STATE OF SOUTH DAKOTA
Richard Kneip, Governor

DEPARTMENT OF NATURAL RESOURCE DEVELOPMENT
Vern W. Butler, Secretary

GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

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MAJOR AQUIFERS IN McPHERSON, EDMUNDS, AND FAULK COUNTIES, SOUTH DAKOTA

by

Louis J. Hamilton
United States Geological Survey
United States Department of the Interior

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ABSTRACT

Deep glacial aquifers, sand and gravel deposits more than 100 feet deep, underlie an area of about 500 square miles in McPherson, Edmunds, and Faulk Counties in north-central South Dakota. The maximum yield of a large-capacity well can range from 200 to nearly 1,000 gallons per minute for these aquifers. The water has an average hardness of 220 milligrams per liter and is dominated by sodium, chloride, and bicarbonate ions.

Shallow glacial aquifers whose tops are less than 100 feet below land surface underlie a 370-square-mile area. The maximum yield for a large-capacity well can range from 50 to 300 gallons per minute for these aquifers. The water has an average hardness of 400 milligrams per liter and is dominated by calcium, magnesium, bicarbonate, and sulfate ions.

Sandstone aquifers, lying more than 1,000 feet beneath the entire area, are capable of supplying wells yielding as much as 500 gallons per minute or more. Wells in the Dakota Sandstone yield high-sodium water having an average hardness of 100 milligrams per liter. The deeper Fall River, Sundance, and Minnelusa Formations have artesian pressures as high as 175 pounds per square inch and flows reported to exceed 1,000 gallons per minute at several places. They yield a water high in calcium, magnesium, and sulfate and having an average hardness of 1,000 milligrams per liter.

INTRODUCTION

This report describes the general distribution, quantity, and quality of water available from major aquifers in McPherson, Edmunds, and Faulk Counties, an area of 3,304 square miles in north-central South Dakota (fig. 1). Comprehensive studies on the geology and the water resources of the three Counties are currently in progress.

Copies of this report and other available county reports may be obtained from the South Dakota Geological Survey in Vermillion or the U.S. Geological Survey in Huron. Persons wishing additional information about the geology and water resources may contact either of the above organizations.

The major aquifers have been grouped as follows: (1) deep glacial aquifers (fig. 1), (2) shallow glacial aquifers (fig. 2), and (3) bedrock aquifers (fig. 3). Deep glacial aquifers are water-bearing sand and gravel deposits that are more than 100 feet beneath the land surface. Shallow glacial aquifers are water-bearing sand and gravel deposits whose tops are within 100 feet of the surface. Bedrock aquifers are water-bearing sandstone formations that generally are more than 1,000 feet below the surface. Because the reader may be interested in ground-water information in only one of the three Counties studied, separate foldout maps showing glacial aquifers on a county-wide basis have been included in this report. Plates 1, 2, and 3 located at the end of the report should be used for this purpose.

Definitions of terms, use of test wells, and a table for converting English units to metric units are in the appendix of this report.

DEEP GLACIAL AQUIFERS

The Grand, Hillsview, Onaka, and Twin Lakes aquifers (table 1) underlie about 500 square miles--15 percent of the study area (fig. 1). They are mainly irregularly layered beds of outwash sand and gravel that were deposited during several episodes of melting of continental ice sheets. Each aquifer may consist of as many as five sand and gravel beds separated by till. Total aquifer thickness averages 50 feet for the Grand aquifer and 30 feet for each of the others. The outwash is mainly fine to very coarse, silty sand and gravel containing thin beds of silty clay (table 1). Deposition of the outwash generally was confined within deep river valleys cut into shale. As a result, the aquifers are narrow, sinuous conduits that generally are less than 3 miles wide.

Well Yields

The quantity of water that a well will yield is best determined by conducting aquifer tests to evaluate the hydrologic characteristics of the aquifer. One such test of the Grand aquifer in Faulk County and other tests of similar deposits in nearby counties indicate that the deep sand and gravel has a high permeability. The maximum yield of a large-capacity well (see appendix for definition of terms) can range from 200 to nearly 1,000 gpm (gallons per minute) for deep glacial aquifers. For many stock and domestic supplies, however, yields of only a few gallons per minute are adequate. Most such wells are designated to provide yields of only about 5 to 15 gpm, although somewhat larger yields could have been obtained if needed.

Where no aquifer-test information is available, the potential yield of a properly-constructed well can be estimated from the thickness of the aquifer. A suitable estimate for the deep glacial aquifers is 5 gpm for each foot of sand and gravel. Thus, the maximum yield for a well in the Grand aquifer, where the aquifer has a maximum thickness of 175 feet, is

Aquifer Name	County			Area (square miles)	Composition	Maximum thickness (feet)	Maximum well yield (gpm)	Well depth (feet)	Water level (feet)	Water Properties	
	Faulk	Edmunds	McPherson							Spec. Conductance (Micromhos per cm at 25°C)	Hardness as $CaCO_3$ (mg/l)
Deep Aquifers											
Grand	X	X	X	360	Sand, fine to very coarse, silty, and silty gravel. Contains thin beds of silty clay.	175	880	150-600	0-213[1]	1,050-3,500	50- 470
Hillsview			X	80	Sand, fine to very coarse, silty, and silty gravel.	40	200	100-290	40-150	1,100-1,660	36- 630
Onaka	X	X		30	Sand, fine to very coarse, and silty gravel. Contains beds of silty clay.	95	480	200-400	45-200	------	------
Twin Lakes			X	30	Sand, fine to coarse, silty, and silty gravel. Contains beds of sandy clay.	40	200	150-380	10- 85	2,400-2,900	1,300-1,400
Shallow Aquifers											
Bowdle		X		60	Sand, very fine to coarse, silty, clayey, and silty gravel. Contains beds of sandy, gravelley clay.	50	200	20-100	3- 40	420-1,900	200- 640
Elm	X	X		103	Sand, fine to medium, silty, and silty gravel. Contains beds of silty clay.	77	300	20-150	3- 50	500-4,100	200-2,300
Selby			X	47	Sand, fine to coarse, silty, and silty gravel. Contains thin beds of silt and clay.	30	100	40-140	0- 63[1]	680-1,740	190- 660
Spring Creek			X	160	Sand, very fine to coarse, silty, and silty gravel. Contains beds of sandy clay.	85	50	20-200	0- 35[1]	500-2,000	200- 850

[1] Wells in topographically low areas may flow at the surface.

Table I. Major glacial aquifers.

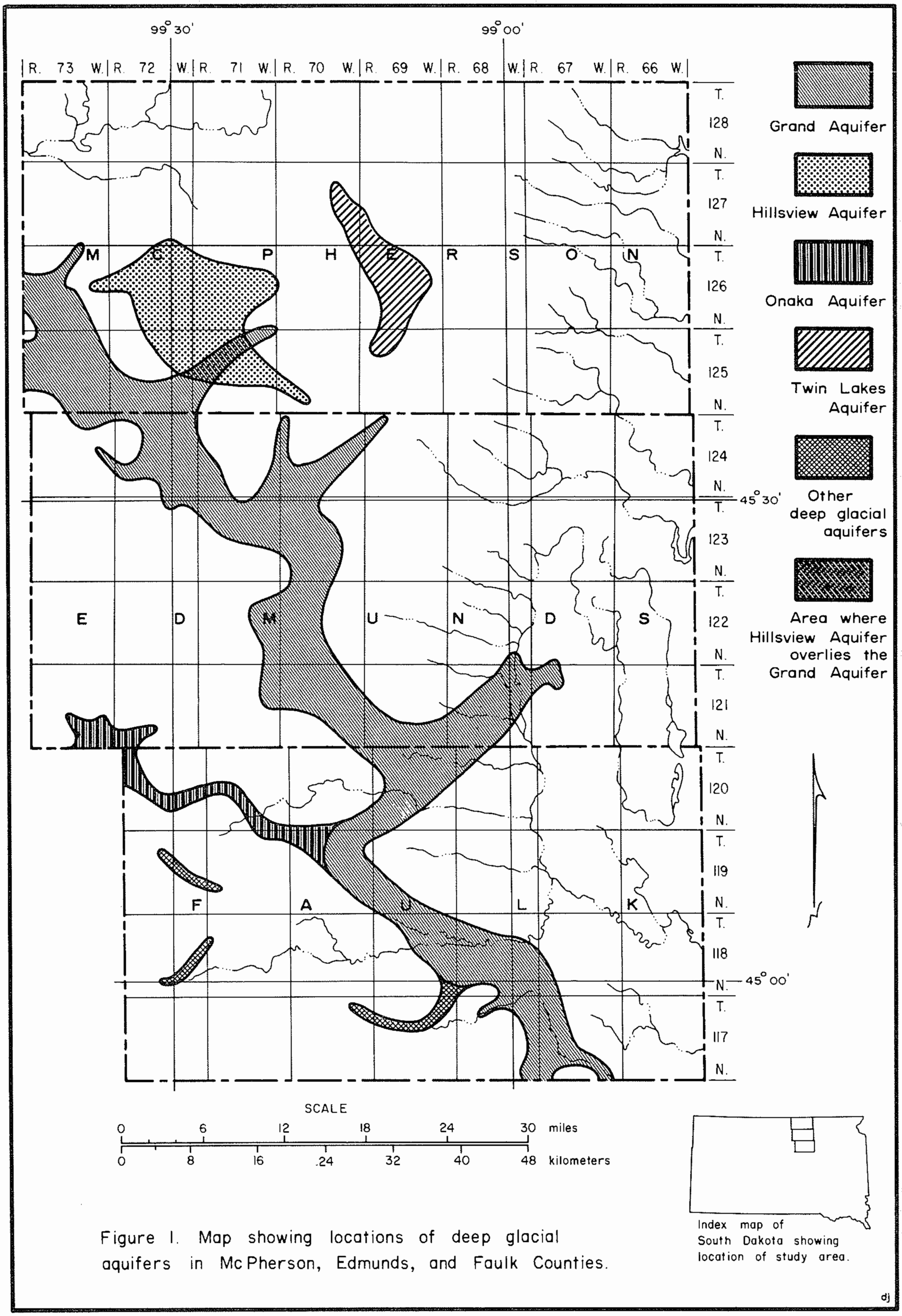

Figure 1. Map showing locations of deep glacial aquifers in McPherson, Edmunds, and Faulk Counties.

estimated to be 880 gpm (table 1). Yields of wells near the poorly-permeable boundaries of the aquifer will be lower than estimated.

Water Quality

The composition of dissolved solids in water from the deep glacial aquifers is a mixture dominated by sodium, chloride, and bicarbonate ions that were leached from shale. The specific conductance of the water (table 1), closely related to the concentration of dissolved solids, ranges from 1,050 to 3,500 and averages 2,200 μmhos/cm (micromhos per centimeter) at 25°C (degrees Celsius). The higher values are for water from wells near shale bedrock. The hardness of the water (table 1) ranges from 36 to 1,400 and averages 220 mg/l (milligrams per liter).

Many wells that tap deep glacial aquifers have been constructed by drilling into the underlying shale and setting casing down through the aquifer to the top of the shale. The casing holds out silt and fine sand and the open hole in shale serves as a reservoir for water. Most of the water yielded by such a well comes from the glacial aquifer and seeps downward along the annular space around the casing and through fractures in the shale. This water is softer but can contain higher concentrations of iron and salt than water from wells finished higher in the aquifers. The dissolved solids total more than 3,000 mg/l in some of these wells.

The chemical quality of water from deep glacial aquifers is suitable for drinking but requires softening for many domestic, commercial, and industrial uses. Unfortunately some wells yield water containing much silt and fine sand. Also, the quality generally is unsuitable for irrigation because of the high specific conductance and large concentrations of sodium and bicarbonate ions.

SHALLOW GLACIAL AQUIFERS

The Bowdle, Elm, Selby, and Spring Creek aquifers (table 1) underlie about 370 square miles--11 percent of the study area (fig. 2). They are mainly outwash sand and gravel deposited during the last episodes of melting of the continental ice sheet. Deposition occurred over a shorter period of time than for the deep aquifers, consequently the shallow aquifers generally consist of only one bed of sand and gravel and are thinner than the deep aquifers. The average thickness is about 20 feet. The outwash is mainly very fine to coarse silty sand and gravel containing beds of silty or sandy clay. Deposition was limited to channels between large blocks of ice and till and consequently the aquifers are narrow sinuous conduits that generally are less than 3 miles wide. Parts of the aquifer that are thicker than average are narrow conduits that have widths of not more than a few hundred feet.

Well Yields

The quantity of water that a well can yield is best determined by conducting aquifer tests to evaluate the hydrologic characteristics of the aquifer. One such test of the Bowdle aquifer in Edmunds County and other tests of similar deposits in nearby counties indicate that shallow sand and gravel has a high permeability. The maximum yield of a large-capacity well can range from 50 to 300 gpm for shallow glacial aquifers For many stock and domestic supplies, however, yields of only a few gallons per minute are adequate. Most such wells are designed to provide yields of only about 5 to 15 gpm, although somewhat larger yields could have been obtained if needed.

Where no aquifer-test information is available, the potential yield of a properly-constructed well can be estimated from the thickness of the aquifer. A suitable estimate for the shallow glacial aquifers generally is 3 to 4 gpm for each foot of sand and gravel. This is lower than for the deep glacial aquifers because the shallow aquifers generally contain more silt and clay which reduces permeability and yields.

Water Quality

The composition of dissolved solids in water from shallow glacial aquifers is a mixture dominated by calcium, magnesium, bicarbonate and sulfate ions that were leached from till. The specific conductance of the water (table 1), closely related to the concentration of dissolved solids, ranges from 420 to 4,100 and averages 1,300 μmhos/cm at 25°C The higher values are for water from wells in thin sand beds within till. The hardness of the water (table 1) ranges from 190 to 2,300 and averages 400 mg/l, higher than for water from deep glacial aquifers.

Many wells in shallow aquifers are constructed of porous concrete culverts that allow water that is much harder than aquifer water to enter the well from till above the aquifer. The quality varies with the amount of pumping. A lightly-pumped well yields mostly till-water that accumulates in the well. Heavy pumping removes this water and draws water from the aquifer.

The chemical quality of water from shallow glacial aquifers is suitable for drinking, but requires softening for many domestic, commercial, and industrial uses. The quality may be unsuitable for irrigation where the specific conductance exceeds 1,000 μmhos/cm at 25°C.

BEDROCK AQUIFERS

The major bedrock aquifers which underlie all of Faulk, Edmunds, and McPherson Counties are the sandstones. They are found in the Dakota Sandstone and the Fall River, Sundance, and Minnelusa

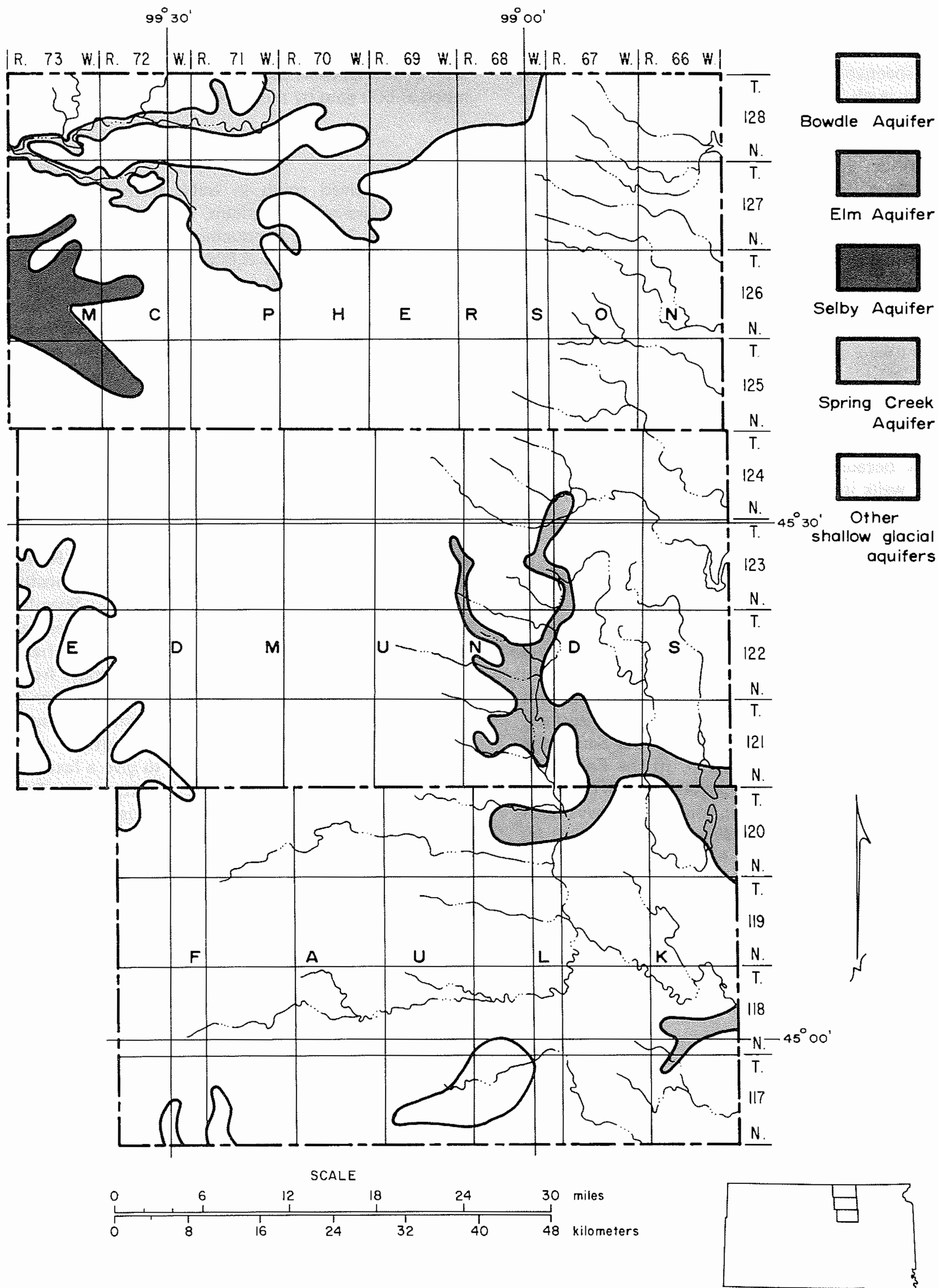

Figure 2. Map showing locations of shallow glacial aquifers in McPherson, Edmunds, and Faulk Counties.

Formations, in order of increasing depth (fig. 3). All thicknesses cited are approximate. The Dakota Sandstone is 300 feet thick, except at the north and south ends of the study area where it is 100 and 50 feet, respectively. The Fall River Formation is 140 to 360 feet thick in the south and thins to 40 feet in the north. The combined Sundance and Minnelusa Formations have a thickness of 150 feet in the south and 300 feet in the north. The depth to the top of an aquifer at a well site near the line of the geologic section (fig. 3) can be estimated from the difference between the altitude of the land surface and the altitude of the top of the aquifer. The aquifers are at shallower depths east and greater depths west of the geologic section because the land surface rises to the west and the aquifers dip to the northwest at 3 to 5 feet per mile.

Most farms in the eastern part of the area have one or more wells in the Dakota Sandstone. Few farms in the western part of the area have wells in bedrock aquifers because these aquifers average 500 feet deeper, wells in the Dakota Sandstone do not flow, and glacial aquifers are more abundant.

Well Yields

Water in the bedrock aquifers occurs under artesian conditions and flowing wells have been obtained from all of them. Wells in the Dakota Sandstone flow at most a few gallons per minute. In the western two-thirds of the area, artesian pressure is not great enough to cause flow at land surface. Properly-constructed wells in the Dakota Sandstone may yield as much as 500 gpm. In the Fall River Formation flows of 5 to 40 gpm and shut-in pressures of more than 90 pounds per square inch have been measured. In the Sundance Formation a flow of 90 gpm and a shut-in pressure of 175 pounds per square inch was measured on a 1,396-foot well at Lake Parmley in eastern Edmunds County. Flows of more than 1,000 gpm have been reported from test holes in the Sundance and Minnelusa Formations at two other sites in eastern Edmunds County. Where large flows are not found, wells can be constructed to produce as much as 500 gpm by pumping.

Water Quality

The dissolved solids in water from the Dakota Sandstone are mostly sodium, chloride, bicarbonate and sulfate. Specific conductance ranges from 2,200 to 6,500 and averages 3,600 µmhos/cm. Hardness ranges from 22 to 400 and averages 100 mg/l. The water is favored for domestic use because it is softer than water from deeper bedrock aquifers or from glacial drift. However, the water is corrosive and is reported to have mottled some teeth because of its high fluoride content. Its salt content makes it unpalatable to many people and may produce a laxative effect. The high specific conductance, indicating highly mineralized water, and high concentrations of sodium and bicarbonate make the water unsuitable for irrigation.

The dissolved solids in water from the Fall River, Sundance, and Minnelusa Formations are mostly calcium, magnesium, and sulfate. Specific conductance ranges from 2,200 to 3,270 and averages 2,600 µmhos/cm. The water generally is very hard and contains 1 to 3 mg/l iron. Hardness ranges from 100 to 1,400 and averages 1,000 mg/l. The water is corrosive and its high fluoride content can cause mottling of teeth. The composition and concentration of ions are reported to give a laxative effect on some people and impart a bitter taste. The water is unsuitable for irrigation because of its high specific conductance, which indicates that the water is highly mineralized.

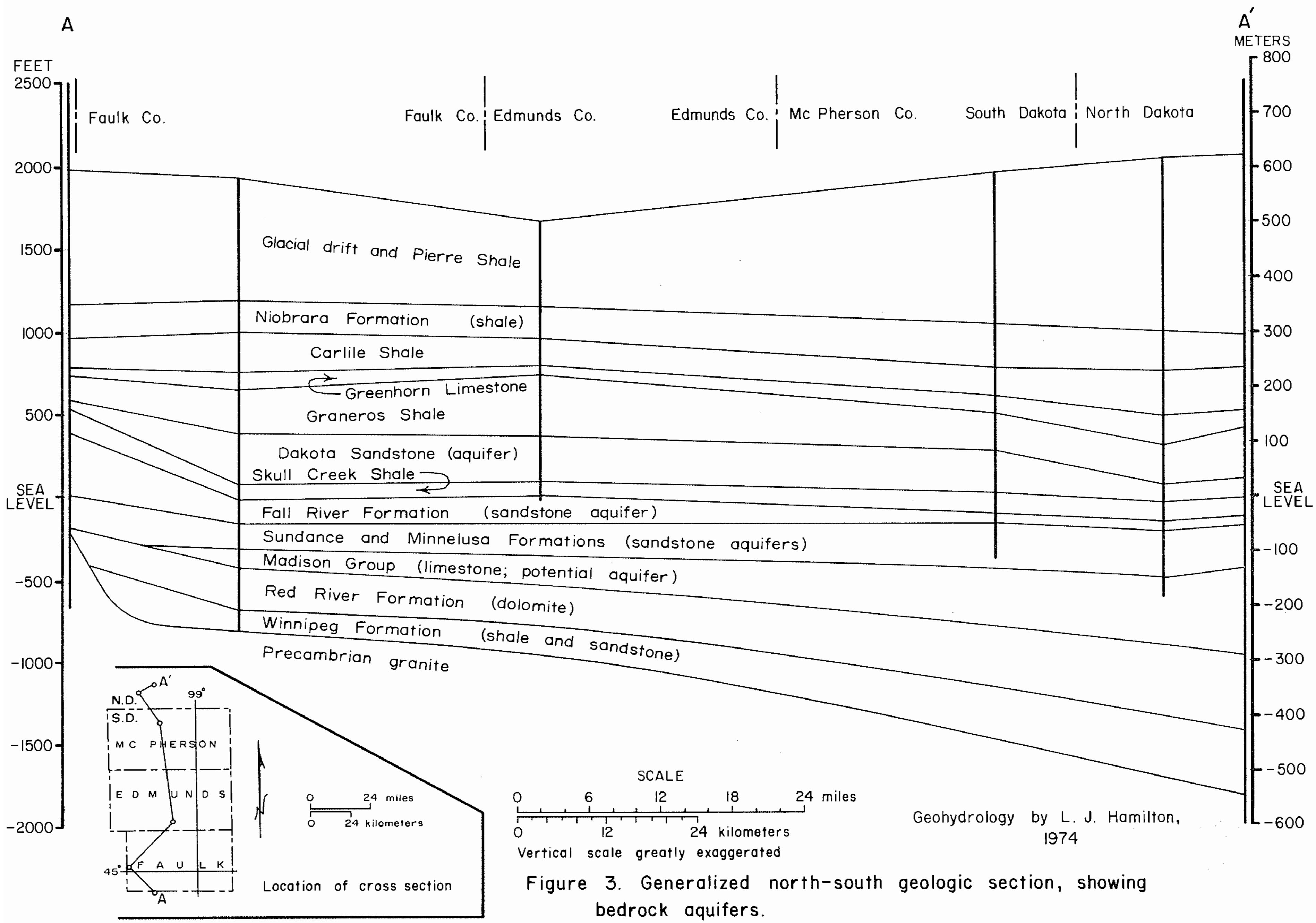

Figure 3. Generalized north-south geologic section, showing bedrock aquifers.

APPENDIX

Definition of Terms

Aquifer - A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. For this report, a major aquifer is one that can supply large-capacity wells.

Artesian water - Confined ground water under sufficient hydrostatic head to rise above the aquifer.

Dip - The downward inclination of a stratum with reference to a horizontal plane.

Electric log - An electrical recording, at the surface of a borehole, obtained by lowering electrodes in the hole and measuring various electrical properties of the geological formations traversed.

Glacial aquifer - A water-bearing formation composed of materials derived from 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 as follows:

	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

Large-capacity well - Defined by South Dakota Law as a well capable of yielding at least 18 gpm (gallons per minute).

Lithology - The description of rocks on the basis of such characteristics as color, structures, mineralogic composition, and grain size.

Outwash - A stratified deposit of sand and gravel that has been washed, sorted, and deposited by meltwater from a glacier.

Permeability - The capacity of a material to transmit a fluid under a potential gradient.

Properly-constructed well - One constructed to admit a maximum amount of water from an aquifer without excessive loss of head at the well. This generally requires installing a well screen or perforating the casing and installing a gravel pack 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.

Shut-in pressure - The hydrostatic pressure measured at the land surface when the flow of an artesian well is stopped.

Specific conductance - The measure of the ability of a water to conduct an electrical current, expressed in micromhos per centimeter is 25°C. 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. The following general relation is applicable:

Specific conductance, in micromhos per centimeter x 0.65 = dissolved solids, in milligrams per liter.

Till - An unsorted, unstratified mixture of clay, silt, sand, gravel, and boulders deposited by a glacier.

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.

Test Wells

It often is desirable to drill a test well in a glacial aquifer at a promising location before the construction of a permanent, large-capacity well. Drilling for the test well will provide samples for determining the grain sizes of the aquifer material and for selecting the proper well screen or type of perforated casing and gravel pack. Electric logs of the hole also are useful in locating the depths of the aquifers and the depths to set the well screen or perforated casing. Generally, a test well is pumped steadily for several days and the discharge rate is measured frequently.

Water levels in the pumped well and nearby observation wells are also measured frequently in order to determine the rate of drawdown, the possible effect on distant wells, and to detect the influence of hydrologic boundaries that may accelerate the rate of drawdown. The test also provides a representative sample of water for chemical-quality analyses.

Conversion of English to Metric Units

The English units used in this report may be converted to metric units by the following conversion factors:

From		Multiply by	To obtain	
Unit	Abbr.		Unit	Abbr.
Foot	(ft)	0.305	Meter	(m)
Gallon	(g)	3.785	Liter	(l)
Pound	(lb)	0.454	Kilogram	(kg)
Square inch	(in^2)	6.452	Square centimeter	(cm^2)
Mile	(mi)	1.609	Kilometer	(km)
Square mile	(mi^2)	2.590	Square kilometer	(km^2)

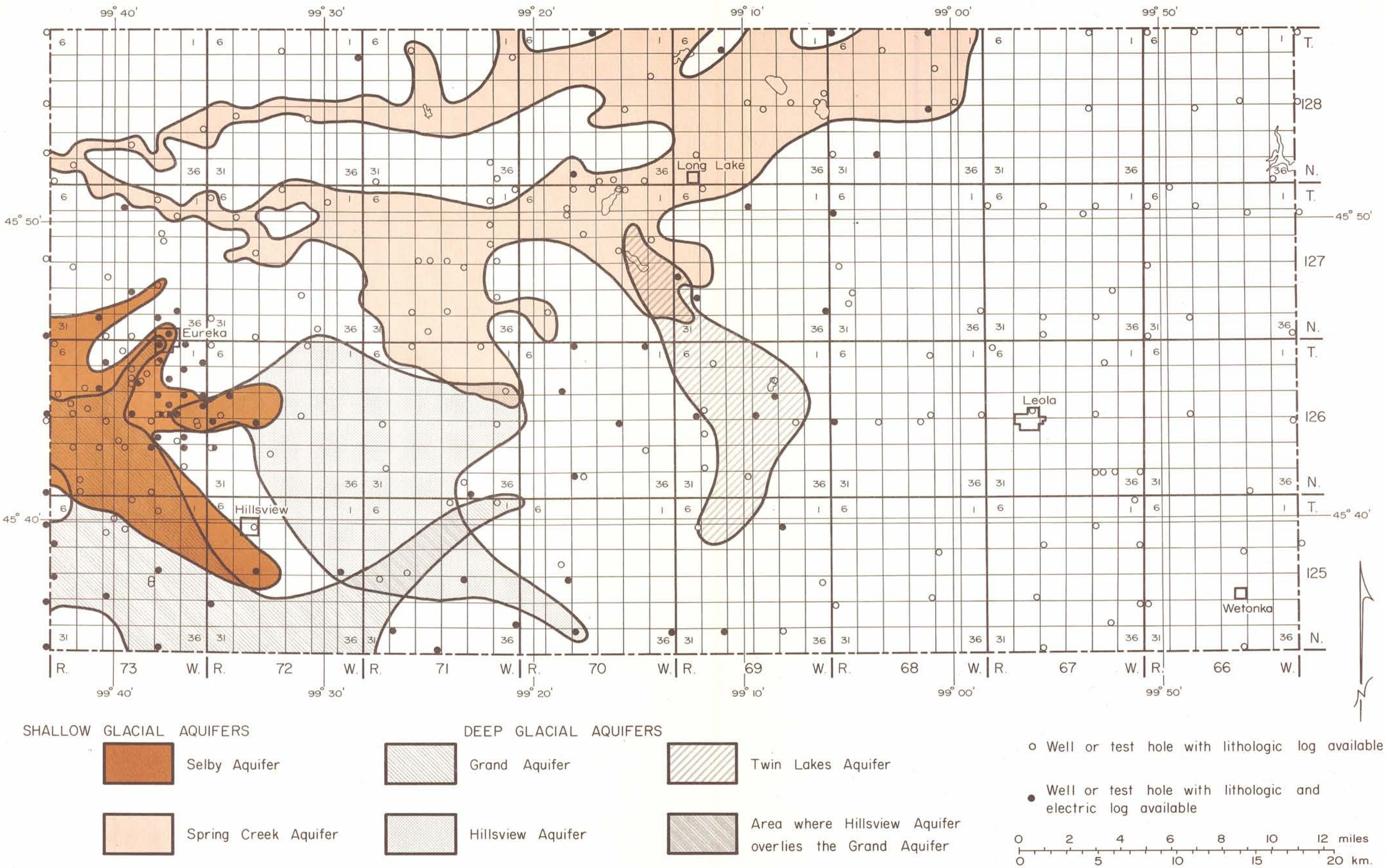

Plate I. Map of McPherson County showing glacial aquifers, test holes, and selected wells. by L. J. Hamilton, 1974

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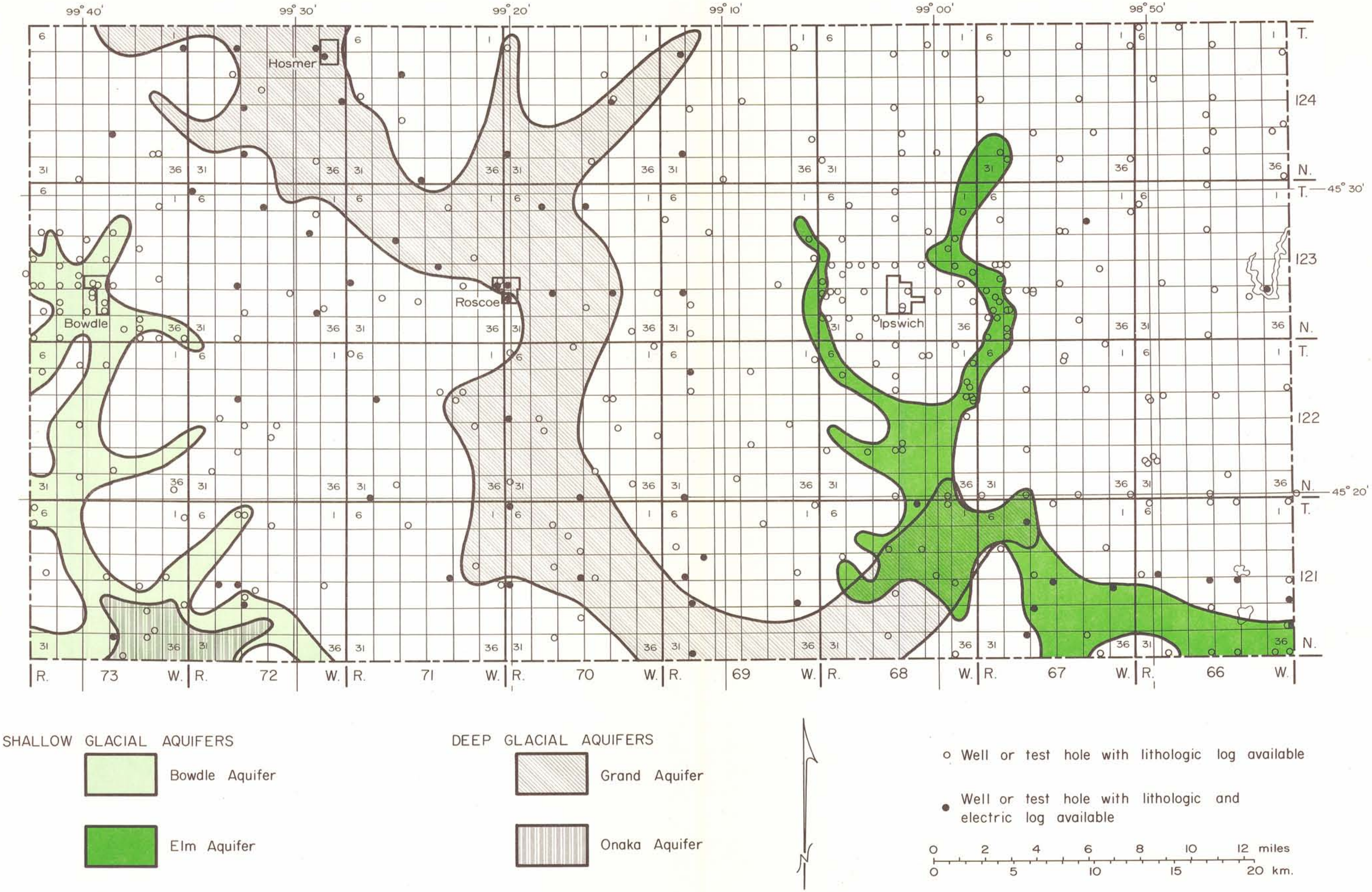

Plate 2. Map of Edmunds County showing glacial aquifers, test holes, and selected wells. by L. J. Hamilton, 1974

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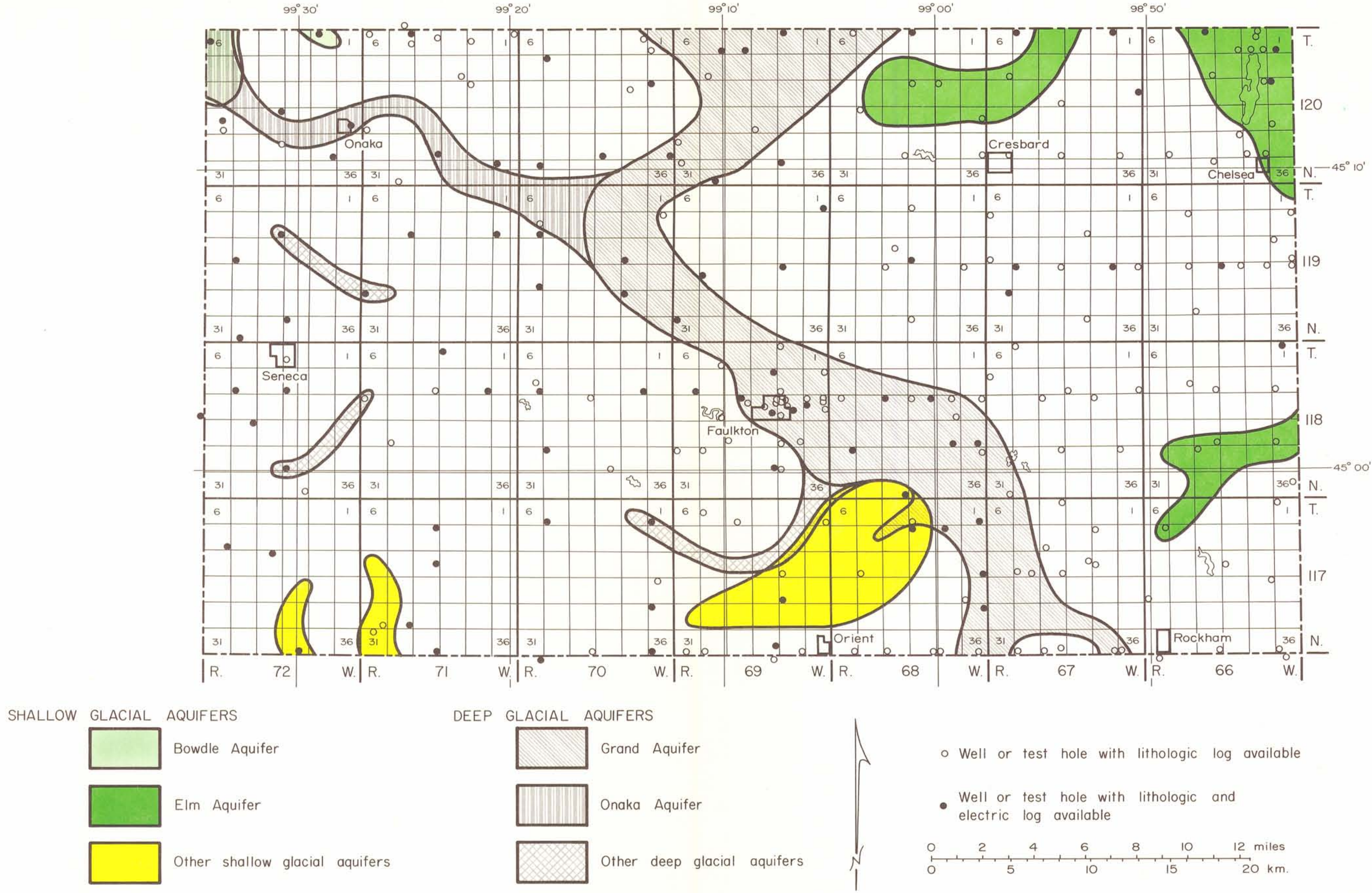

Plate 3. Map of Faulk County showing glacial aquifers, test holes, and selected wells.

by L. J. Hamilton, 1974

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