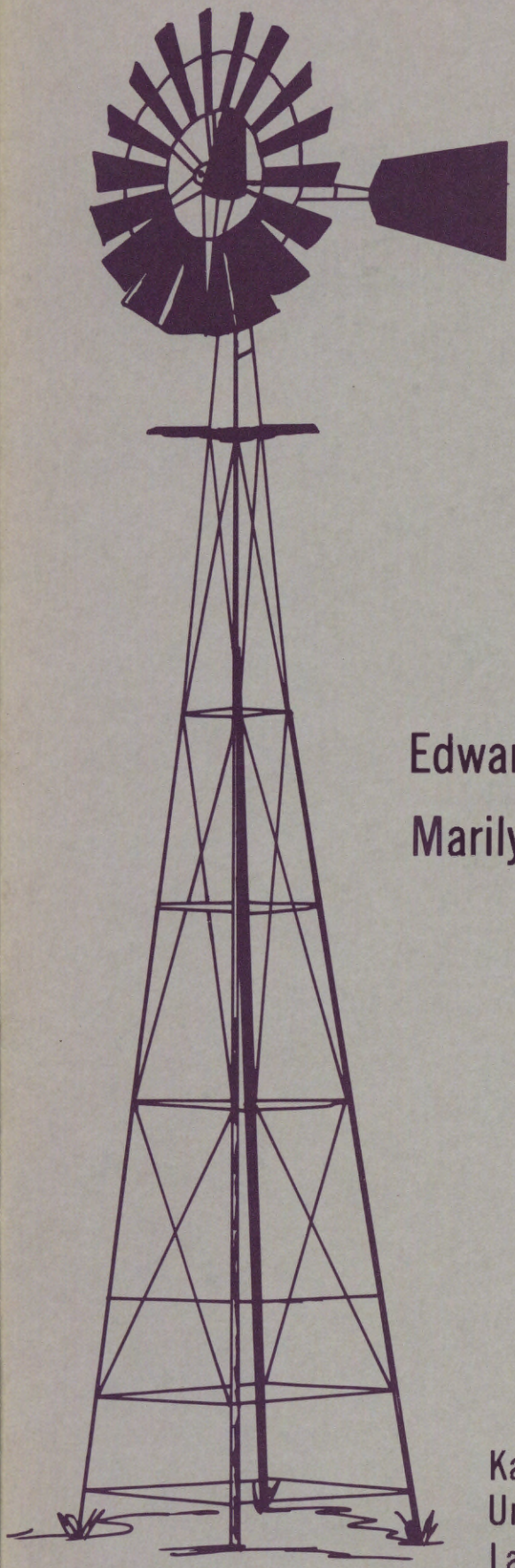

Water-Resources Reconnaissance of NESS COUNTY West-Central Kansas

Edward D. Jenkins
Marilyn E. Pabst

Irrigation Series 3

Kansas Geological Survey
University of Kansas
Lawrence, Kansas

1977

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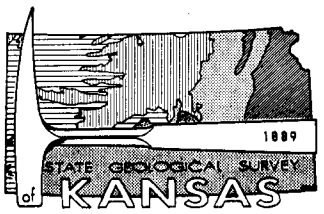

IRRIGATION SERIES 3

Water-Resources Reconnaissance of Ness County, West-Central Kansas

By

Edward D. Jenkins and Marilyn E. Pabst

Prepared cooperatively by
the U.S. Geological Survey and
the Kansas Geological Survey

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EXECUTIVE SUMMARY

The availability of dependable water supplies is becoming increasingly important to the economic growth of predominantly agricultural areas in western Kansas. Because perennial flow in major streams in Ness County has been depleted by pumping, the principal supply of all water uses must be obtained from ground-water sources. Therefore a study of the availability and chemical quality of ground water is of great importance in respect to continued development of municipal, industrial, and irrigation uses.

Alluvium in the Pawnee River and Walnut Creek valleys are the most productive aquifers in Ness County, and the water is of suitable quality for most uses. Extensive development of these water sources, however, probably would impair the rights of current users. The Ogallala Formation yields water of generally suitable quality to supply as much as 250 gallons per minute to wells. This formation could be developed further for municipal, industrial, and irrigation uses. The Dakota Formation, which underlies the county at depths of 100 to 700 feet, is relatively untested. A few stock wells and one irrigation well in the Dakota produce water that is high in sodium and exceeds the recommended limit for dissolved solids in drinking water. More information is needed to evaluate the quantity and quality of water from this potential source.

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Water-Resources Reconnaissance of Ness County, West-Central Kansas

SUMMARY AND CONCLUSIONS

Ness County is a 1,080 square-mile[1] area in the eastern edge of the High Plains section of western Kansas. The altitude ranges from about 2,050 to 2,650 feet above sea level. The mean annual precipitation is 21.39 inches. The population in 1975 was 4,653.

Rocks significant as sources of water supply range in age from Early Cretaceous to Pleistocene. The principal aquifers[2] are the Lower Cretaceous Dakota Formation, the Tertiary (Pliocene) Ogallala Formation, and the Quaternary alluvium.

The Dakota Formation is the only productive aquifer that underlies the entire county. One irrigation well (19-23W-1CCB), which was drilled to a depth of 450 feet obtains water from the Dakota aquifer between 350 and 425 feet. This well yields 800 gallons per minute of water with a drawdown of 92 feet after 54 hours pumping. The transmissivity was computed to be 2,800 feet squared per day. Several wells are drilled to the Dakota for stock use. Water from the Dakota is high in sodium and exceeds the concentration limits recommended by the Kansas Department of Health and Environment for dissolved solids in drinking water. More studies are needed to test the water-yielding characteristics of the Dakota Formation and its water quality in Ness County.

The Ogallala Formation underlies the northern tier of townships, and some erosional remnants of the formation, about 15 square miles each, extend into the western part of the county. Yields of wells range from 5 to 245 gallons per minute. Seven irrigation wells irrigate 100 acres, and nine public-supply wells furnish water for a population of about 800. The saturated thickness decreases toward areas of outcrop where the formation is being drained of water along its contact with the underlying bedrock. Therefore, areas of greatest saturated thickness and potential yield are likely to be found farthest from the Ogallala outcrop. Isolated channels in the bedrock may provide increased saturated thickness where yields may exceed 245 gallons per minute, but this possibility can be verified only by test drilling. Quality of water in the Ogallala is within the recommended limits for dissolved solids in drinking water and is suitable for most uses. The Ogallala could be developed further for industrial, irrigation, or municipal uses where demands per well are less than 250 gallons per minute and where suitable quality of water is desired.

[1] A conversion table of English to metric units and abbreviations is given on page 2.

[2] Definitions of hydrologic terms used in this report are given in the glossary.

The Quaternary alluvium of Pawnee River and Walnut Creek valleys is the most productive aquifer and the least costly for construction of irrigation, industrial, or public-supply wells. The area underlain by the alluvium, however, is small compared to the total area of the county. Maximum yields from wells tapping the alluvium of the Pawnee River and Walnut Creek valleys were measured as 900 and 770 gallons per minute, respectively.

The maximum thickness of the alluvium is about 127 feet in Pawnee River valley. Wells in the alluvium and unconsolidated material in smaller valleys or draws that act as catchment basins generally are adequate for domestic and stock use and yield from 1 to 140 gallons per minute. The water is very hard and slightly exceeds the recommended limit for dissolved solids in drinking water, but is suitable for most uses.

Continuous development of wells and increased pumping along the Pawnee River and Walnut Creek valleys have lowered the water table until the streams no longer maintain base flow; however, the stream channels are a source of recharge when precipitation is great enough to cause runoff. A total of about 11,000 acre-feet of ground water was pumped for irrigation and municipal uses in 1975.

Further development of ground water in these valleys for industrial and municipal use is attractive because of the large well yields that are obtainable, but extensive development would impair the rights of current users.

INTRODUCTION

This report presents information on the groundwater resources of Ness County. The study was begun in 1974 as part of a cooperative program between the Kansas Geological Survey and the U.S. Geological Survey, with data and support provided by the Division of Water Resources of the Kansas State Board of Agriculture and the Division of Environment of the Kansas Department of Health and Environment.

Purpose of Study

The objective of this project is to describe the general availability and chemical quality of the ground water in Ness County with respect to municipal, industrial, and irrigation use. Increased development of water for irrigation in Ness County depends upon knowledge of the availability and chemical quality of water.

Metric Units

For readers familiar with or interested in the metric system, the English units of measurement given in this report are listed with equivalent metric units using the following abbreviations and conversion factors:

English unit	*Multiply by*	*Metric unit*
Length		
inches (in)	2.54	centimeters (cm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
Area		
acres	.4047	square hectometers (hm^2)
square miles (mi^2)	2.590	square kilometers (km^2)
Volume		
gallons (gal)	3.785	liters (L)
acre-feet (acre-ft)	1.233×10^{-3}	cubic hectometers (hm^3)
	1233	cubic meters (m^3)
barrels (for petroleum, 42 gal)	.1590	cubic meters (m^3)
Flow		
gallons per minute (gal/min)	.06309	liters per second (L/s)
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)
Hydraulic conductivity		
feet per day (ft/day)	.3048	meters per day (m/day)
Transmissivity		
feet squared per day (ft^2/day)	.0929	meters squared per day (m^2/day)
Specific capacity		
gallons per minute per foot [(gal/min)/ft]	.207	liters per second per meter [(L/s)/m]

Description of Area

Ness County is located in the fourth tier of counties south of the Kansas-Nebraska border, and is the fifth county east of the Kansas-Colorado border (fig. 1). The bordering counties are Trego and Gove on the north, Lane on the west, Hodgeman on the south, and Rush and Pawnee on the east. The county extends from T.16 S. through T.20 S. and from R.21 W. through R.26 W., and has an area of 1,080 square miles.

The average population density for the county is 4.3 per square mile as compared with about 28 for the entire State. Ness County had a population of 4,653 and Ness City, the county seat, 1,754 in 1975.

The average precipitation at Ness City is 21.39 inches per year (fig. 2). The climate of Ness County is characterized by abundant sunshine, moderate precipitation, high rates of evaporation, moderate to high wind velocities, and frequent and abrupt weather changes. Hot days and cool nights are typical in sum-

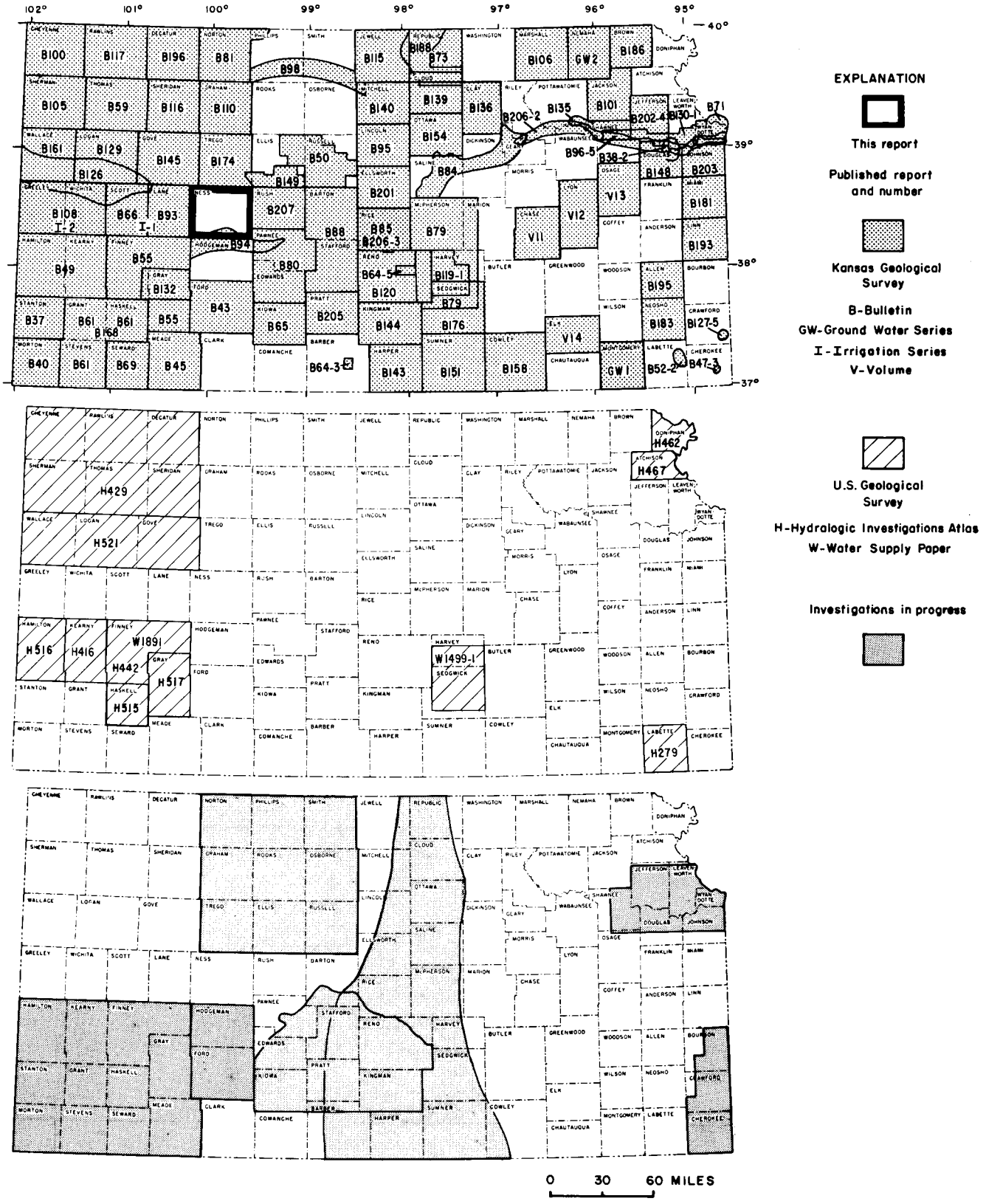


FIGURE 1.—Index maps showing area discussed in this report, and other areas for which ground-water reports have been published or are in preparation.

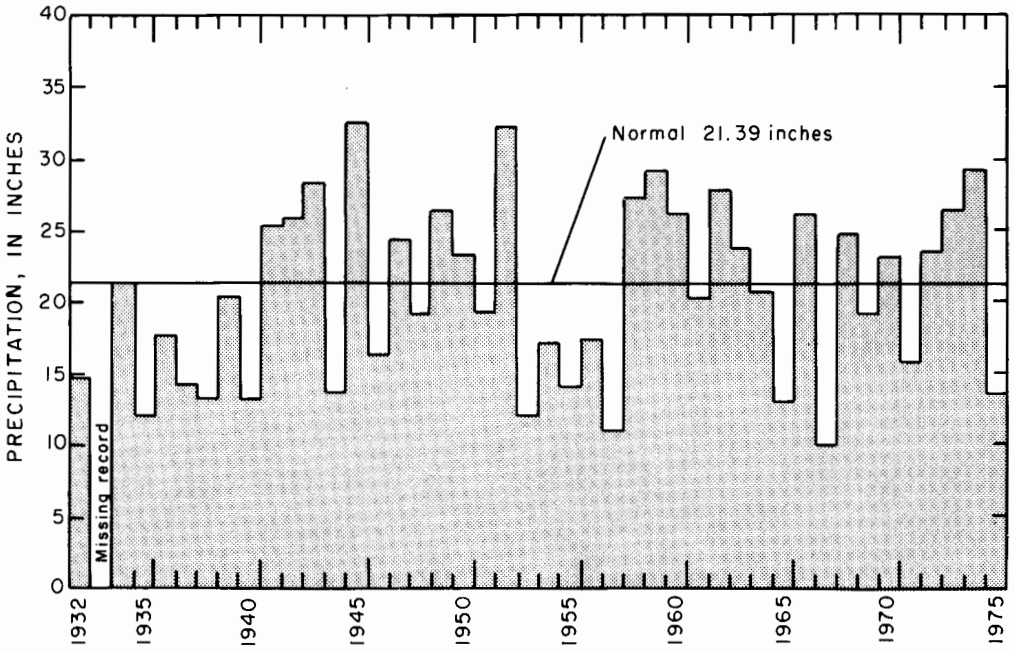


FIGURE 2.—Annual precipitation at Ness City.

mer. During winter, temperatures are moderate to cold with occasional short periods of severe cold. Thunderstorms are prevalent in spring and summer, and blizzards occur in winter. Approximately three-fourths of the precipitation in Ness County occurs from April through September, which coincides with the growing season. The growing season at Ness City averages 170 days.

Agriculture is the dominant economic activity in the county. The principal crops are wheat, milo, corn, oats, barley, and hay. Mineral resources of the county include oil and gas, sand and gravel, and limestone, in addition to ground water. During 1974, there were 604 producing oil wells in Ness County, which produced 2,690,276 barrels (Beene, 1974).

Most of Ness County is in the Arkansas River drainage basin; a narrow strip, 4 to 8 miles wide along the north edge of the county, drains into the Smoky Hill River (fig. 3). Most of Ness County drains into Walnut Creek, which heads in Lane County and flows eastward across Ness and Rush Counties to join the Arkansas River. The southern part of Ness County drains into the Pawnee River, which begins in Finney County and joins the Arkansas River at Larned. Total relief in the county is about 600 feet. The highest point, west of Utica on the divide between the Smoky Hill River and Walnut Creek, is about 2,650 feet above sea level, and the lowest point, where Walnut Creek leaves Ness County, is 2,050 feet. Physiographically, Ness County lies on the eastern edge of the High Plains. The Ogallala-capped divides between the larger streams form the eastern margin of the High Plains. Because the major drainage of the area is toward the east, the divides trend and slope eastward. The south flanks of the divides slope rather gently to the streams, but the north flanks have short steep slopes. The major streams have developed flood plains, some of which are more than 2 miles wide. The flood plains, the gently sloping south flanks, and the flat divides are utilized chiefly for cultivating wheat and corn. The steeply sloping north flanks are used mostly for grazing.

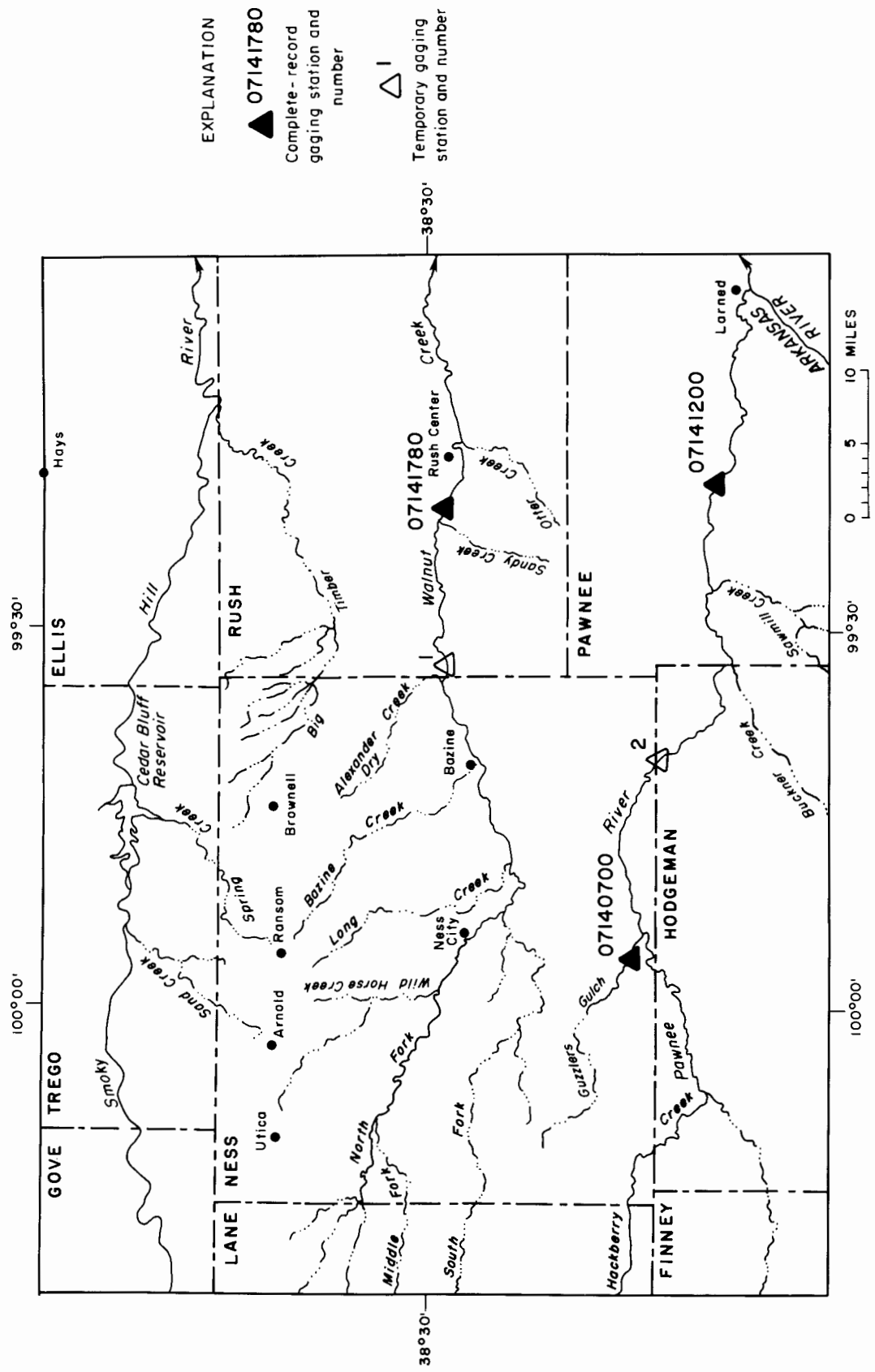


FIGURE 3.—Drainage in Ness and adjacent counties, and location of surface-water gaging stations.

Well-Numbering System

The wells and test holes are numbered in this report according to the Bureau of Land Management's system of land subdivision. In this system, the first set of digits of a well number indicates the township; the second set, the range east or west of the sixth principal meridian; and the third set, the section in which the well is located (fig. 4). The first letter denotes the quarter section or 160-acre tract; the second letter, the quarter-quarter section or 40-acre tract; the third letter, the quarter-quarter-quarter section or 10-acre tract. The 160-acre, 40-acre, and 10-acre tracts are designated A, B, C, and D in a counterclockwise direction beginning in the northeast quadrant. As an example well 18-25W-33ADC is in the SW¼SE¼NE¼ sec.33, T.18 S., R.25 W. Where two or more wells are located within a 10-acre tract, wells are numbered serially, beginning with 2, according to the order in which they were inventoried.

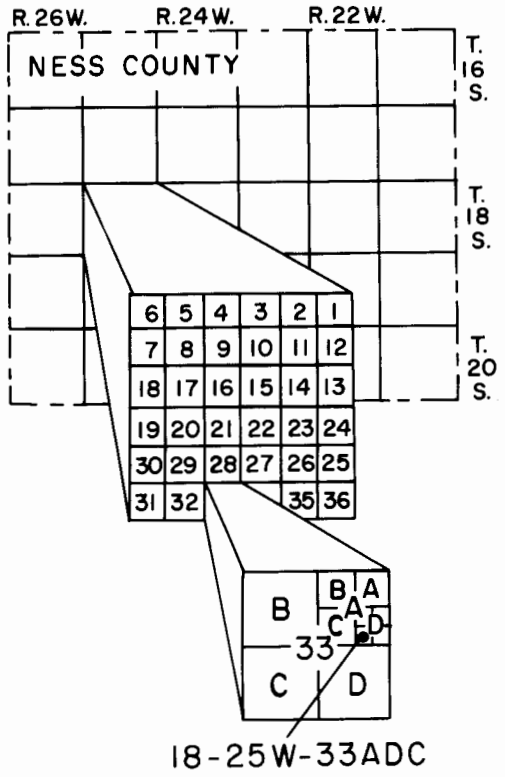


FIGURE 4.—System of numbering wells.

Acknowledgments

Thanks and appreciation are expressed to the many county residents who permitted access to their property and supplied information on their wells, to municipal officials who provided information on city water supplies, to well drillers who supplied well and test-hole logs, and to oil and service companies who provided logs. Special acknowledgment is made to owners of wells that were used in making discharge, drawdown, and power-consumption measurements; to the Ness County Agricultural Extension Council; Soil Conservation District; and to Mr. Carlyle Thompson of the Fort Hays Experiment Station who provided information on wells and irrigation practices.

GEOHYDROLOGY

The surface rocks of Ness County are of Cretaceous, Tertiary, and Quaternary age. The Cretaceous rocks, composed of the Greenhorn Limestone, Carlile Shale, and Niobrara Chalk, are the oldest rocks exposed in the area; the Tertiary (Pliocene) Ogallala Formation is the next oldest; and the Quaternary deposits, which consist of undifferentiated Pleistocene deposits and alluvium, are the most recent. The geologic map (fig. 5) shows the formations that crop out or directly underlie a very thin mantle of undifferentiated Pleistocene deposits (loess) in Ness County.

Availability of Ground Water

Rocks that are significant as sources of water supply in Ness County range in age from Early Cretaceous to Pleistocene. The Upper Cretaceous rocks, although of geologic importance, generally are not significant as aquifers. The principal aquifers in Ness County are the Lower Cretaceous Dakota Formation, the Pliocene Ogallala Formation, and the Pleistocene alluvium. The Lower Cretaceous Cheyenne Sandstone is considered to be an aquifer, but is not known to have been tapped for water supply in Ness County. The physical character and the water-supply characteristics of these aquifers and other geologic units that underlie the county are described in table 1. For a more complete discussion of the geologic units listed in table 1, the reader is referred to Bass (1926, p. 84-89) and to Moss (1932, p. 10-42).

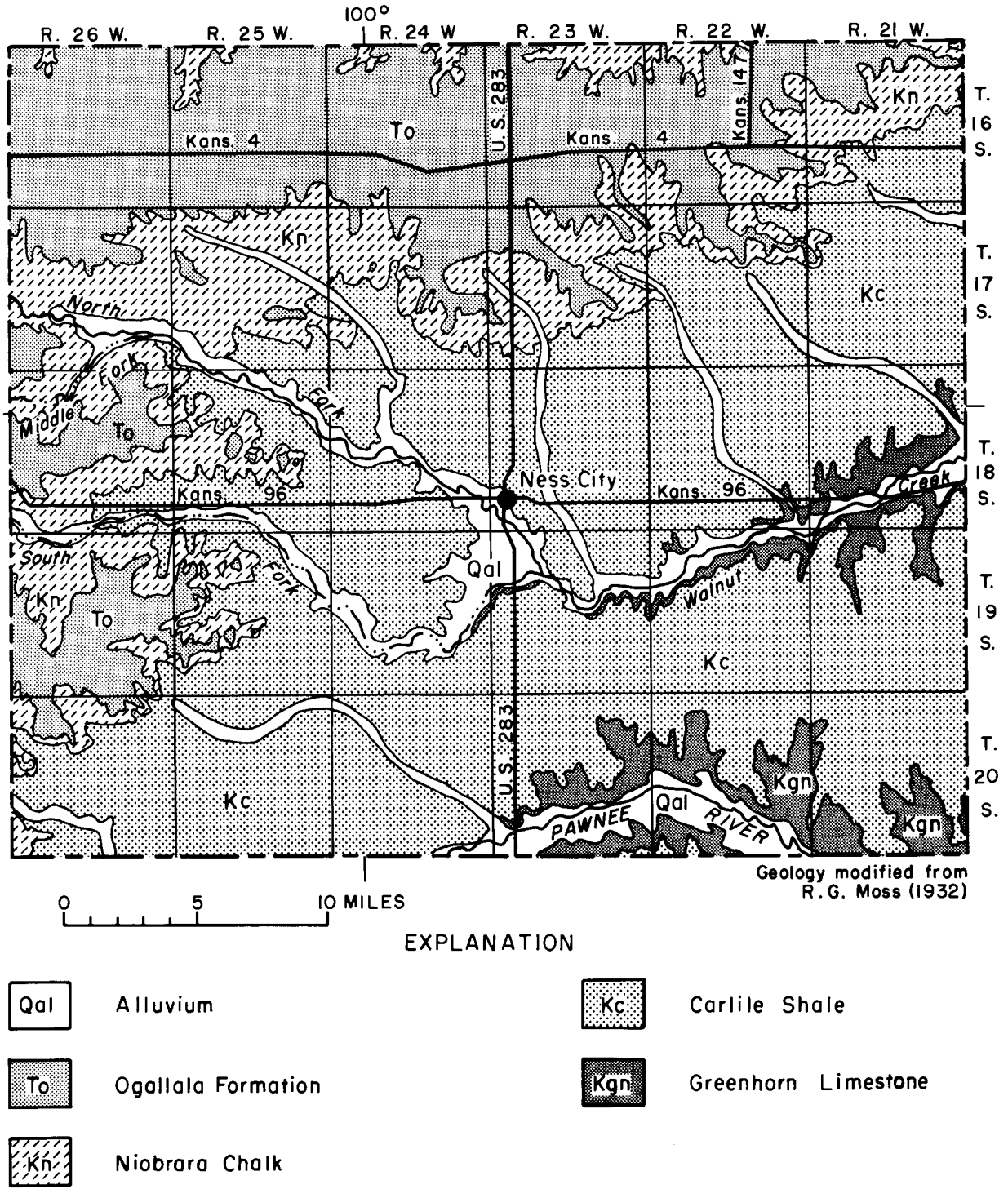
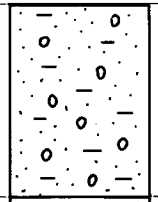
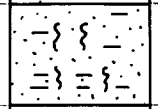
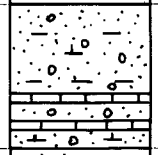
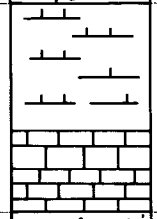
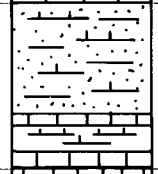
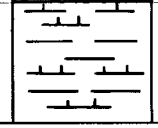
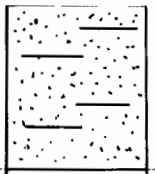


FIGURE 5.—Geologic map.

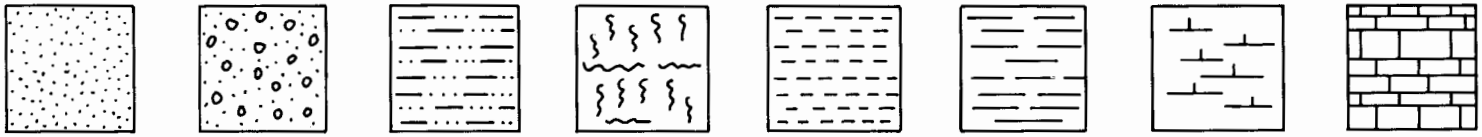
TABLE 1.—Generalized section of geologic units.[1]

System	Series	Geologic unit	Thickness (feet)	Rock symbol	Physical character	Water supply
QUATERNARY	Pleistocene	Alluvium	0-127		Stream-laid deposits ranging from clayey silt to coarse sand and gravel that occur along principal stream valleys.	Yields to wells commonly range from 85 to 900 gal/min in principal valleys and 1 to 40 gal/min in tributary valleys. Chemical quality of water may be objectionable for some uses in localities where thin deposits of alluvium are in contact with Upper Cretaceous rocks.
		Undifferentiated deposits	0-15		Silt and fine sand, mostly eolian (loess), mantle most of the upland and mask much of the valley walls.	Most of the deposits are above the water table, but locally yield small quantities of water to wells.
TERTIARY	Pliocene	Ogallala Formation	0-100		Sand, gravel, silt, clay, and caliche, largely unconsolidated but cemented locally by calcium carbonate or silica.	Yields 30 to 245 gal/min of water to wells in north and west parts of the area; may yield 5 gal/min or less to wells or springs along edges of outcrop. Water quality generally suitable for most uses.
CRETACEOUS	Upper Cretaceous	Niobrara Chalk	0-370		Upper unit (Smoky Hill Chalk Member) consists of yellow to orange-yellow chalk and light- to dark-gray beds of chalky shale that locally weather to ochre-yellow. Lower unit (Fort Hays Limestone Member) consists of a white to yellow massive chalky limestone; contains thin beds of dark-gray to brownish-gray chalky shale.	Not known to yield significant amounts of water to wells.
		Carlile Shale	0-300		Upper part consists of dark-gary to bluish-black noncalcareous to slightly calcareous shale that locally is interbedded with calcareous silty very fine-grained sandstone. Lower part consists of very calcareous dark-gray shale and thin interbedded limestone.	Not known to yield significant amounts of water to wells.
		Greenhorn Limestone	0-120		Alternating light- to dark-gray thin-bedded chalky limestone and calcareous shale. Contains layers of bentonite.	Not known to yield significant amounts of water to wells.
		Graneros Shale	20-40		Dark-gray calcareous shale interbedded with black noncalcareous shale. Contains thin beds of bentonite, gray limestone, and fine-grained silty sandstone.	Not known to yield significant amounts of water to wells.

	Lower Cretaceous	Dakota Formation	150-300		Brown to gray fine- to medium-grained sandstone interbedded with gray sandy shale and varicolored shale. Locally sandstone beds are cemented with calcium carbonate or iron oxide.	Yields as much as 800 gal/min to wells tapping loosely cemented sandstone beds, but locally may yield only small quantities from cemented beds. Water from Dakota is more mineralized than from Ogallala Formation and alluvium.
		Kiowa Formation	60-170		Dark-gray to black shale interbedded with tan and gray sandstone.	Not known to yield significant amounts of water to wells.
		Cheyenne Sandstone	50-220		Gray to brown fine- to medium-grained sandstone interbedded with dark-gray shale.	The sandstone beds, although untested, may be a potential aquifer. Water probably too highly mineralized for most uses.

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

EXPLANATION OF ROCK SYMBOLS



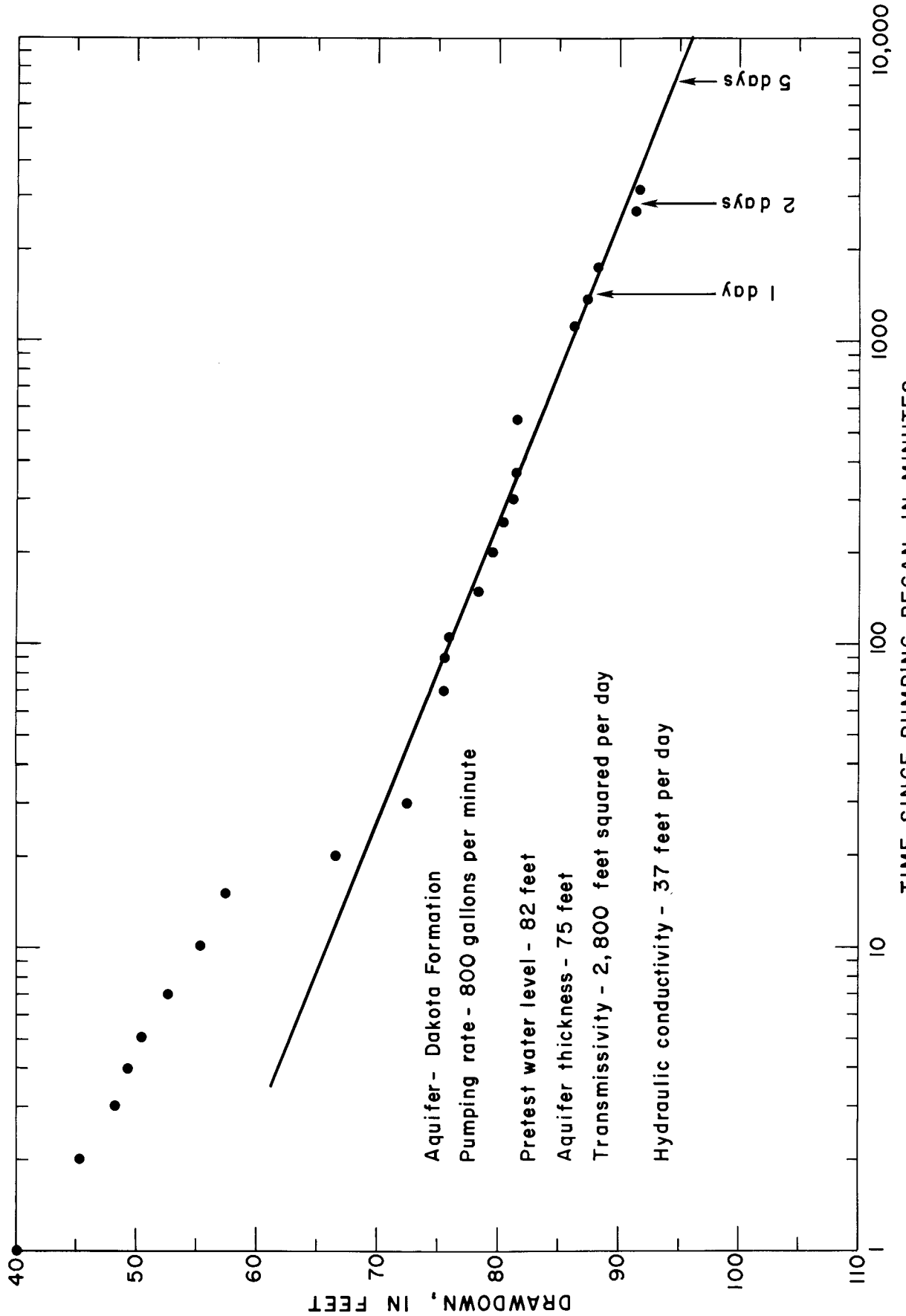


FIGURE 6.—Aquifer-test data from well 19-23W-1CCB.

CHEYENNE SANDSTONE

The Cheyenne Sandstone is a gray to brown fine- to medium-grained sandstone interbedded with shale. It lies below and is separated from the Dakota Formation by the Kiowa Formation as indicated in table 1. No information was collected concerning the Cheyenne Sandstone during this study, but from an examination of oil-well geophysical logs, it is estimated to range in thickness from 50 to 220 feet in Ness County.

DAKOTA FORMATION

The Dakota Formation is the oldest formation from which water is pumped for irrigation in Ness County. It is composed of lenticular brown to gray sandstone, gray sandy shale, and varicolored shale. The sandstone beds are commonly interbedded with shale. The sandstone may be cemented with calcium carbonate or with iron oxide. The beds that are cemented with iron oxide are generally harder than others.

Only one large-capacity well, described at the end of this report (table 4) as well number 19-23W-1CCB, pumped water for irrigation from the Dakota aquifer in 1975. The well is used to irrigate 120 acres of corn, milo, and wheat. The depth of the well is 450 feet, and the casing is screened opposite sandstone from 350 to 425 feet. The aquifer is confined and the static water level stood at a depth of 82 feet below land surface in July 1975. The well was pumped at 800 gal/min in July 1975 with a drawdown of 88 feet after 24 hours pumping and 92 feet after 54 hours pumping. The specific capacity, therefore, was 9.1 (gal/min)/ft after 24 hours and 8.7 (gal/min)/ft after 54 hours, as given in table 4. The transmissivity and hydraulic conductivity were computed to be 2,800 ft^2/day and 37 ft/day respectively, from the aquifer-test results illustrated in figure 6.

The Dakota Formation which ranges in thickness from about 150 to 300 feet, underlies all Ness County at depths ranging from about 100 to 700 feet below land surface (fig. 7). The map showing the depth to the top of the Dakota Formation in Ness County (fig. 7) was adapted from a map prepared in 1973 by K. M. Keene, Kansas Geological Survey (written commun.). It indicates that the Dakota is near land surface in the southeastern part of Ness County, but becomes increasingly deeper to the northwest. Several domestic wells have been drilled to this aquifer where shallower aquifers are missing or inadequate.

Considerable interest exists in testing the Dakota Formation for adequate irrigation supplies. Owing to differences in lithology, the hydraulic conductivity of the sandstone is variable, and yields differ from place to place. Analysis of several test holes drilled in the vicinity of the Clouston well (19-23W-1CCB) showed that not only does the lithology of the sandstone differ within a few hundred feet, but also the depth and thickness of sandstone lenses in the Dakota Formation are unpredictable.

A well tapping the Dakota Formation anywhere in the county could be expected to yield about 20 gal/min, but only sufficient test drilling will show where a well capable of yielding more than 100 gal/min can be constructed.

OGALLALA FORMATION

The Ogallala Formation, which consists chiefly of alluvial deposits, is the principal aquifer in western Kansas. Unfortunately, the Ogallala aquifer in Ness County is thin and largely drained by valleys cut into the bedrock. The eastern edge of the Ogallala Formation occurs as erosional remnants in the western part of Ness County and thins to the east probably owing to a lesser amount of original deposition. The Ogallala Formation is as much as 100 feet thick in northwestern Ness County. One remnant extends across two-thirds of the northern tier of townships and the other remnants, of about 15 square miles each, extend into the western part of the county (see fig. 5).

The Ogallala Formation consists of sand, gravel, silt, clay, and caliche and is largely unconsolidated, but cemented by calcium carbonate locally into "mortar beds." The materials composing the Ogallala deposits were derived from erosion of older rocks to the west, chiefly from the flanks of the Rocky Mountain uplift; however, subsequent erosion has completely removed any connection with the Rocky Mountains.

The Ogallala aquifer does not yield sufficient water in Ness County for large-scale development of irrigation, industrial, or municipal uses, but it may be a source of supply where demands are less than 250 gal/min. Reported depths of wells drilled through the Ogallala Formation range from 34 to 100 feet. The saturated thickness of the Ogallala ranges from 0 to 30 feet and the yield to irrigation wells commonly ranges from 30 to 245 gal/min. Isolated channels may exist in the bedrock where the saturated thickness is greater than 30 feet, and the yield might be greater than 245 gal/min, but none were reported during the study. Seven irrigation wells pumped from the Ogallala Formation in 1975 to irrigate about 100 acres. Nine public-supply wells furnish water for the towns of Brownell, Ransom, and Utica, which have a total population of about 800.

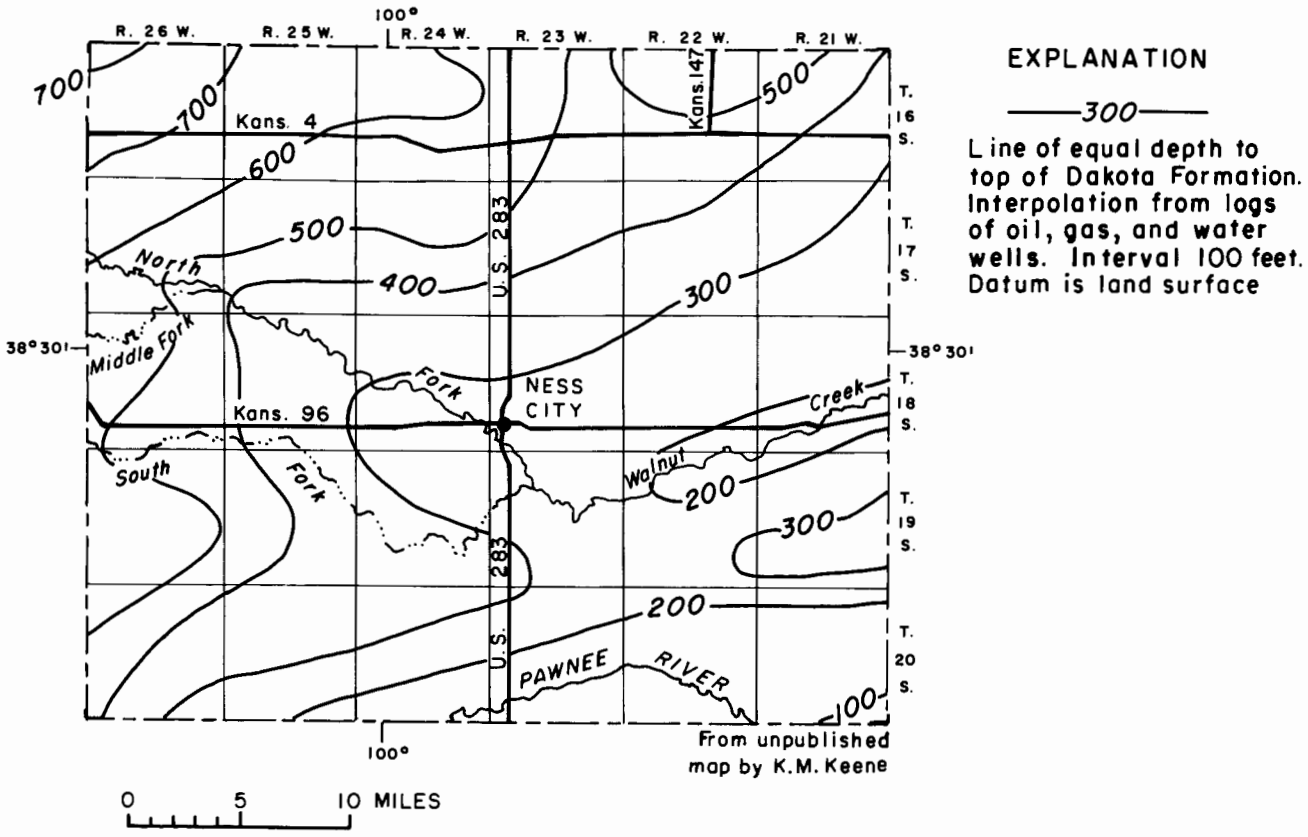


FIGURE 7.—Generalized depth to top of the Dakota Formation.

Domestic and stock wells generally yield 5 gal/min where the Ogallala aquifer has at least 5 feet of saturated material. Where the Ogallala is drained, residents use cisterns, haul water, or drill to the Dakota Formation for a water supply.

ALLUVIUM

Alluvium underlies the flood plains and occurs along valleys of major streams and their tributaries. The principal valleys are the Pawnee River in the southern part, and Walnut Creek, which flows eastward across the center of the county (see fig. 5). The alluvium of the two valleys supplies more water for irrigation and municipal use than any other source in Ness County. However, the area underlain by the alluvium is small compared to the total area of the county.

The alluvium consists predominantly of sand, gravel, and lesser amounts of silt and clay, derived from the Ogallala Formation and Niobrara Chalk. The upper few feet of the alluvium consists predominantly of silt, clay, and sand; however, these finer deposits do not limit or seriously hinder recharge by precipitation or streamflow. The deposits are as much as 127 and 82 feet thick in Pawnee River and Walnut Creek valleys, respectively, but only 90 feet or less of the alluvium is saturated in the Pawnee River valley and 40 feet or less in Walnut Creek valley. For a more detailed discussion of the ground-water resources of Pawnee River valley, the reader is referred to Fishel (1952).

Measured yields from wells along the Pawnee River valley and its tributaries range from 125 to 900 gal/min, but yields of as much as 1,800 gal/min were reported (see table 4). Yields of 85 to 770 gal/min were measured along Walnut Creek valley.

Sixty-seven irrigation wells pump from the alluvium of Walnut Creek valley to irrigate about 2,100 acres, and 70 irrigation wells pump from the alluvium of the Pawnee River valley to irrigate about 4,800 acres. One irrigation well in Pawnee River valley was used only as an observation well in 1975. Eighteen public-supply wells furnish water for the towns of Bazine and Ness City, which have a total population

of about 2,150. Smaller yielding 6-inch diameter wells supply water from the alluvium of the principal valleys and their tributaries for many domestic and stock uses.

The number of irrigation and public-supply wells is increasing each year as new wells are drilled in the alluvium of Pawnee River and Walnut Creek valleys to supplement decreasing yields that occur late in the summer. Decreasing yields result from well interference and declines in water levels.

Yields from wells in the alluvium of smaller valleys, tributaries, and draws are considerably less than in the two major valleys because of the presence of finer, less permeable materials. As a result, wells generally are adequate for only domestic or stock use, and yield 1 to 140 gal/min. These smaller valleys are underlain, to a large part, by the Carlile Shale. Because groundwater storage in the smaller valleys is limited, water levels fluctuate primarily in response to rainfall. Sometimes wells go dry after prolonged periods of little precipitation.

Chemical Quality of Ground Water

Chemical character of ground water in Ness County is indicated by analyses of water collected from 2 wells tapping the Dakota Formation, 2 wells tapping the Ogallala Formation, and 21 wells tapping alluvium of the Pawnee River and Walnut Creek valleys. The chemical character of water from the Cheyenne Sandstone is inferred by analysis of data from adjacent counties. Concentrations of dissolved constituents in water from wells are listed in table 5.

In the analyses of water samples for selected chemical constituents (table 5), values also are listed for dissolved solids, hardness, sodium-adsorption ratio (SAR), and specific conductance. Water containing more than 1,000 mg/L (milligrams per liter) of dissolved solids generally is objectionable for most uses. Hardness of water, expressed in terms of $CaCO_3$ (is classified Durfor and Becker, 1964) as: soft, less than 60 mg/L; moderately hard, 61-120 mg/L; hard, 121-180 mg/L; and very hard, more than 180 mg/L. The suitability of water for irrigation described here is based on the classification by the U.S. Salinity Laboratory Staff (1954). The salinity hazard of waters used for irrigation is determined on the basis of specific conductance, and the sodium hazard is determined on the basis of the sodium-adsorption ratio.

Analysis of water samples collected from wells tapping the Cheyenne Sandstone and examination of electric logs from adjacent counties to the east and south indicate that the water is high in dissolved-solids concentration. It probably would be unsatisfactory for most irrigation, industrial, and public-supply uses.

The Dakota Formation yields a mixed sodium bicarbonate sulfate type or a sodium chloride bicarbonate type water, based on predominant ions. The analyses of the two samples of water from the Dakota show a dissolved-solids concentration of 684 and 1,420 mg/L. This water, which has a high to very high salinity hazard and a very high sodium hazard, is considered to be marginal for irrigation of most crops and for most soil conditions. Water in the Dakota (ranging in hardness from 40 to 64 mg/L) is soft to moderately hard, but it contains more dissolved solids than water in the Ogallala and alluvium.

Wells developed in the Ogallala Formation in northwestern Ness County yield a calcium chloride bicarbonate type water. The two samples analyzed from wells 16-26W-23ABB and 16-26W-35CCD contained 297 and 446 mg/L of dissolved solids. This water, having a medium salinity hazard and a low sodium hazard, is considered to be suitable for irrigation. The water (with hardness of 208 and 334 mg/L) is very hard.

Water from the alluvium in Ness County is of the calcium bicarbonate type, and the dissolved-solids concentrations range from 404 to 794 mg/L. This water generally has a high salinity hazard and a low sodium hazard when used for irrigation. The water (ranging from 233 to 565 mg/L) is very hard.

Water from the alluvium would probably require some special practices to keep the soil salinity to a low enough level unless an excess of irrigation water is applied to cause leaching. While similar to the water from the alluvium, the water from the Ogallala Formation has a lower leaching requirement. Water from the Dakota Formation probably would cause difficulty if used for irrigation because of both soil salinity and poor tilth created by the high sodium concentration.

Maximum concentrations for use in drinking water recommended by the Kansas Department of Health and Environment are shown as follows:

Constituent	*Recommended limits in milligrams per liter*
Dissolved solids	500
Iron (Fe)	.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1.5
Nitrate (NO_3)	45

Availability of Surface Water

Most of Ness County is within the Arkansas River drainage basin. Walnut Creek drains all Ness County except the strip on the north edge and another along

the south edge. Walnut Creek begins in Lane County and flows eastward across the county into Rush County and joins the Arkansas River about 50 miles east of the Ness County border. Only a narrow strip, 4 to 8 miles wide along the north edge of Ness County drains into the Smoky Hill River to the north, as shown in figure 3. The southern part of Ness County drains into the Pawnee River, which begins in Finney County and joins the Arkansas River at Larned.

Numerous seeps and pot holes containing water were observed along the Walnut Creek drainage where it intersects the Ogallala Formation in the western and northern part of the county. The seeps act as drains along the eastern edge of the Ogallala Formation. The ground-water contribution to streamflow is not great in any one drainage because transpiration and evaporation consume this supply within a few miles downstream, but the amount of water contributed to all the tributaries could amount to a significant figure.

Ten surface-water rights have been appropriated to divert water from Walnut Creek and two have been appropriated from Pawnee River in Ness County. In 1974, only 17 acre-feet was diverted to irrigate 25 acres along Walnut Creek and none was diverted along the Pawnee River. In 1975, no water was diverted from either stream because both the Pawnee River and Walnut Creek had no flow for many days during the 1975 irrigation season.

The status of streamflow was observed at temporary station sites (fig. 3) from July 15, 1975 to February 3, 1976, and both streams were dry until January 26, 1976. Sometime between January 26 and February 3, 1976, Walnut Creek began to flow and on February 3, 1976, had a flow of 0.48 ft^3/s at temporary station 1, but the Pawnee River at temporary station 2 remained dry.

The annual discharge of principal streams that flow through Ness County is given in table 2. Locations of gaging stations are shown in figure 3.

Residents along the Pawnee River and Walnut Creek valleys report that prior to pump irrigation, these streams flowed continually with enough water to support fish and to fill depressions in the stream channel that made good swimming holes. Subsequently, wells along the Pawnee River valley, both in Ness County and in counties upstream, have pumped water from the alluvium. Pumping by wells has lowered the water table below the creek bed so that water moves from the stream to the aquifer during periods of streamflow resulting from precipitation. The loss to the stream is a gain to the aquifer as recharge. Pumping along the valley also intercepts ground water that would have moved toward the stream, thereby resulting in a depletion or reduction in base flow. Likewise, pumping by wells depletes streamflow along Walnut Creek.

TABLE 2.—Annual discharge of principal streams that flow through Ness County.

Water Year[1]	Station 07141780 Walnut Creek near Rush Center (12 mi. east of Ness County) (acre-feet)	Station 07141200 Pawnee River near Larned (14 mi. southeast of Ness County) (acre-feet)	Station 07140700 Guzzlers Gulch near Ness City (acre-feet)
1970	17,350	27,650	243
1971	12,250	26,050	1,900
1972	17,800	33,000	636
1973	62,730	84,320	3,360
1974	16,820	26,120	2
1975	14,130	11,230	1,440
AVERAGE	23,470[2]	54,990[3]	1,710[4]

[1] 12-month period, October 1 through September 30 of the year shown.
[2] 6 years.
[3] 51 years.
[4] 14 years.

Better farm management in the upland dryland farming areas has reduced runoff to the streams. Terracing, farm retention dams, and tillage retard runoff and make more water available for seepage into the ground for plant use. The use of large machinery has resulted in better cultivation practices that have increased infiltration of precipitation. Yields of dryland crops have increased over the years by development of better varieties and by use of fertilizers. However, increased yields consume more of the water that has been made available, to a large part, by improved farming practices.

GROUND-WATER DEVELOPMENT

Ground-water development for irrigation began in the 1930's along the Pawnee River and Walnut Creek valleys. Early development occurred along the valleys because water levels were shallow, generally less than 30 feet, and depths to bedrock were less than 100 feet; therefore, the cost of constructing wells and pumping water was not as great in comparison to other areas where water levels exceeded 100 feet and depths to bedrock exceeded 300 feet. About 50 irrigation and public-supply wells were constructed before 1950, about 30 in the 1950's, 60 in the 1960's, and 45 during 1970-75, as shown in figure 8. All irrigation and public-supply wells are equipped with deep-well-turbine or submersible-turbine pumps. The power units for the pumped wells are electric motors or internal-combustion engines.

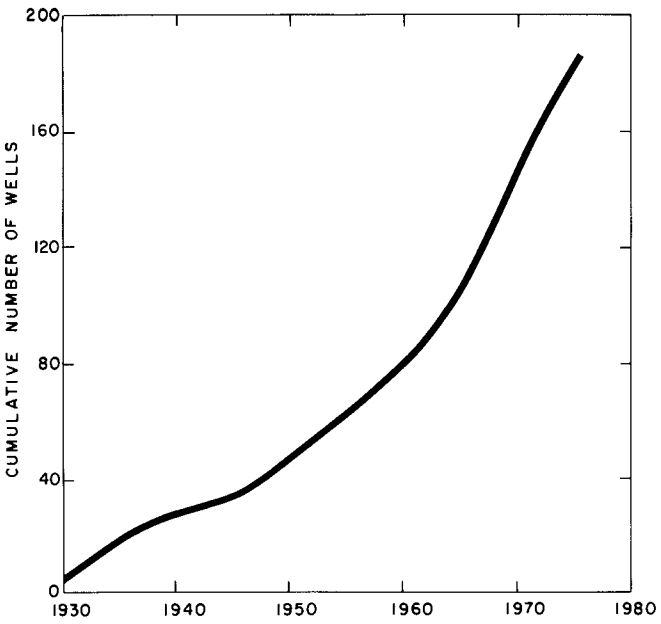


FIGURE 8.—Cumulative number of irrigation and public-supply wells constructed during 1930-75.

Location

Location of irrigation, public-supply, and selected stock wells are shown on plate 1. Included are observation wells used to measure annual or quarterly water levels.

The most intensively developed areas are along the Pawnee River and Walnut Creek valleys. There are 71 irrigation wells located in a 24-square-mile area along the Pawnee River with 7 wells in sec.28, T.20 S., R.22 W. The greatest concentration of wells along Walnut Creek is near Bazine, in sec.31, T.18 S., R.21 W., where 11 irrigation and public-supply wells have been drilled.

Records of 191 wells in Ness County are presented in table 4. Included are 159 irrigation, 3 observation, 27 public-supply, and 2 stock wells. Several irrigation wells also are used as observation wells. Table 4 and plate 1 were intended to include all irrigation and public-supply wells, however, a few may not have been located. Yields listed in table 4 were measured under the operating conditions of the day of measurement and do not necessarily indicate the maximum yield of the well. Well yields generally differ during the irrigation season, and are higher in the spring after water levels have recovered a large percentage of their past season's decline. A decrease in the yield of irrigation wells in the alluvial valleys occurs during the summer because of generally lowered water levels and local well interference.

Withdrawals

Yields from irrigation wells differ because of differences in the thickness and hydraulic conductivity of the water-bearing materials (aquifer). Measured yields ranged from 85 to 900 gal/min; estimated withdrawal was 0.4 to 4 acre-feet per day. An estimate of annual pumpage from irrigation and public-supply wells for 1975 is given in table 3.

Energy Consumption

Energy for irrigation and public-supply wells is from electricity, LPG (liquefied petroleum gas), diesel, or gasoline. The most common sources of energy in Ness County are electricity and LPG. The amount of electricity or fuel to pump 1 acre-foot of water was determined by measuring the rate of discharge and the amount of electricity or fuel used per unit of time at selected wells.

Electrical records can be obtained from utility companies that maintain records of consumption by month and year. Invoices of other fuels are supplied to purchasers by vendors at the time of purchase. The amount of water pumped per well or area is directly related to the amount of energy consumed. Therefore, a record of the amount of electricity or fuel used for irrigation can be used to estimate the amount of water pumped per month or year.

TABLE 3.—Estimated quantity of water pumped from irrigation and public-supply wells.

Area	Aquifer	Number of wells	Acres irrigated	Population served	Withdrawal[1] in 1975 (acre-feet)
Pawnee River	Alluvium	70	4,800		7,200
Walnut Creek	Alluvium	67	2,100		3,150
Walnut Creek	Alluvium	18		2,150[2]	480
Uplands	Ogallala	7	100		150
Uplands	Ogallala	9		800[3]	180
Uplands	Dakota	1	120		180
				TOTAL	11,340

[1] Assuming: 1.5 feet of water applied annually per acre; 200 gallons daily use per person.
[2] Number of persons served in Bazine and Ness City.
[3] Number of persons served in Brownell, Ransom, and Utica.

Electrical-energy input to pump an acre-foot of water is determined by applying the equation:

$$E_e = \frac{(1.955 \times 10^4)\ R\ K_h}{Q\ t_e}$$

where

E_e = kilowatt-hours to pump 1 acre-foot of water (Kwhr/acre-ft);

R = revolutions of meter disc in t_e seconds;

K_h = constant for each meter (generally stamped on nameplate of the instrument) giving watt-hours represented by one revolution of meter disc;

Q = pump discharge, in gallons per minute;

t_e = time, in seconds, for the meter disc to make R revolutions.

Example:

R = 10 revolutions in t_e seconds;

t_e = 40 seconds;

K_h = 24;

Q = 1,000 gallons per minute;

$$E_e = \frac{1.955 \times 10^4 \times 10 \times 24}{1{,}000 \times 40}$$

= 117 kilowatt-hours per acre-foot.

The amount of fuel-energy input to pump an acre-foot of water is determined by applying the equation:

$$E_f = \frac{(5.431 \times 10^3)\ t_f}{Q}$$

where

E_f = gallons of fuel to pump 1 acre-foot of water (gal/acre-ft);

Q = pump discharge in gallons per minute;

t_f = gallons of fuel consumed per hour.

The amount of electricity to pump an acre-foot of water in the Pawnee River and Walnut Creek valleys, as measured at 43 wells, ranged from 97 to 416 Kwhr and averaged 160 Kwhr; the amount of LPG fuel, measured at 14 wells, ranged from 14 to 59 gallons and averaged 34 gallons; and the amount of diesel fuel was 12 and 18 gallons, as measured at two wells. Fifty-four gallons of LPG fuel were consumed per acre-foot of water pumped from the Dakota Formation.

The quantity of water pumped from irrigation wells, for which energy-consumption and pump-discharge data are available, is computed from the following equation:

$$A = \frac{\text{Kwhr}}{E_e} \quad \text{or} \quad A = \frac{F}{E_f}$$

where

A = water pumped from well during the month or year, in acre-feet;

Kwhr = kilowatt-hours of electrical energy consumed during the month or year (the records generally are available from power company);

F = gallons of fuel energy consumed during the month or year.

Power consumption varies with differences in motor, pump, well efficiency, and total head. Inadequate maintenance and improper operating procedures reduce both the efficiency and the life of pumping equipment.

Water-Level Fluctuations

The water table or potentiometric surface is not stationary, but fluctuates much like the water surface of a lake or reservoir. The water table rises when recharge exceeds discharge and declines when discharge exceeds recharge. In Ness County, the alluvium and Ogallala aquifers are unconfined ground-water bodies (water table), and the Dakota is a confined ground-water body (artesian).

The principal factors controlling decline are the amount of water drawn from the ground-water reservoir by transpiration and evaporation, the amount discharged into streams through springs and seeps, and the amount pumped from wells.

The principal factors controlling a rise in water table are direct infiltration of precipitation, seepage of water from streams, and percolation of irrigation water applied to the land. Local rises in the water table may occur near a well or well field after a pumping season as water moves laterally to restore the normal water-table gradient.

The alluvium in Ness County is recharged by precipitation, by seepage of water from streams, and by infiltration of irrigation water. Residents along the Pawnee River and Walnut Creek valleys reported that

at times the streams have flowed continually. This occurs when the water table in the alluvium is higher than the stream, thus contributing a base flow to the stream through springs and seeps. In recent years, the streams are dry much of the time because pumpage and evapotranspiration exceed the amount of natural recharge to the system. The hydrographs for wells 20-22W-20CCC and 20-23W-32CDA along the Pawnee River valley, as shown in figure 9, reflect both the effects of precipitation and pumping. Water levels were fairly constant during the 1940's; that is, recharge and discharge were nearly equal. During 1950 and 1951, water levels rose as a result of above-normal precipitation. During 1952-56, water levels declined as more ground water was discharged to streamflow, transpired through plants along the valley, and pumped by wells. Water levels again responded to recharge from above-normal precipitation in 1958-60, then began a gradual decline of about 0.8 feet per year from 1960 to 1975 with some partial recovery during years of above-normal precipitation. The continuous development of wells along the Pawnee River, both in Ness County and upstream, has lowered the water table until there is essentially no base flow to the stream.

During 1975, small pools or sumps were occasionally present in both the Pawnee River and the Walnut Creek streambeds that contained water. However, most of the ground-water contribution, if any, was consumed by evaporation from the water surface of the pools and by transpiration through trees and plants along the stream channels. In reality, the water level in the alluvium was below the streambed; therefore, during any period of streamflow from precipitation, water is lost from the stream to the ground-water reservoir and is a source of recharge to the aquifer. In one respect, lowering the water level is beneficial because it provides space for percolation of excess runoff that occurs during high streamflow and flooding. Thus, stream channels in the alluvial valleys are line sources of recharge when precipitation is great enough to cause runoff.

Wells along Walnut Creek also have practically dried up the base flow, and streamflow occurs only during periods of sufficient precipitation. Hydrographs for observation wells 19-23W-8CBB and 18-21W-31CAA along Walnut Creek valley (fig. 9) indicate that water levels rose in 1967, then declined until 1971-72. Water levels rose again during the 1972-74 period because of above-normal precipitation.

Ground water pumped from the alluvial valleys of Ness County is renewable during periods of above-normal precipitation; however, pumpage for irrigation is great enough to cause depletions during dry periods.

Gillespie and Slagle (1972) report that recharge from high flows in Walnut Creek and its tributaries can be substantial. High flows produced water-level rises in observation wells in adjacent Rush County of about 6 to 14 feet in 1959, about 2 to 11 feet in 1967, and about 0.5 to 4 feet in 1970.

Declining water levels occur in the alluvium of the tributary valleys and upland draws during extended periods of below-normal rainfall, with subsequent drying up of wells. In addition, because of the relatively shallow depth to water, transpiration by deep-rooted plants during the growing season often results in a decline in water levels.

In contrast to the alluvium, the Ogallala Formation in Ness County receives very little recharge. Annual recharge from precipitation is estimated to be about 0.25 inch or about 1 percent of the average precipitation. The water level in the Ogallala, for the most part, is above the stream valleys. Only small valleys exist in the western part of Ness County where the Ogallala is present. Streams have eroded through the Ogallala into the bedrock, and in this way, act as drains. This has been occurring for a long period of time, so discharge from the Ogallala is about equal to recharge. The amount of ground water draining from the Ogallala to each valley is small, but the amount of water contributed to all tributary valleys could be significant. Field inspections during October and November 1975 revealed only small trickles of less than 0.1 ft^3/s from seeps along contacts of the Ogallala with the bedrock. The seepage, which filled sumps along the channel, subsequently was lost through evaporation, transpiration, or seepage into cracks of the bedrock before reaching the principal valleys of the Pawnee River and Walnut Creek in Ness County and the Smoky Hill River in Trego County. The seeps are enough to support tree growth and grass. Very few wells have been drilled into the Ogallala (see table 4) because the saturated material is thin and, to a large part, drained. Therefore, water-level fluctuations are small because discharge and recharge are small.

The Dakota Formation receives no known recharge in Ness County. Nearest areas of recharge are in adjacent counties to the east and south along outcrops and where the alluvium of deep valleys is in contact

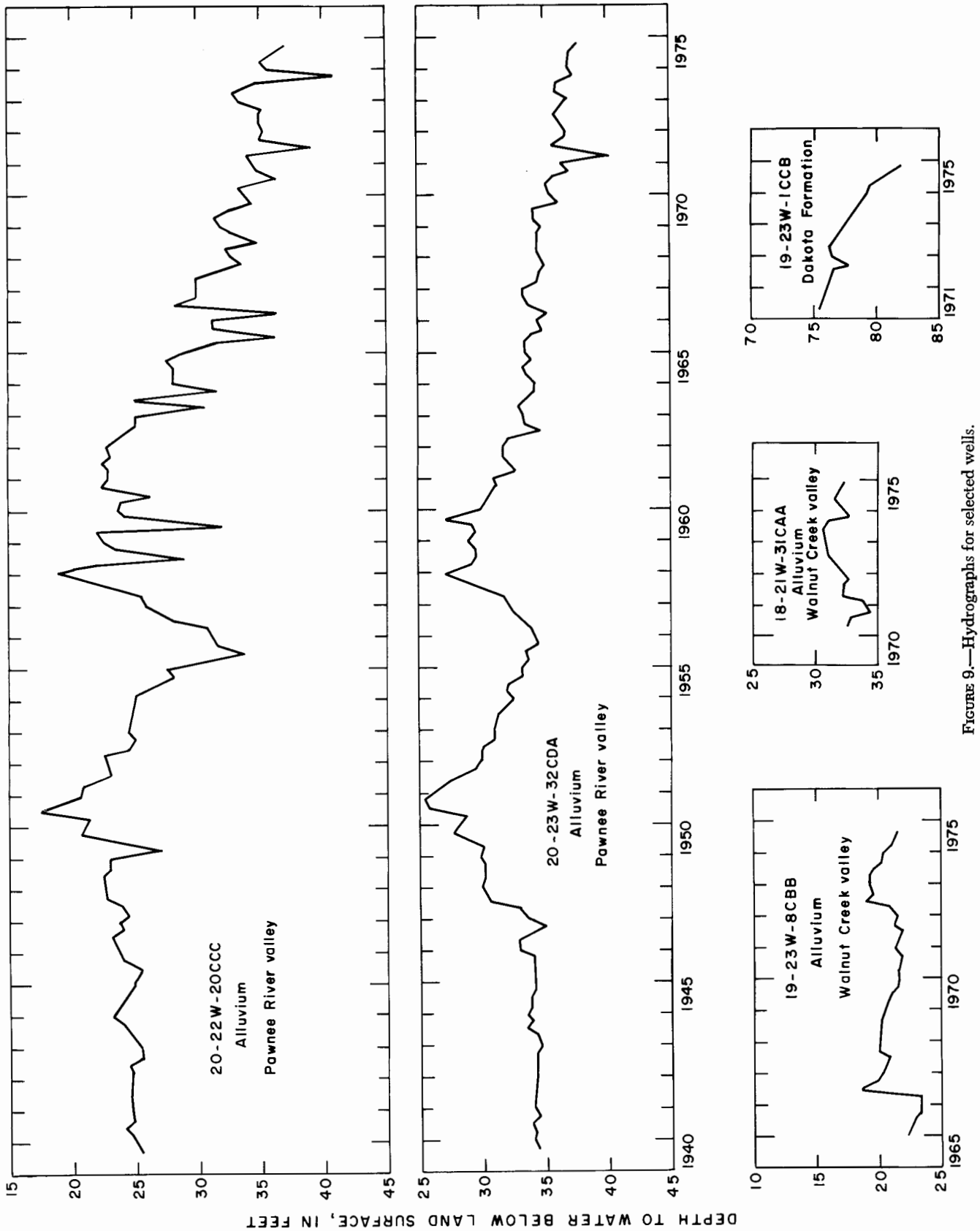


FIGURE 9.—Hydrographs for selected wells.

with the underlying Dakota. The hydrograph (fig. 9) of irrigation well 19-23W-1CCB, which taps the Dakota, indicates that the water level (potentiometric surface) is declining about 1.5 feet per year. This decline probably is the result of ground-water withdrawals at this site because the nearest irrigation well tapping the same aquifer is more than 15 miles.

Potential for Additional Development

The greatest potential for future development of ground water in Ness County is from the Dakota Formation. This aquifer is areally extensive and is the only developed aquifer that underlies the entire county. Well 19-23W-1CCB, in 1975, yielded 800 gal/min for irrigation from the Dakota. The performance of the well and fluctuations of water level are shown in figures 6 and 9, respectively. Several irrigation wells tap the Dakota in Hodgeman County, which adjoins Ness County on the south.

The Dakota differs greatly in lithology and degree of cementing. In general, the cementing reduces the hydraulic conductivity of the aquifer. Yields of wells a few hundred feet apart differ by several hundred gallons per minute.

The quality of water available from the Dakota for irrigation use is speculative because the concentration of sodium may be high enough to affect the tilth of calcium soils. This, however, is the only ground water in Ness County that is soft to moderately hard. Extensive tests to monitor the effects of using high sodium water from the Dakota Formation for irrigation in Ness County are being conducted by the Fort Hays Experiment Station at the site of irrigation well 19-23W-1CCB. Although water from the Dakota may be considered as a supply for industrial, irrigation, and municipal use, its quality should be considered in connection with the economic feasibility of treatment for the intended use.

More studies are needed to test the performance of the Dakota aquifer and its water quality throughout western Kansas. Much interest has been shown in developing a water supply from the Dakota where the Ogallala Formation is missing or inadequate and where additional ground water is needed to supplement existing supplies.

Although the Ogallala in Ness County yields less than 250 gal/min to wells, it probably stores as much or more water than the alluvium because of its greater areal extent. The saturated thickness of the Ogallala decreases toward the edges of the areas of outcrop (see fig. 5), where it is being drained of water along its contact with the underlying bedrock. Likewise, its saturated thickness should be greatest farthest from the outcrops. Therefore, areas such as those along Kansas Highway No. 4, which connects the towns of Utica, Arnold, Ransom, and Brownell, and along the western tier of R.26 W. in Tps. 18 and 19 S. could be sites for further exploration for water in the Ogallala (see figs. 3 and 5).

The Ogallala could be developed further for industrial, minor irrigation, or municipal use in northern and western Ness County if demands are less than 250 gal/min per well and if good quality water is desired. Generally, industries and municipalities can afford to pay more per unit of water than the irrigator. Thus, more wells can be constructed to supply these needs—even though the wells may yield only 50 to 100 gal/min. Land acquisition and well spacing would be factors in developing water stored in the Ogallala, as construction of wells too near or too far apart may not provide best utilization of the ground-water supply. For ultimate development of the Ogallala aquifer in Ness County, construction of a well on every 10-acre tract might be possible in some areas, but management policy might prohibit this practice.

New wells are being drilled into the alluvium of Pawnee River and Walnut Creek valleys in Ness County to maintain irrigation supplies when well yields decrease late in the season owing to well interference and water-level declines.

The greatest concentration of large-capacity wells, those with yields of 100 gal/min or more, is along the entire length of the Pawnee River reach and in the vicinities of Bazine and Ness City along Walnut Creek (see pl. 1). Water stored in the alluvium is depleted gradually year after year and is replenished only in years of excess precipitation, such as 1950-51 and 1958-60. Since 1961, water levels have declined steadily at the rate of about 0.8 feet per year in response to significant increases in the amount of ground water pumped. Because of the high transmissivity and limited storage capacity of the alluvial aquifer, it can be depleted readily by heavy pumping, as well as recharged when excess precipitation and streamflow occur.

Further development of ground water along these valleys for industrial and municipal use is attractive because of the large well yields that are obtainable from rather shallow wells, but extensive development would impair the rights of current users. Unless management restrictions are imposed, ground-water development in these two major valleys will no doubt continue.

The potential for developing any great amounts of water from alluvium and undifferentiated deposits in

tributary creek valleys and draws that overlie the Carlile Shale is not very promising. However, these deposits may contain small amounts of water and serve as local catchment basins to yield small quantities for domestic and stock use. The water in these deposits is reported to be of poorer quality than that from the alluvium of the principal valleys.

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GLOSSARY OF HYDROLOGIC TERMS

Most of the definitions of hydrologic terms given below are taken from Lohman and others (1972).

Aquifer—Formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquifer test—Measurements of the effect with time of a discharging well on the water level in the well and in nearby wells. Data from aquifer tests are used primarily to determine the hydraulic conductivity, transmissivity, and storage coefficient or specific yield of an aquifer.

Artesian—Synonymous with confined. Artesian water is equivalent to confined ground water. The water level in an artesian well stands above the top of the artesian water body it taps. If the water level in an artesian well stands above the land surface, the well is a flowing artesian well.

Confined ground water—Ground water that is under pressure significantly greater than atmospheric, and has as its upper limit the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

Drawdown—The lowering of the potentiometric surface as a result of pumping. It is the arithmetic difference between the pumping level and the static level of the water surface.

Hydraulic conductivity—If a porous medium is isotropic and the fluid is homogeneous, the hydraulic conductivity of the medium is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Percolation—Laminar flow of water, usually downward, by the force of gravity or under hydrostatic pressure, through small openings within a porous material.

Potentiometric surface—A surface that represents the static head. As related to an aquifer, it is defined by the levels to which water will rise in tightly cased wells.

Saturated thickness—The amount (thickness) of aquifer material that contains all the water in interstices that it is capable of holding.

Specific capacity—The rate of discharge of water from a well divided by the drawdown of water level within the well.

Transmissivity—The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Unconfined ground water—Water in an aquifer that has a water table.

Water table—That surface in an unconfined ground-water body at which the water pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body enough to hold standing water. The water table is a particular potentiometric surface.

TABLE 4.—Records of selected wells.

Well number (1)	Owner or user	Year completed (19—)	Depth of well (2)	Diameter of casing (inches)	Geologic unit (3)	Method of lift and type of power (4)	Use (5)	Yield (gallons per minute) (6)	Specific capacity: Gallons per minute per foot of drawdown (7)	Specific capacity: Hours	Altitude of land surface above mean sea level (feet) (8)	Depth to water below land surface datum (feet) (9)	Date of measurement (10)	Chemical data (11)	Acres irrigated	Power consumption per acre-foot: KWH (12)	Power consumption per acre-foot: Gallons of fuel
16-22W-27BAA	City of Brownell	53	65 R	18	TO	T,E	PS	165 R				47 R	53				
16-24W-15ABB	F. H. Flax	56	38 R	24	TO	SUB,E	I,O					29.9	1/75				
16-24W-15ACA	F. H. Flax	56	41 R	24	TO	SUB,E	I	215	44			23.7	1/75		10	149	
16-24W-15ACC	F. H. Flax	72	84 R	12	TO	SUB,E	I	245	20			64 R	72		25	100	
16-24W-15ADB	F. H. Flax	56	42 R	24	TO	SUB,E	I	215	35			21.5	1/75		10	193	
16-24W-15DDD	City of Ransom	38	40 R	8	TO	T,E	PS	150 R				28.0	3/76				
16-24W-15DDD2	City of Ransom	38	40 R	8	TO	T,E	PS	150 R				28.0	3/76				
16-24W-15DDD3	City of Ransom	68	40 R	8	TO	T,E	PS	150 R				28.0	3/76				
16-26W-23ABB	City of Utica	56	34 R	18	TO	T,E	PS	30 R				24 R	56	C			
16-26W-35CCD	City of Utica	53	40 R	13	TO	T,E	PS	40 R			2568	30 R	53	C			
16-26W-35CDC	City of Utica	53	35 R	18	TO	T,E	PS	60 R			2562	25 R	53				
17-25W- 7AA	Duane Stutz	49	35 R	24	QA	T,E	I	120 R				25 R	49		5		
17-25W- 7AA2	Duane Stutz	51	39 R	16	QA	T,E	I	110 R				22 R	51		5		
17-25W- 7AA3	Duane Stutz	70	40 R	16	QA	T,E	I	65 R				25 R	70		5		
17-25W- 7AA4	Duane Stutz	70	45 R	16	QA	T,E	I	35 R				30 R	70		5		
17-25W- 7AA5	Duane Stutz	70	38 R	16	QA	T,E	I	100 R				22 R	70		5		
17-25W- 7AA6	Duane Stutz	70	39 R	16	QA	T,E	I	120 R				20 R	70		5		
17-25W- 7AA7	Duane Stutz	73	40 R	16	QA	T,E	I	200 R				20 R	73		5		
17-25W- 8BB	Duane Stutz	70	25 R	16	QA	T,E	I	140 R				5 R	70		5		
17-25W- 8BB2	Duane Stutz	73	12 R	16	QA	T,E	I	110 R				5 R	73		5		
17-25W- 8BB3	Duane Stutz	73	35 R	16	QA	T,E	I	65 R				20 R	73		5		
17-26W- 2BAA	City of Utica	56	52 R	18	TO	T,E	PS	40 R			2562	40 R	56				
17-26W- 2BAB	City of Utica	66	40 R	18	TO	T,E	PS	50 R			2552						
18-21W-24ACA	James Seltman	74	62 R	16	QA	T,E	I	520	47		2098	41.0	9/75		50	135	
18-21W-24BAC	James Seltman	74	80 R	16	QA	T,E	I	675 R			2110	45.0	11/74		133		
18-21W-25AAA	Lon Wells, Jr.	65	50 R	16	QA	T,E	I	350 R			2085	30.7	11/74		22		
18-21W-25AAB	Lon Wells, Jr.	66	50 R	16	QA	T,E	I,O	275 R			2085	28.6	11/74		23		
18-21W-27CBC	E. H. Marshall	67	48 R	16	QA	C,E	I	300 R			2100	32.0	11/74		50		
18-21W-30ACB	Emanuel Kuehn	73	32 R	24	QA	T,G	I	200 R			2122	20 R	73		22		
18-21W-31ACA	Glenn Schniepp	70	52 R	16	QA	T,LPG	I	350 R			2123	27.5	12/74		55		
18-21W-31CAA	George Diemer		44 R	5	QA		O				2122	33.8	12/71				
18-21W-31CAB	City of Bazine	35	48 R	12	QA	T,E	PS	150 R			2126						
18-21W-31CAD	City of Bazine	50	48 R	12	QA	T,E	PS	220 R			2127						
18-21W-31CCA	Reuben Dewald	57	49 R	19	QA	T,T	I	230 R			2131	35.0	11/74		5		
18-21W-31CCC	Reuben Dewald	61	62 R	19	QA	T,E	I	60 R			2132	42.7	11/74		2		
18-21W-31CDBB	Reuben Dewald	57	49 R	18	QA	T,T	I	330 R			2129	34.9	11/74		6		
18-21W-31CDBC	Waldimore Strecker	35	54 R	18	QA	T,T	I	400 R			2129	35.0	11/74		26		
18-21W-31DBA	Glenn Schniepp	65	36 R	16	QA	T,E	I	175 R			2118	18.1	12/74		25		
18-21W-31DBB	Glenn Schniepp	71	48 R	16	QA	T,E	I	50 R			2126	30.1	12/74		25		
18-21W DBD	Glenn Schniepp	65	50 R	16	QA	T,E	I	175 R			2121	32.7	12/74		25		
18-22W-13DCC	J. F. Wunder	67	21 R	15	QA	SUB,E	I	30 R			2148	97.5	11/74		7		
18-22W-13DCC2	J. F. Wunder	67	21 R	15	QA	SUB,E	I	50 R			2148				7		

TABLE 4.—continued.

Well number (1)	Owner or user	Year completed (19...)	Depth of well (2)	Diameter of casing (inches)	Geologic unit (3)	Method of lift and type of power (4)	Use (5)	Yield (gallons per minute) (6)	Specific capacity: Gallons per minute per foot of drawdown (7)	Specific capacity: Hours	Altitude of land surface above mean sea level (feet) (8)	Depth to water below land surface datum (feet) (9)	Date of measurement (10)	Chemical data (11)	Acres irrigated	Power consumption per acre-foot: KWH (12)	Power consumption per acre-foot: Gallons of fuel
18-22W-13DCC3	J. F. Wunder	67	21 R	15	QA	SUB,E	I	75 R			2148				8		
18-22W-13DCC4	J. F. Wunder	74	21 R	15	QA	SUB,E	I	30 R			2148				7		
18-22W-16ADD	Vernon Schwartz	39	52 R	16	QA	T,LPG	I	140			2204	30.8	11/74		14		
18-22W-35DCA	Larry Kleweno	74	55 R	16	QA	T,E	I	440 R			2142	30.8	11/74		60		
18-22W-35DCC	Larry Kleweno	74	53 R	16	QA	T,E	I	318 R			2142	31.5	11/74		24		
18-22W-36DCC	Galen Ely	56	58 R	18	QA	T,G	I	400 R			2134	34.8	12/74		26		
18-23W-30BCC	City of Ness City	75	60 R	18	QA	T,E	PS	125 R			2240	29.0	1/76				
18-23W-30CBC	City of Ness City	69	54 R	16	QA	T,E	PS	90 R			2245	38.0	1/74				
18-23W-30CBD	City of Ness City	32	51 R	12	QA	T,E	PS	65 R			2242	35.0	1/74				
18-23W-30CCA	City of Ness City	32	52 R	12	QA	T,E	PS	50 R			2245	42.0	1/74				
18-23W-30CCA2	City of Ness City	34	52 R	12	QA	T,E	PS	65 R			2242	32.0	9/74				
18-23W-31ADB	City of Ness City	75	82 R	18	QA	T,E	PS	125 R			2240	55.0	1/76				
18-23W-31CAC	City of Ness City	47	48 R	16	QA	T,E	PS	90 R			2233	31.0	1/74				
18-23W-31DCB	City of Ness City	47	48 R	16	QA	T,E	PS	125 R			2229	31.0	1/74				
18-24W-16DCC	Bert Jones	55	68 R	19	QA	T,E	I	200 R			2278	28.5	12/74		25		
18-24W-22CCB	Junior Gabel	69	67 R	16	QA	T,E	I	250 R			2279	29.4	10/74		35		
18-24W-23DCC	Ummel Brothers		45 R	18	QA	T,T	I	450 R			2259	23.1	11/74		37		
18-24W-23DDC	Ummel Brothers	-	45 R	18	QA	T,T	I	450 R			2259	23.2	11/74		38		
18-24W-25ACB	City of Ness City	69	51 R	16	QA	T,E	PS	135 R			2250	32.0	1/74				
18-24W-25ADC	City of Ness City	67	52 R	16	QA	T,E	PS	125 R			2241	32.0	1/74				
18-24W-25BBA	Glen Pember	66	54 R	18	QA	T,E	I	95	9	94	2254	26.4	11/74	C	17		
18-24W-25DCA	City of Ness City	54	56 R	16	QA	T,E	PS	115 R			2243	37.0	1/74				
18-24W-25DCC	City of Ness City	55	58 R	16	QA	T,E	PS	40 R			2251	43.0	5/74				
18-24W-26DAA	Dwaine Radke	55		18	QA	T,LPG	I	350 R				17.7	12/74		35		
18-24W-26DBC	Dwaine Radke	60	62 R	18	QA	T,D	I	250 R				28.5	12/74		37		
18-24W-27ADB	Otto Stoppel	67	66 R	18	QA	T,LPG	I	300 R			2270	35.1	10/74				
18-24W-36AAA	City of Ness City	75	60 R	18	QA	T,E	PS	125 R			2240	35.0	1/76				
18-24W-36ADB	Keith Parkerson	71	59 R	16	QA	T,LPG	I	320	32		2235	36.4	10/74		40		
18-25W- 5ACA	Leonard Norton	72	70 R	16	QA	T,E	I	400	12		2376	26.6	12/74		50	145	
18-25W- 5ACB	Leonard Norton	72	62 R	16	QA	T,E	I	165	5		2383	26.8	12/74		20	212	
18-25W-33ADC	Chris Dinges	65	48 R	20	QA	T,E	I	350 R			2388				24		
18-25W-33BAD	Chris Dinges	65	48 R	20	QA	T,E	I	485	44		2393	18.8	11/74		29	97	
18-25W-33BBC	Chris Dinges	65	48 R		QA	T,T	I,O	350 R			2402	24.2	11/74				
18-25W-33BCB	Chris Dinges	65	48 R	20	QA	T,E	I	350 R			2398	22.2	11/74		30		
18-25W-33BDB	Chris Dinges	65	48 R	20	QA	T,E	I	600 R			2392	18.4	11/74				
18-26W- 6BAB	C. J. Whipple	58		12	QA,TO	SUB,E	I				2570	6.8	12/74		13		
18-26W- 6BAB2	C. J. Whipple	58		12	QA,TO	SUB,E	I,O				2570	7.4	12/74		13		
18-26W- 6BAB3	C. J. Whipple	58		12	QA,TO	SUB,E	I				2570	3.7	12/74		14		
19-21W- 6BBC	Waldimore Strecker	67	47 R	19	QA	T,E	I	50 R			2132	35.7	11/74		14		
19-21W- 6BCA	L. A. Strecker	56	55 R	16	QA	T,E	I	185			2132			C	9		
19-21W- 6BCB	L. A. Strecker	64	52 R	16	QA	T,E	I	450 R			2132				9		
19-22W- 1ACA	Herbert Moore	71	50 R	16	QA	T,E	I	350 R			2132	36.0	11/74		50		

TABLE 4.—continued.

Well number (1)	Owner or user	Year completed (19—)	Depth of well (2)	Diameter of casing (inches)	Geologic unit (3)	Method of lift and type of power (4)	Use (5)	Yield (gallons per minute) (6)	Specific capacity: Gallons per minute per foot of drawdown (7)	Specific capacity: Hours	Altitude of land surface above mean sea level (feet) (8)	Depth to water below land surface datum (feet) (9)	Date of measurement (10)	Chemical data (11)	Acres irrigated	Power consumption per acre-foot: KWH (12)	Power consumption per acre-foot: Gallons of fuel
19-22W- 1ADA	Herbert Moore	71	50 R	16	QA	T,E	I	225 R			2131	34.4	11/74		50		
19-22W- 1BAA	Herbert Moore	71	50 R	16	QA	T,E	I	300 R			2133	33.8	11/74		51		
19-22W- 3ACD	Larry Kleweno	68	47 R	16	QA	T,E	I	85	7	120	2142	31.1	11/74	C	23	338	
19-22W- 3ADC	Larry Kleweno	74	53 R	16	QA	T,E	I	120	7	168	2141	31.5	11/74		25	416	
19-22W- 4DCD	A. Elaine Gross		54 R	16	QA	T,E	I	300 R			2153	28.6	11/74		30		
19-22W- 7AAD	George Knotts	56	59 R	16	QA	T,E	I	135	10	72	2167	35.8	10/74		57	323	
19-22W- 7ADC	George Knotts	58	49 R	16	QA	T,LPG	I	250	31	72	2172	37.8	10/74	C	57		43
19-22W- 7ADD	George Knotts	70	55 R	16	QA	T,E	I	115	23	72	2170	38.1	10/74		57	230	
19-22W- 8ABB	Richard Stenzel	74	56 R	16	QA	T,E	I	400 R			2160	30.3	11/74		50		
19-22W- 8ADB	Richard Stenzel	71	52 R	16	QA	T,E	I	300 R			2163				50		
19-22W- 8BCA	Ron Eckels	69	61 R	16	QA	T,LPG	I	770	59		2166	36.9	10/74		50		14
19-22W- 8BCB	Ron Eckels	49	58 R	12	QA	T,LPG	I	670	61	504	2168	36.0	10/74	C	50		16
19-23W- 1CCB	J. R. Clouston	70	450 R	16	KD	T,LPG	I,O	800	9	54	2214	79.5	3/75	C	120		54
19-23W- 5BDB	Alvin Langer	66	65 R	16	QA	T,D	I	355	18		2222	33.6	10/74		60		12
19-23W- 5CCD	City of Ness City	71	70 R	16	QA	T,E	PS	105 R			2218	30.0	1/74				
19-23W- 5CD	City of Ness City	58	70 R	16	QA	T,E	PS	95 R			2218	32.0	1/74				
19-23W- 5DCC	City of Ness City	58	72 R	16	QA	T,E	PS	115 R			2210	36.0	1/74				
19-23W- 6AAA	Alvin Langer	74	65 R	16	QA	T,D	I	155	11		2227	30.2	10/74		32		18
19-23W- 8CBA	Robert Schniepp	70	48 R	16	QA	T,LPG	I	260	22		2222	31.9	10/74		30		21
19-23W- 8CBB	Robert Schniepp		52 R	1	QA	N	O				2220	21.3	8/71				
19-23W- 8CCC	Robert Schniepp	44	42 R		QA	T,LPG	I	200 R			2223	27.1	10/74		10		
19-23W-11BBD	George Clouston	56	44 R	16	QA	T,LPG	I	250 R			2191	26 R	10/74				
19-23W-11BBD2	George Clouston	58	44 R	16	QA	T,LPG	I				2191	26 R	10/74				
19-23W-14BAD	H. H. Cooper	58	58 R	16	QA	T,LPG	I	350 R			2184	37.5	10/74		17		
19-23W-14DBA	Orville Pfaff	64	70 R	18	QA	T,LPG	I	350 R			2177	37.8	10/74		35		
19-23W-21DA	Ralph Stum	75	282 R	4	KD	T,E	S				2240			C			
19-24W- 7CDA	Charles Shauers	48	34 R	19	QA	T,D	I	450 R			2330	16.4	11/74		48		
19-24W- 7DBC	M. L. McCoy	65	60 R	18	QA	T,E	I	350 R			2345	43.4	11/74		35		
19-24W- 8DCC	Art Pember	68	64 R	18	QA	T,E	I	370	30		2332	36.9	11/74		25	127	
19-24W-17BAA	Art Pember	68	63 R	18	QA	T,E	I	135	14		2332	36.5	11/74		25	170	
19-24W-17BAA2	Art Pember	68	67 R	18	QA	T,E	I	350	25		2332	36.3	11/74		25	141	
19-24W-17BAD	Art Pember	69	55 R	18	QA	T,E	I	200	30		2329	34.6	11/74	C	25	113	
19-25W- 2DBC	W. B. Baldwin	53	55 R	14	QA	T,D	I	225 R			2360	30 R	7/74		55		
20-22W- 3DDD	Fred Stoecklein	74	315 R	5	KD	CY,W	S	80 E			2250	135 R	12/74				
20-22W-19CCD	T. F. Brennan	40	75 R	18	QA	T,E	I	830		72	2190			C	110	126	
20-22W-19DDC	T. F. Brennan	20	75 R	18	QA	T,LPG	I	1000 R			2195				40		
20-22W-20CCC	C. L. Whitley		51 R	20	QA	N	O				2189	34.4	8/71				
20-22W-20CCC2	M. A. Whitley	35	93 R	16	QA	T,E	I	500			2189	24 R	8/45		49	129	
20-22W-20CCC3	M. A. Whitley	72	127 R	16	QA	T,E	I	870	41		2188	33.7	10/74	C	49	112	
20-22W-20DCA	C. G. Holmes	64	86 R	18	QA	T,E	I	800 R			2182	32.4	10/74		97		
20-22W-20DCC	C. G. Holmes	64	90 R	18	QA	T,E	I	1000 R			2184	32.6	10/74		98		
20-22W-21DBB	J. J. Bowman	42	70 R	18	QA	T,E	I	220	10		2178	38.0	10/74	C	40	200	
20-22W-21DBB2	J. J. Bowman	71	70 R	18	QA	T,E	I	220	22		2180	32.5	10/74		40	133	

TABLE 4.—continued.

Well number (1)	Owner or user	Year completed (19....)	Depth of well (2)	Diameter of casing (inches)	Geologic unit (3)	Method of lift and type of power (4)	Use (5)	Yield (gallons per minute) (6)	Specific capacity: Gallons per minute per foot of drawdown (7)	Specific capacity: Hours	Altitude of land surface above mean sea level (feet) (8)	Depth to water below land surface datum (feet) (9)	Date of measurement (10)	Chemical data (11)	Acres irrigated	Power consumption per acre-foot: KWH (12)	Power consumption per acre-foot: Gallons of fuel
20-22W-27BCD	Harry Shanks	65	63 R	16	QA	T,E	I	300	30		2177	34.3	10/74		48	110	
20-22W-27CBB	A. Barricklow	47	59 R	16	QA	T,E	I	760 R			2175	33.2	10/74		48		
20-22W-27DCD	Thelma Stone				QA	T,E	I	1000 R			2171				33		
20-22W-28AAC	A. Barricklow	51	65 R	16	QA	T,LPG	I	1000 R			2178	28 R	51		43		
20-22W-28ACC	A. Barricklow	51	91 R	16	QA	T,E	I	1180 R			2172	28 R	51		60		
20-22W-28BCC	Dale Bowman	56	98 R	16	QA	T,E	I	770	77		2185	37.6	10/74	C	70	120	
20-22W-28CBC	J. L. McFadden	33	60 R	18	QA	T,E	I				2185				53		
20-22W-28CCB2	H. M. McFadden	33	90 R	18	QA	T,E	I				2185	41.9	10/74				
20-22W-28CCC	Nellie McFadden	29	60 R	18	QA	T,E	I				2185	42.8	10/74				
20-22W-28DCC	Omar Cook	30	60 R	24		T,E	I				2181	30 R	30		40		
20-22W-29ACD	R. F. Uehling	55	80 R	14	QA	T,E	I	800 R			2188	42.0	10/74		115		
20-22W-29BDA	R. F. Uehling	74	125 R	16	QA	T,E	I	550 R			2190				110		
20-22W-29CBB	Harry Hall	66	87 R	16	QA	T,LPG	I	600	16	1	2191	39.3	10/74	C	30		18
20-22W-29DBB	Harry Hall	57	108 R	19	QA	T,LPG	I	950 R			2190	41.7	10/74		77		
20-22W-30AAB	Harry Hall	74	81 R	16	QA	T,LPG	I	650	17	96	2189	36.9	10/74		45		25
20-22W-30ABC	Harry Hall	43	65 R	19	QA	T,LPG	I	1200 R			2195				65		
20-22W-30BCD	Harry Hall	49	63 R	19	QA	T,LPG	I	580			2198			C	138		37
20-22W-30CBA	F. E. Roth	35	60 R	19	QA	T,E	I	520			2195	40.0	10/74		85	155	
20-22W-32AAA	Ervin Koerner	46	60 R	18	QA	T,LPG	I	275			2185	42.7	10/74	C	20		59
20-22W-33ABC	W. D. Barricklow	69	90 R	16	QA	T,LPG	I	870	79		2183	40.6	10/74		70		31
20-22W-33BAD	W. D. Barricklow	52	60 R	16	QA	T,E	I	435	73		2181	41.1	10/74		44	138	
20-22W-33BBA	W. D. Barricklow	48	60 R	16	QA	T,E	I	750			2183	40.7	10/71		36		
20-22W-33DAD	Ray McFadden	24	56 R	18	QA	T,E	I	800 R			2175	36.8	10/74		14		
20-22W-34ACC	Earl Cure	51	90 R	18	QA	T,E	I	1800 R			2173				155		
20-22W-34BCC	Wilma McFadden	66	86 R	16	QA	T,E	I	1600 R			2181				115		
20-22W-34DCB	Orville Pfaff	50	80 R	24	QA	T,LPG	I	1200 R			2171	30 R	50		100		
20-22W-35ACC	T. C. Bowie	35	78 R	16	QA	T,LPG	I	900 R			2166				80		
20-22W-35BCC	Leslie Cox	35	68 R	14	QA	T,E	I,O	700 R			2168	35.4	10/74		100		
20-22W-35CCB	Emerson Cox	69	81 R	19	QA	T,E	I	1000 R			2171	38.2	10/74		131		
20-22W-36CCC	Chester Jordan	72	100 R	16	QA	T,E	I	540	8		2164	38.6	10/74		80	190	
20-22W-36DCB	Melvin Murphy				QA	T,E	I				2155	37.6	10/74				
20-23W-23CCD	H. A. Reinert	60	58 R	18	QA	T,E	I	350	44	1	2215	45.4	10/74	C	60	128	
20-23W-24DCC	M. A. Whitley	35	97 R	16	QA	T,E	I	700 R			2192	26.3	8/45		65		
20-23W-25ACB	Carl Reinert	37	65 R	16	QA	T,E	I	297	30		2201	40.2	10/74		48	132	
20-23W-25ADB	Carl Reinert	71	65 R	16	QA	T,E	I	429	61		2195	41.4	10/74		48	132	
20-23W-25ADC	Carl Reinert	33	61 R	19	QA	T,E	I	374			2201	33 R	33		49	137	
20-23W-25BBC	Donald Dansel	74	30 R	18	QA		I	500 R			2205						
20-23W-25BCC	Donald Dansel	64	65 R	18	QA	T,E	I	500 R			2205	36.1	10/74				
20-23W-25CCB	Carl Reinert	36	113 R	16	QA	T,E	I	445	44		2208	44.5	10/74		50	134	
20-23W-25CCB2	Carl Reinert	45	60 R	16	QA	T,E	I	335	42		2208	44.8	10/74		50	125	
20-23W-26ACD	O. J. Marhofer	53	82	18	QA	T,E	I	630	23		2211	43.9	10/74	C	110	154	
20-23W-26BDC	O. J. Marhofer	48	72 R	18	QA	T,LPG	I	400 R			2209	41.2	10/74		40		
20-23W-26CAB	Harkness & Benson	74	90 R	16	QA	T,E	I	535	6	720	2211	43.1	10/74	C	73	167	
20-23W-26CBD	Harkness & Benson	63	120 R	16	QA	T,E	I	610			2211	44.5	10/74		72	154	
20-23W-26DBC	O. J. Marhofer Est.	74	85 R	16	QA	T,E	I	565	28		2212	44.2	10/74		70	131	
20-23W-26DCC	O. J. Marhofer Est.	45	63 R	19	QA	T,E	I	455	50		2212	40.5	10/74		70	114	

20-23W-27DCB	Ethel Edwards	69	75 R	16	QA	T,E	I	620	44	480	2215	38 R	69	C	70	160	
20-23W-27DDC	Parks & Harkness	69	85 R	16	QA	T,E	I	810	115		2216	41.6	10/74		70	129	
20-23W-28DDA	James Burdett	36	70 R	19	QA	T,E	I	400 R			2220				35		
20-23W-32BBC	Marlin Stum	67	100 R	14	QA	T,LPG	I	900	35		2230	35.	6/75	C	212		24
20-23W-32CDA	J. E. Ficken	34	67 R	19	QA	T,LPG	I,O	1000 R			2233	36.4	12/71		84		
20-23W-33AAB	E. Jedlicka	37	60 R	16	QA	T,LPG	I	700 R			2222	43.	10/74		60		
20-23W-33BCA	Frusher & Frusher	40	85 R	16	QA	T,E	I	455			2225	41.5	10/74		70		
20-23W-33BCC	Frusher & Frusher	65	90 R	16	QA	T,E	I	360	17		2222	41.8	10/74	C	40	163	
20-23W-33CBD	Frusher & Frusher	71	75 R	16	QA	T,E	I	650 R			2225	40.6	10/74		132		
20-23W-34BAC	Frusher & Frusher	72	85 R	16	QA	T,E	I	600	46		2215	41.1	10/74	C	75	134	
20-23W-34BBA	Frusher & Frusher	72	105 R	16	QA	T,E	I	305	9		2216	41.8	10/74		45	185	
20-23W-35BBB	A. Reinert	61	80 R	18	QA	T,E	I	645	49		2217	43.7	10/74		100	138	
20-24W-36BDA	Humburg Ranch Inc.	59	85 R	16	QA	T,LPG	I	415	69		2242	31.7	11/74		107		47
20-24W-36CBB	Humburg Ranch Inc.	67	63 R	16	QA	T,LPG	I	330	47		2245	34.5	9/74		53		47
20-24W-36CCC	Humburg Ranch Inc.	46	54 R	16	QA	T,LPG	I	535	67		2245	33.3	11/74		150		36
20-24W-36CDA	Humburg Ranch Inc.	71	57 R	16	QA	T,E	I	125	25		2245	36.8	9/74	C	15	188	
20-26W- 7BDC	Lyle Davidson	70	50 R	16	QA	T,LPG	I,O	300 R				23.8	12/74		72		
20-26W- 7BDC2	Lyle Davidson	70	50 R	16	QA	T,LPG	I	300 R				26.4	12/74		73		

(1) Numbering system described in text.
(2) Depths of wells given in feet below land surface—no letter after number, measured; R, reported.
(3) Geologic unit—QA, Alluvium; TO, Ogallala Formation; KD, Dakota Formation.
(4) Method of lift—C, centrifugal; CY, cylinder; N, none; SUB, submersible; T, turbine.
Type of power—D, diesel; E, electric; G, gasoline; LPG, liquid petroleum gas; T, tractor; W, wind.
(5) Use—I, irrigation; N, none; O, observation; PS, public supply; S, stock.
(6) Yield given in gallons per minute—no letter, measured during present study; E, estimated; R, reported.
(7) Specific capacity—gallons per minute per foot of drawdown for the time shown in hours.
(8) Altitude of land surface in feet above mean sea level determined by topographic map.
(9) Depth to water below land surface datum (LSD) in feet—measured depths less than 100 feet are given to nearest 0.1 foot and those greater than 100 feet are given to nearest foot; R, reported.
(10) Date of measurement—month and year.
(11) Chemical data—C, complete analysis.
(12) Power consumption—KWH/acre foot, kilowatt hours of electricity per acre-foot of water pumped; gallons/acre-foot, gallons of fuel per acre-foot of water pumped.

TABLE 5.—Chemical analyses of water from selected wells.

[Dissolved constituents and hardness given in milligrams per liter. Analyses by Kansas Department of Health and Environment]

Local well number	Well depth (feet)	Geologic source[1]	Date of collection	Temperature (°C)	Dissolved silica (SiO_2)	Total iron (Fe)	Dissolved manganese (Mn)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved solids calculated)	Hardness (Ca, Mg)	Hardness Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
16-26W-23ABB	34	TO	12-23-75	....	9.5	..	....	54	18	20	5.3	0	124	49	78	.3	2.0	297	208	106	.6	540	7.5
16-26W-35CCD	40	TO	12-23-75	....	36	..	.	104	18	20	6.6	0	349	33	28	.3	28	446	334	48	.5	710	7.7
18-24W-25BBA	54	QA	7-18-75	15.0	43	.16	.	160	21	33	7.0	0	324	140	89	.2	16	666	480	214	.7	1080	7.5
19-21W- 6BCA	55	QA	5-22-75	..	41	.00	.00	200	16	41	6.5	0	444	209	55	.2	7.4	794	565	201	.8	1160	....
19-22W- 3ACD	47	QA	7-17-75	17.0	37	.08	.00	126	14	67	7.5	0	310	186	43	.6	17	650	372	118	1.5	1020	7.5
19-22W- 7ADC	49	QA	5- 7-75	15.0	42	.05	.00	149	22	45	7.2	0	359	124	81	.4	19	666	462	168	.9	1030	7.5
19-22W- 8BCB	58	QA	5- 7-75	14.5	41	.05	.00	179	23	31	7.0	0	329	168	112	.4	16	739	541	271	.6	1170	7.4
19-23W- 1CCB	450	KD	7-17-75	19.0	8.6	.03	.00	9.6	3.9	240	5.8	0	244	132	161	2.4	.9	684	40	0	17	1220	7.7
19-23W-21DA	282	KD	8-25-75	....	8.1	.11	.20	16	5.8	510	9.8	0	390	240	30	5.2	.1	1420	64	..	28	2470	8.0
19-24W-17BAD	55	QA	6-20-75	....	38	.09	.00	72	13	45	5.5	0	310	52	20	.5	6.1	404	233	0	1.3	641	7.7
20-22W-19CCD	75	QA	5- 7-75	14.0	39	.03	.00	136	16	32	8.5	0	342	146	26	.2	13	585	406	126	.7	890	7.5
20-22W-20CCC3	127	QA	5-15-75	....	41	.00	.00	112	16	43	8.5	0	339	121	32	.6	1.7	543	346	68	1.0	830	7.6
20-22W-21DBB	70	QA	6-17-75	....	51	.02	.00	130	13	30	6.0	0	349	101	37	.6	7.4	548	378	92	.7	840	7.5
20-22W-28BCC	98	QA	6-17-75	....	43	.02	.00	112	42	40	11	0	346	201	38	.3	.2	658	452	168	.8	980	7.7
20-22W-29CBB	87	QA	5- 9-75	14.5	42	.27	.00	178	18	15	6.5	0	388	158	33	.1	25	667	518	200	.3	1000	7.5
20-22W-30BCD	63	QA	5-15-75	....	44	.02	.00	179	25	31	8.2	0	268	254	86	.3	28	....	550	330	.6	1160	7.4
20-22W-32AAA	60	QA	5- 8-75	13.5	25	.06	....	141	12	15	4.5	0	346	8.8	26	.2	32	524	402	118	.3	820	7.5
20-23W-23CCD	58	QA	5- 8-75	14.5	30	.11	.00	120	9.8	20	4.5	0	273	76	42	.2	37	474	340	116	.5	760	7.5
20-23W-26ACD	82	QA	5-16-75	....	41	.02	.00	179	17	37	9.0	0	368	233	40	.3	10	748	516	214	.7	1090	7.6
20-23W-26CAB	90	QA	5- 8-75	14.5	44	.06	.00	142	17	33	7.2	0	322	164	37	.5	7.8	611	424	160	.7	920	7.4
20-23W-27DCB	75	QA	5- 8-75	14.0	41	.06	....	163	21	25	8.2	0	310	204	53	.3	6.4	675	493	239	.5	1010	7.5
20-23W-32BBC	100	QA	6-18-75	....	35	1.3	.00	126	15	27	7.0	0	310	140	30	.3	4.3	537	376	122	.6	810	7.7
20-23W-33BCC	90	QA	6-18-75	....	39	.02	.00	120	13	19	6.2	0	305	93	30	.3	7.8	478	353	103	.5	740	7.6
20-23W-34BAC	85	QA	5-22-75	....	40	.02	.00	133	9.7	19	5.0	0	310	85	41	.3	18	503	372	118	.4	770	7.8
20-24W-36CDA	57	QA	6-19-75	....	32	.02	.00	168	17	56	7.2	0	381	162	86	.2	22	738	489	177	1.1	1160	7.6

[1] Geologic units abbreviated as follows: KD, Dakota Formation; TO, Ogallala Formation; QA, Alluvium.