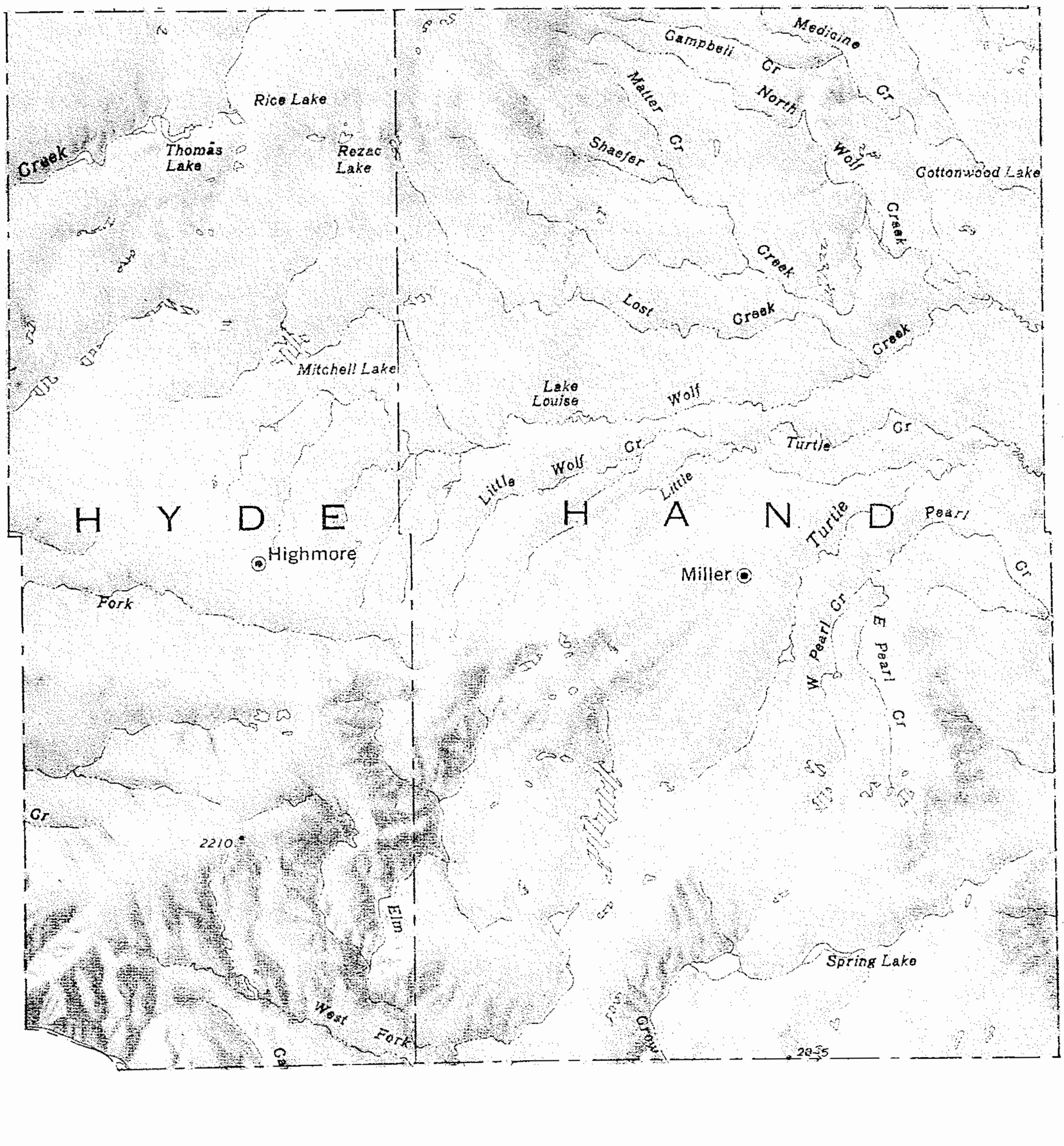
BULLETIN 28

GEOLOGY AND WATER RESOURCES OF HAND AND HYDE COUNTIES, SOUTH DAKOTA

PART II: WATER RESOURCES

by Neil C. Koch
United States Department of the Interior, US Geological Survey



Prepared in cooperation with the South Dakota Geological Survey, Hand and Hyde Counties, and the Oahe Conservancy Sub-District

DEPARTMENT OF WATER AND NATURAL RESOURCES — GEOLOGICAL SURVEY 1980

STATE OF SOUTH DAKOTA
William Janklow, Governor

DEPARTMENT OF WATER AND NATURAL RESOURCES
Warren Neufeld, Secretary

GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Bulletin 28

GEOLOGY AND WATER RESOURCES OF HAND AND HYDE COUNTIES, SOUTH DAKOTA

PART II: WATER RESOURCES

by

Neil C. Koch
United States Department of the Interior
United States Geological Survey

Prepared in cooperation with the
South Dakota Geological Survey,
Hand and Hyde Counties, and the
Oahe Conservancy Sub-District

Science Center
University of South Dakota
Vermillion, South Dakota
1980

CONTENTS

ILLUSTRATIONS

FIGURES **Page**

FIGURES -- continued. Page

TABLES

Page

GLOSSARY

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.

Artesian aquifer.--An aquifer in which the water in a well rises above the top of the aquifer.

Bedrock.--A general term for the rock, usually solid, that underlies soil, sand, clay or other unconsolidated material. In Hand and Hyde Counties the uppermost bedrock deposit is shale.

Dissolved solids.--Includes all material in water that is in solution.

Drift.--A collective term applied to all material transported and deposited by glacial ice.

Evapotranspiration.--Water withdrawn by evaporation and plant transpiration from water surfaces and moist soil.

Glacial aquifer.--A water-bearing formation composed of material deposited by a glacier. In this report it is mainly unconsolidated sand and gravel deposited as outwash from a glacier.

Hardness.--Dissolved calcium and magnesium salts that reduce the lathering ability of soap and form scale in boilers and pipes. Hardness is reported as calcium carbonate and is classified by the U.S. Geological Survey (Durfor, 1964) as follows:[1]

Hydraulic conductivity.--The rate of flow of water in gallons per day through a porous medium of cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot at the prevailing kinematic viscosity.

Outwash.--Sand, gravel, silt, and clay which is deposited by water from melting ice. For the purposes of this report, outwash is restricted to sand and gravel.

Potentiometric surface.--The levels to which water will rise in tightly cased wells.

Properly constructed well.--One constructed to admit a maximum amount of water from an aquifer without excessive head loss. Proper construction generally requires either installing a well screen or perforating the casing and installing a gravel pack around the casing opposite the depth interval of the aquifer. It also requires pumping the well in such a manner as to remove drilling mud and other fine-grained material from the aquifer adjacent to the well.

Recurrence interval.--The average interval of time within which the given flood will be equaled or exceeded once.

Specific capacity.--The rate of discharge of water from the well divided by the drawdown of water level within the well.

Specific yield.--The ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume.

Storage coefficient.--The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, it is virtually equal to the specific yield.

Subsurface outflow.--Ground water that leaves the area of this report underground.

Till.--Unsorted, unstratified drift deposited directly by glaciers. Till is composed of a heterogeneous mixture of clay, silt, and sand and contains lesser amounts of rock fragments ranging in size from gravel to huge boulders.

Transmissivity.--The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Water table.--That surface in an unconfined water body at which the pressure is atmospheric. Generally this is the upper surface of the zone of saturation, except where the surface is formed by a poorly permeable body.

[1]Description	Milligrams per liter (mg/L)	Grains per gallon (gpg)
Soft	0- 60	0- 3.4
Moderately hard	61-120	3.5- 7.0
Hard	121-180	7.1-10.5
Very hard	More than 180	More than 10.5

ABSTRACT

Hand and Hyde Counties, agricultural counties in central South Dakota, have an area of 2,300 square miles (5,957 square kilometers).

Glacial outwash and bedrock deposits are the major water-bearing deposits in these counties. Four glacial outwash aquifers, the Tulare, Elm Creek, Highmore, and Bad-Cheyenne River aquifers contain about 5 million acre-feet (6.2 billion cubic meters) of water in storage. These aquifers can provide yields of 1,000 gallons per minute (63 liters per second) to wells.

The Tulare aquifer underlies about 950 square miles (2,460 square kilometers) in northern Hand and Hyde Counties. It is from 10 to 200 feet (3 to 60 meters) below land surface and contains water mostly under artesian conditions. The water generally is of suitable quality for domestic, stock, municipal, and irrigation uses.

The Elm Creek aquifer, in southwestern Hand County and southeastern Hyde County, underlies an area of 25 square miles (65 square kilometers), ranges from 2 to 100 feet (0.6 to 30 meters) below land surface, and contains water under artesian conditions in the Elm Creek flood plain and under water-table conditions in the West Fork Elm Creek flood plain. The water is of suitable quality for domestic, stock, municipal, and irrigation use.

The Highmore aquifer underlies an area of about 100 square miles (259 square kilometers) in central Hyde County and is from 20 to 200 feet (6 to 61 meters) below land surface. It contains water mostly under artesian conditions that generally is of suitable quality for domestic, stock, municipal, and irrigation uses.

The Bad-Cheyenne River aquifer underlies an area of about 200 square miles (518 square kilometers) in Hyde and Hand Counties. It crosses north-central Hyde County and extends to the southeast across Hand County. The aquifer is from 150 to 500 feet (46 to 152 meters) below land surface and contains water under artesian conditions. The water is of suitable quality for stock and domestic uses. It is not suitable for irrigation use because of a high percent sodium and dissolved solids content.

The major bedrock aquifers which underlie Hand and Hyde Counties are the sandstones found in the Dakota, Fall River, Sundance, and Minnelusa Formations. These aquifers contain about 130 million acre-feet (160 billion cubic meters) of water in storage and can provide yields of as much as 1,000 gallons per minute (63 liters per second).

The Dakota aquifer has an average thickness of 240 feet (73 meters) at depths greater than 900 feet (275 meters) below land surface in eastern Hand County to depths greater than 1,750 feet (533 meters) below land surface in southern Hyde County.

The Fall River, Sundance, and Minnelusa Formations are hydraulically connected and act as a single aquifer in Hand and Hyde Counties. The aquifer has an average thickness of about 200 feet (60 meters) at depths greater than 1,400 feet (430 meters) below land surface in eastern Hand County to depths greater than 2,400 feet (730 meters) in western Hyde County.

The water in the bedrock aquifers is used for domestic, stock, and municipal purposes. Its high dissolved solids makes it unsuitable for irrigation use.

Surface water covers about one percent of Hand and Hyde Counties. It includes many small intermittent streams and some marshes, ponds, and lakes. The average annual discharge of creeks ranges from 0.6 to 14.4 cubic feet per second (0.01 to 0.4 cubic meters per second).

INTRODUCTION

In July 1972, the South Dakota Geological Survey and the U.S. Geological Survey began a 4-year study of the geology and water resources of Hand and Hyde Counties, an area of 2,300 mi^2 (5,957 km^2) in central South Dakota. The investigation is part of a cooperative program of water-resources evaluation in South Dakota. The status of that program is shown in figure 1.

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

Work performed included preparation of a geologic map (Part I of this Bulletin), compilation and evaluation of data concerning the geology and hydrology of the area, well inventories, collection and analysis of water samples, measurement of water levels in wells, and test drilling.

For those readers interested in using the metric system, the English units used in this report may be converted to metric units by the following conversion factors:[2]

Well-numbering System

The wells and test holes are numbered according to a system based on the Federal land-survey of eastern South Dakota (fig. 2).

Acknowledgments

Appreciation is expressed to the residents of Hand and Hyde Counties and municipal officials for providing needed information. Valuable information about the water-yielding characteristics of aquifers was provided by local well drillers and is greatly appreciated.

WATER RESOURCES

Water in Hand and Hyde Counties occur in surface streams, ponds, reservoirs, and aquifers in glacial deposits and bedrock strata. Most of the streamflow is derived from snowmelt and spring rains within the counties.

Average annual precipitation in Hand and Hyde Counties is about 18 in (46 cm) which is about 2.2 million acre-ft per year (2.7 billion m^3). Of this amount, about 30,000 acre-ft (37 million m^3) leaves the area as surface runoff and 40,000 acre-ft (49 million m^3) is evaporated from reservoirs and ponds.

[2]

From		Multiply by	To obtain	
Unit:	*Abbreviation:*		*Unit:*	*Abbreviation:*
Inches	(in)	25.40	Millimeters	(mm)
Inches	(in)	2.54	Centimeters	(cm)
Feet	(ft)	.3048	Meters	(m)
Square miles	(mi^2)	2.590	Square kilometers	(km^2)
Gallons	(gal)	3.785	Liters	(L)
Gallons	(gal)	.003785	Cubic meters	(m^3)
Miles	(mi)	1.609	Kilometers	(km)
Acre-feet	(acre-ft)	1233	Cubic meters	(m^3)
Acres		.4047	Hectares	(ha)
Gallons per minute	(gal/min)	.06309	Liters per second	(L/s)
Pounds per square inch	(lb/in^2)	.07031	Kilograms per square centimeter	(kg/cm^2)
Feet per mile	(ft/mi)	.1894	Meters per kilometer	(m/km)
Cubic feet per second	(ft^3/s)	.02832	Cubic meters per second	(m^3/s)

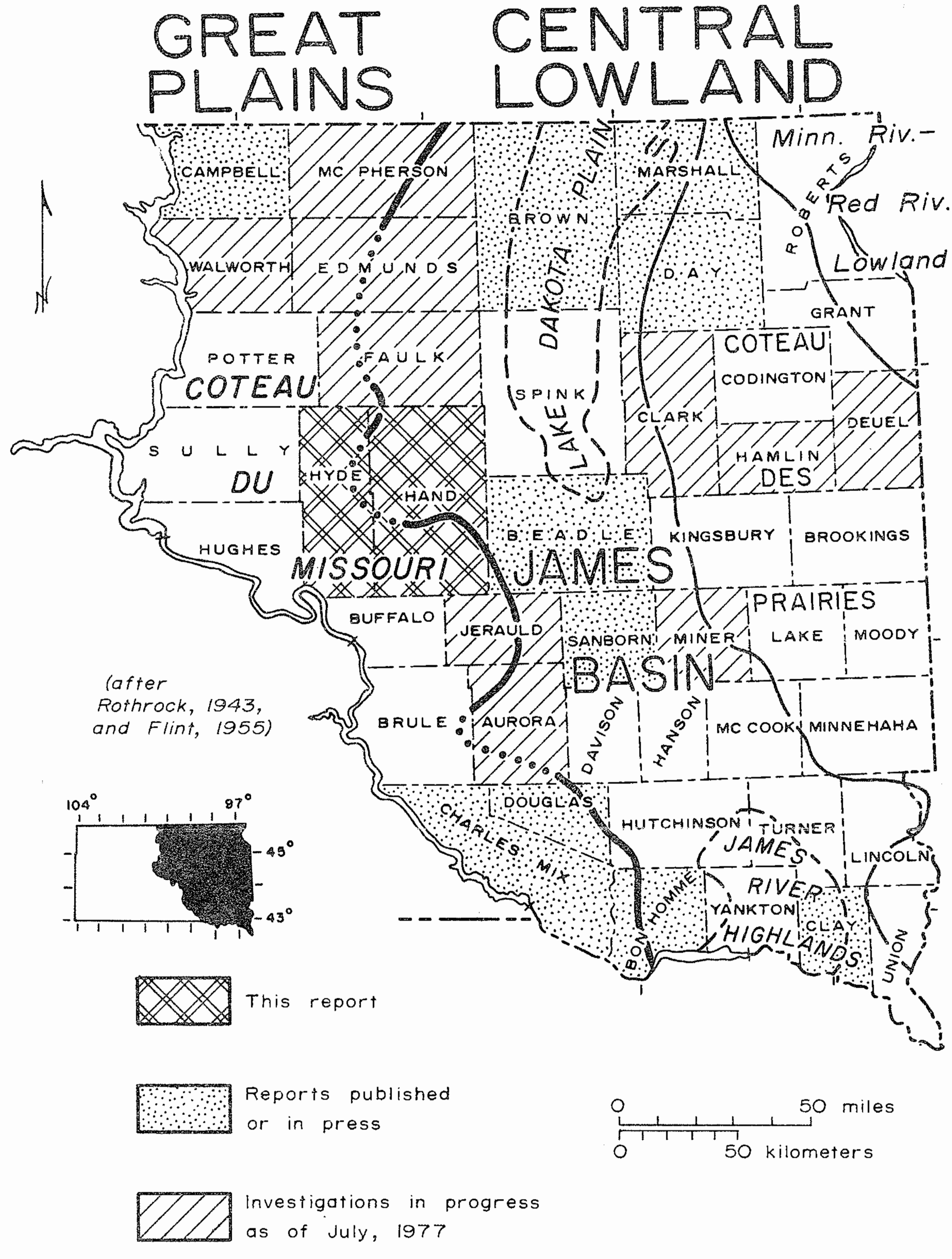


Figure 1. Index map of eastern South Dakota showing area of this report, status of county investigations, and major physiographic divisions.

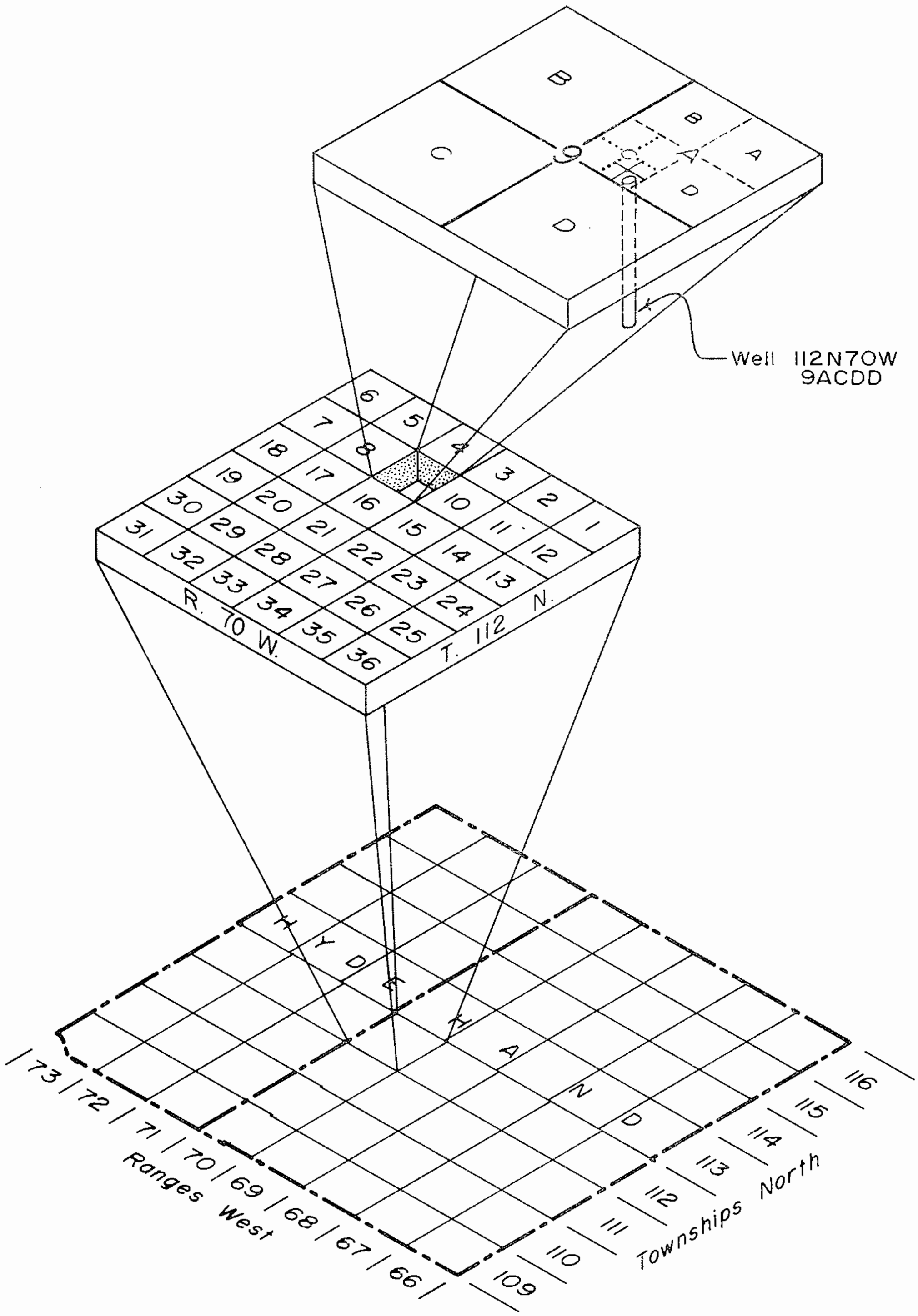
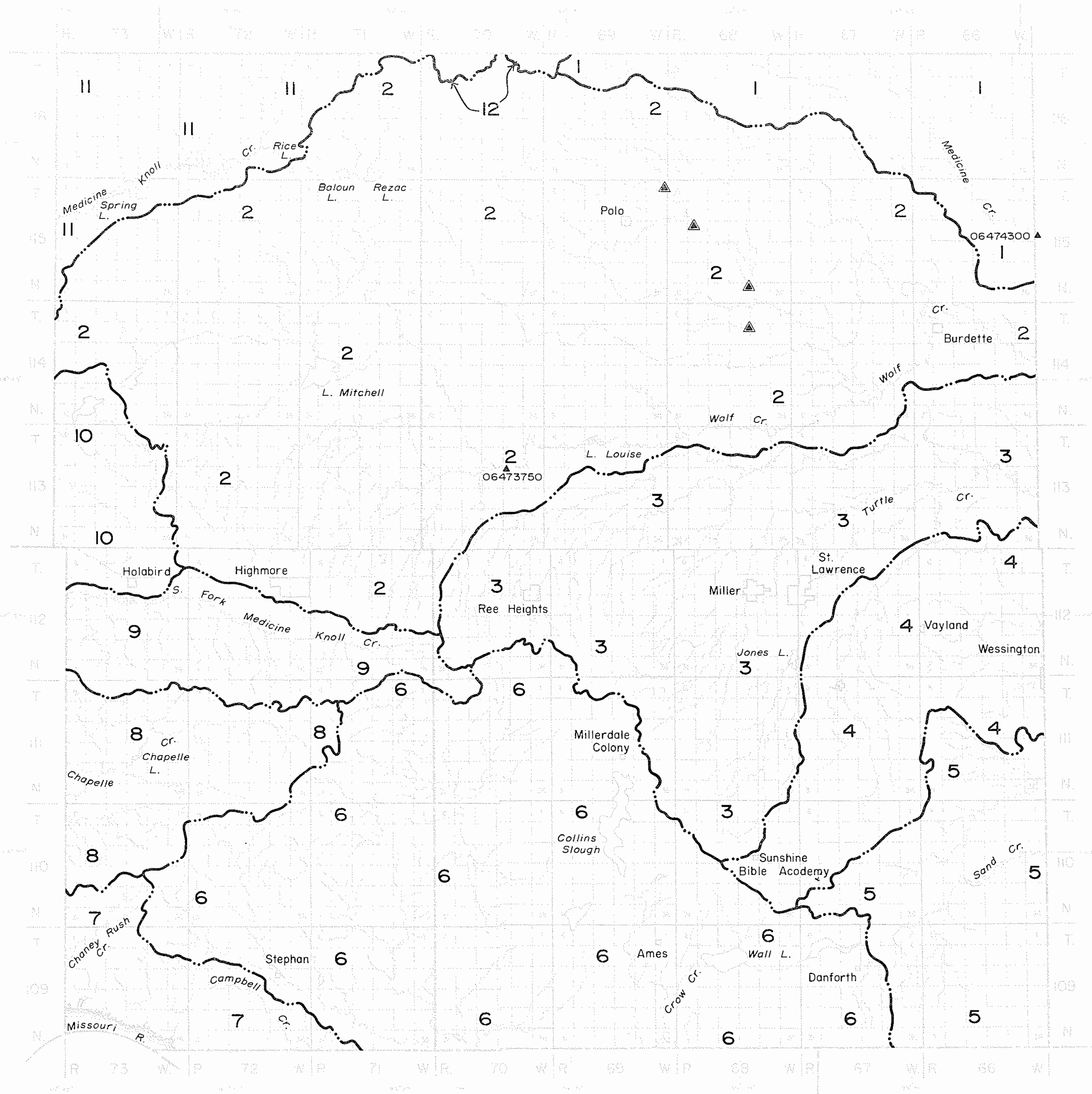


Figure 2. Well-numbering diagram. The well number consists of township followed by "N," range followed by "W," and section number, followed by a maximum of four uppercase letters that indicate, respectively, the 160, 40, 10, and 2½-acre tract in which the well is located. These letters are assigned in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



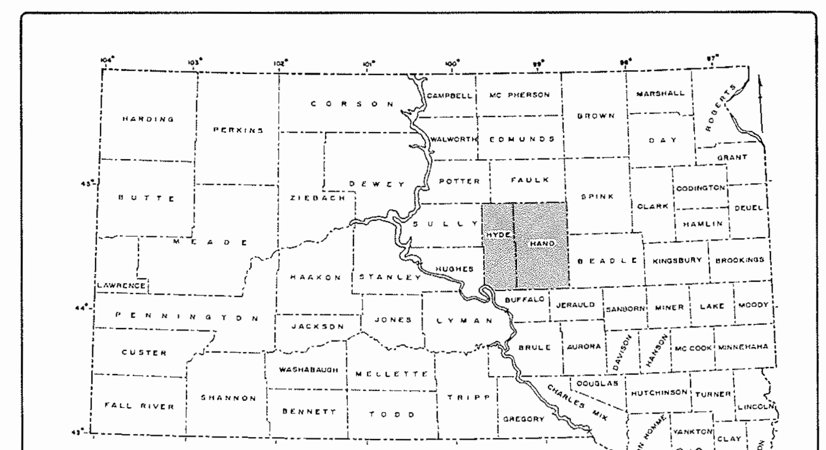
06474300 ▲ Continuous-record gaging station *(number is station number.)*

▲ Partial-record gaging stations *(floods)*

Drainage divides

DRAINAGE BASINS

1. Medicine Creek
2. Wolf Creek
3. Turtle Creek
4. Pearl Creek
5. Sand Creek
6. Crow Creek
7. Chaney Rush-Campbell Creek
8. Chapelle Creek
9. South Fork Medicine Knoll Creek
10. Tributary to Medicine Knoll Creek
11. Medicine Knoll Creek
12. South Fork Snake Creek



Index map of South Dakota showing location of Hyde and Hand Counties.

0 5 10 15 20 miles

0 5 10 15 20 25 30 kilometers

Base from South Dakota Highway Department county highway maps.

Figure 3. The headwaters of nine creek systems rise in Hyde and Hand Counties.

Evapotranspiration from vegetation and soil (not including aquifers) accounts for about 2.1 million acre-ft (2.6 billion m^3). The remaining 30,000 acre-ft (37 million m^3) recharges surficial aquifers. Natural discharge from the aquifers is by evapotranspiration and subsurface outflow.

Surface water leaves the area through a number of small creeks flowing east, south, and west. Many of these creeks originate in the two counties.

Ground water in Hand and Hyde Counties is obtained from confined aquifers in bedrock deposits and from confined and unconfined aquifers in glacial drift. Aquifers in the glacial drift contain about 5 million acre-ft (6.2 billion m^3) of water in storage. They are separated or confined by a pebbly clay called till. The till deposits are often discontinuous and lenticular. This situation results in varying degrees of permeability in the till between the aquifers. The confined Dakota, and Fall River-Sundance-Minnelusa (bedrock) aquifers contain about 130 million acre-ft (160 billion m^3) of water in storage.

Surface Water

Water on the land surface is a minor feature, covering about 28 mi^2 (72 km^2) or 1 percent of Hand and Hyde Counties. The surface water supply includes many small intermittent streams and some marshes, ponds, and lakes.

Drainage Basins

A well developed network of intermittent streams covers most of the area (fig. 3). However, Medicine Knoll Creek (11, see fig. 3) and South Fork Snake Creek (12) basins, the northeastern part of the Crow Creek basin (6), and the western part of the Wolf Creek basin (2) are poorly drained. Medicine, Wolf, Turtle, Pearl, and Sand Creeks drain to the east into the James River. The other creeks drain south and west into the Missouri River. Wolf and Turtle Creeks join 2 mi (3 km) east of the Hand County line.

The present drainage is the result of glacial alterations of pre-existing valleys. Even though glacial action has reshaped the bedrock surface and glacial drift has been spread as a blanket up to several hundred feet thick over the bedrock surface the major valleys and highlands are in the same areas today as they were in preglacial time. For example, the preglacial valleys, Great Ree Valley and James River Lowland, are still lowland areas today (fig. 4). The preglacial highlands, Orient Hills, Ree Hills, and Wessington Hills, which are bedrock highs, are still highland areas today.

Streamflow

The rate, volume, and distribution of runoff depend upon climate and upon the physical characteristics of the watershed. Seasonal variations in streamflow, which are closely related to climate, have similar patterns over relatively large areas. In Hand and Hyde Counties most streamflow and all floods occur in the spring and early summer from snowmelt and precipitation. Except for Medicine, Wolf, and Turtle Creeks which receive discharge from ground-water storage (fig. 5) creeks commonly have no flow in summer, fall, and winter.

The average annual discharge of creeks in the area ranges from 0.6 to 14.4 ft^3/s or 0.02 to 0.4 m^3/s (table 1). Gaging stations record day-to-day streamflow fluctuations on Wolf, Medicine, and Turtle Creeks (table 2).

Flow Duration

The duration of streamflow in most creeks in this area is very short. Flow-duration curves (fig. 6) give a measure of the probability of flow being equal to or greater than the indicated flow. The shape of the curve for a given stream is greatly influenced by the geologic and hydrologic characteristics of the basin. For example, where most of the streamflow is direct runoff, flow is highly variable and the curve will be steep. Where there is a large amount of ground water discharging into the stream from underground storage the streamflow is more constant and the curve is relatively flat.

Floods

In this area, extreme floods are rare events whereas periodic flooding of the bottom land in a stream valley is common. Use of a stream and the land along it is governed by the magnitude and frequency of flooding. Table 3 gives the magnitude of floods occurring every 2, 5, 10, and 25 years for selected creeks in the area (in part from Becker, 1974).

Lakes, Ponds, Dugouts, and Stock Dams

Lakes and ponds cover about 1 percent of Hand and Hyde Counties. Table 4 gives information about several lakes in the area. Even though there are only a few lakes they are valuable in that they provide esthetic and recreational resources. Therefore efforts should be made to maintain these lakes in usable existence for as long as possible. Factors that are important in determining the usability of a lake are many, but three are of major importance--lake levels, water quality, and depth. If these factors can be maintained within desirable standards the useful life of the lakes will be prolonged.

The South Dakota Department of Environmental Protection has classified the lakes in South Dakota according to their beneficial uses (table 4). This classification does not limit the actual use of such

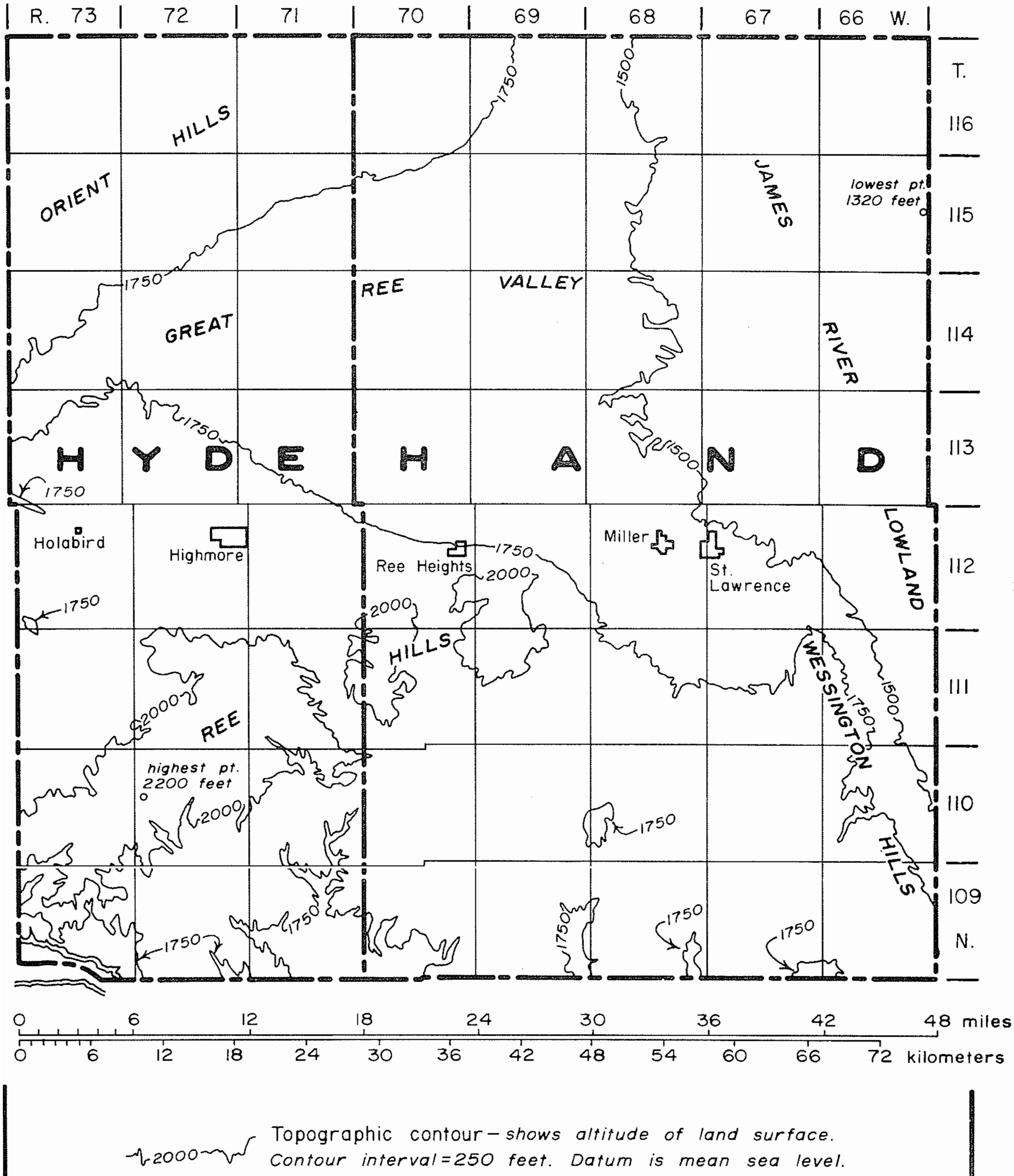


Figure 4. The Great Ree Valley is a major preglacial valley in Hyde and Hand Counties.

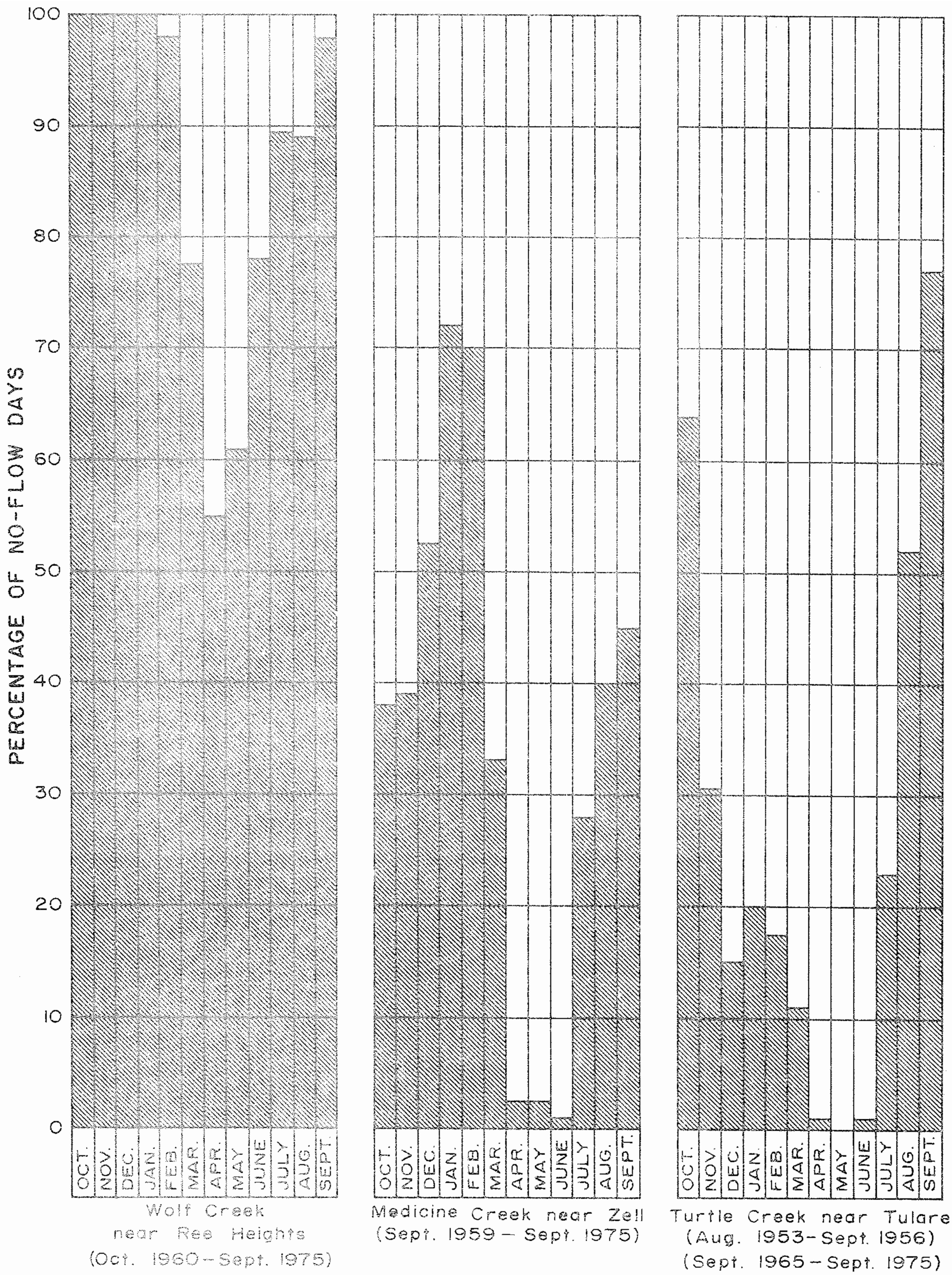


Figure 5. Ground-water discharge into Medicine and Turtle Creeks helps reduce the number of no-flow days. Ground-water also discharges into Wolf Creek in the eastern part of Hand County downstream from the gaging station. However, upstream from the Wolf Creek gaging station there is almost no ground-water discharge into Wolf Creek.

TABLE 1. Estimated average annual flows in selected drainage basins.

No.[2]	Drainage basin Name	Drainage area (mi^2)	Average annual streamflow[1] Acre-feet per square mile	Cubic feet per second	Acre-feet (rounded)
1	Medicine Creek	210	13.8	3.99	2,890
2	Wolf Creek	800	12.9	14.24	10,300
3	Turtle Creek	303	13.5	5.66	4,100
4	Pearl Creek	146	14.0	2.82	2,040
5	Sand Creek	121	14.1	2.36	1,710
6	Crow Creek	444	13.3	8.14	5,890
7	Chaney Rush-Campbell Creek	62	14.6	1.25	906
8	Chapelle Creek	89	14.4	1.76	1,280
9	South Fork Medicine Knoll Creek	84	14.4	1.67	1,210
10	Tributary to Medicine Knoll Creek	48	14.8	.98	710
11	Medicine Knoll Creek	100	14.3	1.97	1,430
12	South Fork Snake Creek	5	None	None	None
	Total	2,412			32,470

[1] Estimated using the method described by Larimer (1970).
[2] Number refers to drainage basin location in figure 3.

TABLE 2. Summary of streamflow data for gaging stations in the area.

Station number	Station name and location	Drainage area (mi^2)	Period of record	Discharge for period of record (ft^3/s) Maximum	Minimum	Average
06473750	Wolf Creek near Ree Heights 113N70W11CC	265	1959-75	990	0	4.39
06474000	Turtle Creek near Tulare 115N65W25DD	1,120	1953-56 1965-75	6,000	0	14.7
06474300	Medicine Creek near Zell 115N65W19BB	210	1959-75	2,210	0	6.29

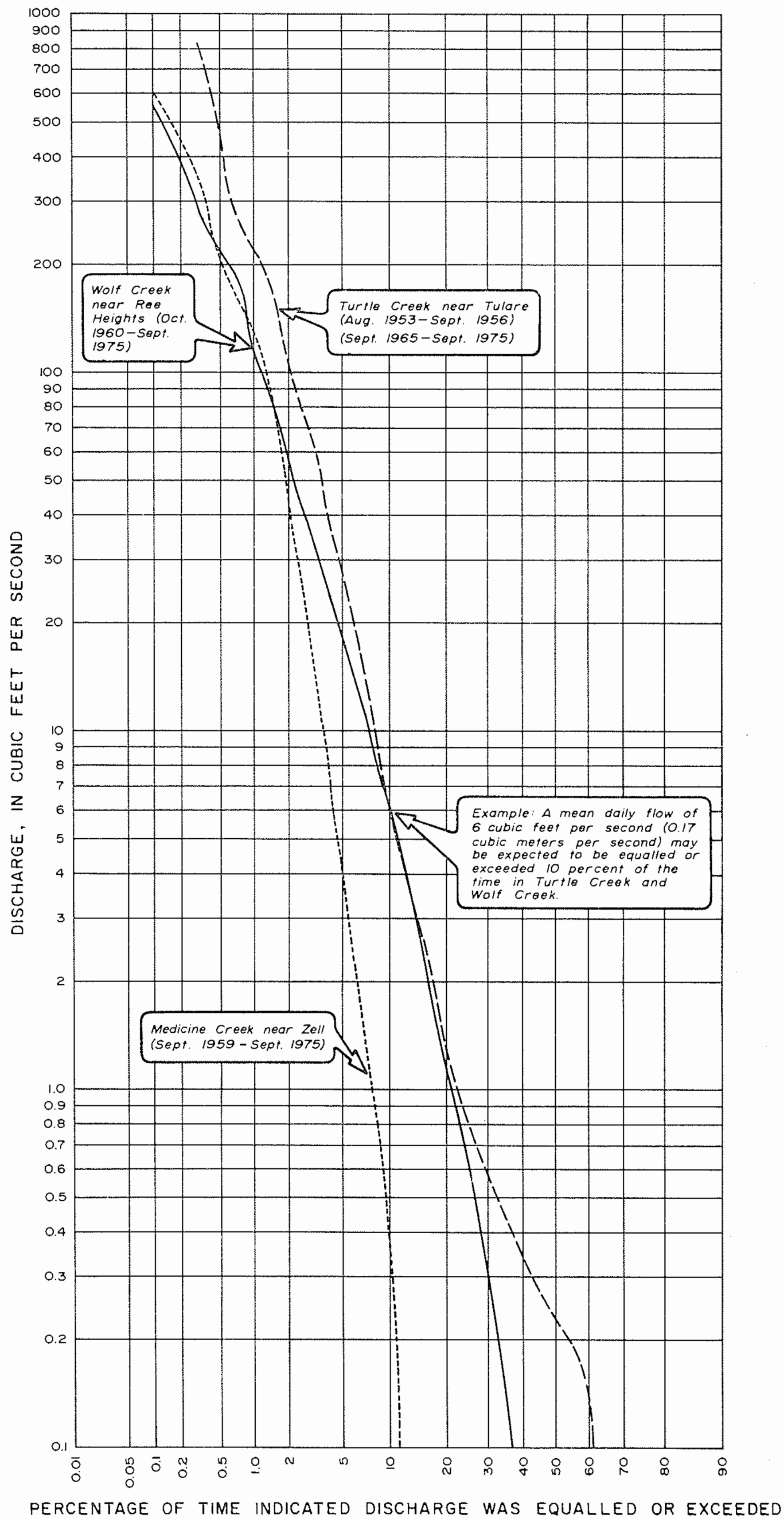


Figure 6. Flow duration curves for three streams illustrate variations in flow characteristics.

TABLE 3. Drainage-basin and flood-frequency characteristics at county line and selected gaging stations in Hand and Hyde Counties, South Dakota.

Station number, name, and location	Drainage area (mi^2)	Basin characteristics: Mean basin elevation (ft)	Mean annual precipitation (in)	Flood characteristics: Discharge, in cfs, for indicated recurrence intervals, in years			
				2	5	10	25
06473750 Wolf Creek near Ree Heights 113N70W11CC	265	1,700	17.0	30	226	641	---
06473800 Matter Creek tributary near Orient 115N69W1AD	5.41	1,600	17.6	15	102	245	564
06473820 Shaefer Creek near Orient 115N68W17BB	45.1	1,600	17.5	82	334	694	1,490
06473850 Shaefer Creek tributary near Orient 115N68W34AD	6.08	1,500	17.5	37	117	190	295
06473880 Shaefer Creek tributary near Miller 114N68W10A	5.75	1,500	17.5	17	65	130	266
06474000 Turtle Creek near Tulare 115N65W25DD	1,120	1,600	17.5	101	846	2,820	---
06474300 Medicine Creek near Zell 115N65W19BB	210	1,500	18.0	166	642	1,280	---
Pearl Creek at county line[1]	146	---	17.5	75	360	800	1,700
South Fork Medicine Knoll Creek at county line[1]	84	---	17.5	55	280	600	1,350

[1] Discharge estimates based on method used by Becker (1974).

TABLE 4. Summary of lake data

Name	Location	Depth (feet)[1]		Surface area[1] (acres)	Storage capacity (acre-ft)	Maintained for beneficial use[2]
		Maximum	Average			
Boehm	109N71W18	15	6.5	57	370	5,7,8
Chapelle	111N73W22	19	6	34	200	5,7,8
Dakotah	112N69W35	21	11	12	130	4,7,8
Holabird	112N72W22	---	---	20	---	6,7,8
Jones	112N68W25,36	18	8	84	670	5,7,8
Louise	113N69W4	25	9	137	1,230	5,7,8
Pearl	111N67W4,5	12	5.5	22	120	5,7,8
Peno	110N71W9,16	20	8	70	560	5,7,8
Quirk	111N71W14	20	8	40	320	5,7,8
Rezac	116N71W34,35	---	---	320	---	---
Rice	116N72W26	---	---	360	---	---
Rose Hill	110N66W21,28	31	12.9	35	450	4,7,8
Spring	109N67W5-9	8	4	500	2,000	---
Stephan	109N72W11	8	4	20	80	6,7,8
Wall	109N68W8-10	---	---	700	---	---

[1] Written communication from South Dakota Department of Game, Fish, and Parks

[2] 4 - warm water permanent fish life propagation waters
5 - warm water semipermanent fish life propagation waters
6 - warm water marginal fish life propagation waters
7 - imersion recreation waters
8 - limited contact recreation waters

waters but designates the quality which must be maintained for each assigned use. All lakes in the area are assigned the beneficial use of wildlife propagation and stock watering.

There are 5,028 dugouts and stock dams in Hand and Hyde Counties; 3,055 are in Hand and 1,973 are in Hyde (Soil Conservation Service, Huron, South Dakota, oral communication, Sept. 1976). When the dugouts and stock dams are full the water surface covers about 1,200 acres (486 ha) in the two counties. In August 1976, 3,094 dugouts or stock dams were dry because of the drought.

Chemical Quality

Water quality varies with the magnitude of flow of streams and with the season of the year. Dissolved-solids concentration of water from streams in Hand and Hyde Counties generally varies inversely with the volume of streamflow. Because the specific conductance is related to the number and specific chemical types of ions in solution, it can be used for approximating the dissolved-solids content in the water. Table 5 shows how the specific conductance varies with variation in flow in several creeks from a low 200 micromhos per centimeter at 25°C with an

TABLE 5. Temperature and specific conductance of stream waters.

Date	Instantaneous discharge (ft^3/s)	Temperature (°C)	Specific conductance (µmho/cm at 25°C)
06474300 - Medicine Creek near Zell, South Dakota Latitude - 44°45′52″ Longitude - 98°42′13″			
7-16-73	0.030	27	480
9-10-73	.025	26	510
11- 6-73	---	----	1,800
3-25-74	.03	----	2,000
7- 8-74	.04	28	1,810
10-29-74	.01	14.5	2,000
11-25-74	.019	20	2,000
4-15-75	10	25.0	----
4-22-75	6.3	10.5	----
5- 5-75	1.9	18.5	1,080
5-28-75	.51	12.0	1,460
6-16-75	.42	24	1,600
7-14-75	.02	23.5	1,570
8-12-75	.01	24.0	2,000
11- 3-75	.01	10.0	1,970
2-23-76	4.17	0.0	290
3-22-76	.10	4.0	950
4-19-76	.04	10.5	1,730
06474000 - Turtle Creek near Tulare, South Dakota Latitude - 44°44′06″ Longitude - 98°35′09″			
3-25-74	27	5.5	690
4-15-75	5.1	2	----
4-23-75	2.1	7	510
5- 5-75	.55	18.5	630
5-28-75	.23	16	710
6-16-75	.27	24	810
2-23-76	.33	2	1,320
3-22-76	.28	2	900
06473750 - Wolf Creek near Ree Heights, South Dakota Latitude - 44°36′25″ Longitude - 99°13′54″			
4-22-75	.24	9.0	----
5- 5-75	.02	17	290
5-27-75	.10	14.5	200

TABLE 6. Chemical analyses of stream and lake waters.

Date	Dissolved silica (SiO_2) (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Alkalinity as ($CaCO_3$) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved nitrite plus nitrate (N) (mg/L)	Dissolved phosphorus (P) (mg/L)	Dissolved boron (B) (ug/L)	Dissolved solids (sum of constituents) (mg/L)	Dissolved solids (tons per acre-ft)	Hardness (Ca, Mg) (mg/L)	Noncarbonate hardness (mg/L)	Sodium adsorption ratio	Specific conductance (micromhos)	pH (units)
Medicine Creek near Zell, South Dakota[1]																				
3-22-76	13	81	30	150	10	318	261	290	69	0.1	0.01	0.08	160	800	1.09	330	65	3.6	950	7.9[2]
Chapelle Lake																				
4- 7-76	1.7	82	82	200	32	270	236	690	28	.3	.15	.06	320	1,260	1.71	540	310	3.7	1,900	8.9[2]
Jones Lake																				
4- 6-76	12	45	33	16	19	266	232	54	8.7	.2	.04	.03	70	327	.44	250	17	.4	550	8.8[2]
Lake Louise																				
10-13-59	7.2	36	15	18	18	161	---	58	9.8	.2	.5	---	140	264	.36	150	18	.6	410	7.3
11-19-59	---	---	---	---	---	178	---	---	---	---	1.0	---	150	278	.38	160	14	---	470	7.5
12-17-59	1.5	9.7	3.8	7.7	6.9	49	---	19	4.5	.1	.2	---	60	77	.10	40	0	.5	154	7.1
1-14-60	6.4	38	17	20	18	185	---	63	11	.2	.7	---	150	283	.38	164	12	.7	452	7.2
2-11-60	---	---	---	---	---	206	---	---	---	.3	.5	---	160	---	---	179	10	---	479	7.3
3-11-60	8.8	44	21	22	21	220	---	67	13	.3	.9	---	180	331	.45	196	16	.7	515	7.5
4- 7-60	4.7	6.3	2.3	1.7	5.4	30	---	6.0	.0	.1	3.0	---	50	60	.08	25	0	.1	78	6.3
4-26-60	7.4	8.5	3.6	---	---	46	---	---	---	.0	.9	---	50	---	---	36	0	---	116	6.5
6-18-60	14	22	1.5	3.8	8.2	76	---	12	.0	.1	1.6	---	70	117	.16	61	0	.2	161	6.9
7- 8-60	---	21	4.3	---	---	88	---	---	---	.1	.4	---	90	124	.17	70	0	---	179	7.1
8-17-60	2.1	25	6.0	5.7	9.0	113	---	13	3.7	.1	.7	---	80	181	.18	87	0	.3	214	7.6
9-26-60	---	---	---	---	---	112	---	---	---	.1	1.1	---	60	---	---	84	0	---	218	7.5
3-13-61	1.2	15	2.3	2.8	3.7	60	---	3.8	1.0	.1	.1	---	0	70	.10	47	0	.2	117	6.9
4-12-61	2.3	31	7.9	7.3	8.7	143	---	13	3.5	.1	.3	---	20	164	.22	110	0	.3	266	7.1
7- 6-61	2.4	28	9.5	9.7	9.8	141	---	16	4.3	.2	.1	---	70	159	.22	109	0	.4	283	7.0
9-20-61	7.1	27	9.6	11	11	139	---	17	5.6	.1	.4	---	90	176	.24	107	0	.5	277	6.9
12- 6-61	5.9	31	11	12	11	154	---	24	6.5	.2	1.1	---	80	183	.25	122	0	.5	320	7.7
3- 8-62	6.7	36	13	13	12	188	---	22	6.8	.2	.4	---	80	216	.29	145	0	.5	358	7.6
6- 6-62	7.7	35	13	14	11	170	---	29	8.7	.2	.7	---	80	213	.29	141	2	.5	362	7.5[2]
9- 4-62	12	32	14	16	11	175	---	25	9.3	.2	2.3	---	100	280	.38	139	0	.6	371	7.4
12-13-62	11	42	16	19	13	211	---	34	12	.0	.2	---	120	267	.36	171	0	.6	441	7.1
3- 7-63	7.2	40	15	19	13	203	---	32	12	.2	.9	---	100	250	.34	163	0	.7	418	7.9
4-23-63	8.6	41	17	21	13	216	---	35	12	.3	1.4	---	110	260	.35	172	0	.7	441	8.0
9-24-63	6.4	29	17	22	14	189	---	28	14	.3	2.2	---	120	235	.32	142	0	.8	398	7.5
12- 6-63	.6	28	18	23	14	161	---	29	20	.2	.5	---	130	244	.33	144	0	.8	415	7.3
3- 9-64	.9	23	15	19	11	157	---	24	12	.1	1.2	---	80	204	.28	119	0	.8	342	7.2
5-22-64	1.8	21	27	25	14	209	---	35	14	.2	1.3	---	120	270	.37	162	0	.9	448	7.5
Pearl Lake																				
4- 6-76	3.3	60	34	11	17	200	169	150	5.1	.2	.01	.02	30	382	.52	290	120	.3	640	8.9[2]
Rose Hill Lake																				
4- 7-76	1.7	34	16	19	11	153	132	74	5.9	.1	.06	.07	50	242	.33	150	19	.7	420	9.1[2]
Spring Lake																				
4- 7-76	30	49	46	130	53	586	537	13	52	.1	.01	.49	250	698	.95	310	0	3.2	1,120	8.8[2]

[1]Instantaneous discharge .10 cfs; total phosphorus (P) .16 mg/L; time 1215; dissolved solids (tons per day) .22

[2]Field pH

instantaneous discharge of 0.10 ft^3/s (0.003 m^3/s) to 2,000 micromhos with a discharge of 0.01 ft^3/s (0.0003 m^3/s).

Seasonal changes in water quality also occur in lakes. As ice forms, it incorporates very little dissolved solids and thereby causes the concentration of dissolved solids in the water beneath the ice to increase. Generally a decrease in dissolved solids occurs in the spring by dilution from snowmelt and ice melt. Lake Louise, sampled for water quality over a 5-year period from 1959 to 1964, had dissolved solids ranging from 60 to 331 mg/L (table 6).

Ground-water Occurrence and Quality

Glacial Aquifers

Glacial aquifers are mostly unconsolidated sand and gravel deposited as outwash from a glacier. Outwash deposits can be buried by hundreds of feet of glacial till or intermixed with till. Till, because of its large clay content, has low permeability and, in general, is a poor source of water. However, locally it contains small sand lenses that may yield as much as 5 gal/min (0.3 L/s) to wells.

A complex system of aquifers exists in glacial deposits. The boundaries of these aquifers and the hydrologic relationships between them can be determined only after detailed investigations have been made throughout the area. This report is primarily concerned with discussing the areal extent, thickness, and water-bearing properties of outwash deposits.

Four major aquifers in outwash are here named the Tulare, Elm Creek, Highmore, and Bad-Cheyenne River aquifers. The Tulare aquifer is a continuation of the same named aquifer in Beadle County (Howells and Stephens, 1969). It is also a continuation of the Grand aquifer in Faulk County (Hamilton, in preparation). A summary of hydrologic characteristics of these aquifers is given in table 7. The thickness of the sand and gravel is shown in figure 7.

Tulare Aquifer

The Tulare aquifer (fig. 8) is a complex system of interconnected sand and gravel layers which are separated by till (fig. 9). Thickness and extent of the aquifer are shown in figure 8. The aquifer in Hyde County and western Hand County contains less fine sand than does the aquifer in eastern Hand County. The aquifer is at or within 40 ft (12 m) of the land surface in northeastern Hand County (fig. 9). To the south and west the aquifer is overlain by a thicker deposit of till. See table 7 for hydrologic characteristics of the Tulare aquifer.

The general direction of water movement is from upland areas to lowland areas as indicated by arrows which are at right angles to the contours (fig. 10). The slope of the water table is about 10 ft/mi (2 m/km). The gradient is the steepest (about 40 ft/mi or 8 m/km) on the east flank of the Orient Hills in northwestern Hand County. The water levels in a large number of domestic and observation wells were measured in 1951. The gradient of the potentiometric surface and the direction of flow were about the same in 1977.

Recharge to the Tulare aquifer is by infiltration of precipitation and snowmelt directly into the aquifer or through overlying alluvium and glacial drift. Recharge takes place rapidly where permeable sediments overlie the aquifer but slowly where till overlies the aquifer.

Natural discharge from the Tulare aquifer is by evapotranspiration, by subsurface outflow into Spink and Beadle Counties, and locally into the creeks that have cut into or are hydraulically connected to the aquifer.

Water-level fluctuations, such as those shown in figure 11 are caused by seasonal changes in recharge. Water levels rise from about March to June because of recharge from snowmelt and spring and early summer rains. Water levels decline from July to March because discharge, mostly evapotranspiration from July to October, exceeds recharge. The aquifer near wells 113N66W11CBCC and 114N67W27CCCB may have been discharging water to the creeks in April, May, and June 1975. At other times the creeks recharge the aquifer. The aquifer penetrated by well 115N66W14AADD discharges water to Medicine Creek the year around, however, evapotranspiration is great enough to keep the creek dry most of the summer. The water level in this well (115N66W14AADD) begins to rise in September while in other wells the water level continues to drop until March. Water from Schaefer Creek recharges the aquifer tapped by well 114N67W8BBCB.

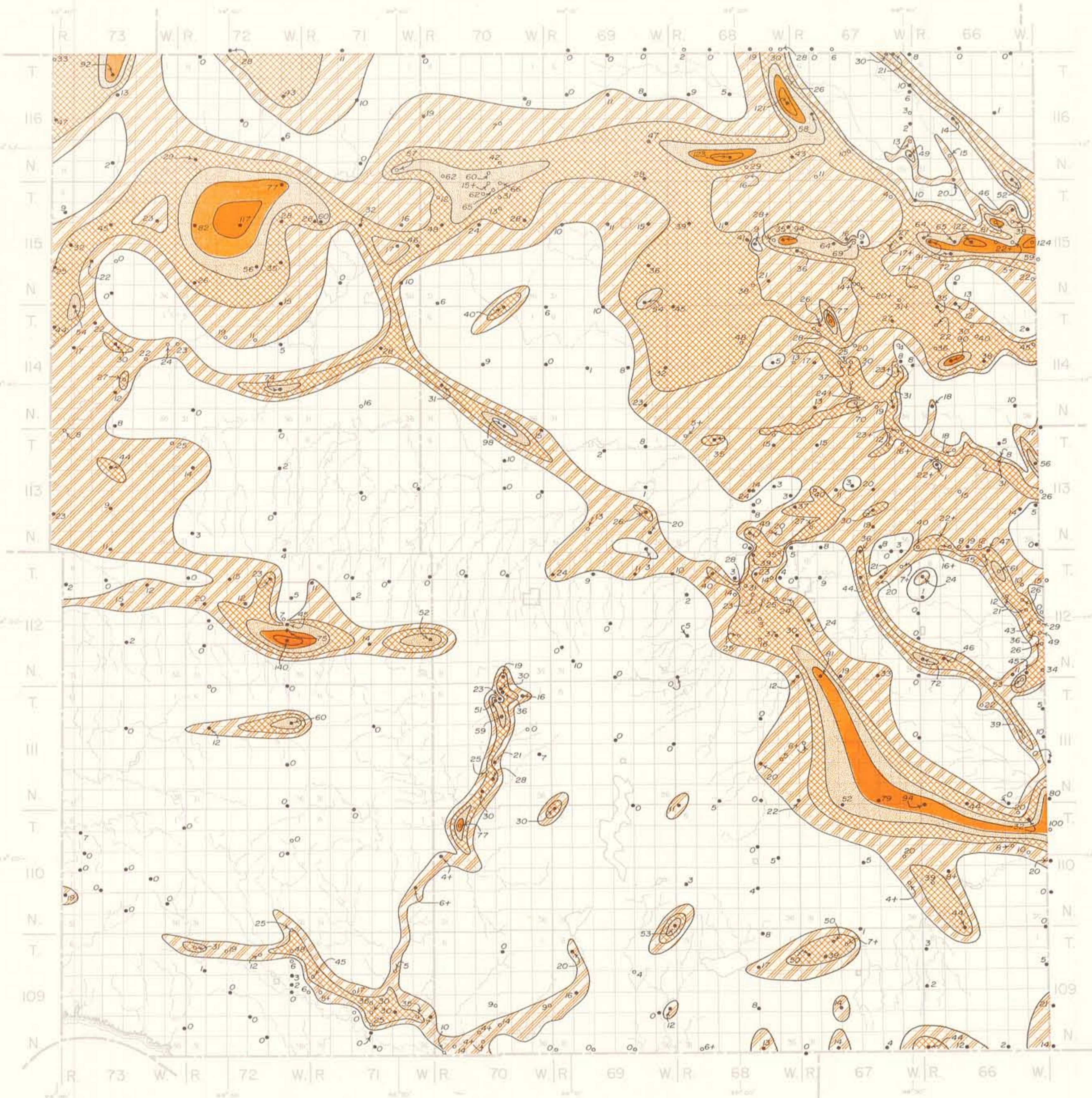
Records of long-term water-level fluctuations (fig. 12) show a close correlation with long-term trends in precipitation. Gradual water-level declines in 1959 and from 1963-66 were caused by below-normal precipitation. The hydrograph in figure 13 shows a greater magnitude of water-level fluctuations in response to above or below-normal precipitation than that shown in figure 12 because of the greater removal of ground water by natural discharge (evapotranspiration) from the aquifer penetrated by well 112N69W3DCB.

The quantity of water that can be pumped from a well is best determined by conducting pumping tests

TABLE 7. Summary of hydrologic characteristics of major aquifers.

Aquifer	Areal extent (mi^2)	Range in depth below land surface (ft)	Range of water level below land surface[1] (ft)	Maximum thickness (ft)	Average thickness (ft)	Artesian (A) and/or water-table (WT) aquifer	Estimated water storage[2] (acre-ft)	Estimated maximum well yield (gal/min)	Suitable for irrigation use[3]
Tulare	950	10- 200	0-100	124	30	A, WT	3.6 million	1,000	Yes, may be marginal.
Elm Creek	25	2- 100	5- 30	77	30	A, WT	100,000	1,000	Yes, may be marginal.
Highmore	100	20- 200	5-150	140	20	A, WT	250,000	1,000	Yes, may be marginal.
Bad-Cheyenne River	200	150- 500	10-210	100	40	A	1 million	1,000	No.
Dakota	2,306	900-2,300	F-400	280	240	A	70 million	500	No.
Fall River-Sundance-Minnelusa	2,306	1,400-2,600	F-150	240	200	A	60 million	1,000	No.

[1] F = flow.
[2] Based on average thickness (feet) times areal extent (acres) times an estimated porosity of 20 percent.
[3] Based on quality of water.



Index map of South Dakota showing location of Hyde and Hand Counties.

Base from South Dakota Highway Department county highway maps.

Hydrology by N. C. Koch, 1975

Figure 7. Map showing thickness of sand and gravel.

37+• Test hole or well. *(number indicates thickness of sand and gravel, in feet. A plus (+) indicates minimum thickness is number shown, but total thickness is not known.)*

Thickness, in feet

- 1 to 10
- 10 to 25
- 25 to 50
- 50 to 75
- 75 to 100
- more than 100

Index map of South Dakota showing location of Hyde and Hand Counties.

Scale: 0 5 10 15 20 miles; 0 5 10 15 20 25 30 kilometers

Base from South Dakota Highway Department county highway maps.

Hydrology by N. C. Koch, 1975

Figure 8. Map showing location and thickness of the Tulare aquifer.

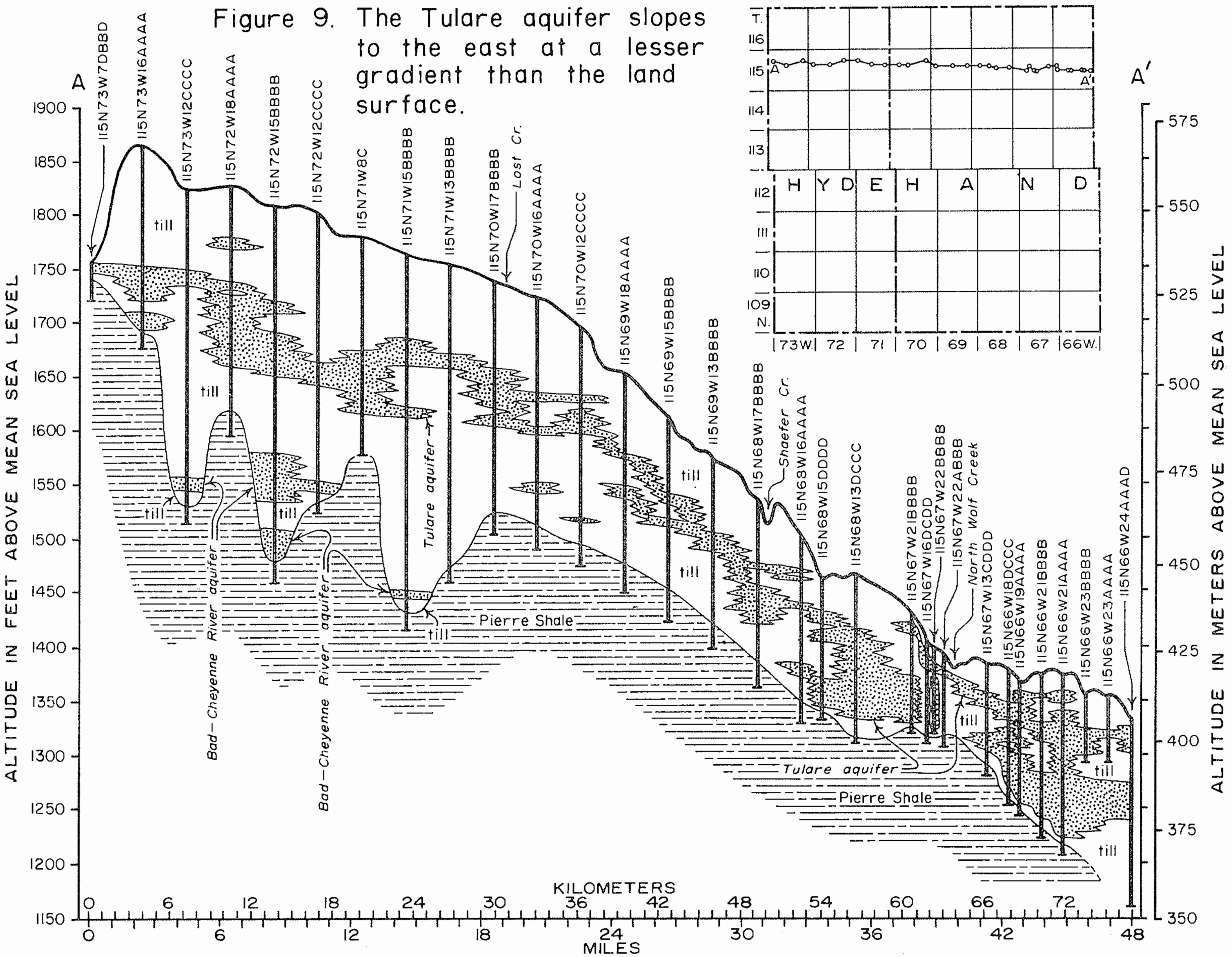


Figure 9. The Tulare aquifer slopes to the east at a lesser gradient than the land surface.

to evaluate the hydrologic characteristics of an aquifer. Two characteristics of an aquifer indicate the aquifers ability to transmit and store water. Transmissivity measures the capacity of an aquifer to transmit water (see glossary). In general, the higher the transmissivity value the less the drawdown will be at any given pumping rate. Storage coefficient is a measure of the capacity of an aquifer to store and release water. Several aquifer tests which provided this type of data (table 8) were run in the early 1950's in cooperation with the U.S. Bureau of Reclamation.

The predominant chemical constituents in water from the Tulare aquifer are calcium, sodium, bicarbonate, and sulfate (table 9). Dissolved solids average 1,150 mg/L and range from 296 to 2,100 mg/L. Water in the upper part of the aquifer generally is of calcium bicarbonate type and in the lower part of the aquifer sodium sulfate type. It generally is of suitable quality for domestic, stock, municipal, and irrigation use.

Elm Creek Aquifer

The Elm Creek aquifer is outwash sand and gravel that underlies most of the Elm Creek and West Fork Elm Creek flood plains (fig. 14). Water in that part of the aquifer underlying Elm Creek is under artesian conditions. The potentiometric surface slopes to the south at about 10 ft/mi (2 m/km) and is 5 to 15 ft (2 to 4 m) below land surface in the spring of the year. The aquifer, overlain by 25 to 55 ft (8 to 17 m) of till, consists mostly of clean, medium to coarse sand and gravel and very few clay layers (fig. 15). See table 7 for hydrologic characteristics of the Elm Creek aquifer.

That part of the aquifer underlying the West Fork Elm Creek drainage basin is at land surface or within 10 ft (3 m) of land surface and is considerably different than the aquifer underlying Elm Creek. Water in the aquifer is under water-table conditions and moves toward the east. The water table averages about 25 ft (8 m) in depth, ranges from 5 to 35 ft (2 to 11 m) below land surface, and slopes 20 to 35 ft/mi (4 to 7 m/km) to the east. Over half of the total thickness of sand and gravel in Township 109 N. (fig. 14) is above the water table and consequently is dry.

Recharge to the Elm Creek aquifer is by infiltration of precipitation and snowmelt directly into the aquifer or through the overlying alluvium and glacial drift.

Natural discharge from the Elm Creek aquifer is by evapotranspiration and by subsurface outflow into Buffalo County.

Water-level fluctuations are caused by seasonal changes in recharge and pumpage from irrigation wells. Seasonal changes in recharge result in water levels in wells rising from about February to June and declining from June to September (fig. 16). Irrigation results in the water levels in wells declining from June to September.

The predominant chemical constituents in water from the Elm Creek aquifer are calcium, bicarbonate, and sulfate. Table 10 gives the chemical analyses of some of the major constituents in water from six wells in the aquifer. Dissolved solids average 910 mg/L and range from 673 to 1,250 mg/L. The water is of suitable quality for domestic, stock, municipal, and irrigation use.

Highmore Aquifer

The Highmore aquifer (fig. 17) is a complex system of interconnected sand and gravel layers which are separated by till (fig. 18). Thickness and extent of the aquifers are shown in figure 17. Except for two areas in T. 112 N., where the aquifer is the thickest much of the aquifer consists of thin sand and gravel layers less than 10 ft (3 m) in thickness. Additional test hole data are needed to determine the degree of interconnection between various sand layers. For example, the sand layer in well 113N73W30BBBB (fig. 17) may not be connected to the aquifer. See table 7 for hydrologic characteristics of the Highmore aquifer.

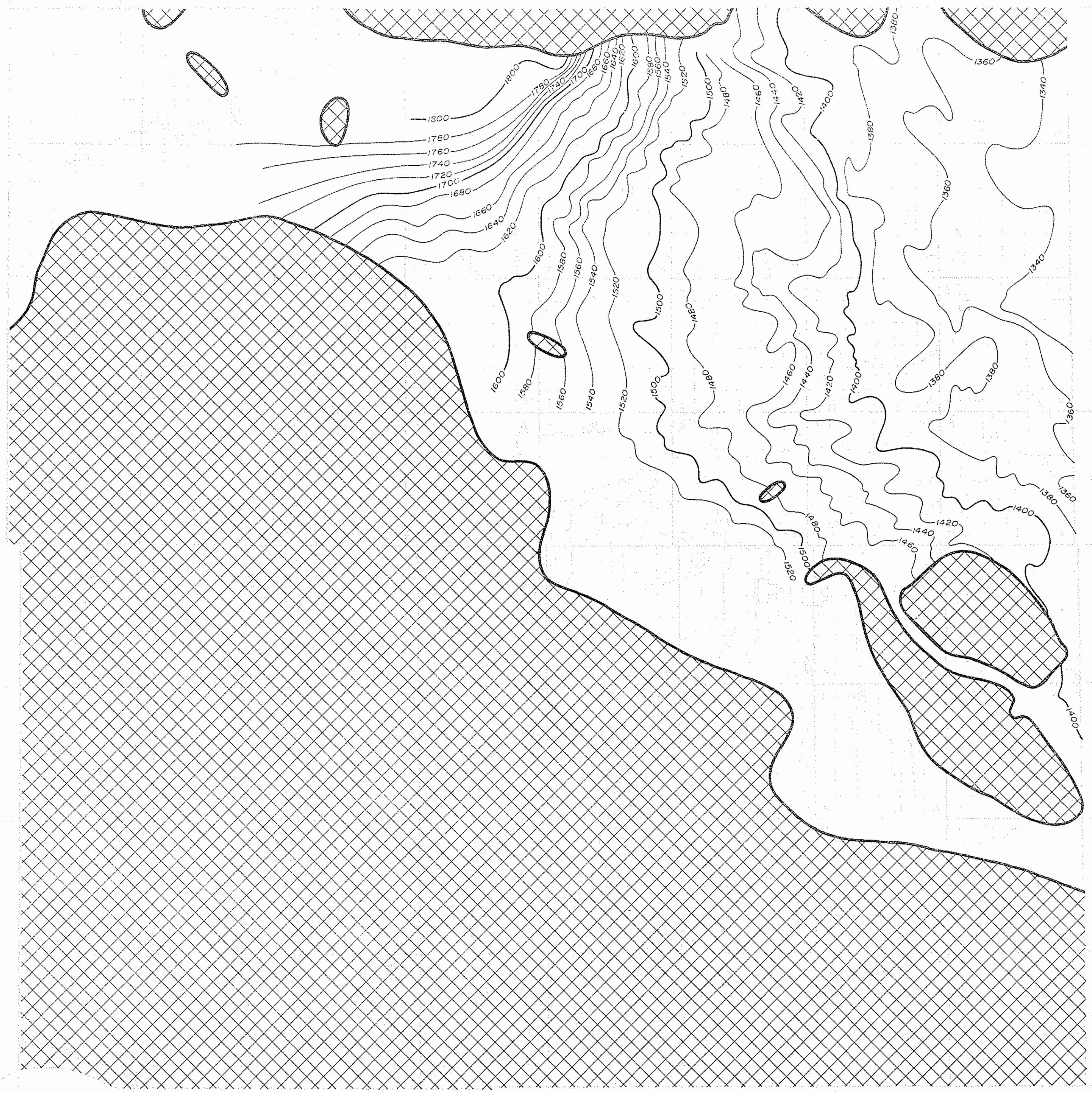
The general direction of water movement in the aquifer is from east to west (fig. 18) at a gradient of about 10 ft/mi (2 m/km). The depth to water in wells is generally less than 100 ft (30 m) below land surface except in T. 113 N. where it is as much as 150 ft (46 m).

Recharge to the Highmore aquifer is by infiltration of precipitation and snowmelt through overlying alluvium and glacial drift.

Natural discharge is by evapotranspiration, subsurface outflow toward the west into Hughes and Sully Counties, and locally, discharge into South Fork Medicine Creek.

Water-level fluctuations, such as those shown in figure 19, are caused by seasonal changes in recharge. Water levels decline from about July to March and rise from March to July. The annual low water level during the period 1972-76 has dropped about a half a foot a year as a result of below normal precipitation.

An aquifer test was run with the city of Highmore production well by Layne-Minnesota Company of Minneapolis, Minnesota, in April 1960. The well was

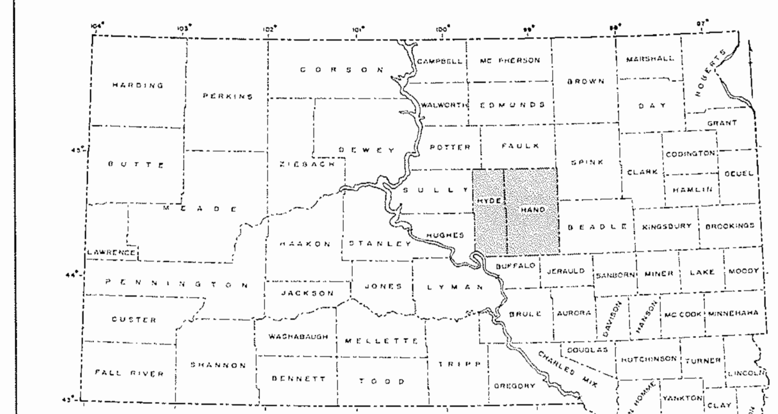


Potentiometric contour *(shows altitude at which water level would have stood in tightly closed wells, 1951. Contour interval is 20 feet. Datum is mean sea level.)*

Arrow indicates direction of ground-water flow

Area of Tulare aquifer.

Area beyond the Tulare aquifer.



Index map of South Dakota showing location of Hyde and Hand Counties.

0 5 10 15 20 miles

0 5 10 15 20 25 30 kilometers

Base from South Dakota Highway Department county highway maps.

Figure 10. The potentiometric surface of the Tulare aquifer slopes to the east.

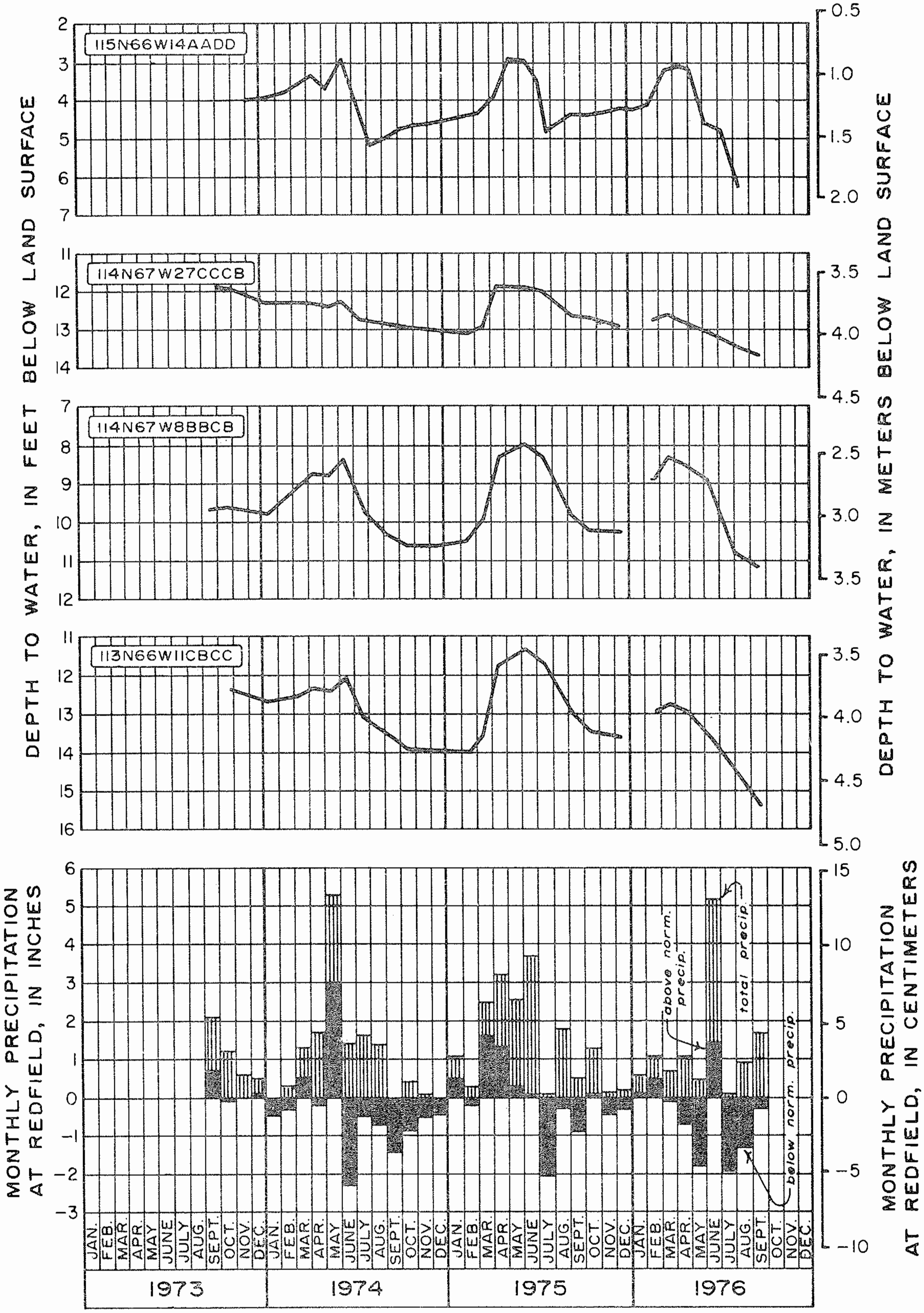


Figure 11. Water levels in wells rise from March to June and decline from July to February.

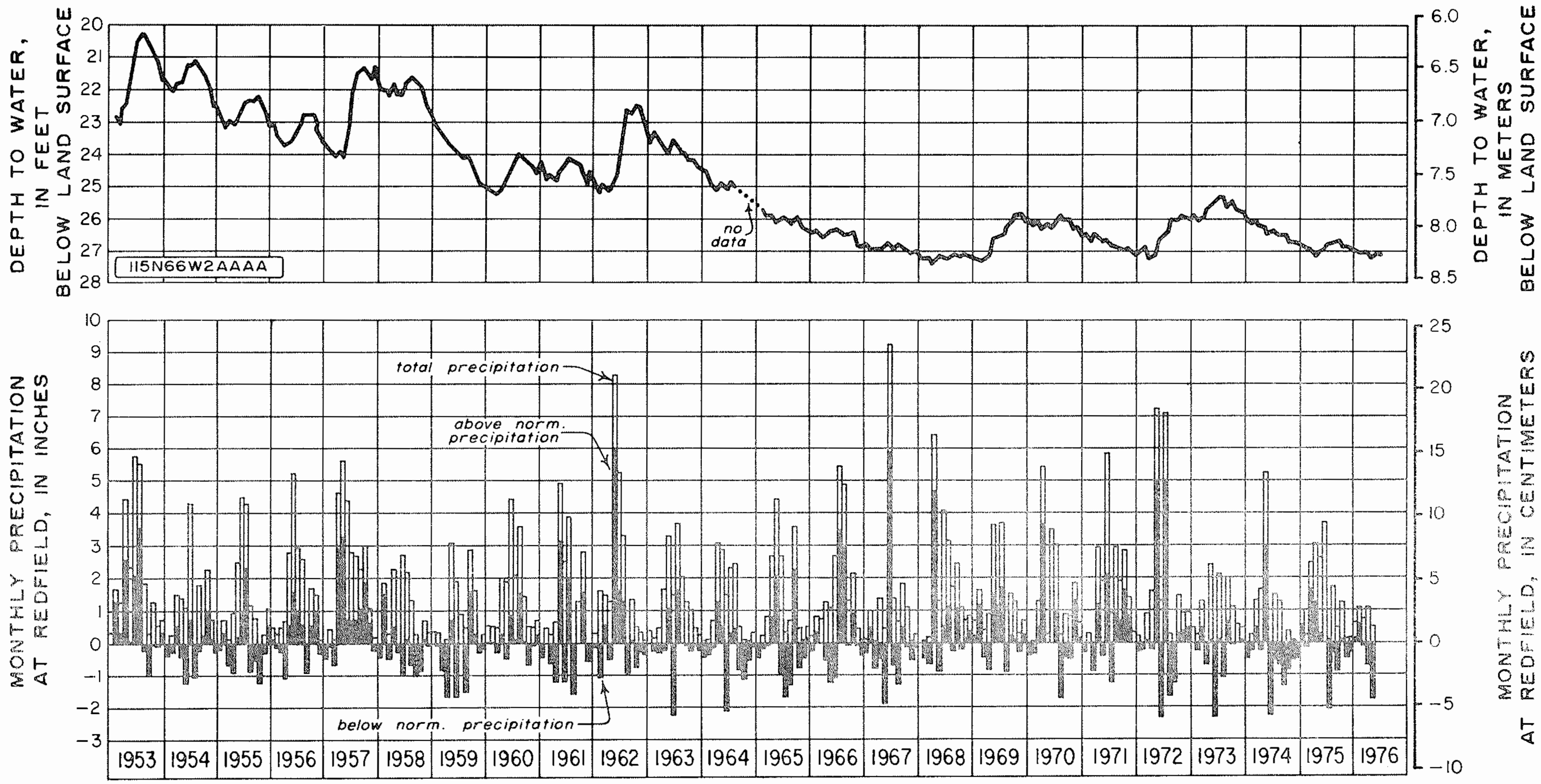


Figure 12. Water levels in well 115N66W2AAAA fluctuated on the average of one foot per year and declined about eight feet from 1953 to 1976.

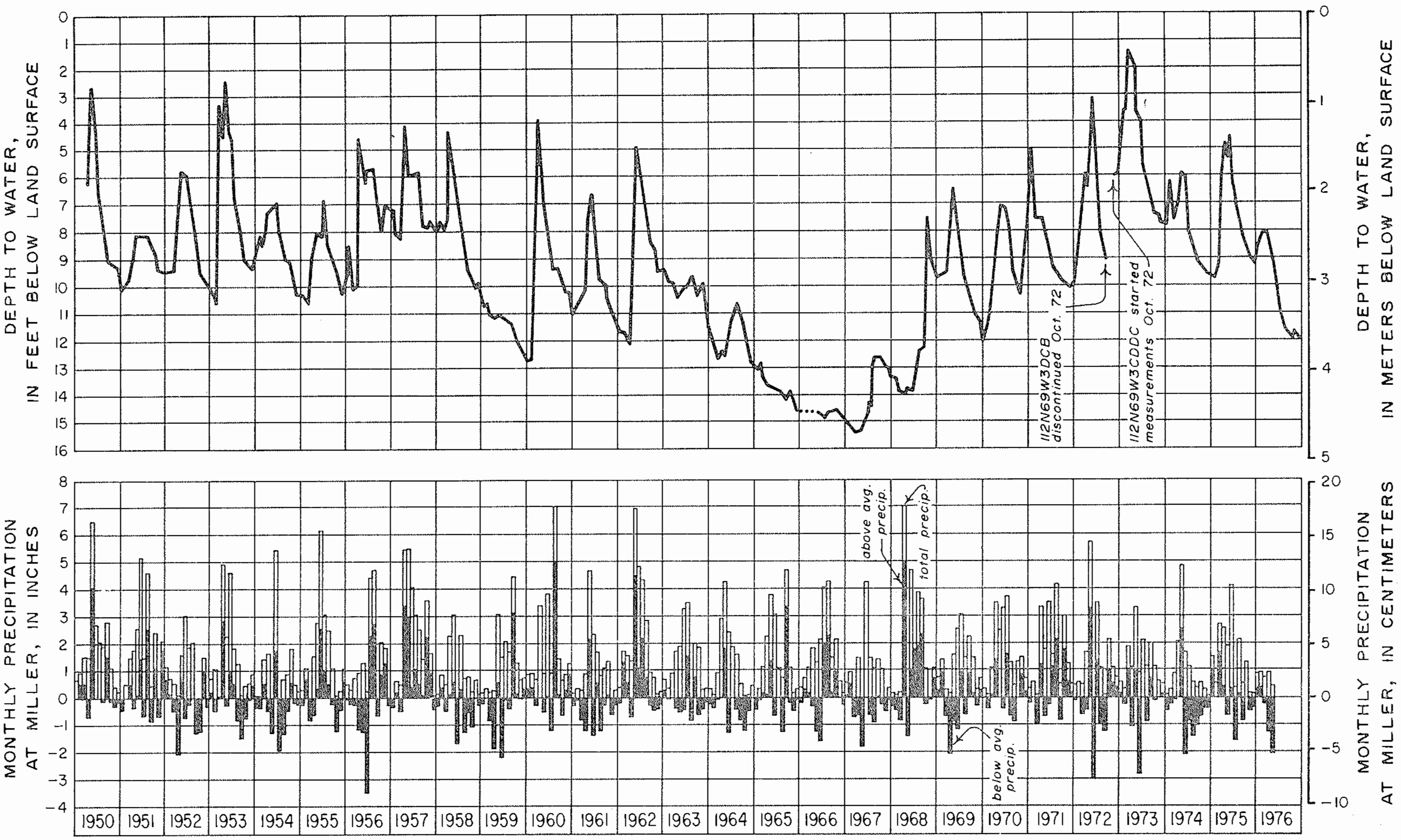


Figure 13. Water levels in well 112N69W3DCB and 112N69W3CDDC fluctuated on the average of five feet per year and about 14 feet from 1950 to 1976.

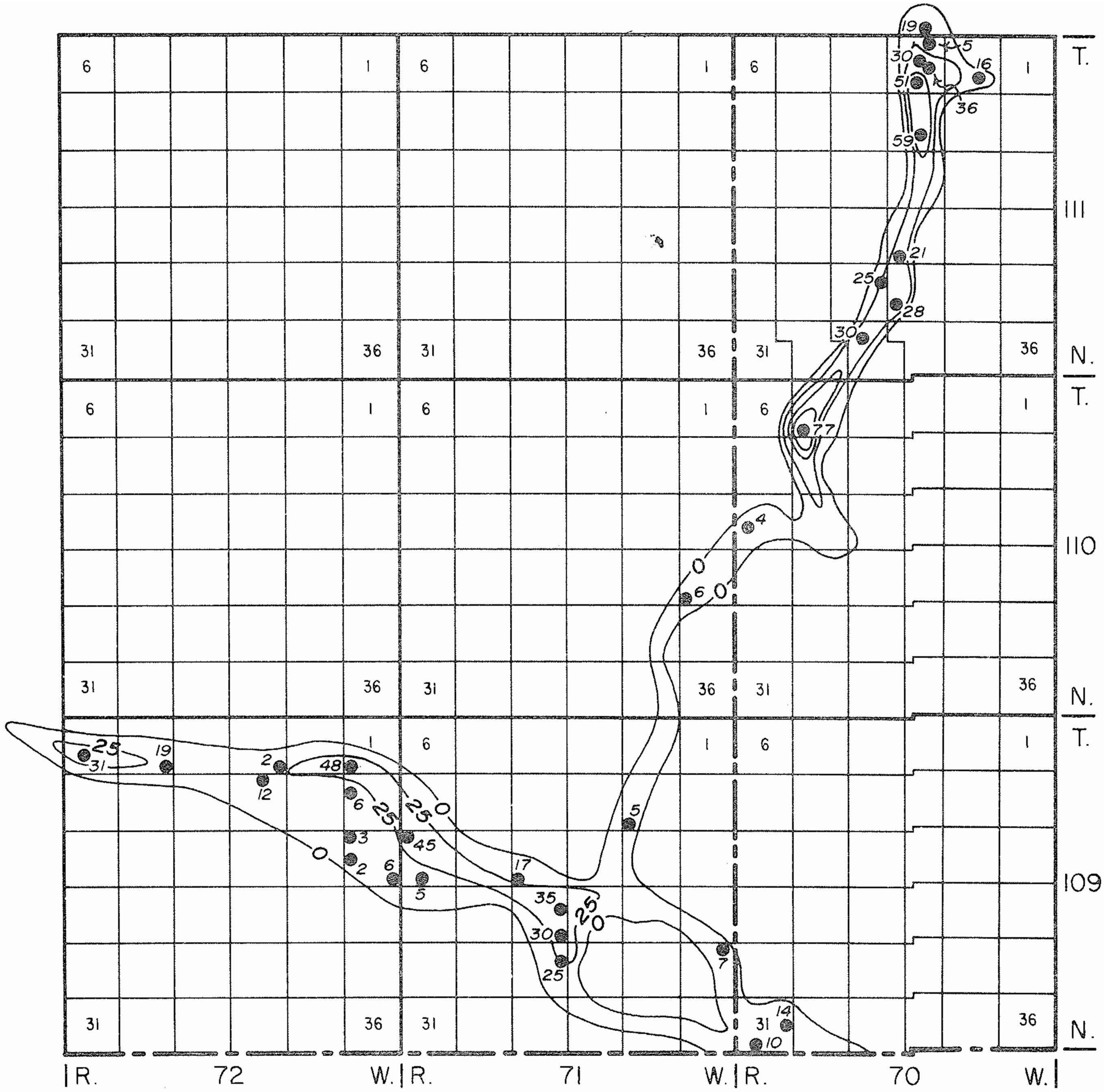
TABLE 8. Aquifer-test data for the Tulare aquifer.

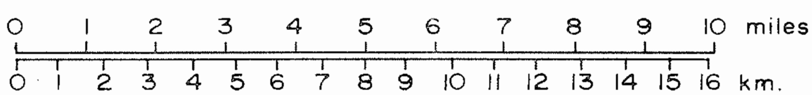
Well number	Depth of well (ft)	Aquifer thickness (ft)	Average pumping rate (gal/min)	Drawdown in pumped well (ft)	Length of test (days)	Transmissivity in gallons per day per foot (ft^2/d)	Storage coefficient	Hydraulic conductivity (ft/d)
115N66W18DCCC	110	71	300	14	7	43,000 (5,750)	0.0135	81
115N66W20DABD	70	30	150	---	3	26,000 (3,476)	.15	116
115N66W20DADB4	72	30	300	---	1	26,000 (3,476)	.28	116
115N66W20DACA	136	80	300	20	4	57,000 (7,620)	.14	95
115N66W20DABD3	137	40	830	---	--	65,000 (8,690)	.00038	217
115N67W19CABB2	192	53	100	19	3	55,000 (7,350)	.00016	139
115N67W19CABB3	166	53	400	---	1	55,000 (7,350)	.00016	139
115N68W23BBAB	62	19	25	10	4	2,900 (388)	.00052	20

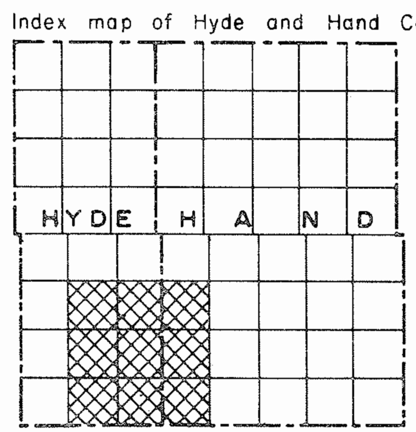
TABLE 9. Chemical analyses of water from the Tulare aquifer.

Local identifier	Total depth of well (ft)	Date of sample	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved boron (B) (ug/L)	Dissolved solids (sum of constituents) (mg/L)	Hardness (Ca, Mg) (mg/L)	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos)	pH (units)
111N66W 1ABB	19	9- 8-48	94	47	72	1.2	440	204	15	120	702	428	27	1.5	1020	8.0
111N66W14A	80	6- 9-76	180	45	36	8.0	395	300	14	---	---	640	11	.6	1080	7.3
112N66W 3DDDC	32	10-24-73	110	35	53	5.6	324	210	24	110	630	420	21	1.1	958	7.5
112N67W18BBAA	160	4- -58	97	18	420	13	590	620	80	---	1560	318	73	10	---	7.9
113N66W 8BCCB	17	10-24-73	230	84	240	17	451	870	110	370	1820	920	36	3.4	2500	7.7
113N67W 6CB	45	9- 8-48	150	42	32	10	460	170	36	120	710	540	11	.6	1010	7.9
114N66W13AAAD	17	10-24-73	63	18	3.7	4.6	230	20	3.0	70	296	230	3	.1	446	7.7
114N66W17BCCB	19	10-24-73	120	40	110	6.0	381	280	71	420	851	460	34	2.2	1320	7.6
114N67W 8BBCB	17	10-24-73	140	43	83	9.6	419	260	58	100	838	530	25	1.6	1270	7.3
115N66W14BB	110	9- 4-57	81	27	390	18	670	E400	160	980	---	310	72	9.6	2090	7.4
115N66W14CACC	126	9- 5-75	69	22	380	13	685	340	150	920	1350	260	75	10	2000	7.5
115N66W20DABD4	77	9- 3-57	110	37	42	9.3	430	E143	22	---	---	430	17	.9	930	7.5
115N66W21DDA	32	9- 9-48	65	32	47	6.4	350	114	6.3	200	480	290	25	1.2	700	7.9
115N66W30DC	44	9- 9-48	180	100	82	4.0	260	740	57	410	1320	870	17	1.2	1560	8.0
115N66W31BCBB	20	10-24-73	170	61	60	7.8	403	330	67	80	931	680	16	1.0	1410	7.3
115N67W19CABB3	166	7-27-54	170	49	290	14	720	520	110	740	1540	620	49	5.2	2200	7.2
115N68W28AA	46	9- 9-48	230	63	370	12	660	780	190	740	2040	820	49	5.6	2630	7.7
115N70W 7CCBD	105	10-12-56	136	87	340	20	409	760	37	---	2100	700	51	5.6	2600	7.5
115N70W14A	70	2- -74	35	11	160	10	390	100	34	---	---	130	71	5.9	791	7.6
115N72W 1BBBB	100	10-26-73	80	20	75	9.9	318	160	6.9	330	540	280	36	1.9	825	7.6
116N66W 7BBAC	20	9- 9-48	210	120	86	6.8	650	640	55	0	1500	1000	22	1.2	1720	8.0
116N67W 4BA	34	9- 9-48	190	140	110	10	320	850	120	60	1600	1020	22	1.5	1840	8.0
116N67W 7BC	12	9- 9-48	140	70	120	.0	420	430	83	0	1090	650	22	2.1	1540	---
116N67W17CCCB	36	9- -72	120	33	110	11	---	310	68	210	---	430	35	2.2	2270	6.5
116N67W25DDDD	37	10-24-73	98	29	230	13	496	320	86	340	1050	360	57	5.2	1620	7.5
116N70W32CDD2	27	5-11-64	140	110	82	10	310	550	100	---	---	810	18	1.3	1750	---

E = estimated.







35 Well-number is thickness of aquifer.

25 Contour line connecting points of equal thickness of aquifer. Contour interval is 25 feet.

Figure 14. Map showing location and thickness of the Elm Creek aquifer.

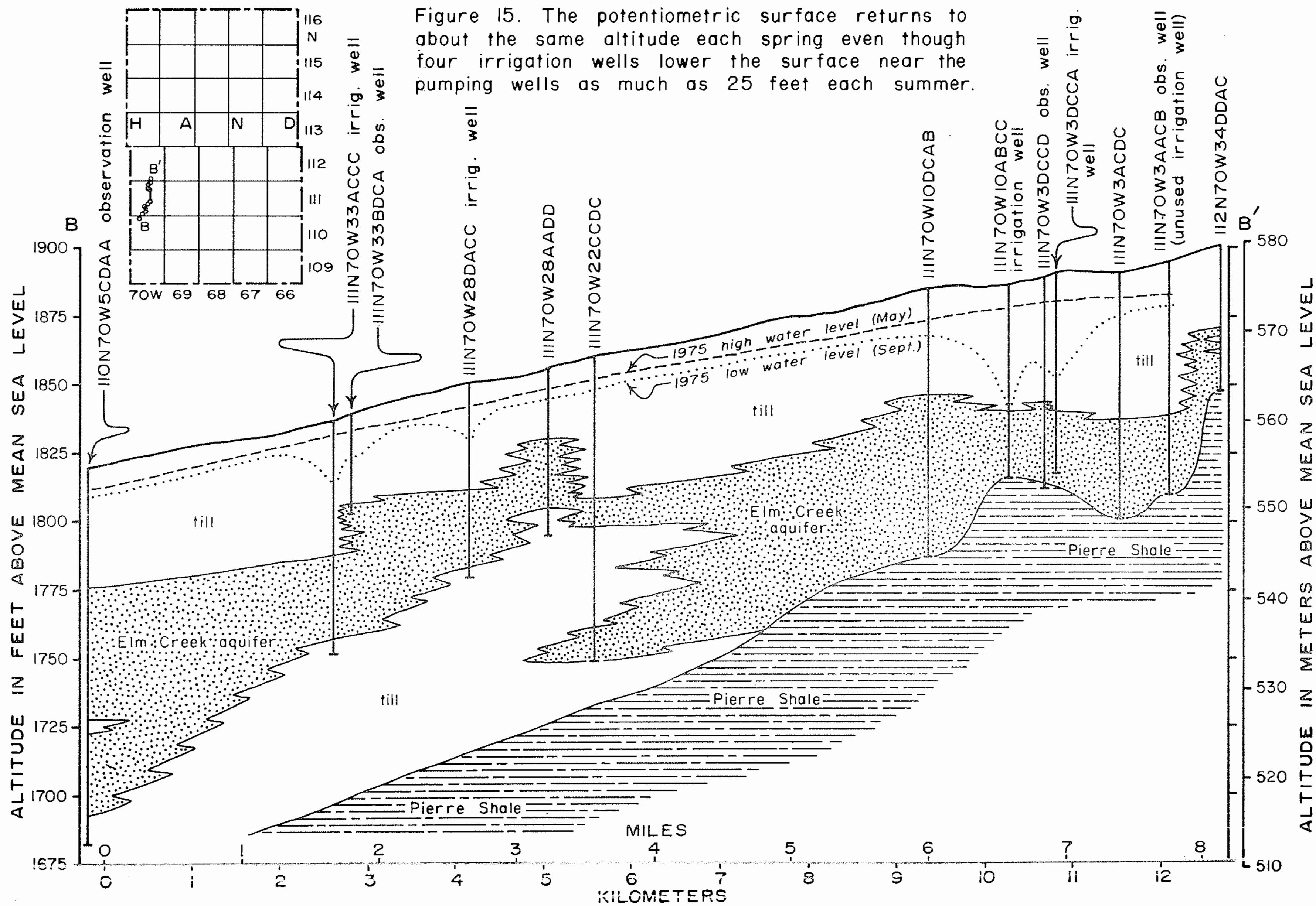


Figure 15. The potentiometric surface returns to about the same altitude each spring even though four irrigation wells lower the surface near the pumping wells as much as 25 feet each summer.

SEPT.

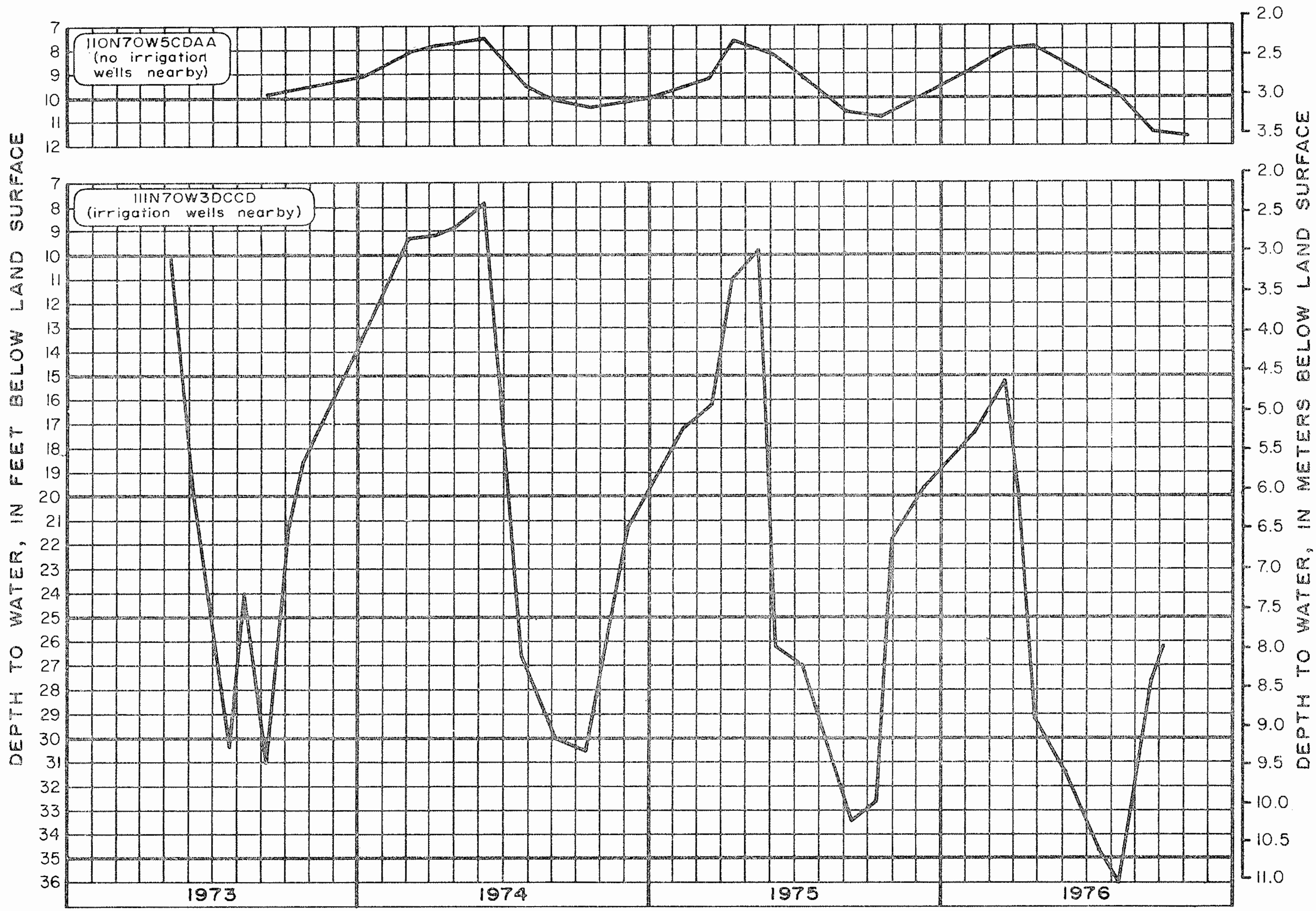


Figure 16. Water levels in wells in the Elm Creek aquifer fluctuate about 3 feet each year except near pumping irrigation wells where fluctuations are nearly 25 feet.

TABLE 10. Chemical analyses of water from the Elm Creek aquifer.

	110N70W 5CDA	111N70W 3AACB	111N70W 3DCCA	111N70W 10ABCC	111N70W 33ACCC	112N70W 34DDCA
Total depth of well (ft)	37	82	75	75	85	40
Date of sample	10-26-73	4- 6-76	9- 6-74	10- 7-68	4-15-68	3-15-67
Dissolved calcium (Ca) (mg/L)	100	160	150	152	140	200
Dissolved magnesium (Mg) (mg/L)	33	49	42	47	20	9.6
Dissolved sodium (Na) (mg/L)	79	170	100	59	160	170
Dissolved potassium (K) (mg/L)	14	18	15	14	19	15
Bicarbonate (HCO_3) (mg/L)	416	499	417	450	356	450
Dissolved sulfate (SO_4) (mg/L)	200	550	400	390	260	480
Dissolved chloride (Cl) (mg/L)	10	23	15	---	4.0	20
Dissolved boron (B) (ug/L)	260	570	400	---	---	---
Dissolved solids (sum of constituents (mg/L)	673	1250	965	756	---	---
Hardness (Ca, Mg) (mg/L)	390	600	550	570	430	550
Percent sodium	30	37	28	18	44	40
Sodium adsorption ratio	1.8	3.0	1.9	1.1	3.4	3.2
Specific conductance (micromhos)	1030	1700	1390	1350	1040	1540
ph (units)	7.4	7.6	---	7.8	7.4	7.2

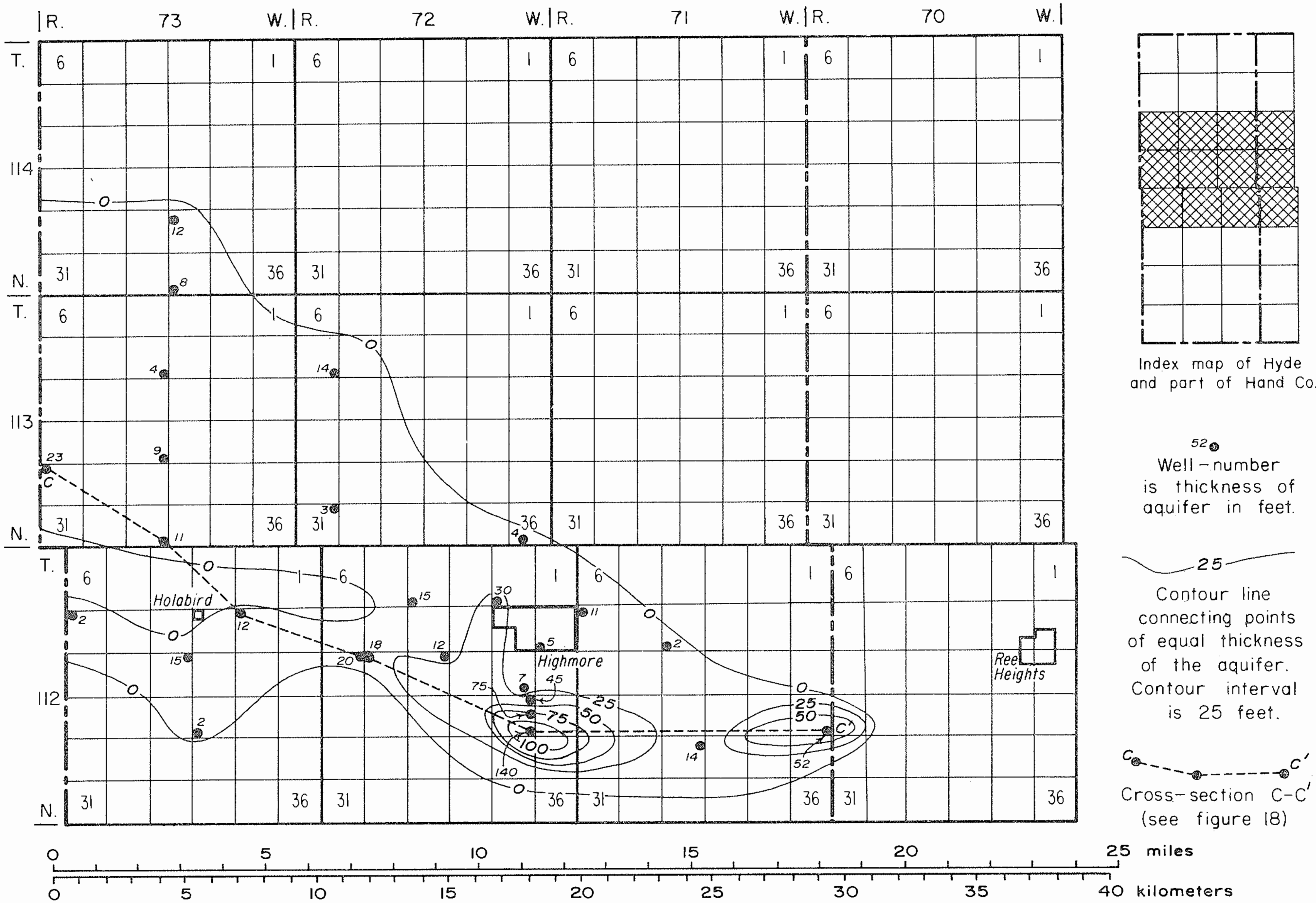
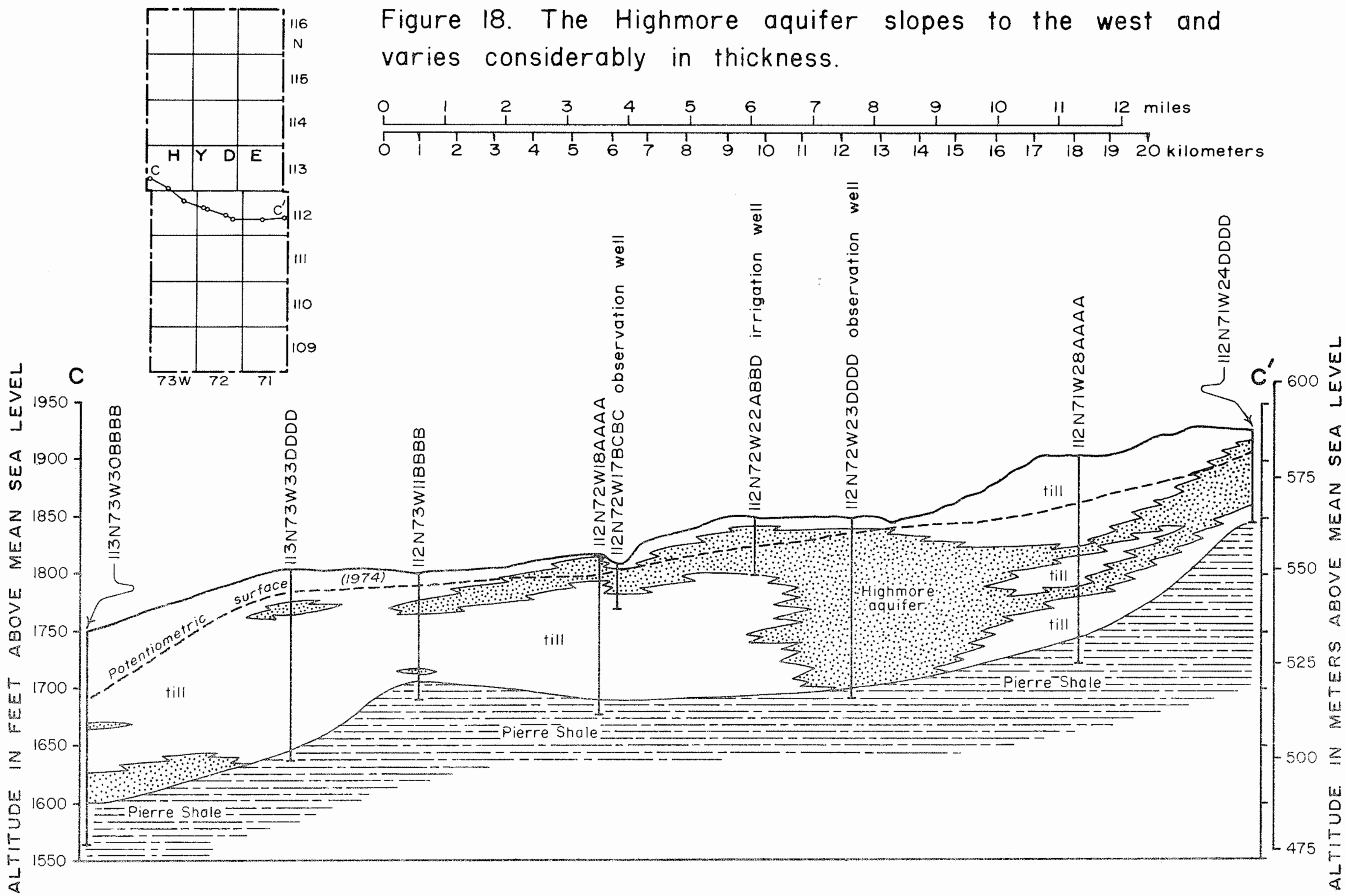


Figure 17. Map showing location and thickness of the Highmore aquifer.

Figure 18. The Highmore aquifer slopes to the west and varies considerably in thickness.



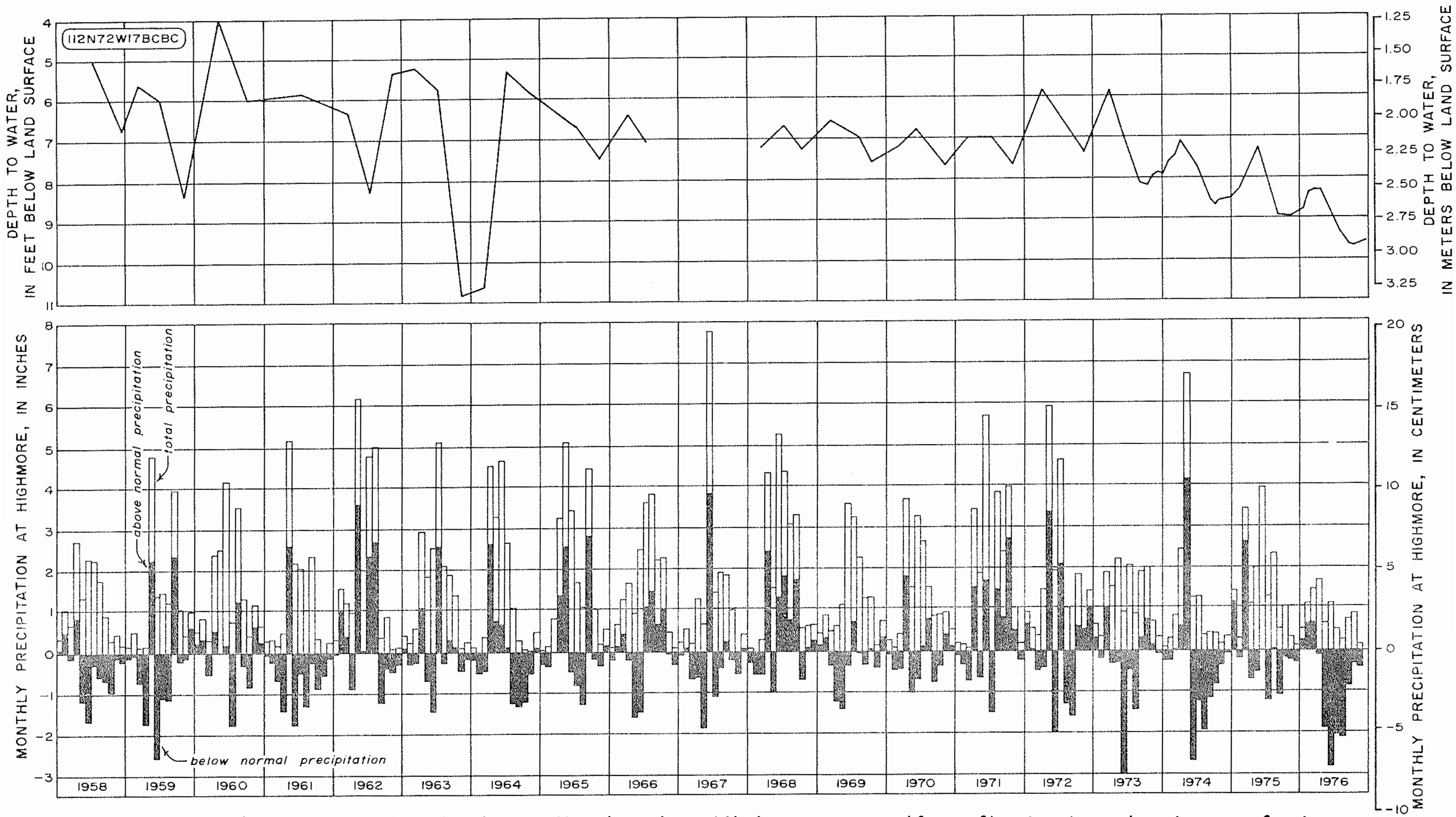


Figure 19. Water levels in wells in the Highmore aquifer fluctuate about one foot per year when precipitation is near normal.

TABLE 11. Chemical analyses of water from the Highmore aquifer.

	112N72W 17BCBC	112N72W 23AADD	112N72W 23ADAD
Total depth of well (ft)	20	145	133
Date of sample	4- -70	4- -57	2- -63
Dissolved calcium (Ca) (mg/L)	97	63	96
Dissolved magnesium (Mg) (mg/L)	31	21	25
Dissolved sodium (Na) (mg/L)	110	37	40
Dissolved potassium (K) (mg/L)	11	5.1	5.9
Bicarbonate (HCO_3) (mg/L)	395	300	347
Dissolved sulfate (SO_4) (mg/L)	270	35	140
Dissolved chloride (Cl) (mg/L)	32	14	7.0
Dissolved boron (B) (ug/L)	500	---	---
Dissolved solids (sum of constituents) (mg/L)	1000	366	520
Hardness (Ca, Mg) (mg/L)	360	260	340
Percent sodium	39	24	20
Sodium adsorption ratio	2.5	1.0	.9
Specific conductance (micromhos)	1280	---	---
pH (units)	8.3	7.7	7.5

pumped for 10 hours at 350 gal/min (22 L/s). Maximum drawdown in an observation well 100 ft (30 m) from the pumped well was 2.08 ft (0.63 m) and in an observation well 500 ft (152 m) from the pumped well was 0.16 ft (0.05 m). Based on this aquifer test the transmissivity was calculated to be 5,900 ft^2/day or 44,000 (gal/d)/ft and the storage coefficient was calculated to be .00040 (written communication, Layne-Minnesota Co.). The water level in the city well was about 85 ft (26 m) below land surface and the drawdown was estimated to be 11 ft (3 m). The aquifer is 41 ft (12 m) thick at the city well.

The predominant chemical constituents in water from the Highmore aquifer are calcium, sodium, bicarbonate, and sulfate. Table 11 gives the chemical analyses of some of the major constituents in water from three wells in the aquifer. Water samples were collected from other wells in the Highmore aquifer and several constituents were determined at the well sites (table 12); they show that there is a wide variation in the chemical composition of the water. However, the extreme or higher concentrations of chloride and high specific conductances are in water from wells located near the margin of the aquifer. For example, chloride ranges from 20 to 120 mg/L in water from most of the wells sampled. But water from five wells close to the margin of the aquifer showed chloride ranging from 270 to 670 mg/L.

Water in the Highmore aquifer generally is of suitable quality for domestic, stock, municipal, and irrigation use and is used for those purposes.

TABLE 12. Field tests - chemical quality of water from the Highmore aquifer.

To help determine variations in the chemical quality of water within an aquifer, field tests were made to determine chemical properties of ground water. The results of the field tests for hardness, chloride, and bicarbonate are not as accurate as laboratory analyses, but are useful in that they give a general indication of water quality.

Location	Depth of well (ft)	Specific conductance (μmho/cm at 25°C)	Hardness as $CaCO_3$ (mg/L)	Chloride (mg/L)	Bicarbonate (mg/L)
112N71W 9CCCB	87	2,800	560	270	690
112N71W20BCA2	82	1,570	710	60	580
112N71W21BDDD	100	1,300	460	60	520
112N71W26ABB	57	940	460	60	460
112N71W27CBB	25	1,420	640	60	380
112N71W34AAA	86	1,500	670	60	560
112N72W 1BBAB	130	4,200	2,000	330	690
112N72W 7BBC	64	1,880	500	120	810
112N72W 7CDCD	40	---	630	90	520
112N72W14DD	30	1,450	860	90	440
112N72W17ADD	100	940	540	20	420
112N72W18AA	35	2,800	100	420	560
112N72W21DAA	85	2,800	110	670	540
112N73W 4ADAA	26	3,100	1,800	120	330
112N73W 4DDA	65	3,400	1,800	120	630
112N73W17DADA	60	3,500	360	450	290
112N73W20DC	130	4,000	590	640	440
113N72W20ABBA	220	2,400	60	520	330
113N73W19ADDA	85	3,200	840	120	730
113N73W27CAA	130	2,800	710	90	750
113N73W29AAAA	160	2,100	370	90	750
114N73W27CDAA	90	2,100	440	60	560

Bad-Cheyenne River Aquifer

The Bad-Cheyenne River aquifer is a buried, interconnected system of ancient (pre-glacial) and ice-marginal river channels (fig. 20). The aquifer is outwash and alluvium consisting of sand and gravel. The ancient river channel crossed Hyde County and at one time probably extended to the east or northeast in T. 114 N., R. 70 W., however, the glacier probably removed most of the evidence of a river channel east of R. 70 W. That part of the channel that extends to the southeast from R. 70 W. may have been developed in front of an ice margin. See table 7 for hydrologic characteristics of the Bad-Cheyenne River aquifer.

The direction of water movement in the aquifer in Hand County is from west to east at a gradient of about 8 ft/mi (2 m/km). In Hyde County, in R. 71 W. and R. 72 W., where the potentiometric surface is the highest, water movement is both to the east and to the west.

Some recharge to the Bad-Cheyenne River aquifer is by infiltration of precipitation and snowmelt through the overlying glacial drift. However, the main recharge areas may be where the aquifer is separated by only a few feet of till from the overlying Tulare aquifer or where it is hydraulically connected with the Tulare aquifer such as in the northeast corner of T. 114 N., R. 70 W. and in T. 110 N. (fig. 20).

Natural discharge is by subsurface outflow toward the west into Sully County and eastward into Beadle County.

Water levels measured in two wells have fluctuated less than 1 ft (0.3 m) from June 1974 to July 1976. A longer period of record and measurements from more observation wells are needed to compare water-level fluctuations with precipitation.

The predominant chemical constituents in water from the Bad-Cheyenne River aquifer are sodium, bicarbonate, and chloride. Table 13 gives the complete chemical analyses of water from five wells in the aquifer. Water samples also were collected from 16 wells in the aquifer for partial analysis at the well site (table 14).

The high sodium and dissolved solids concentration in the water makes it unsuitable for irrigation use. It is of suitable quality for stock and domestic uses.

Bedrock Aquifers

The major bedrock aquifers which underlie Hand and Hyde Counties are the sandstones which are at depths greater than 900 ft (274 m) below land surface. They are found in the Dakota, Fall River, Sundance, and Minnelusa Formations, in order of increasing depth. Table 15 describes the principal bedrock units and their water-bearing characteristics. Water in the bedrock aquifers occurs under artesian conditions.

Dakota Aquifer

The Dakota aquifer is composed of beds of fine-grained, poorly consolidated sandstone interlayered with shale. The top of the aquifer ranges from 900 ft (274 m) below land surface in eastern Hand County to 1,750 ft (533 m) below land surface in southern Hyde County (fig. 21). See table 7 for hydrologic characteristics of the Dakota aquifer.

The altitude of the potentiometric surface ranges from 1,775 ft (541 m) above sea level in southwestern Hyde County to 1,350 ft (411 m) in northeastern Hand County (fig. 22). The slope of the potentiometric surface varies from 3 ft/mi (0.6 m/km) in Hyde County to 16 ft/mi (3 m/km) in Hand County.

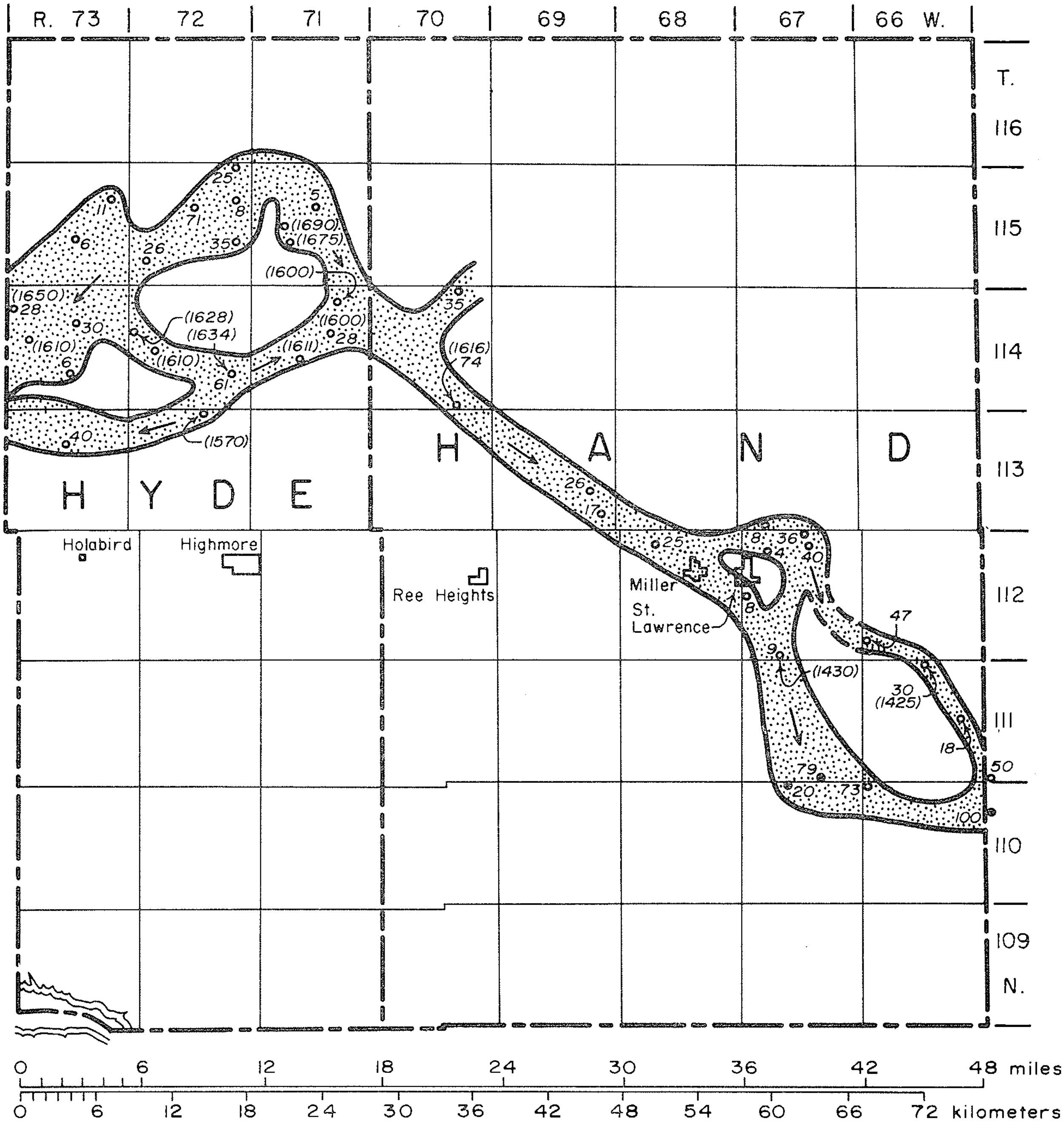
Artesian wells in the Dakota aquifer flow in about one-fourth of the area (fig. 23). In the 1880's the artesian pressure measured in wells completed in the Dakota aquifer in the Miller area was 120 lb/in^2 (8 kg/cm^2) (Darton, 1896). Flows ranged from about 300 to 500 gal/min (19 to 32 L/s). In 1906 the artesian pressure was still about 120 lb/in^2 (8 kg/cm^2), however, 9 years later the pressure was only about 30 lb/in^2 (2 kg/cm^2) (South Dakota State Eng., 1916). This is equivalent to a drop of 208 ft (63 m) in the potentiometric surface. Since that time the potentiometric surface has dropped an additional 100 ft (30 m) and at present (1976) wells in the Dakota aquifer no longer flow in the Miller area. In the Highmore area the potentiometric surface in 1976 was about 200 ft (61 m) lower than in the late 1880's.

Artesian pressure in the Dakota aquifer has continued to decline--slightly less than a foot (0.3 m) a year during the last 14 years in Hand County and about 1½ ft (0.4 m) a year during the last 16 years in Hyde County (fig. 24).

Recharge to the Dakota aquifer is by subsurface inflow from the west and by upward leakage from deeper aquifers; natural discharge is by subsurface outflow to the east.

Fall River-Sundance-Minnelusa Aquifer

The Fall River-Sundance-Minnelusa Formations are hydraulically connected and act as a single aquifer



(1650) 28 Test well. *Number is thickness of aquifer in feet. Number in parentheses is altitude of potentiometric surface in feet above mean sea level, June 1976.*

79 Test well. *Possible hydraulic connection with Tulare aquifer. Number is thickness of aquifer in feet.*

Direction of water movement.

Area of Bad–Cheyenne River aquifer.

Figure 20. Map showing location and thickness of the Bad–Cheyenne River aquifer.

TABLE 13. Chemical analyses of water from the Bad-Cheyenne River aquifer.

	114N70W 35CCCC	114N71W 2CCBC	114N72W 25BBBB	114N73W 13AADA	114N73W 29BCBC
Total depth of well (ft)	236	151	280	300	320
Date of sample	4- 6-76	4-29-76	10-30-73	6-11-75	6-11-75
Dissolved calcium (Ca) (mg/L)	52	31	52	19	21
Dissolved magnesium (Mg) (mg/L)	19	7.6	13	7.4	5.3
Dissolved sodium (Na) (mg/L)	710	270	460	520	610
Dissolved potassium (K) (mg/L)	12	7.9	1.2	7.5	9.6
Bicarbonate (HCO_3) (mg/L)	1090	549	781	819	452
Dissolved sulfate (SO_4) (mg/L)	210	180	190	190	350
Dissolved chloride (Cl) (mg/L)	470	52	240	270	510
Dissolved boron (B) (ug/L)	710	770	720	970	2300
Dissolved solids (sum of constituents) (mg/L)	2040	854	1370	1460	1770
Hardness (Ca, Mg) (mg/L)	210	110	180	78	74
Percent sodium	87	83	84	93	94
Sodium adsorption ratio	21	11	15	26	31
Specific conductance (micromhos)	3150	1340	2280	2450	3000
pH (units)	7.6	7.9	8.2	7.9	7.9

TABLE 14. Field tests - chemical quality of water from the Bad-Cheyenne River aquifer.

To help determine variations in the chemical quality of water within an aquifer, field tests were made to determine chemical properties of ground water. The results of the field tests for hardness, chloride, and bicarbonate are not as accurate as laboratory analyses, but are useful in that they give a general indication of water quality.

Location	Depth of well (ft)	Specific conductance (µmho/cm at 25°C)	Hardness as $CaCO_3$ (mg/L)	Chloride (mg/L)	Bicarbonate (mg/L)
111N66W 4AAAA	175	3,200	550	180	560
113N72W 3AAA	228	3,180	130	640	230
114N70W35CCCC2	244	3,300	240	390	1,100
114N71W 2CCBC	151	1,270	100	90	500
114N71W14BBB	140	2,300	120	330	690
114N71W21CDC	194	3,380	180	580	960
114N72W20BCAC	360	2,200	170	270	730
114N72W25BBBB	280	2,170	160	270	810
114N73W 7ACDC	250	2,400	200	390	520
114N73W 9CBB	250	1,880	270	170	440
114N73W13AADA	300	2,300	80	270	750
114N73W17DCA	255	3,150	340	420	560
114N73W29BCBC	320	3,800	80	820	630
115N71W10BACA	250	1,620	240	50	540
115N71W20ADC	243	2,350	90	420	270
115N71W29AAB	245	2,800	140	670	600

TABLE 15. Principal bedrock units and their water-bearing characteristics.

SYSTEM	SERIES	BEDROCK UNIT	DESCRIPTION	Max. known thickness in feet.	WATER—BEARING CHARACTERISTICS
CRETACEOUS	Upper	Pierre Shale	*Shale*	850	*Poorly permeable. Yields small amounts of mineralized water to wells.*
		Niobrara Formation	*Shale, calcareous*	150	*Poorly permeable. May yield small amounts of mineralized water to wells.*
		Carlile Shale	*Shale*	300	*Impermeable.*
		Greenhorn Limestone	*Shale, calcareous*	115	*Poorly permeable. May yield small amounts of mineralized water to wells.*
		Graneros Shale	*Shale*	355	*Impermeable.*
	Lower	Dakota Formation	*Sandstone and shale*	310	*Permeable. Can supply wells yielding as much as 500 g.p.m.*
		Skull Creek Shale	*Shale*	115	*Impermeable.*
		Fall River Formation	*Sandstone and shale*	105	*Permeable. Can yield to flowing wells as much as 1,000 g.p.m.*[1]
JURASSIC	Upper and Middle	Sundance Formation	*Sandstone and shale*	100	*Permeable. Can yield to flowing wells more than 1,000 g.p.m.*
PERMIAN PENNSYLVANIAN	Lower	Minnelusa Formation	*Sandstone, limestone, and shale*	115	*Permeable. Can yield to flowing wells more than 1,000 g.p.m.*
MISSISSIPPIAN	Upper and Lower	Madison Group	*Limestone*	210	*Unknown. Probable aquifer.*
ORDOVICIAN	Upper	Red River Formation	*Dolomite*	160	*Unknown. Probable aquifer.*
	Middle	Winnipeg Formation	*Shale and sandstone*	120	*Unknown.*
PRECAMBRIAN	---	Igneous rocks	*Granite*	---	*Impermeable, except locally along shallow fractures.*

[1] The Fall River, Sundance, and Minnelusa Formations are a single aquifer in Hyde and Hand Counties.

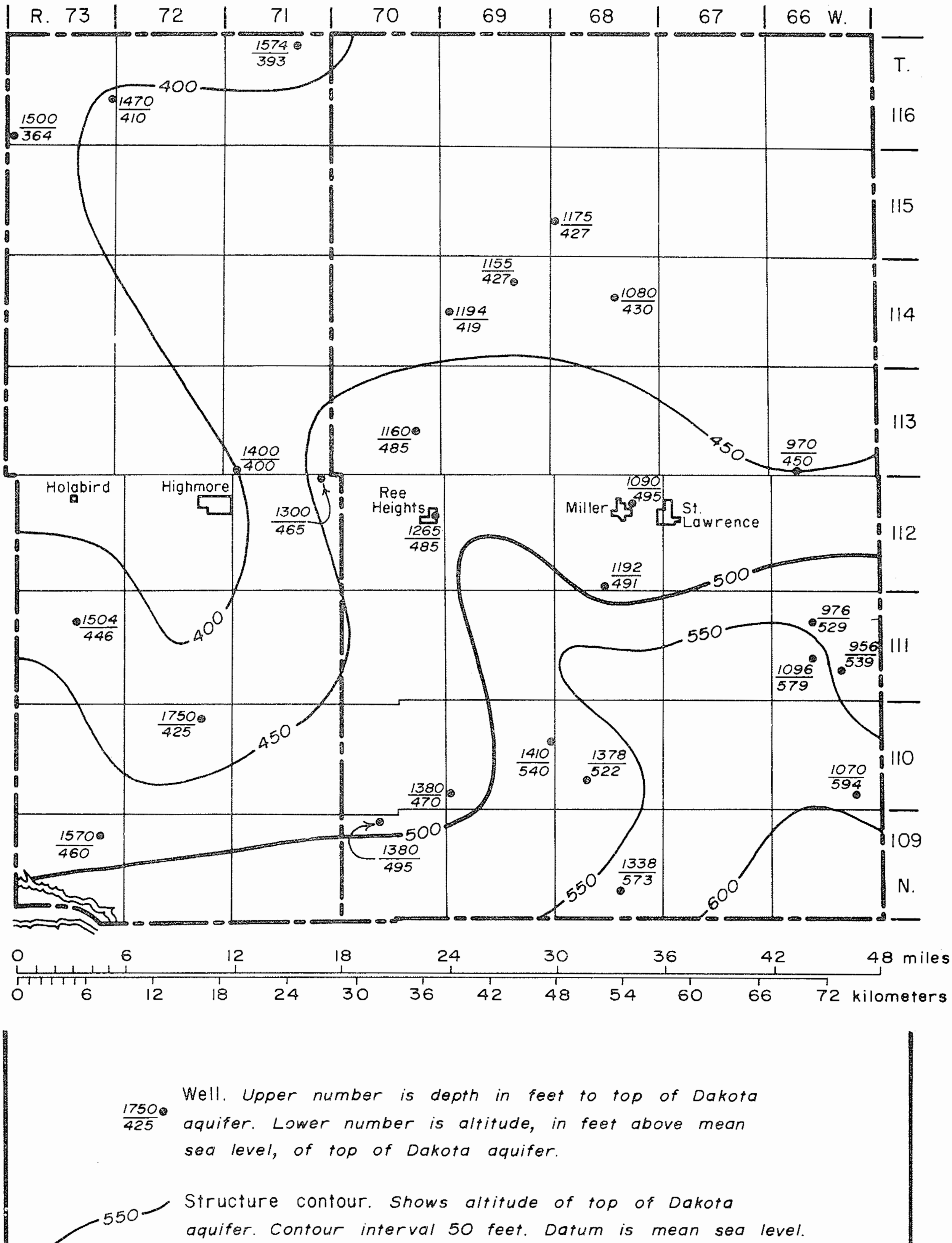
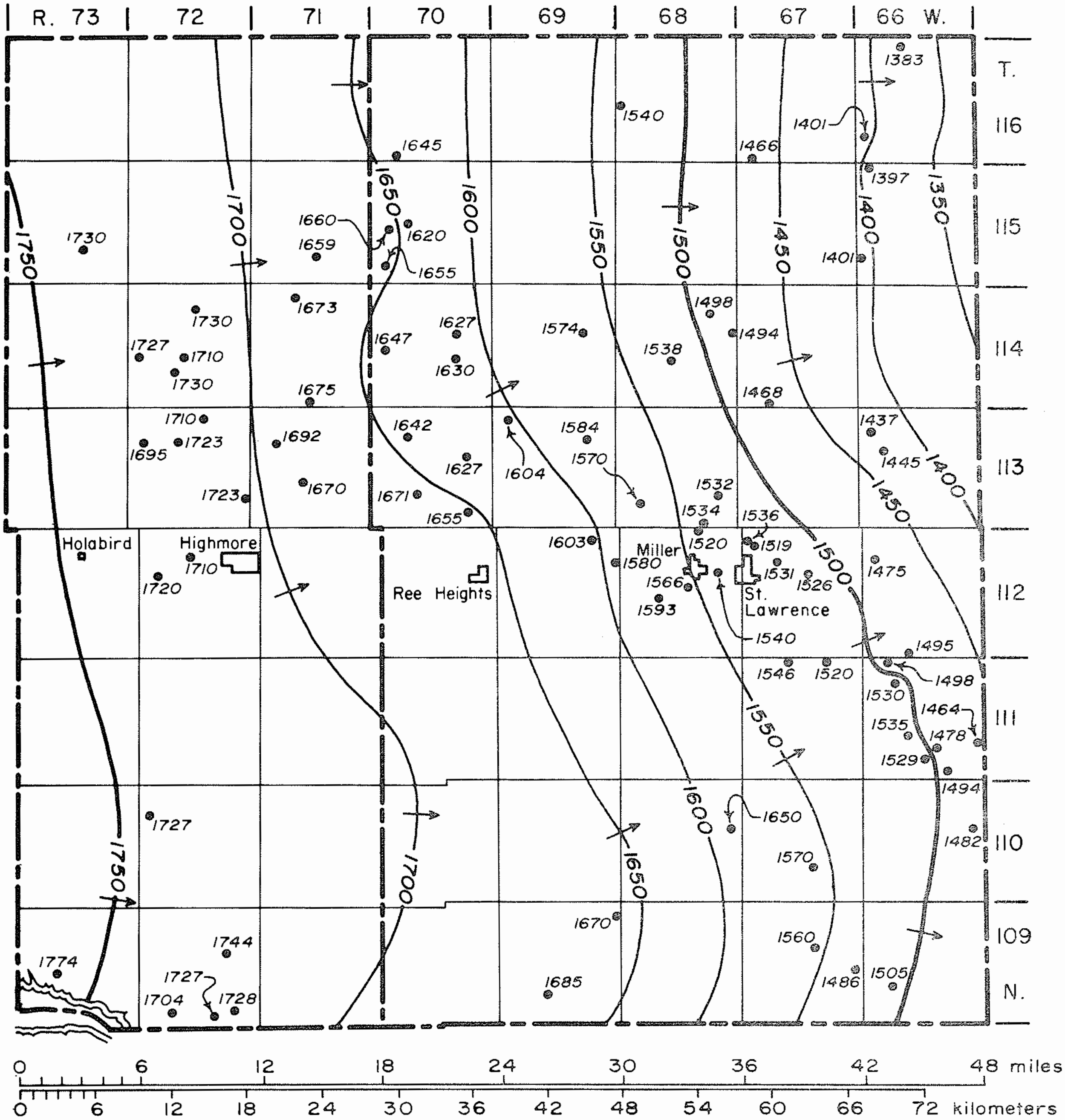


Figure 21. Structure contours on the top of the Dakota aquifer decrease in altitude northwestward.



1655 Well. *Number is altitude of potentiometric surface in feet above mean sea level.*

1700 Potentiometric contour. *Shows altitude of water level, 1969–1974. Contour interval 50 feet (15 meters). Datum is mean sea level.*

→ General direction of water movement.

Figure 22. The direction of water movement in the Dakota aquifer is to the east.

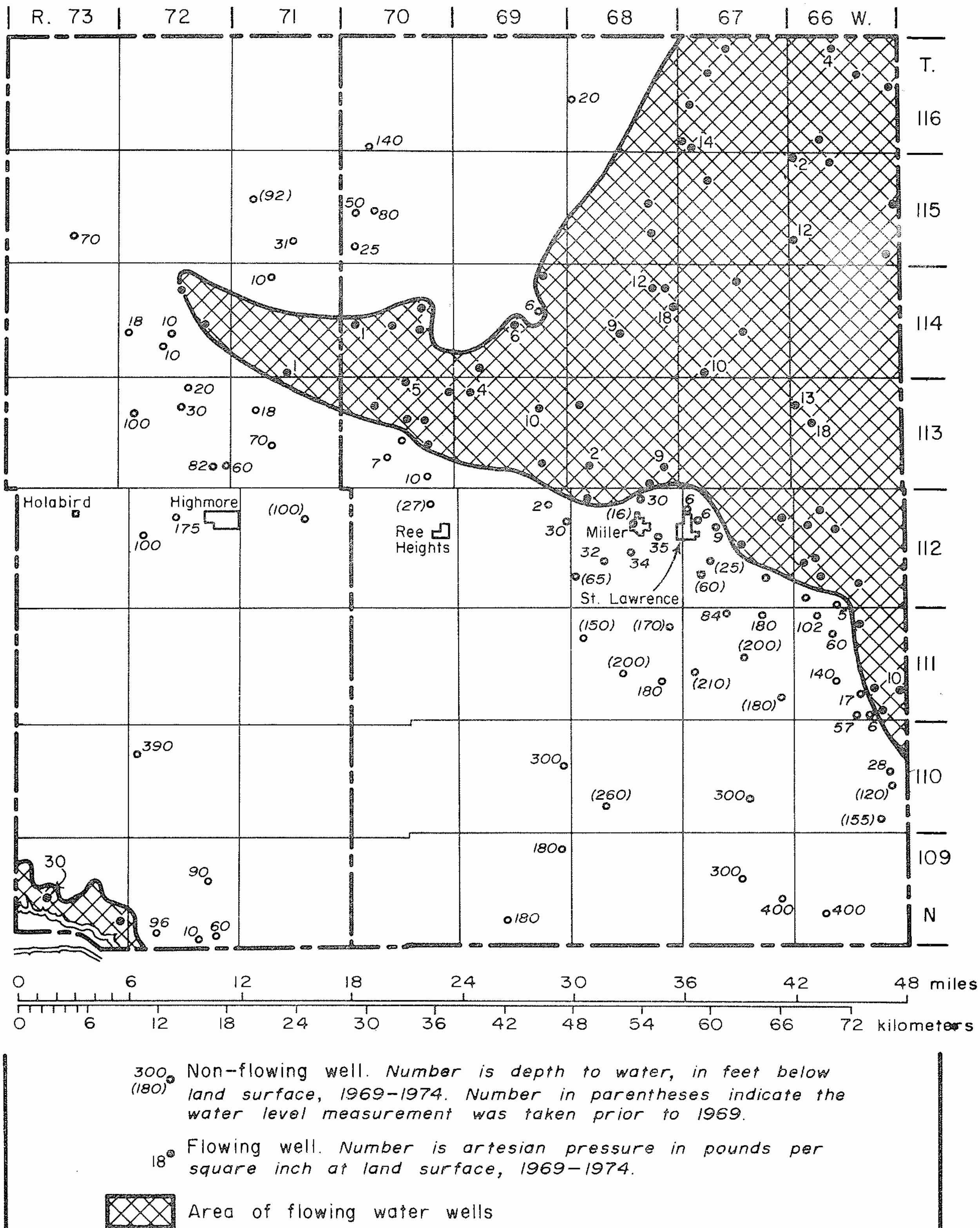


Figure 23. The artesian pressure in the Dakota aquifer is as much as 30 pounds per square inch at land surface in the southwestern part of Hyde County. Depth to water is as much as 400 feet below land surface in the southeastern part of Hand County.

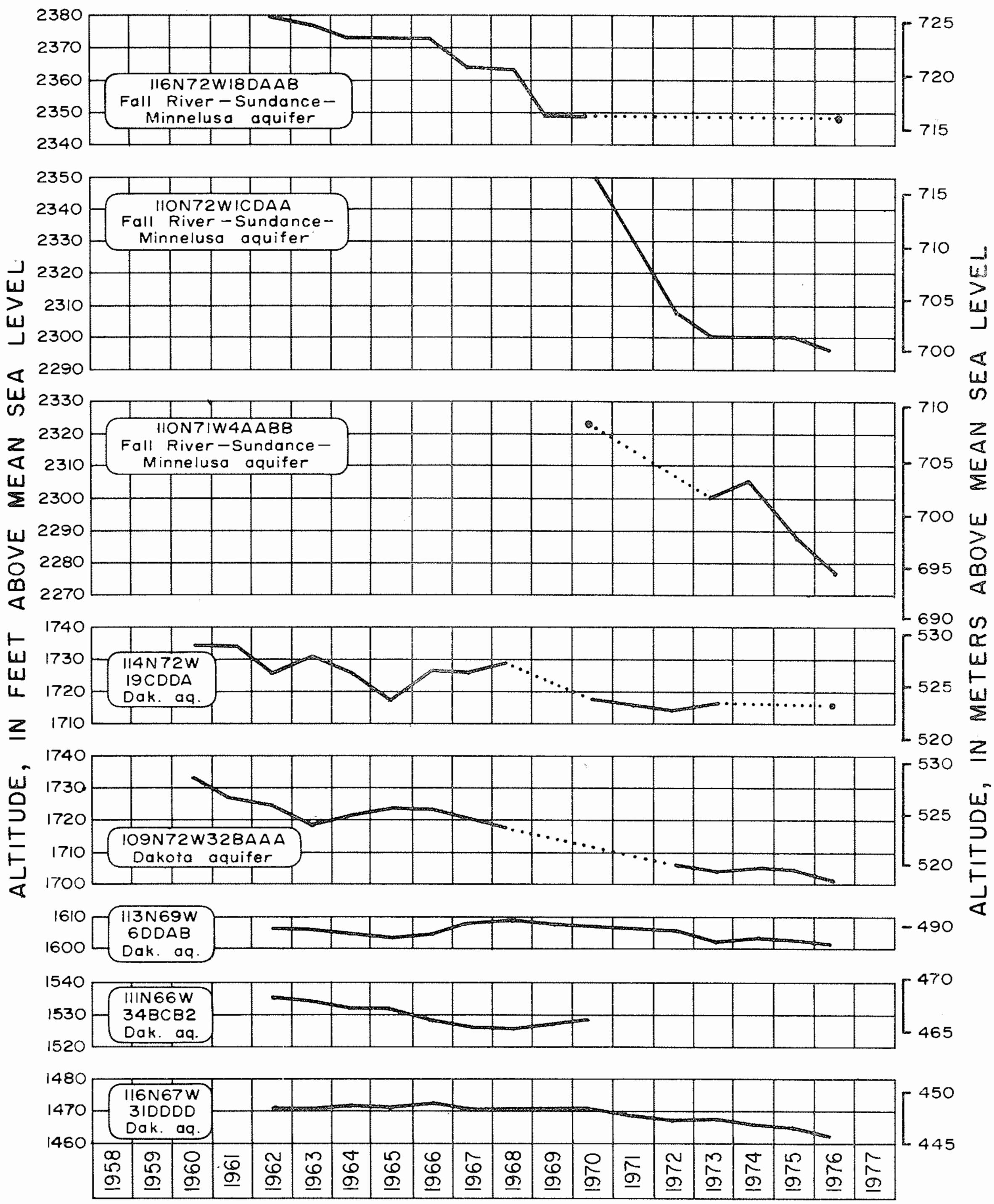


Figure 24. Water levels in wells in the Dakota aquifer dropped from 0.5 to 2.0 feet per year during the last 17 years and in the Fall River-Sundance-Minnelusa aquifer dropped from 2 to 9 feet per year.

(table 7). The aquifer has an average thickness of about 200 ft (61 m). Depths to the top range from 1,400 ft (427 m) below land surface in eastern Hand County to more than 2,400 ft (732 m) in western Hyde County. The altitude of the potentiometric surface ranges from about 2,400 ft (732 m) above sea level in western Hyde County to 1,450 ft (442 m) above sea level in eastern Hand County (fig. 25). The slope of the potentiometric surface varies from 12 to 100 ft/mi (2 to 19 m/km). Although the head in wells in the aquifer has declined from 2 to 9 ft (0.6 to 3 m) per year during the last 6 to 14 years (fig. 24), wells flow in all but a 400 mi^2 (1036 km^2) area in southeastern Hand County (fig. 26). Recharge is by subsurface inflow from the west and by upward leakage where deeper aquifers occur. Natural discharge is by upward leakage and subsurface outflow to the south and east.

Chemical Quality of Water In Bedrock Aquifers

The chemical constituents of water from the Dakota and Fall River-Sundance-Minnelusa aquifers indicate some degree of mixing of water from the two aquifers. Water movement is, in general, from west to east across the counties and from lower aquifers to higher aquifers. Because the chemical constituents of water change where mixing occurs these aquifers are best described beginning with the lowermost aquifer. Chemical analyses of water from the Dakota and Fall River-Sundance-Minnelusa aquifers are given in table 16. There are no known wells in the aquifers below the Fall River-Sundance-Minnelusa aquifer (table 15) in Hand and Hyde Counties; consequently the chemical quality of the water and water-bearing characteristics of deeper aquifers are unknown.

Fall River-Sundance-Minnelusa water is of a calcium sulfate type with dissolved solids ranging from 1,900 to 2,200 mg/L. The water is very hard (about 1,400 mg/L). The Dakota water is a sodium chloride type with dissolved solids ranging from 1,500 to 2,600 mg/L. Water hardness ranges from 12 mg/L (soft) to 1,600 mg/L (very hard) in the Dakota aquifer (fig. 27).

Where water from the Fall River-Sundance-Minnelusa aquifer has mixed with water in the Dakota aquifer, the major constituents become a composite of the two water types (fig. 28).

The water in bedrock aquifers is used for domestic, stock, and municipal purposes. Its poor chemical quality makes it unsuitable for irrigation use.

WATER USE

Water use in Hand and Hyde Counties was estimated to be about 1.4 billion gal (5.3 billion L) in 1975 (table 17). Over half the water used (52 percent) comes from the four major glacial aquifers, 32 percent from the two bedrock aquifers, and 16 percent from minor aquifers, dugouts, and dams. Only a small percentage of the water comes directly from surface water. Most of the dams and dugouts in Hyde County and over half of the dugouts in Hand County receive their water from surface runoff.

WATER MANAGEMENT

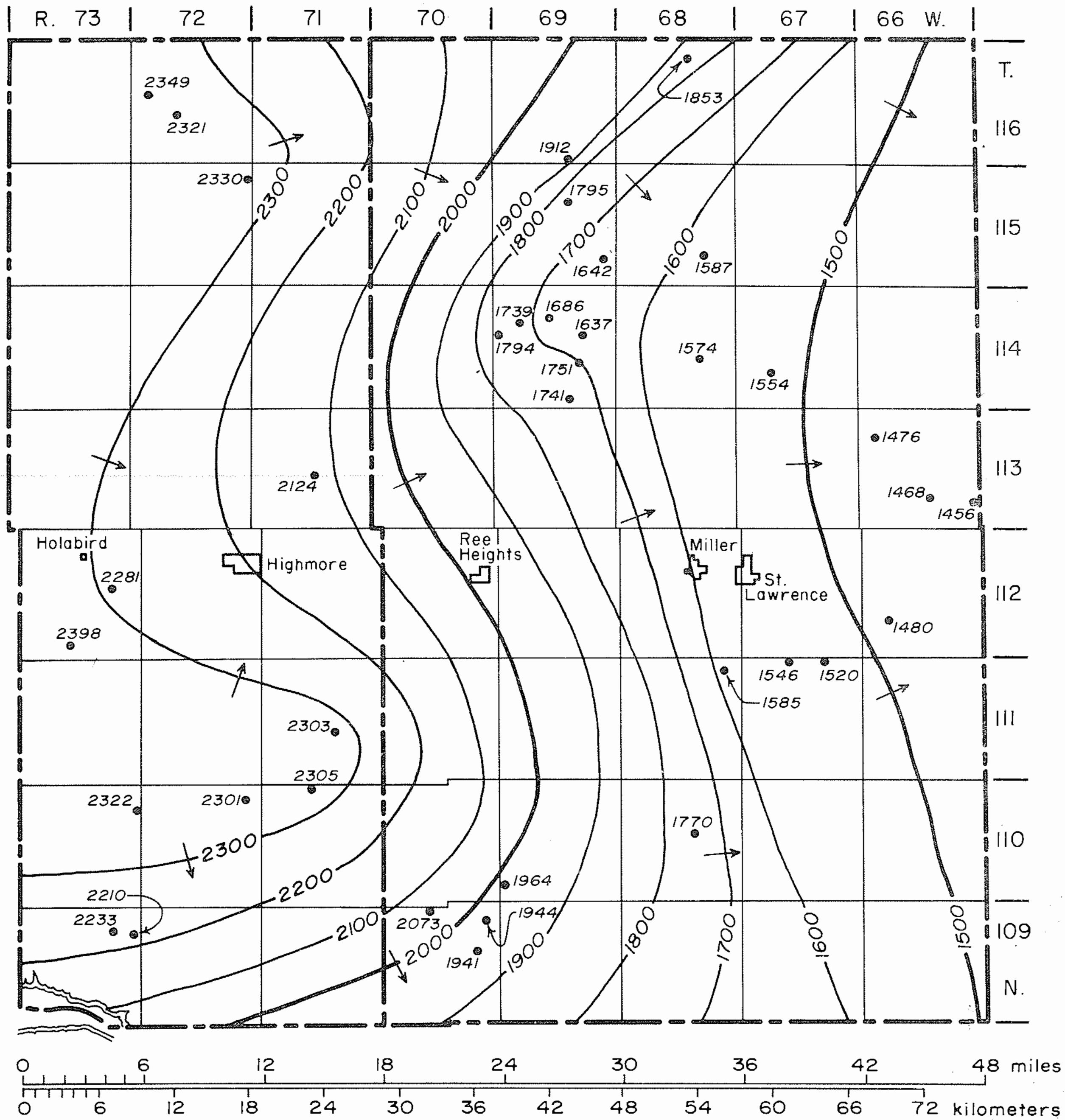
In 1975 only a small amount of water was withdrawn from the major aquifers (table 18). Recharge to the glacial aquifers during a year of average snowmelt and spring rains generally equals discharge. However, recharge has not kept pace with discharge from the bedrock aquifers since the early 1900's. As development of the glacial aquifers increases, total discharge from these aquifers will begin to exceed annual recharge, and hence the ground water in storage will start to be depleted. A continuing program of collection and analysis of pumpage and water-level data is needed to monitor the changes and to provide a basis for sound water-management decisions.

SUMMARY

Surface water covers about 1 percent of Hand and Hyde Counties. A well developed network of streams covers most of the area. Most streamflow and all floods occur in spring and early summer as a result of snowmelt and precipitation. Streams commonly have no flow in summer, fall, and winter. The average annual discharge of creeks in the area ranges from 0.6 to 14.4 ft^3/s (0.02 to 0.4 m^3/s).

The Tulare aquifer underlies an area of about 950 mi^2 (2,460.5 km^2) in northern Hand and Hyde Counties. The aquifer may yield as much as 1,000 gal/min (63 L/s) of water to properly constructed wells at depths ranging from 10 to 200 ft (3 to 61 m). Aquifer thickness averages about 30 ft and ranges from 1 to 124 ft (0.3 to 38 m). Water in the aquifer occurs mostly under artesian conditions except where the aquifer underlies the creeks in eastern Hand County.

Water in the Tulare aquifer is predominantly of calcium bicarbonate or sodium sulfate type with dissolved solids averaging 1,150 mg/L and ranging generally from 296 to 2,100 mg/L. Water in the upper part of the aquifer generally is calcium bicarbonate type and in the lower part of the aquifer sodium sulfate type. It generally is of suitable quality for domestic, stock, municipal, and irrigation use and is used for those purposes.

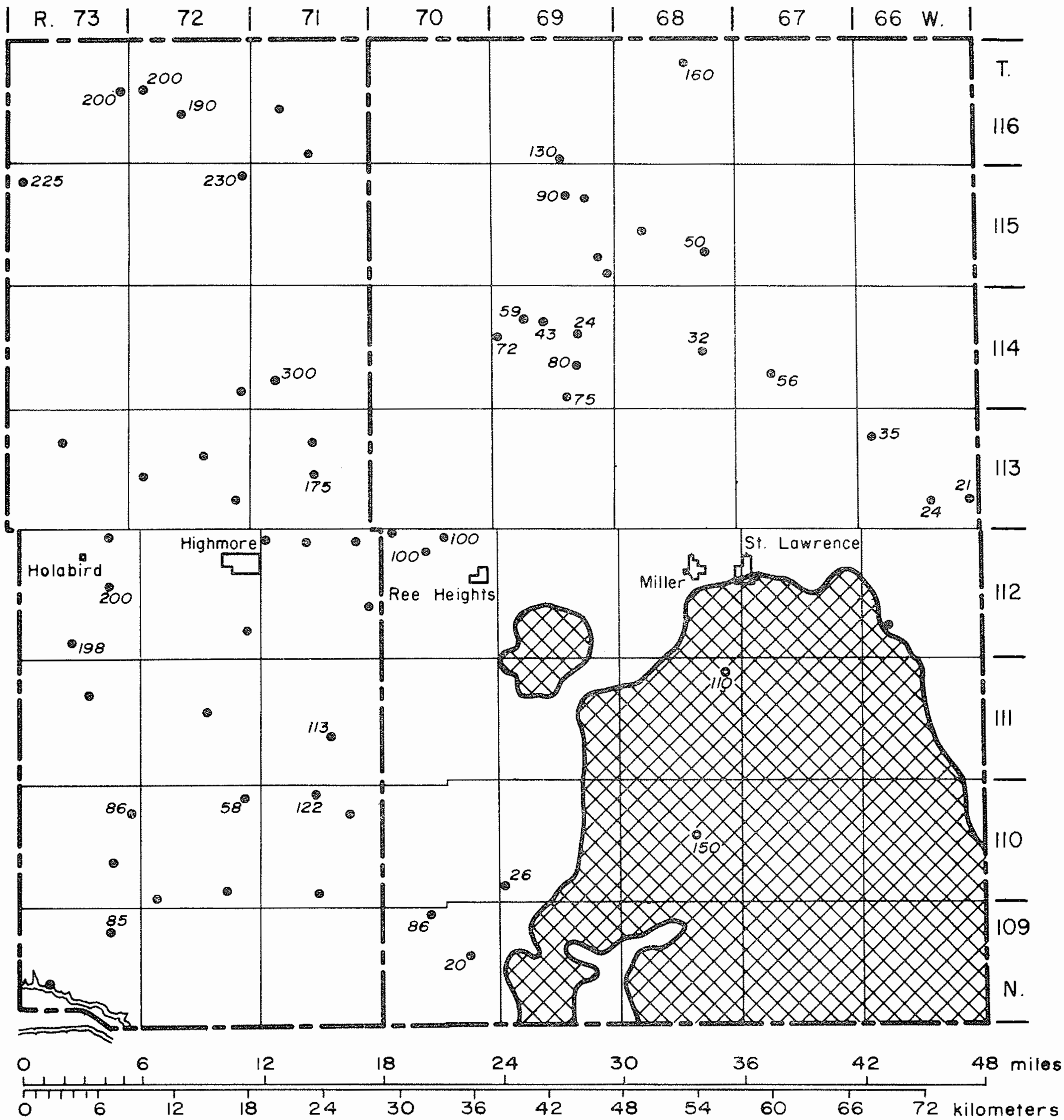


2303 • Well–*Number is altitude of water level.*

2200 Potentiometric contour–*Shows altitude at which water would have stood in tightly cased wells, 1969–1974. Contour interval 100 feet (30 meters). Datum is mean sea level.*

→ General direction of water movement.

Figure 25. The direction of water movement in the Fall River–Sundance–Minnelusa aquifer is to the east.



110 Non-flowing well. *(Number is depth to water, in feet below land surface, 1969–1974)*

58 Flowing well. *(Number is artesian pressure in pounds per square inch at land surface, 1969–1974)*

Area where water in wells is below land surface.

Figure 26. The artesian pressure in the Fall River-Sundance-Minnelusa aquifer is as much as 300 pounds per square inch in the northwern part of the area. Depth to water is as much as 150 feet below land surface in the southeastern part

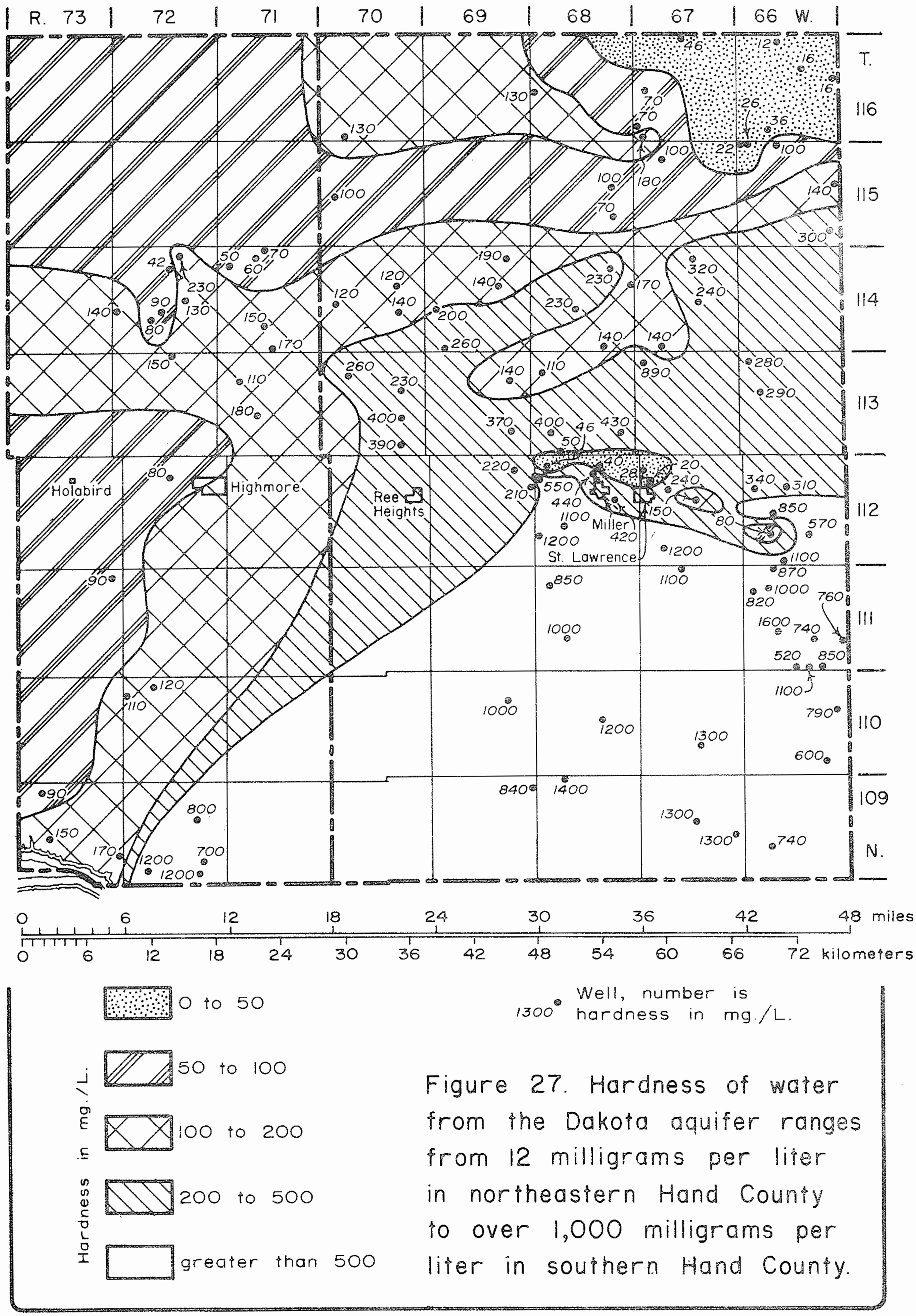


Figure 27. Hardness of water from the Dakota aquifer ranges from 12 milligrams per liter in northeastern Hand County to over 1,000 milligrams per liter in southern Hand County.

TABLE 16. Chemical analyses of water from the Dakota and Fall River-Sundance-Minnelusa aquifers.

Numbers refer to figure 28	Local identifier	Total depth of well (ft)	Date of sample	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved boron (B) (ug/L)	Dissolved solids (sum of constituents) (mg/L)	Hardness (Ca, Mg) (mg/L)	Percent sodium	Sodium adsorption ratio	Specific conductance (microhoms)	pH (units)
Wells tapping the Dakota aquifer where little or no water from the Fall River-Sundance-Minnelusa aquifer has recharged and mixed with Dakota water.																	
32	110N72W 7BBAD	1,820	6- 9-70	30	8.7	490	7.9	320	730	130	----	1,590	110	90	20	2,380	8.0
8	111N66W34BCB2	1,150	6-21-63	120	52	610	18	230	920	530	1,900	2,380	520	71	12	3,630	7.2
10	112N66W29AABC2	1,010	5-19-75	18	7.2	1,300	18	629	6.8	1,600	5,200	3,280	76	97	66	6,000	8.4
12	112N67W32ADA	1,115	10- 7-64	60	61	580	14	280	1,200	150	----	----	400	75	13	3,200	----
15	113N66W17BBAA	1,048	5-20-75	66	21	510	12	266	880	150	2,500	1,790	250	81	14	2,700	7.9
18	113N69W 6DDBD	1,593	6-21-63	61	20	490	14	304	710	260	3,000	1,720	240	81	14	2,680	7.6
19	113N69W 6DDBD	1,593	6- 5-69	62	20	450	14	294	730	190	3,700	1,620	240	79	13	2,410	8.0
20	113N69W 6DDBD	1,593	6-18-75	62	23	440	16	281	740	190	3,600	1,630	250	78	12	2,460	7.5
35	113N71W21CDBD	1,445	6-18-75	26	10	670	14	543	480	480	6,700	1,970	110	92	28	3220	8.1
37	114N71W 4ACAC	1,464	6-17-75	17	7.4	570	11	488	400	390	5,800	1,660	73	93	29	2,740	8.0
39	114N72W19CDDA	1,622	4-20-61	36	19	500	6.0	280	450	380	----	----	170	86	17	2,600	---
	114N72W19CDDA	1,622	5-22-68	37	12	490	14	300	450	350	4,800	1,530	140	87	18	2,520	8.2
24	115N66W13DCDC	1,012	5-21-75	36	11	560	11	297	790	190	2,100	1,760	140	89	21	2,760	8.0
26	116N67W31DDDB	1,143	6-21-63	27	9.6	560	10	390	620	280	2,300	1,720	110	91	24	2,900	7.6
	116N67W31DDDB	1,143	6- 5-69	31	25	520	12	380	610	270	4,500	1,670	180	85	17	2,560	----
	116N67W31DDDB	1,143	5-21-75	26	9.5	540	9.7	411	520	270	4,500	1,600	110	91	23	2,640	8.1
Wells tapping the Dakota aquifer where water from the Fall River-Sundance-Minnelusa aquifer has recharged the Dakota and mixed with Dakota water.																	
2	109N69W 1DDCD	1,492	5-19-75	370	82	300	27	224	1,300	300	880	2,510	1,300	34	3.7	3,300	7.8
27	109N72W14BDBB	1,500	8- -63	150	34	370	16	180	1,100	70	----	1,790	510	60	7.1	----	7.4
42	109N72W32BAAA	1,500	9-10-75	140	55	260	7.9	11	760	170	150	1,410	580	49	4.7	1,930	8.3
5	110N68W15DDCB	1,565	11- 2-61	270	58	280	---	190	1,000	130	----	2,020	910	40	4.0	3,500	8.2
7	111N66W21CCCA	1,424	9-10-75	540	32	1,400	19	55	1,300	2,200	1,500	5,530	1,500	67	16	8,500	7.2
9	111N68W 7AAD3	1,435	5-19-75	240	72	210	22	113	1,100	68	800	1,780	900	33	3.1	2,300	8.0
16	113N66W32D[1]	1,260	1-18-54	220	52	450	---	E150	1,100	320	----	2,350	750	57	7.1	----	----
17	113N67W 6ADA	1,200	5- 1-51	320	20	230	30	280	------	110	----	----	890	35	3.4	2,220	6.8
Wells tapping the Dakota aquifer where water from the Fall River-Sundance-Minnelusa aquifer has recharged the Dakota and replaced the Dakota water.																	
1	109N67W15BCC	1,505	6-18-75	400	93	110	23	145	1,300	130	310	2,150	1,400	15	1.3	2,530	7.5
28	109N72W32BAAA	1,500	5- 4-60	260	80	150	17	23	1,100	90	340	1,740	970	25	2.1	2,180	6.8
29	109N72W32BAAA	1,500	4-18-67	360	69	190	17	0	1,300	150	310	2,180	1,200	26	2.4	2,690	----
6	110N68W15DDCB	1,565	1-30-62	360	61	140	7.0	122	1,100	90	----	----	1,200	21	1.8	2,850	----
Wells tapping the Fall River-Sundance-Minnelusa aquifer.																	
4	109N70W 4BABD	1,945	5-19-75	420	97	56	20	166	1,300	80	170	2,080	1,500	8	.6	2,400	7.3
30	109N73W11ABBC	2,140	5-27-69	400	94	69	17	190	1,300	74	120	2,060	1,400	10	.8	2,360	7.8
	109N73W11ABBC	2,140	9-10-75	420	99	63	18	172	1,300	82	150	2,080	1,500	8	.7	2,325	7.4
31	110N71W11ABAA	2,156	6-17-75	420	97	53	21	170	1,300	75	200	2,070	1,400	7	.6	2,420	7.2
33	111N73W10CBD	1,855	4-28-60	430	110	74	20	240	1,100	82	----	2,300	1,500	9	.8	2,500	7.3
11	112N66W29AABC3	1,390	5-19-75	300	79	200	21	160	1,200	96	740	1,990	1,100	28	2.7	2,450	7.5
13	112N70W 9ACDD	1,705	6-27-67	420	96	83	20	----	960	80	----	----	1,400	11	.9	2,500	8.1
34	112N73W33BAA	2,050	5- 7-68	430	82	61	19	----	1,400	62	----	----	1,400	8	.7	2,420	6.9
14	113N66W 7ADD	1,187	5-20-75	330	80	170	22	164	1,200	94	280	1,990	1,200	24	2.2	2,560	7.4
21	113N69W17BCCB	1,545	6-18-75	400	95	70	22	168	1,300	81	200	2,070	1,400	10	.8	2,440	7.5
36	113N73W 9DBA	1,852	- -62	390	86	130	19	170	1,300	62	380	2,110	1,300	17	1.6	2,490	7.3
22	114N67W29ADAA	1,430	5-20-75	400	100	87	21	167	1,300	94	240	2,100	1,400	12	1.0	2,500	7.3
23	114N69W 8CDC	1,603	5-20-75	410	97	73	21	166	1,300	84	210	2,080	1,400	10	.8	2,440	7.2
38	114N71W29 CDDC	1,820	6-18-75	400	97	64	20	173	1,300	81	180	2,060	1,400	9	.7	2,430	7.1
25	115N68W20BAAB	1,600	5-21-75	400	76	86	22	170	1,200	92	280	1,980	1,300	12	1.0	2,500	7.3
40	115N72W 1DDAA	1,980	6-11-75	400	97	56	19	179	1,300	75	170	2,050	1,400	8	.7	2,450	7.2
41	116N72W18DAAB	1,969	9-14-62	420	95	76	18	179	1,300	72	170	2,050	1,400	10	.9	2,400	7.4
	116N72W18DAAB	1,969	5- 8-69	400	94	79	20	190	1,300	70	140	2,030	1,400	11	.9	2,430	7.9
	116N72W18DAAB	1,969	6-17-75	420	95	67	19	171	1,300	83	170	2,090	1,500	9	.8	2,430	7.1

[1]Casing is perforated opposite both aquifers.
E - estimated.

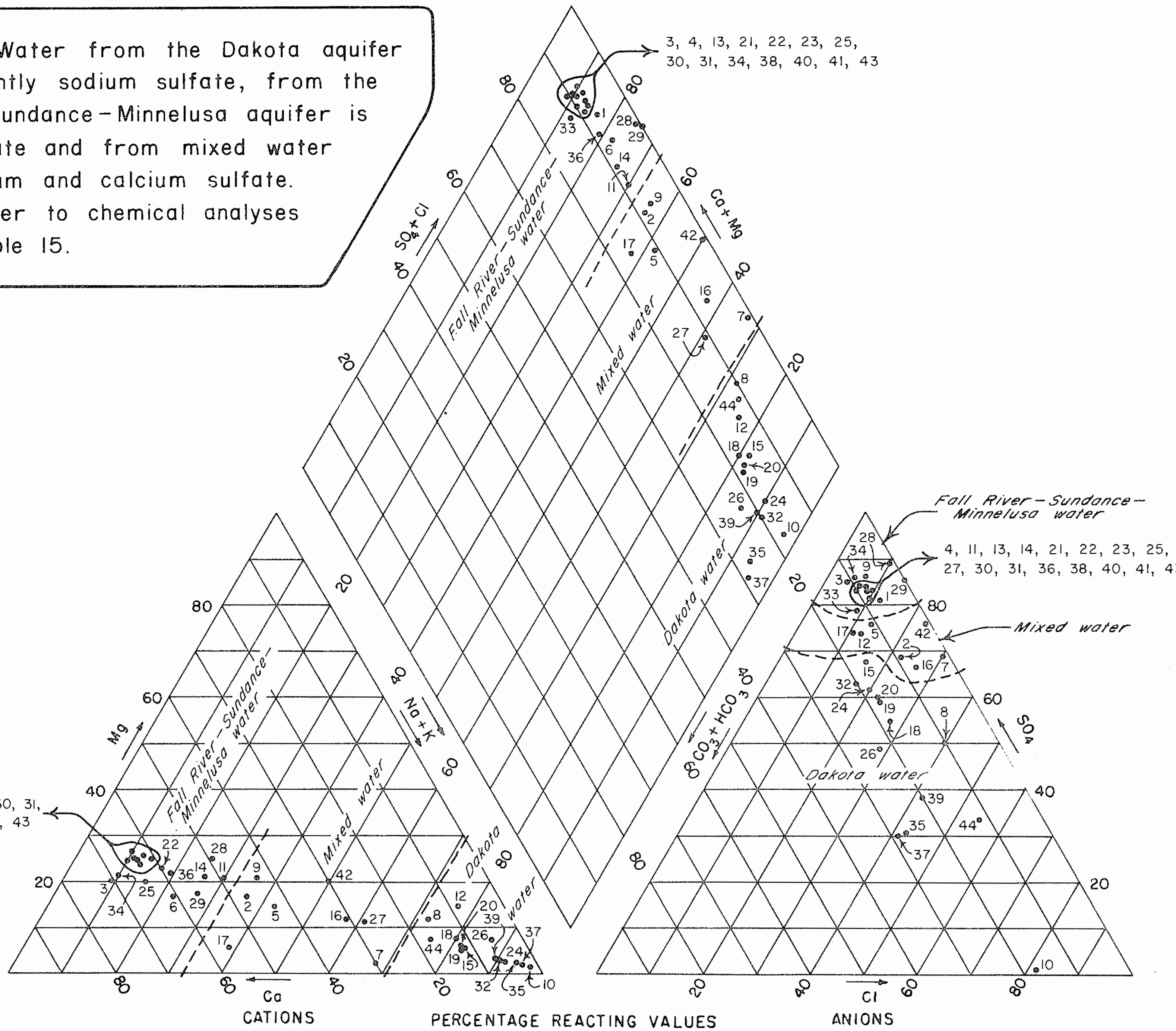


Figure 28. Water from the Dakota aquifer is predominantly sodium sulfate, from the Fall River-Sundance-Minnelusa aquifer is calcium sulfate and from mixed water is both sodium and calcium sulfate. Numbers refer to chemical analyses shown on table 15.

TABLE 17. Water use in Hand and Hyde Counties for 1975.

Source	Area underlain by aquifer in Hand and Hyde Counties		Number of private wells	Number of irrigation wells	Number of city wells	Amount withdrawn (million gallons)	Estimated actual use (million gallons)	Percent of total use
	Square miles	Percent of total						
Tulare aquifer	950	41	370	3	2	429	429	31
Elm Creek aquifer	25	1	42	4	0	195	195	14
Highmore aquifer	100	4	32	1	2	89	89	6
Bad-Cheyenne River aquifer	200	9	15	0	0	13	13	1
Dakota aquifer	2,306	100	about 350	0	4	440[1]	340	25
Fall River-Sundance-Minnelusa aquifer	2,306	100	about 115	0	0	1,500[1]	100	7
Other (Minor aquifers, dugouts, and dams)	----	----	----	----	----	224	224	16
Total			924	8	8	2,890	1,390	100

[1]Some of the flow is unused and not put to beneficial use. About 23 percent of the flow of the Dakota and 98 percent of the Fall River-Sundance-Minnelusa, totaling 77 percent of the amount withdrawn from bedrock aquifers, was unused.

TABLE 18. Amount of water withdrawn from major aquifers in Hand and Hyde Counties in 1975.

	Amount withdrawn (acre-ft)	Aquifer storage (acre-ft)	Percent of total storage withdrawn
Tulare aquifer	1,317	3,600,000	.04
Highmore	273	250,000	.11
Elm Creek	598	100,000	.60
Bad Cheyenne River aquifer	40	1,000,000	.004
Dakota aquifer	1,350	70,000,000	.002
Fall River-Sundance-Minnelusa aquifer	4,603	60,000,000	.008
Total	8,181	134,950,000	.006

The Elm Creek aquifer underlies an area of 25 mi^2 (65 km^2) in southwestern Hand County and southeastern Hyde County. The aquifer may yield as much as 1,000 gal/min (63 L/s) to properly constructed wells at depths ranging from 2 to 100 ft (0.6 to 30 m). Water in the aquifer underlying the Elm Creek drainage area occurs under artesian conditions; underlying the West Fork Elm Creek drainage area it occurs under water-table conditions.

Water in the Elm Creek aquifer is predominantly of calcium bicarbonate or calcium sulfate type with dissolved solids averaging 910 mg/L and ranging from 673 to 1,250 mg/L. It is of suitable quality for domestic, stock, and irrigation use and is being used extensively for those purposes.

The Highmore aquifer underlies an area of about 100 mi^2 (259 km^2) in central Hyde County. The aquifer may yield as much as 1,000 gal/min (63 L/s) of water to properly constructed wells at depths ranging from 20 to 200 ft (6 to 61 m). Water in the aquifer occurs mostly under artesian conditions except where it underlies the South Fork Medicine Knoll Creek. The depth to water in wells is generally less than 100 ft (30 m) below land surface except in T. 113 N. where it is as much as 150 ft (46 m).

Water in the Highmore aquifer is predominantly of calcium bicarbonate or sodium sulfate type. It generally is of suitable quality for domestic, stock, municipal, and irrigation use and is used for those purposes.

The Bad-Cheyenne River aquifer underlies an area of about 200 mi^2 (520 km^2) in Hyde and Hand Counties. It crosses north-central Hyde County and extends to the southeast across Hand County. The aquifer may yield as much as 1,000 gal/min (63 L/s) of water to properly constructed wells at depths ranging mostly from 150 to 500 ft (46 to 152 m). Water in the aquifer occurs under artesian conditions. The depth to water in wells ranges from 10 to 210 ft (3 to 64 m) below land surface.

Water in the Bad-Cheyenne River aquifer is of the sodium bicarbonate type with dissolved solids ranging from 854 to 2,040 mg/L. It is of suitable quality for stock and domestic uses. Chemical analyses of water indicate it is not suitable for irrigation use.

The major bedrock aquifers that underlie Hand and Hyde Counties are the sandstones which are at depths greater than 900 ft (274 m) below land surface. They are in order of increasing depth, the Dakota, Fall River, Sundance, and Minnelusa Formations. The Dakota aquifer has an average thickness of 240 ft (73 m). The top of the aquifer is more than 900 ft (274 m) below land surface in eastern Hand County and more than 1,750 ft (533 m) below land surface in southern Hyde County. The Fall River, Sundance, and Minnelusa Formations are hydraulically connected and act as a single aquifer which has an average thickness of about 200 ft (61 m). Depths to the top of the aquifer range from 1,400 ft (427 m) below land surface in eastern Hand County to more than 2,400 ft (732 m) in western Hyde County.

Water in the bedrock aquifers occurs under artesian conditions. Wells in the Dakota aquifer flow in northeastern Hand County and east central Hyde

County. Elsewhere water levels in wells developed in the Dakota range from 30 ft (9 m) below land surface in Hyde County to 400 ft (122 m) below land surface in southeastern Hand County. Wells in the Fall River-Sundance-Minnelusa aquifer flow in most of the area except for the topographically high area in southeastern Hand County where water levels in wells are as much as 150 ft (46 m) below land surface.

The Dakota water is a sodium chloride type with dissolved solids ranging from 1,500 to 3,280 mg/L; hardness-causing constituents in the water range from 12 mg/L (soft) to 1,300 mg/L (very hard). Fall River-Sundance-Minnelusa water is a calcium sulfate type with dissolved solids ranging from 1,980 to 2,300 mg/L; hardness is very high, averaging about 1,400 mg/L.

The water in bedrock aquifers is used for domestic, stock, and municipal purposes. Its high dissolved solids make it unsuitable for irrigation use.

SELECTED REFERENCES

Becker, Lawrence D., 1974, A method of estimating magnitude and frequency of floods in South Dakota. U.S. Geol. Survey Water Resources Inv. 35-74, 78 p.

Christensen, Cleo M., 1962, Ground water supply for the city of Miller: South Dakota Geol. Survey Spec. Rept. 17, 23 p.

Darton, N. H., 1896, Preliminary report on artesian waters of a portion of the Dakotas: U.S. Geol. Survey 17th Ann. Rept., pt. 2, p. 627-629.

------ 1909, Geology and underground waters of South Dakota: U.S. Geol. Survey Water-Supply Paper 227, 156 p.

Durfor, C. N., and Becker, Edith, 1964, Public water supplies of the 100 largest cities in the United States, 1962: U.S. Geol. Survey Water-Supply Paper 1812, 364 p.

Flint, R. F., 1955, Pleistocene geology of eastern South Dakota: U.S. Geol. Survey Prof. Paper 262, 173 p.

Hamilton, L. J., in preparation, Geology and water resources of McPherson, Edmunds, and Faulk Counties, South Dakota: Part II, Water resources: South Dakota Geol. Survey Bull. 26.

Howells, L. W., and Stephens, J. C., 1969, Geology and water resources of Beadle County, South Dakota: Part II, Water resources: South Dakota Geol. Survey Bull. 18, 65 p.

Larimer, Owen J., 1970, A proposed streamflow data program for South Dakota: U.S. Geol. Survey open-file report, 46 p.

Machlis, J. A., and Williams, B. H., 1930, Soil survey of Hyde County, South Dakota: U.S. Dept. Agriculture, Series 1925, no. 18.

Petri, L. R., and Larson, L. R., (no date), Quality of water in selected lakes of eastern South Dakota: South Dakota Water Resources Comm., Rept. Inv. no. 1, 55 p.

Rothrock, E. P., 1941, Sources of water supply for the city of Miller, South Dakota: South Dakota Geol. Survey Rept. Inv. 40, 15 p.

South Dakota State Engineer, 1916, Sixth biennial report of the State Engineer for the years 1915-1916, 282 p.

U.S. Geological Survey, 1964, Compilation of records of surface waters of the United States October 1950 to September 1960, Part 6A, Missouri River Basin above Sioux City, Iowa: U.S. Geol. Survey Water-Supply Paper 1729, 507 p.

------ 1969, Surface water supply of the United States 1961-65, Part 6, Missouri River Basin, v. 2, Missouri River Basin from Williston, North Dakota to Sioux City, Iowa: U.S. Geol. Survey Water-Supply Paper 1917, 560 p.

------ 1973, Surface water supply of the United States 1966-70, Part 6, Missouri River Basin, v. 2, Missouri River Basin from Williston, North Dakota to Sioux City, Iowa: U.S. Geol. Survey Water-Supply Paper 2117, 612 p.

------ 1971-75, (published annually), Surface water records of South Dakota: Huron, S. Dak., Water Resources Division.

U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: U.S. Environmental Protection Agency, 159 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture Handb. 60, 160 p.

White, E. M., Westin, F. C., and Buntley, G. J., 1963, Soil survey of Hand County, South Dakota: U.S. Dept. Agriculture Series 1956, no. 21.