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DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
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DIVISION OF GEOLOGICAL SURVEY
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Information Pamphlet No. 46

MAJOR AQUIFERS IN MINNEHAHA COUNTY, SOUTH DAKOTA

by

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Prepared in cooperation with the
South Dakota Geological Survey,
Minnehaha County, and the
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ABSTRACT

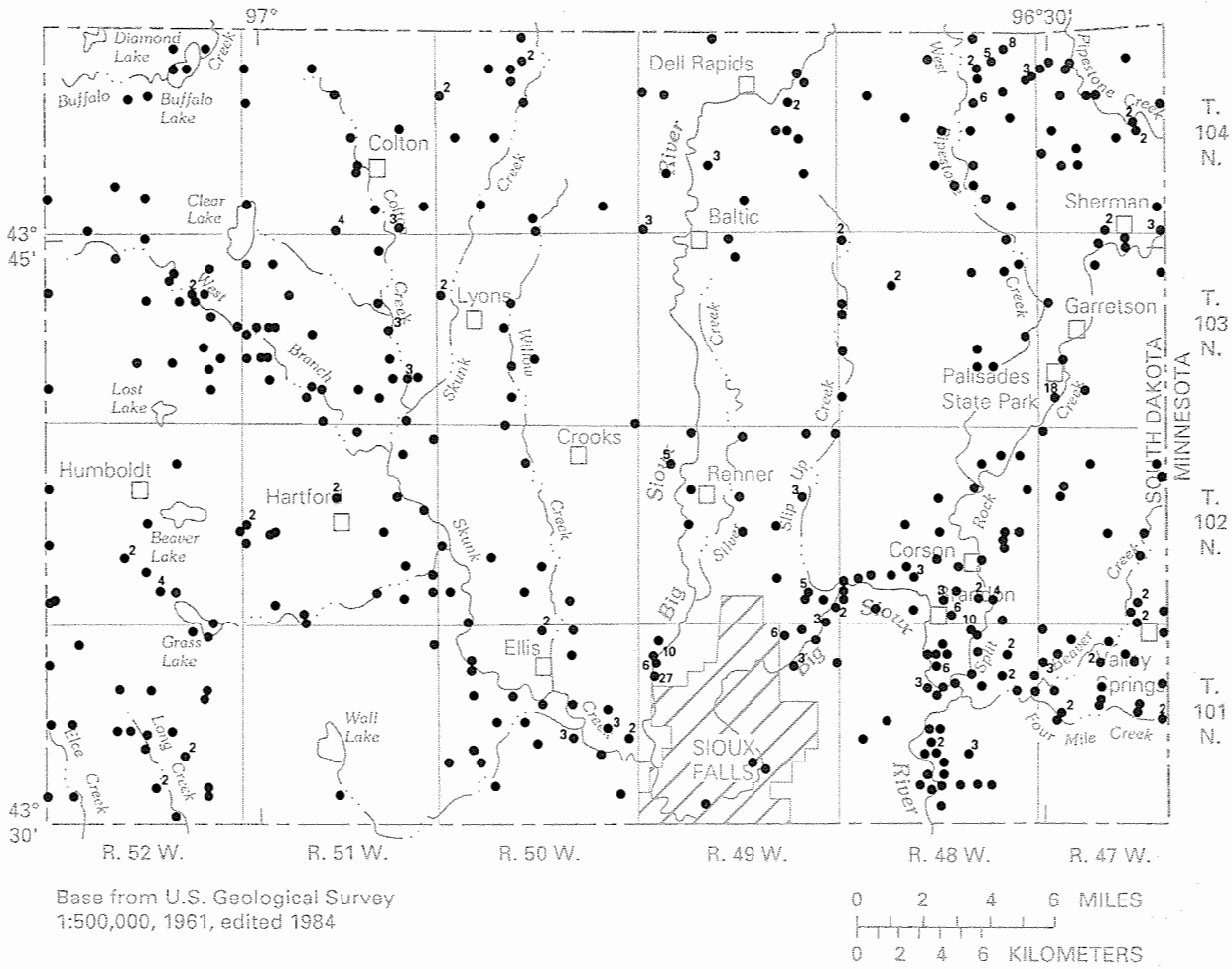
Nine major glacial aquifers have been identified in Minnehaha County. They are composed primarily of unconsolidated sand and gravel deposited as outwash from glaciers and contain about 735,000 acre-feet of water in storage. The Big Sioux, Skunk Creek, Pipestone Creek, Beaver Creek, Brandon, and Colton aquifers are predominantly shallow, water-table aquifers with average cumulative thicknesses ranging from about 12 to 22 feet for the Big Sioux, Skunk Creek, Pipestone Creek, Beaver Creek, and Colton aquifers to about 35 feet for the Brandon aquifer. Estimated maximum well yields are about 1,000 gallons per minute for the Big Sioux and Skunk Creek aquifers and about 500 gallons per minute for the Pipestone Creek, Beaver Creek, Brandon, and Colton aquifers. The predominant chemical constituents in water from the Big Sioux and Skunk Creek aquifers are calcium, sulfate, and bicarbonate; from the Colton aquifer are calcium, magnesium, and sulfate; and from the Pipestone Creek, Beaver Creek, and Brandon aquifers are calcium and bicarbonate. The Wall Lake, Howard, and Valley Springs aquifers are buried, confined aquifers overlain by 19 to 265 feet of till; the average cumulative thicknesses of these aquifers are about 33, 28, and 15 feet, respectively. Estimated maximum well yields are about 500 gallons per minute for the Wall Lake and Howard aquifers and about 200 gallons per minute for the Valley Springs aquifer. The predominant chemical constituents in water from the Wall Lake aquifer are calcium and sulfate, while water from the Howard and Valley Springs aquifers is high in calcium and bicarbonate. Average dissolved-solids concentrations ranged from 443 to 1,100 milligrams per liter, and average hardness concentrations (as calcium carbonate) ranged from 310 to 810 milligrams per liter in the major glacial aquifers.

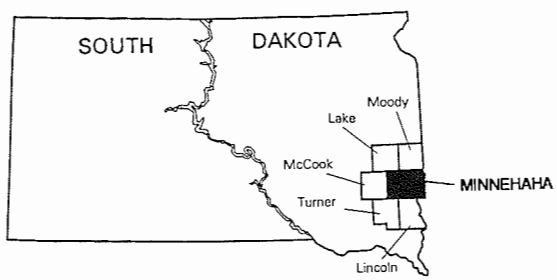
Two major bedrock aquifers, the Split Rock Creek and Sioux Quartzite aquifers, are important sources of water in Minnehaha County. The Split Rock Creek aquifer contains about 890,000 acre-feet of water in storage with an average cumulative thickness of sand and gravel layers of about 48 feet. The Sioux Quartzite is a locally well-fractured and jointed rock that is used extensively as a source of water in western and east-central Minnehaha County. The amount of water contained in storage in the Sioux Quartzite aquifer is unknown because the depth and development of the fracture system is not well known. Estimated maximum well yields are about 500 gallons per minute for the Split Rock Creek aquifer and about 150 gallons per minute for the Sioux Quartzite aquifer. The predominant chemical constituents in water from the Split Rock Creek and Sioux Quartzite aquifers are calcium and sulfate. Average dissolved-solids concentrations were 890 and 1,030 milligrams per liter, and average hardness concentrations (as calcium carbonate) were 620 and 820 milligrams per liter in the Split Rock Creek and Sioux Quartzite aquifers, respectively.

Water use from glacial and bedrock aquifers in Minnehaha County in 1985 was estimated to be 5.87 billion gallons. Ninety-four percent of the water used was withdrawn from glacial aquifers and 6 percent of the water used was withdrawn from bedrock aquifers. Eighty-five percent of the water withdrawn from the aquifers in Minnehaha County was used for municipal purposes.

INTRODUCTION

This Information Pamphlet is one of a series of reports on water-resources studies of South Dakota counties. It is designed to acquaint the reader with the general distribution, quantity, and quality of ground water available from the major aquifers in Minnehaha County. Information in this pamphlet is based on data (figs. 1, 2, and 3) collected by the U.S. Geological Survey and the South



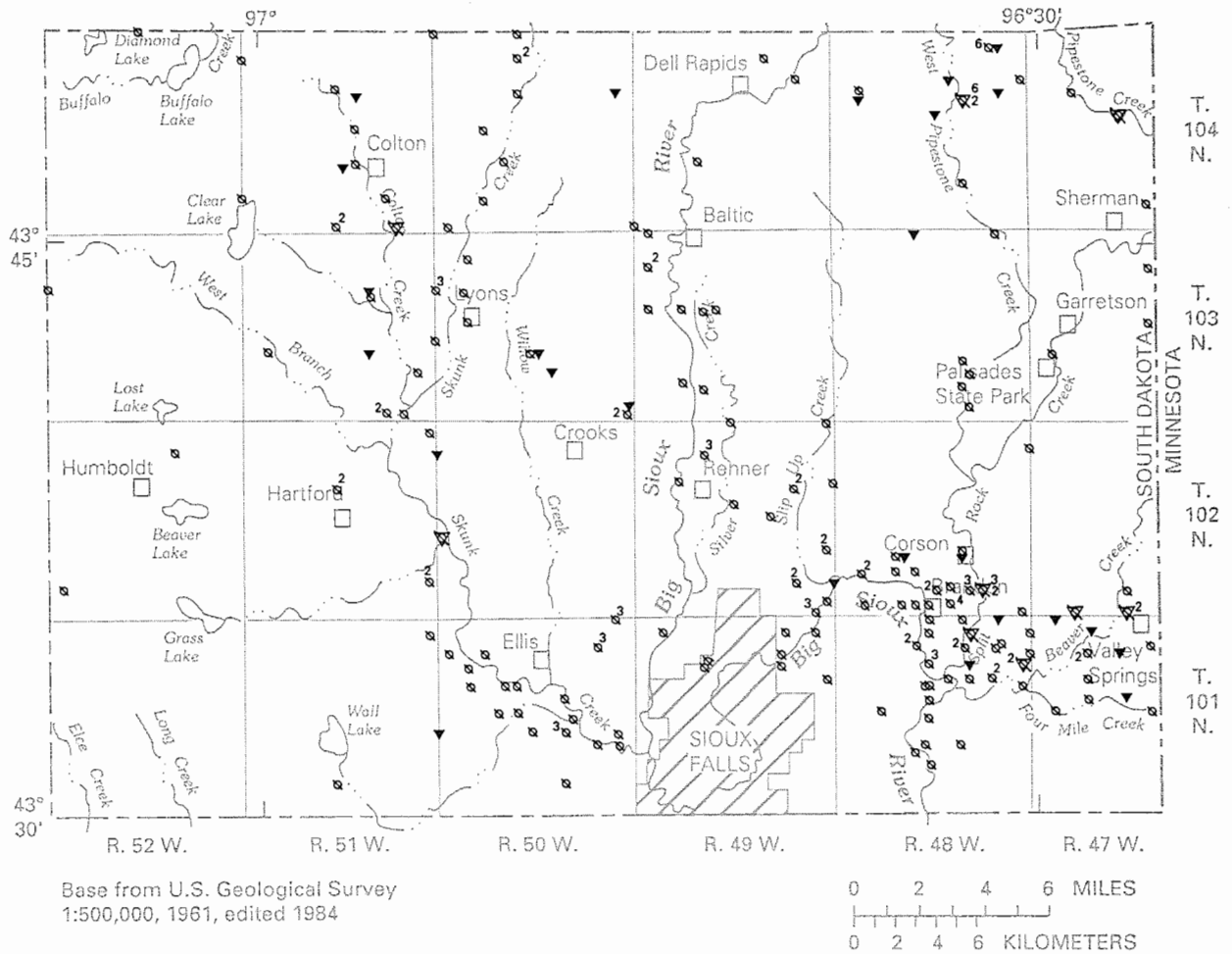


North

EXPLANATION

•[3] TEST-DRILLING SITE--Number indicates number of holes at site where more than one.

Figure 1. Location of test-hole sites for this study.



EXPLANATION

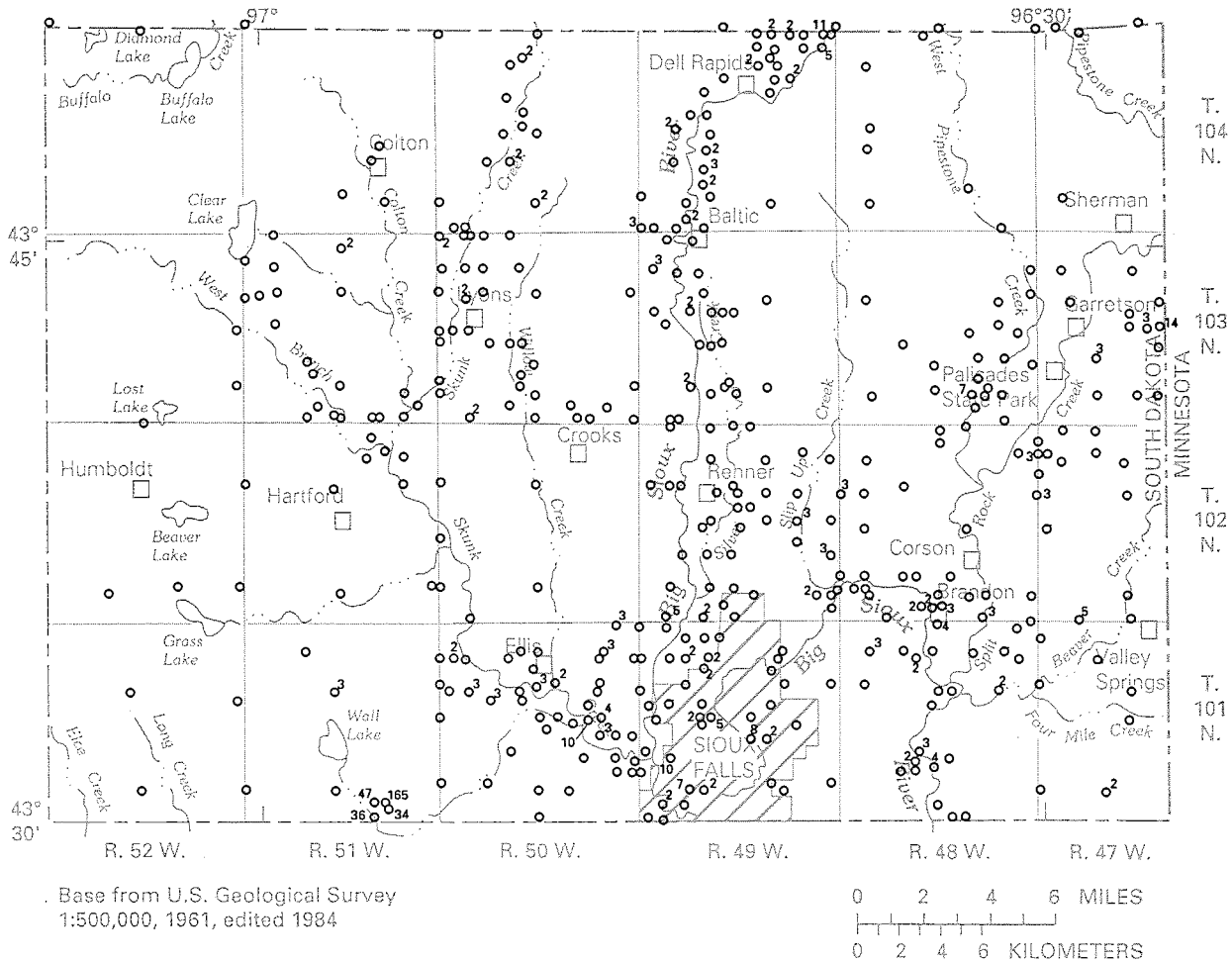
$\varnothing^2$ OBSERVATION-WELL SITE--Records of periodic water-level measurements are available from the U.S. Geological Survey. Number indicates number of wells at site where more than one.

▼ WATER-QUALITY SAMPLE SITE--Complete chemical analyses obtained for this study are available from the U.S. Geological Survey.

$\varnothing^6_2$ OBSERVATION-WELL AND WATER-QUALITY SAMPLE SITE--Upper number indicates number of observation wells at site where more than one. Lower number indicates number of water-quality wells at site where more than one.

North

Figure 2. Location of observation-well and ground-water-quality sampling sites.



EXPLANATION

$_{o}{}^{2}$ TEST-DRILLING SITE--Number indicates number of wells or test holes at site where more than one.

North

Figure 3. Location of additional test-hole sites from other studies.

Dakota Geological Survey during 1982 through 1989. Other data from previous studies also were used. More detailed information on the water resources of Minnehaha County is contained in a report by Lindgren and Niehus (1992).

Copies of this publication and other county reports may be obtained from the South Dakota Geological Survey as they become available. Additional information about the hydrology and geology may be obtained from U.S. Geological Survey offices in Huron and Rapid City or the South Dakota Geological Survey in Vermillion.

The inch-pound units used in this report may be converted to metric (SI) units by the following conversion factors:

Multiply inch-pound unit	By	To obtain metric unit
acre-foot (acre-ft)	1,233	cubic meter
billion gallons (Bgal)	3,785,000	cubic meter
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
mile (mi)	1.609	kilometer
million gallons (Mgal)	3,785	cubic meter
million gallons per year (Mgal/yr)	0.00012	cubic meter per second
square mile (mi^2)	2.590	square kilometer

DEFINITIONS OF TERMS

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

Bedrock: A general term for the rock, usually consolidated, that underlies soil, sand, clay or other unconsolidated material. In Minnehaha County, the uppermost bedrock usually is shale, siltstone, or quartzite.

Confined aquifer: An aquifer in which the water in a well completed in the aquifer rises above the top of the aquifer.

Dissolved solids: The sum of all dissolved material in water, expressed as the weight of solute per unit volume of water.

Glacial aquifer: As used in this report, an aquifer consisting mainly of unconsolidated sand and gravel deposited as outwash from a glacier.

Glacial outwash: Gravel, sand, silt, and clay that was deposited by water from melting ice. In this report, the term is restricted to sand and gravel.

Hardness: Dissolved calcium and magnesium salts in water that decrease the lathering ability of soap and form scale in boilers and pipes. Hardness is reported as concentration of calcium carbonate and is classified by the U.S. Geological Survey as follows:

Water classification	Milligrams per liter	Grains per gallon
Soft	0 - 60	0 - 3.5
Moderately hard	61-120	3.6 - 7.0
Hard	121-180	7.1-10.5
Very hard	More than 180	More than 10.5

Large-capacity well: Defined by South Dakota law as a well capable of yielding at least 18 gallons per minute on a sustained basis.

Milligrams per liter (mg/L): A unit expressing the concentration of chemical constituents in solution as mass (milligrams) of solute per unit volume (liter) of water. One milligram per liter is approximately equal to one part per million.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Specific conductance: The ability of water to conduct an electric current. Generally, this is a measure of the dissolved chemical constituents in water.

Till: A general term applied to all unsorted rock material (clay, silt, sand, gravel, and boulders) transported by glaciers and deposited directly on land.

Water table: That water surface in an unconfined aquifer at which the pressure is atmospheric.

GLACIAL AQUIFERS

Glacial aquifers, primarily unconsolidated sand and gravel deposited as outwash by meltwater from glaciers, underlie about 240 mi^2 of Minnehaha County. Outwash deposits can be at land surface or be buried by till or alluvium. Till has a very low hydraulic conductivity and therefore is a poor source of water. Locally, however, the till can contain thin, discontinuous sand and gravel lenses that can yield as much as 5 gal/min to wells. Depths to the top of the aquifers range from land surface to 265 ft for the major glacial aquifers in Minnehaha County. The average cumulative thicknesses of sand and gravel range from about 12 to 35 ft.

The Big Sioux, Skunk Creek, Pipestone Creek, Beaver Creek, Brandon, and Colton aquifers are predominantly shallow, water-table aquifers. Average cumulative thicknesses range from about 12 to 22 ft for the Big Sioux, Skunk Creek, Pipestone Creek, Beaver Creek, and Colton aquifers to about 35 ft for the Brandon aquifer. The Wall Lake, Howard, and Valley Springs aquifers are buried, confined aquifers overlain by 19 to 265 ft of till. The average cumulative thicknesses of these aquifers are 33, 28, and 15 ft, respectively. Hydrologic characteristics of the aquifers are given in table 1.

Table 1. Summary of the hydrologic characteristics of major aquifers in Minnehaha County

[--, no data; >, greater than]

Aquifer name	Areal extent (square miles)	Maximum cumulative thickness (feet)	Average cumulative thickness (feet)	Range of depth below land surface (feet)	Average depth below land surface (feet)	Range of water level above (+) or below land surface (feet)	Confined (C) and/or water table (WT) aquifer (predominantly)	Estimated volume of water in storage[1] (acre-feet)	Estimated maximum well yield (gallons per minute)
GLACIAL AQUIFERS									
Big Sioux	69	71[2]	22	0-82	10	2-42	WT	195,000	1,000
Skunk Creek	40	84[2]	22	0-93	9	2-86	WT	115,000	1,000
Pipestone Creek	20	>36	15	1-52	11	+1-23	WT	40,000	500
Beaver Creek	11	49	17	0-118	22	6-29	WT	25,000	500
Brandon	6	62[2]	35	0-24	7	11-56	WT	25,000	500
Colton	8	26	12	1-57	20	4-18	WT	10,000	500
Wall Lake	58	88	33	19-205	106	9-156	C	245,000	500
Howard	15	63	28	123-265	202	6-146	C	55,000	500
Valley Springs	14	26[2]	15	93-207	131	20-147	C	25,000	200
Total								735,000	
BEDROCK AQUIFERS									
Split Rock Creek	145	222[2]	48	21-337	160	+10-187	C	890,000	500
Sioux Quartzite	815	--	--	2-510	120	0-300	C	([3])	150

[1] Storage was estimated by multiplying average thickness times areal extent times an estimated porosity of 20 percent.

[2] Includes multiple layers.

[3] Storage unknown because the depth and development of the fracture system is not well known.

Big Sioux Aquifer

The Big Sioux aquifer underlies about 69 mi^2 near the Big Sioux River in Minnehaha County (fig. 4). Most of the aquifer is under the flood plain of the Big Sioux River. The top of the aquifer is near land surface in the Big Sioux River flood plain, is up to 67 ft below land surface in northeastern T. 101 N., R. 50 W., and reaches a maximum of 82 ft below land surface near the eastern boundary of the aquifer in T. 102 N., R. 49 W., where the aquifer is overlain by till. The average depth below land surface is about 10 ft. The maximum cumulative thickness is 71 ft and the average cumulative thickness of the aquifer is about 22 ft. The Big Sioux aquifer is composed of fine to coarse, poorly sorted sand and fine to coarse pebble gravel with thin (3- to 5-ft thick) interbedded clay and till layers in some areas. Properly constructed wells completed in the Big Sioux aquifer may yield as much as 1,000 gal/min where the thickness exceeds 25 ft.

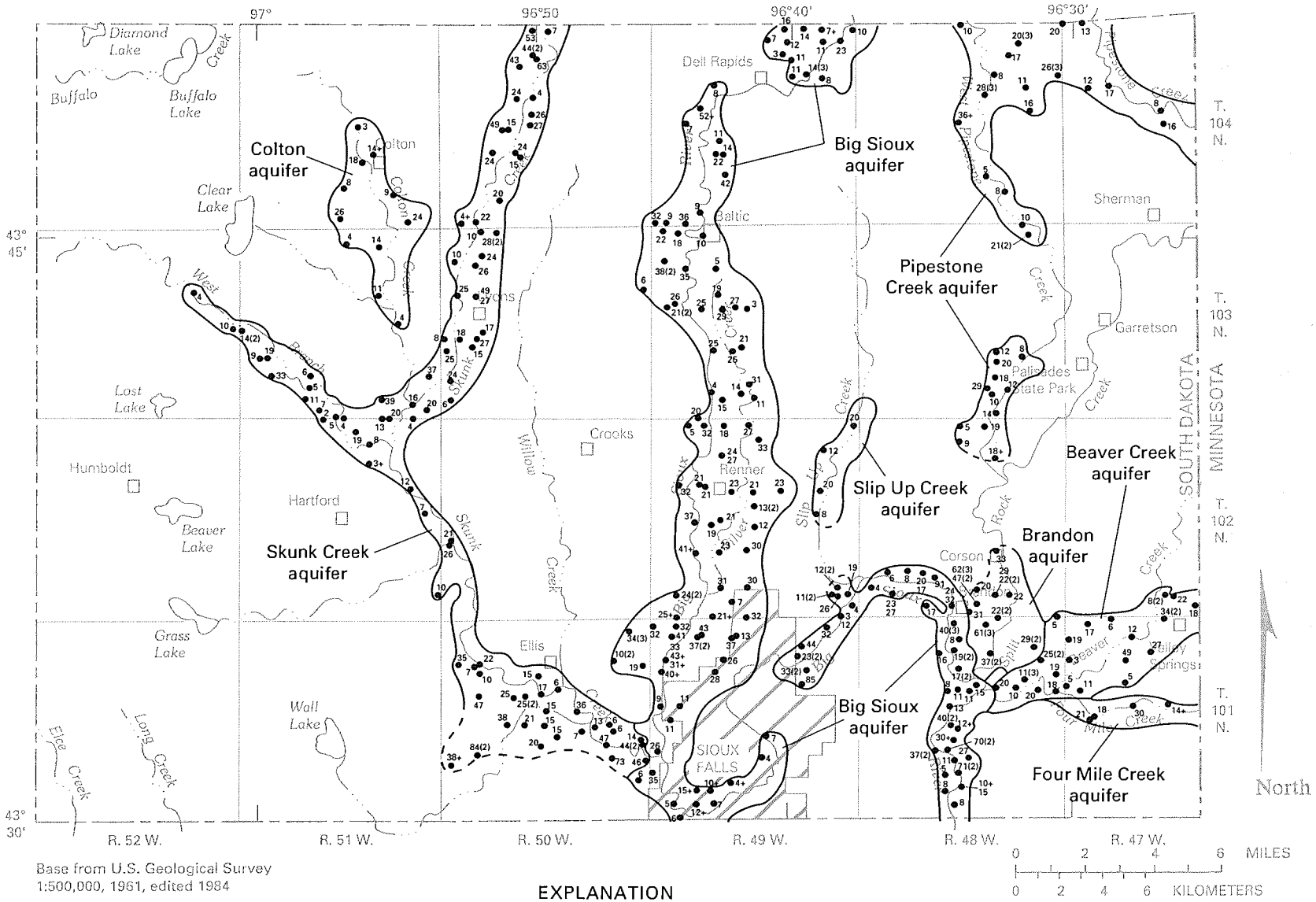
Recharge to the Big Sioux aquifer is from: (1) infiltration of precipitation in the flood plain of the Big Sioux River, (2) seepage from the Big Sioux River when river stage is higher than the water table in the aquifer because of spring snowmelt or storm events, (3) the Skunk Creek aquifer, (4) the Beaver Creek aquifer, (5) the Brandon aquifer, (6) the Split Rock Creek aquifer, (7) the Wall Lake aquifer, and (8) the Sioux Quartzite aquifer. The Big Sioux aquifer is mostly under water-table conditions. The depth to water in wells generally is less than 10 ft below land surface in the Big Sioux River flood plain and ranges from 9 to 42 ft in areas where the aquifer is overlain by till. Discharge from the Big Sioux aquifer is: (1) by evapotranspiration where the aquifer is at or near land surface, (2) by seepage to the Big Sioux River when river stage is lower than the water table in the aquifer, as is generally the case except during spring snowmelt and storm event peak flows, and (3) by pumping wells.

The predominant chemical constituents in water from the Big Sioux aquifer are calcium, sulfate, and bicarbonate. Concentrations of dissolved solids ranged from 260 to 1,540 mg/L and averaged 490 mg/L. Hardness concentrations (as $CaCO_3$) ranged from 180 to 840 mg/L and averaged 350 mg/L.

Water from the Big Sioux aquifer is used for stock watering, domestic, municipal, and irrigation purposes. The principal user of water withdrawn from the Big Sioux aquifer in Minnehaha County is the city of Sioux Falls, using about 91 percent (about 4,665 Mgal/yr) of the total water withdrawn from the aquifer.

Skunk Creek Aquifer

The Skunk Creek aquifer underlies about 40 mi^2 near Skunk and West Branch Skunk Creeks in western Minnehaha County (fig. 4). The top of the aquifer ranges from land surface in the Skunk Creek flood plain to 93 ft below land surface, south of Skunk Creek in T. 101 N., R. 50 W. where the aquifer is overlain by till. The average depth below land surface is about 9 ft. The maximum cumulative thickness is 84 ft and the average cumulative thickness is about 22 ft. The Skunk Creek aquifer ranges from a fine to coarse, poorly sorted sand and fine to medium pebble gravel to a well-sorted sand and gravel with thin (2- to 6-ft thick) interbedded silty clay layers in some areas. Properly constructed wells completed in the Skunk Creek aquifer may yield as much as 1,000 gal/min where the thickness exceeds 25 ft.



Base from U.S. Geological Survey
1:500,000, 1961, edited 1984

EXPLANATION

APPROXIMATE AQUIFER BOUNDARY
Dashed where limited data exist.

84(2) TEST HOLE - Number is thickness of sand and gravel, in feet. Number in parenthesis refers to number of layers of sand and gravel, if more than one is present. A plus (+) indicates thickness greater than shown.

Figure 4. Areal extent and thickness of the Big Sioux, Skunk Creek, Pipestone Creek, Beaver Creek, Brandon, Colton, Slip Up Creek, and Four Mile Creek aquifers.

Recharge to the Skunk Creek aquifer is from infiltration of precipitation in the flood plain of Skunk Creek and from the Wall Lake aquifer in southeastern T. 101 N., R. 50 W. Although hydraulically connected, the boundary between the Skunk Creek and Wall Lake aquifers is poorly defined. The Skunk Creek aquifer is mostly under water-table conditions. The depth to water in wells is less than 8 ft below land surface north of the confluence of Skunk Creek and West Branch Skunk Creek. South of the confluence of Skunk Creek and West Branch Skunk Creek the depth to water in wells ranges from 5 ft below land surface in the Skunk Creek flood plain to 86 ft below land surface where the aquifer is overlain by till. Discharge from the Skunk Creek aquifer is: (1) by evapotranspiration in the Skunk Creek flood plain where the aquifer is at or near land surface, (2) by seepage to Skunk Creek, (3) to the Big Sioux aquifer, and (4) to stock, domestic, and irrigation wells.

The predominant chemical constituents in water from the Skunk Creek aquifer are calcium, sulfate, and bicarbonate. Concentrations of dissolved solids ranged from 180 to 750 mg/L and averaged 460 mg/L. Hardness concentrations (as $CaCO_3$) ranged from 150 to 1,100 mg/L and averaged 407 mg/L.

Water from the Skunk Creek aquifer is used for stock watering, domestic, and irrigation purposes. About 172 Mgal of water were pumped from the Skunk Creek aquifer in 1985 for irrigation, accounting for about 75 percent of the total water use from the Skunk Creek aquifer.

Pipestone Creek Aquifer

The Pipestone Creek aquifer underlies about 20 mi^2 near Pipestone and West Pipestone Creeks in northeastern and east-central Minnehaha County (fig. 4). The top of the aquifer ranges from near land surface in the flood plains of Pipestone and West Pipestone Creeks to 52 ft below land surface in northern T. 104 N. where the aquifer is overlain by till. The average depth below land surface to the top of the aquifer is about 11 ft. The maximum cumulative thickness is greater than 36 ft and the average cumulative thickness is about 15 ft. The Pipestone Creek aquifer is composed of fine to coarse sand and fine to coarse pebble gravel with 5- to 10-ft-thick interbedded silty clay layers in the extreme northern part of the aquifer. Properly constructed wells completed in the Pipestone Creek aquifer may yield as much as 500 gal/min but typically yield less than 100 gal/min because the average thickness is only about 15 ft.

Recharge to the Pipestone Creek aquifer is from infiltration of precipitation where the aquifer is at or near land surface. The Pipestone Creek aquifer is under water-table conditions in the flood plains of Pipestone and West Pipestone Creeks and under confined conditions outside the flood plains where the aquifer is overlain by till. The depth to water in wells generally is less than 12 ft below land surface with a maximum depth to water of about 23 ft. Wells completed in the Pipestone Creek aquifer in the Pipestone Creek flood plain near the Minnehaha-Moody County line may flow during years with above-normal precipitation and during the spring months when water levels in wells are high. Discharge from the Pipestone Creek aquifer is: (1) by evapotranspiration where the aquifer is at or near land surface, (2) by seepage to Pipestone and West Pipestone Creeks, and (3) to stock and domestic wells.

The predominant chemical constituents in water from the Pipestone Creek aquifer are calcium and bicarbonate. Concentrations of dissolved solids for water from three wells completed in the

Pipestone Creek aquifer were 480, 860, and 860 mg/L. Hardness concentrations (as $CaCO_3$) from the same three wells were 370, 470, and 840 mg/L.

Water from the Pipestone Creek aquifer is used for stock watering and domestic purposes.

Beaver Creek Aquifer

The Beaver Creek aquifer underlies about 11 mi^2 near Beaver Creek in southeastern Minnehaha County (fig. 4). The top of the aquifer ranges from land surface in the Beaver Creek flood plain to 49 ft below land surface near the southern boundary, to 118 ft below land surface near the northeast boundary where the aquifer is overlain by till. The maximum cumulative thickness is 49 ft and the average cumulative thickness is about 17 ft. The Beaver Creek aquifer is composed of fine to coarse sand and fine to coarse pebble gravel. Properly constructed wells completed in the Beaver Creek aquifer may yield as much as 500 gal/min where the thickness exceeds 25 ft. Yield from wells completed in the western part of the aquifer generally are less than 300 gal/min because the thickness is less than 20 ft.

Recharge to the Beaver Creek aquifer is from infiltration of precipitation in the flood plain of Beaver Creek. The Beaver Creek aquifer is mostly under water-table conditions. The depth to water in wells ranges from 6 ft in the flood plain of Beaver Creek to 29 ft where the aquifer is overlain by till. Discharge from the Beaver Creek aquifer is: (1) by evapotranspiration where the aquifer is at or near land surface, (2) by seepage to Beaver Creek, (3) to the Big Sioux aquifer, (4) to the Brandon aquifer, and (5) to stock and domestic wells.

The predominant chemical constituents in water from the Beaver Creek aquifer are calcium and bicarbonate. Concentrations of dissolved solids for water from three wells completed in the Beaver Creek aquifer were 450, 450, and 880 mg/L. Hardness concentrations (as $CaCO_3$) for water from the same three wells were 370, 390, and 680 mg/L.

Water from the Beaver Creek aquifer is used for stock watering and domestic purposes.

Brandon Aquifer

The Brandon aquifer underlies about 6 mi^2 near Split Rock Creek in southeastern Minnehaha County (fig. 4). The top of the aquifer ranges from land surface in and west of the Split Rock Creek flood plain to 24 ft below land surface where the aquifer is overlain by till. The average depth below land surface is about 7 ft. The maximum cumulative thickness is 62 ft and the average cumulative thickness is about 35 ft. The Brandon aquifer is composed of fine to coarse, poorly sorted sand and fine to coarse pebble gravel with about 10 ft of interbedded clay layers in most areas. Properly constructed wells completed in the Brandon aquifer may yield as much as 500 gal/min where the thickness exceeds 20 ft. Yields from wells for most of the aquifer are less than 100 gal/min because the thickness is less than 20 ft.

Recharge to the Brandon aquifer is from infiltration of precipitation, from the Beaver Creek aquifer, from the underlying Split Rock Creek aquifer, and probably through fractures in the Sioux Quartzite from Sioux Quartzite outcrop areas located near the northern boundary of the Brandon

aquifer. The Brandon aquifer is mostly under water-table conditions. The depth to water in wells ranges from 11 ft in the Split Rock Creek flood plain to 39 ft east of Split Rock Creek where the aquifer is overlain by till and to 56 ft on the topographic high west of the flood plain. Discharge from the Brandon aquifer is: (1) by evapotranspiration where the aquifer is at or near land surface, (2) by seepage to Split Rock Creek, (3) to the Big Sioux aquifer, and (4) to stock, domestic, and municipal wells.

The predominant chemical constituents in water from the Brandon aquifer are calcium and bicarbonate. Concentrations of dissolved solids for water from three wells completed in the Brandon aquifer were 410, 440, and 480 mg/L. Hardness concentrations (as $CaCO_3$) for water from the same three wells were 370, 380, and 380 mg/L.

Water from the Brandon aquifer is used for stock watering, domestic, municipal, and irrigation purposes. About 83 percent of the water withdrawn from the Brandon aquifer in 1985 was used by the city of Brandon.

Colton Aquifer

The Colton aquifer underlies about 8 mi^2 near Colton Creek in northwestern Minnehaha County (fig. 4). Depth to the top of the aquifer averages about 20 ft below land surface. The maximum cumulative thickness is 26 ft in the central part of the aquifer and decreases to the north and to the south. The average cumulative thickness is about 12 ft. The Colton aquifer is composed of fine to coarse sand and fine to coarse pebble gravel. Properly constructed wells completed in the Colton aquifer may yield as much as 500 gal/min where the thickness exceeds 20 ft. Well yields typically are less than 100 gal/min, however, because the average thickness is only about 12 ft.

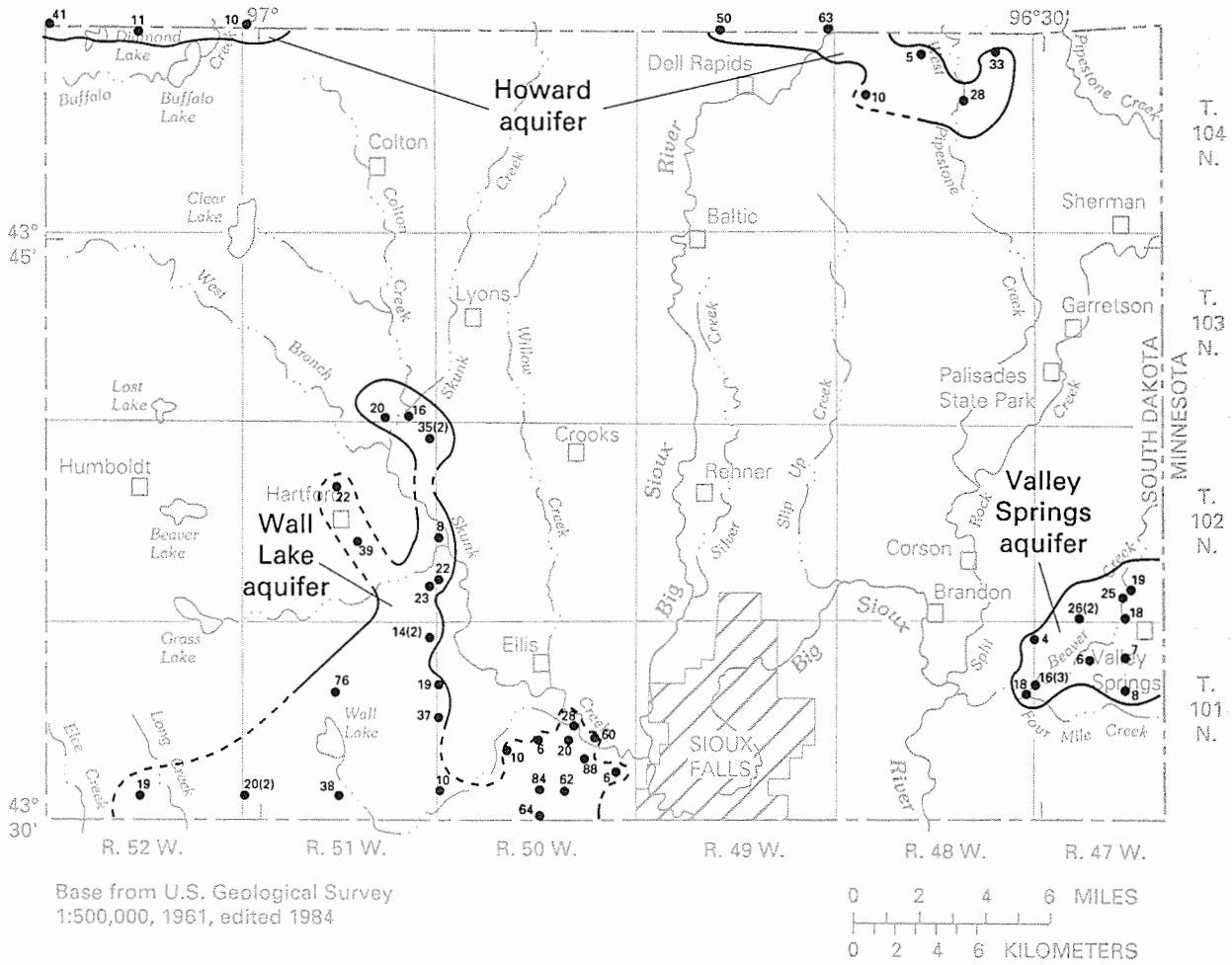
The Colton aquifer is under water-table conditions and receives recharge from infiltration of precipitation. The depth to water in wells generally is less than 10 ft below land surface with a maximum depth to water of 18 ft. Discharge from the Colton aquifer is: (1) by evapotranspiration where the aquifer is at or near land surface, (2) by seepage to Colton Creek, and (3) to stock, domestic, and municipal wells.

The predominant chemical constituents in water from the Colton aquifer are calcium, magnesium, and sulfate. Concentrations of dissolved solids ranged from 690 to 2,000 mg/L and averaged 1,100 mg/L. Hardness concentrations (as $CaCO_3$) ranged from 560 to 1,400 mg/L and averaged 810 mg/L.

Water from the Colton aquifer is used for stock watering, domestic, and municipal purposes. About 60 percent of the water withdrawn from the Colton aquifer is used by the city of Colton.

Wall Lake Aquifer

The Wall Lake aquifer underlies about 58 mi^2 in southwestern Minnehaha County (fig. 5). Because of limited data, the western boundary of the aquifer is inferred. Depth to the top of the aquifer ranges from 19 ft near Skunk Creek to 205 ft and averages about 106 ft. The maximum cumulative thickness is 88 ft and the average cumulative thickness is about 33 ft. The Wall Lake



EXPLANATION

APPROXIMATE AQUIFER BOUNDARY--Dashed where limited data exist.

20(2) TEST HOLE--Number is thickness of sand and gravel, in feet. Number in parenthesis refers to number of layers of sand and gravel, if more than one layer is present.

North

Figure 5. Areal extent and thickness of the Wall Lake, Howard, and Valley Springs aquifers.

aquifer is composed of fine to coarse, well-sorted quartzose sand and fine pebble gravel with interbedded 2- to 3-ft-thick clay layers in some areas. Properly constructed wells completed in the Wall Lake aquifer may yield as much as 500 gal/min where the thickness exceeds 50 ft. Well yields generally are less than 250 gal/min for much of the western part of the aquifer where the thickness is 25 ft or less.

Recharge to the Wall Lake aquifer probably is from infiltration of precipitation into fractures in the Sioux Quartzite near the northwestern part of the Wall Lake aquifer where the Sioux Quartzite is at or near land surface. Water subsequently moves southward from the Sioux Quartzite topographic high through fractures in the Sioux Quartzite and then into the directly overlying Wall Lake aquifer. The Wall Lake aquifer is mostly under confined conditions. The depth to water in wells ranges from 9 ft below land surface near Skunk Creek in the eastern part of the aquifer to 156 ft below land surface in the western part and exceeds 75 ft below land surface for most of the aquifer. Discharge from the Wall Lake aquifer is to: (1) the Big Sioux aquifer near the confluence of Skunk Creek and the Big Sioux River, (2) the Skunk Creek aquifer, and (3) stock and domestic wells.

The predominant chemical constituents in water from the Wall Lake aquifer generally are calcium and sulfate. Concentrations of dissolved solids ranged from 420 to 1,500 mg/L and averaged 1,010 mg/L. Hardness concentrations (as $CaCO_3$) ranged from 340 to 1,000 mg/L and averaged 660 mg/L.

Water from the Wall Lake aquifer is used for stock watering and domestic purposes.

Howard Aquifer

The Howard aquifer underlies about 15 mi^2 in extreme northeast and northwest Minnehaha County (fig. 5). Because of limited data, the areal extent of the aquifer in the northeast is inferred. The main body of the aquifer is to the north in Lake and Moody Counties. Depth to the top of the aquifer in Minnehaha County ranges from 123 to 265 ft and averages 202 ft. The maximum cumulative thickness is 63 ft and the average cumulative thickness is about 28 ft. The Howard aquifer is composed of fine to coarse sand and fine to medium pebble gravel. Yield from properly constructed wells completed in the Howard aquifer may be as much as 500 gal/min in the extreme northeast part of the aquifer but generally is less than 100 gal/min.

There is no known source of recharge to the Howard aquifer in Minnehaha County. The Howard aquifer is overlain by the Pipestone Creek aquifer in the Pipestone Creek flood plain in the northeast part of the aquifer in Minnehaha County. However, the two aquifers are separated by more than 75 ft of till. In northeastern Minnehaha County, the Howard aquifer is separated from the Split Rock Creek aquifer by 35 to 50 ft of till. The recharge area for the Howard aquifer probably is located to the north of the study area. The Howard aquifer is under confined conditions in Minnehaha County. The depth to water in wells ranges from 6 to 49 ft below land surface in northeastern Minnehaha County and from 99 to 146 ft below land surface in northwestern Minnehaha County. Discharge from the Howard aquifer in Minnehaha County is: (1) to fractures in the Sioux Quartzite and to the Dell Rapids quarry and (2) to stock and domestic wells.

The predominant chemical constituents in water from one well completed in the Howard aquifer in Minnehaha County were calcium and bicarbonate. Concentrations of dissolved solids and hardness (as $CaCO_3$) from one sample from this well were 470 and 310 mg/L, respectively.

Water from the Howard aquifer is used for stock-watering and domestic purposes.

Valley Springs Aquifer

The Valley Springs aquifer underlies about 14 mi^2 near the city of Valley Springs in southeastern Minnehaha County (fig. 5). Depth to the top of the aquifer ranges from 93 ft in the Beaver Creek flood plain to 207 ft, south of the Beaver Creek flood plain near the South Dakota-Minnesota State line. The average depth below land surface is about 131 ft. The maximum cumulative thickness is 26 ft and the average cumulative thickness is about 15 ft. The Valley Springs aquifer is composed of fine to coarse sand and fine to medium pebble gravel with layers of interbedded silty clay and till 5 to 10 ft thick in some areas. Yield from properly constructed wells completed in the Valley Springs aquifer may be as much as 200 gal/min in the northern part of the aquifer but generally is less than 10 gal/min in the south-central part where the thickness is less than 10 ft.

There is no known source of recharge to the Valley Springs aquifer in Minnehaha County. The Valley Springs aquifer is overlain by the Beaver Creek aquifer in the Beaver Creek flood plain but the two aquifers are separated by about 50 ft of till. The recharge area for the Valley Springs aquifer probably is located to the east of the study area in Minnesota. The Valley Springs aquifer is under confined conditions. The depth to water in wells ranges from about 20 to 147 ft below land surface, generally increasing in depth from the western to the eastern part of the aquifer. Discharge from the Valley Springs aquifer is to stock, domestic, and municipal wells and possibly to the Split Rock Creek aquifer. The layer of siltstones and shales separating the Valley Springs aquifer from the underlying sand of the Split Rock Creek aquifer ranges in thickness from 7 ft near the southwestern boundary of the Valley Springs aquifer to about 200 ft near the South Dakota-Minnesota State line. These siltstones and shales are often fractured and downward leakage of water from the Valley Springs aquifer to the Split Rock Creek aquifer may occur, particularly near the southwestern boundary of the Valley Springs aquifer where the layer of siltstones and shales is thinnest.

The predominant chemical constituents in water from the Valley Springs aquifer are calcium and bicarbonate. Concentrations of dissolved solids ranged from 450 to 920 mg/L and averaged 620 mg/L. Hardness concentrations (as $CaCO_3$) ranged from 320 to 640 mg/L and averaged 440 mg/L.

Water from the Valley Springs aquifer is used for stock watering, domestic, and municipal purposes. About 90 percent of the water withdrawn from the Valley Springs aquifer is used by the city of Valley Springs.

Minor Glacial Aquifers

The Slip Up Creek and Four Mile Creek aquifers are classified as minor aquifers in Minnehaha County (fig. 4). The sand and gravel deposits are present underlying the flood plains of Slip Up and Four Mile Creeks. The deposits are small in areal extent, less than 5 mi^2, with cumulative thicknesses generally of less than 20 ft.

There also are a few small areas of outwash about 1 mi^2 or less in areal extent near the city of Garretson (Hilton and Barari, in preparation) and underlying the flood plain of Split Rock Creek near the city of Sherman. These areas are not illustrated due to their limited area extent.

BEDROCK AQUIFERS

The major bedrock aquifers in Minnehaha County are the Split Rock Creek and Sioux Quartzite aquifers. During Cretaceous time, the Precambrian Sioux Quartzite was a topographic high and subject to erosion. Either wave action or streams reworked sediment from the weathered quartzite and deposited the Split Rock Creek Formation in valleys cut into Sioux Quartzite. Within the Split Rock Creek Formation is the Split Rock Creek aquifer (composed of layers of predominantly quartz sand interbedded with layers of siltstone, shale, and silty clay). The Sioux Quartzite is extensively used as a source of water in areas where neither glacial aquifers nor the Split Rock Creek aquifer is present, which includes most of western and east-central Minnehaha County.

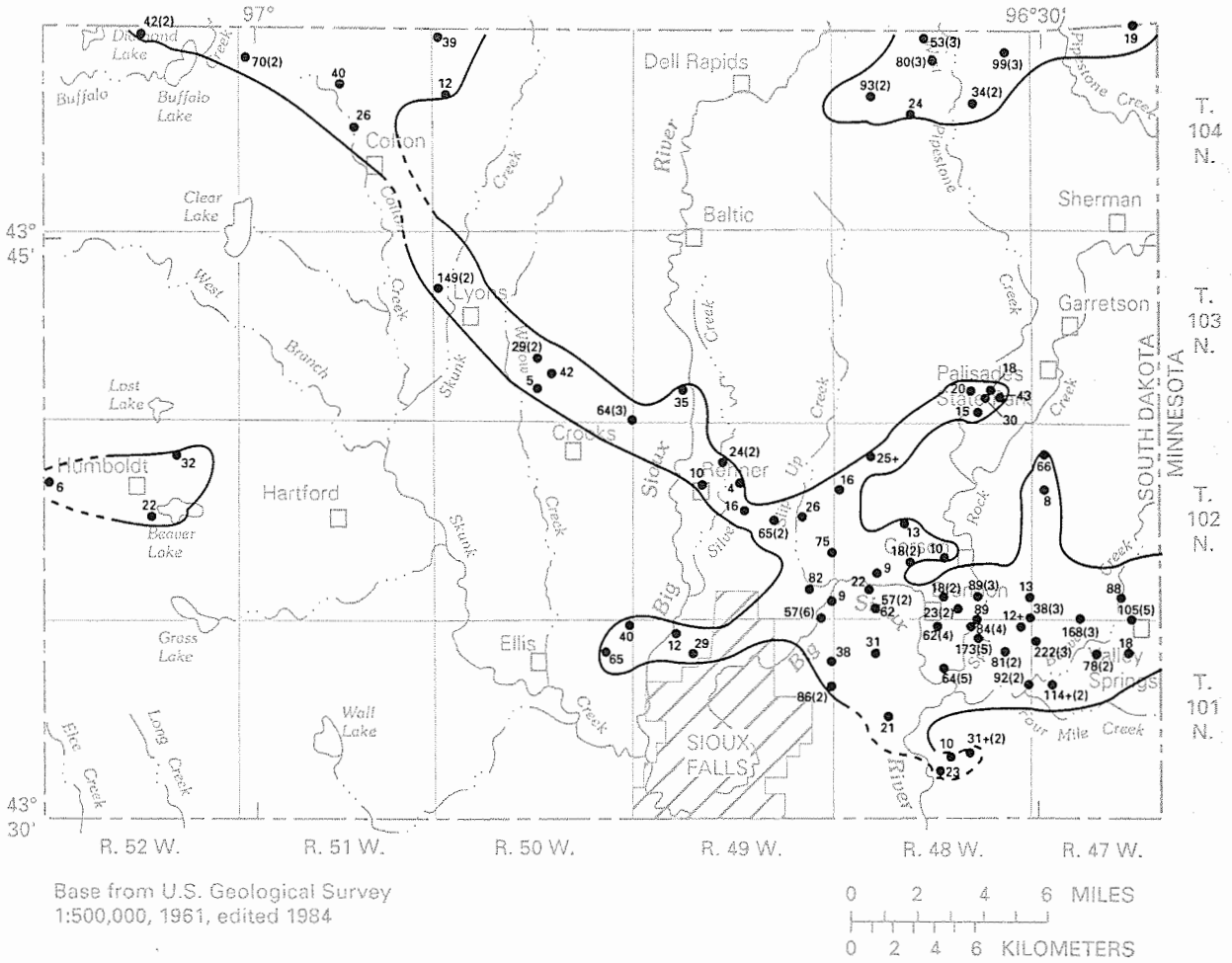
Split Rock Creek Aquifer

The Split Rock Creek aquifer underlies about 145 mi^2 in Minnehaha County, predominantly in the southeastern part of the county (fig. 6). Depth to the top of the aquifer ranges from 21 ft in T. 103 N., R. 48 W. to 337 ft near the Minnehaha-Lake County line. The maximum cumulative thickness of the sand and gravel (predominantly sand) layers of the Split Rock Creek aquifer is 222 ft and the average cumulative thickness is about 48 ft. The Split Rock Creek aquifer is composed predominantly of 1 to 5 layers of fine to coarse well-sorted quartzose sand interbedded with 4- to 45-ft-thick layers of siltstone, shale, and claystone. Properly constructed wells may yield as much as 500 gal/min where the cumulative thickness exceeds 75 ft, but yields usually are much less because of smaller thicknesses, interbedded layers of silt and clay, and cementation of the sand grains.

Recharge to the Split Rock Creek aquifer probably is from infiltration of precipitation that falls on Sioux Quartzite outcrops and subsequently moves along fractures in the quartzite and into the Split Rock Creek aquifer. Sioux Quartzite outcrops occur to the north, south, and west of the aquifer in southeastern Minnehaha County. The aquifer may also receive recharge from the Valley Springs aquifer. The Split Rock Creek aquifer is mostly under confined conditions. Water levels in wells range from 10 ft above to 187 ft below land surface. Wells completed in the Split Rock Creek aquifer in the Big Sioux River flood plain in the southwestern part of T. 102 N., R. 48 W. flow most of the time. The depth to water in the majority of wells completed in the Split Rock Creek aquifer is 50 to 100 ft below land surface. Discharge from the Split Rock Creek aquifer is: (1) to the Big Sioux aquifer in northern T. 101 N., R. 48 W., southern T. 102 N., R. 48 W., and southeastern T. 102 N., R. 49 W, (2) to the Brandon aquifer, and (3) to stock, domestic, and municipal wells.

The predominant chemical constituents in water from the Split Rock Creek aquifer are calcium and sulfate. Concentrations of dissolved solids ranged from 230 to 2,300 mg/L and averaged 890 mg/L. Hardness concentrations (as $CaCO_3$) ranged from 180 to 1,700 mg/L and averaged 620 mg/L.

Water from the Split Rock Creek aquifer is used for stock watering and domestic purposes. The city of Brandon has a municipal well completed in the aquifer.



EXPLANATION

APPROXIMATE AQUIFER BOUNDARY--Dashed where limited data exist.

114+(2) TEST HOLE--Number is thickness of sand and gravel, in feet. Number in parenthesis refers to number of layers of sand and gravel, if more than one layer is present. A plus (+) indicates thickness greater than shown.

North

Figure 6. Areal extent and thickness of the Split Rock Creek aquifer.

Sioux Quartzite Aquifer

The Sioux Quartzite aquifer underlies all of Minnehaha County. An altitude map of the top of the Sioux Quartzite surface is shown in figure 7. The Sioux Quartzite is a locally well-fractured and jointed rock that will yield water to wells in amounts sufficient for domestic and municipal supplies. The aquifer is utilized extensively as a source of water in western and east-central Minnehaha County. In some places, the Sioux Quartzite is directly overlain by a discontinuous layer of fine to coarse, well-sorted quartzose sand that is derived from weathering of the Sioux Quartzite. The depth and development of the fracture system in the Sioux Quartzite is unknown. Water-supply wells commonly penetrate the quartzite to a depth of 200 ft or less. The top of the Sioux Quartzite surface ranges from at or near land surface to 510 ft below land surface, often with large changes in depth in a short distance. Reported yields from properly constructed wells completed in the Sioux Quartzite aquifer are as much as 150 gal/min but generally are less than 50 gal/min. The yield to wells depends on the extent of the local fracturing and interconnection of fractures in the Sioux Quartzite.

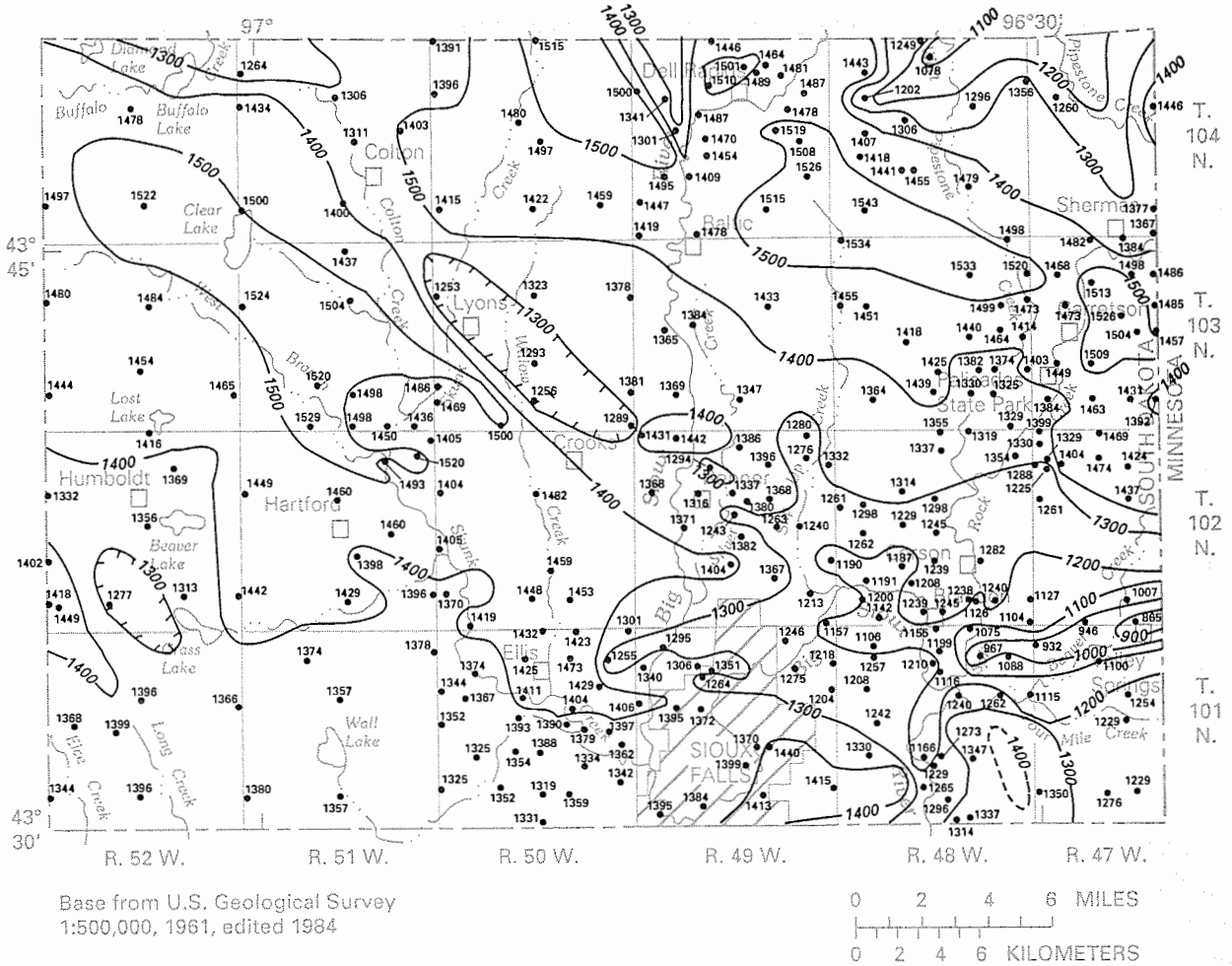
Recharge to the Sioux Quartzite aquifer is from infiltration of snowmelt and rainfall in areas where the Sioux Quartzite is at or near land surface. Split Rock Creek probably is also a source of recharge to the Sioux Quartzite aquifer in Palisades State Park and in some areas to the south where water in the creek flows directly over the quartzite surface. The Sioux Quartzite aquifer is under water-table conditions near the Sioux Quartzite outcrop areas and generally is under confined conditions elsewhere in Minnehaha County. The depth to water in wells ranges from land surface at the outcrop areas to 300 ft below land surface in west-central Minnehaha County. Discharge from the Sioux Quartzite aquifer is to: (1) the Big Sioux aquifer in northern T. 104 N. and southern T. 101 N., R. 48 W., (2) the Brandon aquifer, (3) the Wall Lake aquifer, (4) the Split Rock Creek aquifer, and (5) stock-watering, domestic, and municipal wells.

The predominant chemical constituents in water from the Sioux Quartzite aquifer are calcium and sulfate. Concentrations of dissolved solids ranged from 320 to 3,300 mg/L and averaged 1,030 mg/L. Hardness concentrations (as $CaCO_3$) ranged from 280 to 3,000 mg/L and averaged 820 mg/L.

Water from the Sioux Quartzite aquifer is used for stock watering, domestic, and municipal purposes. About 48 percent of the water withdrawn from the Sioux Quartzite aquifer is used for rural domestic purposes and about 28 percent is used by municipalities.

LARGE-CAPACITY WELLS

The best possibilities for developing large-capacity wells capable of supplying more than 500 gal/min are in the areas where the aquifers are composed of coarse sand and gravel and are more than 20 ft thick. Before supply wells are constructed, test holes often are drilled to determine the thickness of the aquifer and to provide samples for determining the grain size of the aquifer material. This information helps in the selection of the proper slot size and length of screen to be used in the construction of a well. Controlled pumping of the well during an aquifer test helps to indicate the yield of the aquifer at that locality and provides a representative water sample for chemical analysis. Measurement of the recovery of water level in the well provides information that is useful for estimating the yield of a well during longer pumping periods. If the well is to be used for irrigation, knowledge of the type of soil, subsoil, and topography are also important in selecting the most



EXPLANATION

1200 ----- STRUCTURE CONTOUR--Shows altitude of the top of the Sioux Quartzite surface. Dashed where limited data exist. Contour interval, 100 feet. Datum is sea level.

1380 TEST HOLE--Number is altitude of the top of the Sioux Quartzite surface, in feet. Datum is sea level.

North

Figure 7. Altitude and configuration of the top of the Sioux Quartzite surface.

suitable irrigation system. Increased ground-water development, especially in stream valleys, may cause a decrease in streamflow.

WATER USE

Surface water in Minnehaha County is used predominantly for stock-watering and irrigation purposes. Total surface-water use in Minnehaha County in 1985 was about 416 Mgal. About 60 percent of the total was for stock-watering purposes and about 40 percent was for irrigation.

Water use from glacial and bedrock aquifers in Minnehaha County in 1985 was estimated to be about 5.87 Bgal. About 94 percent of the water used was withdrawn from glacial aquifers and about 6 percent of the water used was withdrawn from bedrock aquifers. Eighty-five percent of the water withdrawn from the aquifers in Minnehaha County was used for municipal purposes and 94 percent of the water withdrawn for municipal purposes was used by the city of Sioux Falls. About 347 Mgal (6 percent of the estimated 1985 water use) of water were withdrawn from the Big Sioux, Skunk Creek, and Brandon aquifers in 1985 for irrigation purposes. About 35 percent of the water withdrawn from the aquifers for rural domestic purposes was withdrawn from the Sioux Quartzite aquifer.

SUMMARY

The nine major glacial aquifers in Minnehaha County are composed primarily of unconsolidated sand and gravel deposited as outwash and contain about 735,000 acre-ft of water in storage. The Big Sioux, Skunk Creek, Pipestone Creek, Beaver Creek, Brandon, and Colton aquifers are predominantly shallow, water-table aquifers with average cumulative thicknesses ranging from about 12 to 22 ft for the Big Sioux, Skunk Creek, Pipestone Creek, Beaver Creek, and Colton aquifers to about 35 ft for the Brandon aquifer. Estimated maximum well yields are about 1,000 gal/min for the Big Sioux and Skunk Creek aquifers and about 500 gal/min for the Pipestone Creek, Beaver Creek, Brandon, and Colton aquifers.

The predominant chemical constituents in water from the Big Sioux and Skunk Creek aquifers are calcium, sulfate, and bicarbonate; from the Colton aquifer are calcium, magnesium, and sulfate; and from the Pipestone Creek, Beaver Creek, and Brandon aquifers are calcium and bicarbonate. The average dissolved-solids concentrations ranged from 443 to 1,100 mg/L, and the average hardness concentrations (as $CaCO_3$) ranged from 350 to 810 mg/L in these aquifers.

The Wall Lake, Howard, and Valley Springs aquifers are buried, predominantly confined aquifers overlain by 19 to 265 ft of till with average cumulative thicknesses of about 33, 28, and 15 ft, respectively. Estimated maximum well yields are about 500 gal/min for the Wall Lake and Howard aquifers and about 200 gal/min for the Valley Springs aquifer. The predominant chemical constituents in water from the Wall Lake aquifer are calcium and sulfate and in water from the Howard and Valley Springs aquifers are calcium and bicarbonate. Concentrations of dissolved solids and hardness (as $CaCO_3$) averaged 1,010 and 660 mg/L, respectively, for the Wall Lake aquifer, and 620 and 440 mg/L, respectively, for the Valley Springs aquifer. Concentrations of dissolved solids and hardness (as $CaCO_3$) for one sample from the Howard aquifer were 470 and 310 mg/L, respectively.

The two major bedrock aquifers present in Minnehaha County are the Split Rock Creek and Sioux Quartzite aquifers. The Split Rock Creek aquifer is composed of layers of predominantly quartz sand interbedded with layers of siltstone, shale, and claystone. The Split Rock Creek aquifer contains about 890,000 acre-ft of water in storage with an average cumulative thickness of sand and gravel layers of about 48 ft. The Sioux Quartzite is a locally well-fractured and jointed rock that is extensively utilized as a source of water in western and east-central Minnehaha County. The amount of water contained in storage in the Sioux Quartzite aquifer is unknown because the depth and development of the fracture system is not well know. Estimated maximum well yields are about 500 gal/min for the Split Rock Creek aquifer and about 150 gal/min for the Sioux Quartzite aquifer. The predominant chemical constituents in water from the Split Rock Creek and Sioux Quartzite aquifers are calcium and sulfate. Concentrations of dissolved solids and hardness (as $CaCO_3$) averaged 890 and 620 mg/L, respectively, for the Split Rock Creek aquifer and 1,030 and 820 mg/L, respectively, for the Sioux Quartzite aquifer.

Ground-water use from glacial and bedrock aquifers in Minnehaha County in 1985 was estimated to be about 5.87 Bgal. Ninety-four percent of the water used was withdrawn from glacial aquifers and 6 percent of the water used was withdrawn from bedrock aquifers. Eighty-five percent of the water withdrawn from the aquifers in Minnehaha County was used for municipal purposes.

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