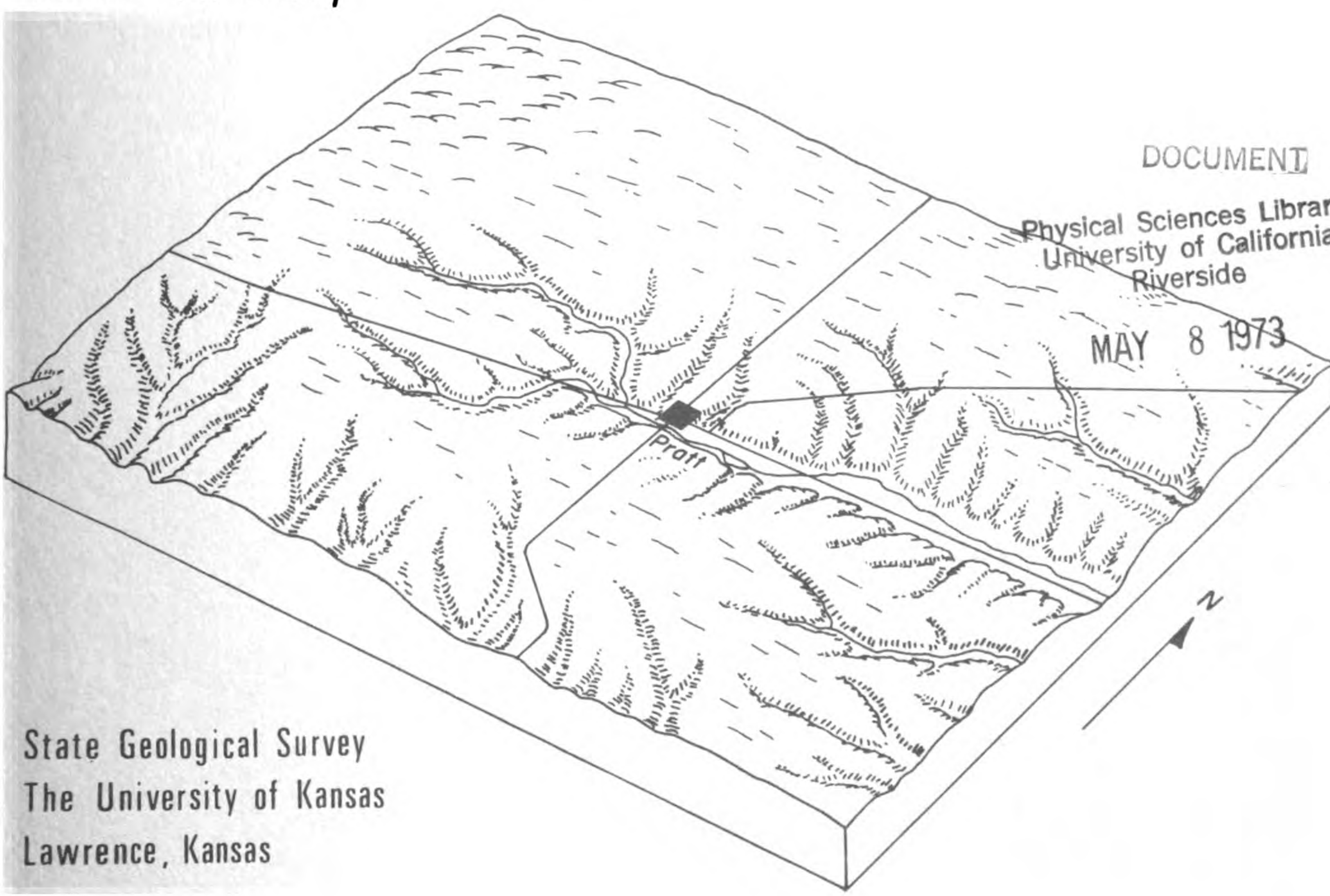
Geology and Ground-Water Resources
PRATT COUNTY
South-Central Kansas

Donald W. Layton
Delmar W. Berry

Bulletin 205



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BULLETIN 205

Geology and Ground-Water Resources of Pratt County, South-Central Kansas

By

Donald W. Layton and Delmar W. Berry

Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the cooperation of the Division of Environmental Health of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture.

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ABSTRACT

Pratt County comprises an area of 729 square miles in south-central Kansas. The county is underlain by unconsolidated deposits of Pleistocene age that, in some areas, could yield as much as 3,000 gallons of water per minute to wells. About 26,000 acre-feet of ground water is withdrawn annually for municipal, industrial, and irrigation uses. This withdrawal probably could be doubled without causing serious depletion of storage in the ground-water reservoir or of flow in the South Fork Ninnescah River.

The ground water in Pratt County generally is suitable chemically for all the common uses. However, water in deposits of Pleistocene age in a small area near Cairo is contaminated by saline water from underlying rocks of Permian age. The dissolved-solids discharge in a 7.7-mile reach of the South Fork Ninnescah River near Cairo increases from 30 to 185 tons per day.

INTRODUCTION

Purpose and History of Investigation

This report is part of a continuing program of ground-water investigations that was begun in 1937 to define and describe the occurrence, availability, and chemical quality of ground water in Kansas. Participants in the program are the U.S. Geological Survey and the State Geological Survey of Kansas, in cooperation with the Division of Environmental Health of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture. The present status of the program is shown on figure 1.

Nearly all water supplies in Pratt County are obtained from wells. Thus, ground water is one of the principal natural resources of the county. Although supplies in most of the county are adequate for most uses at the present rate of withdrawal, a better understanding of the quantity, chemical quality, and distribution of the ground water is needed to meet anticipated increases in water use and to guide the future development and management of the resource.

The results of cooperative ground-water studies have been published for most of the counties adjacent to Pratt County. The geology and ground-water resources of Stafford County were described by B. F. Latta (1950), and those of Reno County were described by C. K. Bayne (1956). Similar studies were made by C. W. Lane (1960) in Kingman County, B. F. Latta (1948) in Kiowa County, and T. G. McLaughlin (1949) in Edwards County.

Pertinent general studies include "Pleistocene Geology of Kansas," by J. C. Frye and A. B. Leonard (1952) and "The Geologic History of Kansas," by D. F. Merriam (1963). Other geologic and hydrologic reports are listed in the Selected References.

Since 1961, a continuing study of the chemical quality of the streamflow of the South Fork Ninnescah River has been in progress as part of the cooperative program between the U.S. Geological Survey and the Kansas State Department of Health. The objectives of this investigation are to appraise the quality of the streamflow and to identify the principal sources of and extent of natural and man-made pollution.

Methods and Scope of Investigation

Field work for this report was done in the summer and fall of 1951, from April to October 1964, and in August 1965. The work consisted of (1) geologic mapping, (2) inventory of 150 wells, (3) drilling of 145 test holes, (4) measurement of discharge of the South Fork Ninnescah River, North Branch Elm Creek, and Turkey Creek, and (5) collection of water samples for chemical analysis. The test drilling was done with auger and hydraulic rotary rigs owned and operated by the State Geological Survey of Kansas. Chemical analyses of water samples were made by the Division of Environmental Health of the Kansas State Department of Health.

Location and Extent of Area

Pratt County, in south-central Kansas, is bounded on the north by Stafford County, on the east by Reno and Kingman Counties, on the south by Barber County, and on the west by Kiowa and Edwards Counties.

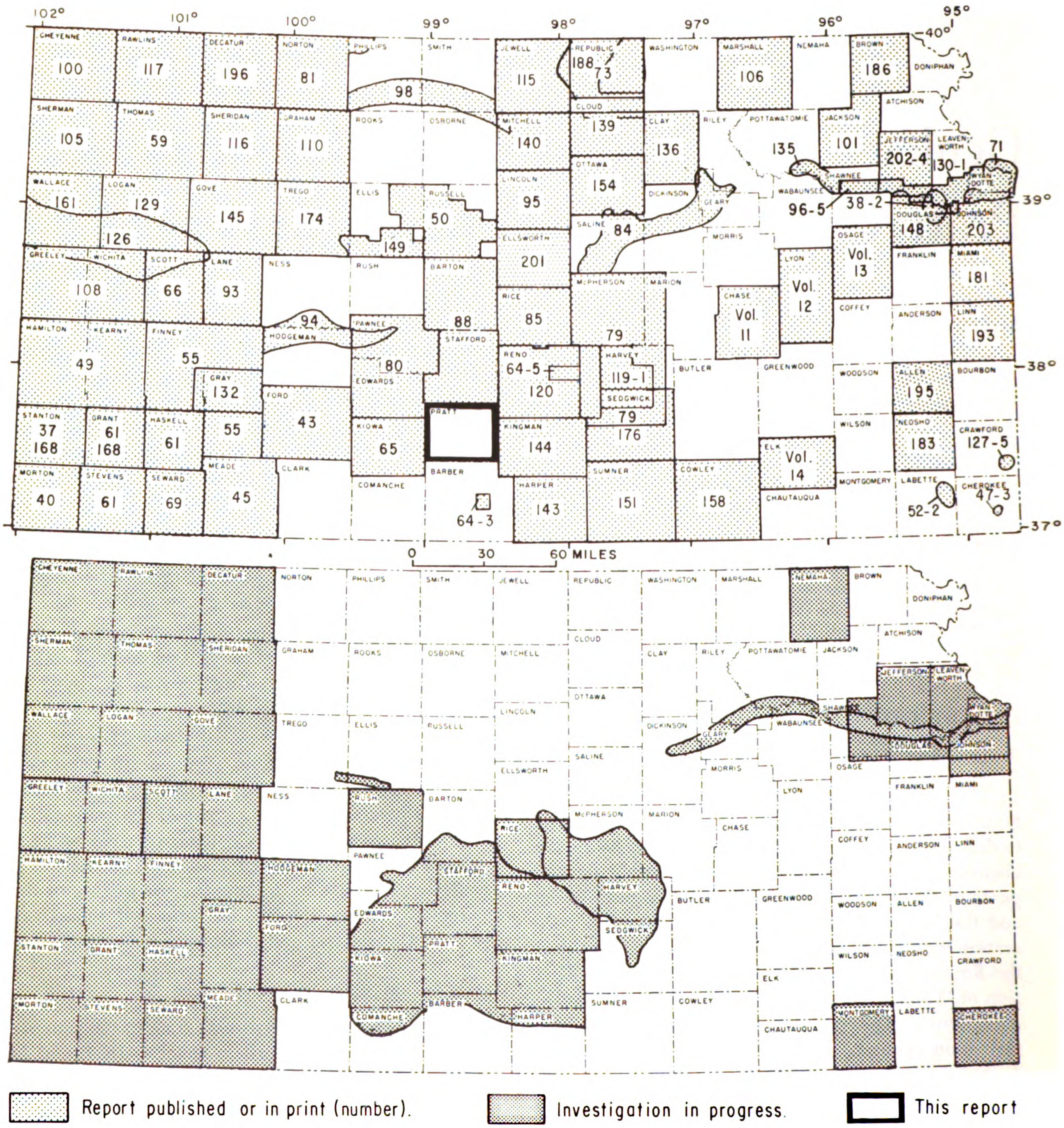


FIGURE 1.—Index maps of Kansas showing area discussed in this report, and other areas for which ground-water reports have been published by the State Geological Survey or are in preparation.

The county contains 20 townships and has an area of 729 square miles. The location of the county is shown on figure 1. Most of the county lies between 37°30′ and 37°50′ N. latitude and between 98°30′ and 99°00′ W. longitude.

Well-Numbering System

Wells and test holes in this report are numbered by their location according to the scheme of General Land Office surveys. The well number is composed of the township, the range, and the section number followed by letters that indicate the subdivision of the section in which the well is located (fig. 2). The first letter denotes the quarter section; the second letter denotes the quarter-quarter section or 40-acre tract; and the third letter, when used, indicates the quarter-quarter-quarter section, or 10-acre tract. The 160-acre (quarter section), or 40-acre, and 10-acre tracts are designated *a, b, c,* and *d,* in a counterclockwise direction, beginning in the northeast quarter. Where two or more wells are located in a 10-acre tract, consecutive numbers beginning with 1 are added to the letters.

Acknowledgments

Appreciation and thanks are expressed to the many residents of Pratt County who supplied information on wells and to the city officials who supplied data on municipal water supplies. Special thanks are due to Mr. G. R. Calhoun, Soil Conservation Service, Pratt, and to Mr. Stacy, the farm representative of the Peoples National Bank.

The cooperation of those who permitted the use of their wells for aquifer tests is gratefully acknowledged. Logs of selected wells were obtained from Dole Drilling Co. and Griffith Drilling Co.

Well records and water-quality data were programmed by members of the Kansas District, U.S. Geological Survey, for analysis and tabulation at The University of Kansas Computation Center. Field work was facilitated by the assistance of members of both the Federal and State Geological Surveys.

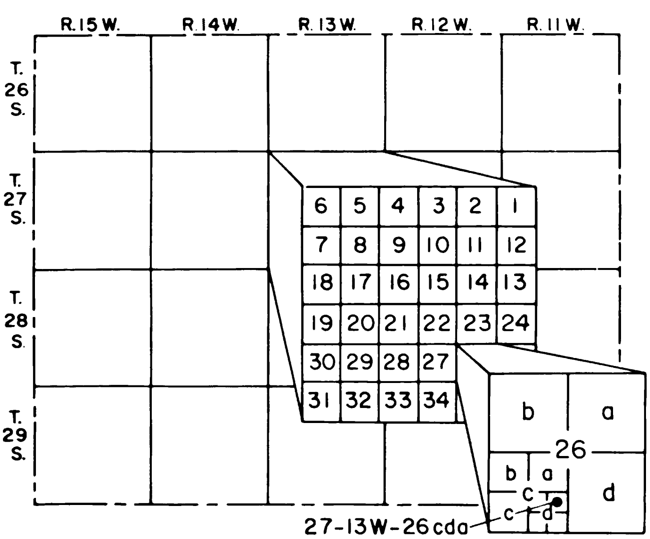


FIGURE 2.—Well-numbering system used in this report.

GEOGRAPHY

Topography and Drainage

Most of Pratt County lies within the High Plains section of the Great Plains physiographic province (Schoewe, 1949). The northern margin is considered to be part of the Arkansas River Lowlands section of the Central Lowland physiographic province.

Topography of the county consists of nearly level to gently rolling plains, with steeper slopes along the major drainageways and in the sand hills. The highest point measured, 2,105 feet above mean sea level, is on the western margin of the county in T.28 S. The lowest point measured, 1,665 feet above mean sea level, is at the east county line where the South Fork Ninnescah River leaves the county. Although the total relief in the county is about 440 feet, the local relief does not exceed 100 feet. The surface of the High Plains slopes gently eastward at about 10 feet per mile in Pratt County.

The northern third and the southeast corner of Pratt County are covered by a thin veneer of dune sand. True dune topography is best developed in the northwestern part of the county. The only tract of active dunes is near the southeast corner of T.26 S., R.15 W. Most of the dunes are stabilized by sparse vegetation.

The major stream in Pratt County is the South Fork Ninnescah River. This perennial stream flows eastward from near Cullison and, with its tributaries, drains about 256 square miles of the county. The stream gradient is about 15 feet per mile in the headwater area and about 10 feet per mile in the eastern part of the county.

Turkey Creek and North Branch Elm Creek, which are perennial streams tributary to Medicine Lodge River (Barber County), drain 127 square miles of southern Pratt County. These creeks have gradients of about 20 feet per mile.

The Chikaskia River and its tributary, Sand Creek, head in the small sand-hills area in the southeast corner of Pratt County. These intermittent streams drain an area of 67 square miles.

Although Rattlesnake Creek crosses the extreme northwest corner of the county, the creek has no contributing drainage area within the county. The creek is a losing stream in Pratt County and adds a minor amount of water to the ground-water reservoir.

Undrained sand-hill areas of Pratt County total 268 square miles in the north and northwest and 11 square miles in the southeast. These areas contain many small basins where precipitation collects and evaporates or seeps into the ground.

Climate

The climate of Pratt County is semiarid with moderate but variable precipitation and a high rate of evaporation. It is classified semiarid because the average precipitation is insufficient for the evapotranspiration demand. Although summer days are hot, the heat is relieved somewhat by good air movement. The winters are moderate with occasional severe cold periods of short duration.

The following climatic data were compiled from the 68-year record of the National Weather Service (formerly U.S. Weather Bureau) at the Pratt station. The mean monthly temperature at Pratt is 82°F in July and 34°F in January. Temperature extremes recorded at Pratt were 115°F in 1911 and 1936 and −24°F in 1899. The normal annual precipitation at Pratt is 24.04 inches. More than two-thirds of the precipitation is in the form of brief heavy thunderstorms during the growing season (fig. 3). The distribution of precipitation throughout the year and from year to year is irregular. Maximum precipitation on record was 39.30 inches in 1957; minimum precipitation was 10.96 inches in 1956. The eastern part of the county receives as much as 2 inches more and the western part about 2 inches less than the annual average of 24 inches received at Pratt. Maximum 24-hour precipitation of 6.65 inches was recorded in July 1928.

Evaporation is not measured at the Pratt weather station. However, data from stations at Garden City (Finney County) and Kanopolis Dam (Ellsworth County) can be used to approximate evaporation potential in Pratt County. At Garden City, 46 to 92 inches of potential evaporation was measured from April through September of years 1961-65. At Kanopolis Dam the potential evaporation ranged from 50 to 63 inches during the period April through October of years 1961-65. These values far exceed the average annual precipitation and result from the typically hot windy summers. Evaporation continues during the winter but at a much lower rate.

Population

In 1970 Pratt County had a population of 10,056, an average of 13.8 inhabitants per square mile. However, more than two-thirds of the county population live in the city of Pratt. When the populations of other communities are added to that of Pratt, more than 75 percent of the people in the county live in towns. The communities and their 1970 populations are: Byers, 46; Coats, 152; Cullison, 117; Iuka, 210; Pratt, 6,736; Preston, 239; and Sawyer, 164 (Kansas State Board of Agriculture, 1971).

Agriculture

Agriculture is the major economic activity in Pratt County. According to the census of the State Board of Agriculture, there were 672 farms in 1969 with 214,265 total acres harvested. The value of the field crops was about 8.5 million dollars, and the value of livestock and poultry was about 9.4 million dollars. Harvested acreage of the principal crops is listed in table 1.

TABLE 1.—Acreage of principal crops harvested in Pratt County in 1969 (Kansas State Board of Agriculture, 1971).

Crop	Acreage harvested
Wheat	161,000
Sorghum	41,600
Corn	3,370
Oats	200
Barley	720
Rye	1,320
Alfalfa	3,300
Wild hay and pasture	2,600

Mineral Resources

The three principal mineral resources in Pratt County, in addition to ground water, are oil and gas, sand and gravel, and volcanic ash.

OIL AND GAS

The first commercial oil well in the Pratt County area was drilled as a westward extension of the Cunningham pool in 1935. In 1964, 596 wells produced 1.2 million barrels of oil from 49 pools. Cumulative production from formations of Mississippian and Pennsylvanian age in Pratt County totals 53.7 million barrels. The producing horizons are at depths ranging from 3,600 to 4,700 feet (Oros and Beene, 1965).

Twenty gas fields in Pratt County produce gas from rocks of Mississippian, Pennsylvanian, and Permian age at depths ranging from 1,900 to 4,600 feet. Gas production in 1964 was 2.49 billion cubic feet; cumulative production was 33.3 billion cubic feet. A

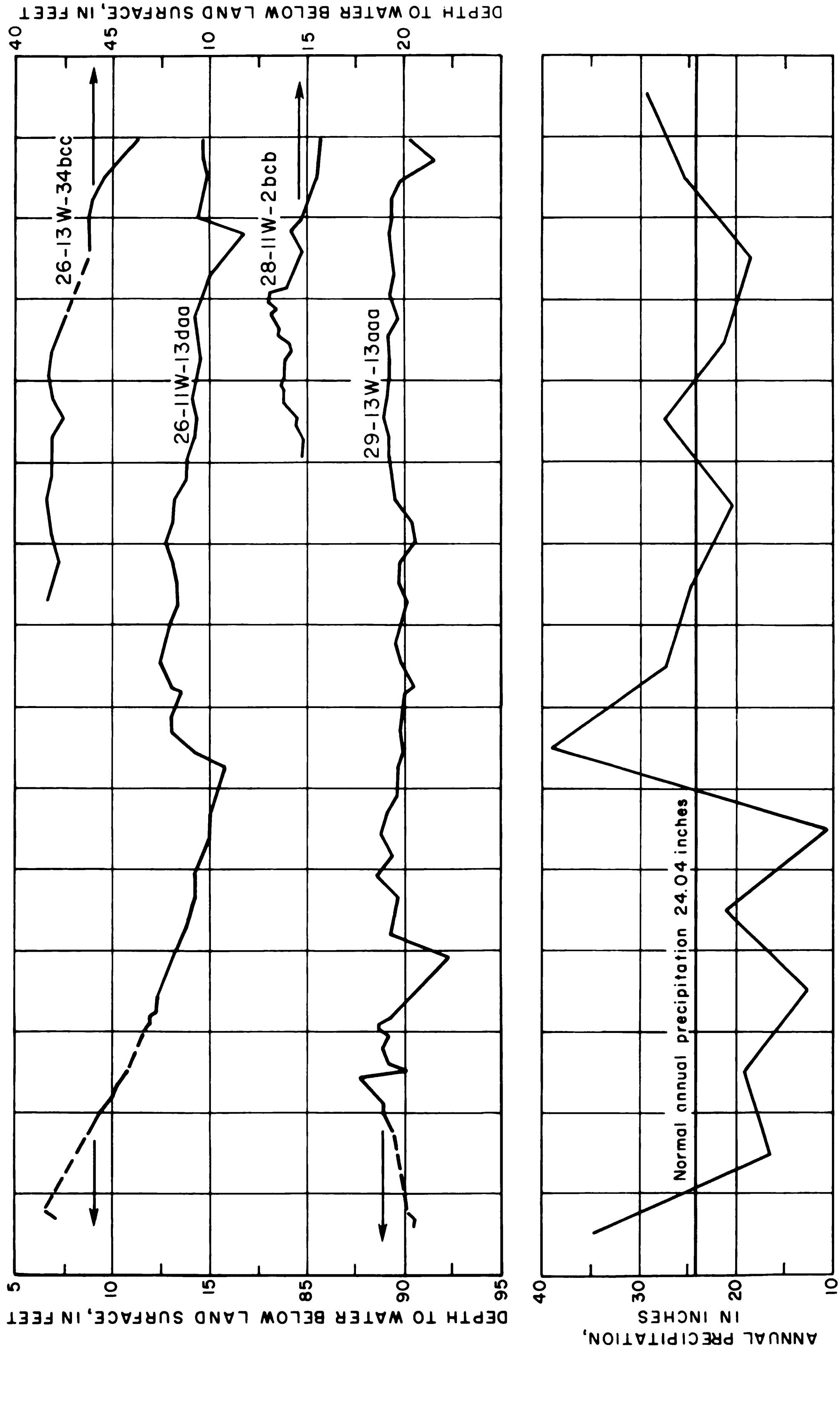


FIGURE 3.—Fluctuations of water levels in selected wells and corresponding annual precipitation at Pratt.

more complete discussion of oil and gas in Pratt County can be found in oil and gas bulletins of the State Geological Survey of Kansas.

SAND AND GRAVEL

Sand and gravel is used for concrete aggregate and road metal. Although sand and gravel deposits of Pleistocene age underlie all Pratt County, the Grand Island and Sappa Formations are the best source of material. Gravel in these formations crops out in the southern part of the county and along the South Fork Ninnescah River. In active commercial gravel pits near Pratt (pl. 1) the material is quarried and sorted hydraulically.

VOLCANIC ASH

Common uses of volcanic ash are as an abrasive, a ceramic glaze material, an additive to cement and road asphalt, and a sweeping compound. Potential uses include the manufacture of light-weight aggregate, cellular blocks, and glass and ceramic bodies, and as an inert filler (Carey and others, 1952).

Five deposits of volcanic ash have been located (pl. 1) and sampled in Pratt County. The thickest of these is in the S½SW¼ sec. 21, T.27 S., R.12 W. where 14 feet of volcanic ash is exposed in a pit. The deposit is reported to extend eastward into the adjacent quarter section and southward across the section line into sec. 28 and is estimated to contain a reserve of 48,000 tons of ash. Another deposit is in the NE¼SE¼ sec. 22, T.28 S., R.14 W., where 10 feet of ash is overlain by 2.5 feet of mixed ash and sand. Four feet of volcanic ash, exposed in a pit in the NW¼SE¼ sec. 34, T.27 S., R.12 W., is overlain by about 6 feet of mixed ash, sand, and silt. This deposit extends westward into sec. 33, T.27 S., R.12 W. Ash also has been found in the SW¼SW¼ sec. 23, T.27 S., R.11 W., and in the northeast driveway of the El Rancho Cafe (NW¼ NW¼ sec. 4, T.27 S., R.13 W.).

Volcanic ash is reported to underlie a 40-acre tract at the center of sec. 31, T.27 S., R.12 W. The owner reported that the ash deposit, which is not exposed, is 15 to 20 feet thick. The reserve of ash in this location is reported to be approximately 54,000 tons (Carey and others, 1952).

The presence of volcanic ash has been explained by Swineford (1949), who stated that the ash may have been derived from the explosion of Valle Grande Caldera in north-central New Mexico. Carried by winds over Kansas and adjacent areas, the ash eventually settled to the ground, forming a thin layer spread extensively over the land surface. This readily erodable material overloaded the small streams leading into ponds and undrained depressions on the extensive alluvial plain that existed in Pleistocene time. Such a mode of accumulation accounts for the sharp lenticularity and range in thickness of the deposits and for the varying amount of silt and sand contained in some of the deposits.

The irregularity with which volcanic ash has been deposited hinders prospecting for commercial deposits. However, the determination of the proper stratigraphic position of the ash serves to eliminate much unproductive territory and, therefore, is a valuable aid in exploration.

GEOLOGY[1]

The areal distribution of the geologic units exposed in Pratt County is shown on plate 1. Descriptions of the rocks and their water-bearing properties are given in table 2. The stratigraphic position of the units is shown by the geologic sections on plate 2.

Summary of Stratigraphy

The rocks pertinent to the hydrology of Pratt County range in age from Permian to Recent. All the geologic units that yield water suitable for the common uses lie above the red beds of the Nippewalla Group and Whitehorse Formation. In the northwestern part of the county the red beds are overlain by the Kiowa Formation of Cretaceous age. Together, the Permian and Cretaceous rocks form the bottom of the fresh ground-water reservoir in Pratt County. The configuration of this bedrock surface is shown on figure 4.

The bedrock formations are overlain by unconsolidated fluvial and eolian deposits of Pleistocene age. The Holdrege and Fullerton Formations of Nebraskan age unconformably overlie the bedrock throughout most of Pratt County at depths ranging from 35 to 300 feet below land surface.

The Nebraskan fluvial deposits are overlain by the Grand Island and Sappa Formations of Kansan age, which are distributed throughout Pratt County. The Kansan rocks crop out in the valley of the South Fork Ninnescah River and along many of its tributaries. The rocks crop out and form rugged topography along tributaries of Medicine Lodge River. The Pearlette ash bed in the Sappa Formation commonly is used as a time-stratigraphic marker.

The Crete and Loveland Formations of Illinoisan age, which include eolian (wind-deposited) as well

[1] The classification and nomenclature of the rock units used in this report are those of the State Geological Survey of Kansas and differ somewhat from those of the U.S. Geological Survey.

TABLE 2.—Generalized section of geologic formations and their water-bearing properties.

System	Series	Stage	Stratigraphic unit	Maximum thickness (feet)	Physical characteristics	Water supply[2]
Quaternary	Pleistocene	Recent and Wisconsinan	Alluvium and terrace deposits	60	Stream deposits of silt, sand, and gravel in and near channels of major streams; small areal extent.	Yields small to medium supplies of water to wells along major streams.
			Dune sand	50	Very fine to medium sand in upland areas; well-sorted.	Generally lies above potentiometric surface. Yields small supplies of water to wells in northwestern part of county.
		Sangamonian	Sangamon Soil	60	Eolian silt and fluvial silt and clay; thin basal sand and gravel (Crete Formation).	Generally lies above potentiometric surface, but yields small to medium supplies of water to wells in northwestern part of county and in areas where ground water is perched.
		Illinoisan	Loveland and Crete Formations			
		Yarmouthian	Yarmouth Soil	200	Silt, sand, and gravel. Locally contains clay lenses and a volcanic ash lens. Calcareous zones commonly near top and center; gravel more abundant toward base.	Yields large supplies of water to wells. Major aquifer in the county.
		Kansan	Sappa[1] and Grand Island Formations			
		Aftonian	Afton Soil	85	Silt, sand, and gravel; clay and calcareous zones common.	Yields medium supplies of water to wells. Water highly mineralized in Cairo area.
		Nebraskan	Fullerton and Holdrege Formations			
Unconformity						
Cretaceous	Lower		Kiowa Formation	60	Gray to black silty shale with thin lenses of well-sorted white quartzose sandstone.	Yields no water to wells; forms base of ground-water reservoir in northwest part of county.
Unconformity						
Permian	Upper		Whitehorse Formation	270	Red beds of shale, siltstone, sandstone, dolomite, anhydrite, and salt.	Yields no water to wells; forms base of ground-water reservoir under most of county.
	Lower		Nippewalla Group	1,000		

[1] Locally contains the Pearlette ash bed.
[2] In this report, small supplies refers to yields generally less than 100 gpm, medium supplies to 100 to 1,000 gpm, and large supplies to greater than 1,000 gpm.

as fluvial sediments, overlie the Kansan rocks throughout the upland area of Pratt County. The formations once blanketed the entire county but they have been removed, in part, by stream erosion.

The Illinoisan deposits are overlain discontinuously by dune sand of Wisconsinan and Recent age. The dune sand mantles most of northern Pratt County and the upland area in the southeastern part of the county. Alluvium and terrace deposits of Wisconsinan and Recent age occur in the channels and banks of the larger streams in the county.

Geologic Structure

The Pratt anticline is a post-Mississippian structure that is a southern extension of the Central Kansas uplift (fig. 5). The large, broad, southerly plunging anticline separates the Hugoton embayment from the Sedgwick basin (Merriam, 1963, p. 182). Merriam (1963, p. 252) has mapped eight northeasterly trending faults in Pratt County that are related to the Pratt anticline. Many of these faults exhibit vertical displacement (west side upthrown) in the Precambrian and lower Paleozoic rocks, but none of the faults reaches land surface.

At 6:00 a.m. on January 6, 1956, an earthquake of moderate magnitude (intensity V on the modified Mercalli scale) occurred coincident with the Pratt anticline. The epicenter was in Barber County, near Coats, with the hypocenter at a depth of 20 miles. The earthquake was felt over an area of 18,500 square miles; it had an estimated duration of 9 seconds. For more detailed information the reader is referred to Dellwig (1956).

Geologic Units and Their Water-Bearing Properties

PERMIAN ROCKS

Nippewalla Group and Whitehorse Formation

Pratt County is underlain by red beds of Permian age that were deposited in shallow nearshore and low-lying continental environments. The rocks compose the Nippewalla Group and the Whitehorse Formation and consist of reddish-brown siltstone, shale, and sandstone with lesser amounts of salt, gypsum, anhydrite, limestone, and dolomite. The rocks are as

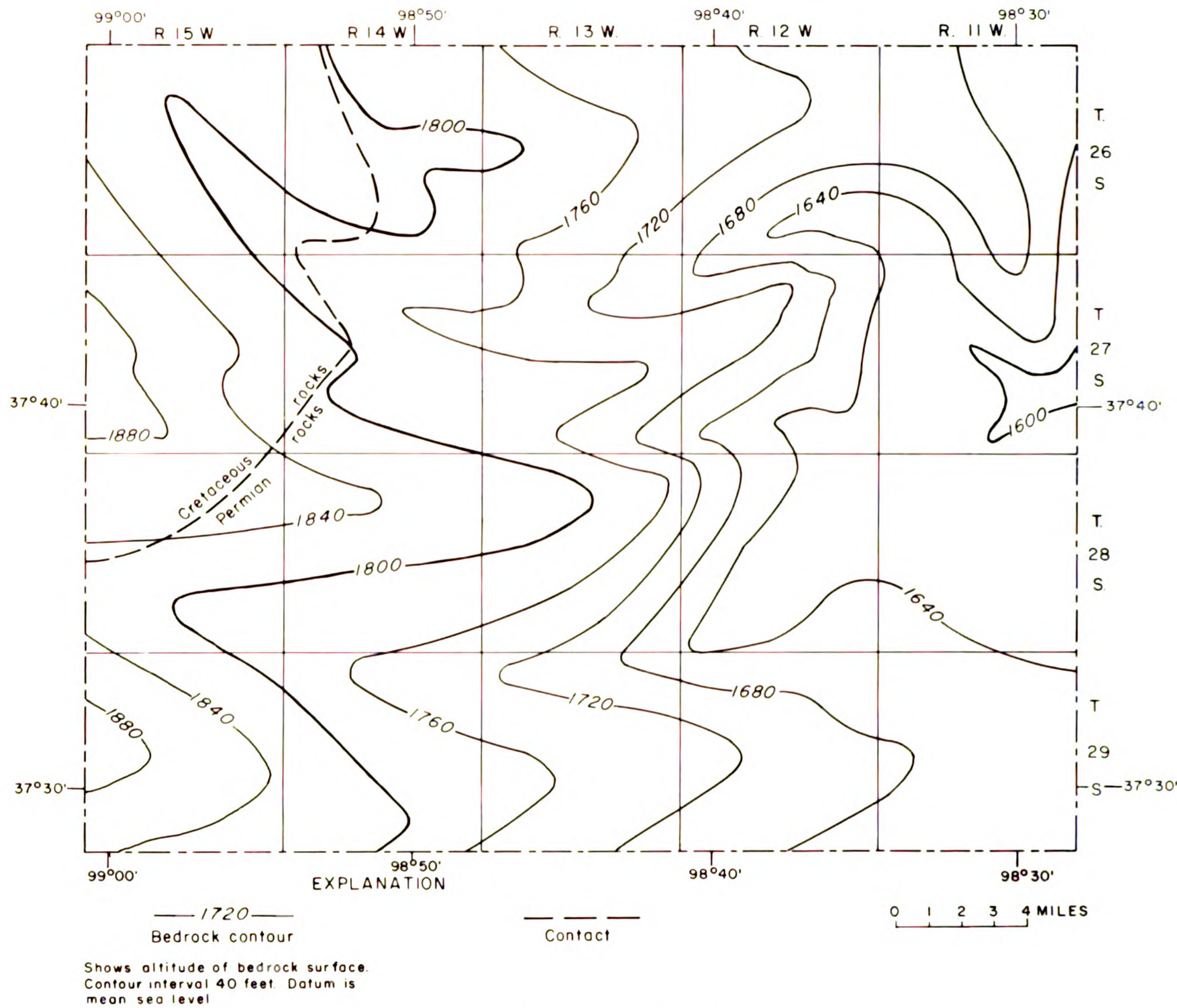


FIGURE 4.—Configuration and general geology of the bedrock surface.

much as 1,270 feet thick, but are not exposed in Pratt County; outcrops can be seen to the south and east in Barber and Kingman Counties. Depth to the formations below land surface ranges from 35 feet in the lower drainage area of Turkey Creek to about 300 feet in the uplands in southeastern Pratt County. The rocks are truncated by a major unconformity.

No wells are known to obtain water from the Nippewalla Group or the Whitehorse Formation in Pratt County. Water from wells in these Permian red beds probably would be too highly mineralized for any of the common uses.

CRETACEOUS ROCKS

KIOWA FORMATION

Extensive marine deposits of Cretaceous age once underlaid Pratt County, but subsequent erosion has left only the Kiowa Formation in the northwestern part of the county (fig. 4; geologic section A-A′, pl. 2). The formation unconformably overlies rocks of Permian age and consists of gray to black fossiliferous shale having well-sorted white quartzose sandstone lenses. From the erosional edge shown on figure 4, the formation thickens to more than 50 feet at the western margin of the county. Depth to the Kiowa Formation ranges from about 160 to about 250 feet below land surface. The Kiowa is not exposed in Pratt County, but the type location of the formation is to the west in neighboring Kiowa County.

In two test holes in the N½ T.27 S., R.15 W., drillers were unable to penetrate a hard sandstone beneath 25 to 50 feet of black shale. This indurated

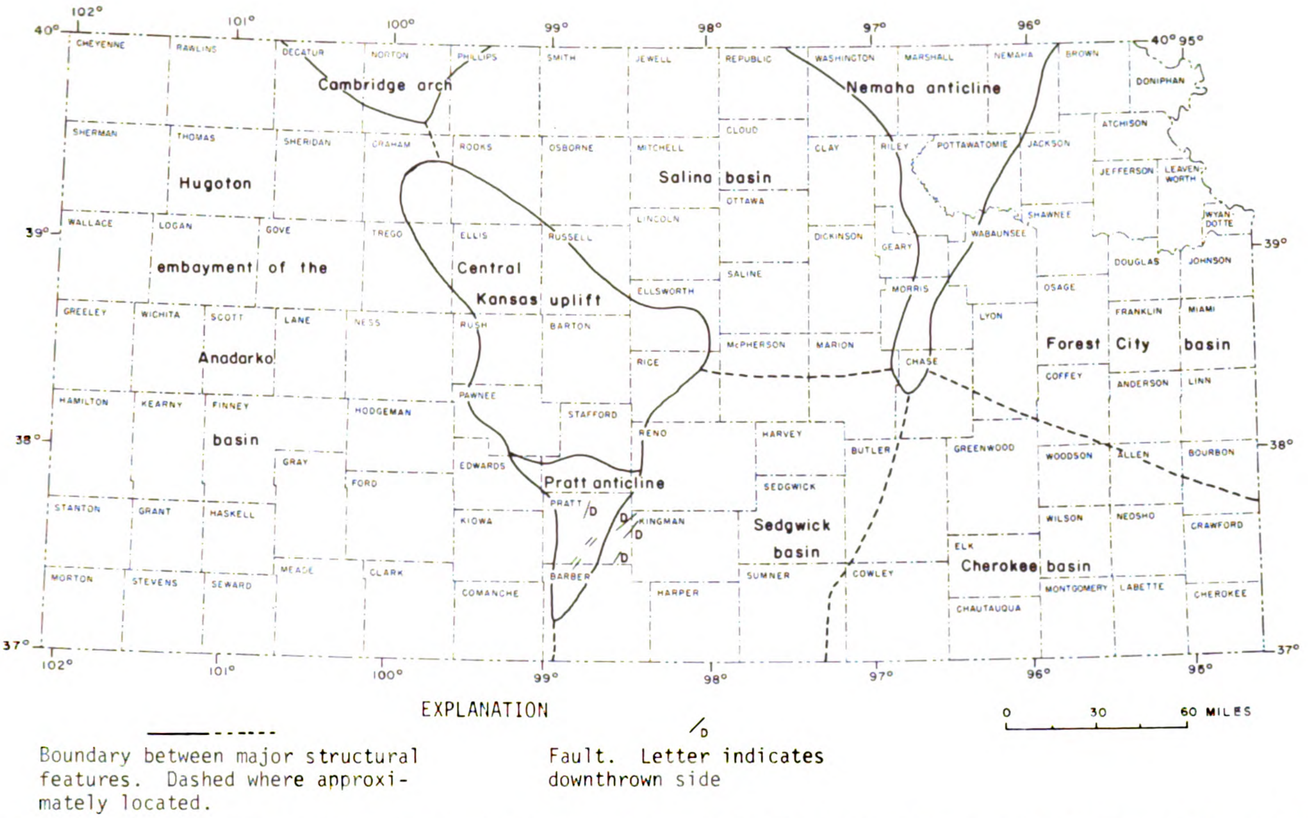


FIGURE 5.—Major post-Mississippian structural features in Kansas, and faults in Pratt County (after Merriam, 1963, pp. 178 and 252).

rock may be the Cheyenne Sandstone of Cretaceous age that crops out in southern Kiowa County.

The Kiowa Formation is not considered to be an aquifer in Pratt County. Although small quantities of water may be available to wells, the chemical quality of the water probably renders it unsuitable for any of the common uses.

QUATERNARY ROCKS

The Pleistocene Series in Kansas is divided into four glacial stages (Nebraskan, Kansan, Illinoisan, Wisconsinan), and four interglacial stages (Aftonian, Yarmouthian, Sangamonian, Recent), as given in table 2. Deposits representing all the Pleistocene stages probably occur in the county, but not all can be differentiated clearly in test-hole samples. Logs of test holes 26-12W-34cdd and 28-13W-26dcb2, described in this report, show most distinctly the individual formations penetrated. The interrelationship of these formations is illustrated on the geologic sections on plate 2.

Each of the Pleistocene formations was deposited under similar conditions during successive glacial stages. The stages commonly began with a period of downcutting in the stream valleys followed by deposition of coarse sand and gravel. Lateral shifting of the streams resulted in blanket deposition of coarse material. As the glacial stage progressed and precipitation lessened, the ability of the streams to carry sediment decreased and progressively finer material was deposited. The fine-grained deposits of the late part of the glacial stage generally included eolian silt or sand. The interglacial stages were times during which neither erosional nor depositional processes were dominant and soils developed on the surface of the Pleistocene formations. Remnants of some of these soils are exposed in Pratt County (fig. 6).

Holdrege and Fullerton Formations

Nebraskan time in Pratt County is represented by deposits of sand, gravel, silt, and clay of the Holdrege and Fullerton Formations, which unconformably overlie rocks of Permian and Cretaceous age. These formations do not crop out in Pratt County, but they can be seen along the South Fork Ninnescah River to the east in Kingman County. The formations compose an almost continuous blanket that is more than 80 feet thick in places. The contact between the Holdrege and Fullerton Formations could not be recognized in some test holes. One test hole (26-11W-35ccc2) near

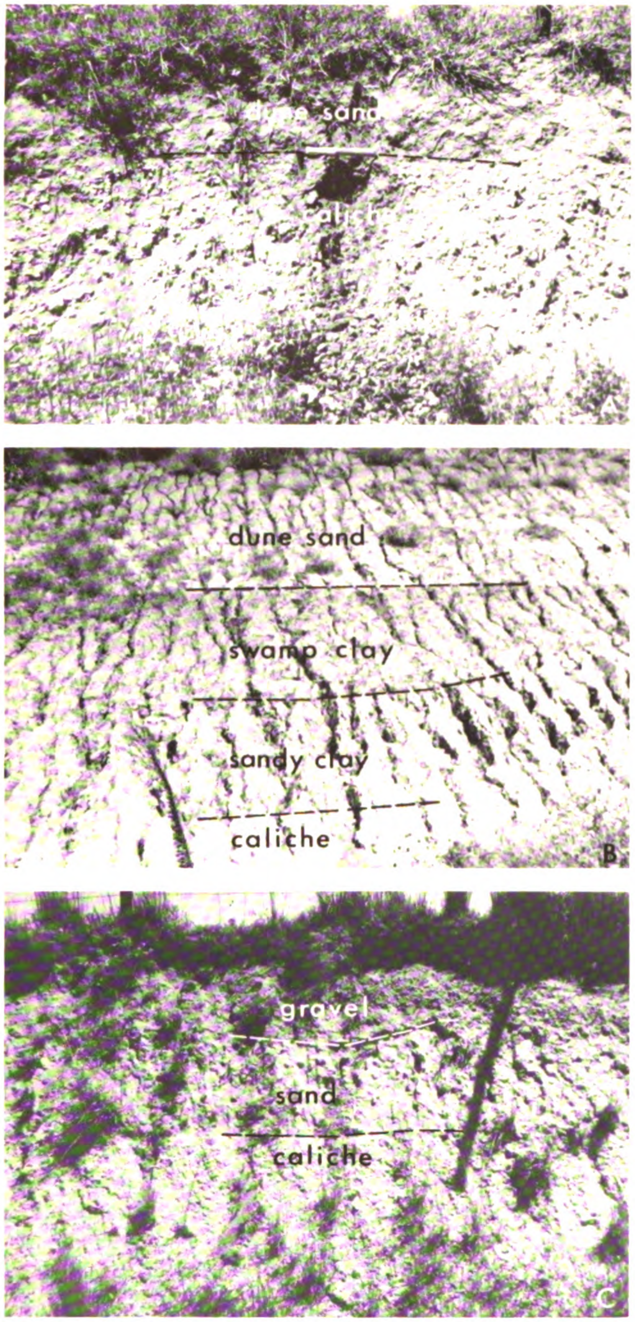


FIGURE 6.—*A*, Typical nodular caliche in clay of the Sangamon paleosol overlain by 1 foot of dune sand in the NE¼NE¼NE¼ sec. 14, T.29 S., R.11 W. *B*, Sangamon nodular caliche and reddish-brown sandy clay overlain by a gray silty mud swamp deposit with a horizontal surface and Wisconsinan eolian deposits of tan silt and fine sand in an 18-foot road cut in the SW¼NW¼NW¼ sec. 2, T.28 S., R.14 W. *C*, Gravel of the Crete Formation overlying leached orange-brown sand and granular caliche of the Yarmouth paleosol in the NE¼SE¼SE¼ sec. 22, T.27 S., R.12 W.

the east end of geologic section A-A′ (pl. 2) did not penetrate these formations above Permian rocks.

Character.—The Holdrege Formation consists of sand and sandy gravel with silt and clay lenses. The gravel commonly contains pebbles of ironstone derived from Cretaceous rocks. The silt and clay lenses are pinkish-tan, tan, or light gray.

The Fullerton Formation generally is finer textured than the underlying Holdrege Formation, and consists of sand and silty sand with lenses of clay and silt. Nodular caliche near the top of the formation probably is the eroded remnant of Afton Soil. This paleosol (ancient soil) is found in many test holes, but nowhere was a complete soil profile found.

Water Supply.—The Holdrege and Fullerton Formations compose an aquifer that is an important source of water in most of Pratt County. Wells drilled to bedrock generally penetrate 20 to 30 feet of sand and gravel that, with the average overlying aquifers, should yield 2,000 to 3,000 gpm (gallons per minute). However, very few of the existing irrigation wells tap this aquifer because sufficient quantities of water generally can be obtained from shallower formations.

The Holdrege and Fullerton Formations contain highly saline water near Cairo where the concentration of dissolved solids exceeds 10,000 mg/l (milligrams per liter). The areal extent of the highly saline water has not been determined in this study. Some details of the Cairo area are discussed in the quality of water section of this report.

Grand Island and Sappa Formations

The Kansan Stage of Pleistocene deposition is represented by the Grand Island and Sappa Formations, which are the oldest rocks exposed in Pratt County. The Grand Island Formation rests on the eroded surface of the Holdrege Formation, the Fullerton Formation, or the Afton Soil in most of the county. However, in the area of the bedrock high in T.26 S., R.11 W. (fig. 4), the Grand Island rests unconformably on eroded Permian red beds. The contact between the Grand Island and Sappa Formations is indistinct and is placed arbitrarily where the deposit changes from sand and gravel to overlying sand and silt.

The Kansan deposits are the thickest Pleistocene sediments in Pratt County; they form a continuous blanket that ranges in thickness from less than 30 to more than 196 feet. Minimal thicknesses are found at low altitudes in the river valleys. Outcrops of the formations, as illustrated on plate 1, form a dendritic pattern along the South Fork Ninnescah River eastward from Cullison and along tributaries of Medicine Lodge and Chikaskia Rivers in the southern part of the county. The formations were mapped as a single unit although the Sappa is absent in part of the area.

Character.—The Grand Island Formation consists of fine to coarse sand and gravel with minor amounts of silt. Gravel is found throughout the formation but is most common near the base. A zone of gravel or sand that has been stained black by iron and manganese is common in this formation.

The following measured section, which includes 65 feet of Grand Island and Sappa Formations, was described in 1951 at an exposure along the South Fork Ninnescah River in sec. 4, T.28 S., R.12 W.

	Thickness, in feet
Quaternary System	
Pleistocene Series	
Crete and Loveland Formations	
7. Soil	1.2
6. Sand and medium to coarse gravel	2.8
Grand Island and Sappa Formations	
5. Silt, brown; contains some lime; grades to leached silt	4.7
4. Silt, sandy to compact, tan to brown; contains heavy lime accumulation	13.9
3. Sand, fine to very fine; contains lime nodules	5.2
2. Sand, medium, yellowish-brown	10.4
1. Sand and fine to coarse gravel, arkosic	31.2
Total measured	69.4

The Sappa Formation consists of sand and silt with lesser amounts of gravel and clay. Clay associated with caliche near the top of the formation represents remnants of the Yarmouth Soil. The white deposits of caliche (lime or calcium carbonate) are frequently, but mistakenly, called "gyp" or gypsum when seen on the surface or in drill cuttings. The clays and clayey silts generally are buff or tan, but other shades of brown and also gray were found in test-hole samples.

A lenticular bed of volcanic ash, called the Pearlette ash bed, is present near the top of the Sappa Formation. Details of the known locations and thicknesses of the isolated lenses of volcanic ash are described in the mineral resources section of this report. The Pearlette ash is recognized throughout a large area of the Great Plains physiographic province and is one of the most positively dated units of Pleistocene age.

Water Supply.—The Grand Island Formation is the major aquifer in Pratt County. All public supply, industrial, and irrigation wells penetrate at least part of the formation, and abundant supplies of good-quality water are available in most of the area. The Sappa Formation also contributes water to wells in areas where the sand and gravel in the formation contain little silt.

In the northern half of the county the Grand Island and Sappa Formations are saturated, or nearly saturated, but in the highlands south of the South Fork Ninnescah River the potentiometric surface may be more than 100 feet beneath the top of the Sappa Formation (pl. 2). Most of the county is underlain by at least 100 feet of saturated Grand Island and Sappa deposits, and, in these areas, well yields of 1,000 to 2,000 gpm can be expected from these formations. However, in an area north of Cairo the chloride content of water from these formations exceeds the maximum concentration recommended by the U.S. Public Health Service (1963) for drinking water (table 6).

Crete and Loveland Formations

The Crete and Loveland Formations, which were deposited during the Illinoisan Stage, comprise the surface rocks in much of Pratt County. The formations have been mapped as a single unit (pl. 1), although either may be absent locally. Logs of wells and test holes indicate that the formations are essentially continuous beneath the dune sand in the northern and southeastern parts of the county. The maximum thickness of the deposits in Pratt County is about 60 feet, which occurs in the northwest part of the county. (See log of test hole 27-15W-2abb.) The formations are thicker in adjacent counties to the north and west.

The Crete and Loveland Formations were deposited on the eroded surface of either the Yarmouth Soil (fig. 6) or the Sappa Formation. In places, the gravel and coarse sand of the Crete Formation are missing and the Yarmouth Soil has been eroded, which makes it difficult to distinguish between silts of the Sappa and Loveland Formations. In some areas both the Crete and Loveland Formations have been eroded and the Sangamon Soil has developed on the eroded Yarmouth paleosol, resulting in coalescing and intermingling caliche zones.

Character.—Sand and gravel of Illinoisan age are assigned to the Crete Formation, and the overlying silt and fine sand are assigned to the Loveland Formation. However, both coarse and fine material, including clay lenses, commonly occur in each formation. The clay generally is tan, but black, orange, and yellow shades are not uncommon. Silt in the Loveland Formation commonly is tan or light gray. Gray silt and fine sand generally are stream deposits. Tan silt generally is eolian.

During the Sangamonian Stage the weathered surface of the Crete and Loveland Formations developed into the Sangamon Soil which, due to subsequent erosion, is represented only by clay and caliche zones at the top of the formations. Remnants of the Sangamon Soil have been preserved in much of the dune area in the northern and southeastern parts of the county.

Water Supply.—The Crete and Loveland Formations yield small to medium quantities of water to wells. In most of northern Pratt County the sand and gravel of the Crete Formation is saturated and yields water to many stock and domestic wells. Small unreliable supplies are available also in the upland area of the southern and northeastern parts of the county where the water is perched.

Dune Sand

More than 250 square miles of Pratt County are underlain by dune sand, which consists of fine sand and silt with minor lenses of medium sand and clay. The clay lenses commonly are buff, tan, and light gray.

Two types of dune topography are recognized in the county. Type 1 consists of moderately steep dunes, partly covered with grass and yucca, that surround shallow undrained depressions. These dunes, which may be as much as 30 feet high, are active (Smith, 1940) and intermittently are in motion. Test holes drilled in relatively low spots penetrated as much as 30 feet of dune sand. Considering the height of some of the dunes, the maximum thickness of dune sand in type 1 areas may be about 50 feet. Fine sand is the primary constituent of the active dunes. Silt is predominant in the depressions, although minor amounts of clay are common. Type 1 dunes are most extensive and best developed in the northwestern part of the county. Small areas of active dunes are scattered throughout the northern and southeastern parts of Pratt County.

Dunes in areas of type 2 topography are passive, having been anchored by vegetation that prevents movement. These dunes are subdued by weathering and creep, and rarely are more than 5 feet thick. However, isolated dunes may reach a thickness of 15 feet. In most type 2 areas, an immature soil has developed on the gently undulating dune surface, indicating that the surface may have stabilized during Wisconsinan time. Much of this area is cultivated and some is irrigated.

The potentiometric surface generally is below the dune sand in Pratt County and the deposits yield water to only a few wells. The well-sorted sand in the dune areas is, however, an excellent recharge medium, because much of the precipitation on the dunes percolates to the underlying deposits.

Alluvium and Terrace Deposits

Alluvium and terrace deposits of Wisconsinan and Recent age occur in and adjacent to the channels of the major streams in Pratt County. The deposits consist primarily of silt, sand, and gravel derived from adjacent exposures of Grand Island, Sappa, and Crete Formations, and are difficult to distinguish from the underlying formations because of the similarity of the material. However, in the lowermost reach of the South Fork Ninnescah River, a discontinuous black mud zone of Wisconsinan(?) age underlies the alluvium and terrace deposits. The thickest section of the deposits penetrated by test holes drilled for this study was 60 feet in 27-11W-32daa, which is in the flood plain of the South Fork Ninnescah River near Cairo. The deposits yield small to medium supplies of water to domestic and stock wells, but the limited thickness and areal extent of the deposits preclude their being a major aquifer in Pratt County.

GROUND WATER

Fresh ground water that is chemically suitable for the common uses occurs under three conditions in Pratt County—confined, unconfined, and perched (fig. 7). Confined ground water in the county is found in the South Fork Ninnescah Valley downstream from near Cairo where a clay lens occurs at depths from 10 to 20 feet below land surface. Ground water below the clay lens in this area is under hydraulic (artesian) pressure and wells at low altitudes near the stream will flow. The abandoned industrial well 27-11W-

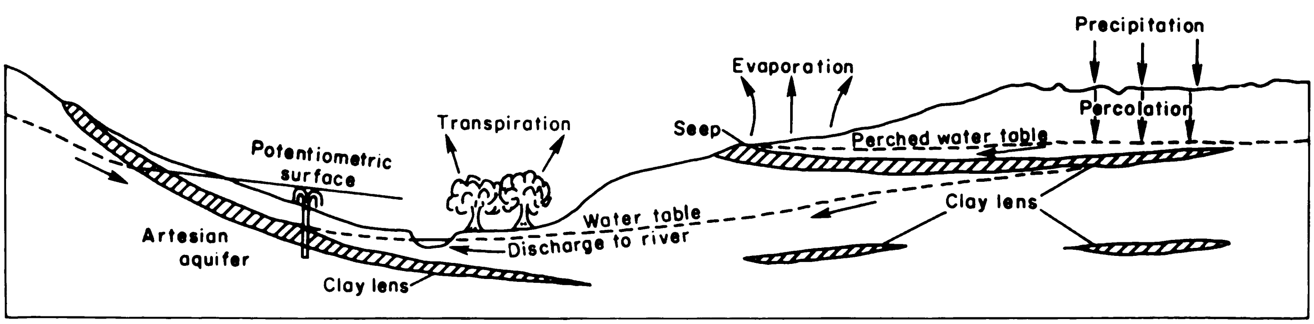


FIGURE 7.—Generalized occurrence and movement of water in east-central Pratt County. Arrows indicate direction of movement of water and water vapor.

25cdb is a flowing artesian well. The surface defined by the levels to which water will rise or stand in tightly cased wells is the potentiometric surface.

Unconfined ground water is found in most of the wells in Pratt County. This water is under atmospheric pressure only and will not rise in wells above the level where it is first found. The upper surface of the unconfined ground water is the water table, which is a particular potentiometric surface.

Perched ground water also is unconfined, but is trapped above a relatively impermeable layer of clay or silt that lies in unsaturated deposits above the potentiometric surface in the area. Perched ground water generally is limited in areal extent; it was found in several test holes drilled in Pratt County as part of this study.

Potentiometric Surface and Movement of Ground Water

The potentiometric surface in Pratt County is constantly rising or falling in response to changes in the rate of recharge to and discharge from the aquifer. The configuration of the potentiometric surface in late spring and summer 1964 is shown by contours on plate 1. Any given contour connects points of equal altitude of the potentiometric surface. Ground-water movement is perpendicular to the contours in a downslope direction. In Pratt County, the movement is generally eastward and the gradient is about 9 feet per mile. The rate of movement is slow; it ranges from less than 1 inch per day in silt and clay to several feet per day in well-sorted sand and gravel.

Recharge

Although the total amount of recharge to the ground-water reservoir in Pratt County is unknown, sources of recharge are (1) infiltration of part of the precipitation on the county, (2) movement of ground water into the county from adjacent areas to the west, (3) return of some of the ground water pumped for irrigation, and (4) upward leakage of saline water from Permian rocks. Recharge by seepage of streamflow through stream channels is considered to be negligible in Pratt County.

PRECIPITATION

The annual precipitation in Pratt County averages about 933,000 acre-feet of water. From 5 to 10 percent of this annual average is estimated to recharge the ground-water reservoir in the county, with the higher percentage occurring in areas that are underlain by dune sand. Recharge from precipitation in Pratt County probably averages about 62,000 acre-feet of water annually.

SUBSURFACE INFLOW

The ground-water reservoir in Pratt County also is recharged by the movement of ground water into the county from adjacent areas to the west. The amount of subsurface inflow can be estimated using the formula $Q = KIA$, where:

Q = the quantity of water;
K = the hydraulic conductivity of the aquifer;
I = the hydraulic gradient;
A = the area through which the water moves.

The hydraulic conductivity, as determined from aquifer tests described elsewhere in this report, is about 134 feet per day. Contours of the potentiometric surface (pl. 1) show that the hydraulic gradient across the western boundary of the county is about 9 feet per mile. The cross-sectional area through which water moves across the western boundary of the county is about 19.5 million square feet, as determined from the saturated thickness shown on figure 8. Using these values and the equation above, the subsurface inflow to Pratt County is estimated to be about 38,000 acre-feet per year.

IRRIGATION RETURN

Recharge to the ground-water reservoir in Pratt County from ground water withdrawn for irrigation is unknown. However, much of the irrigation in the county is by sprinkler systems. The percentage of the applied irrigation water that returns to the ground-water reservoir probably is similar to the percentage recharge from precipitation.

SALINE-WATER INFLOW

A sudden increase in the flow and in the concentration of dissolved solids in the South Fork Ninnescah River occurs near Cairo. The increase, which is discussed in more detail elsewhere in this report, is attributed in part to upward leakage of saline water from underlying Permian rocks. The amount of this leakage is unknown. However, the concentration of chemical constituents in the stream during periods of low flow could result from an inflow of saline water of about 1,500 acre-feet annually.

Discharge

Water is discharged from the ground-water reservoir in Pratt County by (1) streams, which are the

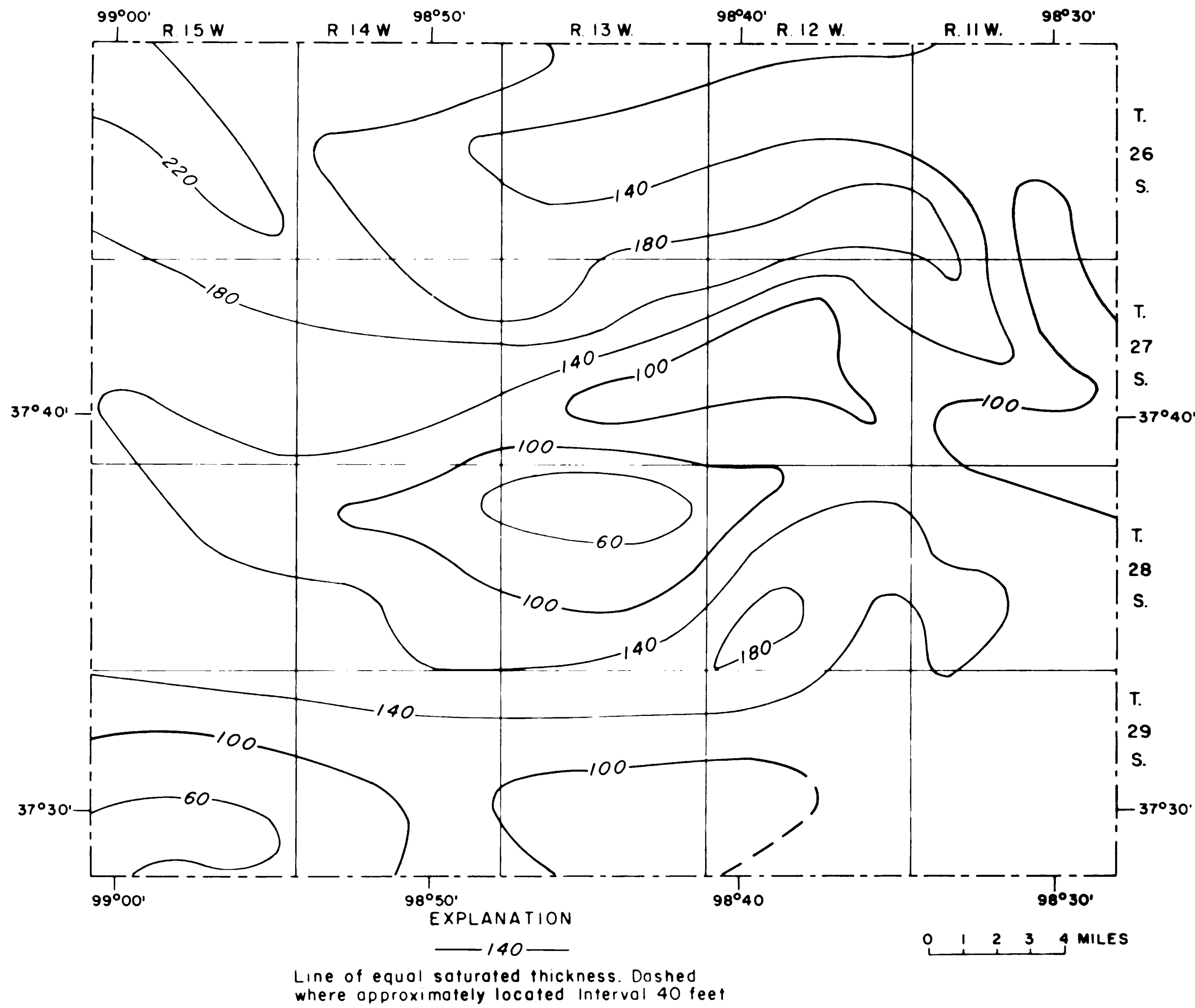


FIGURE 8.—Saturated thickness of Pleistocene deposits, 1964.

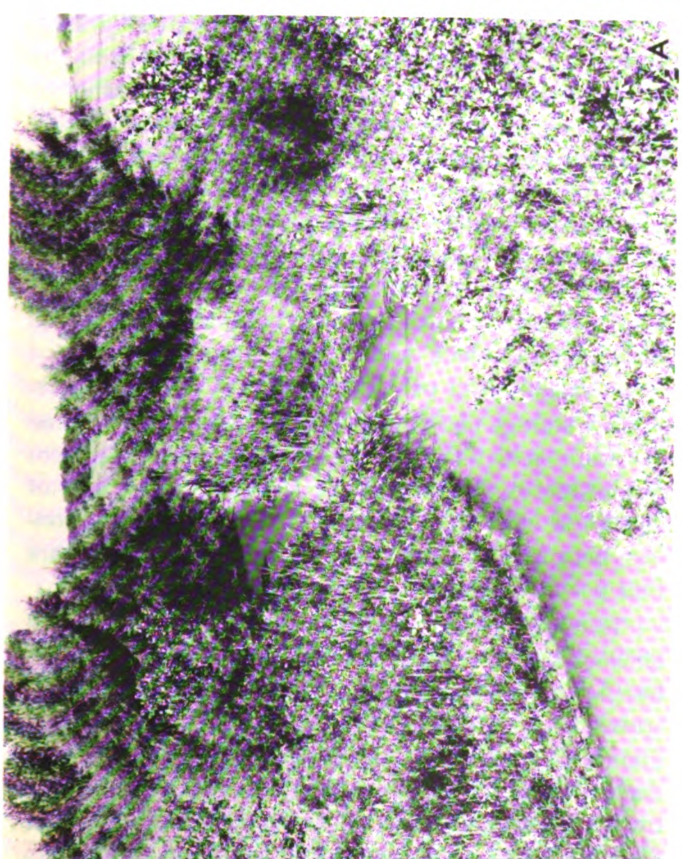
natural drains of the aquifers, (2) movement of ground water out of the county to adjacent areas to the east and south, (3) evapotranspiration, which is a combination of evaporation and of transpiration by plants, and (4) withdrawals of ground water by wells. Total discharge from the ground-water reservoir in Pratt County is unknown, but it must be about equal to recharge as no long-term changes in ground-water storage have been detected.

STREAMFLOW

The perennial streams in Pratt County discharge water from the ground-water reservoir. The gaining condition of the South Fork Ninnescah River and Turkey Creek is shown by the upstream bending of potentiometric contours on plate 1. In July 1964, the low-flow discharge of perennial streams was about 6 cfs (cubic feet per second) in Turkey Creek, about 4 cfs in North Branch Elm Creek, and about 60 cfs in the South Fork Ninnescah River at the Pratt County line (fig. 9 C). This flow, which would total about 51,000 acre-feet per year, may be representative of the amount of water discharged from the ground-water reservoir in Pratt County by streams.

SUBSURFACE OUTFLOW

Discharge by movement of ground water out of the county occurs along the eastern border and along the southern border in the vicinity of North Branch Elm and Turkey Creeks. The amount of this discharge can be estimated by the same method described for computing subsurface inflow to the county.



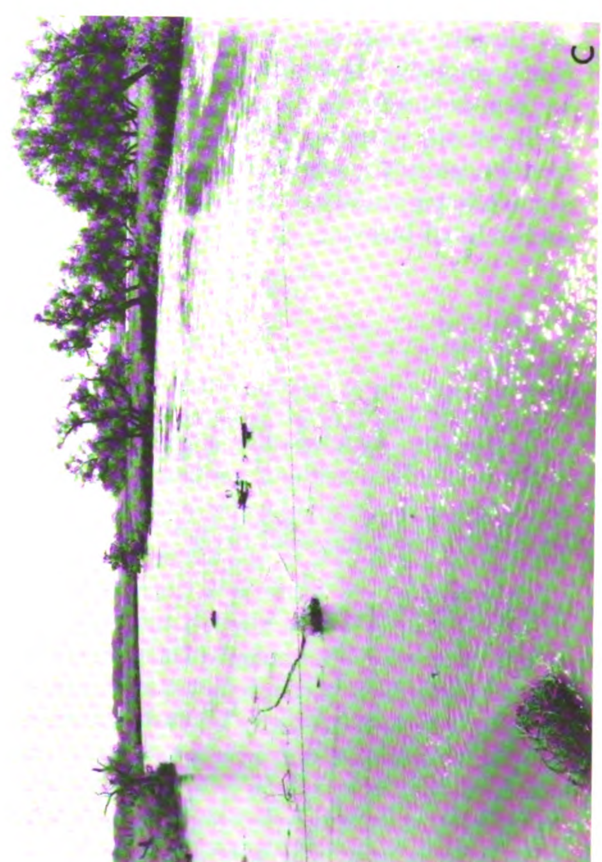


FIGURE 9.—Flow in the South Fork Ninnescah River, July 1964. A, South of the city of Pratt in the SW¼ sec. 4, T.28 S., R.13 W. *B*, 4 miles east of Pratt on U.S. Highway 54 in sec.4, T.28 S., R.12 W. Low-flow discharge was 8.9 cfs. C, At east county line, sec. 25, T.27 S., R.11 W. Low-flow discharge was about 60 cfs.

The hydraulic conductivity and gradient are about 134 feet per day and 9 feet per mile, respectively, the same as for the western boundary of the county. The area through which ground water moves out of the county is about 13.5 million square feet on the east and 5.6 million square feet on the south. Therefore, the subsurface outflow from the county amounts to about 37,000 acre-feet per year, which is about the same amount computed for subsurface inflow.

EVAPOTRANSPIRATION

Most of the precipitation in Pratt County is consumed by evapotranspiration, which is the combination of evaporation and of water use by plants (transpiration). The water transpired by plants generally is derived from soil moisture that results from infiltration of precipitation. In low-lying areas of the perennial-stream valleys, where the potentiometric surface is near land surface, many plants transpire water directly from the ground-water reservoir. The amount of water lost annually by evapotranspiration from the ground-water reservoir in Pratt County is unknown.

WITHDRAWALS BY WELLS

Ground water is the major source of water in Pratt County. Table 8 contains information on all the public supply, industrial, and irrigation wells in the county in 1966. The table also contains information on representative domestic, stock, and observation wells in the county. Although accurate water-use records are not available, the estimated amount of ground water withdrawn annually for the large-scale uses is listed below.

Use	Number of wells (1966)	Average annual withdrawal (acre-feet)
Municipal	19	4,000
Industrial	15	2,000
Irrigation	54	20,000
TOTAL	88	26,000

Ground-water withdrawals in the county probably could be doubled without causing serious depletions of storage in the ground-water reservoir or of flow in the South Fork Ninnescah River.

Water in Storage

To determine the quantity of ground water in storage in the Pleistocene deposits, a map showing the saturated thickness (fig. 8) of the deposits was prepared by superimposing a contour map of the potentiometric surface (pl. 1) on a contour map of the bedrock surface (fig. 4) and connecting points of equal saturated thickness. The areas between lines of equal saturated thickness were measured with a planimeter and were multiplied by the average saturated thickness to give the volume of saturated material. Assuming a specific yield of 15 percent from the saturated material, approximately 9 million acre-feet of ground water is stored in the Pleistocene deposits in Pratt County. However, much less water than this is available for pumping because the deposits cannot be completely drained by wells.

Hydrologic Properties of Water-Bearing Materials

The amount of ground water that an aquifer will yield to wells depends primarily on the ability of the aquifer to transmit and to store water. These hydrologic properties, known as transmissivity and storage coefficient, commonly are determined by aquifer tests in which the effect of a discharging well on the water level in the surrounding aquifer is measured periodically during the test. The results of three aquifer tests that were made as part of this study are given in table 3. Records of the irrigation wells used in the tests are given in table 8.

Transmissivity, as used in this report, is defined as the rate at which ground water is transmitted through a vertical strip that is the full saturated height of the aquifer and 1 foot wide, under a hydraulic gradient of 1 foot per foot. The units of transmissivity are reported in square feet per day, which results from the computation of cubic feet of water per day per foot of aquifer. A closely related hydrologic property is the hydraulic conductivity of the aquifer. As used in this report (see section on subsurface inflow), hydraulic conductivity is the rate at which ground water is transmitted through a 1-square-foot section of aquifer per day, under a hydraulic gradient of 1 foot per foot. The units of hydraulic conductivity are reported in feet per day, which results from the computation of cubic feet of water per day per square foot of aquifer.

The storage coefficient, as used here, is the volume of water released from or taken into storage per square foot of surface area of the aquifer per foot of change in head. The storage coefficient is dimensionless because the units, being cubic feet per square foot per foot, cancel.

The computations of transmissivity and storage coefficient from the tests listed in table 3 were affected by (1) intermittent pump stoppage for lubrication or sprinkler relocation, (2) areal changes in lithology (nonhomogeneity) of the aquifer, (3) semiartesian conditions in part of the area, and (4) partial penetration of the aquifers by wells 26-13W-19bdb and 27-13W-21acal. The transmissivity values in table 3

TABLE 3.—Results of aquifer tests, August-September 1963.

Well number	Well yield (gpm)	Duration of test: Pumping phase (hours)	Duration of test: Recovery phase (hours)	Transmissivity (square feet per day)	Storage coefficient	Remarks
26-13W-19bdb	800	148	188	20,000	0.0004	Observation wells at 100 and 400 feet from discharging well.
27-13W-21aca1	760	95		21,000	.001	Observation wells at 150 and 296 feet from discharging well.
28-13W-26dcb1	1,600	56	....	21,000	.002	Observation wells at 225 and 425 feet from discharging well.

were adjusted because of these conditions. The values based on test data alone ranged from 14,700 to 24,000 square feet per day, depending, in part, on the method of calculation. If the tests had been continued for long times, the storage coefficients probably would have been in the range from 0.10 to 0.15, owing to slow drainage of water from fine material in the upper part of the aquifers.

CHEMICAL QUALITY OF GROUND WATER

The chemical character of ground water in Pratt County is indicated by analyses of 64 water samples from 46 wells and 11 test holes (table 4). The results in table 4 are given in milligrams per liter of mineral constituents and can be expressed in milliequivalents per liter by multiplying milligrams per liter by conversion factors given in table 5. Except near Cairo, ground water in Pratt County is chemically suitable for most uses.

The chemical analyses in table 4 do not indicate the sanitary quality of the water, although a large amount of certain mineral constituents, such as nitrate or chloride, may indicate pollution. Water containing mineral matter that imparts an objectionable taste or odor may be free from harmful bacteria and safe for drinking. Conversely, water that is clear and pleasant to the taste may contain harmful bacteria. Great care should be taken to protect domestic and public water supplies from pollution. To guard against contamination, a well must be sealed to keep out dust, insects, vermin, debris, and surface water. Wells should not be placed where runoff or leakage from barnyards, privies, or cesspools are possible sources of pollution.

Water from private wells may be tested for bacteriological content by the Division of Environmental Health of the Kansas State Department of Health at little or no cost to the well owner. This service can be obtained by the County Health Officer.

Water to be used for drinking should not contain excessive amounts of iron, magnesium, chloride, sulfate, or nitrate. Water to be used for cooking should have neither an excessive hardness nor a high bicarbonate content. The quality of water in relation to use is described in table 6.

The modified Piper diagram (Piper, 1953; Hem, 1959) shown on figure 10 illustrates the chemical type of ground water from 34 wells and 10 test holes in Pratt County. Milliequivalents per liter of cations or anions are plotted as percentages of total milliequivalents per liter of all cations or anions; thus, the position of the analysis on the diagram reflects the predominant anions and cations. The analyses plot in three general groups. The group in the upper left represents waters of the sodium chloride type. All these waters are from the Cairo area. Calcium and bicarbonate are the predominant ions for the analyses in the lower right, which are typical of ground water in the High Plains. The middle grouping of analyses represents mixed waters that probably result from the influx of saline water from Permian rocks.

The numerical values of these water analyses can be shown graphically by the Stiff technique (Stiff, 1951; Hem, 1959) as an aid in classifying and correlating the water types. The patterns produced by plotting the data are useful for quick comparison of water types. Stiff diagrams representing the three water types found in Pratt County are illustrated on figure 11.

Suitability for Irrigation

This discussion of the suitability of water for irrigation is based on Agriculture Handbook 60, U.S. Department of Agriculture (U.S. Salinity Laboratory Staff, 1954).

In areas of sufficient rainfall and ideal soil conditions, soluble salts in the soil or salts added to the soil by water are carried downward by percolation and ultimately reach the potentiometric surface. Soil that was originally nonsaline and nonalkaline may become unproductive if an excess of soluble salts or exchangeable sodium is allowed to accumulate as a result of improper irrigation and soil management. If the amount of water applied to the soil is less than that needed by plants, water will not percolate below the root zone, and mineral matter will accumulate in the

TABLE 4.—Chemical analyses of water from selected wells and test holes.
[Chemical constituents reported in milligrams per liter. Analyses by Kansas State Department of Health.]

Well or test-hole number[1]	Sample number (fig. 11)	Date of collection	Temperature (°C)	Dissolved solids (residue at 180° C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium[2] (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Remarks[3]
26-11W- 8aaa	1	11-29-51	14	260	18	0.24	...	66	6.4	18	222	8.6	19	0.2	15	190	9	...	...	
-13daa	2	11-23-51	16	404	7.0	...	...	111	13	14	312	31	21	.4	53	330	74	...	...	
-29cbc	3	11-29-51	14	152	10	.30	...	18	4.2	24	57	30	10	.8	27	62	16	...	...	
-30add1	4	8- 6-64	...	348	19	.00	0.00	83	6.1	34	271	26	23	.3	23	232	10	540	...	
26-12W- 2aac	...	5- -64	...	...	...	...	...	...	...	...	...	...	83	...	...	...	...	670	...	
-34cdd	5	8- 7-64	...	381	3.5	.46	.06	51	8.8	83	144	22	140	.6	.4	165	45	690	...	TH, 50
26-13W- 2ccc	6	11-29-51	15	215	11	...	...	49	5.8	18	167	11	10	.3	28	146	9	...	...	
26-15W- 6baa	7	11-28-51	16	739	8.2	.07	...	123	16	95	321	52	52	.2	235	373	110	...	...	
-26bda	8	11-28-51	15	138	19	.06	...	27	4.8	8.5	85	2.9	9.0	.2	25	87	17	...	...	
-32cbb	9	11-28-51	14	144	17	...	...	27	5.4	17	138	2.5	6.0	.4	.7	90	0	...	...	
27-11W-18cbb	10	8- 6-64	18	325	18	.01	.00	68	8.4	37	268	15	15	.3	32	204	0	510	...	
-19bbc	...	7-20-64	...	150	...	...	...	43	2.1	8.2	139	7.0	9.0	...	...	116	...	260	...	TH, 65
-25cdb	11	11-23-51	16	375	12	.19	...	62	8.2	66	200	18	100	.3	10	188	24	...	...	
-30bcb	12	9-19-56	...	229	20	.47	...	55	4.2	19	188	7.0	13	.2	18	154	0	...	...	TH, 56
-30bcb	13	9-19-56	...	2,230	20	.39	...	59	9.5	787	227	119	1,120	.3	8.0	186	0	...	...	TH, 116
-30ccc	14	9-18-56	...	2,480	21	.34	...	107	16	817	226	155	1,240	.2	8.0	333	147	...	...	TH, 45
-30ccc	15	9-18-56	...	10,200	19	.54	...	261	76	3,536	207	720	5,480	.3	13	964	794	...	...	TH, 95
-32cba	16	11-29-51	15	283	14	.04	...	74	7.0	17	239	12	14	.3	27	214	18	...	...	
-35dad	17	9-19-51	15	685	15	...	...	170	14	63	210	6.2	307	.2	6.6	482	310	...	...	
27-12W- 9aaa	18	7-22-64	...	8,860	14	.28	.00	152	41	3,240	220	451	4,845	.3	5.3	548	368	15,000	...	TH, 106
-13add	19	7-21-64	21	19,360	1.0	.26	.00	448	112	6,835	73	1,202	10,700	.6	3.6	1,578	1,518	29,100	...	TH, 210
-14adb	20	7-21-64	18	805	17	.01	.00	119	17	155	232	33	336	.2	14	367	177	1,410	...	
-25daa	21	7-20-64	...	1,460	4.0	...	...	131	13	404	178	96	720	.3	2.0	380	234	2,660	...	TH, 41
-25daa	22	7-20-64	17	3,060	5.5	...	.38	119	18	1,034	215	170	1,600	.2	6.2	371	195	5,480	...	TH, 90
-26dda	23	7-17-64	23	336	21	...	...	52	3.5	61	188	26	65	.6	14	144	0	550	...	TH, 27
-26dda	24	7-17-64	18	2,270	12	...	.00	93	12	749	222	134	1,150	.3	6.6	282	100	4,150	...	TH, 116
-35aab	...	7-17-64	...	276	...	...	...	69	2.9	...	215	11	11	...	...	184	...	420	...	
-36bcb	25	7-20-64	17	298	14	.23	.00	64	6.0	33	210	21	20	.3	37	184	12	450	...	TH, 32
-36bcb	26	7-20-64	16	271	17	...	.00	52	4.5	41	202	20	25	.3	12	148	0	410	...	TH, 69
-36daa	27	9-21-56	...	275	26	...	...	54	6.2	32	195	23	25	.3	12	160	0	...	...	TH, 26
-36daa	28	9-21-56	...	242	22	.12	...	47	6.6	29	185	13	24	.3	8.4	144	0	...	...	TH, 105
27-13W-21aca1	...	5- -64	...	...	...	...	...	...	...	...	...	...	40	...	...	...	...	440	...	
-32bbb	29	11-28-51	15	158	17	.37	...	40	5.2	7.4	144	4.5	7.5	.2	4.9	122	4	...	...	
-33dcb	30	9- 3-64	17	323	17	...	...	66	7.4	30	190	14	50	.2	14	195	39	510	7.2	
-34cad	31	9- 3-64	17	321	16	...	...	58	1.8	59	181	17	72	.2	11	152	4	550	7.4	
-34dab	32	9- 3-64	16	355	15	...	...	66	3.8	57	195	25	72	.2	16	180	20	600	7.4	
27-15W- 6ddd	33	7-10-64	17	218	...	.67	.00	38	3.2	32	144	18	8.0	.4	30	108	0	320	...	TH, 59
- 6ddd	34	7-10-64	19	213	16	...	...	51	3.2	21	181	14	5.0	.6	14	140	0	330	...	TH, 128

-34ccc	....	5- -64	....	...	...	...	...	...	...	...	...	...	6.0	...	...	...	...	230	....
-35cdc	35	11-27-51	16	155	19	.26	...	38	5.2	7.6	144	1.6	5.0	.2	7.5	116	0	...	....
28-11W-18bdc	....	5- -64	....	...	...	...	...	...	...	...	...	...	18	....	...	...	...	430	....
28-12W-14bbd	....	5- -64	....	...	...	...	...	...	...	...	...	...	240	....	...	...	...	1,110	....
-21bad	....	5- -64	....	...	...	...	...	...	...	...	...	...	22	....	...	...	...	390	....
28-13W- 1bdb	....	5- -64	....	...	...	...	...	...	...	...	...	...	48	....	...	...	...	500	....
- 3aca	36	9- 3-64	16	349	20	.01	.0	62	8.2	48	178	33	57	.1	20	188	22	570	8.3
- 3bad	....	9- 2-64	....	317	...	.09	.0	57	8.8	...	185	24	45	....	24	178	...	510	....
- 4dbd	37	9- 3-64	16	378	16	...	...	54	5.0	82	200	28	84	.3	15	155	0	640	7.3
-26dcb1	38	7-14-64	16	230	19	.00	.00	48	3.9	28	181	15	21	.3	5.8	136	0	360	....
28-14W- 7bbb	39	-64	....	207	22	.08	.00	38	7.6	25	161	7.4	20	.3	7.5	126	0	340	7.6
-11bba	40	11-30-51	15	207	17	.10	...	51	5.6	16	190	3.3	14	.2	5.8	150	0	...	....
-11bbd	....	5- -64	....	253	...	...	...	49	5.4	...	166	7.0	41	....	6.2	...	...	410	....
-22ccc	....	7- 9-64	17	196	...	...	...	50	5.1	...	185	4.0	9.0	....	...	146	...	320	....
28-15W-25cdd	41	9- 2-64	16	185	19	...	...	44	1.2	18	161	3.2	8.0	.2	4.0	115	0	280	7.1
29-11W- 4aaa	....	5- -64	....	...	...	...	...	...	...	...	...	...	16	....	...	...	...	500	....
-29bbb	42	8- 7-64	16	287	17	...	...	74	2.3	23	254	7.8	13	.2	13	194	0	460	7.3
-34baa	43	11-29-51	14	171	12	.14	...	40	6.8	14	167	4.5	10	.3	1.5	128	0	...	....
29-13W- 6baa	44	7- 8-64	18	223	21	...	...	51	3.2	22	181	8.0	15	.3	8.9	140	0	350	7.6
-24ddd	45	9- 1-64	16	275	15	...	...	67	3.2	18	210	12	10	.2	23	180	8	420	7.3
29-14W- 4cdd	46	11-27-51	16	176	15	.40	...	46	5.6	8.5	163	6.2	7.5	.2	6.6	138	4	...	....
-19ddc	47	9- 2-64	16	148	19	.03	.00	28	4.4	15	107	5.8	10	.2	12	88	0	230	8.1
-23bba1	48	9- 2-64	20	237	16	...	...	54	6.7	18	195	9.1	13	.2	10	162	2	370	7.6
-23bba2	49	11-27-51	16	209	9.8	.56	...	54	6.8	13	196	7.8	8.0	.2	12	162	2	...	....
29-15W- 2dab	50	11-28-51	15	203	15	...	...	51	6.2	13	186	8.6	9.0	.2	8.4	152	0	...	....
-16aaa	51	11-28-51	16	87	14	.25	...	17	3.4	4.8	56	6.2	5.0	.2	8.8	56	10	...	....

[1] Well- and test-hole numbering system described in text.
[2] Includes potassium reported as sodium.
[3] TH, test hole; number (such as 50) designates depth below land surface, in feet, from which water sample was collected for chemical analysis.

TABLE 5.—Factors for converting milligrams per liter to milliequivalents per liter.

Mineral constituent	Chemical symbol	Multiply by
Calcium	Ca^{++}	0.04990
Magnesium	Mg^{++}	.08226
Sodium	Na^{+}	.04350
Bicarbonate	HCO_3^{-}	.01639
Sulfate	SO_4^{--}	.02082
Chloride	Cl^{-}	.02821
Fluoride	F^{-}	.05264
Nitrate	NO_3^{-}	.01613

zone. Likewise, impermeable soil zones near the surface can retard the downward movement of water and cause waterlogging of the soil and deposition of salts.

The characteristics that seem to be most important in determining the suitability of water for irrigation are the concentration of sodium ion and dissolved solids. For diagnosis and classification, the dissolved-solids concentration of irrigation water can be estimated from specific conductance, which is a measure of the capacity of the inorganic salts in solution to conduct an electrical current. The specific conductance can be measured accurately in the laboratory, or it can be approximated by multiplying the total milliequivalents per liter of cations (calcium, magnesium, sodium, and potassium) by 100 or by dividing the dissolved-solids content in milligrams per liter by 0.64.

Salt-sensitive crops such as strawberries, green beans, and red clover may be affected adversely by irrigation water having a specific conductance exceeding 250 micromhos per centimeter, but water having a specific conductance below 750 micromhos per centimeter generally is satisfactory for irrigation, insofar as salt content is concerned. Water in the range of 750 to 2,250 micromhos per centimeter is widely used, and satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of water having a conductivity of more than 2,250 micromhos per centimeter is the exception, although a few cases can be cited where such water has been used successfully.

When the sodium-adsorption ratio and the electrical conductivity of a water are known, the suitability of the water for irrigation can be determined graphically by plotting these values on the diagram shown on figure 12. The sodium-adsorption ratio (SAR) is determined by dividing the concentration of sodium, expressed in milliequivalents per liter, by the square root of one-half the sum of the concentrations of calcium and magnesium, also expressed in milliequivalents per liter, as shown below:

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

Low-sodium water (S1) can be used for irrigation

TABLE 6.—Quality of water in relation to use, Pratt County.

Constituent	Principal characteristics	Recommended maximum concentration[1] (mg/l)
Dissolved solids	Water high in dissolved-solids concentration may have a disagreeable taste or a laxative effect. When water is evaporated the residue consists mainly of the minerals listed in table 4.	500
Hardness	Hardness is caused by calcium and magnesium. Forms scale in vessels used in heating or evaporative processes. Hardness is commonly noticed by its effect when soap is used with the water. Carbonate hardness can be removed by boiling, noncarbonate hardness cannot.	120 (easily detected) 200 (sometimes softened for household use)
Iron (Fe)	Stains cooking utensils, plumbing fixtures, and laundry. Water may have a disagreeable taste.	0.3
Fluoride (F)	Fluoride concentrations of about 1 mg/l in drinking water used by children during the period of calcification of teeth prevent or lessen the incidence of tooth decay. However, concentrations in excess of 1.5 mg/l may cause mottling of the tooth enamel (Dean, 1936). Bone changes may occur with concentrations of 8 to 20 mg/l.	1.5
Nitrate (NO_3)	Comly (1945) states that concentrations of 45 mg/l may be harmful to infants. Adverse effects from drinking water high in nitrate concentration are also possible in older children and adults.	45
Sulfate (SO_4)	Derived from solution of gypsum and oxidation of iron sulfides (pyrite, etc.). Concentrations of magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt) may have a laxative effect on some persons.	250
Chloride (Cl)	Chloride in ground water may be derived from connate marine water in sediments, surface contamination, or solution of minerals containing chloride. Causes water to taste salty and, in high concentrations, increases the corrosiveness of the water.	250

[1] Concentration recommended by the U.S. Public Health Service (1962).

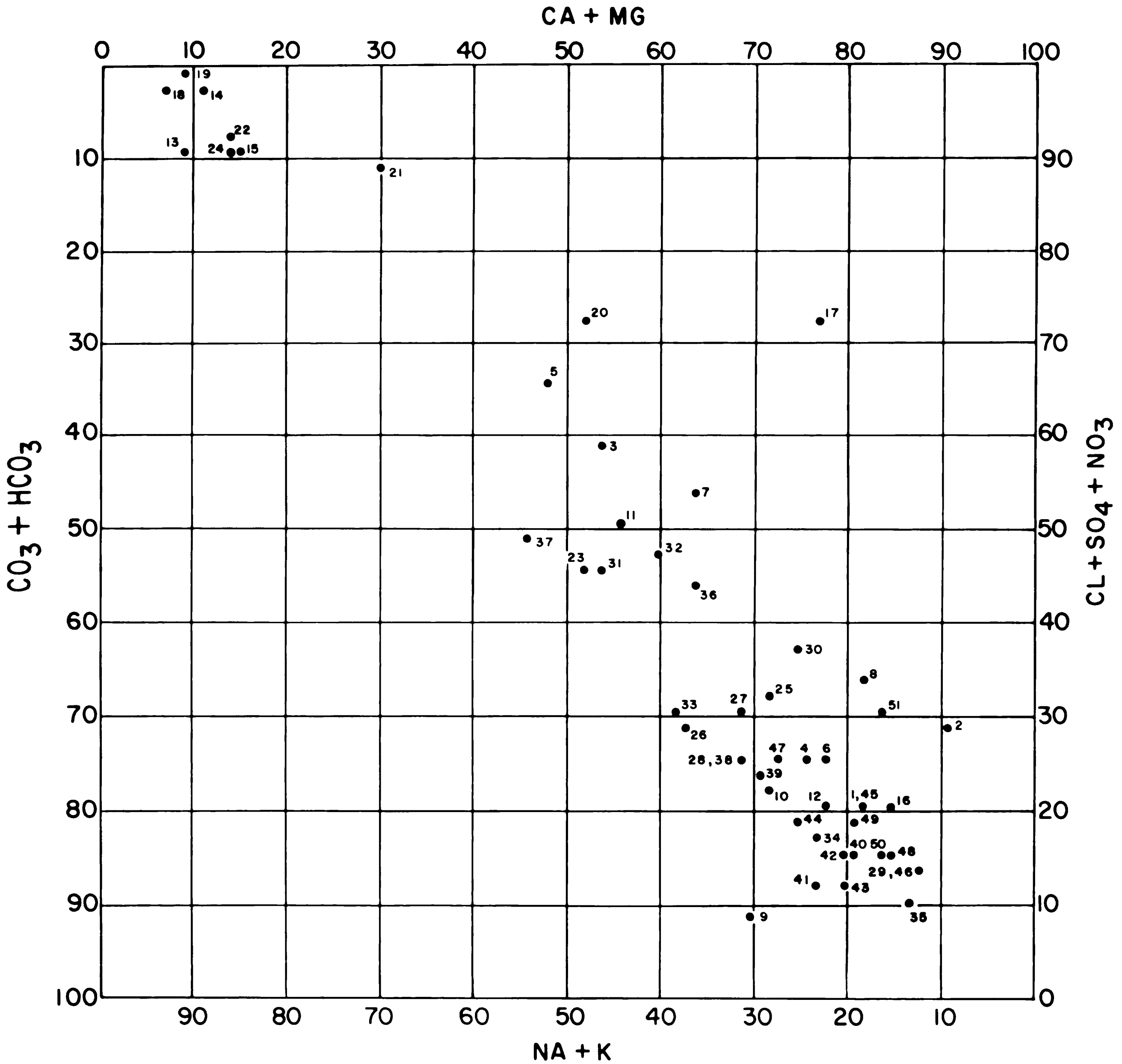


FIGURE 10.—Modified Piper diagram showing grouping of analyses of water from wells. Numbers by symbols are sample-identification numbers from table 4.

on almost all soils with little danger that harmful levels of exchangeable sodium will develop. Medium-sodium water (S2) may be used safely on coarse-textured or organic soils having good permeability, but S2 water will present an appreciable sodium hazard in certain fine-textured soils, especially under poor leaching conditions. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage, leaching, and additions of organic matter. Very high sodium water (S4) generally is unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops that tolerate moderate amounts of salt, such as potatoes, corn, wheat, oats, and alfalfa, can be irrigated with C2 water without special practices. High-salinity water (C3) cannot be used on soils having restricted drainage. Very high-salinity water (C4) can be used only on certain crops and then only if special practices are followed.

Chemical analyses of water from wells in the two major aquifers in the county were selected for determining irrigation suitability (table 7). Specific conductance ranged from 230 to 1,410 micromhos, with the latter value probably being caused by contamination. The analysis of this high-salinity water sample from an irrigation well (27-12W-14adb) in the Cairo area is plotted separately on figure 13. All the other samples are classified as low-sodium (S1) and low- to medium-salinity (C1-C2) water, because they plot within the hachured area shown on figure 12.

The Cairo Area

An investigation of the chemical quality of water in the South Fork Ninnescah River basin is being made currently as part of the cooperative program between the Kansas State Department of Health and the U.S. Geological Survey. The principal objectives are to (1) determine the chemical quality of the water resources, (2) determine the relation between water quality and the major hydrologic and cultural factors that influence water quality, and (3) identify the principal sources and extent of natural and man-made

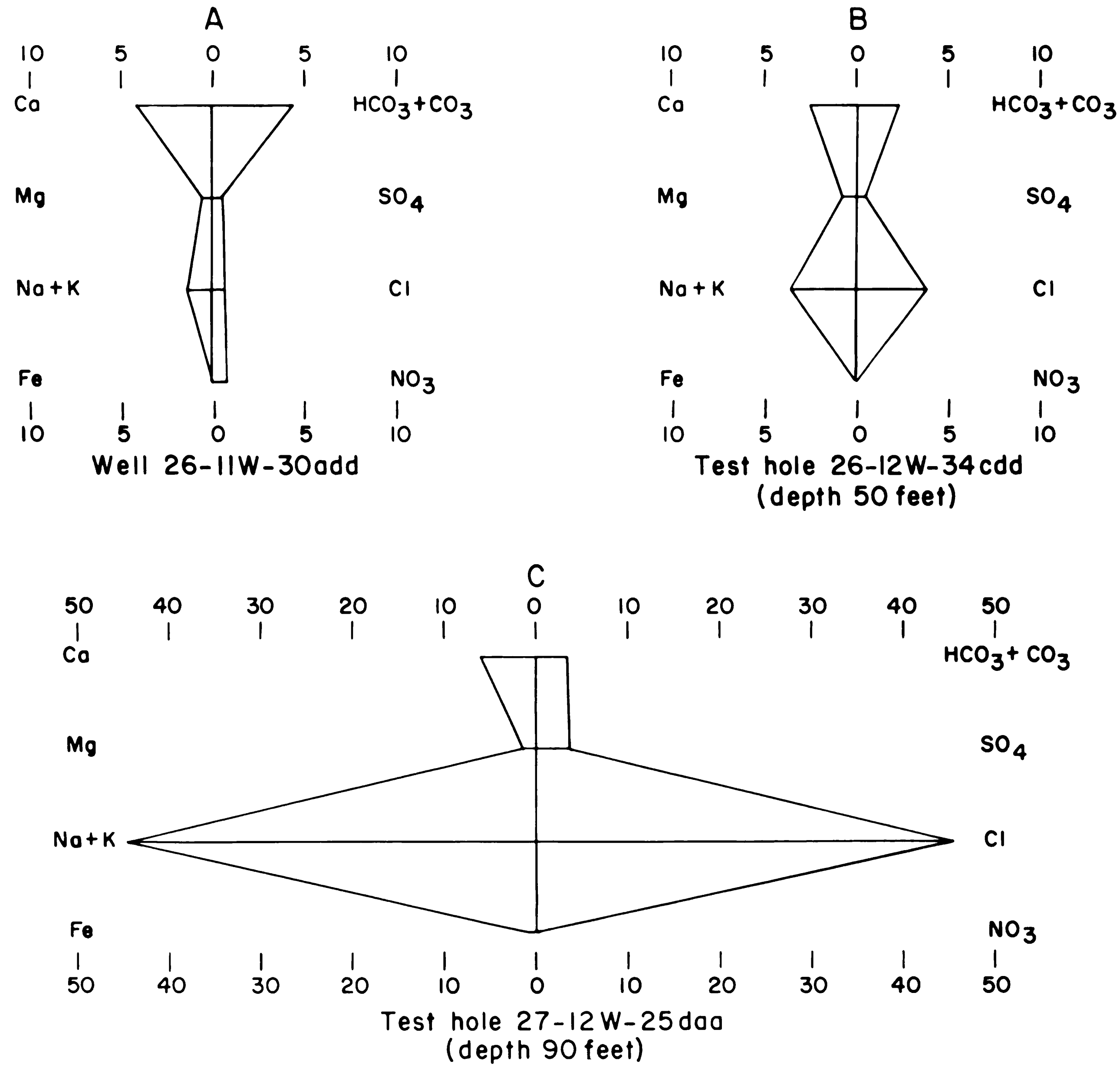


FIGURE 11.—Stiff diagrams of selected analyses of water. *A*, Calcium bicarbonate water, typical of ground water in Pratt County. *B*, Mixed calcium bicarbonate and sodium chloride water. *C*, Sodium chloride water, typical of ground water in the Cairo area. Units are milliequivalents per liter.

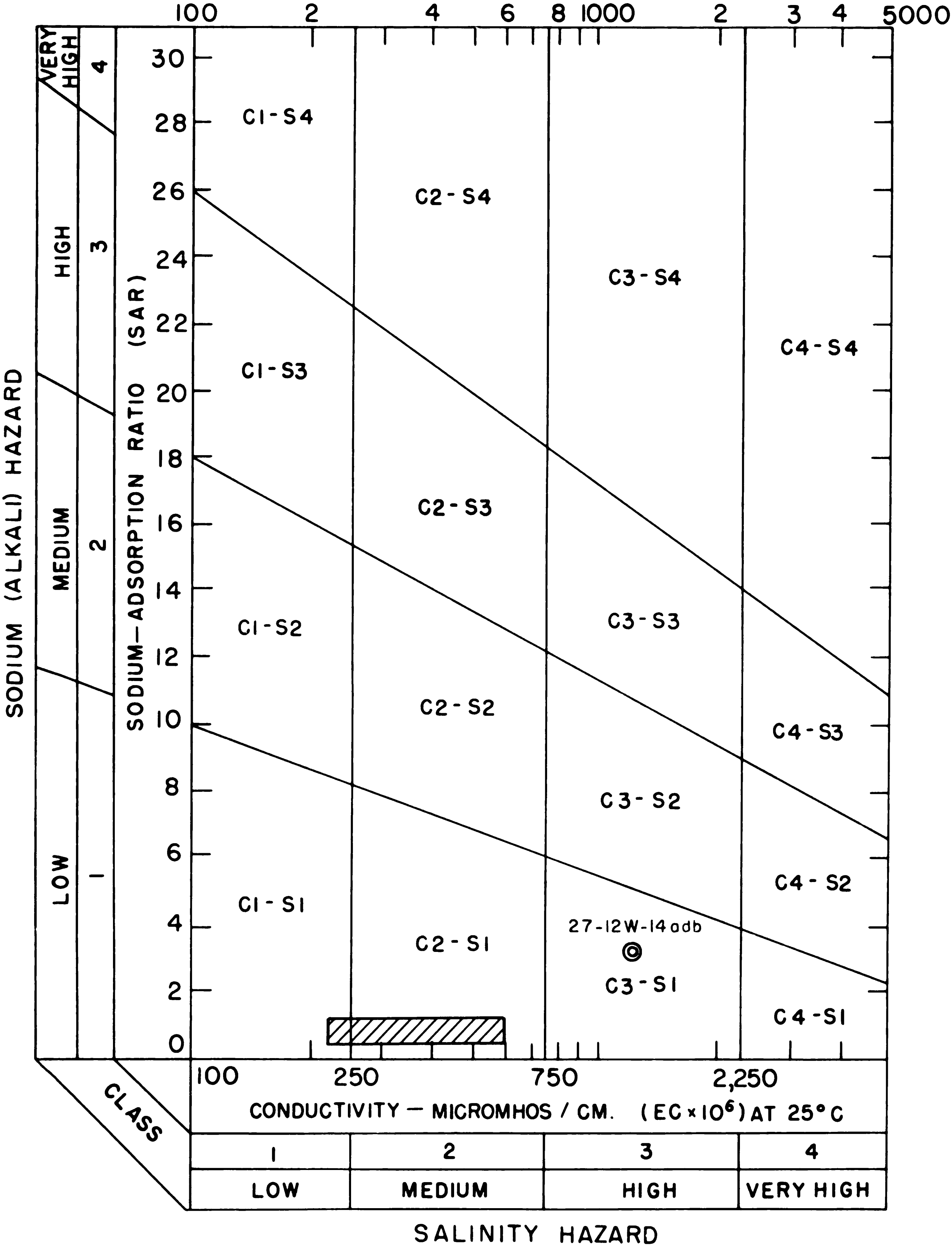


FIGURE 12.—Classification of water used for irrigation. Hachured area includes analyses of water from Holdrege and Grand Island Formations given in table 7.

TABLE 7.—Sodium-adsorption ratios and specific conductances of water samples from selected wells and test holes.

Well or test-hole number	Sodium-adsorption ratio	Specific conductance (micromhos per centimeter at 25 C)
26-11W-30add1	0.91	540
27-11W-18cbb	1.06	510
27-12W-14adb[1]	3.40	1,410
27-12W-36bcb	1.35	410
27-13W-34dab	1.68	600
27-15W- 6ddd	1.17	320
28-13W-26dcb1	.97	360
28-15W-25cdd	.48	280
29-11W-29bbb	.62	460
29-13W- 6baa	.73	350
29-13W-24ddd	.51	420
29-14W-19ddc	.60	230

[1] Analysis plotted separately on figure 12.

pollution. Such information is essential to wise planning for development of the water resources of the basin.

A. M. Diaz (1965) stated: "The deterioration of water quality in the South Fork Ninnescah River by the inflow of saline waters has been known for many years. Parker and Bailey of the U.S. Geological Survey reported in 1911 that the concentration of chloride in the water of the South Fork Ninnescah increased considerably in the area between Pratt and Kingman [Kingman County]. However, the increase was attributed to inflow from salt mines near Kingman. The occurrence of saline inflow to the river from the slough area between Cairo and Cunningham was reported by the U.S. Bureau of Reclamation in administrative reports of low-flow studies made in 1956."

Water samples are collected during periodic discharge measurements of the South Fork Ninnescah River. The measuring and sampling stations along the river are designated by the number of river miles the station is upstream from the confluence with the North Fork Ninnescah River; thus, station 60.8 is near Cunningham in Kingman County, and station 70.3 is near Cairo. Sampling stations pertinent to the Cairo area are shown on figure 13.

The discharge of chemical constituents and of the stream at stations in the Cairo area is shown on figure 14. The discharge values increase at a relatively low and uniform rate to station 76.8, which is about 5 river miles east of Pratt. From there to station 66.1, which is 2.5 river miles upstream from the county line, the discharge values increase markedly. The rate of increase is greatest in the 7.7-mile reach between stations 73.8 and 66.1. The dissolved-solids discharge in this reach increases from 30 to 185 tons per day and streamflow increases from 32 to 60 cfs. The increased discharge of chemical constituents is attributed to inflow of saline water in the reach. The increase in streamflow is attributed partly to the saline-water inflow, but primarily to discharge of ground water from the Holdrege Formation. The Fullerton Formation contains a confining layer of silt and clay in the Cairo area, and water in the underlying deposits of Nebraskan age is under hydraulic pressure. The confining layer has been breached in the South Fork Ninnescah Valley by Wisconsinan erosion, and alluvium and terrace deposits in the river valley are hydraulically connected to the lower Fullerton and to the Holdrege Formations (fig. 15). Ground water from these Nebraskan deposits moves through the alluvium and terrace deposits to the stream. The increased streamflow in the Cairo area is indicated also by the sharp upstream bend of the potentiometric contours shown on plate 1.

A limited amount of test drilling and collection of ground-water samples for chemical analysis was done in an attempt to determine the source of the saline water. The sources considered were (1) leakage of oil-field brine from evaporation ponds or through faulty oil-well casing, and (2) inflow of saline water from rocks of Permian age that underlie the South Fork Ninnescah Valley.

Test holes were drilled and cased along a north-northwesterly trend from Cairo toward the oil-producing area near Natrona and Carmi (fig. 13). Water samples for chemical analysis were collected from these test holes and from wells in the area. The samples were collected from various depths and from both the Holdrege and Grand Island Formations. The analyses showed that saline water is present along the trend and that it occurs on the north side of the river only. However, the upper aquifer (Grand Island) did not contain saline water, so leakage from brine-evaporation ponds on the land surface is not considered a likely source of the contamination.

Leonard (1964) has shown that the ratio of sodium concentration to chloride concentration in Kansas oil-field brines is less than 0.60. This value has been confirmed by analyses of 24 brine samples from 18 oil wells in eastern Pratt County in which the sodium to chloride ratio ranged from 0.43 to 0.59 (A. M. Diaz, written commun., 1967). Saline-water contamination was found in seven of the samples collected from test holes drilled in the Cairo area. The sodium to chloride ratios in these samples ranged from 0.64 to 0.70, which is typical of water from Permian rocks, not oil-field brine from rocks of pre-Permian age (A. M. Diaz, written commun., 1967). The chemistry of the water, therefore, indicates that the contamination is by upward leakage of saline water from rocks of Permian age that underlie the South Fork Ninnescah Valley. The conclusion of a

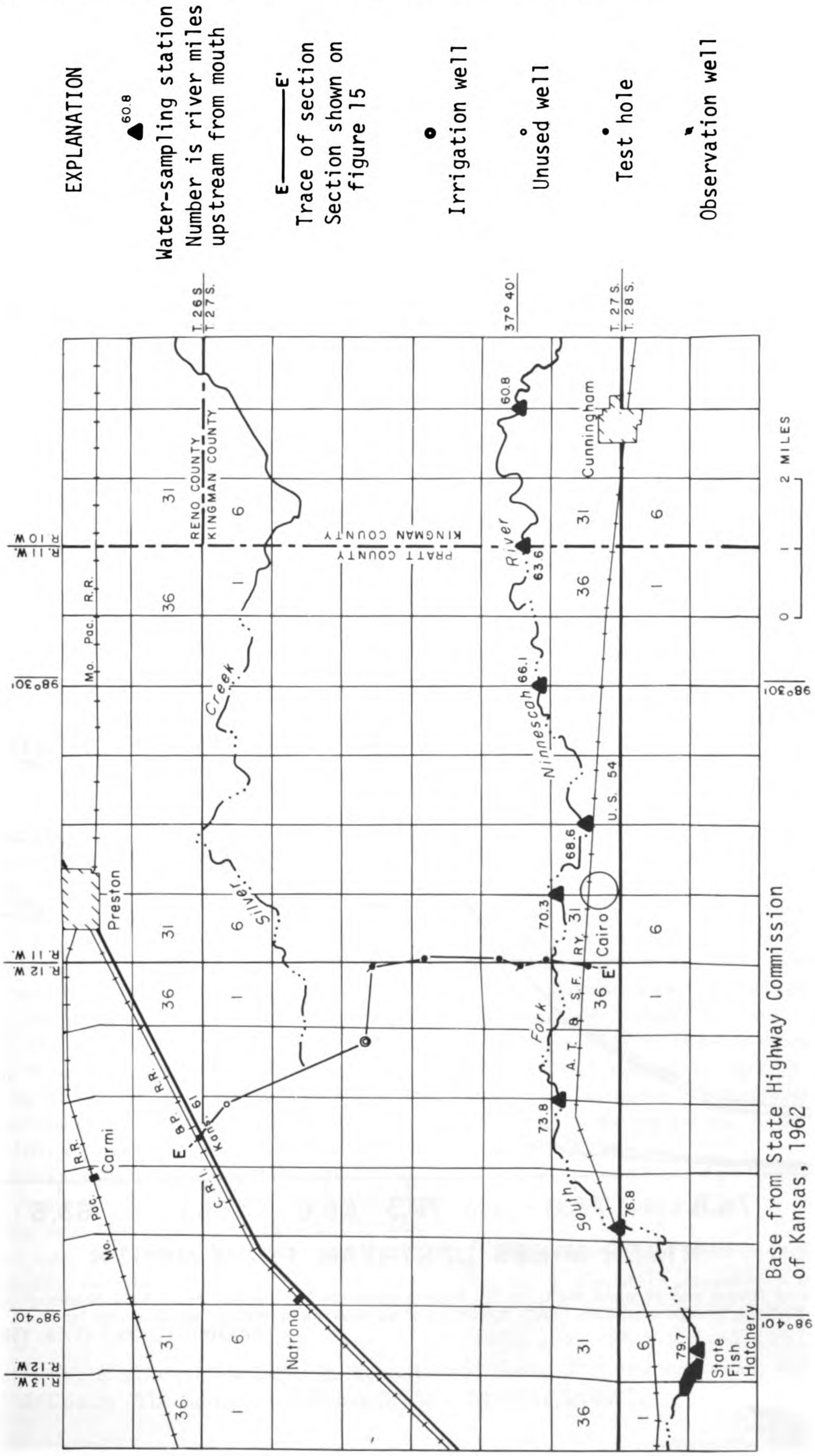


FIGURE 13.—Locations of water-sampling stations and selected wells in the Cairo area.

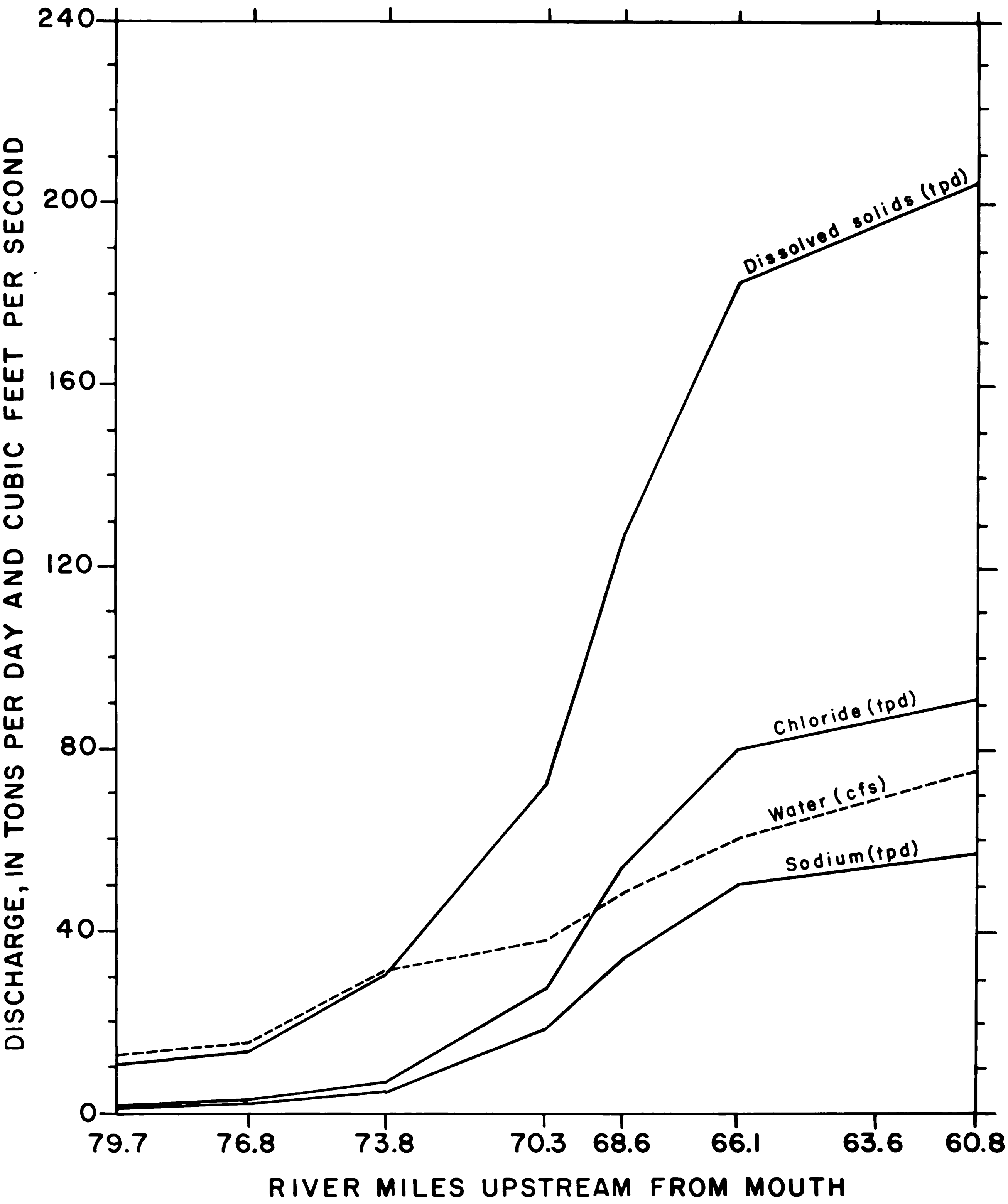


FIGURE 14.—Relation of stream and chemical discharge to distance upstream from mouth, South Fork Ninnescah River, April 1963 (A. M. Diaz, written commun., 1965). Locations of water-sampling stations are shown on figure 13.

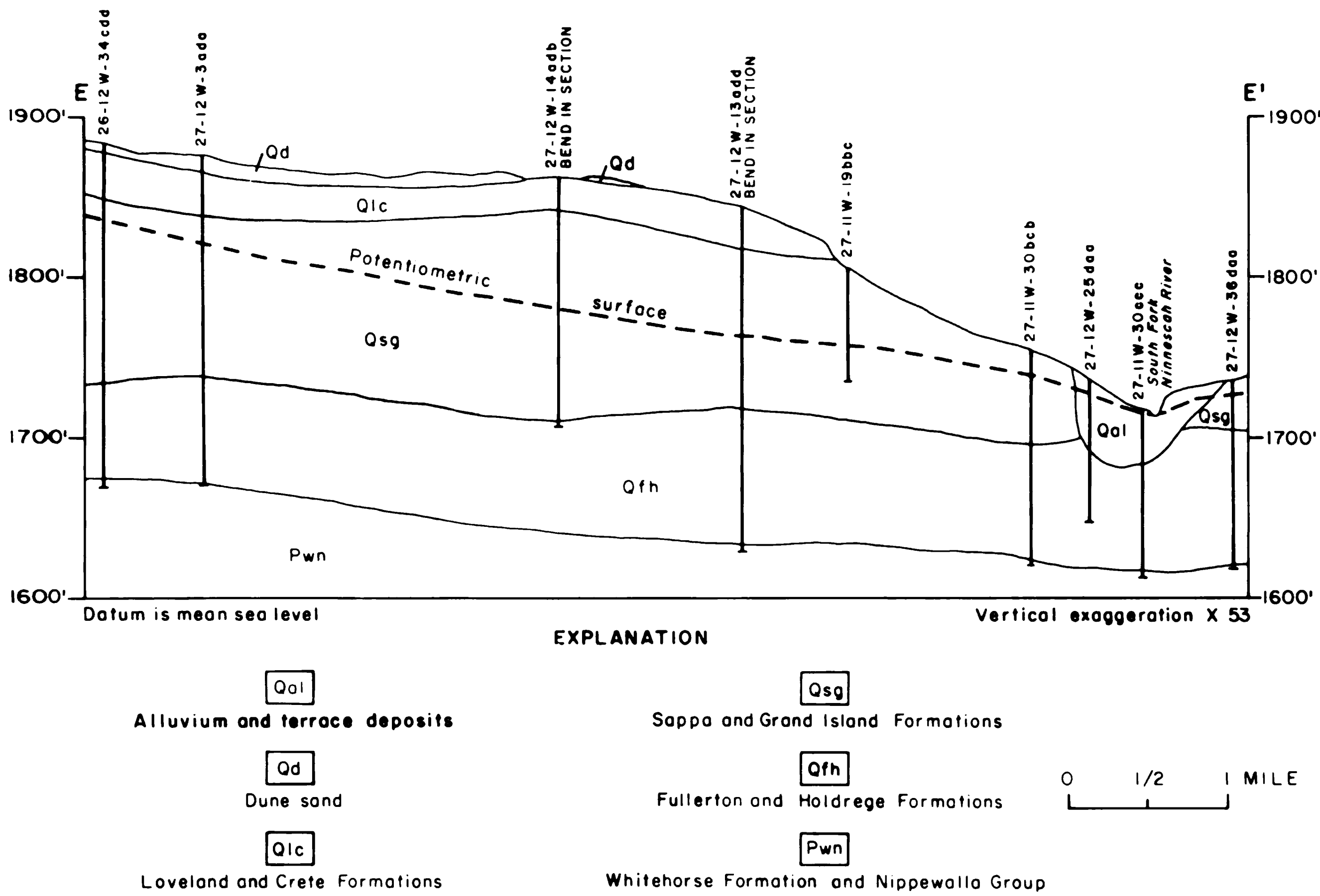


FIGURE 15.—Geologic section showing the hydraulic connection between the alluvium and terrace deposits and the Holdrege and Fullerton Formations in the Cairo area. Trace of section is shown on figure 13.

natural rather than a man-made source is further supported by the fact that the contamination was known many years before oil production began in Pratt County.

Further study of the Cairo area is needed to determine whether (1) saline water moves upward along a geologic fault in eastern Pratt County (fig. 5), or (2) the ancesteral South Fork Ninnescah River has eroded the Permian rocks sufficiently to permit direct movement of saline water into the Holdrege Formation. Hydraulic pressure that would cause movement of the water, by either path, is known to exist. Parker (1911, p. 160) reported that salt water rose to within 15 feet of land surface in an 800-foot deep well drilled at Pratt. Pressure sufficient to raise water this high would cause saline water to move into the Holdrege Formation, into the alluvium and terrace deposits, and, eventually, into the river.

SUMMARY AND CONCLUSIONS

Ground water is an important factor in the economy of Pratt County. The future population and economic growth of the area depend largely on the availability and extent of development of the ground-water resource.

Pratt County is fortunate in being underlain by extensive aquifers from which good-quality water can be withdrawn by wells. Well yields of 500 gpm are possible almost anywhere in the county, and yields of 2,000 gpm are possible in much of the area. Even though ground water in the Holdrege Formation near Cairo is contaminated by upward leakage of saline water from Permian rocks, good-quality water is available from wells completed in the shallower Grand Island Formation.

RECORDS OF WELLS

Information about wells in Pratt County is given in table 8. The wells are listed in order by townships from north to south, and by ranges from east to west. Within a township, the wells are listed in order by sections. The well-numbering system used is illustrated on figure 2.

TABLE 8.—Records of wells.

Well number[1]	Owner or user	Depth of well below land surface, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing unit: Character of material[4]	Principal water-bearing unit: Geologic source[5]	Method of lift,[6] type of power[7]	Use[8]	Depth to water below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Remarks[9]
26-11W- 8aaa	Frank Bauman	65R	2	G	Sd, Gr	Qg	Cy, H, W	D, S	25 R	11-51	1,855.2	C
13daa	H. C. Jeffers	29	8	T	Sd, Gr	Qc	Cy, H	O	14.0	8-51	1,789.4	C
13daa	do	29	8	T	Sd, Gr	Qc	Cy, H	O	13.4	1-64	1,789.4	C
17ccd	Paul Jorns	53	4	G	Sd, Gr	Qc	......	N	43.8	11-51	1,869.6	
27aac	L. V. Hastings	140R	17	....	Sd, Gr	Qg	T, D	I	27.3	6-64	1,808.5	
29bcb	City of Preston	45R	....	....	Sd, Gr	Qc, Qg	T, E	PS	19.8	8-64	1,830.3	150R
29cbc	do	8	72	N	Sd, Gr	Qc	....	N	3.4	9-51	1,827.1	C
30add1	do	60R	18	C	Sd, Gr	Qc, Qg	T, E	PS	46 R	9-51	1,850.4	C, 100R
30add2	do	60R	....	....	Sd, Gr	Qc, Qg	Cy, E	PS	47 R	9-51	1,849.8	
32aaa	L. G. Simon	57	7	G	Sd, Gr	Qc, Qg	....	N	17.4	9-51	1,825.0	
35ccc1	G. W. Huff	36	3	I	Sd, Gr	Qc	....	N	11.8	8-51	1,793.2	
26-12W- 1cbd	I. F. Gatz	190R	....	....	Sd, Gr	Qg	T, D	I	25 R	8-58	....	760R
2aac	Edward Slade	135R	60	....	Sd, Gr	Qc, Qg	T, D	I	35.1	6-64	1,872.5	C, 960R
2dbd	Merlin O. Mardis	135R	16	C	Sd, Gr	Qc, Qg	T, D	I	27.3	4-64	1,868.1	770R
3ccc	School District	46	2	G	Sd, Gr	Qc, Qg	N	N	26.7	4-64	1,883.0	
16cca	Gerhardt Trimpe	170R	6	....	Sd, Gr	Qc, Qg	T, D	I	35.2	6-64	1,901.1	615R
29bdb	J. W. Hoeme	73	8	G	Sd, Gr	Qg	Cy, G	N	40.7	7-51	1,911.1	
30daa	Morgan Inc.	75R	6	G	Sd, Gr	Qg	....	ID	46.4	8-64	1,913.3	
26-13W- 2ccc	C. A. Long	41	6	G	Sd, Gr	Qc, Qg	Cy, H, W	S	9.6	11-51	1,916.3	C
5ada	Royena K. Fincham	51	8	....	Sd, Gr	Qc, Qg	N	ID	2.9	1-50	1,933.2	
6dbd	Texaco Inc.	101R	16	C	Sd, Gr	Qc, Qg	....	ID	12.5	4-64	1,950.3	
13aca	T. H. Jorns	149R	....	....	Sd, Gr	Qg	T, D	I	33.2	6-64	1,911.6	565R
19bdb	Annie E. Bennett	112R	16	C	Sd, Gr	Qc, Qg	T, D	I	17.6	6-64	1,953.2	800
25cbc	George Helmke	78R	6	G	Sd, Gr	Qg	Cy, W	S	42.0	4-64	1,928.4	
28ddd	F. G. Frisbie	80	8	G	Sd, Gr	Qg	N	N	33.7	7-51	1,946.4	
33bad	B. Y. Taylor	74	8	G	Sd, Gr	Qg	N	N	37.4	1-50	1,952.8	
34bcc	George Soaken	75	6	G	Sd, Gr	Qg	N	O	44.5	6-64	1,949.6	
34dca	Lorence Briggeman	170R	16	S	Sd, Gr	Qg	T, D	I	43.8	6-64	1,940.1	735
35cca	Carl C. Briggeman	190R	16	S	Sd, Gr	Qg	T, D	I	40.6	6-64	1,932.2	1,000R
26-14W- 9bbd	R. V. Hemphill	140R	8	S	Sd, Gr	Qc, Qg	T, E	ID	22 R	6-63	....	227
10bdb	Marvin G. Moore	82R	16	....	Sd, Gr	Qc, Qg	T, G	I	14.7	4-64	1,985.1	650
16ddd	C. H. Henderson	40	6	G	Sd, Gr	Qc, Qg	Cy, W	S	7.8	9-51	2,000.1	
17dcb	W. H. Hemphill	100R	....	....	Sd, Gr	Qc, Qg	T, D	I	16.5	4-64	2,015.6	900
22ddb	Harry W. Carr	100R	16	S	Sd, Gr	Qc, Qg	T, D	I	18.7	6-64	1,987.8	630R
29bbb	C. C. Schoonover	116	16	S	Sd, Gr	Qc, Qg	Cy, E	D	18.6	4-64	2,018.0	
31aca	Glenn D. McAhren	111R	17	C	Sd, Gr	Qc, Qg	T, D	I	21.5	6-64	2,020.9	600R
26-15W- 2bbd	Arden Reiman	65R	....	....	Sd, Gr	Qc, Qg	T, E	I	17.1	4-64	2,027.5	400R
6baa	John Haley	33	6	G	Sd, Gr	Qc, Qg	Cy, H	S	8.5	10-51	2,055.8	C
14ada	W. F. Hemphill	22	6	G	Sd, Gr	Qc, Qg	Cy, W	S	12.8	10-51	2,037.0	
26bda	G. A. Curtis	18	24	I	Sd, Gr	Qc, Qg	Cy, W	S	16.0	10-51	2,048.2	C
32cbb	J. H. Tatlock	6	36	C	Sd, St	Qd	Cy, W	S	4.6	11-51	2,058.7	C
27-11W-18cbb	Don Dietz	156R	6	S	Sd, Gr	Qg	A, E	D	95 R	5-64	....	C
25cdb	Edith Griffith	57	7	G	Sd, Gr	Qg	N	N	Flowing	5-64	1,676.4	C
32cba	Cairo Co-op	35R	2	G	Sd, Gr	Qal	Cy, H	D	4.1	11-51	1,723.4	C
35dad	Ralph Shoap	57	7	G	Sd, Gr	Qg	J, E	D, S	43.2	8-64	1,724.4	C
27-12W- 3ada	Gene Brubaker	206R	16	S	Sd, Gr	Qg	N	N	53.3	8-64	1,878.7	
14adb	J. S. Barnes Est.	152R	16	C	Sd, Gr	Qg	T, D	I	82.6	4-64	1,862.3	C, 950R
28cdb	Lee Lunt	80R	4	G	Sd, Gr	Qg	N	ID	25.8	9-64	1,804.6	
22cba	Rient S. Bergner	96R	16	G	Sd, Gr	Qal, Qg	T, G	I	3.4	6-64	1,777.0	518
35aab	Charles Bergner	28R	6	G	Sd, Gr	Qal, Qg	....	D	0.0	7-64	1,732.3	C

27-13W- 2ddb	Robert L. Sheegog	107R	7	G	Sd, Gr	Qg	T, NG	I	15 R	8-57	1,895.2	263
4aac	Carl Briggeman	196R	16	S	Sd, Gr	Qg	T, NG	I	54.2	6-64	1,961.0	555
6aac	C. C. Mott	208R	14	G	Sd, Gr	Qg	T, D	I	40.1	6-64	1,967.2	640
9dda	City of Pratt	191	12	I	Sd, Gr	Qg	T, E	PS	46.0	4-64	1,945.8	50R
9ddd	do	200R	12	I	Sd, Gr	Qg	T, E	PS	59.7	4-64	1,956.2	C
12bcc	Katie Beck	80	8	G	Sd, Gr	Qg	Cy, G	ID	39.2	7-51	1,918.4	
13ddc	Walter R. McGuire	112R	17	G	Sd, Gr	Qg	T, D	I	61.7	6-64	1,886.6	460
14bab	L. C. Rolf	94	10	G	Sd, Gr	Qg	N	ID	54.8	1-50	1,929.4	
17abc	City of Pratt	......	....	....	Sd, Gr	Qg	T, E	ID	38.3	4-64	1,957.6	300R
19aac	W. H. Lampe	190R	16	G	Sd, Gr	Qg	T, D	I	54.1	4-64	1,965.1	
21aca1	S. G. Darling	160R	16	C	Sd, Gr	Qg	T, D	I	65.8	6-64	1,949.8	C, 1,190
26cda	T. Montford	80R	4	G	Sd, Gr	Qg	N	ID	64.2	9-64	1,902.5	
32bbb	Harley Greenstreet	50R	6	G	Sd, Gr	Qg	Cy, E	D, S	21.1	11-51	1,921.6	C
33dcb	City of Pratt	88R	....	....	Sd, Gr	Qg	T, E	PS	45.5	10-51	1,899.3	C, 500R
34aca	do	116R	19	C	Sd, Gr	Qg	T, E	PS	71.1	9-64	1,908.1	
34cad	do	109R	19	C	Sd, Gr	Qg	T, E	PS	69.0	9-64	1,900.9	C, 600
34cbb1	Western Lt.	125R	8	G	Sd, Gr	Qg	T, E	ID	35 R	10-51	1,911.3	120R
34cbb2	do	125R	6	G	Sd, Gr	Qg	T, E	ID	35 R	10-51	1,911.3	
34dab	City of Pratt	97R	19	C	Sd, Gr	Qg	T, E	PS	48 R	9-64	1,873.3	C
35bcc	Frank Doskocil	86R	6	G	Sd, Gr	Qg	T, D	I	44.7	6-64	1,872.0	811
35dcc	C. E. Devlin	63	7	G	Sd, Gr	Qg	N	D	33.6	9-51	1,861.4	
27-14W-10cab	J. M. Logue	155R	16	S	Sd, Gr	Qg	T, D	I	42.4	4-64	2,003.0	
12baa	E. F. Tolman	70	5	G	Sd, Gr	Qg	Cy, W	S	48.3	4-64	1,982.8	
12dcc	Vernon E. Reschke	172R	16	C	Sd, Gr	Qg, Qh	T, NG	I	56.9	6-64	1,988.9	
21caa	L. B. Jones	74	18	I	Sd, Gr	Qg	T, G	I	39.2	4-64	1,998.5	
28adc	Wendell Reed	150R	16	S	Sd, Gr	Qg	T, NG	I	17.2	4-64	1,969.8	
29ddb	Ivan Adams	139R	16	C	Sd, Gr	Qg	....	I	43.4	8-64	2,008.8	455
31bcd	M. D. Seyfert	155R	....	....	Sd, Gr	Qg	N	N	60.7	5-64	2,033.8	
27-15W-18add	J. C. Lemon	53	2	G	Sd, St	Qd	Cy, W	S	18.5	11-51	2,064.4	
32add	B. Y. Bryant	57	2	G	Sd, Gr	Qg	N	N	49.7	4-64	2,061.3	
34ccc	H. F. Rose	118R	2	G	Sd, Gr	Qg	Cy, W	S	60 R	-57	2,061.5	C
35cdc	H. Baumgartner	118	2	G	Sd, Gr	Qg	Cy, H, W	D, S	71.9	11-51	2,064.3	C
28-11W- 2bcb	E. H. Armitstead	66	6	G	Sd, Gr	Qg	N	O	15.5	6-64	1,731.2	
18bdc	Lester Lunt	134R	17	C	Sd, Gr	Qg, Qh	T, NG	I	40.3	6-64	1,806.4	C
33dac	Albert J. Bortz	70R	16	....	Sd, Gr	Qg	T, D	I	.....	....	1,756.7	1,250R
28-12W-14bbd	Clarence Hillard	156R	16	C	Sd, Gr	Qg	T, D	I	72.9	4-64	1,847.6	C
21bad	L. K. Martin	150R	16	....	Sd, Gr	Qg	T, D	I	82.8	6-64	1,881.5	C
26bbb	B. Magaffin	62	8	G	Sd, Gr	Qg	N	N	60.9	9-51	1,854.4	
30daa	Curt Henry	111	7	G	Sd, Gr	Qg	N	N	85.3	11-51	1,900.5	
28-13W- 1bdb	Charley Hillard	94R	16	C	Sd, Gr	Qg	T, D	I	24.1	6-64	1,838.5	C
1cdd	State Fish Hatchery	60R	6	G	Sd, Gr	Qal, Qg	T, E	ID	6.6	8-64	1,817.3	250R
2ddc	do	105R	18	....	Sd, Gr	Qal, Qg	T, E	ID	8.8	9-64	1,827.2	
3aca	City of Pratt	83R	19	C	Sd, Gr	Qg	T, E	PS	18 R	11-54	....	C
3baa	do	84R	24	C	Sd, Gr	Qg	T, E	PS	44 R	11-47	1,879.5	500R
3bad	do	104	18	C	Sd, Gr	Qg	T, E	PS	47 R	9-64	1,878.1	C, 700R
3bda	do	84R	18	C	Sd, Gr	Qg	T, E	PS	22 R	9-64	1,852.4	500R
3cab	do	75R	2	G	Sd, Gr	Qal, Qg	N	N	7.1	4-64	1,845.1	
4bac	do	132R	19	C	Sd, Gr	Qg	T, E	PS	52 R	7-61	1,899.7	
4dad	do	71R	19	C	Sd, Gr	Qg	T, E	PS	28 R	9-64	1,858.8	700R
4dbd	do	66R	19	C	Sd, Gr	Qg	T, E	PS	30 R	9-64	1,873.3	C, 400R
28-13W- 5dca	M. R. Barnes	......	....	....	Sd, Gr	Qg	T, E	I	22 R	9-60	1,886.9	
6caa	C. B. Harris	93R	16	S	Sd, Gr	Qg	T, D	I	28.8	9-64	....	
7cac	L. Maars	126R	4	G	Sd, Gr	Qg	N	N	55.8	8-64	1,930	
9abc	M. K. Irwin	50R	16	C	Sd, Gr	Qc, Qg	T, D	I	11.0	5-64	1,862.6	800R
10aba	Park Hills Club	132R	6	G	Sd, Gr	Qg	T, E	ID	82 R	5-57	....	
11aab	G. T. Chandler	75R	....	....	Sd, Gr	Qal, Qg	C, E	D	14 R	12-62	....	207R

TABLE 8.—Records of wells (*concluded*).

Well number[1]	Owner or user	Depth of well below land surface, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing unit: Character of material[4]	Principal water-bearing unit: Geologic source[5]	Method of lift,[6] type of power[7]	Use[8]	Depth to water below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Remarks[9]
12aac	Perry Fincham	80R	13	S	Sd, Gr	Qal, Qg	C, LPG	I	4.9	6-64	1,813.9	467
12bba	Donald L. Fincham	80R	12	S	Sd, Gr	Qg	....	I	11.0	5-64	1,825.3	
16ddb	Mrs. F. Swisher	138R	17	C	Sd, Gr	Qg	T, D	N	67.5	5-64	1,921.2	650
17aaa	Frank L. Smith	135R	17	C	Sd, Gr	Qg	T, D	I	72.0	5-64	1,938.4	670
26dcb1	Donald L. Fincham	190R	16	C	Sd, Gr	Qg	T, NG	I	93.2	5-64	1,916.4	C, 1,050
27bba	H. E. Randle	180	4	G	Sd, Gr	Qg	N	N	97.9	8-64	1,945.5	
28-14W- 7bbb	City of Cullison	128	12	I	Sd, Gr	Qg	T, E	PS	84.3	8-64	2,041.2	C, 100R
9ddb	H. B. Lunt	184R	....	....	Sd, Gr	Qg	T, D	I	....	......	2,027.0	
11bba	Charley Leak	91R	2	G	Sd, Gr	Qg	J, E	D, S	75 R	11-51	1,995.0	C
11bbd	Harold Leak	160R	12	S	Sd, Gr	Qg	T, D	I	94.0	5-64	2,005.2	C, 551
14ccc	Loren Baker	152R	16	....	Sd, Gr	Qg	T, LPG	I	79.6	5-64	1,984.0	
18bdd	W. Jenkins	99	6	G	Sd, Gr	Qg	N	N	96.7	9-51	2,012.0	
22ccc	R. F. Eads	50R	2	G	Sd, Gr	Qg	....	S	....	......	1,970.7	C
25bba	C. D. Woolfolk	......	....	....	Sd, Gr	Qg	Sub, E	D	76.7	7-64	1,976.0	
26bba	L. E. Hatfield	60	7	G	Sd, Gr	Qg	N	N	29.7	11-51	1,936.6	
28-15W- 2bbb	A. Brown	96	4	....	Sd, Gr	Qg	N	N	65.3	8-51	2,072.2	
7bbd	G. W. Clarkson	500R	16	....	Sd, Gr	Qg, Qh	....	I	91.6	6-64	2,104.2	
9ccd	E. Norby	120R	6	....	Sd, Gr	Qg	J, E	D	92.0	7-64	2,096.1	
11add	D. G. Stonestreet	120R	4	G	Sd, Gr	Qg	N	N	91.9	8-64	2,061	
12cbb	H. S. Rezeau	122	7	G	Sd, Gr	Qg	N	N	95.9	10-51	2,057.3	
23cbb	H. L. Miller	225R	....	....	Sd, Gr	Qg, Qh	T, LPG	I	103	5-64	2,067.0	1,800
25cdd	C. Cook	190R	4	G	Sd, Gr	Qg	N	N	113	9-64	2,053	C
28dda	R. E. Frazier	112	12	I	Sd, Gr	Qg	T, G	I	68.4	5-64	2,037.8	725R
29-11W- 4aaa	George Weir	70R	6	G	Sd, Gr	Qg	Cy, W	S	28.4	5-64	1,830.3	C
9add	Carl Terry	97R	12	S	Sd, Gr	Qg	T, LPG	I	55.3	6-64	1,830.0	600R
29bbb	Irna M. Rose	120R	12	....	Sd, Gr	Qg	T, G	I	66.8	5-64	1,852.7	C, 172
34baa	Lillie Harding	28R	2	G	Sd, St	Qd	Cy, W	S	2.8	11-51	1,830.1	C
29-12W-22bac	J. A. Brubaker	110R	16	C	Sd, Gr	Qg	T, NG	I	66.3	6-64	1,868.5	
29bad	V. J. Hirt	177R	....	....	Sd, Gr	Qg	T, LPG	I	90.1	5-64	1,896.0	350
29-13W- 4bbb	J. H. Shaw	120	7	G	Sd, Gr	Qg	N	N	74.4	8-51	1,934.6	
6baa	C. E. Hertlein	140R	6	....	Sd, Gr	Qg	Sub, E	D	105	7-64	1,981.2	C
9ddd	Sam Cromer	128R	6	G	Sd, Gr	Qg	N	ID	57.0	5-64	1,910.9	
13aaa	E. R. Kessler	125	10	G	Sd, Gr	Qg	N	O	89.4	6-64	1,917.1	
13ddb	May Killingsworth	189R	16	C	Sd, Gr	Qg	T, G	I	91.2	5-64	1,918.4	415
24ddd	City of Sawyer	120	....	I	Sd, Gr	Qg	T, E	PS	98.0	9-64	1,919.6	C, 100R
31acc	M. E. Lambert	80R	12	....	Sd, Gr	Qg	T, G	I	31.3	5-64	1,892.6	500R
29-14W- 4cdd	Ralph Moore	125	4	I	Sd, Gr	Qg	Cy, H, W	D, S	123	8-51	2,030.6	C
19ddc	M. L. Schrepel	207R	16	G	Sd, Gr	Qg	N	I	125	5-64	2,028.4	C
23bba1	City of Coats	110R	4	....	Sd, Gr	Qg	T, E	PS	88.4	9-64	1,964.0	C
23bba2	I. J. Fletcher	100R	2	G	Sd, Gr	Qg	Cy, E	D	91.7	8-51	1,975.5	C
33aaa	I. N. Shriver	126	6	G	Sd, Gr	Qg	N	N	93.5	8-51	1,981.2	
29-15W- 2dab	B. L. Goeller	110	7	G	Sd, Gr	Qg	J, E	D, S	84.1	11-51	2,018.3	C
16aaa	J. G. Perdue	60	7	G	Sd, Gr	Qg	Cy, W	S	31.7	11-51	1,976.5	C
16bbd	do	110R	....	....	Sd, Gr	Qg	T, D	I	78.0	5-64	2,028.9	

[1] Well-numbering system described in text.
[2] R, reported.
[3] C, concrete; G, galvanized; I, black iron; N, none; S, steel; T, tile.
[4] Gr, gravel; Sd, sand; St, silt.
[5] Qal, alluvium and terrace deposits; Qc, Crete Formation; Qd, dune sand; Qg, Grand Island Formation; Qh, Holdrege Formation.
[6] A, airlift; C, centrifugal; Cy, cylinder; J, jet; N, none; Sub, submersible; T, turbine.
[7] D, diesel; E, electric; G, gasoline; H, hand; LPG, liquefied petroleum gas; NG, natural gas; W, wind.
[8] D, domestic; I, irrigation; ID, industrial; N, none; O, observation; PS, public supply; S, stock.
[9] C, chemical analysis given in table 4; number indicates well yield in gallons per minute; R, reported.

LOGS OF WELLS AND TEST HOLES

Sample logs of test holes drilled or augered by the State Geological Survey of Kansas are given on the following pages. Additional logs are on file in the State and U.S. Geological Survey offices, Lawrence, Kans., and may be examined there.

26-11W-35ccc2.—Sample log of test hole in the SW¼SW¼SW¼ sec. 35, T.26 S., R.11 W., 30 feet east of big corner cottonwood tree; drilled June 1964. Altitude of land surface, 1,787.0 feet; depth to water, 17.7 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Dune sand		
Soil, silty, black	1	1
Silt, tan	1	2
Loveland and Crete Formations		
Clay, tan, and caliche	2	4
Clay, white, and caliche	2	6
Clay, light-olive	9	15
Clay, buff, with sand streaks	8	23
Clay, sandy and silty, light-gray, with fine to coarse sand streaks	5	28
Sappa and Grand Island Formations		
Clay, yellow, with caliche layer	2	30
Sand, fine to medium	2	32
Sand, fine to coarse, gravelly	7	39
Clay, white, with caliche nodules	1	40
Clay, very light gray, with caliche layers	4	44
Clay, tan	4	48
Sand, fine to medium, silty	6	54
Sand, fine to coarse, and some gravel	7	61
Sand, fine to medium, silty, slightly clayey, yellow-stained	1	62
Sand, fine to medium	5	67
Sand, fine to coarse, and fine gravel streaks	16	83
PERMIAN SYSTEM		
Lower Permian Series		
Nippewalla Group		
Claystone, reddish-brown	12	95
Shale, silty, red-spotted gray	5	100

26-12W-34cdd.—Sample log of observation well in the SE¼SE¼SW¼ sec. 34, T.26 S., R.12 W., at south edge of railroad right-of-way and 200 feet east of intersection with county road; drilled July 1964. (Two casings in same hole with sand points at 145 and 210 feet.) Altitude of land surface, 1,883.6 feet; depth to water, 44.1 and 46.3 feet, respectively.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Dune sand		
Silt, dark-brown	1	1
Clay, dark-brown	1	2
Silt, buff	4	6
Loveland and Crete Formations		
Clay, silty, tan, with caliche	2	8
Silt, light-gray, with clay and caliche streaks	4	12
Sand, fine to medium, silty, tan and orange-tan	22	34
Sappa and Grand Island Formations		
Sand, fine to medium, silty, tan, with abundant caliche	20	54
Clay, tan, with caliche and tan silt streaks	8	62
Sand, fine to coarse, with fine gravel	33	95
Clay, tan and white, and silt and caliche streaks	7	102
Sand, fine to medium, silty, tan and light-gray	8	110
Silt, tan, with clay and sand streaks	10	120
Sand, fine to coarse, with tan and light-gray silt and clay streaks	12	132
Sand, fine to medium	17	149
Fullerton and Holdrege Formations		
Silt, tan, with white clay and caliche	3	152
Sand, fine to coarse	2	154
Sand, fine to medium, silty, tan and yellow, with light-gray clay streaks	10	164
Sand, fine to medium, with fine gravel; contains ironstone	22	186
Sand, fine to medium, with cemented zones	14	200
Sand, fine to coarse, with fine to medium gravel; contains ironstone	9	209
PERMIAN SYSTEM		
Lower Permian Series		
Nippewalla Group		
Siltstone, reddish-brown	6	215

27-11W-32daa.—Sample log of test hole in the NE¼NE¼SE¼ sec. 32, T.27 S., R.11 W.; drilled 1964. Altitude of land surface, 1,706.9 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium and terrace deposits		
Clay, silty, calcareous, dark-gray; contains some fine to medium sand	4	4
Clay, calcareous, gray	3	7
Sand, coarse to very coarse, and dark-gray calcareous silty clay; contains some very fine gravel	6	13
Clay, calcareous, bluish-gray	1.5	14.5
Clay, silty, calcareous, tan	9.5	24
Clay, silty, calcareous, gray	2	26
Gravel, very fine to fine, arkosic, and very coarse sand	2.5	28.5
Sand, coarse to very coarse, arkosic; contains clay stringer at 51 feet	31.5	60
Fullerton and Holdrege Formations		
Sand, coarse to very coarse; contains some very fine gravel and calcareous clay stringer for 3 feet at 73.5 feet	20	80
Sand, coarse to very coarse, arkosic, derived from Cretaceous rocks	17.5	97.5
Sand, very coarse, and pink calcareous clay	2	99.5
PERMIAN SYSTEM		
Lower Permian Series		
Nippewalla Group		
Siltstone and sandstone, calcareous, red to grayish-green	6.5	106

27-15W-2abb.—Sample log of test hole in the NW¼NW¼NE¼ sec. 2, T.27 S., R.15 W.; drilled June 1964. Altitude of land surface, 2,039.0 feet; depth to water, 26 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Dune sand		
Silt, brown	3	3
Silt, tan	15	18
Loveland and Crete Formations		
Silt, very clayey, tan	4	22
Silt, very clayey, very light gray; contains abundant ironstain spots	16	38
Sand, fine to coarse	7	45
Clay, orange	1	46
Sand, fine to coarse, clayey, yellowish-brown	4	50
Sand, fine to coarse; contains few orange clay streaks	18	68
Sand, fine to coarse, with fine gravel, yellow-stained	2	70
Gravel, fine to medium	4	74
Sappa and Grand Island Formations		
Clay, sandy, white	3	77
Gravel, coarse, sandy	3	80
Sand, fine to coarse, and gravel	45	125
Sand, very clayey, tan and light-gray; contains some caliche	10	135
Sand, fine to coarse, with fine gravel	5	140

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains streaks of gravel and clay	10	150
Sand, fine to coarse, with fine gravel	6	156
Fullerton and Holdrege Formations		
Clay, sandy, light-gray; contains caliche near top	24	180
Sand, fine to coarse, with light-gray clay and caliche streaks	10	190
Sand, fine to coarse, silty	10	200
Sand, fine to coarse, silty, with tan clay streaks and caliche nodules	10	210
Sand, fine to coarse, silty	20	230
CRETACEOUS SYSTEM		
Lower Cretaceous Series		
Kiowa Formation		
Shale, black	24	254
Sandstone, fine- to medium-grained, quartzose, very hard	2	256

28-13W-26dcb2.—Sample log of observation well in the NW¼ SW¼SW¼ sec. 26, T.28 S., R.13 W., 225 feet south and 40 feet west of irrigation well on east edge of drainage ditch; drilled July 1964. Altitude of land surface, 1,916.4 feet; depth to water, 94 feet.

QUATERNARY SYSTEM	Thickness, feet	Depth, feet
Pleistocene Series		
Loveland and Crete Formations		
Silt, clayey, brown	4	4
Clay, light-gray	2	6
Clay, silty, tan	2	8
Clay, silty, buff; contains white clay streaks	7	15
Sand, fine to medium, silty	3	18
Silt, tan and buff; contains caliche and clay streaks	7	25
Sappa and Grand Island Formations		
Clay, tan, buff, and light-gray; contains caliche and white clay streaks	15	40
Silt, slightly clayey, buff; contains fine to medium sand streaks	15	55
Sand, fine to coarse, orange; contains streaks of fine gravel	7	62
Gravel, fine, sandy	6	68
Clay, tan, yellow-stained in part	2	70
Silt, tan and buff	5	75
Sand, fine to coarse; contains tan silt streaks	5	80
Clay, light-gray and white; contains caliche	3	83
Silt, buff and tan	5	88
Silt, buff and tan; contains caliche	4	92
Silt, buff and tan	3	95
Sand, fine to medium, orange	7	102
Sand, fine to coarse, with fine to medium gravel	23	125
Silt, clayey, light-gray and tan; contains caliche	2	127
Gravel, fine, sandy; contains a few clay streaks	23	150
Fullerton and Holdrege Formations		
Silt, buff; contains white and tan clay and caliche	2	152
Sand, fine to coarse, with fine to medium gravel; contains ironstone toward base	23	175
Silt, yellow, and light-gray clay; contains caliche	2	177
Sand, fine to coarse, with fine to medium gravel; contains ironstone	9	186
Silt, tan, and pink clay; contains caliche	1	187
Sand, fine to coarse, with fine to medium gravel; contains ironstone	6	193
Clay, white	1	194
Sand, fine to medium, quartzose	5	199
PERMIAN SYSTEM		
Upper or Lower Permian Series		
Whitehorse Formation or Nippewalla Group		
Siltstone, reddish-brown	11	210

29-11W-21ccc.—Sample log of test hole in the SW¼SW¼SW¼ sec. 21, T.29 S., R.11 W., 300 feet east of intersection; drilled June 1964. Altitude of land surface, 1,847.0 feet; depth to water, 61.3 feet.

QUATERNARY SYSTEM	Thickness, feet	Depth, feet
Pleistocene Series		
Dune sand		
Silt and fine sand, buff	3	3
Silt with fine sand, slightly clayey, black	3	6
Silt, very clayey, buff, tan, and light-gray	3	9
Silt with fine sand, slightly clayey, buff	4	13
Loveland and Crete Formations		
Clay, tan, light-green, yellow, and orange	4	17
Clay, white; contains caliche	4	21
Silt, slightly clayey, buff	5	26
Sappa and Grand Island Formations		
Clay, grayish-green	1	27
Clay, white; contains caliche	1	28
Clay, grayish-green, tan, and white; contains caliche nodules in center third	15	43
Caliche with white clay, massive	1	44
Silt, slightly clayey, orange-buff; contains caliche nodules	7	51
Clay, sandy and silty in part, grayish-green, tan, and white; contains caliche streaks	16	67
Sand, fine, silty, tan, pink, and orange-brown	11	78
Sand, fine to coarse, with fine to medium gravel toward base, black-stained	6	84
Gravel, fine to coarse, sandy	30	114
Sand, fine to medium, silty, slightly clayey, tan and orange-brown	7	121
Clay, tan	1	122
Sand, fine to coarse	4	126
Gravel, fine to coarse	9	135
Fullerton and Holdrege Formations		
Caliche	2	137
Sand, fine to coarse, clayey, pinkish-tan; calcareous in lower third	11	148
Sand, fine to coarse	6	154
Sand, fine to coarse, with fine gravel	2	156
Caliche, massive	4	160
Sand, fine to coarse, silty	10	170
Sand, fine to coarse, with streaks of caliche and pink clayey silt	14	184
Sand, fine to coarse, with fine gravel; contains ironstone	3	187
PERMIAN SYSTEM		
Lower Permian Series		
Nippewalla Group		
Siltstone, clayey, reddish-brown	6	193
Lost circulation	.	193

29-15W-11ddd.—Sample log of test hole in the SE¼SE¼SE¼ sec. 11, T.29 S., R.15 W., 75 feet west of intersection; drilled June 1964. Altitude of land surface, 2,008.2 feet.

QUATERNARY SYSTEM	Thickness, feet	Depth, feet
Pleistocene Series		
Loveland and Crete Formations		
Silt, black	1	1
Silt, clayey, dark-brown	1	2
Silt, very clayey, buff; contains caliche nodules	4	6
Sappa and Grand Island Formations		
Silt with fine sand, buff; contains a few white clay and caliche streaks	11	17
Sand, fine to medium, silty; contains a few white clay and caliche streaks	10	27
Sand, fine to medium, with fine to medium gravel	13	40
Clay, white and yellow	2	42
Clay, yellow and grayish-green; contains some caliche	3	45
Sand, fine to coarse, with fine to medium gravel; contains a few tan and olive clay streaks	37	82
Clay, orange	1	83

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains some black-stained fine to medium gravel	12	95
Gravel, fine to coarse, sandy	62	157
Fullerton and Holdrege Formations		
Clay, grayish-green	2	159
Silt, sandy and clayey, pink	20	179
Clay, grayish-green	1	180
PERMIAN SYSTEM		
Upper Permian Series		
Whitehorse Formation		
Siltstone, pink and reddish-brown	10	190
Siltstone, clayey, reddish-brown	10	200

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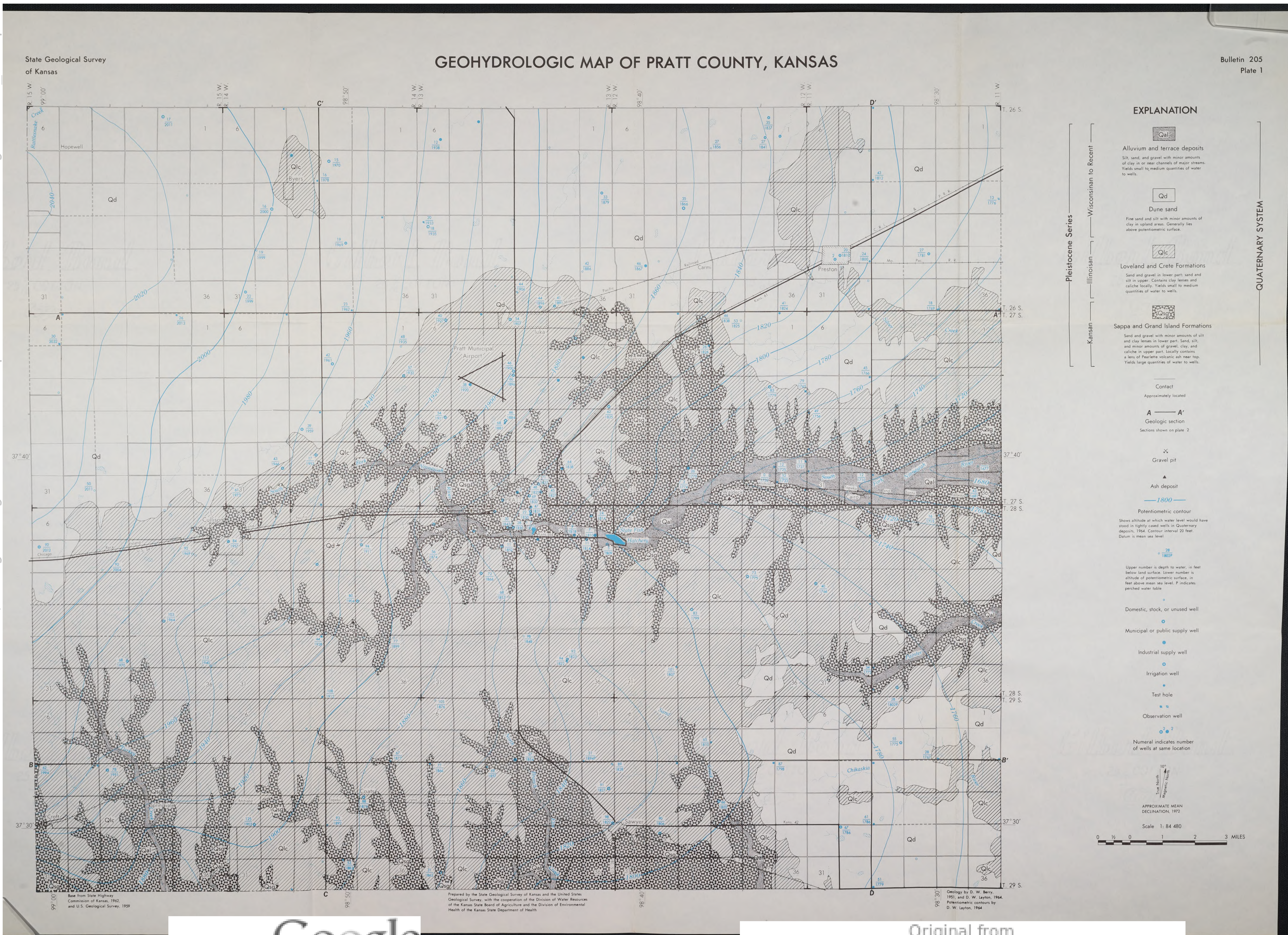
GEOHYDROLOGIC MAP OF PRATT COUNTY, KANSAS

Bulletin 205
Plate 1



State Geological Survey
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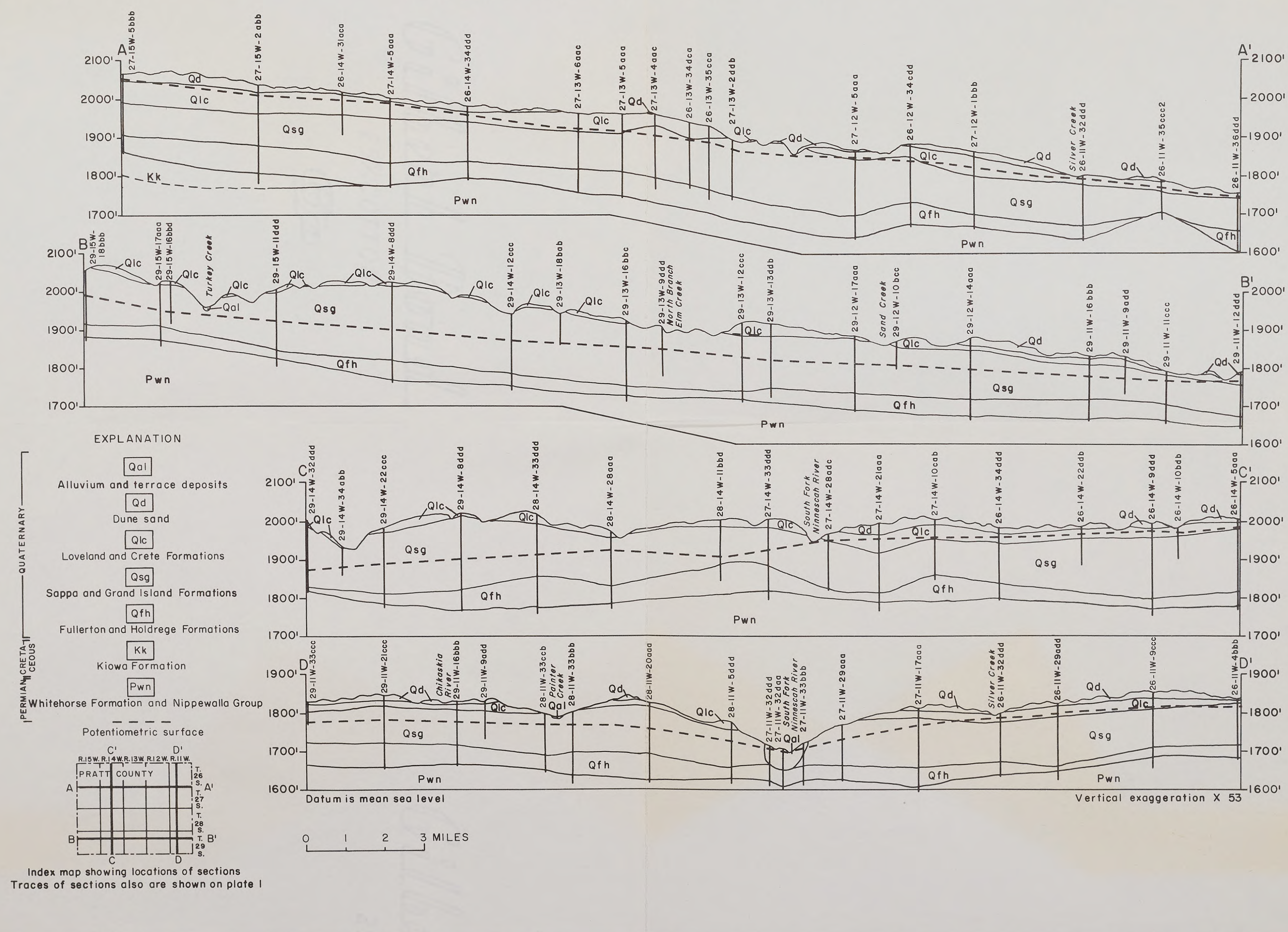
Bulletin 205
Plate 2

GEOLOGIC SECTIONS IN PRATT COUNTY, KANSAS



State Geological Survey
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GEOHYDROLOGIC MAP OF PRATT COUNTY, KANSAS

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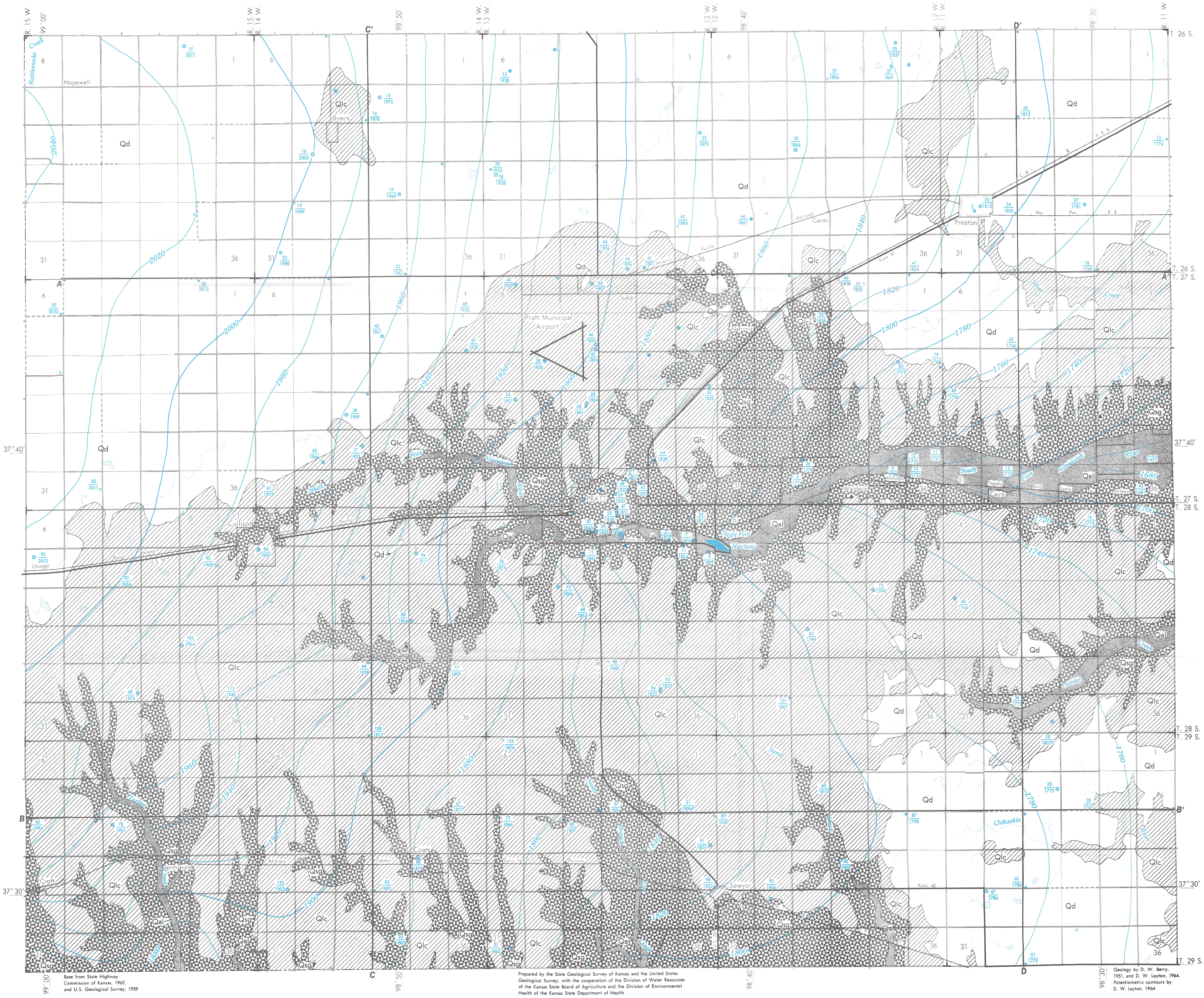

EXPLANATION

QUATERNARY SYSTEM — Pleistocene Series

Wisconsinan to Recent

Qal — Alluvium and terrace deposits

Silt, sand, and gravel with minor amounts of clay in or near channels of major streams. Yields small to medium quantities of water to wells.

Qd — Dune sand

Fine sand and silt with minor amounts of clay in upland areas. Generally lies above potentiometric surface.

Illinoisan

Qlc — Loveland and Crete Formations

Sand and gravel in lower part; sand and silt in upper. Contains clay lenses and caliche locally. Yields small to medium quantities of water to wells.

Kansan

Qsg — Sappa and Grand Island Formations

Sand and gravel with minor amounts of silt and clay lenses in lower part. Sand, silt, and minor amounts of gravel, clay, and caliche in upper part. Locally contains a lens of Pearlette volcanic ash near top. Yields large quantities of water to wells.

Contact
Approximately located

A —— A'
Geologic section
Sections shown on plate 2

Gravel pit

Ash deposit

—1800—
Potentiometric contour
Shows altitude at which water level would have stood in tightly cased wells in Quaternary deposits, 1964. Contour interval 20 feet. Datum is mean sea level

28/1802P
Upper number is depth to water, in feet below land surface. Lower number is altitude of potentiometric surface, in feet above mean sea level. P indicates perched water table

Domestic, stock, or unused well

Municipal or public supply well

Industrial supply well

Irrigation well

Test hole

Observation well

2 2
Numeral indicates number of wells at same location

10°
True North
Magnetic North

APPROXIMATE MEAN DECLINATION, 1972

Scale 1: 84 480

0 ½ 0 1 2 3 MILES

Base from State Highway Commission of Kansas, 1962, and U.S. Geological Survey, 1959

Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the cooperation of the Division of Water Resources of the Kansas State Board of Agriculture and the Division of Environmental Health of the Kansas State Department of Health

Geology by D. W. Berry, 1951, and D. W. Layton, 1964. Potentiometric contours by D. W. Layton, 1964

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Plate 2

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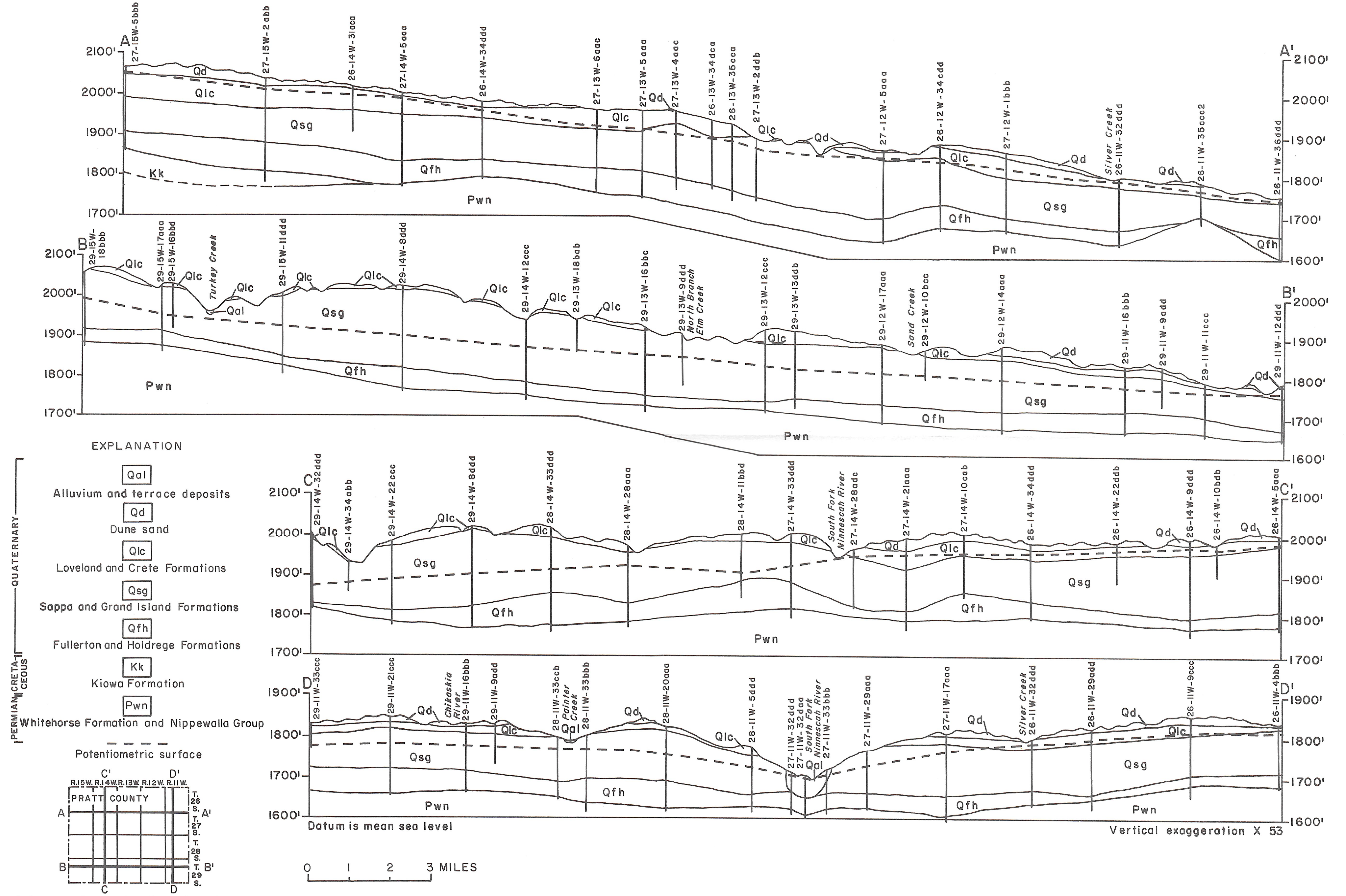

Index map showing locations of sections
Traces of sections also are shown on plate I