

STATE OF SOUTH DAKOTA
Nils Boe, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 45

GROUND-WATER INVESTIGATION FOR THE CITY OF
BROOKINGS, SOUTH DAKOTA

by
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Science Center
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Vermillion, South Dakota
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INTRODUCTION

Present Investigation

This report contains the results of a special water investigation by the South Dakota Geological Survey from July 26 to August 23 and from September 5 to September 7, 1967, in the vicinity of the city of Brookings, Brookings County, South Dakota (fig. 1).

Brookings now obtains its water from 7 wells which are located in the valley of Six Mile Creek on the north edge of the city. A treatment plant at the well field has a maximum treatment capacity of 4,000,000 gallons per day. The safe operating capacity of the plant is approximately 3,000,000 gallons per day, which is the quantity of water used during peak consumption.

The water investigation includes (1) a review of the geology of the area as mapped by the South Dakota Geological Survey (Lee, 1958a, b, c, and 1960a, b), (2) the drilling of 101 auger test holes and 3 rotary test holes, (3) a well inventory, and (4) collecting and analyzing 36 water samples.

The results of the water investigation show three areas, area A, area B, and area C (fig. 2), which might be considered for an additional city water supply. Priority rating of the areas is based on both potential quality and quantity of water.

All field work was performed under the supervision of Merlin J. Tipton, Assistant State Geologist, and Lynn S. Hedges, Associate Geologist. Preparation of the report was performed under the supervision of Lynn S. Hedges. Analyses of water samples was done by the State Geological Survey's water quality laboratory and the State Chemical Laboratory.

Cooperation of local city officials, Mayor Forrest Frie, City Engineer Lloyd Darnall, Superintendent of Utilities Elmer K. Thon, and City Commissioner William Gamble, was greatly appreciated. The help of Vern W. Butler, Manager-Engineer of the East Dakota Conservancy Sub-District is acknowledged. Special thanks are due Don Rust, local well driller, for making his well records available.

Topography and Drainage

Topography of the Brookings area ranges from a gently sloping surface of glacial outwash east and west of the area (fig. 3) to undulating morainic topography around Brookings and to the north where till is at the surface.

All streams in the area form an integrated drainage system that drains into the Big Sioux River.

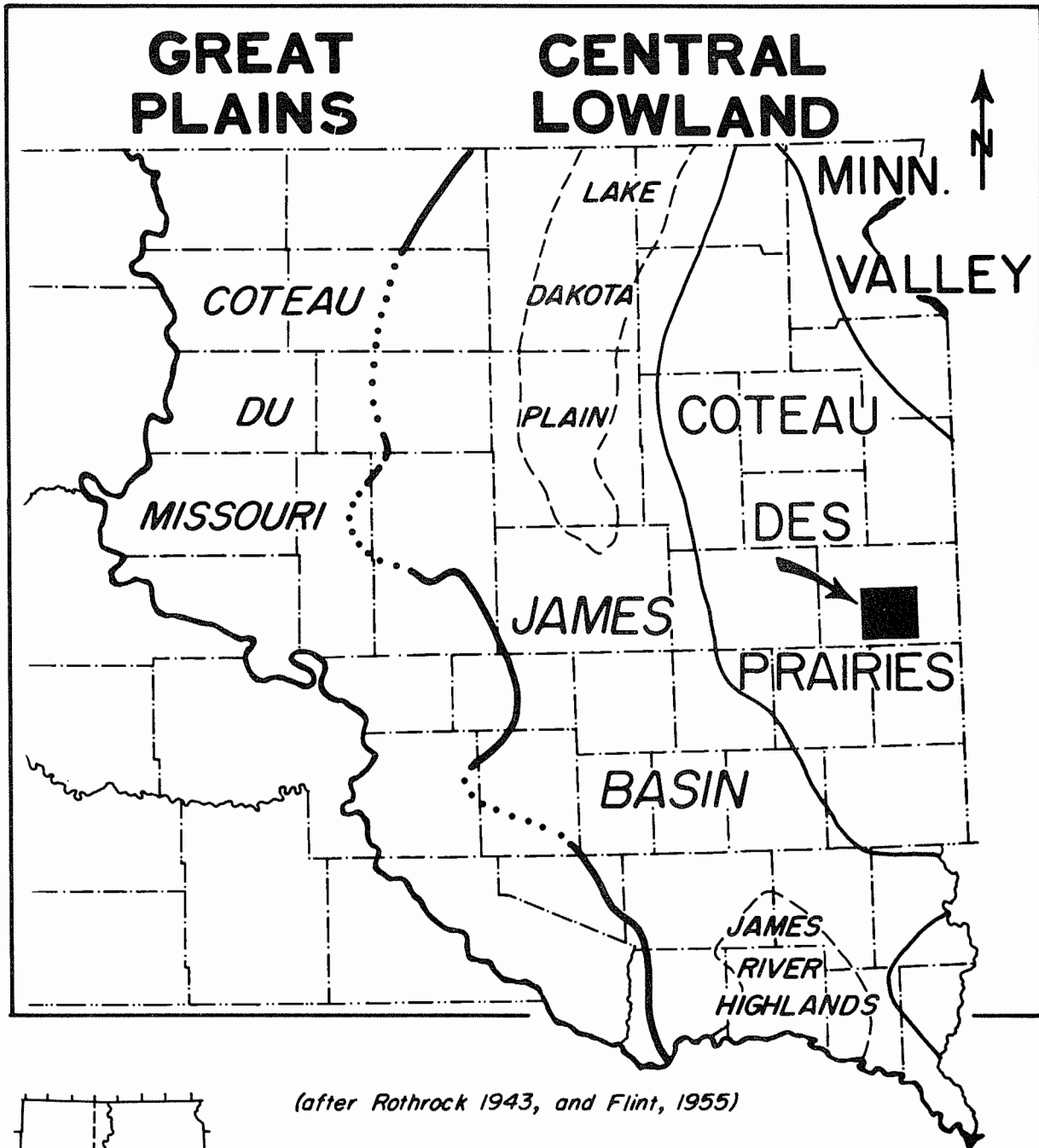
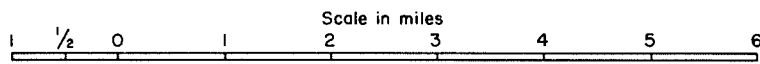
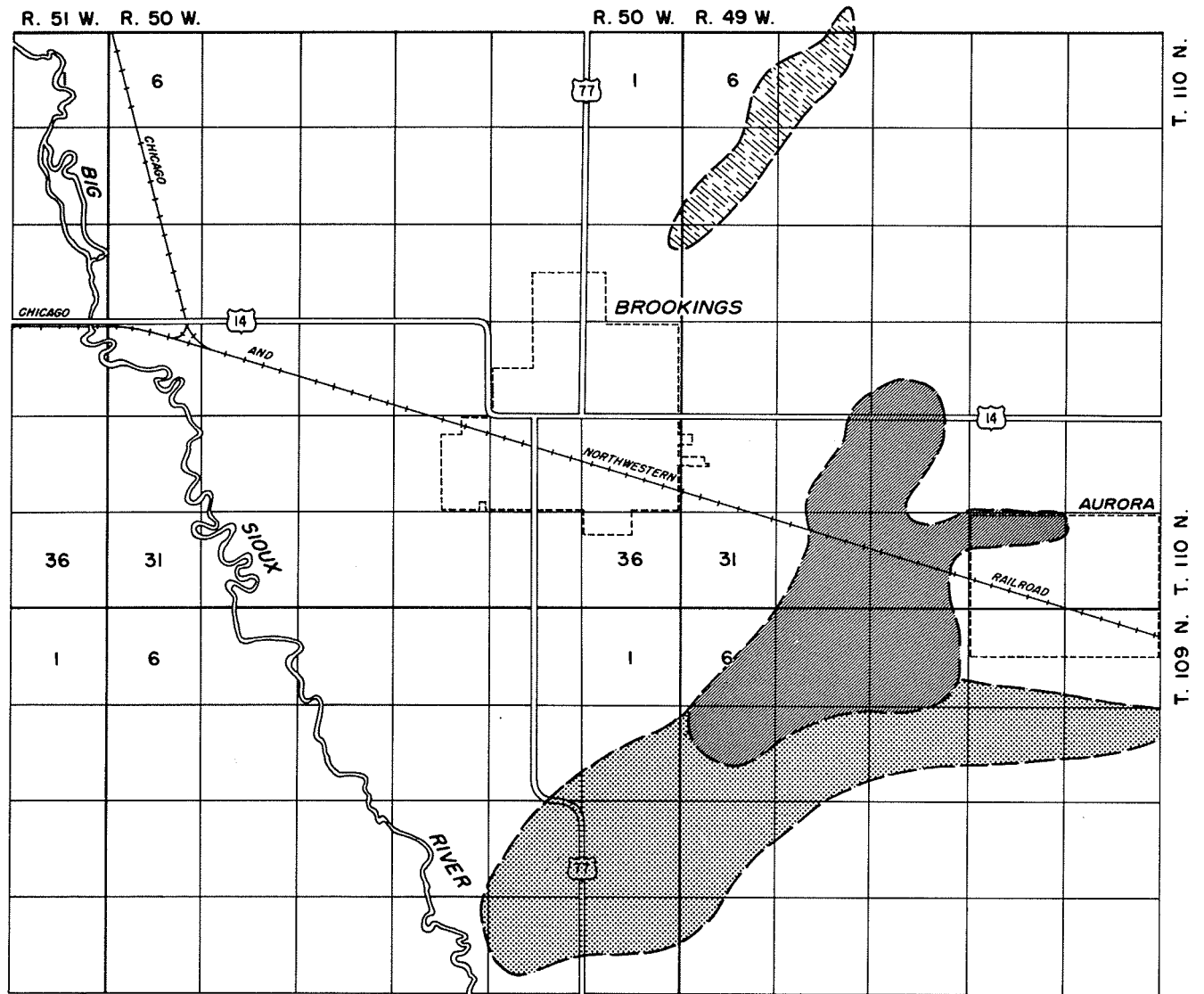


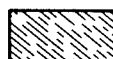


Figure 1. Map of eastern South Dakota showing the major physiographic divisions and location of the Brookings area.



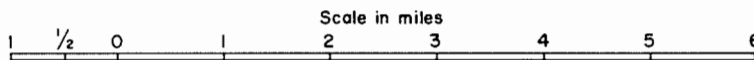
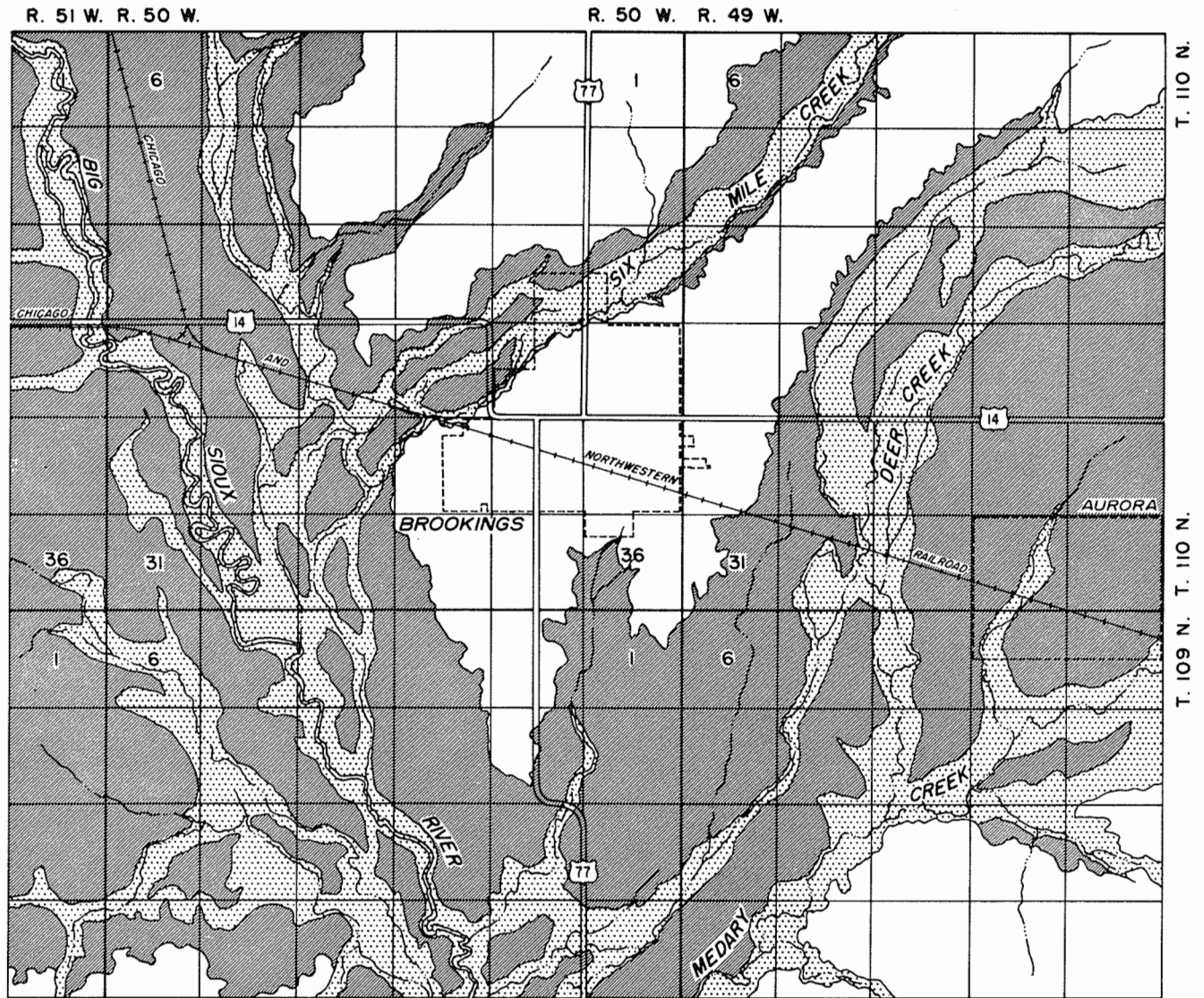
EXPLANATION

-  Recommended area A
-  Recommended area B
-  Recommended area C

by Assad Barari, 1967
 drafted by D. W. Johnson



Figure 2. Map showing location of recommended areas for additional water supplies at Brookings.



EXPLANATION

QUATERNARY	RECENT		Alluvium
	PLEISTOCENE		Outwash
			Till

by Assad Barari, 1967
 drafted by D. W. Johnson



Figure 3. Generalized geology map of the Brookings area.
 (Modified from K. Y. Lee, 1958 a and b - 1960 a and b.)

Local relief in the area is about 148 feet with land elevations ranging from 1,574 feet 5 miles south of the city to 1,722 feet 3 miles north of the city.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Brookings area are chiefly the result of glaciation late in the Pleistocene Epoch of geologic time. 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; all were carried and deposited by the ice itself. Outwash material was deposited by meltwater streams issuing from the ice; such material is more completely sorted, consisting mostly of gravel and sand with minor amounts of silt. Alluvium is found along the Big Sioux River and its tributaries, Six Mile Creek, Deer Creek, and Meday Creek. Alluvium consists of clay and silt with minor amounts of sand. The distribution of these deposits around Brookings is shown on figure 3.

Subsurface Bedrock

The subsurface information is extrapolated to the Brookings area from a water well owned by Gene Cotton Company in Volga, the R. Kleinjan farm well, sec. 25, T. 110 N., R. 52 W., and from wells in the adjacent counties.

Stratified sedimentary bedrock of Cretaceous Age are present beneath approximately 540 feet of unconsolidated glacial deposits in the Brookings area. These bedrock deposits in descending order are Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, and Dakota Formation.

The Pierre Shale consists of light- to dark-gray clayey shale and is approximately 200 feet thick in this area. Beneath the Pierre Shale is 60 feet of the Niobrara Marl; within the Marl are shaly layers.

The Carlile Shale underlies the Niobrara Marl and consists of light-gray to black shale interbedded with silt or sand. Near the top of the Carlile, the Codell Sandstone Member may be present. All data indicates the presence of as much as 100 feet of the Codell in the Brookings area. Total thickness of the Carlile is about 200 feet.

The Greenhorn Limestone is composed of about 25 feet of hard, light-colored limestone. It is underlain by 150 feet of the dark-gray clayey Graneros Shale.

The Dakota Formation is a sequence of alternating sand, sandstone, and shale beds. The approximate thickness of the Dakota Formation is 150 feet. Beneath the Dakota are rocks of Pre-Cambrian Age, usually quartzites and granite.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Ground water is defined as that water contained in the voids or openings within rocks or sediments below the water table. The water table is the upper surface of the zone of saturation. All open spaces in the rocks that lie beneath the water table are filled with water. Rocks (including the soil) that lie above the water table are in the zone of aeration. Some of the interstices in this zone are also filled with water, but the water is either held in them by molecular attraction or is moving downward toward the zone of saturation. Water within the ground moves downward through the unsaturated zone under the action of gravity, whereas in the saturated zone, it moves in a direction determined by the surrounding hydraulic head.

Contrary to popular belief, ground water does not occur in "veins" that crisscross the land at random. Instead it can be shown that water is found nearly everywhere beneath the surface, but at varying depths.

Nearly all water is derived from precipitation, i.e., rain, melting snow, ice, etc. This water 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 into the rocks.

Recharge is the addition of water to an aquifer (formation having structures that permit appreciable water to move through it under ordinary field conditions), and is accomplished in four main ways: (1) downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, (3) by lateral underflow of water in transient storage, and (4) by artificial recharge, which takes place from excess irrigation, seepage from canals, and water purposely applied to augment ground-water supplies.

Discharge of ground water from an aquifer is accomplished in four main ways: (1) by evaporation and transpiration of plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water in transient storage, and (4) by pumping from wells, which constitutes the major artificial discharge of ground water.

The porosity of a rock or soil is a measure of the contained open pore spaces, and it is expressed as the percentage of void spaces to the total volume of the rock. The porosity of a sedimentary deposit depends chiefly on (1) the shape and arrangement of its constituent particles, (2) the degree of assortment of its particles, (3) the cementation and compaction to which it has been subjected since its deposition, (4) removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rock, resulting in joints and other openings. Thus, the size of the material has no or little effect on porosity if all other factors are equal.

The permeability of a rock is its capacity for transmitting a fluid. Water will pass through a material with interconnected pores, but will not pass through material with unconnected pores, even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms.

Ground Water in Alluvium

Alluvium is present along the streams in the Brookings area (fig. 3). Because of high clay and silt content the alluvium does not readily yield large volumes of water.

Ground Water in Glacial Deposits

It was stated earlier that glacial deposits are divided into till and outwash. Till does not yield water readily because of its highly unsorted nature and low permeability. Locally there are some lenses of sand within the till which provide an adequate supply for farm wells but are not important as a possible city water supply.

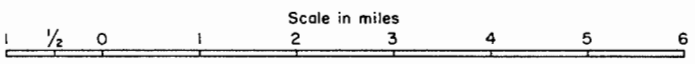
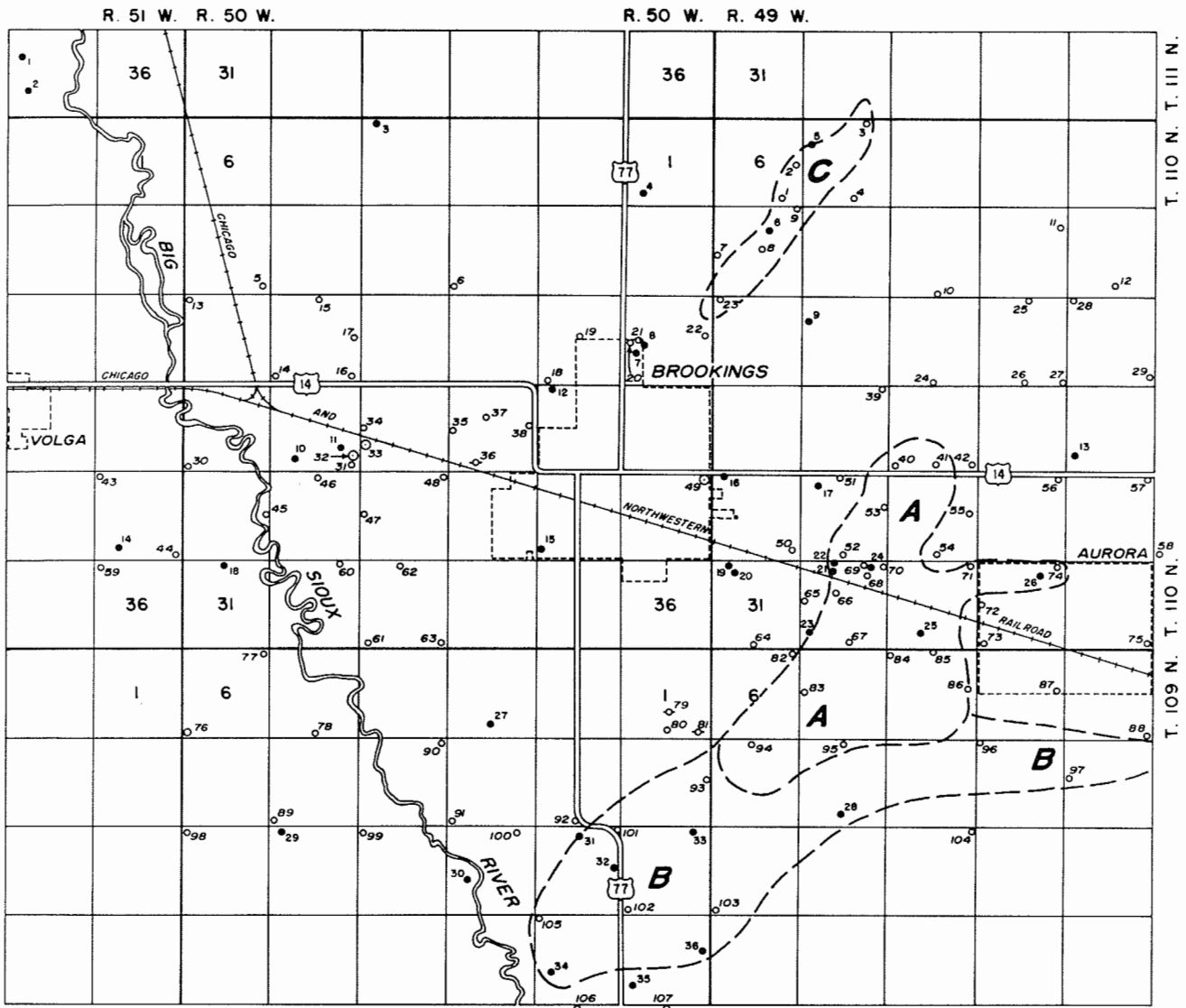
Outwash deposits (fig. 3) comprise the main shallow aquifer in the study area. Three main areas of aquifer potential in glacial outwash deposits exist in the vicinity of the city of Brookings: (1) outwash along Deer and Medary Creeks, (2) outwash along Six Mile Creek, and (3) outwash along the Big Sioux River. Figure 4 shows the location of test holes, wells, and water samples used to define and delineate the various areas. On figure 5 the total saturated sand and gravel thickness is shown although a 10 to 15 foot clay layer may be present (for example see test hole 105, appendix A).

1. Outwash along Deer and Medary Creeks has a maximum thickness of 75 feet of saturated sand and gravel (fig. 5) and includes both area A and B. There are already some high capacity wells in this outwash (for instance, the Whitehead Irrigation well, 1,000 gpm., appendix B).

2. Outwash about 50 feet thick along Six Mile Creek provides water for the city. A greater thickness of saturated sand and gravel is encountered in the northeast part of the outwash (area C, fig. 2) where it is 65 feet thick in test hole 1 (appendix A). The greatest thickness of saturated sand and gravel in the southwest part of this outwash is 75 feet where it joins the Big Sioux River outwash (test hole 47, appendix A, and fig. 5).

3. The average thickness of saturated sand and gravel along the Big Sioux River is approximately 20 feet (fig. 5).

Interpretation of the geologic map (fig. 3) and the map showing areas A, B, and C (fig. 2) show the water storage and recharge potential in area A-B is much greater than in the Six Mile Creek aquifer which includes area C.

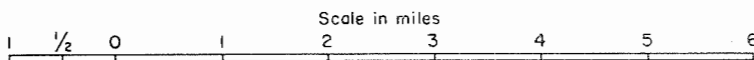
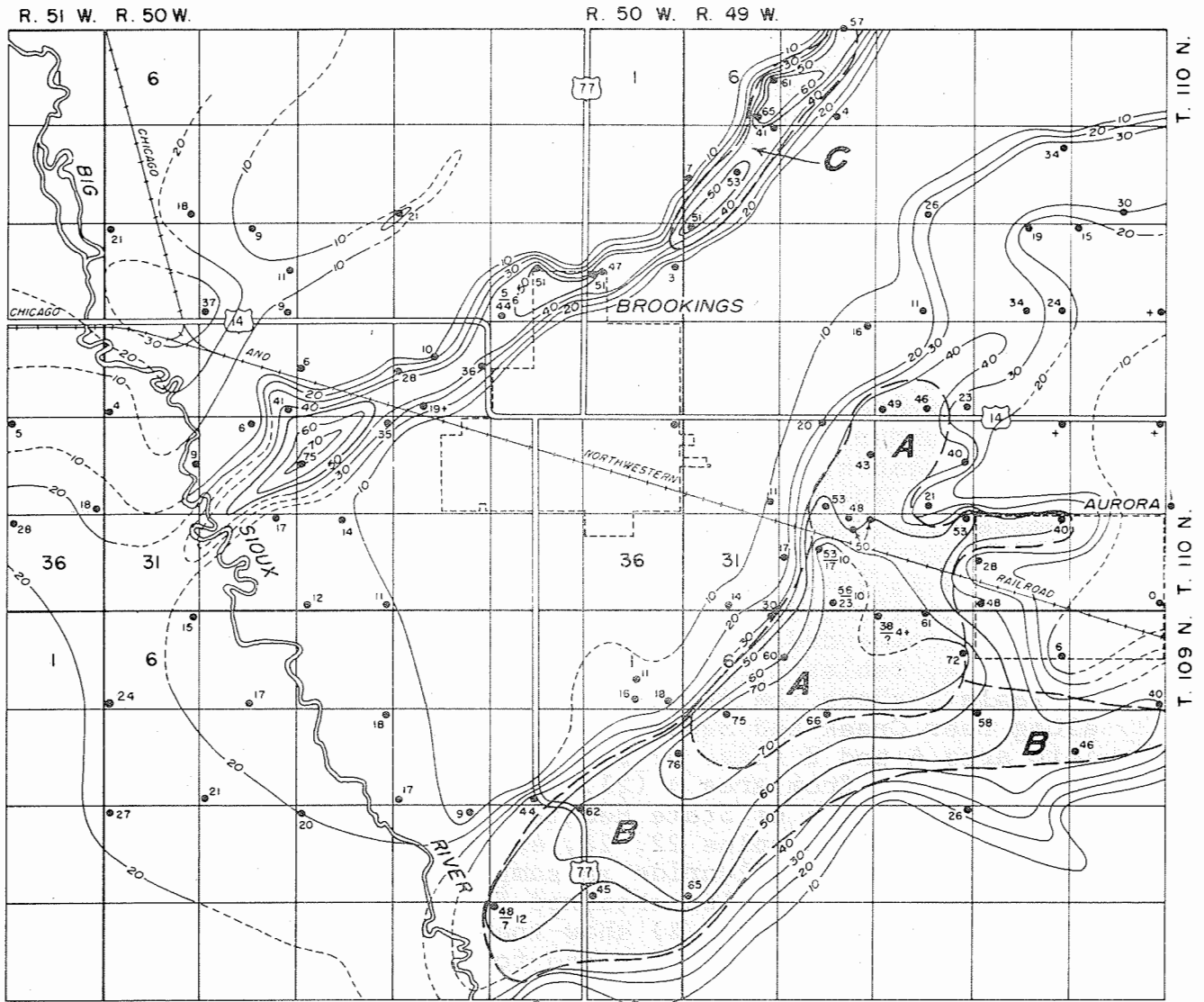


EXPLANATION

- 44° Auger test hole, 1967
- 79° South Dakota Geological Survey test hole, 1965
- 33° Rotary test hole, 1967
- 30° Water sample (see Tables I through 4)
- Outline of recommended areas A, B, and C by Assad Barari, 1967
- drafted by D. W. Johnson



Figure 4. Data map of the Brookings area.



EXPLANATION

- 20— Lines showing equal thickness of saturated sand and gravel; contour interval=10 feet.(dashed lines in areas of limited data).
- ₇₂ Test hole, number shows thickness of saturated sand and gravel; a plus (+) indicates that full thickness of sand and gravel was not penetrated.

Test hole:

- ₅₃ 53 feet of saturated sand
- ₁₇ 10 feet of clay
- ₁₇ 17 feet of sand

— Yellow patterns show recommended areas A,B, and C.

by Assad Barari, 1967
drafted by D. W. Johnson



Figure 5. Map showing thickness of saturated sand and gravel in the Brookings area.

Ground Water in Bedrock

The Dakota Formation is the only bedrock aquifer which could supply significant quantities of water in the Brookings area. However, little data is available about the availability of water or its quality in the study area. From what is known concerning water from the Dakota, yields from wells probably would not exceed 100 gallons per minute and the water would contain about three times the total solids that the present supply contains.

Quality of Ground Water

Ground water always contains dissolved chemical substances in various amounts. Contained chemicals are derived (1) from the atmosphere as water vapor condenses and falls, (2) from soil and underlying deposits as the water moves downward to the water table, and (3) from rock deposits below the water table where the water is circulating. In general, the more chemical substances that a water contains, the poorer its quality.

Tables 1, 2, 3, and 4 show the quality of water from the various aquifers in the Brookings area as compared with the limits recommended by the U. S. Department of Public Health (sample A, tables 1, 2, 3, and 4 show the recommended limits).

Table 1 shows the quality of water from surface outwash along Deer Creek and Medary Creek. This outwash is divided into area A and B (fig. 2) based on the quality of water. Samples taken from area A (21, 22, 23, 24, 25, and 26) are within the limits of State Health Standards except for a high iron content in samples 22, 23, and 24, high magnesium in sample 24, and low fluoride in sample 24. Comparison of these samples with the samples obtained from the present city wells (table 2, samples 7 and 8) show that generally waters from area A are lower in hardness and total solids than water samples from the present city well field. Comparison of water samples from area B (samples 28, 31, 33, and 36) show that the water is slightly higher in total solids and hardness than area A but slightly less than in area C.

In those areas where the surface outwash contains a clay layer in the lower part (see fig. 5) the water quality, especially in the lower part, may vary. However, no water analyses from the lower part are available for comparison.

Table 2 shows the results of water analyses from the outwash along Six Mile Creek. Samples 7 and 8 are taken from the present city well system. Samples 5 and 6 (fig. 4) are taken from area C northeast of the well field and are comparable in quality to the present supply.

Table 1.--Chemical analyses of water samples from the surface outwash along Deer Creek and Medary Creek.

Sample	Area	Parts Per Million											
		Calcium	Sodium	Magne- sium	Chloride	Sulfate	Iron	Manga- nese	Nitrogen	Fluoride	pH	Hardness CaCO ₃	Total Solids
A				50	250	500*	0.3	0.05	10.0	0.9 1.7**			1000*
13		90		29	Tr.	55	0.03				7.8	345	490
17		41	13	43	0	77	1.3	0	0	0.2	7.6	280	326
21	AA	98		26	7	120	0.13				7.5	350	505
22	AA	117		27	10	240	0.44				8.0	400	644
23	AA	91		30	6	108	0.49				7.5	340	475
24	AA	84	17	67	0	262	1.4		0.14	0.4	8.0	484	574
25	AA	84		21	Tr.	90	0				7.5	295	445
26	AA	92		29	0	196	0				8.1	350	555
28	AB	146		36	16	349	0				7.4	510	700
31	AB	136		44	20	210	0.49				7.9	520	706
32	AB	112		25	14	0	0				7.6	380	595
33	AB	141		34	14	240	0				7.7	490	700
35		143		25	10	240	1.36				7.7	460	652
36	AB	128		37		245	0.31				7.7	470	755

*Modified for South Dakota by the State Department of Health
(written communication, February 5, 1962)

**Optimum

AAWater samples from area A

ABWater samples from area B

Samples 17 and 24, except for pH, were analyzed by the State Chemical Laboratory, the rest of the samples were analyzed by the water quality laboratory of the State Geological Survey.

Location of Water Samples
along Deer and Medary Creeks

(for map location see figure 4)

- A. Drinking Water Standards, U. S. Public Health Service, (1962).
13. SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 23, T. 110 N., R. 49 W., D. Sanderson, 48 feet deep, water table 33 feet.
17. SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 29, T. 110 N., R. 49 W., D. Gilkerson, 22 feet deep, (irrigation well), water table 7 feet.
21. NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W., C. Freyberg, 12 feet deep (house well).
22. NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W., C. Freyberg, 12 feet deep (house well)
23. SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W., R. Zakrezewski, 20 feet deep.
24. SW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W., W. Knight, 24 feet deep, water table 7 feet.
25. SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 33, T. 110 N., R. 49 W., N. Jensen, 14 feet deep.
26. NE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 34, T. 110 N., R. 49 W., G. Whitehead, 60 feet deep, water table 12 feet, irrigation well.
28. SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 109 N., R. 49 W., J. Biggar, 12 feet deep, water table 7 feet.
31. NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 14, T. 109 N., R. 50 W., A. Vawser, water table 6 feet.
32. SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 14, T. 109 N., R. 50 W., D. Zemlicka, 18 feet deep, water table 6 feet.
33. NE $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 13, T. 109 N., R. 50 W., L. Vockrodt, 11 feet deep.
35. NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 24, T. 109 N., R. 50 W., R. Craddock, 12 feet deep.
36. SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 24, T. 109 N., R. 50 W., L. Telkamp, 17 feet deep, water table 12 feet.

Samples #17 and 24, except for pH, were analyzed by the State Chemical Laboratory.

Table 2.--Chemical analyses of water samples from the outwash along Six Mile Creek.

Sample	Area	Parts Per Million											
		Calcium	Sodium	Magne- sium	Chloride	Sulfate	Iron	Manga- nese	Nitrogen	Fluoride	pH	Hardness CaCO ₃	Total Solids
A	--	---	--	50	250	500*	0.3	0.05	10.0	0.9 1.7**	---	---	1000*
5		82	22	38	1	120	0		1.2	0.6	7.8	364	448
6	AC	120		39	6	276	Tr.				7.8	460	730
7		269		59	10	673	1.57				7.2	920	1130
8		99	22	54	1	366	3.73		0.08	0.2	7.9	472	722
12		341		127	45	995	0				7.4	1370	1680

*Modified for South Dakota by the State Department of Health
(written communication, February, 1962)

**Optimum

AC Area C

Samples 5 and 8, except for iron and pH, were analyzed by the State Chemical Laboratory. The rest of the samples were analyzed by the water quality laboratory of the State Geological Survey.

Location of Water Samples
along Six Mile Creek

(for map location see figure 4)

- A. Drinking water Standards, U. S. Public Health Service, (1962).
- 5. SE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 5, T. 110 N., R. 49 W., H. Dean, 22 feet deep, water table 12 feet.
- 6. SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 110 N., R. 49 W., R. Barnett, 50 feet deep, water table 10 feet. (Irrigation well, approximately 550 gpm.)
- 7. SE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 110 N., R. 50 W., City well #6, approximately 470 gpm.
- 8. NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 110 N., R. 50 W., City well #7, approximately 800 gpm.
- 12. SE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 23, T. 110 N., R. 50 W., B. McCackan, 25 feet deep, water table 14 feet.

Table 3.--Chemical analyses of water samples from the surface outwash along the Big Sioux River

Sample	Parts Per Million										
	Calcium	Magne- sium	Chloride	Sulfate	Iron	Manga- nese	Nitrogen	Fluoride	pH	Hardness CaCO ₃	Total Solids
A		50	250	500*	0.3	0.05	10.0	0.9 1.7**	---	---	1000*
3	107	44	0	224	0.10				7.9	445	609
10	165	43	30	360	0.07				8.0	585	820
11	184	59	0	480	3.15				7.6	700	959
14	100	75	8	25	0				7.7	345	495
18	167	56	5	426	0				7.4	645	848
27	177	54	86	240	0.11				7.5	660	1045
29	152	49	0	396	0.09				7.8	590	776
30	94	35	14	156	0				7.6	380	579
34	125	40	4	270	0				8.0	475	665

*Modified for South Dakota by the State Department of Health
(written communication, February 5, 1962)

**Optimum

Samples were analyzed by the water quality laboratory of the State Geological Survey.

Location of Water Samples
along the Big Sioux River

(for map location see figure 4)

- A. Drinking Water Standards, U. S. Public Health Service, (1962).
3. NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 110 N., R. 50 W., D. Larson, 24 feet deep, water table 16 feet.
10. SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 20, T. 110 N., R. 50 W., K. Knutson, 12 feet deep, water table 8 feet.
11. SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 20, T. 110 N., R. 50 W., M. C. Green, 12 feet deep.
14. SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 25, T. 110 N., R. 51 W., M. Karlstad, 18 feet deep.
18. NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 110 N., R. 50 W., R. Doop, 15 feet deep.
27. SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 3, T. 109 N., R. 50 W., K. Opland, 10 feet deep, water table 8 feet.
29. NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 109 N., R. 50 W., N. Berkland, 23 feet deep.
30. SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 15, T. 109 N., R. 50 W., S.D.S.U., 35 feet deep, water table 7 feet (Irrigation well).
34. SE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 23, T. 109 N., R. 50 W., A. Ponto, 11 feet deep.

Table 4.--Chemical analyses of water samples from
the buried sand and gravel

Sample	Parts Per Million										
	Calcium	Magne- sium	Chloride	Sulfate	Iron	Manga- nese	Nitrogen	Fluoride	pH	Hardness CaCO ₃	Total Solids
A	---	50	250	500*	0.3	0.05	10.0	0.9 1.7**	--	---	1000*
1	228	49	Tr.	565	0				7.2	770	1035
2	193	48	0	469	0.83				7.5	675	822
4	318	54	55	312	0.13				7.6	1010	1339
9	622	100	Tr.	1560	0				7.4	1960	2240
15	240	59	10	936	0.95				7.6	840	1362
16	265	46	20	216	0.08				7.8	850	1270
19	233	71	35	337	0.58				7.8	870	1321
20	253	49	0	673	1.26				7.6	830	1165

*Modified for South Dakota by the State Department of Health
(written communication, February 5, 1962)

**Optimum

Samples were analyzed by the water quality laboratory of
the State Geological Survey.

Location of Water Samples
from buried sand and gravel

(For map location see figure 4)

- A. Drinking Water Standards, U. S. Public Health Service, (1962).
1. SW $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 111 N., R. 51 W., A. J. VanderWal, 39 feet deep, water table 30 feet.
 2. SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 35, T. 111 N., R. 51 W., A. J. VanderWal, 102 feet deep (Irrigation well).
 4. SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 1, T. 110 N., R. 50 W., A. Justice, 70 feet deep.
 9. NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 110 N., R. 49 W., L. Barnett, 60 feet deep.
 15. SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 110 N., R. 50 W., V. Janssen, 400 feet deep.
 16. NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T. 110 N., R. 49 W., N. Mayland, 60 feet deep.
 19. NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 110 N., R. 49 W., J. DeWitt, 50 feet deep.
 20. SE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 110 N., R. 49 W., J. DeWitt, 435 feet deep, water table approximately 80 feet.

Table 3 shows the quality of water from surface outwash along the Big Sioux River. These samples show a range in quality approximately between area A and area C.

Table 4 shows the results of water analyses from various buried sands and gravels in the Brookings area. These samples generally are higher in chemical content than the samples from areas A, B, or C.

CONCLUSIONS AND RECOMMENDATIONS

There are three areas in the vicinity of the city of Brookings each of which would probably provide at least as much water as the city is presently using. These areas in order of preference (based on quality and quantity) are areas A, B, and C (figs. 2 and 4).

From the results of this study it appears that area A has the best potential water development possibilities. Area A is part of an extensive aquifer and contains the highest average saturated thickness. Available data suggests that wells in this area should readily produce 800-1,000 gallons per minute. Area A also contains the best overall water quality that would be an improvement over the present city supply. The city owns land in NE $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W., which it is considering for water development, and it is not located in the area of maximum aquifer thickness. However, there should be no problem obtaining the desired quantity or quality of water.

Area B is part of the same extensive aquifer as area A and contains nearly as much saturated aquifer material; therefore, the quantity of water available for future development by the city is assured. However, in this area the general overall water quality is not as good as in area A.

Area C is about one-half to three miles northeast of the city's present well field but is in the same aquifer. Present data show that ground water underlying area C will produce yields to wells comparable to yields from the present well field. Quality data show the water in area C to be at least as good as the present supply and maybe slightly better.

Because area C and the city's present supply are part of the same aquifer, any large-scale development of area C would require additional testing to determine the effect on the present city supply.

Although controlled pumping tests have not been conducted in the present well field, observations of the city's present closely spaced wells indicate that additional wells in this field would interfere with the yield from existing wells. Thus, if the city wishes to expand the present well field, it is recommended that they drill in area C. It is recommended that the city does not expand its present well field to the immediate southwest because the aquifer thins in that direction. However,

about 2 miles to the southwest the aquifer attains a thickness of 75 feet, but there is a possibility of contamination and the water would probably be no better quality than the present supply.

When an area is selected for additional development it is recommended that a test well be installed. Then a pump test should be conducted by qualified engineers for a minimum of 72 hours. A pump test is desirable for the following reasons: (1) to determine the expected yield from wells; (2) to determine the proper spacing of wells; (3) to obtain data for final design of the well or well system; and (4) to obtain a water sample from the selected area for chemical analysis.

The State Water Resources Commission should be consulted with regard to obtaining a water right and a permit to drill a city well. The State Department of Health should be consulted with regard to the biological and chemical suitability of the water.

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APPENDIX A

Logs of Test Holes in the Brookings Area

(for location see figure 4)

Test Hole No. 1

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 6, T. 110 N., R. 49 W.

Surface elevation: 1635 feet

Depth to water: 7 feet

0- 5	Sand, brown, fine, silty
5- 15	Gravel and sand
15- 72	Sand, coarse, gravel
72- 84	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 2

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 6, T. 110 N., R. 49 W.

Surface elevation: 1644 feet

Depth to water: 20 feet

0- 2	Topsoil
2- 8	Clay, brown, some fine sand
8- 11	Sand, coarse, gravel
11- 16	Sand, fine to coarse, some clay
16- 20	Clay, light-gray, some sand
20- 81	Sand, coarse, gravel
81- 94	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 3

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 5, T. 110 N., R. 49 W.

Surface elevation: 1643 feet

Depth to water: 10 feet

0- 4	Clay, black, sandy
4- 10	Sand, coarse, gravel
10- 67	Sand and gravel
67- 79	Clay, dark olive-brown, pebbly, (till)

* * * *

Test Hole No. 4

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T. 110 N., R. 49 W.

Surface elevation: 1637 feet

Depth to water: 9 feet

Test Hole No. 4 (cont.)

0- 6	Road bed
6- 9	Sand and gravel
9- 13	Gravel, sand
13- 24	Clay, gray, few pebbles, (till)

* * * *

Test Hole No. 5

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 7, T. 110 N., R. 50 W.

Surface elevation: 1600 feet

Depth to water: 4 feet

0- 3	Clay, black, silty
3- 22	Sand and gravel
22- 34	Clay, dark gray, pebbly, (till)

* * * *

Test Hole No. 6

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 10, T. 110 N., R. 50 W.

Surface elevation: 1623 feet

Depth to water: 6 feet

0- 6	Sand and gravel
6- 27	Gravel and sand
27- 51	Clay, dark-gray, pebbly
51-	Could not penetrate, boulders

* * * *

Test Hole No. 7

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 7, T. 110 N., R. 49 W.

Surface elevation: 1729 feet

Depth to water: 10 feet

0- 1	Topsoil
1- 5	Clay, black, silty
5- 10	Sand and gravel
10- 17	Sand and gravel, unsorted
17- 39	Clay, dark brownish-gray, pebbly, (till)

* * * *

Test Hole No. 8

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 110 N., R. 49 W.

Surface elevation: 1633 feet

Depth to water: 8 feet

Test Hole No. 8 (cont.)

0-	1	Topsoil
1-	5	Sand, fine, silty
5-	8	Sand and gravel
8-	51	Gravel and sand
51-	61	Sand and gravel, some boulders
61-	74	Clay, dark-blue, pebbly, (till)

* * * *

Test Hole No. 9

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 110 N., R. 49 W.
 Surface elevation: 1635 feet
 Depth to water: 6 feet

0-	1	Topsoil
1-	3	Sand
3-	47	Sand, coarse, gravel
47-	59	Clay, olive-brown, pebbly, (till)

* * * *

Test Hole No. 10

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 110 N., R. 49 W.
 Surface elevation: 1635 feet
 Depth to water: 4 feet

0-	2	Topsoil
2-	21	Sand and gravel
21-	28	Clay?
28-	35	Gravel and sand
35-	110	Clay, dark blue-gray, pebbly, (till)

* * * *

Test Hole No. 11

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T. 110 N., R. 49 W.
 Surface elevation: 1640 feet
 Depth to water: 6 to 7 feet

0-	5	Roadbed
5-	11	Sand, brown
11-	21	Sand and gravel
21-	41	Sand, coarse, gravel, well sorted
41-	47	Clay?
47-	49	Sand and gravel
49-	53	Clay
53-	60	Sand and gravel
60-	74	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 12

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 110 N., R. 49 W.

Surface elevation: 1648 feet

Depth to water: 8 feet

0- 6	Road bed
6- 8	Sand and gravel
8- 38	Gravel and sand
38- 49	Clay, gray-olive brown, pebbly, (till)

* * * *

Test Hole No. 13

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 18, T. 110 N., R. 50 W.

Surface elevation: not measured

Depth to water: 4 feet

0- 1	Topsoil
1- 4	Sand and gravel
4- 25	Sand, coarse, gravel
25- 39	Clay, dark-gray, pebbly, compact, (till)

* * * *

Test Hole No. 14

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 17, T. 110 N., R. 50 W.

Surface elevation: 1595 feet

Depth to water: 3 feet

0- 1	Topsoil
1- 3	Sand
3- 40	Gravel and sand
40- 49	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 15

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 110 N., R. 50 W.

Surface elevation: 1600 feet

Depth to water: 6 feet

0- 2	Sand, fine
2- 6	Sand and gravel
6- 15	Sand, coarse, some gravel
15- 64	Clay, light gray-brown to black-blue, pebbly, (till)

* * * *

Test Hole No. 16

Location: SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 17, T. 110 N., R. 50 W.

Surface elevation: 1598 feet

Depth to water: 6 $\frac{1}{2}$ feet

Test Hole No. 16 (cont.)

0-	1	Topsoil
1-	7	Sand
7-	16	Sand and gravel
16-	29	Clay, dark blue-gray, pebbly, (till)

* * * *

Test Hole No. 17

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 17, T. 110 N., R. 50 W.

Surface elevation: 1600 feet

Depth to water: 6 feet

0-	1	Topsoil
1-	3	Clay, black, silty
3-	6	Sand, gravel
6-	17	Gravel and sand
17-	29	Clay, dark-brown, pebbly, (till)

* * * *

Test Hole No. 18

Location: SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 14, T. 110 N., R. 50 W.

Surface elevation: 1605 feet

Depth to water: 8 feet

0-	1	Topsoil
1-	5	Clay, dark-brown, silty
5-	8	Sand, some gravel
8-	13	Sand and gravel
13-	19	Clay, dark-gray, pebbly
19-	63	Sand, fine to coarse
63-	74	Clay, dark blue-gray, pebbly, (till)

* * * *

Test Hole No. 19

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 14, T. 110 N., R. 50 W.

Surface elevation: 1607 feet

Depth to water: 9 feet

0-	6	Clay, black
6-	9	Sand and gravel
9-	17	Gravel and sand
17-	37	Sand and gravel, clayey
37-	60	Gravel and sand
60-	69	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 20

Location: SW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 110 N., R. 50 W.

Surface elevation: 1610 feet

Depth to water: 13 feet

0- 13	Clay, brown to black
13- 15	Sand, brown
15- 64	Sand and gravel
64- 74	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 21 (Observation Well)

Location: NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 110 N., R. 50 W.

Surface elevation: 1610 feet

Depth to water: around 23 feet

0- 2	Clay, black, silty
2- 9	Clay, dark-brown
9- 25	Sand, coarse
25- 71	Sand and gravel
71- 79	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 22

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 13, T. 110 N., R. 50 W.

Surface elevation: 1620 feet

Depth to water: 10 feet

0- 6	Roadbed
6- 10	Sand
10- 13	Sand, some gravel
13- 29	Clay, light-gray, pebbly, (till)

* * * *

Test Hole No. 23

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 18, T. 110 N., R. 49 W.

Surface elevation: 1623 feet

Depth to water: 6 feet

0- 1	Topsoil
1- 7	Sand
7- 57	Gravel and sand
57- 64	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 24

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 16, T. 110 N., R. 49 W.

Surface elevation: 1623 feet

Depth to water: 7 feet

0- 7	Sand and gravel
7- 18	Gravel and sand
18- 29	Clay, light-gray, pebbly, (till)

* * * *

Test Hole No. 25

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 15, T. 110 N., R. 49 W.

Surface elevation: 1640 feet

Depth to water: 5 feet

0- 1	Topsoil
1- 5	Sand, silty
5- 24	Sand and gravel
24- 34	Clay, brown, pebbly, (till)

* * * *

Test Hole No. 26

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 110 N., R. 49 W.

Surface elevation: 1638 feet

Depth to water: 6 feet

0- 1	Topsoil
1- 6	Sand, fine
6- 40	Sand and gravel
40- 49	Clay, dark-olive brown, pebbly, (till)

* * * *

Test Hole No. 27

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 110 N., R. 49 W.

Surface elevation: 1645 feet

Depth to water: 11 feet

0- 11	Sand
11- 35	Sand and gravel
35- 44	Clay, olive-brown, pebbly, (till)

* * * *

Test Hole No. 28

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 14, T. 110 N., R. 49 W.

Surface elevation: 1647 feet

Depth to water: 8 feet

Test Hole No. 28 (cont.)

0- 3 Clay, black
 3- 8 Sand and gravel
 8- 23 Gravel and sand
 23- 34 Clay, dark blue-gray, pebbly, (till)

* * * *

Test Hole No. 29

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 14, T. 110 N., R. 49 W.

Surface elevation: 1672 feet

Depth to water: dry

0- 16 Sand and gravel, some pebbles, could not penetrate

* * * *

Test Hole No. 30

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 110 N., R. 50 W.

Surface elevation: not measured

Depth to water: 3 feet

0- 1 Topsoil
 1- 3 Sand
 3- 7 Sand, coarse, some gravel
 7- 19 Clay, olive-brown, pebbly, (till)

* * * *

Test Hole No. 31

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 20, T. 110 N., R. 50 W.

Surface elevation: 1595 feet

Depth to water: 7 feet

0- 7 Clay, black, silty, sandy
 7- 48 Sand and gravel
 48- 54 Clay, dark brownish-gray, pebbly, (till)

* * * *

Test Hole No. 32 (Rotary test hole)

Location: NE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 20, T. 110 N., R. 50 W.

Surface elevation: 1595 feet

Depth to water: not measured

0- 2 Topsoil
 2- 30 Gravel
 30- 65 Clay, gray, (till)
 65- 80 Clay, brown, (till)

* * * *

Test Hole No. 33 (Rotary test hole)

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 21, T. 110 N., R. 50 W.

Surface elevation: 1595 feet

Depth to water: not measured

0- 16	Gravel
16- 30	Clay, gray, very tough, (till)
30- 35?	Clay, brown, very tough
35- 80	Clay, gray, drilled easier
80- 95	Clay, brown, slightly calcareous, some gypsum
95-125	Clay, brown, with gypsum, (till)

* * * *

Test Hole No. 34

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 21, T. 110 N., R. 50 W.

Surface elevation: 1595 feet

Depth to water: 11 feet

0- 4	Roadbed
4- 10	Clay, black
10- 17	Sand, fine, some gravel
17- 34	Clay, dark-blue, pebbly, (till)

* * * *

Test Hole No. 35

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 22, T. 110 N., R. 50 W.

Surface elevation: 1599 feet

Depth to water: 5 feet

0- 1	Topsoil
1- 5	Sand, fine
5- 10	Sand and gravel, some boulders
10- 33	Sand, coarse to fine, not well sorted
33- 44	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 36 (SDGS Test Hole, 1965)

Location: SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 22, T. 110 N., R. 50 W.

Surface elevation: 1598 feet

Depth to water: 7 feet

0- 3	Topsoil
3- 9	Sand, light- to dark-brown, fine to coarse
9- 16	Sand and gravel, brownish
16- 19	Sand and gravel, grayish

* * * *

Test Hole No. 37

Location: SE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 110 N., R. 50 W.

Surface elevation: 1600 feet

Depth to water: 7 feet

0- 1	Topsoil
1- 7	Clay, black, silty, sandy
7- 17	Sand, coarse, gravel
17- 34	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 38

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 22, T. 110 N., R. 50 W.

Surface elevation: 1605 feet

Depth to water: 7 feet

0- 10	Clay, black, silty, sandy
10- 16	Sand, gray, fine
16- 31	Clay and sand
31- 46	Sand, some gravel
46- 54	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 39

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 110 N., R. 49 W.

Surface elevation: 1628 feet

Depth to water: 5 feet

0- 5	Roadbed
5- 16	Sand, coarse, some gravel
16- 21	Sand and gravel
21- 29	Clay, blue-gray, pebbly, (till)

* * * *

Test Hole No. 40

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 21, T. 110 N., R. 49 W.

Surface elevation: 1625 feet

Depth to water: 3 feet

0- 3	Clay, silty
3- 14	Sand and gravel
14- 52	Sand, coarse, some gravel
52- 64	Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 41

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 21, T. 110 N., R. 49 W.

Surface elevation: 1625 feet

Depth to water: 4 feet

0- 4	Clay, black, silty
4- 50	Gravel and sand
50- 59	Clay, buff to brown, pebbly, (till)

* * * *

Test Hole No. 42

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 21, T. 110 N., R. 49 W.

Surface elevation: 1641 feet

Depth to water: 18 feet

0- 2	Topsoil
2- 29	Sand, some gravel
29- 41	Sand and gravel
41- 49	Clay, dark-blue gray, pebbly, (till)

* * * *

Test Hole No. 43

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 25, T. 110 N., R. 51 W.

Surface elevation: not measured

Depth to water: 8 feet

0- 2	Clay, brown, hard
2- 8	Sand and gravel
8- 13	Gravel and sand, some boulders
13- 24	Clay, dark-brownish gray, pebbly, (till)

* * * *

Test Hole No. 44

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 25, T. 110 N., R. 51 W.

Surface elevation: not measured

Depth to water: 5 feet

0- 2	Topsoil
2- 5	Sand and gravel
5- 23	Sand, fine to coarse
23- 34	Clay, light-gray, (till)

* * * *

Test Hole No. 45

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 30, T. 110 N., R. 50 W.

Surface elevation: 1591 feet

Depth to water: 6 to 7 feet

Test Hole No. 45 (cont.)

0- 1	Topsoil
1- 6	Clay, black, silty
6- 11	Sand, coarse
11- 16	Sand, fine to coarse
16- 24	Clay, dark blue-gray, pebbly, (till)

* * * *

Test Hole No. 46

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 29, T. 110 N., R. 50 W.

Surface elevation: 1591 feet

Depth to water: 6 feet

0- 1	Topsoil
1- 3	Clay, black, silty
3- 6	Sand and gravel, coarse
6- 12	Sand, coarse, fine gravel
12- 24	Clay, dark-brown, pebbly, (till)

* * * *

Test Hole No. 47

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 28, T. 110 N., R. 50 W.

Surface elevation: 1590 feet

Depth to water: 7 feet

0- 6	Roadbed
6- 8	Sand, coarse
8- 24	Sand and gravel
24- 32	Sand, coarse, well sorted
32- 82	Sand, some gravel
82- 94	Clay, dark-olive, pebbly, (till)

* * * *

Test Hole No. 48

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28, T. 110 N., R. 50 W.

Surface elevation: 1595 feet

Depth to water: 7 feet

0- 7	Clay, black
7- 23	Sand, fine to coarse, some gravel
23- 29	Sand, fine, well sorted
29- 42	Sand and gravel
42- 54	Clay, dark-gray, pebbly, (till)

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Test Hole No. 49 (Rotary test hole)

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 25, T. 110 N., R. 50 W.

Surface elevation: 1665 feet

Depth to water: not measured

0- 12	Clay, yellowish-brown, (till)
12- 17	Silt, bright yellowish-brown
17- 32	Clay, brown
32- 40	Clay, gray, sandy
40- 45	Clay, light-gray, calcareous
45- 65	Clay, brown, pebbly
65-215	Clay, gray, some boulders
215-220	Sand, with clay
220-400	Clay, gray, sandy
400-440	Clay, some gravel stringers
440-460	Sand, with clay
460-480	Clay, sandy, with gravel stringers
480-500	Gravel, clay
500-510	Gravel
510-525	Clay, gravel stringers

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Test Hole No. 50

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 30, T. 110 N., R. 49 W.

Surface elevation: 1615 feet

Depth to water: 6 feet

0- 1	Topsoil
1- 6	Sand and gravel
6- 17	Gravel and sand
17- 29	Clay, dark-brown, pebbly, (till)

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Test Hole No. 51

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 29, T. 110 N., R. 49 W.

Surface elevation: 1623 feet

Depth to water: 6 feet

0- 1	Topsoil
1- 6	Sand, clay and silty
6- 26	Sand and gravel
26- 34	Clay, dark-blue gray, pebbly, (till)

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Test Hole No. 52

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 29, T. 110 N., R. 49 W.

Surface elevation: 1617 feet

Depth to water: 10 feet

Test Hole No. 52 (cont.)

0- 10	Clay, silty
10- 20	Sand and gravel
20- 24	Gravel and sand
24- 57	Sand, coarse, some gravel
57- 63	Gravel and sand
63- 69	Clay, dark-blue gray, pebbly, (till)

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Test Hole No. 53

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 29, T. 110 N., R. 49 W.

Surface elevation: 1618 feet

Depth to water: 8 feet

0- 8	Clay, black, silty
8- 24	Sand and gravel
24- 44	Sand and fine gravel
44- 51	Gravel and sand
51- 59	Clay, dark-brown, pebbly, (till)

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Test Hole No. 54

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 28, T. 110 N., R. 49 W.

Surface elevation: 1628 feet

Depth to water: 13 feet

0- 13	Sand and gravel
13- 34	Gravel and sand
34- 44	Clay, blue-gray, pebbly, (till)

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Test Hole No. 55

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28, T. 110 N., R. 49 W.

Surface elevation: 1640 feet

Depth to water: 21 feet

0- 1	Topsoil
1- 21	Sand, coarse to fine, some gravel
21- 48	Gravel and sand
48- 51	Clay
51- 57	Sand and gravel
57- 61	Gravel and boulders
61- 74	Clay, dark-gray, pebbly, (till)

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Test Hole No. 56

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 27, T. 110 N., R. 49 W.

Surface elevation: 1653 feet

Depth to water: dry

0-	1	Topsoil
1-	7	Clay, olive-brown
7-	16	Sand and gravel

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Test Hole No. 57

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 26, T. 110 N., R. 49 W.

Surface elevation: 1653 feet

Depth to water: dry

0-	11	Sand and gravel, could not penetrate
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Test Hole No. 58

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 25, T. 110 N., R. 49 W.

Surface elevation: 1645 feet

Depth to water: approximately 23 feet

0-	22	Sand and gravel
22-	24	Sand and gravel, dark-gray
24-	44	Clay, dark-gray, pebbly, (till)

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Test Hole No. 59

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 110 N., R. 51 W.

Surface elevation: not measured

Depth to water: 8 feet

0-	1	Topsoil
1-	8	Sand and gravel
8-	36	Sand, coarse, some gravel
36-	49	Clay, olive-brown, pebbly, (till)

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Test Hole No. 60

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 32, T. 110 N., R. 50 W.

Surface elevation: 1590 feet

Depth to water: 7 feet

Test Hole No. 60 (cont.)

0- 3 Clay, black, sandy
 3- 10 Sand, fine, some clay
 10- 24 Sand, fine to coarse, some gravel
 24- 37 Clay?
 37- 85 Sand and gravel
 85- 94 Clay, dark gray-blue, pebbly, (till)

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Test Hole No. 61

Location: SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 33, T. 110 N., R. 50 W.
 Surface elevation: 1588 feet
 Depth to water: 10 feet

0- 2 Topsoil
 2- 10 Clay, black, sand
 10- 22 Sand, fine to coarse, some gravel
 22- 34 Clay, dark brownish-gray, pebbly, (till)

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Test Hole No. 62

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 33, T. 110 N., R. 50 W.
 Surface elevation: 1592 feet
 Depth to water: 3 feet

0- 1 Topsoil
 1- 3 Clay, black
 3- 6 Sand, coarse
 6- 17 Sand, coarse to fine
 17- 34 Clay, dark blue-gray, pebbly, (till)

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Test Hole No. 63

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 33, T. 110 N., R. 50 W.
 Surface elevation: 1588 feet
 Depth to water: 6 feet

0- 6 Sand and gravel
 6- 9 Sand, coarse to fine, some gravel
 9- 17 Sand, coarse to fine sand
 17- 34 Clay, dark-gray, pebbly, (till)

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Test Hole No. 64

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 31, T. 110 N., R. 49 W.
 Surface elevation: 1610 feet
 Depth to water: 4 feet

Test Hole No. 64 (cont.)

0- 4 Sand, coarse to fine
 4- 18 Sand and gravel
 18- 29 Clay, dark to light brownish-gray, pebbly, (till)

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Test Hole No. 65

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.

Surface elevation: 1613 feet

Depth to water: 3 feet

0- 20 Sand and gravel
 20- 49 Clay, dark blue-gray, pebbly (till)

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Test Hole No. 66

Location: NE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.

Surface elevation: 1611 feet

Depth to water: 5 feet

0- 3 Clay, black, silty
 3- 7 Clay, light-brown, some fine sand
 7- 46 Sand and gravel
 46- 60 Gravel and sand
 60- 70 Clay?
 70- 87 Gravel and sand
 87-104 Clay, dark blue-gray, pebbly, (till)

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Test Hole No. 67

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.

Surface elevation: 1610 feet

Depth to water: 8 feet

0- 1 Topsoil
 1- 4 Clay, black
 4- 8 Sand and gravel, some boulders
 8- 16 Gravel, some boulders
 16- 57 Sand and gravel, not too coarse
 57- 64 Gravel, coarse, well sorted
 64- 74 Clay?
 74- 97 Sand and gravel
 97-109 Clay, brownish-gray, pebbly, compact, (till)

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Test Hole No. 68

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.

Surface elevation: 1616 feet

Depth to water: 5 feet

0-	1	Topsoil
1-	7	Clay, black, sandy
7-	16	Sand, coarse
16-	19	Gravel and sand
19-	57	Sand, some gravel
57-	94	Clay, olive-brown, pebbly, (till)

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Test Hole No. 69

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.

Surface elevation: 1615 feet

Depth to water: 8 feet

0-	8	Clay, black, silty
8-	24	Sand and gravel
24-	50	Sand, coarse, fine gravel
50-	56	Gravel and sand
56-	64	Clay, dark blue-gray, pebbly, (till)

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Test Hole No. 70

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.

Surface elevation: 1615 feet

Depth to water: 8 feet

0-	8	Clay, black, silty
8-	14	Sand, gravel
14-	29	Gravel, sorted
29-	44	Sand, coarse, some gravel
44-	58	Sand, gravel
58-	69	Clay, dark-brown, pebbly, (till)

* * * *

Test Hole No. 71

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 33, T. 110 N., R. 49 W.

Surface elevation: 1635 feet

Depth to water: 18 feet

0-	18	Sand, very coarse, gravel
18-	71	Sand, very coarse, pebbles
71-	79	Clay, dark-brown, pebbly, (till)

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Test Hole No. 72

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 34, T. 110 N., R. 49 W.

Surface elevation: 1630 feet

Depth to water: 16 feet

0-	1	Topsoil
1-	6	Sand, fine to coarse
6-	16	Sand and gravel
16-	44	Sand, coarse, gravel
44-	54	Clay, dark-gray, pebbly, compact, (till)

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Test Hole No. 73

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 34, T. 110 N., R. 49 W.

Surface elevation: 1617 feet

Depth to water: 5 feet

0-	5	Clay, brown, silty
5-	9	Sand and gravel
9-	19	Sand, some gravel
19-	53	Sand, coarse, gravel
53-	64	Clay, dark blue-gray, pebbly, (till)

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Test Hole No. 74

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 34, T. 110 N., R. 49 W.

Surface elevation: 1635 feet

Depth to water: 17 feet

0-	17	Sand, coarse, gravel
17-	54	Sand, very coarse, gravel
54-	69	Clay, dark blue-gray, pebbly, (till)

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Test Hole No. 75

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 35, T. 110 N., R. 49 W.

Surface elevation: 1631 feet

Depth to water: dry

0-	1	Topsoil
1-	13	Sand and gravel
13-	19	Clay, brown, pebbly, compact, (till)

* * * *

Test Hole No. 76

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 6, T. 109 N., R. 50 W.

Surface elevation: not measured

Depth to water: 5 to 11 feet

Test Hole No. 76 (cont.)

0- 4 Roadbed
 4- 7 Silt, black
 7- 11 Sand, dark-brown, very fine, silty
 11- 35 Sand, fine to coarse, some gravel
 35- 59 Clay, dark-gray, pebbly, (till)

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Test Hole No. 77

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 6, T. 109 N., R. 50 W.

Surface elevation: 1585 feet

Depth to water: 7 feet

0- 7 Clay, black, sandy
 7- 12 Sand, fine to coarse
 12- 22 Sand, coarse, some gravel
 22- 34 Clay, dark gray-blue, some pebbles, (till)

* * * *

Test Hole No. 78

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T. 109 N., R. 50 W.

Surface elevation: 1584 feet

Depth to water: 6 feet

0- 6 Clay, black
 6- 9 Sand, black, silty
 9- 23 Sand and gravel
 23- 54 Clay, dark blue-gray, few pebbles
 54- 74 Clay, dark olive-gray, pebbly, (till)

* * * *

Test Hole No. 79 (SDGS Test Hole, 1965)

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 1, T. 109 N., R. 50 W.

Surface elevation: 1598 feet

Depth to water: approximately 6 feet

0- 3 Topsoil, black
 3- 7 Sand and gravel, light-brown to tan, silty
 7- 9 Sand and gravel, tan, some silt
 9- 18 Sand, fine to coarse, some gravel
 18- 19 Clay, light-tan, some pebbles, (till)

* * * *

Test Hole No. 80

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 1, T. 109 N., R. 50 W.

Surface elevation: 1600 feet

Depth to water: 7 feet

Test Hole No. 80 (cont.)

0- ½ Topsoil
 ½- 23 Sand and gravel
 23- 24 Clay, pebbly, (till)

* * * *

Test Hole No. 81 (SDGS test hole, 1965)

Location: SW¼SE¼SE¼SE¼ sec. 1, T. 109 N., R. 50 W.

Surface elevation: 1602 feet

Depth to water: 11 feet

0- 2 Topsoil, dark-brown
 2- 14 Sand, fine to coarse, some silt
 14- 19 Sand, fine to coarse, some gravel
 19- 29 Sand, tan to buff, coarse

* * * *

Test Hole No. 82

Location: NE¼NE¼NE¼NE¼ sec. 6, T. 109 N., R. 49 W.

Surface elevation: 1610 feet

Depth to water: 3 feet

0- 1 Topsoil
 1- 3 Sand and gravel
 3- 20 Sand, coarse, gravel
 20- 26 Clay?
 26- 33 Gravel
 33- 44 Clay, dark-brown, pebbly, (till)

* * * *

Test Hole No. 83

Location: NW¼NW¼NW¼SW¼ sec. 5, T. 109 N., R. 49 W.

Surface elevation: 1608 feet

Depth to water: 7 feet

0- 1 Topsoil
 1- 7 Sand and gravel
 7- 67 Gravel and sand
 67- 79 Clay, dark-gray, pebbly, (till)

* * * *

Test Hole No. 84

Location: NW¼NW¼NW¼NW¼ sec. 4, T. 109 N., R. 49 W.

Surface elevation: 1612 feet

Depth to water: 7 feet

Test Hole No. 84 (cont.)

0-	5	Clay, black, silty
5-	7	Sand, brown, fine
7-	9	Sand, coarse, some gravel
9-	45	Gravel, coarse
45-	59	Clay, dark blue-gray, pebbly, (till)

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Test Hole No. 85

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 109 N., R. 49 W.

Surface elevation: 1615 feet

Depth to water: 6 feet

0-	1	Topsoil
1-	6	Sand and gravel
6-	10	Sand, fine to coarse
10-	67	Sand and gravel
67-	79	Clay, light-gray, pebbly, compact, (till)

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Test Hole No. 86

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 4, T. 109 N., R. 49 W.

Surface elevation: 1612 feet

Depth to water: 8 feet

0-	1	Topsoil
1-	3	Clay, black
3-	8	Sand and gravel
8-	60	Sand, coarse, gravel, some boulders
60-	95	Clay, dark-blue gray, pebbly, compact, (till)

* * * *

Test Hole No. 87

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 3, T. 109 N., R. 49 W.

Surface elevation: 1620 feet

Depth to water: 8 feet

0-	14	Sand and gravel
14-	24	Clay, dark-gray, pebbly, compact, (till)

* * * *

Test Hole No. 88

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 2, T. 109 N., R. 49 W.

Surface elevation: 1615 feet

Depth to water: 8 feet

Test Hole No. 88 (cont.)

0-	5	Roadbed
5-	8	Clay, black
8-	14	Sand and gravel
14-	29	Sand, fine
29-	48	Sand and gravel
48-	59	Clay, dark-gray, pebbly, compact, (till)

* * * *

Test Hole No. 89

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 8, T. 109 N., R. 50 W.

Surface elevation: 1590 feet

Depth to water: 5 feet

0-	1	Topsoil
1-	7	Sand and gravel
7-	26	Sand, coarse, some gravel
26-	39	Clay, light-gray, pebbly, (till)

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Test Hole No. 90

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 9, T. 109 N., R. 50 W.

Surface elevation: 1585 feet

Depth to water: 3 feet

0-	3	Clay, black, sandy
3-	7	Sand, fine to coarse
7-	21	Sand and gravel
21-	34	Clay, dark gray-blue, pebbly, (till)

* * * *

Test Hole No. 91

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 10, T. 109 N., R. 51 W.

Surface elevation: 1580 feet

Depth to water: 3 feet

0-	3	Sand and gravel
3-	20	Sand, coarse, some gravel
20-	69	Clay, dark brownish-gray, pebbly, (till)

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Test Hole No. 92

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 11, T. 109 N., R. 50 W.

Surface elevation: 1590 feet

Depth to water: 8 feet

Test Hole No. 92 (cont.)

0- 8	Sand, fine, some gravel
8- 25	Sand and gravel
25- 52	Gravel
52- 64	Clay, dark, pebbly, (till)

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Test Hole No. 93

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 12, T. 109 N., R. 50 W.

Surface elevation: 1599 feet

Depth to water: 7 feet

0- 2	Clay, black, silty
2- 7	Sand and gravel
7- 70	Gravel and sand
70- 83	Gravel
83- 94	Clay, dark-gray, pebbly, (till)

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Test Hole No. 94

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 7, T. 109 N., R. 49 W.

Surface elevation: 1605 feet

Depth to water: 9 feet

0- 24	Sand and gravel
24- 76	Sand, coarse, some gravel
76- 84	Sand and gravel
84- 94	Clay, dark blue-gray, pebbly, (till)

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Test Hole No. 95

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 8, T. 109 N., R. 49 W.

Surface elevation: 1605 feet

Depth to water: 7 feet

0- 1	Topsoil
1- 53	Sand and gravel
53- 73	Gravel and sand
73- 84	Clay, gray, pebbly, compact, (till)

* * * *

Test Hole No. 96

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 10, T. 109 N., R. 49 W.

Surface elevation: 1607 feet

Depth to water: 7 feet

Test Hole No. 96 (cont.)

0-	1	Topsoil
1-	3	Clay, black, silty
3-	7	Sand and gravel
7-	65	Sand and gravel, coarse, some boulders
65-	79	Clay, dark gray-blue, pebbly, (till)

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Test Hole No. 97

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 11, T. 109 N., R. 49 W.

Surface elevation: 1608 feet

Depth to water: 6 feet

0-	5	Clay, black
5-	12	Sand, fine to coarse, some gravel
12-	28	Sand, brown, fine
28-	52	Sand and gravel
52-	53	Clay, brown, pebbly
53-		Boulder, could not penetrate

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Test Hole No. 98

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 18, T. 109 N., R. 50 W.

Surface elevation: not measured

Depth to water: 6 feet

0-	1	Topsoil
1-	6	Sand and gravel
6-	13	Sand and gravel, well sorted
13-	33	Sand, coarse, some gravel
33-	49	Clay, dark-gray, pebbly, compact, (till)

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Test Hole No. 99

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T. 109 N., R. 50 W.

Surface elevation: 1580 feet

Depth to water: 3 feet

0-	1	Topsoil
1-	7	Sand, black, silty, coarse to fine
7-	23	Sand, coarse to fine
23-	44	Clay, dark-gray, some pebbles, (till)

* * * *

Test Hole No. 100

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 15, T. 109 N., R. 50 W.

Surface elevation: 1581 feet

Depth to water: 3 feet

Test Hole No. 100 (cont.)

0-	1	Topsoil
1-	3	Sand and gravel
3-	12	Sand, fine to coarse, some gravel
12-	24	Clay, dark-gray, pebbly, (till)

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Test Hole No. 101

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 14, T. 109 N., R. 50 W.

Surface elevation: 1592 feet

Depth to water: 6 feet

0-	1	Topsoil
1-	22	Sand and gravel
22-	68	Gravel and sand
68-	79	Clay, dark blue-gray, few pebbles, (till)

* * * *

Test Hole No. 102

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 109 N., R. 49 W.

Surface elevation: 1586 feet

Depth to water: 6 feet

0-	1	Topsoil
1-	6	Sand and gravel
6-	22	Sand, coarse, some gravel
22-	40	Sand, fine to coarse
40-	51	Sand and gravel
51-	57	Clay
57-	83	Sand, coarse, gravel
83-	94	Clay, dark-gray, pebbly, (till)

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Test Hole No. 103

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 18, T. 109 N., R. 49 W.

Surface elevation: 1591 feet

Depth to water: 7 feet

0-	7	Sand, silty, fine
7-	43	Sand and gravel
43-	72	Gravel, coarse
72-	84	Clay, dark-brown, pebbly, (till)

* * * *

Test Hole No. 104

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 16, T. 109 N., R. 49 W.

Surface elevation: 1601 feet

Depth to water: 7 feet

0-	1	Topsoil
1-	5	Clay, dark-brown, silty
5-	7	Sand, fine to coarse
7-	14	Sand and gravel
14-	33	Sand, brown, fine, well sorted
33-	39	Clay, brown, sandy
39-	49	Clay, brownish-gray to dark-gray, compact, (till)

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Test Hole No. 105

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 23, T. 109 N., R. 50 W.

Surface elevation: 1575 feet

Depth to water: 5 feet

0-	5	Clay, black, sandy
5-	22	Sand and gravel
22-	44	Sand, coarse, gravel
44-	53	Sand, fine
53-	65	Clay
65-	72	Sand and gravel
72-	79	Clay
79-	83	Gravel
83-	94	Clay, dark-olive, pebbly, (till)

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Test Hole No. 106

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 26, T. 109 N., R. 50 W.

Surface elevation: 1576 feet

Depth to water: 6 feet

0-	1	Topsoil
1-	13	Sand and gravel
13-	24	Clay, dark olive-brown, pebbly, (till)

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Test Hole No. 107

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 25, T. 109 N., R. 49 W.

Surface elevation: 1585 feet

Depth to water: 6 feet

0-	6	Sand and gravel
6-	18	Sand, coarse, gravel
18-	29	Clay, dark-gray, pebbly, (till)

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APPENDIX B

Well Records in the Brookings Area

Source: 0, surface outwash; Ob, buried sand lenses
and outwash

Use: D, domestic; S, stock; I, irrigation

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
VanderWal, A.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 111 N., R. 51 W.	39	30	Ob	D,S
VanderWal, A.	SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 35, T. 111 N., R. 51 W.	102	26	Ob	I
Howard, D.	SE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 5, T. 110 N., R. 49 W.	22	12	0	D,S
Barnett, R.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 110 N., R. 49 W.	50	10	0	I
Barnett, L.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 110 N., R. 49 W.	60			S
Barnett, L.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 110 N., R. 49 W.	30			D
Sanderson, D.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 23, T. 110 N., R. 49 W.	48	33	P	D,S
Hemmer, C.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 27, T. 110 N., R. 49 W.	60		0	D,S
Lievan, W.	SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 27, T. 110 N., R. 49 W.	28	28		D
Gilkerson, D.	SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 29, T. 110 N., R. 49 W.	22	7	0	I
Gilkerson, D.	NE $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 29, T. 110 N., R. 49 W.	13	6	0	D
Mayland, N.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T. 110 N., R. 49 W.	60		Ob	D
Dewitt, J.	SE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 110 N., R. 49 W.	435	80-90	Ob	S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Dewitt, J.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 110 N., R. 49 W.	50	30	Ob	D
Freyberg, C.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32 T. 110 N., R. 49 W.	12	8	0	D
Freyberg, C.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.	12	7	0	S
Knight, W.	SW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.	24?	7	0	none
Zakrezewski, R.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 32, T. 110 N., R. 49 W.	20	6	0	D
Jensen, N.	SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 33, T. 110 N., R. 49 W.	14		0	D
Whitehead, G.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 34, T. 110 N., R. 49 W.	60	12	0	I
Justice, A.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 1, T. 110 N., R. 50 W.	70			D,S
Larson, D.	NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 110 N., R. 50 W.	24	16	0	D,S
Knutson, K.	SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 20 T. 110 N., R. 50 W.	12	8	0	D,S
Green, M.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 20 T. 110 N., R. 50 W.	12		0	D,S
McCrackan, B.	SE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 23, T. 110 N., R. 50 W.	25		0	D
McCrackan, B.	SE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 23 T. 110 N., R. 50 W.	22		0	S
Janssen, V.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 110 N., R. 50 W.	400			D
Doop, R.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 110 N., R. 50 W.	15		Ob	D,S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Flittie, R.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 35 T. 110 N., R. 50 W.	200		Ob	D,S
City of Volga	SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 23 T. 110 N., R. 51 W.	26	10	0	City
Karlstad, M.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 25 T. 110 N., R. 51 W.	18		0	D,S
Collins, B.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 3, T. 109 N., R. 49 W.	20	10	0	D,S
Biggar, J.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 109 N., R. 49 W.	12	7	0	D
Nelson, K.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 2, T. 109 N., R. 50 W.	90		Ob	D
Opland, K.	SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 3, T. 109 N., R. 50 W.	10	8	0	D,S
Shelden, H.	SE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T. 109 N., R. 50 W.	15		0	D,S
Vockrodt, L.	NE $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 13, T. 109 N., R. 50 W.	11	5	0	D,S
Vawser, A.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 14, T. 109 N., R. 50 W.		6	0	D,S
S.D.S.U.	SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 15, T. 109 N., R. 50 W.	about 35	7	0	I
Berkland, N.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 109 N., R. 50 W.	20		0	D,S
Ponto, A.	SE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 23 T. 109 N., R. 50 W.	11	6	0	D,S
Craddock, R.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 24, T. 109 N., R. 50 W.	12	6	0	D,S
Telkamp, L.	SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 24, T. 109 N., R. 50 W.	17	12	0	D,S