WATER RESOURCES OF CODINGTON AND GRANT COUNTIES, SOUTH DAKOTA

By Donald S. Hansen

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CONVERSION FACTORS

For readers who may prefer to use metric (International System) units rather than inch-pound units, the conversion factors for the terms in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon per minute (gal/min)	0.06309	liter per second
inch	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second
square mile (mi^2)	2.590	square kilometer

Sea level: In this report "sea level" refers to the 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 Sea Level Datum of 1929.

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ABSTRACT

The primary sources of surface water in Codington and Grant Counties are Lakes Kampeska and Pelican and numerous potholes and sloughs in western Codington County. Seasonal variations in streamflow and lake levels are directly related to seasonal variation in precipitation and evapotranspiration. Long-term lake-level fluctuations indicate correlation with departure from normal precipitation. Dissolved-solids concentrations in water from streams and lakes increase as stream discharge decreases and lake levels decline.

Seven glacial aquifers and two bedrock aquifers were delineated in Codington and Grant Counties. The areal extent of the glacial aquifers was determined to be 30 square miles for the Antelope Valley aquifer; 140 to 190 square miles for the Lonesome Lake, Big Sioux, and Revillo aquifers; 260 square miles for the Veblen aquifer; 760 square miles for the Prairie Coteau aquifer; and 840 square miles for the Altamont aquifer.

The average thickness of the glacial aquifers ranges from 21 to 63 feet. Recharge to glacial aquifers is from direct infiltration and subsequent percolation of precipitation mostly in the spring and early summer and by leakage from till. The Big Sioux and Antelope Valley aquifers generally are less than 10 feet below land surface, the Veblen aquifer averages about 52 feet below land surface, the Prairie Coteau aquifer averages 138 feet below land surface, the Lonesome Lake aquifer averages 270 feet below land surface, the Revillo aquifer averages 295 feet below land surface, and the Altamont aquifer averages 460 feet below land surface. The buried aquifers are overlaid and underlaid by till except for the Revillo and Altamont aquifers which, in most locations, lie on shale bedrock.

Discharge from glacial aquifers is by evapotranspiration where the aquifers are close to land surface; by withdrawals from domestic, stock-watering, irrigation, and municipal wells; and by outflow to nearby streams and lakes. Reported well yields are the largest (800 gallons per minute or more) from the Big Sioux, Antelope Valley, and Prairie Coteau aquifers.

Predominant chemical constituents are calcium and bicarbonate in water from the Big Sioux, Antelope Valley, Prairie Coteau, Veblen, Revillo, and Lonesome Lake aquifers. Significant concentrations of sulfate also are present in water from the Veblen and Revillo aquifers. Sodium and sulfate are predominant in water from the Altamont aquifer. Average dissolved-solids concentrations in water from the aquifers range from 350 to 2,120 milligrams per liter.

The two bedrock aquifers delineated are the Dakota and granite wash. The Dakota aquifer is at about 1,230 feet below land surface and the water level has declined 10 feet from 1958-85. Predominant chemical constituents in water from the Dakota aquifer are sodium and sulfate. The water has a dissolved-solids concentration of 1,480 milligrams per liter. The granite

wash aquifer is limited to eastern Grant County and has an average thickness of 37 feet. Predominant chemical constituents in water from the granite wash aquifer are sodium and sulfate.

The average annual water use in Codington and Grant Counties is 18.34 million gallons per day. Seventeen percent of the water used is for irrigation.

INTRODUCTION

Codington and Grant Counties encompass 1,415 mi^2 of northeastern South Dakota. Codington County and western Grant County are within the Coteau des Prairies, a highland plateau between the Minnesota River lowland to the east and the James River lowland to the west (fig. 1). Eastern Grant County lies in the western part of the Minnesota River lowland. Land-surface altitudes range from 970 ft in northeast Grant County to 2,015 ft above sea level on the crest of the coteau in northern Codington County.

Previous water-resource studies within the Big Sioux River basin were designed for a specific purpose and were completed as county water-resource investigations, ground-water simulation studies, or city water-supply studies. The studies never were intended to assess hydrologic conditions and evaluate the water-supply potential of the entire basin. As a result, water development has occurred at a rapid rate in some areas of the basin while, in other areas, development has proceeded much more slowly.

The Big Sioux basin hydrologic study, which started in 1982, is a 7-year comprehensive investigation of the water-resources of Codington, Grant, Minnehaha, Lincoln, and Union Counties to develop a hydrologic data base and subsequently to develop digital models of the Big Sioux aquifer. This report is the result of a 4-year water-resources investigation of Codington and Grant Counties.

Purpose and Scope

This report describes the results of a hydrogeologic study in Codington and Grant Counties. The study included test drilling through the glacial drift to bedrock, installation of observation wells, measurement of water levels, and chemical analysis of ground water. Figure 2 shows the test-hole and geologic-section locations and observation-well and water-quality sampling sites in Codington and Grant Counties. The wells and test holes are numbered according to the Federal land survey system (fig. 3).

This report describes: (1) The surface-water resources; (2) the extent of the major glacial outwash and bedrock aquifers; (3) the recharge to, movement, and discharge from the major glacial aquifers; and (4) the quality of the surface and ground water in Codington and Grant Counties.

Acknowledgments

The author would like to acknowledge the cooperation of residents of Codington and Grant Counties for providing information on their water wells, and of the local drilling companies for supplying test-hole information.

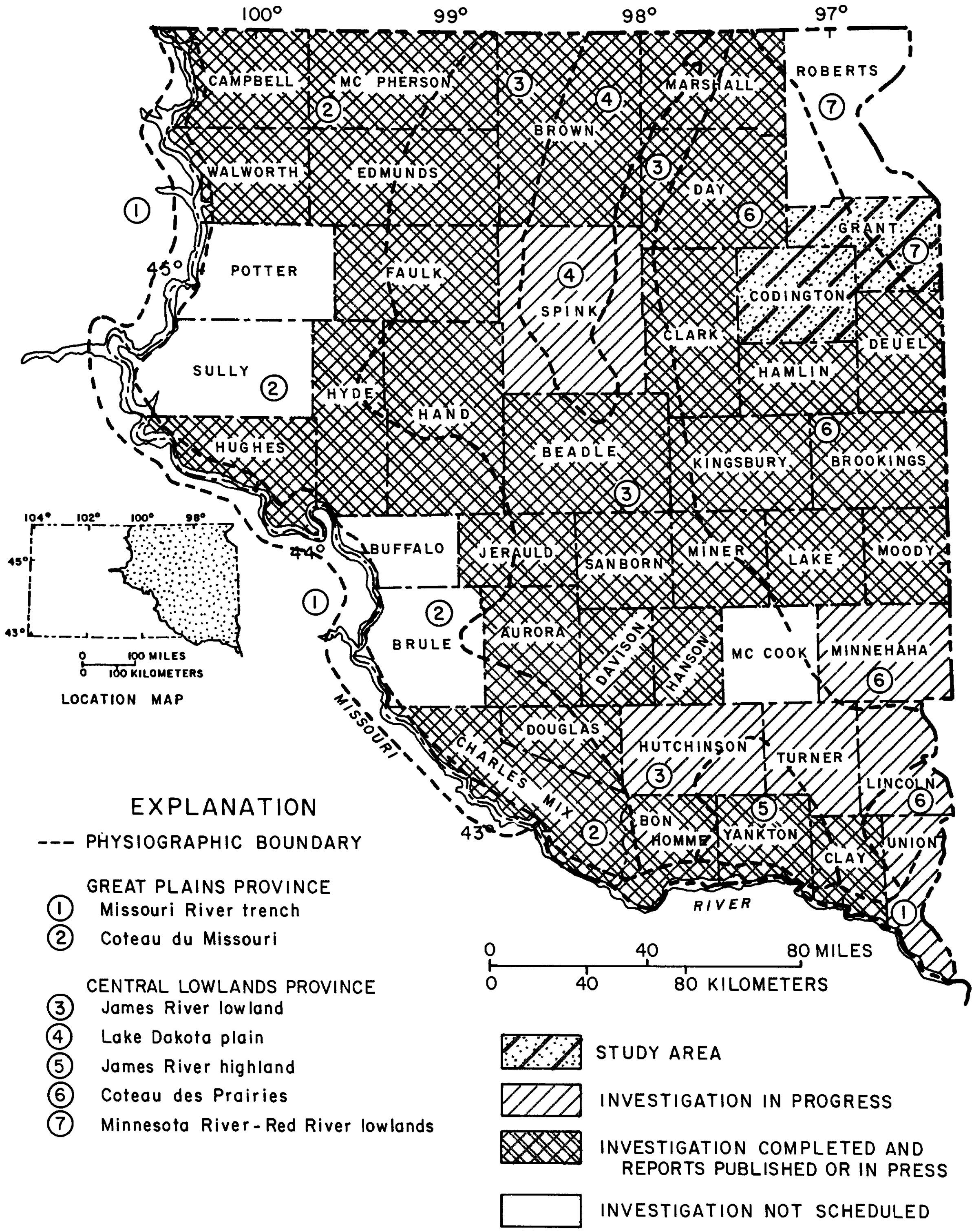


Figure 1.--Index map of eastern South Dakota showing area of this report, status of county investigations, and major physiographic divisions.

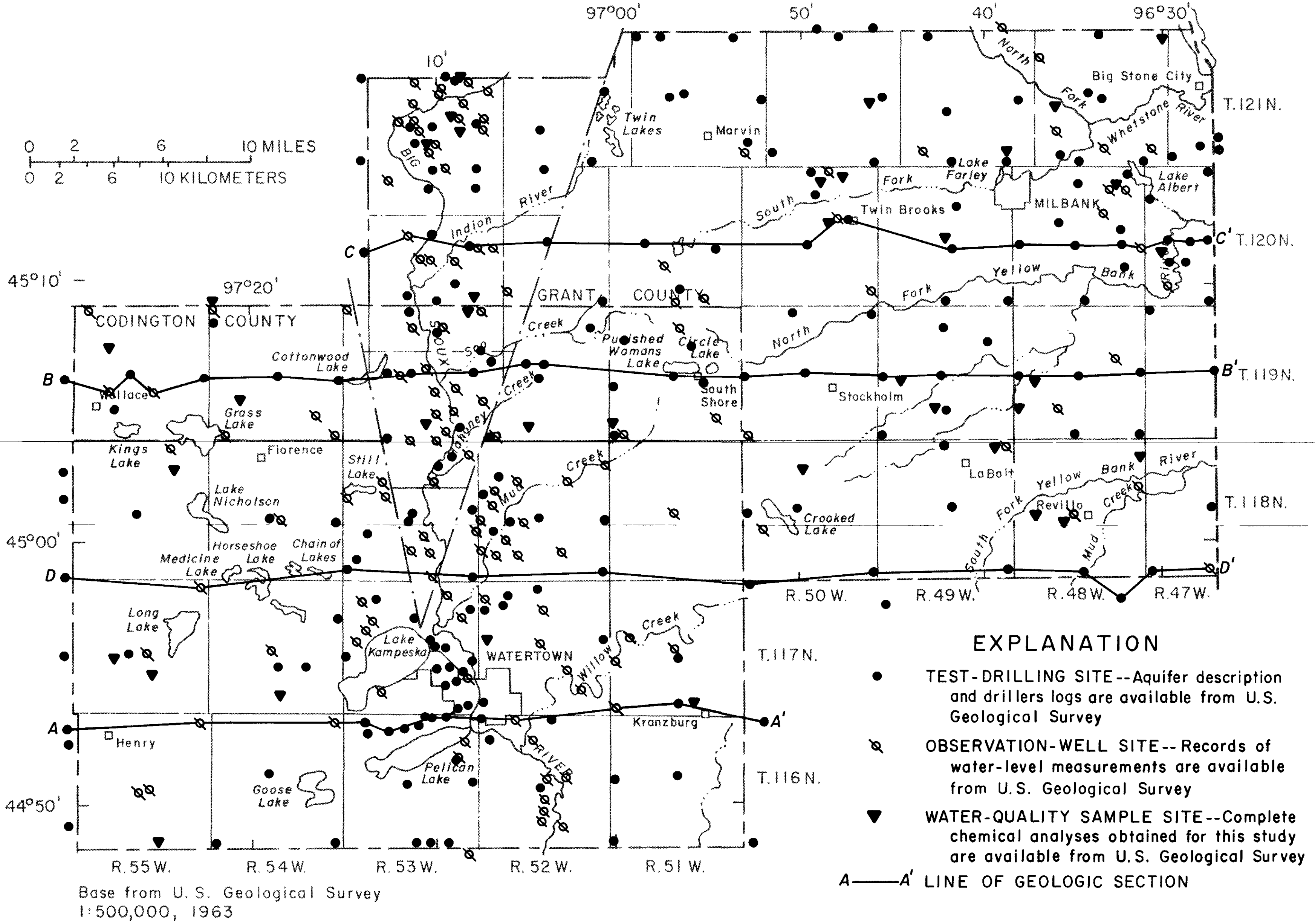


Figure 2.--Location of data sites and geologic sections in Codington and Grant Counties.

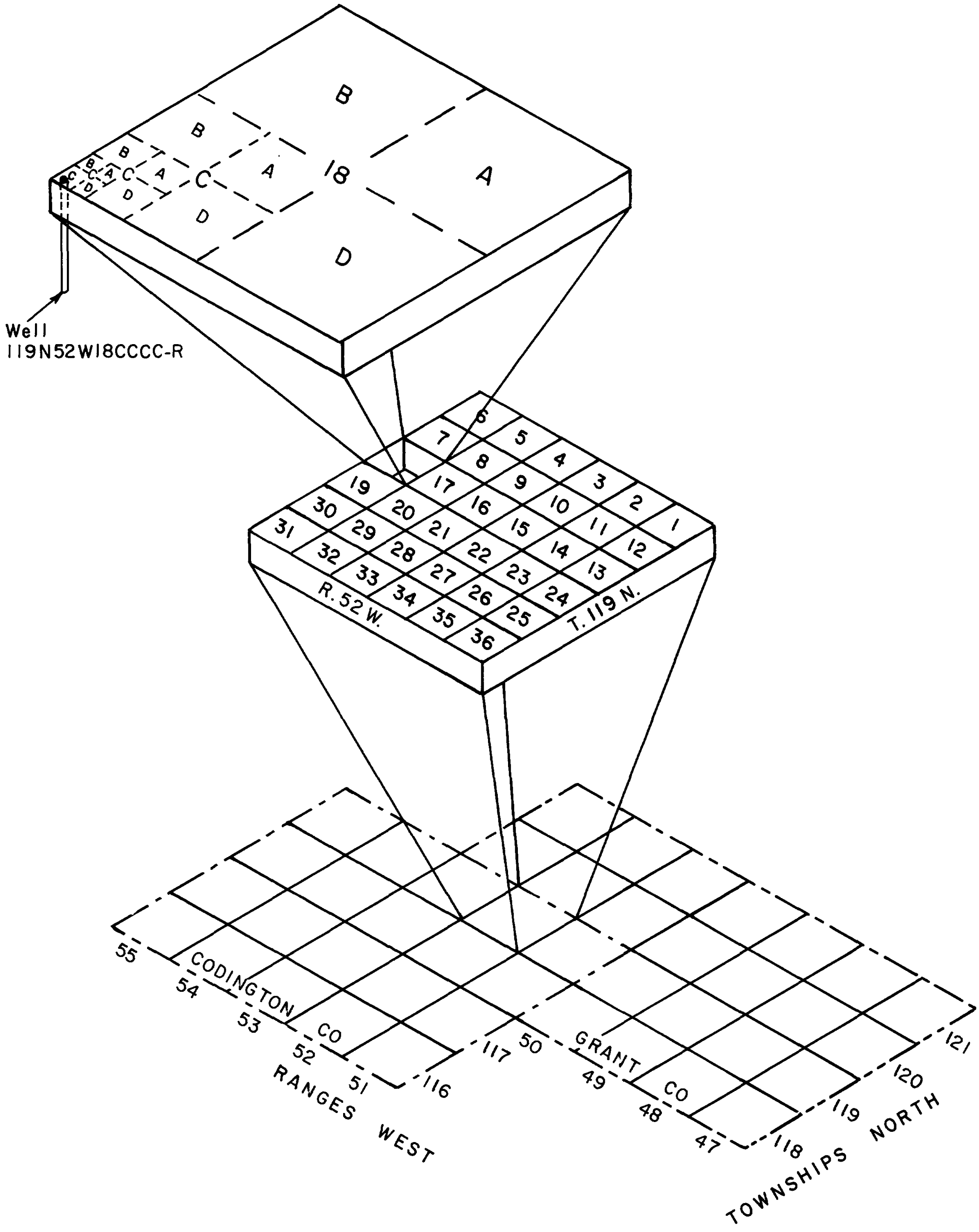


Figure 3.--Well-numbering diagram. The well number consists of township followed by "N," range followed by "W," and section number, followed by a maximum of four uppercase letters that indicate, respectively, the 160-, 40-, 10-, and 2½-acre tract in which the well is located. These letters are assigned 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. The last letter "R" in well designation denotes that the well is located on the Sisseton Indian Reservation.

WATER RESOURCES

The average annual precipitation at Watertown from 1951-80 was 22.3 inches (U.S. National Oceanic and Atmospheric Administration, 1987). About 75 to 85 percent of the precipitation is returned to the atmosphere by evaporation and transpiration. About 5 percent of the average annual precipitation becomes streamflow; however, this quantity may vary from year to year because of climatic variations. Ten to 20 percent of the precipitation percolates through the root zone to become ground water. In a given year, the water budget shows a change in ground-water storage that can be detected by, and calculated from, water-level changes in observation wells in the aquifers. The long-term (greater than 10 years) changes in storage are small, unless ground-water discharge to wells increases.

Drainage in eastern Codington and western Grant Counties (fig. 4) is primarily by the Big Sioux River and its tributaries. Western Codington County is poorly drained, is characterized by numerous closed-basin lakes that do not have an outlet, and is a noncontributing part of the Big Sioux River drainage basin. Drainage in eastern Grant County is well developed and consists of the North and South Forks of the Whetstone and Yellow Bank Rivers. These rivers drain into the Minnesota River. The drainage divide between the Minnesota and Big Sioux River basins is located in extreme northeastern Codington and western Grant Counties (Amundson and others, 1985). This area is characterized by numerous small lakes and potholes.

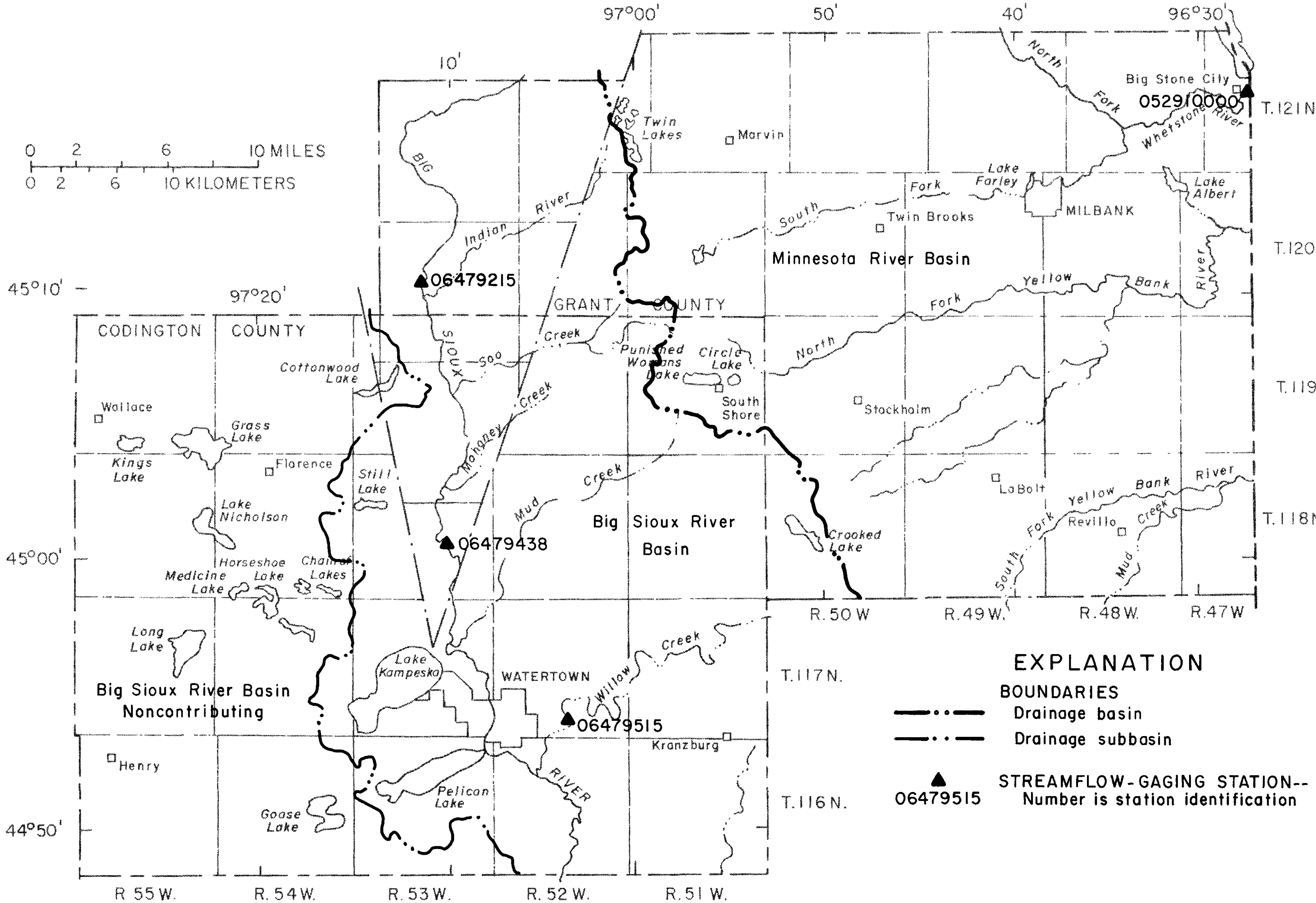
Surface Water

Streamflow

Streamflow depends on seasonal variations in precipitation, evapotranspiration, and ground-water storage. Rivers and creeks generally flow during spring and early summer because of snowmelt and rainfall runoff and because of peak storage in aquifers. Creeks and the upper reaches of the Big Sioux River in Grant County generally do not flow during late fall and winter because of: (1) Decreased runoff; (2) decreased ground-water discharge; (3) evaporation; and (4) ice formation. During years of above-normal precipitation, Willow Creek and the North and South Forks of the Whetstone and Yellow Bank Rivers may not go dry during late fall and winter. Under normal precipitation conditions, the Big Sioux River may receive 15 to 25 ft^3/s from ground water between the Grant-Roberts County line and the streamflow-gaging station on the Big Sioux River near Castlewood, located 5 mi south of the Codington-Hamlin County line. A summary of data for streamflow-gaging stations within the study area is given in table 1.

Specific conductance of water from rivers and streams varies with the volume of streamflow. Specific conductance generally decreases as stream discharge increases because of dilution from snowmelt and rainfall runoff. The observed specific conductance of water from the Big Sioux River near Watertown decreased from 650 $\mu S/cm$ (microsiemens per centimeter at 25 °Celsius) when the instantaneous discharge was 12 ft^3/s in October 1985 to 260 $\mu S/cm$ when the instantaneous discharge was 2,140 ft^3/s in March 1986.

Flooding in Grant County is unlikely because of the well-developed drainage. Valley bottoms and areas of internal drainage in western Codington County are flooded almost every year because of snowmelt and rainfall runoff. Maps of flood-prone areas adjacent to the Big Sioux River have been prepared and are available from the U.S. Geological Survey, Huron, South Dakota 57350. The flood-prone areas, shown on topographic maps at a scale of 2.5 inches to the mile, are areas that have about a 1 in 100 chance, on the average, of being inundated during any year.



Base from U.S. Geological Survey
1:500,000, 1963

Figure 4.--Drainage basins and U.S. Geological Survey streamflow-gaging stations in Codington and Grant Counties.

Table 1.--Summary of data for streamflow-gaging stations in Codington and Grant Counties

[--, not computed]

Station no.	Station name	Contributing drainage area (square miles)	Period of record (water years)	Discharge (cubic feet per second) Maximum instantaneous	Minimum daily	Average
06479215	Big Sioux River near Florence, S. Dak.[1]	67.9	1984-85	268	0	--
06479438	Big Sioux River near Watertown, S. Dak.	228	1972-85	3,720	0	21.3
06479515	Willow Creek near Watertown, S. Dak.	110	1971-85	4,040	0	15.2
05291000	Whetstone River near Big Stone City, S. Dak.	389	1932-85	6,870	0	47.0
05293000	Yellow Bank River near Odessa, Minn.[2]	398	1939-85	6,970	0	54.8

[1]Streamflow-gaging station established June 6, 1984.
[2]Streamflow-gaging station located 6 miles southeast of Big Stone City. The North and South Forks of the Yellow Bank River join 6 miles south and 5 miles east of Big Stone City.

Lakes

Lakes in Codington and Grant Counties cover about 27 mi^2, or about 3 percent of the study area. Lakes Kampeska and Pelican (fig. 4) cover about 7,600 acres and were formed by stagnant ice blocks positioned at the margin of the receding Wisconsin age glacier (J. P. Gilbertson, South Dakota Geological Survey, written commun., 1986).

Long-term records of lake-level fluctuations for Lake Kampeska indicate correlation with departure from normal precipitation (fig. 5). Lake levels rose from 1970-73, 1977-80, and 1984-86 because of above-normal precipitation. Lake levels generally declined from 1973-76 and from 1980-83 because of below-normal precipitation. In recorded history, Lake Kampeska has never been known to dry up completely (South Dakota State Lakes Preservation Committee, 1977).

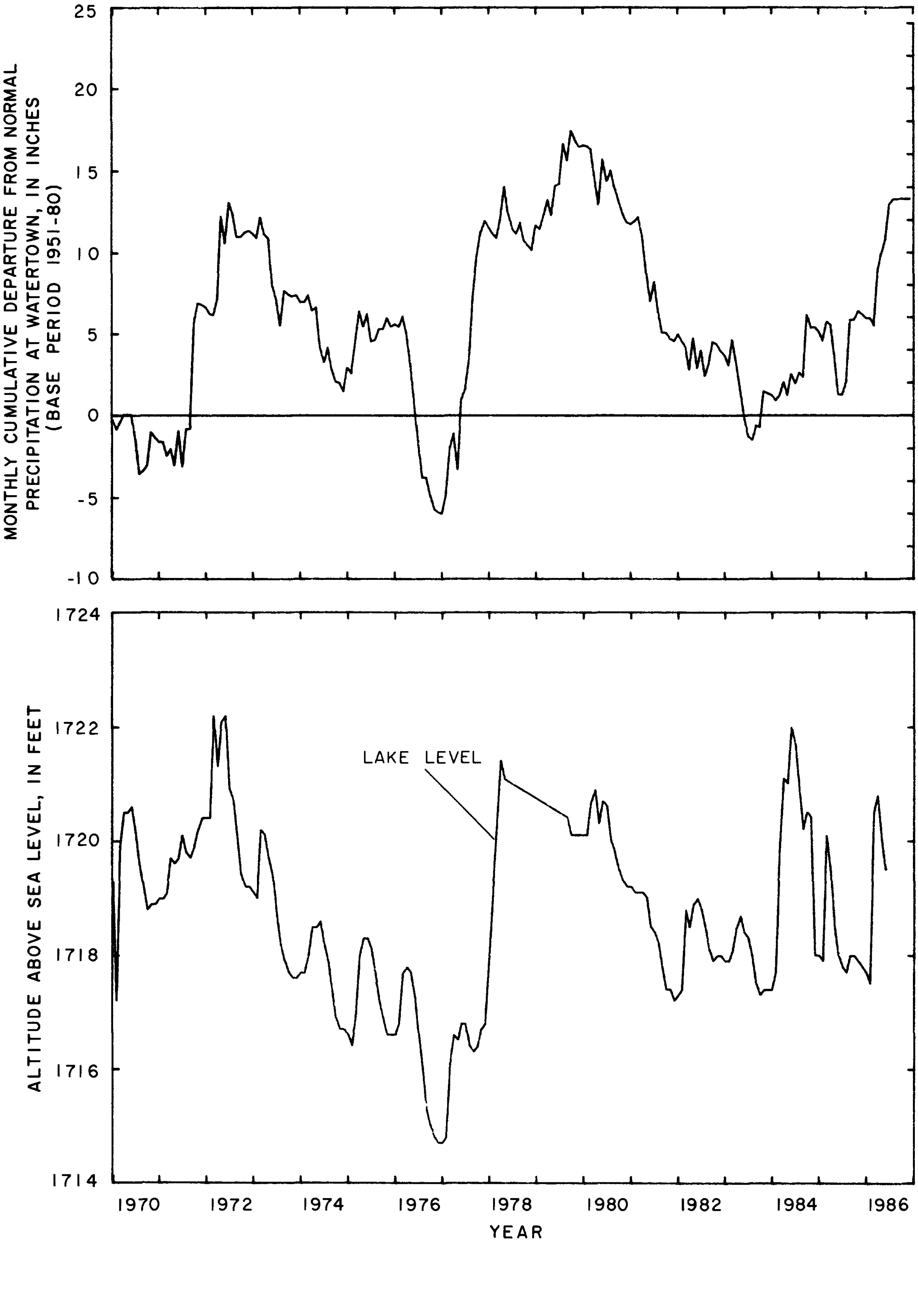


Figure 5.--Lake-level fluctuations for Lake Kampeska and monthly cumulative departure from normal precipitation at Watertown.

Table 2.--Summary of chemical analyses for selected lakes in Codington County

[Analyses based on data collected from 1964-75, State Lakes Preservation Committee, 1977. Results are average value in milligrams per liter except as indicated; --, not analyzed]

	Lakes connected to an aquifer and having an outlet		Lakes not connected to an aquifer and having no outlet		
	Kampeska	Pelican	Medicine	Nicholson	Long
Specific conductance (microsiemens per centimeter at 25 °C)	490	1,280	--	61,000	4,700
pH	8.5	8.8	8.1	9.1	8.2
Alkalinity, total	220	260	1,820	2,200	110
Dissolved solids	330	970	87,500	148,000	13,000
Dissolved calcium	44	60	590	1,400	410
Dissolved magnesium	32	100	12,000	14,000	1,200
Dissolved sodium	11	55	8,000	23,000	1,300
Dissolved potassium	10	22	1,270	1,700	190
Dissolved sulfate	68	280	57,000	99,000	9,000
Dissolved chloride	4.2	21	1,100	1,100	250
Dissolved nitrogen	.1	.1	.17	--	--
Dissolved phosphorus	1.1	<.01	1.1	--	--

The chemical quality of water in lakes is determined by the hydrologic setting of the lake and seasonal changes in precipitation. Lakes in areas of internal drainage having no outlet generally contain water that is one to two orders of magnitude higher in dissolved solids than lakes having external drainage or having good hydraulic connection with a surficial aquifer. Table 2 shows the average chemical quality of water of selected lakes in Codington County. Lakes Kampeska and Pelican are in hydraulic connection with the Big Sioux aquifer and have a total dissolved-solids concentration two orders of magnitude less than Medicine, Nicholson, and Long Lakes. Medicine, Nicholson, and Long Lakes receive recharge by overland runoff and rainfall; however, the only source of discharge is by evaporation. Dissolved-solids concentrations in water from lakes generally decrease during the spring because of dilution from snowmelt and rainfall runoff and then increase during summer and late fall because of reduced inflow and increased evaporation. Dissolved-solids concentrations in water from Medicine Lake increase with depth. Dissolved solids increase from 65,000 mg/L (milligrams per liter) at 2.5 ft to 171,000 mg/L at 7.5 ft (South Dakota State Lakes Preservation Committee, 1977).

Ground-Water Occurrence and Chemical Quality

Glacial Aquifers

Seven aquifers were delineated in Codington and Grant Counties. Hydrologic characteristics of these aquifers are given in table 3. Glacial-outwash aquifers consist of unconsolidated sand and gravel deposited by meltwaters from receding glaciers. Test drilling has shown that the aquifers are overlaid and underlaid by till. Till in Codington and Grant Counties consists of grayish-blue clay with minor amounts of sand and silt. Till in

Table 3.--Summary of the hydrologic characteristics of the major aquifers in Codington and Grant Counties

[--, not determined]

	Areal extent (square miles)	Maximum aquifer thickness (feet)	Average aquifer thickness[1] (feet)	Range in aquifer depth below land surface (feet)	Average depth of aquifer below land surface[1] (feet)	Range of ground-water level below land surface[2] (feet)	Average water level below land surface[3] (feet)	Artesian (A) and (or) water-table (WT) aquifer	Estimated volume of water in storage[4] (acre-feet)	Range of reported well discharges[5] (gallons per minute)	Suitability for irrigation[6]
GLACIAL AQUIFERS											
Big Sioux	150	50	24	0-12	3	-1 - 31	8	WT	350,000	50-1,100	Yes.
Antelope Valley	30	52	34	1-57	9	2 - 22	10	WT	100,000	50-800	Yes.
Prairie Coteau	760	58	21	21-380	138	-2.54 - 101	33	A	1.5 million	50-1,100	Yes.
Veblen	260	155	28	1-210	52	1 - 81	29	A	700,000	10-50	Yes.
Lonesome Lake	140	98	32	200-380	270	80 - 100	90	A	430,000	10-20	Yes.
Revillo	190	150	63	105-665	295	-1 - 71	30	A	1.0 million	50-150	No.
Altamont	840	94	40	319-668	460	5 - 250	150	A	3.3 million	10-50	No.
BEDROCK AQUIFER											
Dakota[7]	--	--	--	1,230	--	--	--	A	--	--	No.
Granite wash	190	94	37	75-444	190	-3 - 116	22	A	650,000	10-550	No.

[1] Arithmetic mean from test-hole data.
[2] A negative number indicates feet above land surface.
[3] Arithmetic mean from observation-well data.
[4] Storage was estimated by multiplying average thickness by areal extent and multiplied by specific yield of 0.15 (Hansen, 1987).
[5] Reported data.
[6] Based on the South Dakota irrigation-water classification diagram (fig. 6).
[7] Data for aquifer available from only one well.

eastern South Dakota has a hydraulic conductivity of about 10^{-5} ft/d (Barari, 1985). The till will not yield a sufficient quantity of water to wells even for domestic use; however, locally it may contain thin, discontinuous sand and gravel lenses that reportedly yield 2 to 15 gal/min to domestic and stock-watering wells.

Water-level fluctuations in observation wells screened in the glacial aquifers, with the exception of the Altamont, are caused by seasonal changes in recharge and discharge. Water levels generally rise from February through June because recharge from snowmelt and spring rainfall is greater than discharge. Water levels generally decline from July through January because discharge from wells and evapotranspiration are greater than recharge.

Suitability of water for irrigation from the glacial aquifers may be determined by use of the South Dakota irrigation-water diagram (fig. 6) (Koch, 1983). The diagram is based on South Dakota irrigation-water standards, revised January 7, 1982, and shows the State of South Dakota's water-quality and soil-texture requirements for the issuance of an irrigation permit.

Big Sioux aquifer

The Big Sioux aquifer (fig. 7) consists of poorly to well-sorted surficial outwash that ranges from medium sand to medium gravel; it generally is less than 10 ft below land surface. The aquifer is limited to the flood plain of the Big Sioux River and its tributaries, and is underlaid by till. In most locations, the aquifer becomes coarser and more sorted with depth. The aquifer generally is under water-table conditions, except in the Lake Pelican area where the aquifer is confined by 3 to 5 ft of till. A geologic section of the aquifer is shown in figure 8.

Recharge to the aquifer is by direct infiltration and subsequent percolation of rainfall and snowmelt through the overlying 1 to 2 ft of topsoil. Recharge to the aquifer ranges from 4 to as much as 10 in/yr (Hansen, 1988). The general direction of water movement in the aquifer is to the south and toward the Big Sioux River (fig. 9), which flows from north to south. The gradient of the water-table surface generally is about 6 to 10 ft/mi. Lakes Kampeska and Pelican are connected hydraulically to the Big Sioux aquifer. During spring and early summer, lake levels commonly exceed the water level in the aquifer and, thus, the lakes recharge the aquifer. During summer and fall, when evaporation exceeds precipitation, the lake levels are less than water levels in the surrounding Big Sioux aquifer and water from the aquifer discharges to the lakes.

Discharge from the Big Sioux aquifer is by withdrawals from irrigation, domestic, municipal, and stock-watering wells; by evapotranspiration; and by ground-water discharge to lakes and the Big Sioux River. The average annual reported pumpage by irrigation and municipal wells was about 2,100 acre-ft from 1972-80 (South Dakota Department of Water and Natural Resources, written commun., 1972-80). The average annual reported pumpage by irrigation wells was 2,800 acre-ft during the drought years of 1975-77. Reported discharge from irrigation wells in the Big Sioux aquifer is as much as 1,100 gal/min.

Records of long-term water-level fluctuations in well 118N52W21BBCB show correlation with long-term trends in precipitation (fig. 10). The water-level rise during 1972, 1977-79, and 1984-86 was caused by above-normal precipitation. The decline from 1973-76 and 1980-81 was caused by below-normal precipitation.

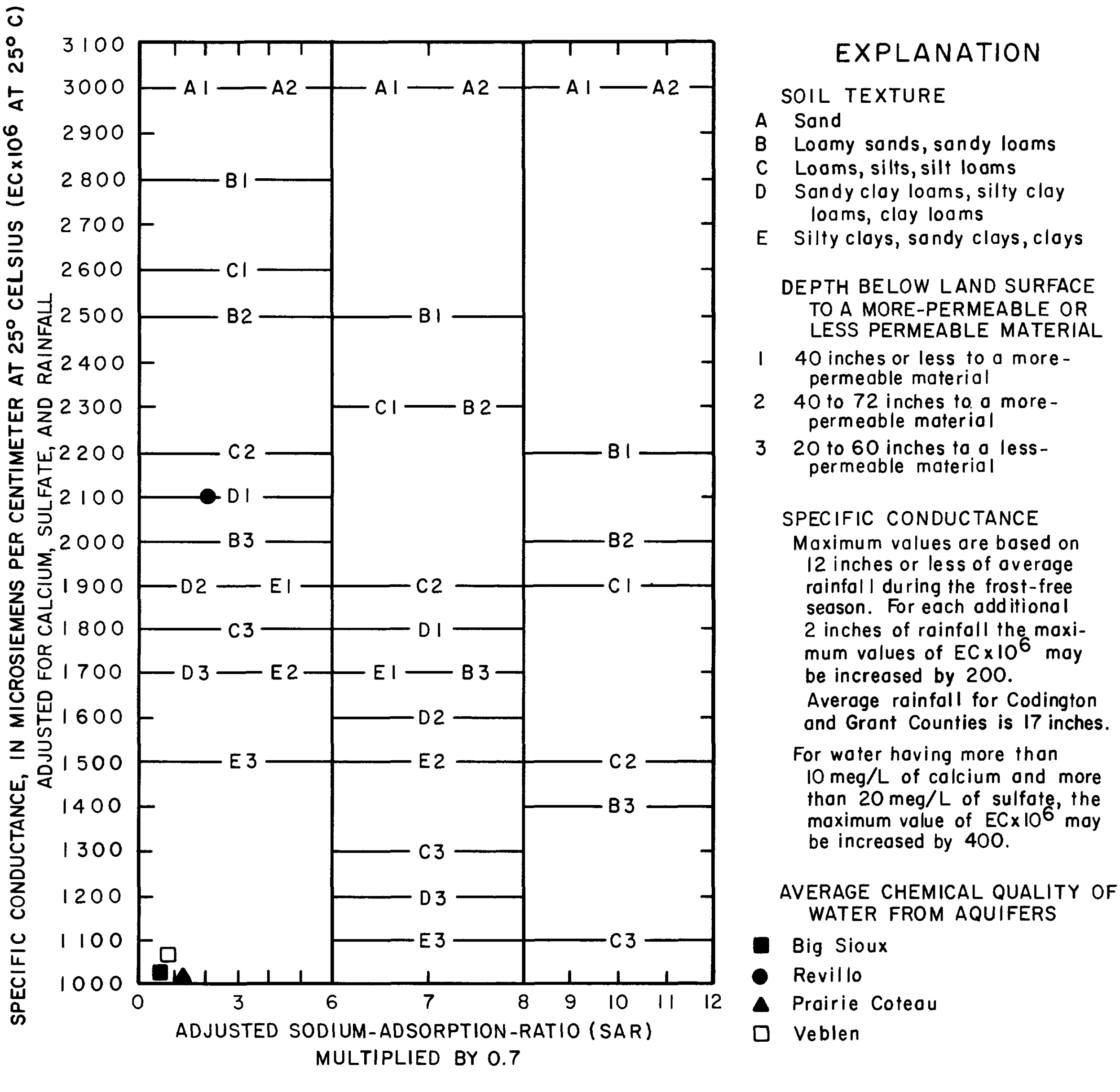


Figure 6.--South Dakota irrigation-water classification diagram based on South Dakota standards (revised Jan. 7, 1982) for maximum allowable specific conductance and adjusted sodium-adsorption-ratio values for which an irrigation permit can be issued for applying water under various soil-texture conditions. Water can be applied under all conditions at or above the plotted point but not below it provided other conditions as defined by the State Conservation Commission are met.

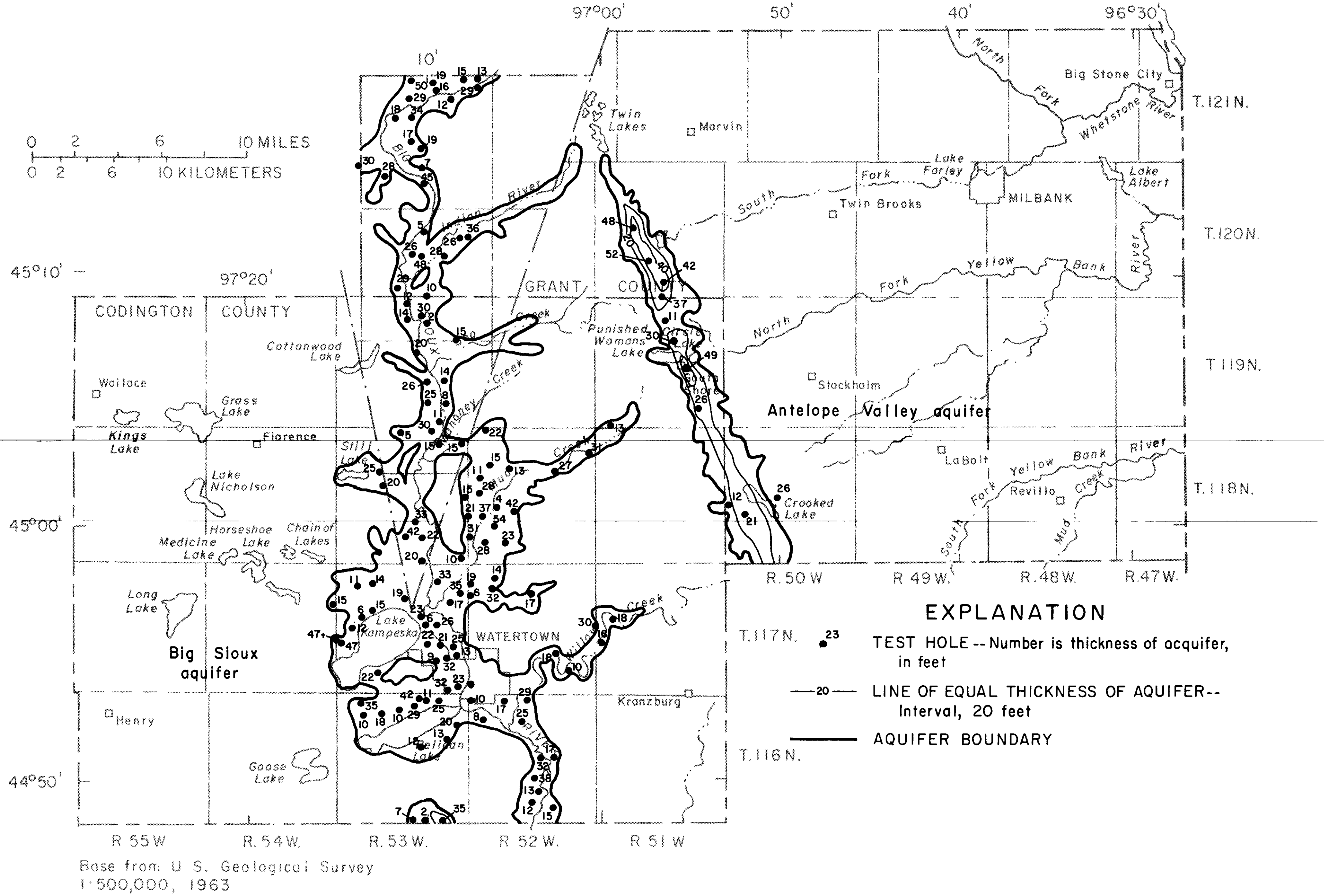


Figure 7.--Extent and thickness of the Big Sioux and Antelope Valley aquifers in Codington and Grant Counties.

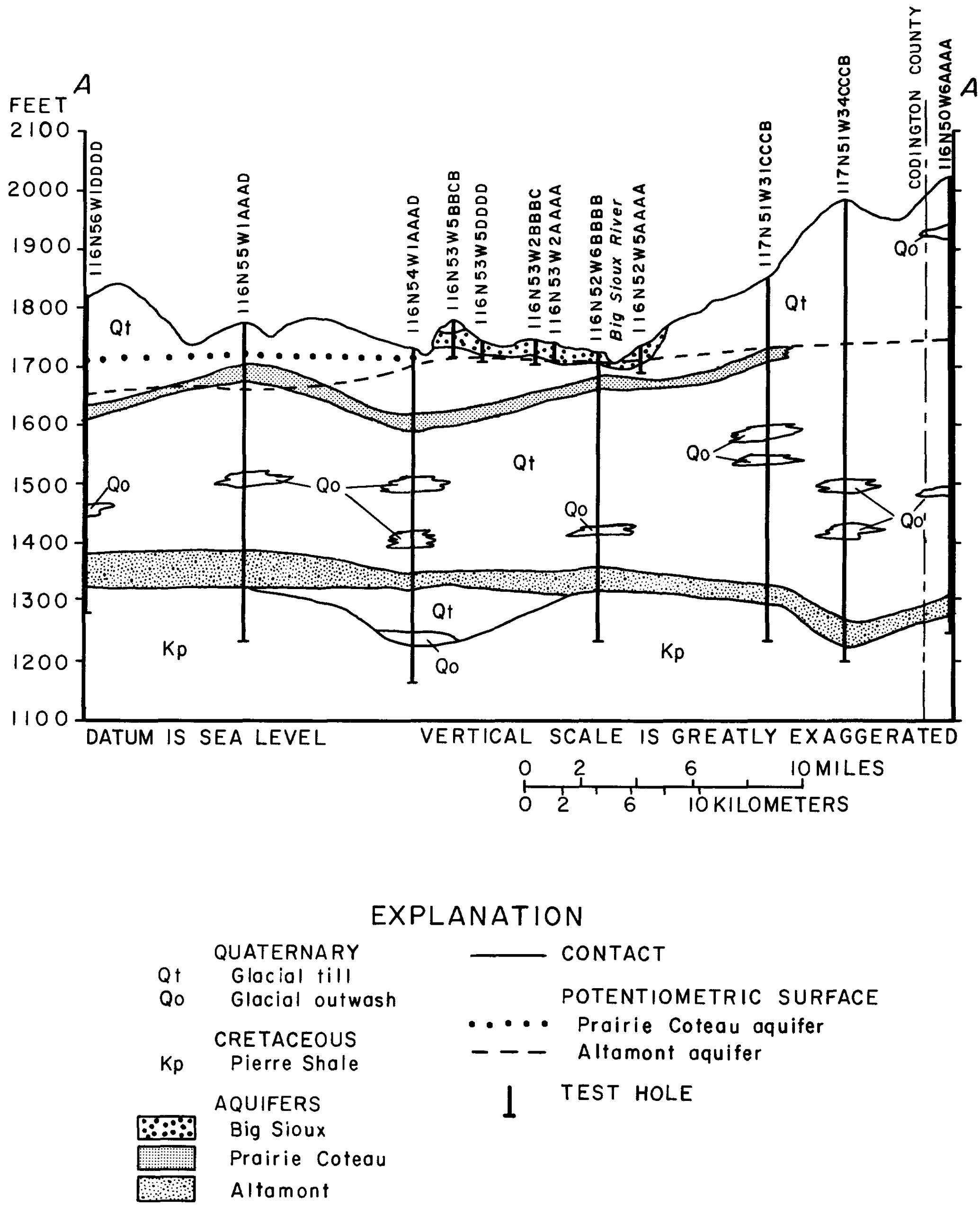


Figure 8.--Geologic section A-A' showing the Big Sioux, Prairie Coteau, and Altamont aquifers. (Section A-A' is shown in figure 2.)

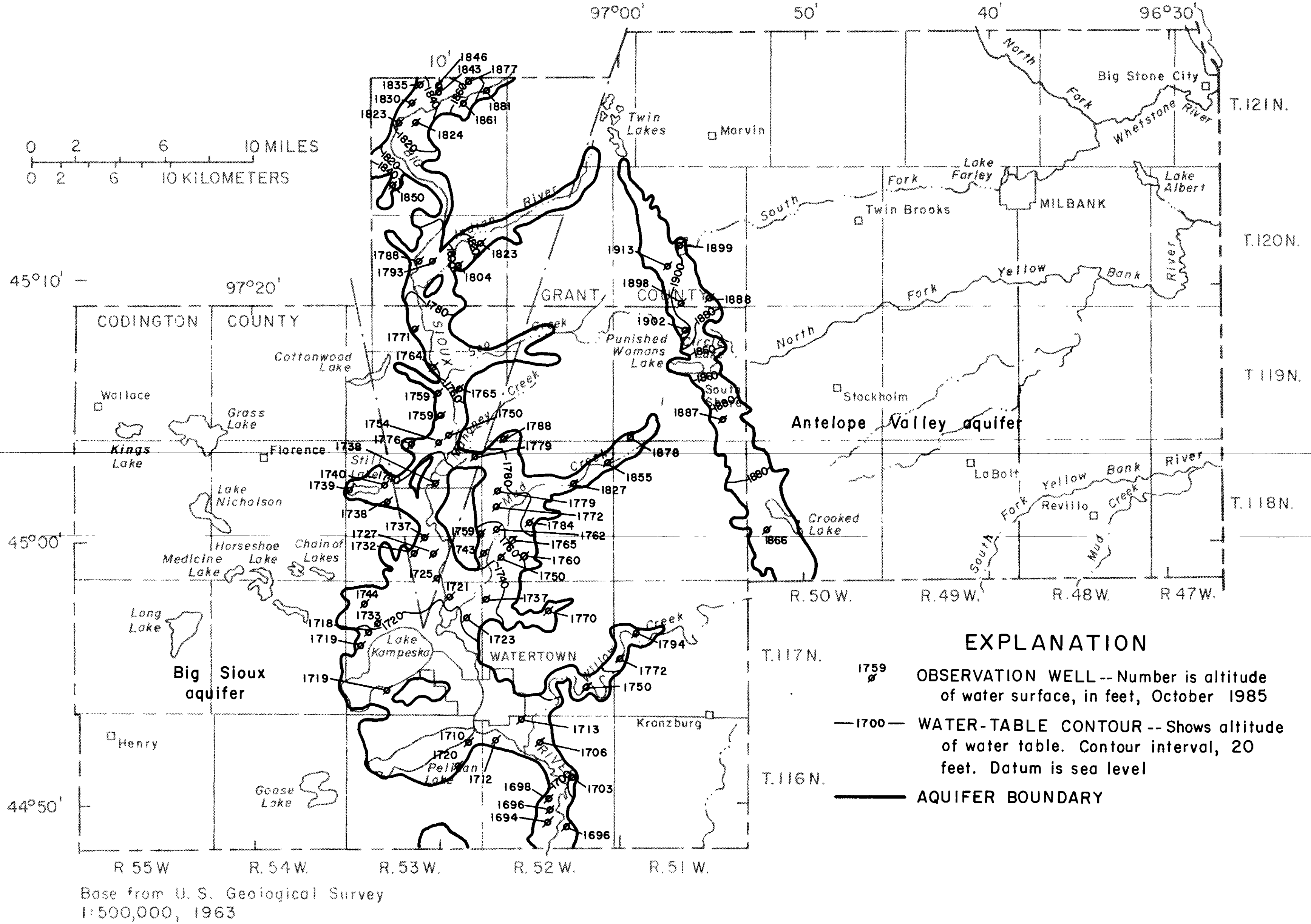


Figure 9.--Water-table surface of the Big Sioux and Antelope Valley aquifers in Codington and Grant Counties, October 1985.

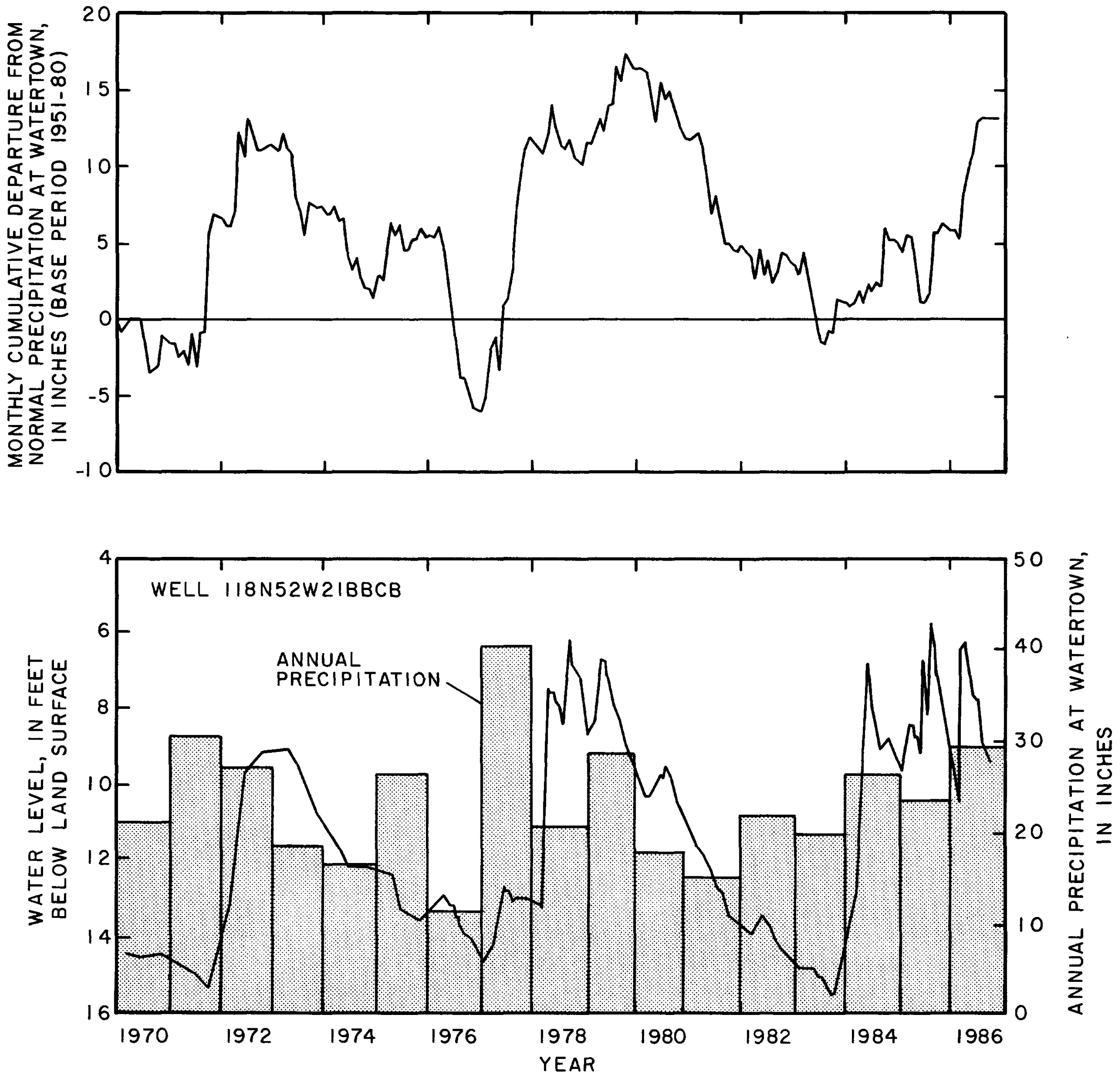


Figure 10.--Water-level fluctuations in the Big Sioux aquifer and annual precipitation and monthly cumulative departure from normal precipitation at Watertown.

Predominant chemical constituents in water from the Big Sioux aquifer are calcium and bicarbonate (table 4). Dissolved-solids concentrations averaged 580 mg/L. Hardness concentrations determined by onsite analysis averaged 400 mg/L. Water from the aquifer is of suitable quality for irrigation (fig. 6). Water from the aquifer also is used for municipal, industrial, domestic, and stock-watering purposes.

Antelope Valley aquifer

The Antelope Valley aquifer is an unconfined glacial-outwash aquifer that lies at or near land surface in northeastern Codington and western Grant Counties (fig. 7). The aquifer is located in the axis of the drainage divide between the Big Sioux and Minnesota Rivers (fig. 4) and is hydraulically connected to numerous small lakes and sloughs. The aquifer is composed of brown, very coarse sand to coarse gravel. The aquifer generally is under water-table conditions; however, at well 119N51W3CCCC the aquifer is covered by 43 ft of till and is under artesian conditions. The aquifer is shown in geologic section B-B' (fig. 11), and hydrologic characteristics are given in table 3.

Recharge to the aquifer is by direct infiltration and subsequent percolation of rainfall and snowmelt through the overlying 1 to 2 ft of topsoil. Test-hole data indicate that Crooked, Punished Womans, and Round Lakes are hydraulically connected to the aquifer. The general direction of water movement in the aquifer is from northwest to southeast. The direction of water movement within 2 mi of Punished Womans, Round, and Crooked Lakes, and numerous sloughs and small lakes located in T. 120 N., R. 51 W. is toward these lakes and sloughs.

Discharge from the aquifer is by: (1) irrigation, domestic, and stock-watering wells; (2) evaporation directly from the water-table surface where the aquifer is at or near land surface; (3) outflow to Punished Womans, Round, and Crooked Lakes; and (4) outflow to small lakes and sloughs in T. 120 N., R. 51 W. near the eastern edge of the aquifer.

Records of long-term water-level fluctuations in wells 119N51W3DDDA and 120N51W34CCCC (fig. 12) show correlation with long-term trends in precipitation. The water-level decline from 1979-83 was caused by below-normal precipitation. The water-level rise from 1983-87 was caused by four years of above-normal precipitation. The sharp annual decline during June and July in well 119N51W3DDDA is caused by pumpage from nearby irrigation wells.

Predominant chemical constituents in water from the Antelope Valley aquifer are calcium and bicarbonate. Specific conductance, determined from onsite analyses, ranged from 320 to 1,850 μS/cm and averaged 1,000 μS/cm. Hardness concentrations, also determined by onsite analyses, ranged from 150 to 890 mg/L and averaged 500 mg/L. A summary of laboratory analyses of water from the aquifer is given in table 4. Water from the aquifer is used for irrigation, domestic, and stock-watering purposes.

Table 4.--Summary of chemical analyses of water from the Big Sioux and Antelope Valley aquifers in Codington and Grant Counties

[Analyses by U.S. Geological Survey. Results in milligrams per liter except as indicated; --, not analyzed]

	Big Sioux aquifer				Antelope Valley aquifer			
	Number of samples	Mean	Minimum value	Maximum value	Number of samples	Mean	Minimum value	Maximum value
Specific conductance, (microsiemens per centimeter at 25 °C)	10	890	650	1,300	17	820	480	1,970
pH, field (units)	8	[1]7.6	7.1	8.4	16	[1]7.4	6.9	8.0
Temperature, water (°C)	4	5.5	5	6.0	5	11.5	7.0	20.5
Dissolved solids	16	580	280	1,140	4	350	344	352
Dissolved calcium	18	100	52	180	17	110	70	220
Dissolved magnesium	18	40	14	65	17	35	7	130
Dissolved sodium	16	26	5.0	82	17	13	2.6	37
Dissolved potassium	16	3	1	7	13	4	2	8
Bicarbonate	9	320	210	380	15	330	220	550
Dissolved sulfate	17	130	19	260	17	150	18	590
Dissolved chloride	18	14	.8	45	17	13	1.0	120
Dissolved fluoride	12	.3	.2	.9	2	.3	.2	.3
Dissolved nitrate	12	4.2	0	14	3	.13	0	.32
Dissolved boron (micrograms per liter)	9	220	20	450	4	120	0	370
Dissolved iron (micrograms per liter)	4	320	40	600	2	1,600	480	2,700
Dissolved manganese (micrograms per liter)	4	160	70	240	--	--	--	--

[1]Median value.

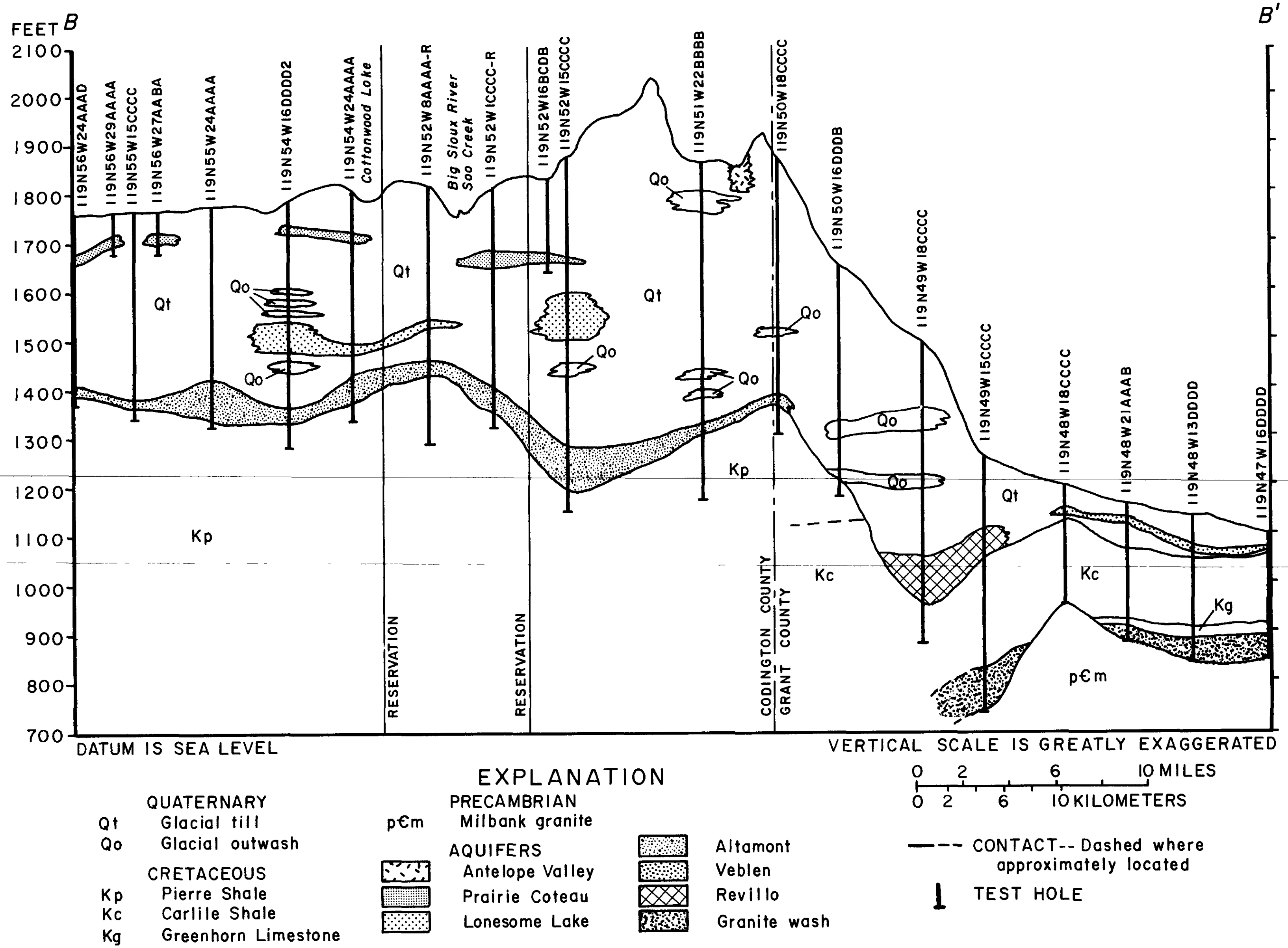


Figure 11.--Geologic section B-B′ showing the Antelope Valley, Prairie Coteau, Lonesome Lake, Altamont, Veblen, Revillo, and granite wash aquifers. (Section B-B′ is shown in figure 2.)

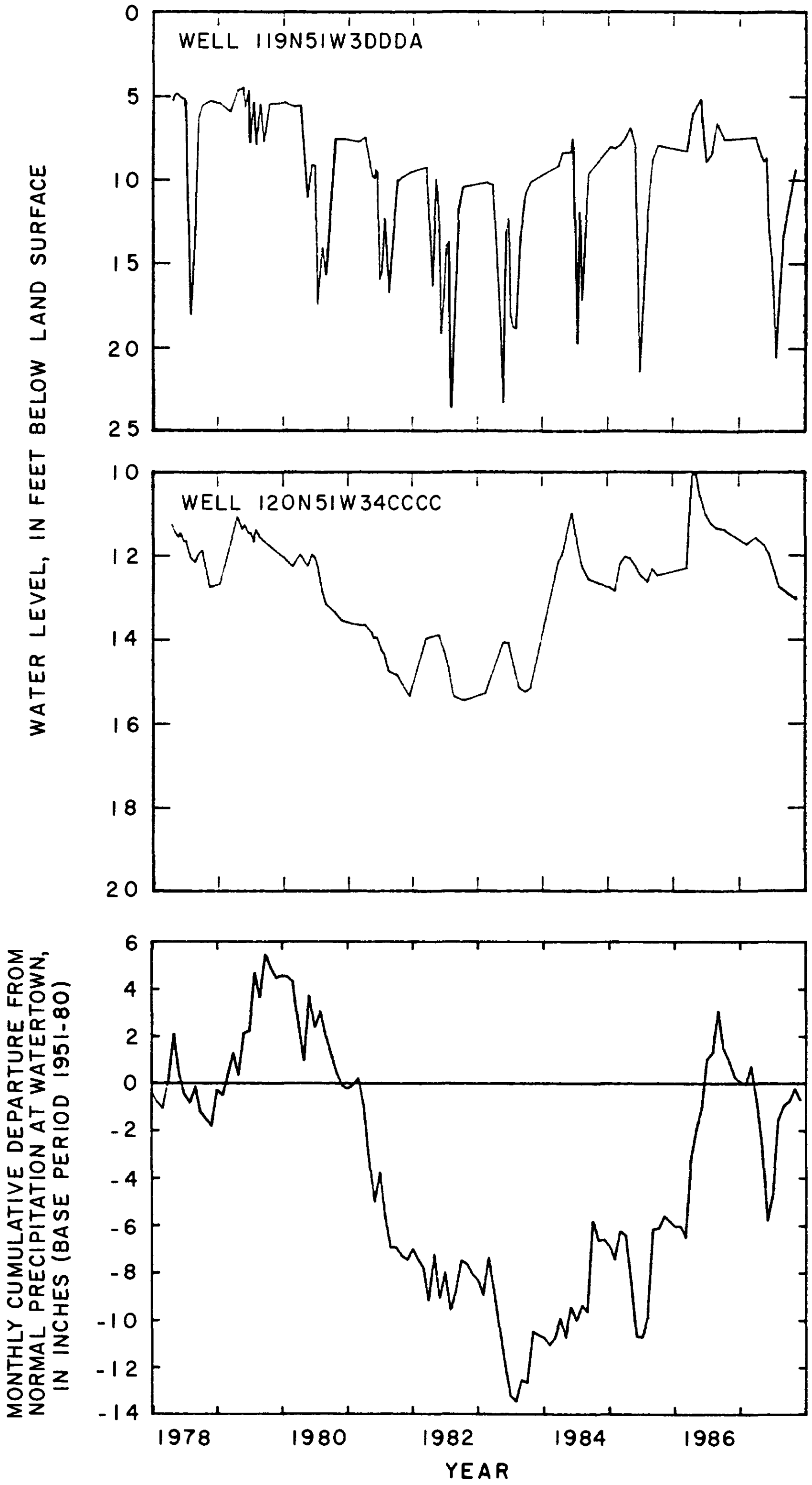


Figure 12.--Water-level fluctuations in the Antelope Valley aquifer and cumulative departure from normal precipitation at Watertown.

Prairie Coteau aquifer

The Prairie Coteau aquifer is composed of brown to gray, coarse to very coarse, well-rounded sand and fine gravel. The aquifer covers most of western Codington County and the western two townships of Grant County (fig. 13). The top of the aquifer may be as much as 380 ft below land surface in eastern Codington County to as little as 21 ft below land surface in northwestern Codington County. Geologic sections of the aquifer are shown in figures 8 and 11. Hydrologic characteristics are given in table 3.

Test-hole data in T. 122 N., R. 52 W. (Roberts County, fig. 1) indicate surficial outwash in that area as much as 65 ft thick. The outwash, known as the Coteau Lakes aquifer (J. A. Goodman, South Dakota Department of Water and Natural Resources, written commun., 1987) may be in hydraulic connection with the Prairie Coteau aquifer and may be the principle source of recharge to the Prairie Coteau aquifer. Recharge to the Prairie Coteau aquifer in western Codington County may be by direct infiltration and subsequent percolation of rainfall and snowmelt in areas where the aquifer is near land surface (fig. 11). These areas include T. 119 N., R. 54 and 55 W.; T. 118 N., R. 54 and 55 W.; and T. 117 N., R. 52 and 53 W. Recharge to the aquifer also may be by leakage from the Big Sioux aquifer. The Big Sioux aquifer and the Prairie Coteau aquifer are separated by 15 to 25 ft of silty, sandy till in T. 120 N., R. 52 W. and T. 116 N., R. 52 W. Recharge to the Prairie Coteau aquifer also may be by leakage from the till. The direction of water movement in the aquifer is from northeast to southwest toward Clark and Hamlin Counties. The gradient of the potentiometric surface is about 6 ft/mi (fig. 14). In T. 119 N., R. 52 W., the gradient is 20 ft/mi, which may be caused by finer aquifer material in this area.

Discharge from the Prairie Coteau aquifer is by: (1) Irrigation wells in western Grant and northern Codington Counties, (2) stock-watering and domestic wells, and (3) possibly, to Long Lake in western Codington County. Specific conductance of water from Long Lake is an order of magnitude less than of water from Nicholson and Medicine Lakes (table 2), which may indicate discharge from the Prairie Coteau aquifer to Long Lake. The average annual reported pumpage from 1980-85 from irrigation wells in western Grant and northern Codington Counties was about 1,700 acre-ft (South Dakota Department of Water and Natural Resources, written commun., 1980-85).

Records of long-term water-level fluctuations in well 121N52W22CCCC-R (fig. 15) show correlation with long-term trends in precipitation. The water-level decline from 1979-83 was caused by below-normal precipitation. The water-level rise from 1983-87 was caused by four years of above-normal precipitation.

Water from the Prairie Coteau aquifer is of the calcium bicarbonate type, based on predominant ions, in western Grant County and eastern Codington County and is of the calcium sulfate type in western Codington County (table 5). Dissolved-solids concentrations ranged from 650 to 2,250 mg/L and averaged 1,490 mg/L in western Codington County. Dissolved-solids concentrations ranged from 430 to 660 mg/L and averaged 510 mg/L in western Grant County and eastern Codington County. The smaller dissolved-solids concentrations in eastern Codington and western Grant Counties probably result from the inflow of less-concentrated water from the nearby recharge area in Roberts County (T. 122 N., R. 52 W.). Water from the aquifer is of suitable quality for irrigation based on South Dakota irrigation-water standards, revised January 1982 (fig. 6).

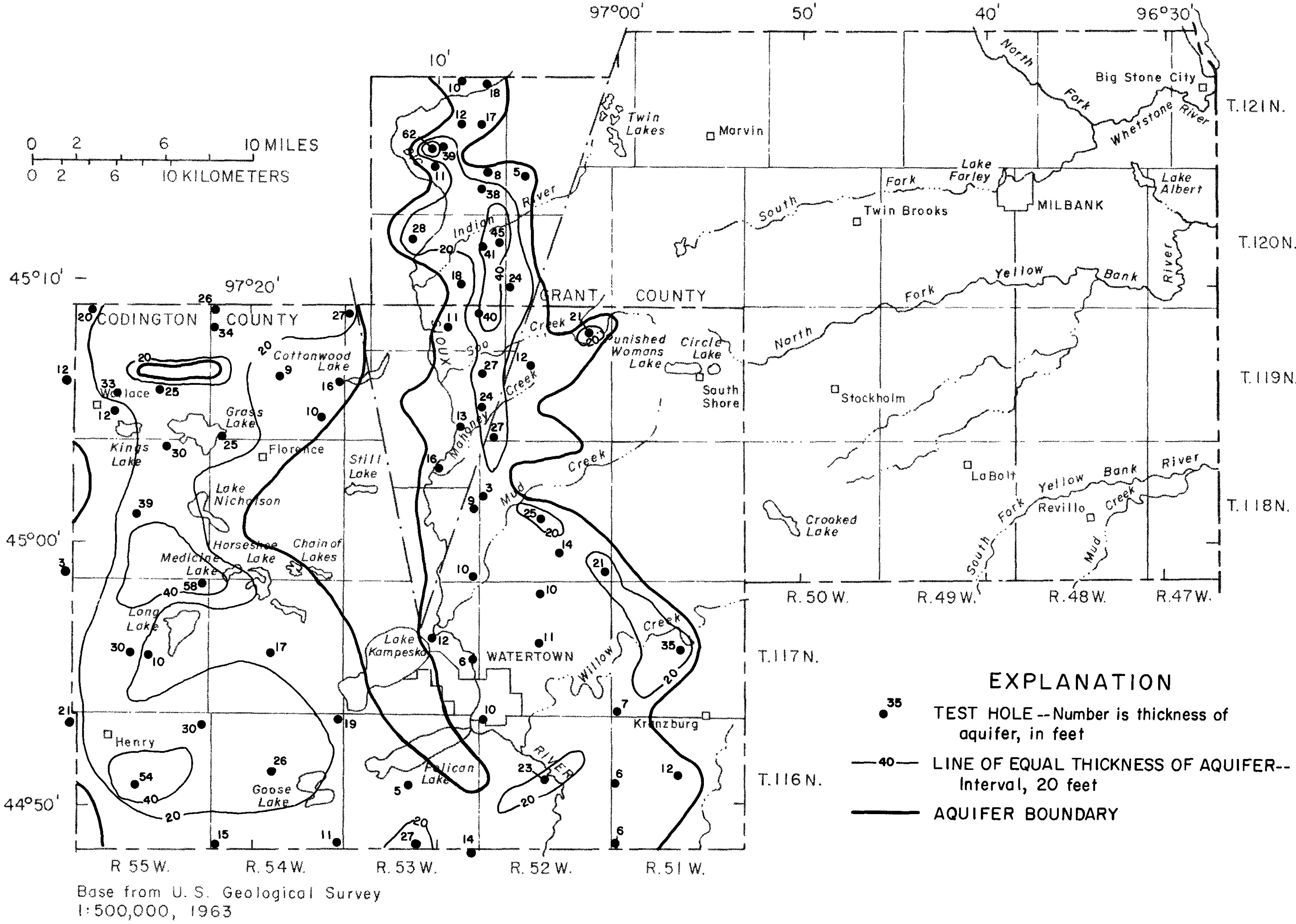


Figure 13.--Extent and thickness of the Prairie Coteau aquifer in Codington and Grant Counties.

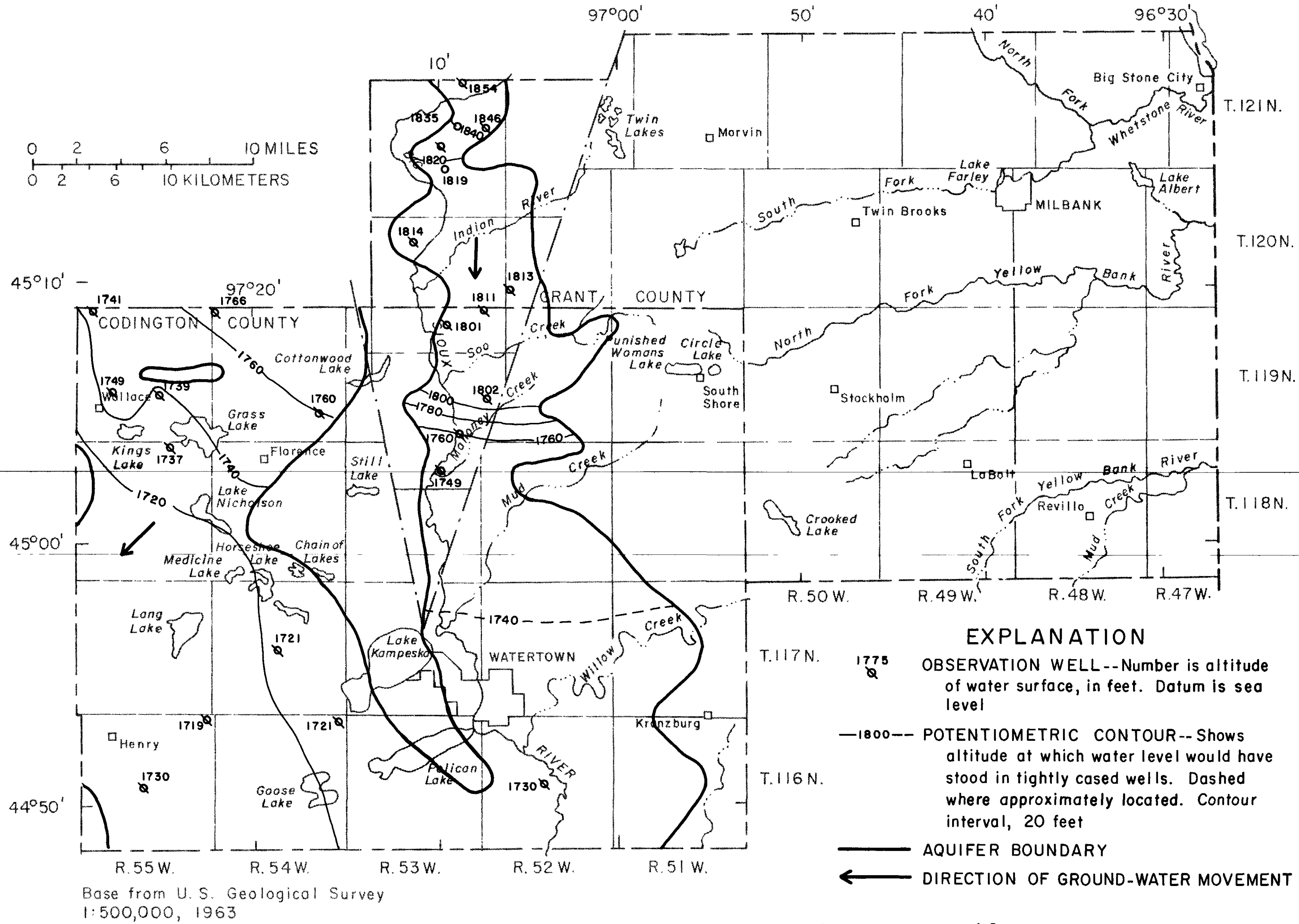


Figure 14.--Potentiometric surface of the Prairie Coteau aquifer in Codington and Grant Counties, October 1985.

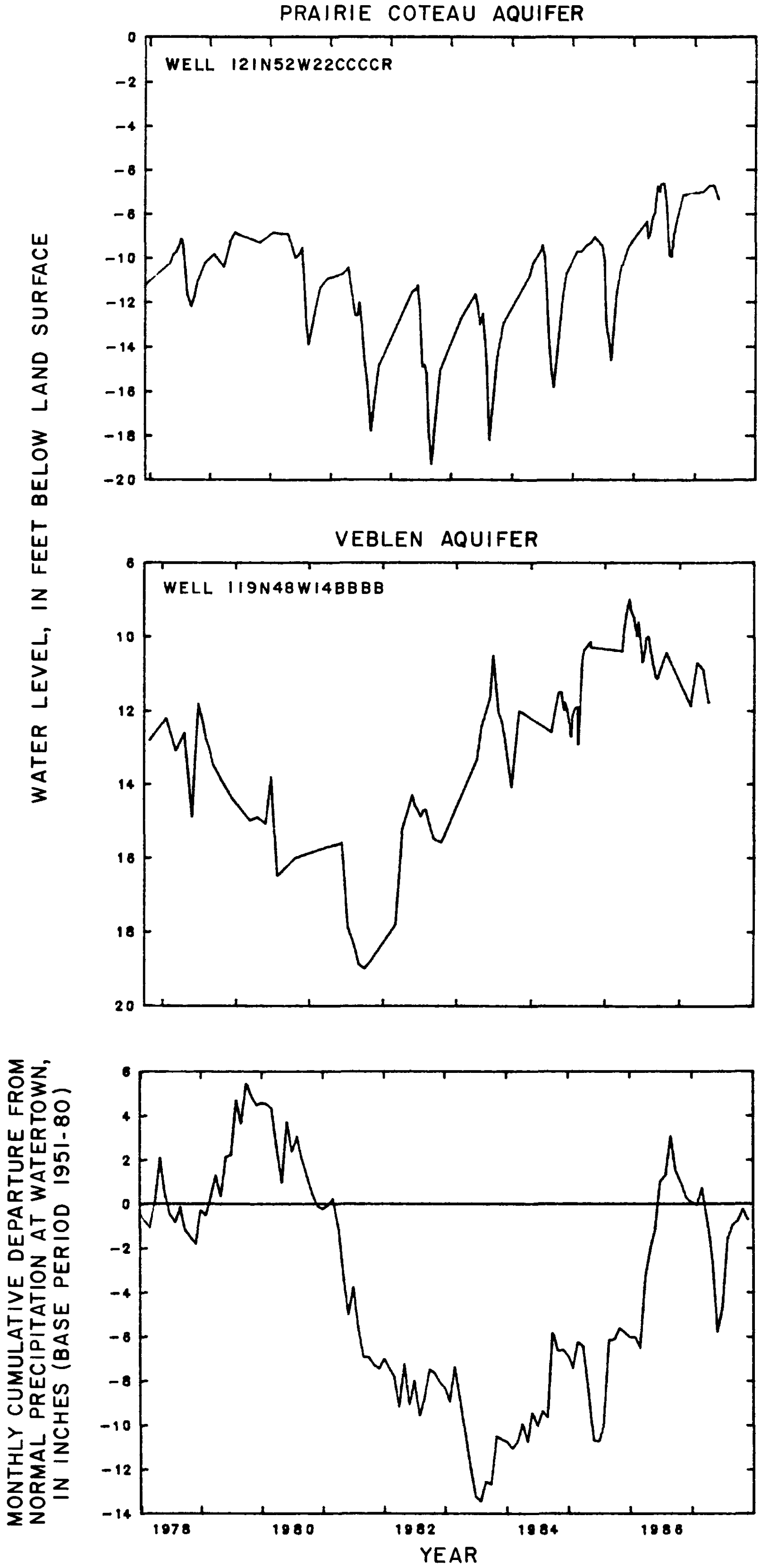


Figure 15.--Water-level fluctuations in the Prairie Coteau and Veblen aquifers and monthly cumulative departure from normal precipitation at Watertown.

Table 5.--Summary of chemical analyses of water from the Prairie Coteau aquifer in Codington and Grant Counties

[Analyses by U.S. Geological Survey and South Dakota Geological Survey. Results in milligrams per liter except as indicated; --, not analyzed]

	Western Grant County and eastern Codington County				Western Codington County			
	Number of samples	Mean	Minimum value	Maximum value	Number of samples	Mean	Minimum value	Maximum value
Specific conductance, field (microsiemens per centimeter at 25 °C)	8	920	630	1,200	32	2,000	1,010	6,510
Dissolved solids	8	510	430	660	16	1,490	650	2,250
Hardness	8	440	320	520	41	1,090	490	3,500
Alkalinity	8	410	250	500	26	360	250	500
Dissolved calcium	8	95	61	140	41	250	110	500
Dissolved magnesium	8	42	29	56	41	75	25	310
Dissolved sodium	8	26	14	48	41	110	14	540
Dissolved potassium	8	2	1	3	16	11	4	43
Bicarbonate	8	500	300	610	25	450	200	860
Dissolved sulfate	8	77	26	130	40	900	250	3,200
Dissolved chloride	8	8.2	1	42	28	18	1	42
Dissolved nitrate	3	4	3	5.8	17	2.1	0	17
Dissolved iron (micrograms per liter)	--	--	--	--	5	2,500	20	6,800
Dissolved manganese (micrograms per liter)	--	--	--	--	5	1,050	50	4,200

Veblen aquifer

The Veblen aquifer is located in eastern Grant County (fig. 16) and is composed of brown, medium to coarse sand and fine gravel. Coarse sand to coarse gravel was found in T. 121 N., R. 47 W., near the North and South Forks of the Whetstone River. As much as 154 ft of sand and gravel is present 2 to 3 mi northeast of Milbank. The extent of this thick section of sand and gravel was limited to about 1 mi^2. The aquifer slopes to the east at about 13 ft/mi and is under artesian conditions in most areas. In T. 120 N., R. 47 W. and the southern part of T. 121 N., R. 46 and 47 W., the aquifer is at or near land surface and is under water-table conditions. A geologic section of the aquifer is shown in figure 11 and hydrologic characteristics are given in table 3.

Recharge to the Veblen aquifer in Grant County is by direct infiltration and subsequent percolation of rainfall and snowmelt in T. 121 N., R. 46 W. where the aquifer is at land surface. The aquifer may be at land surface near the western aquifer boundary in Range 49 West, however, test drilling could not confirm this because of inaccessibility. Recharge to the Veblen aquifer also occurs in Marshall and Roberts Counties (Koch, 1975) where the aquifer is at land surface. Recharge to the aquifer also may occur by leakage from the till.

The direction of water movement (fig. 17) in the aquifer generally is from west to east. The direction of water movement in T. 121 N., R. 47 W. is toward the Whetstone River.

Discharge from the aquifer is: (1) From municipal, domestic, and stock-watering wells; (2) to the Whetstone River in northern Grant County; (3) to the Yellow Bank River in T. 120 N., R. 47 W.; (4) to Big Stone Lake; (5) to granite quarries located 6 mi east of Milbank; and (6) to the Minnesota River located 3 mi east of the Minnesota-South Dakota State line.

Water-level fluctuations (fig. 15) are caused by seasonal changes in recharge and discharge. Water levels in observation wells generally rose from September 1985 to April 1986 because of recharge from snowmelt and spring rainfall. Above-normal precipitation from September 1983 to April 1986 (about 11 inches) caused water levels in well 119N48W14BBBB to rise about 9 ft (fig. 15). The water-level decline from 1980-83 was caused by below-normal precipitation.

Water from the Veblen aquifer is a mixed chemical type in which calcium and sulfate are predominant but which also contains significant concentrations of magnesium and bicarbonate (table 6). Ninety percent of the reacting cations in water from the aquifer are calcium and magnesium, 65 percent of the anions are sulfate, and 35 percent are bicarbonate (fig. 18). Dissolved-solids concentrations ranged from 880 to 3,000 mg/L and averaged 1,300 mg/L. Hardness concentrations ranged from 390 to 2,170 mg/L and averaged 860 mg/L. The average concentration of chemical constituents in water from the aquifer was used to plot the datum point on the South Dakota irrigation-water classification diagram (fig. 6), which indicates that water from the aquifer generally is of suitable quality for irrigation.

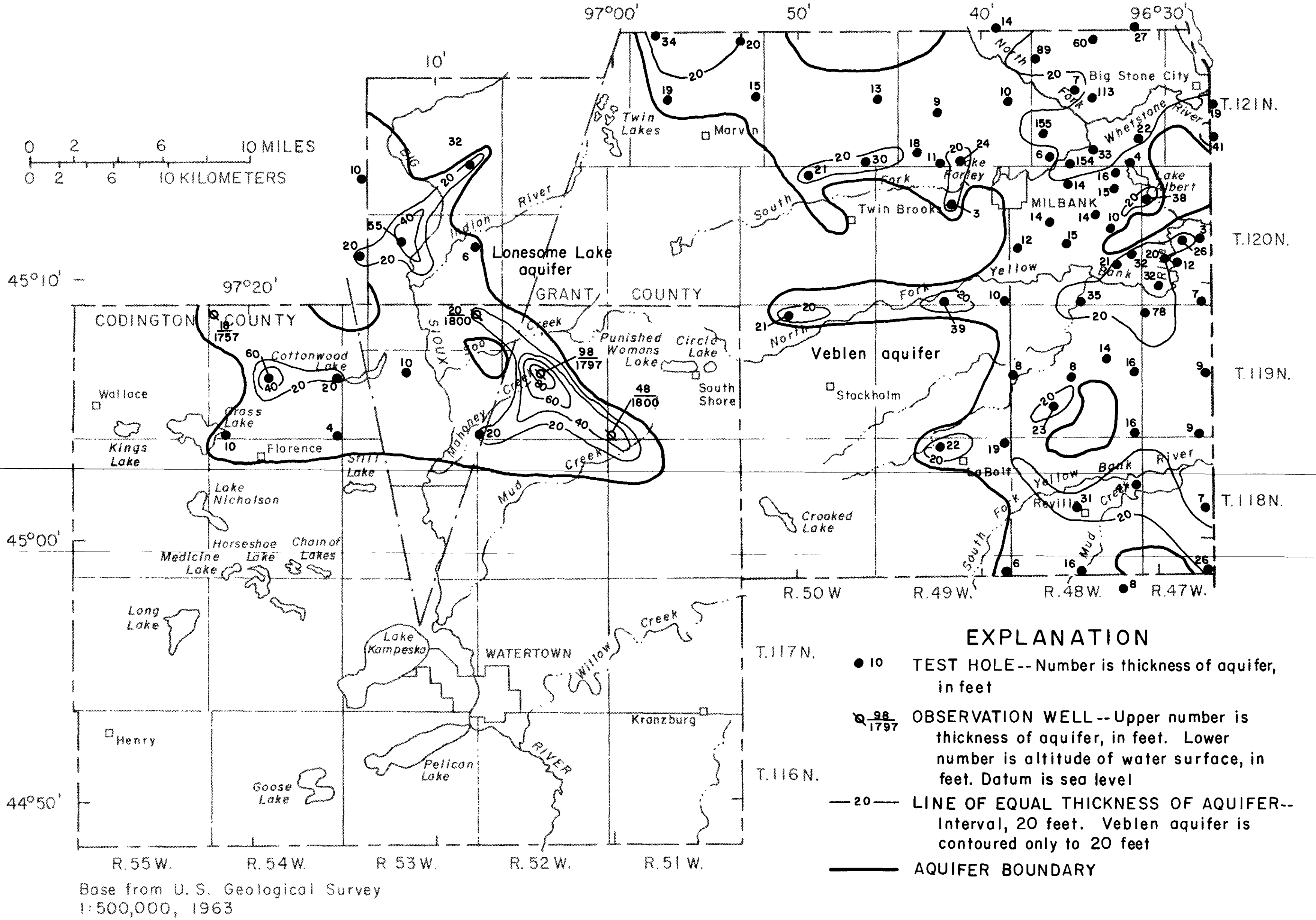


Figure 16.--Extent, thickness, and water-surface altitude of the Lonesome Lake and Veblen aquifers in Codington and Grant Counties, October 1985.

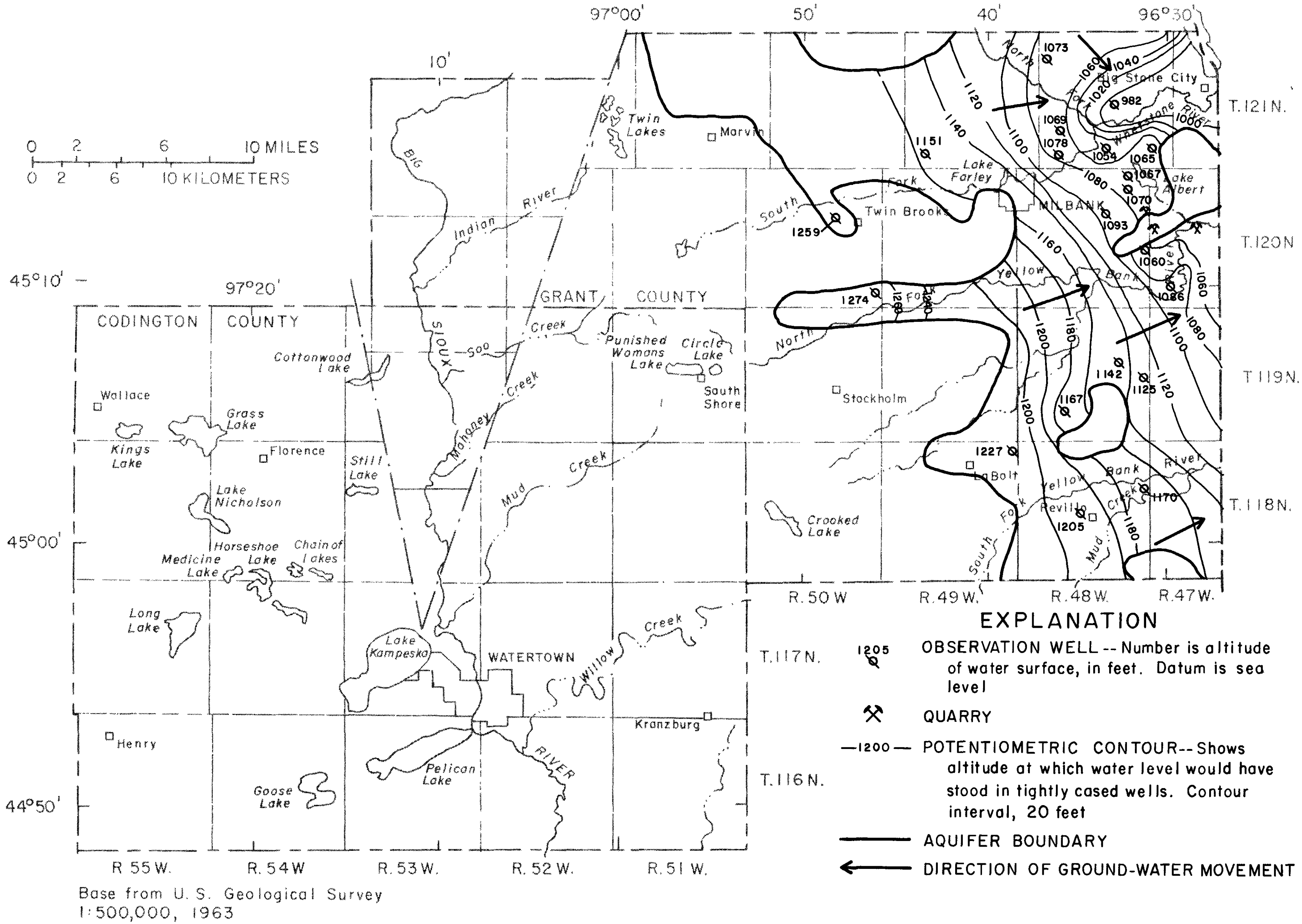


Figure 17.--Potentiometric surface of the Veblen aquifer in Grant County, October 1985.

Table 6.--Summary of chemical analyses of water from the Veblen and Revillo aquifers in Grant County

[Analyses by U.S. Geological Survey and South Dakota Geological Survey. Results in milligrams per liter except as indicated; --, not analyzed]

	Veblen aquifer				Revillo aquifer			
	Number of samples	Mean	Minimum value	Maximum value	Number of samples	Mean	Minimum value	Maximum value
Specific conductance, field (microsiemens per centimeter at 25 °C)	9	1,600	1,100	2,900	8	1,480	1,070	1,900
Hardness	9	860	390	2,170	8	625	490	1,000
Dissolved solids	8	1,300	880	3,000	8	1,200	870	1,500
Dissolved calcium	9	220	86	600	8	160	120	210
Dissolved magnesium	9	78	36	160	8	54	45	80
Dissolved sodium	9	65	26	250	8	120	55	260
Sodium absorption ratio	9	1	.3	6	0	--	--	--
Dissolved potassium	9	10	4	12	8	8	6	9
Bicarbonate	9	420	140	530	8	420	400	460
Dissolved sulfate	9	590	310	1,500	8	520	350	800
Dissolved chloride	9	22	2.0	96	8	22	4.0	43
Dissolved nitrate	8	<.04			8	<.04		
Dissolved iron (micrograms per liter)	9	2,600	0	18,000	8	2,600	50	7,200
Dissolved manganese (micrograms per liter)	9	420	40	1,200	8	220	96	480

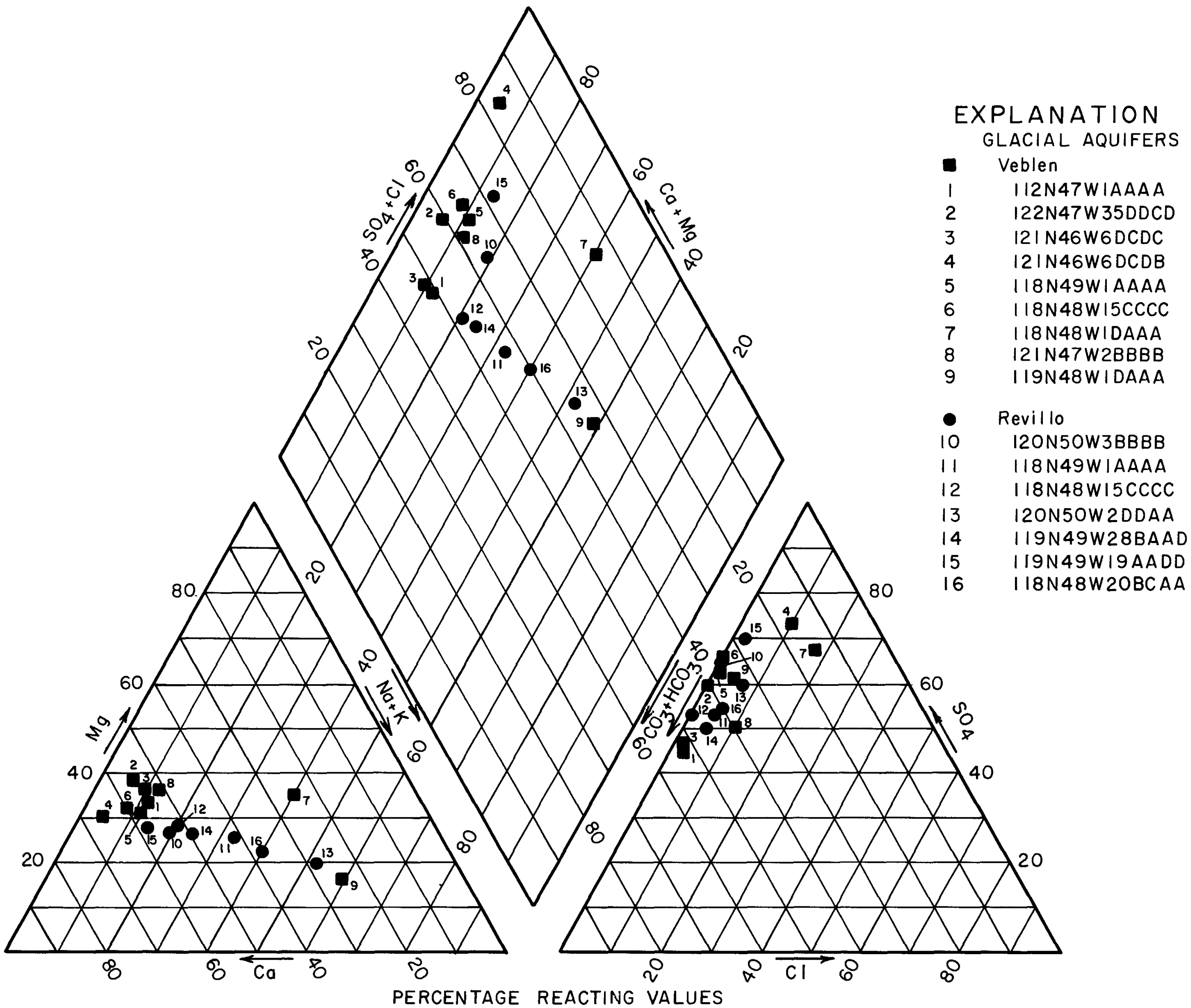


Figure 18.--Trilinear diagram of predominant chemical constituents in water from the Veblen aquifer are calcium and sulfate, and from the Revillo aquifer are calcium, bicarbonate, and sulfate.

Lonesome Lake aquifer

The Lonesome Lake aquifer, located in northern Codington and western Grant Counties (fig. 16), consists of light brown to gray, coarse sand to fine gravel. The sand grains and pebbles are subangular to well rounded and may contain as much as 20 percent clay near the bottom of the aquifer. The aquifer generally occurs between 1,500 and 1,600 ft above sea level, is overlaid by as much as 380 ft of till in eastern Codington County, and is under artesian conditions. A geologic section of the aquifer is shown in figure 11, and hydrologic characteristics of the aquifer are given in table 3.

Water-level fluctuations in four observation wells screened in the aquifer (fig. 16) indicate seasonal changes in recharge and discharge. Water levels in observation well 120N52W26AAAA-R (fig. 19) rose about 4 ft from October 1985 through May 1986 and declined about 1 ft from June 1986 to September 1986. Above-normal precipitation from October 1986 to June 1987 caused water levels to rise about 2 ft. Recharge to the Lonesome Lake aquifer is by leakage from till and by direct infiltration and subsequent percolation of rainfall and snowmelt where the aquifer is at or near land surface in Day County. Test drilling showed that the Lonesome Lake aquifer ranged from 200 to 380 ft below land surface in Codington County.

Predominant chemical constituents in water from the Lonesome Lake aquifer are calcium and sulfate (table 7). Field specific conductance in water samples from three observation wells were 1,380, 1,220, and 2,730 μS/cm.

Revillo aquifer

The Revillo aquifer, located in central Grant County (fig. 20), lies in a buried, preglacial bedrock valley that trends northwest-southeast. In northern Grant County, the aquifer is separated from the Veblen aquifer to the east by a buried shale bedrock ridge (figs. 11 and 21). Test-hole data in Roberts County, 20 mi north of Twin Brooks, indicate that the Revillo and Veblen aquifers may be in hydraulic connection. Koch (1972) described the Veblen aquifer in northeast Marshall County (fig. 1) as glacial outwash that lies in a buried bedrock valley and extends to land surface. The Veblen aquifer in Marshall County (Koch, 1972) may be the same hydrologic unit as the Revillo aquifer described in this report.

The Revillo aquifer consists of glacial outwash composed of gray, fine to very coarse gravel. The aquifer is as much as 150 ft thick in southern Grant County. The base of the aquifer in T. 121 N., R. 49 W. occurs at about 1,050 ft above sea level, declines to 1,000 ft above sea level at Twin Brooks (fig. 22), and declines to 950 ft above sea level at the Grant-Deuel County line. Hydrologic characteristics of the aquifer are given in table 3.

Recharge to the aquifer is by direct infiltration and subsequent percolation of rainfall and snowmelt in Roberts and Marshall Counties where the aquifer is at or near land surface (Koch, 1972) and by leakage from till. The direction of water movement in the aquifer is from north to south. The gradient of the potentiometric surface, based on five observation wells screened in the aquifer, increases from 0.15 ft/mi between Twin Brooks and LaBolt, to about 5.5 ft/mi from LaBolt to the Grant-Deuel County boundary. Discharge from the aquifer primarily is by municipal wells located at Twin Brooks for the city of Milbank, a municipal well located at Revillo for the town of Revillo, and by stock-watering and domestic wells.

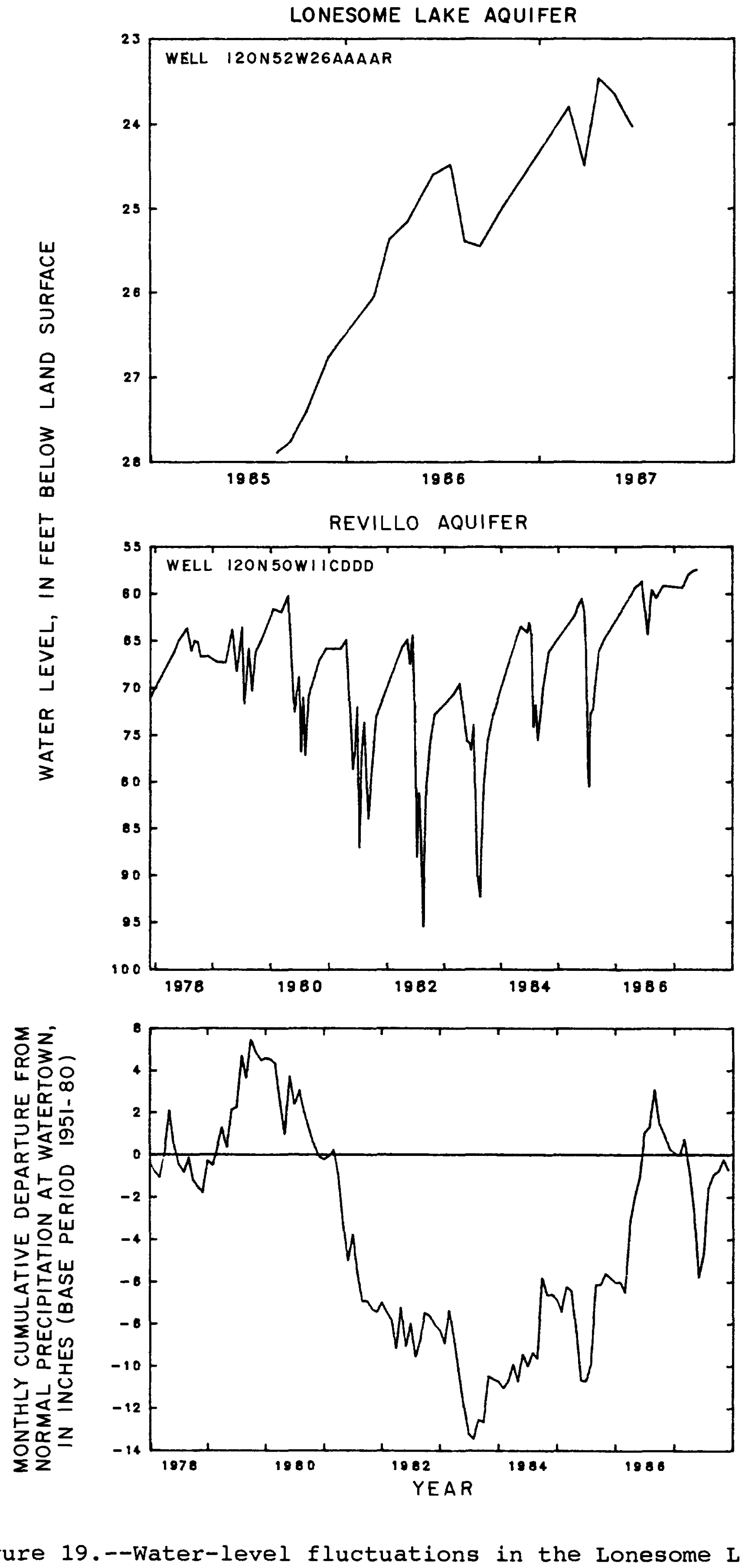


Figure 19.--Water-level fluctuations in the Lonesome Lake and Revillo aquifers and monthly cumulative departure from normal precipitation at Watertown.

Table 7.--Chemical analyses of water from the Altamont, granite wash, Lonesome Lake, and Dakota aquifers in Codington and Grant Counties

[Analyses by U.S. Geological Survey. Results in milligrams per liter except as indicated; --, not analyzed; <, less than]

Location	Dissolved calcium	Dissolved sodium	Dissolved magnesium	Dissolved potassium	Alkalinity	Dissolved sulfate	Dissolved nitrate
			Lonesome Lake aquifer				
119N51W31CCCC	72	130	100	15	220	1,400	0.10
119N52W15CCCC2	140	56	55	7	340	330	.10
119N54W 6BBBB	190	46	56	10	330	470	.10
			Altamont aquifer				
116N51W 4AAB	260	240	120	7	430	1,200	0.1
116N55W34BABB	87	600	61	10	320	1,500	.1
117N55W21BBCB	71	390	58	8	300	970	.1
118N55W11ABBD	140	430	56	15	280	1,200	.1
			Dakota aquifer				
116N52W 2CBBC	6.5	449	27	9	200	760	--
			Granite wash aquifer				
119N48W24AAAA	30	440	8.6	10	310	930	--
119N47W 7DAAD	40	510	11	12	300	1,000	--
119N48W 4DDCC	70	630	19	14	200	1,100	--
120N48W30DAAA	24	580	10	15	420	1,100	--
120N49W 8AAAB	17	590	5.5	14	360	1,200	--
121N49W35DDDC	15	540	5.6	9	370	1,600	--

Table 7.--Chemical analyses of water from the Altamont, granite wash, Lonesome Lake, and Dakota aquifers in Codington and Grant Counties--Continued

Location	Dissolved chloride	Dissolved iron (micrograms per liter)	Dissolved manganese (micrograms per liter)	Dissolved fluoride	Dissolved solids	Specific conductance (field) (microsiemens per centimeter)	pH (field) (units)
			Lonesome Lake aquifer				
119N52W31CCCC	3.6	20	20	0.3	--	2,730	7.6
119N52W15CCCC2	2.6	<10	150	.4	--	1,220	7.3
119N54W 6BBB	7.0	<10	1,700	.5	--	1,380	7.2
			Altamont aquifer				
116N51W 4AAB	17	920	1,500	0.5	2,100	2,600	7.0
116N55W34BABB	96	1,700	210	.2	2,600	3,440	7.6
117N55W21BBCB	9.5	730	240	.2	1,700	2,660	7.8
118N55W11ABBD	92	3,700	230	.4	2,100	2,870	7.5
			Dakota aquifer				
116N52W 2CBBC	110	90	50	--	1,480	2,310	9.5
			Granite wash aquifer				
119N48W24AAAA	--	10	<2	--	--	4,190	7.5
119N47W 7DAAD	--	<10	22	--	--	3,990	8.0
119N48W 4DDCC	--	<10	19	--	--	6,050	7.8
120N48W30DAAA	--	<10	<2	--	--	4,430	8.0
120N49W 8AAAB	--	<10	<2	--	--	4,440	7.7
121N49W35DDDC	--	<10	10	--	--	4,350	8.3

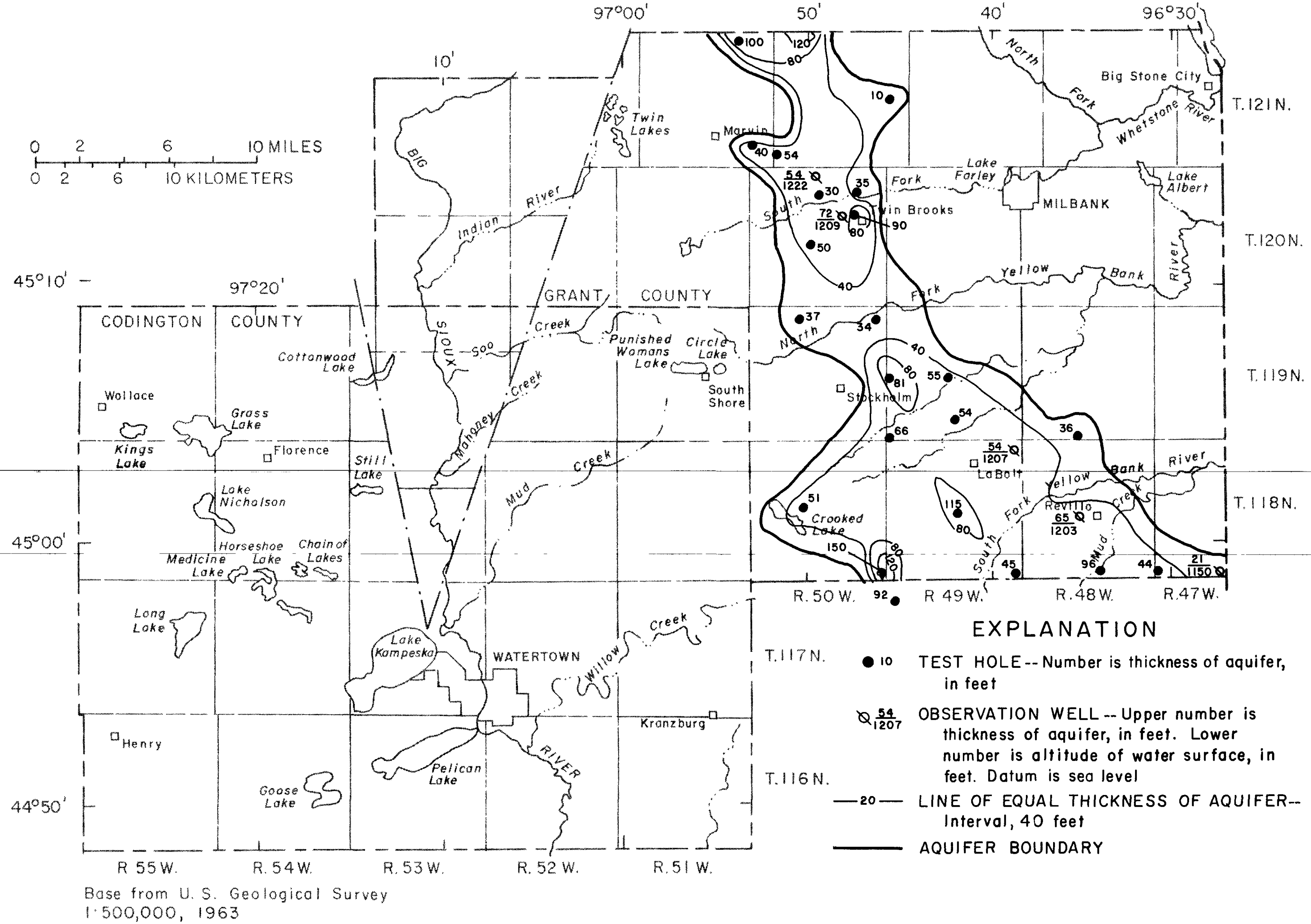


Figure 20.--Extent and thickness of the Revillo aquifer in Grant County.

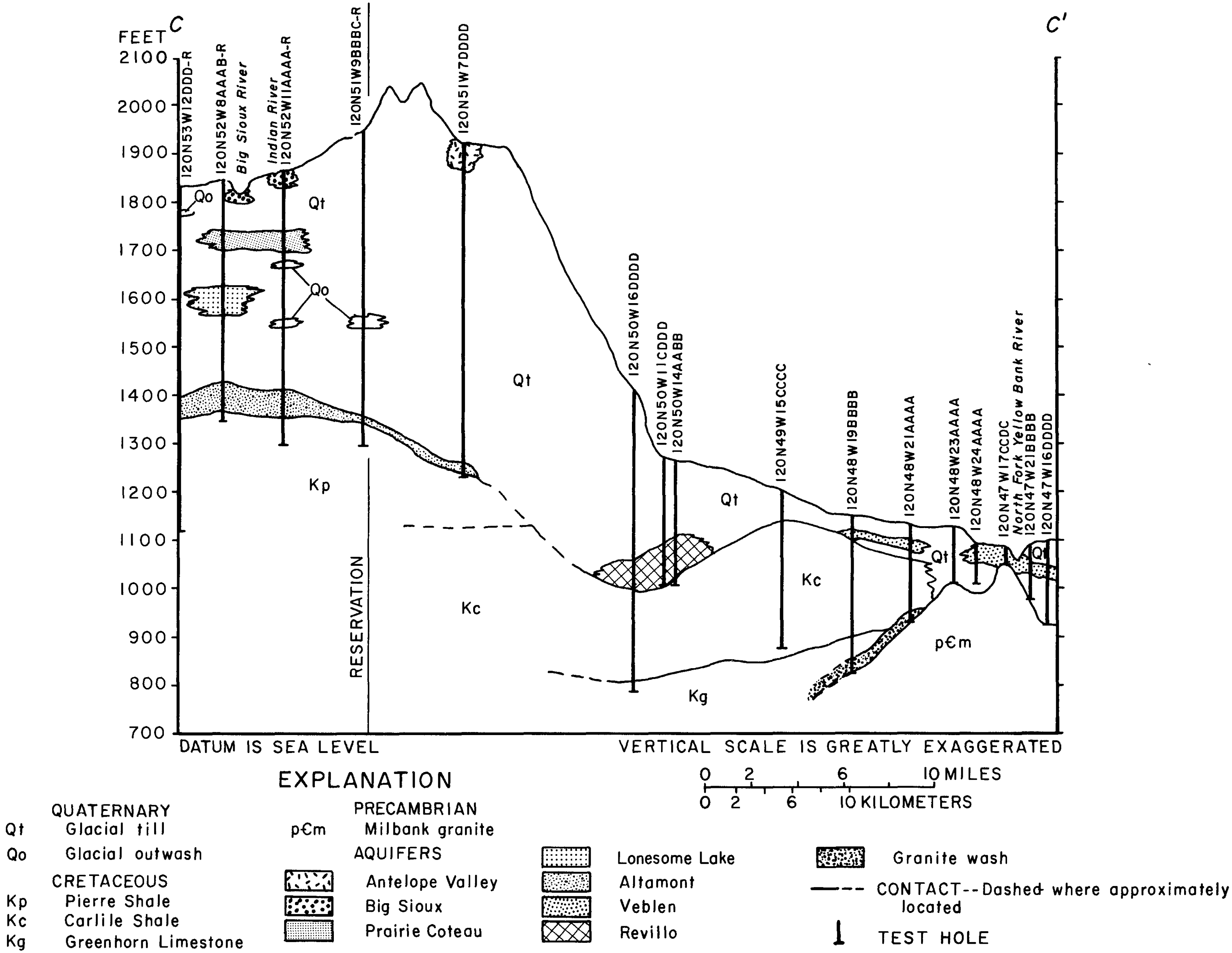


Figure 21.--Geologic section C-C′ showing the Antelope Valley, Big Sioux, Prairie Coteau, Lonesome Lake, Altamont, Veblen, Revillo, and granite wash aquifers. (Section C-C′ is shown in figure 2.)

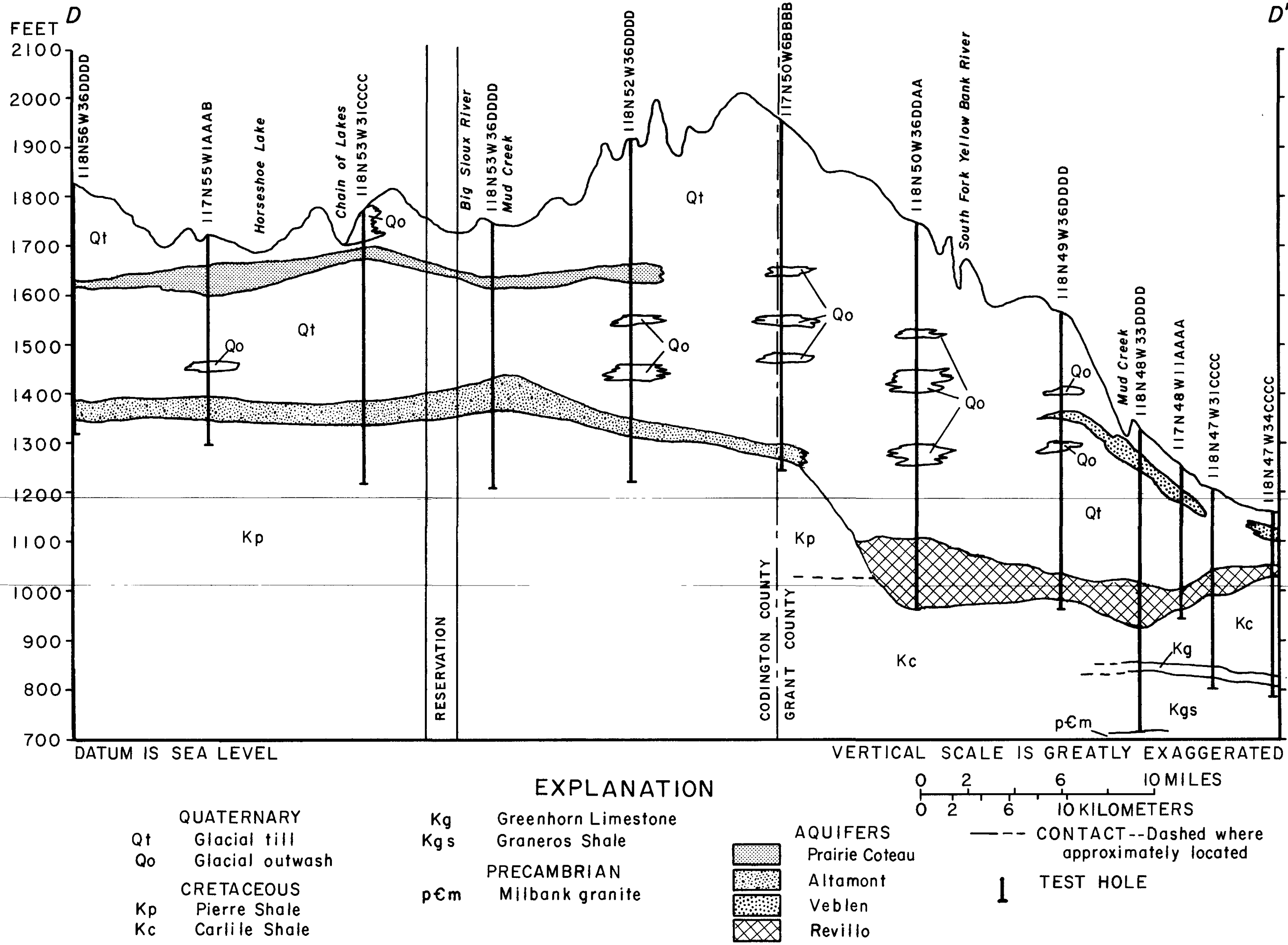


Figure 22.--Geologic section D-D' showing the Prairie Coteau, Veblen, Revillo, and Altamont aquifers. (Section D-D' is shown in figure 2.)

Water-level fluctuations in 5 observation wells screened in the aquifer reflect seasonal changes in recharge and discharge, as well as pumpage from municipal wells (fig. 19). Water levels generally declined from May to August because discharge from municipal wells was greater than recharge. Water levels rose from September to April because recharge from snowmelt and rainfall was greater than discharge. Records of long-term water-level fluctuations in well 120N50W11CDDD show correlation with long-term trends in precipitation. The water-level decline from 1979-83 was caused by below-normal precipitation. The water-level rise from 1983-87 was caused by four consecutive years of above-normal precipitation.

Predominant chemical constituents in water from the Revillo aquifer are calcium and sulfate with significant concentrations also of bicarbonate (table 6). Dissolved calcium ranged from 120 to 210 mg/L and averaged 160 mg/L. Dissolved-sulfate concentrations ranged from 350 to 800 mg/L and averaged 520 mg/L. Specific conductance of water from the aquifer, determined by onsite analysis, ranged from 1,070 to 1,900 μS/cm and averaged 1,480 μS/cm. A comparison of the chemical analysis of water from the Veblen and Revillo aquifers shows that dissolved calcium, bicarbonate, sulfate, and dissolved-solids concentrations are similar. Percent-reacting values of the major constituents in water from the Revillo aquifer are shown in figure 18. Sodium concentrations range from 16 to 52 percent. The variation may be the result of cation exchange with calcium in the clay layers within the aquifer. Water from the aquifer is used primarily for municipal and domestic use and may be suitable for irrigation based on South Dakota irrigation-water standards, revised January 1982 (fig. 6).

<u>Altamont aquifer</u>

The Altamont aquifer is present in most of Codington County and western Grant County (fig. 23). It is composed of well-rounded, medium to coarse sand. The aquifer is interbedded with silt and clay layers in the northwest quarter of Codington County. The average depth to the top of the aquifer is 460 ft below land surface; it occurs between 1,250 and 1,500 ft above sea level. The average thickness of the aquifer is about 40 ft; however, in T. 121 N., R. 52 W. and T. 118 N., R. 52 W., average aquifer thickness is about 65 ft. Hydrologic characteristics of the aquifer are given in table 3 and geologic sections of the aquifer are shown in figures 8, 11, and 21.

Recharge to the Altamont aquifer probably is by leakage from the overlying till. The direction of water movement is to the southwest at a gradient of about 5 ft/mi (fig. 24). Water-level fluctuations in an observation well screened in the aquifer are shown in figure 25. Discharge from the aquifer is primarily by pumping from stock-watering and domestic wells; however, with the introduction of rural water systems (public supply of water to the rural community), stock-watering and domestic wells are being abandoned and water use is declining.

Predominant chemical constituents in water from the Altamont aquifer are sodium and sulfate (table 7). Dissolved-solids concentrations ranged from 1,700 to 2,600 mg/L and averaged 2,120 mg/L. Specific conductance, determined from 40 onsite analyses, ranged from 1,950 to 4,020 μS/cm and averaged 3,160 μS/cm. Hardness concentrations, determined from 40 onsite analyses, ranged from 530 to 1,800 mg/L and averaged 840 mg/L.

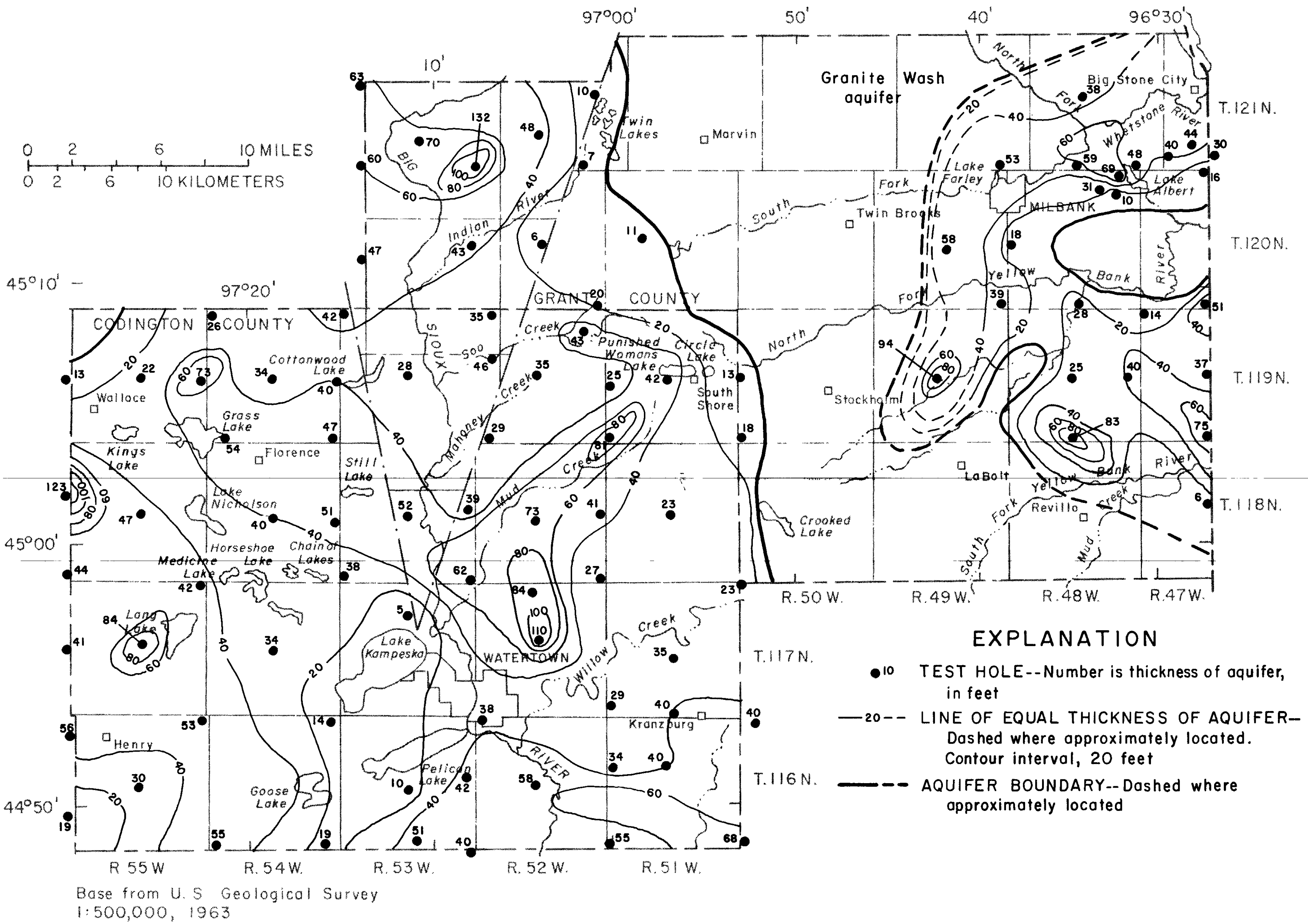


Figure 23.--Extent and thickness of the Altamont and granite wash aquifers in Codington and Grant Counties.

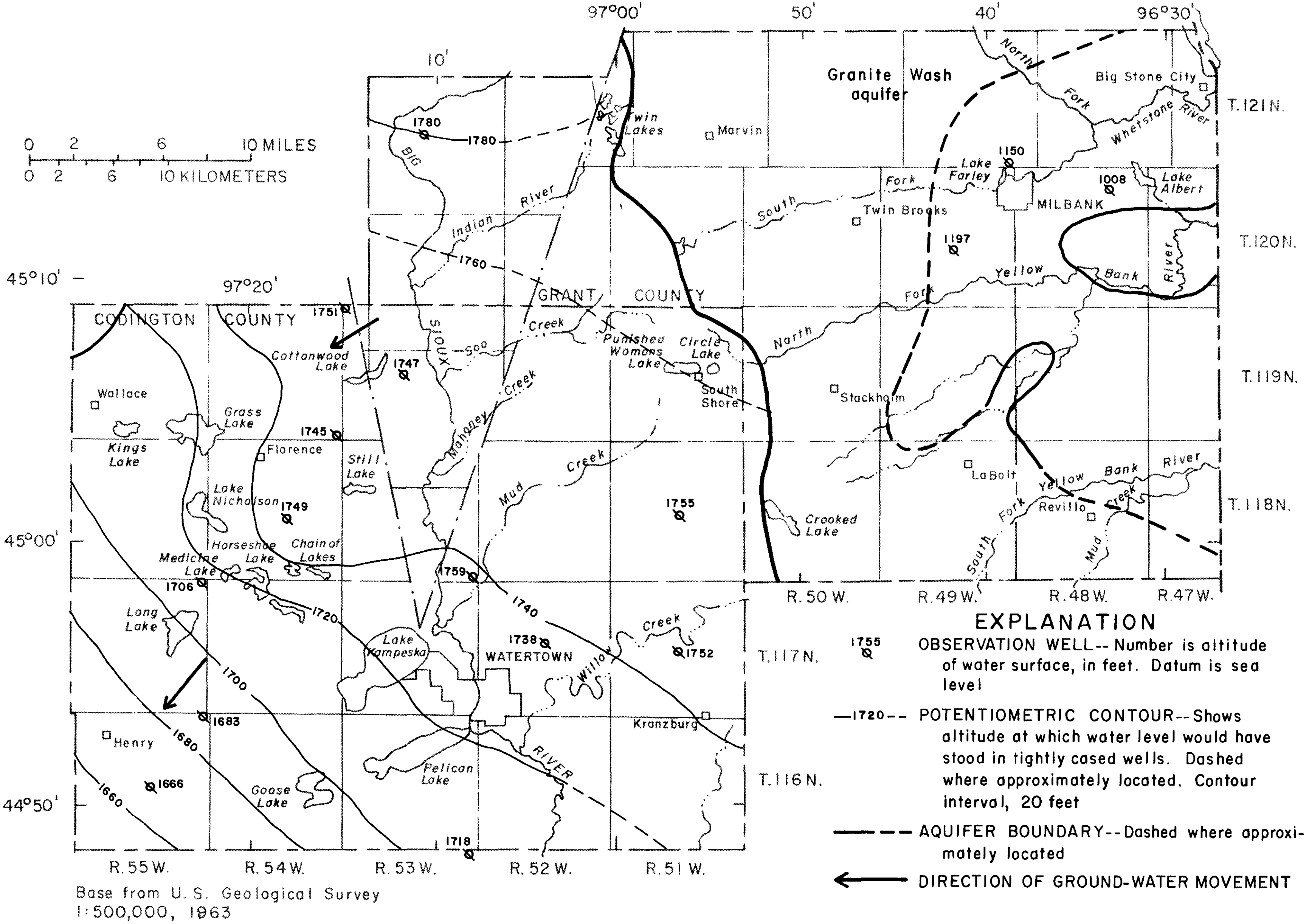


Figure 24.--Potentiometric surface of the Altamont aquifer in Codington and Grant Counties, October 1985.

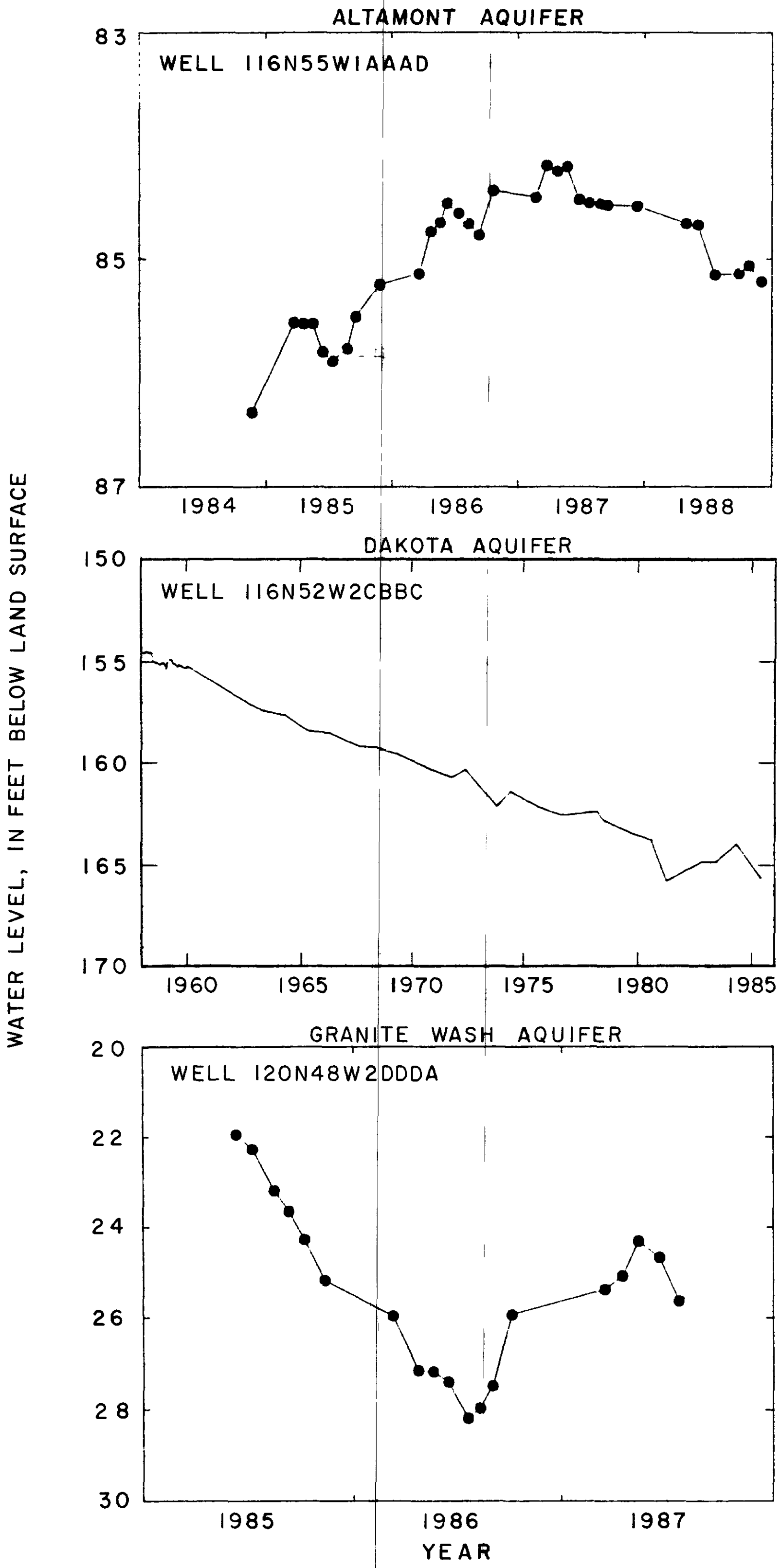


Figure 25.--Water-level fluctuations in the Altamont, Dakota, and granite wash aquifers.

Bedrock Aquifers

Dakota aquifer

The Dakota aquifer, in the Dakota Formation of Cretaceous age, is composed of a fine-grained, gray to brown sandstone that contains interbedded layers of shale. Data for the aquifer are available only from well 116N52W2CBBC. The top of the aquifer is at 1,230 ft below land surface. Water-level fluctuations in the well screened in the aquifer are shown in figure 25. The water level in the Dakota aquifer has declined about 10 ft from 1958-85. A chemical analysis of water from well 116N52W2CBBC, shown in table 7, indicates that water from the aquifer is a sodium sulfate type with a dissolved-solids concentration of 1,480 mg/L.

Granite wash aquifer

The granite wash aquifer (fig. 23) is composed of uncemented, coarse, sub-angular to well-rounded, pink to blue to gray, quartzose and feldspathic sand, containing about 50 percent feldspar. The aquifer overlies the informally named Milbank granite in eastern Grant County. The western boundary of the aquifer in Grant County was approximated because test holes did not penetrate the entire thickness of the Cretaceous sedimentary rocks. A geologic section of the aquifer is shown in figure 11 and hydrologic characteristics are given in table 3.

Water-level fluctuations in observation well 120N48W2DDDA (fig. 25) generally indicate seasonal changes in recharge to and discharge from the aquifer. Water levels in the well rose about 4 ft from September 1985 to June 1986 because recharge from snowmelt and spring rainfall was greater than discharge. Water levels declined from July 1986 to July 1987 because discharge was greater than recharge. Below-normal snowmelt and precipitation probably caused the continued decline of the water level during the spring months of 1987.

Based on three observation wells, the author believes that the direction of water movement in the aquifer may be from west to east. Discharge from the aquifer also is from stock-watering and domestic wells, fractures in the Milbank granite, and to granite quarries located 6 and 15 mi east of Milbank.

Predominant chemical constituents in water from the granite wash aquifer are sodium and sulfate. Dissolved-sodium concentrations ranged from 440 to 630 mg/L and averaged 550 mg/L. Dissolved-sulfate concentrations ranged from 930 to 1,600 mg/L and averaged 1,200 mg/L. Specific conductance ranged from 3,990 to 6,050 μS/cm and averaged 4,575 μS/cm. Chemical analyses of water samples collected from the aquifer are given in table 7.

WATER USE

The primary users of water in Codington and Grant Counties during 1985 (table 8) were gravel-mining companies. The 1985 water use by the companies was 7 Mgal/d. Seventeen percent of the total amount of water used in the counties was for irrigation, and 98 percent of the water used for irrigation was ground water. About 33 percent of the ground water used for irrigation was withdrawn from the Big Sioux aquifer and about 66 percent was withdrawn from the Prairie Coteau aquifer. All the withdrawals in Codington and Grant Counties for public-water supply were from ground water. The city of Watertown and the Sioux Rural Water System obtain water from the Big Sioux aquifer. The cities of Milbank and Revillo obtain their supply from the Revillo aquifer. About sixty percent of the water used for stock watering was derived from surface-water sources and 40 percent from ground-water sources. Well-inventory data indicate that the primary source of ground water for stock watering is the Prairie Coteau and Altamont aquifers. Total water use in Codington and Grant Counties in 1985 was about 18 Mgal/d.

Table 8.--Water use, in million gallons per day, for Codington and Grant Counties during 1985

	Live-stock	Public water supply	Power genera-tion	Self-supplied domestic	Self-supplied commercial/ industrial/ gravel mining	Irriga-tion	Total
Codington County							
Ground water	0.22	2.41	0	0.08	3.92	1.55	8.18
Surface water	.36	0	0	0	4.19	.05	4.60
Grant County							
Ground water	.24	.67	.03	.05	.10	1.50	2.08
Surface water	.36	0	2.59	0	0	.02	3.48
Total	1.18	3.08	2.62	.13	8.21	3.12	18.34

SUMMARY

The primary sources of surface water in Codington County include Lakes Kampeska and Pelican and numerous small lakes, potholes, and sloughs in the western part of the county. Seasonal variations in streamflow and lake levels are directly related to seasonal variations in precipitation. Long-term lake-level fluctuations indicate correlation with departure from normal precipitation. Specific conductance of water from streams and lakes is inversely related to stream discharge and lake levels, respectively. Dissolved-solids concentration in water from streams and lakes increases as stream discharge decreases and lake levels decline.

Seven glacial aquifers and two bedrock aquifers were delineated in Codington and Grant Counties. The Big Sioux and Antelope Valley aquifers, composed of glacial outwash, generally are less than 10 feet below land surface. The Prairie Coteau, Lonesome Lake, and Veblen aquifers are overlaid by as much as 380 feet of till and are underlaid by till. The Altamont and Revillo aquifers are overlaid by as much as 668 feet of till and, in most locations, lie on top of shale bedrock.

The average thickness of the Big Sioux aquifer is 24 feet and the average thickness of the Antelope Valley aquifer is 34 feet. Recharge to these aquifers is by direct infiltration and subsequent percolation of snowmelt and spring rainfall. Discharge is by domestic, stock-watering, irrigation, and municipal wells, evapotranspiration, outflow to the Big Sioux River from the Big Sioux aquifer, and by outflow to Punished Womans Lake from the Antelope Valley aquifer. Predominant chemical constituents in water from the aquifers are calcium and bicarbonate. Dissolved solids in the Big Sioux aquifer averaged 580 milligrams per liter and dissolved solids in the Antelope Valley aquifer averaged 350 milligrams per liter.

The average thickness of the Prairie Coteau, Lonesome Lake, and Veblen aquifers ranged from 21 to 32 feet. The Veblen aquifer is as much as 155 feet thick. Recharge to the Prairie Coteau and Veblen aquifers is by direct infiltration and subsequent percolation of snowmelt and spring rainfall. Recharge to the Lonesome Lake aquifer is by leakage from till. Test-hole and observation-well data indicate that the recharge area of the Prairie Coteau aquifer may be in T. 122 N., R. 52 W. in Roberts County. Discharge from these aquifers is by evapotranspiration and by domestic, stock-watering, irrigation, and municipal wells. Discharge from the Prairie Coteau aquifer also may occur as outflow to Long Lake. Discharge from the Veblen aquifer also is to granite quarries 6 miles east of Milbank and to Big Stone Lake. Predominant chemical constituents in water from the Prairie Coteau aquifer in northern Codington and western Grant Counties are calcium and bicarbonate and in western Codington are calcium and sulfate. Predominant chemical constituents in water from the Veblen aquifer are calcium and sulfate with significant concentrations of bicarbonate. Dissolved-solids concentrations in water from the Prairie Coteau aquifer averaged 510 milligrams per liter in northeastern Codington and western Grant Counties and 1,490 milligrams per liter in western Codington County. Dissolved-solids concentrations in water from the Veblen aquifer averaged 1,300 milligrams per liter.

The average thickness of the Revillo aquifer is 63 feet and the average thickness of the Altamont aquifer is 40 feet. Recharge to the Revillo aquifer is by direct infiltration and subsequent percolation of snowmelt and rainfall north of the study area in Roberts and Marshall Counties. Water-level fluctuations in the Revillo aquifer are caused by seasonal changes in recharge and by pumpage from municipal wells. Records of long-term water-level fluctuations show correlation with long-term trends in precipitation. Recharge to the Altamont aquifer is by leakage from till. Discharge from the aquifers is by stock-watering and domestic wells. Discharge from the Revillo aquifer also is by municipal wells.

Predominant chemical constituents in water from the Big Sioux, Antelope Valley, Prairie Coteau, Veblen, Revillo, and Lonesome Lake aquifers are calcium and bicarbonate. Significant concentrations of sulfate also are present in water from the Veblen and Revillo aquifers. Sodium and sulfate are predominant in water from the Altamont aquifer. Average dissolved-solids concentrations in water from the aquifers range from 350 to 2,120 milligrams per liter.

The Dakota aquifer is 1,230 ft below land surface in Codington County. The water level in one observation well screened in the aquifer has declined 10 ft in the last 30 years. Water from the aquifer is a sodium sulfate type with a dissolved-solids concentration of 1,480 milligrams per liter.

The average thickness of the granite wash aquifer is 37 feet. Water-level fluctuations in an observation well indicate seasonal changes in recharge and discharge. Discharge from the aquifer is primarily from stock-watering and domestic wells and to granite quarries located 6 and 15 miles east of Milbank. Predominant chemical constituents in water from the granite wash aquifer are sodium and sulfate.

Total water use in Codington and Grant Counties during 1985 was about 18 million gallons per day. The primary users of water in Codington and Grant Counties are gravel-mining companies. Seventeen percent of total water use was for irrigation, of which 98 percent was ground water.

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