting cause local variations in the regional dip.

The Seneca graben is a major crustal discontinuity that cuts across the study unit. The Seneca graben trends northeast from the vicinity of Pryor in Mayes County, through southeastern Ottawa County, and extends into southwestern Missouri (Miser, 1954). McKnight and Fischer (1970) describe the Seneca graben as a "complex feature in which bounding faults are not continuous" but are associated with several parallel faults with small displacements. The graben block is dropped a maximum of ~150 ft. Along the Seneca graben, where the sedimentary rocks apparently did not break, folded sedimentary rocks replace bounding faults.

Another crustal discontinuity in the study unit is the Miami trough. It is a tectonic feature like the Seneca graben, but its surface expression is not as obvious; it does not appear on the geologic map of Oklahoma (Miser, 1954). The Miami trough trends north–northeast from Afton, passing west of Miami and Picher, and extends into Kansas. As along the Seneca graben, folded sedimentary rocks sometimes replace bounding faults.

GEOHYDROLOGY

The objectives of the geohydrologic part of the Roubidoux aquifer study were to determine the potentiometric surface and the aquifer's hydraulic characteristics. These characteristics include specific yield, transmissivity, storage, and leakance of the confining layer.

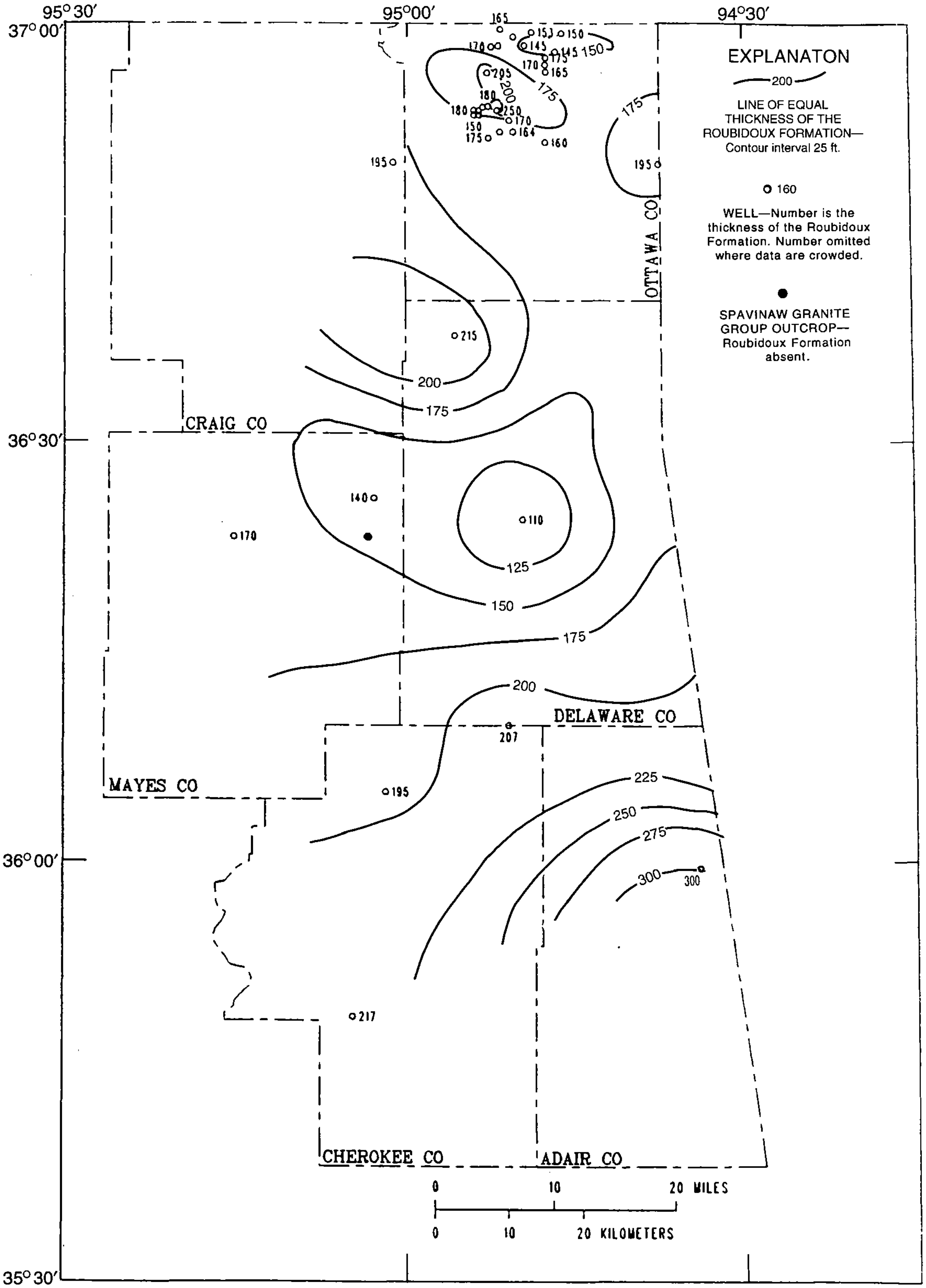

Figure 5. Thickness of the Roubidoux Formation in northeastern Oklahoma.

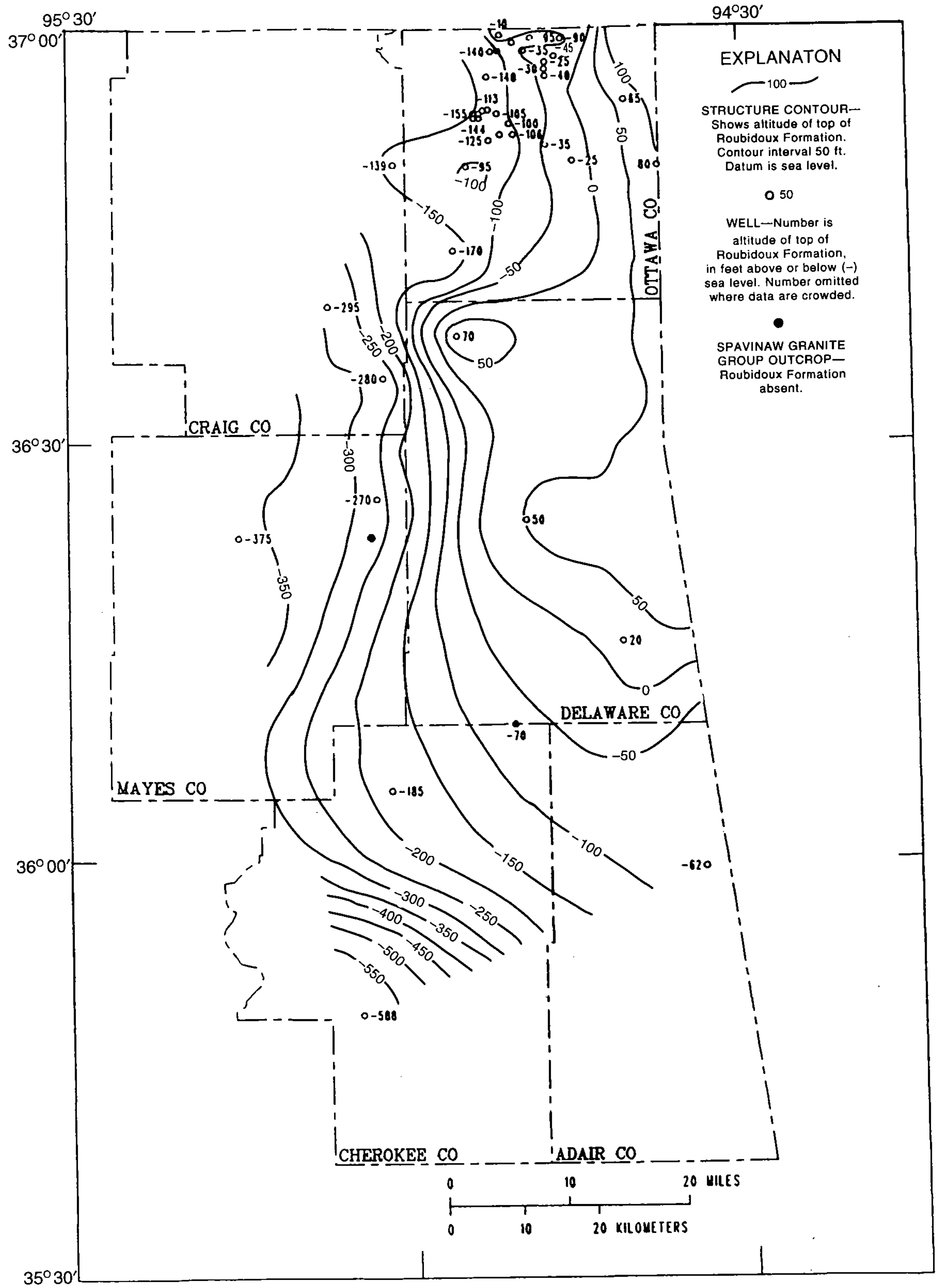

Figure 6. Altitude of the top of the Roubidoux Formation in northeastern Oklahoma.

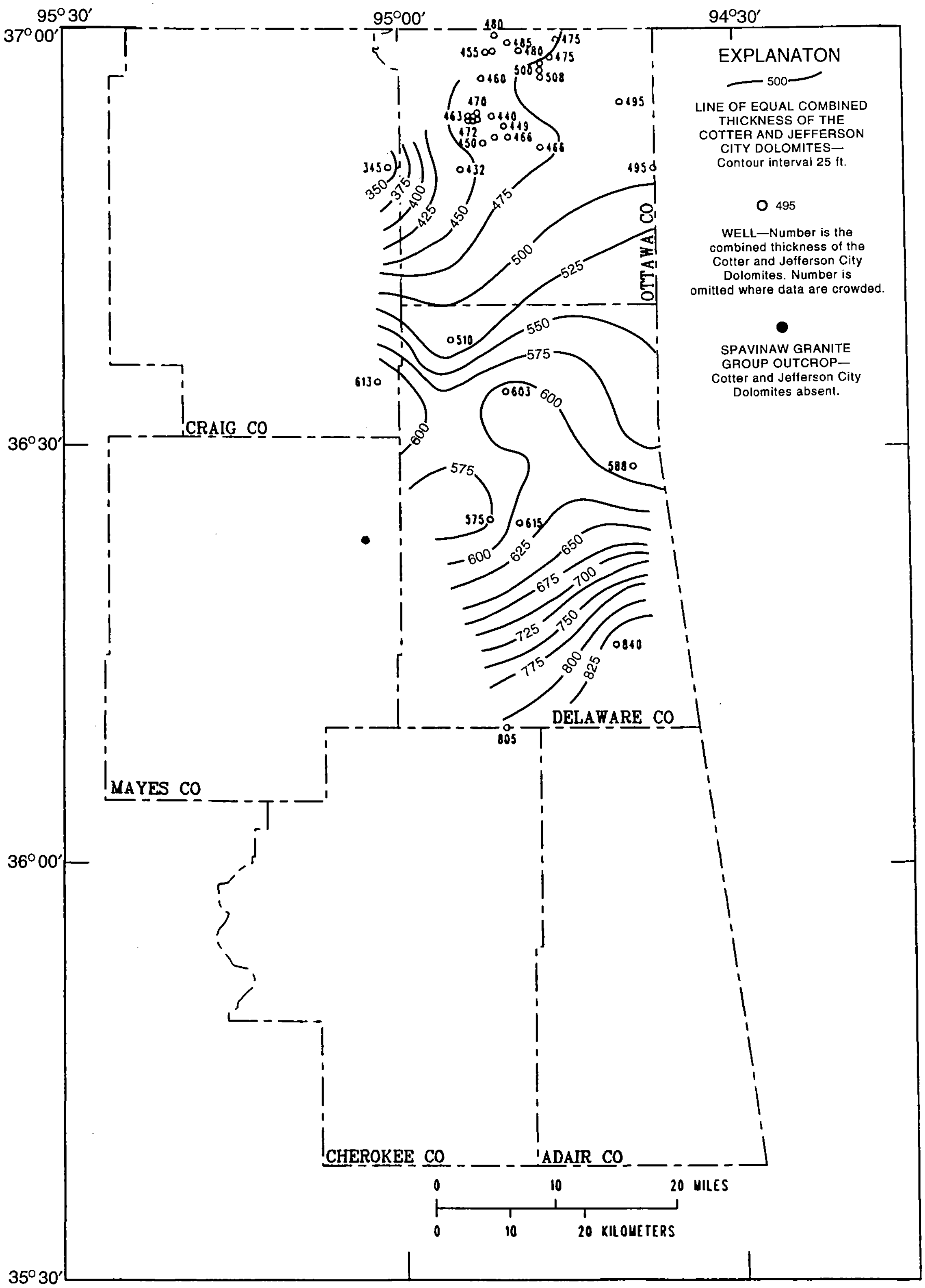

Figure 7. Thickness of the Cotter and Jefferson City Dolomites in northeastern Oklahoma.

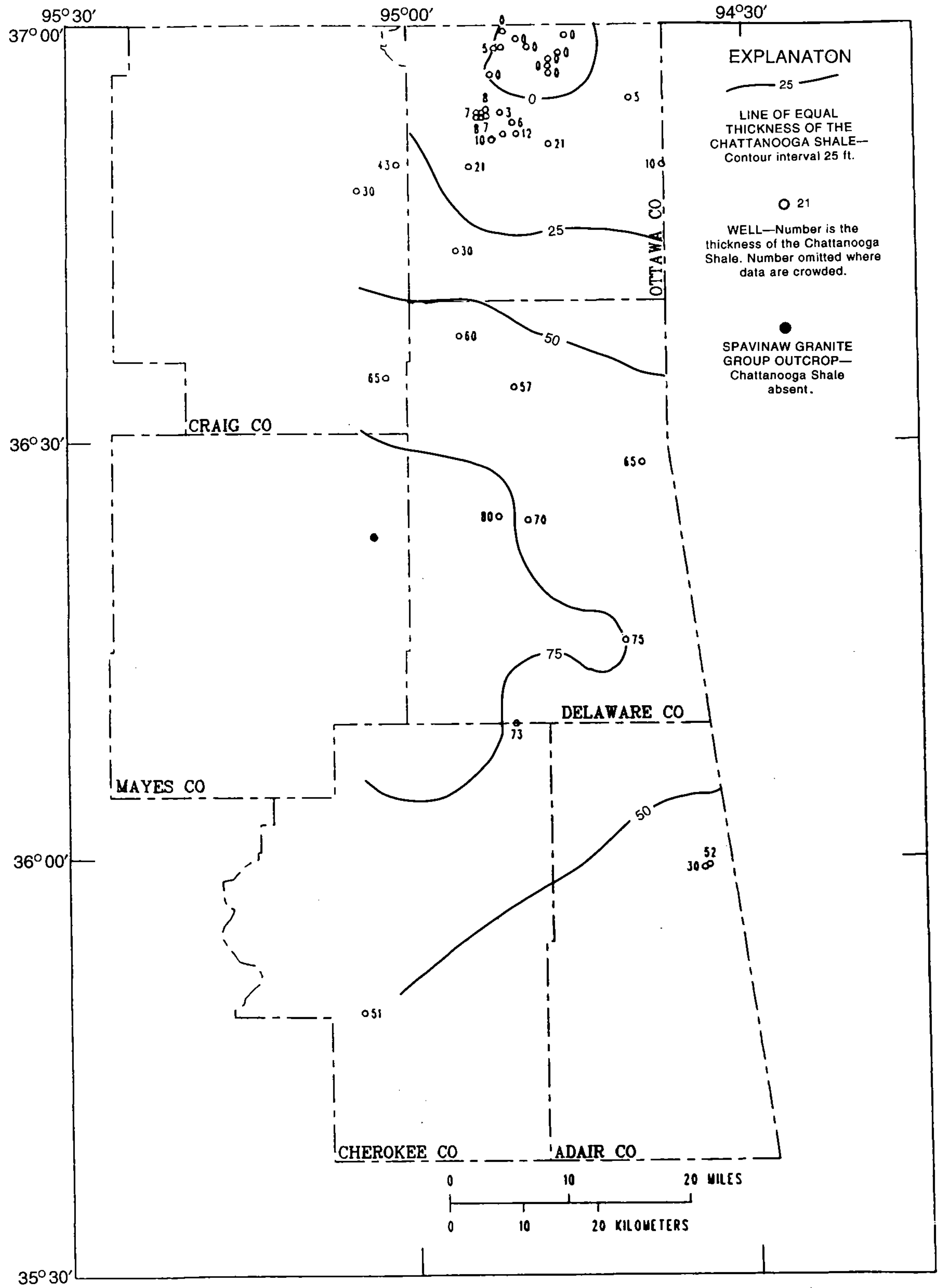

Figure 8. Thickness of the Chattanooga Shale in northeastern Oklahoma.

Ground-Water Withdrawals

Wells were first drilled in the Roubidoux aquifer in northeastern Oklahoma at the beginning of the 20th century. Withdrawals of ground water from the Roubidoux aquifer increased steadily through the mid-1980s. In 1937, the State Mineral Survey (in Reed and others, 1955) reported the total ground-water withdrawals in Ottawa County to be ~1.75 million gal/day. Reed and others (1955) estimated that 2.25–2.50 million gal/day were withdrawn from the Roubidoux aquifer in 1944. They estimated withdrawals at ~4 million gal/day in 1948. The estimated withdrawal from the Roubidoux aquifer in 1981 in the study unit was ~4.8 million gal/day, of which 90% was withdrawn in Ottawa County. In that year, ~75% of the ground water withdrawn from the Roubidoux aquifer in Ottawa County was pumped by the City of Miami and the B. F. Goodrich Co. The B. F. Goodrich Co. closed its Miami tire-manufacturing operation in early 1986, and water use in Ottawa County decreased at that time.

Water Levels

When wells were first completed in the Roubidoux aquifer near the beginning of the 20th century, the wells flowed at the land surface (Siebenthal, 1908). Since then, water levels have declined as a result of ground-water withdrawals. A cone of depression, centered around the City of Miami, has been created by large withdrawals of water. During 1981, as part of this study, water levels were measured in many of the wells completed in the Roubidoux aquifer in Oklahoma (Appendix 2); water levels ranged from 22 to 471 ft below land surface. Water-level data from 1981 were used to construct the potentiometric surface map shown in Figure 9. A water-table aquifer exists in the shallow geohydrologic units in the study unit, and potentiometric head in the water-table aquifer is much higher than the head in the Roubidoux aquifer. Thus, vertical hydraulic gradients exist between the geohydrologic units in the study unit and probably within the Roubidoux aquifer. Many of the Roubidoux aquifer wells in which water levels were measured have large open intervals, and many are completed from the top of the Cotter Dolomite to the bottom of the well in the Roubidoux Formation or Gasconade Dolomite. Because head varies in the vertical direction and deep wells are open to large intervals, water levels measured in deep wells are an integrated measurement of a range of head. Although the potentiometric surface shown in Figure 9 is considered to be a reasonable approximation of the potentiometric head in the Roubidoux aquifer, there is some variation in head with depth at each well shown in Figure 9.

Water levels were measured periodically in selected wells completed in the Roubidoux aquifer to determine seasonal variations and long-term trends. Hydrographs for two wells in Craig County and for three wells in Delaware County are shown in Figure 10; hydrographs for five wells in Ottawa County are shown in Figure 11. The water levels in all 10 wells were relatively stable during the two-year period in which they were measured. None of the wells had a large seasonal variation or a consistent increase or decrease in water level.

The long-term trend of the water level in a well completed in the Roubidoux aquifer located in the City of Miami (28N–23E–30 DBC 1) is shown in Figure 12. The water level in this well has been monitored sporadically since 1907. The well flowed when it was drilled, and measurements discussed in Reed and others (1955) place the water level at 28 ft above land surface prior to 1907. The water level in the well was relatively stable between 1972 and 1986 at an approximate depth of 440 ft below land surface (corresponding to an altitude of 330 ft). Water levels in the well began to rise in 1986, at about the time the B. F. Goodrich Co. ceased its manufacturing operation in Miami.

Specific Capacity

Specific capacity is one measure of a well's ability to yield water. Specific capacity is computed by dividing the well yield, commonly measured in gallons per minute, by the drawdown, commonly measured in feet. Specific capacity is a function of the hydraulic characteristics of the well and of the geohydrologic units in which the well is completed. In general, large diameter wells will have a greater specific capacity than small diameter wells completed in the same aquifer. For similarly constructed wells of the same diameter, greater aquifer transmissivity is indicated by the wells with greater specific capacities.

The specific capacities of selected wells completed in the Roubidoux aquifer range from 0.29 to 18.50 gal/min/ft of drawdown (Table 2). The wells that were tested for specific capacity were pumped at rates that ranged 102–1,016 gal/min. Many factors contribute to the large range in specific capacity:

1) The specific-capacity tests were not run for the same length of time. Shorter specific-capacity tests give greater specific capacities than longer tests because drawdown commonly increases with time.

2) The thickness of the Roubidoux aquifer varies at each well. Wells completed in thicker sections of the aquifer may intersect a greater amount of permeable aquifer, which tends to increase the specific capacity of the well.

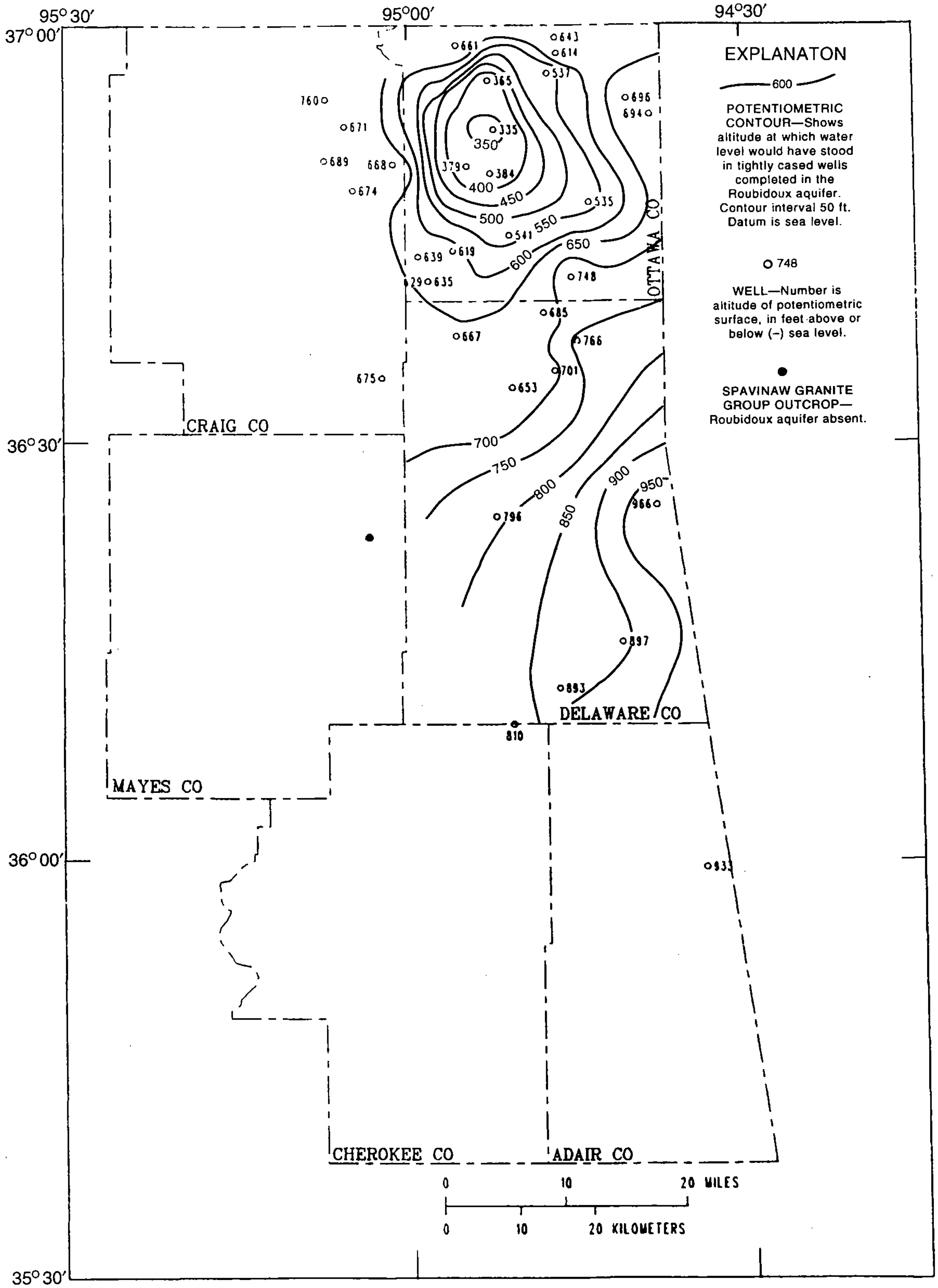

Figure 9. Altitude of the potentiometric surface in the Roubidoux aquifer, 1981, in northeastern Oklahoma.

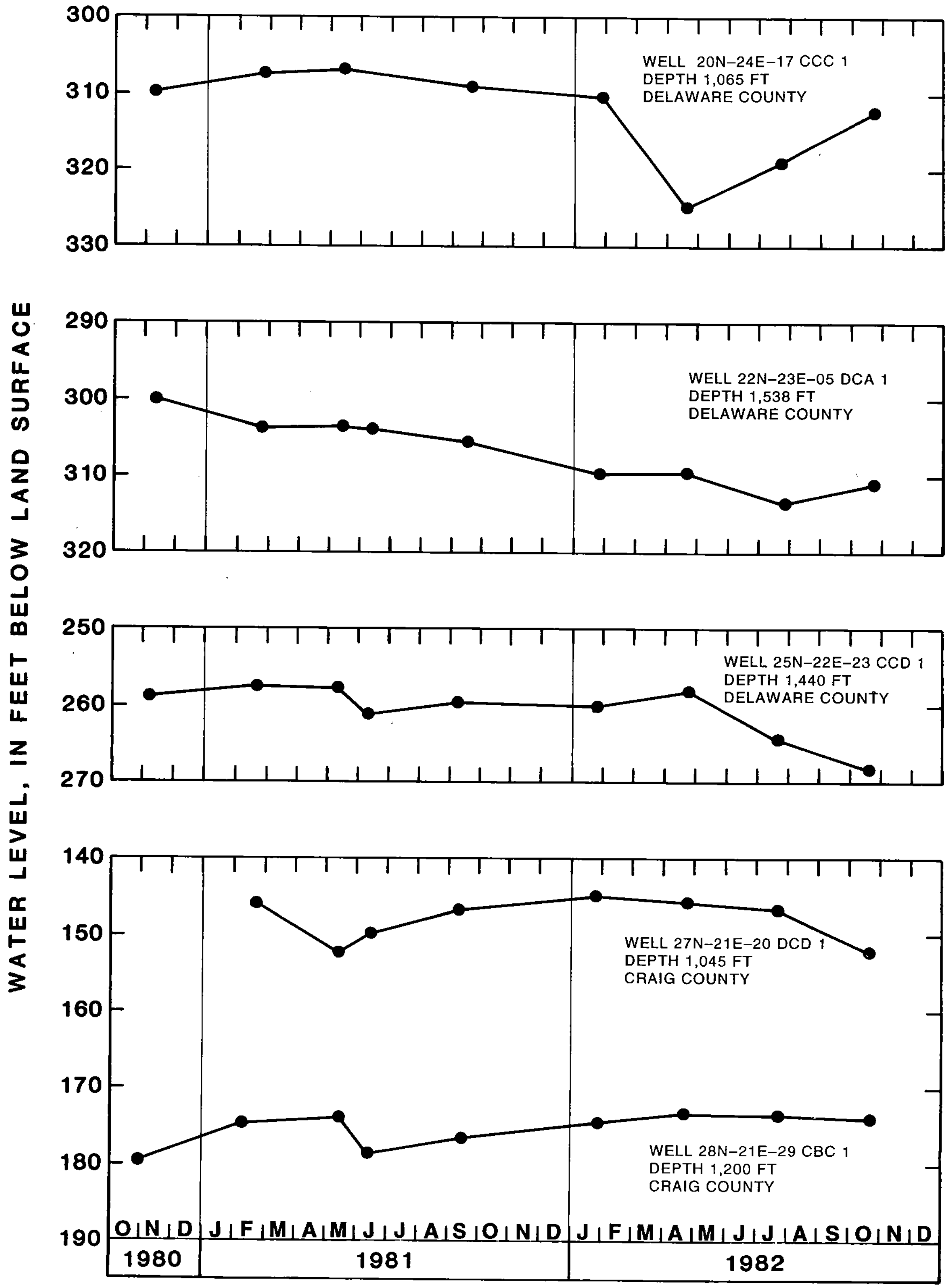

Figure 10. Hydrographs for selected wells in Craig and Delaware Counties, Oklahoma.

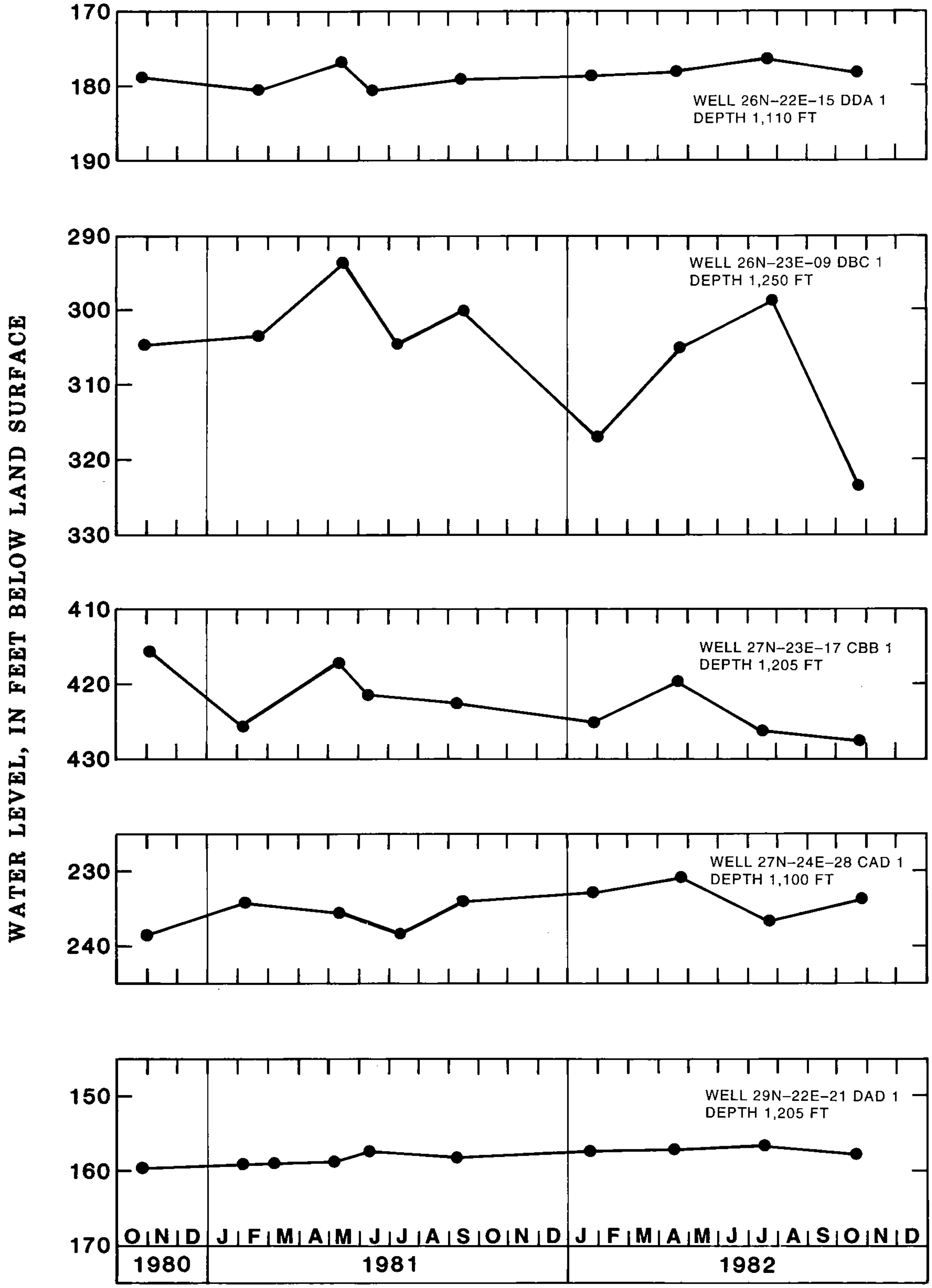

Figure 11. Hydrographs for selected wells in Ottawa County, Oklahoma.

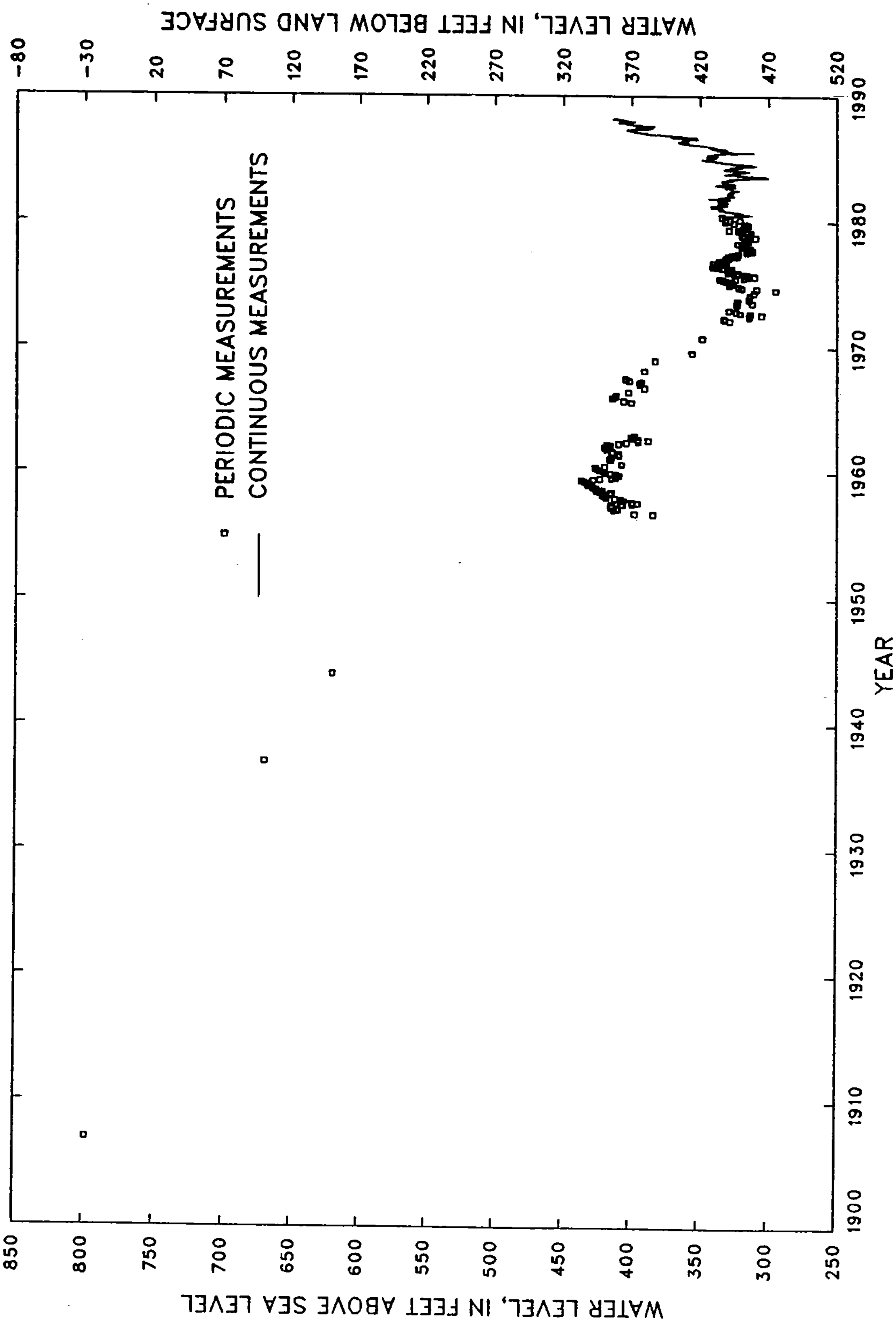

Figure 12. Hydrograph for well 28N–23E–30 DBC 1 at Miami, Oklahoma.

TABLE 2.—SUMMARY OF SPECIFIC CAPACITIES OF SELECTED WELLS COMPLETED IN THE ROUBIDOUX AQUIFER IN NORTHEASTERN OKLAHOMA[a]

Local identifier	Well depth (ft)	Yield (gal/min)	Duration of test (hr)	Drawdown (ft)	Specific capacity ([gal/min]/ft)
		~ ADAIR COUNTY ~			
18N–26E–31 DAD 1	1,510	150	7.0	296	0.51
		~ CRAIG COUNTY ~			
27N–21E–12 CCB 1	1,352	305	20.0	72	4.24
27N–21E–20 DCD 1	1,045	110	48.0	380	0.29
		~ DELAWARE COUNTY ~			
20N–24E–17 CCC 1	1,065	260	48.0	250	1.04
21N–25E–31 BBB 1	1,350	135	48.0	200	0.68
22N–23E–05 DCA 1	1,538	102	12.0	330	0.31
22N–23E–11 BBB 1	1,442	200	—[b]	173	1.16
24N–23E–15 BBC 1	1,145	275	48.0	183	1.50
25N–22E–23 CCD 1	1,440	302	12.0	129	2.34
		~ OTTAWA COUNTY ~			
26N–22E–15 DDA 1	1,110	110	50.0	325	0.34
27N–23E–17 CBB 1	1,205	192	24.0	84	2.29
27N–25E–09 CAC 1	1,247	407	8.0	263	1.55
28N–23E–20 BCB 1	1,250	1,016	0.5	150	6.77
28N–23E–33 BAB 1	1,526	934	4.0	264	3.54
28N–23E–36 CCC 1	1,190	185	4.0	10	18.50
28N–25E–20 CAA 1	1,418	200	2.0	35	5.71
29N–22E–21 DAD 1	1,205	300	7.5	30	10.00
29N–23E–13 DAC 1	1,115	150	—[b]	138	1.09

[a]Data from this study or from well completion reports.
[b]No data available.

3) The rocks constituting the Roubidoux aquifer are fractured. It is not known what percentage of the water moving through the aquifer moves through fractures and what percentage moves through the voids between grains. Water moving through fractures tends to increase the effective diameter of the well, which increases the specific capacity.

4) Well completion techniques are different for each individual well. Many of the wells were acidized and "shot" (nitroglycerine was detonated within the well bore) to increase fracturing, which increases the effective diameter of the well.

All these factors contribute to the wide range in specific capacities.

Aquifer Test

An aquifer test to determine the transmissivity and storage coefficient of the Roubidoux aquifer was conducted on wells at the B. F. Goodrich Co. plant in Miami, Oklahoma, in 1944. The test was conducted by pumping a production well (28N–22E–24 CBC 1) and measuring the decline in water levels in another well (28N–22E–24 CAD 1) at a distance of 2,575 ft. The aquifer test was analyzed by Reed and others (1955) using the Theis type-curve solution (Theis, 1935). However, the data did not fit the Theis curve very well: Reed and others (1955) speculated that the boundary faults associated with the Miami trough may reduce the transmissivity of the Roubidoux aquifer and thus cause the poor fit between the measured drawdown and the Theis curve. Another possible explanation for the poor fit is that water was released from storage in the confining layer, which violates an assumption of the Theis type-curve solution.

Since the work of Reed and others (1955), a type-curve solution has been developed that accounts for water released from storage in a confining layer (Hantush, 1960, as reported in Reed, 1980). Using this type-curve solution, the 1944 test was analyzed to determine the transmissivity and storage coefficient (dimensionless) of the Roubidoux aquifer, and the product of the leakance (the ratio of vertical hydraulic conductivity to the thickness of the confining layer, K'/b') and the storage coefficient of the confining layer (S'). The results are shown below:

Transmissivity:	600 ft^2/day
Aquifer storage coefficient (S):	1.0×10^{-6}
$K'S'/b'$:	1.3×10^{-8} per day

Drawdowns were calculated by substituting these estimates of the aquifer's properties into the analytical solution in Reed (1980). A comparison between the measured time-drawdown data and the computed time-drawdown values for the aquifer test conducted at the B. F. Goodrich Co. plant is shown in Figure 13. The storage coefficient computed above is smaller than would be expected for an aquifer as thick as the Roubidoux. The storage coefficient of an aquifer can be expressed as:

$$S = (S_{sw} + S_{sa})\, b \qquad (1)$$

where S = aquifer storage coefficient (dimensionless),
S_{sw} = specific storage due to elasticity of water,
S_{sa} = specific storage due to elasticity of aquifer skeleton,
b = the thickness of the aquifer (ft).

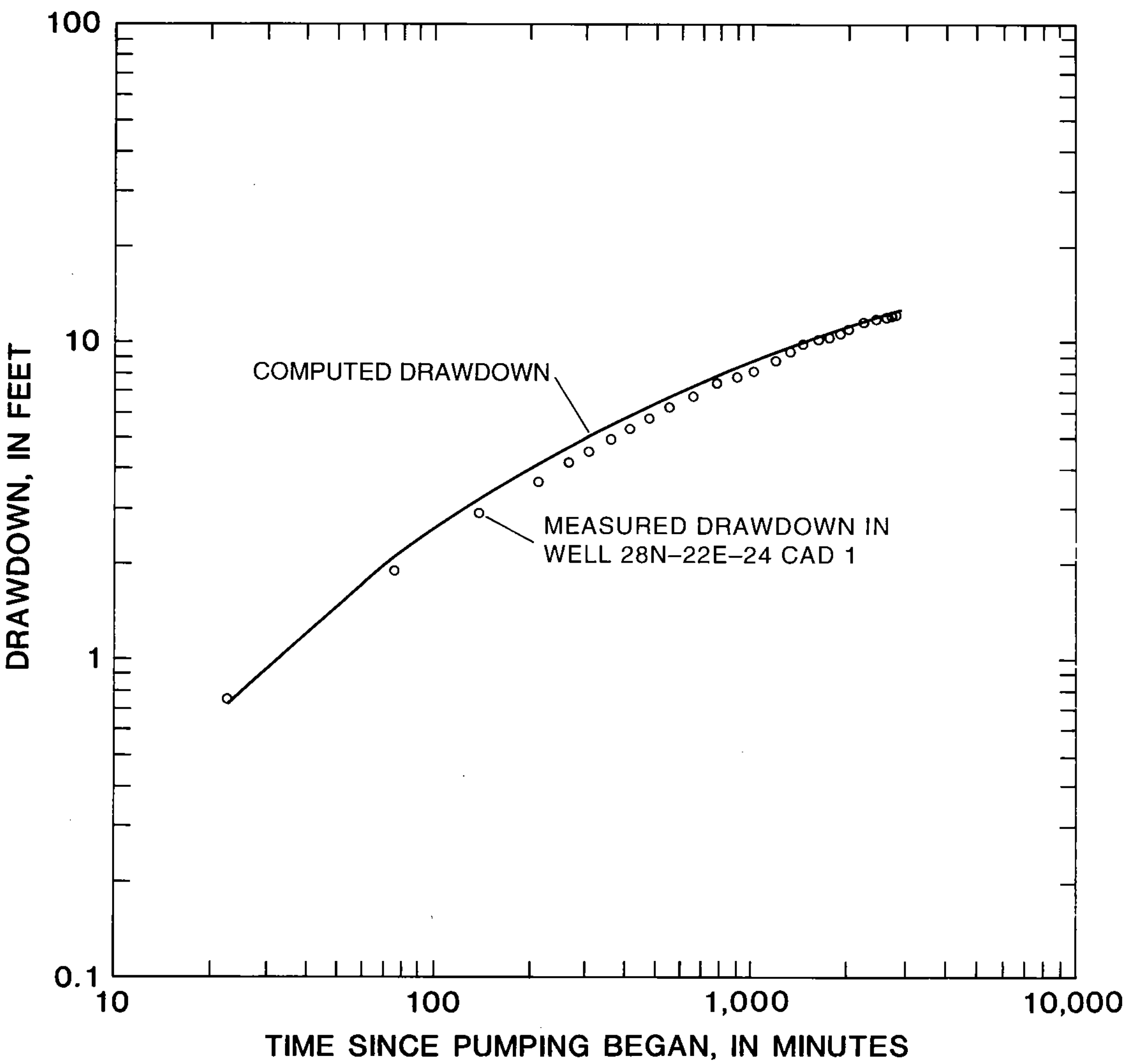

Figure 13. Measured and computed drawdown for the 1944 Roubidoux aquifer test at B. F. Goodrich Co. plant in Miami, Oklahoma.

This can be written:

$$S = \left(\frac{nA_w}{E_w} + \frac{A_w}{E_a}\right) b \qquad (2)$$

where n = porosity of the aquifer (dimensionless),
A_w = the specific weight of water (lbs/ft^3),
E_w = the modulus of elasticity of water (lbs/ft^2),
E_a = the modulus of elasticity of the aquifer (lbs/ft^2).

Although the modulus of elasticity of the Roubidoux aquifer is not known, the modulus of elasticity of water has been measured, and it is possible to compute a minimum storage coefficient for an aquifer based on the expansion of the water alone. The specific weight of water is 62.4 lbs/ft^3 and the modulus of elasticity of water is approximately 4.6×10^7 lbs/ft^2. If the porosity of the Roubidoux aquifer is 0.01 (a likely minimum value), the storage coefficient per foot of aquifer, or specific storage, is approximately 1.36×10^{-8} per foot; if the porosity of the aquifer is 0.3 (a likely maximum value), the specific storage is approximately 4.07 $\times 10^{-7}$ per foot. The component of storage due to the compression of each foot of aquifer would be added to this number and the total multiplied by the thickness of the formation. If the Roubidoux aquifer were completely inelastic (a very unlikely possibility), the second term in equation (2) would be zero. Solving equation (2) for b using the modulus of elasticity of water alone indicates that the Roubidoux aquifer is between 73.7 ($n = 0.01$) and 2.46 ($n = 0.3$) ft thick. Figure 5 shows the Roubidoux Formation (the principal geohydrologic unit in the Roubidoux aquifer) is >150 ft thick at the site of the aquifer test. The source of this discrepancy is not understood.

The characteristics of the confining layer ($K'S'/b'$) determined by the 1944 aquifer test were left as a product, because the analytical solution provides no means of determining any of these numbers individually. A range for the leakance of the confining layer (K'/b') can be calculated based on a range of plausible values for the storage coefficient of the confining layer (S'). The storage coefficient could range from 0.3 (the upper limit of porosity) to 1.0×10^{-7} (a storage coefficient based on the modulus of elasticity of water alone); thus, the leakance of the confining layer could range from 4.3×10^{-8} to 0.13 per day. The thickness of the confining layer could not be determined independently. Because both the pumping and observation wells are open to the Cotter and Jefferson City Dolomites, it is possible that these geologic units are acting as part of the aquifer. It is also possible that if the Cotter and Jefferson City Dolomites have only small transmissivities, they may be part of the confining layer.

Digital-Model Analysis

Digital-model simulations of the cone of depression in the potentiometric surface in the vicinity of the City of Miami were used to determine the transmissivity of the Roubidoux aquifer and the hydraulic characteristics of the overlying confining layer. Water levels within the cone of depression were relatively stable in 1981 (as shown for well 28N–23E–30 DBC 1, Fig. 12), which indicates that the flow system in the vicinity of the cone was in an approximate steady-state condition at that time. This steady-state condition simplifies the modeling process by eliminating from the analysis any consideration of storage changes. The digital-model simulations were used to provide both an estimate of the transmissivity of the aquifer and a range for the vertical hydraulic conductivity of the confining layer.

Steady-state conditions imply that outflows of water are equal to inflows of water, with no change in the amount of water in storage. In the case of the cone of depression near Miami, outflow is the withdrawal of ground water from wells in and near Miami. The inflow of water could occur by two different processes:

1) The lateral flow of water through the Roubidoux aquifer to the cone of depression. In this case, water moves laterally through the aquifer from areas of higher head outside of the cone of depression toward the lower head within the cone.

2) The vertical flow of water into the cone of depression in the Roubidoux aquifer through confining layers from overlying geohydrologic units. Heads in the Roubidoux have been lowered by ground-water withdrawals, and heads are higher in the overlying geohydrologic units (such as the Boone Formation). Water flows downward from the higher heads in the overlying geohydrologic units through the confining layer to the Roubidoux aquifer. Such vertical flow through confining layers is generally referred to as leakage.

The volume of lateral ground-water flow through the aquifer and vertical flow as downward leakage is dependent on the transmissivity of the aquifer, the vertical hydraulic conductivity and thickness of the confining layer, and the distribution of head in the aquifer and the overlying geohydrologic units. Some volume of water probably is entering the cone of depression by both processes, but the proportions are unknown.

A digital ground-water flow model was used to evaluate the various hydraulic factors that control ground-water flow. By adjusting the digital-model parameters that correspond to the hydraulic characteristics of aquifers and confining layers, the distribution of head was simulated. The combinations of digital-model parameters that produced acceptable agreement between computed and measured heads are possible descriptions of the corresponding combinations of aquifer and confining layer hydraulic properties. Realizing that there is no unique solution to the infinite number of possible combinations of aquifer and confining layer characteristics that can produce a given head distribution, the digital model was used to evaluate certain combinations of parameters. Although a digital model does not provide a unique solution, it does provide a range of hydraulic characteristics that are likely to occur in the ground-water flow system.

In some investigations, digital models undergo an extensive calibration and verification process, and the models are used to simulate many aspects of the ground-water flow system. This was not done for the digital model discussed here. No attempt was made to undertake a complete model analysis of the ground-water flow system in northeastern Oklahoma. The objective of the digital-model simulation of the cone of depression near Miami was to establish ranges for the hydraulic properties of the aquifer and confining layer.

The digital-model code used was that of the U.S. Geological Survey's modular finite-difference model (McDonald and Harbaugh, 1984). The digital-model grid was established using 40 columns, 40 rows, and two layers. The lower layer represented the Roubidoux aquifer and the upper layer represented the overlying Boone Formation. An intervening confining layer, representing the Chattanooga Shale and possibly including the Cotter and Jefferson City Dolomites, was represented by the leakance between the upper and lower layers, but not by an actual layer in the digital model. The upper layer in the digital model was assigned to be constant head because the Boone Formation receives large amounts of recharge and discharges most of the recharge to streams that maintain heads at a relatively constant level.

The model grid spacing was variable in the x and y directions. A fine mesh in the center of the digital model represented the center of the cone of depression, and the grid gradually became coarser toward the outer region of the zone of simulation. The smallest grid spacing in the center of the zone of simulation was 1 mi, and the largest grid spacing at the edge of the zone of simulation was 4.3 mi.

Various combinations of aquifer characteristics and boundary conditions were assigned to the digital model to simulate the measured head distribution. The goodness of fit between measured and computed heads in the Roubidoux aquifer was measured by the mean head difference between measured and computed heads (MHD) and by the mean of the absolute value of head difference between measured and computed heads (MAVHD) at nodes in Ottawa County. Only those nodes that correspond to the area representing Ottawa County in the flow model were used in the computations because the density of head data is greatest in that county.

The MHD was computed by summing the difference between measured and computed head at each node and dividing by the total number of nodes. Ideally, the MHD should be reduced to zero. A zero MHD indicates that deviation between measured and computed heads is, on average, zero and that positive differences are balanced by negative differences.

The MAVHD was computed by summing the absolute value of the difference between measured and computed heads at each node and dividing by the number of nodes. During the modeling process, the MAVHD is minimized as the differences between measured and computed heads become smaller. Ideally, the MAVHD should be reduced to the estimated error of the measured heads. The estimated error for heads measured in the Roubidoux aquifer in 1981 was large, probably >50 ft. A number of factors contributed to the size of the error: (1) the altitude of the wells was estimated from topographic maps, which could introduce an estimated error of ±10 ft (the contour interval of the map); (2) many of the wells in which the water levels were measured are operational water-supply wells, and they were affected by pumping prior to the water-level measurements from which heads were calculated; (3) wells pumping close to wells in which the water-level measurements were made also affected the measured heads; (4) because of the open-borehole nature of wells in the Roubidoux, the measured head in a well was somewhere between the highest and lowest heads in the formations within the open interval in the well; the difference between the highest and lowest head can be many tens of feet in an aquifer with significant vertical flow.

During the modeling process, ideally, the errors between computed and measured heads should be normally distributed around the mean, an indication that the errors are random, not systematic.

Three different conceptual models were tested with the digital-model simulations:

Model 1.—Water pumped from the cone of depression is entering the cone only as lateral flow through the Roubidoux aquifer. This conceptual model was tested by setting the leakance of the confining layer equal to zero, which allowed no vertical leakage, and by setting constant-head nodes along the perimeter of the digital model, which allowed an unlimited amount of lateral flow through the Roubidoux aquifer. The transmissivity of the layer that corresponded to the Roubidoux aquifer was adjusted to produce the best fit between measured and computed head distributions.

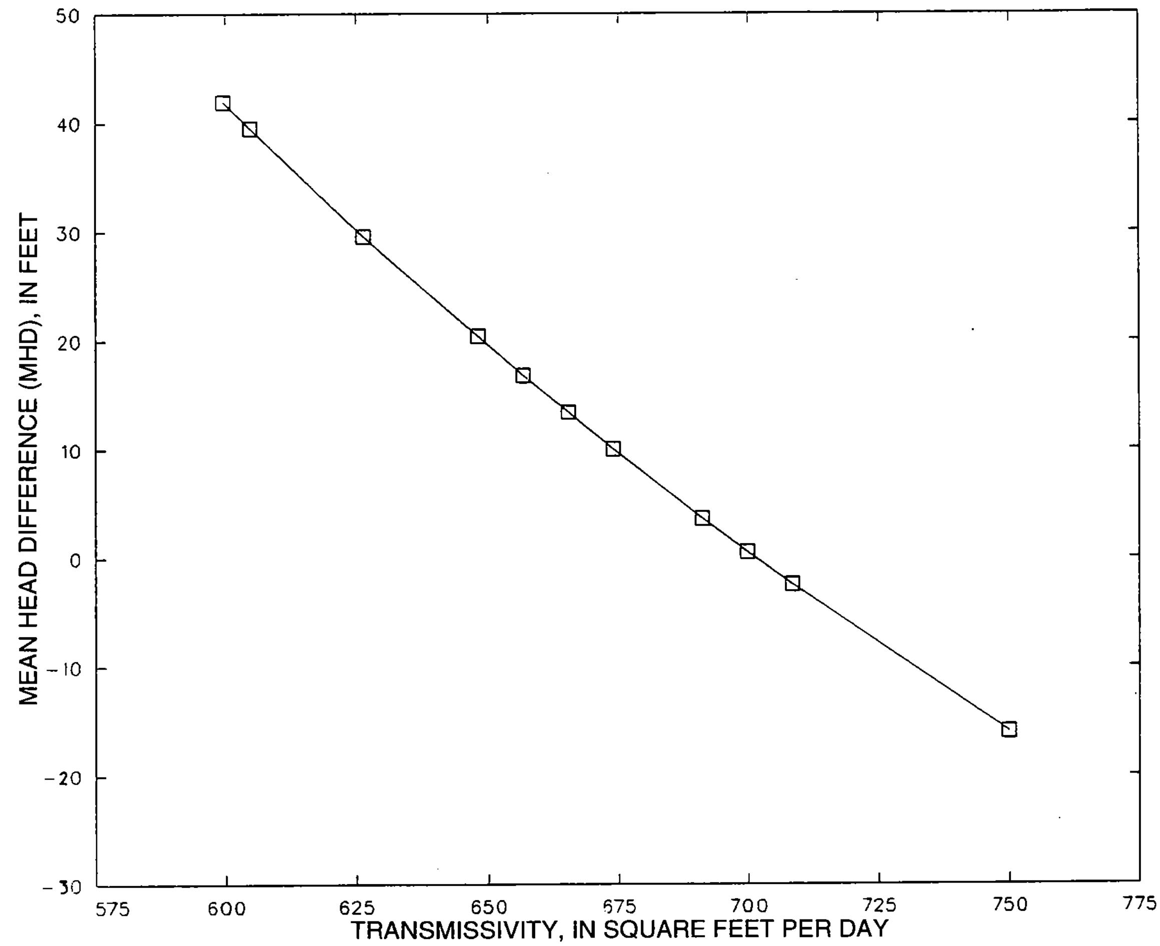

Figure 14. Relation of transmissivity to mean head difference (MHD) for model 1 (lateral flow only).

Model 2.—Water pumped from the cone of depression is entering the cone only as vertical flow through the confining layer. This conceptual model was tested by removing the constant-head nodes from the perimeter of the digital model, in effect surrounding the model with an impermeable barrier. Leakance was set to a positive value and adjusted, along with the transmissivity of the aquifer, to obtain the best fit between measured and computed head distribution.

Model 3.—Water pumped from the cone of depression is entering the cone by a combination of lateral flow through the Roubidoux aquifer and vertical flow through the confining layer. Constant-head nodes were set around the perimeter of the digital model and leakance was adjusted, along with transmissivity, to obtain the best fit between measured and computed head distribution. By using both constant-head nodes and setting leakance to a positive value, both lateral flow through the Roubidoux and vertical leakage through the confining layer were simulated.

Figure 14 shows that in model 1 (lateral flow only) an MHD of zero was achieved using a transmissivity of 700 ft^2/day. Figure 15 shows that a minimum MAVHD of 62.7 ft was achieved with a transmissivity of 660 ft^2/day. Examination of the residuals (the differences between computed and measured heads at each model node) shows that the errors are skewed. A smaller number of nodes with large positive residuals (a positive sign means that computed head is lower than measured head) are balanced by a larger number of nodes with small negative residuals. The negative residuals tend to occur in the center of the cone of depression, and the positive differences occur along the periphery.

Although the minimum MAVHD of 62.7 ft is slightly larger than the estimated error for the measured heads (50 ft), it is close enough to consider model 1 a reasonable representation of the aquifer system. That is, the conceptual model of all the water entering the cone of depression as lateral flow, with no

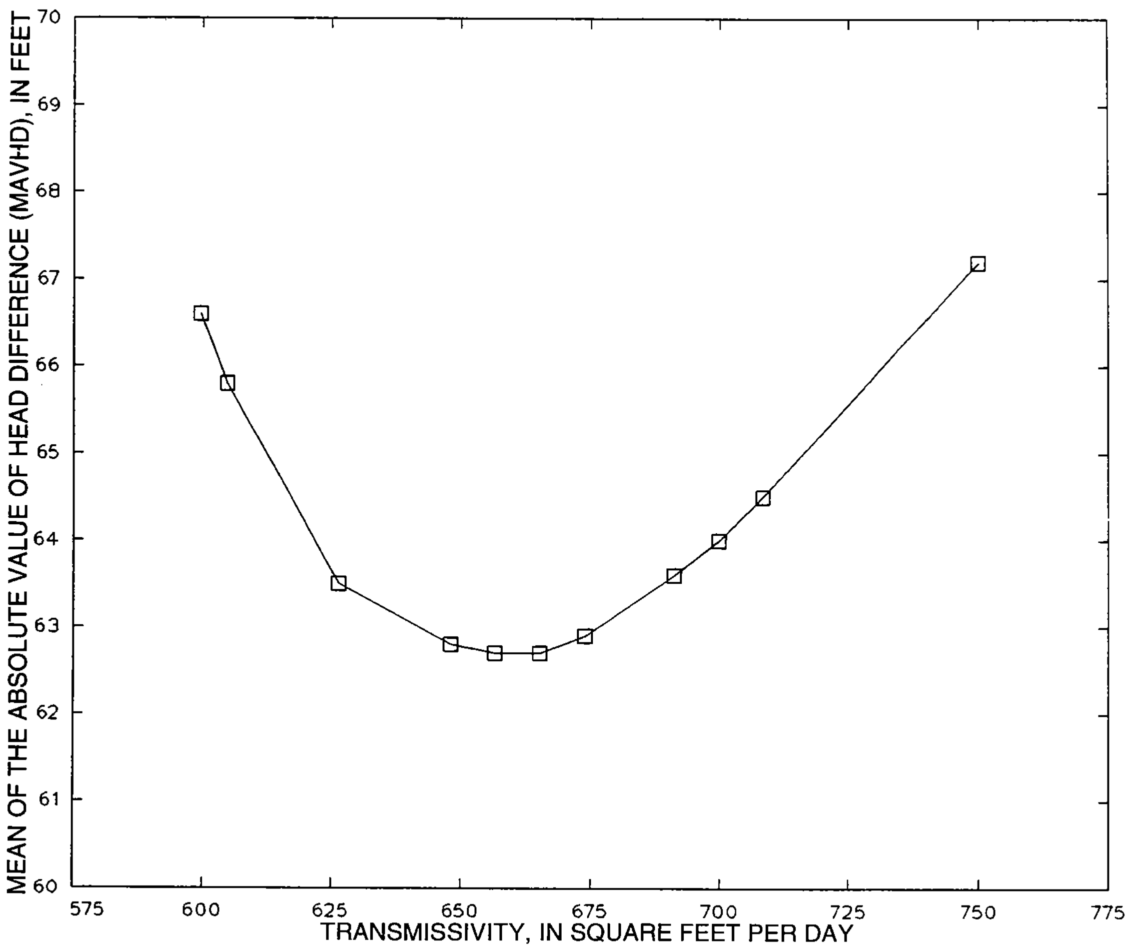

Figure 15. Relation of transmissivity to the mean of the absolute value of head difference (MAVHD) for model 1 (lateral flow only).

vertical leakage, is plausible. In addition, the best fit transmissivities from model 1 of 700 ft^2/day and 660 ft^2/day are close to the 600 ft^2/day calculated from the aquifer test at the B. F. Goodrich Co. plant.

The results of model 2 (vertical flow only) are shown in Figures 16 and 17. These figures are more complicated than Figures 14 and 15 because both the transmissivity of the Roubidoux aquifer and the leakance of the confining layer are being varied. Figure 16 shows that a best-fit MHD of zero was achieved with all values for leakance that were tried. Figure 17 shows that the minimum MAVHD of 59.9 ft was achieved with an aquifer transmissivity of 400 ft^2/day and with a leakance of 7.4×10^{-8} per day. With an aquifer transmissivity of 400 ft^2/day, the best-fit MHD of zero was achieved with a leakance of 7.7×10^{-8} per day, as shown in Figure 16. The residuals are less skewed for model 2 than for model 1. Because the MAVHD is ~3 ft less for model 2 than for model 1, and because the residuals for model 2 are less skewed, model 2 is better than model 1 at reproducing the measured heads. The best-fit transmissivity of 400 ft^2/day for model 2 is close to the 600 ft^2/day transmissivity calculated from the aquifer test conducted at the B. F. Goodrich Co. plant.

The results of model 3 are shown in Figures 18 and 19. Model 3 is a combination of models 1 and 2; in model 3 water can enter the cone of depression both as lateral and vertical flow. Figure 18 shows that for all values of aquifer transmissivity and leakance an MHD of zero was achieved. Figure 19 shows that the best-fit minimum MAVHD between measured and computed heads was 59.8 ft, obtained with an aquifer transmissivity of 450 ft^2/day and a leakance of 4.7×10^{-8} per day. With an aquifer transmissivity of 450 ft^2/day, the best-fit MHD of zero was achieved with a leakance of 4.8×10^{-8} per day, as shown in Figure 18. Because the MAVHD is 0.1 ft less for model 3 than for model 2, and the best fits as measured by the MHD and the

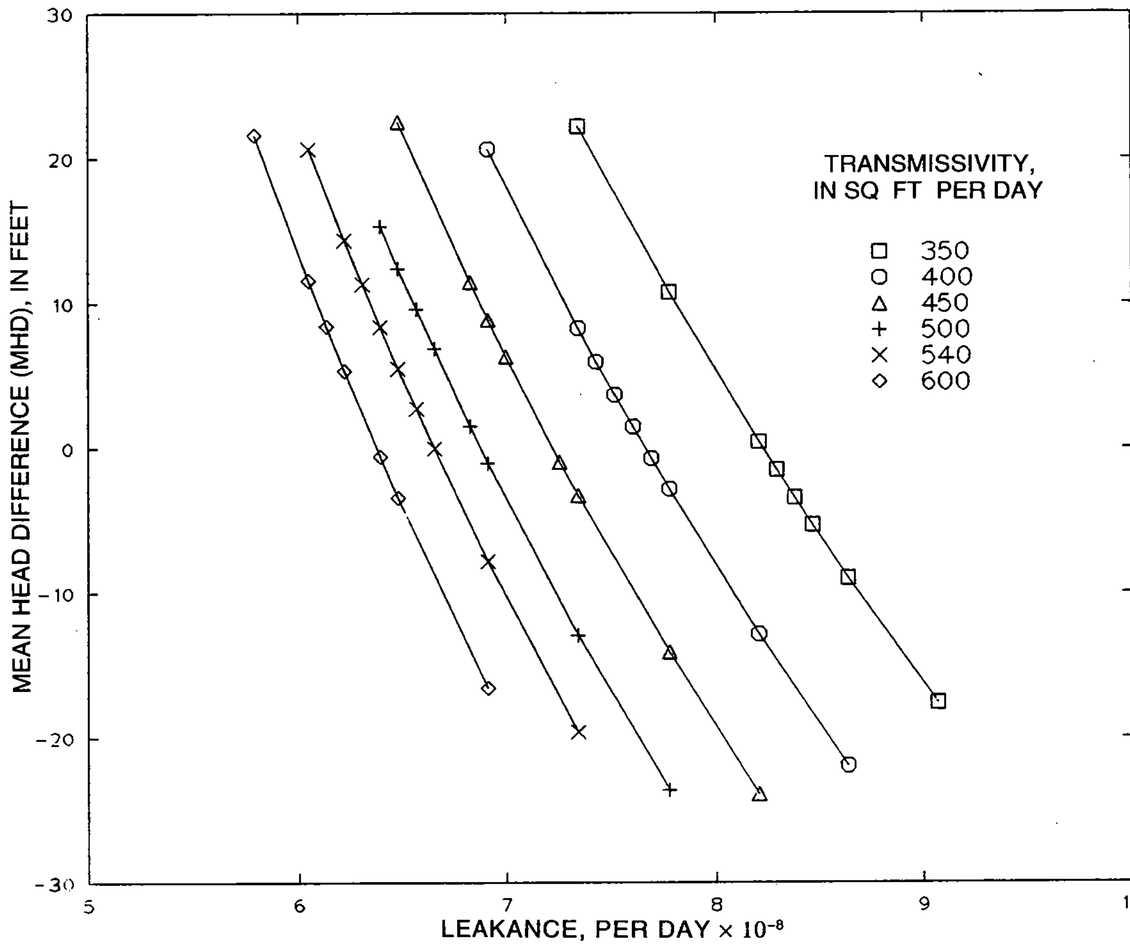

Figure 16. Relation of transmissivity and leakance to mean head difference (MHD) for model 2 (vertical flow only).

MAVHD occur at almost the same aquifer and confining layer properties, model 3 is a very slight improvement over model 2 in reproducing the measured heads.

The results of the three different digital-model simulations place limits on the range of aquifer transmissivity and the leakance of the confining layer. In the three simulations, the aquifer transmissivity ranged 400–700 ft^2/day, and the leakance ranged from 0 to 7.7×10^{-8} per day. This narrow range for aquifer transmissivity includes the transmissivity calculated from the aquifer test conducted at the B. F. Goodrich Co. plant. Because the aquifer transmissivity calculated by two independent methods was similar, it is inferred that the calculated transmissivities are a good estimate of the transmissivity of the Roubidoux aquifer in Ottawa County.

The leakance calculated from the digital-model simulations ranged from 0 to 7.7×10^{-8} per day, and the leakance calculated from the aquifer test ranged from 4.3 $\times 10^{-8}$ to 0.13 per day. Although the total range of leakance for the two methods is very large, the range where the values calculated by the two methods overlap is quite narrow. Only in this narrow range of leakance are the results for the flow model and the aquifer test analysis consistent with the measured data. This range, from 4.3 $\times 10^{-8}$ to 7.7×10^{-8} per day, is considered to be the best estimate for the leakance of the confining layer.

WATER QUALITY

A preliminary assessment of the chemical composition of water in the Roubidoux aquifer is presented in this section. The following topics are discussed: (1) available chemical data for ground water, (2) major-ion chemistry of the aquifer, (3) summary statistics of water-quality data, (4) comparison of water-quality data to drinking-water standards, and (5) water-quality problems in the aquifer.

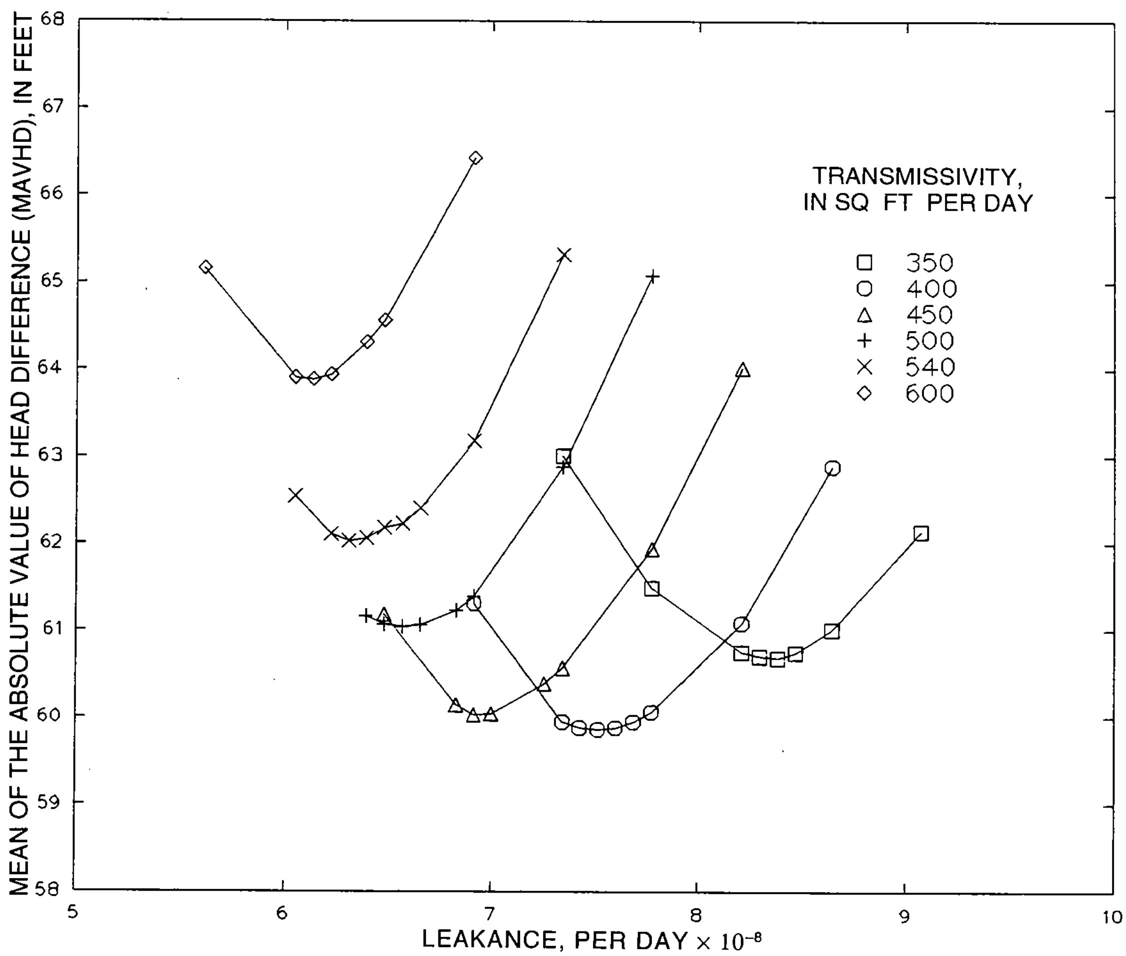

Figure 17. Relation of transmissivity and leakance to the mean of the absolute value of head difference (MAVHD) for model 2 (vertical flow only).

Available Chemical Data for Ground Water

The chemical data from samples of wells completed in the Roubidoux aquifer were obtained from three sources: (1) U.S. Geological Survey files, (2) the Oklahoma State Department of Health, and (3) the present study.

The U.S. Geological Survey files provided 37 analyses for samples collected from 1942 through 1969. Most of these data were analyses of ground-water samples from industrial and municipal wells. Generally, the major ions, iron, and nitrate were analyzed to determine the suitability of the water for drinking-water supplies and industrial purposes.

Nineteen analyses were obtained from the Oklahoma State Department of Health for samples collected from 1977 through 1980. Samples from municipalities and rural water districts were analyzed for major ions and trace elements for which drinking-water regulations have been established. Six additional analyses of ground water from Quapaw's municipal wells were obtained for samples taken in 1981.

There were 208 analyses of ground-water samples collected from 1980 to 1983 as part of the present study. Of those, 106 analyses included only field measurements of pH, specific conductance, and temperature. The remaining 102 samples were analyzed for major ions, trace elements, and/or radioactive constituents, as well as for the field-measured parameters. Samples were generally obtained at the well head using the existing pumps. Some samples collected in 1982 and 1983 were obtained from wells without pumps, using a down-hole sampling device. The device was opened by remote control so that samples could be collected from a specific depth within the well. Alkalinity was measured in the field, and samples for other constituents were taken and preserved for subsequent

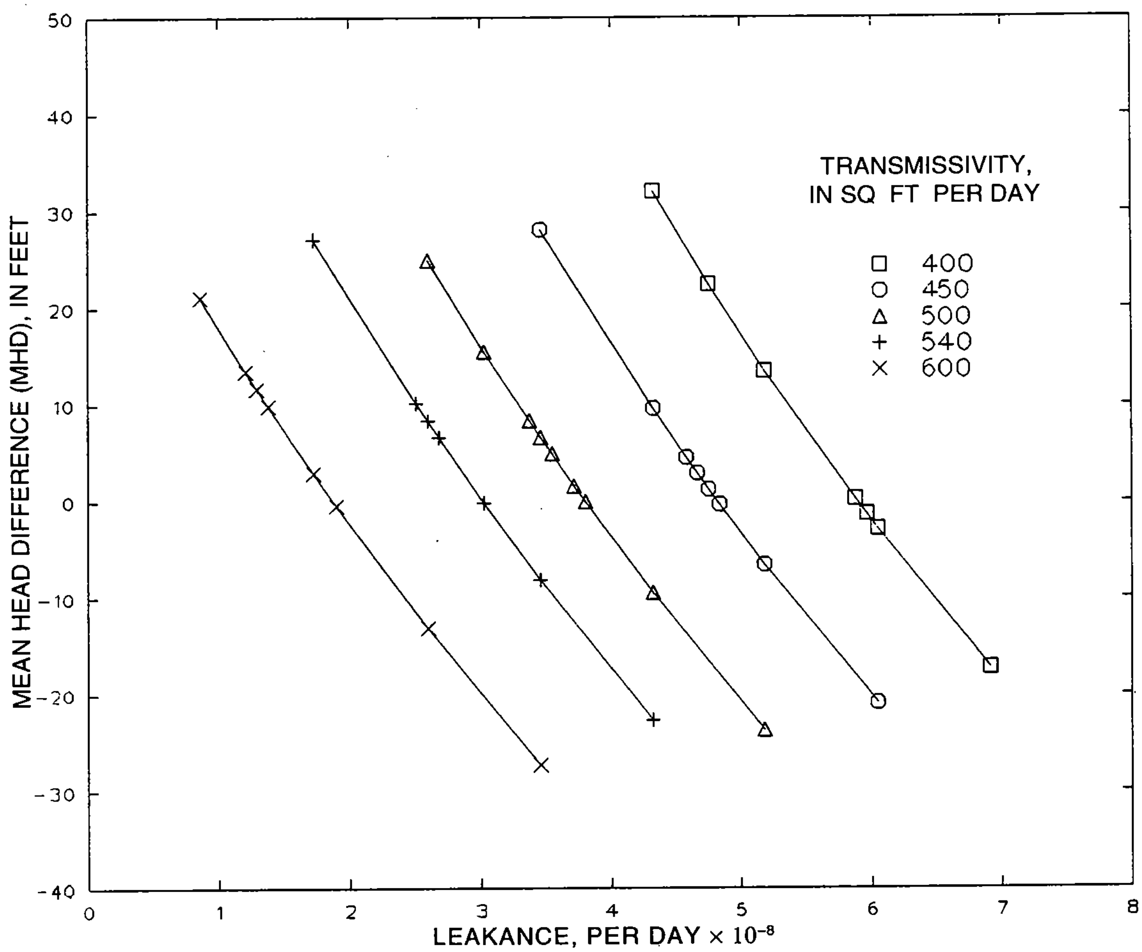

Figure 18. Relation of transmissivity and leakance to mean head difference (MHD) for model 3 (lateral and vertical flow).

laboratory analysis by the use of standard methods (Brown and others, 1970). The laboratory of the Oklahoma Geological Survey analyzed most of the major-ion and trace-element samples. Radioactive constituents were analyzed by the National Water Quality Laboratory of the U.S. Geological Survey in Denver, Colorado.

Appendixes 3–5 present the data that are used in this report. Appendix 3 presents the concentrations of common constituents and physical properties of water. Appendix 4 presents the concentrations of trace elements. Appendix 5 presents the concentrations of radioactive constituents.

Major-Ion Chemistry

The concentrations of major ions are shown on Figure 20 along with the dissolved-solids concentrations for selected wells in the study unit. Each small diagram on Figure 20 is a water-quality diagram, which displays the concentrations of all the major ions of a water sample in milliequivalents per liter (meq/L). The left side of a water-quality diagram shows, from top to bottom, the concentrations of calcium, magnesium, and sodium plus potassium. The right side shows, from top to bottom, the concentrations of bicarbonate, sulfate, and chloride.

A large change in major-ion chemistry occurs in ground water in the Roubidoux aquifer in northeastern Oklahoma. In the easternmost part of the study unit, wells produce ground water with relatively small dissolved-solids concentrations, approximately 100–200 mg/L. The dominant ions generally are calcium, magnesium, and bicarbonate, which are derived from dissolution of dolomite and limestone in the aquifer. Concentrations of sodium, sulfate, and chloride generally are small.

In the westernmost part of the study unit, wells produce ground water with relatively large dissolved-

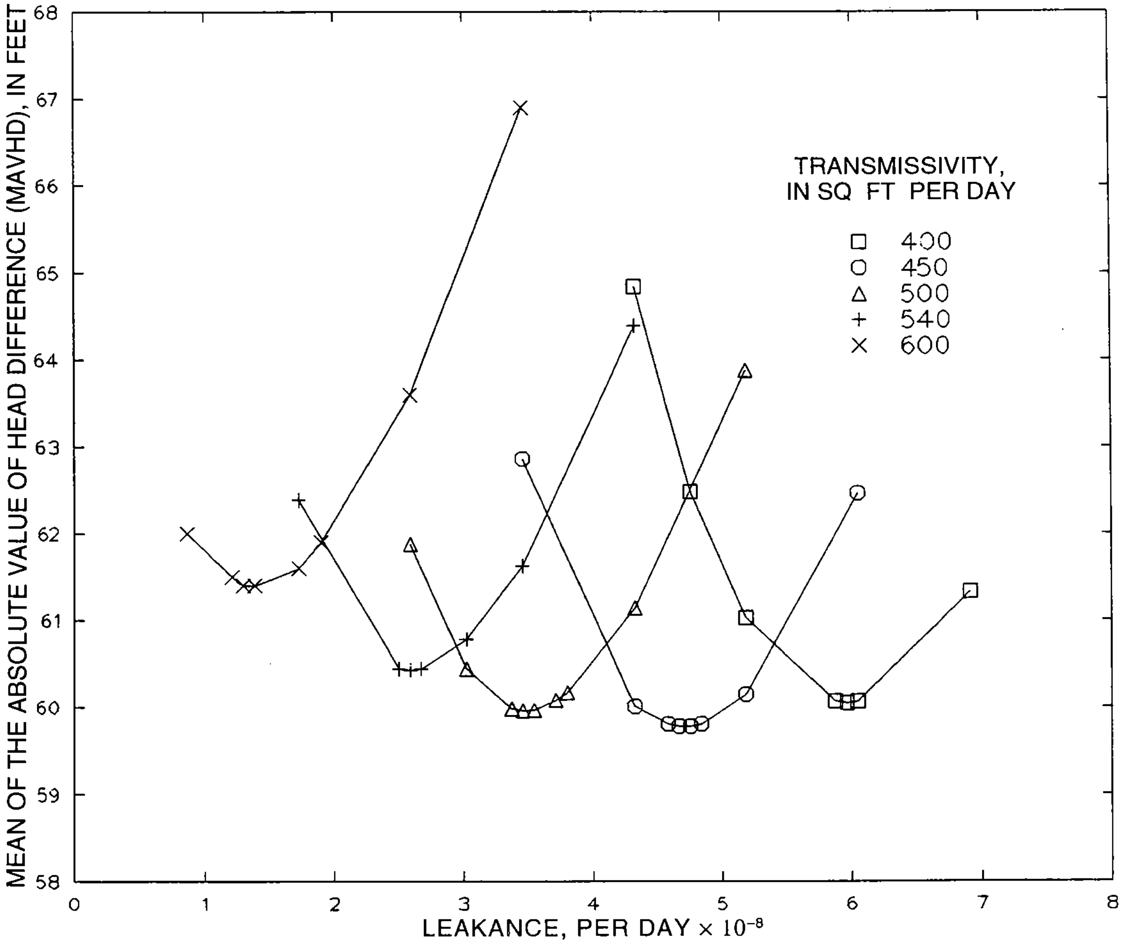

Figure 19. Relation of transmissivity and leakance to the mean of the absolute value of head difference (MAVHD) for model 3 (lateral and vertical flow).

solids concentrations, ~800 mg/L or greater. The dominant ions are sodium and chloride.

A transition zone in water composition occurs between the easternmost and westernmost parts of the study unit. Wells in the transition zone generally have intermediate chloride concentrations (25–250 mg/L or 0.7–7 meq/L) and intermediate dissolved-solids concentrations (200–800 mg/L). A few wells in this zone have increased sodium concentrations that are not accompanied by equally increased chloride concentrations. Ion-exchange reactions with clays probably are responsible for the increased sodium in these few wells. In the ion-exchange reaction, sodium is replaced by calcium and magnesium on ion-exchange sites in clays.

Sulfate concentrations in ground water generally are small in most of the study unit. Samples from a few wells in the vicinity of Picher and Quapaw had substantial sulfate concentrations. The sulfate concentrations are probably related to the abandoned lead and zinc mines of the Picher field. Water-quality problems related to the abandoned mines are discussed below.

Summary Statistics of Water-Quality Data

Selected statistics were determined from the available data. The most recent analysis for each constituent was used to represent each well. If analyses were available from different sampling depths of a single well, the most recent analysis for each constituent from each sampling depth was included in the calculation of the statistics.

The data for many constituents include values that are reported as less than a specified minimum-reporting level. These values are called censored values. It is common to have several different minimum-reporting levels for a single chemical constituent because of differences in analytical methods. Percentiles below the largest minimum-reporting level cannot be calculated accurately using standard methods. A procedure developed by Helsel and Cohn (1988) for calculating percentiles in data with one or more minimum-reporting levels was used to calculate percentiles for any constituent that had censored values. The procedure used a statistical model to calculate any percentiles that were less than the largest minimum-reporting level. In order to use the procedure, it was necessary to eliminate any zero values. For those constituents with censored values, data that were reported as zero were set equal to the largest minimum-reporting level. If no censored data were present for a constituent, percentiles were calculated by standard methods. No percentiles were calculated if fewer than 20 analyses were available for a constituent.

The number of analyses, the largest minimum-reporting level, the minimum value, selected percentiles, and the maximum value for all of the constituents measured in the study unit are listed in Table 3. The table also lists the method used to calculate the percentiles for each constituent. Because the samples are not evenly distributed areally and vertically, the statistics are only an approximate description of the overall water resource.

Many percentiles calculated by the method of Helsel and Cohn (1988) are smaller than the minimum value. The maximum values often greatly exceed the 95th percentile. Many of the maximum values are related to samples of ground water with very large sodium and chloride concentrations or to samples of ground water affected by the abandoned mines of the Picher mining area.

Comparison of Water-Quality Data to Drinking-Water Standards

Water-quality standards set by the primary and secondary drinking-water regulations of the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 1986a,b) are listed in Table 4 for 20 inorganic and radioactive constituents. The primary regulations set maximum contaminant levels (MCLs) to protect public health. The secondary regulations set secondary maximum contaminant levels (SMCLs) for aesthetic reasons related to public acceptance of drinking water. The regulations for MCLs and SMCLs apply only to public water systems and are not enforceable for domestic and other types of wells.

Table 4 lists the number of sites that have been sampled and the number of sites that have had at least one sample that exceeded the water-quality standard. Tabulations for two data sets are presented in Table 4: (1) data set 1 included all analyses from all wells, and (2) data set 2 excluded analyses with dissolved solids >5,000 mg/L, analyses with specific conductance >5,000 microsiemens per centimeter (μS/cm) at 25°C, and analyses from wells that are within the Picher mining area (all wells in T. 29 N., R. 23 E. plus the wells of the City of Commerce). Data set 2 is intended to be more representative of the usable water in the Roubidoux aquifer unaffected by human activities.

The tabulation for data set 1 shows that no analyses of any ground-water samples have exceeded the water-quality standards for nitrate, arsenic, barium, copper, lead, mercury, selenium, or silver. Most differences between data set 1 and data set 2 are related to the analyses from wells in the mining area. These wells account for the increased number of analyses in data set 1 relative to data set 2 that exceeded the following standards: pH <6.5, sulfate, cadmium, iron, manganese, and zinc.

In data set 2, no analyses of ground-water samples exceeded the water-quality standards for sulfate, cadmium, or zinc, in addition to nitrate, arsenic, barium, copper, lead, mercury, selenium, or silver. Dissolved-solids and chloride concentrations exceeded the standards in 16 of 64 and 14 of 68 wells sampled, respectively. The large dissolved-solids concentrations were always caused by large concentrations of sodium and chloride. Sodium and chloride concentrations increase so much from east to west across the study unit that water in the westernmost part is unsuitable for most uses. Few, if any, water wells are completed in the Roubidoux aquifer west of R. 20 E. (Fig. 20).

A few analyses exceeded the SMCLs for pH, iron, and manganese (Table 4, data set 2). However, the occurrences of these constituents at concentrations that exceed the SMCLs are not common. Furthermore, since the SMCLs are not related to health considerations, the occurrence of these constituents does not pose a hazard to human health.

The MCL for fluoride was exceeded in analyses of ground-water samples from four of the 61 wells sampled (Table 4, data set 2). The four wells with fluoride concentrations >4 mg/L are in adjoining townships. Two of the wells are in the town of Bluejacket, T. 27 N., R. 21 E., and the other two are in T. 27 N., R. 22 E., and T. 27 N., R. 23 E. The MCL for chromium was exceeded in analyses of ground-water samples from two of the 56 wells sampled (Table 4, data set 2). The two wells with chromium concentrations greater than the MCL are in T. 26 N., R. 23 E., and T. 27 N., R. 22 E. The available data indicate that concentrations of fluoride and chromium that exceed the MCLs may occur in the Roubidoux aquifer, but such occurrences are relatively rare.

Relatively large levels of gross-alpha radioactivity occur in the ground water of the Roubidoux aquifer. Gross-alpha radioactivity, including the contribution

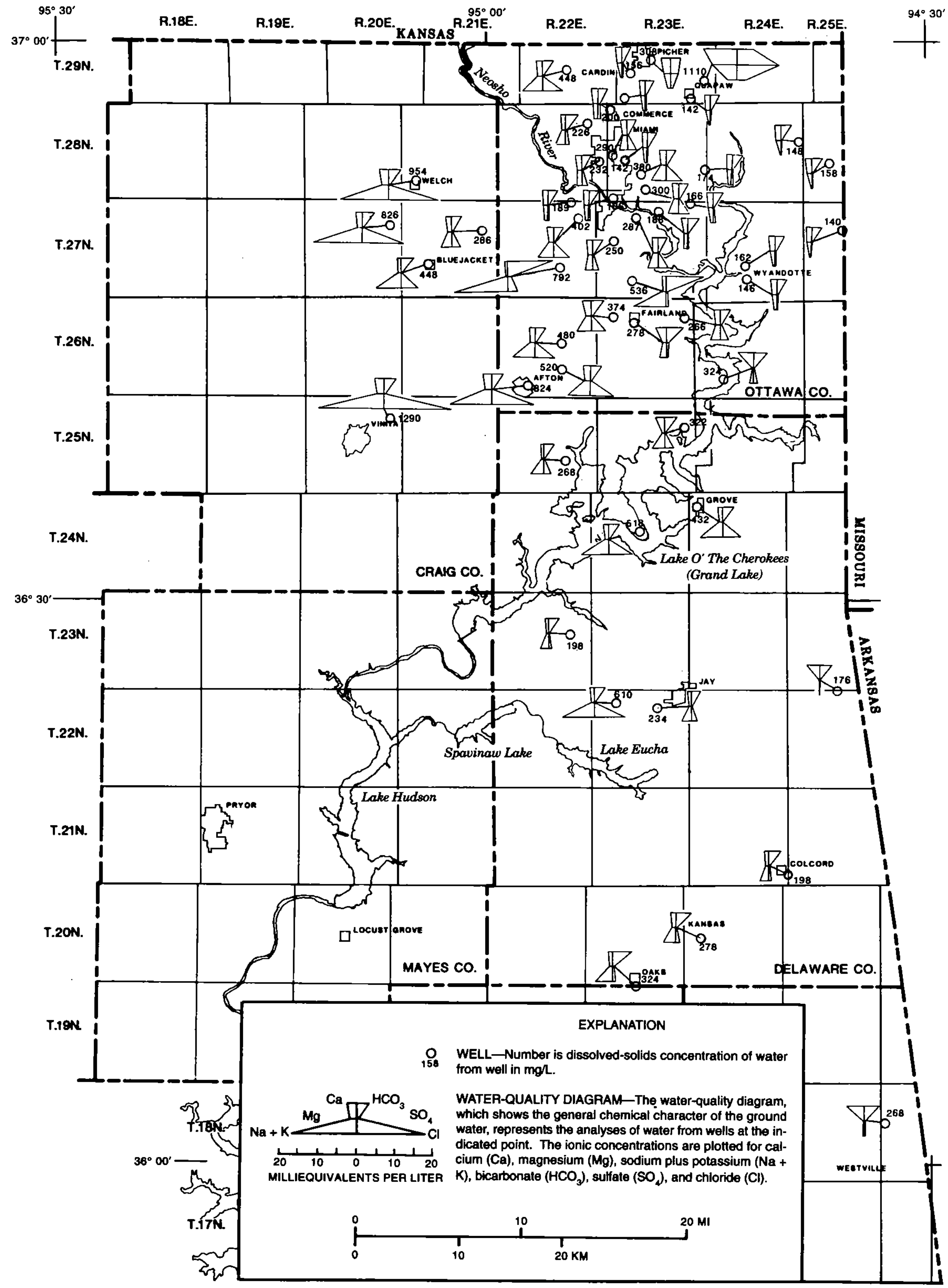

Figure 20. Map showing dissolved-solids concentration and water-quality diagrams for water samples from selected wells that are completed in the Roubidoux aquifer in northeastern Oklahoma.

from uranium, exceeded 15 pCi/L (picocuries per liter) in nine of 53 wells sampled (Table 4, data set 2). The MCL for gross-alpha radioactivity is 15 pCi/L exclusive of the contribution from uranium. Uranium was not analyzed in any of the samples; hence, it is not possible to determine if any of the samples actually exceeded the MCL for gross-alpha radioactivity. If uranium radioactivity contributes a small part of the gross-alpha radioactivity, it is possible that the water from these nine wells exceeded the gross-alpha radioactivity MCL. If uranium radioactivity contributes a large part of gross-alpha radioactivity, ground water that exceeds the gross-alpha radioactivity MCL would be rare.

The MCL for radium is 5 pCi/L for the sum of radium-226 and radium-228 radioactivity. Seven wells that had large gross-alpha radioactivity and two wells that had large censored values for gross-alpha radioactivity were resampled and analyzed for radium-226 (an alpha emitter) and radium-228 (a beta emitter). Concentrations of radium-228 were reported as censored values in all nine samples. However, concentrations of radium-226 exceeded the 5-pCi/L MCL in samples from all seven of the wells that had samples with large uncensored gross-alpha radioactivity.

Water-Quality Problems

Three water-quality problems are apparent in the Roubidoux aquifer in northeastern Oklahoma: (1) contamination by mine water, (2) large concentrations of sodium and chloride, and (3) large concentrations of radium-226. In this section, the spatial occurrence of these problems is discussed.

Mine-Water Contamination

Lead and zinc sulfides were mined from the Boone Formation in the northeastern part of the study unit from about 1900–70. The mines were dewatered during mining operations by extensive pumping, but later filled with water when pumping ceased. The compositions of the mine waters in the Boone Formation are detailed in Playton and others (1980) and in Parkhurst (1987). Sulfate is the dominant anion in the mine waters, and calcium, magnesium, iron, and zinc are the dominant cations. Large concentrations of cadmium, copper, fluoride, lead, manganese, and nickel have been analyzed in some mine water.

Because the hydraulic head in the Boone Formation is higher than the head in the Roubidoux aquifer, water will tend to move from the mine workings in the Boone Formation downward through pores and fractures in the rock units, toward the Roubidoux aquifer. The Chattanooga Shale and the Northview Shale are stratigraphically below the Boone Formation and have very small vertical hydraulic conductivity. Although they are not impervious, they could slow the downward movement of water. However, the two shale formations are absent in a large part of the mining area.

Mine water could reach the Roubidoux aquifer through leaky well casings as well as through the pores and fractures of the rock units. According to Reed and others (1955), ~100 wells were drilled into the Roubidoux aquifer in the mining area to supply water for milling operations. Leaks in the casings at the level of the mine workings would allow movement of mine water down into the Roubidoux aquifer. Movement of this type was demonstrated in two abandoned wells in the mining area, 29N–23E–16 DDD 1 and 29N–23E–32 AAB 1. These wells were logged with a downhole flowmeter, and the data showed downward water flow in both wells. The flow rate in each well was estimated to be <2 gal/min. The U.S. Environmental Protection Agency has funded work to locate and plug any abandoned wells in the mining area that penetrate the Roubidoux aquifer. Both wells described here were plugged in 1984.

Several municipalities in the mining area have had water-quality problems related to the mines. In two of the public-supply wells for the City of Commerce, concentrations of sulfate, iron, zinc, and dissolved solids increased between July 1981 and October 1982. Repairs were made in the casings of these wells, and the water quality returned to acceptable limits for public supply. The problems were apparently due to mine water entering the wells through leaks in the casings or through the grout seals of the wells.

Quapaw has also had water-quality problems related to the mines. When a water-supply well, 29N–23E–25 BDB 1, was completed in November 1977, the iron concentration in water from the well was ~100 μg/L and the pH was 7.8. By July 1981, the pH was 7.0 and the iron concentration was 20,000 μg/L. The well was abandoned and plugged. The large iron concentration and lowered pH indicate mine-water contamination.

The background concentrations of sulfate in the Roubidoux aquifer are relatively low. Three samples from the Picher water-supply wells (29N–23E–21 BBC 1; 29N–23E–21 BBC 2), which were taken between 1942 and 1951, had sulfate concentrations ranging from 11 to 18 mg/L (Appendix 3). These concentrations are similar to the median concentration of 16 mg/L for all of the available data (Table 3). Mine-water concentrations of sulfate are large, ~3,000 mg/L (Playton and others, 1980). If sulfate migrates into the Roubidoux aquifer, it is expected to be conservative (unreactive). Therefore, increasing sulfate concentration is an indicator of mine-water contamination. Samples taken during this study (1981 and 1982) from the Picher water-supply wells (29N–23E–21 BBC 1;

TABLE 3.—SUMMARY STATISTICS OF SELECTED CHEMICAL CONSTITUENTS AND PHYSICAL PROPERTIES MEASURED IN THE STUDY UNIT

Constituents and properties	Method[a]	Sample size	Largest MRL[b]	Minimum value	Percentiles 5	25	50	75	95	Maximum value
Specific conductance (μS/cm at 25°C)	1	96	—[c]	140	284	369	566	1,086	9,226	125,000
pH (standard units)	1	89	—	5.2	6.6	7.6	7.9	8.0	8.2	9.3
Hardness, total (mg/L as $CaCO_3$)	1	81	—	58	78	123	142	171	291	1,550
Calcium, dissolved (mg/L as Ca)	1	78	—	14	18	29	32	42	83	440
Magnesium, dissolved (mg/L as Mg)	1	78	—	1.1	3.1	11	14	16	26	110
Sodium, total (mg/L as Na)	4	8	10	<10	—	—	—	—	—	60
Sodium, dissolved (mg/L as Na)	1	73	—	1.4	4.4	16	54	110	342	3,200
Sodium plus potassium, dissolved (mg/L as Na)	4	19	—	3.2	—	—	—	—	—	2,830
Potassium, dissolved (mg/L as K)	1	71	—	0.4	1.2	2.1	2.8	3.7	8.1	25
Alkalinity, total (mg/L as $CaCO_3$)	1	79	—	119	121	129	143	159	221	594
Alkalinity, total, laboratory (mg/L as $CaCO_3$)	1	61	—	116	117	125	135	152	220	435
Sulfate, dissolved (mg/L as SO_4)	1	94	—	3	7.4	13	16	22	97	2,000
Chloride, dissolved (mg/L as Cl)	1	93	1	<1	2.9	15	55	190	2,162	65,000
Fluoride, total (mg/L as F)	4	9	—	0.2	—	—	—	—	—	0.8
Fluoride, dissolved (mg/L as F)	1	84	—	0.1	0.1	0.4	0.7	1.4	4.1	13
Silica, dissolved (mg/L as SiO_2)	1	71	—	7.4	8	9	10	10	13	36
Dissolved solids, residue at 180°C (mg/L)	1	86	—	88	143	200	290	519	3,994	113,000
Dissolved solids, residue at 105°C (mg/L)	4	8	—	153	—	—	—	—	—	718
Nitrogen, nitrate, dissolved (mg/L as N)	1	23	—	0	0	0.01	0.05	0.2	0.8	1.0
Nitrogen, nitrite plus nitrate, total (mg/L as N)	4	9	0.5	0.1	—	—	—	—	—	0.1
Aluminum, dissolved (μg/L as Al)	3	80	100	<60	—	—	—	—	—	48,000
Arsenic, total (μg/L as As)	4	8	10	0	—	—	—	—	—	—
Arsenic, dissolved (μg/L as As)	3	64	10	<10	—	—	—	—	—	14
Barium, total (μg/L as Ba)	4	9	100	<100	—	—	—	—	—	100
Cadmium, total (μg/L as Cd)	4	10	2	<1	—	—	—	—	—	2
Cadmium, dissolved (μg/L as Cd)	3	80	4	<1	—	—	—	—	—	710
Chromium, total (μg/L as Cr)	4	9	10	<10	—	—	—	—	—	50
Chromium, dissolved (μg/L as Cr)	3	80	12	<1	—	—	—	—	—	23

Copper, total recoverable (μg/L as Cu)	4	9	4	<4	—	—	—	—	—	35
Copper, dissolved (μg/L as Cu)	3	80	60	<12	—	—	—	—	—	320
Iron, total (μg/L as Fe)	2	21	100	0	1.1	8.7	37	154	8,030	8,700
Iron, dissolved (μg/L as Fe)	2	80	20	<8	2.7	30	60	160	9,580	260,000
Lead, total (μg/L as Pb)	4	10	20	<5	—	—	—	—	—	25
Lead, dissolved (μg/L as Pb)	3	78	10	<5	—	—	—	—	—	29
Manganese, total (μg/L as Mn)	4	10	20	<10	—	—	—	—	—	70
Manganese, dissolved (μg/L as Mn)	2	80	10	<2	0	0.1	1.2	10	1,910	4,400
Mercury, total recoverable (μg/L as Hg)	4	9	0.5	<0.5	—	—	—	—	—	—
Mercury, dissolved (μg/L as Hg)	3	64	0.5	<0.5	—	—	—	—	—	0.5
Molybdenum, dissolved (μg/L as Mo)	4	9	2	<1	—	—	—	—	—	—
Selenium, total (μg/L as Se)	4	9	5	<1	—	—	—	—	—	—
Silver, total (μg/L as Ag)	4	9	3	<2	—	—	—	—	—	3
Zinc, total (μg/L as Zn)	4	11	2	0	—	—	—	—	—	1,700
Zinc, dissolved (μg/L as Zn)	2	81	20	<10	0.5	4.8	26	56	3,560	84,000
Alpha radioactivity, dissolved (pCi/L)	2	64	23.8	<2.9	0.2	0.8	2.3	6.6	27	57
Alpha radioactivity, suspended (pCi/L)	2	30	0.4	0.3	0.1	0.3	0.4	0.4	2.4	3.2
Alpha radioactivity, dissolved (μg/L as U natural)	2	64	35	<4.2	0.2	1.1	3.3	9.8	40	84
Alpha radioactivity, suspended (μg/L as U natural)	3	61	0.4	<0.4	—	—	—	—	—	4.7
Beta radioactivity, dissolved (pCi/L as ^{137}Cs)	2	64	13	<2	1	2.4	4.2	7.4	21	25
Beta radioactivity, suspended (pCi/L as Sr^{90}/Y^{90})	3	64	1.5	<0.4	—	—	—	—	—	2.8
Beta radioactivity, suspended (pCi/L as ^{137}Cs)	3	64	1.5	<0.4	—	—	—	—	—	2.7
Beta radioactivity, dissolved (pCi/L as Sr^{90}/Y^{90})	2	64	12	<2	1	2.3	4	7.1	20	24
Radium-226, dissolved, planchet count (pCi/L)	4	9	—	3.4	—	—	—	—	—	14
Radium-228, dissolved (pCi/L)	4	9	3	<2	—	—	—	—	—	—

Note: These statistics were calculated including only the most recent analysis for each constituent for each well. If analyses were available for different sampling depths from the same well, the most recent analysis for each constituent from each sampling depth of the well was included.

[a]Method: 1, no censored data, ordinary percentile calculation; 2, censored data present, percentiles calculated using methods of Helsel and Cohn (1988); 3, no calculation, >80% of the data were censored; 4, no calculation, fewer than 20 analyses for the constituent.

[b]Largest minimum reporting level: Percentiles less than this value were estimated using the methods of Helsel and Cohn (1988); percentiles greater than this value are the same as ordinary percentile calculation.

[c]— has three different meanings. Largest MRL, — = no censored data for this constituent; Percentiles, — = no statistic was calculated; Maximum value, — = all data were censored for this constituent.

TABLE 4.—WATER-QUALITY STANDARDS FOR INORGANIC CONSTITUENTS, NUMBER OF WELLS SAMPLED, AND NUMBER OF WELLS WITH SAMPLES THAT EXCEEDED THE STANDARD

		Data set 1[a] Number of wells		Data set 2[b] Number of wells	
Constituent	Water-quality standard[c]	Sampled	Exceeded water-quality standard	Sampled	Exceeded water-quality standard
pH, field (standard units)	6.5 SMCL	78	4	63	1
pH, field (standard units)	8.5 SMCL	78	4	63	3
Sulfate, dissolved (mg/L as SO_4)	250 SMCL	84	3	68	0
Chloride, dissolved (mg/L as Cl)	250 SMCL	83	16	68	14
Fluoride (mg/L as F)	4 MCL	75	4	61	4
Dissolved solids (mg/L)	500 SMCL	77	19	64	16
Nitrate (mg/L as N)	10 MCL	37	0	27	0
Arsenic (μg/L as As)	50 MCL	64	0	53	0
Barium (μg/L as Ba)	1,000 MCL	10	0	6	0
Cadmium (μg/L as Cd)	10 MCL	71	4	56	0
Chromium (μg/L as Cr)	50 MCL	70	2	56	2
Copper (μg/L as Cu)	1,000 SMCL	70	0	56	0
Iron (μg/L as Fe)	300 SMCL	75	16	60	5
Lead (μg/L as Pb)	50 MCL	71	0	56	0
Manganese (μg/L as Mn)	50 SMCL	71	6	56	1
Mercury (μg/L as Hg)	2 MCL	64	0	53	0
Selenium (μg/L as Se)	10 MCL	10	0	6	0
Silver (μg/L as Ag)	50 MCL	10	0	6	0
Zinc (μg/L as Zn)	5,000 SMCL	72	2	57	0
Gross-alpha radioactivity (pCi/L)	15 MCL	64	9	53	9
Radium (pCi/L)	5 MCL	9	7	9	7

[a]Data set 1 includes all of the data.
[b]Data set 2 excludes analyses with dissolved solids >5,000 mg/L, analyses with specific conductance >5,000 μS/cm at 25°C, and analyses from wells in the Picher mining area (all wells in T. 29 N., R. 23 E., plus wells of the City of Commerce).
[c]MCL = maximum contaminant level; SMCL = secondary maximum contaminant level.

29N–23E–21 BBC 2; 29N–23E–21 BBC 3) had sulfate concentrations ranging from 47 to 92 mg/L. The increase in sulfate concentrations between the early samples and the samples of this study (Appendix 3) indicates mine-water contamination. Iron concentrations in the samples of this study were slightly greater than the median, but no other trace elements showed increased concentrations. In 1985, one of Picher's three water-supply wells (29N–23E–21 BCC 1) began producing water with large concentrations of sulfate, iron, and dissolved solids. This well was subsequently abandoned and a new well was drilled in a new location.

At present (1990), all instances of ground-water contamination by mine water can be explained by faulty seals or leaky casings in wells that pass through the zone of mine workings and down to the Roubidoux aquifer. All of the wells that have had problems with mine-water contamination are within the perimeter of the mining area. None of the data available in 1990 indicate that mine water has migrated from the Boone Formation through the pores and fractures of the intervening geologic units to the Roubidoux aquifer, although the available data do not preclude that possibility.

Large Sodium and Chloride Concentrations

In the western part of the study unit, the large concentrations of sodium and chloride in ground water from the Roubidoux aquifer make the water unsuitable for most purposes. Farther west, in central Oklahoma, sodium and chloride concentrations approach the level of halite saturation (~300,000 mg/L dissolved solids) in geologic units equivalent to the geologic units comprising the Roubidoux aquifer. Thus, the increase in dissolved-solids concentration, which was noted earlier in relation to water-quality standards, continues beyond the study unit into central Oklahoma.

In this report, the part of the aquifer in which chloride increases from 25 to 250 mg/L is defined to be the transition zone. The position of this transition zone varies horizontally and vertically within the Roubidoux aquifer. Figure 21 shows a simplified map view of the areas where chloride is <25 mg/L or >250 mg/L. The choice of threshold levels is arbitrary, but 250 mg/L was chosen because it is the SMCL for chloride, and 25 mg/L was chosen because it is one-tenth of the SMCL.

Figure 21 does not describe the vertical component of the transition zone. Throughout the study unit, a well drilled to sufficient depth will encounter ground water with large concentrations of sodium and chloride. Well 28N–23E–20 BCB 1 in Miami was drilled in 1976 to a depth of 1,511 ft. In 1978, water from the well had a chloride concentration of 711 mg/L. The bottom 300 ft of the well was plugged, and the chloride concentration in the water decreased to 8 mg/L. An observation well in Miami, 28N–23E–30 DBC 1, was sampled with the downhole sampler. The chloride concentration from the sample at 1,480 ft was 5,600 mg/L and from the sample at 800 ft was 65 mg/L (Appendix 3). Data from the downhole sampler are not completely reliable because it is not known whether the water standing in the well is representative of the formation at the same depth. Well 18N–26E–31 DAD 1 in Westville was drilled to a depth of 1,510 ft. The chloride concentration in water at a depth of 1,500 ft was 250 mg/L; chloride concentration in water at 1,175 ft was 5 mg/L (Test Drilling Service Co., personal communication, 1981). Based on the limited information from these three wells, the depth to the bottom of the transition zone is approximately 1,200–1,500 ft below land surface in the eastern part of the study unit.

In the northwestern part of the study unit in Craig County, most wells completed in the Roubidoux aquifer have chloride concentrations >250 mg/L. Thus, the transition zone in the Roubidoux aquifer must occur east of these wells. In the northern part of the study unit, it is inferred that the position of the bottom of the transition zone must slope from above the top of the Roubidoux aquifer in eastern Craig County and western Ottawa County to below the base of the Roubidoux aquifer in central Ottawa County.

In the central and southern part of the study unit, there are very few analyses. One analysis of water from a well in Pryor that was completed in the undivided Arbuckle Group had a chloride concentration of 3,925 mg/L (Smith, 1942). The formations comprising the Roubidoux aquifer are stratigraphically equivalent to the upper part of the Arbuckle Group; thus, chloride concentrations are large in the Roubidoux equivalent in Mayes County. However, there are too few analyses to locate the transition zone in the south-central or southwestern part of the study unit.

Occurrence of Radium-226

Water samples from 64 wells in the study unit were analyzed for gross-alpha radioactivity (including uranium). Many measurements are reported as censored (less than the reporting level) values. The wells that had samples with gross-alpha radioactivity >15 pCi/L and were not censored generally were located near the western edge of the transition zone (Fig. 22). Gross-alpha radioactivity was correlated with chloride concentration, but the data are limited because most of the gross-alpha-radioactivity data were censored.

Spiker (1977) studied public water supplies in Cherokee and Crawford Counties, Kansas, which are adjacent to the study unit. Of the 28 public water supplies Spiker sampled, the radium-226 concentration in seven exceeded the 5-pCi/L MCL. In Spiker's study, there was a strong correlation between radium-226 concentrations and chloride concentrations in ground water. Keefer and Fenyves (1980) studied radium-226 concentrations in 11 water-supply systems in Ottawa and Craig Counties. All ground-water samples from Afton and some samples from Welch had radium-226 concentrations >5 pCi/L. The data for Afton indicated a correlation between dissolved solids and radium-226 concentrations.

In the present study, samples from nine wells were analyzed for radium-226 and radium-228. All samples had concentrations of radium-226 that were >3.3 pCi/L, and all measurements of radium-228 were reported as censored values. Generally, wells that had large concentrations of gross-alpha radioactivity were found to have concentrations of radium-226 greater than the MCL. Thus, radium-226 is correlated with gross-alpha radioactivity and, as previously stated, gross-alpha radioactivity is correlated with chloride and dissolved-solids concentrations. The data of this study are consistent with studies of Spiker (1977) and Keefer and Fenyves (1980) that show that radium-226 is correlated with chloride or dissolved solids.

Radium-226 was measured at seven wells that had samples with gross-alpha radioactivity >15 pCi/L and two wells that had censored values >15 pCi/L. No wells were sampled that had uncensored gross-alpha radioactivity concentrations in the range of 5–15 pCi/L.

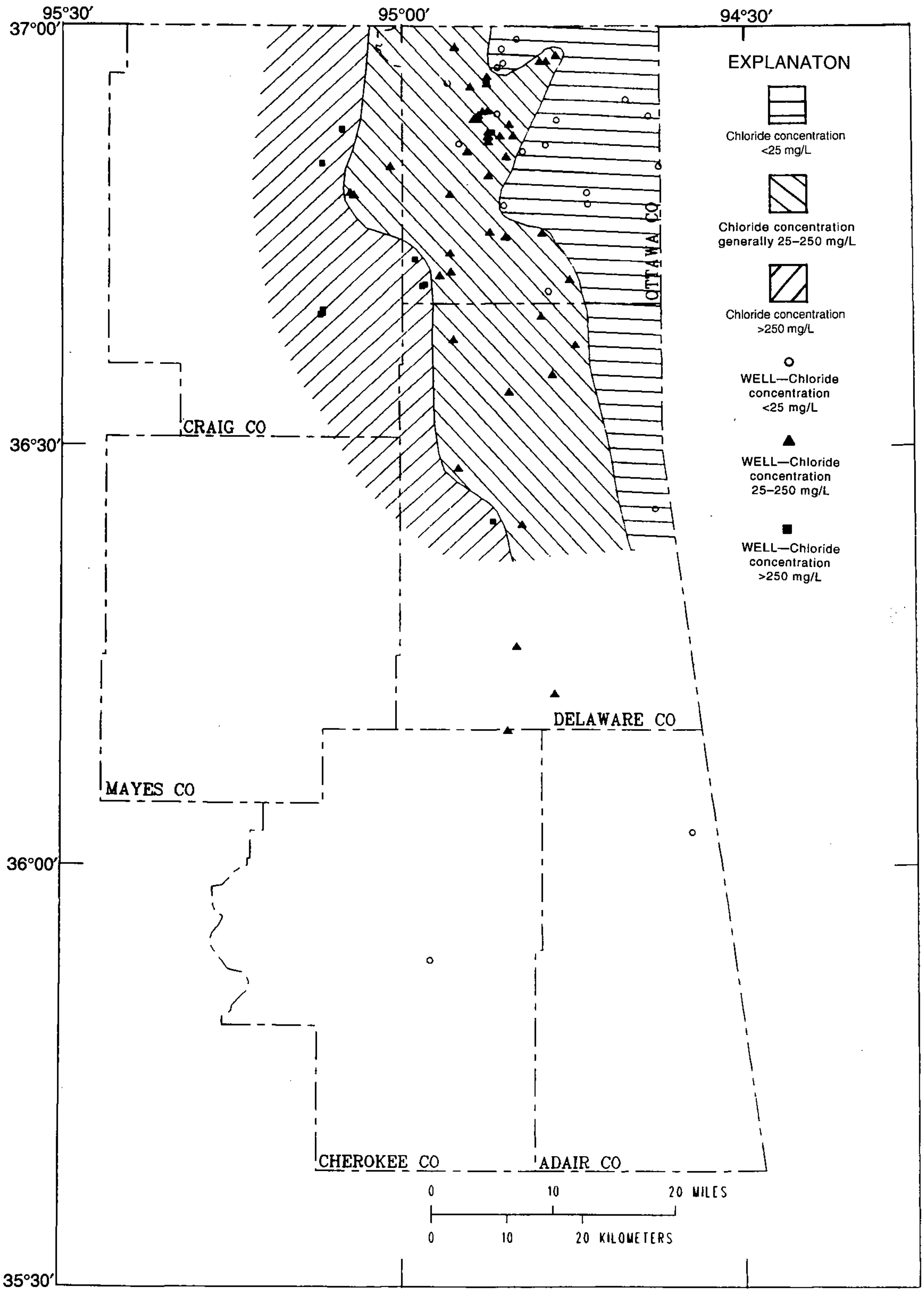

Figure 21. Locations of wells where chloride concentrations were measured.

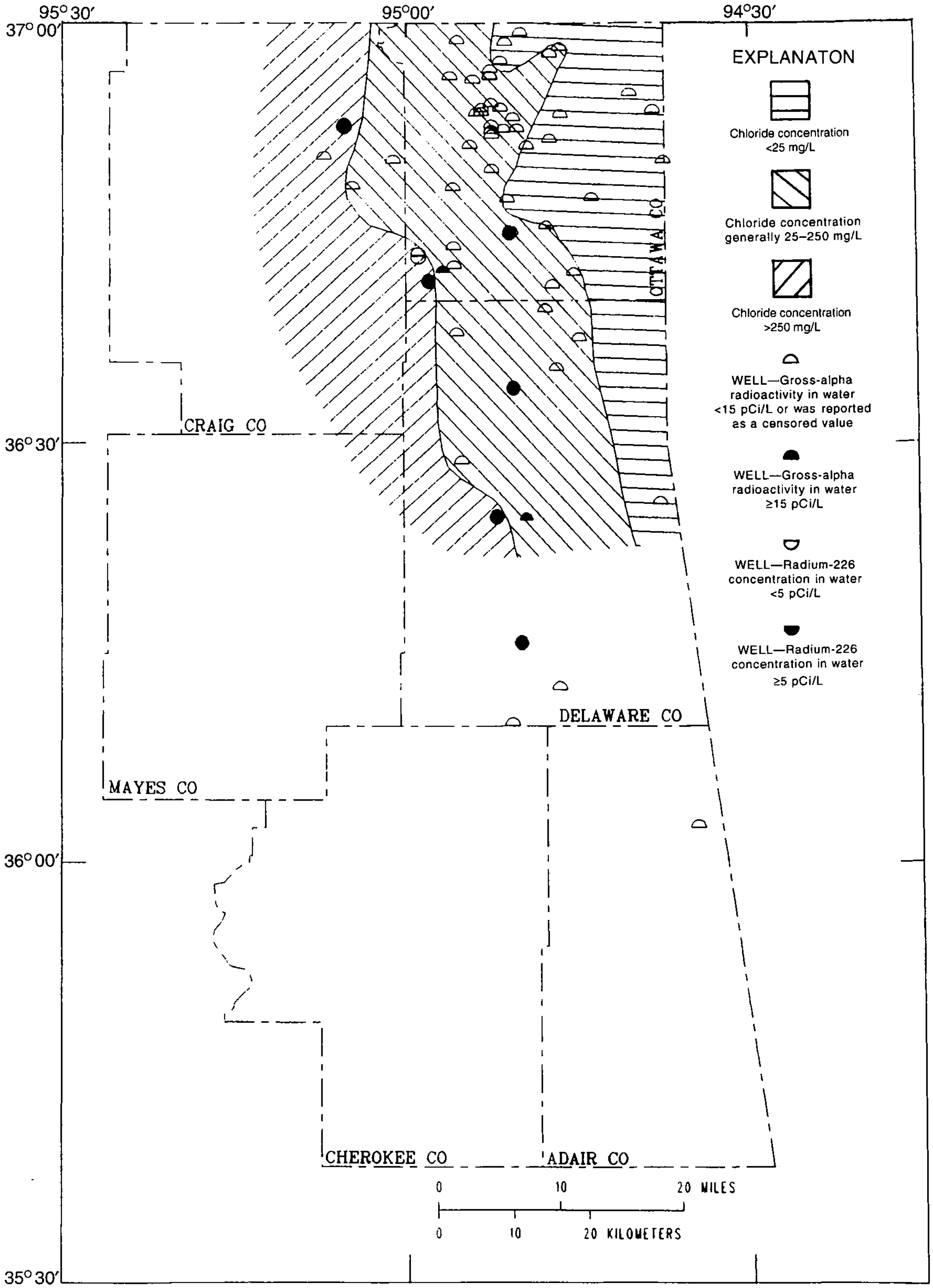

Figure 22. Locations of wells where gross-alpha radioactivity and radium-226 concentrations were measured.

In this concentration range, it is possible that radium-226 exceeds the 5-pCi/L MCL. Thus, inferences made from Figure 22 may underestimate the areal extent of ground water that exceeds the radium MCL.

SUMMARY

The Roubidoux aquifer is an important source of fresh water for public supplies, commerce, industry, and rural water districts in northeastern Oklahoma. The Roubidoux aquifer consists of the Roubidoux Formation, the overlying Cotter and Jefferson City Dolomites, and the underlying Gasconade Dolomite. Deep wells in northeastern Oklahoma generally are completed in the Roubidoux Formation, and the wells are left open to the overlying Cotter and Jefferson City Dolomites. Some wells are drilled deeper and left open to the underlying Gasconade Dolomite. Because the wells with the greatest yield are completed in the Roubidoux Formation, it is inferred that the Roubidoux Formation contributes most of the water. The top of the Roubidoux Formation in wells in the study unit was at depths of 770–1,300 ft below land surface.

The Roubidoux Formation consists of a sequence of cherty dolomite and sandstone, 0–300 ft thick; average thickness is ~175 ft. The Cotter and Jefferson City Dolomites (0–840 ft thick) are cherty dolomites, with lenses of sandstone. The Gasconade Dolomite (0–350 ft thick) is also a cherty dolomite with sandstone layers.

Ground-water withdrawals from the Roubidoux aquifer in 1981 were estimated to be 4.8 million gal/day, of which ~90% was withdrawn in Ottawa County. Wells drilled at the beginning of the 20th century originally flowed at the land surface, but in 1981 water levels ranged 22–471 ft below land surface. A major cone of depression has resulted from ground-water withdrawals near the City of Miami. Wells completed in the Roubidoux aquifer have yields that range from ~100 to >1,000 gal/min.

An aquifer test and a digital ground-water flow model were used to estimate aquifer and confining-layer hydraulic characteristics. Using these methods, the transmissivity of the aquifer was estimated to be within a range of 400–700 ft^2/day. The leakance of the confining layer was determined to be within a range of 0–0.13 per day, with a best-estimate value in a range from 4.3×10^{-8} to 7.7×10^{-8} per day.

In 1980 through 1983, as part of the present study, water samples from wells completed in the Roubidoux aquifer were collected and analyzed for major ions, trace elements, and radioactive constituents. Additional chemical data for ground water were compiled from previous work of the U.S. Geological Survey and from the Oklahoma State Department of Health.

A large change in major-ion chemistry occurs in ground water in the Roubidoux aquifer in northeastern Oklahoma. The ground water in the easternmost part of the study unit has relatively small dissolved-solids concentrations (<200 mg/L), with calcium, magnesium, and bicarbonate as the major ions. Ground water in the westernmost part of the study unit has relatively large dissolved-solids concentrations (>800 mg/L), with sodium and chloride as the major ions. A transition zone of intermediate sodium, chloride, and dissolved-solids concentrations exists between the easternmost and westernmost parts of the study unit.

Descriptive statistics were calculated for each chemical constituent, including percentiles, minimum values, and maximum values. Drinking-water standards were compared to the chemical data in two data sets. Data set 1 included chemical data from all wells; data set 2 excluded: (1) samples with dissolved-solids concentration >5,000 mg/L, (2) ground-water samples that had specific conductance >5,000 μS/cm at 25°C, and (3) samples from wells that were within the mining area. Data set 2 is more representative of the usable, uncontaminated ground-water resource.

The water samples from wells in the mining area that were included in data set 1 accounted for most of the analyses that exceeded the standards for sulfate, cadmium, iron, manganese, zinc, and pH <6.5. In data set 2, sulfate, nitrate, arsenic, barium, cadmium, copper, lead, mercury, selenium, silver, and zinc concentrations did not exceed the MCLs or SMCLs for any samples. Dissolved-solids and chloride concentrations exceeded standards in 16 of 64 and 14 of 68 wells sampled, respectively (data set 2). Gross-alpha radioactivity exceeded 15 pCi/L in nine of 53 wells sampled (data set 2), but because uranium was not measured, it was not possible to determine if the MCL for gross-alpha radioactivity was exceeded. Concentrations of radium-226 exceeded the MCL for radium in seven of nine wells sampled. The available data indicate that concentrations of fluoride and chromium rarely exceed the MCLs in the Roubidoux aquifer.

Three water-quality problems are apparent in the Roubidoux aquifer in northeastern Oklahoma: (1) contamination by mine water, (2) large concentrations of sodium and chloride, and (3) large concentrations of radium-226.

Many wells in the mining area have been affected by mine-water contamination. At present (1990), all instances of ground-water contamination by mine water can be explained by faulty seals or leaky casings in wells that pass through the zone of mine workings and down to the Roubidoux aquifer. None of the available data indicate that mine water has migrated from the Boone Formation through the pores and fractures of the intervening geologic units to the Roubidoux aquifer, although the available data do not preclude that possibility. Sulfate is an indicator of mine-water contamination.

The transition zone is defined to be where the chloride concentrations in ground water range 25–250 mg/L. In the northern part of the study unit, it is inferred that the position of the bottom of the transition zone slopes from above the top of the Roubidoux aquifer in eastern Craig County and western Ottawa County to below the base of the Roubidoux aquifer in central Ottawa County. Based on limited information from three wells, the depth to the bottom of the transition zone is approximately 1,200–1,500 ft below land surface in the eastern part of the study unit. The data are too few to define the position of the transition zone in the southern part of the study unit.

Large concentrations of gross-alpha radioactivity in ground water occur near the western edge of the transition zone. Generally, wells that had samples with large concentrations of gross-alpha radioactivity had large concentrations of radium-226. Both gross-alpha radioactivity and radium-226 concentrations appear to be correlated with chloride concentrations.

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APPENDIXES

APPENDIX 1: Conversion Factors

Inch–pound unit	Multiply by	To obtain metric units
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer
square foot per day (ft^2/d)	0.09290	square meter per day
square mile (mi^2)	2.590	square kilometer

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = (5/9)\,(°F - 32)$$

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

APPENDIX 2: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

[Primary use of water: C, commercial; H, domestic; I, irrigation; N, industrial; P, public supply; R, recreation; S, stock; T, institutional; U, unused. ft, feet; --, no data.]

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
		Adair County					
18N-26E-18 BDC 1	Hudson Fm Inc	360225094344001	1,110	1,360	N	--	--
18N-26E-31 DAD 1	Westville, OK	355931094340001	1,123	1,510	P	190.40	08-07-81
18N-26E-31 DCC 1	Westville, City of	355930094341001	--	1,100	--	100	-47
		Cherokee County					
16N-21E-33 DCA 1	Pine, W H	354856095044501	710	2,093	--	--	--
16N-22E-03 CCB 1	Bracken Oil Co	355319094574001	834	1,450	U	--	--
19N-21E-35 AD 1	M & F Oil Co	360502095015201	800	1,935	--	--	--
		Craig County					
24N-21E-11 BDB 1	Lewis, F	363439095020901	790	1,948	--	115.1	09-08-81
25N-20E-12 BDD 1	E. State Hosp.	363950095070201	725	1,139	P	55	03-01-50
25N-20E-12 C 4	E. State Hosp.	363930095071504	--	1,139	P	190	05-01-50
25N-20E-12 CAC 3	E. State Hosp.	363935095070503	--	1,240	P	--	--
25N-20E-12 CAD 2	E. State Hosp.	363935095070202	--	1,080	P	--	--
27N-20E-12 BDD 1	Neill, C E	365013095070501	900	688	S	219	01-01-60
27N-20E-12 BDD 2	Neill, C E	365016095070501	900	1,090	S	212.50	10-28-80
						211.03	02-04-81
						217.07	05-12-81
						215.10	06-08-81
						207.69	01-25-82
						208.80	04-19-82
27N-21E-12 CCB 1	RWD-3	365000095010101	876	1,352	P	217	08-14-80
						208.03	02-04-81
						208.63	05-12-81
						207.97	09-10-81
						211.39	01-26-82
						207.63	04-20-82
						210.32	07-21-82
						209.02	10-20-82
27N-21E-20 DCD 1	Bluejacket, OK	364808095043501	820	1,045	P	147.32	06-09-77
						145.85	02-18-81
						152.21	05-11-81
						149.88	06-09-81
						146.92	09-09-81
						145.21	01-25-82
						145.85	04-19-82
						146.45	07-19-82
						152.28	10-19-82
27N-21E-28 BBB 1	Bluejacket, OK	364759095041401	785	1,418	--	--	--
28N-20E-13 ACC 1	Shorter, Jim	365440095065701	860	1,501	U	89.59	11-24-80
						99.73	03-16-81
28N-21E-29 CBC 1	Welch, OK	365242095051701	845	1,200	P	178.74	06-07-77
						177.37	10-29-80
						175.26	02-04-81
						173.97	05-12-81
						178.50	06-06-81
						176.57	09-09-81
						174.50	01-25-82
						173.50	04-19-82
						173.80	07-20-82
						174.08	10-21-82
28N-21E-29 CBD 1	Welch, OK	365240095051501	--	1,250	P	177.37	10-29-80
						175.26	02-04-81
		Delaware County					
20N-23E-34 CCA 1	Oaks, OK	360946094504901	1,090	1,375	P	369	11-01-70
						280.26	06-10-81
20N-24E-17 CCC 1	Kansas, OK	361221094463901	1,200	1,065	P	310	11-07-80
						307.34	02-19-81
						307.27	05-13-81
						309.29	09-17-81
						310.12	01-29-82
						325.10	04-23-82
						319.20	07-23-82
						312.48	10-22-82

APPENDIX 2 *(Continued)*: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
21N-25E-31 BBB 1	Colcord, OK	361544094410101	1,205	1,350	P	307.58	05-07-81
						302.90	09-15-81
						324.88	01-28-82
						306.42	04-23-82
						335	07-22-82
						321.43	10-22-82
22N-23E-05 DCA 1	RWD-1	362442094520801	1,100	1,538	P	288	06-18-79
						300	11-06-80
						303.51	02-19-81
						303.54	05-13-81
						303.72	06-10-81
						305.62	09-15-81
						309.82	01-29-82
						309.30	04-23-82
						313.52	07-22-82
						310.90	10-22-82
22N-23E-11 BBB 1	Jay, OK	362427094493001	1,070	1,442	P	249	07-27-82
23N-22E-14 ADC 1	Lakemont Shores	362829094550901	940	1,003	R	--	--
23N-25E-17 BDB 1	Commercial Oil Co	362832094392201	1,045	1,023	--	--	--
23N-25E-33 DDC 1	Curry, A	362532094375501	1,080	1,160	S	114	07-09-81
	Curry	362532094374501	--	1,160	--	--	--
24N-23E-15 BBC 1	Shangri-La Resort	363357094503701	805	1,145	P	80	03- -70
						174.02	09-04-80
						152.14	06-11-81
24N-24E-06 DCA 1	Grove, OK	363510094464501	850	975	P	149	03-11-81
						154.83	06-11-81
25N-22E-23 CCD 1	Bernice, OK	363740094553101	925	1,440	P	261	03-08-79
						259.10	11-06-80
						257.82	02-19-81
						257.87	05-12-81
						261	06-10-81
						259.81	09-10-81
						260.27	01-28-82
						258.06	04-22-82
						264.10	07-21-82
						268.15	10-21-82
25N-23E-13 BAB 1	Hickory Meadows Dev	363921094474301	775	1,080	P	90.38	06-11-81
25N-24E-28 BBB 1	Prather	363718094444501	805	1,600	H	15	02-01-68
						39.05	07-09-81
		Mayes County					
22N-19E-14 BDC 1	Renfro	362314095150801	700	1,415	--	--	--
22N-21E-15 CAC 2	--	362310095030001	--	--	U	--	--
23N-21E-34 ACA 1	Davis	362600095025001	670	1,622	--	--	--
		Ottawa County					
25N-23E-01 AAA 1	Grays Ranch	364103094470401	760	850	P	--	--
26N-22E-15 DDA 1	NE OK Voc School	364349094554501	800	1,110	--	178.98	10-31-80
						180.76	02-19-81
						176.93	05-12-81
						181.65	06-12-81
						179.70	09-09-81
						178.93	01-26-82
						178.15	04-21-82
						176.60	07-22-82
						178.55	10-20-82
26N-22E-20 BCC 1	Helmick, D	364323094585101	790	1,145	H	151.35	03-02-81
						150.85	06-12-81
26N-22E-27 ADD 1	Albro Aleen	364227094554301	805	--	C	--	--
26N-22E-27 CBC 1	Grnd Valley Fm	364211094564101	800	980	S	--	--
26N-22E-32 ACD 1	Afton, OK	364136094575801	786	991	P	168	07-01-68
						159.20	10-31-80
						150.62	02-17-81
						160.40	05-12-81
						144.90	09-16-81
						158.26	01-26-82
						150.30	04-21-82
						143.23	10-21-82

APPENDIX 2 *(Continued)*: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
26N-22E-32 ACD 2	Afton, OK	364137094575902	784	900	P	168	07-01-68
						155.25	06-11-81
26N-22E-32 ADC 1	Afton Well 1	364135094580001	--	991	--	--	--
26N-22E-32 ADC 2	Afton Well 2	364135094580002	--	900	--	--	--
26N-22E-32 DBB 1	Afton, OK	364130094581501	785	1,066	P	--	--
26N-23E-08 BBC 1	Shell Oil Co	364520094521501	--	1,100	P	--	--
26N-23E-09 CA 1	Fairland, OK	364501094505301	835	1,253	P	--	--
26N-23E-09 DBC 1	Fairland, OK	364454094504401	845	1,250	P	304.68	10-30-80
						303.55	02-18-81
						293.26	05-14-81
						304.97	07-08-81
						300.02	09-15-81
						317.56	01-27-82
						305.25	04-22-82
						298.56	07-22-82
						323.56	10-21-82
26N-23E-12 BAD 1	Ogeechee Farms	364516094473501	835	1,253	I	292	09-13-73
26N-24E-32 ABA 1	Koenig, R J	364155094451001	770	850	H	22.38	07-30-81
27N-22E-01 CCC 1	RWD-2	365103094541501	790	--	P	--	--
27N-22E-12 CCC 1	CO. Poor Farm	364951094542601	850	1,065	P	150	01-01-36
						471.12	07-16-81
27N-22E-27 AAB 1	McPherson	364801094554601	--	950	--	--	--
27N-23E-03 BCC 1	Lakewood Shores	365100094491701	770	900	P	--	--
27N-23E-04 DCC 1	De Mier, F	365042094504701	790	1,033	H	--	--
27N-23E-17 CBB 1	RWD-6	364921094522201	810	1,205	P	430	04-10-79
						415.60	11-05-80
						425.83	02-05-81
						417.52	05-12-81
						421.60	06-09-81
						422.53	09-10-81
						425.70	01-26-82
						419.71	04-20-82
						426.37	07-21-82
						427.89	10-20-82
27N-23E-28 CDC 1	Newton, F	364712094510101	810	1,000	U	256	07-01-46
27N-24E-08 B 1	Kenny, S I	365018094451101	850	1,030	--	--	--
27N-24E-21 CD 1	Seneca Ind. Sch.	364806094433701	800	1,040	P	100	07-01-46
27N-24E-28 CAD 1	RWD-1	364717094433101	770	1,100	P	235.45	06-26-80
						238.45	11-04-80
						234.63	02-05-81
						235.77	05-13-81
						238.48	07-08-81
						233.99	09-14-81
						232.73	01-27-82
						231.04	04-21-82
						236.59	07-20-82
						233.88	10-20-82
27N-25E-09 CAC 1	Milnot Co	364957094371501	850	1,247	N	125	08-31-50
28N-22E-11 ABB 1	Robinson, J	365543094535801	--	1,150	H	--	--
28N-22E-23 BAA 1	Dalrymple, J	365357094541901	770	826	U	90.50	07-28-82
28N-22E-24 AAB 1	Goodrich Rubber Co Well 4	365358094525001	788	1,235	N	--	--
28N-22E-24 BCB 1	Goodrich Rubber Co Well 2	365344094534701	765	1,200	N	219	05-01-44
28N-22E-24 BDA 1	Goodrich Rubber Co Well 5	365342094531301	792	1,465	I	--	--
28N-22E-24 CAD 1	Goodrich Rubber Co Well 3	365324094531301	798	1,055	N	249	02- -44
28N-22E-24 CBC 1	Goodrich Rubber Co Well 1	365323094534001	786	1,200	N	254	08-01-44
28N-22E-24 DAB 1	McCoy Nursery	365330094524901	--	1,046	U	--	--
28N-22E-35 DCC 1	Robinson, J	365133094545901	--	1,130	H	200	07-01-46
28N-23E-01 BBB 1	Quapaw, City of, Well 4	365633094471001	845	1,350	N	308	08-26-81
28N-23E-06 BAB 1	Commerce, City of, Well 3	365627094522201	810	1,440	P	480	05-13-80
28N-23E-06 BAB 2	Commerce, City of, Well 4	365627094522101	810	1,250	P	--	--
28N-23E-06 CCA 1	Commerce, City of, Well 1	365600094523001	809	1,050	P	200	08-01-42
						443.67	07-07-81
28N-23E-06 CBD 2	Commerce, City of, Well 2	365557094522701	800	1,115	P	--	--
28N-23E-18 CDC 1	Goodrich Rubber Co Well 6	365402094522201	777	1,145	N	--	--
28N-23E-20 BCB 1	Miami, City Of, Well 8	365344094513301	795	1,250	P	--	--

APPENDIX 2 *(Continued)*: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
28N-23E-24 DDA 1	Springriver RWD	365316094461601	--	1,035	H	367	03-01-54
28N-23E-28 BBB 1	Miami, City of, Well 7	365301094502901	800	1,535	P	--	--
28N-23E-30 CAC 1	Miami, City of, Well 1	365229094522101	790	1,233	H	--	--
28N-23E-30 DBC 1	Miami, City of, Ice Plant Well	365229094520201	770	1,490	U	-28	- -07
						100	- -37
						150	- -44
						385.5	10-02-56
						372	10-22-56
						356.6	01-30-57
						359.5	02-21-57
						358.8	03-26-57
						354.8	04-25-57
						355.2	05-31-57
						355	06-23-57
						362	07-09-57
						363	07-10-57
						370.4	07-23-57
						374	08-21-57
						370	09-25-57
						364	11-06-57
						362	12-01-57
						357.5	01-04-58
						351.0	02-03-58
						350.0	03-07-58
						350.0	03-21-58
						348.0	04-20-58
						354	05-21-58
						355	06-20-58
						346	07-19-58
						344	08-02-58
						348	08-20-58
						343	09-26-58
						343.5	10-21-58
						341.0	11-30-58
						338	01-07-59
						339	02-06-59
						337	02-28-59
						337.0	03-26-59
						335	05-02-59
						333	06-01-59
						341.5	06-22-59
						346.5	07-22-59
						355.5	08-05-59
						358.0	08-18-59
						359.0	09-19-59
						360.5	10-20-59
						358.0	11-25-59
						354.0	12-21-59
						350.5	01-19-60
						348.5	02-19-60
						346	03-19-60
						344.5	04-20-60
						343	05-22-60
						343	06-22-60
						350	07-19-60
						362.5	09-21-60
						354.5	01-11-61
						354.0	02-23-61
						355.0	04-18-61
						360.5	06-06-61
						360.5	07-19-61
						355.7	08-22-61
						355.5	09-20-61
						351.5	11-22-61
						351.0	12-18-61

APPENDIX 2 *(Continued)*: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
28N-23E-30 DBC 1	Miami, City of, Ice Plant Well	365229094520201	770	1,490	U	350.0	01-27-62
						351.8	02-21-62
						354.0	04-05-62
						352.0	04-18-62
						360.2	05-22-62
						366.0	06-19-62
						374.5	07-18-62
						382.0	08-21-62
						374.5	09-19-62
						371.0	10-23-62
						369.5	11-21-62
						372.0	12-19-62
						369.5	08-26-65
						364	10-04-65
						356	12-22-65
						357.6	02-02-66
						358.5	03-18-66
						367.5	06-22-66
						379	10-14-66
						376	01-23-67
						376	03-06-67
						377	04-06-67
						368	05-20-67
						365.5	07-06-67
						379	03-06-68
						387.0	12-18-68
						414.0	08-08-69
						421.5	10-01-70
						441.6	02-29-72
						437.5	04-04-72
						437.4	05-01-72
						455.73	06-05-72
						455.8	07-07-72
						464.8	08-08-72
						456.45	09-18-72
						448.91	10-05-72
						446.15	11-16-72
						440.9	12-21-72
						446.8	06-23-73
						457.9	07-19-73
						447.1	09-07-73
						455.65	11-07-73
						456	02-12-74
						459.35	05-20-74
						475	07-23-74
						461.1	09-04-74
						450.0	10-04-74
						448.10	11-08-74
						441.27	12-20-74
						443.5	01-29-75
						444.0	02-28-75
						442.8	03-31-75
						438.25	05-01-75
						436.45	05-30-75
						434.1	06-16-75
						445.55	06-30-75
						451.85	07-16-75
						452.35	07-30-75
						455.15	08-18-75
						459.45	08-29-75
						455.2	09-16-75
						454.50	09-30-75
						451.90	10-16-75
						446.35	10-31-75
						446.42	11-17-75

APPENDIX 2 *(Continued)*: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
28N-23E-30 DBC 1	Miami, City of, Ice Plant Well	365229094520201	770	1,490	U	447.57	12-02-75
						443.95	12-17-75
						440.42	12-30-75
						442.45	01-15-76
						442.15	02-02-76
						441.65	02-17-76
						442	03-17-76
						443	04-05-76
						437.65	04-30-76
						436.06	05-05-76
						431.52	05-18-76
						429.1	06-07-76
						433.52	07-01-76
						433.38	07-15-76
						436.37	08-12-76
						429.43	09-07-76
						432.85	09-16-76
						438.65	10-08-76
						436.21	11-02-76
						433.88	11-16-76
						436.32	12-02-76
						439.10	12-15-76
						438.28	01-07-77
						441.34	01-27-77
						439.12	02-17-77
						442.95	03-15-77
						446.70	03-22-77
						440.53	04-06-77
						443.15	04-29-77
						445.55	05-25-77
						447.40	06-09-77
						454.05	07-27-77
						455.38	08-16-77
						457.89	09-01-77
						458.03	09-15-77
						455.90	10-03-77
						454.82	10-21-77
						456.25	11-28-77
						450	12-30-77
						450.10	01-23-78
						450.80	02-23-78
						450.21	03-10-78
						451.20	03-21-78
						447.29	04-18-78
						453.85	05-12-78
						452.65	06-07-78
						455.20	07-07-78
						454.60	08-24-78
						455.60	09-14-78
						460.30	10-13-78
						452.20	11-21-78
						450.80	12-19-78
						456.9	02-14-79
						454.80	03-05-79
						449.95	04-02-79
						447.68	05-10-79
						441.0	05-23-79
						450.0	06-11-79
						452.76	07-23-79
						451.74	08-17-79
						454.6	09-27-79
						453.25	10-30-79
						444.60	12-10-79
						438.40	01-24-80
						441.71	02-27-80

APPENDIX 2 *(Continued)*: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
28N-23E-30 DBC 1	Miami, City of, Ice Plant Well	365229094520201	770	1,490	U	448.85	03-05-80
						438.60	04-03-80
						436.07	06-04-80
						434.97	09-07-81
						433.69	06-20-85
						417.98	02-26-86
						406.20	05-07-86
						406.94	06-18-86
						430.32	06-24-86
						407.93	10-09-86
						402.52	11-05-86
						389.18	12-16-86
						377.40	01-27-87
						370.25	03-23-87
						367.59	05-06-87
						380.38	06-30-87
						368.21	10-28-87
						361.10	12-17-87
						350.70	03-16-88
						361	07-12-88
						366	08-22-88
						353.70	11-16-88
						346.10	01-04-89
						337.60	05-10-89
						346.25	07-27-89
						343.74	10-25-89
						340.55	10-31-89
						339.33	11-13-89
						338.49	11-14-89
						341.36	01-11-90
						337.48	02-07-90
						337.91	02-08-90
						334.14	03-30-90
						335.34	05-11-90
						341.29	06-14-90
						357	07-26-90
28N-23E-31 BAB 1	Miami, City of, Well 2	365210094522101	780	1,247	N	--	--
28N-23E-31 BAC 1	Miami, City of, Well 3	365206094522201	780	1,116	P	480	01-01-52
28N-23E-31 CBA 1	Miami, City of, Well 4	365146094522201	770	1,250	P	300	01-01-41
28N-23E-32 BAB 1	Miami, City of, Well 5	365212094511901	780	1,345	P	--	--
28N-23E-33 BAB 1	Miami, City of, Well 6	365213094500701	800	1,526	H	366	05-01-55
28N-23E-36 CCC 1	RWD-4 W-2	365128094471301	915	1,190	P	530	09-25-80
28N-24E-13 ABD 1	RWD-3	365445094400701	965	1,165	P	269.07	07-14-81
28N-25E-20 CAA 1	RWD-5	365335094380701	1,050	1,418	P	350	05-11-78
						356.50	03-17-81
						355.51	05-08-81
						354.53	06-09-81
						354.75	09-09-81
						360.26	01-25-82
						353.52	04-21-82
						355.39	07-20-82
						351.30	10-19-82
29N-22E-21 DAD 1	RWD-7	365833094551901	820	1,205	P	162	11-12-79
						159.61	10-29-80
						159.01	02-04-81
						158.81	03-06-81
						158.32	05-12-81
						157.51	06-09-81
						158.03	09-10-81
						157.36	01-26-82
						157.01	04-20-82
						156.58	07-20-82
						157.80	10-20-82
29N-22E-25 AAA 1	Commerce M & R Co	365820094520401	820	1,229	--	--	--
29N-23E-13 DAC 1	Semple, C Y	365916094454201	840	1,115	U	212	09-01-38

APPENDIX 2 *(Continued)*: Information About Selected Wells Penetrating the Roubidoux Aquifer in Northeastern Oklahoma That Were Used as Control Points

Local identifier	Well owner	Site identification number	Altitude of land surface (ft above sea level)	Well depth (ft)	Primary use of water	Water level (ft below land surface)	Water-level date
29N-23E-15 CDB 1	Beck Mining	365920094482501	825	1,073	N	--	--
29N-23E-16 DDD 1	Consolidated 2, Well 2	365917094484701	--	1,061	--	44.83	02-16-81
29N-23E-18 DBC 1	Gordon Mine	365934094511401	840	1,176	--	--	--
29N-23E-19 DCC 1	Eagle-Picher	365824094512401	820	1,772	U	285	01-01-38
29N-23E-19 DDC 1	Cardin, OK	365823094510701	--	1,150	P	--	--
29N-23E-20 AAA 1	Netta Mine	365901094500501	830	1,365	U	--	--
29N-23E-21 BBC 1	Picher, OK	365905094494601	822	1,077	P	380	08-01-42
29N-23E-21 BBC 2	Picher, OK	365905094494602	822	1,125	P	380	08-01-42
29N-23E-21 BBC 3	Picher, OK	365905094494603	822	1,125	P	--	--
29N-23E-21 DCA 1	United Zinc	365825094490501	830	1,040	N	--	--
29N-23E-24 BBA 1	Ontario Smelter	365908094462501	850	1,050	U	104	01-01-18
						206.64	07-14-81
29N-23E-25 AAA 1	Eagle-Picher Co	365757094464601	835	1,229	N	236	10-01-45
29N-23E-25 BDC 1	Quapaw Well 3	365800094461701	845	1,350	N	230.55	07-07-81
29N-23E-26 CDD 1	Quapaw Well 2	365734094471001	840	1,200	--	--	--
29N-23E-31 BDD 1	Eagle-Picher	365704094513101	834	1,175	N	325	11-01-41
29N-23E-32 AAB 1	Consolidated	365722094500401	820	985	U	--	--
29N-23E-35 BDD 1	Quapaw Well 1	365734094471101	850	1,325	P	258	07-01-42

APPENDIX 3: Concentrations of Common Constituents and Physical

[Agency analyzing sample: 1028, U.S. Geological Survey (specific laboratory not identified); 80020, National Water Quality Laboratory of the U.S. Geological

Local identifier	Date	Time	Site identification number	Agency analyzing sample	Sampling depth (ft)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (° C)	Hardness, total (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Alkalinity, whole water, field, IT (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, residue at 180°C, dissolved
Adair County													
18N-26E-18 BDC 1	10-28-81	1300	360225094344001	80020	--	459	7.3	18.5	230	16	200	200	268
18N-26E-31 DAD 1	08-20-81	--	355931094340001	1028	--	1,650	--	19.0	--	--	--	--	--
Cherokee County													
16N-22E-03 CCB 1	12-28-82	1330	355319094574001	84041	--	500	6.1	13.5	--	--	--	--	286
Craig County													
24N-21E-11 BDB 1	03-23-83	1330	363439095020901	84041	120	140	7.2	17.0	--	--	--	--	88
24N-21E-11 BDB 1	03-23-83	1345	363439095020901	84041	700	1,120	7.8	18.0	--	--	--	--	668
24N-21E-11 BDB 1	03-23-83	1450	363439095020901	84041	1,700	125,000	6.3	18.0	--	--	--	--	113,000
25N-20E-12 BDD 1	03-10-50	--	363950095070201	1028	--	2,210	7.9	--	190	--	102	--	1,210
25N-20E-12 BDD 1	09-05-51	--	363950095070201	1028	--	2,350	7.7	--	220	--	165	--	1,290
25N-20E-12 C 4	05-29-50	--	363930095071504	1028	--	2,750	7.3	--	300	--	146	--	1,570
25N-20E-12 CAC 3	04-12-47	--	363935095070503	1028	--	5,390	--	21.5	300	--	149	--	--
25N-20E-12 CAD 2	04-12-47	--	363935095070202	1028	--	2,030	--	20.0	180	--	173	--	--
27N-20E-12 BDD 1	01-14-69	--	365013095070501	1028	--	1,620	8.2	--	120	--	162	--	872
27N-20E-12 BDD 2	10-28-80	1700	365016095070501	1028	--	1,610	8.7	17.5	--	--	--	--	--
27N-20E-12 BDD 2	02-04-81	1300	365016095070501	1028	--	1,700	8.0	17.0	140	3.0	--	152	878
27N-20E-12 BDD 2	05-12-81	1300	365016095070501	1028	--	1,540	8.2	23.0	--	--	--	--	--
27N-20E-12 BDD 2	06-08-81	1400	365016095070501	80020	--	1,500	7.8	28.0	150	4.7	159	155	826
27N-20E-12 BDD 2	01-25-82	1230	365016095070501	1028	--	1,550	8.0	19.5	--	--	--	--	--
27N-21E-12 CCB 1	05-12-81	1100	365000095010101	1028	--	580	8.0	21.5	--	--	--	--	--
27N-21E-12 CCB 1	07-09-81	1030	365000095010101	80020	--	542	7.9	23.5	120	2.1	138	129	286
27N-21E-12 CCB 1	01-26-82	1215	365000095010101	1028	--	600	8.0	25.5	--	--	--	--	--
27N-21E-12 CCB 1	04-20-82	830	365000095010101	1028	--	644	7.9	20.5	--	--	--	--	--
27N-21E-12 CCB 1	07-21-82	900	365000095010101	1028	--	634	8.0	24.5	--	--	--	--	--
27N-21E-12 CCB 1	10-20-82	1330	365000095010101	1028	--	618	8.0	20.5	--	--	--	--	--
27N-21E-20 DCD 1	02-01-81	1430	364808095043501	1028	--	892	8.2	19.5	--	--	--	--	--
27N-21E-20 DCD 1	02-04-81	1430	364808095043501	1028	--	--	--	--	76	2.0	--	156	468
27N-21E-20 DCD 1	02-18-81	1130	364808095043501	1028	--	869	8.1	21.5	--	--	--	--	--
27N-21E-20 DCD 1	05-11-81	1300	364808095043501	1028	--	856	8.2	23.0	--	--	--	--	--
27N-21E-20 DCD 1	06-09-81	1100	364808095043501	80020	--	832	8.1	25.5	84	2.5	174	159	448
27N-21E-20 DCD 1	09-09-81	1100	364808095043501	1028	--	846	8.0	22.5	--	--	--	--	--
27N-21E-20 DCD 1	01-25-82	1130	364808095043501	1028	--	838	8.0	21.5	--	--	--	--	--
27N-21E-20 DCD 1	04-19-82	1200	364808095043501	1028	--	871	7.9	21.5	--	--	--	--	--
27N-21E-20 DCD 1	07-19-82	1400	364808095043501	1028	--	878	7.9	24.5	--	--	--	--	--
27N-21E-20 DCD 1	10-19-82	1409	364808095043501	1028	--	943	7.9	22.5	--	--	--	--	--
27N-21E-28 BBB 1	04-12-47	--	364759095041401	1028	--	930	--	18.0	78	--	176	--	--
28N-20E-13 ACC 1	03-16-81	--	365440095065701	1028	--	9,830	9.2	18.0	--	--	--	--	--
28N-20E-13 ACC 1	03-23-83	1700	365440095065701	84041	170	9,120	9.3	16.5	--	--	--	--	5,300
28N-20E-13 ACC 1	03-23-83	1730	365440095065701	84041	1,460	27,000	7.9	16.5	--	--	--	--	17,800
28N-21E-29 CBC 1	10-29-80	900	365242095051701	1028	--	1,820	8.3	21.0	--	--	--	--	--
28N-21E-29 CBC 1	02-04-81	1100	365242095051701	1028	--	1,830	8.2	11.0	210	3.0	--	152	996
28N-21E-29 CBC 1	05-12-81	1200	365242095051701	1028	--	1,710	8.0	23.0	--	--	--	--	--
28N-21E-29 CBC 1	06-09-81	900	365242095051701	80020	--	1,680	7.7	27.5	210	6.9	162	146	954
28N-21E-29 CBC 1	09-09-81	1400	365242095051701	1028	--	1,710	7.9	26.0	--	--	--	--	--
28N-21E-29 CBC 1	01-25-82	1330	365242095051701	1028	--	1,820	7.9	21.0	--	--	--	--	--
28N-21E-29 CBC 1	04-19-82	1400	365242095051701	1028	--	1,830	7.8	22.5	--	--	--	--	--
28N-21E-29 CBC 1	06-15-82	1425	365242095051701	80020	--	1,850	7.6	24.5	--	--	--	--	--
28N-21E-29 CBC 1	07-20-82	1400	365242095051701	1028	--	1,820	7.8	25.5	--	--	--	--	--
28N-21E-29 CBD 1	06-09-81	930	365240095051501	80020	--	1,730	7.9	25.0	220	7.2	154	150	986
28N-21E-29 CBD 1	06-15-82	1430	365240095051501	80020	--	1,990	6.9	21.5	--	--	--	--	--
28N-21E-29 CBD 1	07-20-82	1400	365240095051501	1028	--	1,820	7.8	25.5	--	--	--	--	--
28N-21E-29 CBD 1	10-21-82	1400	365240095051501	1028	--	1,730	7.8	23.0	--	--	--	--	--
Delaware County													
20N-23E-34 CCA 1	06-10-81	930	360946094504901	80020	--	561	7.9	21.5	94	13	257	222	324
20N-24E-17 CCC 1	11-07-80	830	361221094463901	1028	--	484	8.1	19.0	--	--	--	--	--
20N-24E-17 CCC 1	02-19-81	845	361221094463901	1028	--	486	8.0	19.0	--	--	--	--	--
20N-24E-17 CCC 1	05-13-81	845	361221094463901	1028	--	527	8.2	19.0	--	--	--	--	--
20N-24E-17 CCC 1	06-10-81	800	361221094463901	80020	--	477	8.1	21.5	110	4.7	200	175	278
20N-24E-17 CCC 1	09-18-81	835	361221094463901	1028	--	503	8.0	--	--	--	--	--	--
20N-24E-17 CCC 1	01-29-82	845	361221094463901	1028	--	469	8.0	18.0	--	--	--	--	--
20N-24E-17 CCC 1	04-23-82	830	361221094463901	1028	--	479	7.9	19.0	--	--	--	--	--
20N-24E-17 CCC 1	07-23-82	845	361221094463901	1028	--	472	8.0	20.0	--	--	--	--	--
20N-24E-17 CCC 1	10-22-82	830	361221094463901	1028	--	487	8.0	18.0	--	--	--	--	--
21N-25E-31 BBB 1	11-06-80	1400	361544094410101	1028	--	357	8.3	18.5	--	--	--	--	--
21N-25E-31 BBB 1	06-10-81	1045	361544094410101	80020	--	363	8.0	23.0	86	2.5	156	140	198
21N-25E-31 BBB 1	09-15-81	1500	361544094410101	1028	--	358	8.2	20.5	--	--	--	--	--
21N-25E-31 BBB 1	01-28-82	1530	361544094410101	1028	--	346	8.1	22.0	--	--	--	--	--
21N-25E-31 BBB 1	06-16-82	1330	361544094410101	80020	--	379	8.0	21.5	--	--	--	--	--
21N-25E-31 BBB 1	07-22-82	1000	361544094410101	1028	--	410	8.2	25.0	--	--	--	--	--
21N-25E-31 BBB 1	10-22-82	1500	361544094410101	1028	--	361	8.0	20.5	--	--	--	--	--
22N-23E-05 DCA 1	11-06-80	1300	362442094520801	1028	--	1,210	8.2	21.0	--	--	--	--	--
22N-23E-05 DCA 1	05-13-81	1130	362442094520801	1028	--	1,140	8.2	18.5	--	--	--	--	--

Properties of Water from Wells Completed in the Roubidoux Aquifer

Survey; 84041, Oklahoma Geological Survey; 84042, Oklahoma State Department of Health. IT, incremental titration; --, indicates no data are available.]

Solids, residue at 105°C, dissolved	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, total recoverable (mg/L as Na)	Sodium, dissolved (mg/L as Na)	Sodium + potassium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, whole water, total, IT (mg/L as $CaCO_3$)	Carbonate, whole water, total, IT (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate + nitrite, dissolved (mg/L as N)
Adair County															
--	88	1.9	--	7.7	--	1.0	270	0	15	10	--	0.10	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cherokee County															
--	--	--	--	5.2	--	--	--	--	10	5.8	--	0.10	--	--	--
Craig County															
--	--	--	--	--	--	--	--	--	3.0	2.7	--	0.10	--	--	--
--	--	--	--	--	--	--	--	--	10	260	--	2.1	--	--	--
--	--	--	--	--	--	--	--	--	690	65,000	--	0.40	--	--	--
--	38	23	--	370	--	27	120	0	28	620	--	2.2	12	1.00	--
--	50	22	--	390	--	11	200	0	21	630	--	3.6	9.2	0.250	--
--	68	31	--	450	--	25	180	0	28	780	--	2.2	12	0.610	--
--	--	--	--	--	--	--	180	--	64	1,800	--	--	--	0.110	--
--	--	--	--	--	--	--	210	--	26	550	--	--	--	0.230	--
--	--	--	--	--	2,800	--	200	0	3.2	400	--	--	--	0.180	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	33	13	--	270	--	8.1	--	--	8.5	400	--	3.9	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	34	15	--	290	--	7.9	190	0	14	390	--	3.8	11	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	29	12	--	65	--	4.3	170	0	14	78	--	1.3	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	18	7.6	--	150	--	4.9	--	--	7.3	170	--	4.2	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	19	8.8	--	150	--	4.7	210	0	11	160	--	4.2	12	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	18	8.0	--	--	180	--	210	0	15	200	--	4.4	--	0.00	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	100	3,100	--	0.30	--	--	--
--	--	--	--	--	--	--	--	--	20	10,000	--	0.80	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	49	21	--	270	--	8.5	--	--	12	450	--	2.6	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	49	22	--	290	--	7.9	200	0	19	460	--	3.0	12	--	--
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--	50	23	--	300	--	8.4	190	0	23	480	--	2.7	12	--	--
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Delaware County															
--	21	10	--	100	--	3.1	310	0	22	30	--	2.6	9.0	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	26	11	--	70	--	2.1	240	0	16	41	--	0.90	12	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	20	8.8	--	49	--	1.9	190	0	13	25	--	1.0	14	--	--
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APPENDIX 3 *(Continued)*: Concentrations of Common Constituents and Physical

Local identifier	Date	Time	Site identification number	Agency analyzing sample	Sampling depth (ft)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (° C)	Hardness, total (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Alkalinity, whole water, field, IT (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, residue at 180°C, dissolved
22N-23E-05 DCA 1	06-10-81	1200	362442094520801	80020	--	1,140	8.0	20.0	94	2.2	143	129	610
22N-23E-05 DCA 1	06-18-82	950	362442094520801	80020	--	1,200	7.5	21.5	--	--	--	--	--
22N-23E-05 DCA 1	07-22-82	1200	362442094520801	1028	--	1,210	8.2	22.5	--	--	--	--	--
22N-23E-11 BBB 1	07-27-82	--	362427094493001	1028	--	475	7.7	16.5	--	--	--	--	--
22N-23E-11 BBB 1	03-21-83	1445	362427094493001	84041	--	415	8.0	20.0	82	--	121	--	234
23N-22E-14 ADC 1	06-10-81	1245	362829094550901	80020	--	366	8.0	21.5	68	2.5	148	133	198
23N-25E-33 DDC 1	12-18-68	--	362532094375501	1028	--	311	7.9	--	160	--	159	--	167
23N-25E-33 DDC 1	07-09-81	1445	362532094375501	80020	--	317	7.6	20.5	170	7.3	159	151	176
24N-23E-15 BBC 1	06-11-81	930	363357094503701	80020	--	951	8.0	23.0	110	3.2	144	135	518
24N-23E-15 BBC 1	06-17-82	1000	363357094503701	80020	--	967	8.0	23.0	--	--	--	--	--
24N-24E-06 DCA 1	03-18-81	--	363510094464501	1028	--	853	8.2	16.0	--	--	--	--	--
24N-24E-06 DCA 1	06-11-81	1230	363510094464501	80020	--	784	8.1	24.0	99	1.7	151	140	432
25N-22E-23 CCD 1	11-06-80	1400	363740094553101	1028	--	569	8.0	19.0	--	--	--	--	--
25N-22E-23 CCD 1	02-19-81	1300	363740094553101	1028	--	544	8.1	20.0	--	--	--	--	--
25N-22E-23 CCD 1	05-12-81	1700	363740094553101	1028	--	527	8.0	21.0	--	--	--	--	--
25N-22E-23 CCD 1	06-10-81	1500	363740094553101	80020	--	487	8.1	21.0	69	1.7	143	128	268
25N-22E-23 CCD 1	09-10-81	1400	363740094553101	1028	--	578	8.0	22.0	--	--	--	--	--
25N-22E-23 CCD 1	01-28-82	1430	363740094553101	1028	--	531	8.0	19.5	--	--	--	--	--
25N-22E-23 CCD 1	04-22-82	1400	363740094553101	1028	--	593	8.0	19.5	--	--	--	--	--
25N-22E-23 CCD 1	07-21-82	1200	363740094553101	1028	--	824	7.9	21.5	--	--	--	--	--
25N-22E-23 CCD 1	08-17-82	1115	363740094553101	1028	--	590	7.9	22.0	--	--	--	--	290
25N-22E-23 CCD 1	10-21-82	1300	363740094553101	1028	--	570	8.0	20.0	--	--	--	--	--
25N-23E-13 BAB 1	06-11-81	1330	363921094474301	80020	--	577	7.6	24.0	140	5.2	166	162	322
25N-24E-28 BBB 1	12-15-68	--	363718094444501	1028	--	668	7.8	--	140	--	180	--	350
25N-24E-28 BBB 1	07-09-81	1200	363718094444501	80020	--	681	7.2	22.5	110	24	205	188	358
				Ottawa County									
25N-23E-01 AAA 1	07-15-81	1700	364103094470401	80020	--	555	7.9	21.5	130	2.0	149	140	308
26N-22E-15 DDA 1	10-31-80	1000	364349094554501	1028	--	885	8.1	18.5	--	--	--	--	--
26N-22E-15 DDA 1	02-19-81	1530	364349094554501	1028	--	864	8.2	20.5	--	--	--	--	--
26N-22E-15 DDA 1	06-12-81	1000	364349094554501	80020	--	885	7.9	22.0	140	1.5	141	135	480
26N-22E-15 DDA 1	01-26-82	1400	364349094554501	1028	--	869	8.3	18.5	--	--	--	--	--
26N-22E-15 DDA 1	04-21-82	1100	364349094554501	1028	--	913	8.2	20.0	--	--	--	--	--
26N-22E-15 DDA 1	07-22-82	1100	364349094554501	1028	--	913	8.4	21.0	--	--	--	--	--
26N-22E-15 DDA 1	10-20-82	1100	364349094554501	1028	--	898	8.3	19.5	--	--	--	--	--
26N-22E-20 BCC 1	03-02-81	--	364323094585101	1028	--	1,160	8.2	17.5	--	--	--	--	--
26N-22E-20 BCC 1	06-12-81	900	364323094585101	80020	--	1,090	8.1	22.0	160	3.2	149	140	592
26N-22E-20 BCC 1	06-16-82	900	364323094585101	80020	--	1,140	8.0	19.5	--	--	--	--	--
26N-22E-27 ADD 1	07-08-81	830	364227094554301	80020	--	958	7.9	22.5	160	2.4	143	135	520
26N-22E-27 CBC 1	06-11-81	1600	364211094564101	80020	--	694	7.8	23.5	140	7.4	171	159	370
26N-22E-32 ADC 1	09-06-51	--	364136094575801	1028	--	1,420	7.8	--	170	--	137	--	758
26N-22E-32 ADC 1	06-11-81	1500	364136094575801	80020	--	1,420	7.8	24.0	190	4.2	149	136	782
26N-22E-32 ADC 1	06-16-82	1005	364136094575801	80020	--	1,560	7.6	21.5	--	--	--	--	--
26N-22E-32 ADC 2	10-31-80	1330	364137094575902	1028	--	1,440	7.6	20.5	--	--	--	--	--
26N-22E-32 ADC 2	02-17-81	1630	364137094575902	1028	--	1,450	8.7	25.0	--	--	--	--	--
26N-22E-32 ADC 2	05-12-81	1530	364137094575902	1028	--	1,390	8.0	21.5	--	--	--	--	--
26N-22E-32 ADC 2	06-11-81	1300	364137094575902	80020	--	1,500	7.7	24.0	190	5.2	153	138	824
26N-22E-32 ADC 2	09-16-81	1300	364137094575902	1028	--	1,380	8.1	20.0	--	--	--	--	--
26N-22E-32 ADC 2	01-27-82	1330	364137094575902	1028	--	1,280	8.0	20.5	--	--	--	--	--
26N-22E-32 ADC 2	04-21-82	1300	364137094575902	1028	--	1,390	7.9	20.5	--	--	--	--	--
26N-22E-32 ADC 2	06-16-82	1000	364137094575902	80020	--	1,380	7.7	21.0	--	--	--	--	--
26N-22E-32 ADC 2	07-21-82	1030	364137094575902	1028	--	1,520	8.0	22.5	--	--	--	--	--
26N-22E-32 DBB 1	07-29-44	--	364130094581501	1028	--	--	8.2	--	190	--	138	--	--
26N-23E-08 BBC 1	07-25-46	--	364520094521501	1028	--	663	--	--	180	--	166	--	374
26N-23E-09 CA 1	07-29-44	--	364501094505301	1028	--	--	8.4	20.0	150	--	135	--	--
26N-23E-09 CA 1	09-06-51	--	364501094505301	1028	--	613	8.1	--	140	--	136	--	320
26N-23E-09 CA 1	05-03-78	--	364501094505301	84042	--	--	8.2	--	140	--	142	--	--
26N-23E-09 CA 1	03-19-80	--	364501094505301	84042	--	--	7.3	--	140	--	112	--	--
26N-23E-09 CA 1	07-08-81	945	364501094505301	80020	--	504	7.5	21.5	190	16	221	204	278
26N-23E-09 CA 1	06-18-82	800	364501094505301	80020	--	819	7.5	21.5	--	--	--	--	--
26N-23E-09 DBC 1	10-30-80	900	364454094504401	1028	--	469	7.6	20.5	--	--	--	--	--
26N-23E-09 DBC 1	02-18-81	930	364454094504401	1028	--	592	7.8	19.5	--	--	--	--	--
26N-23E-09 DBC 1	05-14-81	1000	364454094504401	1028	--	543	8.0	20.0	--	--	--	--	--
26N-23E-09 DBC 1	07-08-81	930	364454094504401	80020	--	560	7.8	23.0	140	4.2	141	131	306
26N-23E-09 DBC 1	09-15-81	1000	364454094504401	1028	--	544	8.0	20.5	--	--	--	--	--
26N-23E-09 DBC 1	01-27-82	1030	364454094504401	1028	--	602	7.9	20.0	--	--	--	--	--
26N-23E-09 DBC 1	04-22-82	1030	364454094504401	1028	--	557	7.8	21.0	--	--	--	--	--
26N-23E-09 DBC 1	07-22-82	1000	364454094504401	1028	--	593	8.0	22.0	--	--	--	--	--
26N-23E-09 DBC 1	10-21-82	830	364454094504401	1028	--	588	7.9	19.0	--	--	--	--	--
26N-23E-12 BAD 1	07-08-81	1040	364516094473501	80020	--	514	7.8	22.5	140	1.9	133	126	266
26N-24E-32 ABA 1	07-30-81	1400	364155094451001	80020	--	511	7.2	18.0	220	11	180	173	324
27N-22E-01 CCC 1	05-01-78	--	365103094541501	84042	--	--	8.4	--	140	--	137	--	367
27N-22E-01 CCC 1	07-16-81	800	365103094541501	80020	--	721	7.7	22.0	150	2.0	133	127	402
27N-22E-27 AAB 1	07-09-81	900	364801094554601	80020	--	1,270	7.9	20.0	58	8.2	594	342	792
27N-23E-03 BCC 1	07-08-81	1630	365100094491701	80020	--	351	7.5	21.0	130	4.7	149	139	188

Properties of Water from Wells Completed in the Roubidoux Aquifer

Solids, residue at 105°C, dissolved	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, total recoverable (mg/L as Na)	Sodium, dissolved (mg/L as Na)	Sodium + potassium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, whole water, total, IT (mg/L as $CaCO_3$)	Carbonate, whole water, total, IT (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate + nitrite, dissolved (mg/L as N)
--	22	9.4	--	190	--	3.2	170	0	10	280	--	2.0	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	20	7.9	--	59	--	2.1	--	--	11	49	--	1.2	12	--	--
--	16	6.8	--	52	--	2.4	180	0	7.6	26	--	1.7	10	--	--
--	--	--	--	--	3.2	--	190	0	0.30	1.6	--	--	--	0.450	--
--	66	1.1	--	2.9	--	0.40	190	0	3.9	1.7	--	0.10	8.0	--	--
--	27	11	--	160	--	4.0	180	0	10	220	--	1.6	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	23	10	--	130	--	3.6	180	0	6.8	160	--	1.4	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	16	7.1	--	78	--	3.2	170	0	11	68	--	0.30	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	45	7.1	--	74	--	2.7	200	0	12	80	--	1.1	9.0	--	--
--	--	--	--	--	82	--	220	0	7.9	90	--	--	--	0.020	--
--	44	1.1	--	87	--	3.4	250	0	9.3	96	--	1.4	10	--	--
								Ottawa County							
--	31	13	--	69	--	3.0	180	0	13	24	--	1.2	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	31	15	--	130	--	4.3	170	0	14	190	--	1.0	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	35	17	--	170	--	5.3	180	0	96	270	--	1.3	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	38	17	--	130	--	5.7	170	0	16	220	--	1.2	10	--	--
--	32	14	--	98	--	4.3	210	0	12	110	--	3.1	8.0	--	--
--	39	18	--	220	--	2.6	170	0	18	350	--	1.8	9.1	0.200	--
--	43	20	--	220	--	6.2	180	0	18	360	--	1.5	9.0	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	44	20	--	250	--	6.2	190	0	18	390	--	1.3	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	43	20	--	--	220	--	170	--	16	360	--	--	--	0.630	--
--	45	16	--	--	86	--	180	10	16	130	--	--	--	0.050	--
--	34	16	--	--	66	--	160	--	17	100	--	--	--	0.050	--
--	32	15	--	--	71	4.1	170	0	15	100	--	0.70	9.4	0.050	--
331	--	--	66	--	--	--	--	--	13	110	0.7	--	--	--	<0.100
309	--	--	60	--	--	--	--	--	10	100	0.8	--	--	--	<0.500
--	56	12	--	41	--	1.7	270	0	30	15	--	2.4	8.0	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	32	15	--	65	--	3.6	170	0	15	24	--	0.60	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	31	14	--	57	--	2.8	160	0	16	74	--	0.50	10	--	--
--	83	3.2	--	22	--	1.2	220	0	12	40	--	0.10	12	--	--
--	--	--	--	80	--	--	--	--	11	120	0.8	--	--	--	0.100
--	36	15	--	94	--	3.6	160	0	15	150	--	0.80	10	--	--
--	14	5.6	--	320	--	3.7	720	0	46	89	--	13	9.0	--	--
--	35	11	--	21	--	1.9	180	0	10	13	--	0.90	10	--	--

APPENDIX 3 *(Continued)*: Concentrations of Common Constituents and Physical

Local identifier	Date	Time	Site identification number	Agency analyzing sample	Sampling depth (ft)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (° C)	Hardness, total (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Alkalinity, whole water, field, IT (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, residue at 180°C, dissolved
27N-23E-04 DCC 1	05-01-48	--	365042094504701	1028	--	541	--	--	140	--	121	--	287
27N-23E-17 CBB 1	11-05-80	900	364921094522201	1028	--	445	8.0	18.5	--	--	--	--	--
27N-23E-17 CBB 1	02-05-81	830	364921094522201	80020	--	504	8.2	16.0	130	2.0	--	124	180
27N-23E-17 CBB 1	05-12-81	945	364921094522201	1028	--	441	8.2	17.5	--	--	--	--	--
27N-23E-17 CBB 1	06-09-81	1545	364921094522201	80020	--	431	7.9	24.0	130	1.0	134	125	250
27N-23E-17 CBB 1	09-10-81	1030	364921094522201	1028	--	439	7.9	19.0	--	--	--	--	--
27N-23E-17 CBB 1	01-26-82	1030	364921094522201	1028	--	451	8.1	19.0	--	--	--	--	--
27N-23E-17 CBB 1	04-20-82	1000	364921094522201	1028	--	476	7.9	19.0	--	--	--	--	--
27N-23E-17 CBB 1	07-21-82	900	364921094522201	1028	--	458	8.2	20.5	--	--	--	--	--
27N-23E-17 CBB 1	10-20-82	1000	364921094522201	1028	--	471	7.8	19.0	--	--	--	--	--
27N-23E-28 CDC 1	07-08-81	1130	364712094510101	80020	--	897	7.8	20.0	96	18	484	435	536
27N-24E-21 CD 1	07-24-46	--	364806094433701	1028	--	276	--	--	140	--	127	--	162
27N-24E-28 CAD 1	05-03-78	--	364717094433101	84042	--	--	8.4	--	130	--	137	--	--
27N-24E-28 CAD 1	03-10-80	1435	364717094433101	84042	--	--	7.9	--	140	--	139	--	--
27N-24E-28 CAD 1	11-04-80	1430	364717094433101	1028	--	297	8.0	19.5	--	--	--	--	--
27N-24E-28 CAD 1	02-05-81	1230	364717094433101	1028	--	326	8.2	13.0	150	2.0	--	124	126
27N-24E-28 CAD 1	05-13-81	1445	364717094433101	1028	--	301	8.0	19.5	--	--	--	--	--
27N-24E-28 CAD 1	07-08-81	1500	364717094433101	80020	--	316	8.0	23.5	140	2.6	133	125	146
27N-24E-28 CAD 1	09-14-81	1430	364717094433101	1028	--	306	8.0	20.5	--	--	--	--	--
27N-24E-28 CAD 1	01-27-82	1505	364717094433101	1028	--	317	8.0	19.0	--	--	--	--	--
27N-24E-28 CAD 1	04-21-82	1500	364717094433101	1028	--	323	8.0	19.0	--	--	--	--	--
27N-24E-28 CAD 1	07-20-82	1500	364717094433101	1028	--	332	8.0	23.0	--	--	--	--	--
27N-24E-28 CAD 1	10-20-82	1500	364717094433101	1028	--	319	7.9	19.5	--	--	--	--	--
27N-25E-09 CAC 1	07-14-81	1030	364957094371501	80020	--	261	8.1	21.0	130	2.0	128	125	140
28N-22E-11 ABB 1	07-25-46	--	365543094535801	1028	--	298	--	17.0	120	--	135	--	183
28N-22E-11 ABB 1	07-10-81	830	365543094535801	80020	--	454	8.0	26.0	110	3.8	167	153	226
28N-22E-23 BAA 1	07-28-82	--	365357094541901	1028	--	750	8.0	16.5	--	--	--	--	--
28N-22E-24 AAB 1	08-03-44	--	365358094525001	1028	--	--	8.4	20.0	150	--	124	--	201
28N-22E-24 BDA 1	07-16-81	1330	365342094531301	80020	--	412	7.9	27.5	140	2.0	123	117	232
28N-22E-24 CAD 1	07-16-81	1430	365324094531301	80020	--	376	7.9	22.5	130	1.0	131	126	208
28N-22E-24 CBC 1	07-16-81	1315	365323094534001	80020	--	428	7.8	24.0	140	1.0	126	121	--
28N-22E-35 DCC 1	07-26-46	--	365133094545901	1028	--	303	--	17.0	130	--	129	--	189
28N-23E-06 BAB 1	07-07-81	900	365627094522201	80020	--	499	7.7	23.0	170	5.2	134	125	270
28N-23E-06 BAB 1	10-21-82	1800	365627094522201	84041	900	307	7.9	18.5	--	--	--	--	178
28N-23E-06 BAB 1	10-21-82	1830	365627094522201	84041	1,050	890	7.8	18.0	--	--	--	--	530
28N-23E-06 BAB 2	10-20-82	1830	365627094522101	84041	750	290	7.9	16.0	--	--	--	--	162
28N-23E-06 BAB 2	10-20-82	1900	365627094522101	84041	1,100	452	7.9	16.0	--	--	--	--	255
28N-23E-06 BAB 2	03-22-83	920	365627094522101	84041	--	335	7.6	20.0	150	--	120	--	200
28N-23E-06 CBD 2	07-07-81	830	365557094522701	80020	--	285	8.0	21.0	120	2.1	138	124	150
28N-23E-06 CCA 1	09-03-42	--	365600094523001	1028	--	--	--	--	140	--	120	--	--
28N-23E-06 CCA 1	09-06-51	--	365600094523001	1028	--	277	7.9	--	120	--	120	--	149
28N-23E-06 CCA 1	03-22-83	900	365600094523001	84041	--	313	7.6	20.0	110	--	129	--	166
28N-23E-18 CDC 1	07-16-81	1340	365402094522201	80020	--	519	7.9	27.0	140	2.0	130	116	290
28N-23E-20 BCB 1	07-15-81	1030	365344094513301	80020	--	290	8.0	27.5	120	1.0	121	116	142
28N-23E-24 DDA 1	05-02-78	--	365316094461601	84042	--	--	8.3	--	130	--	128	--	--
28N-23E-24 DDA 1	03-12-80	1130	365316094461601	84042	--	--	8.0	--	130	--	122	--	--
28N-23E-24 DDA 1	10-30-80	1145	365316094461601	1028	--	285	8.0	17.5	--	--	--	--	--
28N-23E-24 DDA 1	07-15-81	1400	365316094461601	80020	--	342	7.9	26.0	140	1.0	133	125	174
28N-23E-28 BBB 1	07-14-81	1700	365301094502901	80020	--	747	8.1	23.5	160	<1.0	126	119	380
28N-23E-30 CAC 1	03-30-59	--	365229094522101	1028	--	747	7.8	--	170	--	123	--	441
28N-23E-30 CAC 1	07-15-81	900	365229094522101	80020	--	536	7.8	22.0	140	2.0	125	119	290
28N-23E-30 DBC 1	10-08-82	1330	365229094520201	84041	--	1,400	7.5	14.5	--	--	--	--	686
28N-23E-30 DBC 1	12-08-82	1300	365229094520201	84041	800	485	7.4	14.5	--	--	--	--	228
28N-23E-30 DBC 1	12-08-82	1400	365229094520201	84041	1,480	16,800	7.3	15.0	--	--	--	--	9,410
28N-23E-31 BAB 1	05-20-52	--	365210094522101	1028	--	592	7.9	21.0	140	--	121	--	320
28N-23E-31 BAB 1	03-30-59	1200	365210094522101	1028	--	308	7.7	--	120	--	130	--	191
28N-23E-31 BAB 1	03-30-59	1201	365210094522101	1028	--	316	7.7	--	130	--	131	--	200
28N-23E-31 BAC 1	03-30-59	--	365206094522201	1028	--	300	7.8	--	130	--	125	--	187
28N-23E-31 BAC 1	07-15-81	1100	365206094522201	80020	--	705	7.9	22.5	140	1.0	130	122	360
28N-23E-31 CBA 1	09-03-42	--	365146094522201	1028	--	--	--	--	160	--	125	--	--
28N-23E-31 CBA 1	07-15-81	930	365146094522201	80020	--	331	7.9	22.0	140	1.0	125	120	166
28N-23E-32 BAB 1	03-30-59	--	365212094511901	1028	--	416	7.7	--	140	--	118	--	242
28N-23E-32 BAB 1	12-29-80	1000	365212094511901	1028	--	475	8.0	18.5	--	--	--	--	--
28N-23E-32 BAB 1	02-05-81	1445	365212094511901	1028	--	604	8.0	16.5	150	2.0	--	117	278
28N-23E-32 BAB 1	07-15-81	1130	365212094511901	80020	--	572	7.9	22.0	79	1.0	128	120	294
28N-23E-33 BAB 1	03-30-59	--	365213094500701	1028	--	625	7.8	--	140	--	120	--	351
28N-23E-33 BAB 1	07-14-81	1615	365213094500701	80020	--	573	8.0	23.5	150	<1.0	123	117	300
28N-23E-36 CCC 1	07-15-81	1300	365128094471301	80020	--	336	7.9	25.5	140	2.0	130	124	166
28N-24E-13 ABD 1	10-16-68	--	365445094400701	1028	--	--	7.9	--	160	--	120	--	--
28N-24E-13 ABD 1	03-12-80	1150	365445094400701	84042	--	--	8.0	--	140	--	146	--	--
28N-24E-13 ABD 1	07-14-81	1230	365445094400701	80020	--	287	8.0	22.0	140	2.0	148	136	148
28N-25E-20 CAA 1	05-24-79	--	365335094380701	84042	--	--	7.9	--	150	--	137	--	--
28N-25E-20 CAA 1	03-12-80	1245	365335094380701	84042	--	--	7.9	--	150	--	139	--	--
28N-25E-20 CAA 1	02-18-81	1600	365335094380701	1028	--	294	8.0	20.5	--	--	--	--	--

Properties of Water from Wells Completed in the Roubidoux Aquifer

Solids, residue at 105°C, dissolved	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, total recoverable (mg/L as Na)	Sodium, dissolved (mg/L as Na)	Sodium + potassium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, whole water, total, IT (mg/L as $CaCO_3$)	Carbonate, whole water, total, IT (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate + nitrite, dissolved (mg/L as N)
--	30	16	--	--	61	--	150	0	15	94	--	0.20	--	1.00	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	30	13	--	46	--	2.8	--	--	8.2	58	--	0.80	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	30	14	--	44	--	2.7	160	0	14	55	--	0.70	9.0	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	22	10	--	190	--	2.6	590	0	21	21	--	5.9	9.0	--	--
--	32	14	--	--	10	--	140	8	17	10	--	--	--	0.050	--
171	--	--	13	--	--	--	--	--	11	12	0.5	--	--	--	<0.100
166	--	--	13	--	--	--	--	--	15	17	0.3	--	--	--	<0.500
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	35	14	--	12	--	1.9	--	--	13	11	--	0.40	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	32	14	--	13	--	1.9	160	0	17	10	--	0.40	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	29	14	--	6.1	--	2.0	160	0	10	2.3	--	0.20	8.0	--	--
--	28	13	--	--	20	--	150	7	17	11	--	--	--	0.050	--
--	25	11	--	58	--	3.1	200	0	22	39	--	2.1	9.0	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	32	16	--	16	--	3.0	150	--	15	32	--	0.20	11	0.050	--
--	32	14	--	31	--	2.1	150	0	13	48	--	0.40	11	--	--
--	30	13	--	25	--	2.8	160	0	14	30	--	0.80	12	--	--
--	32	14	--	38	--	2.5	150	0	16	52	--	--	10	--	--
--	30	14	--	--	17	--	140	10	16	17	--	--	--	0.050	--
--	41	17	--	36	--	2.8	160	0	38	55	--	0.40	10	--	--
--	--	--	--	--	--	--	--	--	22	5.5	--	0.80	--	--	--
--	--	--	--	--	--	--	--	--	63	160	--	0.50	--	--	--
--	--	--	--	--	--	--	--	--	18	4.6	--	0.70	--	--	--
--	--	--	--	--	--	--	--	--	16	66	--	0.30	--	--	--
--	34	15	--	20	--	2.5	--	--	26	28	--	0.40	9.8	--	--
--	29	12	--	15	--	3.3	170	0	17	3.8	--	1.0	10	--	--
--	32	15	--	--	1.8	--	150	--	12	7.0	--	0.50	--	0.500	--
--	28	13	--	--	9.6	2.2	150	0	16	8.0	--	0.50	9.8	0.050	--
--	26	12	--	17	--	3.0	--	--	20	5.5	--	1.1	9.0	--	--
--	33	15	--	51	--	2.1	160	0	16	81	--	0.40	12	--	--
--	28	13	--	11	--	1.7	150	0	14	8.6	--	0.50	10	--	--
163	--	--	<5.0	--	--	--	--	--	11	6.0	0.2	--	--	--	<0.100
153	--	--	<10	--	--	--	--	--	15	15	0.2	--	--	--	<0.500
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	32	15	--	14	--	2.0	160	0	14	22	--	0.30	10	--	--
--	36	16	--	87	--	2.8	150	0	14	150	--	0.50	10	--	--
--	42	16	--	82	--	3.3	150	0	14	150	--	0.50	10	0.020	--
--	33	15	--	54	--	2.6	150	0	15	83	--	0.50	10	--	--
--	--	--	--	--	--	--	--	--	16	330	--	0.70	--	--	--
--	--	--	--	--	--	--	--	--	14	65	--	0.90	--	--	--
--	--	--	--	3,200	--	--	--	--	13	5,600	--	2.1	--	--	--
--	32	15	--	63	--	3.0	150	0	18	100	--	0.70	10	0.00	--
--	29	11	--	--	22	2.9	160	0	14	12	--	1.2	8.4	0.020	--
--	31	12	--	--	19	2.9	160	0	30	14	--	1.2	9.4	0.020	--
--	32	12	--	15	--	2.8	150	0	13	12	--	0.90	8.0	0.050	--
--	33	15	--	86	--	3.4	160	0	16	130	--	0.70	10	--	--
--	37	16	--	--	42	--	150	--	12	78	--	0.50	--	0.590	--
--	31	14	--	16	--	2.1	150	0	14	21	--	0.50	9.0	--	--
--	33	13	--	34	--	2.7	140	0	14	50	--	0.50	9.6	0.00	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	35	15	--	56	--	2.9	--	--	9.9	91	--	0.50	--	--	--
--	18	8.2	--	58	--	2.7	160	0	16	92	--	0.50	10	--	--
--	38	12	--	--	68	3.2	150	0	13	110	--	0.60	10	0.00	--
--	34	15	--	61	--	2.6	150	0	13	99	--	0.50	10	--	--
--	33	15	--	14	--	1.9	160	0	14	21	--	0.30	10	--	--
170	38	14	--	11	--	1.4	140	5	8.0	12	--	0.38	--	0.00	--
153	--	--	<10	--	--	--	--	--	11	5.0	0.2	--	--	--	<0.500
--	31	16	--	5.1	--	1.1	180	0	12	3.6	--	0.10	9.0	--	--
184	--	--	--	--	--	--	--	--	23	7.0	0.2	--	--	--	0.100
153	--	--	10	--	--	--	--	--	15	10	0.2	--	--	--	<0.500
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

APPENDIX 3 *(Continued)*: Concentrations of Common Constituents and Physical

Local identifier	Date	Time	Site identification number	Agency analyzing sample	Sampling depth (ft)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (° C)	Hardness, total (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Alkalinity, whole water, field, IT (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, residue at 180°C, dissolved
28N-25E-20 CAA 1	03-17-81	1600	365335094380701	1028	--	357	8.0	19.5	--	--	--	--	--
28N-25E-20 CAA 1	05-08-81	1500	365335094380701	1028	--	286	7.8	18.5	--	--	--	--	--
28N-25E-20 CAA 1	06-09-81	1330	365335094380701	80020	--	283	8.1	24.0	140	1.5	144	135	158
28N-25E-20 CAA 1	09-09-81	1630	365335094380701	1028	--	296	7.9	21.0	--	--	--	--	--
28N-25E-20 CAA 1	01-25-82	1430	365335094380701	1028	--	305	8.0	17.5	--	--	--	--	--
28N-25E-20 CAA 1	04-21-82	910	365335094380701	1028	--	313	7.8	18.0	--	--	--	--	--
28N-25E-20 CAA 1	07-20-82	1600	365335094380701	1028	--	297	8.0	23.0	--	--	--	--	--
29N-22E-21 DAD 1	10-29-80	1100	365833094551901	1028	--	775	8.6	16.5	--	--	--	--	--
29N-22E-21 DAD 1	02-04-81	1615	365833094551901	1028	--	866	8.3	16.0	140	2.0	--	146	378
29N-22E-21 DAD 1	03-06-81	900	365833094551901	1028	--	869	8.3	17.5	--	--	--	--	--
29N-22E-21 DAD 1	05-12-81	900	365833094551901	1028	--	877	8.3	18.0	--	--	--	--	--
29N-22E-21 DAD 1	06-09-81	1700	365833094551901	80020	--	841	8.2	23.5	150	<1.0	151	184	448
29N-22E-21 DAD 1	09-10-81	1130	365833094551901	1028	--	957	7.7	21.5	--	--	--	--	--
29N-22E-21 DAD 1	01-26-82	900	365833094551901	1028	--	948	8.3	17.0	--	--	--	--	--
29N-22E-21 DAD 1	04-20-82	900	365833094551901	1028	--	955	7.9	19.0	--	--	--	--	--
29N-22E-21 DAD 1	07-20-82	830	365833094551901	1028	--	1,010	8.0	22.0	--	--	--	--	--
29N-22E-21 DAD 1	10-20-82	900	365833094551901	1028	--	983	8.0	20.0	--	--	--	--	--
29N-22E-25 AAA 1	04-15-47	--	365820094520401	1028	--	918	--	21.0	180	--	132	--	--
29N-23E-16 DDD 1	12-26-82	1500	365917094484701	84041	300	4,100	5.9	--	--	--	--	--	--
29N-23E-19 DCD 1	05-02-78	--	365823094510701	84042	--	--	8.3	--	130	--	134	--	--
29N-23E-19 DCD 1	03-11-80	--	365823094510701	84042	--	--	7.9	--	130	--	127	--	--
29N-23E-19 DCD 1	07-14-81	830	365823094510701	80020	--	292	7.9	23.0	140	2.0	126	121	156
29N-23E-21 BBC 1	09-03-42	--	365905094494601	1028	--	--	--	20.0	150	--	121	--	--
29N-23E-21 BBC 1	09-06-51	--	365905094494601	1028	--	300	8.1	--	130	--	--	119	157
29N-23E-21 BBC 1	07-07-81	1415	365905094494601	80020	--	410	7.8	22.5	190	3.1	130	122	222
29N-23E-21 BBC 1	07-23-81	1100	365905094494601	1028	--	425	7.9	19.0	180	--	120	130	235
29N-23E-21 BBC 1	09-02-82	830	365905094494601	84041	--	429	7.3	22.0	170	1.0	121	--	238
29N-23E-21 BBC 2	04-28-48	--	365905094494602	1028	--	303	--	--	140	--	121	--	178
29N-23E-21 BBC 2	07-07-81	1420	365905094494602	80020	--	399	7.8	24.0	180	6.1	126	121	226
29N-23E-21 BBC 2	09-02-82	831	365905094494602	84041	--	425	7.3	22.0	160	1.0	121	--	222
29N-23E-21 BBC 3	07-07-81	1430	365905094494603	80020	--	488	7.8	24.0	220	2.8	133	125	280
29N-23E-21 BBC 3	09-02-82	832	365905094494603	84041	--	549	7.3	22.0	210	1.0	128	--	308
29N-23E-25 BDC 1	10-19-77	800	365800094461701	84042	--	--	7.6	--	170	--	123	--	--
29N-23E-25 BDC 1	10-19-77	1200	365800094461701	84042	--	--	7.8	--	160	--	126	--	--
29N-23E-25 BDC 1	10-19-77	1600	365800094461701	84042	--	--	8.4	--	160	--	124	--	--
29N-23E-25 BDC 1	10-01-79	--	365800094461701	84042	--	--	--	--	150	--	--	--	--
29N-23E-25 BDC 1	03-11-80	1515	365800094461701	84042	--	--	7.3	--	290	--	149	--	--
29N-23E-25 BDC 1	04-09-81	800	365800094461701	84042	--	913	--	--	--	--	161	--	--
29N-23E-25 BDC 1	07-07-81	1100	365800094461701	80020	--	1,430	7.0	21.0	740	59	197	165	1,170
29N-23E-25 BDC 1	07-07-81	1230	365800094461701	80020	--	1,430	7.0	21.0	730	49	216	171	1,110
29N-23E-26 CDD 1	05-02-78	--	365734094471001	84042	--	--	8.4	--	150	--	128	--	--
29N-23E-26 CDD 1	03-11-80	1435	365734094471001	84042	--	--	7.9	--	190	--	137	--	--
29N-23E-26 CDD 1	07-07-81	1045	365734094471001	80020	--	515	7.8	24.0	250	5.4	144	135	326
29N-23E-31 BDD 1	09-12-42	--	365704094513101	1028	--	--	--	21.0	130	--	118	--	--
29N-23E-31 BDD 1	07-10-81	930	365704094513101	80020	--	366	7.9	22.0	140	1.9	136	126	214
29N-23E-32 AAB 1	04-20-82	1730	365722094500401	84041	210	447	7.6	17.0	220	--	--	--	--
29N-23E-32 AAB 1	04-20-82	1750	365722094500401	84041	300	3,640	5.2	16.0	1,600	--	--	--	--
29N-23E-35 BDD 1	03-11-42	--	365734094471101	1028	--	--	--	18.0	420	--	180	--	--
29N-23E-35 BDD 1	09-06-51	--	365734094471101	1028	--	262	8.0	--	130	--	119	--	142

Properties of Water from Wells Completed in the Roubidoux Aquifer

Solids, residue at 105°C, dissolved	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, total recoverable (mg/L as Na)	Sodium, dissolved (mg/L as Na)	Sodium + potassium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, whole water, total, IT (mg/L as $CaCO_3$)	Carbonate, whole water, total, IT (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, total (mg/L as F)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate + nitrite, dissolved (mg/L as N)
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	32	15	--	4.4	--	1.8	180	0	9.3	3.0	--	0.20	10	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	32	15	--	110	--	4.3	--	--	8.2	160	--	1.5	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	32	16	--	120	--	4.5	180	0	8.2	190	--	0.70	9.0	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	40	20	--	--	120	--	160	0	19	--	--	0.50	--	0.00	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
166	--	--	6.0	--	--	--	--	--	11	7.0	0.5	--	--	--	<0.100
163	--	--	<10	--	--	--	--	--	18	2.0	0.4	--	--	--	<0.500
--	32	15	--	8.6	--	1.8	150	0	16	8.4	--	0.40	10	--	--
--	34	16	--	--	3.7	--	150	--	11	16	--	0.40	--	0.380	--
--	29	14	--	12	--	1.9	150	0	16	16	--	0.30	9.8	0.050	--
--	44	19	--	12	--	2.0	160	0	68	9.9	--	0.40	10	--	--
--	42	18	--	12	--	2.0	--	--	74	9.7	--	0.30	8.0	--	--
--	40	17	--	12	--	2.7	--	--	58	10	--	0.40	8.8	--	--
--	30	16	--	--	14	--	150	0	18	23	--	0.10	--	0.00	--
--	41	18	--	13	--	2.1	150	0	63	11	--	0.40	10	--	--
--	36	16	--	12	--	2.4	--	--	47	11	--	0.40	8.8	--	--
--	50	22	--	20	--	3.1	160	0	86	24	--	0.30	10	--	--
--	49	21	--	18	--	2.8	--	--	92	19	--	0.30	9.2	--	--
210	--	--	--	--	--	--	--	--	38	11	0.4	--	--	--	<0.100
210	--	--	--	--	--	--	--	--	34	12	0.3	--	--	--	<0.100
210	--	--	--	--	--	--	--	--	33	11	0.3	--	--	--	<0.100
--	--	--	--	--	--	--	--	--	--	15	--	--	--	--	<0.500
441	--	--	26	--	--	--	--	--	160	40	0.2	--	--	--	<0.500
718	--	--	--	--	--	--	--	--	2,600	--	--	--	--	--	--
--	170	76	--	50	--	3.7	240	0	560	78	--	0.20	12	--	--
--	170	75	--	50	--	3.4	260	0	530	87	--	0.20	14	--	--
191	--	--	5.0	--	--	--	--	--	20	7.0	0.2	--	--	--	<0.100
260	--	--	12	--	--	--	--	--	83	25	0.3	--	--	--	<0.500
--	56	26	--	15	--	2.7	180	0	95	7.0	--	0.20	11	--	--
--	29	14	--	--	12	--	140	--	13	16	--	0.40	--	0.360	--
--	33	14	--	19	--	3.9	170	0	46	22	--	1.0	10	--	--
--	80	4.9	--	1.4	--	1.6	--	--	86	<1.0	--	--	7.4	--	--
--	440	110	--	51	--	3.8	--	--	2,000	7.6	--	--	36	--	--
--	110	38	--	--	--	--	220	--	120	80	--	0.30	--	0.500	--
--	29	14	--	4.4	--	1.5	150	0	18	4.0	--	0.30	9.7	0.00	--

APPENDIX 4: Concentrations of Trace Elements in Water

[Agency analyzing sample: 1028, U.S. Geological Survey (specific laboratory not identified); 80020, National Water Quality Laboratory of the U.S. Geological

Local identifier	Date	Time	Site identification number	Agency analyzing sample	Sampling depth (ft)	Aluminum, dissolved (µg/L as Al)	Arsenic, total (µg/L as As)	Arsenic, dissolved (µg/L as As)	Barium, total recoverable (µg/L as Ba)	Cadmium, total recoverable (µg/L as Cd)	Cadmium, dissolved (µg/L as Cd)	Chromium, total recoverable (µg/L as Cr)
Adair County												
18N-26E-18 BDC 1	10-28-81	1300	360225094344001	80020	--	<60	--	<10	--	--	<1.0	--
Cherokee County												
16N-22E-03 CCB 1	12-28-82	1330	355319094574001	84041	--	<100	--	--	--	--	8.0	--
Craig County												
24N-21E-11 BDB 1	03-23-83	1330	363439095020901	84041	120	<100	--	--	--	--	<4.0	--
24N-21E-11 BDB 1	03-23-83	1345	363439095020901	84041	700	<100	--	--	--	--	<4.0	--
24N-21E-11 BDB 1	03-23-83	1450	363439095020901	84041	1,700	440	--	--	--	--	13	--
25N-20E-12 BDD 1	03-10-50	--	363950095070201	1028	--	--	--	--	--	--	--	--
25N-20E-12 BDD 1	09-05-51	--	363950095070201	1028	--	--	--	--	--	--	--	--
25N-20E-12 C 4	05-29-50	--	363930095071504	1028	--	--	--	--	--	--	--	--
27N-20E-12 BDD 2	02-04-81	1300	365016095070501	1028	--	--	--	<10	--	--	<2.5	--
27N-20E-12 BDD 2	06-08-81	1400	365016095070501	80020	--	<60	--	<10	--	--	<1.0	--
27N-21E-12 CCB 1	07-09-81	1030	365000095010101	80020	--	<60	--	<10	--	--	<1.0	--
27N-21E-20 DCD 1	02-04-81	1430	364808095043501	1028	--	--	--	<10	--	--	<2.5	--
27N-21E-20 DCD 1	06-09-81	1100	364808095043501	80020	--	<60	--	<10	--	--	<1.0	--
28N-20E-13 ACC 1	03-23-83	1700	365440095065701	84041	170	<100	--	--	--	--	8.0	--
28N-20E-13 ACC 1	03-23-83	1730	365440095065701	84041	1,460	<100	--	--	--	--	8.0	--
28N-21E-29 CBC 1	02-04-81	1100	365242095051701	1028	--	--	--	<10	--	--	<2.5	--
28N-21E-29 CBC 1	06-09-81	900	365242095051701	80020	--	<60	--	<10	--	--	<1.0	--
28N-21E-29 CBD 1	06-09-81	930	365240095051501	80020	--	<60	--	<10	--	--	<1.0	--
Delaware County												
20N-23E-34 CCA 1	06-10-81	930	360946094504901	80020	--	<60	--	<10	--	--	<1.0	--
20N-24E-17 CCC 1	06-10-81	800	361221094463901	80020	--	<60	--	<10	--	--	<1.0	--
21N-25E-31 BBB 1	06-10-81	1045	361544094410101	80020	--	<60	--	<10	--	--	<1.0	--
22N-23E-05 DCA 1	06-10-81	1200	362442094520801	80020	--	<60	--	<10	--	--	<1.0	--
22N-23E-11 BBB 1	03-21-83	1445	362427094493001	84041	--	<100	--	<10	--	--	<1.0	--
23N-22E-14 ADC 1	06-10-81	1245	362829094550901	80020	--	<60	--	<10	--	--	<1.0	--
23N-25E-33 DDC 1	07-09-81	1445	362532094375501	80020	--	<60	--	<10	--	--	<1.0	--
24N-23E-15 BBC 1	06-11-81	930	363357094503701	80020	--	<60	--	<10	--	--	<1.0	--
24N-24E-06 DCA 1	06-11-81	1230	363510094464501	80020	--	<60	--	<10	--	--	<1.0	--
25N-22E-23 CCD 1	06-10-81	1500	363740094553101	80020	--	<60	--	<10	--	--	<1.0	--
25N-22E-23 CCD 1	08-17-82	1115	363740094553101	1028	--	--	--	--	--	--	--	--
25N-23E-13 BAB 1	06-11-81	1330	363921094474301	80020	--	<60	--	<10	--	--	<1.0	--
25N-24E-28 BBB 1	07-09-81	1200	363718094444501	80020	--	<60	--	<10	--	--	<1.0	--
Ottawa County												
25N-23E-01 AAA 1	07-15-81	1700	364103094470401	80020	--	<60	--	<10	--	--	<1.0	--
26N-22E-15 DDA 1	06-12-81	1000	364349094554501	80020	--	<60	--	<10	--	--	<1.0	--
26N-22E-20 BCC 1	06-12-81	900	364323094585101	80020	--	<60	--	<10	--	--	<1.0	--
26N-22E-27 ADD 1	07-08-81	830	364227094554301	80020	--	<60	--	<10	--	--	<1.0	--
26N-22E-27 CBC 1	06-11-81	1600	364211094564101	80020	--	<60	--	<10	--	--	<1.0	--
26N-22E-32 ADC 1	09-06-51	--	364136094575801	1028	--	--	--	--	--	--	--	--
26N-22E-32 ADC 1	06-11-81	1500	364136094575801	80020	--	<60	--	<10	--	--	<1.0	--
26N-22E-32 ADC 2	06-11-81	1300	364137094575902	80020	--	<60	--	<10	--	--	<1.0	--
26N-23E-09 CA 1	05-03-78	--	364501094505301	84042	--	--	<1	--	<100	<1	--	68
26N-23E-09 CA 1	03-19-80	--	364501094505301	84042	--	--	<10	--	<100	<2	--	<10
26N-23E-09 CA 1	07-08-81	945	364501094505301	80020	--	<60	--	<10	--	--	<1.0	--
26N-23E-09 DBC 1	07-08-81	930	364454094504401	80020	--	<60	--	<10	--	--	<1.0	--
26N-23E-12 BAD 1	07-08-81	1040	364516094473501	80020	--	<60	--	<10	--	--	<1.0	--
26N-24E-32 ABA 1	07-30-81	1400	364155094451001	80020	--	<60	--	<10	--	--	<1.0	--
27N-22E-01 CCC 1	05-01-78	--	365103094541501	84042	--	--	<1	--	100	<1	--	50
27N-22E-01 CCC 1	07-16-81	800	365103094541501	80020	--	<60	--	<10	--	--	<1.0	--
27N-22E-27 AAB 1	07-09-81	900	364801094554601	80020	--	<60	--	<10	--	--	<1.0	--
27N-23E-03 BCC 1	07-08-81	1630	365100094491701	80020	--	<60	--	<10	--	--	<1.0	--
27N-23E-17 CBB 1	02-05-81	830	364921094522201	80020	--	--	--	<10	--	--	<2.5	--
27N-23E-17 CBB 1	06-09-81	1545	364921094522201	80020	--	<60	--	<10	--	--	<1.0	--
27N-23E-28 CDC 1	07-08-81	1130	364712094510101	80020	--	<60	--	<10	--	--	<1.0	--
27N-24E-28 CAD 1	05-03-78	--	364717094433101	84042	--	--	<1	--	<100	<1	--	10
27N-24E-28 CAD 1	03-10-80	1435	364717094433101	84042	--	--	<10	--	<100	<2	--	11
27N-24E-28 CAD 1	02-05-81	1230	364717094433101	1028	--	--	--	<10	--	--	<2.5	--
27N-24E-28 CAD 1	07-08-81	1500	364717094433101	80020	--	<60	--	<10	--	--	<1.0	--
27N-25E-09 CAC 1	07-14-81	1030	364957094371501	80020	--	<60	--	<10	--	--	<1.0	--
28N-22E-11 ABB 1	07-10-81	830	365543094535801	80020	--	<60	--	<10	--	--	<1.0	--
28N-22E-24 AAB 1	08-03-44	--	365358094525001	1028	--	--	--	--	--	--	--	--
28N-22E-24 BDA 1	07-16-81	1330	365342094531301	80020	--	<60	--	<10	--	--	<1.0	--
28N-22E-24 CAD 1	07-16-81	1430	365324094531301	80020	--	<60	--	<10	--	--	<1.0	--
28N-22E-24 CBC 1	07-16-81	1315	365323094534001	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-06 BAB 1	07-07-81	900	365627094522201	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-06 BAB 1	10-21-82	1800	365627094522201	84041	900	390	--	--	--	--	<4.0	--
28N-23E-06 BAB 1	10-21-82	1830	365627094522201	84041	1,050	120	--	--	--	--	<4.0	--
28N-23E-06 BAB 2	10-20-82	1830	365627094522101	84041	750	<100	--	--	--	--	<4.0	--
28N-23E-06 BAB 2	10-20-82	1900	365627094522101	84041	1,100	<100	--	--	--	--	<4.0	--
28N-23E-06 BAB 2	03-22-83	920	365627094522101	84041	--	<100	--	<10	--	--	<1.0	--
28N-23E-06 CBD 2	07-07-81	830	365557094522701	80020	--	<60	--	<10	--	--	<1.0	--

from Wells Completed in the Roubidoux Aquifer

Survey; 84041, Oklahoma Geological Survey; 84042, Oklahoma State Department of Health. IT, incremental titration; --, indicates no data are available.]

Chromium, dissolved (µg/L as Cr)	Copper, total recoverable (µg/L as Cu)	Copper, dissolved (µg/L as Cu)	Iron, total, recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, total recoverable (µg/L as Pb)	Lead, dissolved (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Mercury, total recoverable (µg/L as Hg)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Selenium, total recoverable (µg/L as Se)	Silver, total recoverable (µg/L as Ag)	Zinc, total recoverable (µg/L as Zn)	Zinc, dissolved (µg/L as Zn)
Adair County															
<1	--	<60	--	<20	--	<5	--	<10	--	<0.5	--	--	--	--	1,300
Cherokee County															
<10	--	<12	--	130	--	<5	--	40	--	--	--	--	--	--	550
Craig County															
<10	--	<12	--	<10	--	<5	--	50	--	--	--	--	--	--	37
<10	--	<12	--	20	--	<5	--	30	--	--	--	--	--	--	<10
<10	--	17	--	9,800	--	--	--	2,100	--	--	--	--	--	--	110
--	--	--	100	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	20	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
--	--	<100	--	200	--	<5	--	10	--	<0.5	<1	--	--	--	24
2	--	<60	--	180	--	<5	--	<10	--	<0.5	--	--	--	--	26
<1	--	<60	--	200	--	<5	--	<10	--	<0.5	--	--	--	--	22
--	--	<100	--	80	--	<5	--	20	--	<0.5	<1	--	--	--	<20
<1	--	<60	--	100	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<10	--	<12	--	<10	--	<5	--	90	--	--	--	--	--	--	10
<10	--	<12	--	<10	--	--	--	2,000	--	--	--	--	--	--	12
--	--	<100	--	200	--	6	--	30	--	<0.5	<1	--	--	--	28
1	--	<60	--	120	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	60	--	<5	--	<10	--	<0.5	--	--	--	--	<20
Delaware County															
<1	--	<60	--	290	--	<5	--	30	--	<0.5	--	--	--	--	32
<1	--	<60	--	80	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	80	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<10	--	<12	--	50	--	<5	--	10	--	<0.5	--	--	--	--	43
<1	--	<60	--	100	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	40	--	<10	--	<10	--	<0.5	--	--	--	--	720
<1	--	<60	--	70	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	280	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	<20
--	--	--	--	8	--	--	--	<2	--	--	--	--	--	--	--
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	61
<1	--	<60	--	170	--	<5	--	<10	--	<0.5	--	--	--	--	<20
Ottawa County															
<1	--	<60	--	60	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	80	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	30	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	20	--	<5	--	<10	--	<0.5	--	--	--	--	34
<1	--	<60	--	50	--	<5	--	<10	--	<0.5	--	--	--	--	<20
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
<1	--	<60	--	60	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	80	--	<5	--	<10	--	<0.5	--	--	--	--	<20
--	2	--	920	--	5	--	10	--	<0.50	--	--	<1	<2	30	--
--	<4	--	460	--	25	--	<20	--	<0.50	--	--	<5	3	<2	--
<1	--	<60	--	810	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	110	--	<5	--	<10	--	<0.5	--	--	--	--	26
<1	--	<60	--	60	--	<5	--	<10	--	<0.5	--	--	--	--	34
<1	--	<60	--	30	--	<5	--	<10	--	<0.5	--	--	--	--	1,400
--	11	--	2,000	--	<5	--	<10	--	<0.50	--	--	<1	<2	40	--
<1	--	<60	--	50	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	70	--	<5	--	<10	--	<0.5	--	--	--	--	30
--	--	<100	--	80	--	6	--	10	--	<0.5	<1	--	--	--	38
<1	--	<60	--	200	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	120	--	<5	--	<10	--	<0.5	--	--	--	--	28
--	3	--	1,200	--	6	--	<10	--	<0.50	--	--	<1	<2	40	--
--	<4	--	<100	--	<20	--	20	--	<0.50	--	--	<5	<3	60	--
--	--	<100	--	<20	--	<5	--	10	--	<0.5	<1	--	--	--	68
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	69
<1	--	<60	--	60	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<1	--	<60	--	280	--	<5	--	<10	--	<0.5	--	--	--	--	<20
--	--	--	60	--	--	--	--	--	--	--	--	--	--	--	--
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	26
<1	--	<60	--	70	--	<5	--	<10	--	<0.5	--	--	--	--	32
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	32
<1	--	<60	--	80	--	<5	--	<10	--	<0.5	--	--	--	--	<20
20	--	21	--	4,400	--	26	--	30	--	--	--	--	--	--	3,200
20	--	18	--	5,400	--	29	--	40	--	--	--	--	--	--	4,700
20	--	<12	--	1,100	--	<5	--	20	--	--	--	--	--	--	40
20	--	22	--	2,200	--	12	--	40	--	--	--	--	--	--	100
<10	--	<12	--	20	--	<5	--	<10	--	<0.5	--	--	--	--	15
<1	--	<60	--	90	--	<5	--	<10	--	<0.5	--	--	--	--	<20

APPENDIX 4 *(Continued)*: Concentrations of Trace Elements in

Local identifier	Date	Time	Site identification number	Agency analyzing sample	Sampling depth (ft)	Aluminum, dissolved (µg/L as Al)	Arsenic, total (µg/L as As)	Arsenic, dissolved (µg/L as As)	Barium, total recoverable (µg/L as Ba)	Cadmium, total recoverable (µg/L as Cd)	Cadmium, dissolved (µg/L as Cd)	Chromium, total recoverable (µg/L as Cr)
28N-23E-06 CCA 1	09-03-42	--	365600094523001	1028	--	--	--	--	--	--	--	--
28N-23E-06 CCA 1	09-06-51	--	365600094523001	1028	--	--	--	--	--	--	--	--
28N-23E-06 CCA 1	03-22-83	900	365600094523001	84041	--	<100	--	<10	--	--	<1.0	--
28N-23E-18 CDC 1	07-16-81	1340	365402094522201	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-20 BCB 1	07-15-81	1030	365344094513301	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-24 DDA 1	05-02-78	--	365316094461601	84042	--	--	<1	--	<100	<1	--	24
28N-23E-24 DDA 1	03-12-80	1130	365316094461601	84042	--	--	<10	--	<100	<2	--	<10
28N-23E-24 DDA 1	07-15-81	1400	365316094461601	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-28 BBB 1	07-14-81	1700	365301094502901	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-30 CAC 1	03-30-59	--	365229094522101	1028	--	--	--	--	--	--	--	--
28N-23E-30 CAC 1	07-15-81	900	365229094522101	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-30 DBC 1	10-08-82	1330	365229094520201	84041	--	<100	--	--	--	--	6.0	--
28N-23E-30 DBC 1	12-08-82	1300	365229094520201	84041	800	<100	--	--	--	--	<4.0	--
28N-23E-30 DBC 1	12-08-82	1400	365229094520201	84041	1,480	<100	--	--	--	--	18	--
28N-23E-31 BAB 1	05-20-52	--	365210094522101	1028	--	--	--	--	--	--	--	--
28N-23E-31 BAB 1	03-30-59	1200	365210094522101	1028	--	--	--	--	--	--	--	--
28N-23E-31 BAB 1	03-30-59	1201	365210094522101	1028	--	--	--	--	--	--	--	--
28N-23E-31 BAC 1	07-15-81	1100	365206094522201	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-31 CBA 1	09-03-42	--	365146094522201	1028	--	--	--	--	--	--	--	--
28N-23E-31 CBA 1	07-15-81	930	365146094522201	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-32 BAB 1	03-30-59	--	365212094511901	1028	--	--	--	--	--	--	--	--
28N-23E-32 BAB 1	02-05-81	1445	365212094511901	1028	--	--	--	<10	--	--	<2.5	--
28N-23E-32 BAB 1	07-15-81	1130	365212094511901	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-33 BAB 1	03-30-59	--	365213094500701	1028	--	--	--	--	--	--	--	--
28N-23E-33 BAB 1	07-14-81	1615	365213094500701	80020	--	<60	--	<10	--	--	<1.0	--
28N-23E-36 CCC 1	07-15-81	1300	365128094471301	80020	--	<60	--	<10	--	--	<1.0	--
28N-24E-13 ABD 1	10-16-68	--	365445094400701	1028	--	--	--	--	--	--	--	--
28N-24E-13 ABD 1	03-12-80	1150	365445094400701	84042	--	--	<10	--	<100	<2	--	<10
28N-24E-13 ABD 1	07-14-81	1230	365445094400701	80020	--	<60	--	<10	--	--	<1.0	--
28N-25E-20 CAA 1	05-24-79	--	365335094380701	84042	--	--	<1	--	<100	<2	--	<5
28N-25E-20 CAA 1	03-12-80	1245	365335094380701	84042	--	--	<10	--	<100	<2	--	11
28N-25E-20 CAA 1	06-09-81	1330	365335094380701	80020	--	<60	--	<10	--	--	<1.0	--
29N-22E-21 DAD 1	02-04-81	1615	365833094551901	1028	--	--	--	<10	--	--	<2.5	--
29N-22E-21 DAD 1	06-09-81	1700	365833094551901	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-16 DDD 1	12-26-82	1500	365917094484701	84041	300	210	--	--	--	--	34	--
29N-23E-19 DCD 1	05-02-78	--	365823094510701	84042	--	--	<1	--	<100	<1	--	6
29N-23E-19 DCD 1	03-11-80	--	365823094510701	84042	--	--	<0	--	<100	<2	--	<10
29N-23E-19 DCD 1	07-14-81	830	365823094510701	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-21 BBC 1	09-03-42	--	365905094494601	1028	--	--	--	--	--	--	--	--
29N-23E-21 BBC 1	09-06-51	--	365905094494601	1028	--	--	--	--	--	--	--	--
29N-23E-21 BBC 1	07-07-81	1415	365905094494601	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-21 BBC 1	07-23-81	1100	365905094494601	1028	--	--	--	0	--	--	3.0	--
29N-23E-21 BBC 1	09-02-82	830	365905094494601	84041	--	<100	--	<10	--	--	<1.0	--
29N-23E-21 BBC 2	07-07-81	1420	365905094494602	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-21 BBC 2	09-02-82	831	365905094494602	84041	--	<100	--	<10	--	--	<1.0	--
29N-23E-21 BBC 3	07-07-81	1430	365905094494603	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-21 BBC 3	09-02-82	832	365905094494603	84041	--	<100	--	<10	--	--	<1.0	--
29N-23E-25 BDC 1	10-19-77	800	365800094461701	84042	--	--	--	--	--	--	--	--
29N-23E-25 BDC 1	10-19-77	1200	365800094461701	84042	--	--	--	--	--	--	--	--
29N-23E-25 BDC 1	10-19-77	1600	365800094461701	84042	--	--	--	--	--	--	--	--
29N-23E-25 BDC 1	10-01-79	--	365800094461701	84042	--	--	--	--	--	--	--	--
29N-23E-25 BDC 1	03-11-80	1515	365800094461701	84042	--	--	<10	--	<100	<2	--	<10
29N-23E-25 BDC 1	02-23-81	--	365800094461701	84042	--	--	--	--	--	8	--	--
29N-23E-25 BDC 1	04-09-81	800	365800094461701	84042	--	--	<10	--	--	2	--	--
29N-23E-25 BDC 1	07-07-81	1100	365800094461701	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-25 BDC 1	07-07-81	1230	365800094461701	80020	--	<60	--	14	--	--	<1.0	--
29N-23E-26 CDD 1	05-02-78	--	365734094471001	84042	--	--	<1	--	<100	<1	--	9
29N-23E-26 CDD 1	03-11-80	1435	365734094471001	84042	--	--	<10	--	<100	<2	--	<10
29N-23E-26 CDD 1	02-19-81	--	365734094471001	84042	--	--	--	--	--	5	--	--
29N-23E-26 CDD 1	04-13-81	--	365734094471001	84042	--	--	--	--	--	2	--	--
29N-23E-26 CDD 1	07-07-81	1045	365734094471001	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-31 BDD 1	09-12-42	--	365704094513101	1028	--	--	--	--	--	--	--	--
29N-23E-31 BDD 1	07-10-81	930	365704094513101	80020	--	<60	--	<10	--	--	<1.0	--
29N-23E-32 AAB 1	04-20-82	1730	365722094500401	84041	210	<100	--	--	--	--	<4.0	--
29N-23E-32 AAB 1	04-20-82	1750	365722094500401	84041	300	48,000	--	--	--	--	710	--
29N-23E-35 BDD 1	03-11-42	--	365734094471101	1028	--	--	--	--	--	--	--	--
29N-23E-35 BDD 1	09-06-51	--	365734094471101	1028	--	--	--	--	--	--	--	--
29N-23E-35 BDD 1	02-19-81	--	365734094471101	84042	--	--	--	--	--	6	--	--
29N-23E-35 BDD 1	04-13-81	--	365734094471101	84042	--	--	--	--	--	<2	--	--

Water from Wells Completed in the Roubidoux Aquifer

Chromium, dissolved (µg/L as Cr)	Copper, total recoverable (µg/L as Cu)	Copper, dissolved (µg/L as Cu)	Iron, total, recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, total recoverable (µg/L as Pb)	Lead, dissolved (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Mercury, total recoverable (µg/L as Hg)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Selenium, total recoverable (µg/L as Se)	Silver, total recoverable (µg/L as Ag)	Zinc, total recoverable (µg/L as Zn)	Zinc, dissolved (µg/L as Zn)
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	10	--	--	--	--	--	--	--	--	--	--	--	--
<10	--	<12	--	50	--	<5	--	<10	--	<0.5	--	--	--	--	<11
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	34
<1	--	<60	--	20	--	<5	--	<10	--	<0.5	--	--	--	--	<20
--	4	--	740	--	5	--	<10	--	<0.50	--	--	<1	<2	30	--
--	8	--	<100	--	<20	--	20	--	<0.50	--	--	<5	<3	10	--
<1	--	<60	--	<20	--	<5	--	<10	--	<0.5	--	--	--	--	51
<1	--	<60	--	30	--	<5	--	<10	--	<0.5	--	--	--	--	32
--	--	--	10	--	--	--	--	--	--	--	--	--	--	--	--
<1	--	<60	--	70	--	<5	--	<10	--	<0.5	--	--	--	--	26
<10	--	<12	--	<10	--	<5	--	10	--	--	--	--	--	--	26
<10	--	<12	--	<10	--	<5	--	10	--	--	--	--	--	--	83
<10	--	<12	--	730	--	<5	--	290	--	--	--	--	--	--	66
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	100	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	10	--	--	--	--	--	--	--	--	--	--	--	100
<1	--	<60	--	50	--	<5	--	<10	--	<0.5	--	--	--	--	36
--	--	--	20	--	--	--	--	--	--	--	--	--	--	--	--
<1	--	<60	--	20	--	<5	--	<10	--	<0.5	--	--	--	--	22
--	--	--	0	--	--	--	--	--	--	--	--	--	--	0	--
--	--	<100	--	40	--	<5	--	10	--	<0.5	<1	--	--	--	32
<1	--	<60	--	40	--	<5	--	<10	--	<0.5	--	--	--	--	26
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	100
<1	--	<60	--	30	--	<5	--	<10	--	<0.5	--	--	--	--	30
<1	--	<60	--	30	--	<5	--	<10	--	<0.5	--	--	--	--	26
--	--	--	0	--	--	--	0	--	--	--	--	--	--	--	--
--	4	--	<100	--	<20	--	20	--	<0.50	--	--	<5	<3	80	--
<1	--	<60	--	70	--	<5	--	<10	--	<0.5	--	--	--	--	32
--	--	--	--	--	--	--	--	--	--	--	--	<1	--	--	--
--	8	--	<100	--	<20	--	20	--	<0.50	--	--	<5	<3	40	--
<1	--	<60	--	250	--	<5	--	<10	--	<0.5	--	--	--	--	<20
--	--	<100	--	100	--	<5	--	40	--	<0.5	<1	--	--	--	<20
<1	--	<60	--	390	--	<5	--	40	--	<0.5	--	--	--	--	<20
<10	--	<12	--	260,000	--	6	--	4,400	--	--	--	--	--	--	84,000
--	17	--	1,300	--	6	--	<10	--	<0.50	--	--	<1	<2	140	--
--	4	--	<100	--	<20	--	<20	--	<0.50	--	--	<5	<3	60	--
<1	--	<60	--	20	--	<5	--	<10	--	<0.5	--	--	--	--	93
--	--	--	30	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	20	--	--	--	--	--	--	--	--	--	--	--	--
<1	--	<60	--	130	--	<5	--	<10	--	<0.5	--	--	--	--	<20
0	--	0	--	330	--	0	--	10	--	0	--	--	--	--	30
<10	--	<12	--	230	--	6	--	10	--	<0.5	--	--	--	--	72
<1	--	<60	--	80	--	<5	--	<10	--	<0.5	--	--	--	--	26
<10	--	<12	--	30	--	5	--	<10	--	<0.5	--	--	--	--	24
<1	--	<60	--	150	--	<5	--	<10	--	<0.5	--	--	--	--	20
<10	--	<12	--	60	--	5	--	10	--	<0.5	--	--	--	--	21
--	--	--	<100	--	--	--	10	--	--	--	--	--	--	--	--
--	--	--	150	--	--	--	10	--	--	--	--	--	--	--	--
--	--	--	<100	--	--	--	10	--	--	--	--	--	--	--	--
--	--	--	310	--	--	--	--	--	--	--	--	--	--	--	--
--	35	--	1,900	--	<20	--	20	--	<0.50	--	--	<5	<3	590	--
--	--	--	3,000	--	<20	--	70	--	--	--	--	--	--	1,600	--
--	--	--	8,700	--	<20	--	--	--	--	--	--	--	--	1,700	--
<1	--	<60	--	20,000	--	<5	--	210	--	<0.5	--	--	--	--	3,300
<1	--	<60	--	19,000	--	<5	--	100	--	0.5	--	--	--	--	3,600
--	13	--	1,700	--	5	--	20	--	<0.50	--	--	<1	<2	80	--
--	8	--	<100	--	<20	--	20	--	<0.50	--	--	<5	<3	130	--
--	--	--	550	--	<20	--	30	--	--	--	--	--	--	5	--
--	--	--	120	--	<20	--	<20	--	--	--	--	--	--	10	--
<1	--	<60	--	70	--	<5	--	<10	--	<0.5	--	--	--	--	81
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
<1	--	<60	--	50	--	<5	--	<10	--	<0.5	--	--	--	--	<20
<10	--	<12	--	<8	--	<5	--	50	--	--	<2	--	--	--	210
20	--	320	--	88,000	--	16	--	3,300	--	--	<2	--	--	--	20,000
--	--	--	4,600	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	320	--	<20	--	40	--	--	--	--	--	--	20	--
--	--	--	280	--	<20	--	30	--	--	--	--	--	--	30	--

APPENDIX 5: Concentrations of Radioactive Constituents

[--, indicates no data are available. All samples analyzed by the

Local identifier	Dates	Time	Site identification number	Gross alpha, dissolved (pCi/L as U–nat)	Gross alpha, suspended total (pCi/L as U–nat)
Adair County					
18N-26E-18 BDC 1	10-28-81	1300	360225094344001	<5.4	--
Craig County					
27N-20E-12 BDD 2	06-08-81	1400	365016095070501	<14	0.3
27N-21E-12 CCB 1	07-09-81	1030	365000095010101	<6.8	--
27N-21E-20 DCD 1	06-09-81	1100	364808095043501	<7.5	0.3
28N-21E-29 CBC 1	06-09-81	900	365242095051701	23	0.3
28N-21E-29 CBC 1	06-15-82	1425	365242095051701	--	--
28N-21E-29 CBD 1	06-09-81	930	365240095051501	<24	0.3
28N-21E-29 CBD 1	06-15-82	1430	365240095051501	--	--
Delaware County					
20N-23E-34 CCA 1	06-10-81	930	360946094504901	<4.8	3.2
20N-24E-17 CCC 1	06-10-81	800	361221094463901	6.3	0.3
21N-25E-31 BBB 1	06-10-81	1045	361544094410101	17	0.3
21N-25E-31 BBB 1	06-16-82	1330	361544094410101	--	--
22N-23E-05 DCA 1	06-10-81	1200	362442094520801	57	1.7
22N-23E-05 DCA 1	06-18-82	950	362442094520801	--	--
22N-23E-11 BBB 1	03-21-83	1445	362427094493001	21	--
23N-22E-14 ADC 1	06-10-81	1245	362829094550901	<2.9	0.3
23N-25E-33 DDC 1	07-09-81	1445	362532094375501	<3.6	--
24N-23E-15 BBC 1	06-11-81	930	363357094503701	24	0.3
24N-23E-15 BBC 1	06-17-82	1000	363357094503701	--	--
24N-24E-06 DCA 1	06-11-81	1230	363510094464501	<7.5	1.2
25N-22E-23 CCD 1	06-10-81	1500	363740094553101	<3.7	0.3
25N-23E-13 BAB 1	06-11-81	1330	363921094474301	<7.5	--
25N-24E-28 BBB 1	07-09-81	1200	363718094444501	<11	--
Ottawa County					
25N-23E-01 AAA 1	07-15-81	1700	364103094470401	<6.3	--
26N-22E-15 DDA 1	06-12-81	1000	364349094554501	14	0.3
26N-22E-20 BCC 1	06-12-81	900	364323094585101	<16	0.3
26N-22E-20 BCC 1	06-16-82	900	364323094585101	--	--
26N-22E-27 ADD 1	07-08-81	830	364227094554301	14	0.5
26N-22E-27 CBC 1	06-11-81	1600	364211094564101	24	0.3
26N-22E-32 ADC 1	06-11-81	1500	364136094575801	42	0.3
26N-22E-32 ADC 1	06-16-82	1005	364136094575801	--	--
26N-22E-32 ADC 2	06-11-81	1300	364137094575902	28	0.3
26N-22E-32 ADC 2	06-16-82	1000	364137094575902	--	--
26N-23E-09 CA 1	07-08-81	945	364501094505301	25	0.3
26N-23E-09 CA 1	06-18-82	800	364501094505301	--	--
26N-23E-09 DBC 1	07-08-81	930	364454094504401	<6.7	--
26N-23E-12 BAD 1	07-08-81	1040	364516094473501	<7.5	--
26N-24E-32 ABA 1	07-30-81	1400	364155094451001	<7.5	--
27N-22E-01 CCC 1	07-16-81	800	365103094541501	<10	--
27N-22E-27 AAB 1	07-09-81	900	364801094554601	<14	--
27N-23E-03 BCC 1	07-08-81	1630	365100094491701	<3.7	<0.4
27N-23E-17 CBB 1	06-09-81	1545	364921094522201	12	0.3
27N-23E-28 CDC 1	07-08-81	1130	364712094510101	<12	--
27N-24E-28 CAD 1	07-08-81	1500	364717094433101	<3.6	--
27N-25E-09 CAC 1	07-14-81	1030	364957094371501	<3.3	0.5
28N-22E-11 ABB 1	07-10-81	830	365543094535801	<5.8	0.4
28N-22E-24 BDA 1	07-16-81	1330	365342094531301	<5.0	--
28N-22E-24 CAD 1	07-16-81	1430	365324094531301	<6.1	--

in Water from Wells Completed in the Roubidoux Aquifer

National Water Quality Laboratory of the U.S. Geological Survey.]

Gross alpha, dissolved (µg/L as U-nat)	Gross alpha, suspended (µg/L as U-nat)	Gross beta, dissolved (pCi/L as ^{137}Cs)	Gross beta, suspended total (pCi/L as ^{137}Cs)	Gross beta, dissolved (pCi/L as Sr^{90}/Y^{90})	Gross beta, suspended total (pCi/L as Sr^{90}/Y^{90})	Radium-226 dissolved planchet count (pCi/L)	Radium-228 dissolved (pCi/L as ^{228}Ra)
Adair County							
<7.9	<0.4	<3.2	<0.4	<3.0	<0.4	--	--
Craig County							
<21	0.5	14	<0.4	14	<0.4	--	--
<10	<0.4	5.3	0.8	5.1	0.8	--	--
<11	<0.4	<5.6	<0.4	<5.4	<0.4	--	--
34	<0.4	15	<0.4	14	<0.4	--	--
--	--	--	--	--	--	3.4	<2.0
<35	<0.4	17	<0.4	16	<0.4	--	--
--	--	--	--	--	--	6.4	<3.0
Delaware County							
<7.1	4.7	<3.5	<1.5	<3.3	<1.5	--	--
9.2	<0.4	3.5	<0.4	3.4	<0.4	--	--
25	<0.4	9.2	<0.4	8.8	<0.4	--	--
--	--	--	--	--	--	5.2	<3.0
84	2.5	21	0.6	20	0.6	--	--
--	--	--	--	--	--	8.9	<3.0
31	<0.4	10	<0.4	9.9	<0.4	--	--
<4.3	<0.4	3.5	<0.4	3.4	<0.4	--	--
<5.3	<0.4	<2.6	<0.4	<2.4	<0.4	--	--
35	<0.4	15	<0.4	14	<0.4	--	--
--	--	--	--	--	--	7.5	<3.0
<11	1.8	<5.2	<0.4	<5.0	<0.4	--	--
<5.4	<0.4	3.9	<0.4	3.7	<0.4	--	--
<11	<0.4	<4.5	<0.4	<4.5	<0.4	--	--
<16	<0.4	<6.1	<0.4	<5.9	<0.4	--	--
Ottawa County							
<9.3	<0.4	5.0	<0.4	4.9	<0.4	--	--
21	<0.4	9.6	<0.4	9.2	<0.4	--	--
<23	<0.4	<9.1	<0.4	<8.7	<0.4	--	--
--	--	--	--	--	--	4.3	<3.0
20	0.7	7.7	1.5	7.4	1.6	--	--
35	<0.4	13	<0.4	12	<0.4	--	--
62	<0.4	25	<0.4	24	<0.4	--	--
--	--	--	--	--	--	14	<3.0
41	<0.4	19	<0.4	18	<0.4	--	--
--	--	--	--	--	--	7.3	<3.0
36	0.4	22	1.9	21	1.9	--	--
--	--	--	--	--	--	6.5	<2.0
<9.8	<0.4	5.0	<0.4	4.8	<0.4	--	--
<11	<0.4	<4.5	<0.4	<4.3	<0.4	--	--
<11	<0.4	<5.7	<0.4	<5.4	<0.4	--	--
<15	<0.4	5.8	<0.4	5.5	<0.4	--	--
<20	<0.4	<10	<0.4	<9.7	<0.4	--	--
<5.4	<0.4	<2.4	<0.4	<2.3	<0.4	--	--
17	<0.4	6.4	<0.4	6.1	<0.4	--	--
<17	<0.4	8.4	<0.4	8.0	<0.4	--	--
<5.3	<0.4	<3.5	<0.4	<3.3	<0.4	--	--
<4.8	0.8	8.4	0.5	8.0	0.5	--	--
<8.5	0.6	4.4	2.7	4.3	2.8	--	--
<7.4	<0.4	<2.8	<0.4	<2.7	<0.4	--	--
<9.0	<0.4	4.6	<0.4	4.4	<0.4	--	--

APPENDIX 5 *(Continued)*: Concentrations of Radioactive Constituents

Local identifier	Dates	Time	Site identification number	Gross alpha, dissolved (pCi/L as U–nat)	Gross alpha, suspended total (pCi/L as U–nat)
28N-22E-24 CBC 1	07-16-81	1315	365323094534001	<7.5	--
28N-23E-06 BAB 1	07-07-81	900	365627094522201	<5.7	--
28N-23E-06 BAB 2	03-22-83	920	365627094522101	8.2	--
28N-23E-06 CBD 2	07-07-81	830	365557094522701	<4.2	--
28N-23E-06 CCA 1	03-22-83	900	365600094523001	5.2	--
28N-23E-18 CDC 1	07-16-81	1340	365402094522201	7.5	--
28N-23E-20 BCB 1	07-15-81	1030	365344094513301	<3.1	--
28N-23E-24 DDA 1	07-15-81	1400	365316094461601	<6.3	--
28N-23E-28 BBB 1	07-14-81	1700	365301094502901	<8.8	--
28N-23E-30 CAC 1	07-15-81	900	365229094522101	<6.3	--
28N-23E-31 BAC 1	07-15-81	1100	365206094522201	<7.5	--
28N-23E-31 CBA 1	07-15-81	930	365146094522201	<3.3	--
28N-23E-32 BAB 1	07-15-81	1130	365212094511901	11	--
28N-23E-33 BAB 1	07-14-81	1615	365213094500701	<6.3	--
28N-23E-36 CCC 1	07-15-81	1300	365128094471301	<6.8	--
28N-24E-13 ABD 1	07-14-81	1230	365445094400701	<5.7	--
28N-25E-20 CAA 1	06-09-81	1330	365335094380701	<2.9	0.3
29N-22E-21 DAD 1	06-09-81	1700	365833094551901	<10	0.3
29N-23E-19 DCD 1	07-14-81	830	365823094510701	<3.4	--
29N-23E-21 BBC 1	07-07-81	1415	365905094494601	<6.3	<0.4
29N-23E-21 BBC 2	07-07-81	1420	365905094494602	<5.2	<0.4
29N-23E-21 BBC 3	07-07-81	1430	365905094494603	<7.5	<0.4
29N-23E-25 BDC 1	07-07-81	1100	365800094461701	<21	1.4
29N-23E-25 BDC 1	07-07-81	1230	365800094461701	<20	0.5
29N-23E-26 CDD 1	07-07-81	1045	365734094471001	<8.2	--
29N-23E-31 BDD 1	07-10-81	930	365704094513101	<4.2	0.5

in Water from Wells Completed in the Roubidoux Aquifer

Gross alpha, dissolved (µg/L as U–nat)	Gross alpha, suspended (µg/L as U–nat)	Gross beta, dissolved (pCi/L as ^{137}Cs)	Gross beta, suspended total (pCi/L as ^{137}Cs)	Gross beta, dissolved (pCi/L as Sr^{90}/Y^{90})	Gross beta, suspended total (pCi/L as Sr^{90}/Y^{90})	Radium-226 dissolved planchet count (pCi/L)	Radium-228 dissolved (pCi/L as ^{228}Ra)
<11	<0.4	<4.9	<0.4	<4.7	<0.4	--	--
<8.4	<0.4	<4.0	<0.4	<3.9	<0.4	--	--
12	<0.4	5.4	<0.4	5.2	<0.4	--	--
<6.2	<0.4	3.9	<0.4	3.8	<0.4	--	--
7.6	<0.4	5.4	<0.4	5.1	<0.4	--	--
11	<0.4	<5.7	<0.4	<5.4	<0.4	--	--
<4.6	<0.4	2.3	<0.4	2.2	<0.4	--	--
<9.2	<0.4	<4.2	<0.4	<4.0	<0.4	--	--
<13	<0.4	<5.3	<0.4	<5.1	<0.4	--	--
<9.3	<0.4	<3.5	<0.4	<3.4	<0.4	--	--
<11	<0.4	<4.7	<0.4	<4.6	<0.4	--	--
<4.8	<0.4	2.2	<0.4	2.1	<0.4	--	--
16	<0.4	7.5	<0.4	7.2	<0.4	--	--
<9.2	<0.4	4.3	<0.4	4.1	<0.4	--	--
<10	<0.4	<4.3	<0.4	<4.1	<0.4	--	--
<8.4	<0.4	<4.0	<0.4	<3.9	<0.4	--	--
<4.2	<0.4	<2.0	<0.4	<2.0	<0.4	--	--
<15	<0.4	7.5	<0.4	7.2	<0.4	--	--
<5.0	<0.4	3.3	<0.4	3.1	<0.4	--	--
<9.3	--	<3.4	<0.4	<3.3	<0.4	--	--
<7.7	--	<4.1	<0.4	<3.9	<0.4	--	--
<11	--	5.7	<0.4	5.5	<0.4	--	--
<31	2.0	15	<0.4	15	<0.4	--	--
<30	0.8	<13	<0.4	<12	<0.4	--	--
<12	<0.4	<4.2	<0.4	<4.1	<0.4	--	--
<6.2	0.8	3.0	1.1	2.8	1.1	--	--

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