STATE OF SOUTH DAKOTA
Richard F. Kneip, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 47

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

by

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1972

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INTRODUCTION

Present Investigation

This report contains the results of a special ground-water investigation conducted by the South Dakota Geological Survey from July 25 to August 16, 1968, in and around the city of Howard, Miner County, South Dakota (fig. 1). The purpose of this investigation was to assist the city in locating an additional water supply.

In the spring of 1968 pumpage from three municipal wells located within the city limits could not adequately satisfy the demands for water; consequently, the city hired Minnehaha Waters to drill a new well. A well was drilled north of Highway 34 within the city limits and a layer of gravel approximately 20 feet thick was penetrated at a depth of 175 feet. Following this, the South Dakota Geological Survey installed an observation well 75 feet east of the well to test the aquifer as a potential water supply. On June 18, 1968, a pump test was conducted at a rate of 180 gallons per minute for 24 hours. After finding favorable results, the well was completed and water from the well has been used since the installation of a pump.

In addition to the pump test this study included (1) the mapping of the geology of 72 square miles, (2) the drilling of 29 rotary and 62 auger test holes, (3) the surveying of the elevation of rotary test holes, (4) a well inventory, and (5) a collection and analyses of 18 water samples.

Results from the investigation indicate that the city could obtain additional water from a buried sand and gravel deposits approximately 170 feet below the land surface. Other shallow and deep potential sources of water have also been found, which require additional testing.

Cooperation of the residents of Howard, especially former Mayor R. D. Sherman, Ray Callanan, former General Superintendent of Municipal Utilities, and Bernard Mengenhausen, Water Superintendent, was greatly appreciated. Assistance of the Minnehaha Water Co. during the pump test, and of the State Chemical Laboratory for analyzing the water samples is acknowledged.

The project was financed by the South Dakota Geological Survey, East Dakota Conservancy Sub-District, and the city of Howard.

Location and Extent of Area

The Howard area as used in this report includes a region that measures nine miles north-south and eight miles east-west. The city lies within the James Basin, a part of the Central Lowlands physiographic province (fig. 1).

GENERAL GEOLOGY

Surficial Deposits

Surficial deposits of the Howard area are chiefly the results of glaciation late in the Pleistocene Epoch of geologic time. Glacial deposits are collectively called drift, and are divided into till and outwash deposits. Till consists of a heterogeneous mixture of boulders, pebbles and sand in a matrix of clay directly deposited by the ice. Outwash material, on the other hand, is a sorted deposit consisting of mostly sand and gravel with minor amounts of clay deposited by meltwater streams issuing from the ice. The thickness of the glacial drift is approximately 200 feet in this area. Alluvium is deposited in the present streams (fig. 2). Alluvium consists of silt, clay and small amounts of sand and gravel.

Subsurface Bedrock

Beneath the glacial deposits lie sedimentary rocks of Cretaceous age. In the Howard area these

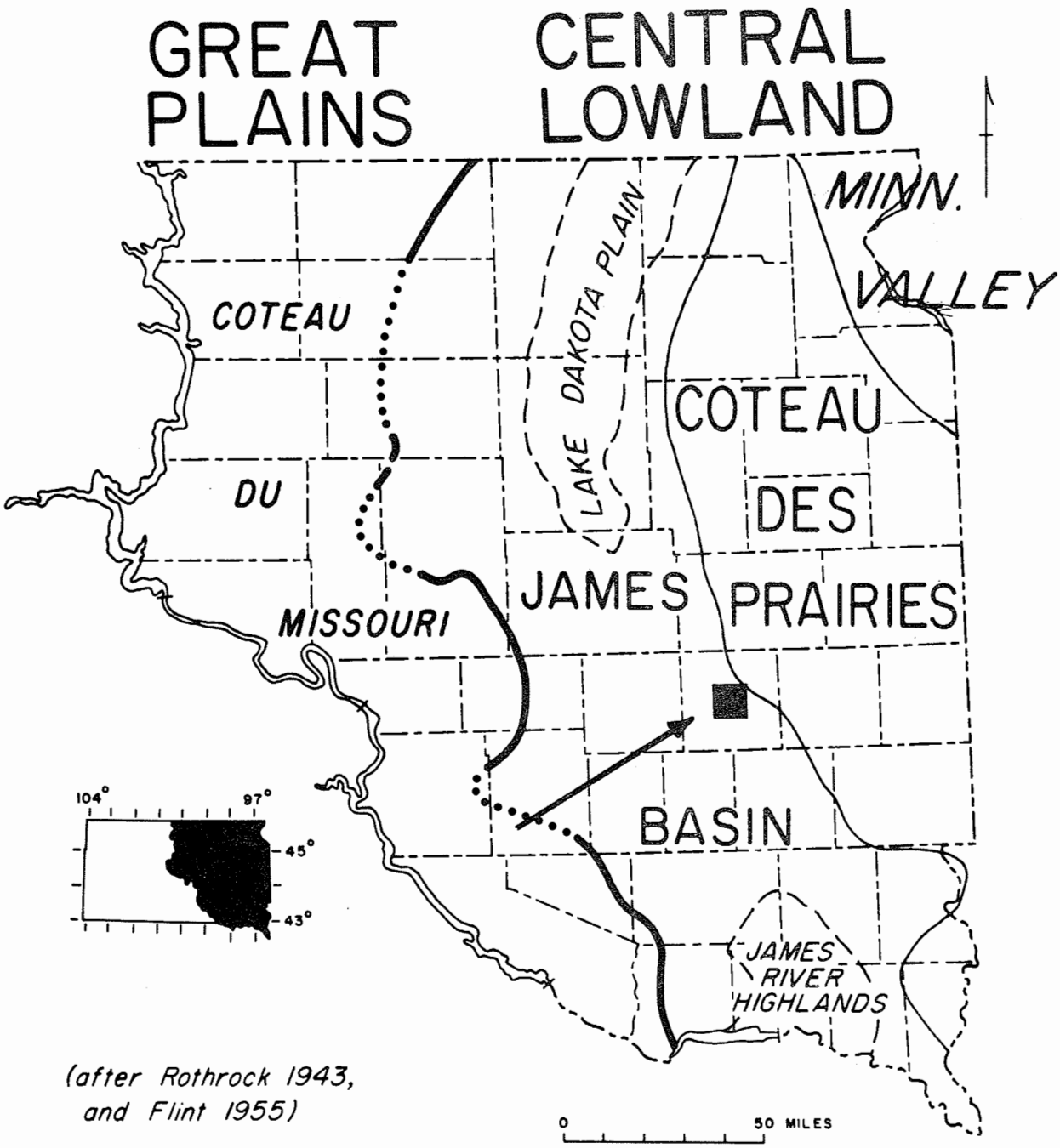


Figure 1. Major physiographic divisions of eastern South Dakota and location of the Howard area.

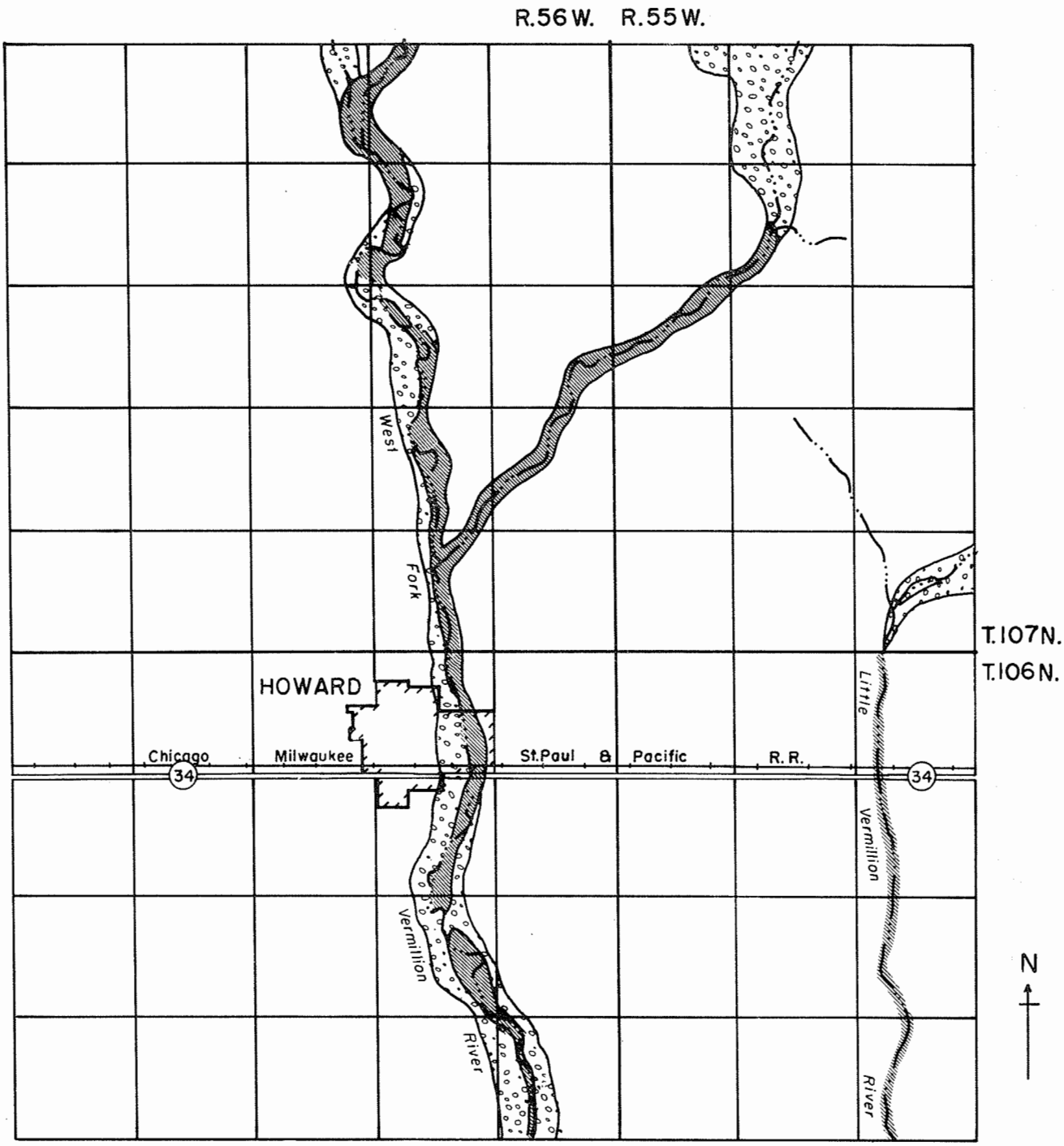


Figure 2. Generalized geologic map of the Howard area.

rock formations in descending order are: Pierre Shale, Niobrara Marl, and Carlile Shale.

The Pierre consists of dark-gray noncalcareous shale. Although this formation was penetrated by most of the deep test holes in the area, it was not present in the new well field nor was it indicated in the log of the well drilled next to the standpipe.

The Niobrara consists of light-to dark-gray marl or chalk. It is up to 90 feet thick, and is located at a depth of approximately 200 feet below the surface.

The Carlile consists of medium-to dark-gray bentonitic shale interbedded with silt or sand layers.

The well inventory from northwest of the study area indicates that the Dakota Formation consisting mostly of sandstone is present, but more information is needed to identify the depth and the thickness of this formation.

The Sioux Quartzite which consists predominantly of fine grains of iron-coated quartz cemented with silica. The "Wash" which consists of a mixture of sand-to pebble-size fragments of Sioux Quartzite is present above the cemented quartzite (Jorgensen, 1960). This formation is at a depth of approximately 400 feet below the city. The well inventory from northwest of the study area indicates that it is deeper than 1,000 feet.

GROUND WATER

Principles of Occurrence

Ground water is defined as 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 which is under atmospheric pressure. Practically all open spaces in the rocks that lie below 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 by molecular attraction, or is moving downward toward the zone of saturation. Water within the ground above the saturated zone moves downward under the influence of gravity, whereas in the saturated zone, it moves in a direction determined by the 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 ground water is derived from precipitation in the form of rain, melting snow, or ice. This water either evaporates, 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 (a formation having structures that permit appreciable water to move through it under ordinary field conditions), and is accomplished in four main ways: (1) by 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 into the area, 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 out of the area, and (4) by pumping from wells, which constitutes the major artifical discharge of ground water.

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. 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 little or no effect on porosity if all other factors are equal.

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 found along the West Fork of the Vermillion River and small amount along the Little Vermillion River (fig. 2). Because of high clay and silt content the alluvium does not readily yield large volumes of water. It should not be considered as a water source for the city.

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; whereas, outwash deposits generally do exhibit good permeability and therefore if they are extensive enough make good aquifers.

Surface outwash, found along present streams (fig. 2), and buried outwash are present in the Howard area. Thickness of saturated surface sand and gravel outwash is shown on figure 3. Buried sand lenses and outwash were penetrated at varying depths by test holes in this area. Figure 4 shows the elevations of the test hole sites, depth to each layer of sand and gravel, and the thickness of each sand and gravel deposit. Because of rapid changes in the thickness of these deposits and the varying depths to each layer contours are not shown.

Ground Water in Bedrock

Sandstones of the Dakota Formation, where they are present, yield water to artesian wells in most parts of the State. Artesian wells which have higher hydraulic head than the ground surface produces flowing wells. Well inventory from the area indicates that the Dakota Formation is present 4 miles north of the city; however, well logs from within the city indicate that the Dakota Formation is absent beneath the city. More information is required to define the areal extent and water yielding capacity of this aquifer in the Howard area.

The "Wash" which is a porous and permeable deposit overlies the Sioux Quartzite. Some of the city wells produce water from the "Wash" and quartzite which are hydraulically connected.

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 rocks below the water table where the water is moving. In general, the more chemical substances that a water contains, the poorer its quality.

Table 1 shows the chemical analyses of water samples collected from the Howard area (for location of samples, see fig. 5).

Samples W-1, W-2, W-5, W-8, W-17, and W-18 were collected from the surface outwash in the area. Samples W-2, W-17, and W-18 have higher sulfate; samples W-17 and W-18 have high iron content; and sample W-1 has higher nitrogen than the recommended limits. Except for total solids in sample W-5, all samples in this group have higher total solids and manganese and less fluoride content than the recommended limits set by the South Dakota Department of Health.

Samples W-11 to W-16 were collected in different periods from the new city well which obtains water from the buried outwash. All samples in this group have higher sulfate, manganese,

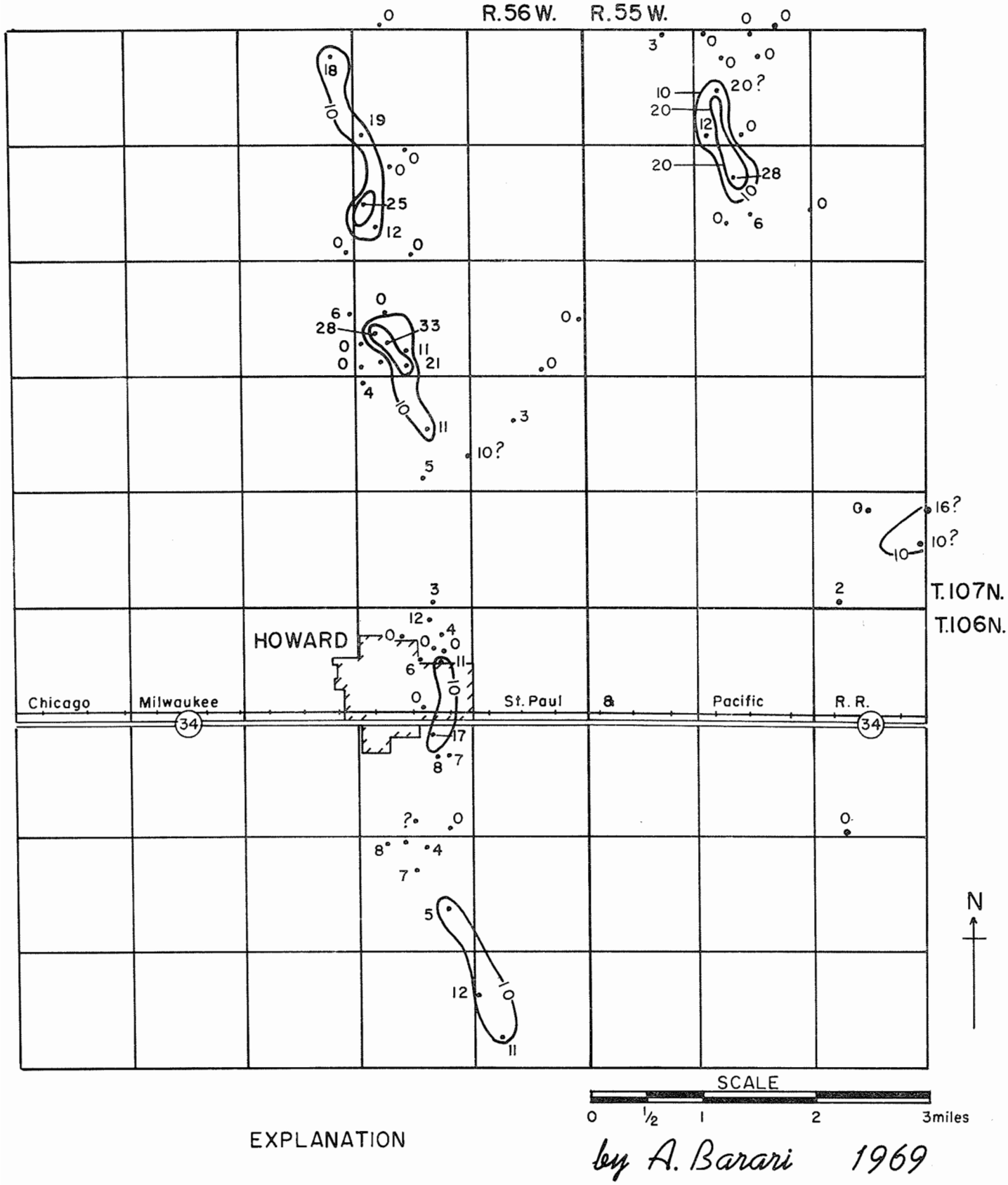
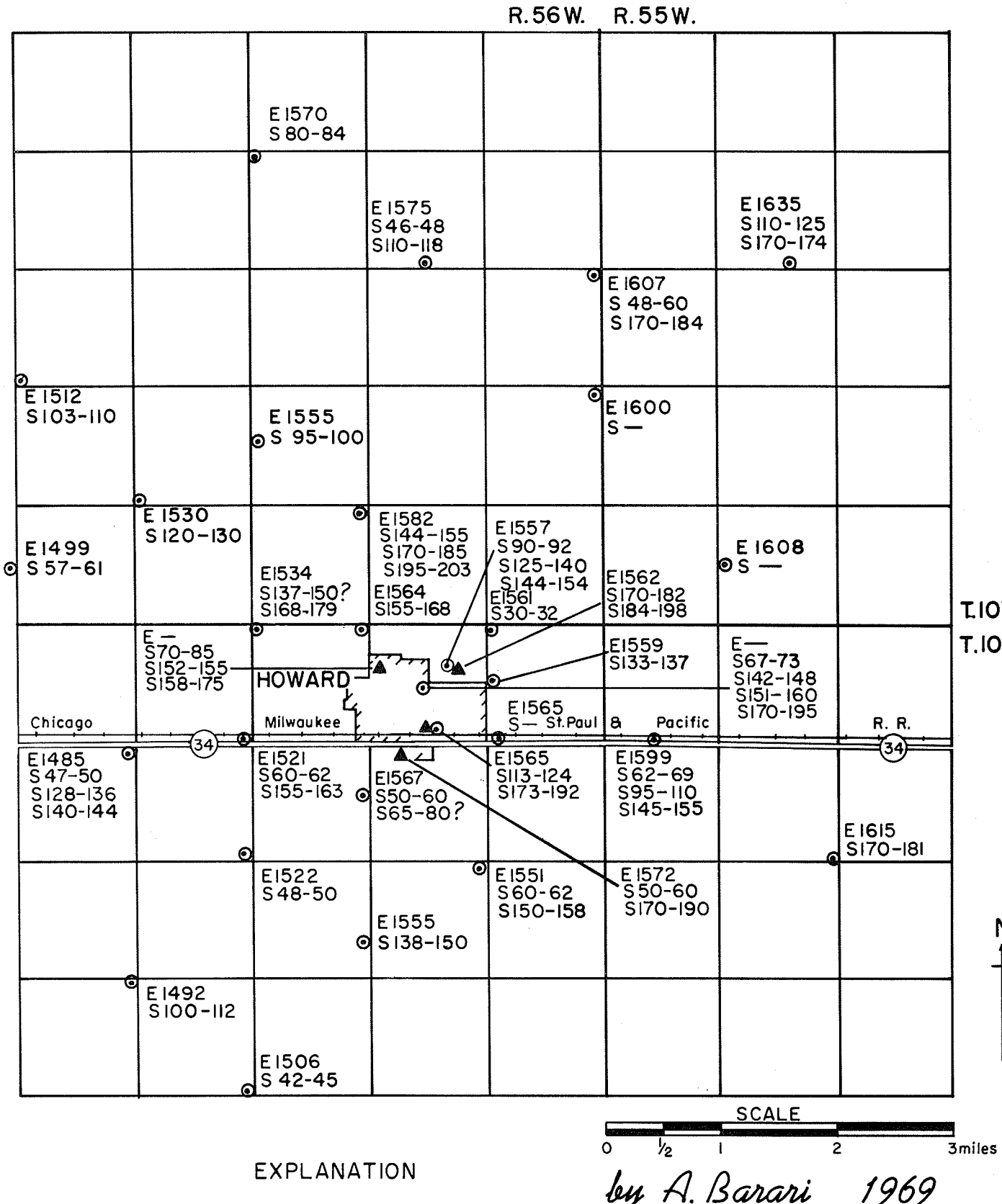


Figure 3. Map showing the thickness of saturated surface and shallow sand and gravel along the present streams in the Howard area.



EXPLANATION

by A. Barari 1969

⊙ E = Elevation
S 110-125 = Sand from depth of 110 to 125 feet. Test hole drilled by S. D. G. S. Rotary rig

▲ E – S similar data as above. Test hole or well drilled by drilling companies.

Figure 4. Map showing thickness of saturated buried sand and gravel in the Howard area.

Table 1. - Chemical analyses of water samples from the Howard area

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A					250	500[1]	0.3	0.05	10 [1]	0.9[2]– 1.7			1000[1]
W-1	S	376		91	94	475	0.01	3	60.5	0.60	7.4	1065	1365
W-2	S	208		106	42	670	0.12	0.7	0	0.40	7.5	960	1250
W-5	S	200		49	32	332	0.11		10.0	0.24	7.5	700	940
W-8	S	192		75	76	462	0		8.25	0.43	7.6	790	1220
W-17	S	256		122	440	1500	0.75	2.8	0		7.6	1140	3000
W-18	S	252		46	0	600	1.5	0.6	0		7.2	820	1015
W-11	B	171	254	28	22	1008	0.1	1.28	4	0.8	7.2	542	1946
W-12	B	178		37	22	1010		1.6	0.4			598	1872
W-13	B	164	310	41	20	1016	0.3	1.6	16	0.8		576	1914
W-14	B	166	303	47	18	1008	0.7	1.82	22	0.8		608	1830
W-15	B	172	300	51	19	1070	2.3	1.7		0.6		640	1908
W-16	N	268		44	24	1320	4.85	0	0	1.90	7.3	850	2180
W-3	D	12		0	59	619	0.92	0	0	1.65	8.3	30	1473
W-4	D	30		8	222	937	3.68	0	0	6.50	7.7	110	2470
W-6	D	30		2	234	950	4.90	0	0	5.75	8.2	85	2560
W-7	Q	196		37.5	135	1050	0.11				7.3	640	2030
W-9	Q	203	255	46	124	1125	0.87	0	14	3		695	2116
W-10	Q	179	256	50	109	1072	4.1	0.12	1	3		651	2090

[1] Modified for South Dakota by Department of Health (Written Communication Water Sanitation Section, March 20, 1968).

[2] 1.2 is optimum for South Dakota. Samples W-11, W-13, W-14, and W-15 were analyzed by the South Dakota Chemical Laboratory. All other samples were analyzed by the South Dakota Geological Survey.

Source S – Surface outwash
B – Buried sand lenses and outwash
N – Niobrara Marl
Q – Sioux Quartzite
D – Dakota Formation

Location of Water Samples
in the Howard area

(For map location, see fig. 5.)

A Drinking water standards, U. S. Public Health Service, (1962)

W- 1 NW¼NW¼NW¼NW¼ sec. 8, T. 107 N., R. 55 W., A. Bergheim, 19 feet deep, water table 3 feet

W- 2 SE¼SW¼SW¼SW¼ sec. 8, T. 107 N., R. 55 W., H. Hegdahl, 24 feet deep, water table 17 feet

W- 3 SW¼NW¼NW¼NW¼ sec. 14, T. 107 N., R. 56 W., A. Sherman, 586? feet deep, water table 400? feet

W- 4 NE¼NE¼NE¼NE¼ sec. 14, T. 107 N., R. 56 W., E. Hauge, 1,000 feet deep

W- 5 SW¼NW¼SE¼NW¼ sec. 17, T. 107 N., R. 55 W., L. Eide, 20 feet deep

W- 6 SE¼SE¼NE¼NE¼ sec. 22, T. 107 N., R. 56 W., F. Collin, 800 feet deep

W- 7 NE¼NE¼ sec. 3, T. 106 N., R. 56 W., City well, 575 feet deep

W- 8 NE¼SE¼SW¼NE¼ sec. 2, T. 106 N., R. 56 W., 18 feet deep

W- 9 SW¼NE¼ sec. 2, T. 106 N., R. 56 W., City Well (golf course), 412 feet deep

W-10 SW¼NW¼ sec. 2, T. 106 N., R. 56 W., City Well, 410 feet deep

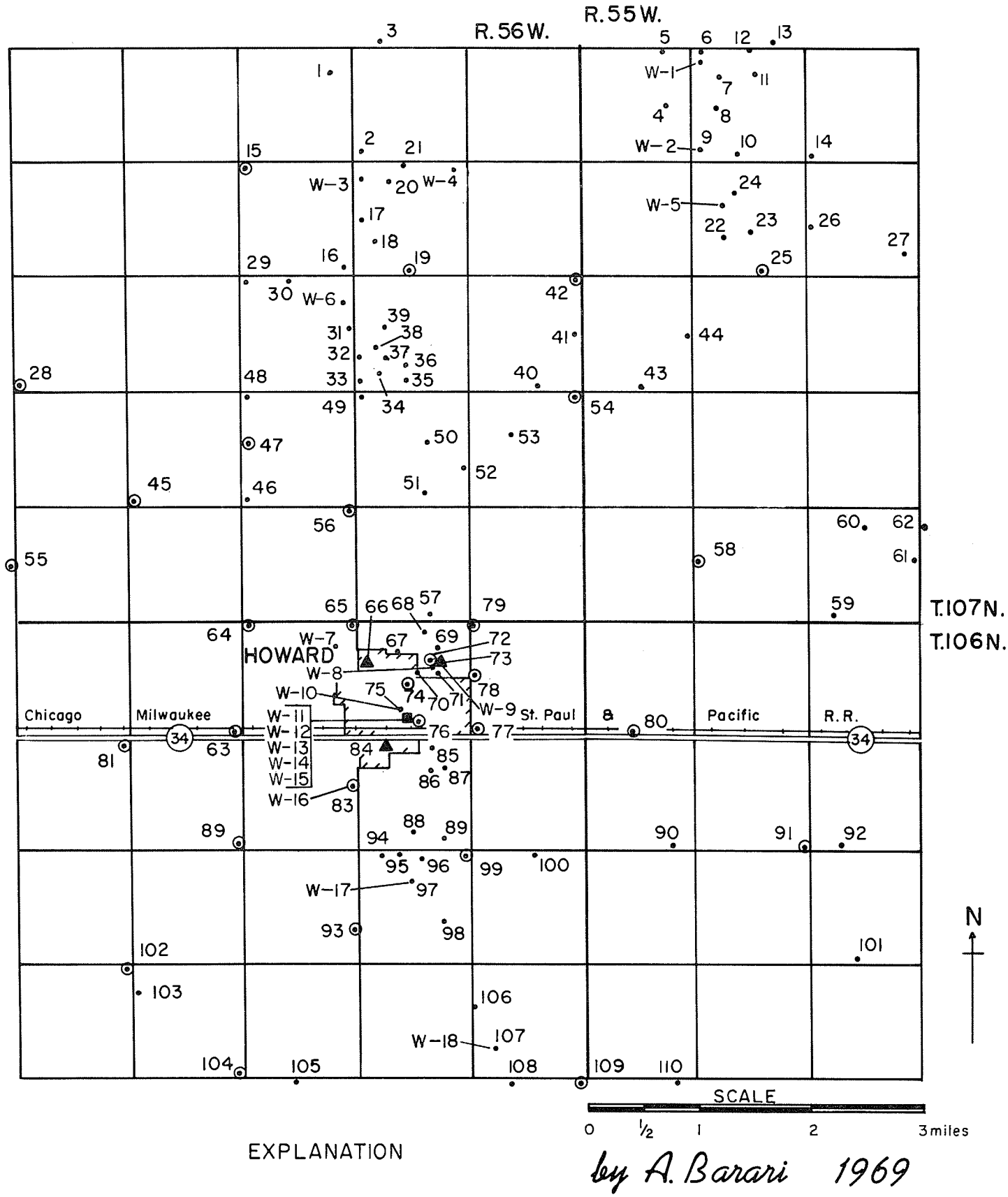
W-11, 12, 13, 14, and 15 SE¼SW¼ sec. 2, T. 106 N., R. 56 W., City new well,

- W-11 After 1½ hours pumping
- W-12 After 5 hours pumping
- W-13 September 6, 1968
- W-14 September 14, 1968
- W-15 February 12, 1970

W-16 NE¼NE¼NE¼SE¼ sec. 10, T. 106 N., R. 56 W., L. Scott, 240 feet deep

W-17 NE¼NE¼SE¼NW¼ sec. 14, T. 106 N., R. 56 W., Test hole 97, water table 7 feet

W-18 NE¼NE¼SW¼SW¼ sec. 24, T. 106 N., R. 56 W., Test hole 107, water table 8 feet



- • 44 Auger test hole
- ⊙ 56 Rotary test hole
- ▲ Test hole or well by drilling company
- ■ New city well
- •W-11 Water sample

Figure 5. Data map of the Howard area.

total solids, lower fluoride and samples W-13 and W-14 have higher nitrate (nitrate nitrogen) than the recommended limits. Also samples W-14 and W-15 have higher iron than the recommended limits. Generally water samples from the surface outwash are harder than water from other sources in the area.

Samples W-16 is from the Niobrara Marl. This sample has higher sulfate, iron, fluoride, and total solids than the recommended limits.

Samples W-3, W-4, and W-6 are from the Dakota Formation. These samples have less hardness than the rest of the samples collected in the area, but they are higher in sulfate, iron, fluoride, and the total solids than the recommended limits.

Samples W-7, W-9, and W-10 are taken from wells producing from the Sioux Quartzite. These samples have higher sulfate and total solids than the recommended limits set by the U. S. Department of Health. Also samples W-9 and W-10 have higher iron, fluoride and sample W-9 has higher nitrate (nitrate nitrogen) than the recommended limits. The quality of water samples from the Sioux Quartzite and the buried outwash are comparable.

Table 2 shows the significance of some chemical and physical properties of drinking water.

CONCLUSIONS AND RECOMMENDATIONS

There are four potential sources of water for the city of Howard. These sources are:

1. **Layers of buried glacial sand and gravel deposits.** Thickness and depth to each sand and gravel layer varies in different locations. Figure 4 shows the elevation of test hole sites and the depth and thickness of each sand layer penetrated by the drill. Beneath the city, at a depth of approximately 170 feet, there is a sand and gravel layer with an approximate thickness of 20 feet. The new city well is producing water from this sand and gravel layer. The logs from test holes and the results of the pump test indicate that this deposit will sustain additional wells with a minimum spacing of 600 feet between the wells with a pumping rate not to exceed 200 gallons per minute. Water from this deposit has lower chloride and fluoride than the water from the Sioux Quartzite, whereas the rest of the chemicals are comparable with the water from the Sioux Quartzite (table 1).

Water samples from all sources, except some samples from the surface outwash, have higher sulfate content than the limit set by the South Dakota Department of Health. Water samples W-14 and W-15 have higher iron than recommended limits. It appears that buried glacial sand and gravel deposits are the most favorable source of water for the city of Howard.

If the city should decide to drill additional wells in the buried sand and gravel, it is recommended that the well location be chosen by considering the thickness of the deposit penetrated by the test holes (fig. 4). It is also recommended that the city of Howard consult an engineering firm with regard to the cost of removing some of the chemicals from the water.

2. **Sioux Quartzite and the "Wash,"** which is located at a depth of approximately 400 feet below the city, could produce additional water similar in quality to water samples W-7, W-9, and W-10 which are from the old city well (table 1).

3. **Surface Outwash deposits** are present along the present streams in the area. Two locations where the sand has maximum thickness, could be considered; these locations are 2½ miles north of the city along the West Fork of the Vermillion River, and 5½ miles northeast of the city. No sample was collected from the first location, but samples W-1, W-2, and W-5 were collected from the second location. Samples from this surface outwash indicated a higher degree of hardness than any other source in the area. If the city decides to test this aquifer, it is recommended that they hire a well drilling company to construct a pump test well. This test should be conducted by a qualified hydrologist or engineer and run for a minimum of 72 hours.

4. **The Dakota Formation** from analyses of well inventory information indicates that the Dakota is present approximately 4 miles north and northwest of the city. Water samples W-3, W-4, and W-6 collected from this formation indicate that this water has the lowest hardness of any other water in the study area, but has higher sulfate, iron, and fluoride than the

Table 2.--Significance of some chemical and physical properties of drinking water.

Chemical Constituents	Significance	Recommended Limits (ppm)[1]
Calcium (Ca) and Magnesium (Mg)	Cause most of the carbonate hardness and scale-forming properties of water by combining with carbonate and bicarbonate present in the water. Seldom can be tasted except in extreme concentrations.	Ca—None Mg—None
Sodium (Na)	Large amounts in combination with chloride will give water a salty taste. Large amounts will limit water for irrigation and industrial use.	None
Chloride (Cl)	Large amounts in combination with sodium give water a salty taste. Large quantities will also increase corrosiveness of water.	250
Sulfate (SO_4)	Large amounts of sulfate in combination with other ions give a bitter taste to water and may act as a laxative to those not used to drinking it. Sulfates of calcium and magnesium will form hard scale. U. S. Public Health Service recommends 250 ppm maximum concentration.	500[2]
Iron (Fe) and Manganese (Mn)	In excess will stain fabrics, utensils, and fixtures and produce objectionable coloration in the water. Both constituents in excess are particularly objectionable.	Fe—0.3 Mn—0.05
Nitrogen (N)	In excess may be injurious when used in infant feeding. The U. S. Public Health Service regards 45 ppm as the safe limit of nitrate (NO_3) or 10 ppm nitrogen (N).	10
Fluoride (F)	Reduces incidence of tooth decay when optimum fluoride content is present in water consumed by children during period of tooth calcification. Excessive fluoride in water may cause mottling of enamel.	0.9-1.7[3]
pH	A measure of the hydrogen ion concentration; pH of 7.0 indicates a neutral solution, pH values lower than 7.0 indicate acidity, pH values higher than 7.0 indicate alkalinity. Alkalinity tends to aid encrustation and acidity tends to aid corrosion.	None
Hardness	Hardness equivalent to carbonate and bicarbonate is called carbonate hardness. Hardness in excess of this amount is noncarbonate hardness. Hardness in water consumes soap and forms soap curd. Will also cause scale in boilers, water heaters, and pipes. Water containing 0-60 ppm hardness considered soft; 61-120 ppm moderately hard; 121-180 ppm hard, and more than 180 ppm very hard. Good drinking water can be very hard.	None
Total Solids	Total of all dissolved constituents. U. S. Public Health Department recommends 500 ppm maximum concentration. Water containing more than 1000 ppm dissolved solids may have a noticeable taste; it may also be unsuitable for irrigation and certain industrial uses.	1000[2]

Modified from Jorgensen (1966).
[1] (ppm) parts per million.
[2] Modified for South Dakota by the South Dakota Department of Health (written communcation, Water Sanitation Section, March 20, 1968).
[3] 1.2 is optimum for South Dakota.

recommended limits. If the city should decide to test this aquifer, it is recommended that the city follow the same procedure as was recommended for testing the surface outwash.

Before a permanent well is drilled the city officials should consult with the South Dakota Water Resources Commission to obtain water rights and a permit to drill a city well, and with the South Dakota Department of Health to determine the biological and chemical suitability of the water.

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APPENDIX A

Logs of test holes and wells in the Howard area

(For map location see fig. 5.)

Test Hole 1
Location: SE¼SW¼NE¼NE¼ sec. 10, T. 107 N., R. 56 W.
Depth to water: 2 feet

0- 2	Topsoil, sandy
2- 15	Sand and gravel; some clay
15- 20	Sand and gravel; more clay
20- 74	Clay; some sand and gravel, (till)

* * * *

Test Hole 2
Location: SW¼SW¼SW¼SW¼ sec. 11, T. 107 N., R. 56 W.
Depth to water: 9 feet

0- 9	Clay, dark-brown, sandy
9- 24	Gravel and clay
24- 43	Sand; some gravel; some clay
43- 74	Clay, some pebbles, (till)

* * * *

Test Hole 3
Location: SE¼SE¼SW¼SW¼ sec. 2, T. 107 N., R. 56 W.
Depth to water: 35 feet

0- 4	Roadbed
4- 10	Clay, light-brown, sandy
10- 69	Clay, sandy; some pebbles, (till)

* * * *

Test Hole 4
Location: NW¼NW¼NE¼SE¼ sec. 7, T. 107 N., R. 55 W.
Depth to water: 16 feet

0- 3	Clay, dark-brown; some sand
3- 16	Clay, sandy
16- 28	Clay, gray; some pebbles
28- 33	Sand, gray, fine; much clay
33- 74	Clay, dark-gray; some pebbles, (till)

* * * *

Test Hole 5
Location: NW¼NW¼NE¼NE¼ sec. 7, T. 107 N., R. 55 W.
Depth to water: 13 feet

0- 1	Topsoil
1- 13	Clay, brown, sandy
13- 15	Sand, brown, coarse

Test Hole 5 -- continued.

15- 17	Clay, blue-gray, pebbly
17- 41?	Sand, coarse
41?- 74	Clay, gray, pebbly

* * * *

Test Hole 6
Location: NW¼NW¼NW¼NW¼ sec. 8, T. 107 N., R. 55 W.
Depth to water: not measured

0- 1	Topsoil
1- 5	Sand and gravel, brown
5- 45	Clay, brown grading to gray, pebbly
45- 74	Clay, gray, pebbly

* * * *

Test Hole 7
Location: NE¼NE¼SW¼NW¼ sec. 8, T. 107 N., R. 55 W.
Depth to water: not measured

0- 1	Topsoil
1- 16	Clay, light-brown; few pebbles
16- 74	Clay; some pebbles and boulders, (till)

* * * *

Test Hole 8
Location: NE¼NE¼NW¼SW¼ sec. 8, T. 107 N., R. 55 W.
Depth to water: approximately 10 feet

0- 2	Topsoil
2- 4	Clay, light-brown, sandy
4- 30?	Sand and gravel, brown
30?- 74	Clay, gray, pebbly

* * * *

Test Hole 9
Location: SE¼SW¼SW¼SW¼ sec. 8, T. 107 N., R. 55 W.
Depth to water: 8 feet

0- 1	Topsoil
1- 8	Clay, dark-brown, sandy
8- 20?	Sand, brown, coarse
20?- 53	Clay, sandy
53- 74	Clay, pebbly, (till)

* * * *

Test Hole 10
Location: SW¼SE¼SE¼SW¼ sec. 8, T. 107 N., R. 55 W.
Depth to water: 31 feet

0- 31	Clay, light-brown, sandy

Test Hole 10 -- continued.

31- 74	Clay, gray, pebbly, (till)

* * * *

Test Hole 11
Location: SW¼SW¼NW¼NE¼ sec. 8, T. 107 N., R. 55 W.
Depth to water: dry

0- 3	Topsoil
3- 15	Clay, light-brown; few pebbles
15- 74	Clay, brown to dark-gray, sandy, (till)

* * * *

Test Hole 12
Location: NE¼NE¼NE¼NW¼ sec. 8, T. 107 N., R. 55 W.
Depth to water: dry

0- 2	Topsoil
2- 74	Clay, light-brown grading to gray, pebbly

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Test Hole 13
Location: SE¼SE¼SW¼SE¼ sec. 5, T. 107 N., R. 55 W.
Depth to water: dry

0- 3	Topsoil, dark-gray
3- 13	Clay, light-brown; some pebbles, (till)
13- 65	Clay, gray; some pebbles, (till)

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Test Hole 14
Location: SW¼SW¼SW¼SW¼ sec. 9, T. 107 N., R. 55 W.
Depth to water: 5 feet

0- 1	Topsoil
1- 13	Clay, brown, pebbly
13- 46	Clay, gray, pebbly, (till)
46- 74	Clay, gray-brown, pebbly, (till)

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Test Hole 15 (Rotary Test Hole)
Location: NW¼NW¼NW¼NW¼ sec. 15, T. 107 N., R. 56 W.
Surface elevation: 1570 feet
Depth to water: not measured

0- 17	Clay, yellowish-brown, pebbly, (till)
17- 50	Clay, gray, gravelly
50- 65	Clay, very sandy and gravelly, (till)
65- 80	Clay, gray, pebbly
80- 84	Sand
84-140	Clay; gravel, (till)

Test Hole 15 -- continued.

140-155	Clay, (till)
155-170	Shale, dark-gray

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Test Hole 16
Location: SE¼SE¼SE¼SE¼ sec. 15, T. 107 N., R. 56 W.
Depth to water: 13 feet

0- 3	Gravel, brown
3- 7	Clay, dark-brown, pebbly
7- 12	Clay, gray
12- 70	Clay, dark-gray, sand, (till)

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Test Hole 17
Location: NE¼NW¼NW¼SW¼ sec. 14, T. 107 N., R. 56 W.
Depth to water: 13 feet

0- 13	Sand and gravel; much clay
13- 15	Clay, gray; gravel
15- 33	Gravel, gray; some sand
33- 40	Sand, very coarse; much clay
40- 74	Clay, dark-gray, sandy, (till)

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Test Hole 18
Location: SE¼SE¼NW¼SW¼ sec. 14, T. 107 N., R. 56 W.
Depth to water: not measured

0- 3	Topsoil
3- 6	Clay, dark-gray
6- 40	Clay, sandy
40- 52	Sand; clay
52- 74	Clay, dark-gray; few pebbles

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Test Hole 19 (Rotary Test Hole)
Location: SE¼SE¼SE¼SW¼ sec. 14, T. 107 N., R. 56 W.
Surface elevation: 1575 feet
Depth to water: not measured

0- 2	Topsoil
2- 20	Clay, yellow, pebbly
20- 46	Clay, yellow, sandy
46- 48	Gravel
48-110	Clay, gray, pebbly, (till)
110-118	Gravel; some clay stringers; some coal
118-154	Clay, very gravelly, (till)
154-170	Chalk, dark-gray

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Test Hole 20
Location: SW¼SW¼NE¼NW¼ sec. 14, T. 107 N., R. 56 W.
Depth to water: not measured

0- 1	Topsoil
1- 6	Sand and gravel, dark-brown; much clay
6- 16	Clay, brown, sandy, (till)
16- 49	Clay, dark-gray, sandy, (till)

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Test Hole 21
Location: NE¼NE¼NE¼NW¼ sec. 14, T. 107 N., R. 56 W.
Depth to water: not measured

0- 3	Topsoil
3- 25	Clay, brown, sandy
25- 74	Clay, gray, sandy, (till)

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Test Hole 22
Location: SW¼SW¼NE¼SW¼ sec. 17, T. 107 N., R. 55 W.
Depth to water: 18 feet

0- 1	Topsoil
1- 66	Clay, brown to gray, pebbly, (till)
66- 74	Clay, gray-brown; pebbles, (till)

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Test Hole 23
Location: NE¼SE¼NE¼SW¼ sec. 17, T. 107 N., R. 55 W.
Depth to water: 6 feet

0- 2	Topsoil
2- 6	Clay, dark-brown, sandy
6- 12	Sand, gray, coarse; some gravel; clay
12- 46	Clay, gray, sandy
46- 74	Clay, gray-brown, sandy

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Test Hole 24
Location: NE¼NW¼SE¼NW¼ sec. 17, T. 107 N., R. 55 W.
Depth to water: 3 feet

0- 1	Topsoil
1- 3	Clay, dark-brown, sandy
3- 31	Sand, coarse; gravel; increasing clay content toward the bottom of the interval
31- 74	Clay, gray, pebbly, (till)

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Test Hole 25 (Rotary Test Hole)
Location: SE¼SW¼SW¼SE¼ sec. 17, T. 107 N., R. 55 W.
Surface elevation: 1635 feet
Depth to water: not measured

0- 2	Topsoil
2- 6	Gravel, coarse
6- 95	Clay, gray, pebbly
95-110	Clay; gravel
110-125	Gravel, grading to gravelly till
125-170	Clay; gravel, (till)
170-174	Gravel, coarse
174-190	Clay, sandy, (till)
190-200	Chalk, dark-gray

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Test Hole 26
Location: NW¼NW¼NW¼SW¼ sec. 16, T. 107 N., R. 55 W.
Depth to water: not measured

0- 3	Roadbed
3- 15	Clay, brown; some sand
15- 74	Clay, dark-gray; some sand, (till)

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Test Hole 27
Location: NE¼NW¼SE¼SE¼ sec. 16, T. 107 N., R. 55 W.
Depth to water: not measured

0- 2	Topsoil, sandy
2- 22	Clay, dark-brown, sandy, (till)
22- 74	Clay, dark-gray, sandy, (till)

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Test Hole 28 (Rotary Test Hole)
Location: SW¼SW¼SW¼SW¼ sec. 20, T. 107 N., R. 56 W.
Surface elevation: 1512 feet
Depth to water: not measured

0- 3	Topsoil, dark-gray
3- 25	Clay, yellow, pebbly, (till)
25-103	Clay, gray, pebbly, (till)
103-110	Sand and gravel
110-112	Clay, gray, very sandy
112-180	Clay, dark-gray, (shale)
180-185	Chalk, dark-gray

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Test Hole 29
Location: NW¼NW¼NW¼NW¼ sec. 22, T. 107 N., R. 56 W.
Depth to water: 30 feet

0- 1	Topsoil

Test Hole 29 -- continued.

1- 37	Clay, light-brown, sand; some pebbles
37- 48	Clay, gray, pebbly

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Test Hole 30
Location: NE¼NE¼NE¼NW¼ sec. 22, T. 107 N., R. 56 W.
Depth to water: 26 feet

0- 2	Topsoil
2- 13	Clay, light-brown
13- 26	Clay, dark-brown, (till)
26- 66	Clay, dark-brown, sandy, (till)

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Test Hole 31
Location: SE¼SE¼SE¼NE¼ sec. 22, T. 107 N., R. 56 W.
Depth to water: 35? feet

0- 2	Topsoil
2- 38	Clay, brown grading to gray, sandy, (till)
38- 41	Gravel; clay
41- 89	Clay, gray; some gravel, (till)

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Test Hole 32 (S.D.G.S. Test Hole, 1959)
Location: NW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Surface elevation: 1622 feet
Depth to water: not measured

0- 24	Clay, brown

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Test Hole 33 (S.D.G.S. Test Hole, 1959)
Location: SW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Surface elevation: 1585 feet
Depth to water: not measured

0- 36	Clay, brown

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Test Hole 34 (S.D.G.S. Test Hole, 1959)
Location: SW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Surface elevation: 1573 feet
Depth to water: not measured

0- 5	Clay, brown
5- 9	Gravel and clay
9- 29	Clay, gray; pebbles

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Test Hole 35
Location: NE¼SE¼SE¼SW¼ sec. 23, T. 107 N., R. 56 W.
Depth to water: 11 feet

0-	3	Topsoil
3-	6	Clay, dark-brown
6-	14	Sand and gravel; some clay
14-	32	Gravel and sand, brownish-gray; some clay
32-	74	Clay, dark-gray, sandy, (till)

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Test Hole 36 (S.D.G.S. Test Hole, 1959)
Location: NE¼SW¼ sec. 23, T. 107 N., R. 56 W.
Surface elevation: 1558 feet
Depth to water: 8 feet

0-	15	Clay, dark-gray
15-	19	Gravel and clay
19-	50	Clay and pebbles

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Test Hole 37 (S.D.G.S. Test Hole, 1959)
Location: NW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Surface elevation: 1567 feet
Depth to water: 10 feet

0-	2	Clay, dark-gray
2-	11	Gravel and sand
11-	21	Clay, medium gray; pebbles
21-	49	Sand, fine to medium
49-	54	Sand, fine-medium; clay
54-	64	Clay; sand, fine

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Test Hole 38 (S.D.G.S. Test Hole, 1959)
Location: NW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Surface elevation: 1568 feet
Depth to water: 13 feet

0-	3	Clay, dark-gray
3-	11	Gravel
11-	17	Clay and gravel
17-	44	Sand, medium
44-	64	Sand and clay

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Test Hole 39 (S.D.G.S. Test Hole, 1959)
Location: SE¼NW¼ sec. 23, T. 107 N., R. 56 W.
Surface elevation: 1559 feet
Depth to water: 12 feet

0-	4	Clay, dark-gray; pebbles
4-	5	Clay and gravel

Test Hole 39 -- continued.

5- 9	Clay; sand, coarse
9- 49	Clay

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Test Hole 40
Location: SW¼SE¼SW¼SE¼ sec. 24, T. 107 N., R. 56 W.
Depth to water: not measured

0- 1	Topsoil
1- 7	Clay, dark-brown
7- 54	Clay, gray, pebbly, (till)

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Test Hole 41
Location: NE¼NE¼NE¼SE¼ sec. 24, T. 107 N., R. 56 W.
Depth to water: 31 feet

0- 1	Topsoil
1- 7	Clay, light-brown; some pebbles
7- 74	Clay, dark-gray, sandy, (till)

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Test Hole 42 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 24, T. 107 N., R. 56 W.
Surface elevation: 1607 feet
Depth to water: not measured

0- 24	Clay, yellow, pebbly
24- 48	Clay, gray, pebbly, (till)
48- 60	Sand, coarse
60-170	Clay; gravel, (till)
170-184	Gravel, coarse
184-200?	Clay; gravel, (till)
200?-215	Shale, dark-gray

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Test Hole 43
Location: SW¼SW¼SW¼SE¼ sec. 19, T. 107 N., R. 55 W.
Depth to water: not measured

0- 30	Clay, brown, grading to gray; some pebbles
30- 74	Clay, dark-gray; pebbles, (till)

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Test Hole 44
Location: NE¼NE¼NE¼SE¼ sec. 19, T. 107 N., R. 55 W.
Depth to water: not measured

0- 2	Topsoil
2- 36	Clay, dark-brown, sandy

Test Hole 44 – continued.

36- 74	Clay, dark-gray, sandy, (till)

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Test Hole 45 (Rotary Test Hole)
Location: SW¼SW¼SW¼SW¼ sec. 28, T. 107 N., R. 56 W.
Surface elevation: 1530 feet
Depth to water: not measured

0- 35	Clay, yellow, pebbly
35-120	Clay, gray, sandy
120-130	Gravel, coarse, well sorted
130-155	Shale, dark-gray

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Test Hole 46
Location: SW¼SW¼SW¼SW¼ sec. 27, T. 107 N., R. 56 W.
Depth to water: not measured

0- 2	Topsoil
2- 16	Clay, pebbly
16- 28	Clay, gravelly
28- 74	Clay, dark-gray, sandy and gravelly

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Test Hole 47 (Rotary Test Hole)
Location: SW¼SW¼SW¼NW¼ sec. 27, T. 107 N., R. 56 W.
Surface elevation: 1555 feet
Depth to water: not measured

0- 25	Clay, yellow, pebbly
25- 28	Gravel and sand
28- 32	Clay, dark-brown
32- 95	Clay, gray, sandy
95-100	Gravel, coarse
100-129	Clay, gray, sandy
129-	Boulder
129-155	Shale, dark-gray

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Test Hole 48
Location: NW¼NW¼NW¼NW¼ sec. 27, T. 107 N., R. 56 W.
Depth to water: 30 feet

0- 3	Topsoil
3- 18	Clay, dark-brown, pebbly
18- 43	Clay, dark-gray, sandy
43- 52	Sand, dark-gray, fine
52- 79	Clay, dark-gray, gravelly

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Test Hole 49
Location: NW¼NW¼NW¼NW¼ sec. 26, T. 107 N., R. 56 W.
Depth to water: 25 feet

0- 2	Topsoil
2- 14	Clay, light-brown, pebbly
14- 25	Clay, pebbly
25- 29	Sand and gravel
29- 54	Clay, dark-brown grading to deep-gray, sandy

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Test Hole 50
Location: SW¼SE¼SW¼NE¼ sec. 26, T. 107 N., R. 56 W.
Depth to water: 28 feet

0- 2	Topsoil
2- 28	Clay, red-brown, sandy
28- 47	Clay, light-brown, sandy
47- 58	Sand, light-brown, coarse
58- 79	Clay, dark-gray, pebbly

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Test Hole 51 (S.D.G.S. Test Hole, 1959)
Location: SW¼SE¼ sec. 26, T. 107 N., R. 56 W.
Surface elevation: 1550 feet
Depth to water: 8 feet

0- 4	Clay, dark-gray
4- 9	Clay, sandy
9- 14	Clay and gravel
14- 19	Gravel
19- 24	Clay; sand and gravel
24- 29	Sand
29- 49	Clay, sandy

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Test Hole 52
Location: SE¼SE¼NE¼SE¼ sec. 26, T. 107 N., R. 56 W.
Depth to water: 19 feet

0- 2	Topsoil
2- 38	Clay, red-brown, pebbly
38- 48?	Sand and gravel, dark-gray
48?- 94	Clay, dark-gray; boulders

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Test Hole 53
Location: NE¼NW¼SE¼NW¼ sec. 25, T. 107 N., R. 56 W.
Depth to water: 6 feet

0- 1	Topsoil
1- 6	Clay, dark-brown, sandy
6- 9	Sand, dark-brown, coarse

Test Hole 53 -- continued.

9- 62	Clay, brown, sandy
62- 79	Clay, gray, pebbly

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Test Hole 54 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 25, T. 107 N., R. 56 W.
Surface elevation: 1600 feet
Depth to water: not measured

0- 20	Clay, yellow, pebbly
20- 65	Clay, gray, pebbly
65-140	Clay, gravelly
140-170	Clay; some shale gravel
170-192	Clay, gray, pebbly
192-200	Shale, black

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Test Hole 55 (Rotary Test Hole)
Location: NE¼NE¼NE¼SE¼ sec. 31, T. 107 N., R. 56 W.
Surface elevation: 1499 feet
Depth to water: not measured

0- 45	Clay, yellow to dark-brown, pebbly
45- 57	Clay, gray, pebbly
57- 61	Gravel, coarse
61-110	Clay, gray, pebbly
110-125	Shale; bentonite

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Test Hole 56 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 34, T. 107 N., R. 56 W.
Surface elevation: 1582 feet
Depth to water: not measured

0- 28	Clay, yellow, pebbly
28-107	Clay, gray, pebbly
107-109	Gravel
109-144	Clay, gray, gravelly
144-155	Gravel; coal
155-170	Clay, gravelly
170-185	Gravel, coarse
185-195	Clay, gravelly
195-203	Gravel, coarse
203-215	Shale, calcareous

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Test Hole 57
Location: SW¼SE¼SW¼SE¼ sec. 35, T. 107 N., R. 56 W.
Depth to water: 6 feet

0- 9	Sand and gravel, brown; some clay

Test Hole 57 -- continued.

9- 54	Clay, blue-gray, grades to brown, pebbly

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Test Hole 58 (Rotary Test Hole)
Location: SW¼SW¼SW¼NW¼ sec. 32, T. 107 N., R. 55 W.
Surface elevation: 1608 feet
Depth to water: not measured

0- 20	Clay, yellow, pebbly
20- 80	Clay, gray, pebbly
80-160	Clay, gray, gravelly
160-170	Shale, dark-gray
170-185	Chalk, dark-gray

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Test Hole 59
Location: SE¼SE¼SW¼SW¼ sec. 33, T. 107 N., R. 55 W.
Depth to water: 7 feet

0- 2	Sand, dark-brown
2- 9	Gravel, brown, coarse
9- 25	Clay, dark-gray, gravelly
25- 74	Clay, dark-gray, sandy

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Test Hole 60
Location: NE¼SE¼NE¼NW¼ sec. 33, T. 107 N., R. 55 W.
Depth to water: not measured

0- 1	Topsoil
1- 17	Clay, light-brown, pebbly
17- 74	Clay, dark-gray, pebbly

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Test Hole 61
Location: SE¼SE¼SE¼NE¼ sec. 33, T. 107 N., R. 55 W.
Depth to water: 16 feet

0- 1	Topsoil
1- 11	Clay, light-brown, sandy
11- 24?	Clay, dark-gray, sandy
24?- 34?	Sand and gravel
34?- 94	Clay, dark-gray, pebbly

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Test Hole 62
Location: NW¼SW¼NW¼NW¼ sec. 34, T. 107 N., R. 55 W.
Depth to water: 8 feet

0- 5	Clay; sand and gravel

Test Hole 62 -- continued.

5- 8	Clay, dark-brown, sandy
8- 24?	Sand, brown, medium to coarse
24?- 47	Clay, gray
47- 74	Clay, dark-gray, pebbly, (till)

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Test Hole 63 (Rotary Test Hole)
Location: SE¼SE¼SE¼SE¼ sec. 4, T. 106 N., R. 56 W.
Surface elevation: 1521 feet
Depth to water: not measured

0- 13	Clay, yellowish-brown, pebbly
13- 31	Clay, brown, pebbly
31- 34	Sand, medium to coarse
34- 60	Clay, gray, pebbly
60- 62	Gravel, coarse
62-155	Clay, gray, pebbly
155-163	Gravel, very coarse
163-180	Shale; bentonite

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Test Hole 64 (Rotary Test Hole)
Location: NW¼NW¼NW¼NW¼ sec. 3, T. 106 N. R. 56 W.
Surface elevation: 1534 feet
Depth to water: not measured

0- 20	Clay, light-gray, pebbly
20-137	Clay, gray, sandy
137-150	Gravel?; clay
150-168	Clay, gray, gravelly
168-179	Gravel, coarse
179-200	Shale, dark-gray

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Test Hole 65 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 3, T. 106 N., R. 56 W.
Surface elevation: 1564 feet
Depth to water: not measured

0- 15	Clay, yellow, pebbly
15- 34	Clay, reddish-brown, pebbly
34-155	Clay, gray, pebbly
155-168	Gravel, medium to coarse
168-228	Clay?
228-245	Chalk, dark-gray, (marl)

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Test Hole 66 (Test Hole was drilled by Fredrickson's Inc. and reported by DeWild & Grant, Engineers to the city)
Location: SW¼NW¼ sec. 2, T. 106 N., R. 56 W.
Surface elevation: not measured
Depth to water: not measured

Test Hole 66 -- continued.

0- 2	Topsoil, black
2- 70	Clay, brown
70- 85	Sand, coarse, colored
85-152	Clay, blue
152-154	Sand, colored
154-158	Clay, blue
158-161	Sand, yellow
161-175	Sand, dirty, colored
175-200	Clay, blue
200-244	Shale, black
244-252	Shale, soft, gray
252-478	Shale, hard, gray
478-480	Sand, gray
480-500	Shale lensed with sand
500-	Sioux Quartzite

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Test Hole 67
Location: SE¼SW¼NE¼NW¼ sec. 2, T. 106 N., R. 56 W.
Depth to water: 33 feet

0- 3	Topsoil
3- 33	Clay, dark-brown, sandy
33- 39	Clay, gray
39- 51	Clay, gray-brown, sandy
51- 74	Clay, dark-gray, sandy

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Test Hole 68
Location: SW¼NE¼NW¼NE¼ sec. 2, T. 106 N., R. 56 W.
Depth to water: 22 feet

0- 4	Topsoil
4- 10	Sand and gravel, dark-brown
10- 22	Clay, dark-gray, sandy
22- 34	Sand and gravel; much clay
34- 59	Clay, dark-gray, sandy
52- 69	Clay, dark-gray; hard drilling

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Test Hole 69
Location: SE¼SE¼NW¼NE¼ sec. 2, T. 106 N., R. 56 W.
Depth to water: 32 feet

0- 8	Clay, dark-brown, sandy
8- 69	Clay, dark-gray, pebbly
69- 73	Gravel, dark-gray, coarse
73- 79	Clay, dark-gray, sandy

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Test Hole 70
Location: SW¼SW¼SW¼NE¼ sec. 2, T. 106 N., R. 56 W.
Depth to water: 27 feet

0- 3	Topsoil
3- 12	Clay, brown
12- 25	Clay, dark-brown
25- 33	Sand and gravel, dark-gray
33- 38	Clay, gray, gravelly
38- 42	Sand and gravel, dark-gray
42- 94	Clay, pebbly

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Test Hole 71
Location: SE¼SE¼SW¼NE¼ sec. 2, T. 106 N., R. 56 W.
Depth to water: 7 feet

0- 1	Topsoil
1- 18	Sand and gravel, dark-brown
18- 74	Clay, dark-gray, pebbly

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Test Hole 72 (Rotary Test Hole)
Location: NE¼SW¼NE¼ sec. 2, T. 106 N., R. 56 W.
Surface elevation: 1557 feet
Depth to water: 91.7 feet (buried sand and gravel)

0- 3	Topsoil
3- 20	Clay, yellow, pebbly
20- 90	Clay, gray, pebbly
90- 92	Gravel
92-125	Clay, gray, pebbly
125-140	Gravel, coarse
140-144	Clay, gray
144-154	Gravel, coarse
154-155	Clay

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Test Hole 73 (Test Hole was drilled by Fredrickson's Inc. and reported by DeWild & Grant, Engineers to the city)
Location: SW¼NE¼ sec. 2, T. 106 N., R. 56 W.
Surface elevation: 1562 feet
Depth to water: not measured

0- 3	Topsoil, black
3- 18	Sand, brown, coarse; clay
18-170	Clay, dark-gray; sand
170-182	Sand
182-184	Clay, dark-gray
184-198	Sand, coarse; clay
198-226	Shale (?)
226-274	Clay, sandy
274-344	Shale, gray
344-380	Shale, gray, hard

Test Hole 73 -- continued.

380-405	Shale, gray and dark-gray
405	Sioux Quartzite

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Test Hole 74 (Rotary Test Hole)
Location: SW¼NE¼NE¼SW¼ sec. 2, T. 106 N., R. 56 W.
Depth to water: not measured

0- 6	Gravel
6- 17	Clay, brown, gravelly
17- 20	Gravel, coarse
20- 30	Clay, grayish-tan, sandy
30- 37	Gravel, fine to medium
37- 53	Clay, brown, sandy
53- 57	Sand, coarse
57- 67	Clay, dark-gray, pebbly
67- 73	Gravel, coarse
73-142	Clay, dark-gray, gravelly
142-148	Gravel, medium
148-151	Clay, sandy
151-160	Gravel, coarse
160-170	Clay, dark-gray
170-195	Sand, fine; much clay
195-208	Shale; bentonite
208-215	Chalk, gray, (marl)

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Test Hole 75 (New city well drilled by Grimshaw Drilling Co.)
Location: SE¼SW¼ sec. 2, T. 106 N., R. 56 W.
Surface elevation: not measured
Depth to water: 133 feet

0- 17	Gravel, coarse
17- 25	Clay, gray
25- 60	Sand, gray, fine
60-121	Clay, gray, sandy
121-130	Sand and gravel
130-150	Clay, gray
150-153	Sand
153-175	Clay; some fine sand
175-185	Clay with boulders
185-200	Gravel; some clay

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Test Hole 76 (Observation Well)
Location: SE¼SW¼ sec. 2, T. 106 N., R. 56 W.
Surface elevation: 1565 feet
Depth to water: 133 feet

0- 15	Sand and gravel
15- 25	Clay, dark-gray, sandy
25- 67	Clay, dark-gray; drills hard; sandy

Test Hole 76 -- continued.

67- 72	Sand stringers; easy drilling
72-113	Clay, dark-gray; pebbles
113-124	Gravel, very coarse
124-173	Clay, dark-gray, pebbly
173-192	Gravel, coarse
192-197	Chalk, light to dark-gray

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Test Hole 77 (Rotary Test Hole)
Location: SW¼SW¼SW¼SW¼ sec. 1, T. 106 N., R. 56 W.
Surface elevation: 1565.3 feet
Depth to water: 130 feet

0- 25	Clay, yellow, pebbly
25-150	Clay, gray, pebbly, (till)
150-175	Shale, dark-gray
175-200	Chalk, gray

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Test Hole 78 (Rotary Test Hole)
Location: SW¼SW¼SW¼NW¼ sec. 1, T. 106 N., R. 56 W.
Surface elevation: 1559 feet
Depth of water: not measured

0- 18	Clay, yellowish-brown, pebbly
18- 23	Clay, dark-gray, pebbly
23- 31	Sand, coarse
31- 55	Clay, dark-gray, pebbly
55- 80	Clay, very gravelly
80-133	Clay, dark-gray, pebbly
133-137	Gravel, fine to coarse
137-147	Clay, gravelly
147-155	Shale, dark-gray

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Test Hole 79 (Rotary Test Hole)
Location: NW¼NW¼NW¼NW¼ sec. 1, T. 106 N., R. 56 W.
Surface elevation: 1561 feet
Depth to water: not measured

0- 2	Topsoil
2- 30	Clay, yellow, pebbly
30- 32	Gravel, coarse
32-145	Clay, gray, pebbly
145-170	Shale, dark-gray

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Test Hole 80 (Rotary Test Hole)
Location: SE¼SE¼SE¼SW¼ sec. 6, T. 106 N., R. 55 W.
Surface elevation: 1599 feet
Depth to water: not measured

Test Hole 80 -- continued.

0- 33	Clay, yellow, pebbly
33- 62	Clay, gray, pebbly
62- 69	Gravel, coarse
69- 95	Clay, gray, gravelly
95-110	Gravel; clay stringers
110-145	Clay, sandy
145-155	Gravel, coarse
155-165	Clay, gray
165-170	Shale, gray

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Test Hole 81 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 8, T. 106 N., R. 56 W.
Surface elevation: 1485 feet
Depth of water: not measured

0- 20	Clay, yellow, pebbly
20- 30	Clay, brown, pebbly
30- 47	Clay, gray, pebbly
47- 50	Gravel, coarse
50- 65	Clay; gravel stringers
65-128	Clay, gray, pebbly
128-136	Gravel, coarse
136-140	Clay, gray
140-144	Gravel, very coarse
144-155	Chalk, gray

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Test Hole 82 (Rotary Test Hole)
Location: SE¼SE¼SE¼SE¼ sec. 9, T. 106 N., R. 56 W.
Surface elevation: 1522 feet
Depth of water: not measured

0- 20	Clay, yellowish-gray, pebbly
20- 30	Clay, reddish-brown
30- 45	Clay, gray, pebbly
45- 48	Clay, brown
48- 50	Sand and gravel
50-132	Clay, gray, pebbly
132-140	Shale, dark-gray

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Test Hole 83
Location: SE¼SE¼SE¼NE¼ sec. 10, T. 106 N., R. 56 W.
Surface elevation: 1567 feet
Depth of water: not measured

0- 3	Topsoil
3- 10	Gravel, coarse
10- 20	Clay, brown, pebbly
20- 50	Clay, gray, gravelly
50- 60	Gravel
60- 65	Clay, gravelly

Test Hole 83 -- continued.

65- 80	Sand?; clay
80-170	Clay, gray; hard drilling
170-190	Shale?
190-196	Chalk, gray

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Test Hole No. 84 (Source of data, Special Report No. 6, S.D.G.S.)
Location: NE¼NW¼ sec. 11, T. 106 N., R. 56 W. (at standpipe)
Surface elevation: 1572 feet
Depth to water: 158 feet

0- 20	Till, poorly sorted yellow sand, calcareous sandy clay with gypsum fragments
20- 50	Sand, poorly sorted; with clay
50- 60	Sand; with medium gray clay and sandy clay
60-150	Sand and gravel, poorly sorted with clay as above
150-170	As above, but with much lignite
170-180	Gravel, pebble and granule size
180-190	Gravel and sand; with much lignite
190-200	Niobrara Formation, marl, light-gray; with abundant small white chalk spots; also lignite which may be cavings
200-260	Chalk; spotted marl as above
260-270	Same as above with scattered Inoceramus prisms and shell fragments
270-280	Chalk; spotted marl as above; some lignite
280-290	Same as above
294	(Carlile Formation top E. L.*)
290-300	Sand, fine-to very coarse-grained, angular to subrounded, poorly sorted, loose and calcareous argillaceous sandstone
300-320	Sand and sandstone as above; shale, medium dark-gray bentonitic; pyrite
320-340	Siltstone, yellow-brown; siltstone concretions, sandy, some slightly calcareous
340-350	Shale, micaceous, sandy, medium dark-gray; some fine-grained sandstone
350-360	Sandstone, white, fine-grained, calcareous, micaceous, glauconitic; lignite
360-370	Shale, medium dark-gray
370-380	Shale, dark-gray
380-400	Sand, fine-grained with bentonite
400-402	Sioux Formation, well cemented, siliceous quartzose sandstone

* Formation Tops picked by Electric Logs

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Test Hole 85 (S.D.G.S. Test Hole, 1959)
Location: NW¼NE¼ sec. 11, T. 106 N., R. 56 W.
Depth to water: 12 feet

0- 4	Clay and sand

Test Hole 85 -- continued.

4-	8	Sand and gravel
8-	22	Clay and gravel
22-	39	Sand, medium
39-	40	Clay, gray

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Test Hole 86 (S.D.G.S. Test Hole, 1959)
Location: SW¼NE¼ sec. 11, T. 106 N., R. 56 W.
Depth to water: 26? feet

0-	4	Clay, dark-gray
4-	6	Gravel and sand
6-	9	Sand and clay
9-	10	Sand and gravel
10-	19	Gravel, medium
19-	29	Gravel, medium, and clay
29-	34	Sand and clay
34-	39	Silt, sand, and clay
39-	44	Silt, sand, clay, and gravel
44-	54	Clay and gravel

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Test Hole 87
Location: SW¼SW¼NE¼NE¼ sec. 11, T. 106 N., R. 56 W.
Depth to water: 10 feet

0-	1	Topsoil
1-	6	Sand and gravel, brown
6-	10	Clay, brown, sandy
10-	17	Sand, light-brown; much clay
17-	24	Clay, gray-brown, sandy

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Test Hole 88 (S.D.G.S. Test Hole, 1959)
Location: SE¼SW¼ sec. 11, T. 106 N., R. 56 W.
Surface elevation: 1527 feet
Depth to water: not measured

0-	7	Gravel and clay
7-	19	Clay, brown, and pebbles

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Test Hole 89 (S.D.G.S. Test Hole, 1959)
Location: SE¼SE¼ sec. 11, T. 106 N., R. 56 W.
Surface elevation: 1519 feet
Depth to water: 4 feet

0-	5	Clay, brown
5-	24	Clay and sand

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Test Hole 90
Location: SE¼SW¼SE¼SE¼ sec. 7, T. 106 N., R. 55 W.
Depth to water: not measured

0- 1	Topsoil
1- 42	Clay, dark-brown
42- 74	Clay, dark-gray, sandy

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Test Hole 91 (Rotary Test Hole)
Location: SE¼SE¼SE¼SE¼ sec. 8, T. 106 N., R. 55 W.
Surface elevation: 1615 feet
Depth to water: not measured

0- 14	Clay, yellow
14- 40	Gravel, grading to sand
40- 58	Clay, gray, pebbly
58-170	Clay, gray, sandy and pebbly
170-181	Gravel, coarse
181-190	Shale, dark-gray

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Test Hole 92
Location: SW¼SW¼SE¼SW¼ sec. 9, T. 106 N., R. 55 W.
Depth to water: not measured

0- 9	Clay, light-brown, sandy
9- 65	Clay, gray, sandy

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Test Hole 93 (Rotary Test Hole)
Location: SE¼SE¼NE¼SE¼ sec. 15, T. 106 N., R. 56 W.
Surface elevation: 1555 feet
Depth to water: not measured

0- 2	Topsoil, black
2- 30	Clay, yellow, grading to dark-brown
30- 80	Clay, gray, sandy
80- 95	Clay, gray, gravelly
95-138	Clay, gray, sandy
138-150	Gravel; some clay stringers
150-170	Chalk, gray

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Test Hole 94 (S.D.G.S. Test Hole, 1959)
Location: NW¼NW¼ sec. 14, T. 106 N., R. 56 W.
Surface elevation: 1516 feet
Depth to water: 8 feet

0- 4	Clay, dark-gray; gravel
4- 9	Clay, sandy
9- 14	Clay
14- 39	Clay, sandy

Test Hole 95 (S.D.G.S. Test Hole, 1959)
Location: NE¼NW¼ sec. 14, T. 106 N., R. 56 W.
Surface elevation: 1539 feet
Depth to water: 7 feet

0- 9	Clay and gravel
9- 24	Clay, sandy
24- 39	Gravel, fine; clay
39- 49	Sand, fine; clay, gray

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Test Hole 96
Location: NE¼NW¼NW¼NE¼ sec. 14, T. 106 N., R. 56 W.
Depth to water: 8 feet

0- 6	Clay, brown; pebbles
6- 12	Sand, dark-brown, coarse; much clay
21- 54	Clay, dark-gray, pebbly

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Test Hole 97
Location: NE¼NE¼SE¼NW¼ sec. 14, T. 106 N., R. 56 W.
Depth to water: 11 feet

0- 2	Topsoil
2- 11	Clay, gray
11- 18	Sand, coarse; clay
18- 39	Clay, dark-gray, sandy

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Test Hole 98
Location: SW¼NW¼NE¼SE¼ sec. 14, T. 106 N., R. 56 W.
Depth to water: 7 feet

0- 7	Clay, dark-gray, sandy
7- 22	Sand, coarse; some clay
22- 54	Clay, dark-gray, pebbly

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Test Hole 99 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 14, T. 106 N., R. 56 W.
Surface elevation: 1551 feet
Depth to water: not measured

0- 15	Clay, yellow, pebbly
15- 60	Clay, gray, pebbly
60- 62	Sand
62-150	Clay, gray, gravelly
150-158	Gravel, coarse
158-170	Chalk, gray

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Test Hole 100
Location: NW¼NW¼NW¼NE¼ sec. 13, T. 106 N., R. 56 W.
Depth to water: not measured

0- 7	Sand, dark-brown, clayey
7- 34?	Clay, brown
34?- 64	Clay, dark-gray; some pebbles

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Test Hole 101
Location: SW¼SE¼SE¼SW¼ sec. 16, T. 106 N., R. 55 W.
Depth to water: 37 feet

0- 10	Clay, brown; some pebbles
10- 25	Clay, gray, sandy
25- 37	Clay, gray; much sand
37- 74	Clay, dark-gray, sandy

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Test Hole 102 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 20, T. 106 N., R. 56 W.
Surface elevation: 1492 feet
Depth to water: not measured

0- 20	Clay, brown
20- 35	Clay, dark-brown; a gravel stringer
35-100	Clay, gray
100-112	Gravel, coarse
112-155	Chalk, gray

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Test Hole 103
Location: SW¼NW¼NW¼ sec. 21, T. 106 N., R. 56 W.
Depth to water: not measured

0- 2	Topsoil
2- 28	Clay; pebbles

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Test Hole 104 (Rotary Test Hole)
Location: SE¼SE¼SE¼SE¼ sec. 21, T. 106 N., R. 56 W.
Surface elevation: 1506 feet
Depth to water: not measured

0- 32	Clay, yellowish-brown
32- 42	Clay, gravelly
42- 45	Gravel
45-122	Clay, gray, gravelly
122-140	Chalk, gray

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Test Hole 105
Location: NE¼NE¼NW¼ sec. 27, T. 106 N., R. 56 W.
Depth to water: not measured

0- 2	Topsoil
2- 29	Clay, pebbles, (till)

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Test Hole 106
Location: SW¼NW¼SW¼NW¼ sec. 24, T. 106 N., R. 56 W.
Depth to water: 11 feet

0- 5	Sand and gravel, brown
5- 11	Clay, sandy and gravelly
11- 23	Sand and gravel; boulders
23- 74	Clay, gray, sandy

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Test Hole 107
Location: SE¼SE¼NW¼SW¼ sec. 24, T. 106 N., R. 56 W.
Depth to water: 8 feet

0- 4	Clay, brown, sandy
4- 11	Clay; some gravel
11- 19	Sand, coarse to very coarse
19- 21	Clay, gray, pebbly
21- 29	Sand, gray; clay
29- 39	Clay, gray

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Test Hole 108
Location: NE¼NW¼NE¼NW¼ sec. 25, T. 106 N., R. 56 W.
Depth to water: not measured

0- 6	Sand and gravel
6- 26	Clay, blue-gray, sandy
26- 38	Sand and gravel; some clay
38- 74	Clay, blue-gray, gravelly

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Test Hole 109 (Rotary Test Hole)
Location: NE¼NE¼NE¼NE¼ sec. 25, T. 106 N., R. 56 W.
Surface elevation: 1569 feet
Depth to water: not measured

0- 5	Gravel, coarse
5- 20	Clay, yellow, pebbly
20-150	Clay, gray, pebbly
150-152	Boulders
152-164	Shale, dark-gray, noncalcareous
164-170	Chalk, light-gray, calcareous

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Test Hole 110
Location: NE¼NW¼NE¼NE¼ sec. 30, T. 106 N., R. 55 W.
Depth to water: 41 feet

0- 2	Topsoil, brown
2- 19	Clay, brown, sandy
19- 52	Clay, gray, sandy
52- 62	Sand, dark-gray; clay
62- 94	Clay, gray to dark-gray

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APPENDIX B

Well Records in the Howard Area

Source: O, Surface outwash, B, Buried sand lenses and outwash; N, Niobrara (Chalk-Marl); D, Dakota Formation

Use: D, domestic; S, stock

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Haine, M.	NE¼SE¼SW¼SE¼ sec. 4, T. 106 N., R. 55 W.	385	100	N	D,S
Seswer, E.	NW¼NW¼SW¼NW¼ sec. 5, T. 106 N., R. 55 W.	160	60	B	D,S
Genzlingery, P.	SW¼SW¼SE¼SE¼ sec. 6, T. 106 N., R. 55 W.	470	270		D,S
Weishaupt, J.	NW¼NW¼SW¼SW¼ sec. 6, T. 106 N., R. 55 W.	200	185	B?N?	D,S
Litterick, J.	NE¼NW¼NW¼NE¼ sec. 7, T. 106 N., R. 55 W.	96		B	D,S
Laible, W.	NW¼NW¼NW¼NW¼ sec. 8, T. 106 N., R. 55 W.	200		N	D,S
Wolff, E.	SE¼SW¼SE¼SW¼ sec. 17, T. 106 N., R. 55 W.	183	60	N	D,S
Feldhous, T.	NE¼NE¼NE¼SW¼ sec. 18, T. 106 N., R. 55 W.	340		N?	D,S
Weidler, V.	NE¼NW¼NW¼NE¼ sec. 19, T. 106 N., R. 55 W.	165		N	D,S
Neiese, L.	SW¼NW¼SE¼NE¼ sec. 20, T. 106 N., R. 55 W.	225		N	D,S
Teman, R.	NW¼NW¼SE¼NW¼ sec. 20, T. 106 N., R. 55 W.	150	65	B	D,S
Shoemaker, C.	SE¼SE¼NE¼NE¼ sec. 21, T. 106 N., R. 55 W.	160		B	D,S
Grant, J.	SW¼SW¼SW¼SW¼ sec. 1, T. 106 N., R. 56 W.	250		N	D,S
Butternob, F.	SW¼SW¼SW¼SW¼ sec. 3, T. 106 N., R. 56 W.	214	160	N	D,S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Noonan, W.	SE¼SW¼SE¼SE¼ sec. 4, T. 106 N., R. 56 W.	255	237	N	D,S
Anderson, L.	SE¼SE¼SE¼NE¼ sec. 4, T. 106 N., R. 56 W.	256	146	N	D,S
Rasmussen, A.	NE¼NE¼NE¼NW¼ sec. 9, T. 106 N., R. 56 W.	180	90	N	D,S
Miller, J.	SE¼SE¼SE¼SE¼ sec. 9, T. 106 N., R. 56 W.	210	90	N	D,S
Schneder, J.	NE¼NE¼NE¼NE¼ sec. 9, T. 106 N., R. 56 W.	215		N	D,S
Calmus, G.	NW¼NW¼NW¼SW¼ sec. 9, T. 106 N., R. 56 W.	210		N	D,S
Scott, L.	NE¼NE¼NE¼SE¼ sec. 10, T. 106 N., R. 56 W.	240		N	D,S
Weishoor, T.	SW¼SW¼NW¼NW¼ sec. 12, T. 106 N., R. 56 W.	200		N	D,S
Thompson, R.	NW¼NW¼NW¼SW¼ sec. 12, T. 106 N., R. 56 W.	200		N	D,S
McCoin, E.	SW¼SW¼SW¼SW¼ sec. 13, T. 106 N., R. 56 W.	155		N	D,S
Reisch, M.	SW¼SW¼SE¼SE¼ sec. 14, T. 106 N., R. 56 W.	234		N	D,S
Rasmussen, C.	NW¼NW¼NW¼NW¼ sec. 15, T. 106 N., R. 56 W.	200	70	N	D,S
Rasmussen, A.	NE¼NE¼NE¼NE¼ sec. 15, T. 106 N., R. 56 W.	200	70	N	D,S
Hafner, W.	SE¼NE¼NE¼SE¼ sec. 17, T. 106 N., R. 56 W.	170	60	N	D,S
Stangoh, R.	SE¼SW¼SE¼SW¼ sec. 22, T. 106 N., R. 56 W.	206	90	N	D,S
Denponpolf, P.	NE¼NW¼NE¼NW¼ sec. 28, T. 106 N., R. 56 W.	106	60	B	D,S
Feldhous, L.	NE¼NE¼NE¼NW¼ sec. 36, T. 106 N., R. 56 W.	7		O	S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Bloem, J.	NW¼NW¼SW¼SW¼ sec. 6, T. 107 N., R. 55 W.	50?		B	D,S
Corey, H.	NW¼NW¼SE¼SW¼ sec. 6, T. 107 N., R. 55 W.	100	70	B	D,S
Bengheim, A.	SE¼SE¼SE¼SE¼ sec. 6, T. 107 N., R. 55 W.	19		O	D,S
Road, A.	NE¼NE¼NE¼NW¼ sec. 7, T. 107 N., R. 55 W.	900	700	D	D,S
Bergheim, A.	NW¼NW¼NW¼NW¼ sec. 8, T. 107 N., R. 55 W.	19	3	O	S
Hegdahl, H.	SE¼SW¼SW¼SW¼ sec. 8, T. 107 N., R. 55 W.	24	17	O	D
Hegdahl, H.	SE¼SW¼SW¼SW¼ sec. 8, T. 107 N., R. 55 W.	16	13	O	S
Jukam, J.	SW¼SE¼SW¼SE¼ sec. 8 T. 107 N., R. 55 W.	160	90	B	S
Almaas, N.	SW¼SE¼SE¼SW¼ sec. 9, T. 107 N., R. 55 W.	240	90	N	D,S
Eide, L.	SE¼NW¼SE¼NW¼ sec. 17, T. 107 N., R. 55 W.	27		O	
Schwader, R.	SW¼SE¼SE¼SW¼ sec. 17, T. 107 N., R. 55 W.	90		B	D,S
Road, L.	NE¼NE¼NE¼SE¼ sec. 18, T. 107 N., R. 55 W.	150	70	B	D,S
Voltz, J.	NE¼NE¼SW¼NW¼ sec. 18, T. 107 N., R. 55 W.	750	10	D	D,S
Henden, A.	NE¼SE¼SE¼NE¼ sec. 19, T. 107 N., R. 55 W.	16	9	O	S
Fjellstad, H.	NW¼NW¼NE¼NW¼ sec. 20, T. 107 N., R. 55 W.	100		B	D,S
Olson, L.	NE¼NE¼NW¼SW¼ sec. 20, T. 107 N., R. 55 W.	55		B	D,S
Braford, R.	SW¼SW¼NW¼SW¼ sec. 21, T. 107 N., R. 55 W.	427	50	N?	D,S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Remacle, P.	NW¼SW¼SW¼NW¼ sec. 21, T. 107 N., R. 55 W.	100		B	D,S
Erikson, A.	SW¼NW¼SW¼NW¼ sec. 27, T. 107 N., R. 55 W.	265		N	D,S
Jacobson, K.	SW¼SW¼NW¼SW¼ sec. 27, T. 107 N., R. 55 W.	220	100	N	D,S
Hardick, C.	NE¼NW¼NW¼NW¼ sec. 28, T. 107 N., R. 55 W.	25	8	O	D,S
Jacobson, W.	NW¼NW¼NW¼SW¼ sec. 28, T. 107 N., R. 55 W.	140	30	B	D,S
Bender, M.	SW¼SW¼NW¼NW¼ sec. 30, T. 107 N., R. 55 W.	180		N	D,S
Schwader, E.	SE¼SW¼SW¼SW¼ sec. 32, T. 107 N., R. 55 W.	168	88	N?	D,S
Haak, G.	NW¼NW¼NE¼NW¼ sec. 32, T. 107 N., R. 55 W.	155	120	B	D,S
Haak, G.	NW¼NW¼NE¼NW¼ sec. 32, T. 107 N., R. 55 W.	700	282	D	D,S
Wombacker, C.	SW¼NW¼SW¼SW¼ sec. 34, T. 107 N., R. 55 W.	200	30	N	D,S
Hardick, B.	NW¼NW¼NW¼NW¼ sec. 34, T. 107 N., R. 55 W.	220	90	N	D,S
Worder, R.	SW¼SW¼SW¼SW¼ sec. 12, T. 107 N., R. 56 W.	612	412	D?	D,S
Hauge, M.	SW¼SE¼SW¼SE¼ sec. 13, T. 107 N., R. 56 W.	90		B	D,S
Cramer, R.	SE¼SE¼SE¼SE¼ sec. 13, T. 107 N., R. 56 W.	140	105	B	D,S
Hauge, E.	NE¼NE¼NE¼NE¼ sec. 14, T. 107 N., R. 56 W.	1000	800	D	D,S
Sherman, A.	SW¼NW¼NW¼NW¼ sec. 14, T. 107 N., R. 56 W.	12	5	O	S
Covigielli, J.	NW¼NW¼SW¼NW¼ sec. 15, T. 107 N., R. 56 W.	530			D,S

Name	Location	Depth of Well (feet)	Depth to Water (feet)	Source	Use
Stock, L.	SW¼SE¼SE¼SE¼ sec. 20, T. 107 N., R. 56 W.	480	320		D,S
Collin, F.	SE¼SE¼NE¼NE¼ sec. 22, T. 107 N., R. 56 W.	800		D?	D,S
Neises, E.	SW¼SW¼SE¼SW¼ sec. 23, T. 107 N., R. 56 W.	612	400		D,S
Bender, M.	SW¼SW¼NW¼SW¼ sec. 24, T. 107 N., R. 56 W.	500			D,S
Hauge, G.	SW¼SW¼NW¼NE¼ sec. 24, T. 107 N., R. 56 W.	180	162		D,S
Feller, A.	SW¼SW¼SW¼SW¼ sec. 25, T. 107 N., R. 56 W.	105	70	B	D,S
Weiss, L.	SW¼SE¼SE¼SW¼ sec. 26, T. 107 N., R. 56 W.	400	200		D,S
Calmus, L.	SE¼SE¼SE¼SE¼ sec. 27, T. 107 N., R. 56 W.	420	52		D,S
Schneder, J.	SW¼SW¼SE¼SW¼ sec. 27, T. 107 N., R. 56 W.	445			D,S
Raichlang, N.	NE¼NE¼NE¼NE¼ sec. 27, T. 107 N., R. 56 W.	600	400		D,S
Stock, O.	NE¼SE¼NE¼NE¼ sec. 28, T. 107 N., R. 56 W.	410			D,S
Feldhaus, L.	NE¼NE¼SE¼SE¼ sec. 34, T. 107 N., R. 56 W.	560			D,S
Hoss, J.	SW¼SE¼SE¼SW¼ sec. 35, T. 107 N., R. 56 W.	18	5	O	D,S