GROUND WATER IN OKLAHOMA

By

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One of the first requisites for the intelligent planning of utilization and control of water and for the administration of laws relating to its use is data on the quantity, quality, and mode of occurrence of the available supplies. The collection, evaluation and interpretation, and publication of such data are among the primary functions of the U. S. Geological Survey. Since 1895 the Congress has made appropriations to the Survey for investigation of the water resources of the Nation. In 1929 the Congress adopted the policy of dollar-for-dollar cooperation with the States and local governmental agencies in water-resources investigations of the U. S. Geological Survey. In 1937 a program of ground-water investigations was started in cooperation with the Oklahoma Geological Survey, and in 1949 this program was expanded to include cooperation with the Oklahoma Planning and Resources Board. In 1957 the State Legislature created the Oklahoma Water Resources Board as the principal State water agency and it became the principal local cooperator.

The Ground Water Branch of the U. S. Geological Survey collects, analyzes, and evaluates basic information on ground-water resources and prepares interpretive reports based on those data. Cooperative ground-water work was first concentrated in the Panhandle counties. During World War II most work was related to problems of water supply for defense requirements. Since 1945 detailed investigations of ground-water availability have been made in 11 areas, chiefly in the western and central parts of the State. In addition, water levels in more than 300 wells are measured periodically, principally in the western half of the State. In Oklahoma current studies are directed toward determining the source, occurrence, and availability of ground water and toward estimating the quantity of water and rate of replenishment to specific areas and water-bearing formations.

Ground water plays an important role in the economy of the State. It is estimated that about one-third of the water used in the State in 1956, or 400,000 acre-feet, came from ground-water sources. In 1957, 71 percent of the irrigation water used in the State came from underground sources, and ground water was used for irrigation in 57 of the State's 77 counties. More than 300 of the towns and cities of the State obtain all their municipal water supplies from ground water.

The major ground-water reservoirs, or aquifers, of Oklahoma may be classed in four general groups: (1) semiconsolidated sand and gravel underlying the High Plains, (2) unconsolidated alluvial deposits of sand and gravel along streams and adjacent to valleys, (3) sandstone aquifers, and (4) limestone aquifers, including, for the purpose of this generalized breakdown, dolomite and gypsum. The locations of these major aquifers are shown on figure 1. Areas on that map do not correspond exactly to outcrops, but are the areas where the formations contain significant quantities of potable water. Near their edges rock formations may be cut through by streams or they may be too thin to contain much water. On the other hand, some formations contain fresh ground water for many miles downdip from their outcrop areas, where wells must first penetrate overlying rocks to reach them.

Deposits of the High Plains

The deposits beneath the High Plains (fig. 1) consist of sand, gravel, silt, and clay which were deposited by ancient streams flowing from the Rocky Mountains. Those deposits, now partly cemented with calcium carbonate, reach a maximum thickness of several hundred feet and contain a large quantity of water. They furnish a large part of the water used for all purposes in the Panhandle and northwestern Oklahoma. They are being tapped increasingly for

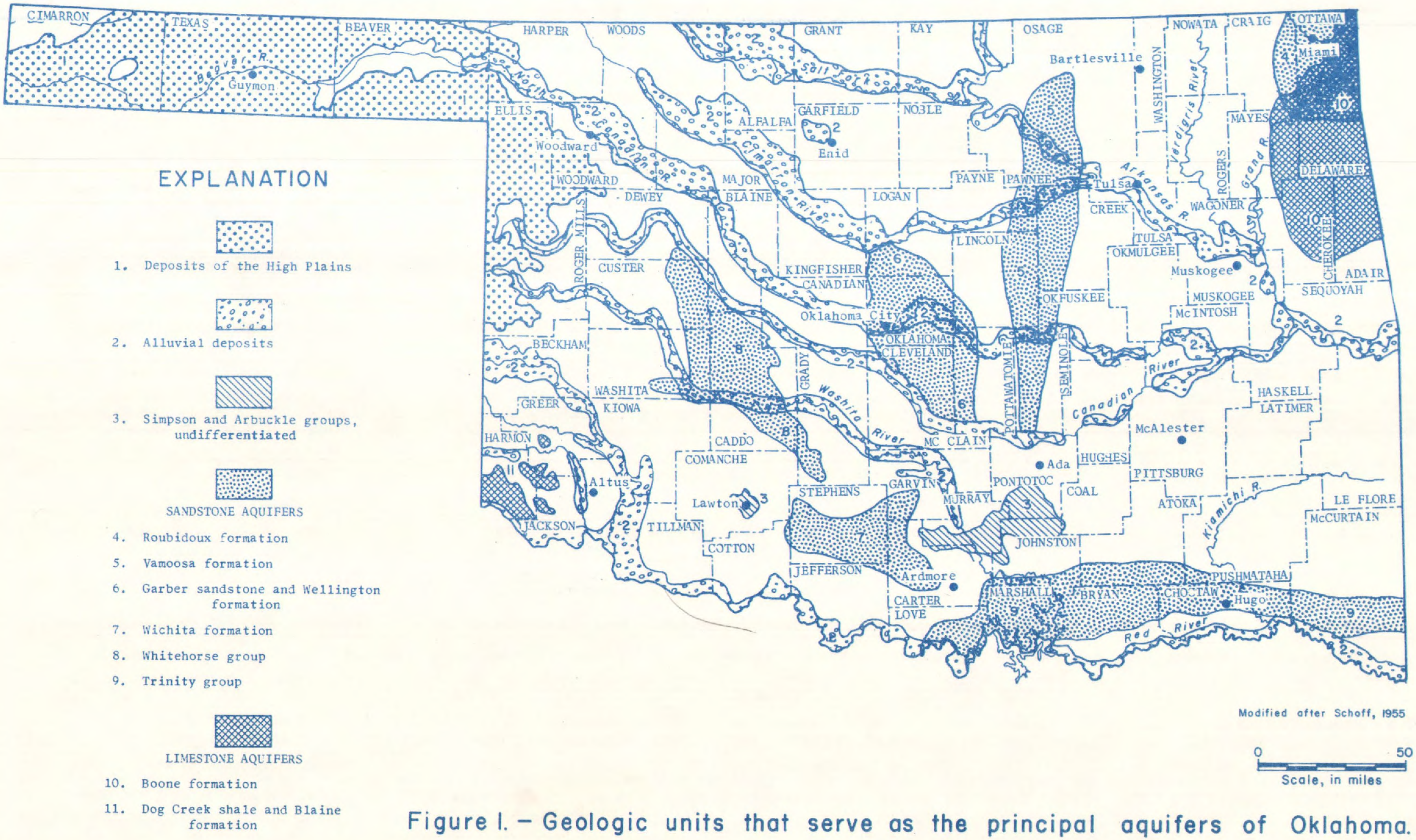

Figure I. – Geologic units that serve as the principal aquifers of Oklahoma.

irrigation, particularly in the Panhandle counties and adjacent parts of Texas and Kansas. The water apparently takes a long time to reach the zone of saturation because water levels in wells in those deposits do not respond quickly to dry or wet periods as shown by the hydrograph of a well in Beaver County (fig. 2).

Wells in the thickest and most permeable sections of these deposits yield as much as 1,000 gpm (gallons per minute), and yields of several hundred gallons per minute are common throughout large areas. It is estimated that more than 100 million acre-feet of water is available from these deposits in Oklahoma. That is 1,000 times the amount pumped to irrigate about 75,000 acres in the High Plains during 1957.

Alluvial Deposits

Alluvial deposits are the sand, gravel, and clay deposited by streams. Before cutting to their present levels, many streams, such as the Red, Cimarron, Canadian, and Arkansas Rivers, had broad valleys at higher levels. Those streams left extensive areas covered by alluvial material that now forms terraces or "second bottoms" along major river valleys (fig. 1). In many places, such as the western part of Oklahoma City, that material has been formed into dunes by the wind.

Alluvium in the valleys of major rivers is commonly 40 to 100 feet thick, and alluvium beneath the terraces is known to be more than 100 feet thick at several places, such as in central Woodward County. In most of the major valleys ground water in the alluvial deposits is in hydraulic connection with water in the streams. In some areas the ground water seeping into the streams helps to maintain their flow during dry seasons. Figure 3 is a cross section across the North Canadian River valley at the western edge of Oklahoma City.

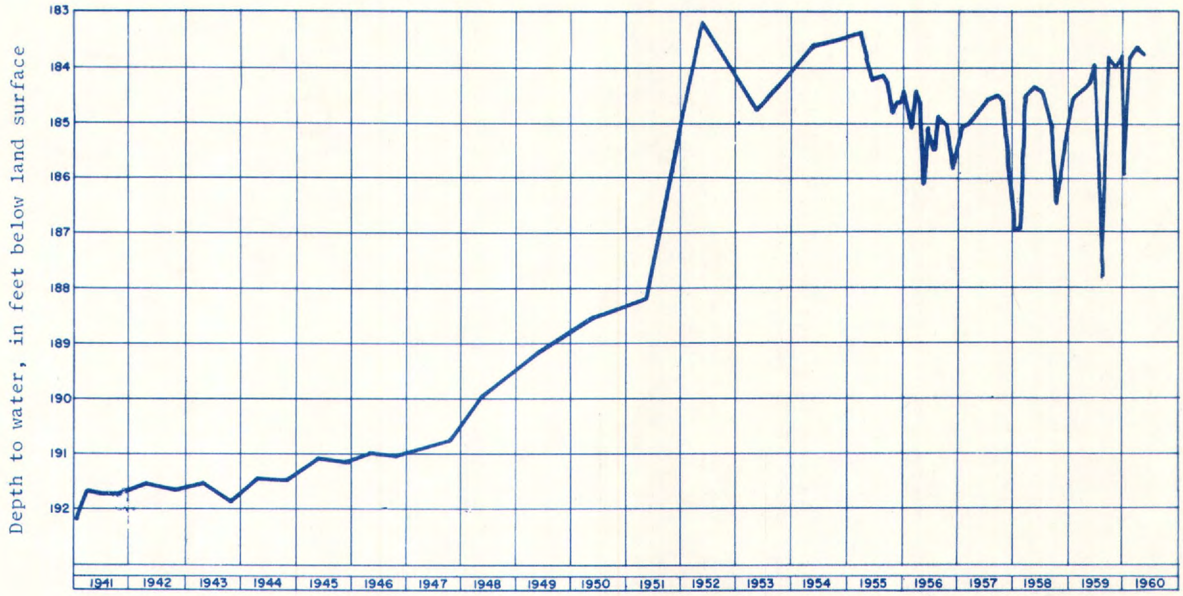

Figure 2.--Water-level fluctuations in a well in Beaver County.

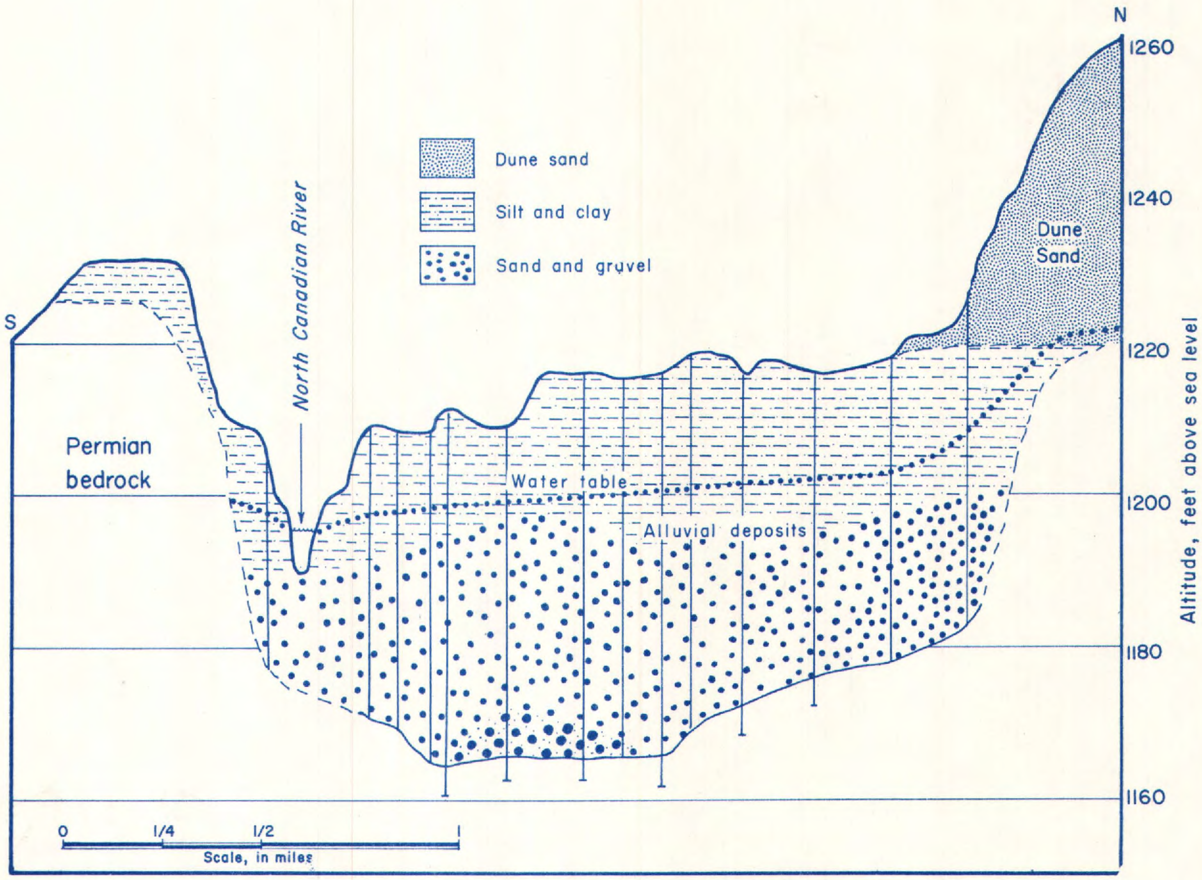

Figure 3.- Cross section of the North Canadian River Valley, near Oklahoma City.

This figure shows that ground water moving from the alluvium is seeping into the river, increasing the flow.

Other streams contribute water to the alluvial ground-water reservoirs, particularly during periods of high stream flow. Figure 4 illustrates such a stream, which is typical of rivers in the western part of the State.

Because of their thickness and high permeability, alluvial deposits commonly yield large quantities of water. They furnish supplies for cities such as Enid and Woodward, as well as water for irrigation and industry in many areas. The combination of shallow water levels, permeable soils, and flat to gently rolling topography provide ideal conditions for replenishment of ground water from precipitation. The rate of replenishment of these deposits is high and has been estimated to be more than 10 percent of the precipitation in areas underlain by the deposits along the Cimarron River. That is about three times the average surface runoff in the same area. Wells tapping alluvial deposits generally yield more than 100 gpm, and yields of several hundred gallons per minute are common in many areas. Along some alluvial valleys tremendous quantities of ground water are used by water-loving plants, such as willow, cottonwood, and saltcedar trees. It has been estimated that the quantity of water used by such plants in the North Canadian valley in Canadian County alone is 40,000 acre-feet a year--more than Oklahoma City's municipal use!

Sandstone Aquifers

The red sandy soils and sandhills of Oklahoma provide ideal catchment areas for the rain that falls on the surface. This water readily moves downward, replenishing the water in sandstone aquifers that lie beneath. Originally these sandstone strata were deposited in a horizontal position,

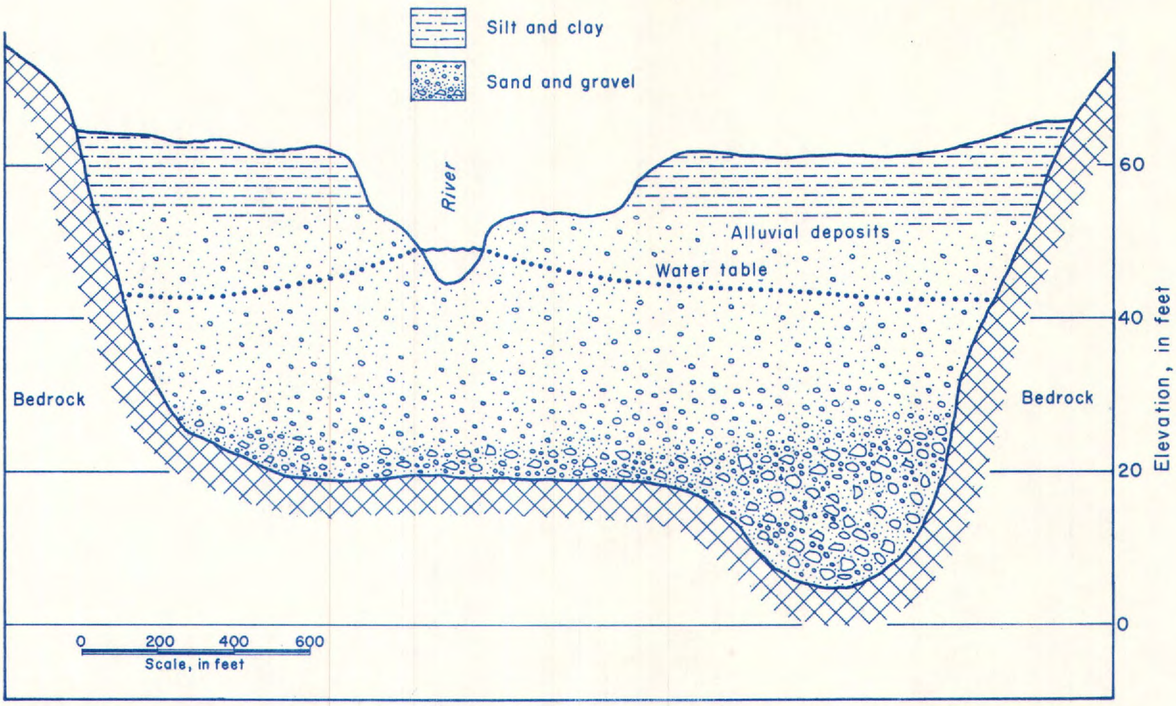

Figure 4.-Diagrammatic cross section of a valley of a stream losing water to the ground-water body.

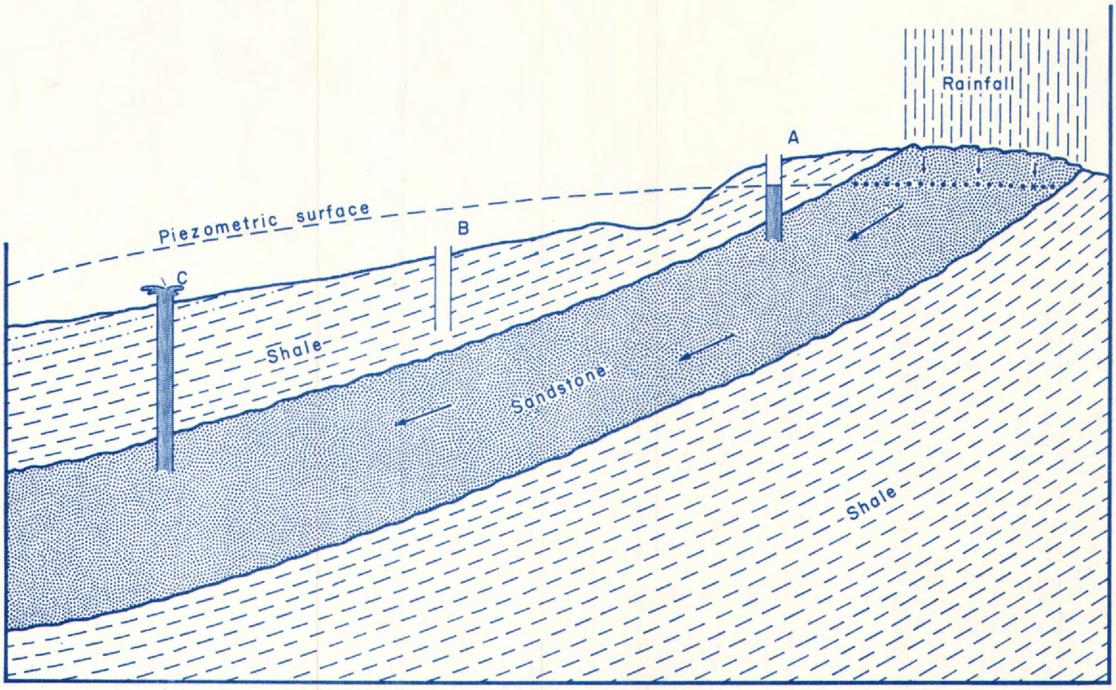

Figure 5.-Diagram illustrating a simple artesian system.

but most of them have been tilted and folded and they now dip at angles ranging from slight to almost vertical. At many places they are confined between less permeable silt and shale beds, so that water in the sandstone is under "confined" (artesian) conditions. Under confined conditions, water will rise above the level at which the water-bearing formation is found in a well, and in some low areas water will flow from the well at land surface. Figure 5 illustrates a confined aquifer similar to the sand of the Trinity group of southeastern Oklahoma. Rain falling on the exposed surface of the sandstone, at the right, seeps into the ground and moves slowly toward the left down the dip of the sandstone bed. Well A yields little or no water until it is drilled into the sandstone; then the artesian pressure in the formation causes the water to rise about halfway to the land surface, to what is known as the artesian-pressure or "piezometric" surface (fig. 5). Well B is a well of the same depth as A, but it did not reach the sandstone and also is "dry." At well C the pressure in the sandstone is sufficient to cause the well to flow at land surface.

The principal sandstone aquifers of Oklahoma are in the following geologic units (fig. 1): the Roubidoux formation, the Simpson group, the Vamoosa formation, the Garber sandstone and Wellington formation, the Wichita formation, the Whitehorse group, and the sands of the Trinity group.

The Roubidoux formation of Early Ordovician age consists of about 150 feet of dolomite and interbedded sandstone. It yields water to wells 800 to more than 1,000 feet deep in the northeastern corner of Oklahoma (fig. 1). Although some wells produce as much as 600 gpm, the aquifer has been overdeveloped locally and water levels have declined several hundred feet since the first wells were drilled more than 40 years ago. The water is moderately hard but low in dissolved solids. It is pumped for both public supply and industrial use.

Simpson group.--In the Arbuckle Mountain region, south of Ada and north of Ardmore, several sandstones of the Simpson group of Middle Ordovician age supply potable water in the outcrop area and for a short distance downdip (fig. 1). A sandstone of equivalent age crops out in Cherokee and Adair Counties in the Ozark part of northeastern Oklahoma and supplies water locally to domestic and farm wells. Little information is available on the sandstones of the Simpson, but apparently they contain highly mineralized water at short distances downdip from the outcrop.

The Vamoosa formation of Pennsylvanian age crops out in a north-south band extending from Seminole to Pawnee County and is an important aquifer in that and nearby areas (fig. 1). The formation consists of 250 to 600 feet of interbedded sandstone, shale, and conglomerate. It supplies water for municipal and industrial use along its outcrop and for several miles downdip to the west. The best wells seem to be in the Seminole area and produce about 150 gpm. Elsewhere yields range from a few gallons per minute to 100 gpm. The water ranges from soft to hard but is too highly mineralized for most uses where the formation is deeply buried.

The Garber sandstone and Wellington formation of Permian age consist of alternating beds of shale and fine-grained sandstone which constitute the most important aquifer in central Oklahoma (fig. 1). They dip gently westward and form a confined aquifer more than 500 feet thick that is tapped by wells as much as 800 feet deep in the Oklahoma City area. Although the transmissibility of the deposits is low and drawdown in wells great, wells yield as much as 300 gpm, and wells yielding more than 100 gpm are common. The water is moderately hard in the outcrop area and at most places downdip. However, in the Norman area in central Cleveland County it is of the sodium bicarbonate type and is very soft. Farther downdip, in McClain County and the western part of Oklahoma County, the sandstone strata grade into shale and water is highly mineralized. In 1957 Oklahoma City pumped about 300 million gallons of water from 21 wells tapping these aquifers. About 1 billion gallons in addition was pumped by small towns in the Oklahoma County area and more than 3 billion gallons was pumped by industries.

The Wichita formation of Permian age consists of fine-grained sandstone and red shale, similar to the rocks of the Garber and Wellington and of roughly equivalent age. This formation supplies water principally for industrial and municipal use in western Garvin, Carter, and southern Stephens Counties (fig. 1). West of Ardmore, fresh water has been reported to depths of as much as 900 feet and wells yield as much as 250 gpm. Yields of more than 100 gpm are common in other areas. The quality is suitable for municipal and industrial purposes, at many places.

The Whitehorse group of Permian age is an important aquifer in a wide area in west-central Oklahoma. This group consists largely of fine to very fine sandstone but contains beds of siltstone, dolomite, and gypsum also. In the main outcrop area from Custer County southeastward through Caddo County to southwestern Grady County, water occurs under water-table or unconfined conditions and the depth to water is generally less than 80 feet. Sandstone beds of this group supply water to hundreds of farm wells, to many small cities, and to an ever-increasing number of irrigation wells, many of which yield more than 500 gpm. In 1957 about 30,000 acres was irrigated with water pumped from more than 400 wells tapping sandstone of the Whitehorse group in Caddo, Custer, and Washita Counties. The peanuts alone produced on 20,000 acres of irrigated land in Caddo County had a value of about $5,000,000. From Dewey County northwestward, the sandstone strata of the Whitehorse contain much fine-grained material and the unit becomes shaly near the Kansas border.

The Trinity group of Early Cretaceous age occurs in southern Oklahoma from Love County eastward (fig. 1). It consists of sand, clay, gravel, and minor amounts of limestone, anhydrite, and gypsum. It includes sand so loose and fine grained that special care is required in constructing wells. It supplies water for municipal and industrial use over a wide area but is just beginning to be tapped for irrigation. Properly constructed wells at favorable sites yield more than 450 gpm. Water quality seems to vary widely over the area, probably indicating the great diversity of conditions affecting ground-water recharge and movement. Locally the Trinity contains potable water to depths of 800 feet. In general, however, water in the Trinity is too salty for most uses downdip from the outcrop along the southern edge of the State.

Limestone Aquifers

Although Oklahoma has several aquifers of the limestone type, few data are available on the occurrence of water in them. In all these rocks, water occurs in openings, some of cavernous size, formed by the solvent action of water moving along joints and crevices. The principal limestone aquifers are the Arbuckle group in the Arbuckle Mountains area (Pontotoc, Johnston, and Murray Counties), the Boone formation of northeastern Oklahoma, and gypsum beds of the Dog Creek shale and Blaine gypsum in southwestern Oklahoma.

The Arbuckle group of Late Cambrian and Early Ordovician age crops out in an irregular area in the northern and western parts of the Arbuckle Mountains and in a small area north of the Wichita Mountains near Lawton. It is composed of a thick section of limestone and dolomite beds which have been tilted, folded, and broken by faults. In and near the outcrop area south of Ada (fig. 1), fresh water occurs in solution openings to depths of more than 2,500 feet and yields of 2,000 gpm are reported from recent tests of wells. Wells at Lawton (fig. 1) yield 600 gpm and the water is used by industries. The aquifer supplies water for municipal, industrial, and irrigation purposes in the Arbuckle Mountains area. Many of the streams of the Arbuckle Mountains, such as Blue, Mill, and Honey Creeks, are fed by springs issuing from the Arbuckle, and one of the largest, Byrds Mill Springs, furnishes the water supply for Ada.

In the outcrop area the water is somewhat hard but contains only a moderate amount of dissolved solids. At varying distances from the outcrop area, water in the Arbuckle is highly mineralized.

The Boone formation of Early and Late Mississippian age consists principally of limestone and cherty limestone and is an important aquifer over a large part of the Ozark area of northeastern Oklahoma (fig. 1). It averages about 300 feet in thickness and contains numerous fracture and solution openings. The Boone forms a sizable ground-water reservoir and is the source for the many springs in that area. Springs issuing from the Boone play an important part in maintaining the year-round flow of streams such as Spavinaw Creek in northern Delaware County. The flow of springs from the Boone in Ottawa County has been estimated at 14 mgd (million gallons per day). If other areas of the formation discharge water at proportionate rates, the total flow from these rocks in the Oklahoma part of the Ozarks is about 100 mgd. Water from the Boone is moderately hard but otherwise is generally of good quality.

The Dog Creek shale and Blaine gypsum of Permian age are important sources of water for irrigation in southwestern Oklahoma in Greer, Harmon, and Jackson Counties (fig. 1). Solution openings have been formed in the numerous gypsum beds, allowing water to move rather freely through those rocks. The pattern of openings is erratic, so a "dry" hole may be drilled within 100 feet of a well of high yield. Many irrigation wells in the area have yields of 500 gpm, and yields of more than 1,000 gpm have been reported. The water generally contains 1,500 to 2,000 ppm (parts per million) sulfate, and locally the water has a high chloride content. In 1955 about 55,000 acre-feet of water was pumped from these rocks, mostly for irrigation, in the southwestern counties.

Fluctuations of Water Levels

Water levels in the ground-water reservoirs, like levels of surface reservoirs, rise and decline in response to the addition of water to or removal of water from the reservoir. Some of the chief factors that affect the rate at which water is added to the underground reservoir are (1) the permeability of the surface soil, (2) the slope of the land surface, (3) the density and type of vegetation, (4) the amount and distribution of precipitation, and (5) the rate of evaporation. In most places where water levels are at shallow depths, such as in alluvial valleys and in the near-surface sandstone aquifers in Payne County, water levels respond rapidly to precipitation (fig. 6). Figure 6 shows the water-level fluctuations in a well tapping the alluvium of the Canadian River near Norman. The water level in this well rose sharply after the heavy rainfall in May 1951, May 1952, and April - June 1957. The water level declined steadily during the dry periods of June - December 1952, June - December 1954, and throughout 1956. Ground-water reservoirs at moderate depths may take several months to respond to the effect of precipitation, and in reservoirs at depths of several hundred feet, such as those in the Panhandle (fig. 2), the response may be delayed for several years.

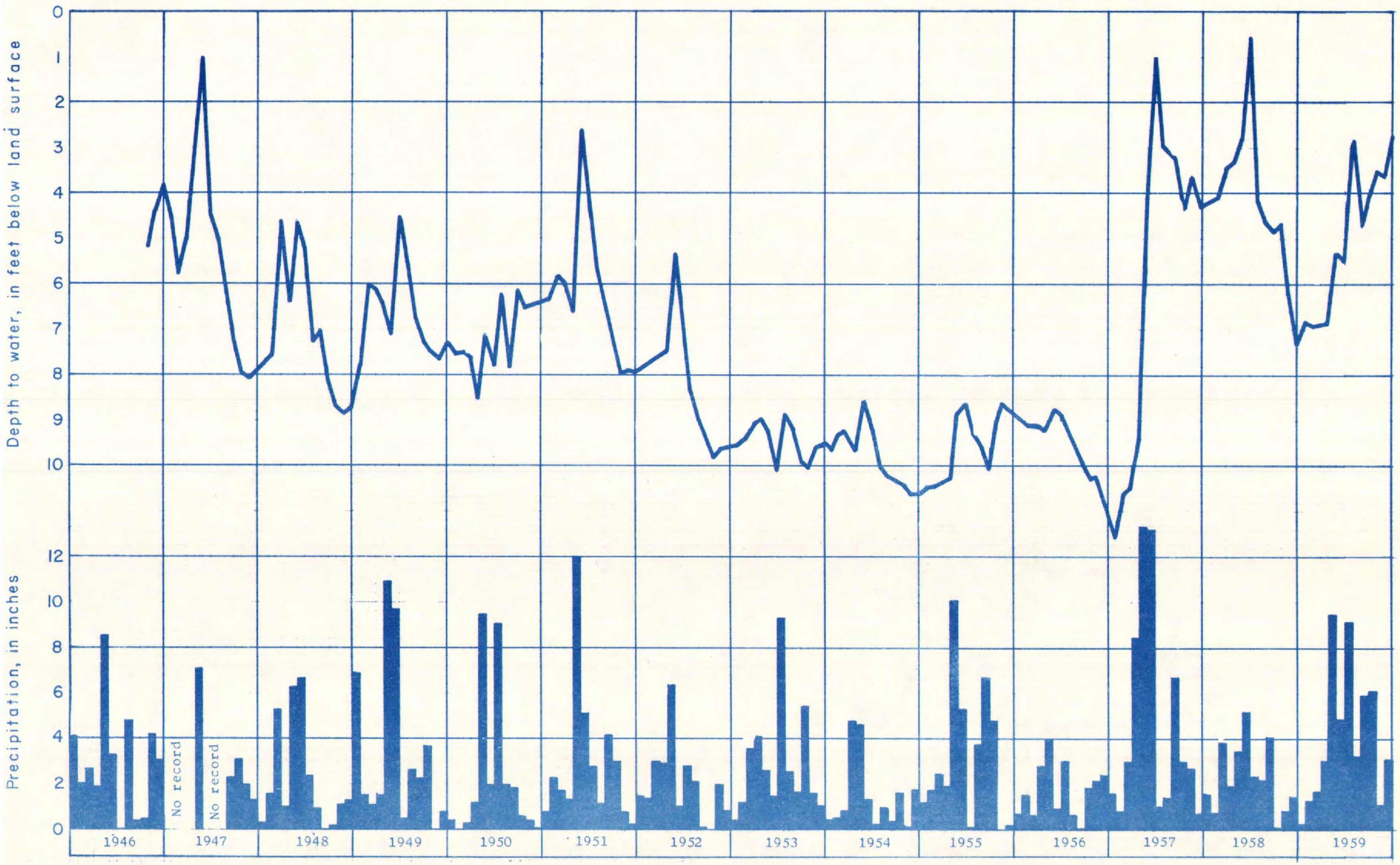

Figure 6.-Hydrograph of a well tapping the alluvium of the Canadian River Valley near Norman and monthly precipitation at Norman.

Disposal into Underground Zones

It has been suggested that porous zones beneath the fresh-water zone might be used for the disposal of industrial wastes. There are many problems associated with such disposal, chief of which are the problem of finding a zone suitable for the disposal of waste products at the rate at which they are produced and the problem of protecting fresh-water zones from contamination. In addition, there are legal problems concerning permission to dispose of waste products underground, and other legal problems which may arise during the operation of such systems.

Underground disposal of waste water is practiced effectively in many oil fields and is feasible in many of the industrial areas of the State. Fortunately, a great mass of geologic data is available for most areas of Oklahoma as a result of oil exploration, and these data will be useful in searching for zones suitable for waste disposal. It should be possible to protect fresh-water formations from contamination if disposal wells are properly constructed and if disposal systems are operated properly.

In conclusion, Oklahoma has tremendous resources of fresh underground water. The exact amount in storage is unknown but is estimated by the Geological Survey to be more than 300 million acre-feet above a depth of 2,000 feet, or more than 40 times the amount of water stored in all the surface reservoirs and lakes of the State and more than 8 times the average annual flow of all the streams draining the State. If spread evenly on the surface, it would cover the entire State to a depth of more than 7 feet. Because some of the water is held tightly in rocks, such as silt and clay, not all of this water is available for man's use, but a large part is. The rate of replenishment is very rapid in some places, such as in the limestones of the Ozark and Arbuckle Mountains; but in others, such as in the High Plains, it is very slow.

Indeed, in some places, it has taken thousands of years for the water to accumulate, and much of the water literally would be mined if it were pumped out rapidly.

Of course, the rate of annual replenishment is more important than the amount in storage, because it determines the amount of water that can be pumped each year far into the future. The available data do not justify an attempt to estimate the annual replenishment closely, but it is equivalent to some substantial fraction of the annual streamflow out of the State.

Much of Oklahoma's great quantity of underground water is only partly developed for man's use. Unfortunately, our knowledge of this resource is far from adequate. Today, when demands for water for irrigation, domestic, municipal, and industrial use are greater than ever before, we have little reason for pride or complacency concerning our knowledge of the State's ground-water resources. We have published reports for only about 9 percent of the area of the State, and half of these are more than 15 years old and need to be brought up to date. Current investigations cover about 14 percent of the State, but our rate of progress averages 2 percent of the State's area per year.

Obviously, if Oklahoma is to utilize her ground-water resources to the fullest extent, information about them will have to be provided at a far greater rate than in the past. There is evidence that the people of Oklahoma, in creating the State Water Resources Board, are anxious to fulfill this need for greater water-resource information. Industry shows signs of being more conscious of the need for protecting the water resources from contamination than at times in the past, and the interest and effort of industrial groups to that end are commendable. The cooperative effort of all groups in the State will be needed to conserve, protect, and develop this vital resource for fullest use by all her citizens.