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GROUND WATER RESOURCES OF CANADIAN COUNTY, OKLAHOMA

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CONTENTS

ILLUSTRATIONS

Plates

TABLES

FIGURES

GROUND-WATER RESOURCES OF CANADIAN COUNTY OKLAHOMA

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ABSTRACT

Canadian County, in central Oklahoma, has an area of 891 square miles. The average annual precipitation in the County is about 29 inches, and the normal annual temperature is about 60°F. Farming is the principal occupation, and wheat is the major crop. Production of oil and gas from the West Edmond pool, flour milling companies, the railroad shops at El Reno, and the Mustang power plant near Lake Overholser are the principal industries.

The rocks at the surface range in age from Permian to Quaternary. The primary purpose of this investigation was to determine the water-bearing properties of the Quaternary terrace deposits and alluvium along the North Canadian River, but the water-bearing character of the Permian rocks also was studied.

Alluvium and terrace deposits consist of interfingering lentils of clay, sandy clay, sand, and gravel. The average thickness of the saturated materials encountered in 156 test holes drilled into the alluvium of the North Canadian River valley was 27 feet. The alluvium of the North Canadian River is the source of water supply for the municipalities of El Reno, Yukon, Okarche, Geary, and Calumet. Oklahoma City supplements its surface-water supply with water from the alluvium, and the Concho Indian Reservation gets its water from the same source. Additional users are the Mustang power plant, which uses ground water for cooling purposes, and irrigation farmers, with 15 wells which are used to irrigate 609 acres in the river valley. The water in the alluvium and terrace deposits of both river valleys is generally hard and locally contains excessive quantities of sulfate. Yields from wells in these deposits may be as much as 600 gpm, depending upon the amount of saturated sand and gravel present and the construction of the well.

Wells in the Rush Springs sandstone, which crops out in the southwestern part of the county, may be expected to yield up to 80 gpm depending on the thickness of the saturated sandstone present. Water from these sandstones is used for domestic purposes. The other Permian rocks in the county are considered to be poor aquifers which yield small amounts of highly mineralized water.

Aquifer tests were made on three wells in the alluvium of the North Canadian River valley. Results of these tests showed that the average coefficient of permeability is about 1,000 gpd per square foot; and the coefficient of storage, within range of fluctuations of the water table due to pumping wells, is about 0.10. For the entire thickness of water-bearing material, 0.15 is considered to be a better estimate of the average coefficient of storage.

The "safe yield" of the alluvium and terrace deposits is estimated tentatively to be about 270 acre-feet per square mile per year. This is based on an estimated recharge of 17.5 percent of the normal

rainfall in the area and on the assumption that all of the natural ground-water discharge could be salvaged. The major part of the natural discharge is due to transpiration by phreatophytes. These phreatophytes, which consist principally of willows and cottonwoods along the North Canadian River, discharge about 40,000 acre-feet per year —six times the present discharge by pumping. The amount of water stored in the alluvium and terrace deposits of the North Canadian River averages about 3,000 acre-feet per square mile.

INTRODUCTION

Purpose and Scope

This report gives results of an investigation in Canadian County, Oklahoma, of the ground-water resources of the bottom lands along the North Canadian River and of a reconnaissance of the ground water of the rest of the County. Begun in 1941 as a study of the relationship of the ground water in the valley to the flow of the river, the project was broadened later to include the ground water of the entire county. It could not, however, be made equally detailed and comprehensive for all parts of the county. Indeed, some areas offer so little promise of substantial quantities of ground water that intensive investigation of them is hardly warranted. For such areas this report indicates the relative abundance and quality of the ground water by reference to a selected minimum of records of wells and chemical analyses of water.

The foregoing does not mean that parts of the county outside this narrow strip are entirely without ground water. On the contrary, ground water is available nearly everywhere, and farms throughout the County generally depend on wells tapping it, but large yields are unlikely except along the river. In a few localities the rocks yield so little water, or the water is so highly mineralized, that water must be hauled from more favored places.

Most of the field work was done on the bottom lands of the North Canadian River and the greater part of this report therefore deals with a narrow strip of land along that stream. This strip has the principal large supply of ground water in the County. It is here that El Reno, Geary, Calumet, Yukon, and Okarche get their public water supplies. Some of the wells put down by Oklahoma City in 1953 to supplement its surface-water supply are in this strip in Canadian County; the rest are in the downstream extension of it in adjacent Oklahoma County. For years former Fort Reno got its water here. The United States Southwestern Reformatory gets its water supply from this strip by way of the El Reno public-supply system. One major electric-generating plant and several irrigators tap this source of ground water. Except possibly for a small area along and southwest of the Canadian River, no other part of the county has ground water in quantities adequate for these purposes. In addition to the wells of the larger users are many small-diameter shallow wells equipped with small electric or gasoline-powered pumps, or windmills, or rope and bucket, which furnish dependable supplies of water for domestic and stock use on farms.

Study of the ground water in the North Canadian valley was suggested in 1939 by Don McBride, then Chief Engineer of the Division of Water Resources, Oklahoma Planning and Resources Board, to Robert H. Dott, at that time Director of the Oklahoma Geological Survey. It was desired to determine the volume and rate of flow of ground water through the alluvium; how much of this ground water was derived from the river; and the effect of flood waters of differing character on the mineral content of the ground water. About that time, too, Oklahoma City was allocated by court order 90,000 acre-feet annually from the flow in the river. What effect might large withdrawals of water through wells for irrigation, municipal, and industrial use in upstream areas have on Oklahoma City's allocation of water? The answers to these questions, insofar as they relate to the authorized field work of the Geological Survey, have been sought by geologic and engineering methods that have become fairly well standardized for investigations of ground water, and these answers are presented in this report.

At all stages the work has been a cooperative project of the State and Federal Geological Surveys. It was begun under the general supervision of the late O. E. Meinzer, for many years Chief of the Ground Water Branch of the U. S. Geological Survey, and Mr. Dott, Director of the Oklahoma Geological Survey. It was continued and completed under A. N. Sayre, Chief of the Ground Water Branch until 1959, and under William E. Ham and Carl C. Branson, successively Acting Director and Director of the Oklahoma Geological Survey.

Location and Extent of Area

Canadian County is in central Oklahoma (fig. 1). The county boundaries follow township lines except for the eastern half of the southern boundary, which follows the channel of the Canadian River as surveyed in 1898; and a triangular extension, totaling less than one square mile, along the Canadian River where it enters the County on the west. The County is almost a rectangle, about 36 miles long from east to west and 24 to 27½ miles from north to south. Its area is about 900 square miles. The county seat is El Reno, which is nearly in the middle of the County and is 28 miles by highway west of Oklahoma City. Other towns are Yukon, Calumet, Mustang, Piedmont, and Union. Geary and Okarche are partly in Canadian County and partly in adjacent Blaine and Kingfisher Counties, respectively. Banner is a siding on the east-west line of the Chicago, Rock Island, and Pacific Railroad between El Reno and Yukon, and has a grain elevator and a few houses but no post office. Karns formerly was a station on the same railroad line between Calumet and Geary. The name survives as the designation of a store about a quarter of a mile south of the old location and beside U. S. Highway 270.

Previous Investigations

Investigation of the ground-water resources of Canadian County goes back to the early years of the century. C. N. Gould (1905) described the topography, geology, surface streams, springs and

Figure 1. Index map.

wells of Oklahoma Territory. On page 118 of that report he summarized the ground-water resources of Canadian County, stating that water is obtainable at moderate depths in practically all parts of the county. He pointed out that much of this water is from redbeds and is hard, but that among the sand hills north of the major streams and in the alluvium along those streams the water is softer. He called attention to springs, naming Caddo Spring as the most noteworthy, and stated that "of 21 wells reported from Canadian County 11 furnish soft water, 9 hard water, and 1 salty water. The average depth is 61 feet."

Many of the early bulletins of the Oklahoma Geological Survey contain brief descriptions, or at least a mention, of Canadian County. Hiram Phillips, J. W. Alvord, and J. W. Billingsley (1913) reviewed several possible ways of augmenting the water supply of Oklahoma City, including developments as far upstream as El Reno. Their recommendation to the mayor and board of commissioners favored the construction of a dam and reservoir on the North Canadian River near the Canadian-Oklahoma County line. Lake Overholser is essentially a fulfillment of this plan.

A. T. Schwennesen (1914) discussed the availability of ground water for irrigation in the North Canadian River valley from El Reno to Shawnee. He gave records of wells at El Reno, Banner and Yukon; logs of wells at El Reno and Banner; and described an irrigation project using ground water at Banner.

A. M. Piper (1931) of the U. S. Geological Survey in a brief manuscript for the U. S. Department of Justice pointed out that two sources were to be considered in seeking a water supply for the Southwestern Reformatory. These are the redbeds of Permian age, which, he concluded, would not yield an adequate water supply, and the alluvium along the North Canadian River.

Methods of This Investigation

The map (plate I, in pocket) showing the major aquifers of Canadian County, is the product of three geologists. S. L. Schoff began mapping the alluvium, terrace deposits, dune sand, and the contacts between these and the redbeds of Permian age in 1941, and completed it in 1954. He and L. V. Davis mapped the base of the Rush Springs sandstone in 1954, and Schoff supervised the compilation of the map. H. D. Miser mapped the several areas of terrace deposits southeast of El Reno while preparing the geologic map of Oklahoma (1954).

The formations of the Permian system older than the Rush Springs are not individually distinguished on Plate I. In general, they are minor aquifers affording only small quantities of water, some of it poor in quality. To map their boundaries with geological precision would require more work and expense than their hydrologic importance justifies. Field studies of their lithologic characteristics were made so that their hydrologic limitations would be better understood. Descriptions of these formations, given elsewhere in this report, indicate approximately where they crop out and where they may be penetrated by ordinary farm wells. The formations are outlined on the Geologic Map of Oklahoma (Miser 1954). P. A. Chenoweth and his students are preparing a geologic map and a report on the county.

Several base maps, on several scales and of several degrees of accuracy, were used in the field. The work was begun on a photostat of a preliminary draft of a base map for Canadian County showing only culture and drainage, on a scale of 1 inch to 1 mile. Other maps are: advance prints (blue-line) of the topography along the North Canadian River, scale about 2.7 inches to the mile; the Fort Reno, Geary, and Binger topographic quadrangles, scale 1:62,500, and the Kingfisher and Chickasha topographic quadrangles, scale 1:125,000. The North Canadian River maps ultimately were issued at scales 1, 2, and 3 inches to the mile, and these were used in office compilations of field data. Also used in office studies but not in the field was the advance print of the Cogar topographic quadrangle, scale 1 inch to 1 mile, an early-day map never released in final form. Contact prints of aerial photographs on a scale of about 3.1 inches to the mile were used in both field and office studies, especially in mapping the alluvium along the Canadian River. For some purposes they were examined stereoscopically.

The inventory of water wells is the work of four men. S. L. Schoff began it in the North Canadian River valley in 1941. Tom McCauley greatly extended the work in the same year, and E. W. Reed added to it in the following year. After World War II, Schoff and J. L. Mogg added a few wells to the records for the valley and extended the inventory into other parts of the county. Where possible, the field men measured the depth to the bottom and the depth to the static water level by lowering a graduated steel tape into the wells. They also measured the diameter of the casing and the height to which it extends above the land surface, and they supplemented the measurements by interviewing well users for information on water-bearing strata, yields of wells, and quality of the water.

With the help of W. A. Davis, Reed greatly augmented the data on depth to water by sinking about 50 drive-point wells into the alluvium of the North Canadian River. They bored holes down to the water table, or to some point below the water table where the hole caved in and deepening by boring became impossible. For this work a 2-inch hand auger was used. Next, they removed the auger and inserted a 1¼-inch well point on the end of a string of ¾-inch pipe. This they drove with a sledge hammer until a water-bearing sand was penetrated. Then they attached a pitcher pump, and pumped until the water coming from the well was reasonably clear. At some locations they had to try at several different depths before the wells would yield water by pumping. They completed the wells by pouring a concrete plug around the pipe, beginning at the ground level, to minimize seepage into the wells, which thereafter were used for observation of water-level fluctuations.

Test holes aggregating 2,000 feet were drilled at 52 sites under a contract between the Oklahoma Geological Survey and C. R. Frazier, of Oklahoma City. Reed supervised the drilling, and S. E. Williams collected the drill cuttings and prepared the field logs. David L. Schacht examined the cuttings in the laboratory of the Oklahoma Geological Survey, making sieve analyses and permeability tests of the sands.

Reed determined the altitudes above sea level of the inventoried wells where water-level measurements were obtained, of the drive-point wells, and of the test holes. He used a dumpy level, began and ended his traverses at standard bench marks, and at different times had as rodmen W. E. Riggs and W. A. Davis.

Reed and Mogg arranged and supervised pumping tests made at several locations in the North Canadian valley, following procedures used in the U. S. Geological Survey. The details of these tests will be found elsewhere in this report.

Reed, Schoff, and Mogg collected samples of water from wells in all parts of the county, emphasizing those tapping water in the alluvium of the North Canadian River. Analyses of these samples were made in laboratories of the U. S. Geological Survey, Quality of Water Branch, Washington, D. C., Austin, Texas, and Stillwater and Oklahoma City, Oklahoma.

Mr. Reed was transferred to the Washington office of the Geological Survey before he could write up the results of the investigation. His contribution to this report, therefore, is the substantial amount of field work that he did, and the review and revision of the report that he made in Washington. The greater part of the task of systematizing, sifting, and summarizing the field data fell to Mogg. He prepared most of the tables and analyzed and interpreted the pumping tests. His principal contribution is to the section on ground-water hydraulics. Schoff wrote the section on geologic formations, and wrote or contributed to some other parts of the report.

Well-Numbering System

The well-numbering system used in this report is based on the township system of the General Land Office. The first part of the well number is the township number, the second is the range number, and the third is the section. Thus 12N5W-1 designates a well in sec. 1, T. 12 N., R. 5 W. Where several wells are recorded in the same section, serial numbers are added to distinguish one from another. For example, well 12N5W-1-2 is the second well recorded in sec. 1.

In Table 9 the wells are grouped by townships. The well numbers are shown in the first, or left-hand, column. Test holes are numbered in the same way as water wells, and cannot be distinguished from the wells by the type of number used. They can be distinguished, however, by the symbols on the map (plate I).

Acknowledgments

Without the cooperation of many individuals who supplied information or aided in the collection of field date, this report would not be possible. It is not practical to mention all contributors, but special thanks are due to Bert Beals, Jr., President, Billington Lumber Co. and Jess Bigham, manager of the Billington farm, for arranging the aquifer test at the Billington farm. Records of wells and test holes, and sieve analyses of sediments encountered in test holes drilled for the Oklahoma City Water Department, were furnished by C. E. Bretz, consulting engineer. Records of water wells, pumpage, and driller's logs were furnished by city officials of El Reno, Geary, Yukon, Okarche, and Calumet. Thanks are also due to D. O. Lima, chief testing engineer, and to other engineers of the Oklahoma Gas and Electric Co. Their assistance during the aquifer test at the Mustang power plant and donations of records of wells and test holes, and sieve analyses were most helpful.

GEOGRAPHY

Topography and Drainage

Canadian County is part of the Central Redbeds Plains. About 40 percent, comprising a central strip extending from northwest to southeast across the County, is drained by the North Canadian River. The Canadian River drains about 32 percent of the county in a triangular area in the southwestern part. The Cimarron River drains about 27 percent of the area, a triangular area in the northeastern part. These streams all empty into the Arkansas River. Somewhat less than one percent of the area, in the extreme southwestern corner, is drained by way of Sugar Creek into the Washita River, which is a tributary of the Red River.

The Canadian and North Canadian Rivers flow at only slightly different altitudes. Comparison of adjacent segments of the two near the western boundary of the County shows the Canadian to be about 50 feet lower in altitude than the North Canadian. On the other hand, both are higher in altitude than the adjacent Cimarron and Washita Rivers. Near El Reno the North Canadian is about 1,300 feet above sea level, whereas an adjacent segment of the Cimarron (in Kingfisher County) is only about 1,000 feet above sea level—about 300 feet lower. The Washita River (in Caddo County) is 100 to 125 feet lower than the Canadian River.

Judged by the divides, the regional slope of the surface in Canadian County is southeastward. Thus, the divide between the North Canadian River and the Canadian River descends from an altitude of about 1,600 feet at the west line of the County to about 1,400 feet at the east line. This is a descent of 200 feet in about 34 miles, or almost six feet per mile. Likewise, the divide between the North Canadian River and the Cimarron River descends from an altitude of about 1,500 feet at the north line of the County to about 1,300 feet at the east line. This is a descent of 200 feet in about 31 miles, or somewhat more than six feet per mile.

Cimarron basin.—The area drained by the Cimarron River is generally rolling and has relatively broad, nearly flat divides. Where valleys are deepest, their bottoms are 20 to about 150 feet below the crests of the divides. The maximum—150 feet—is the difference in altitude between Uncle John Creek at the Kingfisher County line and a bench mark at Okarche, about two and one-half miles distant. At most places the topographic relief is not much more than 100 feet at the most. Slopes range from about 50 to about 120 feet per mile (one to two percent).

Area between Canadian Rivers.—The area between the North Canadian and the Canadian Rivers is a flat to undulating plain from the east line of the County westward to the west line of Range 8. The towns of Mustang and Union are on this plain. Valleys are shallow and slopes are gentle except for a few square miles of canyons bordering the Canadian River south of Mustang. These canyons are 100 feet or more deep at maximum, and at the most are two or three miles long. West of Range 8 the surface is hilly, and has a well-integrated drainage system. There the stream bottoms are 100 to 180 feet below the adjacent ridges. At places the difference in altitude is 160 to 180 feet within half a mile horizontally. Some slopes, therefore, approach seven percent.

Southwestern corner.—The area southwest of the Canadian River also is hilly, much like that just described. There, too, the bottoms of the canyons are 100 to 180 feet below the adjacent ridges, which may be half a mile distant, or less. Nevertheless, some of the uplands in that part of the County are fairly broad and relatively flat, and are being farmed.

North Canadian River.—The North Canadian River enters the County near the northwestern corner at an altitude of about 1,420 feet above sea level and flows southeastward to near the middle of the east line of the County. There it turns south, and winding back and forth across the county line it leaves at a point about eight miles north of the southeastern corner and at an altitude of about 1,200 feet. The length of the river measured along the channel is about 76 miles.

The average gradient of the North Canadian between the bridge north of Geary and the bridge north of Yukon is 2.9 feet per mile. The gradient, however, is not uniform across the County, as the following gradients for different stretches of river will show:

Reach of river	Gradient (feet per mile)
Bridge near Geary to bridge near Karns	2.2
Bridge near Karns to bridge near Calumet	3.0
Bridge near Calumet to bridge near El Reno	3.1
Bridge near El Reno to bridge near Banner	3.5
Bridge near Banner to bridge near Yukon	2.4

Within the County the river drains about 360 square miles. Its drainage basin is seven to 12 miles wide, and averages about nine miles. This is narrow compared with the basin of the Cimarron River, which along an adjacent stretch is 40 to 50 miles wide. On the other hand, it is comparable to the Canadian River basin, which in an adjacent stretch is seven to 14 miles wide.

Tributaries of the North Canadian River are short, especially those coming from the northern side. All the named ones drain from the south and in downstream order are: Sixmile Creek, near Calumet; Target Creek, near former Fort Reno; Fourmile Creek, just west of El Reno; Purcell Creek, near Banner; Shell Creek, about two miles west of Yukon; and Mustang Creek, which empties into the North Canadian River nearly on the east county line.

An impressive feature of the North Canadian River valley is a set of three benches that can be differentiated nearly everywhere. The lowest is the flood plain, and is three to 13 feet above the stream bed. Along most parts of the valley it is between half a mile and a mile wide, but it narrows to slightly more than 0.1 mile at a point about 3.5 miles upstream from El Reno and widens to about 2.5 miles immediately upstream from Calumet. Its surface bears the scars of former meanderings of the river and in general is sandy. Dune sand in hummocky hills covers part of it. Much of it is regarded as unsuited for cultivation. Cottonwoods, other trees, and brush grow on much of it.

At many places a steep slope ranging in height from three to 20 feet separates the flood plain from the intermediate bench. Locally, however, this slope is absent or ill defined. The intermediate bench is eight to 25 feet above the river bed. Along some stretches it is on both sides of the river; along other stretches all of it is on one side or the other, according to the meandering of the channel. Normally between one and one and a half miles wide, the intermediate bench attains a maximum width of about 2.25 miles. Scars of old meanders generally are lacking because they have been obscured by weathering and cultivation. It is typically flat and, being far enough above the channel to escape all but the highest floods; it is largely in cultivation. Many farm homes are on this bench; few are on the flood plain.

On the southern side of the river the slope separating the intermediate bench from the upper one is 10 to 35 feet high, and the bench itself is 17 to 45 feet above the river bed. The upper bench is best developed between old Fort Reno and Geary. Near Calumet it is between one and two and one half miles wide and slopes toward the river at the rate of three or four feet to the mile. A few small tributaries of the North Canadian have notched headward into it, so that in contrast with the intermediate bench it is somewhat dissected. Nevertheless, large areas are remarkably flat.

On the northern side of the river the slope rising from the intermediate bench—or at some places, from the flood plain—ranges from 11 to 65 feet in height. The bench surmounting this slope is at most 80 to 120 feet above the river. Its surface is flat to undulating, and locally is somewhat hilly because of sand dunes. On it is the ill-defined divide between the North Canadian and Cimarron Rivers.

Canadian River.—The Canadian River enters the County from the west near the bridge on U. S. Highway 66, about 11 miles north of the southwestern corner of the County, and at an altitude of about 1,370 feet above sea level. It flows southeastward, and at a point about 16 miles east of the southwestern corner it becomes the county line. Its length in and along the County is about 45 miles, and its altitude as it leaves the County is about 1,150 feet. Its gradient near the western boundary as determined from the Geary topographic quadrangle is about five feet per mile. Farther eastward, as shown by the Cogar quadrangle map (preliminary edition) and the Chickasha quadrangle, the gradient is about four feet per mile. The area within the County drained by this river is about 287 square miles.

Tributaries of the Canadian are relatively short. Those coming from the north are five to eight miles long at the most. The longest of those coming from the south is only about five miles. The only named tributaries in Canadian County are Dry Creek, which heads about five miles east of Union, Boggy Creek, which heads in the southwesternmost township and goes through the northwestern part of Grady County to empty into the main stream east of Minco. The divide marking the northern boundary of the Canadian valley is 230 feet above the stream bed and the divide on the south is about 330 feet above it.

As in the North Canadian River valley, two benches occur above the stream bed at many places in the valley of the Canadian River. Between Union and T. 11 N., R. 9 W. the bottom land rises gradually from the river bank to the bluff without an abrupt change in slope to set off one bench from the other, but in the SW¼ sec. 7, T. 12 N., R. 10 W., there are two benches separated by a steep slope about 25 feet high.

Cimarron and Washita Rivers.—The Cimarron River does not cross Canadian County but is 10 to 20 miles beyond the north line. It drains about 239 square miles of the County by way of Kingfisher, Dead Indian, Uncle John, Cottonwood, Soldier, and Deer Creeks. The Washita River is 20 to 34 miles south of Canadian County, and drains about five square miles adjacent to the southwestern corner of the County.

Climate

Canadian County has a moist-subhumid climate (Thornthwaite, 1941, p. 3, pl. 3). In winter the temperatures generally are moderate with occasional short periods of severe cold and relatively little snow. In summer, temperatures often are uncomfortably hot. Farming without irrigation is practical in most years, but several years of average or above-average rain may be followed by several dry years during which irrigation would be necessary for optimum crop growth.

The normal annual temperatures as reported by the U. S. Weather Bureau for El Reno and Geary are 60.4°F, and 61.3°F, respectively. The normal annual precipitation at El Reno is 28.27 inches; at Geary, 27.58 inches; and at Union, 32.19 inches. Records of temperature and precipitation have been kept at Geary since 1912; records of precipitation have been kept at El Reno since 1914, and at Union since 1913. At all three stations the lowest normal precipitation is in January and the highest in May. Tables 1 and 2 show temperature and precipitation data for El Reno.

TABLE 1
Mean temperature at El Reno, Oklahoma, in degrees Fahrenheit, based on available records 1931 through 1955

January	37.9	July	82.2
February	42.1	August	81.9
March	49.3	September	73.9
April	59.9	October	63.4
May	67.8	November	48.6
June	77.5	December	40.6
		Annual	60.4

TABLE 2
Mean monthly precipitation at El Reno, Oklahoma, based on available records 1931 through 1955

January	1.25	July	2.22
February	1.36	August	2.58
March	1.54	September	2.60
April	2.85	October	2.19
May	4.79	November	1.80
June	3.83	December	1.26
		Annual	28.27

Population

The population of Canadian County according to the 1950 census was 25,644. The population of El Reno was 10,991. Calumet with 339 and Union with 301 were reported separately for the first time in 1950.

Transportation

Canadian County is served by two railroads, and three bus lines. The Chicago, Rock Island and Pacific railroad has two main lines, an east-west line connecting Oklahoma City and Amarillo, Texas, passes through Yukon, El Reno, Calumet, and Geary; a north-south line, which connects Wichita, Kansas, and Fort Worth, Texas, passes through Okarche, El Reno, and Union. The St. Louis and San Francisco railway crosses the southeastern part of the County, passing through Mustang. Bus service is furnished by Midcontinent Trailways, Southwestern Greyhound Lines, and Oklahoma Transportation Co.

U. S. Highway 66 and State Highway 1 cross the County from east to west. U. S. Highway 270 coincides with U. S. 66 and State Highway 1 from the east line of the County to an intersection 8 miles west of El Reno, where it turns north to Calumet and thence northwestward to Geary. U. S. Highway 81 crosses the County from north to south. State Highway 3 extends diagonally southeastward from Okarche toward Oklahoma City. State Highway 4 is a farm-to-market road that extends southward from Piedmont across the North Canadian River to Yukon and thence southeastward from Yukon to connect with N. W. 10th Street, Oklahoma City. State Highway 152 extends east-west through Mustang and joins U. S. Highway 81 at Union to pass southward over the Canadian River. State Highway 37, which connects Moore in Cleveland County with Hinton in Caddo County, crosses the part of Canadian County that is southwest of the Canadian River. Well maintained dirt- and gravel-surfaced roads on section lines give access to practically all parts of the County. A few of the rural roads have been paved.

Agriculture

Agriculture is practiced throughout the County. The principal crops are wheat, hay, oats, and sorghum (table 3), but many other crops are grown. Wheat and pasture lands are mostly on the upland bedrock areas; whereas the North Canadian and Canadian River valleys are devoted principally to hay and corn.

TABLE 3
Agricultural Products of Canadian County, Oklahoma, 1949
(From 1950 Census of Agriculture, U. S. Department of Commerce.)

A. Value of products sold:		
Field crops, other than vegetables, fruits, and nuts	$5,946,203	
Vegetables	15,348	
Fruits and nuts	2,811	
Horticulture specialties	19,320	
All crops		$ 5,983,682
Dairy products	1,195,518	
Poultry and poultry products	502,291	
Livestock and livestock products, other than dairy and poultry	3,358,907	
All livestock and livestock products		5,056,716
Forest products		696
All farm products		$11,041,094
B. Some principal crops, in acres:		
Wheat	185,860	
Hay	23,470	
Sorghum (excluding syrup)	18,234	
Oats	17,817	
Corn	16,749	
Cotton	15,776	
Cowpeas	5,191	
Barley	647	
Rye	428	

Mineral Industries

The mineral industries of Canadian County are the production of oil and gas and building sand. The oil and gas wells of the West Edmond pool extend into the northeastern part of the County. The Tindel Materials Co. of Geary operates a plant producing building sand in the western part of the County, near Bridgeport (Warren, 1954, p. 71; Netzeband, Ham, and Warren, 1954, p. 19). Other plants producing building sand formerly were operated on the northern side of the North Canadian River near El Reno.

The El Reno oil field was opened in 1953 with the discovery of oil in sec. 14, T. 12 N., R. 7 W. As of January 1, 1954, cumulative production was 597 barrels of oil (Rowe, 1954), all from the Huchtemann no. 1 well of the Sinclair Oil and Gas Co.

Early bulletins of the Oklahoma Geological Survey refer to the Okarche gypsum plaster mill, which was in sec. 34, T. 14 N., R. 8 W. Gould (1902, p. 129) stated that the plant had been operating for several years and was then the property of the U. S. Gypsum Co. The raw material was gypsite, or "dirt-gypsum," and at first was obtained at the site. This deposit soon ran out, and by 1902 the raw material was being hauled about two miles in wagons. Water for the plant was obtained from a spring in the sand hills to the south. This plant is mentioned in several later reports, and Snider (1913, p. 174) reported that the mill was closed in 1912. A plant for the manufacture of pressed brick, utilizing local red clay, was operated at El Reno in the early years of the twentieth century (Redfield, 1927, p. 102). The exact period of operation is not reported.

Other Industries

El Reno is the industrial center as well as the agricultural and governmental center of Canadian County. The Chicago, Rock Island & Pacific Railroad Co. maintains its office for its southwestern district at El Reno and also its division yards and shops, including a diesel-repair shop. Other industries in El Reno are plants manufacturing or processing feed and grain, chemicals, dairy products, beverages, and sheet-metal products. Excluding the payroll of the Chicago, Rock Island & Pacific Railroad Co., salaries and wages paid by 12 manufacturers in El Reno were about $1,000,000 in 1950.

GEOLOGY AND WATER-BEARING CHARACTERISTICS OF THE ROCKS

GENERAL GEOLOGY

Canadian County has both consolidated and unconsolidated rocks. The unconsolidated rocks consist largely of sand, gravel, and clay, and occur as alluvium underlying the bottom lands along the streams, as terrace deposits on higher lands adjacent to the streams, and as dune sand overlying both the alluvium and the terrace deposits. Both the alluvium and the terrace deposits are water bearing, yielding water in greater abundance and better in quality than do the consolidated rocks. The unconsolidated rocks belong to the Quaternary system and geologically are much younger than the consolidated rocks. Consolidated rocks are the bedrock and consist of successive strata of shale, siltstone, and very fine-grained sandstone, together with minor amounts of gypsum and dolomite. Except for a sandstone that occurs in the southwestern part of the County, the consolidated rocks are poor aquifers, yielding water of inferior chemical quality and in quantities sufficient only for stock and domestic use on farms. All the consolidated rocks exposed at the surface are of Middle Permian age.

The bedrock formations dip southwestward toward the axis of the Anadarko syncline, a broad asymmetric trough extending from southwestern Garvin County northwestward into the northwestern part of the Panhandle of Texas. This syncline is the dominant structural feature of northwestern Oklahoma, and has within it lesser folds, near which the dip of the rock is either more or less than the average.

The rocks exposed at the surface include a few distinctive layers from which the strike and dip could be determined. In the southwestern part of the County the top of the Marlow formation was identified at several places and the altitude was estimated from topographic maps of the U. S. Geological Survey. This procedure showed a strike of N. 70°W., and a dip to the south of 22 feet to the mile in Tps. 12 and 13 N., R. 10 W. The amount of dip agrees fairly well with Kite's reported 15 to 20 feet to the mile (1927, p. 8), but the direction differs somewhat from the southwestward dip reported by him for the surface rocks.

The difference in strike between the lower formations and the top of the Marlow may be regarded as evidence for an unconformity. Brown (1937, fig. 7) has shown how contours drawn on the base of the Marlow formation diverge from contours drawn on the base of the Blaine near Chickasha, swinging northwestward in Tps. 7 and 8 N., R. 8 W. (Grady County). If traced northwestward across a couple of townships into southwestern Canadian County, these contours might be found to swing farther westward and to aline with the strike determined above for the top of the Marlow. The latter, therefore, may possibly be evidence in support of the unconformity reported by Brown.

GEOLOGIC FORMATIONS

All the bedrock exposed at the surface in Canadian County belongs to the Permian system and because of its dominantly reddish color is often referred to as redbeds. Formations of the Permian that do not crop out within the County but do so farther east are present in the subsurface rocks. Below them are rocks belonging to earlier systems of the Paleozoic, totaling more than 10,000 feet. Although many of these older Paleozoic rocks contain water and might yield it readily enough to wells, the water is too highly mineralized for most uses. None of the older rocks is known to yield potable water.

PERMIAN SYSTEM

The rocks of Permian age exposed in Canadian County are divided into six formations (table 4). The oldest is the Hennessey shale, of which only the upper part is represented. It occurs in the northeastern part of the County and includes at the top the Cedar Hills sandstone member. Overlying this is the El Reno group, consisting of the Flowerpot shale, the Blaine formation, and the Dog Creek shale. The Dog Creek, in turn, is overlain by the Whitehorse group, in which are the Marlow formation and the Rush Springs sandstone. Locally the Marlow includes in its lower part the Verden sandstone member. These formations will yield ground water only in small quantities and of relatively poor chemical quality, except the Rush Springs sandstone, which yields ground water in moderate abundance and of moderately good quality.

Published descriptions give few lithologic details for these formations as they occur in Canadian County. Because the formations of Permian age, excepting the Rush Springs sandstone, are not aquifers of great economic importance susceptible to large-scale development for municipal, industrial, or irrigation use, the

TABLE 4.—GEOLOGIC FORMATIONS IN CANADIAN COUNTY, OKLAHOMA; AND THEIR WATER-BEARING CHARACTER

System	Group	Formation	Member	Thickness (feet)	Lithology and water-bearing character
Quaternary		Dune sand		0-25	Wind-deposited sand, heaped into hummocky hills; locally overlies alluvium and terrace deposits. Thin and above the water table and so yields no water directly to wells.
Quaternary		Alluvium		0-60	Stream-laid sand, gravel, silt, clay, underlying first and second benches above the Canadian and North Canadian Rivers; coarse sand and gravel in lower part yields water freely, but upper part at many places is silt or clay. Yields more per well than other aquifers in Canadian County.
Quaternary		Terrace deposits		0-75	Older alluvium, deposited by streams that subsequently have shifted and deepened their channels; consists of sand, gravel, silt, clay, and is likely to yield water most freely from gravel in the lower part, but yields much lower than in the alluvium. Quality of the water is best in the County.
		UNCONFORMITY			
Permian	Whitehorse	Rush Springs sandstone.		0-240	Fine-grained reddish brown sandstone. Furnishes water of good quality to farm wells south of the Canadian River. Outliers north of the Canadian River are too thin and small to afford much reservoir capacity.
Permian	Whitehorse	Marlow		120±	Siltstone and very fine-grained sandstone; clayey, and gypsiferous. Yields only meager quantities of rather mineralized ground water. Includes Verden member, calcareous sandstone about 10 feet thick, that occurs as a caprock on buttes and small hills, but is not an aquifer.
		UNCONFORMITY			

TABLE 4 (continued)

System	Group	Formation	Member	Thickness (feet)	Lithology and water-bearing character
PERMIAN	El Reno	Dog Creek shale		200±	Shale, reddish brown and reddish orange, discontinuous bands of light greenish gray silt, and thin layers of dolomite; yields from fractures meager quantities of rather highly mineralized ground water.
		Blaine		0?-125	Shale, reddish brown and reddish orange, and interbedded gypsum. May yield small quantities of highly mineralized water from fractures at some places, but in general is not a good source of water.
		Flowerpot shale		150-200	Lenticular reddish brown shale and reddish orange siltstone, with thin bands of light greenish gray silt. Yields ground water meagerly from silty and sandy beds and from fractures in the shale. Water moderately to highly mineralized.
		Hennessey shale	Cedar Hills sandstone	600	Shale and siltstone, reddish brown and reddish orange, specks and spots of light-greenish gray. Yields only meager quantities of ground water.
					Dominantly reddish brown shale, with a few layers of reddish brown and reddish orange siltstone; both shale and siltstone have abundant circular spots and splotches and stringers of light greenish gray at some places. Yields only meager quantities of ground water.
		Garber sandstone			Alternating sandstone and shale, not exposed at surface in Canadian County but present in subsurface rocks; contain highly mineralized water, too saline to drink, in Canadian County, but the sandstones constitute an important aquifer farther east, as in Oklahoma County.
		Wellington		?	
LOWER PERMIAN AND OLDER PALEOZOIC SYSTEMS				10,000±	Many formations of varied lithology, some of which contain highly mineralized water. None known to yield potable water.

detailed work necessary to define their boundaries closely and to map them accurately was not made part of this investigation.

Hennessey Shale

The principal outcrop of the Hennessey shale is in the northeastern part of the County north of the North Canadian River, in Tps. 13 and 14 N., R. 5 W., and the northeastern part of T. 14 N., R. 6 W. As shown on the State geologic map (Miser, 1954), about half of this area is underlain by the Cedar Hills sandstone member of the Hennessey and the remainder by the underlying unnamed shale member. The Hennessey crops out also in a narrow band along the western side of Lake Overholser in Tps. 11 and 12 N., R. 5 W., where the two members are not differentiated. Only the upper two-fifths of the formation crops out at the surface within the county, inasmuch as the lower part is in adjacent Oklahoma County, but all of it should be present in the subsurface rocks at most places west of R. 5.

Rural water wells that begin on the outcrop of the Hennessey almost certainly draw water from the Hennessey. Few or none are deep enough to penetrate the underlying formation. A few wells that begin on the outcrop of the next younger formation within a mile or so of the boundary between that formation and the Hennessey doubtless penetrate the Hennessey and draw water from it.

Lithologic character.—The Hennessey consists dominantly of reddish-brown shale in which are layers of siltstone. The shales are clayey to silty, and the siltstones contain large amounts in the clay sizes. The Cedar Hills sandstone member in Canadian County is not greatly sandier than the unnamed shale member below it. Near the top, however, are silty ledge-making layers that in a general way, at least, distinguish it from the overlying Flowerpot shale.

Unnamed shale member.—The lower member as exposed in Canadian County consists principally of shale but also contains layers of siltstone. Beds of essentially homogeneous shale range from six inches to 10 feet or more in thickness. Much of the shale is massive. Where stratification is evident it ranges rather widely from thinly laminated to medium bedded. Some shales that obviously have rather uniform stratification do not split along that stratification but break in small sharp-edged polygonal fragments, much as massive shale does. The shale typically is moderate reddish brown or pale reddish brown. Some beds are dark reddish brown and others are moderate to reddish orange. Shades between any two or three of these colors also occur.

Some beds of both shale and siltstone have an abundance of light-gray and gray-green spots. Accordingly the Hennessey might be characterized as the gray-spotted formation, but it remains to be determined whether this characteristic is typical. This investigation has shown only that such spots are common in the Hennessey of northeastern Canadian County. The spots range up to three inches in diameter. Many are perfectly circular.

The siltstones are thick bedded and in layers up to two feet thick. Locally they are ripple marked. They are moderate reddish orange, moderate reddish brown and moderate reddish orange, or colors intermediate between these.

Cedar Hills sandstone member.—The shale and siltstone of the Cedar Hills sandstone member of the Hennessey are much like the shale and siltstone of the underlying unnamed member. This similarity is to be expected, inasmuch as the Cedar Hills is regarded as pinching out southward and is not distinguished south of the North Canadian River. The alternating shale and siltstone are even bedded, showing little or no tendency toward lenticularity. This evenness contrasts with the overlying Flowerpot, which in many exposures exhibits marked lenticularity.

The siltstone is in rather well-indurated layers ranging from a fraction of an inch to about four feet in thickness. Some of it is sandy and some is shaly, and some layers are slightly friable. Some beds weather into rather smoothly rounded forms and tend to spall off in flakes diagonal to the bedding. Moderate reddish orange and pale reddish brown are the common colors. Some layers are partly of one of these colors and partly of light greenish gray. The gray, however, makes up only a minor part of the member. One layer of the siltstone is liberally sprinkled with light gray specks and spots, the largest being less than an inch across.

The shale is in layers ranging from one foot to more than 16 feet in thickness. Some beds are flaky; others are massive. Typical colors are pale reddish brown, moderate reddish brown, dark reddish brown, and shades intermediate between these. Light gray occurs in a few circular spots up to two inches in diameter and in stringers of rounded to elongate blotches.

El Reno Group

Flowerpot Shale

The Flowerpot shale overlies the Hennessey shale and is the lowest formation of the El Reno group. Its outcrop is about 10 to 12 miles wide and extends diagonally southeastward across the county. Terrace deposits conceal the Flowerpot shale on the upland between the North Canadian and Cimarron Rivers east of U. S. Highway 81 and in small areas on the upland southeast of El Reno.

The outcrop covers all of T. 14 N., R. 7 W., and large parts of Tps. 10 and 11 N., Rs. 5 and 6 W.; T. 12 N., Rs. 5-7 W.; T. 13 N., Rs. 6 and 7 W.; and T. 14 N., Rs. 6 and 8 W. It also covers small parts of Tps. 10 and 11 N., R. 7 W.; T. 13 N., R. 5 W.; and T. 14 N., Rs. 5 and 9 W.

In the absence of a close determination of the dip of the rocks in the outcrop area of the Flowerpot shale, the thickness of the formation can only be approximated. The width of outcrop is about 12 miles, and if the dip is 15 or 20 feet to the mile, as reported by Kite (1927, p. 8), the thickness is about 180 to 240 feet. Most water wells drilled within the outcrop area tap only the Flowerpot shale. A few near the eastern boundary may go below it to tap the Hennessey shale. Within a mile or so of the western boundary some water wells may tap the Flowerpot although beginning on the overlying Blaine formation.

Lithologic character.—The Flowerpot consists of lenticular reddish-brown shale, reddish-orange siltstone, and very fine-grained sandstone. At many places thin bands of light gray shale or siltstone break the monotony of the redbeds. In contrast with the Hennessey shale, the Flowerpot has few circular gray spots. In the SE¼ sec. 20, T. 14 N., R. 7 W., is a rock clay containing layers, splotches, and stringers of light gray, but none is as perfectly circular as the spots in the Hennessey. Lenticularity and cross-bedding also contrast with the Hennessey, in which even-bedding is the general rule.

The shales are dominantly moderate reddish brown or pale reddish brown. Some beds are dark reddish-brown, and a few are moderate reddish orange. As exposed the shale beds range from a few inches to about 6 feet in thickness. Irregular thin light gray zones and thin hard sandy layers are included at places. In the SE¼ sec. 20, T. 14 N., R. 7 W., a lens of shale pinches out between layers of siltstone and has gray bands at its top and bottom and near the middle.

The shales include thin ledgy layers at places. In the SE¼ sec. 20, T. 14 N., R. 7 W., for example, about six feet of silty laminated shale crops out along a creek bed, and is overlain by a ledge consisting of one to three layers of shaly siltstone separated by shale layers one-half to one inch thick. Each siltstone bed is moderate reddish orange below and light gray above, the gray portion ranging from paper-thin to about one inch in thickness. The individual siltstone beds range from one and one-half to three inches in thickness, and thicken and thin along the outcrop.

The siltstones and sandstones of the Flowerpot are lighter colored than the shales. Typically they are moderate reddish orange. Only a few are moderate reddish brown or an intermediate shade. The more sandy a bed is, the more nearly it approaches moderate reddish orange. The sandstones are only slightly coarser than the siltstones. The layers range from a fraction of an inch to 12 feet in thickness. Some layers show cross-bedding, some show little or no bedding, and some have approximately horizontal beds alternating with thicker zones of irregular or indistinct bedding.

The even bands of light greenish gray range from four to 12 inches in thickness and are so much alike that none is useful as a stratigraphic marker. Furthermore, they seem not to be persistent for long distances, although two or three such bands may extend entirely across a single exposure. The fact that some gray bands are at boundaries between shale and siltstone suggests that they are related to the change in texture of the rock; and, hence, that their color is due to a change that has occurred since deposition. This change might be the result of the concentration of ground water at the boundary between siltstone and shale, and presumably involved the removal of iron oxide from the rock or its reduction from the ferric to the ferrous state.

Blaine Formation

The Blaine formation overlies the Flowerpot shale and is the middle formation of the El Reno group. It is distinguished from formations above and below principally by its content of gypsum. Northward from Canadian County through Blaine, Major, Woods, and Harper Counties it has at most places three thick beds of gypsum and dolomite separated by reddish-brown shale, and at some places it has five beds of gypsum. The gypsum beds thin southeastward from Blaine County and extend only into the northwestern part of Canadian County.

The outcrop of the Blaine in Canadian County is about a mile wide and extends from near the middle of the north line of T. 14 N., R. 9 W., southeastward to the middle of T. 13 N., R. 7 W. There it is concealed by terrace deposits on the upland north of the North Canadian River, and farther south it is concealed by alluvium along the river. It appears west of El Reno, making a north-south band across the western part of T. 12 N., R. 7 W. It has not been mapped south of T. 12 N. in Canadian County, although the formation doubtless is represented by some of the shale in that area.

The outcrop area north of the North Canadian River is rough because the dolomite and gypsum beds of the formation make ledges and a succession of steep and gentle slopes. This area is not well suited to cultivation and because it is not favored for dwelling sites few wells have been drilled there for water. A few wells on the outcrop and a few beginning nearby on the lower part of the Dog Creek shale may tap water in the Blaine. A few wells beginning on the lower part of the Blaine doubtless penetrate and get water from the underlying Flowerpot shale.

Lithologic character.—Green (1936, p. 1468) reported that in T. 14 N., R. 9 W., the Blaine totals 125 feet and has five gypsum beds. The shales between the gypsum beds are unnamed. Greene pointed out that the gypsum beds wedge out southeastward but that dolomite beds immediately below two of the gypsums are reliable stratigraphic markers traceable across the county.

Gray dolomite caps a flat-topped ridge at an altitude of about 1,320 feet in the northwestern part of sec. 11, T. 14 N., R. 9 W., and appears in a small butte known as The Mound, near the east quarter corner of the same section. In the road about a quarter of a mile south of the northwest corner of the section it seems to be two or three feet thick as it is in slabs from the bed that have crept down the slope. In nearby natural exposures, where the underlying reddish-brown shale can be seen, it is only six to 12 inches thick.

A white resistant ledge about one foot thick crops out about 0.3 mile north of the Corner Door school, in the SW¼ sec. 21, T. 14 N., R. 8 W. It probably represents the top of the Blaine at this locality because it is the highest such bed. Only reddish brown shale containing a few gray bands is exposed southward to the boundary with terrace deposits. The resistant ledge is noteworthy because it contains oolitic limestone suggestive of lacustrine deposition. The oolites are 0.2 to 0.3 mm in diameter, and many are hollow. With them are shell fragments, possibly the remains of pelecypods. Oolite makes up much less than half the bed, which includes a couple of thin layers of dense white limestone as well as other types, and a little reddish-brown shale. The altitude of this limestone is about 1,328 feet above sea level.

Gypsum crops out in the section-line road about 0.1 mile north of the above locality and at a substantially lower altitude than the resistant white layer. It appears, also, in the lane leading to a house west of the road, and here a part of it is satin spar. Gypsum possibly representing the base of the Blaine crosses the road about 0.7 mile farther north, in the SW¼SW¼ sec. 16. The difference in the altitude between this bed and the resistant white layer near the Corner Door school is about 60 feet—only about half the thickness Greene reported for the Blaine in the next township to the west.

A gray dolomite having a maximum observed thickness of about 10 inches crops out in the NW¼ sec. 29, T. 14 N., R. 8 W. Under it is about seven feet of shale, including near the middle a two-inch layer of reddish brown and gray siltstone. This location is only a little more than one mile southwest of the white limestone ledge near the Corner Door school, but the altitude of the bed is about 50 feet higher (1,380 feet above sea level).

The shales in the Blaine are thicker than the dolomites and gypsum beds, and make up much more than half the total thickness. They are similar to the shales in the older formations in both color and structure.

Dog Creek Shale

The Dog Creek shale overlies the Blaine gypsum and is the uppermost formation of the El Reno group. In the northern part of the County its outcrop is 0.5 mile to 1.5 miles wide and extends southeastward from near the northeastern corner of T. 14 N., R. 10 W., to U. S. Highway 81. South of the river the outcrop is two to three miles wide from Geary to the vicinity of Calumet. There it swings southward. Near El Reno it is about six miles wide, and near Union it spreads out to a width of about 15 miles. It occurs as narrow bands on both sides of the Canadian River extending upstream beyond the western line of the County.

Many water wells in the outcrop area tap water in the Dog Creek shale. Some beginning on the lower part of the formation may penetrate and draw water from the underlying Blaine formation or the Flowerpot shale. Possibly a few wells that begin on the overlying Marlow formation get water from the Dog Creek.

Lithologic character.—Green (1936, p. 1469) reported that the Dog Creek shale in Canadian County is more than 200 feet thick, and that it has discontinuous layers of dolomite in the lower 50 feet. Field studies for the present report disclosed little to distinguish the shales of the Dog Creek from the shales of the older formations. Most are pale reddish brown or moderate reddish brown or an intermediate shade. Light gray bands similar to those in the Flowerpot are common. They are not persistent but grade into the surrounding reddish-brown shale within relatively short distances. Much of the shale is massive, but included in it are thin hard layers and ledges, most of which are somewhat coarser textured than the shale. They are, as a rule, siltstone or very fine-grained sandstone. A bed of dense, pale reddish-brown clay within 30 feet of the top of the formation crops out beside the road in the NE¼ sec. 2, T. 11 N., R. 10 W., and has a band of light gray associated with it.

Whitehorse Group

Marlow Formation

The Marlow formation overlies the Dog Creek shale and is the lower of the two formations comprising the Whitehorse group. It is composed principally of siltstone and very fine-grained sandstone, and is somewhat coarser textured than the older formations exposed within Canadian County. It includes near the middle the Verden sandstone member, and has at the top two thin dolomite beds known as the Relay Creek dolomites. North of the Canadian River they crop out at the surface or lie immediately below the soil in most of T. 12 N., R. 9 W., and T. 13 N., R. 10 W.; and in the southwestern quarter of T. 13 N., R. 9 W., and the northeastern part of T. 12 N., R. 10 W. South of the Canadian River, they crop out in a narrow band, parallel to the river, that extends from the west line of T. 12 N., R. 10 W., to the south line in T. 11 N., R. 8 W. They crop out, also, along Boggy Creek in the southwestern part of T. 11 N., R. 9 W.

The Marlow formation is 100 to 120 feet thick, and where it underlies large areas, as it does north of the Canadian River and south of Geary, most of the farm wells probably tap water in it. Although it does not rank as a prolific aquifer, it probably yields water more freely than does the underlying Dog Creek shale. Wells are drilled into the less-promising Dog Creek only where the Marlow is too thin to contain much water or is too tight to yield it. On the other hand, the Marlow is less prolific than the overlying Rush Springs sandstone. Wells that begin on the outcrop of that sandstone ordinarily will be drilled into the Marlow only if they fail to find an adequate supply of water in the Rush Springs.

Lithologic character.—Typically, the Marlow is even-bedded reddish-brown siltstone and shale. The formation is gypsiferous, and the ground water in it is hard at most places and contains much sulfate. Included are several white gypsiferous layers, a few of which can be traced for several miles but none of which persists over wide areas (Davis, 1955, p. 64). The gypsum occurs as satin spar, as thin layers, as inclined sheets cutting across bedding, and as chunks one to three inches across. The chunks suggest that gypsum eroded from an older formation—possibly the Blaine—was deposited mechanically as a pebble, not chemically as a precipitate.

The Marlow formation generally is finer grained than the Rush Springs, but at some places the reverse is true. A sample from the upper part of the Marlow in the SE¼ sec. 32, T. 12 N., R. 10 W., for example, was broken down into loose grains and these were shaken by hand through graded three-inch sieves. More was retained in the grade size 0.25-0.125 mm (fine sand) than in grade size 0.125-0.062 mm (very fine sand).

The Verden sandstone member of the Marlow formation has been described by Bass (1939, p. 559) and Evans (1948, p. 42-43, 1949, p. 82-86). According to Bass, it consists of relatively thick beds of medium- to coarse-grained sandstone, composed of well-rounded quartz and subangular chert grains cemented by calcium carbonate. The cement, indeed, makes up about 50 percent of the rock. Included are minor amounts of laminated shale in thin layers. The whole is about 10 feet thick where not eroded. The outcrop is less than 1,000 feet wide at most places, but extends with interruptions northwestward from northern Stephens County through Grady and Caddo Counties into southwestern Canadian County. Its occurrence in the last-named county is not shown on plate I, but is shown on the Geologic Map of Oklahoma (Miser, 1954). Because it is relatively thin and occurs only in small areas, the Verden has little bearing on the occurrence of ground water.

According to Davis (1955, p. 65), two persistent beds of dolomite occur at the top of the Marlow formation, and have been designated by Evans (1931, p. 416) as the upper Relay Creek dolomite and the lower Relay Creek dolomite. These range from paper thin to about four inches in thickness and are separated by zero to 25 feet of shale and red sandstone. Locally the dolomite beds grade into gypsum, and at places one or both may be missing. About one foot below the upper dolomite bed at some places is a layer of shale of a slightly different color from the rest of the formation. Termed the "pink shale," it is approximately moderate orange pink (10 R 7/4) in the rock-color classification. Where this shale occurs below a dolomite, the dolomite may be identified as the upper dolomite of the Relay Creek. Otherwise, a single dolomite cannot be safely identified as either the upper or lower one of the pair. Nor is this type of shale by itself, without associated dolomites, enough to identify the horizon of the upper dolomite, because beds of similar shale occur at other levels within the formation. The upper dolomite marks the top of the Marlow, and was identified in a number of places in Canadian County.

Rush Springs Sandstone

The Rush Springs sandstone overlies the Marlow formation and is the upper of the two formations comprising the Whitehorse group. It is the formation at the surface or immediately below the soil in most of T. 11 N., R. 10 W., in the southwestern one-third of T. 11 N., R. 9 W., and in the southwestern quarter of T. 12 N., R. 10 W. The outcrop of the Rush Springs in these townships is shown on plate I. The formation occurs also as outliers capping ridges north of the Canadian River in Tps. 12 and 13 N., Rs. 9 and 10 W. These outliers are not shown on plate I because they contain little or no ground water.

Most wells drilled in the outcrop area of the Rush Springs tap ground water in that formation. A few wells drilled near the margin of the outcrop or on the outliers may penetrate the Rush Springs without finding water, and therefore may be continued into the underlying Marlow formation.

Lithologic character.—The Rush Springs sandstone is a rather uniformly very fine-grained sandstone, typically cross-bedded and moderate reddish orange. In general it is coarser than the Marlow, but as mentioned under the discussion of that formation, this relationship is reversed locally. At some places the Rush Springs is siltstone rather than fine-grained sandstone, and at some places it includes shale. Because of this similarity it is not everywhere easy to differentiate the Rush Springs from the Marlow unless the position of the upper Relay Creek dolomite is known. Where the Rush Springs has not been eroded, its thickness is about 330 feet (Davis, 1950, p. 6, 17). In Canadian County, however, it has been eroded. The greatest remaining thickness is probably in the NW¼ sec. 17, T. 11 N., R. 10 W., where it is between 200 and 240 feet. In the western half of the same township the thickness of the Rush Springs under the divides is generally between 125 and 200 feet. To the southeast across T. 11 N., R. 9 W., the thickness remaining under the divides is probably between 100 and 150 feet, and the outcrop narrows.

Water-bearing Character of Permian Rocks

Rocks so fine grained as the greater part of the Permian in Canadian County generally are poor aquifers. Their fine texture means that in them the openings, or pore spaces, are small—of sizes such that molecular forces hold tightly to the mineral grains most of the water that may be present. Even in coarse-textured rocks a part of the water is retained in this way, so that the volume of water that will drain from a saturated sand, for example, is less than the total volume of pore space. Shale normally will yield the water contained in its pore spaces slowly. Where shale yields water relatively freely, the water is contained in cavities left by the removal of soluble minerals or in fractures. Although siltstone is composed of somewhat coarser mineral grains than is shale, it ranks as a poor aquifer, capable of delivering no more than a few gallons per minute unless thick. From these general considerations, the formations from the Hennessey upward through the Marlow, inclusive, seem incapable of yielding more than a few gallons of water per minute. No wells of large yield have been reported from them in Canadian County. Nevertheless, exceptions to the general rule have cropped up elsewhere in the State and deserve consideration here.

The city of Enid began pumping ground water from wells in the Hennessey shale about 1949, and in 1954 had 17 wells of this kind. Located about 15 miles southwest of the city, these were yielding 55 to 300 gallons of water per minute per well, and the water was being used to augment ground-water supplies drawn from another aquifer. Tests had been made for 26 additional wells, 10 of which had been completed but were not yet in regular service. Examination of a drill core from a test hole drilled in the area of this development suggests that the water is contained in and moves through solution openings. Fractures also may be effective, but their relative importance could not be determined from the core. Accidental breaks caused in the drilling or in removing the core from the hole could not with certainty be distinguished from natural fractures.

Phenomenal yields have been obtained from wells drilled into the redbeds of Greer, Harmon, and Jackson Counties. Many wells have been completed that yield more than 1,000 gallons per minute, and a few that yield about 2,000. On the other hand, a good many dry holes and wells of small yield have been drilled and abandoned in the midst of seeming plenty. The water-bearing formations here are the Blaine gypsum and the Dog Creek shale. In part of the area, the Dog Creek contains as much gypsum as the Blaine. It is believed that the ground water occurs in solution openings, perhaps even caverns, in the gypsum (Schoff, 1948, p. 5). The water is highly mineralized, containing especially large amounts of calcium sulfate, but thus far it has been used successfully for irrigation.

No evidence has been uncovered to show that Canadian County has geological conditions similar to those in the redbed well field of Enid or those in southwestern Oklahoma. No one is known to have drilled a well of large yield into redbeds older than the Rush Springs sandstone in Canadian County. The gypsum beds of the Blaine are relatively thin and disappear halfway across the County, and the Dog Creek has gypsum only in thin sheets and stringers or disseminated through the shale. These two formations, therefore, do not lend themselves to the development of solution openings as readily as they do in southwestern Oklahoma.

Of the Permian formations in Canadian County, the Rush Springs sandstone is the most likely to yield water in substantial quantities. It is the coarsest textured, although in comparison with many sandstones in other areas it is fine grained. Indications are that its permeability is augmented by solution openings. It is tapped for irrigation near Fort Cobb and Weatherford, where yields of several hundred gallons per minute per well have been obtained (Davis, 1950). As it occurs in Canadian County, the Rush Springs is merely the extension eastward of the same formation of Caddo County. It may be less productive, however, because it has been dissected by tributaries of the Canadian River. The ground water drains naturally toward and into these streams, so that the water table is lower and the saturated thickness is less than farther west. Nevertheless, at most places in the outcrop area of the Rush Springs those who drill for water for domestic or stock use are practically assured an ample supply of water of good quality.

Probably the most important aquifer among the bedrock formations of central Oklahoma is the succession of alternating sandstone and shale known as the Garber sandstone and the Wellington formation, but these strata appear not to contain potable water in Canadian County. The Garber is the formation next older than and immediately below the Hennessey shale, and the Wellington is below it. The Garber and the Wellington crop out in Cleveland and Oklahoma Counties and northward, and have been tapped for substantial municipal and industrial water supplies at Edmond, Midwest City, Tinker Field, Moore, Norman, and Noble and other places. The water-bearing sands are interbedded with shale through a zone as much as 400 feet thick. In parts of Oklahoma City good yields of water of acceptable chemical quality are obtained from wells drilled to about 800 feet, but at Norman the water in sandstones below about 650 feet is of poor quality.

The Garber and the Wellington are present in the subsurface rocks of Canadian County, but seem to contain saline water. In fact, Lake Hefner in Oklahoma County is approximately the western limit of potable water in the Garber. The Yukon Grain and Mill Co. once had a well drilled to 800 or 900 feet, and abandoned it because the water obtained from it was salty (oral communication from company officials). At the depth indicated, this well should have penetrated at least the upper part of the Garber sandstone.

The Boy Scouts of America had a well drilled to a depth of 969 feet at Camp Kickapoo (NE¼ sec. 13, T. 10 N., R. 5 W.) and got water so saline that it could not be used for drinking purposes, although it was considered satisfactory for use in a swimming pool. These two wells are not enough to prove that the Garber sandstone yields only water of poor quality in Canadian County. On the other hand, it probably is significant that the field work for this report disclosed no deep wells in the eastern part of the County that yield water of desirable quality. In all probability several other deep wells have been attempted at one time or another, and when the results proved unsatisfactory they were abandoned and forgotten. Records of such wells are generally elusive.

QUATERNARY SYSTEM

Unconsolidated sand, gravel, silt, and clay comprise the Quaternary system in Canadian County. These are divided into three units which in order of decreasing age are the terrace deposits, the alluvium, and the dune sand.

Terrace Deposits

Terrace deposits consist of alluvium laid down by streams. Since the time of deposition, the streams have shifted their channels laterally and have cut them to lower levels. The terrace deposits, therefore, are adjacent to and topographically higher than the present streams, and they consist of sand, gravel, silt, and clay, and mixtures thereof, in irregular or interfingering layers and in proportions that differ from one place to another. The ground-water supply in them is replenished mainly from the rain that falls on their outcrops.

The principal outcrop of terrace deposits in Canadian County, and the only one of significance as a ground-water reservoir, is on the upland between the North Canadian and Cimarron Rivers. It extends southeastward from the northern part of T. 14 N., R. 10 W., to the vicinity of Lake Overholser, and ranges from one half to about three miles in width. The maximum thickness of sediments in this deposit is about 75 feet. Outliers of a terrace deposit cap the upland southeast of El Reno in T. 11 N., Rs. 6 and 7 W., and T. 12 N., Rs. 6-8 W. These are thin remnants of a deposit that was formerly more extensive. Other remnants, now shown on plate I, occur on divides in different parts of the County and range from scattered pebbles of quartz and quartzite—all that is left after weathering and erosion—to 10 to 15 feet of sediments.

Water wells on the upland between the North Canadian and Cimarron Rivers generally tap water in the terrace deposits. A few located near the edge of the outcrop, or where the deposits are thin or are composed entirely of fine-grained materials, have been drilled into and tap water in the underlying redbeds. Wells beginning on terrace deposits in other parts of the County get no water in them but tap water in the redbeds.

Lithologic character.—The terrace deposits underlying the upland north of the North Canadian River consist of clay, silt, sand, gravel, and mixtures of these materials. As a rule, the coarser, more permeable materials are near the bottom and the finer grained, less permeable ones are near the top, but there are exceptions. The sands, silts, and clays in the lower part are typically reddish, and at places are so like the underlying redbeds in color that they can be distinguished with difficulty. Coarse sand grains and small quartz pebbles included in them show that they belong to the terrace deposit, not to the redbeds. Upward the colors grade into brown, gray, yellowish gray, and white.

Most of the gravel consists of granules and pebbles less than two inches in maximum dimension, but cobbles up to six inches across are included in some beds. The general color of the gravel beds at most places is gray, because many of the component pebbles are gray. Among the pebbles are granite, quartz, quartzite, gneiss, brown sandstone, silicified wood, jasper, and a little limestone or dolomite.

The sands range from fine to coarse and are reddish brown, brown, reddish orange, reddish yellow, or gray. They are not well sorted except locally. The finer ones are commonly silty. Clay balls are included in some sand beds, and pebbles in others. In an exposure of terrace deposits near the south quarter corner sec. 20, T. 13 N., R. 6 W., the lower 10 feet is unconsolidated medium- and fine-grained sand with a few thin layers of clay and some clay balls. This is a type of material which probably would yield water rather freely if saturated. The overlying five feet also is sand but is clayey—a material which, if saturated, would yield little or no water.

The silts are so intimately associated with the sands that many exposures may best be described as silt and sand. They typically are brown grading upward into light gray or white. At places they make nearly vertical cliffs as much as 10 feet high. The clays are shades of reddish brown, or are gray. Some include pebbles an inch or more in diameter.

H. D. Miser mapped the terrace deposits south and southeast of El Reno in 1952. He reported (personal communication, 1953) that a little gravel is included in them at relatively few places. It is embedded in a tight red matrix. The terrace deposits exhibit a soil profile that extends laterally to the redbeds of Permian age, and it is difficult to distinguish them from the redbeds with certainty. Because of deep weathering, Miser (oral communication, 1953) considered these to be the oldest terrace deposits, or among the oldest. Presumably they are older than the deposits on the upland north of the North Canadian River. They are thin and relatively impermeable, and wells beginning on them tap water in the underlying redbeds.

The terrace deposits on the divides in other parts of the County are likewise too thin to be aquifers, but they are not entirely of impermeable materials. At the SE cor. sec. 23, T. 14 N., R. 7 W., the Flowerpot shale is overlain by five to six feet of poorly sorted gravel and sand, which in turn is overlain by two feet of sand and silt containing a few fine pebbles. The Tindel Materials Co. is quarrying a terrace deposit 10 to 15 feet thick that caps the upland east of the bridge over the Canadian River (sec. 5, T. 12 N., R. 10 W.). The lower part of this deposit is sand and fine gravel, but the upper part is clay.

Alluvium

Alluvium is the material deposited by a stream and consists of gravel, sand, silt, clay, and mixtures thereof, in any proportion, and it underlies the flood plain. It is thicker along major rivers than along minor tributaries, but practically every stream, regardless of size, has alluvium somewhere along its course.

The principal areas underlain by alluvium in Canadian County are the bottom lands of the Canadian and North Canadian Rivers (pl. I). In both valleys the area of alluvium is essentially the area of the flood plain and the first bench above it. The gravel and coarse sand are generally in the lower part of the deposit, below the water table. At most places they are capable of yielding water in moderate abundance and at some places they can yield it generously. The alluvium has been tapped in Canadian County for water to meet municipal, industrial, irrigation, domestic, and stock needs.

As mapped for this report (plate I) the alluvium includes deposits of two somewhat different ages although both belong to the Quaternary period and possibly to the Recent epoch. The older part of the alluvium underlies the intermediate benches in the Canadian and North Canadian valleys. The younger part of the alluvium has been deposited in a trough excavated by the rivers in the older alluvium and it underlies the flood plain. At some places the younger alluvium may extend from the surface down to the underlying redbeds, but at other places it may have remains of the older alluvium under it.

The maximum thickness of the alluvium of the North Canadian River is about 60 feet, as shown by test holes of the Oklahoma Gas and Electric Co. drilled near Lake Overholser. Between Calumet and Geary, where the bottom lands are wider, the maximum thickness is only about 35 feet. The thickness is least—next to nothing—at the margins of the outcrop. Information on the thickness of the alluvium in the Canadian River valley is scanty, but the maximum is probably comparable to the maximum in the North Canadian valley.

Lithologic character.—The alluvium, like the terrace deposits, is composed of materials transported by streams. It consists of clay, silt, sand, gravel, and mixtures of these materials which are derived from the formations crossed by the streams or their tributaries. The Canadian and North Canadian, upstream from Canadian County, cross many formations. They have their headwaters in northeastern New Mexico and cross the High Plains of the Texas and Oklahoma Panhandles. The rock formation nearest the surface in the High Plains is a thick deposit consisting principally of sand and gravel, with which are lesser amounts of clay and caliche. Probably these rocks are the principal source of material for the alluvium of these major streams but the rocks of Permian age downstream from the High Plains also supply material, as shown by the red clays and sands reported in well logs.

The distribution of the sands and gravels in the alluvium at any given place depends on the river's history at that place. Rivers continually shift their channels back and forth across their valleys, alternately cutting and filling. Their deposits are alternately coarse and fine, depending on the variations in the strength of the current, which in turn depended on the proximity of the given place to the channel from time to time. In consequence, the gravels and sands thicken and thin from place to place and grade into silt and clay. The gravels, sands, silts, and clays are said to interfinger one with another.

Mere inspection of the river bottom land is not enough to show where the rivers have deposited the thickest and coarsest sands and gravels. To find them, test holes, which under favorable conditions can be supplemented by geophysical surveys, are needed. Many test holes already had been drilled in the North Canadian River valley before the investigation was begun on which this report is based. More were drilled later by public and private agencies, and 2,000 feet of test drilling was done especially for this investigation. Sieve analyses summarized elsewhere in this report indicate how coarse or fine the sands are.

The alluvium along the smaller streams in Canadian County is generally finer grained than that along the major rivers because these streams drain areas underlain principally by fine-grained red-beds. Exceptions are streams draining northward from the terrace deposits on the upland between the North Canadian and Cimarron Rivers. These deposits may contribute some sand and gravel, but not in large quantities because the streams have access to the deposits only along a small fraction of their total length. In general, the alluvium along the smaller streams will yield no more than enough water to meet domestic and stock needs on farms.

Dune Sand

Dune sand has been transported by the wind and then deposited, generally in hummocks and small hills. The hills are the most useful criterion by which to identify the deposit, because their form itself is indicative of their origin. Indeed, thin layers of wind-deposited sand lacking the dune form are practically impossible to distinguish from sand deposited in another manner.

Dune sand may not have traveled far from where it was picked up by the wind. Winds commonly pick up sand from river channels when streams are low or dry, and deposit it nearby on the flood plain or valley bluff. Trees and other vegetation break the wind and cause it to dump its load. Accordingly, dune sand occurs at many places along the Canadian and North Canadian Rivers, as shown on plate I.

The upper surface of the terrace deposits north of the North Canadian is sandy at some places, and the winds have shifted sand from this source, heaping it in dunes. These dunes have not been distinguished on plate I from the terrace deposits. Those in the northern parts of T. 14 N., Rs. 9 and 10 W., are noteworthy.

Dunes built to a height of 20 to 25 feet upon the nearly flat surface of the flood plain have a maximum thickness of sand approximately equal to their height. The minimum thickness approaches zero at the margins of the sand-covered areas.

Lithologic character.—The wind sorts the sand, thereby increasing its porosity and permeability and enhancing its ability to absorb the rain falling on it. The wind is unable to move the pebbles and cobbles, and therefore leaves them behind. It may continue to carry forward the silt and clay fragments after unloading the sand. The result is a loose deposit of sand that is rather uniform in grain size. Accordingly, deposits of dune sand are favorable to the replenishment of any permeable rocks that lie beneath them. On the other hand, the sand deposits are generally above the water table and do not contain water recoverable through wells. When they contain water, it is in transit downward.

Water-bearing Character of Quaternary Rocks

The lithologic descriptions of the formations of the Quaternary system hint at their hydrologic properties. The alluvium is the principal aquifer among those formations primarily because it is capable of the highest yields. The alluvium along the North Canadian River has been extensively tapped in Canadian County for water to meet municipal, industrial, irrigation, domestic, and stock needs. A few wells in it are capable of yielding more than 500 gallons per minute and at many places wells could be drilled that would yield between 100 and 500 gallons per minute. The thickness of this alluvium, the thickness of the saturated part of it, the water table in it, and the depth to water in it are shown by plate II-2, -3, -4, and -5. Its hydraulic properties—its behavior under pumping—are discussed in the analysis of the aquifer tests.

The chief objection to the ground water in this alluvium is its hardness (table 7). In addition, minerals in solution are deposited on well screens and perhaps also in the pore spaces of the sediments, with the result that wells have rather short lives. Locally, constituents other than those causing hardness give the water an objectionable taste or odor or have undesirable effects when the water is used for some purposes. This is true of the water used by Calumet and in 1954 that town was seeking water of a better quality.

The alluvium along the Canadian River has been tapped principally for rural supplies of domestic and stock water. In most places it should be possible to get yields between 100 and 500 gpm from wells appropriately constructed and equipped. For example, the irrigation well of Jake Ast, in SW¼SW¼ sec. 22, T. 11 N., R. 8 W., is reported to yield 650 gpm. The water of this alluvium, like that along the North Canadian, is very hard. Presumably wells in it would be subject to encrustation and so would have relatively short lives.

The alluvium along the tributary streams has been tapped here and there for rural water supplies. Such alluvium is likely to be rather thin—perhaps 10 to 25 feet where thickest—and therefore it affords only relatively small storage capacity. Heavy pumping might deplete the supply in a single year, although by the end of the next rainy season it might be fully replenished. In general, yields are likely to be less than 10 gpm because this alluvium is composed mainly of sediments derived from fine-grained bedrock and therefore is itself fine grained and of low permeability.

The terrace deposits underlying the upland north of the North Canadian River yield water less freely than the alluvium but the water from these deposits is better in chemical quality. Although hard, this water is not nearly as hard as that in the alluvium and it does not have nearly as much sulfate and chloride as the water from the redbeds. The depth to water in these terrace deposits is generally less than 25 feet. At some places wells could be drilled that would yield up to 100 gpm, or more. At many more places they would yield between 10 and 100 gpm, and at some places the deposits are tight from top to bottom and wells would yield practically nothing.

As noted previously, the dune sand is not an aquifer because it is above the water table. Its hydrologic importance stems from the fact that it soaks up nearly all the rain that falls on it, and thereby contributes to the replenishment of the formations below it.

HYDROLOGY

SIEVE ANALYSES AND LABORATORY TESTS OF PERMEABILITY

The coarseness and uniformity of the particles making up sand and gravel may be measured by means of sieve analyses. Sands and gravels are more permeable if they are coarse, well sorted, and well rounded, than if they are fine, poorly sorted, and angular. Their coarseness has a direct bearing on the selection of the screens used in the construction of wells. If the particles are nearly uniform, less pumping will be required to remove the finer sizes during the development of wells—provided, of course, that the well screens are appropriate.

Sieve analyses of 514 samples from 104 test holes in the alluvium of the North Canadian River valley were available from three separate test-drilling programs. In addition laboratory determinations of permeability were made on 197 of the samples from the U. S. Geological Survey test holes.

Sieve Analyses of Samples from Oklahoma City Test Holes

Sieve analyses of 180 samples of silt, sand, and gravel from 39 test holes drilled for the Oklahoma City Water Department in the alluvium of the North Canadian River valley were made. The amount of each grain size as a percentage of the total weight of the sample was determined. The data are on open file with Oklahoma Geological Survey and with U. S. Geological Survey, Norman, and can be examined at these offices. To compare the samples, C. E. Bretz, consulting engineer, Oklahoma City, drew cumulative percentage curves and from these calculated the effective size and uniformity coefficient. Effective size and uniformity coefficient are terms used by Hazen during his experiments on river sands and gravels at Lawrence, Massachusetts (1892). The effective size is defined as "the grain size of a theoretical body of homogeneous material of one grain size that would transmit water at the same rate as the material under consideration" (Tolman, 1937, p. 202). It can be estimated by the use of sieves of known mesh as the grain diameter which is just too large to pass through a sieve that allows 10 percent of the material, by weight, to pass through. Thus, the effective size can be determined from the cumulative percentage curve as the grain size that corresponds to the point where the cumulative curve and the 10-percent line intersect.

The uniformity coefficient is an expression of the sorting of a material. It may be defined as "the quotient of (1) the diameter of a grain that is just too large to pass through a sieve that allows 60 percent of the material, by weight, to pass through, divided by (2) the diameter of a grain that is just too large to pass through a sieve that allows 10 percent of the material, by weight, to pass through" (Meinzer, 1923, p. 46). Thus, the coefficient is unity for perfect sorting, where the grains are all of one size, and as the variety of sizes increases the coefficient increases. The uniformity coefficient is readily determined from the cumulative-percentage curves. It is the grain size at the intersection of the cumulative curve and the 60-percent-line, divided by the grain size at the intersection of the cumulative curve and the 10-percent-line.

The effective size and uniformity coefficient are known in some cases, but could not be determined in others because in some samples more than 10 percent of the sample was finer than the finest sieve. In a test hole the effective size generally increases with the depth of the sample—indicating the downward coarsening of the material.

Sieve Analyses of Samples from Oklahoma Gas and Electric Company Test Holes

Sieve analyses of 129 samples of silt, sand, and gravel from 27 test holes drilled by the Oklahoma Gas and Electric Co. in the alluvium of the North Canadian River valley were made and are on open file at Oklahoma Geological Survey. To compare the samples, company engineers computed the fineness modulus, which is defined as the sum of the percentages of the materials coarser than each standard sieve size, the smallest being 100 mesh (0.147 mm), divided by 100. It expresses size alone, regardless of sorting; in this respect it is similar to the effective size discussed in foregoing paragraphs. The larger the fineness modulus, the coarser the sample. In a test hole the fineness modulus generally increases with increasing depth, indicating the coarsening of the materials downward.

Sieve Analyses and Laboratory Tests of Permeability from U. S. Geological Survey Test Holes

Sieve analyses of 205 samples of silt, sand, and gravel from test holes drilled in the alluvium of the North Canadian River valley were made. The data are on open file at the Oklahoma Geological Survey offices and the U. S. Geological Survey offices in Norman. Tyler screens were used in the sieving, and the samples were shaken mechanically for 10 minutes and manually for two minutes. A few samples suspected of containing drillers' mud were crushed in a mortar and washed with water before sieving.

Figure 2 shows representative cumulative-percentage curves based on the sieve analyses. The percentage indicated by any point on the curve is the percentage of the sample that is coarser than the indicated grade size. This is the percentage that would remain on a screen of the indicated size if all the samples were placed on that screen and shaken until all the particles smaller than the openings had passed through. The farther the curve is to the right on the graph the coarser the particles are. For example: in test hole 13N7W-21-6, sample 9 is much coarser than sample 4. Most of the curves for the samples in a test hole progress toward the right in order of the increasing depth of the samples, indicating the coarsening of the materials downward. (See fig. 2.)

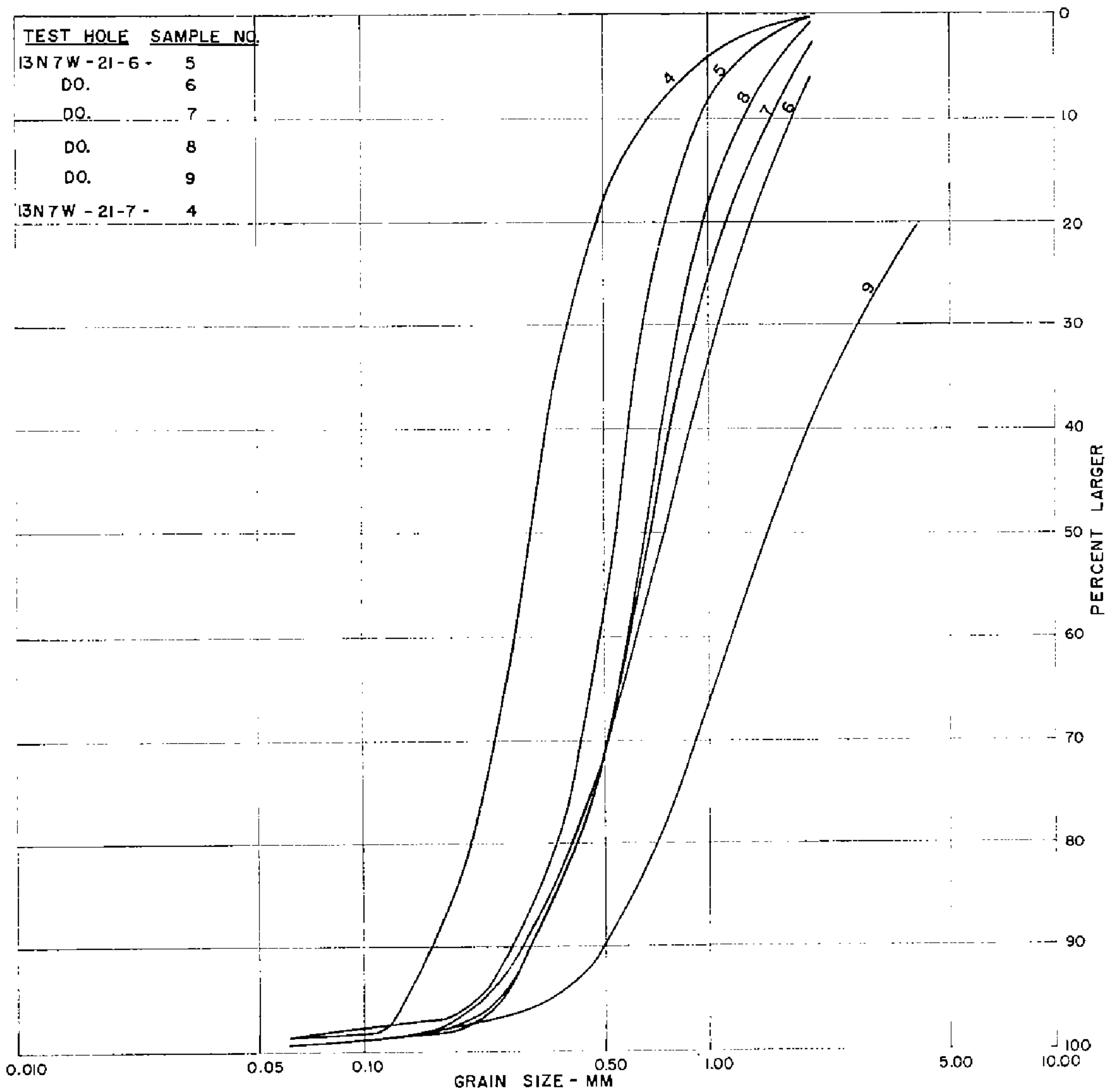

Figure 2. Cumulative percentage curves.

The uniformity or degree of sorting of the materials is reflected by the slope of the percentage curves. In a steep curve, such as sample 5 in test hole 13N7W-21-6 (fig. 2), the materials are well sorted; whereas, in a curve with less slope, such as sample 9 of test hole 13N7W-21-6, the materials are poorly sorted.

To express the degree of sorting quantitatively, so that different materials could be compared, the coefficient of uniformity was used. The range of 198 coefficients is from 1.7 to 8.7 and averages 2.8.

The effective sizes of the 198 samples range from 0.06 to 0.56 mm and average 0.21 mm.

The coefficients of permeability, expressed as gallons per day through a cross-sectional area of one square foot under a hydraulic gradient of 100 percent at a temperature of 60°F were calculated. The 197 coefficients were determined by use of a variable-head discharging type permeameter in the manner described by Wenzel (1942, p. 59-60). They range from 3.3 to 3,105 and average 330 gallons per day per square foot.

GROUND WATER

The pores of permeable rocks that lie below the land surface generally are partly or completely filled with water called "subsurface water." Below a certain level the pores are completely saturated with water, called "ground water"; this zone is called the "zone of saturation." The permeable rocks that lie above the zone of saturation are said to be in the "zone of aeration." This zone is subdivided into the capillary fringe, at the bottom, the intermediate belt, and the belt of soil water at the top—the last immediately below the land surface.

In one form or another, water occurs almost everywhere. Although at any instant most of the total water supply is stored in the oceans, a constant circulation is taking place. Evaporation from the surfaces of the oceans, streams, and lakes is continual. Most of the moisture so evaporated condenses and returns to the earth's surface as rain, snow, or other precipitation. Part of this precipitation is evaporated directly from the earth's surface, part of it returns to the oceans as surface runoff, and part of it infiltrates beneath the surface of the earth. Some of the water that infiltrates into the ground is held by capillarity near the surface and is evaporated;

some is used by vegetation and returned to the atmosphere by transpiration; and some joins the ground water and slowly, by ground-water flow, returns to the streams or oceans or to places where it is discharged by evapotranspiration.

Water-Table and Artesian Conditions

Ground water occurs under either artesian or water-table conditions. Artesian conditions exist when the aquifer contains water under artesian pressure head. This pressure head occurs where a water-bearing stratum is overlain by a relatively impervious stratum that confines the water in the aquifer. Because of this pressure head, water will rise above the upper surface of the aquifer in any well that taps the aquifer.

Water-table conditions exist where the upper surface of the water is not confined by an impermeable bed and the water surface is free to fluctuate. This upper surface of the zone of saturation is the water table. In the area of this report, the ground water in the alluvium and in the terrace deposits is largely unconfined and its upper surface is the water table. The water in the Permian bedrock, except for the Rush Springs sandstone, which is under water-table conditions, is mostly confined and is therefore artesian.

Movement of Ground Water

Ground water, like other liquid, has the tendency to seek equilibrium by moving from a point of higher head to one of lower head. The difference in altitude between any two points on the water table is the difference in head at those two points; therefore, the water loses head as it moves. The material through which the water moves is the aquifer, and the velocity with which water moves depends on the hydraulic gradient and permeability of the aquifer. Permeability depends on the size and arrangement of the particles and on the interconnection of the pore spaces, but it is not directly dependent on the pore space or porosity of the material. A fine-grained sediment, such as clay, may have a high porosity but a low permeability because the openings are so small that the force of molecular attraction offers resistance to the movement of water.

The water table is not a plane or level surface, but an irregular sloping surface that corresponds in general with the slope of the land surface. The water table generally has less relief than the

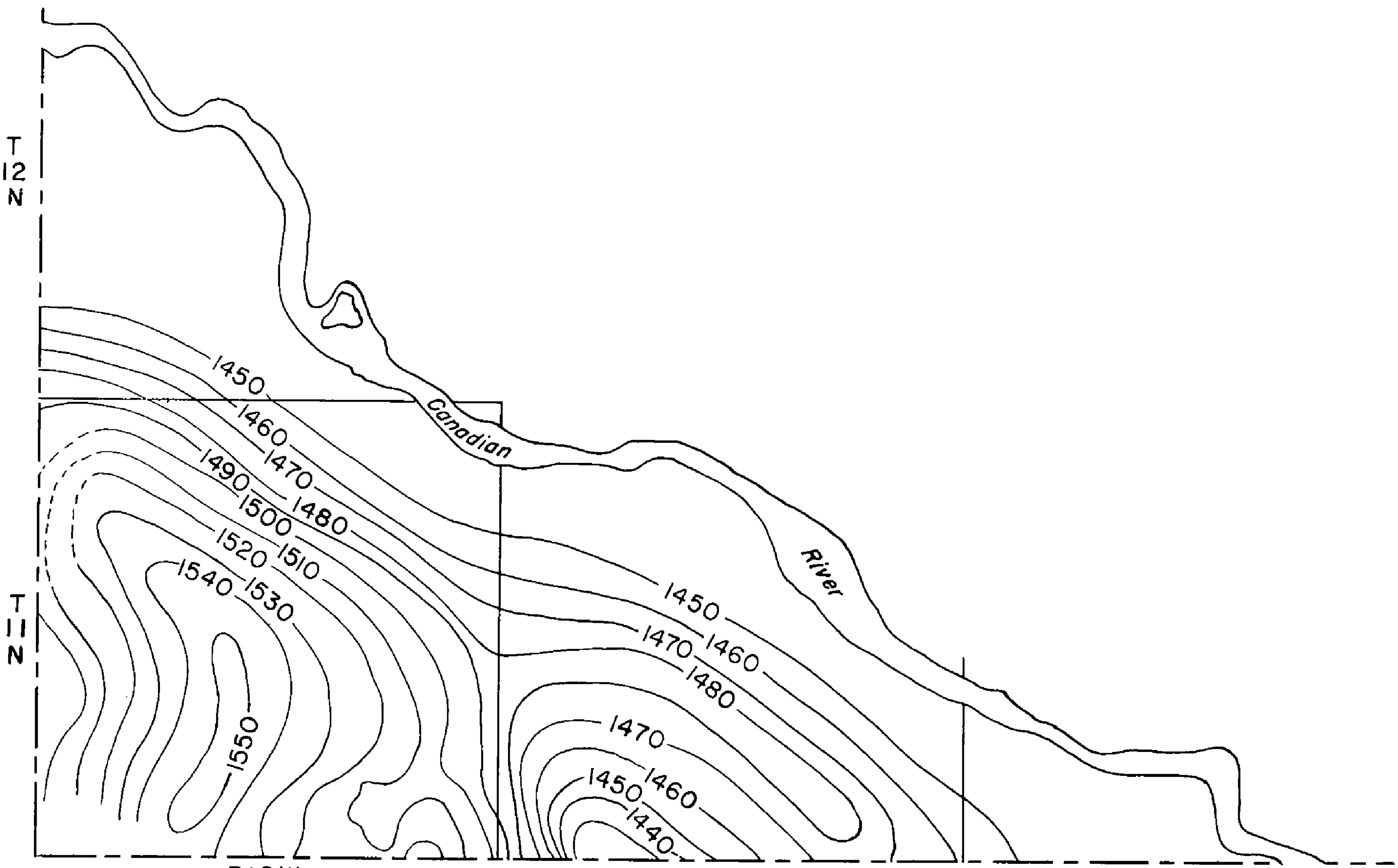

Figure 3. Map showing contours on the water table in the Rush Springs sandstone.

land surface and is a subdued replica of the surface topography. The many irregularities in the shape of the water table are caused by differences in permeability and thickness of the water-bearing material and by unequal additions of water to, or removal from, the ground-water reservoir. Where the rate of replenishment, or recharge, is exceptionally high, the water table may form a mound or a ridge from which the water spreads out to surrounding areas. This spreading out takes place slowly because of the resistance to flow through the aquifer.

The water table in the alluvium of the North Canadian River valley slopes southeastward, about five feet per mile, parallel to the course of the North Canadian River but it also slopes toward the river at least during wet seasons. Thus the water table has the shape of an irregular trough (plate II-2). When stream flow occurs during years of below-normal precipitation, the river apparently loses water into the alluvium and the water table would have a mound along the stream. The average slope of the water table in the Rush Springs sandstone is about 35 feet per mile (fig. 3). The configuration of the water table shows that part of the ground water drains northeastward to the Canadian River, and part of it drains southward and southwestward into tributaries of the Canadian and Washita Rivers.

Fluctuations of Water Level

The water table rises and falls in response to variations in the recharge to and discharge from the underground reservoir. After replenishment during wet seasons, the water table normally is relatively high. After dry seasons, during which the flow of perennial streams has been maintained by discharge of ground water, the water table normally is lower. Discharge of water by evaporation, by transpiration, or by pumping from wells also will lower the water table. The position of the water table at any one time depends on the balance between recharge and all the forms of discharge. It expresses the net effect of the opposing forces, recharge and discharge, and shows whether there has been a gain or loss in storage since the previous measurement. The position of the water table is found by measuring depths to water in wells, and changes in it are detected by measuring the depths periodically.

In the alluvium of the North Canadian River valley the water table is usually highest in late spring and lowest in late fall. The fluctuations range from 3.1 to 17.7 feet and average 7.8 feet for 21 wells which have an average record of 12 years. Plate II-2, -3, and -5 are based mostly on the position of the water table in the latter part of October 1942. The contour lines shown on these plates may be expected to be different at other times.

Discharge of Ground Water

Ground water is discharged from an aquifer by effluent seepage, evaporation, flow or pumping from wells, underflow into another aquifer, and transpiration by plants. The average discharge of ground water from the alluvium of the North Canadian River valley, due to these factors, is estimated to be more than 40 mgd—based on records through 1953.

Effluent Seepage

Discharge by effluent seepage, as the word "effluent" suggests, is that water which flows out of the zone of saturation and into a stream whose surface is lower than the water table. A stream or part of a stream is effluent with respect to ground water if it receives water from the zone of saturation. Conversely, if the stream contributes water to the zone of saturation, it is an influent stream. The North Canadian River is sometimes effluent and sometimes influent. In times of drought the water level falls below the bed of the stream. Then, if heavy rains occur, causing surface runoff, the stream becomes influent for short periods of time. These periods of influent seepage can be recognized by the losses in streamflow between gaging stations.

The contour map of the water table (pl. II-2) shows that although the general slope of the water table in the alluvium of the North Canadian River valley was southeastward, down the valley, there was also a slope toward the stream in October 1942. The ground-water flow lines, perpendicular to the contours generally curve toward the river and indicate effluent seepage. An effort to measure this effluent seepage was made and the results appear to be quite reasonable.

Estimates of effluent seepage, which is a part of the total surface runoff, were made from an analysis of the hydrographs at two stream gaging stations—one at Canton and one at El Reno. These analyses showed that 28.1 percent of the total surface runoff at Canton and 34.7 percent at El Reno was effluent seepage. These computations compare favorably with an estimate made in adjoining Caddo County (Davis, 1950, p. 22). The mean net increase in flow between the gaging stations at Canton and El Reno was multiplied by 31.4 percent (the average of the two computations) to estimate the effluent seepage between these two stations, which was computed to be about 10,000 gallons per day per mile of river. Thus, along the 65 miles of the North Canadian River in Canadian County the effluent seepage averages about 650,000 gpd.

Pumpage

The discharge of ground water from the alluvium of the North Canadian River valley by pumping during 1953 was about one-eighth of the total amount of water discharged by the aquifer. Municipal supply wells used about two mgd, industrial supply wells about 2 mgd, and irrigation wells about 1.5 mgd. Thus, the total pumpage was approximately 5.5 mgd. The amount of water used for stock and domestic purposes is considered to be negligible compared with the amount of water pumped for other uses.

Total pumpage is expected to be more than 13 mgd by the end of 1956. Municipal pumpage by Oklahoma City from 19 wells located at the eastern edge of the County will increase the total pumpage by 6.4 mgd. The Oklahoma Gas and Electric Co. plans to increase its pumpage by 1.2 mgd beginning in 1955. Also additional irrigation wells are being contemplated in many parts of the valley. These increases could easily boost the total pumpage to an amount equivalent to fully half the total available recharge in the valley.

Underflow into Other Aquifers

The low permeability of the underlying redbeds prevents any large movement of water either into or out of these formations. In general the water levels in wells tapping the redbeds are higher than in wells tapping the adjacent alluvium, so the movement of this relatively small amount of water is from the redbeds into the alluvium. Similarly, the water levels in wells tapping the terrace deposits along the northern edge of the valley are higher than in wells tapping the adjacent alluvium, so that movement of ground water is from the terrace deposits into the alluvium.

Transpiration

The discharge of water into the atmosphere by plants during the process of growth is called transpiration. The water may be taken into the roots of plants from the belt of soil moisture, the zone of saturation, and the capillary fringe—which in turn is supplied from the zone of saturation.

Computation of the total amount of transpiration in an area involves many variables that are not yet completely understood. Where plants are able to take water from the zone of saturation, transpiration is a major ground-water discharge factor. These plants that obtain their water supply from the zone of saturation are called phreatophytes (Meinzer, 1923, p. 55). In the area of this report they are much in evidence as the dense growths of willows and cottonwoods along the North Canadian River and its immediate tributaries where the ground water lies at shallow depths below the land surface.

An attempt was made to estimate the amount of water these phreatophytes consumed with a method developed by Blaney (1952, p. 61-66) which correlates existing consumptive-use data with monthly temperatures, percent of daytime hours, precipitation, and frost-free (growing) period. The coefficients so developed for different plants are used to transpose consumptive-use data to other areas where only climatological data are available. Research studies indicate that of all the climate factors, temperature and precipitation, together with daylight, undoubtedly have the greatest influence in plant growth. When applied to the North Canadian River valley, the results of this method showed that the cottonwoods and willows used 64.5 inches of water per year. If phreatophytes in an area are so dense that the addition of one more would mean the removal of an existing plant, the phreatophyte density is 100 percent and the amount of water used in one year would be 5.4 acre-feet per acre. The phreatophyte-populated areas of the North Canadian River valley were planimetered from aerial photographs and found to be 16.25 square miles. The overall density was estimated to be about 70 percent. The product of the area, density, and water usage shows that a total of about 40,000 acre-feet per year is used by these plants. This is equivalent to more than 35 mgd, which is about six times the present discharge by pumping.

Recharge of Ground Water

Under natural conditions an aquifer may receive water from one or more of several sources. Recharge may be obtained from infiltration of precipitation, from streams that introduce water from outside the catchment area of the aquifer, and from underflow from other aquifers. Infiltration of precipitation is the most important source of recharge in the alluvium and terrace deposits of the North Canadian River valley.

Several small ephemeral streams bring water into the alluvium from the outer reaches of the drainage area of the North Canadian River. The drainage area is relatively small, and the streams flow only for short periods in response to precipitation; thus, the recharge from the streams is believed to be negligible.

The alluvium and terrace deposits are underlain by Permian redbeds whose low permeability prevents large-scale movement of water. Thus, recharge by underflow from the redbeds of Permian age probably is negligible.

Seeps are evident along the contact of the redbeds and the terrace deposits where the redbeds crop out between the alluvium and the terrace deposits. Ground water, therefore, is flowing from the terrace deposits into the valley. Where the terrace deposits are in contact with the alluvium ground water can move by underflow from the terrace deposits into the alluvium. Available data are not sufficient to estimate the amount of such underflow. However, the presence of the outcrops of the redbeds between the alluvium and the terrace deposits would indicate that the redbeds are not far below the surface at the contact of the alluvium and terrace deposits. Thus the cross-sectional area through which ground water could move from the terrace deposits into the alluvium probably is small and the amount of underflow likewise probably is small. Also, the divide between the Cimarron River and the North Canadian River is within the outcrop area of the terrace deposits so some of the water in the terrace deposits flows toward the Cimarron, away from the North Canadian. Nevertheless, the terrace deposits are 75 feet thick in places so the possibility remains that the cross-sectional area of contact between the terrace deposits and the alluvium may be large enough in places to permit considerable amounts of water to percolate into the alluvium.

The alluvium and terrace deposits are notably lacking in surface drainage. In Canadian County no well-developed streams cross them to empty into the North Canadian River. Even the road ditches seldom contain water. Large areas have no outside drainage, and the predominantly sandy soil favors a high rate of infiltration. Many shallow depressions are excellent intake areas. These depressions hold the water that falls on the surface until it evaporates or infiltrates into the ground. Relatively few of them retain water for more than one or two days after the rain has stopped.

Monthly measurements of the depth to water below the land surface in well 12N5W-8-4 for the period from February 1945 through December 1949 were used to construct a hydrograph. Comparison of the water-level fluctuations with the cumulative departure from normal precipitation, at El Reno, suggests the relation between departure from normal rainfall and change in ground-water level. The rise of water level in response to rainfall appears to be relatively rapid; thus, it is believed that records from wells that show water-level fluctuations in sediments of known specific yields could be used to provide a reasonable estimate of recharge from precipitation.

How much the ground-water level will rise depends on how much water is added to the reservoir. It also depends on how much space per unit volume is available in the sediments to receive water. If 10 percent of the volume of the sediments, after they are drained, can be filled with water, the addition of one inch of water should cause a rise of 10 inches in ground-water level. Conversely, a rise of 10 inches in ground-water level is equivalent to a layer of water one inch deep. If 25 percent of the volume can be filled, more water will go into each cubic foot of sediment and the addition of one inch of water would cause a rise of four inches in ground-water level. This space factor is approximately the same as the specific yield. In the section on aquifer tests it is shown that the specific yield of medium sand is about 10.5 percent; therefore, wells that show water-level fluctuations in medium sand have been used to estimate the amount of recharge.

Water-level rises in response to precipitation were averaged for two wells in the alluvium of the North Canadian River valley that had a combined total of 10 years' record, to obtain the percentage of precipitation that reached the water table. For example, the total rises (7.77 feet) in well 12N5W-8-4 for the 36-month period (January 1951 to January 1954) were compared to the total rainfall (83.94 inches) at the Lake Overholser station during this same period. The total rises were multiplied by the specific yield to obtain the percent of precipitation that reached the water table, as follows:

$$\frac{7.77\ (12)\ (0.105)}{83.94} = 11.7 \text{ percent}$$

Five such calculations were made, three of them with data from well 12N5W-8-4 and two with data from well 14N10W-17-1. The shortest period of record used was 12 months. The calculated recharge ranged from 11.7 to 23.0 percent, and averaged 17.5 percent. This figure is believed to be low because not all the rises in water level could be determined from monthly measurements and ground water was being discharged during most of the period of rising levels; therefore, calculations based upon them should have a margin of safety.

The normal rainfall for Canadian County, as well as the North Canadian River valley within the County, was calculated by Thiessen's method (Thiessen, 1911, p. 1082) to be 29.12 inches. Thus, the average annual recharge to the 127.3 square miles of alluvium and terrace deposits in the North Canadian River valley of Canadian County is 17.5 percent of 29.12 inches, which is 5.09 inches or about 30 mgd. This is less than the average discharge of about 40 mgd, and because the average discharge should equal the average recharge it appears, as previously stated, to be probable that the estimate of recharge is low. If this 17.5 percent were raised to 23 percent the average annual recharge would equal the average annual discharge.

Utilization of Ground Water

Most of the water used in the County for domestic, stock, industrial, and municipal supplies is ground water. Stock is watered from ponds on the Permian outcrops, but the total amount of water so used is relatively small.

In the approximately 900 square miles considered in this report, 500 wells and test holes were inventoried; of these, 337 were wells, and 163 were test holes which were filled after an examination was made of the materials encountered. More than 90 percent of the 500 wells and test holes are located in the alluvium and terrace deposits of the North Canadian River valley. The remaining 10 percent are considered to be representative of the Permian rocks and the alluvium of the Canadian River, from which only a small fraction of the total ground water used is derived.

The 337 wells consist of 53 public-supply wells, 19 irrigation wells, 8 industrial supply wells, 61 observation wells, and 196 domestic and stock wells.

Domestic Supply Wells

Domestic wells are the privately owned wells that supply water for home use, such as cooking, washing, and sanitary purposes. Most farm and ranch homes are served by such wells, some of which are pumped by mechanical or electrical energy and others by hand. Neither the number nor the average pumpage of these wells was obtained as it is believed that their pumpage is a very small part of the total.

Most domestic wells that tap the alluvium and terrace deposits are driven wells 1¼-inches in diameter and are finished with well points 24 to 36 inches long. Most wells drilled into the bedrock range from four to six inches in diameter; they are partly cased with steel or galvanized iron pipe, and have open bottoms. Dug wells are also used to obtain domestic supplies from the bedrock.

Stock Wells

Wells used to supply water to stock are of the same general construction as the domestic wells, and generally are equipped with cylinder pumps powered by windmills. Many stock wells derive their water from the alluvium of the North Canadian River valley and some are no deeper than 10 feet. As in the case of domestic wells no attempt was made to estimate the number or the average pumpage of these wells.

Public-Supply Wells

Oklahoma City, the cities of El Reno, Yukon, Geary, Okarche, Calumet, and Concho Indian Reservation draw ground water from within the area of this investigation. All the wells tap water in the alluvium of the North Canadian River valley.

OKLAHOMA CITY

In 1953 Oklahoma City constructed 19 water wells in secs. 1, 11, 12, and 13, T. 12 N., R. 5 W. These wells are used to supplement the present Oklahoma City water supply which is derived mainly from flood water in the North Canadian River that has been diverted into two surface reservoirs. The wells have been pumped only during the summer of 1954, when 72,442,000 gallons was pumped, and in 1956, when 20,725,000 gallons was pumped.

The wells range in depth from 45 feet to 63 feet and average 55 feet. They are all drilled to the top of the redbeds and tap water from the sands and gravels of the overlying alluvium. The wells have steel casings 12 inches in diameter and are finished with well screens 10 feet long. Gravel envelopes, 15 inches thick, surround the casings from top to bottom. The wells are equipped with electrically powered turbine pumps and are reported to yield 100 to 300 gpm each.

EL RENO

A total of 31 wells, in sec. 33, T. 13 N., R. 7 W., and in the NE¼ sec. 32, T. 13 N., R. 7 W., have been constructed and used by the city of El Reno for its water-supply system. In 1959, the city had 14 wells, seven of which had been drilled since 1951. The reason for the excess number of wells is that after prolonged use of a well the well screen and surrounding gravel envelope become heavily incrusted with calcium carbonate deposits, thereby materially reducing the yield of the well and requiring the drilling of a replacement well. In recent years acid has been used to clean some of these incrusted wells; however, this is only a temporary measure as the incrustation soon recommences.

TABLE 5—Pumpage for the city of El Reno, Okla.

Year	Total pumpage (millions of gallons)	Year	Total pumpage (millions of gallons)
1952	481	1956	501
1953	492	1957	478
1954	520	1958	483
1955	493		

Month and year 1958	Pumpage (gallons)	Month and year 1959	Pumpage (gallons)
July	48,973,000	Jan.	38,148,000
Aug.	49,238,000	Feb.	36,163,000
Sept.	41,359,000	March	39,470,000
Oct.	41,152,000	April	46,511,000
Nov.	36,808,000	May	47,745,000
Dec.	37,856,000	June	38,293,000

YUKON

The city of Yukon is supplied by four wells in the NE¼ sec. 18, T. 12 N., R. 5 W. All have turbine pumps that are electrically powered. The average depth of the wells is 45 feet, and the average pumpage from all of the wells is estimated to be 150,000 gpd.

GEARY

Before 1950, Geary obtained water from five wells on an upper bench of the alluvium in the NW¼ sec. 18, T. 14 N., R. 10 W., and the NE¼ sec. 13, T. 14 N., R. 11 W. Well 14N11W-13-1 is a dug well 20 feet in diameter, brick lined, with twelve sandpoints three inches in diameter driven horizontically (like spokes from a wheel hub) from the bottom of the well. This well is 34 feet deep and penetrates 16 feet of saturated alluvium. It was reported to yield 200 gpm but can be pumped dry in 10 hours at this rate. The other four wells (14N10W-18-3, 14N10W-18-2, 14N10W-18-4, and 14N11W-13-2) are drilled wells 13 inches in diameter and have gravel envelopes around the casings. The wells have turbine pumps, with the exception of one which has a cylinder pump, and all are electrically powered. These wells were reported to penetrate 13 feet of saturated alluvium.

In 1950 an additional well (14N10W-7-1) was drilled owing to the increasing demands for water and the declining yields of the initial wells. This sixth well is east of the initial wells, closer to the North Canadian River, and on a lower bench of the alluvium. The well is 35 feet deep and has a gravel envelope around the 12-inch diameter casing. It penetrates 28 feet of saturated alluvium, and is reported to yield 100 gpm with a drawdown of seven feet. From

TABLE 6.—Total pumpage for town of Geary, Okla.

Year	Total pumpage (gallons)	Year	Total pumpage (gallons)
1955	48,274,200	1957	50,650,510
1956	54,299,900	1958	47,341,900

Month and year 1958	Pumpage (gallons)	Month and year 1959	Pumpage (gallons)
July	4,606,300	Jan.	3,200,000
Aug.	6,182,400	Feb.	3,976,600
Sept.	4,633,300	March	3,182,700
Oct.	3,703,700	April	3,336,100
Nov	3,583,700	May	2,770,100
Dec.	3,894,000	June	7,371,000

1950 until 1953 the yields of the initial four drilled wells steadily declined, and the yield of the dug well, which had been supplying 180 gpm, declined sharply because the sandpoints were heavily incrusted with calcium carbonate. In 1953 the city decided to drill a new well, and the location was selected by drilling three test holes 700 to 800 feet east of the sixth well which had proved to be better than the initial wells. The best test hole of the three was selected as the well site and the well was constructed in August 1953. This seventh well (14N10W-7-2) is 33 feet deep and penetrates 28 feet of saturated alluvium. It has a turbine pump, electrically powered, and is reported to yield 350 gpm with a drawdown of 15 feet while pumping to waste at the land surface.

After completion of the sixth well in 1950, one well, 14N10W-18-4, was abandoned and in 1953, after completion of the seventh well, 14N11W-13-2 was abandoned. Thus, five wells are used to supply the city of Geary, but only four were pumped during 1959. Table 6 shows the total pumpage for the city of Geary from 1955 through 1958.

OKARCHE

The city of Okarche is supplied by four water wells, three of them in the SW¼SW¼ sec. 13, T. 13 N., R. 8 W., and one in the NE¼NE¼ sec. 23, T. 13 N., R. 8 W. All the wells have turbine pumps that are electrically powered.

The three wells in sec. 13 are approximately 40 feet deep, penetrate 17 feet of saturated alluvium, and are reported to yield from 40 to 50 gpm. The well in sec. 23 is 42 feet deep, penetrates 24 feet of saturated alluvium, and is reported to yield 125 gpm. The total pumpage from the four wells is reported to be 13.5 million gallons a year, or an average of 37,500 gpd.

CALUMET

Calumet is supplied by one water well in the NE cor. sec. 14, T. 13 N., R. 9 W. This well is 45 feet deep and penetrates 25 feet of saturated alluvium. The casing is concrete, eight inches in diameter, and surrounded by a gravel envelope. A turbine pump, electrically powered is used in the well which is reported to yield 75 gpm. The total pumpage for Calumet is estimated to be nine million gallons a year—an average of 25,000 gpd.

FORT RENO

Fort Reno was supplied by two water wells in the NE¼NE¼ sec. 27, T. 13 N., R. 8 W. One well is 42 feet deep and the other is 45 feet deep. Each well has 18-inch concrete casing with the bottom 15 feet screened. The screens are set on top of the redbeds. The wells are equipped with electrically powered turbine pumps and are reported to have drawdowns of 18 feet after pumping 10 hours at a rate of 250 to 300 gpm. The total pumpage from both wells is reported to have been 54 million gallons a year—an average of 150,000 gpd.

CONCHO INDIAN RESERVATION

The Concho Indian Reservation is supplied by three wells in the NW¼NW¼ sec. 19, T. 13 N., R. 7 W. The oldest well is 180 feet deep; it taps water from the alluvium to a depth of 40 feet, and the remainder of the well is cased off to provide the necessary head for an air-lift pump. Both of the other two wells are drilled to the top of the redbeds. They are each 45 feet deep and have electrically powered turbine pumps. The total pumpage from all of the wells is reported to be 36 million gallons a year, or an average of 100,000 gpd.

Industrial Supply Wells

The Oklahoma Gas and Electric Co. owns 19 water wells in secs. 25 and 36, T. 12 N., R. 5 W. Water from the wells is used for cooling purposes in the Mustang power plant. The wells range in depth from 43 to 66 feet and average about 58 feet. They penetrate an average thickness of 35 feet of saturated alluvium. All of the wells are equipped with electrically powered turbine pumps.

Total pumpage for the Mustang power plant of Oklahoma Gas and Electric Co.

Year	Pumpage (millions of gallons)	Year	Pumpage (millions of gallons)
1953	721	1956	882
1954	696	1957	403
1955	858	1958	196

The greatest amount of pumpage was during the drought year of 1956 when an average of 2.4 mgd was pumped, all from a 160-acre well field. Pumpage averaged only 1.2 mgd in 1957 and 0.54 mgd in 1958 because a large part of the plant's water requirements was obtained from the North Canadian River.

Another industrial supply well is in the SW¼NE¼SW¼ sec. 4, T. 12 N., R. 7 W. Water from the well, which is owned by the Chicago, Rock Island, and Pacific Railroad, is used for washing equipment at the El Reno freight yards. The well was dug with an orange-peel bucket to a depth of 44 feet and has a gravel envelope 17 inches thick around the 13-inch concrete casing with the bottom 8½ feet perforated. The yield of this well was not reported.

Irrigation Wells

A total of 19 irrigation wells were recorded within the area of this report. Of this total, three wells had not been used in more than 10 years and it is reported that they have been abandoned. The remaining 16 wells are reported to be used to irrigate a total of 649 acres. The alluvium of the North Canadian River valley is tapped by 15 wells which are used to irrigate 609 acres; and one well, which taps water from the alluvium of the Canadian River, is used to irrigate 40 acres.

Some of the wells have already proved their worth, although they have been in service only a few seasons. The following paragraphs summarize the principal facts about each well.

Jake Ast Well 11N8W-22-4

The Jake Ast well (11N8W-22-4) is about six miles west and one mile north of Union City. It was dug in the winter of 1950, is 62 feet deep and is cased with a 13-inch concrete casing perforated in the lower part to permit the entrance of water into the well. The well is equipped with a turbine pump driven by a propane-powered, 110-horsepower engine and is reported to yield 650 gpm with 22 feet of drawdown after 24 hours of pumping. The specific capacity is about 30 gpm per foot of drawdown. The well taps water from the alluvium of the Canadian River and is used to irrigate 40 acres.

Robert K. Everets Wells 12N5W-5-2 and 12N5W-5-3

The Robert K. Everets wells (12N5W-5-2) and (12N5W-5-3) are about two miles north of Yukon. The wells are about 100 feet apart and were drilled in 1940 to a depth of 80 feet. The casings are steel and extend to a depth of 40 feet, which is the entire thickness of the alluvium. The remaining 40 feet of hole penetrates the redbeds and is uncased. The wells are equipped with turbine pumps driven by natural-gas engines.

It was reported that the wells had not been used in more than 10 years and that there were no existing plans to use them in the near future. Formerly the wells were used to irrigate 40 acres.

P. A. Cornell Well 13N7W-21-9

The P. A. Cornell well (13N7W-21-9) is about four miles north of El Reno. It was constructed in 1948, is 46 feet deep, and is cased with a 14-inch steel casing surrounded by a gravel envelope. The well is equipped with a turbine pump driven by a propane-powered, 110-horsepower engine, and is reported to yield 720 gpm with 16 feet of drawdown. The specific capacity is 45 gpm per foot of drawdown. The static water level was 17 feet below land surface in June 1953. The well was used to irrigate 45 acres of alfalfa in 1953.

Regina Blum Wells 13N9W-1-3 and 13N9W-1-4

The Regina Blum wells (13N9W-1-3 and 13N9W-1-4) are about one mile east and two miles north of Calumet. The wells are about 35 feet apart and are connected to the same centrifugal pump, which is driven by a gasoline-powered engine. They were dug in 1950 by Ben and Harold Blum and are both 23 feet deep with 5½-inch galvanized-iron casings. The wells are reported to yield 300 gpm, together, and are used to irrigate 16 acres.

John Garvey Well 14N9W-31-1

The John Garvey well (14N9W-31-1) is about three miles north and four miles west of Calumet. It was dug in 1939, is 34 feet deep, and is cased with a 14-inch concrete casing. The well is equipped with a turbine pump and is reported to yield 450 gpm. This well has not been used for irrigation for more than 10 years —the reason being that the water is of high alkaline content and therefore unsuitable.

Bill Hall Well 12N6W-7-2

The Bill Hall well (12N6W-7-2) is about five miles east of El Reno. It was drilled in the summer of 1953, is 38 feet deep, and is cased with a 16-inch galvanized-iron casing perforated in the lower part to permit the entrance of water into the well. The static water level is eight feet below land surface; thus, the well penetrates 30 feet of saturated alluvium. After construction the well was test pumped and was reported to yield 525 gpm with 20 feet of drawdown after pumping eight hours. This indicates a specific capacity of about 26 gpm per foot of drawdown. The owner reports that the well is to be used to irrigate 40 acres—beginning with the 1954 growing season.

Frank Grossman Well 12N6W-8-2

The Frank Grossman well (12N6W-8-2) is about five miles east of El Reno. It was drilled in the summer of 1953, is 39 feet deep, and is cased with 16-inch galvanized-iron casing which has the bottom 17.5 feet perforated. The static water level in October 1953 was 10 feet below land surface; thus, the well penetrated 29 feet of saturated alluvium. The well is equipped with a turbine pump driven by a propane-powered engine, and is reported to yield 425 gpm with 17 feet of drawdown after pumping 17 hours. This indicates a specific capacity of about 25 gpm per foot of drawdown. The owner reports that the well is to be used to irrigate 90 acres—beginning with the 1954 growing season.

Billington Lumber Co. Wells

The Billington Lumber Co. of Oklahoma City owns five wells which are used to irrigate 293 acres about three miles north and three miles west of El Reno.

Well 13N8W-23-3 was drilled in the winter of 1949, is 54 feet deep, and is cased with a 12-inch steel casing with 10 feet of copper well screen at the bottom. The well is equipped with a turbine pump driven by a 15-horsepower electric motor and is reported to yield 200 gpm.

Well 13N8W-23-4 was drilled in the spring of 1953, is 54 feet deep, and is cased with a 12-inch steel casing with 10 feet of copper well screen at the bottom. The well is equipped with a turbine pump driven by a 20-horsepower electric motor and is reported to yield 600 gpm. This well is about 45 feet northeast of well 13N8W-23-3 and when both wells are pumping simultaneously the yields are reduced.

Well 13N8W-24-1 was drilled in the winter of 1949, is 54 feet deep, and is cased with an 18-inch concrete casing with eight feet of concrete well screen at the bottom. The casing is surrounded by a gravel envelope nine inches thick. The well is equipped with a turbine pump driven by an electric motor and is reported to yield 1,100 gpm.

Well 13N8W-24-15 was drilled in the spring of 1953, is 54 feet deep, and is cased with a 12-inch steel casing with 10 feet of copper well screen at the bottom. The casing is surrounded by a gravel envelope. The well is equipped with a turbine pump driven by a 15-horsepower electric motor and is reported to yield 500 gpm.

Well 13N8W-26-1 was drilled in the winter of 1949, is 56 feet deep, and is cased with an 18-inch concrete casing with eight feet of concrete well screen at the bottom. The casing is surrounded by a gravel envelope nine inches thick. The well is equipped with a turbine pump driven by an electric motor and the measured yield was 286 gpm in June 1949. The low yield of this well as compared to the similarly constructed well 13N8W-24-1 was reported by the owner to be due to fine sand from above penetrating the gravel envelope around the screen openings in the lower part of the casing.

John Snyder Well 14N9W-36-3

The John Snyder well (14N9W-36-3) is about one mile east and three miles north of Calumet. It was dug in the winter of 1953, is 17 feet deep, and is cased with a 12-inch iron casing which has perforations in the bottom eight feet. The well is equipped with a centrifugal pump driven by a gasoline-powered engine and is reported to yield 125 gpm with nine feet of drawdown after pumping 10 hours. The specific capacity is about 14 gpm per foot of drawdown. The well is used to irrigate 10 acres.

D. W. Walls Wells 14N9W-36-5 and 14N9W-36-6

The D. W. Walls wells (14N9W-36-5 and 14N9W-36-6) are about three miles north of Calumet. They were both drilled to a depth of 40 feet by Jack Harrison, Calumet, Okla., in December 1953 and have 8-inch steel casings. Each well is to be used to irrigate 15 acres and is reported to yield 100 gpm.

Quentin Rowland Well 14N10W-14-3

The Quentin Rowland well (14N10W-14-3) is about four miles north and five miles east of Geary and actually is two separate wells about 10 feet apart. These wells have 2-inch steel casings with sandpoints at the bottom and are 34 feet deep. They are connected to the suction line of a centrifugal pump which is driven by a gasoline-powered, 20-horsepower engine. The well is used to irrigate 40 acres of alfalfa and is reported to yield 70 gpm. Mr.

Rowland reported that an analysis of the water by Oklahoma A. & M. College indicates it to be suitable for irrigation.

R. H. Morgan Well 14N10W-22-3

The R. H. Morgan well (14N10W-22-3) is about three miles north and three miles east of Geary. Constructed by the owner's son, R. H. Morgan, Jr., in June 1953, the well was used for the remainder of the year to irrigate 45 acres of alfalfa. It consists of a battery of six 2-inch driven wells about 32 feet deep, each equipped with a well point and arranged in a rectangular manner with a minimum spacing of about 16 feet between wells. The wells are fitted to a 12-inch manifold which is connected to a centrifugal pump. A gasoline-powered engine drives the pump, which is reported to deliver 750 gpm.

Chemical Character of Ground Water

All natural waters contain mineral matter dissolved from the rocks and soils with which they have come in contact. The quantity of dissolved mineral matter in ground water depends primarily on the type of rocks or soil through which the water has passed, the length of time of contact, and pressure and temperature. In addition to these natural factors are others connected with human activities, such as infiltration from streams and wells used for disposal of sewage and industrial water, diversion and use of water for many purposes, and drainage from oil fields.

The mineral constituents and physical properties of ground waters reported in the analyses of table 7 are those having a practical bearing on the value of the waters for most purposes: silica, iron, calcium, magnesium, sodium, potassium (or sodium and potassium reported together as sodium), bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, dissolved solids, hardness, pH, specific conductance, and temperature.

Chemical analyses of water from 131 wells in Canadian County are listed in table 7. The wells chosen for sampling are scattered widely and the analyses, therefore, represent nearly the full range in quality that may be expected. Of the 131 analyses, 70 are of water from wells in the alluvium, two from wells in the Rush Springs sandstone, 51 from other wells in redbeds of Permian age and eight from wells in the terrace deposits on the north side of the North Canadian River. The water from the terrace deposits is shown to be considerably better than the water from the alluvium or the redbeds.

The following discussion of the chemical constituents of water has been summarized from several papers published by the Quality of Water Branch of the U. S. Geological Survey:

Dissolved Solids

The figures given under "dissolved solids" show approximately the total quantity of dissolved mineral matter as determined by evaporating a measured quantity of clear water and weighing the residue after it has been dried at 180°C for one hour. For 42 samples of water for which approximate dissolved solids are shown, the concentration of dissolved solids ranged from about a hundred to several thousand parts per million.

Hardness

Hardness is a characteristic of water that receives considerable attention with reference to industrial and domestic use. It is generally recognized by the quantity of soap required to produce lather. Hard water is objectionable because it forms a scale in boilers, water heaters, radiators, and pipes, thereby decreasing the rate of heat transfer and creating the possibility of boiler failure and loss of flow. Hardness is caused almost entirely by compounds of calcium and magnesium. Other constituents such as iron, manganese, aluminum, barium, strontium, and free acid also cause hardness, but they are not usually found in appreciable quantities in most natural waters.

Water having a hardness of less than about 50 ppm is generally rated as soft, and does not require softening except for special use. Hardness of 50 to 150 ppm does not seriously interfere with the use of water for most purposes, but it slightly increases the consumption of soap. Its removal, by a softening process, is profitable for laundries or other industries using large quantities of soap. Water having a hardness in the upper part of this range will cause considerable scale in steam boilers. Hardness above 150 ppm can be detected by anyone, and in areas where it is above 300 ppm it is common practice to soften water for household use or to install cisterns for storing rain water. Where municipal supplies are softened an attempt is generally made to reduce the hardness to less than 100 ppm.

Water from the wells of this area is generally very hard, with the exception of water from the terrace deposits north of the North Canadian River. As shown by the analyses, the hardness of water from the terrace deposits ranges from 80 to 232 ppm and averages 154 ppm, the hardness of water from the alluvium ranges from 181 to 1,710 ppm and averages 522 ppm, and the hardness of water from the redbeds ranges from 116 to 3,280 ppm and averages 877 ppm.

Iron

Iron is present in most ground water, but generally only in comparatively small amounts. Water containing more than a few tenths of a part per million of iron is objectionable because of its reddish appearance after exposure to the air and because the iron stains clothing and plumbing fixtures. Such water, therefore, may require treatment. Excessive iron may interfere with the efficient operation of exchange-silicate water softeners. Of the 16 analyses in which results for iron are shown, five indicate an objectionable amount.

Sodium and Potassium

Moderate quantities of sodium and potassium have little effect on the suitability of water for most industrial or domestic uses. More than 50 ppm of the two may cause foaming in steam boilers. Generally, if the equivalents per million of sodium exceed the sum of the equivalents per million of calcium and magnesium in water used for irrigation, there is some danger of damage to the soil. The sodium content, or the sodium and potassium together—as sodium, for these samples in which the concentration of these constituents are reported, ranged from 9.1 to 73 ppm in water from the terrace deposits, from 17 to 369 ppm in water from the alluvium, and from 26 to 422 ppm in water from the redbeds.

Bicarbonate and Carbonate

Bicarbonate is the principal anion in most natural water, especially that from limestone aquifers. A high concentration of sodium and bicarbonate in boiler waters may cause foaming. Carbonate is present in few natural waters, and where present generally amounts to only a few parts per million.

Sulfate

Sulfate may be dissolved in water passing through gypsum or other sulfate salts. It also may be formed by the oxidation of the sulfides of certain metals. When present as a result of solution of calcium and magnesium salts, sulfate contributes to noncarbonate hardness, and hence to boiler scale and to the cost of softening water. For 112 samples in which the content of sulfate is reported, the concentrate ranged from 14 to 5,350 ppm. None of the samples of water from the terrace deposits, 21 samples of water from the alluvium, and 27 samples of water from the redbeds contained more than 250 ppm of sulfate—the suggested upper limit for sulfate in drinking water for use on interstate carriers and for public supplies in general (U. S. Public Health Service, 1946. p. 371).

Chloride

Chloride combined with sodium is common salt, and both chloride and sodium generally are present in ground water. Chloride in small amounts has little effect on the usefulness of water, but concentrations of 300 ppm or more in association with alkali-metal ions give water a salty taste perceptible to most people. Heavy concentrations of chloride may impart corrosiveness to water, requiring frequent replacement of water pipe or measures to prevent corrosion, such as the lining of pipe with noncorroding material. None of the analyses of water from the terrace deposits, 11 analyses of water from the redbeds, and four analyses of water from the alluvium show a chloride content greater than 250 ppm —the suggested upper limit of chloride in water used for drinking.

Fluoride

The principal effect of fluoride in drinking water is on tooth enamel, when the water is used regularly during the period of formation of the permanent teeth. In concentration of about 1.0 ppm, fluoride is believed by many health authorities to lessen the incidence of tooth decay; in concentrations greater than about 1.5 ppm it may contribute to permanent mottling of the tooth enamel.

Of 60 samples, analyzed for fluoride 10 showed concentrations greater than 1 ppm. The highest concentration was 2.6 ppm.

Nitrate

Nitrate in water is considered a final oxidation product of nitrogenous material and, in some instances, may indicate previous contamination by sewage or other organic matter. It has been reported that small concentrations of nitrate in boiler water may decrease intercrystalline cracking of boiler steel.

Water containing an excessive amount of nitrate has been suspected of causing a form of cyanosis or "blue baby" (Waring, F. G., 1949, p. 147) when used in the preparation of formulas for feeding infants. The Oklahoma State Health Department now considers water containing less than 10 ppm of nitrate nitrogen (approximately 45 ppm when reported as nitrate) as safe for use.

Of 79 samples of water analyzed for nitrate, six of water from the alluvium, four of water from the redbeds, and one of water from the terrace deposits showed a nitrate content of more than 45 ppm.

Hydrogen-Ion Concentration (pH)

The acidity or alkalinity of water is indicated by the hydrogen-ion concentration, generally expressed in terms of pH. A pH of 7 indicates neutrality. Values below 7 indicate acidity, whereas those above 7 indicate alkalinity. Waters having a pH much below 7 are generally corrosive. The pH of 11 samples of water from wells in the alluvium ranged from 7.4 to 8.3, the pH of 11 samples from wells in the redbeds ranged from 7.3 to 8.4, and the pH of seven samples from wells in the terrace deposits ranged from 6.2 to 8.3.

Suitability for Drinking

Standards by which to judge the suitability of water for drinking have been established by the U. S. Public Health Service (1946, p. 371). They indicate the maximum concentration of certain constituents, in parts per million, that is acceptable for water used on interstate carriers. The standards have been adopted by many state health departments. Among the constituents included in table 7, six are considered significant and the maximum limits for them as specified by the Public Health Service are given below.

Constituent	Parts per million	
Magnesium (Mg)	125	
Chloride (Cl)	250	
Sulfate (SO_4)	250	
Fluoride (F)	1.5	
Dissolved solids	500	(1,000 acceptable)
Iron and manganese together	0.3	

By the above standards and from partial analytical data, the water from 61 wells is shown to be unsatisfactory for drinking by reason of concentrations in excess of those named above for one or more constituents exclusive of dissolved solids. (See table 7). Of the 61 unsatisfactory waters 31 were from wells tapping the alluvium and 30 were from wells tapping the redbeds.

Suitability for Irrigation

Whether a water is satisfactory for irrigation depends on several factors in addition to the mineral content of the water, among them the type of soil, the amount of water applied to the soil, the amount and distribution of rainfall, and the drainage characteristics of the soil. The following paragraphs on this subject have been adapted from Agriculture Handbook 60 of the U. S. Department of Agriculture (1954).

Any method for the interpretation of analyses of water to be used for irrigation is based on the presumption that the water will be used under average conditions as related to quantity, soil permeability, drainage, climate, and salt tolerance of crop. Large deviations from the average for one or more of these variables may make it unsafe to use what, under average conditions, would be a good water; or may make it safe to use what, under average conditions would be water of doubtful quality.

All waters used for irrigation carry varying quantities of chemicals that are referred to as dissolved salts. If their concentration is not too great, some of the dissolved salts favor the growth

TABLE 7. CHEMICAL ANALYSES OF WATER FROM WELLS IN CANADIAN COUNTY

[1] A, Alluvium; R, Redbeds;
RS, Rush Springs; T, Terrace deposits.
[2] Analyses by Oklahoma Gas & Electric Co.

[Analytical results in parts per million except as indicated]

Well No.	Depth (feet)	Aquifer[1]	Date of collection	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
10N5W- 6-1	62	R	1-48	61	....	......	......	......	......	......
12-1	65	A	1-48	....	....	......	......	......	......	......
15-1	......	A	1-48	62	....	......	......	......	......	......
10N6W- 9-1	40	A	4-48	....	....	......	......	......	......	......
11N5W-10-1	28	A	4-48	62	....	......	......	......	......	......
33-1	100	R	4-48	....	....	......	......	......	......	......
11N6W- 9-1	120	R	6-53	64	....	......	433	143	......	......
30-1	195	R	4-48	63	....	......	......	......	......	......
11N7W- 4-1	24	R	4-48	59	....	......	......	......	......	......
28-1	33	R	4-48	59	....	......	......	......	......	......
11N8W- 2-1	18	R	4-48	56	....	......	......	......	......	......
26-1	26	A	4-48	62	....	......	......	......	......	......
30-1	37	A	7-53	63	....	......	101	38	52	......
11N9W-11-1	33	A	7-53	65	....	......	107	41	28	......
20-1	110	RS	6-53	63	....	......	143	17	23	......
11N10W-22-1	56	RS	6-53	65	....	......	32	9.5	13	......
[2]12N5W- 2-2	75	A	7-52	....	....	......	56	32	44	
3-1	31	A	5-42	61	27	0.54	52	18	22	0.9
[2]3-2	45	A	7-52	....	....	......	52	32	41	
[2]3-3	21	A	7-52	....	....	......	104	61	38	
[2]3-4	......	A	7-52	....	....	......	72	34	26	
5-4	66	A	3-42	....	....	......	......	......	......	
7-1	18	A	4-43	....	....	......	122	46	31	
8-1	27	A	3-42	....	....	......	......	......	......	
14-1	34	A	3-42	....	....	......	......	......	......	
18-2	43	A	3-42	....	....	......	......	......	......	
[2]21-1	30	R	7-52	....	....	......	52	32	85	
[2]22-1	75	R	7-52	....	....	......	56	51	91	
23-1	65	R	3-42	....	....	......	......	......	......	
[2]23-4	75	R	7-52	....	....	......	361	92	337	
[2]23-5	35	R	7-52	....	....	......	128	46	413	
[2]23-6	25	R	7-52	....	....	......	52	29	70	
[2]23-7	75	R	7-52	....	....	......	68	39	74	
[2]25-1	40	A	8-52	....	....	......	88	47	122	
[2]26-1	100	R	7-52	....	....	......	421	90	422	
[2]26-2	......	R	7-52	....	....	......	417	106	239	
[2]26-4	75	R	7-52	....	....	......	55	33	139	
[2]26-5	......	A	8-52	....	....	......	90	42	151	
[2]26-6	45	A	8-52	....	....	......	88	40	167	
[2]26-7	......	A	8-52	....	....	......	121	42	104	
[2]27-3	55	R	7-52	....	....	......	236	75	270	
[2]27-4	30	R	7-52	....	....	......	172	131	124	
[2]27-5	50	R	7-52	....	....	......	124	68	178	
[2]27-6	55	R	7-52	....	....	......	369	85	245	
[2]27-7	75	R	7-52	....	....	......	89	37	68	
[2]27-8	30	R	7-52	....	....	......	68	41	133	

TABLE 7. CHEMICAL ANALYSES (continued)

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue, evaporation at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
156	....	26	28	....	175	....	....	....	234	....	....	574	....
218	....	50	18	....	30	....	....	....	181	....	....	527	....
346	....	40	64	....	7.0	....	....	....	596	....	....	809	....
154	....	300	17	....	10	....	....	....	319	....	....	796	....
234	....	100	50	....	20	....	....	....	218	....	....	809	....
166	....	30	11	....	25	....	....	....	214	....	....	392	....
217	0	....	250	....	....	....	....	....	1,670	1,490	....	4,010	7.5
73	....	5,350	390	....	8.0	....	....	....	1,160	....	....	9,070	....
298	....	380	140	....	6.0	....	....	....	196	....	....	1,050	....
94	....	1,760	945	....	20	....	....	....	1,440	....	....	5,270	....
122	....	1,370	480	....	400	....	....	....	3,280	....	....	4,170	....
75	....	1,000	80	....	10	....	....	....	879	....	....	2,010	....
385	0	....	18	....	......	....	....	....	410	88	22	932	8.3
343	0	....	18	....	......	....	....	....	435	154	12	890	7.8
195	0	....	73	....	......	....	....	....	425	265	11	994	7.9
150	0	....	5.0	....	......	....	....	....	120	0	9	289	8.4
388	0	30	12	....	......	....	....	....	270	0	....	....	....
214	0	16	10	0.2	47	....	300	....	204	....	....	....	....
356	0	26	22	....	......	....	....	....	260	0	....	....	....
449	0	61	114	....	......	....	....	....	510	142	....	....	....
302	0	96	21	....	......	....	....	....	320	72	....	....	....
532	....	600	386	.4	732	....	....	....	1,710	....	....	....	....
526	0	58	48	1.0	0.2	0.07	....	565	494	....	....	958	....
554	....	60	268	2.6	830	....	....	....	810	....	....	....	....
412	....	25	11	1.1	.2	....	....	....	318	....	....	....	....
558	....	125	71	.8	1.0	....	....	....	486	....	....	....	....
393	0	49	51	....	......	....	....	....	260	0	....	....	....
283	0	172	97	....	......	....	....	....	350	118	....	....	....
342	....	400	39	0.6	4.3	....	....	....	562	....	....	....	....
195	0	1,680	72	....	......	....	....	....	1,280	1,120	....	....	....
305	0	1,050	46	....	......	....	....	....	510	260	....	....	....
361	0	81	16	....	......	....	....	....	250	0	....	....	....
368	0	146	27	....	......	....	....	....	330	28	....	....	....
515	0	101	108	....	......	....	....	....	414	0	....	....	....
258	0	1,850	141	....	......	....	....	....	1,420	1,210	....	....	....
222	0	1,540	150	....	......	....	....	....	1,480	1,290	....	....	....
424	0	164	39	....	......	....	....	....	270	0	....	....	....
461	0	183	112	....	......	....	....	....	398	20	....	....	....
449	0	212	114	....	......	....	....	....	386	18	....	....	....
427	0	159	130	....	......	....	....	....	374	124	....	....	....
293	0	1,100	73	....	......	....	....	....	900	660	....	....	....
544	0	505	190	....	......	....	....	....	970	524	....	....	....
517	0	449	61	....	......	....	....	....	590	166	....	....	....
273	0	1,400	87	....	......	....	....	....	1,270	1,050	....	....	....
341	0	156	57	....	......	....	....	....	374	94	....	....	....
422	0	101	126	....	......	....	....	....	340	0	....	....	....

TABLE 7. CHEMICAL ANALYSES OF WATER FROM WELLS IN CANADIAN COUNTY

[1] A, Alluvium; R, Redbeds;
RS, Rush Springs; T, Terrace deposits.
[2] Analyses by Oklahoma Gas & Electric Co.

[Analytical results in parts per million except as indicated]

Well No.	Depth (feet)	Aquifer[1]	Date of collection	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
12N5W-34-1	27	R	3-42	....	....	....	....	....	....	....
[2]34-3	....	R	7-52	....	....	....	180	85	66	
[2]34-4	53	R	7-52	....	....	....	112	56	77	
[2]34-5	28	R	7-52	....	....	....	120	71	198	
35-1	32	A	3-42	....	....	....	....	....	....	....
[2]35-3	65	R	7-52	....	....	....	248	44	121	
[2]35-4	....	R	7-52	....	....	....	224	83	257	
[2]35-5	23	A	8-52	....	....	....	91	50	109	
[2]36-1	23	A	8-52	....	....	....	82	36	63	
36-3	66	A	7-49	64	....	....	67	25	110	
36-4	63	A	7-49	....	....	....	73	28	92	....
36-7	65	A	6-51	....	....	1.0	63	26	106	....
36-8	43	A	5-52	....	....	....	78	35	92	....
12N6W- 5-1	41	A	5-42	62	30	9.2	69	28	46	1.8
7-1	13	A	4-43	....	....	....	116	19	35	
12-1	24	A	4-43	61	....	....	58	33	124	
15-2	18	A	3-42	....	....	....	....	....	....	....
17-1	66	A	3-42	....	....	....	....	....	....	....
18-1	26	A	3-42	....	....	....	....	....	....	....
12N7W- 2-1	46	A	4-43	....	....	....	133	45	84	
4-2	43	A	4-43	....	....	....	167	78	215	
9-1	28	A	3-42	....	....	....	....	....	....	....
10-1	39	A	3-42	....	....	....	....	....	....	....
12-2	32	A	3-42	....	....	....	....	....	....	....
12N8W-20-1	28	R	6-53	63	....	....	449	107	....	....
12N9W-20-1	119	R	4-48	63	....	....	....	....	....	....
12N10W- 3-1	30	R	6-53	60	....	....	273	33	115	....
6-1	29	A	7-53	64	....	....	269	92	168	....
20-1	57	R	7-53	63	....	....	104	21	26	....
13N5W-27-1	35	R	6-53	62	....	....	82	36	32	....
13N6W-23-1	....	T	6-53	62	....	....	54	24	73	....
27-1	33	T	2-54	62	39	0.14	48	10	63	4.0
30-2	50	T	2-54	62	15	0.00	52	14	49	1.5
13N7W-11-1	16	R	7-53	61	....	....	125	32	32	....
19-1	180	A	4-43	....	....	....	114	36	31	
21-2	20	A	4-43	60	....	....	149	49	73	
22-1	92	R	3-42	....	....	....	....	....	....	....
33-3	52	A	3-42	....	....	....	....	....	....	....
35-2	34	A	3-42	....	....	....	....	....	....	....
13N8W- 8-1	24	A	4-43	....	....	....	62	40	198	
9-1	18	A	4-43	..	....	....	203	83	150	
10-2	12	A	4-43	58	....	....	291	63	134	
12-1	35	T	2-54	59	21	0.00	29	8.5	20	0.9
13-1	3	T	4-43	....	....	....	22	7.2	11	
19-1	35	A	3-42	....	....	....	....	....	....	....
20-1	38	A	3-42	....	....	....	....	....	....	....
20-2	28	A	4-43	....	....	....	241	57	135	

TABLE 7. CHEMICAL ANALYSES (continued)

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue, evaporation at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
312	....	140	14	0.2	17	....	....	....	363	....	....	....	....
388	0	440	119	....	......	....	....	....	800	482	....	....	....
280	0	338	68	....	......	....	....	....	510	280	....	....	....
490	0	524	53	....	......	....	....	....	590	188	....	....	....
598	....	250	43	.4	28	....	....	....	690	....	....	....	....
334	0	674	63	....	......	....	....	....	800	526	....	....	....
276	0	1,060	92	....	......	....	....	....	900	674	....	....	....
544	0	171	30	....	......	....	....	....	430	0	....	....	....
439	0	89	27	....	......	....	....	....	352	0	....	....	....
339	....	83	102	.7	0.0	....	580	555	270	0	47	971	7.4
341	0	80	93	....	......	....	535	....	298	18	....	....	....
318	0	57	109	....	......	....	518	....	263	0	....	....	7.5
336	0	95	118	....	......	....	584	....	340	65	....	....	7.4
396	0	48	10	0.5	0.3	....	407	....	287	....	....	....	....
372	0	58	54	.4	1.0	0.02	....	467	368	....	....	819	....
586	0	43	15	1.0	.2	.18	....	563	280	....	....	941	....
520	....	15	17	.2	32	....	....	....	447	....	....	....	....
404	....	220	65	.0	5.6	....	....	....	414	....	....	....	....
514	....	72	22	.2	1.0	....	....	....	381	....	....	....	....
444	0	219	75	.9	.2	.17	....	776	517	....	....	1,230	....
598	0	489	145	.5	.2	.74	....	1,389	738	....	....	2,060	....
400	....	180	120	.2	188	....	....	....	518	....	....	....	....
320	....	300	77	.0	.8	....	....	....	441	....	....	....	....
514	....	200	89	.9	4.5	....	....	....	472	....	....	....	....
272	0	....	590	....	......	....	....	....	1,560	1,340	....	5,060	8.0
196	....	24	14	....	4.0	....	....	....	116	....	....	376	....
365	0	....	18	....	......	....	....	....	815	516	23	1,550	7.3
356	0	....	108	....	......	....	....	....	1,050	758	26	2,330	7.6
214	0	....	17	....	......	....	....	....	346	170	14	740	8.1
286	0	....	29	....	......	....	....	....	350	116	17	829	7.8
304	6	....	28	....	......	....	....	....	232	0	41	711	8.3
226	0	24	43	.3	23	.33	378	366	161	0	45	574	7.5
284	0	14	12	.3	24	.46	322	322	187	0	36	524	8.1
484	0	....	13	....	......	....	....	....	445	48	14	904	7.8
298	12	198	15	.7	9.6	.18	....	563	432	....	....	865	....
420	0	318	39	.8	.2	.22	....	836	574	....	....	1,250	....
280	....	40	13	.3	10	....	....	....	273	....	....	....	....
304	....	200	118	1.0	1.2	....	....	....	465	....	....	....	....
464	....	140	142	0.4	1.7	....	....	....	456	....	....	....	....
598	0	164	60	1.6	0.2	0.22	....	820	319	....	....	1,310	....
514	0	587	75	0.5	43	.28	....	1,395	848	....	....	1,920	....
224	0	901	108	0.7	1.0	.15	....	1,609	985	....	....	2,120	....
50	0	29	12	0.3	75	.34	251	221	107	66	29	339	6.2
66	0	19	5.0	.4	33	.00	....	130	84	....	....	220	....
330	....	600	160	.0	40	....	....	....	570	....	....	....	....
622	....	360	114	.0	4.3	....	....	....	780	....	....	....	....
340	0	345	348	.2	2.0	.04	....	1,296	836	....	....	2,090	....

TABLE 7. CHEMICAL ANALYSES OF WATER FROM WELLS IN CANADIAN COUNTY

[1] A, Alluvium; R, Redbeds;
RS, Rush Springs; T, Terrace deposits.
[2] Analyses by Oklahoma Gas & Electric Co.

[Analytical results in parts per million except as indicated]

Well No.	Depth (feet)	Aquifer[1]	Date of collection	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
13N8W-22-3	17	A	3-42	...	....	......	......	......	....	.....
23-1	25	A	4-43	60	....	......	72	46	17	
24-1	55	A	7-54	62	32	0.00	170	65	112	3.2
27-1	42	A	4-48	60	14	0.05	134	54	123	5.0
27-2	45	A	4-48	60	17	.10	103	39	84	4.5
29-1	17	A	4-43	....	....	......	130	72	184	
31-1	28	R	3-42	....	....	......	......	......	....	.....
13N9W- 1-1	11	A	4-43	....	....	......	138	71	107	
7-1	43	R	3-42	....	....	......	......	......	....	......
9-1	56	R	3-42	....	....	......	......	......	....	.....
14-5	45	A	6-52	....	34	.00	362	137	316	4.0
25-1	56	R	3-42	....	....	......	......	......	....	......
36-1	38	R	5-42	....	18	1.4	208	83	256	5.2
13N10W- 1-1	76	R	3-42	....	....	......	......	......	....	......
14-1	37	R	3-42	....	....	......	......	......	....	......
14N5W-10-1	30	R	6-53	62	....	......	113	36	92	......
32-1	56	R	6-53	....	....	......	......	......	40	......
14N6W-11-1	52	R	6-53	63	....	......	192	46	132	......
14N7W-24-1	59	R	6-53	66	....	......	206	49	190	......
14N8W- 7-1	19	R	7-53	62	....	......	277	126	......	......
12-1	55	R	6-53	63	....	......	109	38	235	......
29-1	27	T	2-54	63	19	0.00	43	12	15	1.4
14N9W- 5-1	17	T	7-53	66	....	......	18	8.3	9.1	......
21-1	41	T	2-54	59	20	0.00	62	18	32	1.5
34-1	32	A	4-43	....	....	......	78	25	51	
36-1	16	A	4-43	59	....	......	70	33	108	
14N10W- 7-1	35	A	6-52	....	31	0.00	76	39	148	1.8
15-2	21	A	4-43	....	....	......	84	27	38	
17-3	14	A	3-42	....	....	......	......	......	....	......
20-2	32	A	4-43	....	....	......	158	74	260	
21-1	23	A	5-42	....	34	.29	93	59	369	4.0
22-1	21	A	5-42	....	24	.50	75	45	97	2.2
23-1	18	A	4-43	....	....	......	274	62	123	
24-1	26	A	4-43	....	....	......	232	144	281	
25-2	27	A	4-43	....	....	......	64	52	49	
28-1	19	A	4-43	....	....	......	92	62	329	
34-2	68	R	3-42	....	....	......	......	......	....	.....
34-3	62	R	3-42	....	....	......	......	......	....	.....

TABLE 7. CHEMICAL ANALYSES (continued)

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue, evaporation at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magne-	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
517	....	250	64	0.6	19	....	....	....	495	....	....	....	....
446	0	28	4	1.7	2.5	0.07	....	391	368	....	...	697	....
493	0	325	122	.8	4.0	.14	1,120	1,080	692	288	26	1,640	7.8
477	0	310	82	.4	1.0	....	970	958	556	166	32	1,430	7.6
419	0	179	52	.8	1.0	....	692	686	418	74	30	1,070	7.5
586	0	404	82	1.4	.2	.18	....	1,162	620	....	...	1,730	....
243	....	2,400	860	....	9.3	....	....	....	2,280	....	...	....	....
514	0	276	110	1.6	1.8	.15	....	959	636	....	....	1,520	....
277	....	750	248	.2	14	...	....	....	870	....	...	....	...
204	....	2,200	161	....	4.7	....	....	....	1,800	....	...	....	....
399	0	1,430	218	.9	2.5	....	3,040	....	1,470	1,140	....	3,400	7.4
493	....	900	132	....	4.7	....	....	....	1,300	....	....	....	....
303	0	698	288	.4	50	....	1,837	....	860	....	....	....	....
194	....	1,500	430	....	13	....	....	....	1,480	....	....	....	....
527	....	1,400	352	....	450	....	....	....	2,130	....	....	....	....
258	9	....	42	....	......	....	....	....	430	204	32	1,130	8.3
......	....	....	15	....	......	....	....	....	....	....	....	....	....
278	10	....	84	....	......	....	....	....	670	426	30	1,650	8.4
376	11	....	45	....	......	....	....	....	715	388	37	1,850	8.3
452	0	....	835	....	......	....	....	....	1,210	840	....	6,100	7.5
237	10	....	126	....	......	....	....	....	430	220	54	1,740	8.4
142	0	29	8	0.3	36	0.27	253	233	157	40	17	373	6.8
53	0	....	12	....	......	....	....	....	80	36	20	218	6.9
224	0	29	44	0.3	16	0.34	352	333	228	45	23	563	6.8
420	0	22	10	0.8	31	0.11	....	425	298	....	....	718	....
492	0	90	15	1.8	27	.13	....	587	310	....	....	961	....
445	0	200	64	.9	3.3	....	783	....	350	0	....	1,220	7.7
276	0	121	26	.7	16	.07	....	449	320	....	....	739	....
298	....	150	80	1.6	226	....	....	....	705	....	....	....	....
476	0	538	222	.5	0.5	.33	....	1,487	699	....	....	2,250	....
624	0	606	110	.4	7.5	....	1,580	....	474	....	....	....	....
453	0	116	50	2.6	13	....	643	....	372	....	....	....	....
234	0	774	140	.5	11	.29	....	1,500	939	....	....	2,030	....
456	24	615	375	.5	245	.09	....	2,140	1,171	....	....	3,110	....
340	26	64	54	1.7	15	.13	....	493	374	....	....	859	....
472	31	599	98	.2	.2	.55	....	1,444	484	....	....	2,160	....
211	....	3,000	292	....	32	....	....	....	1,950	....	....	....	....
242	....	1,250	595	....	5.6	....	....	....	1,740	....	....	....	....

of plants; others are harmful to plant growth and to soils. The total concentration of dissolved salts in waters may range from a few parts to many thousand parts per million, but most irrigation waters range from 100 to 1,500 ppm in dissolved solids. The more important constituents of these waters are the cations, calcium, magnesium, and sodium and the anions, bicarbonate, sulfate, and chloride. Other constituents—potassium, carbonate, nitrate, silica, and boron are usually present, but ordinarily only in low concentrations. Small quantities of other substances may be found in some waters, but their effect on the quality of the water for irrigation ordinarily is not important, and they are usually not considered in an appraisal of quality.

According to Agriculture Handbook 60 the characteristics of an irrigation water that appear to be most important in determining its quality are: (1) total concentration of soluble salts (salinity hazard); (2) relative proportion of sodium to other cations (sodium or alkali hazard); (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium.

In appraising the quality of an irrigation water, first consideration should be given to the salinity and sodium hazards. Then consideration should be given to the boron or other toxic elements and the bicarbonate, any one of which may change the quality rating.

The total concentration of soluble salts in irrigation waters (salinity hazard) is most easily expressed in terms of electrical conductivity. The conductivity is the ability of a water to conduct electric current, and it varies with the amount and kinds of dissolved salts and the temperature. It is a rough measure of the total mineral content (dissolved solids) in the water. In chemical analyses it is reported as specific conductance in micromhos at 25°C. Nearly all irrigation waters that have been used successfully over extended periods of time have specific conductances of less than 2,250 micromhos. Waters of higher conductivity are used occasionally, but crop production, except on unusually well-drained soils, has not been successful.

The sodium (alkali) hazard involved in the use of water for irrigation is determined by the absolute and relative concentrations of the cations, sodium, calcium, and magnesium (and potassium in small quantities). If the proportion of sodium is high the sodium hazard is high; and, conversely, if calcium and magnesium predominate, the sodium hazard is low.

The sodium-adsorption ratio (SAR) of a soil solution is closely related to the adsorption of sodium by the soil; consequently, this ratio has certain advantages over the ratio of sodium to total cations (percent sodium) for use as an index of the sodium or alkali hazard of the water. The SAR is defined by the equation:

$$SAR = Na/\sqrt{(Ca+Mg)/2}$$

where Na, Ca, and Mg represent the concentrations of the respective ions in equivalents per million.

Boron is a constituent of practically all natural waters. It is essential to the normal growth of all plants, but the amount required is very small. Boron frequently occurs in toxic concentrations along with the other salts that are present in saline soils. It can be leached from the soil but, if concentrations are high initially, a quantity of boron sufficient to cause trouble may remain after the concentration of other salts is reduced to a safe level.

TABLE 8. PERMISSIBLE LIMITS OF BORON FOR SEVERAL CLASSES OF IRRIGATION WATERS
(Parts per million)

Boron class	Sensitive crops	Semitolerant crops	Tolerant crops
1	<0.33	<0.67	<1.00
2	0.33 to 0.67	0.67 to 1.33	1.00 to 2.00
3	0.67 to 1.00	1.33 to 2.00	2.00 to 3.00
4	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
5	>1.25	>2.50	>3.75

The crops in the sensitive groups, likely to be damaged by excess boron, include citrus and other fruit trees and a number of other deciduous trees. The semitolerant plants include small grains and cottons and certain vegetables. Tolerant plants include lettuce, root crops (except potatoes and sweet potatoes), alfalfa, and date palms.

Test Drilling

The thickness and lithology of the alluvium of the North Canadian River valley are revealed by 156 test holes that have been drilled in the area of this report. These were drilled at different times under different auspices for Oklahoma City; the Chicago, Rock Island, and Pacific Railroad; the Oklahoma Gas and Electric Co.; the Billington Lumber Co.; the town of Calumet; and the U. S. Geological Survey in cooperation with the Oklahoma Geological Survey. In addition, four test holes for Calumet were drilled in the terrace deposits north of the North Canadian River.

Oklahoma City

In 1953 Oklahoma City had 42 test holes drilled north of Lake Overholser, on both sides of the North Canadian River, under the supervision of C. E. Bretz, consulting engineer. The objective was to locate favorable well sites for a supplementary water supply for Oklahoma City. The depth to bedrock ranged from 20 to 69 feet and averaged 48 feet. The saturated thickness of the alluvium ranged from 2 to 52 feet and averaged 34 feet. About 25 percent of the saturated material was classified as gravel or coarse sand that should be highly permeable.

Chicago, Rock Island, & Pacific Railroad

In 1918 and 1919 the Chicago, Rock Island, & Pacific Railroad had 33 test holes drilled in the alluvium north of El Reno and on the north side of the North Canadian River. These were to find the best location for a pumping station to supply water for the railroad, but the development was not carried out because it was decided to buy water from the city of El Reno.

The depth to bedrock in these test holes ranged from 10 to 52 feet and averaged 42 feet. The saturated thickness of the alluvium ranged from zero to 33 feet and averaged 18 feet. Of the total of 590 feet of saturated alluvium penetrated, 323 feet (55 percent) was gravel and coarse sand. In two test holes, no saturated alluvium was found.

Oklahoma Gas and Electric Co.

In 1952 the Oklahoma Gas and Electric Co. had 27 test holes drilled, most of them south of Lake Overholser near the Mustang power plant. A few tests, however, were drilled along the north and west sides of the lake. This testing was done to determine the thickness and character of the alluvial materials near the Mustang power plant so that data would be available for anticipated future expansion of water needs. The depth to bedrock ranged from 25 to 68 feet and averaged 45 feet. The saturated thickness of the alluvium ranged from 16 to 51 feet and averaged 31 feet.

Billington Lumber Co.

In the winter of 1948 the Billington Lumber Co., of Oklahoma City, drilled five test holes in the alluvium about five miles northwest of El Reno to determine the quantity of water available for a proposed irrigation system. The depth to bedrock ranged from 47 to 56 feet and averaged 52 feet. The saturated thickness of the alluvium ranged from 29 to 36 feet and averaged 33 feet. Of the total of 165 feet of water-bearing material penetrated, 63.5 (38 percent) was coarse sand and gravel.

Calumet

In 1946 the town of Calumet had three test holes drilled about half a mile north of the town, under the supervision of C. E. Bretz, consulting engineer, These holes penetrated the alluvium and reached bedrock at depths that ranged from 18 to 40 feet and averaged 32 feet. The saturated thickness of the alluvium ranged from 13 to 30 feet and averaged 24 feet. A public-supply well was constructed. The water, however, proved rather highly mineralized, and in 1953 the town had several more test holes drilled in the hope of locating water of more acceptable quality. One of these was drilled within the town limits to a depth of 220 feet, 185 feet into the bedrock, and four were drilled in the terrace deposits north of the North Canadian River. The depth to bedrock in the terrace deposits ranged from 30 to 45 feet and averaged 34 feet.

U. S. Geological Survey

In 1942 the U. S. Geological Survey in cooperation with the Oklahoma Geological Survey had 52 test holes drilled; 45 were in the alluvium of the North Canadian River valley and seven were drilled on an upper terrace on the south side of the river. Test holes were drilled along straight lines, perpendicular to the general course of the valley and extending entirely across the width of the valley alluvium. Lines of test holes were located at Yukon, Banner, El Reno, Ft. Reno, Calumet, Karns, and Geary. Samples of the drill cuttings were collected and were examined in the laboratory with a microscope. Permeability tests were made on most of the coarser samples, and sieve analyses were made of almost all the samples. Identification of the bedrock was assured by drilling a few feet into the underlying shale at each test site. Because the drilling mud on the sides of the holes prevented free movement of the water between the hole and the aquifer, reliable measurements of water levels were not obtained.

The depth to bedrock ranged from 20 to 60 feet and averaged 40 feet. For the seven lines of test holes the average depths to bedrock were: Yukon, 46 feet; Banner, 40 feet; El Reno, 45 feet; Ft. Reno, 38 feet; Calumet, 35 feet; Karns, 36 feet; and Geary 36 feet. These lines of test holes show an increase in thickness of the alluvium in the downstream direction.

Aquifer Tests

The amount of water a well will yield depends largely on the hydraulic properties of the aquifer. The hydraulic properties determined by aquifer tests during this investigation are the coefficients of transmissibility and storage. The coefficient of transmissibility of an aquifer may be defined as the rate of flow of water in gallons per day through a vertical strip of the aquifer one foot wide and extending the full saturated height, under a hydraulic gradient of 100 percent at the prevailing temperature of the ground water; and the coefficient of storage of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. These coefficients are determined directly from aquifer tests. For this investigation three tests were made on wells obtaining water from the alluvium of the North Canadian River valley: a public-supply well owned by the city of El Reno, an industrial-supply well owned by the Oklahoma Gas and Electric Co., and an irrigation well owned by the Billington Lumber Co. The tests were analyzed by methods in general use by the U. S. Geological Survey.

City of El Reno 13N7W-33-6

Well 13N7W-33-6 was 51 feet deep and had an 18-inch steel casing with the bottom 18 feet perforated. The static water level was 27 feet below land surface; thus, the well penetrated 24 feet of saturated alluvium. The well was gravel packed and was equipped with an electrically powered turbine pump. Prior to the test six observation wells were drilled—three north of the well at distances of 25, 50, and 100 feet, and three south at the same distances. On November 30, 1942, the pump was started, and the well was pumped continuously for 24 hours at a constant rate of 205 gpm. Water-level measurements of the drawdowns were made in the pumped well and in the six observation wells at frequent intervals. After the pump was shut off water-level recovery measurements were made at frequent intervals over a period of two hours. The coefficient of transmissibility, as determined by use of the distance-drawdown graph of Cooper and Jacob (1946), was about 60,000 gpd per foot, but a reliable coefficient of storage was not obtained (Schoff and Reed, 1951, p. 78). However this method requires at least three reliable observation wells, and a close scrutiny of the drawdown measurements showed that only two wells were working properly. The Theis nonequilibrium formula was applied to the data from these two wells and gave a coefficient of transmissibility of about 98,000 gpd per foot and a coefficient of storage of 0.14.

Oklahoma Gas and Electric Co. Well 12N5W-36-3

Well 12N5W-36-3 was dug with an orange-peel bucket in February 1949. It was 66 feet deep and had 57 feet of 10-inch casing with nine feet of screen at the bottom. The static water level was 24 feet below land surface; thus, the well penetrated 42 feet of saturated alluvium. The well was gravel packed and was equipped with a turbine pump powered by a 50-horsepower electric motor. Before starting the test, five observation wells—four inches in diameter—were drilled through the alluvium to the top of the bedrock. Three of these wells were on a line directly east of the pumped well at distances of 50, 150, and 500 feet from the pumped well. The other two were on a line directly south of the pumped well and were 150 and 500 feet from the well. The pumped well was also equipped with a "clean-out-hole" at the edge of the gravel pack. Measurements of the water level in all the observation wells and the "clean-out-hole" were made several days before starting the test.

On July 18, 1949, the pump was started and the well was pumped continuously for seven days at a near-constant rate of 500 gpm. Measurements of the water levels were made in all observation wells and the "clean-out-hole" during the period of pumping and for four days after pumping had ceased. Samples of water for chemical analysis were taken at regular intervals during the pumping period. The drawdown and recovery measurements were analyzed by means of the Thiem method (Wenzel, 1942, p. 81), the generalized graphical method of Cooper and Jacob (1946, p. 526-534), and the Theis nonequilibrium method (Wenzel, 1942, p. 87). The coefficient of transmissibility as measured in the field was about 60,000 gpd per foot and the coefficient of storage was about 0.02.

Billington Lumber Co. Well 13N8W-24-1

Well 13N8W-24-1 was 55 feet deep and had an 18-inch concrete casing with the bottom eight feet perforated. The static water level was 22 feet below land surface; thus, the well penetrated 33 feet of saturated alluvium. The well was gravel packed and was equipped with an electrically powered turbine pump. Before the test, six observation wells were drilled—three east of the well at distances of 70, 110, and 160 feet, and three west of the well at distances of 70, 110, and 150 feet. On July 1, 1954, the pump was started, and the well was pumped continuously for 72 hours at a near-constant rate of 500 gpm. Water-level measurements of the drawdowns were made in the pumped well and in the six observation wells at frequent intervals. After the pump was shut off water-level recovery measurements were made at frequent intervals over a period of 36 hours. A sample of water for chemical analysis was taken immediately before shutting off the pump. The drawdown and recovery measurements were analyzed by means of the Thiem method and the Theis nonequilibrium method. The coefficient of transmissibility as measured in the field was about 40,000 gpd per foot and the coefficient of storage was about 0.10.

Interpretation of Aquifer Tests

With only three aquifer tests it is impossible to predict exactly the average coefficient of transmissibility for the area as a whole. The transmissibility can be expected to differ widely in such an aquifer, which has large differences in thickness and lithology. In large-scale development of the aquifer, aquifer tests on each well could lead to accurate figures for the average coefficients of transmissibility and storage which in turn could permit selection of the most favorable pumping rates. The three wells tested by pumping were favorable locations. All of the well sites had been selected by test drilling; thus, the figures for the coefficients of transmissibility, as determined from the pumping tests of the three wells, may be high compared to the average figure for the area as a whole. If aquifer tests were made at sites uniformly distributed over the area, they undoubtedly would reveal coefficients of transmissibility both higher and lower than those obtained in this investigation, but the average probably would be lower.

The coefficient of storage at the El Reno well 13N7W-33-6 was 0.14, which is what might be expected from the entire thickness of the saturated portion of the alluvium at that location. However, the well is close to the river and the cone of depression reached the stream. One effect of this boundary condition is to increase the apparent coefficient of storage and therefore the measured coefficient may be too high.

It is concluded, therefore, that a figure of 0.10 may fairly represent the coefficient of storage in the upper part of the alluvium within range of the water table and within the normal range of drawdowns in the rocks surrounding pumping wells, but that 0.14, or, in round numbers, 0.15, may be a more reasonable figure for the entire thickness of water-bearing material.

The average coefficient of permeability, which is the coefficient of transmissibility divided by the saturated thickness of the aquifer, was 1,100 gpd per square foot for the Billington well, 4,100 gpd per square foot for the El Reno well, and 1,400 gpd per square foot for the Oklahoma Gas and Electric Co. well. It is concluded, therefore, that a figure of 1,000 gpd per square foot for the coefficient of permeability might well represent the area as a whole. The average thickness of the saturated part of the alluvium is about 27 feet; thus, the average coefficient of transmissibility might be something like 25,000 to 30,000.

The measured coefficient of storage for the Oklahoma Gas and Electric Co. well 12N5W-36-3 was 0.02 which is much lower than the 0.10 to 0.20 that would be expected from a sand-and-gravel aquifer of this type. The cone of depression showed that the material drained was the hard sandy clay in the upper part of the saturated alluvium, and this hard sandy clay will not release as much water from storage as will the coarse sand and gravel of the lower part of the alluvium.

The coefficient of storage at the Billington Lumber Co. well 12N8W-24-1 was 0.10, which is reasonable, because the sediment drained during the test was medium sand.

Expectable Yields

The yields from wells in the alluvium and terrace deposits of the North Canadian River valley will differ considerably, because the sediments differ in lithology and thickness from place to place. The highest yield measured in the area was from the Oklahoma Gas and Electric Company industrial well 12N5W-36-3. It yielded approximately 700 gpm during an aquifer test on July 12 and 13, 1949. Drawdown in the well was about 18 feet after 28 hours of pumping. The map showing the saturated thickness of the alluvium shows this well to be in the thickest part of a buried channel containing more than 40 feet of saturated materials. Therefore, wells with such yields would be the exception rather than the rule, but yields of 100 to 300 gpm are probable in most of the area of water-bearing alluvium. Yields from the terrace deposits north of the river are somewhat lower and will ordinarily range from 50 to 150 gpm.

The alluvium and terrace deposits of the Canadian River are believed to be similar to the materials in the North Canadian River valley. Therefore, yields may be expected to be of the same magnitude. One irrigation well in the alluvium is reported to yield 650 gpm with a drawdown of 22 feet after 24 hours of pumping.

All the wells tapping water from the Rush Springs sandstone in the southwestern part of the County are of small diameter and are used for domestic or stock purposes. Most of these wells penetrate only a few feet into the saturated part of the aquifer in order to obtain the necessary amount of water with a minimum of depth. The estimated yield of these rocks is about one gpm for each foot of saturated thickness penetrated, and the maximum thickness is 80 feet. Thus, the upper limit for yields from wells tapping the Rush Springs sandstone in Canadian County should be something like 75 to 100 gpm.

The other Permian rocks in the County, which consist mostly of shales, are considered to be poor aquifers. According to the available data, a yield of about 40 gpd for each foot of saturated thickness penetrated seems about what can be expected.

Underflow

The contours of the water table on plate II-2 indicate that ground water percolates into the County from the northeast and out of the County to the southeast through the permeable sand and gravel of the alluvium. The rate of underflow depends on the hydraulic gradient and the coefficient of permeability of the aquifer; and the amount can be computed by use of Darcy's law (Darcy, 1856), which may be written

$$Q = P I A$$

Where Q is the flow in gallons per day, P is the coefficient of permeability in gallons per day per square foot, I is the hydraulic gradient in feet per feet, and A is the area of the saturated thickness in cross section. The assumed average coefficient of permeability is 1,000 gallons per day per square foot; the average hydraulic gradient of the water table, as determined from the water-table map (pl. II-2), is 5 feet per mile; the average saturated thickness of the alluvium is 27 feet; and the average width of valley alluvium perpendicular to the axis of the valley is 2.5 miles. Substituting these values into the equation given above, the quantity of water involved in the underflow is calculated to be about 330,000 gallons per day.

Ground-Water Storage

Although ground water moves from areas of recharge to areas of discharge, the movement is slow—less than one foot a day on the average. Consequently, the water-bearing rocks may be regarded as a huge underground reservoir.

The amount of stored water depends on the thickness and extent of the saturated material and on its porosity. Some of the water is held by molecular attraction and so may be considered to be permanently stored. It will not drain out, and it is not included in computing the specific yield, which is a measure of the amount of stored water that theoretically can be recovered by pumping from wells. Under water-table conditions the specific yield is approximately equal to the coefficient of storage and from the aquifer tests it was concluded that 0.15 is a reasonable figure for the coefficient of storage of the entire thickness of saturated materials in the alluvium and terrace deposits of the North Canadian River valley.

The average thickness of water-bearing material, as shown on plate II-5, is 27 feet. On the basis of the foregoing assumptions the amount of ground water stored per acre equals 27 x 0.15, or 4 acre-feet. The total stored in the 127 square miles of alluvium and terrace deposits is about 325,000 acre-feet, or more than 100 billion gallons. The amount stored per acre differs from place to place because of differences in the thickness of the water-bearing material. For example, the average saturated thickness near Yukon is 33.4 feet and the ground-water storage is estimated to be 5 acre-feet per acre; whereas, near Fort Reno the average saturated thickness is 20.9 feet and the estimated storage is 3.2 acre-feet per acre.

Under natural conditions the quantity of water stored in the alluvium and terrace deposits will vary with the fluctuations of the water table. Not all the stored water can be recovered by pumping from wells, but the large amount of water stored in these materials, especially in the more favored localities, means that pumping could be continued through periods of protracted drought. Here as elsewhere, however, pumping cannot indefinitely exceed the average annual rate of replenishment.

Effect of Pumping on the Water Table

When a well is pumped the hydraulic head in the well is lowered, a hydraulic gradient is set up toward the well from all sides, and water flows into the well. The water table around the well assumes a shape somewhat like an inverted cone, which is called the cone of depression.

As pumping continues, the cone of depression expands and water from progressively greater distances percolates toward the well. The initial expansion is relatively rapid but the rate of drawdown decreases with time and eventually the rate of decline at all points except along the outer edges of the cone becomes equal. Thus, after an initial period of adjustment the cone of depression attains an essentially stable form and maintains it, but it gradually sinks deeper into the zone of saturation and in so doing spreads farther out from the pumping well.

If no recharge occurs, the cone will continue to expand, at a decreasing rate until the limits of the formation are reached, or assuming a constant discharge, until the water level reaches the bottom of the well. In the latter case, however, the saturated thickness of the aquifer would decrease with time and would tend to increase the rate of decline. In actual practice, the discharge of the well would decline or the pump would break suction. If recharge does occur, the expansion and lowering of the cone of depression will be retarded or reversed; thus, the cone will expand during dry periods and shrink during periods when the recharge is greater than the discharge.

The shape and size of the cone of depression around a well being pumped depend on the rate and duration of pumping, the hydraulic properties of the aquifer, the extent of the aquifer, and the amount of recharge. The lowering of the water table at any point within the cone of depression is directly proportional to the rate of pumping. That is, other conditions being the same, the drawdown at a certain distance from a well being pumped at 200 gpm will be twice the drawdown caused by a pumping rate of 100 gpm.

The coefficient of transmissibility governs the depth of the cone of depression in relation to the diameter of the base of the cone. If the coefficient is low the hydraulic gradient will be relatively steep and the cone will be deep but not broad. If the coefficient is high the cone will be broad but shallow.

The coefficient of storage is related to the volume of water withdrawn from the cone of depression. Theoretically, the volume of dewatered material within the cone of depression multiplied by the coefficient of storage should equal the total volume of water pumped, but the theory assumes that the water drains out of the voids instantly. In nature, the water drains slowly from the dewatered part of the aquifer, and the volume of the cone of depression during the early stages of its development must exceed the theoretical volume in order to yield the water pumped. As pumping continues, the draining is more and more complete, and the actual volume of the cone of depression approaches more closely the theoretical volume.

Rock formations are not of infinite extent. They terminate somewhere; that is, they have boundaries. If the cone of depression around a pumped well expands until it meets a formation boundary, its further development depends on the nature of the boundary and the possibilities for recharge. If the boundary is at a stream or lake from which water may enter the formation, an essentially stable hydraulic gradient will develop between the source of recharge and the pumped well, and much of the water supplied to the well will come from the source of recharge. If the supply for recharge is ample, the cone of depression will then stabilize, and expansion of it will stop. If, on the other hand, the boundary is the edge of the formation or a barrier such as a fault along which the aquifer abuts impermeable rock or is filled with gouge that prevents the movement of water across it, no water will be available for recharging the aquifer. Expansion of the cone of depression will be stopped at such a boundary because there is no room for it, but in other directions the expansion will have to be accelerated because more water must come from those directions if the discharge rate is to be maintained. Therefore, at the same time, the drawdown rate in the well being pumped will have to increase.

So far as is known, the only boundaries affecting a cone of depression in the alluvium and terrace deposits are the edges of the deposits and the North Canadian River. Therefore, wells located near the river are in a more favorable location and should be more efficient, in the long run, than wells located near the Permian outcrops. In much of the area between the edges of the deposits and the North Canadian River, the cone of depression of the average well is not likely to expand to these known boundaries.

Because the coefficients of transmissibility and storage of the alluvium differ from place to place in the area considered in this report, an average drawdown curve that would be generally useful in planning development of a well field cannot be prepared. If large quantities of water are sought, adequate preliminary test drilling and test pumping afford the best means of getting the facts on which to base specifications for wells, well spacing, pumps, and power.

An Estimate of the Safe Yield of the Alluvium and Terrace Deposits

In 1949, the Oklahoma State Legislature passed the Oklahoma Ground-Water Law (House Bill 487, 1949). In section 7 of this law, the safe annual yield of a ground-water basin is said to be measured by the average annual recharge of the basin. In a newly developed basin there is usually a large amount of stored water that can be withdrawn. The safe yield can be exceeded for a time without apparent ill effect, but there is a limit to the amount of this stored water that can be withdrawn without adversely affecting water levels in the basin. As this limit is approached, the rate at which withdrawals can be made without lowering the water levels further becomes the amount of average recharge that can be intercepted by pumping. Because, under natural conditions, and over a long period, the recharge equals the discharge, the safe yield is the amount of natural discharge that can be salvaged.

An analysis of records of fluctuations of the ground-water level in the alluvium of the North Canadian River valley suggests that the recharge amounts to about 17.5 percent of the annual precipitation. (See section on recharge of ground water.)

The average annual precipitation for the area, based on the averages at three stations reported by the Weather Bureau, is about 29.35 inches. If 17.5 percent fairly represents the fraction of this annual precipitation that becomes ground water, the average annual recharge is about 270 acre-feet per square mile. This should also be the amount lost from the ground-water reservoir by discharge, but the estimated average annual discharge including pumping was about 360 acre-feet per square mile as of 1953. Therefore, 270 acre-feet per year per square mile appears to be a low figure for recharge but because not all the natural discharge can be salvaged is a conservative but reasonable estimate of the safe yield.

The estimate of safe yield does not consider the factor of induced recharge from the river. If a well is sufficiently close to the river, a large part of the water pumped from the well may come from the river. In most cases, this would be an additional source of water to the aquifer. However, the amount of such recharge depends on the rate and duration of pumping, distance from the stream, the aquifer coefficients, the amount of water in the stream, and the degree of hydrologic interconnection between the river and the aquifer, so that it is impossible to consider induced recharge in estimating the average safe yield of the alluvium over the entire County.

The safe yield of the aquifer is not to be confused with the maximum yield of individual wells. The yield of wells is governed by the ability of the aquifer to transmit to the wells whatever water already is in it. Not until the water stored in the aquifer has been depleted beyond the limits of practical recovery can the safe yield of the aquifer limit the yield of a well, and only approximately. Individual wells can be pumped at rates many times greater than the average safe yield of the aquifer as expressed above in gallons per minute per unit of area, simply because the aquifer is capable of delivering the water in it faster than it may be receiving water. The extra water comes either by drawing recharge water from outlying parts of the aquifer or—if such recharge is being fully utilized—by drawing water from storage. If the draft is on water in storage, and is long continued, practical exhaustion of the underground reservoir will result. What applies to one well applies also to a well field, provided that the field does not embrace the entire aquifer or its net output does not exceed the sum of the total salvaged natural discharge.

Obviously, then, it would be possible to develop a large supply of water by constructing wells of appropriate design in one of the more favorable localities in the alluvium and terrace deposits. The yield from this well field might exceed by several times the recharge received in the immediate vicinity of the field, but pumping could continue indefinitely if recharge received in a large surrounding area could be diverted to the field.

It was stated that the safe yield is the amount of natural discharge that can be salvaged. This means that when a certain amount of water is taken from an aquifer by wells the natural discharge must be reduced by an equal amount or water is taken from storage. Properly spaced wells can intercept ground-water flow and eliminate discharge by underflow and effluent seepage; and, at the same time, transpiration by plants may be reduced or eliminated because of the increased depth to water due to pumping.

SUMMARY

The alluvium and terrace deposits along the North Canadian River in Canadian County are among the best aquifers in the State. In 1953 the total pumpage of ground water from them was about 18 percent of the safe yield as estimated on page 93. Increased pumping by the Oklahoma City municipal wells and the proposed Oklahoma Gas and Electric Co. wells, if carried out as planned, would raise this to about 43 percent beginning in 1955.

It is not correct to apply this 43 percent to the entire area because about three-quarters of this pumping, or about 9.6 out of 13 mgd, will be concentrated in a narrow strip approximately five miles long by one and one-half miles wide in T. 12 N., R. 5 W. Hence, local overdevelopment may occur because the safe yield of such a strip would be only 1.8 mgd if all the recharge came from precipitation over the 7.5 square miles. However, the wells will draw on an area larger than 7.5 square miles—perhaps as much as twice this area; thus, 3.6 mgd could be pumped from these wells if all natural discharge could be stopped. This leaves a remainder of 6.0 mgd that must be supplied from storage or from the North Canadian River by influent seepage.

In times of drought the North Canadian River has no flow for many months; thus, at such times the water requirements of these wells will have to be supplied entirely from storage. The estimated storage in the 15-square mile area assumed to be tributary to the wells is about 4.7 acre-feet per acre, or 14.7 billion gallons in the 15 square miles. If 50 percent of this is available to the wells, enough water could be supplied from storage to allow pumping at the rate of 9.6 mgd for a period of 2 years. Thus, if a drought were prolonged beyond 2 years, it might not be possible to pump the full 9.6 mgd.

The current pumpage from the rest of the area in the North Canadian River valley is about 12 percent of the estimated safe yield; therefore, considerable future development is feasible, if it is kept in mind that the safe yield is about 270 acre-feet per year per square mile. Increases in pumping, of course, will bring reductions in natural discharge—first as reduced streamflow in the North Canadian River and then as reduced use of water by phreatophytes adjacent to the river.

Most of the natural discharge from the alluvium of the North Canadian River is due to transpiration of ground water by phreatophytes; thus, to reclaim this water the phreatophytes must be destroyed. According to Bowser (1952) results of attempts to destroy these plants by mechanical means and by burning have not been encouraging, but in some areas chemical sprays have been effective in eliminating certain types of phreatophytes (Bowser, 1952).

Yields from individual wells differ considerably from place to place because of differences in lithology and thickness of the saturated sediments. On the average, wells can be expected to yield from 100 to 300 gpm, but locally they may yield more than 700 or less than 50 gpm.

The amount of ground water stored in the alluvium and terrace deposits averages about four acre-feet per acre. If half the water in storage could be recovered by pumping, withdrawals at the rate of 270 acre-feet per square mile could continue for a period of about 4.5 years even if no recharge occurred. This means that the amount of water in storage is enough to outlast most droughts. The amount in storage differs from place to place, of course, and in some localities doubtless is insufficient for a protracted drought; however, in most places the stored water is believed to be adequate to sustain a rate of pumping greater than the estimated safe yield for considerable periods without excessive lowering of water levels or decline in yields.

The ground water in the alluvium of the North Canadian River is very hard, and locally contains excessive quantities of sulfate. However, it is being used successfully to irrigate crops, for public supply, and for cooling. The water in the terrace deposits is by far the best in the area; its average hardness being about one-third of the average hardness of water in the alluvium.

The alluvium and terrace deposits of the Canadian River are believed to be similar to the materials in the North Canadian River valley. Therefore, yields of wells and the quality of the water are probably similar.

The Rush Springs sandstone, in the southwestern part of the County, yields moderate amounts of good water. The other Permian formations are not a reliable source of ground water; however, in some areas, they yield enough water for domestic and stock use. The water in these rocks is poor also in quality; on the basis of partial analyses, 59 percent of the waters would rate as unsatisfactory in at least one respect according to standards for drinking water set up by the U. S. Public Health Service.

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TABLE 9. Records of wells and test holes in Canadian County, Oklahoma

Well number	Location in section	Owner or name	Altitudes: Land surface	Altitudes: Water level	Altitudes: Redbeds	Depth of well (feet)	Casing Diameter (inches)	Water-bearing bed	Water level: Depth below land surface (feet)	Water level: Date of measurement
T. 10 N., R. 5 W.										
6-1	SW SE	Jess Hanna	....	....	....	62	6	Redbeds	47	1-21-48
12-1	SE NE	Boy Scouts America	....	....	....	65	6	Alluvium	20	....
15-1	SE SW	....	....	....	....	....	1¼	Alluvium	....	....
T. 10 N., R. 6 W.										
9-1	NE NE	Birt Moore	....	....	....	40	5½	Terrace deposits	....	....
T. 10 N., R. 7 W.										
3-1	SW	U.S.G.S.	....	....	....	12	1¼	Alluvium	7	10-9-46
3-2	NW SE	Union H.S.	....	....	....	30	12	Alluvium	21	....
T. 11 N., R. 5 W.										
1-1	NW NW	Bert Brewer	1,235	1,219	....	23	....	Alluvium	16	11-11-41
10-1	SE NE	George Otis	....	....	....	28	7	Alluvium	16	4-14-48
33-1	SE NE	Mustang H.S.	....	....	....	100	6	Redbeds	....	....
T. 11 N., R. 6 W.										
9-1	NW NE	Clarence White	....	....	....	120	6	Redbeds	37	6-23-53
30-1	NE NW	Albert Mentz	....	....	....	195	4	Redbeds	62	4-14-48
T. 11 N., R. 7 W.										
4-1	SW SW	Rock Island School	....	....	....	24	8	Redbeds	12	4-16-48
28-1	NE NE	Clarence Burr	....	....	....	33	96	Redbeds	19	4-14-48
T. 11 N., R. 8 W.										
2-1	NE NW	Earl Estes	....	....	....	18	42	Redbeds	10	4-16-48
22-4	SW SW	Jake Ast	....	....	....	62	13	Alluvium	8	....
26-1	NW NW	C. E. Bollinger	....	....	....	26	1¼	Alluvium	14	....
30-1	NW NW	H. W. Bartling	1,338	....	....	37	1¼	Alluvium	....	....
31-1	SW SW	J. C. Parker	1,481	1,452	....	33	....	Rush Springs	29	8-19-53
T. 11 N., R. 9 W.										
7-1	SW SW	Nelson Davidson	1,520	1,427	....	177	6	Redbeds	93	9-15-53
7-2	SW SW	Nelson Davidson	1,526	1,456	....	79	36	Rush Springs	70	9-15-53
8-1	SW SW	B. H. Goodnow	1,404	1,374	....	240	10	Redbeds	30	9-15-53
11-1	NW NE	P. R. Boswell	....	....	....	33	1¼	Alluvium	....	....
19-1	SW NW	Kenneth Barrett	1,603	1,483	....	130	6½	Rush Springs	120	9-11-53
20-1	NE SE	J. D. Arnold	1,579	1,485	....	110	6	Rush Springs	94	6-17-53
27-1	SE SW	....	1,529	1,474	....	66	6	Rush Springs	55	8-21-53
31-1	NE SE	....	1,456	1,432	....	28	6	Rush Springs	24	9-11-53
35-1	NW SE	Claude Gilbert	1,552	1,480	....	81	4¼	Rush Springs	72	7-22-53
T. 11 N., R. 10 W.										
4-1	SE SE	Lon Ragen	1,548	1,479	....	73	8	Rush Springs	69	9-11-53
7-1	NE SE	J. E. Craft	1,668	1,533	....	170	6	Rush Springs	135	9-15-53
19-1	NW SE	J. W. Lambert	1,632	1,499	....	152	6	Rush Springs	133	9-11-53
21-1	NE NW	....	1,658	1,550	....	124	6½	Rush Springs	108	9-11-53
22-1	NE NE	L. C. Smith	1,564	1,526	....	56	6	Rush Springs	38	6-17-53
32-1	SE NE	Ross Campbell	1,623	1,552	....	108	7½	Rush Springs	71	9-11-53
35-1	SW SE	R. J. Hedrick	1,541	1,507	....	47	6½	Rush Springs	34	8-21-53
36-1	SW SW	Ruth Hills	1,586	1,522	....	83	....	Rush Springs	64	8-21-53
T. 12 N., R. 5 W.										
1-1	SE SE SE	Oklahoma City	1,265	1,242	1,198	67	....	Alluvium	23	5- -53
1-2	SE SW SE	Oklahoma City	1,260	1,238	1,200	60	....	Alluvium	22	5- -53
1-3	NW SW SE	Oklahoma City	1,253	1,230	1,190	63	....	Alluvium	23	5- -53
1-4	SW NW SE	Oklahoma City	1,266	1,240	1,197	69	....	Alluvium	26	5- -53
1-5	NE NE SW	Oklahoma City	1,262	1,230	1,193	69	....	Alluvium	32	5- -53
1-6	SW SE NW	Oklahoma City	1,249	1,233	1,229	20	....	Alluvium	16	5- -53
1-7	NE SW NW	Oklahoma City	1,252	1,234	1,232	20	....	Alluvium	18	5- -53
1-8	SW SW NW	Oklahoma City	1,249	1,239	1,217	32	....	Alluvium	10	5- -53
1-9	SW NW SW	Oklahoma City	1,254	1,239	1,222	32	....	Alluvium	15	5- -53
1-10	SW SW SW	Oklahoma City	1,252	1,238	1,212	40	....	Alluvium	14	5- -53
1-11	SE SE SE	Oklahoma City	....	....	....	63	12	Alluvium	....	....
1-12	NE SE SW	Oklahoma City	....	....	....	52	12	Alluvium	....	....
2-1	NE SE SE	L. A. Newton	1,253	1,245	1,224	45	6	Alluvium	8	11-7-41
2-2	NW	Ira Tuttle	....	....	....	75	....	Alluvium	....	....
3-1	NE NE	Fred Smith	1,259	1,252	....	31	6	Alluvium	7	11-7-41
3-2	NW	R. E. Lawson	....	....	....	45	....	Alluvium	....	....
3-3	NW	R. E. Lawson	....	....	....	21	....	Alluvium	....	....

TABLE 9. Records of wells and test holes in Canadian County, Oklahoma

Well number	Location in section	Owner or name	Altitudes: Land surface	Altitudes: Water level	Altitudes: Redbeds	Depth of well (feet)	Casing Diameter (inches)	Water-bearing bed	Water level: Depth below land surface (feet)	Water level: Date of measurement
T. 12 N., R. 5 W.										
3-4	NE	W. A. Tillery	....	....	....	....	....	Alluvium	....	....
4-1	NW NE NE	Macklin	1,290	1,262	....	....	36	Redbeds	28	7-31-41
4-4	NW NW SW	U.S.G.S.	1,264	1,258	....	15	1¼	Alluvium	6	8-25-53
4-5	NW SW SW	U.S.G.S.	1,263	....	1,212	53	....	Alluvium	....	....
4-6	NW NW SW	U.S.G.S.	1,261	....	1,224	40	....	Alluvium	....	....
4-7	SW SW NW	U.S.G.S.	1,276	....	1,235	49	....	Alluvium	....	....
5-1	NE SW SE	Ernest Smith	1,269	1,258	....	20	2	Alluvium	11	7-31-41
5-2	NW SW SE	Robert K. Everets	....	....	....	80	8	Alluvium	....	....
5-3	NW SW SE	Robert K. Everets	....	....	....	80	10½	Alluvium	....	....
5-4	NW SW SW	Ernest Smith	1,267	1,261	1,217	66	6½	Alluvium	6	11-6-41
5-5	SE SE	U.S.G.S.	1,264	1,257	....	19	1¼	Alluvium	7	11-20-45
6-1	NW SW SW	W. L. Towe	1,273	1,255	1,223	66	6½	Alluvium	18	11-6-41
7-1	NE NE NE	U.S.G.S.	1,262	1,258	....	18	¾	Alluvium	4	8-21-42
7-2	NE SE SE	U.S.G.S.	1,266	1,262	....	13	¾	Alluvium	4	5-22-42
8-1	SE NE NE	U.S.G.S.	1,266	1,261	....	27	8	Alluvium	5	11-7-41
8-2	SW SW SW	Auton Kaashka	1,271	1,260	....	39	7	Alluvium	11	8-6-41
8-4	SE SE SE	U.S.G S.	1,265	1,257	....	15	1¼	Alluvium	8	7-11-52
8-5	E¼ cor.	U.S.G S	1,268	....	1,222	48	....	Alluvium	....	....
8-6	NE cor.	U.S.G.S.	1,263	....	1,203	60	....	Alluvium	....	....
10-1	SW NW SW	S. J. Sheham	1,261	1,248	....	25	8	Alluvium	13	8-6-41
10-2	SE SW SE	G. E. Long	1,257	1,243	....	38	6	Alluvium	14	8-8-41
10-3	NW SE NE	Oklahoma City	1,258	1,244	1,215	43	....	Alluvium	14	5- -53
10-4	NE SW NE	Oklahoma City	1,253	1,244	1,214	39	....	Alluvium	9	5- -53
10-5	SW NW NE	Oklahoma City	1,258	1,249	1,216	42	....	Alluvium	9	5- -53
10-6	NE NE NW	Oklahoma City	1,250	1,244	1,218	32	....	Alluvium	6	5- -53
11-1	NW NW	Oklahoma City	....	....	....	21	....	Alluvium	....	....
11-2	SW SW SW	Oklahoma City	1,254	1,244	1,215	39	....	Alluvium	10	5- -53
11-3	SW NW SW	Oklahoma City	1,254	1,244	1,213	41	....	Alluvium	10	5- -53
11-4	NW NW SW	Oklahoma City	1,254	1,243	1,213	41	....	Alluvium	11	5- -53
11-5	NW SW NW	Oklahoma City	1,255	1,243	1,213	42	....	Alluvium	12	5- -53
11-6	SE NW NW	Oklahoma City	1,256	1,242	1,203	52	....	Alluvium	14	5- -53
11-7	NE NW NW	Oklahoma City	1,256	1,242	1,205	51	....	Alluvium	14	5- -53
11-8	NW NE NW	Oklahoma City	1,257	1,242	1,204	53	....	Alluvium	15	5- -53
11-9	NW NW NE	Oklahoma City	1,256	1,242	1,211	45	....	Alluvium	14	5- -53
11-10	NE NW NE	Oklahoma City	1,255	1,241	1,212	43	....	Alluvium	14	5- -53
11-11	NE NE NE	Oklahoma City	1,254	1,240	1,212	42	....	Alluvium	14	5- -53
11-12	SE NE SE	Oklahoma City	....	....	....	45	12	Alluvium	....	....
11-13	NE SE NW	Oklahoma City	....	....	....	52	12	Alluvium	....	....
11-14	SE NE NW	Oklahoma City	....	....	....	49	12	Alluvium	....	....
11-15	NW NE NW	Oklahoma City	....	....	....	53	12	Alluvium	....	....
11-16	NE NW NW	Oklahoma City	....	....	....	52	12	Alluvium	....	....
11-17	SW NW NW	Oklahoma City	....	....	....	48	12	Alluvium	....	....
12-1	SW NE SE	Oklahoma City	1,249	1,235	1,204	45	....	Alluvium	14	5- -53
12-2	SE SE NW	Oklahoma City	1,250	1,236	1,203	47	....	Alluvium	14	5- -53
12-3	SW NE NW	Oklahoma City	1,247	1,237	1,196	51	....	Alluvium	10	5- -53
12-4	NW NE NW	Oklahoma City	1,249	1,237	1,193	56	....	Alluvium	12	5- -53
12-5	NW NW NW	Oklahoma City	1,250	1,238	1,200	50	....	Alluvium	12	5- -53
12-6	NW SW NW	Oklahoma City	1,249	1,238	1,189	60	....	Alluvium	11	5- -53
12-7	SW SW NW	Oklahoma City	1,250	1,238	1,199	51	....	Alluvium	12	5- -53
12-8	SW NW SW	Oklahoma City	1,249	1,239	1,207	42	....	Alluvium	10	5- -53
12-9	SW NE NW	Oklahoma City	....	....	....	51	12	Alluvium	....	....
12-10	NW SE NW	Oklahoma City	....	....	....	48	12	Alluvium	....	....
12-11	SE SE NW	Oklahoma City	....	....	....	49	12	Alluvium	....	....
13-1	SE SW SE	....	1,249	1,242	....	23	....	Alluvium	7	11-8-41
13-2	N¼ cor.	Okla. Gas & Elec. Co.	....	....	....	42	....	Alluvium	9	8-8-52
13-3	NW SE NE	Oklahoma City	1,246	1,233	1,188	58	....	Alluvium	13	5- -53
13-4	NE NW NE	Oklahoma City	1,245	1,235	1,205	40	....	Alluvium	10	5- -53
13-5	SW NE SE	Oklahoma City	1,239	1,233	1,194	45	....	Alluvium	6	5- -53
13-6	SE NW SE	Oklahoma City	1,235	....	1,286	49	....	Alluvium	....	5- -53
13-7	SE NE SW	Oklahoma City	1,244	1,233	1,193	51	....	Alluvium	11	5- -53
13-8	SW NE SW	Oklahoma City	1,249	1,232	1,187	62	....	Alluvium	17	5- -53
13-9	SW NW SW	Oklahoma City	1,250	1,232	1,200	50	....	Alluvium	18	5- -53
13-10	SE SE NE	Oklahoma City	1,250	1,234	1,189	61	....	Alluvium	16	5- -53
13-11	SW SE NW	Oklahoma City	1,249	1,234	1,182	67	....	Alluvium	15	5- -53
13-12	SE NW NE	Oklahoma City	....	....	....	57	12	Alluvium	....	....
13-13	NW SE NE	Oklahoma City	....	....	....	61	12	Alluvium	....	....
13-14	SE SE NE	Oklahoma City	....	....	....	59	12	Alluvium	....	....
13-15	SW SW NE	Oklahoma City	....	....	....	64	12	Alluvium	....	....
13-16	SW SE NW	Oklahoma City	....	....	....	64	12	Alluvium	....	....
13-17	SE NE SW	Oklahoma City	....	....	....	57	12	Alluvium	....	....

TABLE 9. Records of wells and test holes in Canadian County, Oklahoma

Well number	Location in section	Owner or name	Altitudes: Land surface	Altitudes: Water level	Altitudes: Redbeds	Depth of well (feet)	Casing Diameter (inches)	Water-bearing bed	Water level: Depth below land surface (feet)	Water level: Date of measurement
T. 12 N., R. 5 W.										
13-18	SW NE SW	Oklahoma City	....	....	....	64	12	Alluvium	....	....
13-19	SE NW SE	Oklahoma City	....	....	....	59	12	Alluvium	....	....
14-1	NE SE NE	D. Davis	1,253	1,241	....	34	6	Alluvium	12	11-8-41
14-2	SW SE	Okla. Gas & Elec. Co.	....	....	....	32	....	Alluvium	8	8-8-52
14-3	NE NE	Okla. Gas & Elec. Co.	....	....	....	42	....	Alluvium	....	....
14-4	SW NE SE	Oklahoma City	1,249	1,233	1,207	42	....	Alluvium	16	5- -53
17-1	SE NE SE	....	1,276	1,262	....	33	6	Alluvium	14	11-7 41
17-2	SE cor. NE¼	U.S.G.S.	1,267	....	1,223	50	....	Alluvium	....	....
17-3	NE cor.	U.S.G.S.	1,265	....	1,221	45	....	Alluvium	....	....
18-1	SE SE NE	City of Yukon	....	....	....	43	18	Alluvium	....	....
18-2	SE SE NE	City of Yukon	....	....	....	43	16	Alluvium	....	....
18-3	SW NW NW	....	1,268	1,264	....	16	10½	Alluvium	4	8-7-41
18-4	SW NW SW	U.S.G.S.	1,265	1,263	....	14	¾	Alluvium	2	5-21-42
18-5	NE SE NE	City of Yukon	....	....	....	45	12	Alluvium	17	8- -52
18-6	SE NE NE	City of Yukon	....	....	....	50	12	Alluvium	16	8- -52
21-1	SE	Joe Maca	....	....	....	30	....	Redbeds	....	....
22-1	SE	Oscar Horn	....	....	....	75	....	Redbeds	....	....
23-1	NW SW SW	W. C. Larkin	1,276	1,242	....	65	6	Redbeds	34	11-10-41
23-2	NE SE SE	....	1,242	1,240	....	28	....	Alluvium	2	11-10-41
23-3	NE NW NE	Lakeview Stock Farm	1,246	1,242	....	19	6	Alluvium	4	11-25-41
23-4	SW	Oscar Horn	....	....	....	75	....	Redbeds	....	....
23-5	SW	Oscar Horn	....	....	....	35	....	Redbeds	....	....
23-6	NW	....	....	....	....	25	....	Redbeds	10	7-21-52
23-7	NW	J. D. Vaught	....	....	....	75	....	Redbeds	....	....
23-8	S¼ cor. SE	Okla. Gas & Elec. Co.	....	....	....	56	....	Alluvium	3	7-8-52
23-9	S¼ cor. SW	Okla. Gas & Elec. Co.	....	....	....	36	....	Alluvium	7	7-9-52
25-1	SW	Jack Graham	....	....	....	40	....	Alluvium	....	....
25-2	W¼ cor. SW	Okla. Gas & Elec. Co.	....	....	....	39	....	Alluvium	12	7-8-52
25-3	W¼ cor. NW	Okla. Gas & Elec. Co.	....	....	....	55	....	Alluvium	5	7-8-52
25-4	W¼ cor.	Okla. Gas & Elec. Co.	....	....	....	25	....	Alluvium	8	7-10-52
25-5	SE NE SE	Okla. Gas & Elec. Co.	....	....	....	47	....	Alluvium	21	7-10-52
25-6	SE cor.	Okla. Gas & Elec. Co.	....	....	....	48	....	Alluvium	24	8-26-52
25-7	NE SE	Okla. Gas & Elec. Co.	....	....	....	49	....	Alluvium	15	8-26-52
25-8	NW NE SE	Okla. Gas & Elec. Co.	....	....	....	52	....	Alluvium	12	8-26-52
25-9	NW SE	Okla. Gas & Elec. Co.	....	....	....	61	....	Alluvium	13	8-26-52
25-10	SW NW	Okla. Gas & Elec. Co.	....	....	....	68	....	Alluvium	17	8-26-52
25-11	SE NE	Okla. Gas & Elec. Co.	....	....	....	49	....	Alluvium	10	8-26-52
26-1	SE SW SW	Willard Heiple	1,263	1,232	....	100	....	Redbeds	31	11-10-41
26-2	SW	Willard Heiple	....	....	....	......	....	Redbeds	....	....
26-4	NW	E. Dolezal	....	....	....	75	....	Redbeds	....	....
26-5	SE	L. S. Horn	....	....	....	....	....	Alluvium	....	....
26-6	SE	L. S. Horn	....	....	....	45	....	Alluvium	....	....
26-7	NE	William Hollman	....	....	....	....	....	Alluvium	....	....
27-1	NE NE NW	William Eskew	1,301	1,277	....	39	48	Redbeds	24	8-8-41
27-2	NE NE SE	H. H. Taylor	1,257	1,244	....	28	6	Alluvium	13	11-10-41
27-3	SE	Tex Baughman	....	....	....	55	....	Redbeds	....	....
27-4	SE	Tex Baughman	....	....	....	30	....	Redbeds	....	....
27-5	SE	Tex Baughman	....	....	....	50	....	Redbeds	....	....
27-6	SE	Tex Baughman	....	....	....	55	....	Redbeds	....	....
27-7	NE	Ed Dolezal	....	....	....	75	....	Redbeds	....	....
27-8	NW	J. W. Team	....	....	....	30	....	Redbeds	....	....
31-1	NE NE NW	V. W. Shedeck	1,345	1,330	....	19	40	Redbeds	15	8-7-41
31-2	NE NW NW	V. W. Shedeck	1,265	1,231	....	54	6	Redbeds	34	8-7-41
32-1	NW NW NE	Roy Kouba	1,381	1,242	....	45	48	Redbeds	39	8-8-41
34-1	NE SE NE	Elmer May	1,264	1,254	....	27	27	Redbeds	10	8-8-41
34-2	NW NE NE	Elmer May	1,278	1,264	....	99	6	Redbeds	14	8-8-41
34-3	NE	Homer Williams	....	....	....	....	....	Redbeds	....	....
34-4	SW	....	....	....	....	53	....	Redbeds	....	....
34-5	NW	Lynn Wagner	....	....	....	28	....	Redbeds	....	....
35-1	NE NE NE	H. R. Zwiacher	1,239	1,227	....	32	6	Alluvium	12	11-10-41
35-2	NW SW	R. Atwood	1,282	1,264	....	35	60	Redbeds	18	8-8-41
35-3	NW	Charles Dvorak	....	....	....	65	....	Redbeds	....	....
35-4	SW	L. H. Mohr	....	....	....	....	....	Redbeds	....	....
35-5	NE	H. R. Zwiacher	....	....	....	23	....	Alluvium	....	....
35-7	N¼ cor.	Okla. Gas & Elec. Co.	....	....	....	36	....	Alluvium	14	8-7-52
35-8	N¼ cor. NE	Okla. Gas & Elec. Co.	....	....	....	36	....	Alluvium	14	8-7-52
36-1	SW SW SE	E. A. Vaught	1,231	1,215	....	23	....	Alluvium	16	11-11-41
36-2	NE NE	J. F. Dudek	1,241	1,218	....	34	7	Alluvium	23	11-10-41
36-3	NW cor. SE	Okla. Gas & Elec. Co.	1,241	1,217	1,174	66	10	Alluvium	24	7-12-49
36-4	NW NE SE	Okla. Gas & Elec. Co.	1,237	1,208	1,174	63	....	Alluvium	29	7- -49
36-5	NE SW SE	Okla. Gas & Elec. Co.	1,228	1,209	1,166	65	....	Alluvium	19	7- -49

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T. 12 N., R. 5 W.										
36-6	SW NW SE	Okla. Gas & Elec. Co.	1,232	1,208	1,171	65	....	Alluvium	24	7- -49
36-7	NE NW SE	Okla. Gas & Elec. Co.	1,238	1,209	....	65	....	Alluvium	29	7- -49
36-8	E¼ cor.	Okla. Gas & Elec. Co.	1,220	1,209	1,177	43	....	Alluvium	11	7- -49
36-9	NW NE	Okla. Gas & Elec. Co.	....	....	....	57	....	Alluvium	16	7-7-52
36-10	NW NW	Okla. Gas & Elec. Co.	....	....	....	39	....	Alluvium	14	7-8-52
36-11	SW SW	Okla. Gas & Elec. Co.	....	....	....	36	....	Alluvium	10	7-9-52
36-12	S¼ cor. SW	Okla. Gas & Elec. Co.	....	....	....	30	....	Alluvium	14	7-9-52
36-13	SE SE	Okla. Gas & Elec. Co.	....	....	....	42	....	Alluvium	17	7-9-52
36-14	S¼ cor.	Okla. Gas & Elec. Co.	....	....	....	41	....	Alluvium	22	7-10-52
36-15	NE NW	Okla. Gas & Elec. Co.	....	....	....	54	....	Alluvium	16	8-6-52
36-16	NE NE	Okla. Gas & Elec. Co.	....	....	....	46	....	Alluvium	20	8-6-52
36-17	SE cor.	Okla. Gas & Elec. Co.	....	....	....	41	....	Alluvium	12	8-14-52
36-18	E¼ cor. NE	Okla. Gas & Elec. Co.	....	....	....	47	....	Alluvium	27	8-26-52
36-19	NE SE	Okla. Gas & Elec. Co.	....	....	....	45	....	Alluvium	....	....
36-20	NW SE	Okla. Gas & Elec. Co.	....	....	....	61	....	Alluvium	....	....
36-21	NW SE	Okla. Gas & Elec. Co.	....	....	....	55	....	Alluvium	....	....
T. 12 N., R. 6 W.										
2-1	SE NE	....	1,290	1,266	....	83	....	Redbeds	24	11-6-41
3-1	SE NE	Ryba Jacob	1,296	1,271	....	34	6	Redbeds	25	11-5-41
3-2	SW SW	U.S.G.S.	1,281	1,273	....	14	¾	Alluvium	8	4-11-42
4-1	SW NW SW	U.S.G.S.	1,295	....	1,251	45	....	Alluvium	....	....
4-2	SW cor.	U.S.G.S.	1,283	....	1,251	35	....	Alluvium	....	....
5-1	SE SE	....	1,293	1,277	....	41	8	Alluvium	16	11-5-41
5-2	NW NW	U.S.G.S.	1,286	1,283	....	19	¾	Alluvium	3	4-6-42
5-3	SW SW	U.S.G.S.	1,285	1,282	....	14	¾	Alluvium	3	5-7-42
5-4	SE SE NE	U.S.G.S.	1,300	....	1,255	47	....	Alluvium	....	....
7-1	NW NE	U.S.G.S.	1,289	1,283	....	13	¾	Alluvium	6	5-7-42
7-2	NE SE NE	Bill Hall	....	....	....	38	16	Alluvium	8	10-20-53
8-1	SE NE	U.S.G.S.	1,280	....	1,235	50	....	Alluvium	....	....
8-2	SW SW NW	F. Grossman	....	....	....	39	16	Alluvium	10	10-20-53
9-1	SW SE	U.S.G.S.	1,278	1,275	....	11	¾	Alluvium	3	5-7-42
11-1	SW SW	U.S.G.S.	1,283	1,269	....	32	¾	Alluvium	14	5-7-42
11-2	NE SE	J. W. Rhodyback	1,277	1,267	....	41	6	Alluvium	10	11-6-41
12-1	NW SW	U.S.G.S.	1,275	1,267	....	24	¾	Alluvium	8	5-6-42
13-1	NW SW	U.S.G.S.	1,274	1,268	....	16	¾	Alluvium	6	5-21-42
15-1	NE SE	Horace Park	1,279	1,271	....	22	8	Alluvium	8	11-7-41
15-2	SW SW	R. C. Lay	1,283	1,272	....	18	48	Alluvium	11	11-7-41
16-1	NW cor. SW	U.S.G.S.	1,286	....	1,239	48	....	Alluvium	....	....
16-2	NW NW NW	U.S.G.S.	1,283	....	1,237	48	....	Alluvium	....	....
17-1	SW SW	Charles H. Phelps	1,304	1,276	....	66	8	Alluvium	28	11-4-41
17-2	SE SE SE	U.S.G.S.	1,287	....	1,267	25	....	Alluvium	....	....
18-1	NW NW	Frank Evans	1,300	1,277	....	26	48	Alluvium	23	11-4-41
18-2	SE NE NE	U.S.G.S.	1,282	1,278	....	15	¾	Alluvium	4	5-22-42
20-1	NE NE	Kurl Bornmann	1,288	1,272	....	20	....	Alluvium	16	11-5-41
T. 12 N., R. 7 W.										
1-1	SE SE	U.S.G.S.	1,301	1,283	....	27	¾	Alluvium	18	8-21-42
2-1	SW SE	Harry Cooksey	....	....	....	46	1¼	Alluvium	....	....
3-1	SE SE	U.S.G.S.	1,209	1,295	....	20	¾	Alluvium	14	8-21-42
4-1	NE SE	Arthur Standley	1,316	1,301	....	30	6	Alluvium	15	11-3-41
4-2	NE SW	C.R.I. and P.R.R.	1,321	1,312	....	43	13	Alluvium	9	10-3-42
5-1	SE NE NE	U.S.G.S.	1,322	....	1,282	43	....	Alluvium	....	....
9-1	NE SE	C. M. Thompson	1,315	1,302	....	28	6	Alluvium	13	11-3-41
10-1	NW NE	Brooks	1,312	1,295	....	39	6	Alluvium	17	11-6-41
11-1	NW SW	R. A. Bachler	....	....	....	37	....	Alluvium	12	11-4-41
11-2	SE SE	L. E. Royse	1,308	1,285	1,267	41	6	Alluvium	23	11-4-41
11-3	SE SE	U.S.G.S.	1,305	1,286	....	27	¾	Alluvium	19	8-21-42
12-1	NE NE	J. P. Neal	1,299	1,281	....	29	6	Alluvium	19	11-4-41
12-2	NW NW	Rich Valley School	1,305	1,288	....	32	6	Alluvium	17	11-4-41
T. 12 N., R. 8 W.										
5-1	NW NE NE	U.S.G.S.	1,370	....	1,365	20	....	Redbeds	....	....
20-1	NE NW	J. T. Riley	....	....	....	28	6	Redbeds	14	6-18-53
T. 12 N., R. 9 W.										
20-1	NE NE NE	Booth	....	....	....	119	7	Redbeds	104	4-16-48
T. 12 N., R. 10 W.										
3-1	SE SW	M. B. Tilley	....	....	....	30	72	Redbeds	25	6-17-53
6-1	NW NW	W.E. Tindel	....	....	....	29	6½	Alluvium	9	7-2-53

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T. 12 N., R. 10 W.										
20-1	SW SW	F. Hagin	1,429	1,406	....	57	6	Redbeds	23	7-2-53
33-1	SE SW	W. R. Grokett	1,553	1,462	....	103	8	Rush Springs	91	8-19-53
T. 13 N., R. 5 W.										
27-1	SE NE	Frank Rubes	....	....	....	35	42	Redbeds	34	6-16-53
31-1	NW NW SE	S. A. Tredway	....	....	....	15	1½	Terrace Deposits	11	8-6-41
31-2	NE NE SE	S. A. Tredway	....	....	....	18	....	Terrace Deposits	17	8-6-41
35-1	NW cor.	R. Coness	....	....	....	61	42	Redbeds	53	1-29-54
T. 13 N., R. 6 W.										
23-1	SE SW	H. Estep	....	....	....	....	36	Terrace Deposits	6	6-16-53
27-1	SW SW	E. T. Hinricksen	....	....	....	33	6	Terrace Deposits	22	1-29-54
29-1	SE SW	R. J. Powell	....	....	....	74	6	Terrace Deposits	52	1-29-54
30-1	SE SE SE	....	....	....	....	13	18	Terrace Deposits	7	9-26-41
30-2	SE SW	E. Powell	....	....	....	50	8	Terrace Deposits	22	1-28-54
31-1	SW NE SW	W. Sharp	1,309	1,287	....	31	42	Alluvium	22	11-5-41
T. 13 N., R. 7 W.										
11-1	NW NE	W. Waller	....	....	....	16	72	Redbeds	8	7-3-53
18-1	NW SW	....	....	....	....	15	42	Terrace Deposits	6	10-10-41
19-1	NW NW NW	U.S. Indian Service	....	....	....	180	....	Alluvium	....	....
19-2	SW SW	C.R.I. and P.R.R.	1,335	1,317	1,288	47	....	Alluvium	18	-19
19-3	NW SW	C.R.I. and P.R.R.	1,337	1,309	1,301	42	....	Alluvium	28	-19
19-6	NW NW	U.S. Indian Service	....	....	....	45	14	Alluvium	....	....
19-7	NW NW	U.S. Indian Service	....	....	....	45	14	Alluvium	....	....
20-1	SE SE SW	C.R.I. and P.R.R.	1,324	1,312	1.288	36	....	Alluvium	12	-19
21-1	SW SW	C.R.I. and P.R.R.	1,322	1,306	1,282	40	....	Alluvium	16	-19
21-2	NW SW	U.S.G S.	1,318	1,308	....	20	¾	Alluvium	10	4-10-42
21-3	SW SE	C.R.I. and P.R.R.	1,322	1.305	1,282	40	....	Alluvium	17	-19
21-4	SE SE	C.R.I. and P.R.R.	1,323	1,313	1,283	40	....	Alluvium	10	-19
21-5	S¼ cor.	Barney Stewart	....	....	....	48	....	Alluvium	....	....
21-6	SW cor.	U.S.G.S.	1,318	....	1,275	45	....	Alluvium	....	....
21-7	W¼ cor	U.S.G.S.	1,321	....	1,275	48	....	Alluvium	....	....
21-8	NW NW NW	U.S.G.S.	1,321	....	1,271	53	....	Alluvium	....	....
21-9	SE NW	P. A. Cornell	....	....	....	46	14	Alluvium	17	6-25-53
22-1	SW SW	T. C. Tennery	1.329	1,311	1,303	92	6	Redbeds	18	10-8-41
22-2	SW SW	C.R.I. and P.R.R.	1,334	....	1,294	40	....	....	....	....
27-1	NW NW NW	U.S.G.S.	....	....	....	15	....	Alluvium	12	10-8-41
27-2	SW SW	C.R.I. and P.R.R.	1 326	1,309	1,276	50	....	Alluvium	17	-19
27-3	SW SW SW	U.S.G.S.	1,320	1,304	....	29	¾	Alluvium	16	5-4-42
27-4	SW NW	C.R.I. and P.R.R.	1,324	1,307	1,279	45	....	Alluvium	17	-19
28-1	SE SE SE	U.S.G.S.	....	....	....	19	....	Alluvium	17	10-8-41
28-2	NW NW NW	U.S.G.S.	....	....	....	16	....	Alluvium	14	10-7-41
28-3	W¼ cor.	U.S.G.S.	1,319	....	1,271	50	....	Alluvium	....	....
28-4	SW cor.	U.S.G.S.	1,322	....	1,269	56	....	Alluvium	....	....
29-1	SW SW SW	U.S.G.S.	1,328	1,309	....	25	¾	Alluvium	19	3-30-42
29-2	NW NW	C.R.I. and P.R.R.	1,329	1,314	1,294	35	....	Alluvium	15	-19
30-1	NE NW	C.R.I. and P.R.R.	1,333	....	1,291	42	....	Alluvium	....	....
30-2	NW NE	C.R.I. and P.R.R.	1,330	1.316	1,292	38	....	Alluvium	14	-19
30-5	SW NE	C.R.I. and P.R.R.	1.333	1,310	1,294	39	....	Alluvium	23	-19
31-1	SW SW SW	J. L. Bodine	1,387	1,344	1,352	65	60	Redbeds	43	10-14-41
32-1	NE NE NE	City of El Reno	....	....	....	52	15	Alluvium	32	4- -48
32-2	NE NE NE	City of El Reno	....	....	....	54	15	Alluvium	32	4- -48
32-3	SW SW SW	U.S.G.S.	1.333	1.329	....	17	¾	Alluvium	4	5-18-42
32-8	E¼ cor.	U.S.G.S.	1,318	....	1,280	40	....	Alluvium	....	....
32-9	NE NE	City of El Reno	....	....	....	....	....	Alluvium	....	....
32-10	NE NE	City of El Reno	....	....	....	....	....	Alluvium	....	....
33-1	SW SE SW	U.S.G.S	1,314	1,301	....	19	¾	Alluvium	13	4-14-42
33-2	NW	Oklahoma City	1,309	1,300	....	23	2	Alluvium	9	11-27-42
33-3	SW NW	City of El Reno	1,321	1.296	1.269	52	22	Alluvium	25	8-17-42
33-4	NE SW	City of El Reno	1.318	1.289	1.268	52	....	Alluvium	29	11-30-48
33-5	SW NW	City of El Reno	....	....	....	53	18	Alluvium	22	4- -39
33-6	SE SE	City of El Reno	....	....	....	51	18	Alluvium	21	8-17-42
33-7	SE SW SW	U.S.G.S.	1.320	....	1,283	38	....	Alluvium	....	....

TABLE 9. Records of wells and test holes in Canadian County, Oklahoma

Well number	Location in section	Owner or name	Altitudes: Land surface	Altitudes: Water level	Altitudes: Redbeds	Depth of well (feet)	Casing Diameter (inches)	Water-bearing bed	Water level: Depth below land surface (feet)	Water level: Date of measurement
T. 13 N., R. 7 W.										
33-8	NW SW NW	U.S.G.S.	1,320	....	1,269	53	....	Alluvium	....	....
33-9	NW NW	City of El Reno	....	....	....	....	16	Alluvium	....	....
33-10	NE SW	City of El Reno	....	....	....	55	16	Alluvium	24	8-17-42
33-11	NE SW	City of El Reno	....	....	....	....	....	Alluvium	....	....
33-12	NE SW	City of El Reno	....	....	....	....	....	Alluvium	....	....
33-13	NE SW	City of El Reno	....	....	....	....	....	Alluvium	....	....
33-14	SW NW	City of El Reno	....	....	....	52	16	Alluvium	....	....
33-15	SW NW	City of El Reno	....	....	....	46	16	Alluvium	....	....
33-16	SW NW	City of El Reno	....	....	....	52	16	Alluvium	....	....
33-17	NW NW	City of El Reno	1,323	1,298	1,269	51	....	Alluvium	25	8-17-42
33-18	NW NW	City of El Reno	1,324	1,292	....	52	....	Alluvium	32	-41
34-2	SW NW	C.R.I. and P.R.R.	1,329	1,305	1,281	48	....	Alluvium	24	-19
34-3	SE SE SE	U.S.G.S.	1,303	1,297	....	14	¾	Alluvium	6	3-31-42
35-1	NW NW NW	U.S.G.S.	1,303	1,299	....	15	¾	Alluvium	4	3-31-42
35-2	NE NE SE	Dick Jensen	1,311	1,291	....	34	6	Alluvium	20	11-5-41
T. 13 N., R. 8 W.										
4-1	SW SW SW	U.S.G.S.	1,348	1,344	....	10	¾	Alluvium	4	8-21-42
5-1	NE SE	....	....	....	....	....	....	Redbeds	35	1-27-54
7-1	SE SE	A. Leighton	1,360	1,344	1,313	50	7	Alluvium	16	10- -53
8-1	SE SE SE	U.S.G.S.	1,252	1,339	....	24	¾	Alluvium	13	8-21-42
8-2	NE cor.	U.S.G.S.	1,349	....	1,321	30	....	Alluvium	....	....
9-1	NE NE	Eldon Royce	....	....	....	18	1¼	Alluvium	....	....
9-2	NW SW NW	U.S.G.S.	1,349	....	1,315	36	....	Alluvium	....	....
10-2	SW SW SE	U.S.G.S.	1,339	1,336	....	12	¾	Alluvium	3	5-12-42
12-1	NW NW	Earl Cardwell	....	....	....	35	5½	Terrace Deposits	20	1-27-54
13-1	NE SW	....	....	....	....	3	22	Terrace Deposits	2	10-20-41
13-2	SW SW	City of Okarche	....	....	....	40	14	Alluvium	....	....
13-3	SW SW	City of Okarche	....	....	....	41	14	Alluvium	....	....
13-4	SW SW	C.R.I. and P.R.R.	1,340	1,325	1,300	40	....	Alluvium	15	-19
13-5	SW cor.NWSW	C.R.I. and P.R.R.	1,349	1,332	1,302	47	....	Alluvium	17	-19
13-6	SE SW SW	C.R.I. and P.R.R.	1,350	1,330	1,304	46	....	Alluvium	20	-19
13-7	SW SW	City of Okarche	....	....	....	40	8	Alluvium	23	-47
13-8	NW NE	U.S. Indian Service	....	....	....	11	312	Terrace Deposits	4	1-27-54
14-1	E¼ cor.	C.R.I. and P.R.R.	1,389	....	1,379	45	....	....	....	....
16-1	NW NW NW	U.S.G.S.	1,350	....	1,319	32	....	Alluvium	....	....
16-2	W¼ cor.	U.S.G.S.	1,345	....	1,304	43	....	Alluvium	....	....
17-1	SE cor.	U.S.G.S.	1,343	....	1,305	40	....	Alluvium	....	....
19-1	NW NW	W. H. Crouch	1,372	1,347	....	35	....	Alluvium	25	10-13-41
20-1	NW NW	K. Reding	1,358	1,334	....	38	1¼	Alluvium	24	10-11-41
20-2	NE NE SW	J. D. Small	....	....	....	28	1¼	Alluvium	....	....
21-1	NW NW NW	U.S.G.S.	1,342	1,335	....	13	¾	Alluvium	7	8-21-42
22-1	SE SE SW	U.S.G.S.	1,336	1,325	....	14	¾	Alluvium	11	8-21-42
22-2	NE NW NW	U.S.G.S.	1,334	1,332	....	8	¾	Alluvium	2	5-13-42
22-3	SW SW	G. Wilkowske	1,342	1,326	....	17	6	Alluvium	16	10-13-41
23-1	SE SE SE	U.S.G.S.	1,336	1,320	....	25	¾	Alluvium	16	5-12-42
23-2	NE NE	City of Okarche	....	....	....	42	11	Alluvium	18	8- -51
23-3	SE SE	Billington Lumber Co.	....	....	....	54	12	Alluvium	24	6- -53
23-4	SE SE	Billington Lumber Co.	....	....	....	54	12	Alluvium	24	6- -53
24-1	SE cor. SWSW	Billington Lumber Co.	1,336	1,316	1,281	55	18	Alluvium	20	11-30-48
24-2	SE SE NE	U.S.G.S.	1,335	1,314	....	34	¾	Alluvium	21	8-21-42
24-3	SE NW SW	Billington Lumber Co.	1,338	1,320	1,286	52	....	Alluvium	18	12-31-48
24-4	NE SW SW	Billington Lumber Co.	1,336	1,316	1,285	51	....	Alluvium	20	1-4-49
24-5	NW cor.SWSW	Billington Lumber Co.	1,336	1,318	1,289	47	....	Alluvium	18	1-5-49
24-6	SE NE	C.R.I. and P.R.R.	1,340	1,315	1,293	47	....	Alluvium	25	-19
24-7	NE NE	C.R.I. and P.R.R.	1,338	....	1,297	41	....	Alluvium	....	....
24-8	NW cor.	C.R.I. and P.R.R.	1,347	1,329	1,301	46	6	Alluvium	18	-19
24-9	NW cor.SWNW	C.R.I. and P.R.R.	1,344	1,324	1,292	52	....	Alluvium	20	-19
24-10	N¼ cor.	C.R.I. and P.R.R.	1,346	1,318	1,297	49	6	Alluvium	28	-19
24-11	SW NW	C.R.I. and P.R.R.	1,344	1,328	1,298	46	....	Alluvium	16	-19
24-12	SE SW	C.R.I. and P.R.R.	1,341	1,326	1,297	44	....	Alluvium	15	-19
24-13	SW SE	C.R.I. and P.R.R.	1,336	1,319	1,291	45	....	Alluvium	17	-19
24-14	SE SE	C.R.I. and P.R.R.	1,336	1,318	1,292	44	....	Alluvium	18	-19
24-15	SE SW	Billington Lumber Co.	....	....	....	54	12	Alluvium	24	5- -53
26-1	NE cor.NWNE	Billington Lumber Co.	1,335	1,315	1,279	56	18	Alluvium	20	11-25-48
27-1	NE NE	U. S. Army	....	....	....	42	18	Alluvium	8	10- -41
27-2	NE NE	U. S. Army	....	....	....	45	18	Alluvium	13	10- -41

TABLE 9. Records of wells and test holes in Canadian County, Oklahoma

Well number	Location in section	Owner or name	Altitudes: Land surface	Altitudes: Water level	Altitudes: Redbeds	Depth of well (feet)	Casing Diameter (inches)	Water-bearing bed	Water level: Depth below land surface (feet)	Water level: Date of measurement
T. 13 N., R. 8 W.										
29-1	NE NE NE	U.S.G.S.	1,346	1,333	....	17	¾	Alluvium	13	8-21-42
29-2	NE cor.	U.S.G.S.	1,345	....	1,291	56	....	Alluvium	....	....
29-3	SE cor.	U.S.G.S.	1,361	....	1,351	20	....	Redbeds	....	....
30-1	NE SE	C. J. Quigley	1,379	1,363	....	37	....	Redbeds	16	10-13-41
31-1	NE NW	Wintermute	1,392	1,376	....	28	24	Redbeds	16	10-13-41
T. 13 N., R. 9 W.										
1-1	NW NW SW	C. Branch	....	....	....	11	1¼	Alluvium	....	....
1-2	SW cor.	U.S.G.S.	1,359	1,354	....	11	1¼	Alluvium	5	3-26-42
1-3	NW SE	Regina Blum	....	....	....	23	5½	Alluvium	6	6-25-53
1-4	NW SE	Regina Blum	....	....	....	23	5½	Alluvium	6	6-25-53
1-5	W¼ cor.	U.S.G.S.	1,359	....	1,333	28	....	Alluvium	....	....
1-6	SW cor.	U.S.G.S.	1,358	....	1,324	35	....	Alluvium	....	....
6-1	NE SE	....	1,411	1,386	....	52	2	Redbeds	25	10-6-41
7-1	NE SE NE	Loeschen	1,415	1,393	....	43	6	Redbeds	22	10-3-41
8-1	NE NE NE	U.S.G.S.	1,385	1,380	....	21	¾	Alluvium	5	5-29-52
8-2	SE SW	....	1,414	1,391	....	43	6	Redbeds	23	10-6-41
8-3	SE NE NE	....	1,401	1,381	....	50	6	Redbeds	20	10-6-41
9-1	NE SE	E. M. Haley	1,400	1,375	....	56	....	Redbeds	25	10-10-41
11-1	NW NW NW	U.S.G.S.	1,379	1,363	....	32	¾	Alluvium	16	5-14-42
11-2	SE SE SE	City of Calumet	....	....	....	39	....	Alluvium	10	-46
12-1	W¼ cor.	U.S.G.S.	1,371	....	1,327	45	....	Alluvium	....	....
12-2	SW cor.	U.S.G.S.	1,371	....	1,330	43	....	Alluvium	....	....
12-3	NW SW NW	G. Morrison	1,371	1,350	1,321	52	5	Alluvium	21	10- -53
13-1	NE NE NE	U.S.G.S.	1,367	1,350	....	25	¾	Alluvium	17	5-16-42
13-2	NW SW	City of Calumet	1,380	....	1,345	220	....	Terrace Deposits	....	....
14-1	NW SE	J. R. Brannon	1,381	1,373	1,367	51	6	Redbeds	8	10-11-41
14-2	SE NE NE	City of Calumet	....	....	....	20	....	Alluvium	5	-46
14-3	SE NE NE	City of Calumet	....	....	....	40	....	Alluvium	10	-46
14-4	SE cor.	U.S.G.S.	1,382	....	1,378	10	....	Redbeds	....	....
14-5	NE cor.	City of Calumet	....	....	....	45	8	Alluvium	20	6-18-53
16-1	NE NE	Guy Stults	1,396	1,383	....	45	6	Redbeds	13	10-10-41
16-2	SE SW	Alex Hufnagel	1,427	1,410	....	37	36	Redbeds	17	10-10-41
22-1	NE NE	....	1,403	1,383	....	34	....	Redbeds	20	10-10-41
23-1	SE NE	....	1,403	1,379	....	41	....	Redbeds	24	10-11-41
25-1	SW NW	....	1,391	1,377	....	56	....	Redbeds	14	10-3-41
36-1	NW NW	W. B. Combs	1,411	1,393	....	38	6	Redbeds	18	10-11-41
T. 13 N., R. 10 W.										
1-1	SW SW	L. T. Samuelson	1,432	1,406	....	76	8	Redbeds	26	10-6-41
1-2	SW cor.	U.S.G.S.	1,437	....	1,432	10	....	Redbeds	....	....
2-1	SW SW	....	1,459	1,437	....	39	6	Redbeds	22	10-14-41
2-2	NE cor.	U.S.G.S.	1,422	....	1,417	10	....	Redbeds	....	....
3-1	NW NW	....	1,465	1,446	....	56	6	Redbeds	19	10-14-41
5-1	NW NW NE	....	1,471	1,452	....	26	6	Redbeds	19	5-20-42
5-2	NE NW	Lyon Brothers	1,469	1,457	....	27	....	Redbeds	12	10-13-41
11-1	SW SW	John Derring	1,481	1,450	....	45	6	Redbeds	31	10-13-41
12-1	NE NE	....	1,423	1,401	....	34	6	Redbeds	22	10-3-41
14-1	NE NE	....	1,447	1,437	....	37	6	Redbeds	10	10-10-41
T. 14 N., R. 5 W.										
10-1	SE NE	T. L. Wolfkill	....	....	....	30	....	Redbeds	21	6-16-53
32-1	NE SE	J. V. Whelan	....	....	....	56	6	Redbeds	29	6-24-53
T. 14 N., R. 6 W.										
11-1	SW SW	M. E. Lyle	....	....	....	52	6	Redbeds	38	6-16-53
T. 14 N., R. 7 W.										
24-1	SW SE	Carl Meyers	....	....	....	59	6	Redbeds	30	6-17-53
T. 14 N., R. 8 W.										
7-1	NW NE	John Hufnagel	....	....	....	19	36	Redbeds	17	7-3-53
12-1	SE SW	Gus Wiewel	....	....	....	55	36	Redbeds	19	6-17-53
29-1	NW SW	G. H. Miller	....	....	....	27	36	Terrace Deposits	24	1-27-54
32-1	SW SW	T. McCray	....	....	....	72	12	Terrace Deposits Redbeds	40	1-27-54
T. 14 N., R. 9 W.										
5-1	SW SW	Lloyd Richert	....	....	....	17	36	Terrace Deposits	11	7-3-53
17-1	SW SW	H. N. Jameson	....	....	....	48	30	Terrace Deposits	22	1-26-54

TABLE 9. Records of wells and test holes in Canadian County, Oklahoma

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T. 14 N., R. 9 W.										
19-1	SE SE SE	U.S.G.S.	1,392	1,390	....	21	¾	Alluvium	2	10-27-42
19-2	NW SW NW	U.S.G.S.	1,395	....	1,366	30	....	Alluvium	....	....
21-1	SW SW	W. R. Galloway	....	....	....	41	6	Terrace Deposits	22	1-26-54
25-1	SE cor.	Moberly	1,409	1,385	1,332	77	5½	Terrace Deposits	24	-53
28-1	SE SW SE	U.S.G.S.	1,382	1,370	....	20	¾	Alluvium	12	5-1-42
30-1	SW cor.	U.S.G.S.	1,387	1,384	....	11	¾	Alluvium	3	7-17-42
31-1	SW NW NE	John Garvey	1,393	1,384	....	34	14	Alluvium	9	11-27-41
33-1	SW SW SW	U.S.G.S.	1,385	1,376	....	14	¾	Alluvium	9	5-1-42
34-1	NW NW	Stough	....	....	....	32	1¼	Alluvium	....	....
36-1	SW SW SW	U.S.G.S.	1,364	1,359	....	16	1¼	Alluvium	5	5-13-42
36-2	SW cor.	U.S.G.S.	1,363	....	1,334	30	....	Alluvium	....	....
36-3	SE SE	J. A. Snyder	....	....	....	17	12	Alluvium	5	6-25-53
36-4	NW cor. NE	G. A. Snyder	....	....	....	29	54	Terrace Deposits	24	1-27-54
36-5	NW SW	D. W. Walls	....	....	....	40	8	Alluvium	19	12- -53
36-6	NE SW	D. W. Walls	....	....	....	40	8	Alluvium	....	....
T. 14 N., R. 10 W.										
5-1	E½ SW SE	E. Lefthand	1,428	1,426	....	10	12	Alluvium	2	11-20-41
6-1	SE SE SW	J. H. Dillon	1,431	1,417	....	24	6	Alluvium	14	11-27-41
7-1	SE SW SE	City of Geary	....	....	....	35	12	Alluvium	12	6-18-53
7-2	SE SE SE	City of Geary	1,413	1,408	1,380	33	....	Alluvium	5	6-26-53
8-1	SW SW SW	U.S.G.S.	1,413	1,412	....	12	¾	Alluvium	1	4-13-42
9-1	E½ NW SE	Ed Ice	1,426	1,413	....	37	6	Alluvium	13	11-20-41
13-1	SW SW SW	U.S.G.S.	1,400	1,397	....	23	¾	Alluvium	3	5-9-42
13-2	SW SE	Harry Coleman	....	....	....	....	....	Alluvium	....	....
14-1	SW SW SW	U.S.G.S.	1,401	1,398	....	14	¾	Alluvium	3	3-16-42
14-2	NW NW SW	U.S.G.S.	1,406	....	1,370	38	....	Alluvium	....	....
14-3	SW SE	Q. Rowland	....	....	....	34	2	Alluvium	11	6-26-53
15-1	SW SW SW	U.S.G.S.	1,408	1,400	....	20	¾	Alluvium	8	5-8-42
15-2	NW cor.	U.S.G.S.	1,410	1,403	....	21	¾	Alluvium	7	7-14-42
15-3	SW cor.	U.S.G.S.	1,408	....	1,373	37	....	Alluvium	....	....
17-1	NE cor.	U.S.G.S.	1,413	1,407	....	12	¾	Alluvium	6	3-25-42
17-2	SW SW SW	U.S.G.S.	1,410	1,409	....	14	¾	Alluvium	1	4-14-42
17-3	NW NW NE	A. Dillon	1,414	1,409	....	14	1¼	Alluvium	5	11-27-41
18-1	SW SW	Lee	1,424	1,410	....	44	6	Redbeds	14	10-21-41
18-2	NE NE NW	City of Geary	....	....	....	33	13	Alluvium	....	....
18-3	SW NW NW	City of Geary	....	....	....	32	13	Alluvium	....	....
18-4	NE NW NW	City of Geary	....	....	....	32	13	Alluvium	....	....
20-1	NW NW SW	[illegible]	1,415	1,405	....	85	4	Redbeds	10	3-13-42
20-2	NW NW	H. Zweiacher	....	....	....	32	1¼	Alluvium	....	....
20-3	SE cor.	U.S.G.S.	1,412	....	1,373	40	....	Alluvium	....	....
21-1	SW SW	....	1,412	1,399	....	23	6	Alluvium	13	10-14-41
22-1	NW NW SW	B. Mabry	1,410	1,400	....	21	1¼	Alluvium	10	11-27-41
22-2	SW SW NW	U.S.G.S.	1,406	....	1,371	38	....	Alluvium	....	....
22-3	SW SW	R. H. Morgan	....	....	....	32	2	Alluvium	6	6- -53
23-1	NE	Schumate	....	....	....	18	1¼	Alluvium	....	....
24-1	SE SE SW	H. L. Morris	....	....	....	26	1¼	Alluvium	....	....
24-2	SE cor.	U.S.G.S.	1,395	....	1,363	35	....	Alluvium	....	....
25-1	NW NW NW	U.S.G.S.	1,406	1,391	....	25	¾	Alluvium	15	4-17-42
25-2	NE SE SE	S. Morris	....	....	....	27	1¼	Alluvium	....	....
25-3	E¼ cor.	U.S.G.S.	1,394	....	1,357	40	....	Alluvium	....	....
25-4	SE cor.	U.S.G.S.	1,388	....	1,348	40	....	Alluvium	....	....
25-5	S¼ cor.	U.S.G.S.	1,391	....	1,348	47	....	Alluvium	....	....
26-1	SE cor.	U.S.G.S.	1,392	....	1,358	35	....	Alluvium	....	....
27-1	W¼ cor.	U.S.G.S.	1,418	1,409	....	25	¾	Alluvium	9	8-22-42
28-1	NW NW NW	U.S.G.S.	1,412	1,401	....	19	¾	Alluvium	11	8-22-42
28-2	NW NE	H. Hinky	1 414	1,398	....	22	6	Alluvium	16	10-14-41
29-1	NW NW	H. Rhodes	1,431	1,409	....	71	6	Redbeds	22	10-14-41
29-2	SE SE	B. White	1,442	1,425	....	26	....	Redbeds	17	10-14-41
30-1	SE cor.	U.S.G.S.	1,446	....	1,441	10	....	Redbeds	....	....
31-1	SW SW	S. Clark	1,492	1,479	....	31	....	Redbeds	13	10-21-41
31-2	SE NE	....	1,450	1,439	....	65	6	Redbeds	11	10-14-41
31-3	SW cor.	U.S.G.S.	1,492	....	1,488	16	....	Redbeds	....	....
32-1	SE SE	--------	1,470	1,442	....	31	....	Redbeds	28	10-13-41
34-1	NE SE SE	U.S.G.S.	1,426	1,414	....	17	¾	Terrace Deposits	12	5-13-52
34-2	SE SE	E. Penrod	1,438	1,412	....	68	6	Redbeds	26	10-13-42
34-3	NW NW	Gus Yellowhair	1,447	1,417	....	62	5	Redbeds	30	10-14-41
36-1	SW SW NW	U.S.G.S.	1,393	1,391	....	11	¾	Alluvium	2	5-11-42
36-2	NE NW NE	G. Draper	1,390	1,388	....	9	....	Alluvium	2	11-27-41
36-3	W¼ cor.	U.S.G.S.	1,393	....	1,358	38	....	Alluvium	....	....

INDEX

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