WATER RESOURCES OF YANKTON COUNTY, SOUTH DAKOTA

By Edward F. Bugliosi

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4241

Prepared in cooperation with the

SOUTH DAKOTA GEOLOGICAL SURVEY,

YANKTON COUNTY, and the

LOWER JAMES CONSERVANCY SUB-DISTRICT

Huron, South Dakota

1986

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CONVERSION FACTORS

For readers who may prefer to use S.I. units rather than inch-pound units, the conversion factors for the terms in this report are listed below:

Multiply	By	To obtain
	LENGTH	
inch (in.)	25.40	millimeter
inch per year (in/yr)	25.40	millimeter per year
inch (in.)	0.0254	meter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	AREA	
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
square foot (ft^2)	0.0929	square meter
	VOLUME	
gallon (gal)	3.785	liter
cubic foot (ft^3)	0.02832	cubic meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot (acre-ft)	0.001233	cubic hectometer
	FLOW	
foot per day (ft/d)	0.3048	meter per day
foot per year (ft/yr)	0.3048	meter per year
foot per mile (ft/mi)	0.18943	meter per kilometer
cubic foot per second (ft^3/s)	28.32	liter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallons per minute (gal/min)	0.06309	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
foot squared per day (ft^2/d)	0.0929	meter squared per day

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) by the following equations:

$$°F = 9/5\ (°C) + 32$$

$$°C = 5/9\ (°F - 32)$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

Artesian and water-table conditions in the Lower James-Missouri aquifer differ at different locations in the county. The water predominantly is a calcium sodium sulfate type; specific conductance and hardness average 1,910 micromhos at 25° Celsius and 870 milligrams per liter, respectively. Wells completed in the Lower James-Missouri aquifer can be expected to yield at least 500 gallons per minute and may yield more than 1,000 gallons per minute. There is subsurface inflow from Hutchinson and Bon Homme Counties, and subsurface outflow into Clay County. Recharge is from the Missouri River in the south, and from precipitation. Discharge is to the Niobrara near T. 96 N., R. 55 W.

The James River at the stream-gaging station 1 mile north of the county line has an average flow for the period of record of 375 cubic feet per second. The Missouri River has an average flow of 26,410 cubic feet per second at the city of Yankton. The Missouri River is dammed about 4 miles west of the city of Yankton, creating a reservoir 25 miles long and containing an average of 410,000 acre-feet of water.

INTRODUCTION

In October 1977, the South Dakota Geological Survey and the U.S. Geological Survey began a 4-year study of the geology and water resources of Yankton County, an area of 524 mi^2 in southeastern South Dakota. The investigation is part of a cooperative program of water-resources evaluation in South Dakota. The status of that program is shown in figure 1.

This report provides information that can be used to plan the development of water supplies. It is a general appraisal of water resources; any large-scale development of ground water should be preceded by test drilling and by determination of local aquifer characteristics.

Methods of Investigation

Standard hydrologic investigative methods were used in the interpretation and presentation of the data. Data from streamflow-gaging stations on the James River at Scotland, Bon Homme County, and at the Missouri River near Yankton were used. Discharge also was measured at three locations on the James River in Yankton County. Historical well records and test drilling provided most of the data used in this report. In addition, existing wells were inventoried to obtain hydrologic data to supplement the drillers' logs and test-drilling data.

Water levels were measured on man-made reservoirs and in observation wells within the county. Water-quality data were obtained from analyses of surface water and ground water and from historical records.

Previous Investigations

Recent hydrology reports have not been published for Yankton County. However, the geology and hydrology for bordering Clay County (Christensen, 1968; Stephens, 1967) and Bon Homme County (Christensen, 1974; Jorgensen, 1971) have been published.

Other workers (Todd, 1894; Darton, 1909; and Flint, 1955) have contributed to the geologic and hydrologic interpretation of either the entire State or the eastern one-half

WATER RESOURCES OF YANKTON

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ABSTRACT

Yankton County, an area of 524 square miles in southeastern South Dakota, contains three major aquifers: the Dakota aquifer, the Niobrara aquifer, and the Lower James-Missouri glacial-outwash aquifer. Glacial deposits including till, sand and gravel, and loess blanket the entire county, overlying Tertiary and Cretaceous bedrock strata. Major surface-water sources are Lewis and Clark Lake, Marindahl and Beaver Lakes, and the Missouri and James Rivers.

The Dakota aquifer is the deepest, ranging from about 300 to more than 500 feet below land surface. Usually, wells completed in the Dakota aquifer in areas below an altitude of 1,260 feet will flow from 3 to 60 gallons per minute at the land surface. Water from this aquifer is predominantly a calcium sulfate type and generally is suitable for domestic, livestock, and irrigation uses. Subsurface inflow is from the west and subsurface outflow is to the east.

The Niobrara aquifer is present only in the northeastern and southwestern parts of the county. The aquifer is under both artesian and water-table conditions in the northeastern part of Yankton County, and only under water-table conditions in the southwestern part. Wells completed in the Niobrara range in yield, but most well yields are sufficient only for domestic supply. The water is predominantly a magnesium sulfate type.

Recharge to the northeastern part of the Niobrara aquifer is from precipitation through the overlying glacial deposits and from the Lower James-Missouri aquifer near T. 96 N., R. 55 W. Discharge is to the Lower James-Missouri aquifer north of Volin. Subsurface outflow is to the east into Clay County. The southwestern part of the Niobrara aquifer receives recharge from precipitation. Subsurface inflow is from Bon Homme County. Discharge is to the Lower James-Missouri aquifer west of the city of Yankton and from springs and seeps along the bluffs adjacent to the Missouri River valley.

The Lower James-Missouri aquifer is an extension of the Lower Vermillion-Missouri aquifer in Clay County. The aquifer underlies about 50 percent of the county. The transmissivity ranges from 20,700 feet squared per day under the Missouri River flood plain where it is uniformly 100 feet thick, to 70,200 feet squared per day under the James Ridge area where there is about 300 feet of saturated thickness.

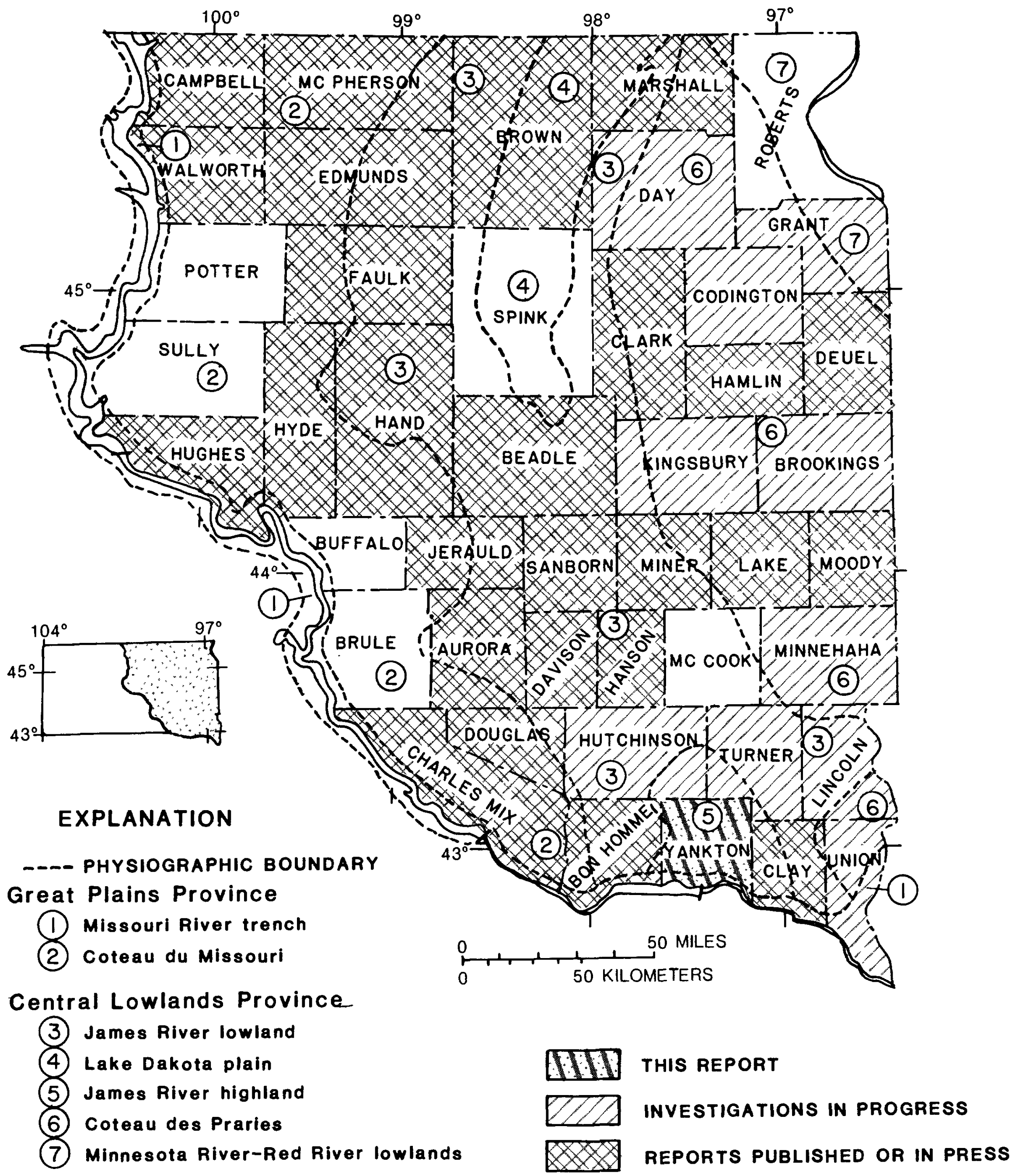


Figure 1.--Physiographic divisions of eastern South Dakota, location of Yankton County, and status of county investigations.

of the State including generalized data for Yankton County. Simpson (1960) mapped the southern one-half of Yankton County and two masters thesis (Lutzen, 1957; Sevon, 1955) contain maps of the surficial geology of most of the remainder of the county. A report on a study of water-supply potential for the city of Lesterville (Rukstad, 1963) contains additional hydrologic data for a part of the county. Other reports on sand and gravel deposits (Rothrock, 1943), and bedrock aquifers (Dyer and Goehring, 1965; Jorgensen, 1960; and Schoon, 1971) describe the hydrogeology in parts of Yankton County.

Well-Numbering System

Wells and test holes are numbered according to a system based on the Federal land-survey of eastern South Dakota (fig. 2). The locations of all test holes are shown in figure 3.

Acknowledgments

The author acknowledges and thanks officials, residents, and businesses of Yankton County for their help and cooperation in data collection for this study.

PHYSICAL SETTING

Physiography and Climate

Yankton County, located in southeastern South Dakota (fig. 1), has an area of 524 mi^2. National Weather Service meteorological records (National Oceanic and Atmospheric Administration, 1979 and 1980) for Yankton indicate that total precipitation for 1979 was 25.8 in., and for 1980 it was 14.6 in.

The county lies at the western margin of the Central Lowlands physiographic province and is mostly within the James River Highlands geomorphic province (fig. 1), which is a dissected upland. The James River valley trends northwestward in Yankton County (fig. 3). The valley is a lowland ranging in altitude from about 1,170 ft at its northwestern entrance into Yankton County, to 1,160 ft at its confluence with the Missouri River southeast of the city of Yankton.

Topographic relief ranges from an altitude of 1,734 ft on Turkey Ridge to 1,155 ft on the flood plain of the Missouri River in the southeastern part of the county. Three conspicuous ridges, James, Turkey, and Yankton are high points in the county (fig. 3). Most of the topography in Yankton County is a result of Pleistocene glaciation.

The Missouri River, which borders the southern part of the county, flows from 1,208 ft altitude, the surface of Lewis and Clark Lake, to 1,145 ft at the southeastern corner of Yankton County. The James and Missouri River flood plains together comprise 26 percent of Yankton County.

The climate of Yankton County is a dry, semi-arid type common to the Northern Great Plains. Yankton County receives an average of about 25 in. of rain each year. Evaporation and plant transpiration is greatest during summer months, averaging 38 in/yr. Temperatures range from -36 to 109°F from winter to summer respectively. The average temperature is 47°F.

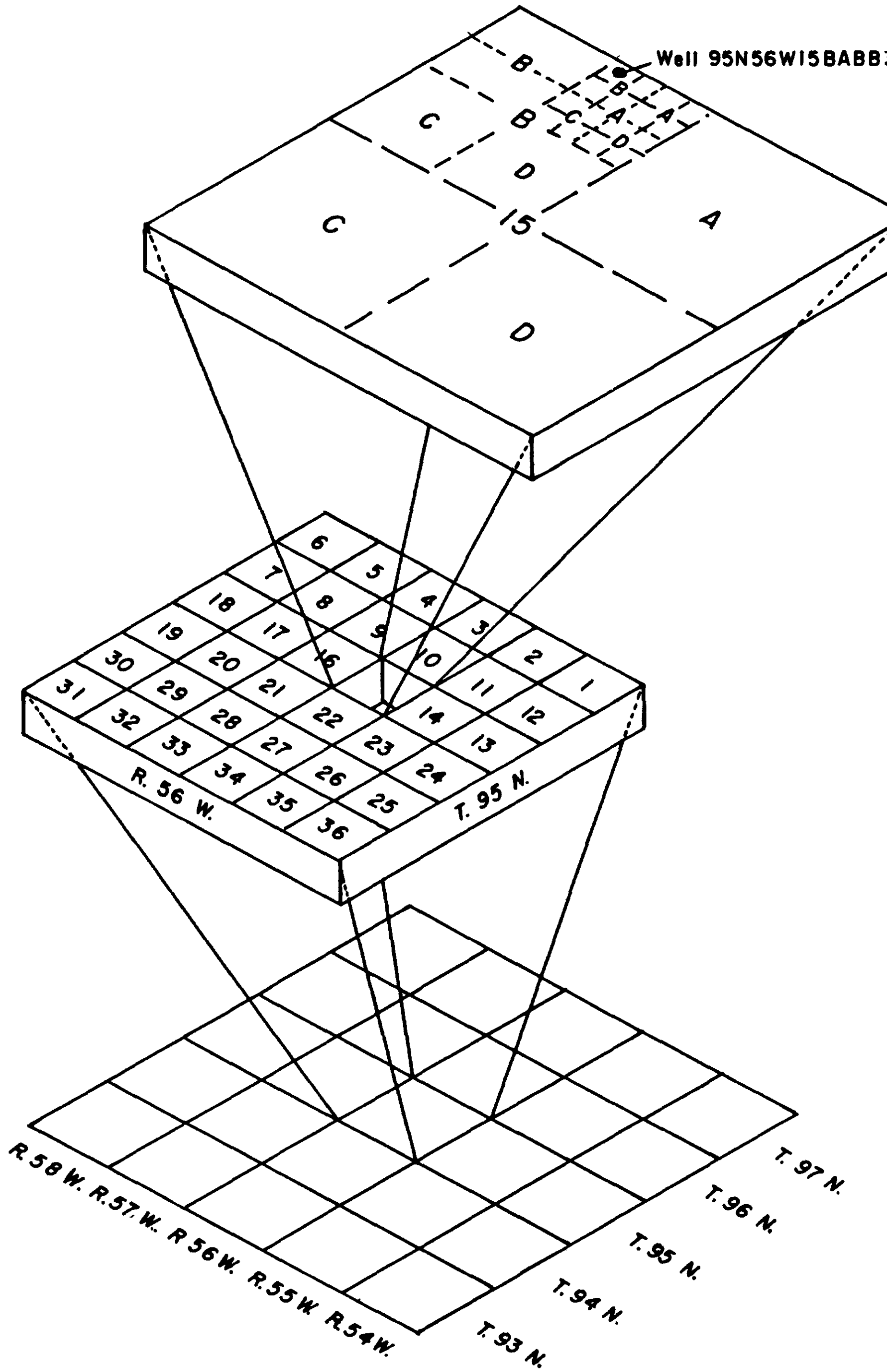


Figure 2.--Well-numbering diagram. The well number consists of township followed by "N," range followed by "W," and section number, followed by a maximum of four uppercase letters that indicate, respectively, the 160-, 40-, 10-, and 2½-acre tract in which the well is located. These letters are assigned in a counter clockwise direction beginning with "A" in the northeast quarter. A serial number following the last letter is used to distinguish between wells in the same 2½-acre tract.

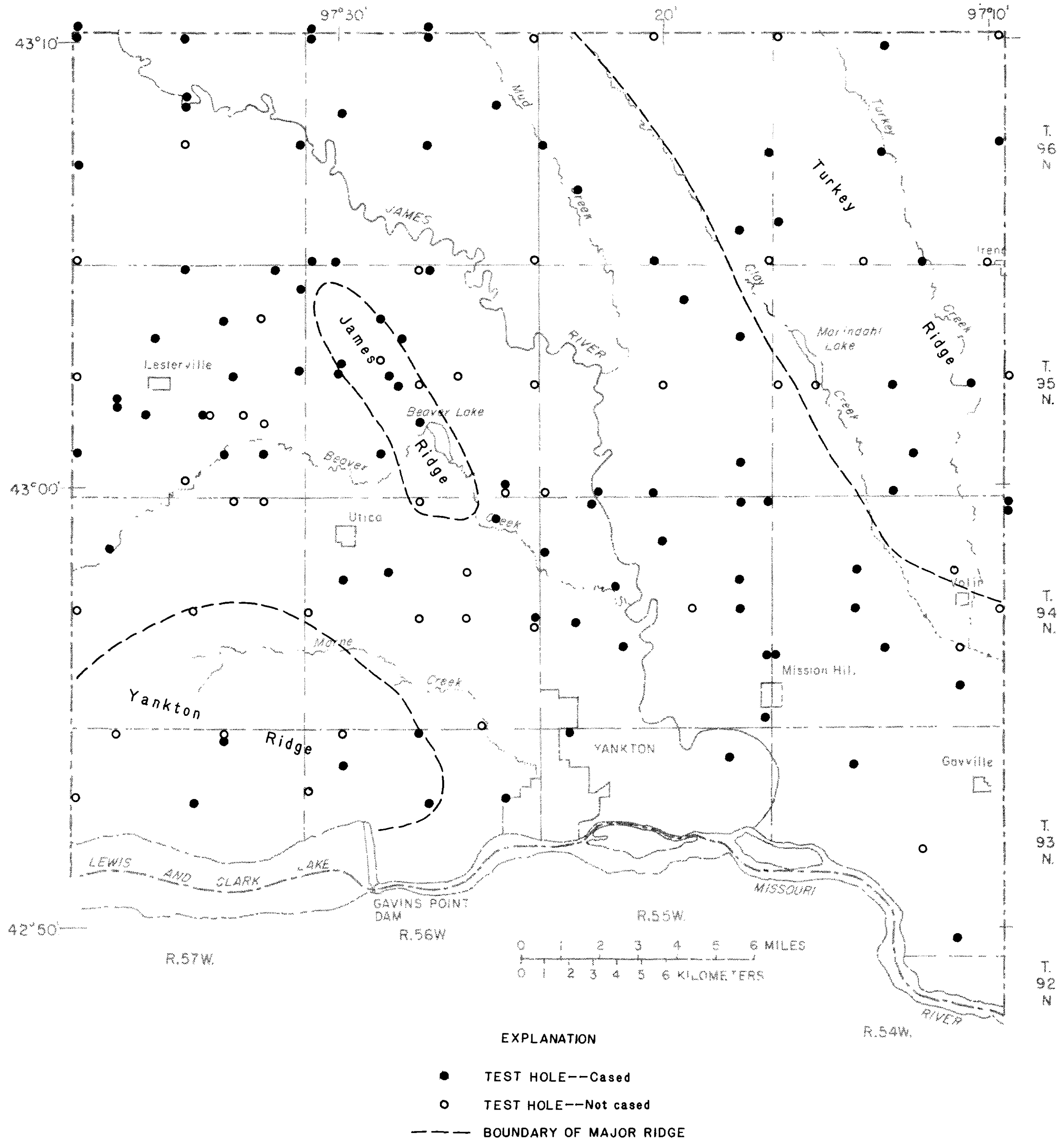


Figure 3.--Location of test holes and major ridges.

Geology

Yankton County is overlain by either Pleistocene glacial, alluvial, and eolian deposits or Holocene alluvium and colluvium. The Pleistocene deposits generally cover the upland areas, whereas the Holocene deposits generally are limited to stream valleys. The buried Pleistocene sand and gravel deposits constitute the major glacial-drift aquifer in the county. Owing to the glacial ice lobe terminating in Yankton County, and the fact that the James River valley, both present and former, trends northwestward through the county, a great volume of coarse, glacial outwash was deposited in this lowland. This is confirmed by the large quantity of coarse sand and gravel penetrated in most test holes in the county. The size of most of the glacial outwash ranges from medium sand to very coarse gravel, with many deposits containing gravel as much as 3 in. in diameter.

The bedrock surface of the county includes the Ogallala Sandstone of Tertiary age, and the Pierre Shale on Turkey and Yankton Ridges, and the Carlile Shale and Niobrara Formation of Cretaceous age between the ridges. The remaining stratigraphic units below the bedrock surface include, in descending order, the Greenhorn Limestone, Graneros Shale, and Dakota Formation of Cretaceous age. The Dakota lies unconformably on crystalline Precambrian basement rock. Bedrock exposures include the Pierre Shale and Niobrara Formation, both of which crop out at Marindahl Lake, on Yankton Ridge, in some of the deeply incised smaller streams, and along the bluffs of the Missouri River near Gavins Point Dam (Simpson, 1960, p. 23 and 33).

Most of the outwash was deposited by braided streams that meandered across topographic lows, while agradding their longitudinal profile by depositing large volumes of coarse material. The resulting glacial-outwash deposits in Yankton County are mostly coarse sands and gravels, which are interbedded.

SURFACE-WATER HYDROLOGY

Surface-water resources in Yankton County consist of rivers, creeks, reservoirs, sloughs, and ponds. These resources are replenished principally by surface-water inflow from outside the county and by precipitation and ground-water seepage within the county. These resources are depleted principally by surface-water outflow from the county, evapotranspiration, and man-induced usage. The only perennial surface-water resources in the county are the Missouri and James Rivers, and Lewis and Clark, Beaver, and Marindahl Lakes, all man-made reservoirs. Creeks generally flow only in response to overland runoff resulting from either snowmelt or intense storms. Sloughs and ponds generally are dry for at least part of the year.

Flow in the Missouri River is gaged at Yankton; this station is the only continuous-record gaging station in the county. During the study, streamflow in the James River was measured twice at three sites (fig. 4) to obtain an estimate of ground-water seepage to the river during low flow.

The drainage areas of the principal streams in the county are delineated in figure 4. The total drainage areas of the streams and that part of the drainage areas in Yankton County are listed in table 1. Also listed in table 1 are both values of drainage area upstream from each of the three streamflow-gaging sites on the James River.

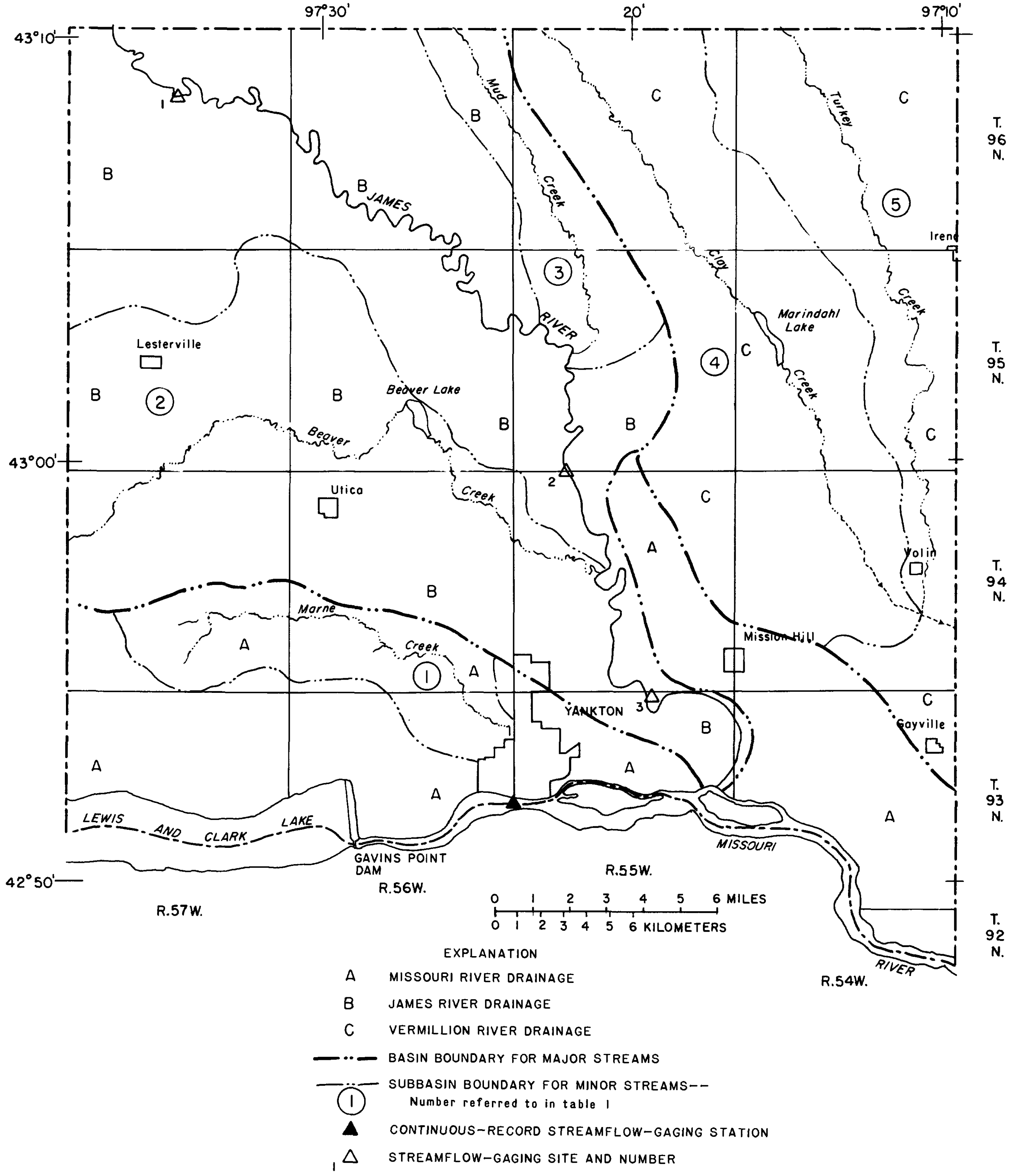


Figure 4.--Location of drainage basins and streamflow-gaging station and sites.

Table 1.--Drainage-basin areas

Designation in figure 4	Drainage basin	Drainage-basin area (square miles) In Yankton County	Drainage-basin area (square miles) Total area
A	Lower Missouri River	120	279,560
1	Marne Creek	23	23
B	James River	252	17,052
2	Beaver Creek	89	146
3	Mud Creek	21	24
--	That part of James River upstream from streamflow-gaging site 1.	17	16,817
--	That part of James River upstream from streamflow-gaging site 2.	127	16,927
--	That part of James River upstream from streamflow-gaging site 3.	243	17,043
C	Vermillion River	156	1,962
4	Clay Creek	94	128
5	Turkey Creek	64	72

Streams

Missouri River

The Missouri River is the largest stream in the area. Discharge averages 26,410 ft^3/s and has been measured at the city of Yankton since 1930. Regulation of the Missouri River upstream from Yankton County began in 1937 with the completion of Fort Peck Dam in Montana. Completion of Fort Randall' Dam in 1952 increased regulation of the river. The present (1980) degree of regulation was achieved with the completion of the Gavins Point Dam, which formed Lewis and Clark Lake, in 1955. Water from the Missouri is used by the city of Yankton for municipal supplies. In 1979 the city pumped 668,329,000 gal (City of Yankton Water Dept., oral commun., 1980). Missouri River water also is used for irrigation in Yankton County. The largest quantity withdrawn at a given time does not exceed 10 ft^3/s. The maximum, minimum, and average flow in the Missouri River near Yankton for the period of record through September 1980 was 480,000, 2,700, and 26,410 ft^3/s respectively.

James River

The James River flows from the northwest corner of Yankton County southeast to its confluence with the Missouri River 5 mi east of the city of Yankton. Records of discharges are available for 1928-80 (U.S. Geological Survey, 1980), for the station near Scotland, S. Dak., which is about 1 mi north of the Yankton-Hutchinson County line. Maximum, minimum, and average flow on the James River at the Scotland stream-gaging station for the period of record through September 1980 was 15,200 ft^3/s, no flow, and 375 ft^3/s respectively.

Water from the James River in Yankton County is used solely by irrigators along the flood plain. The largest quantity withdrawn at a given time from the river is 10 ft^3/s at the Jamesville Hutterite Colony (T. 96 N., R. 56 W., sections 28 and 29) with most other users drawing less than 3 ft^3/s.

Beaver Creek

Beaver Creek flows from Bon Homme County on the western border of Yankton County, eastward to James Ridge (fig. 3) where it has eroded through the ridge. In the middle of the ridge it makes an abrupt bend southward flowing in a large glacial outwash valley to its confluence with the James River about 3 mi northeast of the city of Yankton. A low-flow discharge of 0.4 ft^3/s was measured in the summer of 1979 at the mouth of Beaver Creek; however, in dry years there is no flow at the mouth. Beaver Creek is underlain by glacial-outwash deposits of sand and gravel along its course. In some reaches it receives water from these underlying outwash deposits and in other reaches the creek loses water to them.

Other Streams

Mud, Clay, and Turkey Creeks (fig. 4) all have reaches that contain water, principally seepage from ground-water sources even during extremely dry conditions. Mud and Turkey Creeks are underlain by small glacial-outwash deposits and all are underlain by shallow alluvium. These small creeks are dry during most of the year. No discharge measurements have been made on any of these creeks. In periods of high precipitation or rapid snowmelt in the springtime, these creeks may flow at their mouths or along various reaches upstream.

Floods

The inundation of lowlands by floods is important to anyone who utilizes the flood plain. A method to predict flood frequencies and magnitudes has been developed by Patterson (1966, p. 3-11) and is applicable to Yankton County. The method is based on two sets of curves used to estimate magnitudes of floods with a recurrence interval between 1.1 and 50 years. The recurrence interval is the average interval of time within which a flood of given magnitude will be equaled or exceeded. A flood having a recurrence interval of 20 years is one that has a 5 percent probability of occurring in any year; likewise, a 50-year flood has a 2 percent probability of occurring in any year.

The curves Patterson (1966) developed are shown in figures 5 and 6. The relation between drainage area and mean annual flood is shown in figure 5. Mean annual flood is a flood with a recurrence interval of 2.33 years, or a 43 percent probability of occurring in any year. The relation between the ratio of discharge to mean annual flood and the recurrence interval is shown in figure 6.

The procedure for using these two curves devised by Patterson (1966) is given below in an example to determine the discharge of a 10-year flood at the mouth of Beaver Creek:

1. Determine the size of the drainage area (146 mi^2 for Beaver Creek--see table 1).

2. Determine the discharge, in cubic feet per second, of the mean annual flood for this size drainage area from figure 5. (The discharge for the mean annual flood for a drainage area of 146 mi^2 is about 1,000 ft^3/s).

3. Determine the ratio of the discharge of the flood of the selected recurrence interval to the mean annual flood from figure 6. (The ratio for a flood with a 10-year recurrence interval to the mean annual flood is 2.7.)

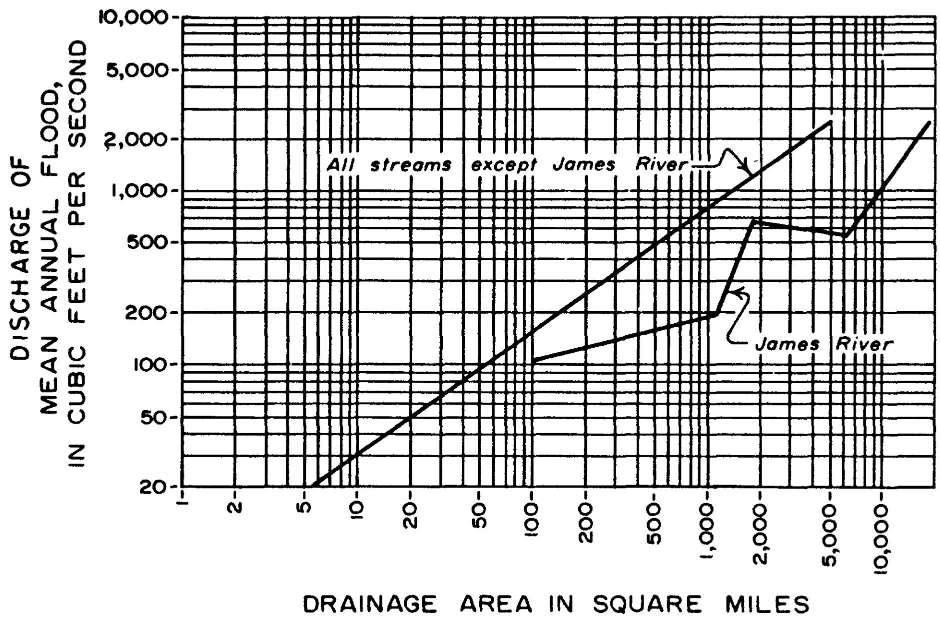


Figure 5.--Variation of mean annual flood with drainage area (after Patterson, 1966).

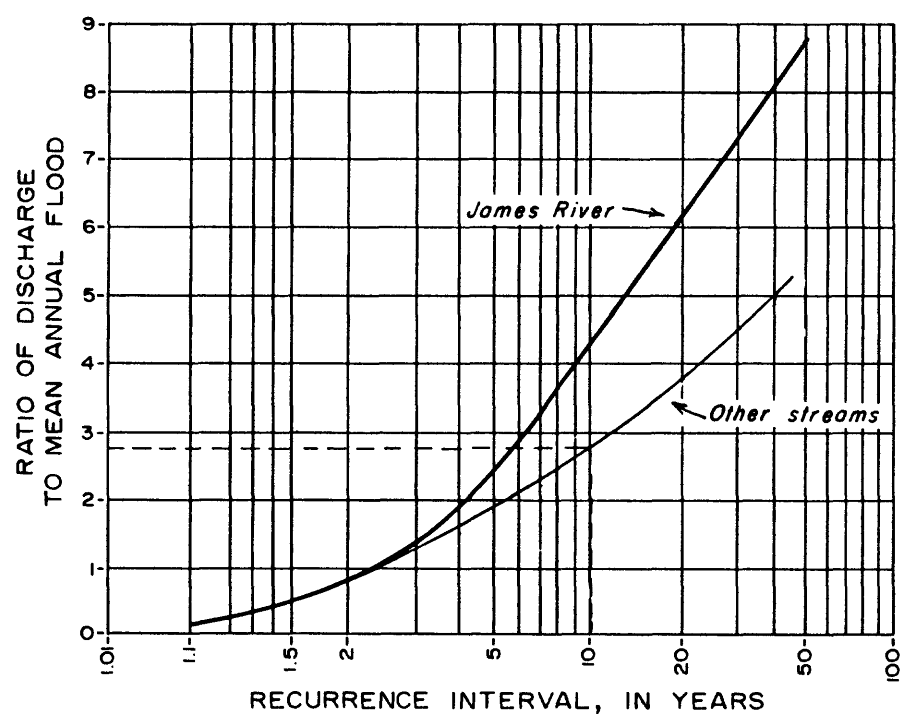


Figure 6.--Variation of flood discharge with recurrence interval (after Patterson, 1966).

4. Multiply the discharge obtained from figure 5 by the ratio obtained from figure 6 to obtain the discharge of the flood, in cubic feet per second. (The discharge of the 10-year flood at the mouth of Beaver Creek would be 1,000 times 2.7, which is 2,700 ft^3/s.)

Lakes and Reservoirs

Lewis and Clark Lake

Water storage in Lewis and Clark Lake, the reservoir farthest downstream on the Missouri River, began in July 1955 with the closure of Gavins Point Dam, 3.75 mi upstream of the city of Yankton (fig. 4). The drainage area of the Missouri River basin upstream from the eastern border of Yankton County is 279,560 mi^2 of which 120 mi^2 is in Yankton County. The maximum capacity is 541,000 acre-ft at the top of the spillway gates at an altitude of 1,210 ft. Maximum storage is 477,000 acre-ft at an altitude of 1,208 ft (U.S. Geological Survey, 1980). Water is used primarily for downstream navigation, recreation, power, and as a source for rural domestic supplies in Yankton County.

Beaver Lake

Beaver Lake, about 3½ mi northeast of Utica (fig. 4), was formed by the damming of Beaver Creek. The spillway altitude is 1,263 ft. At that altitude, the lake has a surface area of 0.33 mi^2. The lake is used for waterfowl production.

Marindahl Lake

Marindahl Lake was formed by the damming of Clay Creek (fig. 4) and is situated between bluffs of bedrock (Niobrara Formation) in a glacial-meltwater channel. The spillway is located at an altitude of 1,322 ft. The surface area of the lake at 1,322 ft is 0.25 mi^2. The lake is used for recreation and waterfowl production.

Other Surface Water Bodies

There are many small ponds and sloughs in the county that commonly are dry during droughts. The ponds are usually man-made and used for watering livestock. Sloughs are natural depressions in the land surface that usually hold some water in the spring. Some sloughs are used to water livestock, but most are unused and are a habitat for wildlife. Some small tributaries have earthen dams constructed on them, but do not pond a significant quantity of water. These tributaries usually are dry during droughts.

GROUND-WATER HYDROLOGY

Alluvial Aquifers

Stream-deposited sediment, or alluvium, consists of fine silt, sand, and clay in Yankton County. Alluvium in Yankton County is present along the flood plains of most streams. Alluvium along the James River, the Missouri River, and Beaver, Turkey, Clay, and Mud Creeks will yield some water. Other creeks have either too little alluvium or the deposits are too fine to be aquifers.

Alluvial deposits along Beaver Creek, the James River, and the Missouri River are hydraulically connected with underlying sand-and-gravel outwash aquifers (Lesterville and Lower James-Missouri aquifers). Where connected with underlying aquifers, the overlying alluvium is either a recharge or discharge area depending on the potentiometric-surface altitude of the underlying sand-and-gravel outwash with respect to that in the overlying alluvium.

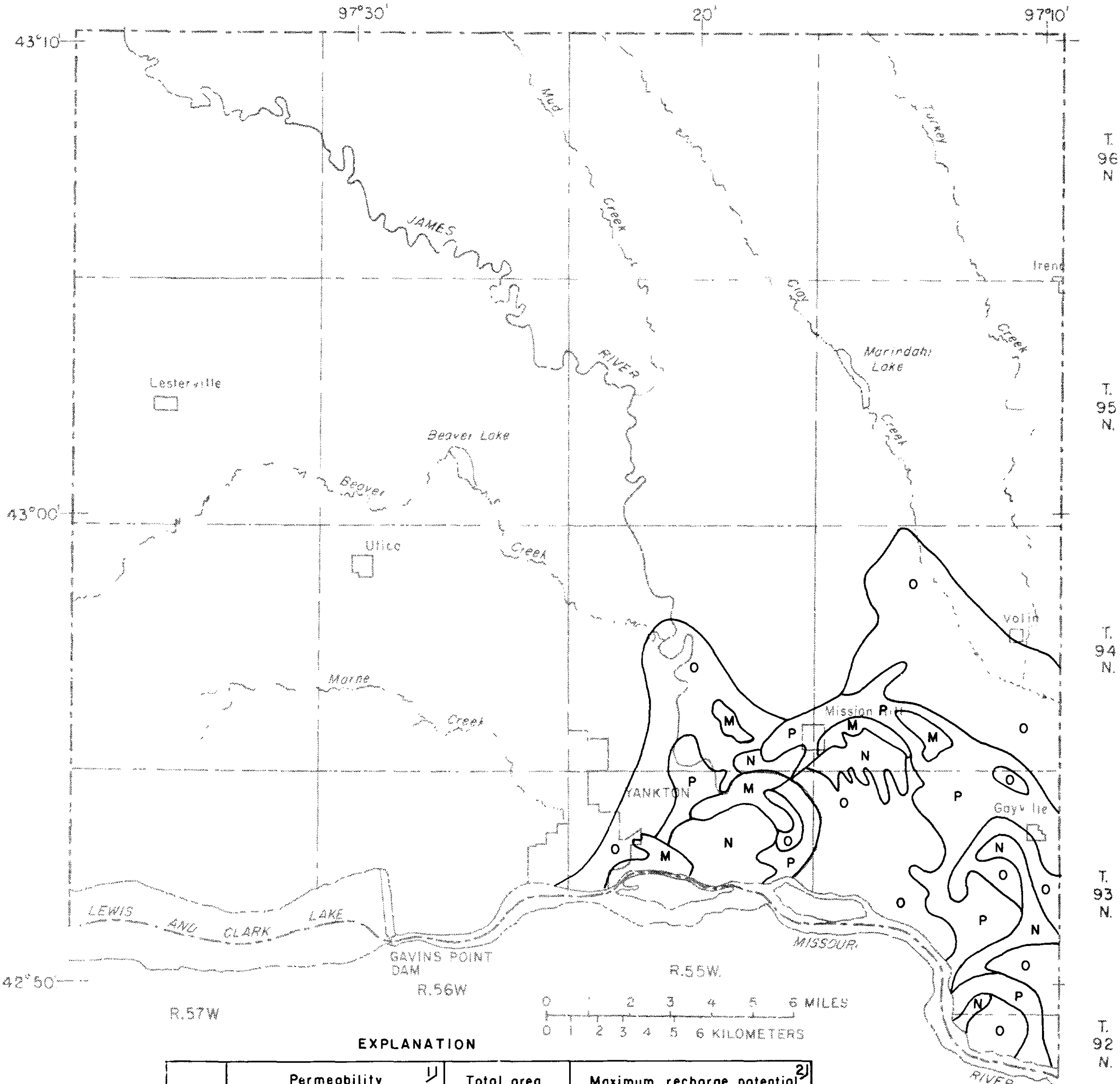
The potentiometric surface in the Lower James-Missouri aquifer along the James River is about 2 ft higher than in the alluvial aquifer directly underlying the river, which results in water moving from the Lower James-Missouri aquifer to the James River by seepage through the flood-plain alluvium.

Three streamflow-gaging sites were established (fig. 4) and data were collected twice during low flow in late August 1980. The data indicate that downstream from gaging site 2, the James River gained 3 ft^3/s of flow. All streams draining into the James River in Yankton County had no flow during the period of measurement; therefore, the increase in flow in the James River can be attributed to ground-water discharge from the Lower James-Missouri aquifer.

A generalized soils map of southeastern Yankton County derived from a soils map of the county prepared by the U.S. Soil Conservation Service (1979) is shown in figure 7. It shows areas of differing permeability of soil at depths greater than 3 ft. The driller's log of test hole 94N54W4CCCC given below is representative of the composition of soil, alluvium, and glacial outwash in the Missouri River flood plain in Yankton County:

Material	Depth (feet)
Soil	
Topsoil, black	0- 2
Alluvium	
Clay, black to gray, silty sandy	2- 20
Glacial outwash	
Sand and gravel, gray, medium	20-114
Bedrock	
Shale, gray, greasy (Carlile Shale)	114-135

About one-half the total area has a soil permeability ranging from 1.2 to 4.0 ft/d (fig. 7). Because of the extremely flat surface of the flood plain, gradient about 1 ft/mi, there is virtually no runoff. On the basis of the significant permeability of the overlying soils, precipitation can easily recharge the underlying alluvium, which is hydraulically connected to the underlying Lower James-Missouri aquifer. However, evapotranspiration would decrease this volume significantly so that possibly only a small amount would actually reach the aquifer.



EXPLANATION

Soil	Permeability [1]		Total area Feet squared X10⁶	Maximum recharge potential [2] per year (acre-feet X10⁶)
	Feet per day	Feet per year		
M	12-40	4,380 - 14,600	440	317.0
N	4.0-12	1,460 - 4,380	230	49.0
O	1.2-4.0	438 - 1,460	1,370	98.0
P	0.12-1.2	44 - 438	780	16.0
			TOTAL	480.0

1/ From U.S. Soil Conservation Service (1979)

2/ Value shown represents permeability times area times 2.15 feet average annual rainfall

Figure 7.--Permeability of soils and total annual maximum recharge potential from soils to underlying flood-plain deposits and Lower James-Missouri aquifer, Missouri River flood plain.

Glacial-Outwash Aquifers

Lower James-Missouri Aquifer

The Lower James-Missouri aquifer, underlying an area of 238 mi^2 or about 50 percent of the land area in Yankton County (fig. 8), is hydraulically connected with the Lower Vermillion-Missouri aquifer in Clay County. This aquifer has been described previously by Tipton (1957), Jorgensen (1960), and Stephens (1967). There is also stratigraphic evidence that the Lower James-Missouri aquifer is in hydraulic connection with the Tyndall-Scotland aquifer (Jorgensen, 1971) in northeastern Bon Homme County.

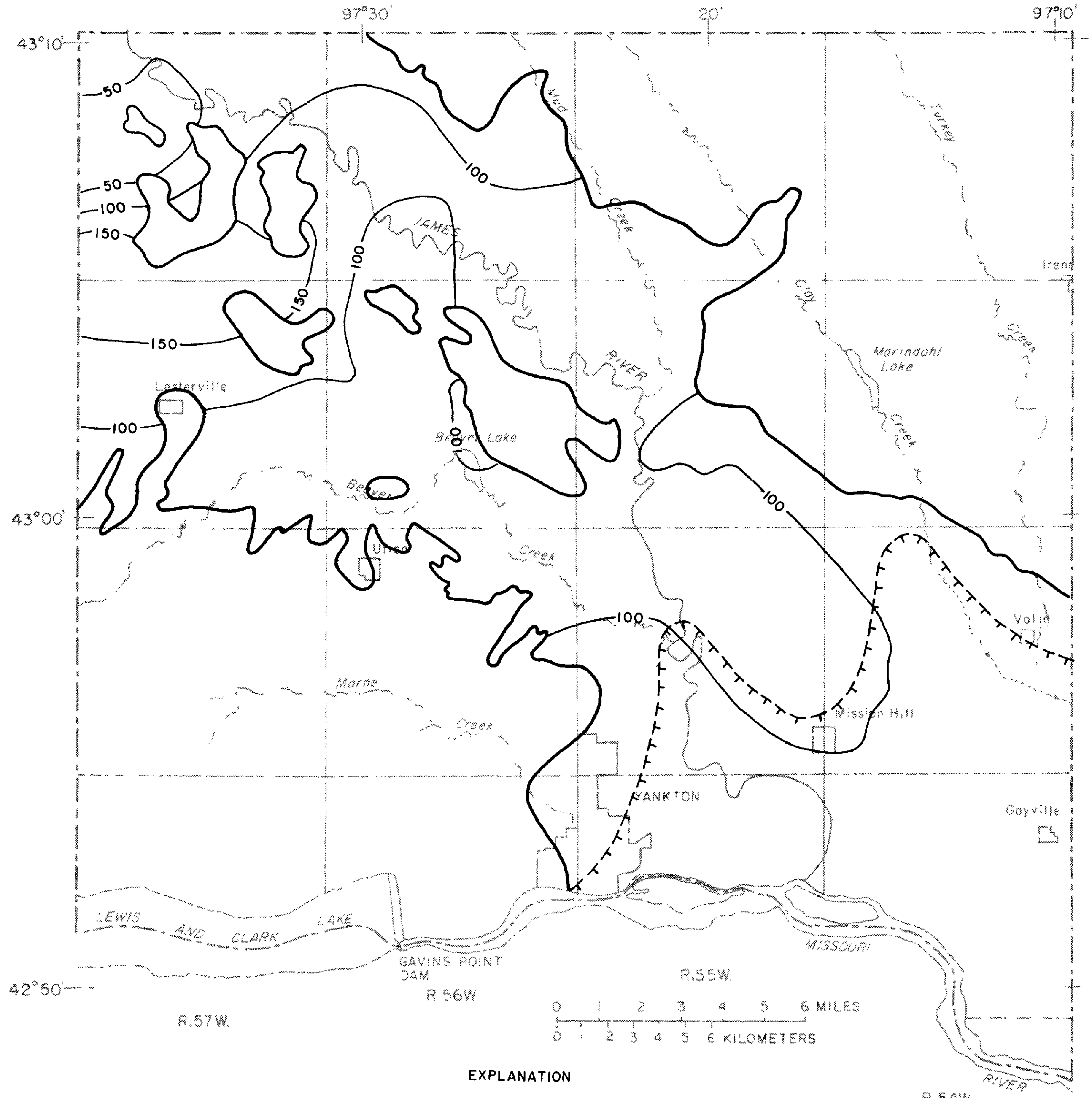
The Lower James-Missouri aquifer was divided into northern and southern areas on the basis of different depositional episodes during the time of glacial deposition that resulted in different thicknesses of deposits in each area. The total thickness of the deposits in the northern area ranges from 60 to 410 ft and averages 150 ft. In the southern area, underlying the Missouri River flood plain, the deposits have a uniform total thickness of about 100 ft. The saturated thickness of the Lower James-Missouri aquifer ranges from 50 to 150 ft in Yankton County (fig. 8). Except for the northeast areas, the average thickness is about 100 ft.

Hydrologic characteristics of the southern area of the aquifer can be estimated from data collected from the part of the aquifer in Clay County to the east (Stephens, 1967, p. 16, table 2) due to the continuity of the aquifer composition and relatively flat potentiometric surface.

The transmissivity of the aquifer in the southern area ranges from 20,700 to 24,700 ft^2/d. The specific capacity ranges from 124 to 173 (gal/min)/ft based on drawdowns in tests of 24 hours and 0.5-hour duration (Stephens, 1967, table 2). Water-table conditions prevail throughout the entire southern area of the aquifer. Specific yield is estimated to be 0.2.

Because of similar lithologic characteristics, the northern area probably has similar hydrologic characteristics except that water is under artesian conditions in some places and under water-table conditions in other places. Wells completed in the Lower James-Missouri aquifer can be expected to yield at least 500 gal/min and may yield more than 1,000 gal/min.

The Lower James-Missouri aquifer in Yankton County receives recharge from seepage from streams and by infiltration of precipitation. Local departures from normal precipitation and long-term climatic fluctuations affect the quantity of recharge received by the aquifer. Most of the recharge is in the spring and early summer (fig. 9). Recharge sources and discharge outlets were determined from observation-well data, water quality, and the altitude and composition of adjacent stratigraphic units. Some recharge is from the Tyndall-Scotland aquifer in Bon Homme County in Tps. 94 and 95 N., R. 57 N. Discharge in the northern area of the aquifer is by leakage to the James River (fig. 10).



EXPLANATION

BOUNDARY OF LOWER JAMES-MISSOURI AQUIFER

—150— LINE OF EQUAL THICKNESS OF SATURATED MATERIAL 1979--
Interval 50 feet

BOUNDARY BETWEEN NORTHERN AND SOUTHERN AREAS OF
LOWER JAMES-MISSOURI AQUIFER

Figure 8.--Saturated thickness, Lower James-Missouri aquifer.

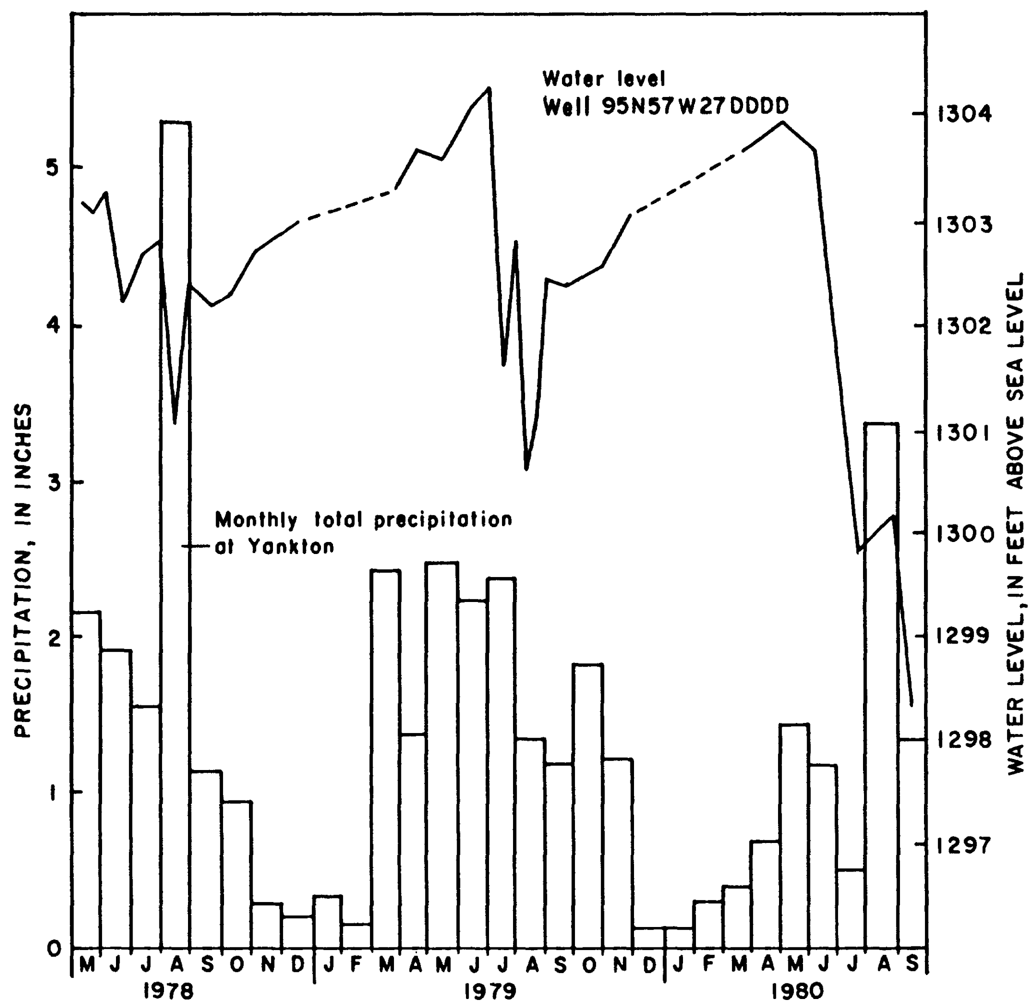


Figure 9.--The relationship of precipitation to water level in well 95N57W27DDDD completed in the Lower James-Missouri aquifer.

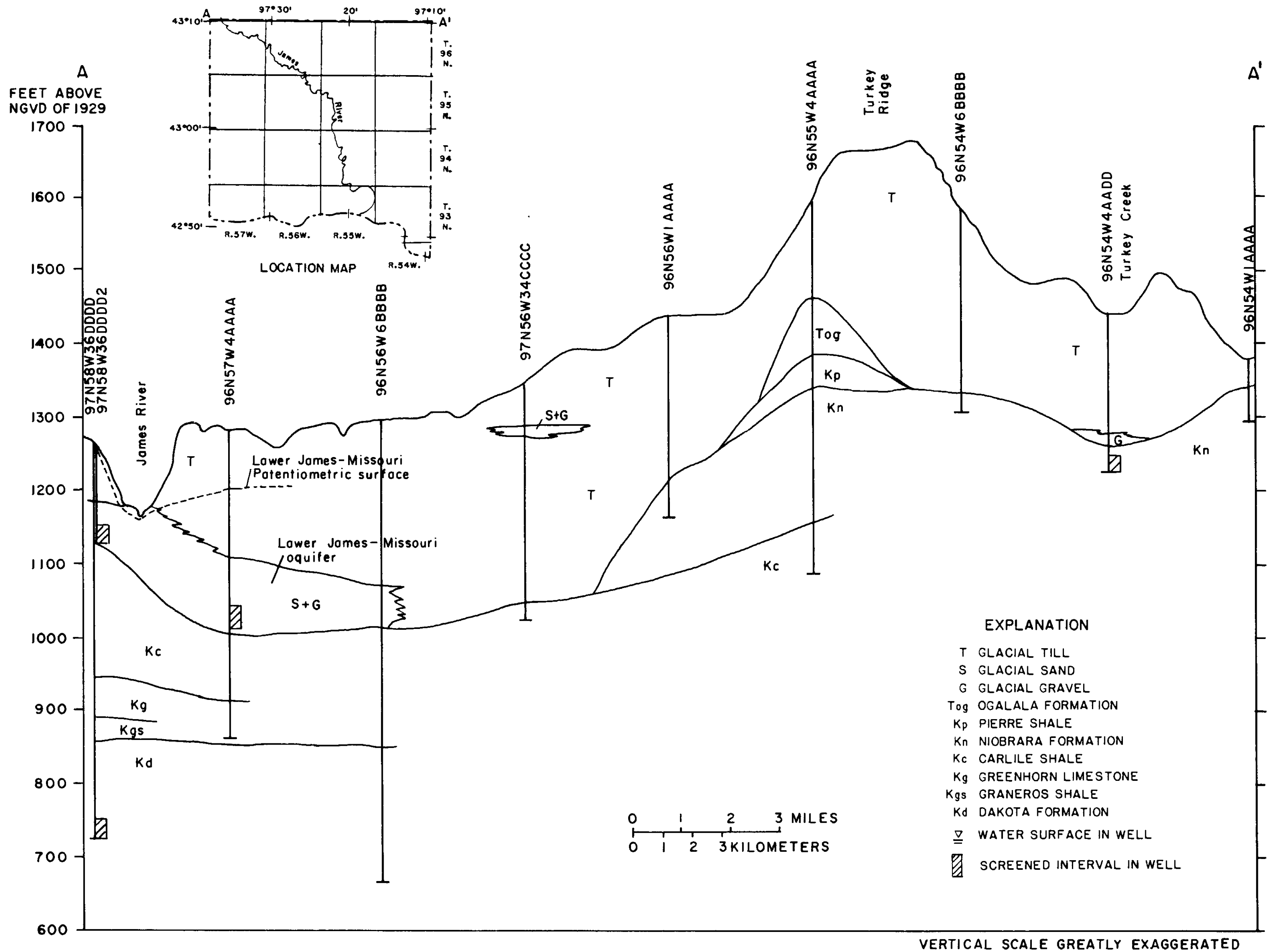


Figure 10.--Hydraulic connection between James River and the Lower James-Missouri aquifer.

The brevity of rainstorms in Yankton County, short-term infiltration rates of flood-plain soils (Stephens, 1967, p. 19) and rapid evapotranspiration rates cause most precipitation falling directly on the southern area of the aquifer to be either evaporated or transpired. Most recharge to the aquifer enters in the northern area of the aquifer; this is supported by a continuity of chemical composition and the potentiometric-surface gradient, which is from northwest to southeast.

Although clayey glacial till usually is considered a confining layer (Stephens, 1967, p. 19 and fig. 8), much of the till in Yankton County is extremely sandy and has greater permeability than tills in other areas with greater clay content.

The projection of the water-surface slope of the Missouri River from the Gavins Point Dam to the Yankton-Clay County border compared with the water levels in nearby wells penetrating the aquifer shows the discharge-potential relationship (fig. 11).

The water of the Lower James-Missouri aquifer predominantly is a calcium sodium sulfate. It also contains relatively large concentrations of iron, manganese, and boron. The water is very hard; hardness ranges from 330 to 1,700 mg/L (milligrams per liter). The quality of water may differ locally as illustrated by the large range of concentrations of most constituents in table 2. Large concentrations of sulfate and dissolved solids are also characteristic of the quality of water in the aquifer. Water in the aquifer is used primarily for domestic and agricultural purposes.

Other Glacial-Outwash Aquifers

Four other glacial-outwash aquifers have been identified from test-drilling and domestic-well data. Of the four, the Lesterville aquifer near the town of Lesterville is the most extensive and best defined (fig. 12). The other aquifers are Turkey Creek, Buried Channel, and Mud Creek. These aquifers mainly are shallow glacial outwash deposits with the same hydraulic conductivity as the Lower James-Missouri aquifer deposits. Beaver Creek is a source of recharge and discharge for the Lesterville aquifer (fig. 13).

The Lesterville aquifer (fig. 12) underlies 22 mi^2 of western Yankton County and has an average thickness of about 40 ft. The aquifer is under artesian conditions. The depth to the aquifer ranges from 30 to 40 ft. The Lesterville aquifer lies above the Lower James-Missouri aquifer in this area. Potentiometric-surface contours indicate recharge from Bon Homme County.

The areas of Turkey Creek, Buried Channel, and Mud Creek aquifers are 10, 3, and 13 mi^2, respectively. The direction of water movement in Turkey Creek aquifer is from north to south. Buried Channel and Mud Creek aquifers may be in hydraulic connection near T. 95 N., R. 55 W., sections 8 and 9. Artesian conditions prevail in all these aquifers, and most wells below a land-surface altitude of 1,345 ft in Mud Creek aquifer flow at a rate of about 2 to 3 gal/min. Other sand-and-gravel outwash deposits are scattered throughout the county, however, most of these deposits do not yield large volumes of water, and in drought years may not even provide adequate volumes of water for domestic purposes.

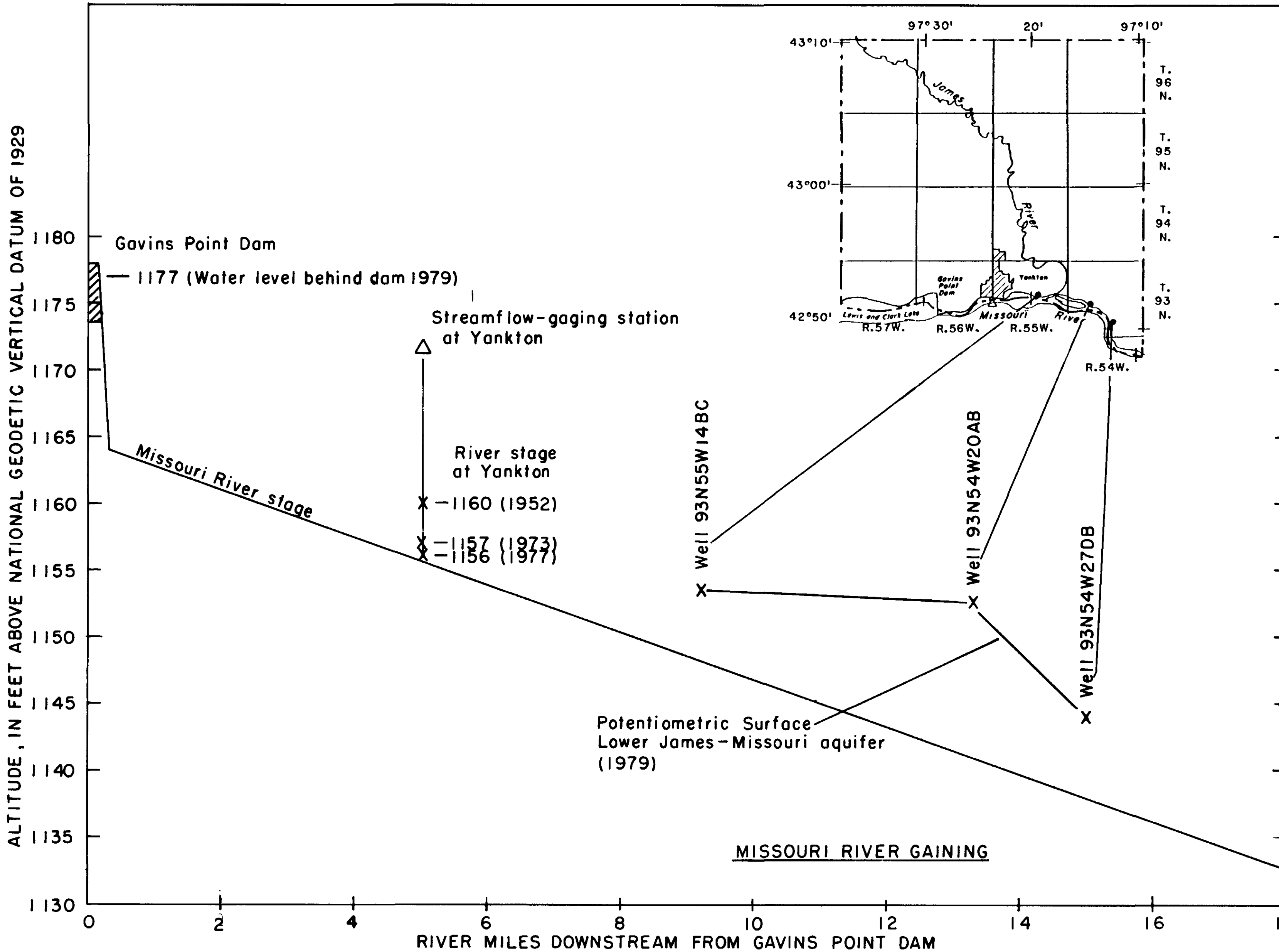
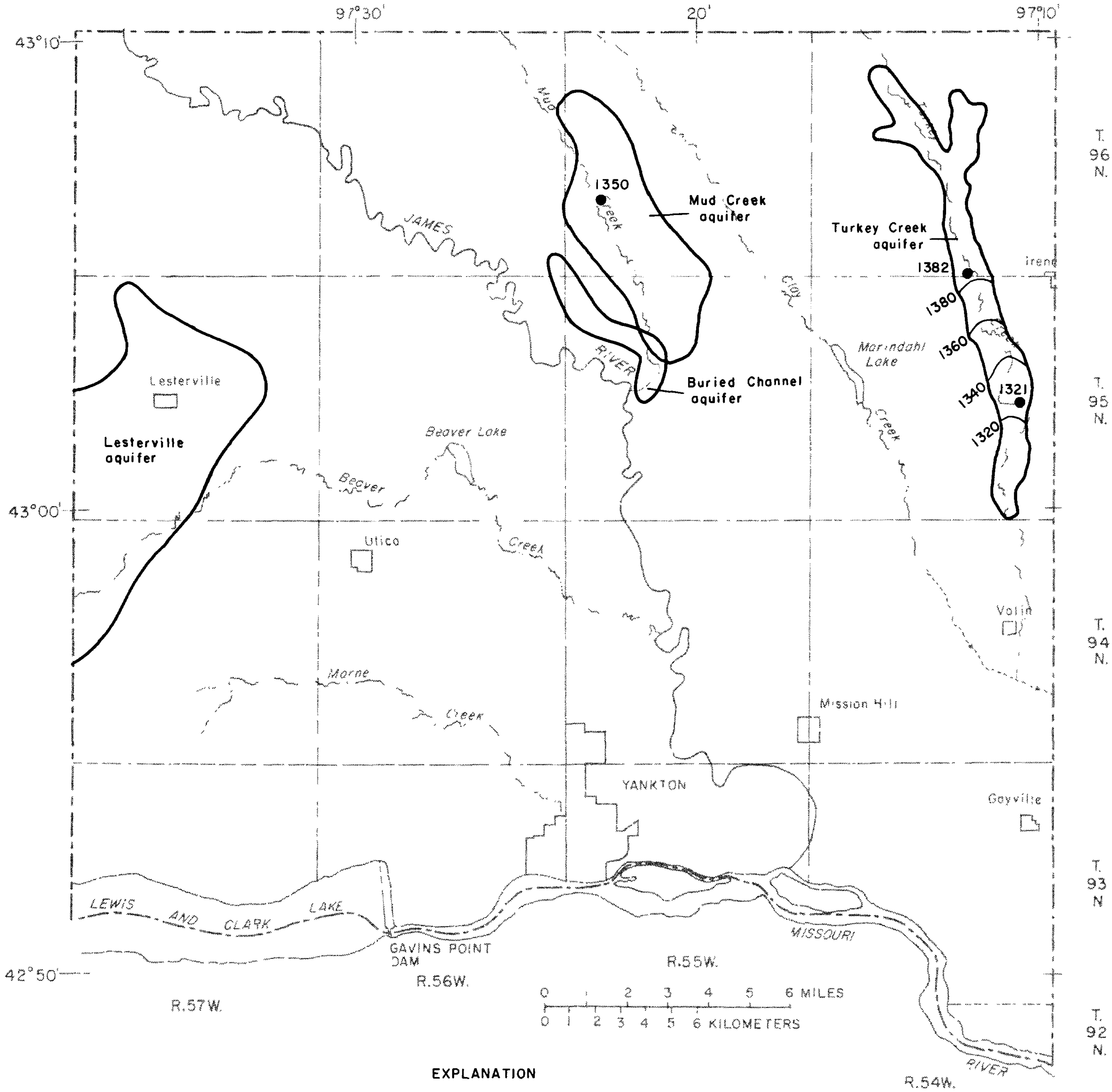


Figure 11.--Relationship between Missouri River slope and potentiometric surface of southern part of Lower James-Missouri aquifer.



EXPLANATION

1380 —— POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells, 1979. Contour interval 20 feet in Turkey Creek aquifer. National Geodetic Vertical Datum of 1929

1350 ● OBSERVATION WELL--Number is altitude of water level, 1979, in feet above National Geodetic Vertical Datum of 1929

Figure 12.--Areal extent of the Lesterville and other minor aquifers.

Table 2.--Representative water-quality analyses from the James River and three major aquifers

[Values in milligrams per liter, except where noted]

Constituent or property	Lower James-Missouri aquifer				Niobrara aquifer				Dakota aquifer				James River
	Number of analyses	Minimum	Maximum	Average	Number of analyses	Minimum	Maximum	Average	Number of analyses	Minimum	Maximum	Average	10/22/80 95N56W12DDDD Discharge = 12.9 cubic feet per second
Calcium (Ca)	15	92	460	240	8	100	540	320	2	280	350	320	140
Magnesium (Mg)	15	27	160	78	8	48	1,700	290	2	70	89	80	77
Sodium (Na)	15	14	260	250	8	13	160	79	2	95	200	150	110
Potassium (K)	15	7	36	20	8	10	34	17	2	23	33	28	16
Bicarbonate (HCO_3)	15	170	600	360	8	160	540	380	2	160	160	160	330
Sulfate (SO_4)	15	250	1,500	860	8	650	1,500	960	2	1,100	1,100	1,100	620
Chloride (Cl)	15	3.8	130	46	8	2.8	100	36	2	60	240	150	42
Fluoride (F)	15	.2	1.1	.6	8	.3	2.9	1.0	2	2.0	2.6	2.3	.1
Nitrate (NO_3)	15	.0	2.0	.3	8	.03	15	6.4	2	.29	.48	.39	0
Boron (B)[1]	14	60	14,000	2,300	8	70	2,100	660	2	230	960	600	380
Iron (Fe)[1]	15	30	3,900	1,100	8	120	13,000	4,200	2	60	130	100	10
Manganese (Mn)[1]	15	2	5,500	2,500	8	80	1,700	530	2	210	450	330	190
Dissolved solids	15	560	2,360	1,560	8	1,240	2,740	1,750	2	1,790	2,030	1,910	1,190
Hardness as $CaCO_3$	15	330	1,700	870	8	860	1,700	1,160	2	1,100	1,200	1,200	670
Specific conductance[2]	15	960	2,750	1,910	8	1,130	3,350	2,140	2	2,310	2,620	2,460	1,650
Percent sodium[3]	15	6	57	21	8	4	23	13	2	15	28	22	26
Sodium adsorption ratio (SAR)	15	.3	5	2	8	.3	2	1	2	1	3	2	2

1/ Units in micrograms per liter.
2/ Units in micromhos per centimeter at 25°Celsius.
3/ Percent of total cations represented.

Bedrock Aquifers

The Niobrara aquifer and the Dakota aquifer are the major bedrock aquifers in Yankton County. The Niobrara aquifer is not as extensively used because of its differing hydraulic conductivity and more mineralized water. The Dakota aquifer is a major source of water for many residents because the water is more potable and water flows from wells at the land surface in many areas.

Niobrara Aquifer

The Niobrara aquifer, the uppermost bedrock aquifer in Yankton County, covers an area of 238 mi^2 (fig. 14) in the southwestern and northeastern corners of the county. The aquifer consists of light-gray to black, soft, calcareous shale composed of an upper and lower unit, the contact of which is exposed at Gavins Point Dam.

The Niobrara aquifer is overlain either by Pierre Shale or by glacial-drift deposits. The aquifer crops out at Marindahl Lake, along the eastern county boundary near Irene, and along the Missouri River bluffs upstream from Gavins Point Dam. It ranges in thickness from more than 250 ft near Marindahl Lake and on Yankton Ridge to zero in areas in the middle of the county where it has been completely removed by glaciation and erosion (figs. 14 and 15).

The northeastern area of the aquifer is under artesian conditions except in parts of Tps. 94 and 95 N., R. 54 W., south to the aquifer boundary where water-table conditions occur. Water-table conditions occur because of the hydraulic connection of the Niobrara aquifer with the overlying Lower James-Missouri aquifer in T. 94 N., R. 54 W. (figs. 16 and 17) allowing the Niobrara to discharge to the Lower James-Missouri aquifer. The northeastern area of the Niobrara aquifer also is in hydraulic connection with the overlying Lower James-Missouri aquifer in Tps. 95 and 96 N., R. 55 W. (figs. 16 and 18) where the outwash aquifer recharges the Niobrara. However, this recharge probably is minimal and affects only the southern margin of the Niobrara aquifer in this area.

The southwestern area of the Niobrara aquifer underlies Yankton Ridge and some of the surrounding area, and is under water-table conditions. The upper 80 to 100 ft of the Niobrara Formation on Yankton Ridge are dry. This is due to the proximity of the Missouri River valley at a lower altitude than the upper part of the Niobrara. This in effect lowers the potentiometric surface of the Niobrara aquifer nearly to the altitude of the surface of the Missouri River. Water from the Niobrara aquifer moves toward the Missouri River and intersects ground level as numerous springs and seeps along the southern margin of Yankton Ridge in gullys that drain into the Missouri River. There are areas in this part of the aquifer that can provide adequate quantities of water for domestic use, however, these areas are relatively small and quantities usually are not adequate for agricultural or livestock purposes.

Water from the Niobrara aquifer in both the northeastern and southwestern areas is a magnesium sulfate type (table 2). The water is very hard, hardness concentration of water in the Niobrara aquifer ranged from 860 to 1,700 mg/L (table 2). The water contains large concentrations of iron, manganese, and nitrate, averaging 4,200 µg/L (micrograms per liter), 530 µg/L, and 6.4 mg/L, respectively.

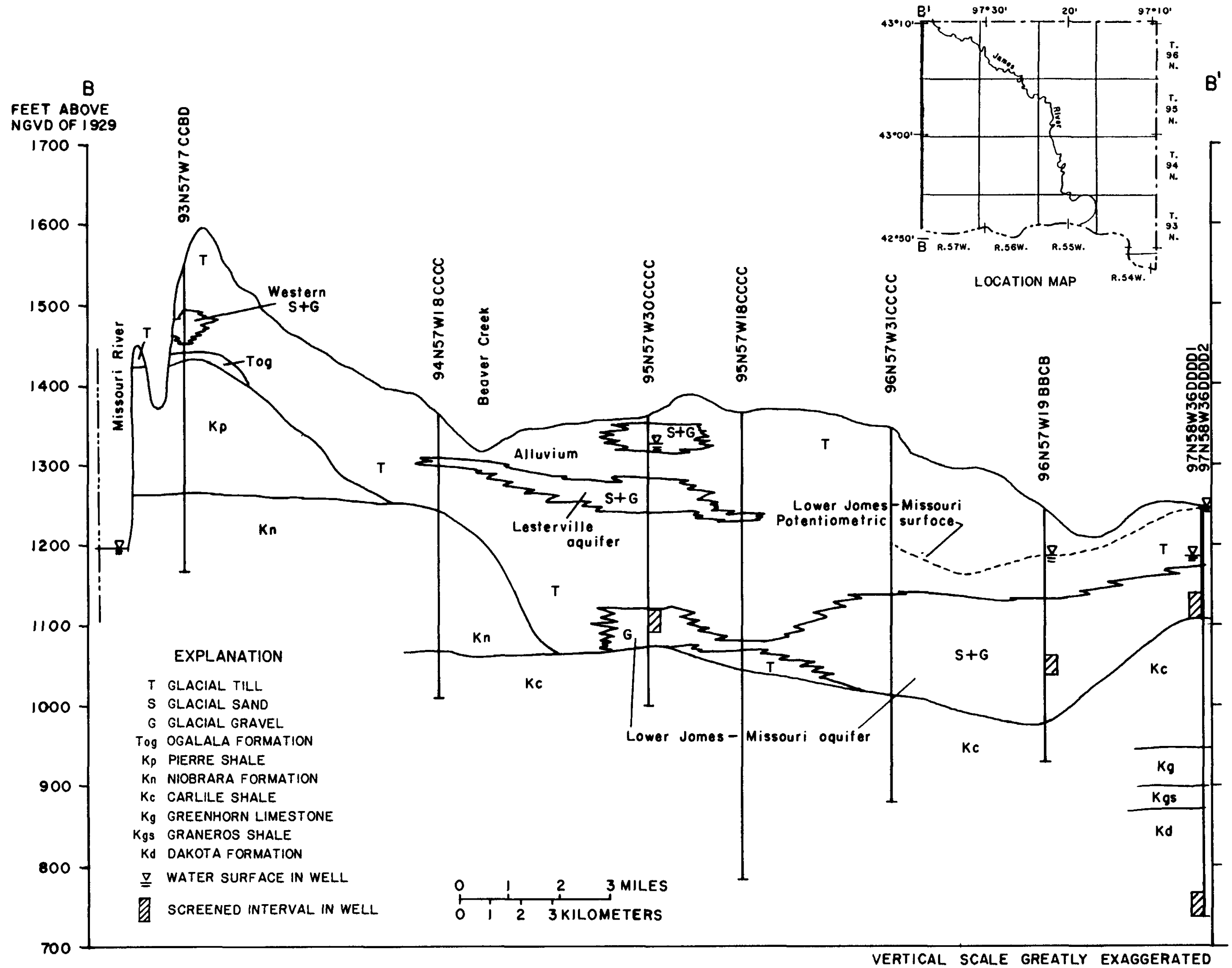


Figure 13.--Hydraulic connection between the Lesterville aquifer and Beaver Creek.

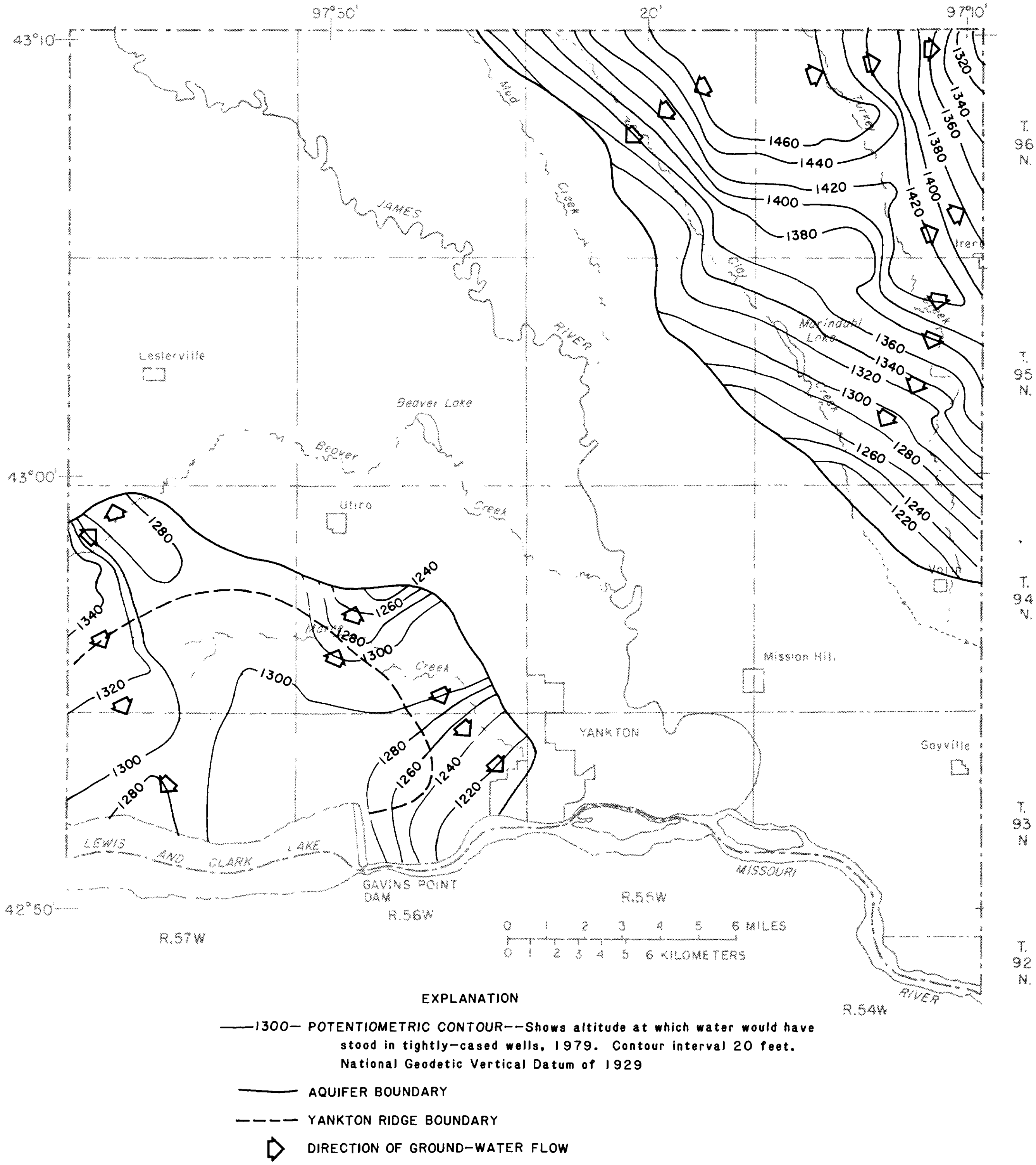
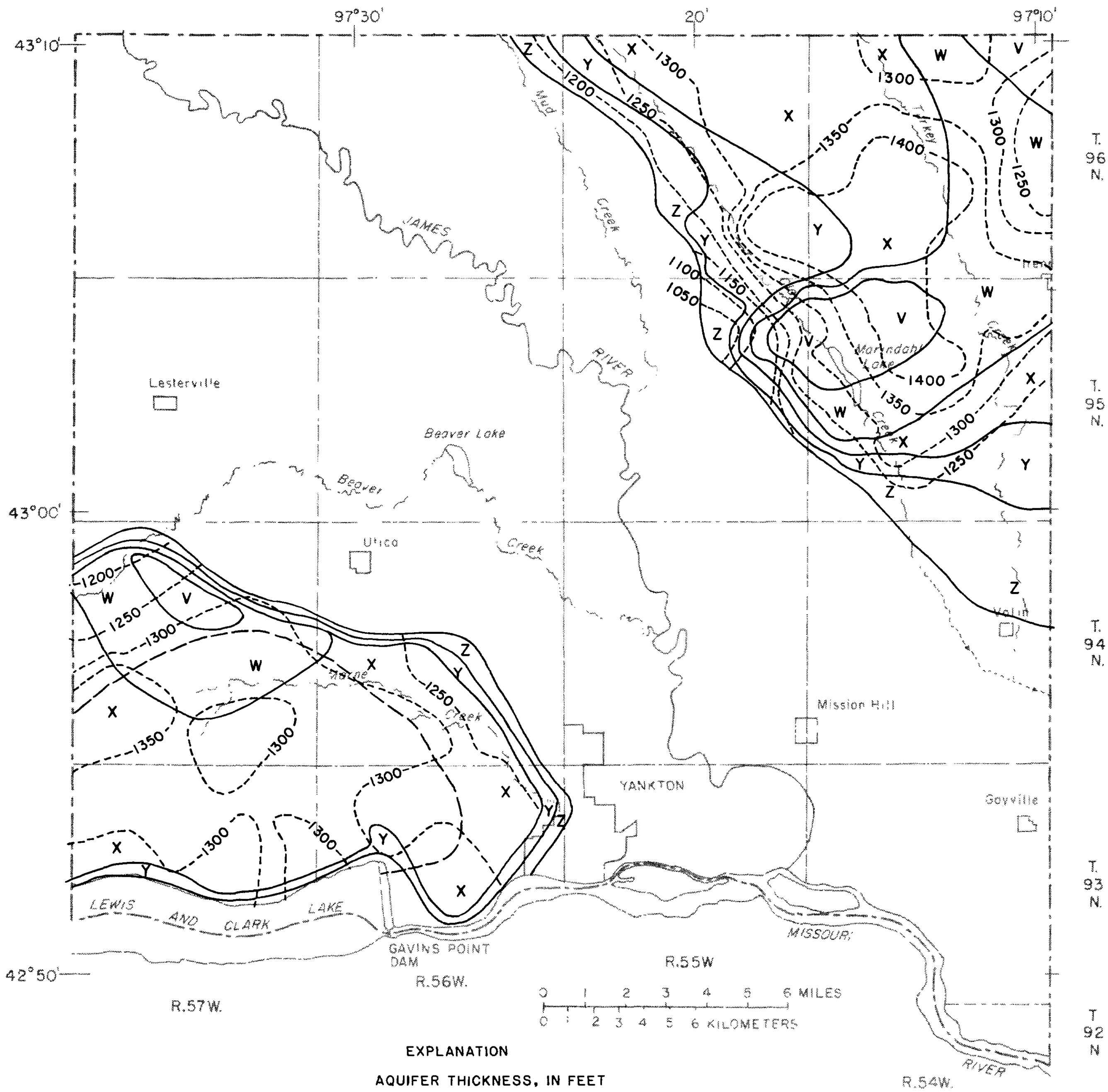


Figure 14.--Extent, potentiometric surface, and ground-water flow directions, Niobrara aquifer.



EXPLANATION

AQUIFER THICKNESS, IN FEET

V	Greater than 250
W	200–250
X	150–200
Y	100–150
Z	Less than 100

----1300-- STRUCTURE CONTOUR--Shows altitude of top of Niobrara aquifer. Contour interval 50 feet. National Geodetic Vertical Datum of 1929

— — — — YANKTON RIDGE BOUNDARY

Figure 15.--Thickness and structure, Niobrara aquifer.

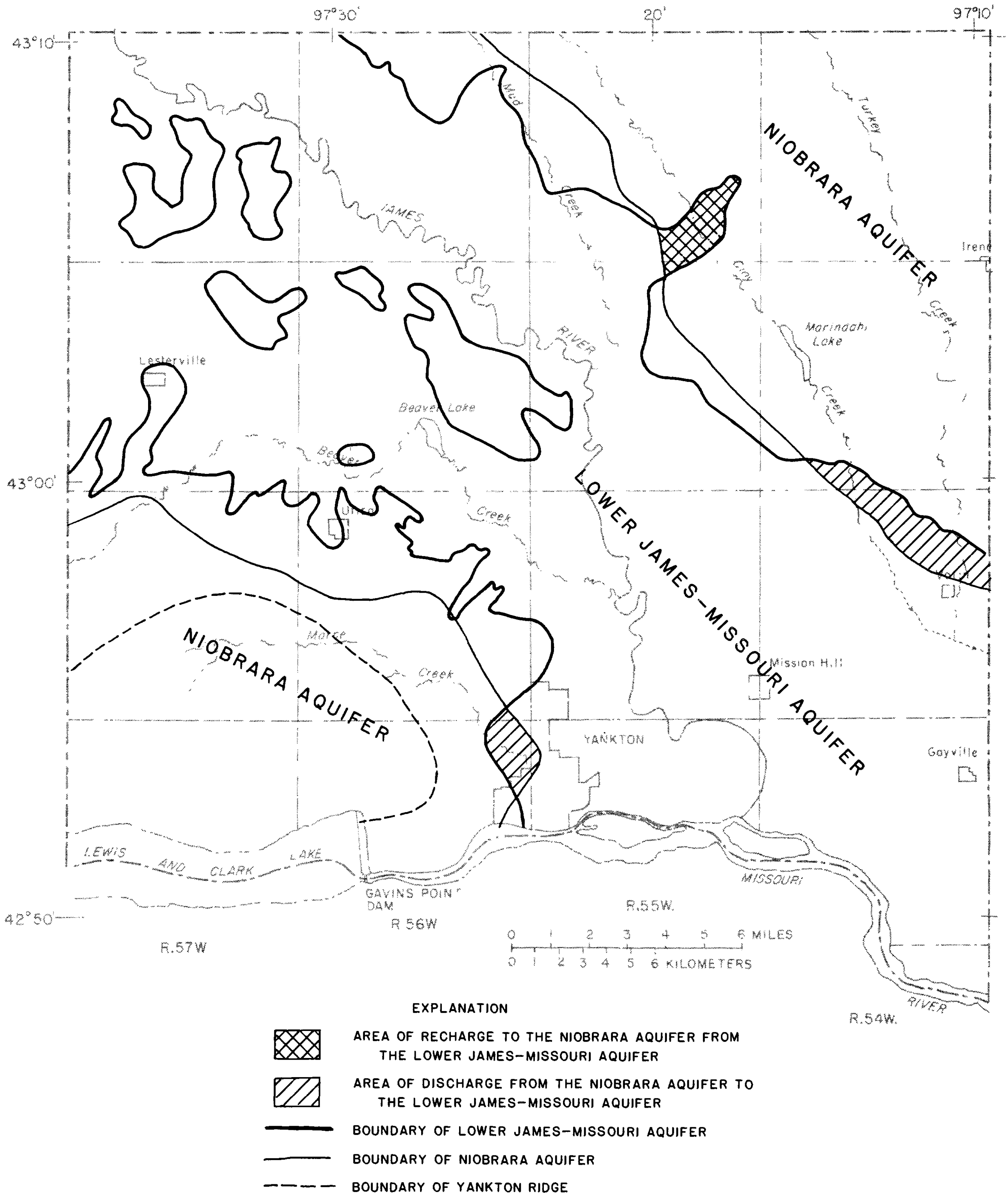


Figure 16.--Areas of hydraulic connection between Lower James-Missouri and Niobrara aquifers, and direction of recharge and discharge between the two aquifers.

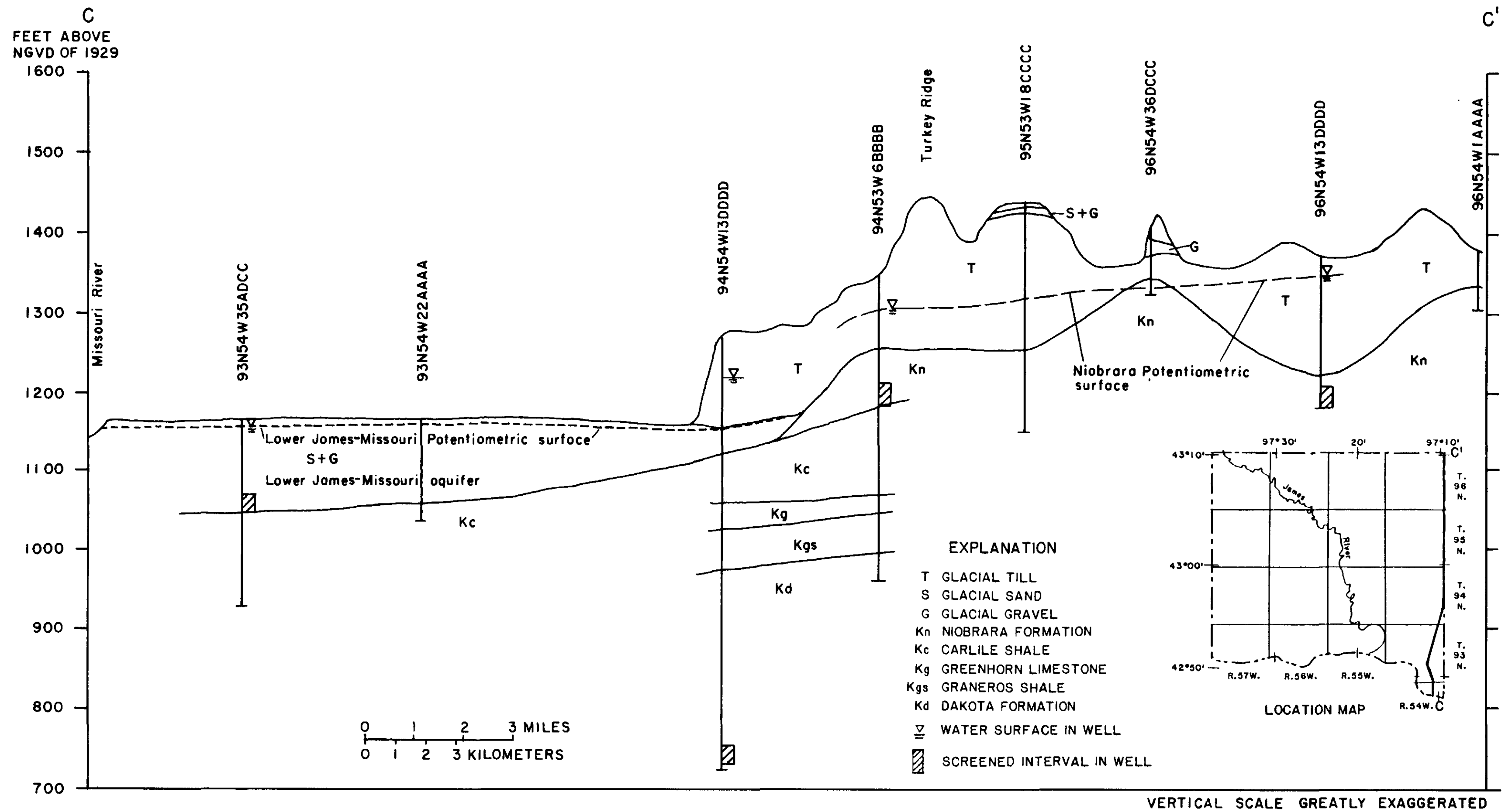


Figure 17.--Hydraulic connection between the Lower James-Missouri and Niobrara aquifers in T. 94 N., R. 54 W.

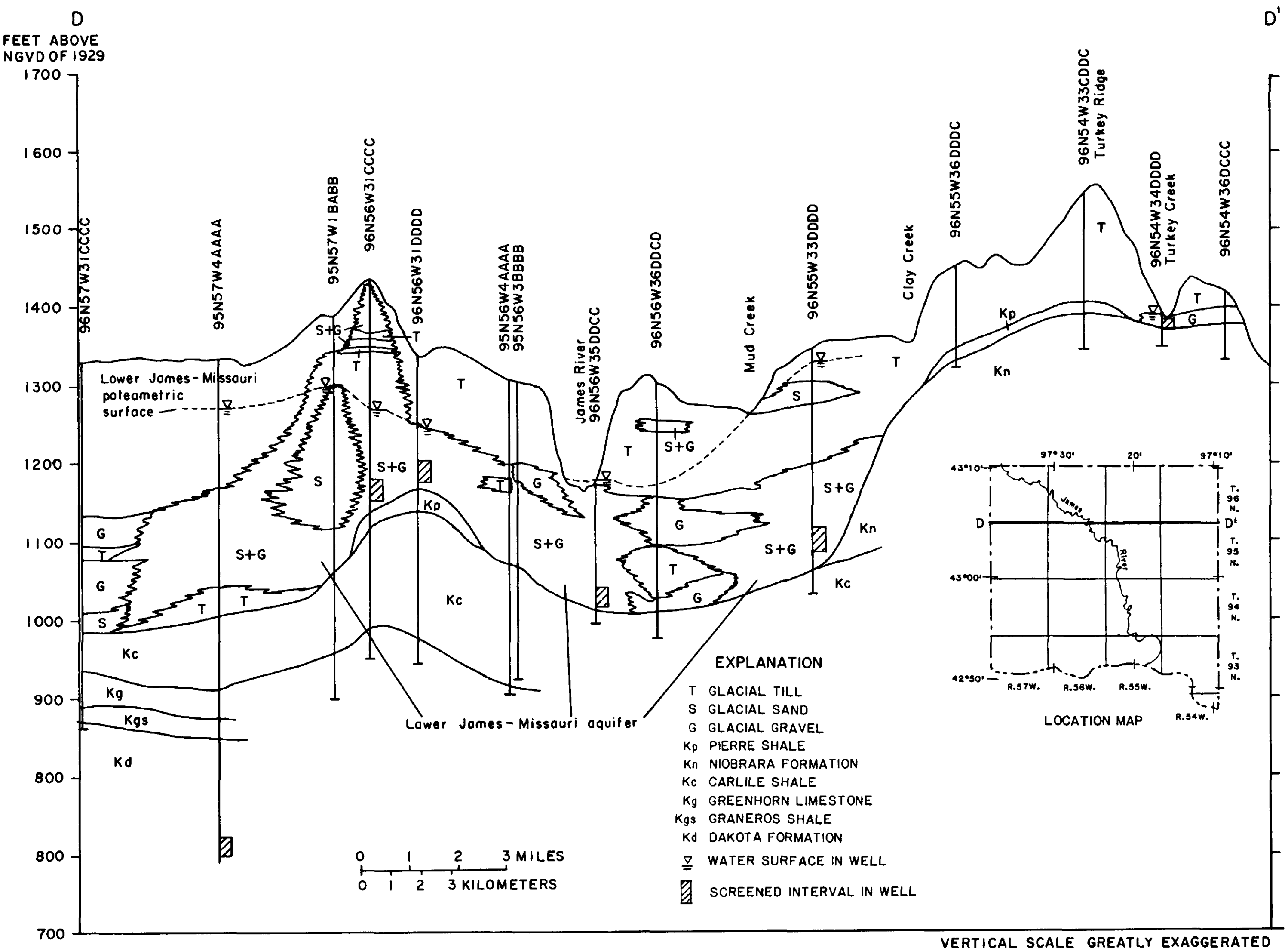


Figure 18.--Hydraulic connection between the Lower James-Missouri and Niobrara aquifers in T. 96 N., R. 55 W.

Dakota Aquifer

The Dakota aquifer underlies all of Yankton County and is composed of interbedded siltstone, shale, and sandstone. Two distinct water-yielding zones (possibly three in some areas) can be recognized. Depth to the top of the aquifer from land surface ranges from 300 ft beneath the James and Missouri River valleys to more than 500 ft beneath the ridges and higher altitudes. Total thickness of the aquifer is not known, but test holes have penetrated as much as 290 ft. The water-yielding zones of the aquifer are 5 to 40 ft thick.

Wells completed in the Dakota aquifer in the James and Missouri River valleys and in areas below about 1,260 ft altitude will flow from 3 to 60 gal/min at the land surface. In other areas, wells must be pumped but yields are similar to those from wells that flow.

Water-level declines in the Dakota aquifer in South Dakota began with the development of the aquifer in the late 1800's. However, water levels in some areas have declined more than in other areas. According to Dyer and Goehring (1965, p. 26), the net decline in the Missouri River valley from Yankton to 35 mi east to Elk Point has been less than 100 ft since initial development, although decreases of 400 ft have been reported in the Fort Thompson and Chamberlain areas northwest of Yankton County.

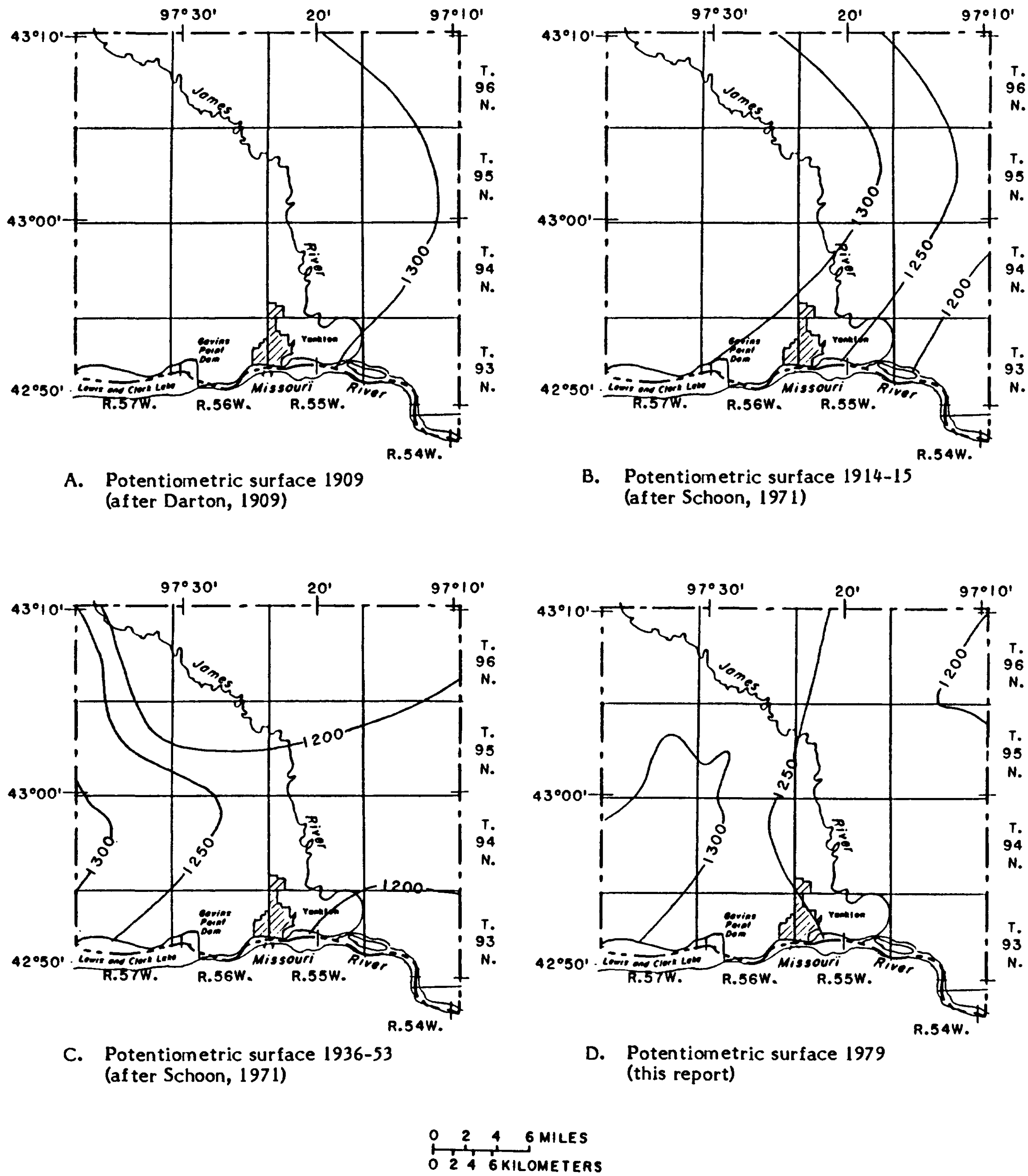
The change in the potentiometric surface of the Dakota aquifer in Yankton County since 1909 is shown in figure 19. The most rapid declines in water levels were from 1914-15 and 1936-53. This probably was the result of rapid development of the aquifer during these periods. From 1953 to 1979, water levels rose in most areas because of less use of the aquifer and sealing of unused flowing wells.

Recharge to the Dakota aquifer is from underlying formations in the western part of South Dakota, especially the Madison Formation and other formations that crop out in the Black Hills (Schoon, 1971). Data collected by the U.S. Geological Survey confirm that recharge is from underlying formations (L. W. Howells, U.S. Geological Survey, written commun., 1980).

Discharge from the aquifer is by domestic, stock, and municipal wells that flow in areas where land altitudes are less than about 1,260 ft. Some of these wells flow continuously and some were covered by the filling of Lewis and Clark Lake and continue to flow, discharging unknown quantities of water from the aquifer. Subsurface outflow is to the east into Clay County (fig. 20).

The Dakota aquifer's water chemistry is derived from water originating in the Madison Formation and traveling upward and laterally through intervening Pennsylvanian, Jurassic, and Lower Cretaceous units from the west until it reaches the Dakota Formation near mid-State (L. W. Howells, written commun., 1980).

Water from the Dakota aquifer is a calcium sulfate type (table 2). Concentrations of dissolved solids and hardness are large. However, concentrations of major cations and anions are relatively less than in the other aquifers in the county.



A. Potentiometric surface 1909 (after Darton, 1909)

B. Potentiometric surface 1914-15 (after Schoon, 1971)

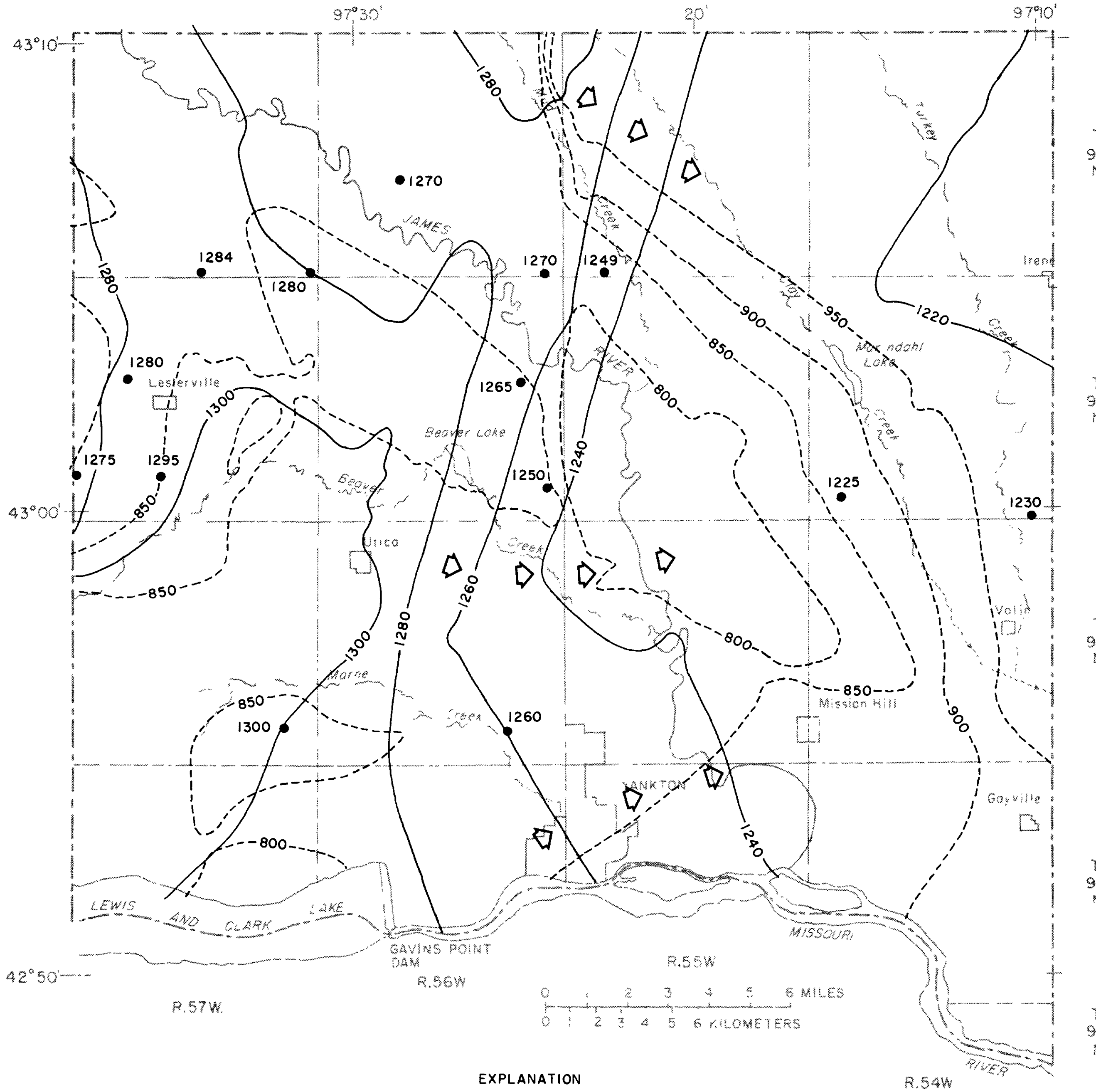
C. Potentiometric surface 1936-53 (after Schoon, 1971)

D. Potentiometric surface 1979 (this report)

EXPLANATION

——1300—— POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells. Contour interval 50 feet. National Geodetic Vertical Datum of 1929

Figure 19.--Historical changes in the potentiometric surface of the Dakota aquifer since 1909.



EXPLANATION

—1260— POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells, 1979. Contour interval 20 feet. National Geodetic Vertical Datum of 1929

----850--- STRUCTURE CONTOUR--Shows altitude of top of Dakota aquifer. Contour interval 50 feet. National Geodetic Vertical Datum of 1929

DIRECTION OF GROUND-WATER FLOW

● OBSERVATION WELL--Number is altitude of potentiometric surface, 1979, in feet above National Geodetic Vertical Datum of 1929

Figure 20.--Structure, potentiometric surface, and direction of ground-water flow, Dakota aquifer.

Water Quality and its Relation to Use

The chemical composition of water determines its suitability for use. The quality of water is affected by natural factors such as climate, geology, topography, and vegetation and by man's activities. The effects of these factors vary with time, place, and quantity.

The major chemical constituents and physical properties of drinking water and the significance and mandatory and recommended limits of the constituents and properties are shown in table 3. Most of the water in the aquifers is very hard and commonly is undesirable for drinking. The fact of this undesirability is shown by the almost total acceptance and purchase of domestic water from a newly established rural water pipeline, which provides surface water to most areas in the county outside of the Yankton metropolitan area.

The quality of water for livestock and irrigation purposes can be significantly different from that used for domestic purposes. Hardness usually is a desirable quality for irrigation water but not for many domestic purposes.

Sodium probably is the most important chemical constituent when considering the suitability of water for irrigation purposes. Sodium salts are a major cause of alkali soils. Water moving through soil may exchange calcium and magnesium ions for sodium ions, thus impairing the permeability of the soil. Calcium and magnesium flocculate soil particles and the soil generally is loose and permeable. Sodium deflocculates soil particles and soils become tight and almost impermeable. Two measurements commonly used in determining the chemical suitability of water for irrigation use are percent sodium and the sodium-adsorption ratio (SAR).

The extent to which irrigation water can enter into ion exchange between sodium, calcium, and magnesium can be approximated by determining the percent sodium (the percentage of total cations represented by sodium). Adverse effects on soil usually do not occur unless the percent sodium is greater than 50. Sodium is a minor constituent of the ground water and streams in Yankton County, and, therefore, is not a limiting factor in irrigation.

The sodium-adsorption ratio is more significant for determining potential effects on the soil. The classification for irrigation use of waters from the major aquifers in Yankton County on the basis of SAR and the specific conductance is shown in figure 21. The data in figure 21 are interpreted as follows:

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation except in soils of extremely limited permeability.

Medium-salinity water (C2) can be used for irrigation if a moderate degree of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special salinity control.

High-salinity water (C3) cannot be used for irrigation on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance are best suited to this type of water.

Table 3.--Selected chemical constituents and physical properties, significance to human consumption, and limits for public water supplies

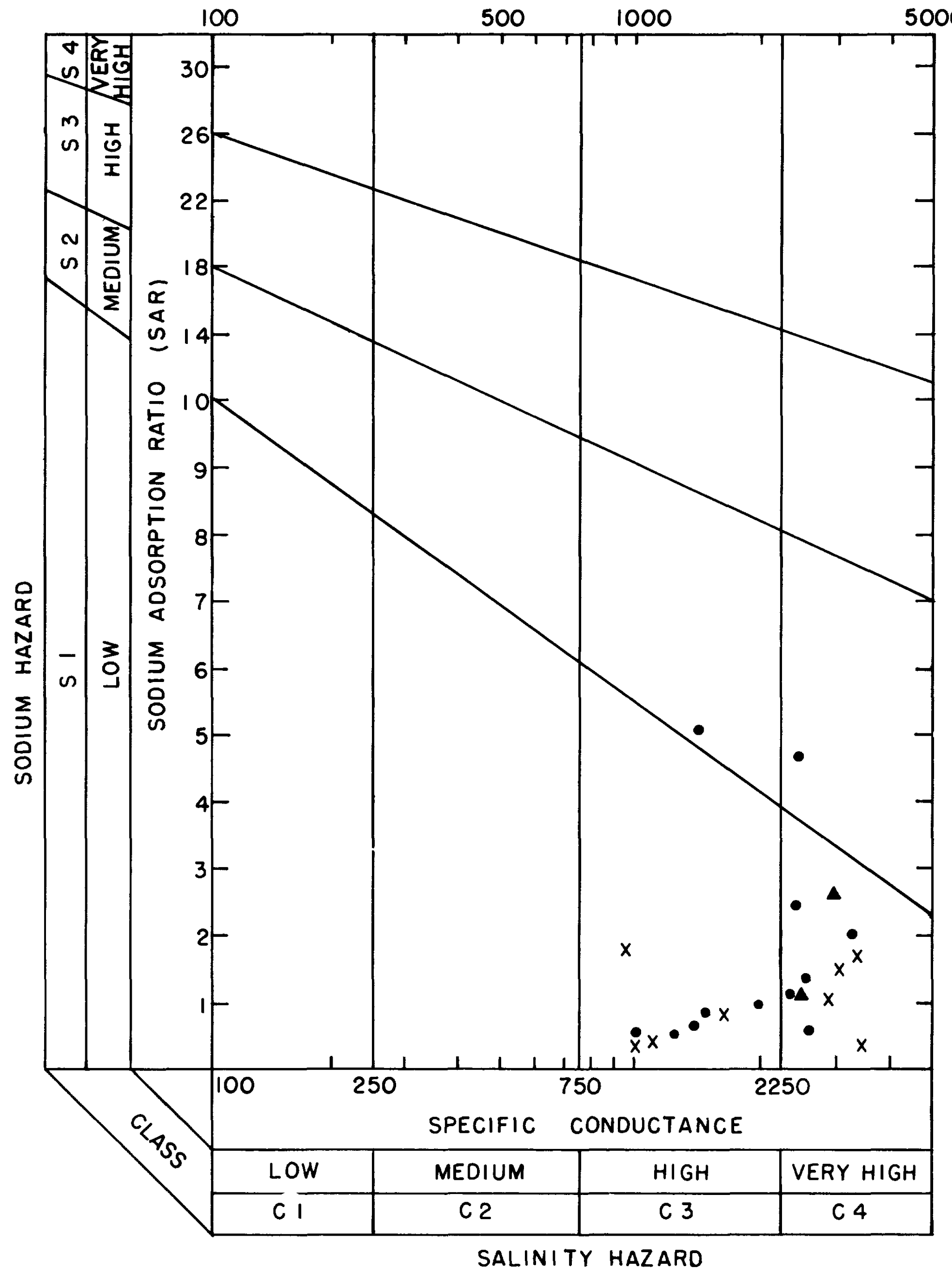
[Modified from Jorgensen (1966)]

Chemical constituent or physical property	Significance	Limits for public water supplies (milligrams per liter)
Calcium (Ca) and Magnesium (Mg)	Cause most of the carbonate hardness and scale-forming properties of water by combining with carbonate and bicarbonate present in the water. Seldom can be tasted except in extreme concentrations.	Ca--None Mg--None
Sodium (Na)	Large concentrations in combination with chloride will give water a salty taste. Large concentrations will limit water for irrigation and industrial use.	None
Chloride (Cl)	Large concentrations in combination with sodium give water a salty taste. Large concentrations also will increase corrosiveness of water.	1/ 250
Sulfate (SO_4)	Large concentrations in combination with other ions give a bitter taste to water and may act as a laxative to those not used to drinking it. Sulfates of calcium and magnesium will form hard scale.	1/ 250
Iron 2/ (Fe) and Manganese 2/ (Mn)	In excess will stain fabrics, utensils, and porcelain fixtures, and produce objectionable coloration in the water. Both constituents in excess are particularly objectionable.	Fe-- 1/ 300 Mn-- 1/ 50
Nitrate nitrogen (N)	In excess may be injurious to infants who drink the water or who are breast fed by mothers who drink the water.	1/ 10
Fluoride (F)	Decreases incidence of tooth decay when optimum fluoride concentration is present in water consumed by children during period of tooth calcification. Excessive fluoride in water may cause mottling of enamel.	3/ 1.4-2.4

Table 3.--Selected chemical constituents and physical properties, significance to human consumption, and limits for public water supplies--Continued

Chemical constituent or physical property	Significance	Limits for public water supplies (milligrams per liter)
Dissolved Solids	Total of all dissolved constituents. Water containing more than 1,000 milligrams per liter of dissolved solids may have a noticeable taste; it also may be unsuitable for irrigation and certain industrial uses.	1/ 500
pH	A measure of the hydrogen-ion concentration; pH of 7.0 indicates a neutral solution, pH values less than 7.0 indicate acidity, pH values more than 7.0 indicate alkalinity. Acidity tends to aid corrosion and alkalinity tends to aid encrustation.	None
Hardness	Hardness in water consumes soap and forms soap curd. Will also cause scale in boilers, water heaters, and pipes. Hardness, as calcium carbonate, of water ranging from 0-60 mg/L is soft; 61-120 mg/L is moderately hard; 121-180 mg/L is hard, and more than 180 mg/L is very hard.	None

1/ U.S. Environmental Protection Agency (1979).
2/ Units in micrograms per liter.
3/ U.S. Environmental Protection Agency (1976).



EXPLANATION

- ● LOWER JAMES-MISSOURI AQUIFER
- X NIOBRARA AQUIFER
- ▲ DAKOTA AQUIFER

Figure 21.--Classification for irrigation use of ground water. (Classification by U.S. Salinity Laboratory staff, 1954.)

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching. Very salt-tolerant crops are best suited to this type of water.

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful concentrations of exchangeable sodium. However, sodium-sensitive crops may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having significant cation-exchange capacity, especially under slight leaching conditions, unless gypsum is present in the soil. This water may be used on permeable, coarse-textured or organic soils.

Water in the Lower James-Missouri aquifer is of suitable quality for use by livestock. The large concentrations of iron and hardness may be a factor affecting domestic use. The water is moderately saline and may need to be applied according to specifications of the U.S. Salinity Laboratory Staff (1954) for irrigation.

Water in the Niobrara aquifer is satisfactory for livestock and domestic purposes. However, water from some areas of the aquifer may require softening and iron removal. Although the water has a high salinity hazard, its sodium hazard is low (fig. 21), and therefore may be used for irrigation with some constraints. However, well yields from this aquifer are not sufficient for large-scale irrigation.

Water from the Dakota aquifer is suitable for both domestic and livestock uses. Domestic uses may require treatment to remove hardness. Although it is suitable for irrigation with some constraints, it has greater chloride concentrations, and SAR and percent-sodium values than waters from the Niobrara and Lower James-Missouri aquifers.

SUMMARY

Surface-water resources in Yankton County include the Missouri and James Rivers, Lewis and Clark Lake, and the numerous stock ponds throughout the valley. The city of Yankton pumped about 670,000,000 gallons from the Gavins Point Dam on Lewis and Clark Lake in 1979. Water from the Missouri River, and to a lesser extent from the James River, is used for irrigation purposes along their flood plains where feasible.

There are three major aquifers in Yankton County: the Lower James-Missouri, the Niobrara, and the Dakota aquifers.

Water in the Lower James-Missouri aquifer is a moderately hard calcium sodium sulfate water. Water is of suitable quality for livestock, and in many cases for domestic use. Water-table and artesian conditions are both encountered at various locations throughout the county. The aquifer underlies approximately 46 percent of the county. Withdrawal rates of more than 1,000 gallons per minute are possible from properly constructed wells.

Recharge to the Lower James-Missouri aquifer is by infiltration of precipitation through overlying till locally where the aquifer lies near the surface, and from subsurface inflow from the west from Bon Homme and Hutchinson Counties. Some subsurface inflow occurs from the northeast part of the Niobrara aquifer north of Volin. The major subsurface outflow from the Lower James-Missouri aquifer in Yankton County is eastward into Clay County. The aquifer discharges to the northwest into Bon Homme County and to the northeast part of the Niobrara aquifer in Yankton County, but some flow may re-enter the system north of Volin where the Niobrara and Lower James-Missouri aquifers are in contact.

The Niobrara aquifer is located in the northeastern and southwestern parts of the county. It is under artesian and water-table conditions in the northeastern section and under water-table conditions in the southwestern section. Water is a magnesium sulfate type and is relatively high in iron concentration. It is suitable for livestock, but may need to be treated for iron and hardness for domestic purposes. The relatively low production rates of wells limit the use for irrigation. The Niobrara aquifer in southwestern Yankton County is recharged, in part, through the overlying glacial deposits and in part, through some inflow from the west. Discharge from this part of the aquifer is to the Missouri River and to the Lower James-Missouri aquifer west of the city of Yankton where the two aquifers lie in contact.

The northern part of the Niobrara aquifer is recharged by precipitation through the overlying glacial deposits and by subsurface inflow from the Lower James-Missouri aquifer in T. 95 N., R. 56 W. Discharge is by subsurface outflow to the Lower James-Missouri aquifer north of the town of Volin where they are in connection, partly to the east by outflow from Turkey Ridge, and by pumping.

The Dakota aquifer is hydrologically and stratigraphically separate from the other two and under artesian conditions throughout the county. Wells located in the Dakota aquifer will flow at altitudes lower than about 1,260 feet and will yield from 3 to 60 gallons per minute. The water is a calcium sulfate type. It is suitable for domestic and livestock purposes and may be used for irrigation with some constraints. The general recharge is from the west by subsurface flow into the county and discharge is to the east by subsurface outflow.

Water resources in Yankton County, South Dakota, are important for domestic, livestock, and agricultural uses. The source of water for private and public purposes has been from ground water in the past. However, with the forming of Lewis and Clark Lake in 1955 and a rural water system delivering water from the Missouri River in 1979, the balance has shifted to surface water for domestic and public use.

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