STATE OF SOUTH DAKOTA
Ralph Herseth, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 12

SHALLOW WATER SUPPLY FOR THE CITY OF SISSETON, SOUTH DAKOTA

by
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UNIVERSITY OF SOUTH DAKOTA
VERMILLION, SOUTH DAKOTA
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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota State Geological Survey during the Summers of 1959 and 1960 in and around the city of Sisseton, Roberts County, South Dakota (fig. 1), for the purpose of helping the city to locate future water supplies. The city now receives its water from two shallow wells about two miles east of town (City Wells No. 1 and 2, fig. 2), each of which produces about 200 gallons of water per minute. This well supply is supplemented by several springs, about three miles west of town on the east flank of the Coteau des Prairies (fig. 1). These springs collectively furnish about 50 gallons of water per minute.

During the summer of 1959, it became evident to the city that these two wells and the springs could no longer furnish an adequate supply of water, and assistance was requested from the State Geological Survey. Under a cooperative agreement with the U. S. Geological Survey office in Huron, a pump test was made of the city wells by engineers of that agency (table 1). On the basis of this test in the summer of 1959, it was recommended that another well be drilled in the same well field, and it was estimated that this well should produce about 200 gallons of water per minute. This new well (City Well No. 3, fig. 2) was drilled in the Spring of 1960, and the driller's pump test showed an estimated production of 200 gallons per minute, as predicted. This should alleviate the City's immediate problem, but will probably not add enough water to satisfy the City's future water needs. Consequently, the State Geological Survey was asked to help the city find additional water supplies in the Summer of 1960.

A survey of the shallow ground water possibilities was made in an area of 72 square miles around the city. This survey consisted of geologic mapping, the drilling of 31 test holes, a well inventory, and the taking of water samples for analysis.

The field work and preparation of this report were performed under the supervision of Dr. Allen F. Agnew, State Geologist, with the geologic assistance of Cleo Christensen, LaMonte Sorenson, Lynn Hedges, Jerry Schweigert, and Mark McDermott. The cooperation of the residents of Sisseton, especially Mayor Elvin Kromer and the City Water Council was greatly appreciated.

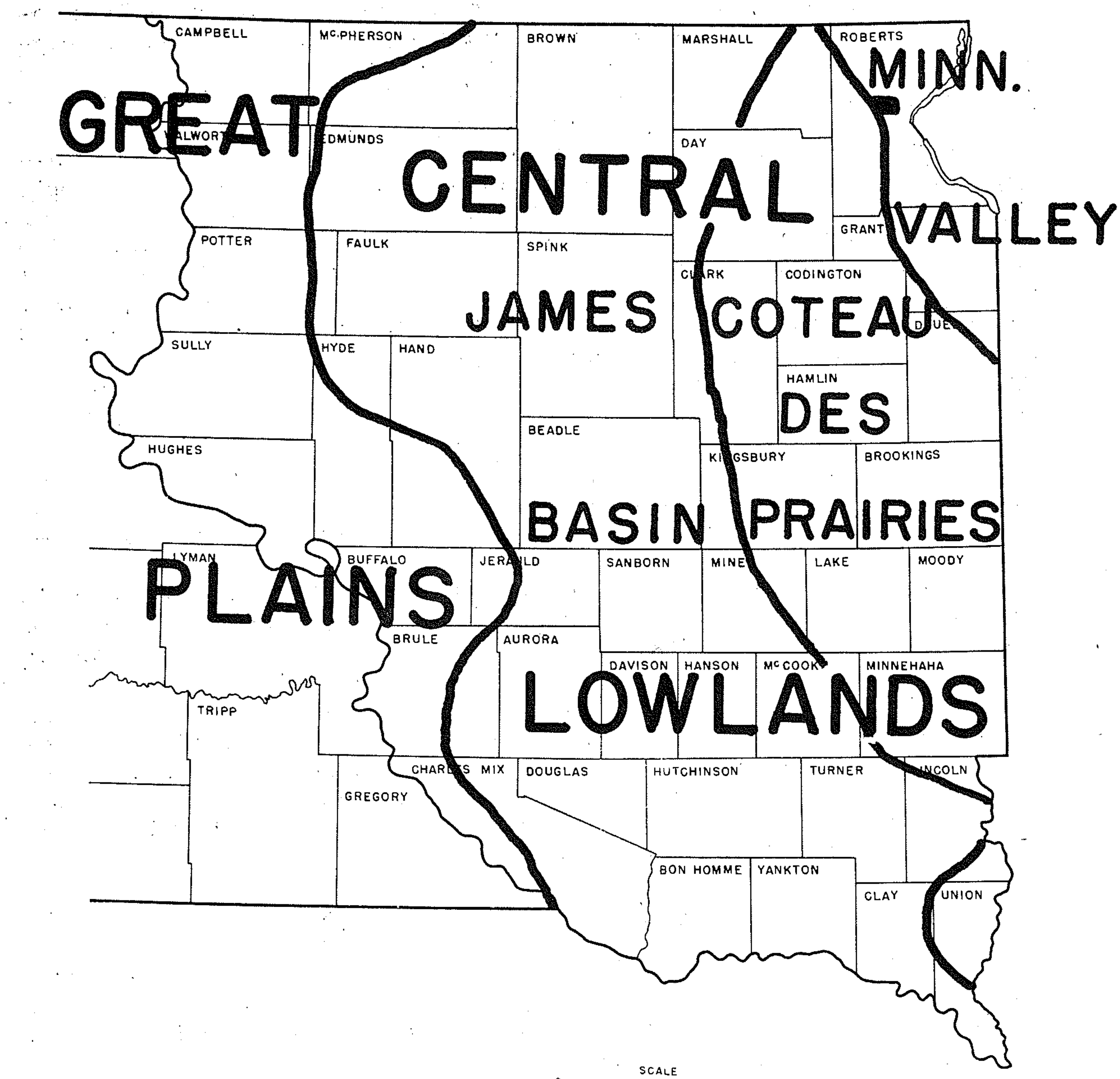
Location and Extent of Area

The city of Sisseton is located in Roberts County in northeastern South Dakota, and has a population of 3218 (1960 census). The area is in the Minnesota River Valley, just east of the Coteau des Prairies (fig. 1).

Climate

The climate is typically continental temperate, with large daily fluctuations in temperature. The average yearly temperature is 44.6° F and the average annual precipitation is 22.4 inches, at the U. S. Weather Bureau Station in Sisseton.

FIGURE I
MAJOR PHYSIOGRAPHIC DIVISIONS OF EASTERN SOUTH DAKOTA



■ SISSETON AREA

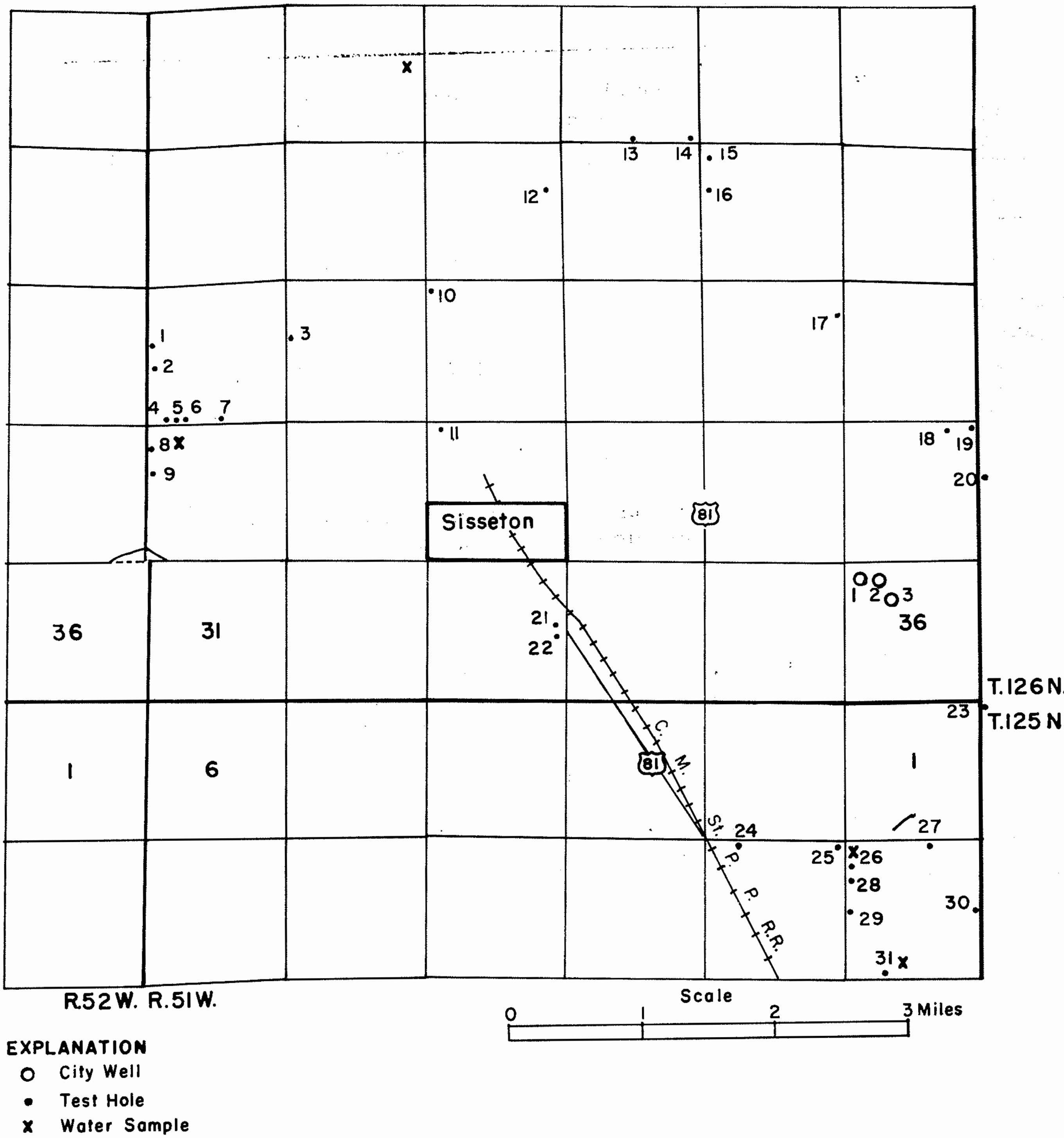


Figure 2. Data Map of Sisseton Area.

Table 1.--Pump Test Data for
the Sisseton City Wells

Well No.	r distance from pumping well (ft.)	Total drawdown (ft. below MP)	Drawdown time (minutes)	Recovery time (minutes)	Remarks
1	221.3	18.27	1079	179	Average
2	231.0	18.51	1079	179	pumping rate
East well 3	155.6	18.86	1079	174	290 gpm

PUMPING

Begin Discharge pump on 10:32 p.m. August 18, 1959
End Discharge pump off 4:32 p.m. August 19, 1959

RECOVERY

Begin 4:32 p.m. August 19, 1959
End 7:30 p.m. August 19, 1959 - Recovery to level at which pumping began

BEGAN FLOWING

	Well #1	8:16 p.m.	1.29' above water level at start of pumping
	Well #2	7:50 p.m.	0.55' " " " " " " "
(East well)	Well #3	8:15 p.m.	1.77' " " " " " " "

Topography and Drainage

The topography of the area is typically youthful glacial moraine--rolling hills and valleys with numerous knobs and kettles. The drainage in the area west of Sisseton is controlled by the steep eastern flank of the Coteau des Prairies, which rises 750 feet in a distance of about five miles. Consequently, all streams flow in a northeasterly direction, have narrow V-shaped cross-sections, steep gradients, and a minimum of meanders.

The streams to the east of Sisseton flow southeasterly across a relatively flat part of the Minnesota River Valley, and consequently have wider valleys and lesser gradients with a more meandering course to the southeast. The largest stream in the area is the Little Minnesota River, which flows southeasterly about three miles east of Sisseton.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Sisseton area are mostly the result of glaciation late in the Pleistocene Epoch. The glacial deposits are collectively called drift, and can be divided into till and outwash deposits. Till consists of clay and silt randomly mixed with boulders, pebbles, and sand, which were carried and deposited by the ice itself. Till usually does not yield water readily because of its unsorted nature. Outwash, on the other hand, normally yields water readily because it is usually better sorted, consisting mostly of pebbles and sand with minor amounts of silt and only a few cobbles and boulders. The outwash material was deposited by meltwater streams from the ice.

Alluvial material has been deposited on the glacial deposits locally by a few larger streams since the retreat of the glaciers. This alluvium consists of clay, silt, and minor amounts of sand and gravel; it does not normally yield water readily because of the large amount of fine material in these deposits.

Exposed Bedrock

A light-gray fissile shale with bands of iron concretions crops out in several places about two miles west of Sisseton (fig. 3). This shale is probably late Cretaceous in age, and may belong to the Pierre Formation. The shale does not yield water readily.

Subsurface Bedrock

Stratified sedimentary rocks of Cretaceous age lie beneath the surface deposits in the Sisseton area. The Pierre (?) Formation, which as mentioned above crops out just west of town, probably lies directly under the glacial deposits in the area studied. The Pierre is underlain in descending order by the following Cretaceous rocks: Niobrara, Carlile, Greenhorn, and Graneros Formations, and the Dakota Group.

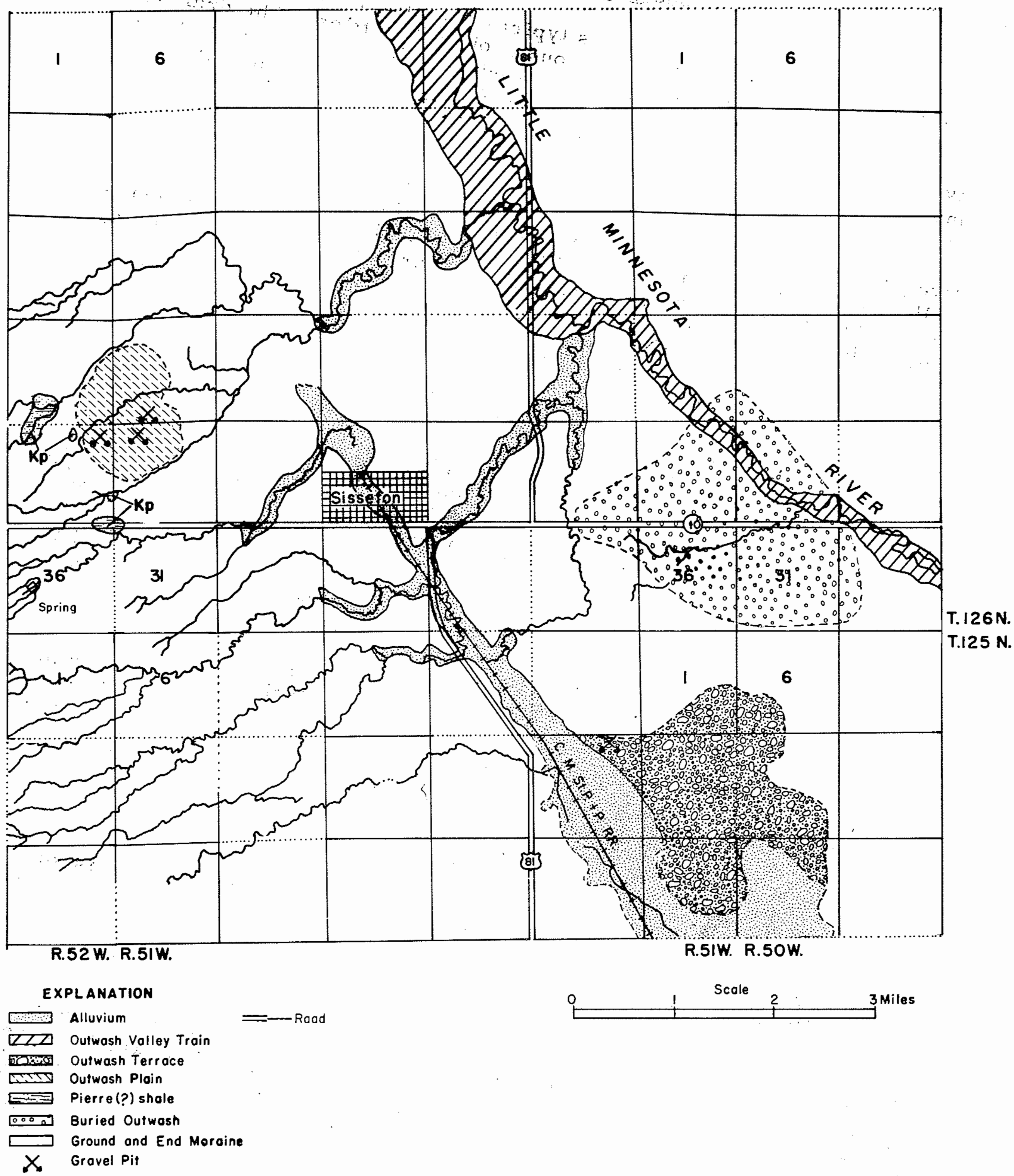


Figure 3. Generalized Geologic Map of Sisseton and Vicinity.

by

M. J. Tipton

1960

The Niobrara Formation consists of a light to medium blue-gray shale, part of which contains numerous microscopic white calcareous specks.

The Carlile Formation consists of medium- to dark-gray bentonitic shale with pyrite concretions, and layers of fine brown siltstone.

The Greenhorn Formation consists of a layer of hard cream to white limestone containing numerous fossil fragments. This limestone layer is overlain (and possibly underlain) by a layer of dark-gray shale containing numerous small white calcareous specks.

The Graneros Formation is hard, light- to dark-gray, siliceous shale. None of the above formations will yield water readily in this area.

The Dakota Group consists of a series of alternating sandstones and shales which yield water to numerous wells in this area (see Appendix B). These sandstones and shales are present between 700 and 900 feet below the surface in this area; their water is under artesian pressure, which causes wells at lower elevations to flow.

The sediments of the Dakota Group are probably underlain by the Milbank granite of Precambrian age, which crops out near Milbank, about 36 miles southeast of Sisseton.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Despite the common belief that ground water occurs in "veins" which criss-cross the country in a disconnected maze, it can be shown that water occurs almost everywhere in the ground, at depths below the surface which vary from a few feet to several tens of feet. The top of this zone of water saturation is known as the water table, and in the Sisseton area it is generally 10-80 feet below the surface except where the Pierre shale is at or near the surface; in these places the water table is usually much deeper.

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the ocean by streams, or percolates downward to the ground water table. In general, ground water moves laterally down the hydraulic gradient, and is said to be in transient storage.

Recharge is the addition of water to an aquifer (water-bearing material), and is accomplished in three ways: (1) downward percolation of precipitation from the ground surface, (2) downward percolation from surface bodies of water, and (3) lateral underflow of water in transient storage.

Discharge, or the removal of ground water from an aquifer, is accomplished in four main ways: (1) by evaporation and transpiration by plants, (2) by seepage upward or laterally into surface bodies of water such as springs, (3) by lateral underflow of water in transient storage, and (4) by pumping.

The volume of water capable of being stored in a saturated material is equal to the volume of voids or pore space of the material. A measurement of the capability of a material to store water is called porosity. Therefore porosity is the ratio of volume of voids in the material to the volume of the rock. The shape and arrangement of grains in a material affects the porosity greatly, but size of the grains has no effect. Therefore a container filled with sand and a similar one filled with gravel, if the sand and gravel have the same shape and packing, could hold the same quantity of water. Sands and gravels usually have porosities that range from 20 to 40 percent. Sandstones normally have porosities of 15-25 percent; the lower porosity is due to closer packing and the degree of cementation.

The rate at which water will drain or pass through a material is a function of the permeability of the substance. Water will pass through a material with interconnected pores, but will not pass through a material with unconnected pores even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms. As an example, till has high porosity but will yield little water because it has low permeability.

The ratio of the volume of water that will drain from a material by gravity, to the volume of the material, is called specific yield. Values for specific yields vary from zero for plastic clays to nearly the total value of the porosity for coarse sands and gravels.

Thus the type of deposit that contains the water governs the amount which can be withdrawn and, in part, how rapidly it can be recharged. For this reason, the object in trying to locate a good water supply is not to find a "vein" but rather, because water occurs almost everywhere, to find a sand or gravel deposit beneath the water table.

Ground Water in Alluvium

Alluvium is present above the valley train deposits along the Little Minnesota River (this alluvium is not shown on Figure 3, as the valley train deposits are more important). Alluvium is also present along some of the tributaries of the Little Minnesota River (fig. 3). The alluvium was deposited by Recent streams, and consists of clay and silt with minor amounts of sand and gravel. That part of the alluvium below the water table holds large quantities of water, but yields the water very slowly because of its low permeability.

Ground Water in Glacial Deposits

It was stated earlier that glacial deposits can be divided into till and outwash, and that outwash materials yield water more readily than till. Four outwash deposits occur in the vicinity of Sisseton: (1) an outwash plain covering a little more than a square mile, about 2 miles northwest of town; (2) an outwash terrace covering about 3 square miles, 4 miles southeast of town; (3) a buried outwash deposit from which the city wells are presently drawing their water supplies, about 2½-miles east of town; and (4) an outwash valley train covering about 4 square miles, along the present course of the Little Minnesota River (fig. 3).

1. The small outwash plain northwest of town covers a very small area and averages about 21 feet thick, of which only the lower 13 feet is water-saturated. The outwash materials range from very large boulders to fine sand and silt, and could probably supply water for small domestic wells but not enough for a municipal supply.

2. The outwash terrace southeast of Sisseton is composed largely of coarse sand with lenses of gravel and fine sand, and in places with thin clay layers. The deposit averages about 31 feet thick, of which only the lower 8 feet is water-saturated. The maximum thickness of water-saturated material occurs in the southern part of Section 12, T. 125 N., R. 51 W., where it consists of 28 feet of sand and gravel with a few clay layers (see test hole 31, Appendix A). These outwash terrace gravels supply abundant water for farm wells, but whether they could supply enough water for a municipal well will have to be determined by further test drilling and pump tests.

3. The buried outwash channel east of town, from which the city is getting its present supply of ground water, is covered by an average thickness of about 40 feet of glacial till. These outwash sediments average about 20 feet thick. They are completely saturated with water, which is under artesian pressure with the impervious till above acting as the confining stratum.

Unfortunately, this buried outwash could not be tested thoroughly as the State Geological Survey does not have drilling equipment which can hold back the artesian pressure of the water. However, several tests were made by the Grimshaw Drilling Company during the Spring of 1960, which resulted in the new city well (No. 3, fig. 2). These test holes plus two drilled by the State Geological Survey (test holes 19 and 23 in Appendix A), coupled with the well inventory, are the basis for the mapped areal extent (fig. 3) and thickness of the aquifer, but several more tests should be made with adequate drilling equipment before the exact extent of this aquifer is known. From the present incomplete information, it is believed that the buried outwash covers at least four square miles (fig. 3). Because of the large amount of water that is pumped from it by the city wells, and for other geologic reasons, its extent is probably much larger.

The pump test of the Sisseton well field was run on August 18 and 19, 1959 and the procedure was as follows:

> Both of the city wells were shut down at 8:00 p.m. on August 18. Water levels were allowed to recover until 10:32 p.m. that night, at which time the pump in the west well was started. The pump discharged to an open sewer at an initial rate of 353 gpm (gallons per minute). However, after 25 minutes the discharge declined to 343 gpm. The pumping rate was then reduced to 290 gpm by partially closing a gate valve on the discharge line. This was done in order to sustain a constant pumping rate for the duration of the test. Pumping then continued at 290 gpm until 4:32 p.m. on August 19.
>
> During the course of the test, drawdown and recovery rates were observed in three observation wells; it was not possible to gain access to the water level in the pumped well.
>
> After the west well had been pumping for several hours, the water was sampled and the temperature was measured at a tap in the discharge line 4 feet west of the wellhead. The temperature of the water was 47.5°F.

On the basis of the test, it appears that the aquifer is strong; however, it is recommended that additional test drilling be done so that the boundaries of the aquifer can be delineated. When this has been done, another pump test should be run to evaluate further the hydrologic properties of the aquifer.

4. The outwash valley train which occurs along the present course of the Little Minnesota River contains deposits that range from fine sand to coarse gravel. The valley train ranges up to 30 feet thick and averages about 25 feet. The average thickness of water-saturated material is 16 feet, with a maximum of 19 feet. The thickest deposits and those containing the thickest water-saturated sand and gravel occur in the northern part of the area, where the valley train is widest (fig. 3).

Ground Water in Bedrock

The sandstones of the Dakota Group are the only known bedrock in the Sisseton area, from which water is produced. As stated earlier, these sandstones occur between 700 and 900 feet below the surface, and their waters are under artesian pressure. The sandstones, if consistent with those in other parts of the State, consist of predominantly quartz sand that has moderate permeability and porosity. The sandstones can yield a moderate supply of water as shown by numerous farm wells in this vicinity (see Appendix B). Some of these farm wells flow as much as 40 gallons of water per minute, whereas others have to be pumped, depending on the surface elevation of the well.

The recharge for these subsurface sandstones probably comes from the Black Hills or the Rocky Mountains, where they are exposed at much higher elevations than in the Sisseton area; this provides the pressure head necessary for the water to rise nearly to the surface, and locally to flow in this area. The overlying Cretaceous shales constitute the impervious layer that confines the water to the sandstones.

Quality of Ground Water

Precipitated water is nearly pure before it reaches the ground. However, all ground water contains minerals which are obtained (1) from the atmosphere as the water vapor condenses and falls, (2) from soil and underlying deposits as the water percolates downward to the water table, and (3) from deposits below the water table, in which the water is circulating.

In general, it can be said the more minerals a water contains, the poorer its quality. The water in the Dakota sandstones is poorer in quality than the water in the surficial glacial deposits.

In Table 2, samples B and D show that the water from City Well No. 1 and the city springs is worse than the Public Health drinking water for magnesium, sulfate, and total solids. Also, the water from both city wells is higher than the standards for iron and manganese.

Samples E and G, from the Lotzer and Musseter farms, are acceptable in quality according to the Public Health drinking water standards.

Sample F, from the Canfield farm, is high in magnesium and is also high in nitrate. A high concentration of nitrate could be harmful to both animals and humans.

Table 2.--Chemical Analyses of Water Samples in the Sisseton Area*

Sample	Parts Per Million										Hard-ness $CaCO_3$	Total Solids
	Ca	Na	Mg	Cl	SO_4	Fe	Mn	N	F	p^H		
A	--	--	50 **	250 **	250 **	0.3 **	0.1 **	10 **	1.0 **	--	---	500 to 1000 **
B	160	37	57	5	354	2.4	0.4	0.0	0.2	7.4	639	945
C	133	36	47	5	233	1.8	0.4	0.0	0.2	7.4	528	750
D	187	35	64	4	497	0.2	0.0	1.5	0.4	7.6	728	1079
E	83	21	35	3	158	Tr.	0.0	2.5	0.2	--	352	508
F	77	25	73	0	238	0.7	0.0	12.0	0.0	--	491	804
G	95	25	32	11	193	0.0	0.0	5.2	0.0	--	370	562
H	199	76	75	9	774	0.0	0.0	0.0	0.0	--	805	1454

A. U. S. Dept. of Public Health Drinking Water Standards (1960)
B. City Well No. 1
C. City Well No. 2
D. City Springs
E. Bernard Lotzer farm, NW1/4 sec. 12, T. 125 N., R. 51 W.
F. Robert Canfield farm, SE1/4 sec. 12, T. 125 N., R. 51 W.
G. Lein Musseter farm, NW1/4 sec. 30, T. 126 N., R. 51 W.
H. Lloyd Stapelton farm, NE1/4 sec. 8, T. 126 N., R. 51 W.

* Samples B, C, and D analyzed by the State Department of Health in Pierre, 1960; other samples analyzed by State Chemical Laboratory in Vermillion, 1960

** not to exceed

Sample H, from the Stapelton farm, is high in magnesium and total solids and is very high in sulfate content.

It should be noted that no wells have been drilled into the valley train deposits along the Little Minnesota River, so no samples of this water could be collected for analysis.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the city of Sisseton test for future water supplies in the valley train outwash deposits along the Little Minnesota River about two miles northeast of town, in the southwestern part of Section 14 and the eastern part of Section 15, T. 126 N., R. 51 W. Test holes in this area show as much as 19 feet of water-saturated sand and gravel (see test holes 15 and 16, Appendix A). It should be noted that this is not as thick as is desirable for a city well; however, it is the thickest clay-free, shallow, water-bearing deposit found in the area. It should also be noted that the quality of the water is at this time unknown, as no wells are pumping from this deposit.

The city should also test the outwash terrace deposits about four miles southeast of town in the southern part of Section 12, T. 125 N., R. 51 W. Test holes in this area penetrated as much as 28 feet of water-saturated sand and gravel with only a few clay layers (see drill hole 31, Appendix A). This area may provide enough water to support a city supply. The quality of the water in this area is shown by samples E and F (table 2).

It may be practicable for the city to drill another well in the buried outwash deposit two miles east of town, where the city wells are pumping at the present time. This cannot be determined until the new well has been put into operation, and by additional pump tests there. The quality of the water in this area is shown by samples B and C.

After favorable test holes have been drilled in any of the above recommended areas, but before new city wells are drilled and pipe lines are laid, it is of the greatest importance that the resulting test wells and pump tests be supervised by qualified engineers, because of the thinness of the water-bearing deposits.

A municipal supply could possibly be obtained from the artesian Dakota sandstones, but the water would have to be pumped and probably would not provide a very large supply. Also, the water is of poor quality.

It is suggested that the city contract with a commercial drilling company licensed by the State of South Dakota to test-drill the areas recommended. The city officials should consult the State Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and the State Department of Health with regard to the biological and chemical suitability of the water. A consulting engineering firm licensed in South Dakota should be hired to run pump tests and to design the water system.

REFERENCES CITED

Hopkins, O. C., and Gullens, Oscar, 1960, New U. S. Public Health Service Standards: Jour. Amer. Water Works Assoc., v. 52, no. 9, p. 1161-8, Sept.

APPENDIX A

Logs of Test Holes in the Sisseton Area

(for location see Figure 2)

Test Hole No. 1
Elevation: 1336 feet
Depth to water: 6 feet

0- 4	sand, coarse to coarse gravel; damp at 3 feet
4- 8	same; water-saturated at 6 feet
8-12	gravel, fine to medium with some clay
12-16	sand, fine to medium; much water
16-20	clay, blue; water changed to dark brown color
20-24	alternating blue clay and sand
24-29	solid blue clay

* * * * * * * *

Test Hole No. 2
Elevation: not measured
Depth to water: none

0- 4	clay, gray
4- 6	clay, brown
6-10	clay, gray
10-14	clay, darker gray
14-19	clay, lighter gray
19-20	clay, brownish-gray
20-22	clay, black, may be shale

* * * * * * * *

Test Hole No. 3
Elevation: not measured
Depth to water: none

0- 1	topsoil
1-12	clay, sandy, dry, brown
12-21	clay, brown

* * * * * * * *

Test Hole No. 4
Elevation: 1357 feet
Depth to water: 13 feet

0- 2	topsoil, black, sandy
2- 8	gravel, coarse and sand
8-10	gravel, fine
10-11	gravel, very coarse

Test Hole No. 4 --continued

11-12	same; wet
12-16	sand, coarse to fine gravel; water
16-26	sand, coarse to medium with some brown clay
26-32	clay, blue

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Test Hole No. 5
Elevation: 1357 feet
Depth to water: none

0- 2	sand, medium
2- 9	gravel, coarse

Hole abandoned at 9 feet, could not penetrate gravel

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Test Hole No. 6
Elevation: 1357 feet
Depth to water: none

0- 1	topsoil
1- 2	sand
2- 4	gravel, coarse

Hole abandoned at 4 feet, could not penetrate gravel

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Test Hole No. 7
Elevation: not measured
Depth to water: none

0- 2	topsoil, brown
2-17½	clay, brown
17½-21½	clay, blue

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Test Hole No. 8
Elevation: not measured
Depth to water: none

0- 4	gravel, very coarse
4- 4½	boulder

Hole abandoned, could not penetrate boulder

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Test Hole No. 9
Elevation: not measured
Depth to water: none

0-10	clay, medium to light brown
10-19	clay, black, damp

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Test Hole No. 10
Elevation: not measured
Depth to water: none

0- 2	clay, brown, sandy
2- 4	sand, fine
4-12	clay, brown
12-16	clay, blue

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Test Hole No. 11
Elevation: not measured
Depth to water: 18 feet

0- 1	topsoil
1- 6	clay, black, damp
6-22	clay, brown
22-28	clay, blue

* * * * * * * *

Test Hole No. 12
Elevation: not measured
Depth to water: none

0- 1	topsoil, black
1- 4	clay, gray, dry
4- 5½	gravel, fine to coarse
5½- 9½	clay, brown, with sand and gravel
9½-14	clay, blue

* * * * * * * *

Test Hole No. 13
Elevation: 1153 feet
Depth to water: 9 feet

0- 4	clay, gray, dry
4- 9	clay, brown, moist with sand and gravel
9-24	sand, coarse and fine gravel, with water
24-29	clay, blue (?)
29-39	clay, blue

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Test Hole No. 14
Elevation: 1146 feet
Depth to water: 6½ feet

0- 4	soil, black
4- 9	soil, brownish-gray, sandy
9-14	sand, coarse; small amount of gravel and clay
14-24	sand, coarse, bluish-gray
24-34	clay, blue

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Test Hole No. 15
Elevation: 1145 feet
Depth to water: 8 feet

0- 4	sand, coarse and gravel; bluish-gray clay
4- 9	till, damp
9-15	sand, medium, wet
15-25	sand, medium to coarse, wet, with some fine gravel
25-26	clay, blue
26-34	sand, coarse, blue to bluish-gray
34-39	clay, blue

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Test Hole No. 16
Elevation: 1145 feet
Depth to water: 9 feet

0- 6	topsoil, black, sandy and mud
6- 9	sand, coarse and fine gravel
9-14	sand, black, muddy with some fine gravel; water
14-18	mud, black and coarse sand
18-28	sand, coarse
28-30	clay, blue (?)
30-38	clay, blue

* * * * * * * *

Test Hole No. 17
Elevation: not measured
Depth to water: 14 feet

0- 3	topsoil
3- 4	clay, brown
4-13	gravel, coarse, moist, sand and clay
13-30	sand, coarse and gravel with some clay
30-34	clay, blue

* * * * * * * *

Test Hole No. 18
Elevation: not measured
Depth to water: 4 feet

0- 2	topsoil, black
2-19	sand, coarse, damp and medium gravel
19-24	clay, blue

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Test Hole No. 19
Elevation: 1120 feet
Depth to water: 22 feet (struck water at 38 feet and it rose to 22 feet because of an artesian head)

0- 8	clay, brown, dry
8-16	clay, brown, dry, sandy
16-20	clay, blue
20-39	clay, gray blue
39-64	sand and blue clay
64-69	clay, blue, hard

* * * * * * * *

Test Hole No. 20
Elevation: 1118 feet
Depth to water: 10 feet

0- 6	sand, fine to coarse, damp at 4 feet
6-19	sand and gravel
19-24	alternating hard and soft layers, no sample
24-34	gravel, fine and clay
34-39	clay, blue

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Test Hole No. 21
Elevation: not measured
Depth to water: 11 feet

0- 1/2	topsoil and gravel
1/2-16	clay, light to medium, brown, with some sand

* * * * * * * *

Test Hole No. 22
Elevation: not measured
Depth to water: 11 feet

0-12	clay, brown; trace of sand
12-13	hard zone
13-16	clay, brown as above
16-20	clay, blue with thin sand layers

* * * * * * * *

Test Hole No. 23
Elevation: 1211 feet
Depth to water: not measured, twisted off augers

0- 4	topsoil, brown
4- 8	clay, brown with some medium sand
8-20	till, brown
20-32	clay, grayish-blue
32-84	clay, blue

* * * * * * * *

Test Hole No. 24
Elevation: 1204 feet
Depth to water: 14 feet

0- 4	clay, gray, wet at 2½ feet
4-16	clay, brown
16-20	clay, blue-black
20-25	clay, brown

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Test Hole No. 25
Elevation: 1214 feet
Depth to water: 30 (?) feet

0- 4	sand, medium
4-30	gravel, medium to coarse
30-51	clay, blue with some sand and gravel imbedded

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Test Hole No. 26
Elevation: not measured
Depth to water: none

0- 7	gravel, medium to coarse
7- 8	clay, moist
8-18	sand, fine to medium, damp, with some clay
18-22	gravel, very moist
	Boulder (hole abandoned)

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Test Hole No. 27
Elevation: 1220 feet
Depth to water: 48 feet

0- 1	topsoil
1-24	sand, fine with trace of clay
24-28	sand, coarse and fine gravel
28-52	clay, damp with some sand
52-57	clay, dark brown
57-62	clay, blue-gray

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Test Hole No. 28
Elevation: 1209 feet
Depth to water: 26 feet

0- 4	gravel, medium to coarse
4-18	sand, medium to coarse
18-20	gravel, coarse
20-25	gravel, medium to coarse
25-40	sand, medium with some clay
40-50	alternating sand and clay beds
50-55	clay, blue

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Test Hole No. 29
Elevation: 1208 feet
Depth to water: none

0- 2	topsoil
2- 4	sand, coarse and fine gravel
4- 6	sand, fine with some clay
6- 9	gravel, medium
9-20	sand, fine with some clay
20-25	clay, blue

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Test Hole No. 30
Elevation: 1193 feet
Depth to water: 7 feet

0- ½	clay, black
½- 4	clay, brown
4- 8	clay, reddish with fine sand
8-37½	sand, fine and blue clay
37½-42	clay, blue

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Test Hole No. 31
Elevation: 1204 feet
Depth to water: 22 feet

0- 4	topsoil, sandy
4- 8	gravel, reddish, medium
8-17	sand, coarse, gray to fine gravel
17-24	sand, fine with some brown clay
24-50	sand, light brown and clay
50-57	clay, blue with some sand layers

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APPENDIX B

Records of Wells

Well Location: Letters stand for quarter section, first numbers for section, second for township north, third for range west.
Type of Well: Du, dug; D, drilled; Sp, spring
Water-bearing material: o, outwash; al, alluvium; sl, sand lense; ss, sandstone

Well Location	Owner or Tenant	Type of Well	Depth of bottom of well below surface (feet)	Diameter of well (inches)	Water-bearing material	Depth to Water (feet)
NW-30-126-50	B. Hanson	D	79	3	o	40
SE-31-126-50	L. Lotzer	D	800	4	ss	--
NW-31-126-50	L. Moshier	D	800	4	ss	flows
SE-31-126-50	C. Lotzer	Du	39	24	--	17
SW-32-126-50	R. Benson	Du	48	24	o	28
NE-8-126-51	A. Stapelton	D	700-800	4	ss	--
SE-8-126-51	J. Stapelton	D	700-800	4	ss	--
NE-8-126-51	L. Stapelton	D	60	24	o	flows
SW-9-126-51	F. McCleary	D	858	4	ss	36
SW-10-126-51	D. Gravdahl	D	700	2	ss	flows
SW-11-126-51	E. Rinas	D	701	4	ss	flows
NE-14-126-51	H. Heinecke	D	600-700	2	ss	flows
NW-15-126-51	L. Pickthorne	D	45	5	sl	9
NE-16-126-51	L. Tchida	D	200	4	o	flows
16-126-51	W. Rinas	D	811	4	ss	flows
NE-16-126-51	T. Gunderson	Du	21	36	o	--
NE-17-126-51	C. Simon	--	--	24	--	flows

Appendix B--Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well be-low land-surface (feet)	Diameter of well (inches)	Water-bearing material	Depth to Water (feet)
NW-17-126-51	W. Wooley	D	--	4	ss	flows
SW-18-126-51	D. Grimsrud	Du	--	36	al	10
NE-18-126-51	R. Arbach	D	700-800	4	ss	flows
SW-18-126-51	D. Grimsrud	D	800	4	ss	flows
SE-19-126-51	K. Roth	D	700-800	4	ss	flows
SW-22-126-51	R. Arbuckle	D	--	2	ss	flows
SE-22-126-51	Bjelland	Du	24	48	al	12
SW-22-126-51	J. Ernster	D	760	2	ss	--
SE-23-126-51	D. Hanson	D	800	4	ss	flows
SW-23-126-51	J. Cloud	Du	16	36	al	10
SW-25-126-51	A. Finnesand	D	60	6	sl	--
SE-26-126-51	J. Larson	D	--	2	ss	flows
NE-26-126-51	C. Week	D	--	-	ss	flows
SW-26-126-51	M. Martinson	D	800-900	3	ss	flows
NE-27-126-51	Stavig Bros.	D	--	4	ss	flows
NW-30-126-51	L. Musseter	Du	10	36	al	9
NE-30-126-51	O. Torvick	D	870	4	ss	flows
SW-32-126-51	J. Sanders	D	800	2	ss	1
SW-33-126-51	Tekakawitha Orphanage	D	700-800	4	ss	flows
NW-35-126-51	A. Jensen	Du	30	24	al	10
SE-31-126-51	W. Winters	Du	12	36	al	3

Appendix B--Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well below land surface (feet)	Diameter of well (inches)	Water-bearing material	Depth to Water (feet)
13-126-52	L. Ringsaker	D	--	2	--	--
NE-24-126-52	J. Roth	Du	30	24	al	10
SE-25-126-52	H. Musseter	D	900	2	ss	45
NE-25-126-52	G. Bendickson	Du	41	24	sl	35
SE-35-126-52	C. Meland	Sp	--	1	sl	flows
NE-6-125-50	G. Benson	D	800	2	ss	flows
NW-1-125-51	H. Nelson	Du	--	24	sl	--
NW-6-125-51	N. Himle	D	30	24	sl	15
C-8-125-51	E. Janisch	Du	--	48	al	16
SW-9-125-51	R. Schmidt	D	850	3	ss	75
SE-9-125-51	St. John	D	--	--	ss	--
NW-11-125-51	H. Carlson	Du	25	36	al	15
SW-11-125-51	E. Monsen	Du	14	2	al	6
NW-12-125-51	B. Lotzer	Du	32	36	o	24
SE-12-125-51	R. Canfield	Du	22	48	o	15
C-15-125-51	M. Hawk	Du	16	120	al	4
NW-15-125-51	I. Crooks	D	--	4	ss	flows
NE-1-125-52	C. Okeson	Du	7	36	al	0