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RECONNAISSANCE OF GROUND WATER IN VICINITY OF WICHITA MOUNTAINS SOUTHWESTERN OKLAHOMA

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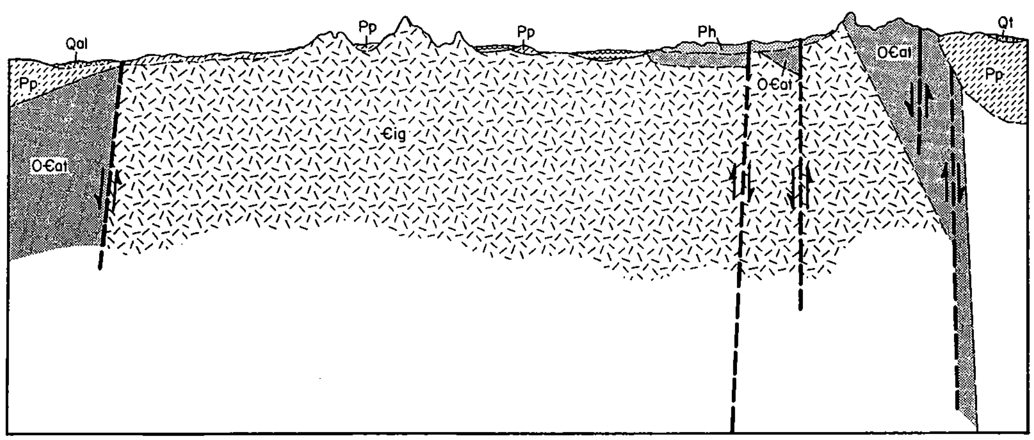
Prepared by the United States Geological Survey in cooperation with the Oklahoma Geological Survey



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Title Page Illustration

Schematic cross section through Wichita Mountains from south (left) to north, depicting igneous core (Ꞓig) in center, with Paleozoic units on both flanks. See plate 1 (in pocket) for explanation of geologic symbols. (Ink drawing by Massoud Safavi.)

GROUND WATER IN VICINITY OF WICHITA MOUNTAINS SOUTHWESTERN OKLAHOMA

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RECONNAISSANCE OF GROUND WATER IN VICINITY OF WICHITA MOUNTAINS SOUTHWESTERN OKLAHOMA

JOHN S. HAVENS[1]

Abstract—Urbanization and industrial growth have increased demands on water supplies in the vicinity of the Wichita Mountains in southwestern Oklahoma. The principal city, Lawton, uses surface water, supplemented by small quantities of ground water from the Arbuckle Group (Cambrian–Ordovician), for industrial and recreational use. During periods of drought, surface-water supplies in the Wichita Mountains area are not adequate to meet fully the increased water demands. An alternative source of water may be ground water from the Arbuckle Group. Other urban and rural consumers use ground water from Quaternary alluvium, the Rush Springs Formation (Permian), or the Arbuckle Group.

The alluvium yields from 5 to 500 gal/min (0.3 to 32 L/s) of water, with dissolved-solids concentrations ranging from 304 to 1,750 mg/L. Recharge to the alluvium is limited to precipitation on the flood plains of the creeks. The Rush Springs and associated formations yield 10 to 300 gal/min (0.6 to 19 L/s) of water that is very hard and contains from 478 to 2,270 mg/L dissolved solids. The Arbuckle Group in the northern part of the area yields as much as 100 gal/min (6.3 L/s) of water from springs and flowing wells; the water is very hard and contains dissolved-solids concentrations ranging from 195 to 940 mg/L. The recharge area probably is limited. South of the Wichita Mountains, the Arbuckle yields as much as 600 gal/min (38 L/s) of soft water with dissolved solids ranging from 279 to 6,380 mg/L. With a fluoride content that ranges from 1.6 to 17 mg/L, the water generally is used only for industrial and recreational supplies. A high sodium concentration may make the water unsuitable for irrigation.

INTRODUCTION

Urbanization, growth of industry, and higher standards of living have increased demands on municipal and rural water supples in the vicinity of the Wichita Mountains in southwestern Oklahoma (fig. 1). The principal city of the area, Lawton, uses surface water from Lake Lawtonka and Lake Ellsworth for its water supply. This supply is supplemented by small quantities of ground water from limestone and dolomite of the Arbuckle Group of Ordovician and Cambrian age, which is used for industrial and recreational purposes. Other towns, communities, and rural water districts in the area use ground water from Quaternary alluvium, the Rush Springs Formation of Permian age, or the Arbuckle Group.

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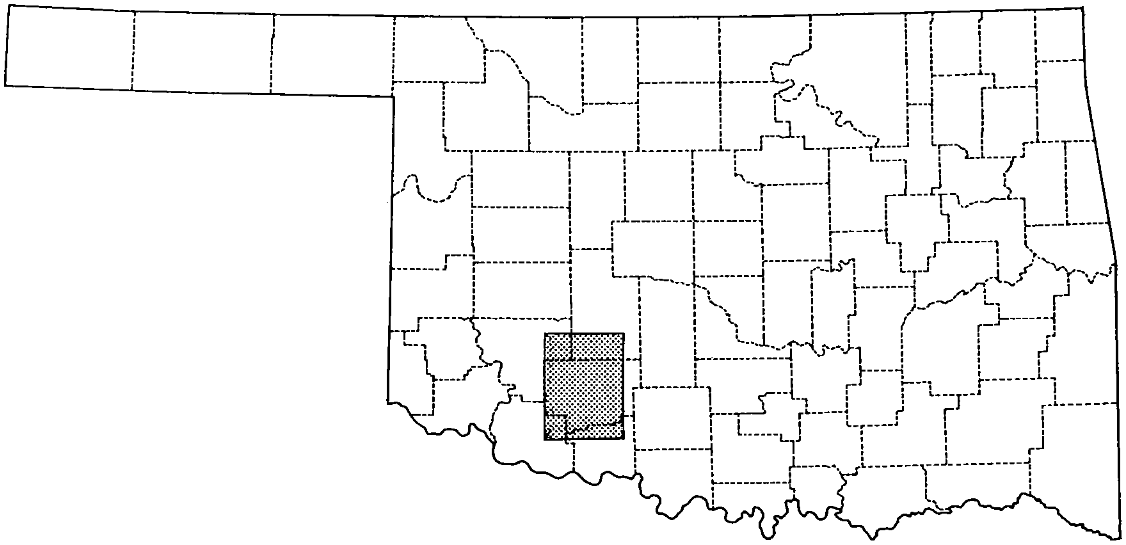


Figure 1. Map of Oklahoma, showing location of study area.

During periods of drought, surface-water supplies in the Wichita Mountains area are not adequate to meet fully the increased demand for water. Faced with the need to furnish additional water, the City of Lawton requested the Oklahoma Geological Survey to evaluate potential sources of ground water, particularly the Arbuckle Group, which yields as much as 600 gal/min (38 L/s) in the immediate vicinity of Lawton. Under a long-standing cooperative agreement, the Oklahoma Geological Survey requested the U.S. Geological Survey to conduct the investigation, which was completed in 1975. The results of the investigation are being presented here so that they may be given as wide circulation as possible.

Although the investigation emphasized the Arbuckle Group, information on other potential aquifers was collected and evaluated also. Among the items of information gathered were data on location, depth, construction, yields of wells, and depths to water; also included were data on location and yields of springs. Chemical analyses were made of water samples from about 70 wells and springs. Two test wells, 997 and 1,002 ft deep (304 and 305 m), respectively, were drilled into the Arbuckle Group to obtain geologic, hydrologic, and quality-of-water data.

Grateful acknowledgment is made for the generous cooperation of officials of the City of Lawton and of other municipalities in providing information and assistance. Local residents assisted greatly by their willingness to provide information, to locate wells and springs and collect water samples, and to allow access to their property. Particular acknowledgments are due Robert Green and R. B. Moore, of Cache, Oklahoma, for allowing test drilling on their property. The Oklahoma State Department of Health and the U.S. Public Health Service (now the U.S. Environmental Protection Agency) furnished drilling, construction, and quality-of-water data on wells and springs in the area.

Well-Numbering System

Because of the many references to well locations and field locations in this report, the normal method of giving locations by fractional section, township, and range has been replaced by a shorter method. In figure 2, the location of the dot would normally be described as the NW¼NE¼SE¼ sec. 21, T. 2 N., R. 11 W. The method used in this report reverses the order and indicates fractional quarter subdivisions of the section by letters. By this method, the location is given as 2N-11W-21DAB1.

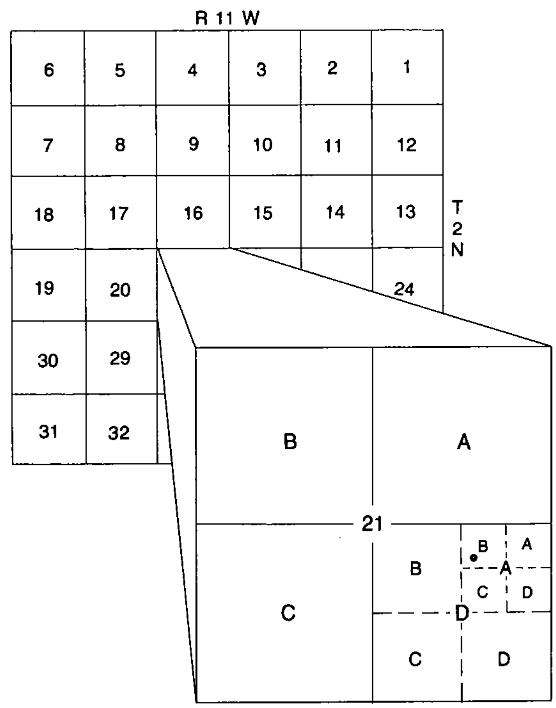


Figure 2. Diagram showing well-numbering system used in this report.

Conversion Factors

English units used in this report can be converted to metric units by the following conversion factors:

Multiply English unit	*By*	*To obtain metric unit*
inches (in.)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
acres	.4047	hectares (ha)
gallons per minute (gal/min)	.06309	liters per second (L/s)

GEOLOGIC SETTING

The geologic structure of the Wichita Mountains is complex. As shown on plate 1 (pocket), the igneous rocks that form the core of the mountains have been uplifted several thousand feet along major northwest-trending faults and are broken by many smaller faults. Also, the Cambrian and Ordovician limestone, shale, and dolomite of the Arbuckle Group have been uplifted a few hundred to several thousand feet and are greatly faulted and folded. For example, in the Limestone Hills segment of the Wichita Mountains, where the Arbuckle is extensively exposed, many beds are vertical or near vertical, and locally some beds are overturned.

The Wichita Mountains are flanked on all sides by gently dipping rocks of Permian age that were derived from sediment and debris eroded from the mountains. Near the mountains, the conglomeratic deposits that make up the Post Oak Conglomerate contain fragments of igneous rock eroded from the igneous core or of calcareous rock eroded from the Arbuckle Group. Farther away from the mountains, the conglomeratic Post Oak grades laterally into beds of shale, siltstone, and sandstone of the Hennessey, Garber, and Wellington formations.

AVAILABILITY AND QUALITY OF GROUND WATER

The principal aquifers in the study area are alluvium, sandstone of the Rush Springs Formation and associated formations, and the Arbuckle Group. The distribution of these aquifers is shown on plate 1 (pocket). Water-level contours have not been shown because of the geologic complexity of parts of the area and the lack of data in other parts.

In order to determine the chemical quality of water from aquifers in the Wichita Mountains area, about 70 samples were collected and analyzed; results of these analyses are given in table 1 (pocket).

Alluvium

Alluvium of Quaternary age, consisting of about 5–52 ft (1.5–16 m) of sand, clay, and gravel, is present along the flood plains of East and West Cache Creeks and their tributaries. Wells in the alluvium, which range in depth from 12 to 52 ft (3.7 to 16 m), yield a maximum of 500 gal/min (32 L/s) for irrigation and rural water-supply wells along West Cache Creek in secs. 1, 11, and 12, T. 1 S., R. 14 W. Estimated yields from wells in alluvium along East Cache Creek generally are less than 300 gal/min (19 L/s), although a well in T. 2 S., R. 14 W., just south of the study area, reportedly yields 400 gal/min (25 L/s). Most wells in the study area yield 5–50 gal/min (0.3–3.2 L/s), and the depth to water ranges from 5 to 30 ft (1.5 to 9.1 m) below land surface. In general, alluvium is confined to the flood plains of principal streams in the area (pl. 1). Ground water in the alluvium is recharged by precipitation on the flood plains and by infiltration along stream channels during periods of high water. Most water now produced from alluvium is for domestic and stock use. Additional development of water supplies from the alluvium probably would be influenced by the limited areal extent of the aquifer.

Water from the alluvium is moderately hard to hard. Chloride ranges from 26 to 630 mg/L (milligrams per liter) but probably is less than 100 mg/L in most shallow wells. Dissolved solids range from 304 to 1,750 mg/L and average about 600 mg/L. The fluoride concentration generally is less than 0.5 mg/L but is 3.3 mg/L in one well (table 1).

Rush Springs Formation and Associated Formations

The Rush Springs aquifer consists of 90–490 ft (27–149 m) of sandstone, gypsum, and dolomite. Several of the sandstone beds may yield as much as 300 gal/min (19 L/s) of water to wells. Wells are 50–300 ft (15–91 m) deep, and depths to water generally are 15–40 ft (4.6–12 m) below land surface. The underlying El Reno Group, consisting of 500–830 ft (152–250 m) of sandstone, shale, and siltstone of the Chickasha Formation and Duncan Sandstone, may yield from 10 to 300 gal/min (0.6 to 19 L/s). Wells are 36–307 ft (11–94 m) deep, and depths to water are 14–24 ft (4.2–7.3 m) below land surface. Recharge to these aquifers is from precipitation on the land surface, from underground flow from outside the study area, and from infiltration from streams. Wells for smaller communities, rural domestic and stock wells, and a few irrigation wells produce water from the Rush Springs and El Reno aquifers within the report area.

Results of analyses of water samples from the Rush Springs Formation and the El Reno Group are given in table 1. Most of the samples tested are rated as very hard. Chloride ranges from 4 to 202 mg/L and averages about 15 mg/L. Dissolved solids range from 478 to 2,270 mg/L and average about 1,200 mg/L.

Arbuckle Group

The Arbuckle Group aquifer consists of from 1,200 to 6,000 ft (370 to 1,800 m) of limestone, dolomite, and shale. Solution of the limestone and dolomite by movement of ground water along bedding planes, fractures, and faults has formed openings and porous zones within which water can be stored and transmitted below the regional water table.

The availability of ground water from the Arbuckle Group in the Limestone Hills area is erratic because of faulting and folding. Dry holes reportedly have been drilled to depths of 500 ft (150 m). Most wells are 500 ft (150 m) deep or more, and water, where present, generally is under artesian conditions. In some wells the potentiometric head is above ground level and the well flows; some wells may flow 100 gal/min (6.3 L/s). Along the northeast and west sides of the Limestone Hills, springs and spring areas discharge from 2 to 100 gal/min (0.1 to 6.3 L/s) and can be pumped to yield greater amounts.

South of the Wichita Mountains the Arbuckle is overlain by as much as 2,000 ft (610 m) of younger rocks (pl. 1). Plate 1 also shows the approximate elevation of the top of the Arbuckle Group in this area, as determined from outcrop elevations near the mountains, from drillers' logs, and from geophysical logs.

Water in the Arbuckle south of the mountains is under artesian conditions and flows from some wells. Well depths range from about 350 ft near the mountains to 2,243 ft (684 m) at Geronimo. Yields of 2 to 600 gal/min (0.1 to 38 L/s) have been reported.

Figure 3 shows water-level fluctuation in an artesian well in the Arbuckle near Cache. The hydrograph shows both short-term fluctuations and seasonal water-level trends in response to precipitation.

Recharge to the Arbuckle aquifer in the Limestone Hills is through surface outcrops of limestone and dolomite. South of the Wichita Mountains, recharge to the Arbuckle probably is principally along the southern flank of the mountains and through the overlying Post Oak Conglomerate. Extensive points of discharge from the Arbuckle are not known within the study area; some wells and springs, however, particularly in the Limestone Hills, discharge as much as 100 gal/min (6.3 L/s). Areas of major gain in streamflow are not known.

To obtain geologic and hydrologic data on the Arbuckle Group south of the Wichita Mountains, the U.S. Geological Survey supervised the drilling of test wells 1 and 2 (1N-13W-4BAA1 and 2N-14W-25ADB1) southeast of Cache. Graphic lithologic and geophysical logs of these wells are shown in figure 4.

Test well 1 was drilled to a depth of 997 ft (304 m) in February and March 1972. The hole was cased to 545 ft (166 m) with 6⅝-inch (168-mm) casing. In this well, alluvium and Post Oak Conglomerate extend to 528 ft (161 m); limestone, shale, and dolomite of the Arbuckle Group extend from 528 to 997 ft (161 to 304 m). An alluvial aquifer 12–28 ft (3.7–5.5 m) below land surface yielded about 15 gal/min (0.9 L/s), but use of heavy drilling mud to prevent caving sealed off any water-bearing zones in the Post Oak. Upon completion, the well was pumped for 5½ hours at a rate of 35 gal/min (2.2 L/s) with a total drawdown of 140 ft (43 m). At this rate, specific capacity (pumping rate divided by drawdown) is 0.25 gal/min per foot (0.05 L/s per meter) of drawdown. Results of analyses of water from this well are shown in table 1. This well has been retained as an observation well in the Arbuckle Group.

Test well 2, drilled in April and May 1972, has 6⅝-inch (168-mm) casing to a depth of 382 ft (116 m) below land surface. Alluvium extends to 32 ft (9.8 m), Post Oak Conglomerate to 363 ft (111 m), and dolomite and shale of the Arbuckle Group to the total depth of 1,002 ft (305 m) (fig. 4). A shallow water-bearing zone was penetrated between 15 and 32 ft (4.6–9.8 m), and again, the use of heavy drilling mud to prevent caving excluded water from the Post Oak. Cavernous dolomite at 632–635 ft (193–194 m) in the Arbuckle probably is the main water-bearing zone. During an 8-hour pumping test, the well produced an average of 28 gal/min (1.8 L/s), with a drawdown of 32 ft (9.8 m), for a specific capacity of 0.88 gal/min per foot (0.2 L/s per meter) of drawdown. Table 1 shows results of a chemical analysis of water from this well. Upon completion of testing, the well was plugged and abandoned.

Water from the Arbuckle Group in the Limestone Hills generally is very hard and is a calcium bicarbonate water. Chloride ranges from 2.5 to 350 mg/L but averages less than 50 mg/L. Dissolved solids range from

195 to about 940 mg/L but generally less than 500 mg/L. The general fluoride range is 0.2 to 5.0 mg/L, and most samples contain less than 2.4 mg/L.

Water from the Arbuckle Group south of the Wichita Mountains generally is soft because of low calcium and magnesium concentrations. Sodium ranges from 96 to 2,400 mg/L, and SAR (sodium-adsorption ratio) ranges from 7.2 to 80. The chloride content ranges

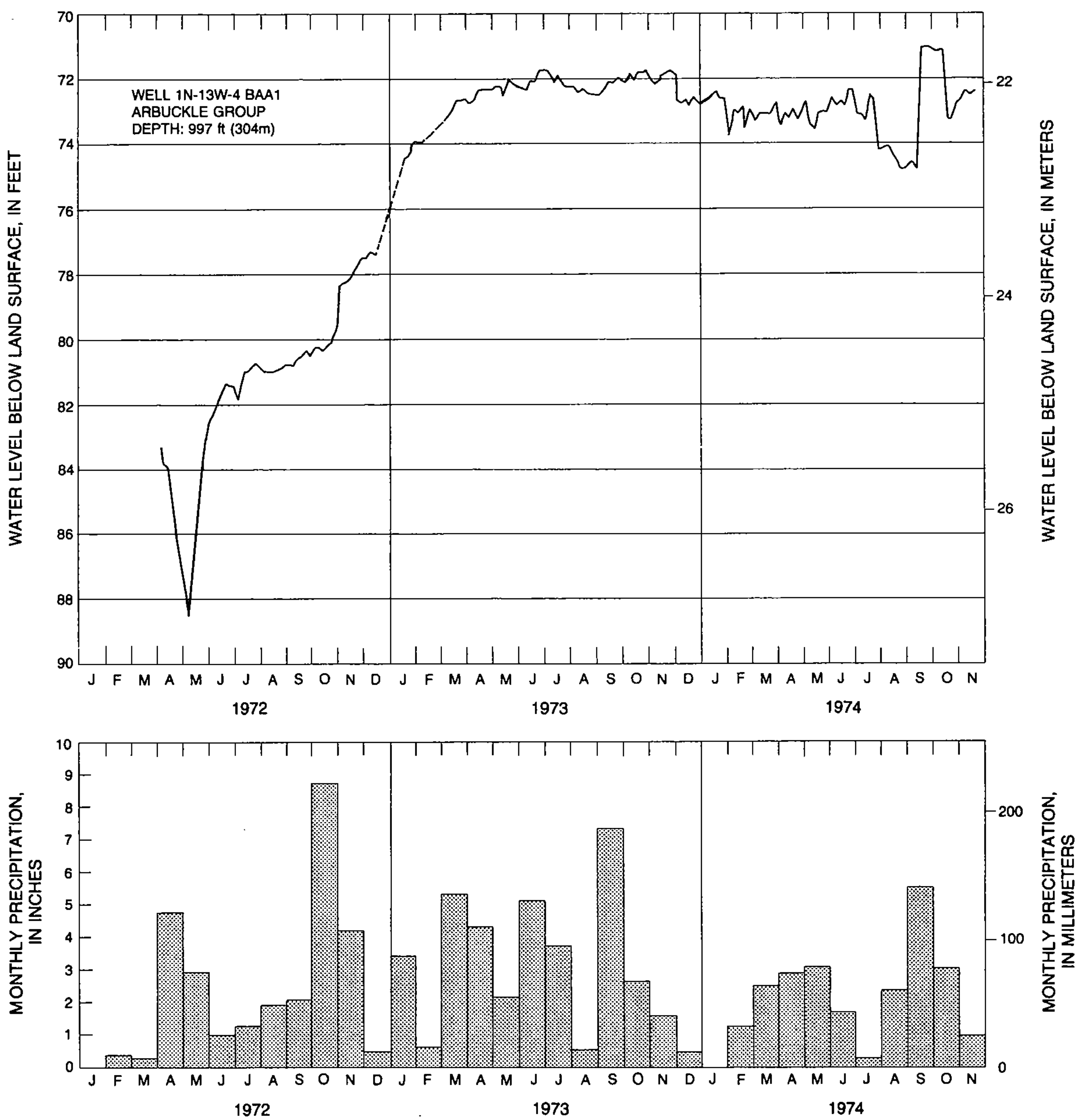


Figure 3. Hydrograph and precipitation data at well 1N-13W-4BAA1, 1972–74.

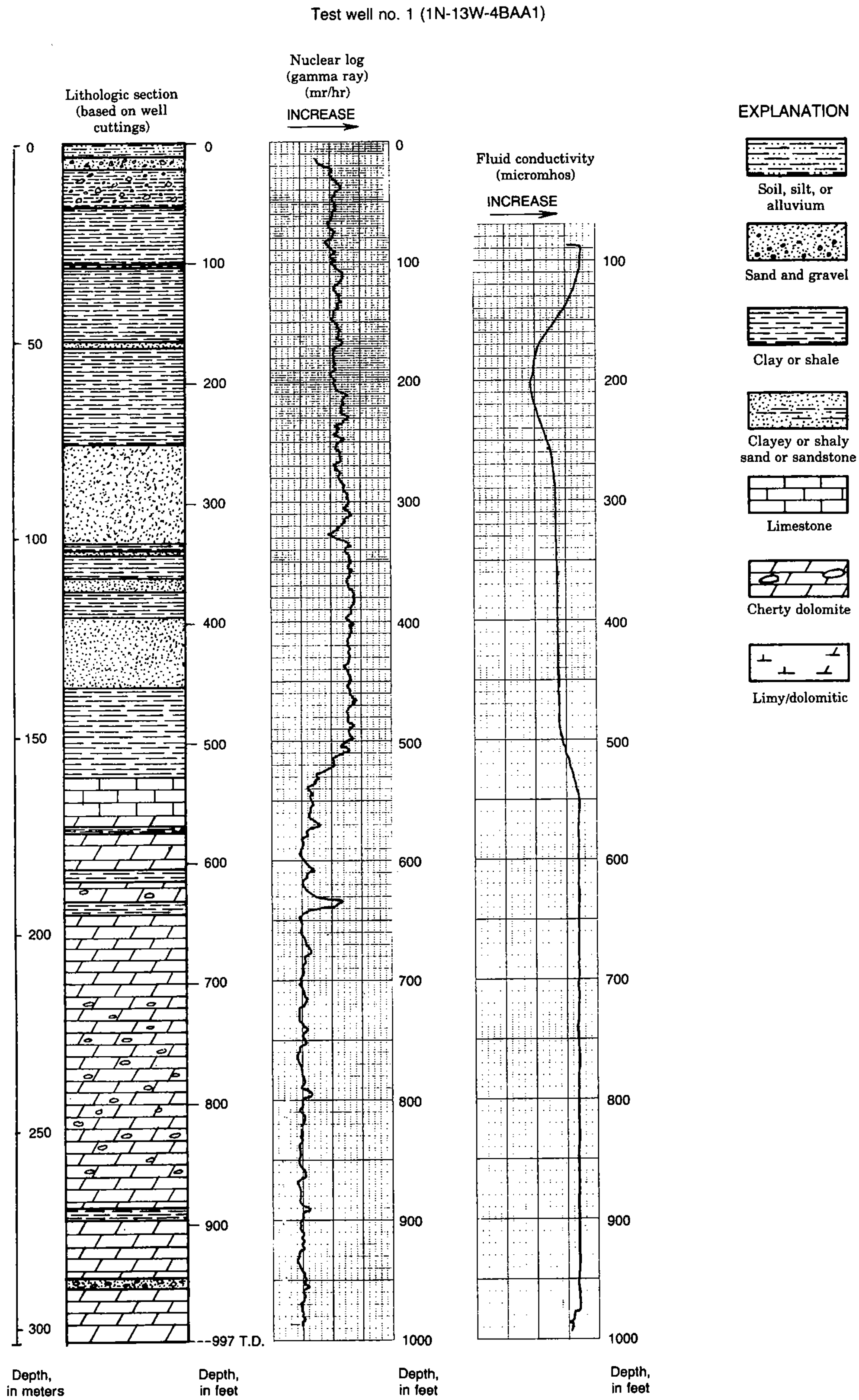
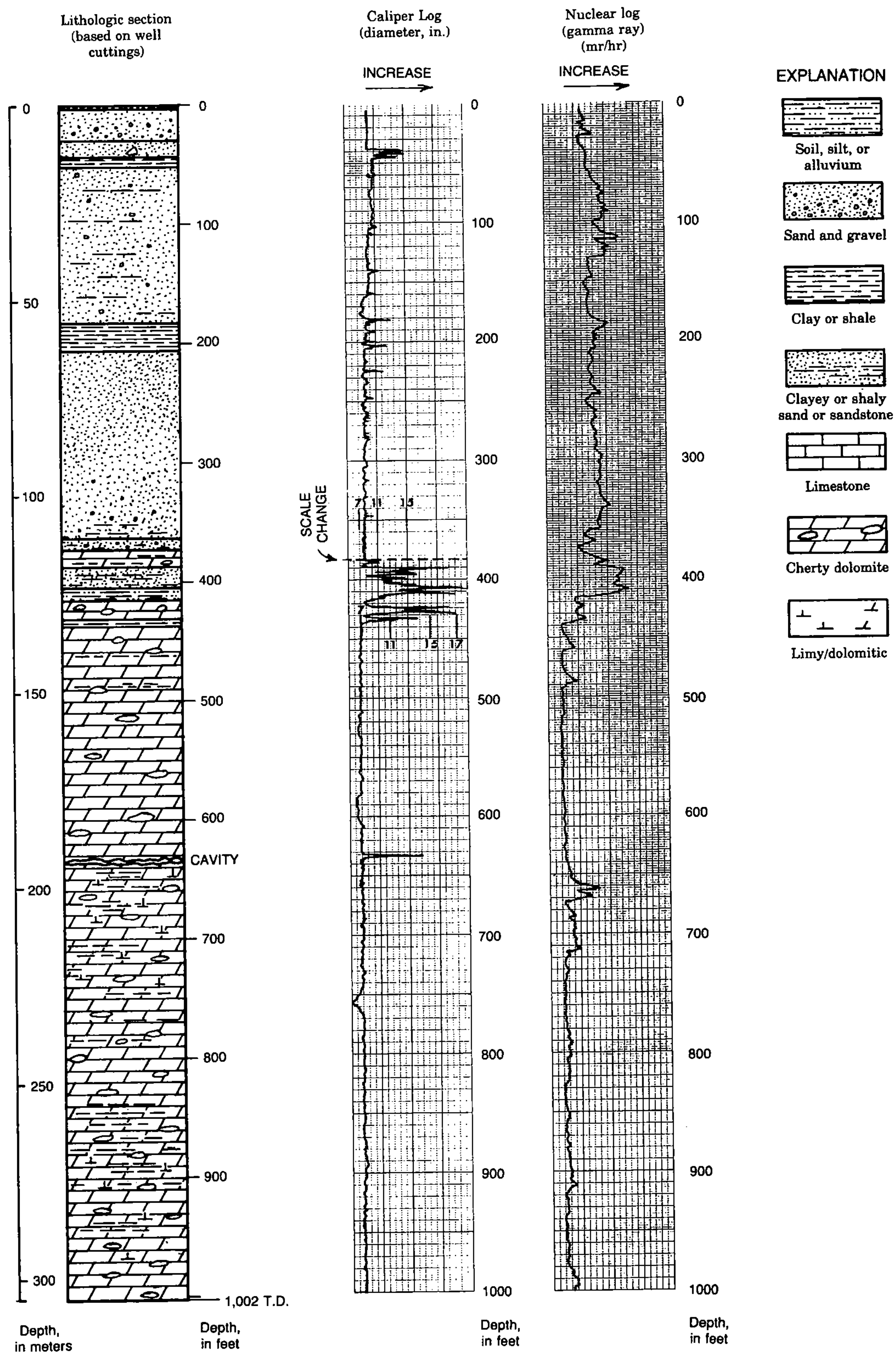


Figure 4. Lithologic and geophysical logs of two test wells. (Logs by U.S. Geological Survey, 1972.)

Test well no. 2 (2N-14W-25ADB1)



from 170 to 3,000 mg/L but generally is 250 to 500 mg/L. Dissolved solids range from 279 to 6,380 mg/L, but the average is about 1,000 mg/L. The fluoride concentration ranges from 1.6 to 17 mg/L and nearly everywhere exceeds 1.6 mg/L.

SIGNIFICANCE OF CHEMICAL CONSTITUENTS

According to standards established by the Oklahoma State Department of Health (1964, p. 7), water used for public supplies shall conform to the limits of chemical quality listed by the U.S. Environmental Protection Agency in EPA–580/9–76–003 (1976). An exception may be allowed where it can be demonstrated that no other source is available.

The chemical constituents that ordinarily influence water quality for domestic or irrigation use are sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), chloride (Cl), bicarbonate (HCO_3), sulfate (SO_4), and fluoride (F).

Although sodium and potassium are dissolved from most rocks and are found in most ground waters, small to moderate quantities have little effect on the usefulness of water. Sodium generally predominates as the amount of dissolved sodium plus potassium increases. The ratio of sodium content to that of calcium plus magnesium in a water is expressed as SAR (sodium-adsorption ratio); water with high SAR values may be unsatisfactory for irrigation.

Calcium is dissolved from many rocks, but higher concentrations generally are found in water that has been in contact with limestone, dolomite, or gypsum; magnesium is dissolved primarily from dolomitic rocks. Calcium and magnesium hardness is expressed in terms of an equivalent quantity of calcium carbonate. Durfor and Becker (1964, p. 27) classify water having hardness less than 60 mg/L as soft; 61 to 120 mg/L, moderately hard; 121 to 180 mg/L, hard; and more than 180 mg/L, very hard.

Chloride is present in many rocks and is a major constituent of some evaporite deposits, such as halite or rock salt. Rocks that have been under the sea at some stage of their formation generally contain some chloride. Chloride is a major constituent of most oil-field brines. Some chloride is present in almost all water, and small quantities are desirable in water for consumption by humans, but excessive chloride renders water unpalatable and tends to accelerate corrosion of metal.

Waters that have been in contact with limestone and dolomite dissolve carbonate and bicarbonate through the action of carbon dioxide and organic acids in the water. Bicarbonate and carbonate in moderate concentrations have little effect on the use of water for most purposes. Most natural waters do not contain large amounts of carbonate.

Sulfate is most plentiful in gypsum and shale but can be formed by the oxidation of iron sulfides. Dissolved gypsum and anhydrite contribute to the sulfate concentration of ground and surface waters. Excessive amounts of sulfate in waters containing calcium and magnesium tend to form hard scale in boilers.

The dissolved solids reported in this study consist of the solid residue left upon evaporation of a water sample. Excessive dissolved solids render the water unpalatable and limit its usability for many purposes.

Nitrate in water generally is considered a final oxidation product of nitrogenous material and may indicate possible pollution and contamination by sewage, organic waste, or nitrate fertilizers.

For many years, small amounts of fluoride have been recognized as necessary and desirable for development of healthy teeth and prevention of tooth decay in children. Excessive fluoride in drinking water, however, produces fluorosis (tooth mottling and staining and bone damage), which increases as fluoride concentration increases (Oklahoma State Department of Health, 1964, p. 7). Optimum fluoride levels for a community depend on the average annual temperature, and the temperature is used as an index of the quantity of water children drink. For the Lawton area, the greatest acceptable concentration of naturally occurring fluoride is 1.6 mg/L at the average annual temperature of 75.5°F (24.2°C) (Oklahoma State Department of Health, 1964, p. 7).

SUMMARY

Aquifers in the vicinity of the Wichita Mountains are alluvium along East and West Cache Creeks, the Rush Springs Formation and associated formations in the northeastern part of the area, and the Arbuckle Group in the Limestone Hills and south of the Wichita Mountains. The alluvium yields from 5 to 500 gal/min (0.3 to 32 L/s) of water with dissolved-solids concentrations ranging from 304 to 1,750 mg/L. However, recharge to the alluvium is limited to precipitation falling directly on the flood plains of the creeks. The Rush Springs and associated formations yield 10–300 gal/min (0.6–19 L/s) of water that is very hard and contains from 478 to 2,270 mg/L dissolved solids. The Arbuckle Group in the Limestone Hills yields as much as 100 gal/min (6.3 L/s) of water from springs and flowing wells; the water is very hard and has dissolved-solids concentrations ranging from 195 to 940 mg/L. The recharge area probably is limited to the Limestone Hills. South of the Wichita Mountains, the Arbuckle yields as much as 600 gal/min (38 L/s) of soft water, with dissolved solids ranging from 279 to 6,380 mg/L. Because the fluoride content ranges from 1.6 to 17 mg/L, the water generally is not consumed by humans but is used for industrial and recreational supplies. The high sodium concentration may make the water unsuitable for irrigation.

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West Cache Creek 4
  aquifers 11
  wells 4
Wichita Mountains 1, 2, 4, 5, 6, 7, 11

Type faces:	Text in 10- and 8-pt. Melior, with 2-pt. leading Front matter in Century Schoolbook Heads in 12-pt. Melior Figure captions in 9-pt. Helvetica, with 2-pt. leading Running heads in 9-pt. Melior
Presswork:	Miller 38-in. 2-color; covers on 23 by 29 Harris
Binding:	Smyth sewn
Paper:	Text on 100-lb. Patina
Covers:	Hardbound on Gane GC10 red linen on 160-pt. binder's board Softbound on 65-lb. Hammermill gray, antique finish