Ground-Water Resources of the Lower Niobrara River and Ponca Creek Basins, Nebraska and South Dakota

By THOMAS G. NEWPORT

With a section on CHEMICAL QUALITY OF THE WATER

By ROBERT A. KRIEGER

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1460-G

Prepared as part of a program of the Department of the Interior for the development of the Missouri River Basin

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1959

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GROUND-WATER RESOURCES OF THE LOWER NIOBRARA RIVER AND PONCA CREEK BASINS, NEBRASKA AND SOUTH DAKOTA

By Thomas G. Newport

ABSTRACT

This report describes the area in north-central Nebraska and south-central South Dakota drained by Ponca Creek and by the Niobrara River below Valentine, Nebr. The Niobrara River and Ponca Creek are neighboring eastward-flowing tributaries of the Missouri River.

The Dakota sandstone of Cretaceous age is the oldest formation tapped by wells; the water it yields to wells in small to moderate quantities is rather highly mineralized and very hard; it is unsuitable for irrigation and most domestic uses. Overlying the Dakota, in ascending order, are the following formations of Cretaceous age: the Graneros shale, Greenhorn limestone, Carlile shale, Niobrara formation, and Pierre shale. None of these is a source of water supply. The Niobrara is the oldest formation exposed, cropping out in only the deeper valleys at the eastern end of the area. The Pierre shale, which is exposed much more extensively, crops out in the deeper valleys throughout nearly all the area.

Except where the Niobrara River, its major tributaries, and Ponca Creek have cut their valleys into them, the Cretaceous rocks are overlain by semi-consolidated rocks of Tertiary age. Two Tertiary formations, the Brule and the Ogallala, are present in the area. The Brule formation underlies all the western part of the area and is exposed in the valleys of both the Niobrara and Keya Paha Rivers. The Ogallala formation, which overlaps the Brule, forms the upland on both sides of the river and is exposed in many places. The Brule is not a source of water supply, whereas the Ogallala yields small to moderately large quantities of water to many wells on the upland. The water in the Ogallala is of the calcium bicarbonate type and is moderately mineralized and hard.

Unconsolidated deposits of Quaternary age mantle the Tertiary rocks throughout nearly all the upland area south of the Niobrara River and in parts of the upland area north of the river. They also floor the Niobrara River valley. Where saturated, these sediments, which consist of stream-deposited sand and gravel and wind-deposited sand, yield small to large amounts of water to wells. The water in the Quaternary deposits is of the calcium bicarbonate type but is less mineralized and softer than that in the Ogallala.

The only significant source of recharge to the Dakota sandstone in the report area is underflow from the west. Except for water yielded to wells tapping the

Dakota, water in the formation is discharged from the area by underflow to the east. In the upland part of the area, the Ogallala formation and the overlying deposits of Quaternary age constitute a single aquifer, water moving from one into the other without apparent hindrance. This aquifer is recharged principally by the direct infiltration of precipitation but in part also by underflow from the west and south and by seepage from intermittent streams and ponds. Water is discharged from the upland aquifer by outflow through springs or seepage into streams, through the process of evapotranspiration, and by wells when they are pumped. Ground water leaves the report area by underflow where the Quaternary deposits in the valleys of the Niobrara River and Ponca Creek merge with the Quaternary deposits in the Missouri River valley .

In places where the Niobrara formation, the Pierre shale, or the Brule formation is at the surface or is mantled by thin deposits of the Ogallala or thin deposits of Quaternary age, only meager amounts of ground water can be obtained unless wells are deep enough to tap the Dakota sandstone. Elsewhere the Ogallala formation and the deposits of Quaternary age generally yield ample water for domestic and stock supplies, and in some places, notably in the vicinity of Ainsworth, they yield enough water for irrigation. Additional large supplies of ground water could be obtained on the upland in the southwestern and west-central parts of the area.

The report contains an annotated bibliography of previous publications on the geology and ground-water resources of the area, brief descriptions of the Cretaceous, Tertiary, and Quaternary rocks, a map showing the contour of the water table, logs of test holes and wells not published elsewhere, results of analyses of ground- and surface-water samples, and records of all wells of large discharge and representative wells of small discharge.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The purpose of this report is to summarize existing data on the geology and ground-water resources of the Niobrara River drainage basin below Valentine, Nebr., and the entire Ponca Creek drainage basin; to determine the extent of existing ground-water development; to appraise the potential for development of additional ground-water supplies; and to determine the chemical quality of the water.

The greater part of the fieldwork for this report was done in the summer of 1952 by the U. S. Geological Survey. The remainder of the fieldwork was done in early 1957 by the U. S. Geological Survey in cooperation with the Conservation and Survey Division of the University of Nebraska. The earlier phase of the study was made as part of the program of the Department of the Interior for development of the Missouri River basin, whereas the later phase was made at the request of the Niobrara River Compact Commission. The Niobrara River Compact Commission was authorized in 1953 by the United States Congress to study and recommend an equitable apportionment of the surface- and ground-water resources of the Niobrara River basin among the States of Wyoming, Nebraska, and South Dakota.

The fieldwork done in 1952 was under the supervision of C. F. Keech, district engineer of the Ground Water Branch of the U. S. Geological Survey, and that done in 1957 was under the joint supervision of Mr. Keech and E. C. Reed, State Geologist. The quality-of-water studies were made under the supervision of P. C. Benedict, regional engineer of the Quality of Water Branch of the U. S. Geological Survey.

METHODS OF INVESTIGATION

Available literature pertaining to the geology and water resources of the area was examined. Information thus obtained was used in preparing the annotated bibliography and much of the sections on geography and geology in this report. Additional data on the geology were obtained by drilling 16 test holes (with State-owned equipment) and by compiling the logs of 9 wells and 6 test holes drilled by commercial drillers. Information on the occurrence of ground water was obtained by examining 52 public-supply wells, 43 irrigation wells, and 121 domestic, livestock, and unused wells. All the known public-supply and irrigation wells and representative other wells were included in the survey. The locations of wells with respect to township and section lines were determined by inspection of topographic maps or by measuring distances with an automobile odometer. Where possible, the depth of the wells and the depth to water in them were measured with a steel tape; reported data were obtained for wells that could not be measured. The altitude of the land surface at many of the wells was interpolated from topographic maps or was determined by aneroid barometer. The altitude at some of the wells, principally on the Ainsworth tableland in Brown County, had been determined by spirit leveling before this study was begun. Altitudes of the water level in wells and of the water surface in streams fed by ground water were used as control points in constructing a map showing the configuration of the water table. Water samples were collected from 15 wells and were analyzed in the laboratory of the U. S. Geological Survey in Lincoln, Nebr. Prior to the field investigation for this study, 38 samples collected from 33 other wells in the area had been analyzed.

WELL-NUMBERING SYSTEM

Wells were assigned numbers according to their location within the system of land subdivision of the United States Bureau of Land Management. A well number indicates the township, range, section, and position of the well within the section (fig. 18). The first segment of a number indicates the township, the second the range, and the third the section in which the well is located. The lowercase

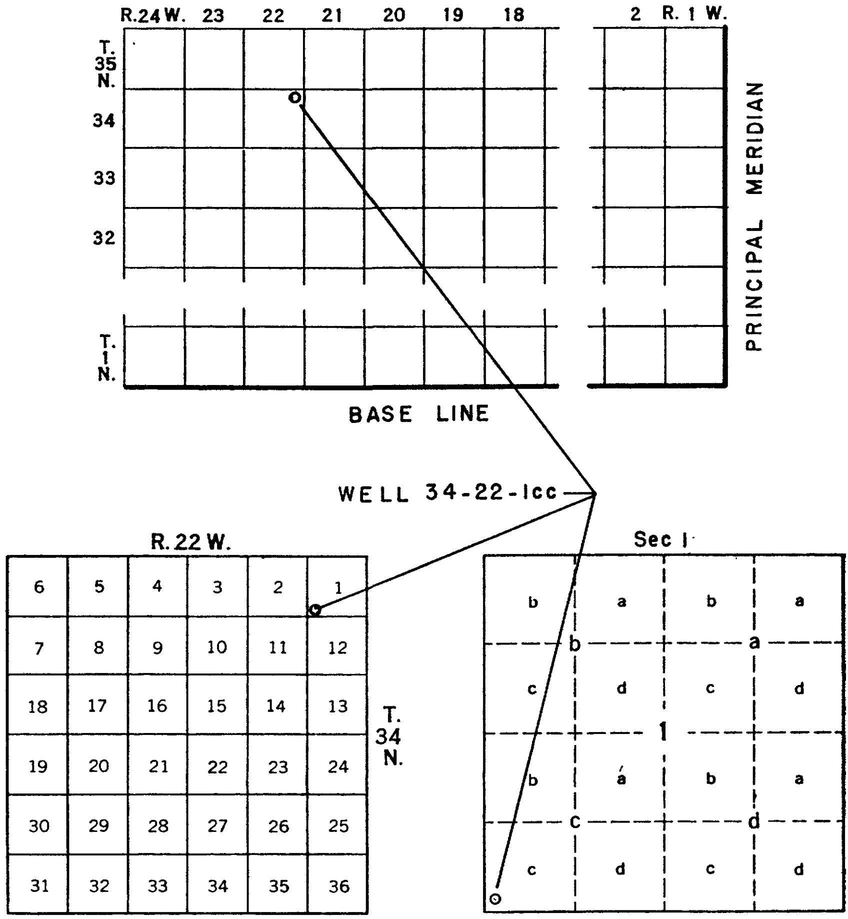

FIGURE 18.—Sketch showing well-numbering system.

letters after the section number locate the well within the section. The first letter denotes the quarter section and the second, the quarter-quarter section (40-acre tract). The subdivisions of the section and quarter section are lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. Springs and test holes also were assigned numbers according to the same numbering system.

ACKNOWLEDGMENTS

Well owners, town officials, and other residents in the area greatly assisted in this study by supplying information about wells, springs, and test holes. Employees of the U. S. Soil Conservation Service supplied much information regarding the location of wells. Drilling contractors furnished well logs and other data. Maps and geologic

data were obtained from the Conservation and Survey Division of the University of Nebraska and from the South Dakota Geological Survey.

SELECTED ANNOTATED BIBLIOGRAPHY

The reports pertaining to the geology and to the occurrence and utilization of ground and surface water in the area were reviewed. A brief summary of each report is given in the list below. A few allied references are included.

Anonymous, 1953, Logs of test holes, Brown County, Nebr., 1931 to 1952, inclusive: Nebraska Conserv. and Survey Div., 15 p.

Contains detailed logs of test holes drilled in Brown County as part of the Federal-State program of geologic and ground-water studies.

——— 1954, Logs of test holes, Knox County, Nebr., 1931 to 1953, inclusive: Nebraska Conserv. and Survey Div., 24 p.

Contains detailed logs of test holes drilled in Knox County as part of the Federal-State program of geologic and ground-water studies.

Baker, C. L., 1948, Additional well borings in South Dakota: South Dakota Geol. Survey Rept. Inv. 61, 40 p.

Contains logs of deep wells, listed by counties.

Condra, G. E., 1908, Geology and water resources of a portion of the Missouri River valley in northeastern Nebraska: U. S. Geol. Survey Water-Supply Paper 215, 59 p., 11 pls.

Describes the geology, streams, springs, and shallow and artesian wells in Boyd, Knox, Cedar, Dixon, and Dakota Counties and a part of Holt County; includes map showing surface geology and artesian-water conditions.

Condra, G. E., and Reed, E. C., 1943, The geological section of Nebraska: Nebraska Geol. Survey Bull. 14, 82 p., 1 pl.

Reviews the age relations and general lithologic character and thickness of the rock formations in Nebraska.

Condra, G. E., Reed, E. C., and Gordon, E. D., 1950, Correlation of the Pleistocene deposits of Nebraska: Nebraska Geol. Survey Bull. 15A, 73 p., 15 pls.

Describes the Pleistocene deposits and shows their areal distribution in Nebraska; discusses water-table fluctuations during the Pleistocene epoch.

Cook, J. F. D., and Towne, W. W., 1941, Data on South Dakota water supplies: South Dakota State Board Health, Div. Sanitary Eng., 19 p.

Contains data on water supplies for towns, cities, and institutions in South Dakota, including source, treatment, and storage facilities; gives chemical analyses of both surface and ground water.

Cronin, J. G., and Newport, T. G., 1956, Ground-water resources of the Ainsworth unit, Cherry and Brown Counties, Nebr., with a section on the chemical quality of the ground water, by R. A. Krieger: U. S. Geol. Survey Water-Supply Paper 1371. [1957]

Describes ground-water conditions in a 1,100-square-mile area in Brown and Cherry Counties, Nebr. Includes a water-table contour map, a depth-to-water map, data on two aquifer tests, geologic sections, logs of wells and test holes, and a section on the chemical quality of the water in the area.

Darton, N. H., 1909, Geology and underground water of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, 156 p., 15 pls.

Contains information on the geology and principal aquifers of the State and itemizes the deep wells and well prospects by counties. Gives note on the construction and management of artesian wells. Includes maps showing the geology and artesian conditions.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., Inc., p. 11–21, 61–79.

Describes the origin of landforms in the western part of the United States; includes descriptions of the sandhill district of Nebraska and the loess plains, both in the High Plains section of the Great Plains province, and the unglaciated Missouri Plateau section, also in the Great Plains province.

Fiedler, A. G., 1929, Report on additional water supply for the Rosebud Boarding School, Rosebud Indian Reservation, S. Dak.: U. S. Geol. Survey open-file rept., Washington, D. C., and Lincoln, Nebr., 53 p.

Discusses the geology and hydrology of the vicinity of the Rosebud Boarding School, with special reference to ground-water conditions.

Flint, R. F., 1955, Pleistocene geology of eastern South Dakota: U. S. Geol. Survey Prof. Paper 262.

Describes the glacial deposits of eastern South Dakota and discusses the drainage changes caused by the continental ice sheets.

Hayes, F. A., Mortlock, H. C., Layton, M. H., Weakley, H. E., and Westerman, J. D., 1924, Soil survey of Antelope County, Nebr.: U. S. Dept. Agriculture, 58 p., 1 pl.

Describes climate, agriculture, and soils in Antelope County.

Hayes, F. A., Nieschmidt, E. A., Brown, L. A., Abashkin, B. J., Gemmel, R. L., Lovald, R. H., and Otte, H., 1930, Soil Survey of Knox County, Nebr.: U. S. Dept. Agriculture, 49 p., 1 pl.

Describes climate, agriculture, and soils in Knox County.

Keech, C. F., and Case, R. L., 1954, Water levels prior to January 1, 1954, in observation wells in Nebraska, pts. 1 and 2: U. S. Geol. Survey open-file rept., Washington, D. C., Denver, Colo., and Lincoln, Nebr., 543 p.

Lists water-level measurements made before January 1, 1954, in observation wells in Nebraska, previously unpublished.

——— 1955, Water levels in observation wells in Nebraska during 1954: U. S. Geol. Survey open-file rept., Washington, D. C., Denver, Colo., and Lincoln, Nebr., 234 p.

Lists water-level measurements made during 1954 in observation wells in Nebraska, not otherwise published.

Lee, W. D., Hayes, F. A., Bacon, S. R., and Gemmel, R. L., 1937, Soil survey of Rock County, Nebr.: U. S. Dept. Agriculture, 37 p., 1 pl.

Describes climate, agriculture, and soils in Rock County.

Lee, W. D., Hayes, F. A., Bacon, S. R., and Lovald, R. H., 1937, Soil survey of Keya Paha County, Nebr.: U. S. Dept. Agriculture, 40 p., 1 pl.

Describes climate, agriculture, and soils in Keya Paha County.

Lugn, A. L., 1935, The Pleistocene geology of Nebraska: Nebraska Geol. Survey Bull. 10, 223 p., 2 pls., 38 figs.

Discusses ground water in relation to Pleistocene deposits. Includes several geologic sections of parts of the State.

——— 1939, Classification of the Tertiary system in Nebraska: Geol. Soc. America Bull., v. 50, no. 8, p. 1245–1275.

Presents the results of research by the Nebraska Geological Survey on Tertiary stratigraphy in Nebraska during a period of more than 10 years, with special reference to the stratigraphic nomenclature. Summarizes, in tabular form, the Tertiary formations of Nebraska.

Moran, W. J., Hayes, F. A., Lee, W. D., Bacon, S. R., Abashkin, B. J., Gemmell, R. L., and Lovald, R. H., 1938, Soil survey of Holt County, Nebr.: U. S. Dept. Agriculture, 36 p., 1 pl.

Describes climate, agriculture, and soils in Holt County.

Moran, W. J., Hayes, F. A., and Lovald, R. H., 1937, Soil survey of Boyd County, Nebr.: U. S. Dept. Agriculture, 42 p., 1 pl.

Describes climate, agriculture, and soils in Boyd County.

Nebraska State Planning Board, 1936, Water resources of Nebraska: Prelim. Rept., 695 p.

A comprehensive study of Nebraska's water resources designed to guide recommendations for their development. Contains maps showing geology, ground-water regions, location of observation wells, and precipitation.

——— 1941, Water resources of Nebraska: Revised February 1941, 305 p.

A revision of the 1936 report.

Nieschmidt, E. A., Hayes, F. A., and Bacon, S. R., 1938, Soil survey of Brown County, Nebr.: U. S. Dept. Agriculture, 48 p., 1 pl.

Describes climate, agriculture, and soils in Brown County.

Petsch, B. C., 1946, Geology of the Missouri Valley in South Dakota: South Dakota Geol. Survey Rept. Inv. 53, 78 p., 4 pls., 29 figs.

Describes the exposed rock formations in the Missouri River valley. Contains a geologic map and section of the river valley.

Reagen, A. B., 1905, Geologic observations in the central part of the Rosebud Indian Reservation, S. Dak.: Am. Geologist, v. 36, p. 229–243.

Gives a general description of the Rosebud Indian Reservation, with brief sections on water, springs, and irrigation; contains geologic sections and a geologic map.

Reed, E. C., 1944, Ground-water survey of the area north of O'Neill, Holt County, Nebr.: Nebraska Univ., Conserv. and Survey Div. Water Survey Paper No. 2, 26 p., 12 figs.

Discusses the possibilities for pump irrigation in a 70-square-mile area northwest of O'Neill; gives records of 13 test holes; and describes the geology, topography, drainage, soils, and occurrence of ground water. Concludes that pump irrigation may be economically feasible on a small scale in part of the area.

——— 1957, Logs of test holes, Keya Paha County and northeast Cherry County, Nebr.: Nebraska Conserv. and Survey Div., 19 p.

Contains detailed logs of test holes drilled in Keya Paha County and northeastern Cherry County as part of the Federal-State program of geologic and ground-water studies.

Rothrock, E. P., 1934, A geology of South Dakota, pt. 1, The surface: South Dakota Geol. Survey Bull. 13, 99 p., 30 pls.

Discusses the physiographic divisions of South Dakota.

——— 1944, A geology of South Dakota, pt. 3, Mineral resources: South Dakota Geol. Survey Bull. 15, 255 p., 14 pls.

Discusses the mineral resources of South Dakota; includes a section on surface- and ground-water supplies.

Schreurs, R. L., 1954, Configuration of the water table in Nebraska: U. S. Geol. Survey Hydrol. Inv. Atlas HA-4.

Briefly describes the water-bearing formations in Nebraska and presents map showing contours on the water table for most of the State, including the lower Niobrara River and Ponca Creek basins.

Smith, F. A., 1958, Logs of test holes, Antelope, Boone, Knox, and Pierce Counties, Nebr.: Nebraska Conserv. and Survey Div., 75 p.

Contains detailed logs of test holes drilled in Antelope, Boone, Knox, and Pierce Counties as part of the Federal-State program of geological and ground-water studies.

South Dakota State Planning Board, 1937, Water resources of the Keya Paha-Ponca River drainage basin: South Dakota Water Resources Comm. Prelim. Rept., 36 p., 9 figs.

Gives a general description of the drainage basin in South Dakota and discusses human occupancy, the extent and adequacy of existing water development, the underground waters, water pollution and deficiencies, future water needs, and a plan for development.

Tolstead, W. L., 1942, Vegetation of the northern part of Cherry County, Nebr.: Ecol. Mon., v. 12, p. 255–292.

Describes flora of sandhills area in Cherry County in relation to soils, geology, precipitation, soil moisture, position of the water table, and salt concentrations in lake water. Discusses water-table fluctuations due to plant transpiration.

U. S. Corps of Engineers, 1934, Niobrara River, Nebraska and Wyoming: U. S. 73d Cong., 1st sess., H. Doc. 90.

Prepared under the provisions of House Document 308, Sixty-ninth Congress, first session. Describes the geography, topography, geology, soils, weather, population, transportation, and drainage in the Niobrara River basin. Includes stream-discharge records.

U. S. Geological Survey, 1889, 1901–08, 1910–15, 1928–36, 1938–55, Surface-water supply of the United States, pt. 6, Missouri River Basin: U. S. Geol. Survey Water-Supply Papers 37, 66, 84, 99, 130, 172, 208, 246, 286, 306, 326, 356, 386, 406, 666, 686, 701, 716, 731, 746, 761, 786, 806, 856, 876, 896, 926, 956, 976, 1006, 1036, 1056, 1086, 1116, 1146, 1176, 1209, 1239, 1279, 1339, and 1389.

Annual reports giving stream-discharge measurements; include measurements for lower Niobrara River basin.

——— 1936–56, Water levels and artesian pressure in observation wells in the United States, pt. 3, North-Central States: U. S. Geol. Survey Water-Supply Papers 817, 840, 845, 886, 908, 938, 946, 988, 1018, 1025, 1073, 1098, 1128, 1158, 1167, 1193, 1223, 1267, and 1323.

Annual reports giving water-level measurements made in observation wells; include measurements for wells in lower Niobrara River basin.

——— 1946–50 1952–53, Quality of surface waters of the United States: U. S. Geol. Survey Water-Supply Papers 1050, 1102, 1132, 1162, 1187, 1251, and 1291.

Annual reports giving records of chemical analysis, suspended sediment, and temperature for surface waters; include analyses and measurements for Ponca Creek and streams in the lower Niobrara River basin.

GEOGRAPHY

LOCATION AND EXTENT OF AREA

The area described in this report includes all of Keya Paha and parts of Cherry, Brown, Rock, Holt, Boyd, Antelope, and Knox Counties, Nebr., and Todd, Tripp, and Gregory Counties, S. Dak. (See fig. 19.) It covers about 6,340 square miles, of which about 1,670 square miles is in South Dakota. The distance from east to west is about 162 miles and from north to south about 76 miles.

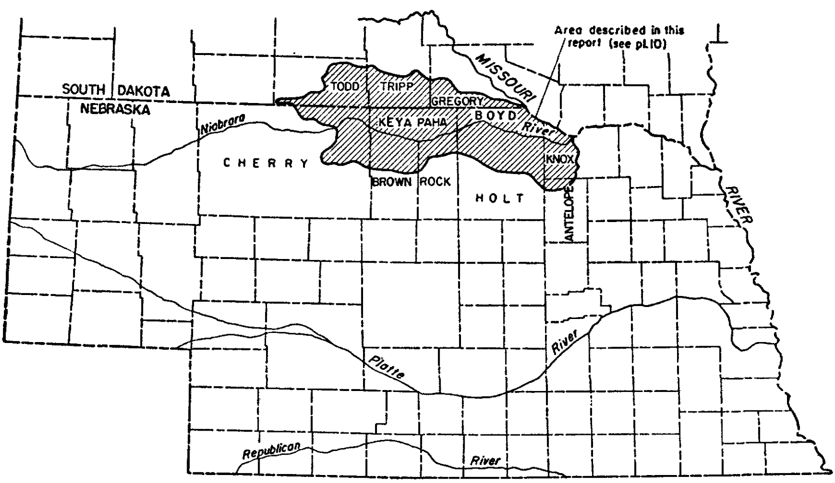

FIGURE 19.—Map of Nebraska and a part of South Dakota showing the location of the lower Niobrara River basin and Ponca Creek basin.

The principal towns in the area are Valentine in Cherry County and Ainsworth in Brown County. Bassett, in Rock County, and O'Neill, in Holt County, are about 2 miles south of the area. The population of these towns, according to the 1950 census, was as follows:

Ainsworth	2,150
Bassett	1,066
O'Neill	3,027
Valentine	2,700

TOPOGRAPHY AND DRAINAGE

The report areas lies in two sections of the Great Plains physiographic province (Fenneman, 1931, pl. 1). The part of the area drained by the Niobrara River upstream from the mouth of the Keya Paha River is in the High Plains section and the remainder is in the unglaciated Missouri Plateau section. In the western half of the area nearly all the upland south of the Niobrara River and part of the upland between the Niobrara and the Keya Paha is covered by dune sand; most of the dunes are mature and are stabilized by a grass cover. The high permeability of the dune sand permits rapid infiltration of precipitation; thus, direct runoff from the land surface is small. Where there is no dune sand, direct runoff is much greater and in places has caused severe erosion.

The upland surface slopes gently eastward. Its altitude ranges from a little more than 2,800 feet above sea level near the western end of the area to slightly more than 1,600 feet above sea level near the eastern end.

The Niobrara River enters the report area at Valentine, Nebr., and flows generally eastward across the area to Niobrara, Nebr., where it enters the Missouri River. The Niobrara drains about 6,600 square miles upstream from Valentine and about 5,500 square miles within the report area. The altitude of the Niobrara River at Valentine is about 2,360 feet and at its mouth is about 1,210 feet.

Minnechaduza Creek, Plum Creek, Long Pine Creek, the Keya Paha River, and the Verdigre River are the principal tributaries of the Niobrara River in the report area. Minnechaduza Creek heads near the State line at the westernmost end of the area, flows generally southeastward, and enters the Niobrara River about 4 miles northeast of Valentine, Nebr. Plum and Long Pine Creeks rise in the Sand Hill region south of the Niobrara in the western part of the area, flow generally northeastward and northward, and enter the Niobrara near Meadville and Riverview, Nebr., respectively. The Keya Paha River heads near Mission, S. Dak., in the northwestern part of the area, and throughout almost all its length it follows a southeasterly course to its junction with the Niobrara, about 7 miles west of Butte, Nebr. The Verdigre River heads near the southeastern corner of the area and enters the Niobrara about 5 miles from its mouth.

The Ponca Creek drainage basin, an area of about 840 square miles, adjoins the Niobrara River drainage basin on the north. Ponca Creek heads near Colome, S. Dak., flows southeastward, and enters the Missouri River about 6 miles upstream from the mouth of the Niobrara.

The sites of stream-gaging stations in the area are shown on plate 10. The mean annual discharge at each of the stations for the period of record is shown below.

Mean annual discharge at stream-gaging stations for the period of record

	Period of record	Mean annual discharge	
		Cubic feet per second	Acre-feet
Ponca Creek at Anoka, Nebr	1949–55	69.4	50,240
Minnechaduza Creek at Valentine, Nebr	1948–55	36.4	26,350
Niobrara River near Sparks, Nebr	1946–55	841	608,900
Niobrara River near Norden, Nebr	1953–55	944	683,500
Plum Creek near Meadville, Nebr	1948–55	111	80,360
Niobrara River at Meadville, Nebr	1951–52	1,190	863,100
Long Pine Creek near Riverview, Nebr	1948–53; 1954–55	135	97,740
Keya Paha River near Hidden Timber, S. Dak	1948–53	38.0	27,500
Keya Paha River at Wewela, S. Dak	1938–40; 1947–55	76.8	55,600
Niobrara River near Spencer, Nebr	1927–36; 1940–55	1,377	996,900
Niobrara River at Niobrara, Nebr	1955	1,760	1,274,000

The monthly discharge of Ponca Creek at Anoka and of Plum Creek near Meadville are shown in figure 20. Despite the fact that the annual discharge of Ponca Creek at Anoka is less than that of Plum Creek near Meadville, the range in monthly discharge of Ponca Creek is many times greater than that of Plum Creek. Ponca Creek has only a very small flow during months of little or no rainfall but a very large flow during months of high rainfall or melting of a heavy snow cover. Plum Creek, on the other hand, has an unusually uniform flow. The Keya Paha River is similar to Ponca Creek in its flow characteristics, and Minnechaduza and Long Pine Creeks are similar to Plum Creek. The marked differences in flow are related to the differences in the geology of the drainage basins. Ponca Creek and the Keya Paha River drain areas in which nearly impermeable bedrock is widely exposed, and because precipitation on the bedrock surface can infiltrate only very slowly, most of it either evaporates or flows overland to the nearest drainage course. The other streams drain areas in which the bedrock is overlain almost everywhere by semiconsolidated and unconsolidated mantle rock that is moderately to highly permeable. Almost no overland runoff occurs in these drainage basins because the precipitation that is not evaporated or absorbed by vegetation infiltrates to

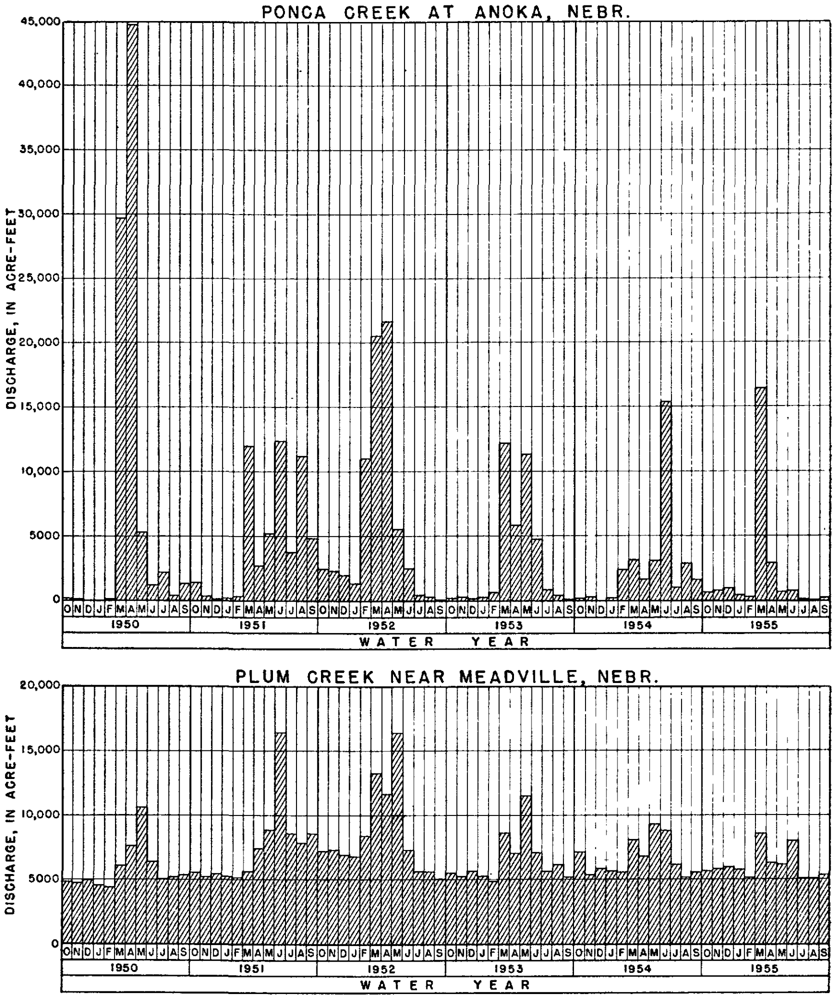

FIGURE 20.—Monthly discharge of Ponca Creek at Anoka, Nebr., and Plum Creek near Meadville, Nebr.

the zone of saturation and then percolates laterally to the nearest drainage course. The Verdigre River receives considerable ground-water discharge as well as considerable overland runoff; consequently, its flow characteristics are intermediate between those of Ponca and Plum Creeks.

CLIMATE

The climate is characterized by wide daily and annual ranges in temperature. The spring months usually are rainy, cool, and windy; the summer months have moderate precipitation, hot days, and cool nights; the autumn months are mild, with only occasional rains; and the winter months are characterized by frequent low temperatures, often accompanied by wind and snow. There are no appreciable differences in climate within the area. The average temperature in January and July at several towns in the area is shown in the table below:

	Average temperature (°F) January	July
Ainsworth	22.0	75.8
Butte	20.7	75.8
Gregory	20.2	77.5
Niobrara	20.5	77.0
Springview	21.2	73.4
Valentine	21.1	75.3

Precipitation data compiled from records of the U. S. Weather Bureau are shown in figures 21 and 22.

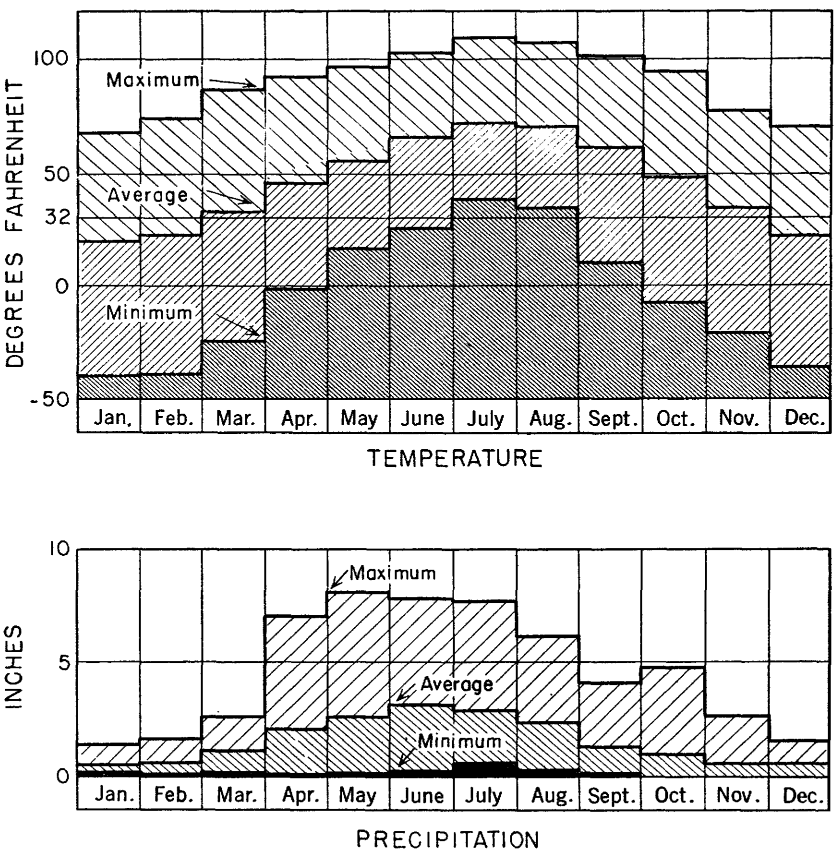

FIGURE 21.—Monthly temperature and precipitation at Valentine Nebr., 1889–1953. Data from records of U. S. Weather Bureau.

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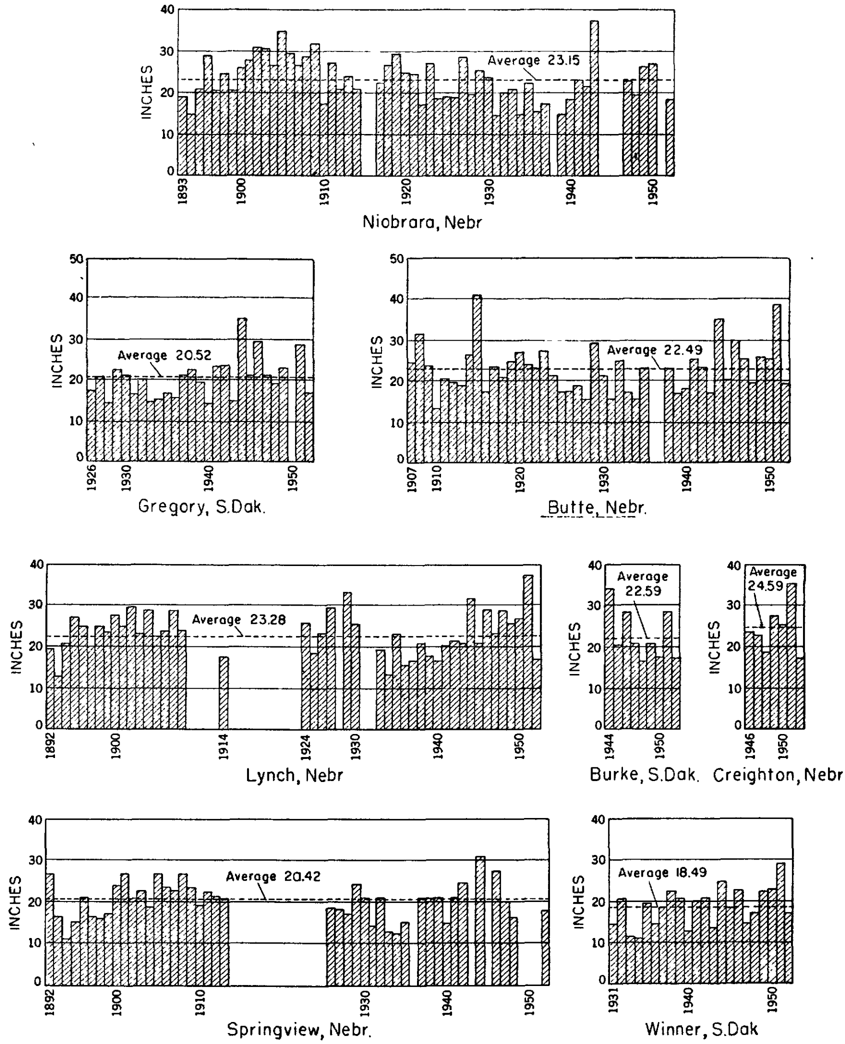

FIGURE 22.—Annual precipitation at eight towns in south-central South Dakota and north-central Nebraska. Data from records of U. S. Weather Bureau.

STRATIGRAPHIC UNITS AND THEIR WATER-YIELDING PROPERTIES

Deposits of Quaternary age, consisting of unconsolidated loess and dune sand, and water-deposited gravel, sand, silt, and clay, cover much of the area. Where these deposits have been removed by erosion, the exposed rocks are of either Tertiary or Cretaceous age. The Tertiary strata are flat lying, whereas the Cretaceous strata dip gently westward. The Tertiary strata are unconsolidated or semiconsolidated continental deposits and the Cretaceous strata are consolidated

Stratigraphic units and their water-yielding properties

System	Series	Subdivision	Thickness (feet)	Physical characteristics and areal distribution	Water supply
Quaternary	Recent Pleistocene	Late Pleistocene and Recent deposits	0–150	Gravel, sand, silt, and clay; includes all dune sand and loess in upland parts of area and thin alluvial deposits beneath floors of principal valleys.	Generally above the water table but, where saturated, the dune sand and coarse grained alluvial deposits yield small to moderate quantities of water to wells. Exposed dune sand readily transmits recharge to zone of saturation.
	Pleistocene	Early Pleistocene deposits	0–175	Gravel, sand, silt, and clay; restricted to upland parts of area, principally south of the Niobrara River.	Saturated thick deposits of sand and gravel yield moderate to large quantitites of water to wells.
Tertiary	Pliocene	Ogallala formation	0–600	Sand, sandy gravel, silt, and clay; contains thin layers of volcanic ash. Some beds are cemented. Underlies all the upland area.	Yields small to moderate quantities of water to wells where zone of saturation is sufficiently thick. In parts of the area would yield large quantities to suitably constructed wells.
	Oligocene	Brule formation	0–350	Siltstone, sandy. Underlies the western part of the area only.	Not a source of water supply; test drilling indicates Brule formation locally contains water under artesian pressure.
Cretaceous	Upper Cretaceous	Pierre shale	0–1,000	Shale containing thin layers of bentonite, shaly chalk, and sandstone. Underlies all parts of the area except the lower end of the valley in the eastern part of the area.	Not a source of water supply.
		Niobrara formation	200–275	Shale, chalky, and chalk. Underlies entire area.	Do.
		Carlile shale	200	Shale containing chalky and sandy layers. Underlies entire area.	Do.
		Greenhorn limestone	25–30	Limestone interbedded with shale. Underlies entire area.	Do.
		Graneros shale	65–200	Shale containing thin beds of limestone and of sandy shale. Underlies entire area.	Do.
	Lower Cretaceous	Dakota sandstone	350–700	Sandstone interbedded with clayey and sandy shale; some ironstone. Underlies entire area.	Yields small to moderate quantities of rather highly mineralized water. Wells flow if situated in topographically low places at east end of area.

marine deposits. Although a few wells tap the deep-lying Dakota sandstone of Cretaceous age, the top of the Brule formation of Tertiary age in the western part of the area and the top of the Pierre shale of Cretaceous age in the eastern part of the area generally are considered to be the lower limit of practicable drilling for a water supply. The generalized section (p. 287) gives the range in thickness, physical characteristics, and importance as a source of water supply for each of the stratigraphic units of Cretaceous, Tertiary, and Quaternary age in the lower Niobrara River basin and in the Ponca Creek drainage basin.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

DAKOTA SANDSTONE

The Dakota sandstone consists of massive and crossbedded fine- to medium-grained sandstone interbedded with clayey and sandy shale; it commonly contains zones of ironstone. The thickness of the Dakota is about 350 to 400 feet in the eastern part of the area but may be as much as 650 to 700 feet in the western part. The depth to the top of the formation is about 500 feet near Niobrara, about 2,000 feet near Valentine, and about 2,250 feet near Mission, S. Dak.

The Dakota sandstone yields small to moderate quantities of water to wells and is an important source of water for stock and domestic use where a water supply is unavailable at shallower depth. The water is rather highly mineralized, containing more than 1,000 ppm (parts per million) of dissolved solids.

UPPER CRETACEOUS SERIES

GRANEROS SHALE

The Graneros shale, which overlies the Dakota sandstone, consists of dark-gray plastic shale that contains thin calcareous beds and some sand and sandy shale; the basal part of the formation contains carbonaceous material also. The formation ranges in thickness from about 65 feet in the eastern part of the area to about 200 feet in the western part. It is not a source of water.

GREENHORN LIMESTONE

The Greenhorn limestone is composed of thin beds of medium-soft gray limestone alternating with beds of gray shale. The formation ranges from 25 to 30 feet in thickness. It is relatively impervious and generally does not yield water to wells.

CARLILE SHALE

The Carlile shale is predominantly bluish-gray shale; the lower part contains thin chalky layers, and the upper part contains sandy zones. The formation is about 200 feet thick. It is relatively impervious and does not yield water to wells.

NIOBRARA FORMATION

The Niobrara formation consists of light-gray to lead-gray chalky shale and chalk. Where weathered the exposed rock is yellowish gray to almost white. The beds of nearly pure chalk range in thickness from less than an inch to as much as 6 feet and grade laterally into chalky shale. The formation is about 200 feet thick in the eastern part of the area and about 275 feet thick in the western part. It is the oldest rock exposed, the Niobrara River and Ponca Creek having cut the lower end of their valleys about 70 feet below the top of the formation. (See fig. 23.) Because the formation is nearly impervious, most of the precipitation on it runs off or evaporates. It does not yield significant quantities of water to wells.

PIERRE SHALE

The Pierre shale is composed principally of black, gray, and brownish-gray clayey shale and contains thin layers of bentonite, indurated shaly chalk, and sandstone. Several well-defined zones of concretions are in the formation. In the eastern and central parts of the area, the Pierre is exposed extensively in the valleys of the Niobrara and Keya Paha Rivers and in the valley of Ponca Creek. (See fig. 23.) It weathers rapidly, forming rolling hills and long slopes. Where not covered by vegetation, the weathered Pierre is conspicuously banded; the light bands are chalky layers and the dark bands are dark clay and iron-bearing beds. The iron-stained chalky layers weather to a yellowish-gray soil.

On the slopes of the high ridge between the Niobrara River and Ponca Creek southeast of Spencer, Nebr., outcropping resistant beds in the Pierre shale form a series of irregular steps. Here the lower, clayey part of the Pierre shale forms gentle slopes, and the stream valleys that are cut into it are relatively wide; it crops out between altitudes of 1,280 and 1,400 feet. The middle, chalky member of the Pierre shale forms steeper slopes and the valleys that are cut into it are relatively narrow; it lies between 1,400 feet and 1,500 feet. The upper, clayey part of the Pierre, which also forms gentle slopes, crops out between 1,500 and 1,560 feet.

TERTIARY SYSTEM

OLIGOCENE SERIES

BRULE FORMATION

During Tertiary time the eroded surface of the Pierre shale was buried beneath an eastward-thinning wedge of continental deposits. The oldest of these deposits that extends into the report area is the Brule formation, which is a massive, compact palé-buff to flesh-colored sandy siltstone. Geologists of the Conservation and Survey Division of the University of Nebraska believe that the Brule, as referred to in this report, may consist in its lower part of beds equivalent to the

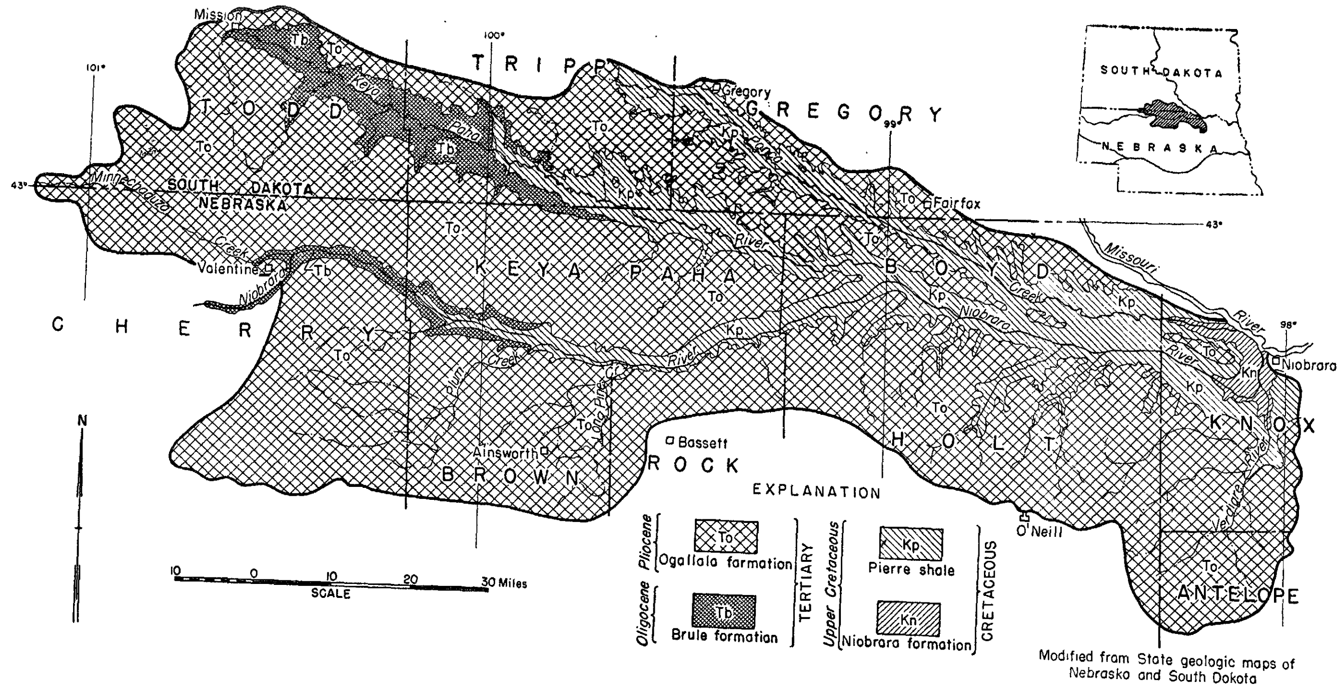

Figure 23.—Map showing the areal distribution of Cretaceous and Tertiary rocks in the lower Niobrara River basin and in the Ponca Creek basin.

Chadron formation. The Chadron and the Brule constitute the White River group in western Nebraska and southwestern South Dakota.

The eastern margin of the Brule formation is a sinuous line that crosses Brown and Keya Paha Counties, Nebr., and Tripp County, S. Dak. The Brule crops out in the valleys of the Niobrara and Keya Paha Rivers (fig. 23) and probably underlies all the western part of the report area. An exposure of the Brule in the Niobrara River valley is shown in plate 11. Two samples of material from the Brule at this location were analyzed in the hydrologic laboratory of the U. S. Geological Survey in Lincoln, Nebr. The percent weights, by grain size, of these samples are as follows:

Material	Grain size (diameter in millimeters)	Percent, by weight	
		Sample from near top of exposure	Sample from near bottom of exposure
Clay	<0.004	6.9	8.0
Silt	0.004–0.0625	54.9	54.0
Very fine sand	.0625–.125	28.0	23.6
Fine sand	.125–.25	7.2	10.6
Medium-grained sand	.25–.5	2.2	3.0
Coarse sand	.5–1.0	.6	.6
Very coarse sand	1.0–2.0	.2	.2

The Brule may be as much as 350 feet thick in places in the western part of the report area.

No wells in the area are known to obtain water from the Brule formation; in the western part of the area the top of the Brule generally is considered by drillers to be the lower limit of practicable drilling for water. However, test drilling by the U. S. Bureau of Reclamation at the site of a proposed dam on the Niobrara River near Sparks is reported to have found water at two horizons in the Brule. It is not known whether the water was contained in fractures or in lenses of permeable sand.

PLIOCENE SERIES

OGALLALA FORMATION

The Ogallala formation of the report area was deposited by streams that, in their upper reaches, were eroding mountains in Wyoming. It consists of interbedded layers of sandy gravel, sand, silt, and clay, some of which have been cemented by calcium carbonate or silica; it also contains beds of volcanic ash. Where the formation is exposed, the cemented layers are more resistant to erosion and stand out as bluff-forming ledges. At the western end of the area, where the formation is thickest, the Niobrara River has cut its valley only a few feet below the base of the Ogallala and the Ogallala is the principal outcropping formation in the valley walls. Toward the eastern end of the area the Ogallala caps the upland ridges only, and the underlying Pierre shale is the principal outcropping formation in the valley walls. In Knox County the divide between Ponca Creek and the Niobrara River is capped by only about 25 feet of the Ogallala. Here the formation is composed principally of crossbedded sandstone but contains a thin layer of sand at its base. The sand erodes readily, thus undermining the overlying harder beds and causing them to break into large blocks that become scattered over the lower slopes of the Pierre shale. In general, the Ogallala is progressively finer textured and less permeable in an eastward direction.

Because the Ogallala was deposited on a rough surface that had been produced by stream erosion and because in Quaternary time it was deeply eroded by streams, it differs considerably in thickness from place to place. The maximum thickness of the formation in the area is not known but probably is nearly 600 feet. In Boyd County several buttes stand about 100 feet higher than the nearly flat surface of the upland between the valleys of Ponca Creek and the Niobrara River. The Twin Buttes are about 4 miles southeast of Naper, and the Stony Buttes are half a mile southwest of Butte. These buttes are residual knobs of the Ogallala and are proof that the original thickness of the formation was somewhat greater than the present thickness.

One sample each of volcanic ash, sandstone, and calcareous siltstone from the Ogallala was analyzed in the hydrologic laboratory of the U. S. Geological Survey in Lincoln, Nebr. The volcanic ash was collected in the NE¼NW¼ sec. 13, T. 32 N., R. 22 W., the sandstone in the NE¼SE¼ sec. 20, T. 31 N., R. 30 W., and the calcareous siltstone in the SE¼NE¼ sec. 8, T. 31 N., R. 30 W. The calcareous siltstone was 74 percent soluble in acid. The percent weights, by grain size, of the volcanic ash and sandstone and of the insoluble residue of the calcareous siltstone are as follows:

Material	Grain size (diameter in millimeters)	Percent, by weight		
		Volcanic ash	Sandstone	Insoluble residue of calcareous siltstone
Clay	<0.004	8.7	5.4	5.7
Silt	.004–.0625	44.7	14.8	88.3
Very fine sand	.0625–.125	27.6	17.6	5.2
Fine sand	.125–.25	17.6	40.8	.4
Medium-grained sand	.25–.5	1.2	20.0	.2
Coarse sand	.5–1.0	.2	1.4	.2

Where the Ogallala formation caps narrow ridges or is near to deeply entrenched streams it generally is too well drained to yield

OUTCROP OF THE BRULE FORMATION IN KEYA PAHA COUNTY, NEBRASKA
Sec. 11, T. 32 N., R. 22 W.

CROSSBEDDING IN PLEISTOCENE SANDY GRAVEL ON LONG PINE CREEK
NE¼ sec. 30, T. 30 N., R. 20 W.

more than meager amounts of water to wells. However, where the Ogallala is thick and at least a few miles distant from deeply entrenched streams, it contains a tremendous quantity of water. In the southwestern part of the area the full thickness of the formation is saturated. Many wells tap the Ogallala, but some of them tap also the overlying Quaternary deposits and extend only a few feet into the Ogallala. These wells generally are small in diameter and yield only enough for domestic use and livestock supply. Where the zone of saturation is thick, wells of larger diameter and drilled deeper into the Ogallala undoubtedly could yield moderately large quantities of water if properly constructed and equipped with adequate pumps. The drilling of a well from which a large discharge is desired should be preceded by the drilling of test holes to determine the most suitable type of construction and the best site for the well.

QUATERNARY SYSTEM

PLEISTOCENE AND RECENT SERIES

EARLY PLEISTOCENE DEPOSITS

At the beginning of Pleistocene time, streams flowing down the eastward-sloping original surface of the Ogallala formation began to entrench and broaden their valleys, thus removing much of the upper part of the Ogallala. Then, when the first continental glacier—the Nebraskan ice sheet—advanced southward into eastern Nebraska, the thick ice became a barrier across the valleys, causing them to fill with impounded water and eventually to overflow. The overflow followed the ice margin southward until it reached a valley draining to the Gulf of Mexico. Meanwhile the blocked valleys were being filled to overflowing with the coarse sediment that the streams dropped when they entered the bodies of impounded water. During the waning phase of glaciation, the coarse-grained sediments were mantled by fine-grained materials—partly wind deposited and partly stream deposited. The coarse-grained sediments constitute the Holdrege formation and the overlying fine-grained sediments the Fullerton formation. During the interglacial stage that followed, the streams again entrenched and broadened their valleys, thus removing much of the material that had been deposited during the Nebraskan glacial stage.

When a second continental glacier, the Kansan ice sheet, advanced into eastern Nebraska, ice again blocked the valleys and caused them to be filled with coarse sediments. These coarse sediments also became mantled by fine-grained material during the waning phase of glaciation. The coarse-grained sediments are the Grand Island formation and the fine-grained sediments the Sappa formation.

Because the Holdrege and Grand Island formations are almost identical in lithology, they can be distinguished with certainty only

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after detailed studies based on test drilling have established their relationships. Because the Holdrege was partly removed by erosion before the Grand Island was deposited, the unconsolidated sandy gravel of Pleistocene age in the upland part of the report area south of the Niobrara River is more likely to be the Grand Island formation than the Holdrege. Significant thicknesses of Pleistocene sandy gravel are not known to be present north of the Niobrara River.

Test drilling on the Ainsworth tableland has revealed the presence of Pleistocene sandy gravel, believed to be the Grand Island formation, as much as 100 feet thick (Cronin and Newport, 1956, p. 20 and pl. 2). Tributaries of the Niobrara River have cut their valleys into this sandy gravel, and several pits have been opened in it. A typical exposure, in the NE¼ sec. 30, T. 30 N., R. 20 W., is shown in plate 12. A sample from the lower part of this exposure was analyzed in the hydrologic laboratory of the U. S. Geological Survey in Lincoln, Nebr., and had percent weights, by grain size, as follows:

Material	Grain size (diameter in millimeters)	Percent, by weight	Material	Grain size (diameter in millimeters)	Percent, by weight
Clay and silt	<0.0625	0.6	Very coarse sand	1.0- 2.0	15.2
Very fine sand	0.0625- .125	1.1	Very fine gravel	2.0- 4.0	12.3
Fine sand	.125 - .25	10.4	Fine gravel	4.0- 8.0	7.1
Medium-grained sand	.25 - .50	29.5	Medium-sized gravel	8.0-16.0	3.6
Coarse sand	.50 -1.0	20.2			

Many domestic and livestock wells and nearly all the irrigation wells in the vicinity of Ainsworth tap these deposits; the discharge from individual irrigation wells is as much as 1,500 gpm.

Similar Pleistocene deposits are known to underlie an upland area in Holt County (Reed, 1944). Test drilling has shown them to be as much as 60 feet thick, but because they are so well drained the maximum thickness of the zone of saturation in them is only about 20 feet and in places they are completely dry. These deposits crop out in the valley sides along Blackbird and Redbird Creeks.

LATE PLEISTOCENE AND RECENT DEPOSITS

Apparently the Niobrara River began the cutting of its present valley soon after the Kansan ice sheet melted. At that time, according to Flint (1955, p. 55, 134, 151, pl. 7), the Missouri River had not yet been diverted into its present course and the Niobrara River (then at a higher level than at present) followed the route of the present Missouri River from the present mouth of the Niobrara to a point about 14 miles downstream on the Missouri River and thence continued northeastward into southeastern South Dakota.

The Niobrara must have ceased its downcutting and then partly filled its valley with alluvium when the Illinoian ice sheet was at its maximum extent. According to Flint (1955, p. 134), the Missouri River valley probably marks the margin of the Illinoian ice sheet, the river becoming entrenched when forced to flow along the ice edge and not returning to its earlier course when the ice sheet melted. Meanwhile a mantle of loess and sand began accumulating on all surfaces not being actively eroded.

During the interglacial stage that followed, the Niobrara renewed its downcutting, first removing much of the alluvial fill that was deposited during Illinoian glaciation and then cutting into underlying rocks. Later, when the Iowan ice sheet of the Wisconsin stage of glaciation advanced into northeastern Nebraska, the Niobrara again must have partly filled its valley with alluvium, but most of this also was removed by the Niobrara when the ice sheet melted and the river renewed its downcutting.

None of the later ice sheets of the Wisconsin stage reached as far as Nebraska. It is not known whether any significant post-Iowan alluviation occurred in the Niobrara River valley, nor is it known whether the thin alluvial deposits underlying the present floor of the valley are wholly of Recent age or partly of late Wisconsin and partly of Recent age.

Deposition of loess and sand in the upland areas by the wind probably continued intermittently throughout late Pleistocene and Recent time. During the longer pauses in deposition, soils developed and some of the deposits were removed by wind and stream erosion. The deposits that remain generally are only a few feet thick, but in the southwestern part of the area many sand dunes stand as high as 125 feet.

Most of the late Pleistocene and Recent deposits are above the zone of saturation and so are not sources of water supply. However, the alluvial fill in the present valleys contains water, as also does some of the sand in the area of sand dunes. These deposits are tapped by a few domestic and stock wells, but they are not potential sources of large supplies of water. Where the late Pleistocene deposits in the upland area consist of permeable sand, they are very important to the ground-water supply in that they facilitate recharge from precipitation. As pointed out in the discussion of drainage, several of the principal tributaries of the Niobrara carry relatively little overland runoff because the areas they drain are mantled by sandy material that permits rapid infiltration of precipitation.

GROUND WATER

The Dakota sandstone, the Ogallala formation, and the deposits of sandy gravel of Quaternary age are the principal water-bearing rocks in the area. The Brule formation is water bearing locally, but no wells are known to tap it in the area.

WATER IN THE DAKOTA SANDSTONE

Because the Dakota sandstone in the report area is between relatively impermeable rock strata, little or no water can enter it from either below or above. Therefore, practically all the water in the Dakota sandstone in the report area entered the formation at some other place, either where it crops out or where it is in contact with other water-bearing permeable strata. Both these conditions exist in the vicinity of the Black Hills of southwestern South Dakota, and it is reasonable to believe that much, if not most, of the water in the Dakota underlying the report area entered the formation in the Black Hills vicinity. Because the places where water enters the formation are at a considerably higher altitude than the altitude of the formation in the report area, the water is under considerable artesian pressure. Consequently, when a hole is first drilled into the formation, water from the formation enters the hole and rises to a level much higher than the top of the formation. Wells 33–10–31cd and 34–13–24ca are believed to tap the Dakota. The first is a flowing well, and the water level in the second is reported to stand about 110 feet below the land surface.

Because the water discharged from wells tapping the Dakota is derived from a depth of several hundred feet, it is warmer than water discharged from wells tapping the shallow aquifers. The temperature of water flowing from well 33–10–31cd was 79.5° F when the well was visited, whereas the temperature of water from wells tapping shallow aquifers in the area ranges from 50° to 55°F. The water in the Dakota moves generally eastward beyond the area to points where it is discharged through wells or issues from springs, or to places where it discharges into mantling deposits. Because water can be obtained from shallower sources in much of the area, the Dakota is likely to be tapped by wells only in those parts of the area where other aquifers are not present nearer the surface. Wells drilled into the Dakota are likely to flow if they are located in topographically low places near the eastern end of the area.

WATER IN THE OGALLALA FORMATION AND DEPOSITS OF QUATERNARY AGE

In the upland part of the area some wells tap the Ogallala formation alone, some the Ogallala formation together with deposits of Quaternary age, and some the deposits of Quaternary age alone. For ease of discussion, the water-bearing materials in the upland part of the area are referred to as the upland aquifer. In the valleys of the Niobrara River and its principal tributary, the Keya Paha River, and also in the valley of Ponca Creek, wells tap the alluvial fill of Quaternary age. This lowland aquifer is hydraulically connected with the upland aquifer through the alluvial fill of the tributary valleys and through the colluvial material that mantles the valley slopes in many places.

The base of both the upland and lowland aquifers is the top surface of the Brule formation in the western part of the area and of the Pierre shale in the central and eastern part. Both the Brule and the Pierre are nearly impermeable and thus prevent significant downward movement of water through them. The water-filled materials overlying these formations constitute the principal zone of saturation, and the top surface of this zone of saturation is called the water table. The water level in wells tapping these aquifers indicates the position of the water table.

CONFIGURATION OF THE WATER TABLE

The approximate configuration of the water table is shown by the contour lines on plate 10. Because ground water moves in the direction of the steepest slope of the water table, the direction of ground-water movement is perpendicular to the contour lines. This being true, the contour lines indicate that ground water is moving into the area by underflow along much of its boundary. The principal exception is along the northern boundary east of the intersection of the boundary with the State line; there a small amount of ground water moves outward from the area toward the Missouri River. Within the area, ground water moves toward those surface drainageways that are incised below the water table.

RECHARGE

The ground water moving into the area by underflow is augmented within the area by infiltrating precipitation. The amount of underflow is relatively constant from year to year, whereas the amount of infiltrating precipitation depends on the amount, distribution, and intensity of the precipitation, the amount of moisture in the soil when rain begins or snow melting starts, the air temperature, the vegetative cover, and the permeability of the intake material at the site of infiltration. Recharge from precipitation is greatest where the materials from the surface down to the water table are dune sand or other such permeable material, less where they are loess or water-laid silty clay, and least where they are cemented fine-grained rock. In the area of sand dunes, recharge from precipitation is estimated to be as much as 5 inches per year. There the water table is so high that in places it intersects the valley floors, forming "water-table lakes." In the loess-mantled areas recharge may average 1 to 2 inches per year, and, where mortar beds of the Ogallala are at or close below the land surface, recharge probably is only a fraction of an inch.

Near Ainsworth some recharge results from the infiltration of irrigation water. At the present time the water used for irrigation is pumped from wells; so in effect the recharge from irrigation is merely replacing some of the water pumped for that purpose. If, as has been proposed, the U. S. Bureau of Reclamation develops the tableland in the vicinity of Ainsworth and in Holt County for irrigation with diverted surface water, infiltrating irrigation water will become a significant source of recharge in those parts of the area.

DISCHARGE

Some of the ground water moving toward the surface drainageways never reaches those outlets because it is discharged through evapotranspiration where the water table is within the reach of plant roots or because it is pumped from wells or issues from springs.

In the valleys of the sand-dune area, much ground water is discharged by evapotranspiration. There native hay grows luxuriantly because it is subirrigated by ground water. Tolstead (1942) reported that the water table in a wet meadow in Cherry County fell 2.78 feet from June 30 to September 1, 1938, as a result of evapotranspiration losses. Evaporation from the water-table lakes also constitutes ground-water discharge because the lakes are fed by ground water. In the valleys of the principal streams, as well as in the valleys of many of their tributaries, the water table is close to the surface and within the reach of plant roots. A schematic cross section of the area a short distance east of the mouth of Minnechaduza Creek illustrates the relation of the water table to the land surface and thus shows where natural ground-water discharge occurs. (See fig. 24.)

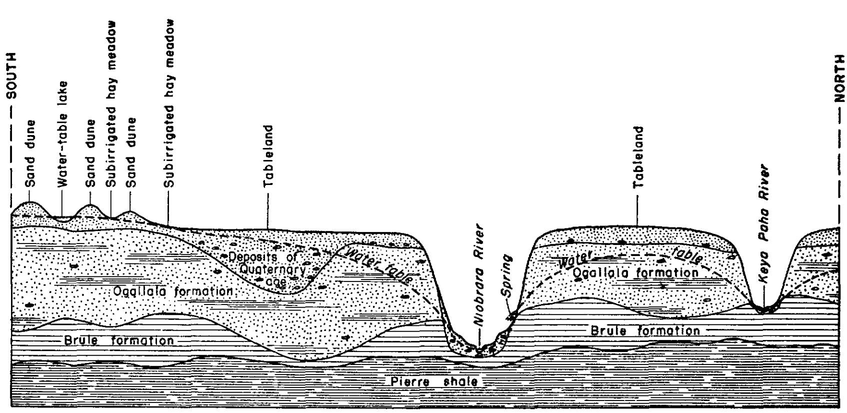

FIGURE 24.—Schematic cross section of the lower Niobrara River basin a few miles east of the mouth of Minnechaduza Creek.

If the base flow, or average discharge of a stream during a fairly long period of insignificant precipitation, is assumed to be derived wholly from the ground-water reservoir, then the ratio of that base flow, on an annual basis, to the average annual discharge would be a measure of the proportion of the ground water in the total annual discharge. An analysis of the discharge records at several stream-gaging stations in the area gave the following results:

	Length of record used in computation (years)	*Ratio of base flow to average annual discharge (percent)*
Ponca Creek at Anoka	6	15
Minnechaduza Creek at Valentine	6	82
Plum Creek near Meadville	6	83
Long Pine Creek near Riverview	5	86
Keya Paha River at Wewela	6	44

Fivemile and Redbird Creeks probably have a high proportion of ground water in the total annual discharge because they drain areas in which overland runoff is small. On the other hand, the Verdigre River probably has a somewhat smaller proportion because its drainage basin is largely loess mantled and therefore produces a greater overland runoff and a correspondingly smaller discharge of ground water.

The average base flow of the Niobrara River during the period 1950–55 was about 790 cfs (cubic feet per second) at the gaging station near Sparks and about 1,320 cfs at the gaging station near Spencer. The ratio of average base flow to the average annual discharge during the same period was about 93 percent near Sparks and about 79 percent near Spencer. The lesser value for the station near Spencer probably reflects the inflow of the Keya Paha River, which discharges more overland runoff than ground water.

Most wells in the area are drilled domestic or livestock wells and are 6 inches or less in diameter. Most of these wells discharge less than 3 gpm because they were neither constructed nor equipped to produce large quantities of water. In the northern and eastern parts of the area nearly all these wells were drilled through the entire thickness of water-bearing material, but in the area drained by Minnechaduza Creek and in the southwestern part of the area few, if any, wells were drilled to the base of the water-bearing material. The relatively few dug domestic and livestock wells range from 3 to 6 feet in diameter and extend only a few feet below the water table. Water for livestock is obtained also from springs, streams, and ponds.

Most of the irrigation and public-supply wells are drilled wells and are 12 to 24 inches in diameter. Several of them discharge more than 1,000 gpm. The most extensive use of ground water for irrigation is in the vicinity of Ainsworth, where about 30 wells were pumped in 1952 to irrigate about 2,000 acres. In addition to water pumped from wells, some water for irrigation is pumped from gravel pits that extend below the water table and from perennial streams. The principal irrigated crops are small grains and alfalfa. All the towns in the area except Verdigre obtain water for public supply from wells and springs. Verdigre obtains water from the Verdigre River. Several towns in the part of the area where the Pierre shale is exposed or is close to the surface have had difficulty in obtaining an ample supply of water of good quality. Anoka has been unsuccessful in obtaining potable water from wells in or near town; water for domestic use is trucked into town from springs several miles away and is distributed from house to house. Long Pine, Bristow, and Lynch obtain water from springs. Data on the municipal supplies are given in the following table.

Municipal water supplies

[See tables 1, 2, and 5 for additional data]

State, County, and Town	Reported daily consumption (gal)	Storage facilities	Wells or springs	
			No.	Reported yield (gpm)
Antelope County, Nebr.				
Orchard	50,000	50,000-gal. steel standpipe	27- 8-3 cb	150
			9aa	225
Royal	10,000	35,000-gal. elevated steel tank	27- 7- 9aa	145
Boyd County, Nebr.				
Anoka		Quality of well water is unsuitable for drinking and cooking; 21,000-gal concrete reservoir; domestic water is brought into town and distributed by truck.	34-13- 3ca	
Bristow		210,000-gal concrete reservoir. Water from springs is collected in shallow cisterns.	33-11-15aa	145
Butte	50,000	60,000-gal elevated steel tank	34-13-21ad1	35
			21ad2	16
			21ad3	16
			21ad4	22
Lynch	100,000	56,000-gal concrete reservoir. Water is pumped from 11 springs.	33-10-15cd	42
Monowi		11,800-gal concrete reservoir	33- 9-13bb	7
Spencer	5,000	Three concrete reservoirs, combined capacity 68,000 gal supplied with water from well 34-12-35ca and springs 34-12-27dd.	34-12-27dd	
			35ca	
Brown County, Nebr.				
Ainsworth	400,000	100,000-gal elevated steel tank. Wells 30-22-26ba1 and 30-22-26ba2 are connected with a siphon tube.	30-22-26ab	550
			26ba1	250
			26ba2	250
Long Pine	100,000	Water is pumped from seven springs; 300,000-gal standpipe.	30-20-31cb	1,000
Cherry County, Nebr.				
Crookston	25,000	20,000-gal concrete reservoir	34-29- 9cc	31
Kilgore	10,000	25,000-gal pneumatic steel tank	34-31-10ab	[1] 75
Wood Lake	38,000	40,000-gal elevated steel tank	31-25-27bb1	150
			27bb2	200

[1] Combined yield of 3 wells.

Municipal water supplies—Continued

State, County, and Town	Reported daily consumption (gal)	Storage facilities	Wells or springs	
			No.	Reported yield (gpm)
Keya Paha County, Nebr.				
Burton	1,500	Windmill pumps water to a small concrete reservoir.	34-19-18dd	3
Springview	35,000	36,000-gal pneumatic steel tank	33-21-24bb1 24bb2	125 55
Knox County, Nebr.				
Niobrara	100,000	100,000-gal elevated steel tank	32- 6-16bc	100
Verdel		12,000-gal pneumatic steel tank	33- 7-30bb	90
Verdigre	150,000	70,000-gal brick-masonry reservoir; water pumped from the Verdigre River.	30- 6- 4cc	
Gregory County, S. Dak.				
Burke	40,000	50,000-gal elevated steel tank	97-71-31ab1 31ab2	60 40
Dallas	15,000	50,000-gal elevated steel tank	97-73- 7bb	[2] 100
Gregory	150,000	Two concrete reservoirs, combined capacity, 120,000 gal.	97-73-12ba 12bb	[3] 250 [4] 100
Herrick	2,000	50,000-gal elevated steel tank	96-71-24dc	50
Tripp County, S. Dak.				
Colome	10,000	Underground 25,000-gal concrete reservoir, and an elevated, 50,000-gal steel tank.	98-75-33dd	[2] 125

[2] Combined yield of 6 wells.
[3] Combined yield of 8 wells.
[4] Combined yield of 4 wells.

The Chicago and North Western Railway owns a well in each of most of the municipalities through which it passes. These wells are small in diameter and discharge only small amounts of water. Because the railroad is progressively converting from steam to diesel power, its use of ground water has been greatly reduced.

Although the discharge from any individual well is an almost insignificant drain on the total available supply of water in the area, the aggregate pumpage from all wells constitutes a small but important part of the total discharge from the ground-water reservoir. Development of ground water for irrigation has increased artificial withdrawals considerably, but the combined discharge by natural and artificial means probably has remained nearly the same, because natural discharge probably has been or eventually will be reduced by an amount about equal to that pumped from wells.

TRANSMISSIBILITY OF THE UPLAND AQUIFER

The transmissibility of an aquifer is the capacity of an aquifer to transmit water—the greater the transmissibility, the greater the

474158—59——5

amount of water that can be transmitted to points of natural discharge or of artificial withdrawal under a given hydraulic gradient. The transmissibility of the upland aquifer differs considerably from place to place; it is greatest in the southwestern and westernmost parts of the area because there the zone of saturation is thickest and the water-bearing materials the most permeable. The coefficient of transmissibility may be defined as the rate of flow of water at the prevailing temperature, in gallons per day, through a vertical cross section of the aquifer 1 foot wide, under a hydraulic gradient of 100 percent. Speaking very generally, the maximum sustained discharge, in gallons per minute, that can be expected from a large-diameter well is about $1/100$ as great as the coefficient of transmissibility. Cronin and Newport (1956) report that the coefficients of transmissibility determined from tests made by pumping wells 30–22–25ab and 30–22–26cc near Ainsworth were 47,500 gpd per foot and 77,000 gpd per foot, respectively. Both these wells discharged a little more than 1,000 gpm during the test period. The coefficients of transmissibility of the water-bearing materials that were penetrated in drilling the test holes along and near the State line were estimated by E. C. Reed, State Geologist, to be as follows:

Test hole No.	*Estimated coefficient of transmissibility (gallons per day per foot)*	*Test hole No.*	*Estimated coefficient of transmissibility (gallons per day per foot)*
34–21–14dd	8,300	35–23–20ba	7,300
34–23–14dd	14,000	35–24–20ad	10,000
34–24–8ad	29,000	35–25–21bb	8,200
34–26–6aa	14,000	35–26–21bb	5,900
34–28–17ab	41,000	35–27–19ad	7,300
35–20–23ab	16,000	35–28–20aa	20,000
35–21–19ab	19,000	35–29–21bb	6,300
35–22–19ba	5,600	35–30–19bb	69,000

The average transmissibility of the upland aquifer in the southeastern part of the area probably is considerably less because the zone of saturation is thinner and the water-bearing material is less permeable. Inasmuch as the water table is below the top of the Ogallala formation in much of this part of the area, the mantling deposits of Quaternary age are not saturated.

In Boyd County, eastern Keya Paha County, southern Tripp County, and southern Gregory County, the upland aquifer is thin and not very permeable. In these parts of the area large supplies of water cannot be obtained from a single well, although in some places a moderately large supply can be obtained by combining the discharge of several wells.

Even though the alluvial fill in the principal valleys generally is fairly thin, moderately large supplies of water could be obtained from a specialized installation, such as a collector well or a battery of wells, if the installation is near a perennially flowing stream. The withdrawal of ground water would induce the infiltration of water from the stream, thus insuring an unfailing supply provided withdrawals were no more than the maximum rate of infiltration of stream water.

CHEMICAL QUALITY OF THE WATER

By Robert A. Krieger

ANALYSES OF WATER

The data on which this section of the report is based include the chemical analyses of water from 32 wells (table 1). The samples were obtained from wells tapping the Dakota sandstone, the Ogallala formation, and unconsolidated deposits of Quaternary age; the locations of these wells are shown on plate 10. In addition, analyses of samples of ground water from 16 municipal supplies were obtained from the Nebraska and South Dakota Health Departments (table 2).

The maximum concentrations of some of the dissolved constituents in the water and the maximum hardness, percent sodium, and specific conductance of the water from 7 streams and 16 lakes in the area are given in table 3; complete analyses of the stream water are given in the annual series of U. S. Geological Survey water-supply papers entitled "Quality of surface waters of the United States" and of the lake water in the report by Cronin and Newport (1956).

GROUND WATER

Most of the sampled wells obtain water from Quaternary deposits in the Sand Hills region and the Ainsworth tableland. Generally, the water from these wells contains less than 200 ppm of dissolved solids, is soft, and is of the calcium bicarbonate type.

The Ogallala formation is calcareous and yields a harder, more mineralized water than do the Quaternary deposits. The quality of water from the Ogallala formation in the eastern part of the report area differs locally; the analyses in table 1 shows the differences in the chemical quality of water from irrigation wells 29–6–22bd and 29–6–22dc, which are less than a mile apart. Water from a nearby irrigation well, 29–6–21dd, which taps both the Quaternary deposits and the Ogallala formation, differs in chemical quality from water from either of the other two wells.

In the Sand Hills region, water from four wells that tap both the Quaternary deposits and the Ogallala formation is similar in chemical quality to water from wells tapping only the Quaternary deposits. However, water from two wells tapping both the Quaternary deposits and the Ogallala formation north of the Niobrara River contains

TABLE 1.—*Chemical analyses of ground water*

[Gregory, Todd, and Tripp Counties in South Dakota; all others in Nebraska. Results in parts per million]

Well No.	County	Depth (feet)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Quaternary deposits																						
29-28-1ad	Cherry	----	Apr. 21, 1950	54	60	----	----	----	5.2	5.4	50	0.0	1.0	0.2	1.1	----	117	26	0	26	94.3	6.6
30-21-12cb	Brown	78	Sept. 29, 1952	53	47	0.10	22	3.2	7.8	6.4	[1] 94	4.0	2.5	.2	7.6	0.04	150	68	0	18	185	8.7
30-21-26bb	do	65	Oct. 18, 1950	53	44	.06	13	1.3	6.6	6.5	56	3.0	2.5	.2	8.3	.10	120	38	0	24	119	7.3
30-22-25cb:																						
½ hr [2]	do	63	Oct. 30, 1951	52	----	.18	----	----	----	----	----	----	----	----	----	----	134	47	----	----	134	----
5 hr [2]				52	----	.02	----	----	----	----	----	----	----	----	----	----	110	39	----	----	104	----
6⅔ hr [2]				52	47	.04	12	1.5	5.7	3.4	56	1.0	1.3	.1	3.0	.01	112	36	0	24	106	7.2
30-22-26ba2 [3]	do	72	Dec. 6, 1949	54	50	.03	19	3.0	7.5	5.7	90	4.0	3.3	.2	3.3	.30	156	60	0	20	180	8.2
30-22-26cc	do	69	Nov. 28, 1950	52	44	.02	13	2.3	5.4	4.0	62	3.0	1.0	.2	2.1	.05	120	42	0	20	----	7.5
½ hr [2]	do	69	Nov. 13, 1951	51	----	.02	----	----	----	----	----	----	----	----	----	----	126	47	----	----	114	----
2⅙ hr [2]			do	51	----	.03	----	----	----	----	----	----	----	----	----	----	126	45	----	----	114	----
5 hr [2]			do	51	50	.02	13	2.3	5.9	4.5	64	3.0	1.0	.2	1.9	.01	120	42	0	21	115	7.0
30-23-18ac	do	58	Jan. 13, 1950	56	36	.04	14	1.9	5.2	2.3	34	7.0	4.0	.1	18	.30	118	43	15	20	125	7.7
30-28-29ba	Cherry	12	Apr. 18, 1950	48	20	----	----	----	3.7	2.2	20	2.0	2.0	.4	1.8	----	56	13	0	33	52.2	6.5
30-29-14ac	do	14	Apr. 19, 1950	48	18	----	----	----	5.0	3.6	26	2.0	4.5	.6	.7	----	78	17	0	34	62.7	8.0
30-29-14cd	do	33	Jan. 11, 1949	56	57	.03	17	2.3	3.3	3.8	74	3.0	1.4	.4	.1	.30	124	52	0	11	127	7.8
30-29-25ca	do	100	Apr. 21, 1950	56	64	----	----	----	6.2	3.5	86	.0	3.0	.6	2.9	----	164	61	0	17	146	8.2
31-25-27bb1 [4]	do	74	Oct. 18, 1950	54	49	.08	14	1.2	4.5	4.0	46	6.0	1.5	.1	9.1	.20	125	40	2	18	112	7.2
31-28-23aa2	do	40	Apr. 21, 1950	53	61	----	----	----	12	15	109	18	20	.2	12	----	258	102	13	18	322	7.1
32-11-18cb	Holt	47	Aug. 6, 1952	53	20	----	22	2.9	2.6	1.4	34	40	1.0	.1	6.8	.01	[5] 122	67	39	7	170	7.4
32-26-28bb	Cherry	68	Jan. 12, 1950	52	51	.44	20	2.3	6.3	4.3	90	2.0	1.1	.1	.2	.30	134	60	0	17	149	8.0

Quaternary deposits and Ogallala formation

29-6-21dd	Knox	182	Mar. 26, 1953	55	----	----	69	6.6	11	4.7	254	----	----	----	----	----	----	199	0	10	428	7.6
31-28-23aa1	Cherry	128	Apr. 21, 1950	49	60	----	----	----	5.7	5.4	93	0.0	1.0	0.2	1.4	----	152	60	0	16	159	6.9
31-28-23da2	do	----	do	53	57	----	----	----	4.8	4.2	54	.0	1.0	.2	1.4	----	120	31	0	22	102	6.6
32-26-17aa	do	95	Jan. 11, 1950	54	58	0.05	17	.8	5.9	4.9	73	4.0	1.1	.6	.2	0.30	134	46	0	20	127	8.1
32-26-29ac	do	129	Jan. 12, 1950	52	57	.03	11	.4	3.9	4.4	44	3.0	1.0	.1	3.3	.30	110	29	0	20	90.8	7.8
34-13-21ad1 [6]	Boyd	53	Aug. 5, 1952	53	49	.09	52	7.2	12	7.2	174	25	4.5	.3	23	.03	278	159	16	13	383	8.0
97-73-12ba1 [7]	Gregory	50	June 19, 1952	53	46	.14	100	16	24	9.5	308	42	26	.2	64	.14	492	314	61	14	719	8.1

Ogallala formation

29-6-22bd	Knox	153	Mar. 21, 1953	53	----	----	50	4.9	9.2	4.7	195	----	----	----	----	----	----	145	0	12	316	8.0
29-6-22dc	do	130	Mar. 22, 1953	53	----	----	94	15	12	6.4	73	245	----	----	----	----	----	297	237	8	639	7.0
30-8-22dd	do	27	Aug. 28, 1952	50	35	----	93	16	8.1	5.6	268	60	6.5	0.2	36	0.11	408	298	78	5	600	7.4
33-21-24bb2 [8]	Keya Paha	254	Aug. 5, 1952	56	54	0.06	21	3.3	4.6	4.5	92	3.0	2.0	.3	2.3	.02	148	66	0	12	162	7.9
35-23-23bb	do	110	July 1, 1952	53	54	----	47	7.2	9.1	8.5	206	3.0	2.0	.3	1.9	.05	234	147	0	11	331	7.9
35-28-29cc	Cherry	132	Aug. 25, 1952	54	46	----	58	13	4.4	7.2	187	3.0	9.5	.3	49	.06	302	197	44	4	419	8.2
38-28-3bd	Todd	45	Aug. 5, 1952	53	50	.08	59	6.1	52	13	317	25	8.0	.2	7.0	.07	390	172	0	37	567	7.7
96-76-20cd	Tripp	36	do	50	35	----	80	9.8	21	10	292	17	4.0	.5	41	.05	378	240	1	15	563	7.7

Dakota sandstone

33-10-31cd	Boyd	785	Dec. 1, 1953	80	12	3.3	161	42	135	21	224	575	60	2.4	0.1	0.79	[5] 1,120	576	392	33	1,570	7.2
34-13-24aa	do	1,100	Aug. 5, 1952	64	13	3.1	258	41	68	17	167	675	110	1.6	.4	.15	[5] 1,270	812	675	15	1,700	7.7

[1] Includes equivalent of 6 ppm of carbonate (CO_3).
[2] Time after pumping began.
[3] Public supply for city of Ainsworth.
[4] Public supply for village of Wood Lake.
[5] Calculated.
[6] Public supply for village of Butte.
[7] Public supply for village of Gregory.
[8] Public supply for village of Springview.

TABLE 2.—*Chemical quality of municipal ground-water supplies*

[Analyses by Nebraska and South Dakota State Health Departments. Results, in parts per million, have been rounded, where necessary, to conform with U. S. Geological Survey standards]

Municipality	Well No.	Date of collection	Iron and manganese (Fe+MN)	Magnesium (Mg)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids
Suggested maximum [1]			0.3	125	250	250	1.5	[2] 44	[3] 500
Nebraska									
[Samples for Nebraska municipalities collected during 1952–54]									
Ainsworth			0.05		12	4.7	0.2	<44	198
Bristow			.0		73	6.0	.3	15	283
Butte			.01		29	5.7	.3	<44	306
Center			.42		173	9.5	.3	<44	684
Crookston			.01		71	11	.6	<44	412
Kilgore			.0		9.0	6.6	.4	<44	220
Long Pine			.0		5.0	1.9	.2	<44	114
Lynch			.0		63	1.9	.3	<44	286
Spencer			.0		82	5.7	.2	<44	346
Wood Lake			.0		9.5	4.7	.2	<44	142
South Dakota									
Burke	97-71-31ab1	10- 9-52	0.04	3.3	5.4	5.5	0.25	0.0	237
	97-71-31ab2	10- 9-52	.00	9.5	14	12	.2	.0	360
Colome	[4] 98-75-33dd	2- 4-54	.00	21	17	6.0	.9	3.1	427
Dallas	[5] 97-73- 7bb	10- 8-52	.00	15	136	53	.4	.0	811
Gregory	[6] 97-73-12ba	10- 9-52	.0	12	45	27	.25	.0	538
Herrick	96-71-24dc	6-22-55	.00	17	87	91	.2	97.0	643

[1] U. S. Public Health Service, 1946, Drinking water standards: Public Health Repts., v. 61, no. 11, p. 371–384.
[2] Maxcy, K. F., 1950, Report on the relation of nitrate concentrations in well waters to the occurrence of methemoglobinemia: Natl. Research Council Bull., Sanitary Engineer.
[3] 1,000 ppm permitted if water of better quality is unavailable.
[4] Composite sample from 6 wells.
[5] Composite sample from 4 wells.
[6] Composite sample from 12 wells.

more dissolved solids and is harder than that from the four wells in the Sand Hills region.

Two deep wells in Boyd County, Nebr., that tap the Dakota sandstone yield slightly saline water of the calcium sulfate type. The water is very hard, and much of the hardness is of the noncarbonate type.

SURFACE WATER

The chemical quality of water in the streams reflects the chemical quality of the ground water, because much of the annual streamflow in the area represents ground-water discharge. For example, about 83 percent of the annual discharge of Plum Creek represents ground-water discharge.

During low-flow periods, water from Ponca Creek, which drains an area where the Pierre shale is exposed extensively, has higher concentrations of dissolved salts (principally calcium and sulfate) and is harder than water from other streams in the report area. (See table 3.)

Some lakes in the Sand Hills region of Cherry County receive ground-water discharge; however, instead of representing depres-

TABLE 3.—*Maximum concentrations in samples of surface water*

[Results in parts per million except as indicated]

Location	Period of record	Number of samples	Bicarbonate (HCO_3)	Sulfate (SO_4)	Boron (B)	Hardness as $CaCO_3$ (calcium, magnesium)	Percent sodium	Specific conductance (micromhos at 25° C)
Streams								
Ponca Creek at Anoka, Nebr.	1949-53	15	345	405	0.44	617	24	1,210
Minnechaduza Creek at Valentine, Nebr.	1947-49	7	204	19	.06	174	24	342
Niobrara River near Sparks, Nebr.	1947-51	15	156	17	.18	108	31	271
Niobrara River near Norden, Nebr.	1953	5	152	11	.08	98	22	263
Plum Creek near Meadville, Nebr.	1947-49	10	151	16	.16	99	31	242
Niobrara River at Meadville, Nebr.	1950-52	5	178	15	.19	126	25	305
Long Pine Creek near Riverview, Nebr.	1947-52	10	146	16	.31	102	32	242
Keya Paha River near Hidden Timber, S. Dak.	1947-49	11	296	18	.16	182	60	459
Keya Paha River at Wewela, S. Dak.	1947-52	12	286	24	.11	177	46	468
Niobrara River near Spencer, Nebr.	1945-48	4	151	28	.08	121	31	270
Verdigre River near Verdigre, Nebr.	1947-49	13	178	64	.10	185	30	418
Lakes								
Little Alkali	April 1950	1	[1] 2,190	135		17	60	3,600
Big Alkali	do	2	680	41		130	64	1,110
Ell	do	1	[2] 981	41		99	63	1,610
Ballard	do	1	1,050	25		277	49	1,600
Trout	do	1	400	7.0		145	45	645
Hay	do	1	483	12		85	60	788
Red Deer	1946-50	2	460	3.3	0.01	268	34	728
Watts	April 1950	1	166	1.0		106	19	264
Hackberry	do	2	238	3.0	.01	131	26	386
Dewey	do	2	223	6.0		124	25	352
Willow	do	2	523	16		147	45	824
North Marsh	do	1	220	2.0		101	30	365
Whitewater	do	1	281	6.0		101	41	496
Pelican	do	2	292	5.0		132	29	469
West Twin	do	1	337	2.0		139	33	539
Dads	do	2	491	26		54	62	803

[1] Includes equivalent of 385 ppm of carbonate (CO_3).
[2] Includes equivalent of 33 ppm of carbonate (CO_3).

sions in the water table toward which ground water moves from all directions, the lakes seem to lie on the sloping water table in such a way that they receive water at the upgradient side and lose it at the downgradient side. The water of these lakes has a greater concentration of dissolved salts (measured as specific conductance) than does the ground water in the vicinity of the lakes. (See tables 1 and 3.) However, concentration of dissolved salts depends on the amount of water that leaves the lakes as underground discharge and on how much evaporates. None of the lake waters analyzed were concentrated enough to suggest that the lakes had no underground outlets.

DOMESTIC USE

The drinking-water standards of the U. S. Public Health Service[1] for water used on interstate common carriers have been accepted by

[1] U. S. Public Health Service, 1946, Drinking water standards: Public Health Repts., v. 61, no. 11, p. 371–384.

the American Water Works Association as standards for public supplies. Although these standards are not compulsory for water that is used locally, they are measures of the suitability of water for domestic use. Some of these standards for chemical characteristics, together with the analyses of municipal water supplies in the area, are given in table 2. The maximum concentration for nitrate is not listed in the 1946 drinking-water standards, but some investigators[2] have recommended that the concentration should not exceed 44 ppm because of the relation between high concentrations of nitrate in drinking water and cyanosis in infants.

The analyses in tables 1 and 2 show that ground water in the report area generally contains less than the suggested maximum concentrations. However, water from the Dakota sandstone contains iron, sulfate, fluoride, and dissolved solids in excess of the suggested maximum amounts; and water from a few wells tapping the Ogallala formation or Quaternary deposits contains iron in excess.

Specific limits of hardness cannot be set for various uses of water, but the following are general criteria:

Rating and usability	*Hardness as $CaCO_3$ (ppm)*
Soft—suitable for many uses without further softening	<60
Moderately hard—usable except in some industrial applications	60 to 120
Hard—softening required by laundries and some other industries	120 to 200
Very hard—requires softening to be satisfactory for most purpose	>200

Water from deposits of Quaternary age is soft to moderately hard, water from the Ogallala formation is moderately hard to very hard, and water from the Dakota sandstone is very hard.

IRRIGATION USE

Dissolved salts in irrigation water may injure plants and soils. High total salinity or high boron concentration may inhibit plant growth; if sodium is the major cation in the water, soil permeability and tilth may be impaired; and if sodium bicarbonate is the predominant dissolved salt, alkali conditions may develop in the soils.

Criteria established by the U. S. Salinity Laboratory Staff[3] for classifying irrigation water are based on average conditions of drainage, infiltration rate, quantity of water used, soil texture, climate, and salt tolerance of plants.

Water is classified as "low-salinity water" when the specific conductance is less than 250 micromhos, as "medium-salinity water"

[2] Maxcy, K. F., 1950, Report on the relation of nitrate concentrations in well waters to the occurrence of methemoglobinemia: Natl. Research Council Bull., Sanitary Engineer, p. 265, App. D.

[3] U. S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U. S. Dept. Agriculture, Agriculture Handb. 60, p. 69–82.

when from 250 to 750 micromhos, and as "high-salinity water" when from 750 to 2,250 micromhos. The terms are explained by the U. S. Salinity Laboratory staff as follows:

Low-salinity water can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability. Medium-salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. High-salinity water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

In the report area, water from wells tapping the deposits of Quaternary age or both the Quaternary deposits and the Ogallala formation generally has a low salinity; water from the Ogallala formation has a medium salinity; and water from the Dakota sandstone has a high salinity. Of the 7 irrigation wells that were sampled, 3 near Ainsworth tapped Quaternary deposits, 2 south of Verdigre and 1 in northern Keya Paha County tapped the Ogallala formation, and 1 south of Verdigre tapped both the Quaternary deposits and the Ogallala formation.

Generally, during periods of low flow, water in streams in the report area has low to medium salinity except for water in lower Ponca Creek, which has medium to high salinity.

Except for water from well 33–10–31cd, which taps the Dakota sandstone, concentrations of boron in ground water of the report area were less than the lower limit for plants most sensitive to boron. Because nearly all the water in the report area contains only minor amounts of sodium, it would not impair soil permeability and tilth.

Thus, with the exceptions of water from the Dakota sandstone, water in lower Ponca Creek during periods of low flow, and water in some lakes, the ground and surface waters of the report area are suitable for irrigation.

POTENTIAL DEVELOPMENT OF GROUND-WATER RESOURCES

Large supplies of ground water are obtainable only in the southwestern part of the report area where the water table is close to the land surface and the zone of saturation is thick. Here wells tapping deposits of Quaternary age are likely to discharge more water per unit of water-level drawdown than do the wells tapping the Ogallala formation; however, both aquifers are capable of transmitting large quantities of water to wells that are deep enough, properly constructed, and equipped with adequate pumps. Near the deeply incised valleys, the Ogallala formation and the Quaternary deposits are so well drained that wells must be deep, and they generally obtain only a small supply of water.

Elsewhere on the upland south of the Niobrara River, and on the upland between the Niobrara and the Keya Paha Rivers, moderately large supplies of water can be obtained if wells are located several miles from the deeply incised valleys. The Ogallala is the principal water-bearing formation in these parts of the area, although locally the lower deposits of Quaternary age also are included in the zone of saturation.

Only small quantities of water can be obtained from wells on the uplands north of the Keya Paha River and north of the Niobrara River below the mouth of the Keya Paha. In these parts of the area the zone of saturation is thin and the water-bearing material is not very permeable. In some places, however, moderately large supplies could be obtained from such installations as collector wells or batteries of wells.

In the valleys of the principal streams, especially in the central and eastern parts of the area, nearly impermeable rocks are widely exposed. The only possible sources of ground-water supply are the thin Quaternary deposits underlying the valley floor and the deep-lying Dakota sandstone. In topographically low places at the eastern end of the area, water will flow from wells drilled into the Dakota. Large supplies of ground water generally are not available in the valleys unless large-diameter wells are drilled into highly permeable deposits that are situated so that they can be recharged by infiltrating stream water.

Except for water from the Dakota, which is somewhat saline and very hard, ground water throughout the area is suitable for irrigation and for most industrial and domestic uses.

If the irrigation projects proposed by the U. S. Bureau of Reclamation for the tableland in the vicinity of Ainsworth and O'Neill are constructed, considerable additional ground-water recharge will result because the soils in both areas are moderately to highly permeable. Measurements of the depth to water should be made periodically so as to detect incipient waterlogging. Drainage measures then could be instituted to prevent a further rise of the water table. Pumping of ground water would be one means of removing excess water and thus forestalling waterlogging.

Additional test-hole drilling would provide needed data on the depth to the water table and on the thickness and permeability of the water-bearing material. Until such additional geologic and hydrologic information is obtained, the ground-water potential of the area cannot be appraised fully.

TABLE 4.—*Logs of test holes and wells*

BROWN COUNTY, NEBR.

Test hole 30-23-11bb

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	4	4	Sand, medium-grained, some gravel	11	52
Clay	6	10	Sand and gravel	4	56
Sand, some gravel	21	31	Sand, some gravel	14	70
Sand	10	41			

Test hole 30-23-12dc

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	3	3	Sand, fine- to medium-grained, some gravel	6	56
Clay, sandy	6	9	Sand and gravel	11	67
Sand	29	38	Sand, fine, some clay	8	75
Sand, some gravel	12	50	Sand, silt, and clay	23	98

Test hole 30-23-13dc

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	4	4	Sand	5	50
Clay, sandy	8	12	Sand, some gravel	7	57
Sand	4	16	Sand, very fine	8	65
Sand and gravel	20	36	Sand, fine	33	98
Sand, some gravel	9	45			

GREGORY COUNTY, S. DAK.

Well 96-71-24dc. City of Herrick

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	3	3	Gravel, coarse	7	39
Gravel	4	7	Sand, very fine	9	48
Sand, fine	25	32			

Test hole 97-71-30cc. City of Burke

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil, dark-brown	2	2	Sand	7	53
Clay, light-gray	4.5	6.5	Claystone, cemented sandstone, greenish	10.5	63.5
Sandstone, fine-grained silty	1.5	8	Sandstone, with lenses of clay, silt	6.5	70
Sandstone, fine-grained silty, soft	5	13	Sand, very fine, loose	52	122
Sandstone, greenish, with silt	6	19	Sand, firm	4.5	126.5
Silt and clay	4	23	Sand, loose	13.5	140
Siltstone, dark-brown	.9	23.9	Sand, some clay lenses	8	148
Clay, light-buff	15.6	39.5	Clay, buff	33	181
Sand, very fine, silty, buff	6.5	46			

HOLT COUNTY, NEBR.

Well 29-9-32dd. Gene Mudloff

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	3	3	Sand and gravel	80	105
Clay	22	25			

Test hole 29-11-6dd

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	1	1	Sand and gravel	21	40
Sand	11	12	Clay, white	11	51
Clay, sandy	3	15	Clay, light-brown	25	76
Sand and clay	2	17	Clay, sandy	22	98
Clay, sandy, white	2	19			

TABLE 4.—*Logs of test holes and wells*—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
HOLT COUNTY, NEBR.—Continued					
Well 31-15-24da. School District					
Topsoil	2	2	Sand and gravel	46	67
Sand and gravel	3	5	Clay	23	90
Clay	2	7	Sand, fine- to medium-grained (Ogallala formation)	60	150
Sand and gravel	8	15			
Clay	6	21			
KEYA PAHA COUNTY, NEBR.					
Well 33-21-24bb2. City of Springview.					
Topsoil	1	1	Sand, very fine to fine (Ogallala formation)	194	254
Sand and gravel	19	20			
Clay	40	60			
KNOX COUNTY, NEBR.					
Well 29-6-22cd. J. Wagner					
Topsoil	55	55	Clay	1	96
Sand and gravel	40	95	Sand, fine (Ogallala formation)	69	165
Well 29-6-22dc. L. Wagner					
Topsoil	36	36	Clay and cemented sand	19	145
Sand, tight	16	52	Clay	20	165
Sand, loose	74	126			
ROCK COUNTY, NEBR.					
Well 32-17-20ca1. Leland Anderson					
Topsoil	1	1	Sandstone, calcareous, cemented, soft	3	73
Sand, fine	15	16	Sandstone, calcareous, cemented, hard	0.5	73.5
Sand, fine, some clay	38	54			
Clay, hard, green	2	56			
Sand, compact, some clay	14	70			
Test hole 32-17-20ca2. Leland Anderson					
Topsoil	1	1	Limestone	2	29
Sand and clay	12	13	Clay, sandy	6	35
Clay, sandy, yellow	3	16	Sand, some clay, dirty	14.5	49.5
Sand	11	27	Sandstone, calcareous, cemented	1.5	51
TODD COUNTY, S. DAK.					
Well 36-28-7dd. ——— Lutter					
Sand, very fine to medium-grained, silty, trace of coarse sand	74	74	Sand, very fine to medium-grained, silty	20	154
Sand, very fine to medium-grained, slightly cemented, siliceous root casts	40	114	Sand, slightly silty, fine to medium-grained	20	174
Marl	10	124	Sandy, silty, very fine to medium-grained, finer below 184 feet	20	194
Silt, sandy, to sand, silty; very fine to medium-grained sand	10	134			

TABLE 4.—*Logs of test holes and wells*—Continued

TODD COUNTY, S. DAK.—Continued

Well 37-29-15c. B. Quigley

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand	56	56	Sand, very fine to medium-grained, trace of coarse sand	10	164
Sand, very fine to medium-grained, trace of coarse sand	28	84	Sand, very fine to fine, trace of medium-grained sand	10	174
Sand, silty, very fine to medium-grained, some cementation	10	94	Sand, fine to coarse	10	184
Sand, very fine to medium-grained, trace of coarse sand	10	104	Sand, very fine to fine, trace of medium-grained sand	10	194
Sand, silty, very fine to fine, trace of medium-grained sand, some cementation	10	114	Sand, fine- to medium-grained	10	204
Sand, fine- to medium-grained, cemented 118-121 feet	10	124	Sand, very fine to medium-grained, trace of coarse sand	10	214
Sand, very fine to fine, trace of medium-grained sand	10	134	Sand, fine to coarse	10	224
Sand, very fine to medium-grained, interbedded white silt lenses	20	154	Sand, fine- to medium-grained, trace of coarse sand	10	234
			Sand, very fine to medium-grained	10	244
			Sand, very fine to fine, trace of medium-grained sand	10	254
			Silt, sandy, very fine to fine sand	10	264

TABLE 5.—*Records of wells and springs*

Well number: See text for description of well-numbering system.
Type of well: Dn, driven well; Dr, drilled well; Du, dug well; Sp, spring.
Depth of well: Measured depths are given in feet and tenths below measuring point. Reported depths are given in feet below land-surface datum.
Type of casing: B, brick; C, concrete; M, iron, galvanized iron, or steel pipe; N, not cased; S, stone; T, tile; W, wood.
Method of lift (first symbol): C, cylinder; Cf, centrifugal; F, flowing well; N, none; P, piston; T, turbine.
Type of power (second symbol): E, electric; G, butane, diesel, gasoline, or propane; H, hand-operated; N, none; W, windmill.
Use of well: D, domestic; I, irrigation; N, not being used; O, observation; PS, public supply; S, stock.
Measuring point: Hpb, top of hole in pump base; Tc, top of casing; Tpl, top of platform.
Altitude of measuring point: Altitudes determined by spirity levelling are given in feet, tenths, and hundredths; altitudes interpolated from topographic maps are given in feet.
Depth to water: Measured depths to water level are given in feet, tenths, and hundredths. Reported depths are given in feet.
Remarks: Ca, water sample collected for chemical analysis. D, discharge in gallons a minute (E, estimated; M, average; R, reported). L, log of well included in this report. T, temperature in degrees Fahrenheit.

Well No.	Owner or tenant	Year completed	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Method of lift and type of power	Use of well	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Depth to water below measuring point (feet)	Date of measurement	Remarks
Antelope County, Nebr.														
27- 7- 6cd	School District		Dr		4	M	C, H	D	Tc	0.0		87.36	8-20-52	
9aa	Royal, Nebr.	1924	Dr	117	6	M	T, E	PS						T, 55
18cc	School District		Dr		4	M	C, W	D	Tc	1.0		91.70	8-20-52	
8- 3cb	Orchard, Nebr.		Dr	130	8	M	T, E	PS						T, 55; D, 150, E
9aa	do	1947	Dr	160	8	M	T, E	PS						T, 55; D, 225, E
28- 6-20cc	School District		Dr	34	4	M	C, H	D	Tc	.0		15.80	8-20-52	T, 54
7-12cb	do		Dr	93	4	M	C, H	D	Tc	.5		59.41	8-20-52	T, 54
22cc	do		Dr	138	4	M	C, H	D	Tc	1.0		87.41	8-20-52	
8- 7ad	do		Dr	57	6	M	C, H	D	Tc	.0		38.42	8-20-52	T, 54
Boyd County, Nebr.														
33- 9-13bb	Monowi, Nebr.		Dr	256	4	M	C, W	PS			1,526			D, 7, E
10-15cd	Lynch, Nebr.		Sp				F, E	PS			1,450			D. 42, E
31cd	Elvin Allen	1953	Dr	785	4	M	F	S			1,500		12- 1-53	Ca; D, 15, E; T, 79.5
11-14db			Dr	14	20	C	C, W	D	Hpb	0.0	1,463	8.98	7-29-52	T, 53
11-15aa	Bristow, Nebr.		Sp				F	PS			1,450			D, 145, E
16aa	C. C. Nelson		Du	14	48	C	C, W	S	Tc	1.0	1,476	9.89	7-30-52	
12- 9aa			Dr	23	24	C	C, W	S	Tc	2.0	1,675	9.67	7-29-52	
34-11- 8bb			Dr	18	24	C	C, H	D	Tc	1.0		11.30	7-29-52	T, 53
20dc	School District		Dr	27	12	C	C, H	D	Tpl	1.0		14.77	7-29-52	

27dd			Du	24	36	B	C, W	S	Tc	.0		11.64	7-29-52	
12-14cd	Spencer, Nebr		Dr	27	48	C	C, W	S	Tc	.0		15.97	7-29-52	
27dd	do		Sp					PS						
35ca	Anoka, Nebr		Du	14	120	C	T, E	PS						
13- 3ca	Butte, Nebr		Du	16		C	P, E	PS						Ca; D, 35, E
21ad1	do		Dr	53	8	M	T, E	PS					8- 5-52	D, 16, E
21ad2	do		Dr	49	8	M	Cf, E	PS						D, 16, E
21ad3	do		Du	53	96	C	Cf, E	PS						D, 22, E
21ad4				53	96	C	P, E	PS						
23cd	F. Lichtenberg		Du	25	36	C	C, W	S	Tc	1.0		9.68	7-29-52	Ca; T, 64
24aa			Dr	1,100	6	M	C, W	S				110	8- 5-52	
14- 4 ld			Du	17	36	B	C, W	S	Tpl	1.0	1,844	6.23	7-29-52	
14cd			Dr	30	18	C	C, W	S	Tc	1.0	1,875	5.70	7-29-52	
34-14-16cc			Dr	28	20	C	C, W	S	Tc	1.0	1,910	5.48	7-29-52	
15-26 1a	School District		Du	25	40	C	C, H	D	Tpl	1.0	1,830	15.36	7-29-52	
16-34dd	do		Dr	54	4	M	C, H	D	Tc	1.0	1,921	49.86	7-28-52	T, 55
35-14-29da			Dr	55	20	C	C, W	S	Tc	2.0	1,836	53.39	7-29-52	
15-32ab			Du	12	30	W	C, W	S	Tc	.0	1,990	9.59	7-28-52	

Brown County, Nebr.

29-21- 6cd	Libby Deer		Du, Dr	85	72	C, M	Cf, G	I	Tc	0.0	2,521.25	5.03	11-14-52	D, 735, M
22-10ac	R. Lucht	1949	Dr	115	18	C	T, G	I	Hpb	.5	2,570.41	13.37	11-14-52	
30-20-31cb	Long Pine, Nebr		Sp			N	F	PS						Ca; D, 1,000, E
21-12cb	Harold Johnson		Dr	78	18	M	T, G	I					9-29-52	Ca; D, 300, E; T, 53
26bb			Dr	65	5	M	C, W	S, O	Tc	1.2	2,425	39.20	12-31-52	Ca; T, 53
30ac	J. Fling	1940	Dr	74	18	M	T, G	I	Hpb	.2	2,511.80	32.62	1-31-52	D, 868, M
30bd	do	1947	Dr		18	M	T, G	I	Hpb	-.2	2,513.87	33.64	10- 5-51	D, 859, M
30cb	C. D. Hall	1944	Dr	76	18	M	T, G	I	Hpb	.2	2,518.82	33.98	9-11-51	D, 862, M
31cc	do	1947	Dr		18	M	T, G	I	Hpb	1.2	2,522.59	11.48	5- 4-50	D, 750, E
31db	G. Coad		Dr		18	M	T, G	I	Hpb	.8	2,513.67	16.86	11-14-47	D, 1,064, M
22-14dc	Skillman		Dr	32	18	M	N, W	N	Tc	.5	2,490.20	15.93	11-14-52	
15cc	E. Kennedy		Dr	70	18	M	T, G	I	Hpb	.5	2,538.71	38.44	11-17-52	D, 513, M
16cd	do	1947	Dr	69.0	18	M	T, G	I	Hpb	.0	2,547.28	38.84	11-17-52	D, 542, M
16dc1	do		Dr	70	18	M	T, G	I	Hpb	.5	2,542.55	39.32	11-17-52	D, 461, M
16dc2	do	1947	Dr	68.5	18	M	T, G	I	Hpb	.3	2,544.71	37.92	11-17-52	D, 718, M
17cb	Clausen		Dr		18	M	T, G	I	Hpb	.3	2,562.60	40.86	11-17-52	D, 400, E
18db	H. Jessen	1952	Dr	201	18	C	T, G	I	Tc	1.5	2,563	40.23	11- 5-51	
21ac	H. Rowher	1944	Dr	66	18	M	T, G	I	Hpb	.4	2,548.93	37.89	11-17-52	
22bc	J. Bejot		Dr	142	18	M	T, G	I	Hpb	.2	2,540.73	38.56	11-14-52	D, 587, M
23dc	K. Hunt	1944	Dr		18	M	T, E	I, O	Tc	.5	2,520.28	36.18	11-14-52	D, 351, M
23dd	Dr. A. G. Rasck	1934	Dr	68	24	M	T, G	I	Tc	.5	2,521.10	39.37	11-14-47	D, 500, E
24db	V. Denny	1942	Dr	71	24	M	T, G	I	Tc	.3	2,512.84	36.58	11-14-52	D, 458, M
25ad	C. D. Hall	1946	Dr		18	M	T, G	I	Hpb	1.2	2,519.10	32.65	9-11-51	
25cb	M. Skinner	1939	Dr	63	60	C	Cf, G	I, O	Tc	.0	2,523.50	22.53	11-14-52	Ca; D, 1,084
25da	do	1949	Dr	74	36	C	T, G	I, O	Tc	.0	2,520.72	31.35	11-14-52	
26ab	Ainsworth, Nebr	1940	Dr	72	16		T, E	PS			2,518.60	33	11-15-41	L; D, 550, E
26ba1	do	1907	Dr					PS	Tc	-18.0	2,500.90	9.0	11-15-41	D, 250, E
26ba2	do	1934	Dr	72	16		T, E	PS	Tc	.0	2,518.60	33.0	11-15-41	Ca; D, 250, E
26cb	M. Skinner	1948	Dr		27	C	T, G	I, O	Tc	.0	2,525.40	20.06	11-14-52	
26cc	O. H. McBride	1948	Dr	69	18	M	T, G	I, O	Hpb	1.0	2,528.94	17.88	11-14-52	Ca; D, 1,069, M; T, 52

TABLE 5.—*Records of wells and springs*—Continued

Well No.	Owner or tenant	Year completed	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Method of lift and type of power	Use of well	Measuring point			Depth to water below measuring point (feet)	Date of measurement	Remarks
									Description	Height above land surface (feet)	Altitude above mean sea level (feet)			
Brown County, Nebr.—Continued														
30-22-26db	M. Skinner	1937	Du, Dr	68	72	C	Cf, G	I, O	Tc	.0	2,525.00	23.51	12-31-52	D, 1,050, M
27dc1	T. S. Bower	1931	Dr	64	12	M	Cf, G	I, O	Tpl	.5	2,534.29	15.61	11-14-52	D, 860, M
27dc2	McCoid	1931	Du, Dr		72	C	Cf, G	I	Tc	.0	2,530.70	17.58	11-14-52	D, 971, M
34ab	W. R. Baker	1934	Dr	68	72	C	T, G	I	Tc	.0	2,535.95	20.95	11-14-52	D, 1,239, M
34bd	O. Feilmeier		Dr		18	M	T, G	I	Hpb	.0	2,545.90	17.67	6-7-51	D, 900, M
35ba	L. Davison		Dr	52			Cf, G	I	Tpl	.2	2,527.80	16.93	6-27-50	
35bb	do			44	60	C	Cf, G	I	Tc	.0	2,516.80	+.45	11-14-52	
23-12cc	Johnson	1939	Dr	70	18	M	T, G	I	Hpb	.3	2,574.20	42.85	11-14-52	D, 750, R
13bc	M. A. Miles		Dr	80	18	M	T, G	I	Tc	1.5	2,574.20	37.79	11-14-52	D, 538, M
18ac	G. Mitchell	1939	Dn	58	6	M	C, E	D					1-13-50	Ca; T, 56
Cherry County, Nebr.														
29-28- 1ad			Dr			M	F	N			2,905		4-21-50	Ca
30-28-29ba	U. S. Geol. Survey	1949	Dn	12	1¼	M	N, N	N	Tc	3.0	2,930.89	7.02	2-6-51	Ca
29-14ac	do	1949	Dn	14	1¼	M	N, N	N	Tc	3.5	2,930.56	6.23	2-5-51	Ca
14cd	U. S. Fish and Wildlife Service.	1936	Dr	33	3	M	C, E	D			2,925		1-11-49	Ca
25ca	School District		Dr	100	2	M	F	S			2,940		4-21-50	Ca
31-25-27bb1	Wood Lake, Nebr		Dr	74	24	M	T, E	PS			2,700	38	10-18-50	Ca; D, 150, E; T, 54
27bb2	do	1949	Dr	60	24	M		PS			2,700	38		D, 200, E
28-23aa1	S. McKelvie Ranch		Dr	128		M	C, W	D			2,880			Ca
23aa2	do		Dr	40		M	C, W	S			2,880			Ca
23da1	U. S. Geol. Survey		Dn	6	1	M	N, N	N	Tc	.3	2,869	1.71	11-3-49	
23da2	S. McKelvie Ranch		Dr			M	F	S			2,869			Ca
32-26-17aa	J. Drayton		Dr	95	1¼	M	F	S			2,700		1-11-50	Ca
28bb	do		Dr	68	3½	M	C, W	S			2,735		1-12-50	Ca
29ac	do		Dr	129	3½	M	C, W	S			2,740		1-12-50	Ca
34-29- 9cc	Crookston, Nebr		Dr	300	6	M	P, E	PS			2,700			D, 31, E
31-10ab1	Kilgore, Nebr		Dr	112	2	M	P, E	PS			2,910	30		D, 75, E; 3 wells
10ab2	do		Dr	112	2	M	P, E	PS			2,910	30		
10ab3	do		Dr	122	2	M	P, E	PS			2,910	30		
35-27-36bb			Du	100	36	S	C, W	S	Tc	.0	2,772	91.67	8-12-52	
28-29cc			Du	132	52	N	C, W	S	Tpl	1.0	2,835	120.47	8-12-52	Ca; T, 54

Gregory County, S. Dak.

95-69-29da		1932	Dr	39	20	C	C, H	S	Tc	1.0		11.08	9- 4-52	
71-29ba			Dr	59	20	C	C, W	S	Tc	.0		44.76	9- 4-52	
73-29bc	School District	1935	Dr	49	20	C	C, H	D	Tc	2.0		40.76	9- 4-52	T, 54
96-70-33aa		1938	Dr	67	20	C	C, W	S	Tc	1.0		61.22	9- 4-52	
71-24dc	Herrick, S. Dak		Dr	48	34	C	T, E	PS	Tc	1.0		33	9- 4-52	D, 50, E; L
30dd			Dr	53	20	C	C, W	S	Tc	1.0		7.68	9- 4-52	
72- 8ad		1926	Dr	55	20	C	C, W	S	Tc	.5		44.14	9- 4-52	
73-17dc	School District	1931	Dr	50	20	C	C, H	D	Tc	.5		8.74	9- 4-52	
97-71-31ab1	Burke, S. Dak	1948	Dr	110	10	M	C, E	PS				82		D, 60, E
31ab2	do	1936	Dr	133	24	M	C, E	PS				82		D, 40, E
72-19aa	School District		Dr	26	20	C	C, H	D	Tc	.0		17.62	9- 4-52	
73- 7bb1	Dallas, S. Dak		Du	60	144	C	T, E	PS				30		D, 100, E; 6 wells
7bb2	do		Dr	60	30	C	T, E	PS				30		
7bb3	do		Dr	45	30	C	T, E	PS				30		
7bb4	do		Dr	60	30	C	T, E	PS				30		
7bb5	do		Dr	50	30	C	T, E	PS				30		
7bb6	do		Dr	60	30	C	T, E	PS				30		
12ba1	Gregory, S. Dak	1925	Dr	50	20	C	P, E	PS				15		
12ba2	do	1925	Dr	56	20	C	P, E	PS				15		
12ba3	do	1927	Dr	90	20	C	P, E	PS				15		
12ba4	do	1922	Dr	70	20	C	P, E	PS				15		
12ba5	do	1927	Dr	85	12	C	P, E	PS				15		
12ba6	do	1925	Dr	50	12	C	P, E	PS				15		
12ba7	do	1925	Dr	60	12	C	P, E	PS				15	6-19-52	Ca
12ba8	do	1925	Dr	60	12	C	P, E	PS				15		
12bb1	do	1930	Dr	50	12	C	P, E	PS				20		
12bb2	do	1930	Dr	50	12	C	P, E	PS				20		
12bb3	do	1930	Dr	75	12	C	P, E	PS				20		
12bb4	do	1930	Dr	80	12	C	P, E	PS				20		
18dd	School District		Dr	23	48	C	C, H	D	Tc	1.0		13.26	9- 4-52	

Holt County, Nebr.

28- 9-11cd	School District	1910	Dr	32	6	M	C, H	D	Tc	0.0		20.12	8-21-52	T, 54
29- 9-14aa	do	1932	Dr	63	6	M	C, H	D	Tc	.5		44.38	8-21-52	
27cc	do		Dr	36	4	M	C, H	D	Tc	.0		25.89	8-21-52	T, 53
32dd	Gene Mudloff	1953	Dr		18	M	T, G	I	Hpb	.0			5- 7-53	L
10-13bb		1924	Dr	16	8	M	C, W	S	Tc	2.0		4.48	8-21-52	
12-10cb	School District	1941	Dr	39	6	M	C, H	D	Tc	.0	2,032.07	17.87	8-21-52	T, 51
30- 9- 2cc	do	1937	Dr	56	6	M	C, H	D	Tc	.0	1,818	35.39	8-21-52	T, 53
10-13ad	do	1936	Dr	63	6	M	C, W	D, S	Tc	.5	1,905	51.89	8-21-52	
21bb		1933	Dr	85	8	M	C, W	S	Tc	1.5	1,950	56.22	8-21-52	
11-14ab	School District	1941	Dr	28	6	M	C, H	D	Tc	.0	1,830	16.79	8-22-52	T, 53
12-15bb		1929	Dr	53	5	M	C, W	S	Tc	1.0	2,015	47.77	8-22-52	
24cc	School District		Dr	33	7	M	C, H	D	Tc	.5	2,003	16.70	8-22-52	
13- 7ad	do	1927	Dr	34	6	M	C, H	D	Tc	.0	2,050	25.33	8-25-52	
26da	do	1935	Dr	36	8	M	C, H	D	Tc	.0	2,016	15.90	8-25-52	T, 52
14- 8dd	do	1946	Dr	50	5	M	C, H	D	Tc	1.0	2,115	36.45	8-25-52	

TABLE 5.—*Records of wells and springs*—Continued

Well No.	Owner or tenant	Year completed	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Method of lift and type of power	Use of well	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Depth to water below measuring point (feet)	Date of measurement	Remarks
Holt County, Nebr.—Continued														
31- 9- 8aa	School District	1934	Dr	19	6	M	C, H	D	Tc	.0	1,767	10.82	8-22-52	
31dd	do	1931	Dr	73	8	M	C, H	D	Tc	1.0	1,896	58.11	8-21-52	T, 55
10-20cc	do		Dr	15	6	M	C, H	D	Tc	.0	1,801	6.04	8-22-52	
11-27cc	do	1931	Dr	55	5	M	C, H	D	Tc	.0	1,835	28.71	8-22-52	T, 53
13-26cc	do	1931	Dr	126	5	M	C, H	D	Tc	.0	1,975	95.05	8-25-52	
14- 3bb	do	1938	Dr	32	6	M	C, H	D	Tc	.0	2,007	12.83	8-25-52	T, 50
21cd	do	1936	Dr	39.5	5	M	C, H	D	Tc	.0	2,088	24.06	8-25-52	T, 52
15- 2cb	do	1934	Dr	28	6	M	C, H	D	Tc	.0	1,998	13.26	8-25-52	T, 53
24da		1953	Dr	150	18	C	T, G	I	Tc	.5	2,095	28.50	5- 7-53	L
32-11-18cb	School District		Dr	47	6	M	C, H	D	Tc	.0	1,728	22.44	8- 6-52	Ca;T,53
32-12- 8da	do		Dr	45	6	M	C, H	D	Tc	.0	1,777.4	32.07	8-25-52	T, 53
13-23bb	do	1951	Dr	28	6	M	C, H	D	Tc	.0	1,945	20.92	8-25-52	T, 52
33cb	do	1949	Dr	78	6	M	C, H	D	Tc	.0	2,040	49.05	8-25-52	
15-10aa	do	1952	Dr	33	4	M	C, H	D	Tc	1.0	1,925	17.21	8-25-52	T, 53
33-14- 3dd	do	1940	Dr	17	6	M	C, H	D	Tc	1.0	1,815	7.10	8-25-52	T, 51
32aa	do	1931	Dr	14	6	M	C, H	D	Tc	.0	1,850	7,39	8-25-52	
Keya Paha County, Nebr.														
33-17-29ad	School District		Dr	39	6	M	C, H	D	Tc	0.0	2,010	11.79	7-16-52	T, 54
19-19cc			Dr	125	3	M	N, N	N	Tc	2.0	1,406	118.08	7-16-52	
20-33bb			Dr	118	3	M	C, W	S	Tc	.0	2,433	115.79	7-16-52	T, 53
21-24bb1	Springview, Nebr	1916	Dr	144	24	C	T, E	PS		.0	2,448	80	7- 8-52	D, 125, E
24bb2	do	1934	Dr	254	8	M	T, E	PS		.0		80	7- 8-52	Ca; D, 55, M; L; T, 53.
26ab		1940	Dr	113	4	M	C, W	S	Tc	.5	2,456.50	81.32	7- 3-52	
29ad			Dr	82	4	M	C, W	S	Tc	.5	2,397.50	54.83	7- 3-52	T, 53
22- 1dd			Dr	119	6	M	C, W	S	Tc	.0	2,475	82.96	7- 1-52	T, 51
8cc			Dr	52	5	M	N, N	N	Tc	2.0	2,413	42.99	7- 3-52	
20cc			Dr	76	4	M	C, W	S	Tc	1.0	2,412	65.36	7- 3-52	T, 53
34-18- 7ab		1949	Dr	45	24	T	C, W	S	Tc	1.0	2,042	11.40	7-14-52	
19- 4dc		1948	Dr	17	24	T	N, N	N	Tc	.0	2,096	7.05	7-14-52	

18dd	Burton, Nebr.	1927	Dr	35	6	M	C, W	PS			2,149			D, 3, E
20- 8bb	F. Schoettger		Dr	39	4	M	C, W	S	Tc	1.0	2,258	18.78	7-14-52	T, 53
25cc			Dr	34	4	M	C, W	S	Tc	1.0	2,208	7.88	7- 3-52	T, 53
21- 3da	R. Kurzenberger	1952	Dr	40	4	M	C, E	S	Tc	4.0	2,259	11.83	7-14-52	T, 49
22- 1ca			Dr	86	3	M	C, W	S	Tc	.5	2,394	12.16	7-14-52	
28bc			Dr	35	6	M	C, W	S	Tc	1.0	2,457	19.15	7- 1-52	
23-11ac			Dr	65	4	M	C, W	S	Tc	.5	2,396	31.93	7- 3-52	T, 53
19cb			Dr	45	3.5	M	C, W	S	Tc	.5		11.45	7- 2-52	T, 52
34bd		1940	Dr	83	4	M	C, W	S	Tc	1.0	2,552	76.85	7- 2-52	T, 54
24- 3bd			Dr	40	4	M	C, W	S	Tc	1.0	2,500	9.13	7- 2-52	
16cb	F. Starkjohann	1920	Dr	75	4	M	C, W	S	Tc	3.0	2,541	41.28	7- 2-52	T, 53
35-17-28bc	School District		Dr		24	T	C, W	S	Tc	1.0	2,106	23.00	7-16-52	T, 54
23-23bb	E. Weston	1950	Dr	110	18	M	T, G	I	Hpb	.0	2,350	20.00	7- 1-52	Ca; T, 53
31dc	R. Jerr	1944	Dr	44	4	M	C, W	S	Tc	3.0	2,500	18.78	7- 2-52	T, 51
24-32bc	Shant	1946	Dr	72	4	M	C, W	S	Tc	1.0	2,513	12.25	7- 2-52	T, 52

Knox County, Nebr.

29- 6-21ca	R. Sorenson	1951	Dr	167	18	M	T, G	I	Hpb	0.0		51.40	3-26-53	D, 300, E
21dd	do	1952	Dr	182	18	M	T, G	I	Hpb	.0		54.01	3-26-53	Ca; D, 800, E
22bd	L. Wagner	1952	Dr	153	18	M	T, G	I	Hpb	.0		16.50	3-24-53	Ca; D, 350, E
22cd	J. Wagner	1952	Dr	142	18	M	T, G	I	Hpb	.0		35.00	3-24-53	D, 800, E; L
22dc	L. Wagner	1952	Dr	130	18	M	T, G	I	Hpb	.0		27.36	3-25-53	Ca; D, 350, E; L; T, 53.
27ac	J. Wagner	1952	Dr	157	18	C	T, G	I	Hpb	.0		42.00	9-15-52	D, 1, 200, E
29bb	R. Sorenson	1951	Dr	220	18	M	T, G	I	Hpb	.0		117.32	3-25-52	D, 300, E
8-10dd	School District	1906	Dr	36	4	M	C, H	D	Tc	.5		28.99	8-28-52	T, 53
30- 6- 4cc	Verdigre, Nebr.		Du	12	36	C	Cf, G	PS			1,352			
8-22dd	School District	1922	Dr	27	4	M	C, H	D	Tc	.0	1,650	19.37	8-28-52	Ca; T, 50
31- 7-29dd	do	1942	Dr	38	8	M	C, H	D	Tc	.0	1,615	15.68	8-28-52	T, 53
8-32aa	do	1912	Dr	28	6	M	C, H	D	Tc	.0	1,690	23.39	8-28-52	
32- 6-16bc	Niobrara, Nebr.		Dr	65	18	M	T, E	PS						D, 100, E
33- 7-30bb	Verdel, Nebr.		Dr	185	6	M	C, G	PS						D, 90, E

Rock County, Nebr.

32-17-20ca1	Leland Anderson	1949	Dr	73	6	M	C, W	S	Tc		2,115	20.19	7-18-52	L
20dc	School District		Dr	40	36	T	C, H	D	Tc	.5	2,100	31.74	7-18-52	T, 52
32aa			Dr	40	4	M	C, W	S	Tc	1.0	2,140	5.82	7-18-52	

Todd County, S. Dak.

36-28- 7dd	Lutter	1951	Dr	194	6	M	C, W	S	Tc			38.00	1-30-53	L
37-29-15c	B. Quigley	1951	Dr	264	6	M	C, W	S	Tc	0.0		103	1-30-53	L
38-28- 3bd	Rosebud Mission School		Du	45	432	C	T, G	PS					8- 5-52	Ca

TABLE 5.—*Records of wells and springs*—Continued

Well No.	Owner or tenant	Year completed	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Method of lift and type of power	Use of well	Measuring point			Depth to water below measuring point (feet)	Date of measurement	Remarks
									Description	Height above land surface (feet)	Altitude above mean sea level (feet)			
Tripp County, S. Dak.														
95-77-19dd	School District	1939	Dr	26	4	M	C, H	D	Tc	0.5		10.16	9- 2-52	
78-17bb	do	1933	Dr	50	4	M	C, H	D	Tc	.0		24.75	9- 2-52	
96-74-30aa	M. Bill	1936	Dr	32	20	C	C, W	S	Tc	1.5		23.24	9- 2-52	
75-31aa		1947	Dr	24	20	C	C, W	S	Tc	1.0		8.28	9- 2-52	
76-20cd	School District		Dr	36	4	M	C, H	D	Tc	1.0		19.00	8- 5-52	Ca
96-77-29ab	do	1931	Dr	26	4	M	C, H	D	Tc	.0		9.22	9- 2-52	
79- 2cc	do		Dr	68	4	M	C, H	D	Tc	.0		23.04	9- 2-52	T, 53
97-74-28dd		1933	Dr	44	18	C	C, W	S	Tc	2.0		31.78	9- 2-52	
75-28bc		1947	Dr	16	36	C	C, W	S	Tc	1.0		8.33	9- 2-52	
77-29ab	School District	1929	Dr	21	12	C	C, H	D	Tc	.0		12.98	9- 2-52	T, 54
78- 9cc	do	1940	Dr	78	4	M	C, H	D	Tc	.0		21.20	9- 2-52	
99-75-33dd	Colome, S. Dak		Dr	35	6	M	C, E	PS				10		D, 125, E; 6 wells

INDEX