Geology and Ground-Water Resources of Richardson County, Nebraska

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1779-W

Prepared in cooperation with the Conservation and Survey Division of the University of Nebraska

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By PHILIP A. EMERY

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGY AND GROUND-WATER RESOURCES OF RICHARDSON COUNTY, NEBRASKA

By PHILIP A. EMERY

ABSTRACT

Richardson County is in the extreme southeast corner of Nebraska. It has an area of 545 square miles, and in 1960 it had a population of 13,903. The county is in the physiographic region referred to as the Dissected Loess-covered Till Prairies. Major drainage consists of the Big Nemaha River, including its North and South Forks, and Muddy Creek. These streams flow southeastward and empty into the Missouri River, which forms the eastern boundary of the county.

The climate of Richardson County is subhumid; the normal annual precipitation is about 35 inches. Agriculture is the chief industry, and corn is the principal crop.

Pleistocene glacial drift, loess, and alluvial deposits mantle the bedrock except in the southern and southwestern parts of the county where the bedrock is at the surface. Ground water is obtained from glacial till, fluvioglacial material, terrace deposits, and coarse alluvial deposits—all of Pleistocene age—and some is obtained from bedrock aquifers of Pennsylvanian and Permian age.

Adequate supplies of ground water are in many places difficult to locate because the water-bearing sands and gravels of Pleistocene age vary in composition and lack lateral persistence. Perched water tables are common in the upland areas and provide limited amounts of water to many of the shallow wells. Very few wells in bedrock yield adequate supplies, as the permeability of the rock is low and water that is more than a few tens of feet below the bedrock surface is highly mineralized.

Recharge is primarily from local precipitation, and water levels in many wells respond rapidly to increased or decreased precipitation.

The quality of the ground water is generally satisfactory for most uses, although all the water is hard, and iron and manganese concentrations, in some areas, are relatively high. Ground water is used mainly for domestic and stock purposes.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report is based on one of a series of detailed areal studies of the geology and ground-water resources of Nebraska. These studies are being made by the U.S. Geological Survey in cooperation with the

Conservation and Survey Division of the University of Nebraska. The report describes Richardson County, an area where ground-water supplies are difficult to obtain and, in general, are relatively small in quantity compared to those obtainable in most areas of Nebraska. The purpose of the study has been to acquire information regarding the occurrence, availability, use, source, movement, destination, and chemical quality of the ground water. The report is designed to provide factual and inferential data that will have immediate application to existing ground-water problems in the area and also to serve as a basis for the solution of special problems that may arise in the future.

LOCATION AND EXTENT OF THE AREA

Richardson County is in the extreme southeast corner of Nebraska (fig. 1). Its eastern boundary is the southeast-trending Missouri River, which forms the Nebraska-Missouri State Line; and its south border is the 40th parallel, which is the Nebraska-Kansas State Line. Pawnee County borders Richardson County on the west, and Nemaha County borders it on the north. The county is 18 miles wide in the north-south direction; its north boundary is slightly more than 24 miles long, and its south boundary is about 37 miles long. The area of Richardson County is 545 square miles, or 348,800 acres.

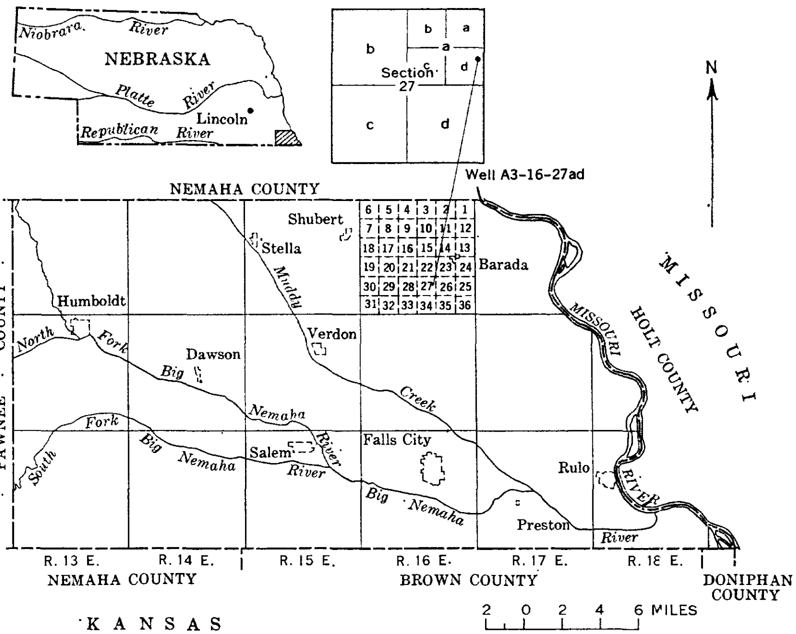

FIGURE 1.—Index map of Richardson County, Nebr., showing well-numbering system.

PREVIOUS INVESTIGATIONS

Very few data on the ground-water resources of Richardson County have been published previously. However, unpublished geologic and hydrologic data have been and are available in the open files of the Conservation and Survey Division of the University of Nebraska. Also, the results of extensive test drilling in Richardson County by the Conservation and Survey Division in cooperation with the U.S. Geological Survey have been described by Schreurs and Keech (1953).

METHODS OF INVESTIGATION

Some of the geologic and hydrologic data on which this report is based were collected in 1940 by the late R. C. Cady of the U.S. Geological Survey. Cady's detailed geologic field notes were freely drawn upon by the writer of this report. During the summer and autumn of 1962, the writer made additional geologic observations in the county and obtained information regarding 126 wells (see table 2). Many wells that had been inventoried in 1940 were visited again in 1962 to obtain a comparison of water levels. Industrial and municipal supplies derived from wells and springs in the county were included in the 1962 inventory.

WELL-NUMBERING SYSTEM

The well and test-hole numbers used in this report give the location of wells according to the system of land subdivision of the U.S. Bureau of Land Management. The capital letter "A" which precedes the first numeral shows that the well is east of the sixth principal meridian. The first numeral in the number indicates the township, the second the range, and the third the section. The first lowercased letter denotes the quarter section, or 160-acre tract; and the second lowercased letter denotes the quarter-quarter section, or 40-acre tract. The quarter sections and the quarter-quarter sections are designated a, b, c, or d in a counterclockwise direction starting in the northeast corner. If two or more wells are within a 40-acre tract, the wells are numbered serially according to the order in which they were drilled or inventoried. Figure 1 illustrates this well-numbering system.

PERSONNEL AND ACKNOWLEDGMENTS

While working in Richardson County, Mr. Cady was assisted by L. P. Murphy, Howard Haworth, H. H. Penneker, and Orville Hansen, all from the Conservation and Survey Division of the University of Nebraska.

This report was completed under the supervision of C. F. Keech, district engineer in charge of ground-water studies in Nebraska. Acknowledgment is due E. C. Reed, V. H. Dreeszen, and R. R. Burchett, all from the Conservation and Survey Division, for their help and advice in the preparation of this report.

Appreciation is also expressed to the many farmers in Richardson County for their help and assistance in the collection of field data. Mr. A. D. Kuhl of the U.S. Soil Conservation Service at Falls City, Nebr., provided information on soils and geology in various parts of the county.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Richardson County is in the physiographic region of the United States referred to as the Dissected Loess-covered Till Prairies of the Central Lowland Province (Raisz, 1957). This name is appropriate because loess and till mantle most of the bedrock in the county, and much of the area has been greatly dissected by erosion. The upland remnants are highest in the southwestern, northwestern, and northeastern parts of the county. In the southwestern part, some of the remnants stand at altitudes of more than 1,300 feet above sea level; in the northwestern and northeastern parts, some remnants stand at altitudes above 1,200 feet; but in the north-central, central, and southeastern parts of the county, the altitude of the upland surface scarcely exceeds 1,100 feet. The upland divides are smooth and gently sloping except along the valley of the Big Nemaha and Missouri Rivers, where deep steep-walled valleys are very numerous and close together.

The North Fork and South Fork of the Big Nemaha River enter the county from the west, flow eastward across the west-central and southwestern parts of the county, and join in the south-central part of the county near Salem. From Salem the Big Nemaha flows eastward and empties into the Missouri in the southeastern part of the county. At this confluence, which is the lowest point in the county, the altitude is about 855 feet. The valleys of the North and South Forks are 150–200 feet below the adjacent parts of the upland plain, and they range in width from less than 1 mile to about 1.5 miles. Below the junction of the two forks, the Big Nemaha River valley is 1–2 miles wide and becomes slightly wider near its mouth. The valley cut by the Missouri River is 6–8 miles wide and is about 250 feet below the highest points on the adjacent upland. The largest tributary of the Big Nemaha River is Muddy Creek, which enters the north-central part of Richardson County, flows southeastward, and empties into the Big Nemaha about 4 miles east of Falls City. Smaller streams, tributary to the Missouri and Big Nemaha Rivers and to

Muddy Creek, are very numerous; most of them are ephemeral or intermittent. The Big Nemaha River, including the North and South Forks, and Muddy Creek have been straightened and deepened to facilitate runoff and lessen the occurrence of floods. Some of the smaller streams also have been straightened.

CLIMATE

The climate of Richardson County is typically continental—that is, it is characterized by rather hot summers, cold winters, and sudden temperature changes. The precipitation comes largely during the warm months in the form of local convection showers, which usually attend the approach of a cold front. In winter the precipitation is likely to be sparse; the light snow soon is blown from unprotected places and sublimated by the wind and sun. Winter precipitation is almost entirely general, as opposed to the summer precipitation of local type. Winds are strong and blow chiefly from the south in summer and from the west and northwest in winter.

Since 1930, with the exception of a few months in 1937 and 1950, continuous records of temperature and precipitation have been maintained at Falls City, about 7 miles southeast of the center of the county. Figure 2 shows the annual precipitation and cumulative departure from average precipitation at Falls City for the period 1930–61; the total precipitation shown for 1937 and 1950 was estimated on the basis of precipitation reported in surrounding areas and climatic conditions reported in southeastern Nebraska for those years. The downward trend of the cumulative-departure curve from 1932 to 1940 shows that the annual precipitation for this period was generally below the average for the period of record. The drought of the 1930's was broken in 1940; after that year, precipitation increased at a fairly steady rate to the flood year of 1951. After 1951 the precipitation decreased; 1953 was the driest year on record, and a drought occurred from 1955 through 1957. Since 1957, precipitation has been above the average for the period of record.

The average temperature in Richardson County is about 53°F. Temperatures in excess of 100°F are common in midsummer; winter temperatures often drop below zero, and lows of −30°F have been recorded. Normally, the highest temperature prevails in July, and August is only slightly cooler. January, the coldest month, is about 50° cooler than July.

The following table summarizes the temperature and precipitation data for Falls City:

Summary of temperature and precipitation records at Falls City from 1930 through 1961

[From records of the U.S. Weather Bur.]

Month	Temperature (°F)			Precipitation (inches)		
	Average	Minimum	Maximum	Average	Driest year (1953)	Wettest year (1951)
January	26.6	−28	68	1.19	0.40	0.89
February	30.6	−30	82	1.22	1.08	2.25
March	40.0	−12	95	2.29	2.10	3.84
April	53.2	10	96	2.99	1.90	5.37
May	63.1	24	104	4.87	3.61	6.82
June	73.1	40	107	5.29	1.90	9.82
July	78.6	44	111	3.24	1.57	6.68
August	76.8	42	112	4.43	1.60	10.18
September	68.3	21	111	4.29	2.28	3.43
October	57.3	0	96	2.33	.62	2.44
November	41.5	−8	82	1.78	1.55	2.00
December	31.5	−21	70	1.24	1.47	.62
Year	53.4	−30	112	35.16	20.08	54.34

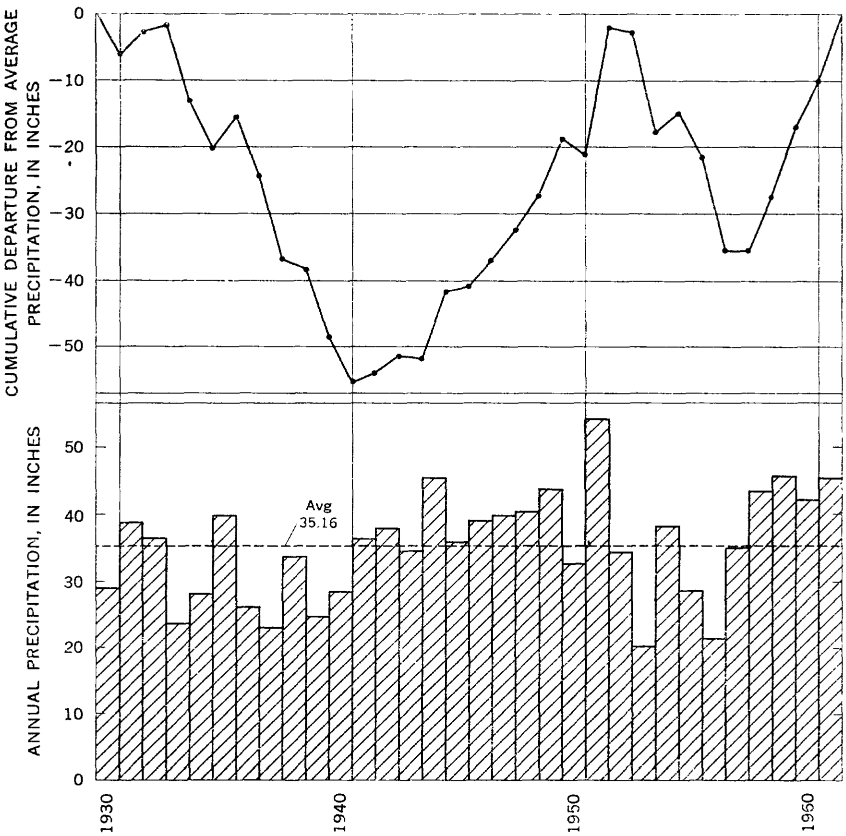

Figure 2.—Graph showing annual precipitation and cumulative departure from average precipitation at Falls City, Nebr., 1930–61. From records of the U.S. Weather Bureau.

POPULATION

The total population of Richardson County in 1960 was 13,903; nearly 63 percent of the inhabitants lived in urban communities, and the rest lived in rural areas. Between 1940 and 1960 there was a 23.5 percent decrease in the county's total population. The rural population suffered two-thirds of this loss and the urban communities the other third. Falls City, the county seat, is the largest community in the county; it had a population of 5,598 in 1960. Humboldt, the next largest community, had a population of 1,322. Of the other communities in the county, only Rulo—412 inhabitants—had a population greater than 300. The smaller communities, listed in order of descending population figures, are Verdon, Dawson, Stella, Salem, Shubert, Preston, and Barada. The total population of these smaller communities was 1,408.

TRANSPORTATION

Richardson County is traversed by the Missouri Pacific and the Chicago, Burlington & Quincy Railroads. The Missouri Pacific enters Falls City from the south and proceeds northwestward through the valley of Muddy Creek. The Chicago, Burlington & Quincy enters the county at Rulo, where it crosses the Missouri River, goes westward to Falls City, thence northwestward through the valley of the Big Nemaha and the North Fork of the Big Nemaha, through Humboldt, and into Pawnee County.

Two national highways, 73 and 75, cross the county from north to south. They are combined from the northern boundary to a point near Dawson, where they separate. U.S. Highway 75 goes directly south to Sabetha, Kans., and U.S. Highway 73 goes eastward from Dawson for about 12 miles, turns southward through Falls City, and from there passes into Kansas. State Highways 4, 8, 62, 67, and 105 connect various communities throughout the county. With the exception of Highway 4, parts of these highways are unpaved. In addition, roads are laid out on most section lines, and some of these roads are graded and gravelled.

AGRICULTURE AND SOILS

Agriculture is the most important economic pursuit in the county. The farm units are smaller than those farther west in the State. Corn, winter wheat, oats, sorghums, and soybeans are the chief crops. Cattle and swine are raised on a small scale and generally are fed on locally grown crops.

The soils of Richardson County, to some extent, are indications of the geologic units on which they are developed. The soils on the upland areas north of the Big Nemaha River include the Wymore, Sharpsburg, and Marshall silty-clay loams and the Monona silt loam. These soils are developed on Peorian Loess. Geary silty-clay loam soils are found on some slopes in the central part of the county and are developed on the Loveland Loess. Other slope soils include the Pawnee, Shelby, and Morrill clay loams which are developed on till. Sogn, Summit, and Labette silty-clay loams are developed on shale slopes in the southwestern part of the county.

The soils on the Missouri River flood plain are called Lrton, Albaton, Onawa, Haynie, Sarpy, Cass, and Carr. The first four have a fine to moderately fine texture; the last three are sandy.

The Wabash soils include the dark-colored fine-textured alluvial soils that occur along the Big Nemaha River and Muddy Creek. The medium to moderately fine textured soils in these valleys are called Colo, Kennebec, and McPaul.

More information about these soils can be obtained from the Richardson County Soil Conservation District, the County Agricultural Agent, or the University of Nebraska.

MINERAL RESOURCES

The first oil field discovered in Nebraska was in Richardson County. Total oil production in the county between 139 and 1961 was 9,032,256 barrels. In recent years, oil production in the county has been decreasing. Most of the oil is produced from Upper Devonian rocks; in addition, some oil is produced from rocks equivalent to the Viola Limestone and St. Peter Sandstone of Middle and Late Ordovician age.

In the past, some coal was produced from Upper Pennsylvanian rocks by drift mining near the town of Rulo.

Lower Permian limestone is quarried and processed for agricultural purposes at a site 2 miles east of Humboldt.

Sand and gravel for road surfacing is obtained from numerous pits and quarries in Quaternary deposits throughout the county.

GEOLOGY IN RELATION TO GROUND WATER

Two widely different types of rock material underlie Richardson County; one is the unconsolidated deposits of Pleistocene age that immediately underlie the land surface in much of the area, and the other is the older consolidated rocks of Paleozoic age on which the unconsolidated deposits rest. In some localities, especially the southwestern part of the county, rocks of Paleozoic age are exposed at the surface.

PALEOZOIC ROCKS

The Paleozoic rocks consist of a succession of beds of shale, siltstone, limestone, dolomite, sandstone, and coal. The uppermost rocks are of Permian age and are underlain successively by rocks of Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, and Cambrian age. The total average thickness of these rocks above the Precambrian basement is approximately 2,800 feet. Of this thickness of rocks, less than 900 feet is exposed in Richardson County.

The rocks beneath all but the western part of Richardson County occupy a deep depositional basin called the Forest City basin. They rest on the eroded surface of the Precambrian rocks and have a gentle northwestward dip that is interrupted locally by low domelike and shallow troughlike structures.

About 3 miles east of the west boundary of the county is the Humboldt fault, which marks the western extremity of the Forest City basin. (See pl. 1.) Although arcuate in plain view, the Humboldt fault nearly bisects Tps. 1, 2, and 3 N., R. 13 E. Immediately west of the fault, all rocks older than Pennsylvanian either were never deposited or were eroded away before the Pennsylvanian rocks were laid down. The absence of these rocks indicates that the Humboldt fault was active in pre-Pennsylvanian time. After the deposition of the Pennsylvanian and Permian rocks, renewed vertical movement caused a relative downward displacement of the beds east of the fault. The amount of vertical displacement, or throw, is several hundred feet. Subsequent erosion has exposed rocks west of the fault that are older than those at the surface immediately east of the fault.

The Paleozoic rocks, which would be exposed if the glacial deposits were stripped off Richardson County, belong to the Virgil Series of the Pennsylvanian System and the Lower Permian Series of the the Permian System. The chief subdivisions, and their approximate thicknesses are as follows:

- Permian System
  - Lower Permian Series
    - Chase Group, 7 feet
    - Council Grove Group, 300 feet
    - Admire Group, 115 feet
- Pennsylvanian System
  - Virgil Series
    - Wabaunsee Group, 400 feet
    - Shawnee Group, thickness not known

With the exception of the Shawnee Group, all the above units are exposed at various localities throughout the county. The generalized areal distribution of these rock units is shown on plate 1.

The oldest bedrock exposed in the county—belonging to the lower part of the Wabaunsee Group—lies in the valleys of the North and South Forks of the Big Nemaha River west of the Humboldt fault and in the extreme southeast corner of the county along the Missouri River.

Younger rock units of the Wabaunsee Group crop out along the Missouri River bluffs to the north of the town of Rulo, along the Big Nemaha River valley east of Falls City, and on upland and valley slopes west of the Humboldt fault.

Rocks of the Admire, Council Grove, and Chase Groups crop out on the upland and valley slopes in the central, west-central and southwestern parts of the county.

In general, the Paleozoic rocks exposed in Richardson County and those rocks that underlie the outcropping formations are poor sources of potable water. Locally, however, the rocks that are not too deeply buried and that lie within the zone of saturation may yield small supplies of fairly good water to wells and springs. On the uplands in the west-central and southwestern parts of the county, Pleistocene deposits are not thick, and the Beattie and Grenola Limestones of the Council Grove Group are sources of ground-water supply. A large spring, which furnishes part of the municipal water supply for the city of Humboldt, issues from one of these limestones. The White Cloud Shale Member of the Scranton Shale of the Wabaunsee Group is composed largely of fine-grained sandstone that doubtless would yield small supplies of potable ground water where it is saturated but not deeply buried. Other limestone beds not described in this report are thin, but locally they may yield small water supplies.

In areas where the bedrock is not mantled by water-bearing surficial material, the following rule is often helpful in locating ground-water supplies in the bedrock: If the uppermost bedrock is limestone, the chances for obtaining ground-water supplies are much better than if it is shale. The reason this usually holds true is that the bedrock was exposed prior to the deposition of the surficial material, and weathering tended to produce voids and fractures in the limestone which may now conduct and hold ground water; the weathering of shale does not produce suitable voids or fractures for containing ground water.

The conditions are moderately favorable for obtaining water supplies from the Paleozoic rocks in the southern and southwestern parts of the county, south of the North Fork of the Big Nemaha River; in the area immediately adjacent to the Humboldt fault; and in the southeastern part of the county, south of the Big Nemaha River.

Water-bearing bedrock formations that are near the land surface in one part of the county probably should not be considered as sources of water supply in other areas where they lie at depths of 100 feet or more below the land surface because the water in them is very likely to be highly mineralized. Thus, the inhabitants of the greater part of the county must rely on ground-water supplies in the unconsolidated material which overlies the bedrock.

QUATERNARY DEPOSITS

PLEISTOCENE SERIES

Most of the ground-water supplies in Richardson County are derived from the unconsolidated sediments of Pleistocene age that mantle the surface of the older rocks previously described. The age and spatial relationships of these deposits are not completely clear, and no attempt has been made to differentiate these deposits for the purpose of geologic mapping or the construction of geologic sections. More extensive test drilling, particularly in upland areas, would enable more adequate description of the Pleistocene deposits. They are believed to consist of two deposits of glacial drift, an intervening interglacial deposit, and deposits of loess that are younger than the drift. In addition, alluvial deposits underlie the floors and make up terraces along the flanks of the river and stream valleys.

NEBRASKAN DRIFT

Two till sheets, the lower of which is regarded as the Nebraskan and the upper as the Kansan, have been reported in southeastern Nebraska by Lugn (1935), in southwestern Iowa by Kay and Apfel (1928), and in northeastern Kansas by Schoewe (1938) and Frye (1941).

Till, believed to be Nebraskan in age, is well exposed in only one place in Richardson County. This outcrop is near the bottom of the railway cut on the west side of the town of Rulo. Near the top of the exposure, the till is yellowish brown, but the lower part—probably the unweathered portion—is uniformly dark gray. The till contains only a moderate scattering of pebbles and cobbles of granite or granitelike rock, limestone, and sandstone. Pebbles of the Sioux Quartzite, such as are common in Kansan till, are either rare or not present.

The upper surface of the Nebraskan till at this exposure is sharply undulating. At one point the till is about 25 feet thick, but a few feet away the surface of the till descends below the level of the railroad track. This exposure of Nebraskan till is overlain successively by Aftonian(?) interglacial deposits, Kansan drift, and younger loess.

Postdepositional erosion of the Nebraskan drift removed it from much of the county. It was preserved only in areas that were topographically low.

Although the Nebraskan drift probably contains less stratified sand or gravel than does the Kansan drift, it is very likely that the Nebraskan drift contains at least some. To the extent that such material does exist, ground water can be stored within the Nebraskan drift and can be released to wells drilled into it. The scanty evidence of the water-bearing capacity of the Nebraskan drift indicates that it is a poor source of ground-water supply.

AFTONIAN(?) INTERGLACIAL DEPOSITS

The Nebraskan drift was largely removed by erosion after the recession of the Nebraskan ice sheet, and the drift that remained was dissected. This stage of erosion was followed by deposition of sediments that are distinctive and easily identifiable. These sediments overlie the Nebraskan drift and extend beyond its limits; in many places they rest on bedrock. They are overlain by Kansan drift, which has a still greater areal distribution.

The precise age of these deposits and the conditions under which they were laid down are uncertain. The definite evidence that a period of erosion followed the melting of the Nebraskan ice sheet minimizes the likelihood that these deposits are related to the Nebraskan Glaciation. Instead, their age is more probably either Aftonian or early Kansan. Because these deposits are fine grained and of uniform texture whereas the fluvial deposits related to the Kansan till are coarse and heterogeneous, it seems probable that the deposits, were laid down during a time of uniform climatic conditions such as probably prevailed during the Aftonian Interglaciation. Hence, these sediments are referred to as Aftonian(?) interglacial deposits.

The Aftonian(?) interglacial deposits consist of two distinct types of sediments—a massive slate-gray clayey silt and an overlying laminated light-gray to light-yellow fine-grained sand. Where these two types of sediment occur together, as they do in most exposures, the fine sand rests unconformably on the clayey silt. The composition and structure of the silt suggest deposition by wind whereas the composition and lamination of the sand suggest deposition in ponds or lakes.

Except in the southern and southwestern parts of the county where the bedrock surface is high, the Aftonian(?) interglacial deposits are rather widely distributed. Because these deposits are generally below the water table, they are of some economic importance as a source of ground water.

A problem often met in obtaining a water supply from the Aftonian(?) interglacial deposits is the presence of large amounts of fine sand. This fine sand, often referred to by drillers as "quick sand" or "sugar sand," causes the wells to fill in and also abrades and wears out pump mechanisms. The use of fine screens or slots in well casings or the packing of wells with coarse sand would enable well drillers to obtain a more successful well in these deposits.

KANSAN DRIFT

The Kansan drift in Richardson County consists of till and associated fluvialglacial deposits. It is not certain that the Kansan deposits always can be distinguished from the Nebraskan; but it is believed that the Kansan till is stonier than the Nebraskan till, has more pebbles of Sioux Quartzite, and is associated with more fluvioglacial material than is the Nebraskan.

The Kansan drift is well exposed in many places in the county except in the valley lowlands or on graded slopes, where it is covered with loess which it superficially resembles. The best exposures are found in roadcuts, gravel pits, and eroded stream banks.

Kansan outwash—consisting mainly of coarse-grained sand and gravel—seems to be most abundant along a line bisecting the county from northwest to southeast (see fig. 3). However, this generalization must be modified to the extent that the Kansan drift may be somewhat sandy and gravelly in other parts of the county. The abundance of outwash along this line seems to indicate that as the glacier approached this line, a vigorous stream flowed along the face of the glacier. The coarseness of the deposits and the crossbedding indicate swift currents and probably large volumes of water. Since till overlies the outwash in most exposures, it is evident that the glacier overrode the outwash as it advanced southward into Kansas.

In certain localities the Kansan drift is a fairly satisfactory source of ground-water supply. It contains beds and lenses of medium- and coarse-grained sand, local pockets of gravel, and sandy till that can contribute water to a well. In the northwestern part of the county, north of Humboldt, outcrops and test holes suggest that a deposit of gravel and sand as much as 30–50 feet thick underlies a considerable area. The exact distribution and areal extent of these deposits are not known, but the area outlined on plate 3 as a moderate and large supply area shows the possible areal extent of these deposits Well A3–13–15bb1 yielded 660 gpm (gallon per minute) in a pumping test, and it is possible that other wells of high yield could be developed in the same general area. Several springs issue from hillsides where the Kansan drift is present but masked by loess.

Although yields are somewhat unpredictable in the Kansan drift in most parts of the county except the southern and southwestern parts, it is a fairly good source of ground-water supply.

ILLINOIAN AND WISCONSIN LOESS

Most of the Kansan drift, the older Pleistocene deposits, and the bedrock formations are covered with loess. The large valleys and many of the small valleys were once partly filled with loess although the loess has since been removed except along the valley walls. The loess is a wind-deposited sediment of the grain size of clay, silt, and fine sand. Both the Loveland and the Peorian Loesses are present. The Loveland Loess is thought to have been deposited during late Illinoian time and the Peorian Loess to have been deposited during a time when the climate was influenced by the Wisconsin Glaciation. As it is not easy to disinguish between the two loess deposits in Richardson County, they are discussed together.

The thickness of the loess can be determined only by test drilling. Because the loess mantles the hillsides, the apparent thickness observed by starting at the bottom of a valley and measuring the visible loess to the top of the divide obviously results in a wrong value. The test holes drilled on the upland divides of Richardson County indicate that the loess is from 15 to 40 feet thick and averages about 30 feet in thickness on uplands where erosion has been least active.

Although the color of the loess is predominantly buff, the Peorian Loess is light yellowish gray and the Lovelend Loess is reddish brown in some exposures. However, the distinctive coloration that characterizes the two loess deposits in the central and south-central parts of the State is not so evident in Richardson County.

Most of the loess is so fine grained that its capacity for transmitting ground water is very small. However, wells drilled or dug on the upland divides do receive small amounts of water from the loess. In some places the colluvial (slope) phase of the Loveland contains some sand and gravel that is capable of furnishing adequate supplies for stock and domestic uses. Water cannot everywhere be obtained from the colluvial phase of the Loveland because in places the material has been drained by gullies and streams.

The colluvial phase of the Loveland is of relatively small worth as a source of water supply, but it may be regarded as a possible source in the central, northern, and northwestern parts of the country. It is less promising as a source of water supply in the areas of high bedrock in the southern and southwestern parts of the county.

TERRACE DEPOSITS AND VALLEY ALLUVIUM OF POST-KANSAN AGE

Since the end of the Kansan Glaciation many cycles of valley cutting and alluviation have taken place and have produced a series of terrace deposits. These deposits are in, or adjacent to, the present stream valleys.

The value of the terrace deposits as a source of ground-water supply differs from place to place. These deposits are primarily fine grained, but a few thin beds and lenses of sand and gravel do exist in them. Hence, if the terrace fills are considered in a terrain that is otherwise barren of ground water, they may be the principal water-bearing beds. In the southern and southwestern parts of the county, most of the wells are in the valleys of small streams where they tap the coarse beds in the terrace deposits. In other parts of the county most wells obtain water from glacial till or associated interglacial deposits and are not necessarily in the stream valleys.

Test holes indicate the presence of coarse alluvium in the valleys of the Big Nemaha River and Muddy Creek. The alluvium appears to have been derived from older terrace deposits as well as from glacial till and outwash, and it probably was deposited in middle or late Wisconsin time.

Except, possibly, for the alluvium beneath the flood plain of the Missouri River, the best water-bearing material in the county is the coarse alluvium of the Big Nemaha River and Muddy Creek. Much of the deposit is well-sorted coarse-grained sand and gravel.

In most places within the inner valleys of the Big Nemaha River and Muddy Creek, it is possible to obtain ground-water supplies ample for domestic and stock purposes. However, the places where supplies sufficient for large industrial or public-supply use can be developed are not numerous.

RECENT SERIES

Because the deposits of late Pleistocene age grade imperceptibly into those of Recent age, it is not possible to define the contact between the two. Some of the colluvial material as well as topsoil, wind-deposited clay, silt, and sand, and much of the alluvium of the stream valleys constitute the deposits of Recent age. The Recent deposits on the uplands and valley slopes are probably only a few inches thick, but the Recent alluvium in the major stream valleys may be as much as 6 feet thick.

CONFIGURATION OF THE BEDROCK SURFACE

Rock outcrops and the logs of test holes provide control for the contour lines which show the configuration of the bedrock surface, shown on plate 1. The contour lines are generalized and do not show local features that doubtless exist, but they show the main features of the bedrock surface and provide a clue to favorable localities where ground-water supplies may be obtained from the Pleistocene deposits.

The configuration of the bedrock surface in Richardson County is the result of a complex series of physical events. Where the bedrock is covered by the Nebraskan drift, it has essentially the surface that existed prior to glaciation. At various times during the Pleistocene Epoch, other parts of the bedrock surface were changed by erosion and later covered by loess, till, or glacial outwash. Where the bedrock is exposed, weathering and erosion are slowly and constantly modifying its configuration.

At some time in the interval between the end of the Kansan Glaciation and the deposition of the Loveland Loess, the Big Nemaha River and Muddy Creek valleys were cut. That the erosion of the valleys took place after the retreat of the Kansan glacier is indicated, first, by the absence of till in the inner valleys and, second, by the manner in which the Kansan till crops out on the Big Nemaha River valley walls. The Loveland Loess, which was deposited after the Big Nemaha River valley and many of its tributary valleys were cut, is believed to be of late Illinoian age. Considerable effort has been made previously in studies of the geology of Nebraska to determine more definitely the time when most of the larger valleys in the State were cut. The conclusions that have been reached are still speculative; certain inferences and analogies, however, lead to the tentative conclusion that the main valley cutting in Nebraska took place during some part of late Kansan and Illinoian time. This valley cutting probably was contemporaneous with cutting of other valleys in the State—namely, the North Platte, Niobrara, Republican, and Nemaha River valleys, their chief tributary valleys, and presumably many other valleys in the Great Plains region.

The relation of the modern Big Nemaha River valley to the Missouri River valley suggests that the Missouri River adopted its present course at the same time as the Big Nemaha River cut its valley. Exposures of Pleistocene deposits indicate that the Kansan till was deposited over the area now occupied by the Missouri River valley at a much higher altitude than that of the floor of the valley, and the surface of the Kansan till does not indicate the presence of a large valley in the vicinity of the present Missouri River valley. However, the Loveland Loess mantles the walls of the Missouri River valley, and it is thus concluded that the present valley adjacent to Richardson County was cut at the same time as the Big Nemaha River valley.

Todd (1914) and Greene and Trowbridge (1935) have presented evidence that in earliest Pleistocene time the Missouri River had not yet come into existence and Nebraska streams crossed the eastern boundary of the State and flowed into distant master streams to the east. According to this theory, the preglacial streams that crossed Richardson County may have been tributaries to a preglacial stream that flowed southeastward across southwestern Iowa and northwestern Missouri.

It is reasonable to assume that as the first glaciers advanced over the Richardson County area, they filled the preglacial stream valleys with till and glacial outwash, perhaps even to the level of adjoining uplands. Although subsequent erosion had modified these deposits, the thickest deposits can be assumed to mark the trend of preglacial streams. Figure 3 shows the thickness of Pleistocene deposits in Richardson County. The maps showing the configuration of the bedrock and the thickness of Pleistocene deposits give clues as to the location of both preglacial and post-Kansan stream channels. In some areas, the present drainage probably follows the same courses as preglacial and late Pleistocene drainage. However, even where the present streams closely follow the late Pleistocene drainage, the location of the present channels in some places has shifted laterally as much as 1 mile.

Determining the location of both post-Kansan and preglacial stream channels is significant because the old stream channels contain some of the thickest deposits of water-bearing materials. As can be seen by examining the geologic sections on plate 2, the old channels are often some distance from the present stream channels. A knowledge of their location can often mean the difference between obtaining adequate or inadequate ground-water supplies.

OCCURRENCE OF GROUND WATER

The ground water in Richardson County occurs in open spaces, called voids or interstices, in the rocks and not, as popularly supposed, in underground veins, streams, or pools. There are no such underground sources of ground water in Richardson County. Although many well sites in the county have been, and still are, selected by "witching" or "dowsing," the writer believes that any success in locating ground water in this manner either is purely concidental or is due to the reliance of the "witch" or "dowser," whether he realizes it or not, on practical knowledge; success is not due to his forked stick or other mystic device.

At some depth below the land surface is the water table, or upper surface of what is termed "the zone of saturation." Water in the zone of saturation is called ground water and is the source of water for wells and springs. Above the water table is the zone of aeration through which water percolates downward to the zone of saturation. Saturated rock capable of supplying water to wells or springs in sufficient quantities to be useful is referred to as an aquifer.

Some of the most successful shallow wells in the county are in the level upland areas some distance from the valleys. These wells, and

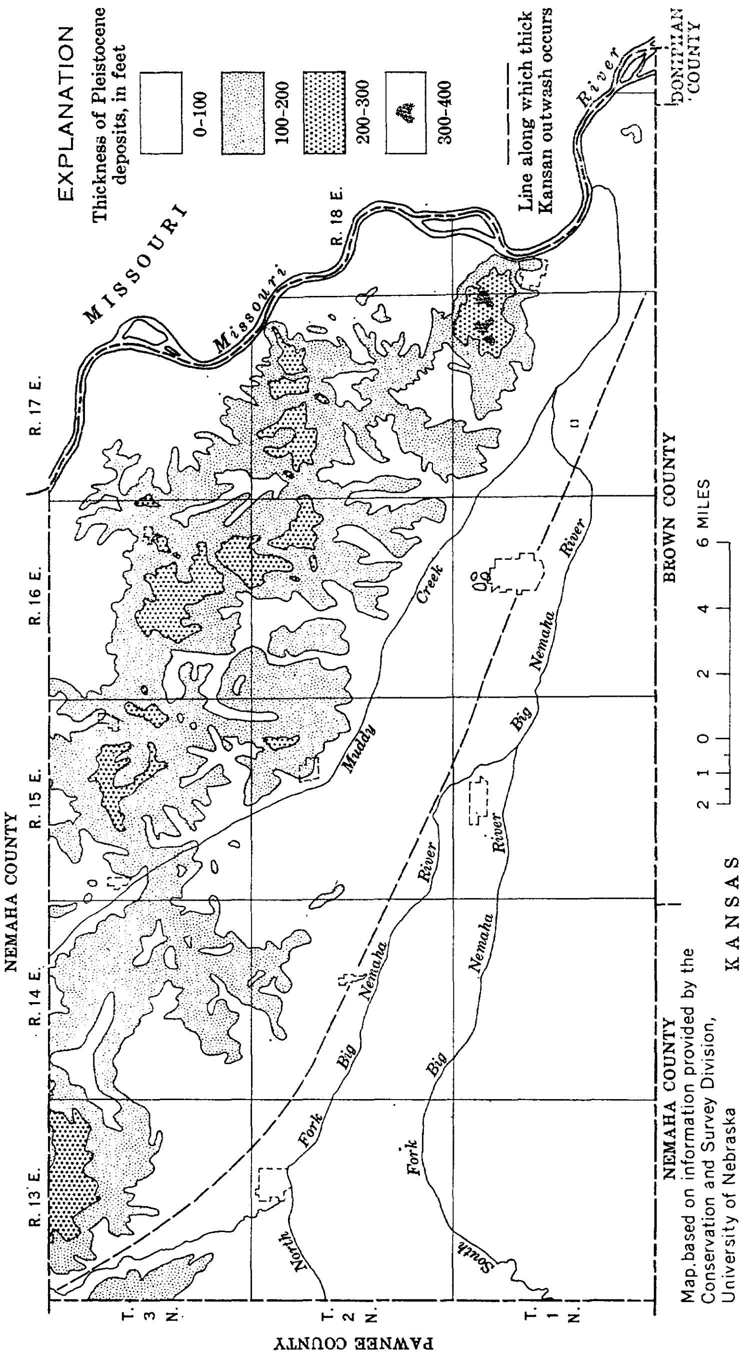

FIGURE 3.—Map of Richardson County, Nebr., showing thickness of Pleistocene deposits.

also some springs, probably owe their existence to what are termed "perched aquifers." In some places, the infiltration of precipitation through the zone of aeration is slowed by the existence of an almost impermeable layer of rock; thus, a ground-water body is supported above the regional water table by unsaturated rock. As a general rule, only small amounts of water man be obtained from perched aquifers.

Nearly all the ground water in Richardson County is derived from the precipitation that falls in the county. Although some water reaches the zone of saturation by seepage from streams or ponded water, most water added to the ground-water reservoir infiltrates through the soil. That the ground-water supply is closely regulated by local precipitation is substantiated in that many shallow wells go dry during periods of low precipitation.

Ground-water discharge takes place in many ways. Where the water table is near the surface, much ground water is taken into the roots of plants and discharged from the plants by transpiration. Ground water is discharged by springs and by diffused seepage into streams, where it runs off. Much ground water along the streams that have been straightened and deepened has probably drained off owing to the fact that the streambed was lowered below the water table.

Ground water is discharged through the many wells in the county. However, the amount of water discharged by these wells is small compared to the discharge by natural means.

DEPTH TO WATER

The depth to water beneath the land surface of Richardson County ranges considerably. In some stream valleys the water table is almost at the surface. In upland regions of the northwestern and east-central parts of the county, the water table is in places more than 100 feet below the land surface. Plate 3 shows the depth to water at numerous points throughout the county.

The depth to water is an important factor to consider when planning to obtain a supply of ground water; the type of well, casing, and pump, as well as the cost of drilling and pumping, are affected by the depth to water.

The depth to water fluctuates from season to season and from year to year. Many wells that were measured in 1940 were measured again in 1962, and a comparison of the water levels shows that over 90 percent of these wells had a higher water level in 1962. This rise in water levels is especially pronounced because the 1940 measurements were made soon after the great drought of the 1930's and the 1962 measurements were made after a 4-year period of greater-than-normal precipitation.

POTENTIAL GROUND-WATER YIELDS

Plate 3 shows the areas in Richardson County where it is known or believed from available evidence that small, moderate, or large ground-water supplies can be obtained.

The bedrock-configuration and Pleistocene thickness maps (pl. 1, fig. 3), plus well logs and data on farm and municipal wells, were used in delineating the areas of potential yield of the water-bearing rocks. The map (pl. 3) should be regarded as a guide, not as a final authority, because moderate or large supplies could very possibly be obtained locally in regions designated as small-supply areas; and it is also true that moderate or large supplies may not be available at every point in the areas so designated. However, the map should be useful in locating sources of ground-water supplies.

CHEMICAL QUALITY AND USE OF GROUND WATER

The ground-water supplies in Richardson County are used almost exclusively for domestic and stock purposes. In 1962, only one well in the conuty had been installed and used specifically for irrigation. There are two principal reasons why the amount of irrigation in the county is small: one, normally precipitation is sufficient for crop production without irrigation; and two, with the exception of a few rather limited areas, supplies adequate for irrigation are unobtainable.

The ground water of Richardson County is, in general, of good quality. Some treatment is necessary, however, if the water is to be used for certain specific purposes. The following discussion of the quality and use of the ground water pertains mainly to its suitability for domestic, stock, and industrial uses.

DOMESTIC USE

Water used for domestic purposes should not contain excessive amounts of substances harmful to health. In addition, it should be free from objectionable taste and odor and from any elements that will stain plumbing fixtures and laundry. The U.S. Public Health Service (1962) has established standards for drinking and culinary water used by public carriers in interstate traffic. The standards that pertain to chemical constituents are, in part, as follows:

Allowable limits, in parts per million, for potable water

Iron	0.3
Manganese	.05
Chloride	250.0
Nitrate	45.0
Sulfate	250.0
Fluoride	[1] 0.8–1.7
Total dissolved solids (good quality)	500.0
Total dissolved solids (if better water is not available)	1,000.0

[1] Depends on annual average of maximum daily air temperature.

The results of chemical analyses of 14 ground-water samples collected in Richardson County are given in table 1. A comparison of the results with the above allowable limits shows that only 7 of the 14 samples from Richardson County meet, in every respect, the standards for good-quality water. It should be stated, however, that people in many areas of the world have used substandard water for their entire lifetime with no apparent ill effects.

With few exceptions, the principal dissolved constituent in the water samples was calcium bicarbonate. The sulfate concentration was relatively high in the water from well A1-13-25aa. Sulfates in the water in excess of 250 ppm (parts per million) can cause an undesirable laxative effect in persons who are not accustomed to drinking such water. Chloride was the predominant ion in the sample from well A2-14-22ab2. Iron and manganese seems to be the most troublesome constituents in the ground water of Richardson County because they stain fabrics, plumbing fixtures, and other articles.

TABLE 1.—*Chemical analyses of ground water in Richardson County*

[Use of water: D, domestic; N, none; PS, public supply; S, stock. Results in parts per million except as indicated]

Location	Date of collection	Depth of well (feet)	Silica (SiO_2)	Manganese (Mn)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)
A1-13-12dc	10-25-40	71.5				101	23	24		391	27
25aa	do	100	11		0.32	508	114	90	4.8	324	1,430
14-14dd	do	30				95	31	43		430	56
15-10ab	9-10-62	60		0.9	2.82	171	15	21	4	444	64
10ba	do	60		2.3	1.32	178	21	29	2	507	64
A2-13-10ba	8- 1-62			.01	<.01	86	17	30	5	351	16
14-22ab2	do	59		2.0	>2.0	146	34	52	6	215	118
15-10dc	do	46		.40	<.01	86	19	32	6	219	90
A3-13-15dd	10-25-40	130				93	33	34		375	124
36cb	8- 1-62	Spring		.01	<.01	74	36	26	6	356	24
15- 7dc	10-25-40	80	25		.06	47	11	28	2	259	5.9
12ca	do	120	32		.05	47	14	20	1.7	231	18
12cd	8- 1-62	120		.35	.47	61	14	22	4	234	20
17-28cc	10-25-40	59.4				107	35	48		533	64

Location	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 103° C)	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption ratio	pH	Use of water	Municipality
					Calcium, magnesium	Noncarbonate					
A1-13-12dc	10		45	[1] 423	347	26	13	0.6		S	
25aa	127	0	0.3	[1] 2,450	1,740	1,470	10	.9		N	
14-14dd	21		22	[1] 480	365	12	20	1.0		D	
15-10ab	65	.46	<44	724	488	124	8	.4	7.2	PS	Salem, Nebr.[2]
10ba	43	.28	<44	720	528	112	11	.5	7.6	PS	Do.[2]
A2-13-10ba	16	.77	<44	338	284	0	18	.8	7.1	PS	Humboldt, Nebr.[2]
14-22ab2	251	.26	25	830	520	344	18	1.0	6.5	PS	Dawson, Nebr.[2]
15-10dc	41	.29	<44	562	292	112	19	.8	7.4	PS	Verdon, Nebr.[2]
A3-13-15dd	1.4		4	[1] 474	368	60	17	.8		D	
36cb	10	.33	<44	346	332	40	14	.6	7.2	PS	Humboldt, Nebr.[2]
15- 7dc	6.0	.1	4.9	[3] 263	163	0	27	1.0		PS	Stella, Nebr.
12ca	6.0	.1	6.2	[3] 252	175	0	20	.7		PS	Shubert, Nebr.
12cd	16	.31	<44	386	208	16	18	.7	7.7	PS	Do.[2]
17-28cc	8		.6	[1] 525	411	0	20	1.0		N	

[1] Calculated.
[2] Analyses by Nebr. Board of Health; some data converted to U.S. Geological Survey standards.
[3] Residue at 180° C.

Hardness is a term which usually represents the soap-consuming capacity of water. Water is said to be hard if large quantities of soap are needed to produce a lather or if incrustations are formed when the water is heated or evaporated. Most of the observed effect with soap results from the presence of calcium and magnesium bicarbonates. The hardness caused mainly by these two compounds is called carbonate or "temporary" hardness and can be removed by simply boiling the water. The noncarbonate or "permanent" hardness, usually caused by chlorides or sulfates of calcium and magnesium, can be removed only by the use of water softeners which form precipitates with these compounds. Specific limits for water hardness have not been set, but the following gradations are generally recognized:

Gradations for water hardness

Hardness as $CaCO_3$ (ppm)	Rating	Suitability
0–60	Soft	Suitable for many uses without further softening.
61–120	Moderately hard	Usable except in some industrial applications.
121–180	Hard	Softening required by laundries and some other industries.
181+	Very hard	Requires softening for many uses.

The water from 11 of the wells sampled in Richardson County can be classified as very hard, and the water from the others is hard.

Ground water is the source of all the municipal water-supply systems in Richardson County. Data on the municipal water supplies are given in the following table:

Municipal water systems in Richardson County, 1962

Town	Number of wells	Reservoir		Treatment	Distribution	
		Capacity (gallons)	Type		Number of hydrants	Number of taps
Dawson	2	40,000	Elevated tank	None	40	140
Humboldt	2	90,000 160,000	Standpipe Underground	Chlorination	40	500
Salem	2	50,000	Standpipe	None	8	90
Shubert	2	50,000	Elevated tank	do	24	85
Stella	1	40,000	do	do	11	112
Verdon	1	40,000	do	do	11	85
Falls City	7	1,000,000 100,000 1,000,000	do do Underground	Filtration and chlorination	120	2,250

Chemical analyses of water from some of the municipal wells, as well as a spring used by Humboldt, are given in table 1.

AGRICULTURAL USE

Water used by livestock is subject to some quality limitations, but most farm animals seem to be able to use water considerably poorer in quality than that considered safe for human beings. All the ground water sampled in Richardson County is satisfactory for stock uses.

The sodium-adsorption ratio (SAR) and percent sodium, as well as the concentration of dissolved solids, are used to predict the suitability of water for irrigation. These values indicate that most of the ground water is suitable for irrigation, at least from the standpoint of chemical quality. The problem associated with development of ground water for irrigation in the county is not one of quality, but one of quantity.

INDUSTRIAL USE

The industrial demand for ground water in Richardson County is small, and nearly all water used in industrial plants is obtained from treated municipal supplies. Most of the water sampled in the county requires treatment to decrease the hardness or the iron and manganese concentrations before it can be used for most industrial purposes.

SUMMARY AND CONCLUSIONS

Ground water in usable amounts is obtained from the Paleozoic rocks; the Nebraskan drift, the Aftonian(?) interglacial deposits; the Kansan drift; the coarse alluvium of the Big Nemaha River, Missouri River, and Muddy Creek valleys; and the terrace deposits in the smaller valleys of the county. No one of these is a significant source of supply throughout the county, but each is a major source in at least some part of the county.

The bedrock is a source of water supply in the southern part of the county, particularly in the southwestern part. It is reported that bedrock wells are more successful along the Humboldt fault than anywhere else in the county. No wells drilled into the bedrock are known to have obtained more than a few gallons of water a minute from the fresh-water zones. Any attempt to develop a large supply by drilling through a great thickness of bedrock is almost certainly destined to fail because below a depth of a few tens of feet, or at most about 100 feet, the water becomes too highly mineralized for most uses.

The Nebraskan drift, the Aftonian (?) interglacial deposits, and the Kansan drift and associated fluvioglacial deposits may be regarded as a unit. In most parts of the east-central, central, and northwestern parts of the county, wells drilled through these deposits yield some ground water of satisfactory chemical quality. Preventing fine sand from entering wells seems to be the greatest problem. This is a technical problem that generally can be solved by the use of fine well screens or by packing wells with medium or coarse-grained sand.

The coarse alluvium of the Big Nemaha River and Muddy Creek valleys is the greatest source of ground-water supply in the county; although to be successful, wells in the alluvium must be properly located and developed. The thickness of the sand and gravel decreases westward from a maximum near the mouth of the Big Nemaha River. In the western part of the county, apparently few places have much more than 10 feet of saturated, coarse, water-bearing alluvium.

The results of test drilling in the northwest corner of the county indicate the existence of a considerable thickness of saturated sand and gravel believed to be Kansan in age.

In the southern and southwestern parts of the county, wells drilled near the axis of small valleys are likely to tap a limited supply of water in the beds and lenses of sand and coarse gravel within the terrace deposits. Water cannot be found in the bedrock in every locality in these parts of the county, and the relative significance of the terrace deposits is attested by the fact that most wells are in the valleys of small streams.

Perched water tables are common, especially in the upland areas, and they provide water to many of the shallow wells.

The chemical quality of the ground water is in general satisfactory, but there are areas where high concentrations of iron and manganese occur.

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TABLE 2.—*Records of wells in Richardson County*

Well: See text for explanation of well-numbering system.
Type of casing: C, concrete; I, iron or steel; R, rock or brick; T, tile; W, wood.
Type of pump: Cy, cylinder pump; J, jet pump; N, none: T, turbine.
Type of power: E, electric; H, hand; N, none; W, wind.
Measuring point description: Ls, land surface; Pb, pump base, Tc, top of casing; Tp, top of platform.
Depth to water below measuring point: Reported distance given in feet; measured distance given in feet and hundredths of a foot.
Use of water: D, domestic; I, irrigation; N, none; O, observation well; PS, public supply; S, stock.
Remarks: Ca, complete chemical analysis (see table 1); L, log of well available.

Well	Owner or user	Year drilled or dug	Depth of well below land surface (feet)	Diameter of casing (inches)	Type of casing	Type of pump	Type of power	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Static water level: Depth to water below measuring point (feet)	Static water level: Date of measurement	Rise (+) or decline (−) in water level since 1940	Draw-down (feet)	Yield (gpm)	Use of water	Remarks
A1-13-12dc	Hiram Hoffman	------	72	48	R	Cy	W	Tp	1.2	1,111	69.76	10- 5-62	−3.52	------	------	S	Ca
16aa	Awin Blecha	------	25	72	R	Cy	W	Pb	0	1,110	6.68	10- 5-62	+5.47	------	------	D, S	
17ba	J. A. Kanel	------	27	36	R	Cy	E	Tp	.5	1,000	18.92	10- 5-62	+2.77	------	------	S	
22cb	Oliver J. Stauffer	------	24	48	R	J	E	Tp	3.0	1,078	18.56	10- 5-62	+2.08	------	------	S	
25aa	Gerald Schmid	------	100	6	I	Cy	H	Tc	.5	1,120	45	10- 5-62	+3.00	------	------	N	Ca
30aa	Ronald Wittwer	------	24	36	R	Cy	H	Tp	1.0	1,130	14.35	10- 5-62	------	------	------	N	
32dd	Louis Habegger	------	150	6	I	Cy	W	------	------	------	130	10- 5-62	------	------	------	S	
14-1aa	F. A. Arnold	------	35	96	R	N	N	Tp	2.0	1,002	15.51	9-20-62	+12.88	------	------	N	
3aa	L. H. Kinsey	------	17	36	R	Cy	W	Tp	3.0	953	7.58	10- 4-62	------	------	------	N	
8bc	Warren Dorland	------	13	72	R	Cy	E	Tp	.9	981	2.45	10- 4-62	+5.65	------	------	S	
10cb	Robert Marsh	------	24	36	R	J	E	Tc	0	1,015	4.64	10- 4-62	------	------	------	D, S	
14dd	George Edelman	------	30	36	R	Cy	H	Tp	0	1,000	6	10- 4-62	+0.72	------	2	D	Ca
19dd	Ella Church	------	46	4	I	Cy	W	Pb	.5	1,085	31.85	10- 4-62	+3.18	------	------	N	
22db	L. B. Feldman	------	80	6	I	Cy	W	Pb	1.0	1,036	35.07	10- 4-62	------	------	------	N	
34bd	Vernon Kaul	------	21	48	R	Cy	E	Tp	1.2	1,151	10.45	10- 4-62	−0.41	------	------	S	
15-5cc	William Babb	------	37	36	R	Cy	H	Tp	1.5	1,001	25.30	9-20-62	------	------	------	S	
7cb	Roy Bonhotel	------	21	96	R	Cy	N	Tp	0	937	15.20	9-20-62	−2.00	------	------	N	
10ab	City of Salem	------	60	------	I	T	E	------	------	------	20	8-30-62	------	------	------	PS	Ca
10ba	do	------	60	------	I	T	E	------	------	------	30	8-30-62	------	------	------	PS	Ca
14cc	A. D. Sargent	------	35	36	R	Cy	W	Tp	0	1,015	19.07	9-19-62	+7.38	------	------	S	
17aa	Charles Dettmann	------	87	6	I	Cy	E	Tc	2.0	997	61.22	10- 4-62	------	------	------	S	
19cd	Ben Stalder	------	38	48	R	J	E	Tp	.2	1,053	26.97	10- 4-62	+2.09	------	------	D	
32da	Mae Wittwer	------	74	4	I	Cy	W	Tc	1.0	1,141	57.14	10- 4-62	+2.34	------	------	N	
34aa	Ben Rannebeck	------	95	6	I	J	E	Tp	2.0	1,142	70.52	9-19-62	−3.28	------	------	D, S	

36dd	D. C. Baird		60	6	I	Cy	H	Tc	1.5	1,055	15.30	9-19-62				N	
16-1ab	W. F. Rieschick			36	R	Cy	W	Pb	2.4	912	4.40	9- 6-62				N	
5ba	C. R. Jones		78	6	I	Cy	W	Pb	2.0	1,042	15.57	9-19-62				N	
7cc	Edna Harper		16	6	I	Cy	W	Tc	1.0	904	1.30	9-19-62				N	
16db	Edwin H. Towle		40	10	I	N	N	Tc	1.0	881	9.54	9-19-62	+5.28			N	
19dc	Towle Realty Co.		16	40	R	N	N	Tp	1.0	936	9.59	9-19-62	-0.90			N	
24ac	S. J. Koelzer		56	6	I	J	E	Tp	2.6	970	35	8-28-62	+6.96			D, S	
29dd	Mabel Boose		33	36	R	Cy	H	Tp	.9	939	18.64	9-19-62	+6.75			N	
35dd	Edward Schmidt		65	18	T	Cy	W	Pb	.5	935	26.70	9- 5-62				D, S	
17-14aa	Elizabeth Murphy		43	36	R	J	E	Tp	1.0	979	32.53	10- 3-62				D	
16bb	University of Nebraska	1940	40	1	I	N	N	Tc	1.7	874	11.72	8-26-62	+7.79			O	
24ac	Donald James	1957	60	18	C	T	E	Pb	1.0	862	1.99	7-26-62		17	750	I	L
27bb	G. C. Walker		26	18	T	Cy	W	Tp	1.0	872	10.05	8-28-62	+15.95			N	
29cd	Thomas Farrell		34	36	R	Cy	W	Pb	0	965	24.39	9- 5-62				D, S	
34bb	Glen Copland		42	48	R	Cy	E	Tp	1.0	931	6.93	8-28-62	+31.23			S	
35cd	Herman Oberst		80	10	T	J	E	Tp	2.1	922	42.70	8-28-62	+11.71			D, S	
18-20cd1	Falls City		65		I	T	E				13	8-30-62				PS	
cd2	do		65		I	T	E				13	8-30-62				PS	
db1	do		65		I	T	E				13	8-30-62				PS	
db2	do		65		I	T	E				13	8-30-62				PS	
db3	do		65		I	T	E				13	8-30-62				PS	
dc1	do		65		I	T	E				13	8-30-62				PS	
dc2	do		65		I	T	E				13	8-30-62				PS	
34ac	B. Ogden		70	48	R	Cy	W	Tp	.8	1,041	59.80	8-28-62	+9.00			N	
A2-13- 1da	Raymond Gergens		30	12	T	Cy	W				5	10- 4-62				S	
2cb	City of Humboldt		30		I	T	E				6	10- 3-62				PS	
2cc	do		55		I	T	E				6	10- 3-62				PS	
4cd	University of Nebraska	1936	19	3	I	N	N	Tc	2.6	985	9.90	10- 3-62	+2.32			O	
6bc	Harmon Glather		34	72	R	Cy	W	Tp	0	1,075	16.00	10- 5-62	+15.33			D, S	
9bb	University of Nebraska	1936	25	3	I	N	N	Tc	2.1	984	24.10	10-30-62				N	
16da	E. P. Hodapp		22	36	R	N	N	Tp	2.5	1,064	14.41	10- 5-62	+0.06			N	
20cd	Jesse Nemechek		25	48	R	J	E	Pb	1.3	1,076	7	10- 5-62	+0.94			D	
26ba	Silas King		31	72	R	Cy	W	Tp	1.0	1,007	5.59	10- 5-62	+13.39			S	
28dc	Joseph Skalak		72	6	I	Cy	H	Tp	1.0	1,071	24.70	10- 5-62				N	
31cd	John Storant		15	48	R	Cy	H	Tp	.5	1,118	3.40	10- 5-62	+4.91			N	
14- 9bb	George Belden, Jr.		86	6	I	Cy	H	Tc	.5	1,120	39.11	10- 4-62				N	
14bb	Robert E. Kean	1962	112	6	I			Tc	1.0	1,071	44.15	9-20-62				N	New well
19dd	John M. Cornelius		26	48	R	Cy	W	Tp	.9	1,001	14.78	10- 4-62	+5.20			S	
22ab1	City of Dawson		59		I	T	E				24	9-20-62				PS	
22ab2	do		59		I	T	E				24	9-20-62				PS	Ca
28cd	Fred Kahlbau		125	4	I	Cy	E				60	9-20-62				D	

TABLE 2.—*Records of wells in Richardson County*—Continued

Well	Owner or user	Year drilled or dug	Depth of well below land surface (feet)	Diameter of casing (inches)	Type of casing	Type of pump	Type of power	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Static water level: Depth to water below measuring point (feet)	Static water level: Date of measurement	Rise (+) or decline (−) in water level since 1940	Drawdown (feet)	Yield (gpm)	Use of water	Remarks
15– 7ab	Stacy Brown		44	12	I	J	E	Tp	0	1,025	19	9-20-62	+18.14			D, S	
10dc	City of Verdon		46		I	T	E	Tc	0	940	16.50	9- 7-62				PS	Ca
15dd	G. C. Heineman		25	48	R	Cy	H	Tc	0	945	6.48	9- 7-62	+12.53			N	
16bc	R. E. Owens		35	12	T	Cy	H	Tp	1.0	1,011	12.50	9-20-62	+11.30			D	
27cb	H. R. Fritz		45	10	T	Cy	W	Tp	.9	961	10.99	9-20-62	+28.70			N	
29ba	Verne Antholz		25	36	R	J	E	Tp	1.0	986	13.28	10- 4-62				D, S	
35cb	C. Arendt		65	36	R	Cy	W	Tp	1.0	951	19.85	9-19-62				S	
16– 1bb	Paul Schawang		89	6	I	Cy	W	Tp	.5	1,132	50	9- 6-62	+5.00			S	
5dc	Herbert Vollmer		66	6	I	J	E				41	9- 7-62				D, S	
11cc	Wilbert Fritz		64	6	I	T	E				49	9- 7-62				D, S	
17dd	Henry Ruegge		37	10	I	Cy	W	Tp	.4	962	21.16	9-19-62	+9.48			N	
18bb	Ben Cooper		85	6	I	J	E	Ls	0	1,010	65	9-19-62				D, S	
24da	Edward O'Grady		65	6	I	Cy	W	Pb	.5	1,030	27.67	8-29-62				S	
30ba	Herbert Steinke		62	6	I	Cy	E	Pb	1.5	981	30.78	9-19-62				D, S	
33dd	Jacob Schaible		25	7	I	J	E	Tp	2.0	962	19.52	9-19-62				D, S	
17-12ac	Fred Miller		41	14	T	Cy	H	Tc	2.9	913	23	8-29-62	+16.26			D	
18ab	Fred Niemeyer		51	18	T	Cy	E	Pb	2.7	978	24.62	9- 6-62	+2.68			D, S	
20dd	H. Harshbarger		36	12	T	Cy	W	Tp	1.0	971	10.60	8-29-62	+7.46			S	
23dd	A. Wintz		96	6	I	Cy	W	Tc	.8	980	79.70	8-29-62				D, S	
24ba	Dale Gerweck		40	12	T	Cy	E	Tp	.5	940	25.86	8-29-62				D, S	
29dd	Fred Pupkes		86	18	T	Cy	E	Tp	1.3	1,061	46.28	8-29-62	+12.03			D, S	
34aa1	George Zimmerman		95	12	T	Cy	W	Tc	2.0	1,077	29.62	9- 6-62				D	
34aa2	do		300	7	I	Cy	W	Tc	1.0	1,081	89.26	9- 6-62				S	
18–30dd	M. N. Jones		33	8	T	Cy	H	Tp	2.3	882	14.28	7-26-62	+8.09			N	
32cc	Glen Martin		306	8	I	Cy	E	Tc	1.0	1,006	161.71	7-26-62	+33.29			S	
A3-13-10ba	George Mehlin	1945	245	6	I	Cy	W				100	7-25-62				S	
10bb	Raymond Clift		35	12	T	J	E	Pb	.3	1,210	19.20	8-22-62	+9.01			D, S	
11dd	G. M. Standerford		70	8	I	J	E	Tp	0	1,145	31.40	7-25-62	+27.10			D, S	
15bb1	City of Humboldt	1957	181	18	I	N	N	Tc	2.3	1,194	114.24	7-25-62			660	N	L
15dd	Donald Harshbarger		130	8	I	J	E	Tc	0	1,182	100	7-25-62	+5.00			D, S	Ca

18cb	Herman Boomgaarn	------	220	6	I	Cy	H	------	------	------	200	10- 3-62	------	------	------	D, S	
19dd	Edward Dahlke	------	42	12	T	Cy	H	Tp	1.0	1,126	32.50	9-18-62	−8.56	------	------	S	
23cc	Warren Gergens	------	14	6	I	Cy	H	Tc	.5	1,164	2.75	7-25-62	+7.12	------	------	N	
24aa	Earl Hoagland	------	60	8	I	Cy	W	------	------	------	45	9-18-62	------	------	------	D	
27bc	Harmon Loenning	------	85	12	T	Cy	E	Tp	.5	1,120	64.18	7-25-62	+4.22	------	------	D, S	
14- 3bc	L. M. Hall	------	114	8	I	Cy	W	Tp	1.4	1,047	85	9-18-62	+9.40	------	------	D, S	
6aa	Guy Mathews	------	62	6	I	Cy	W	Tp	0	1,100	45.78	9-18-62	+14.22	------	------	S	
8dc	Roy Davis	------	30	36	R	Cy	H	Tp	0	1,103	25	9-18-62	+3.91	------	------	D	
15cc	Raymond Monnette	------	60	6	I	Cy	W	Tp	0	1,070	5.34	9-18-62	------	------	------	D	
23dc	F. E. James	------	43	18	I	J	E	Tp	0	1,020	33	9-18-62	+9.60	------	------	D, S	
30bd	Charles Day	------	36	12	T	J	E	Tp	0	1,120	24.56	10- 3-62	------	------	------	D	
33bb	Joseph Slama	------	85	10	I	J	E	Tp	0	1,132	75	10- 4-62	+0.10	------	------	D, S	
35aa	Fred Deckinger	------	32	8	I	Cy	E	Pb	0	1,110	14.89	9-20-62	------	------	------	S	
15- 3cc	Carl Timmerman	------	140	6	I	J	E	------	------	------	20	9-18-62	------	------	------	D, S	
7dc	City of Stella	------	80	------	I	T	E	------	------	------	66	9- 5-62	------	------	------	PS	Ca
12ca	City of Shubert	------	120	------	I	T	E	------	------	------	106	9- 6-62	------	6	------	PS	Ca
12cd	do	------	120	------	I	T	E	------	------	------	106	9- 6-62	------	6	------	PS	Ca
20bb	Leon Harshbarger	------	42	6	I	Cy	W	Tp	.5	1,050	35.88	9- 7-62	+3.38	------	------	N	
22aa	Clarence Dorste	------	61	12	T	N	N	Tp	0	1,123	26.62	9- 7-62	------	------	------	N	
24ba	I. Ahern	------	31	15	T	N	N	Tc	2.0	1,077	6.94	9- 6-62	+5.19	------	------	N	
28bd	K. VonDeventer	------	24	12	T	Cy	H	Tc	0	1,010	16.60	9-18-62	------	------	------	N	
36ba	Homer Watkins	------	29	48	R	Cy	E	------	------	------	12	9- 7-62	------	------	------	D	
16- 3dd	Carl Geoges	------	24	6	I	Cy	H	Tc	.5	960	11.30	9- 6-62	------	------	------	D	
4dd	Daniel Lewis	------	72	4	I	Cy	W	Tc	.5	1,105	20.62	9- 6-62	+17.68	------	------	S	
6ad	Donald Williams	------	50	48	R	Cy	W	Tp	1.0	1,071	32.88	9- 6-62	+9.75	------	------	S	
16da	Art Berg	------	36	36	R	Cy	H	Tp	2.0	1,064	13.12	9- 6-62	+8.30	------	------	N	
27ad	F. N. Arnold	------	76	12	I	Cy	W	Tp	0	1,165	66.63	9- 6-62	+5.23	------	------	S	
29dd	E. J. Keithley	------	70	12	I	J	E	Tp	1.5	1,095	46.41	9- 6-62	------	------	------	D	
17-17bb	Lenard L. Ramer	------	85	14	W	Cy	W	Tp	.5	1,150	40	9- 6-62	+4.10	------	------	S	
28cc•	J. W. Ludwig	------	59	10	T	Cy	H	Tp	0	975	30.34	10- 3-62	+25.07	------	------	N	Ca
32dd	Orin Koso	----	83	7	I	Cy	H	Tc	.5	1,025	24.10	9- 5-62	------	------	------	D, S	

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Contributions to the hydrology of the United States.

Part of illustrative matter fold. in pocket.

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Bibliography: p. 28–29.

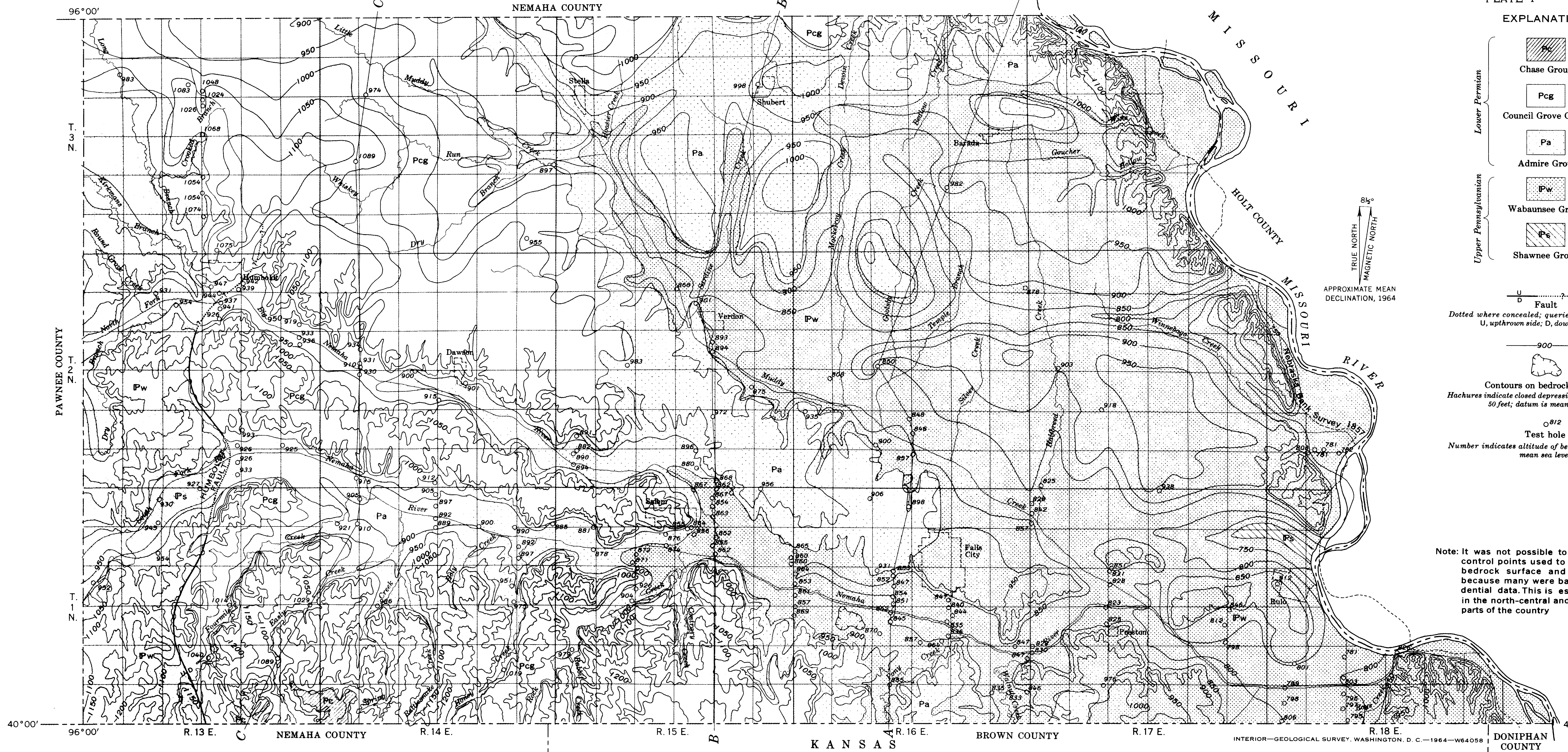
(Continued on next card)

Emery, Philip A 1934– Geology and ground-water resources of Richardson County, Nebraska. 1964. (Card 2)

1. Geology—Nebraska—Richardson Co. 2. Water-Supply—Nebraska—Richardson Co. 3. Water, Underground—Nebraska—Richardson Co. I. Nebraska. University. Conservation and Survey Division. (Series)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-SUPPLY PAPER 1779-W
PLATE 1



EXPLANATION

PERMIAN — *Lower Permian*

Pc — Chase Group

Pcg — Council Grove Group

Pa — Admire Group

CARBONIFEROUS — PENNSYLVANIAN — *Upper Pennsylvanian*

Pw — Wabaunsee Group

Ps — Shawnee Group

U/D ——?—?— Fault

Dotted where concealed; queried where approximate. U, upthrown side; D, downthrown side

——900—— Contours on bedrock surface

Hachures indicate closed depression. Contour interval 50 feet; datum is mean sea level

o812 Test hole

Number indicates altitude of bedrock surface above mean sea level

Note: It was not possible to show all the control points used to delineate the bedrock surface and stratigraphy because many were based on confidential data. This is especially true in the north-central and northeastern parts of the country

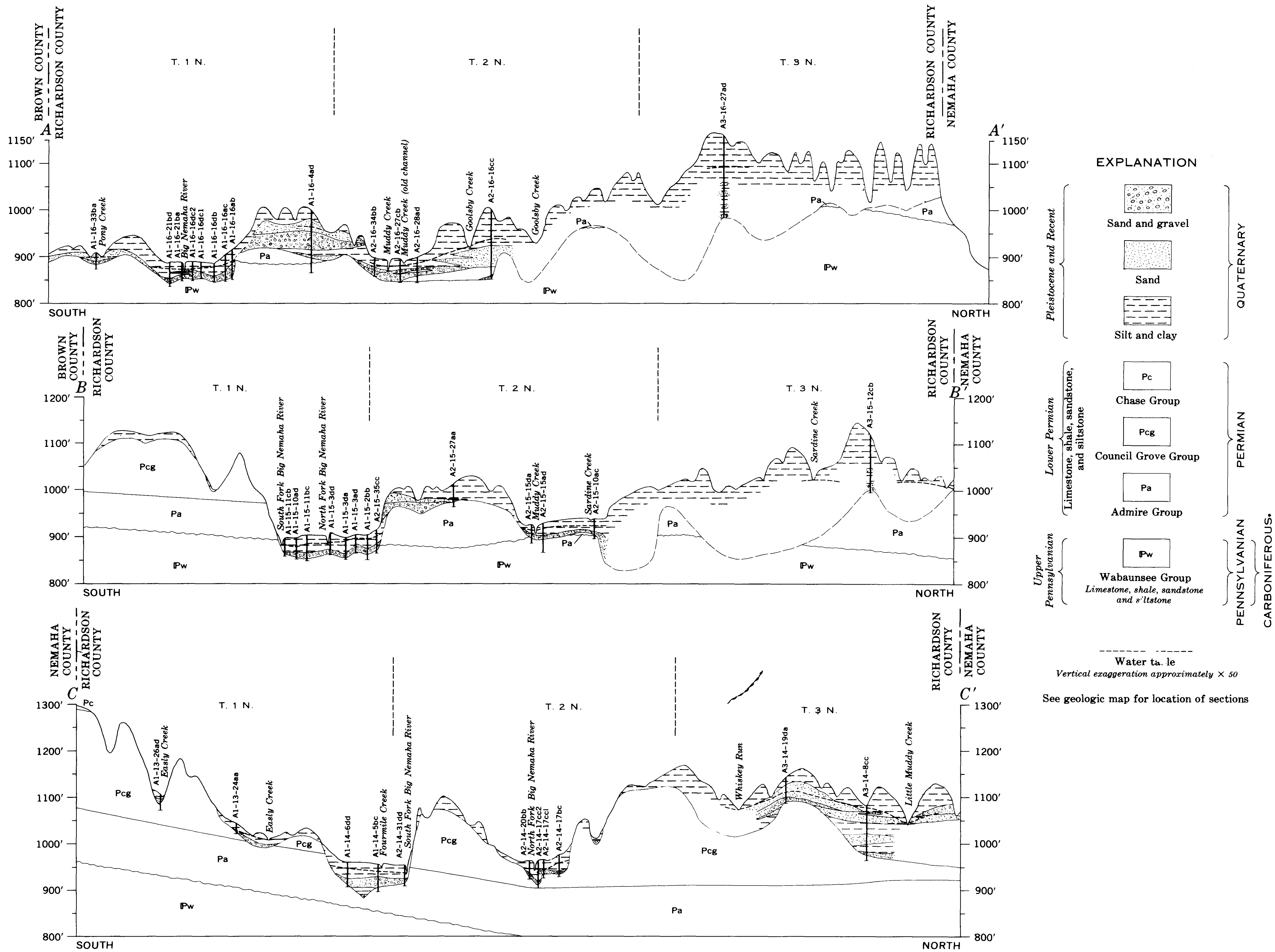
This map is based on information, in part unpublished, made available by the Conservation and Survey Division, University of Nebraska, and compiled by Philip A. Emery

MAP OF RICHARDSON COUNTY, NEBRASKA SHOWING BEDROCK GEOLOGY AND CONFIGURATION OF THE BEDROCK SURFACE

SCALE 1:125 000

2 1 0 2 4 6 8 10 MILES

2 1 0 2 4 6 8 10 KILOMETERS



Geology by Philip A. Emery

GEOLOGIC SECTIONS ACROSS RICHARDSON COUNTY, NEBRASKA

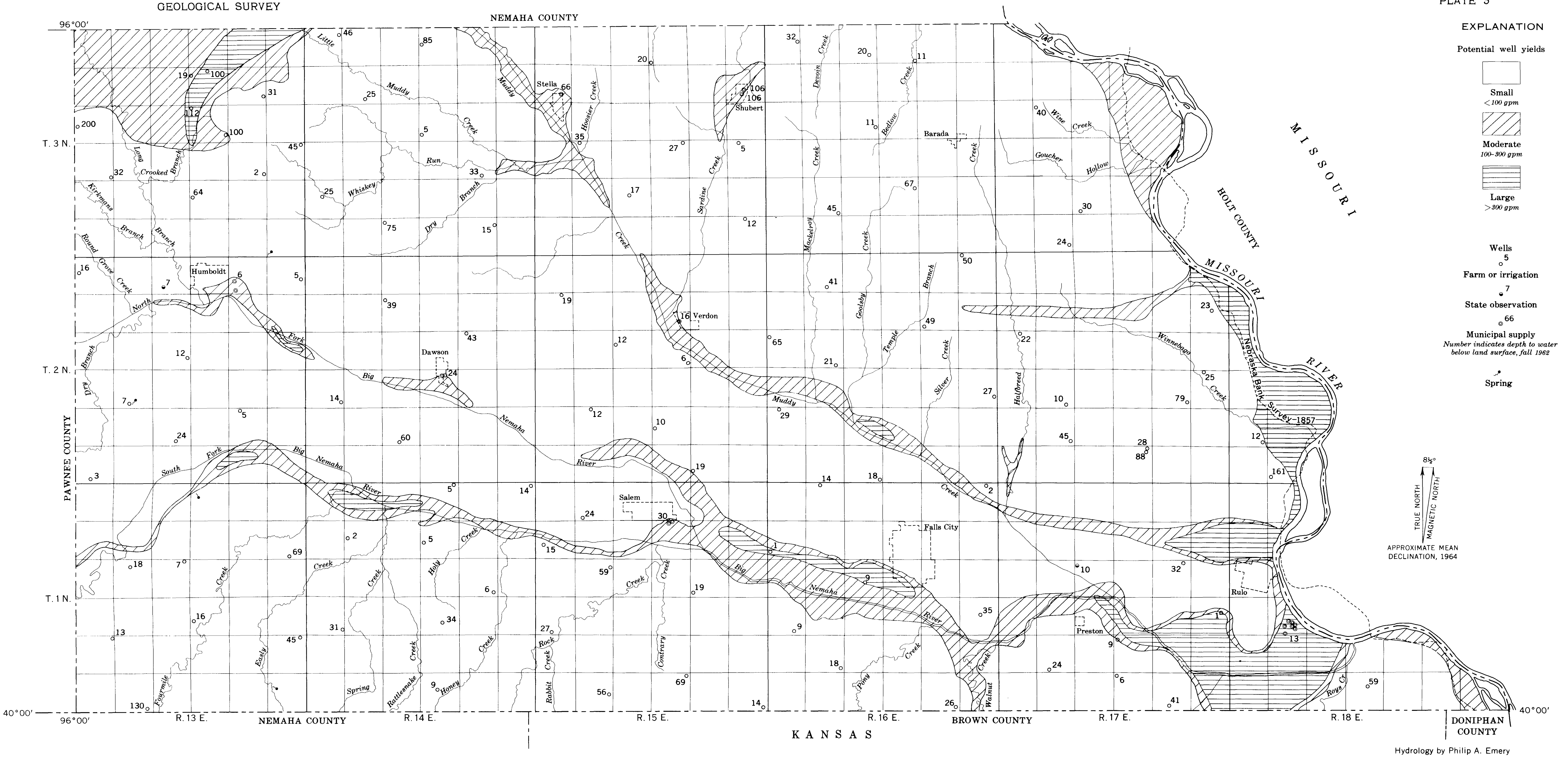
SCALE 1:125 000

2 1 0 2 4 6 MILES

2 1 0 2 4 6 KILOMETERS

DATUM IS MEAN SEA LEVEL

735-992 O - 64 (In pocket)



MAP OF RICHARDSON COUNTY, NEBRASKA SHOWING MEASURED DEPTHS TO WATER AND POTENTIAL YIELD OF GROUND WATER TO WELLS

SCALE 1:125 000

2 1 0 2 4 6 8 10 MILES

2 1 0 2 4 6 8 10 KILOMETERS

735-992 O - 64 (In pocket)