GROUND WATER RESOURCES IN THE VICINITY OF LEEDS, BENSON COUNTY, NORTH DAKOTA

By
P. G. Randich and Edward Bradley
Geological Survey
United States Department of the Interior

NORTH DAKOTA GROUND WATER STUDIES
NO. 44

Prepared by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission, and the North Dakota Geological Survey

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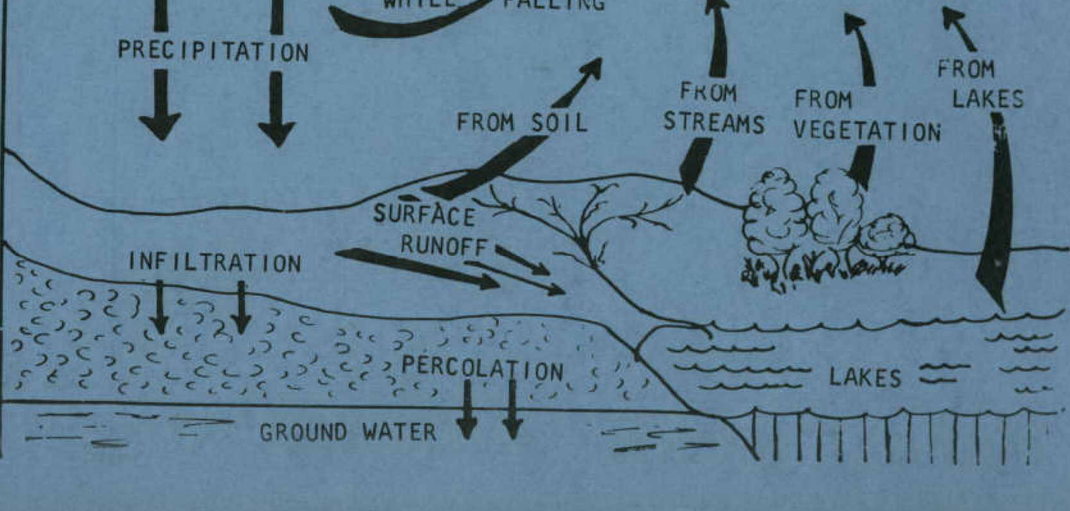

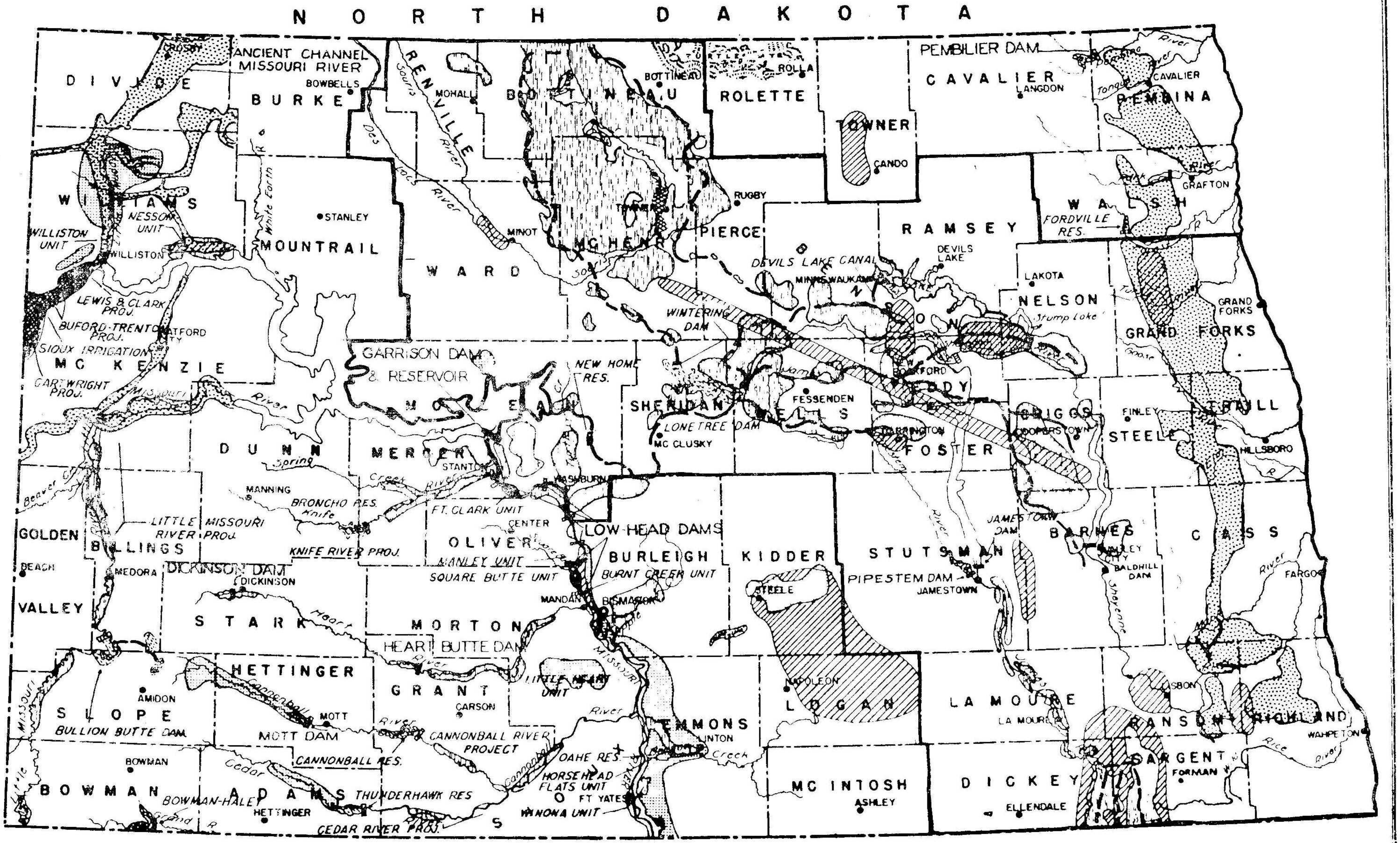

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

- LANDS UNDER IRRIGATION
- AREAS CONSIDERED IRRIGABLE
- AREAS BEING INVESTIGATED
- PROPOSED FOR INVESTIGATION

DAM & RESERVOIR SITES: EXISTING; UNDER CONSTRUCTION OR PROPOSED

PROPOSED CANALS

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RECORDS OF WELLS AND TEST HOLES

Location number	Owner or name	Depth of well (feet below land surface)	Diameter or size (inches)	Type	Date completed	Depth to water (feet below land surface)	Date of measurement	Use	Aquifer	Remarks
155-68										
1dcd	Wallace Tarang	45	48	Du	....	10	.....	D,S	Gravel	Adequate supply.
2cbb	Ingvold Foss	122	5	Dr	1920	61	.....	D,S	Gravel	Do.
6aaa	Test hole 1300	178.5	5	Dr	5-58	....	.....	T	....	See log.
8bbb	Test hole 1302	178.5	5	Dr	5-58	....	.....	T	....	Do.
8ccc	Test hole 1303	178.5	5	Dr	5-58	....	.....	T	....	Do.
12ddd	Stadness Co.	26	30	Dr	....	10	.....	D,S	Sand	Adequate supply.
13adc	J. M.L. Anderson	70	30	Dr	....	40	.....	D,S	....	Do.
19aaa	Test hole 1304	199.5	5	Dr	5-58	30	.....	T	....	See log.
20ccc	Test hole 1305	147	5	Dr	5-58	....	.....	T	....	Do.
21aac1	C. M. Fogelson	60	48	Du	....	50	.....	N	Sand	Adequate supply.
21aac2	Do	275	6	Dr	....	70	.....	N	Clay	Do.
22bb	Do	80	24	Dr	1957	50	.....	D,S	Sand	Do.
23ada1	Mertle E. Haugen	20	24	Dr	1957	10	.....	D	Sand and gravel	Inadequate supply.
23ada2	Do	275	5	Dr	....	5	.....	S	....	Adequate supply; saline.
23bbc	Harold Kenner Sr.	335	5	Dr	....	30	.....	D,S	Sand	Do.
156-68										
2dad	Unknown	50.05	24	Dr	....	24.90	4- 4-58	N	....	Abandoned.
3ccb	Bennet Medhus	306	5	Dr	1933	11	.....	D,S	Shale	Adequate supply.
5ccc	Oscar Jorgenson	70	36	Dr	1952	30	.....	D	Sand	Do.
6bc	Ole Rodland	55	...	...	1910	15	.....	D,S	Sand	Do.
6dad	George Jorgenson	80	4	Dr	1911	27.25	4- 3-58	D,S	Sand	Inadequate supply.
7aaa	Test hole 1299	175	5	Dr	5-58	....	.....	T	....	See log.
7daa	E. Tostenson	60	36	Dr	1916	20	.....	N	....	Adequate supply.
7ddd	Mrs. Runcken	60	36	Dr	1917	25	.....	N	Sand	Do.
8ccc	Inga Quammen	40.15	36	Dr	....	11.20	4- 3-58	D,S	Gravel	Do.
13cda	Olie Eliksmoen	50	36	Dr	1910	35	.....	D,S	Sand	Do.

RECORDS OF WELLS AND TEST HOLES

[illegible]	Owner or name	Depth of well (feet below land surface)	Diameter or size (inches)	Type	Date completed	Depth to water (feet below land surface)	Date of measurement	Use	Aquifer	Remarks
156-68 (Continued)										
15bdd	John R. Coway	31.62	48	Du	....	27.20	4- 4-58	D,S	....	Adequate supply.
17cad	Lewis Peiler	90	4	Dr	....	58	.....	D,S	Sand	Inadequate supply.
18aaa	Test hole 1298	210	5	Dr	5-58	....	.....	T	....	See log.
19aaa	Test hole 1297	189	5	Dr	5-58	....	.....	T	....	Do.
19ac	Stewert Robinson	23.92	36	Du	1943	4.25	4- 2-58	S	Sand	Adequate supply.
20ccc	Chester Johnson	60	36	Du	....	14	.....	D,S	Sand	Do. Chemical analysis.
20dc	Do	40.12	36	Du	....	29.82	4- 2-58	S	Gravel	Do.
21dab1	Joe Blegen	300	6	Dr	1920	30	.....	S	Sand	Adequate supply; saline.
21dab2	Do	70	30	Du	1952	24	.....	D	Gravel	Adequate supply.
22ba	Ernest Elverud	55	2	Dr	....	35	.....	D,S	....	Do.
22cbb	John Paulson	90	24	Du	....	20	.....	D,S	....	Do.
23cba	Norris Gresdahl	31.00	36	Du	....	16.60	4- 4-58	N	Sand	Do.
24bbb	Oris Norhaugen	35.25	36	Dr	....	15.46	4- 3-58	N	....	
[illegible]dd	Ragna Knudson	60	4	Dr	....	35	.....	D,S	Sand	Do.
24dcc	Chester Johnson	19.67	24	Dr	1947	Flow	4- 2-58	S	Gravel	Do.
26ddc1	Oscar Gustafson	42	24	Dr	....	20	.....	S	Sand	Inadequate supply.
26ddc2	Do	59	4	Dr	1956	39	.....	D	Sand	Do.
27bcc1	Peter Blegen	120	6	Dr	1914	20	.....	S	....	Do.
27bcc2	Do	155	6	Dr	1951	20	.....	D	Sand	Inadequate supply; chemical analysis.
27ccc	Test hole 1308	199.5	5	Dr	5-58	....	.....	T	....	See log.
27ddd	Test hole 1309	147	5	Dr	5-58	.....	.....	T	....	Do.
28dac1	Jens Engstrom	270	4	Dr	1928	70	.....	S	Shale	Adequate supply; chemical analysis.
28dac2	Do	30	36	Dr	1943	17	.....	D,S	Sand	Inadequate supply.
29bcd	Emil Engstrom	70	24	Dr	....	35	.....	D,S	Gravel	Do.
29ccb1	Charlie Urness	270	4	Dr	1918	20	.....	N	Sand	Adequate supply.
29ccb2	Do	14.64	36	Du	....	11.42	4- 3-58	N	....	Inadequate supply.
29ddd	Test hole 1307	210	5	Dr	5-58	.....	.....	T	....	See log.
30add	Test hole 1296	220	5	Dr	5-58	....	.....	T	....	Do.
30bbb	Test hole 1311	179	5	Dr	5-58	....	.....	T	....	Do.

RECORDS OF WELLS AND TEST HOLES

Location number	Owner or name	Depth of well (feet below land surface)	Diameter or size (inches)	Type	Date completed	Depth to water (feet below land surface)	Date of measurement	Use	Aquifer	Remarks
156-68 (Continued)										
30bcc	Test hole 1294	168	5	Dr	4-58	....	.....	T	....	See log.
30caa	Test hole 1312	189	5	Dr	5-58	....	.....	T	....	Do.
31aaa	Test hole 1306	199.5	5	Dr	5-58	....	.....	T	....	Do.
31bba	Test hole 1301	189	5	Dr	5-58	....	.....	T	....	Do.
31bdd	Test hole 1295	178.5	5	Dr	5-58	....	.....	T	....	Do.
33add	Grimsrud	180	5	Dr	5-58	....	.....	T	....	Do.
33baa	Kenneth Fox	39.15	24	Dr	....	30	.....	N	Sand	
34abd	J. Johnson	45	24	Dr	1952	11.44	4- 3-58	D,S	Sand	Inadequate supply.
34cdd	Ornald Strand	185	24	Dr	1936	25	.....	D,S	Sand	Adequate supply.
35ddc1	Virgil Anderson	275	4	Dr	10-57	20	.....	D,S	Shale	Do. Chemical analysis.
35ddc2	Do	15.52	4	Dr	....	30	.....	S	Sand	Do.
36bbb	Test hole 1310	178.5	36	Du	....	10.41	4- 3-58	D	Sand	Inadequate supply.
			5	Dr	5-58	....	.....	T	....	See log.
156-69										
[illegible]aa	Martha Straade	45	36	Du	1934	....	.....	S	....	
3aca	Nils Hove	95	6	Dr	1919	35	.....	N	Gravel	Adequate supply.
3ada	Fritz Hove	40.80	5	Dr	....	14.96	4- 4-58	N	....	
10bdd	Walter Oeffer	74	36	Du	1939	27.68	4- 4-58	D,S	Gravel	Do.
13cca1	Robert Peiler	49	12	Du	....	....	.....	S	....	
13cca2	Do	78	3	Dr	1956	26	.....	D	Sand	
14cca	George Peiler	100	5	Dr	....	50	.....	D,S	Sand	Adequate supply.
14cca1	Peter Tousrud	40	4	Dr	1950	16	.....	D	....	
14cca2	Do	30	36	Dr	1938	17.14	4- 4-58	S	....	
21add	Unknown	59.06	36	Du	....	28.43	4- 4-58	N	....	
22dda1	Raymond L. Russell	130	4	Dr	1923	15.71	4- 4-58	D	Sand	
22dda2	Do	42	24	Dr	1949	14	.....	S	Sand	Adequate supply.
23dac	John Stenson	35	32	Du	1935	....	.....	D,S	Sand	Adequate suply; chemical analysis.
24ada	Oscar and Iver Crist	55	24	Dr	....	12.78	.....	D	....	
24cba	Tom Stenson	65	...	Dr	1906	30	.....	D,S	Gravel	Adequate supply; chemical analysis.

[illegible]

[illegible]

Location number	Owner or name	Depth of well (feet below land surface)	Diameter or size (inches)	Type	Date completed	Depth to water (feet below land surface)	Date of measurement	Use	Aquifer	Remarks
156-69 (Continued)										
25cda	Unknown	42.40	36	Du	....	19.86	4- 3-58	N	....	
25dba	Test hole 1313	189	5	Dr	5-58	....	.....	T	....	See log.
28ddd	Walter Larson	90	5	Dr	1935	30	.....	D,S	Sand	Adequate supply.
34cdc	C. E. Follman	100	4	Dr	....	20	.....	D,S	....	Do.
35aaa	Test hole 1291	178	5	Dr	4-58	....	.....	T	....	See log. Chemical analysis
35bbb	Test hole 1293	210	5	Dr	4-58	....	.....	T	....	Do. do do
35daa	Unknown	69.60	48	Du	....	8.49	4- 3-58	...	....	
36aaa	Test hole 1314	173	5	Dr	5-58	....	.....	T	....	See log.
36abc	Test hole 1292	178.5	5	Dr	4-58	....	.....	T	....	Do.
36add	Test hole 1315	179	5	Dr	5-58	....	.....	T	....	Do.
36ddd	Test hole 1290	178.5	5	Dr	4-58	....	.....	T	....	Do.

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Contents

Illustrations

Tables

GROUND-WATER RESOURCES IN THE VICINITY OF LEEDS, BENSON COUNTY, NORTH DAKOTA

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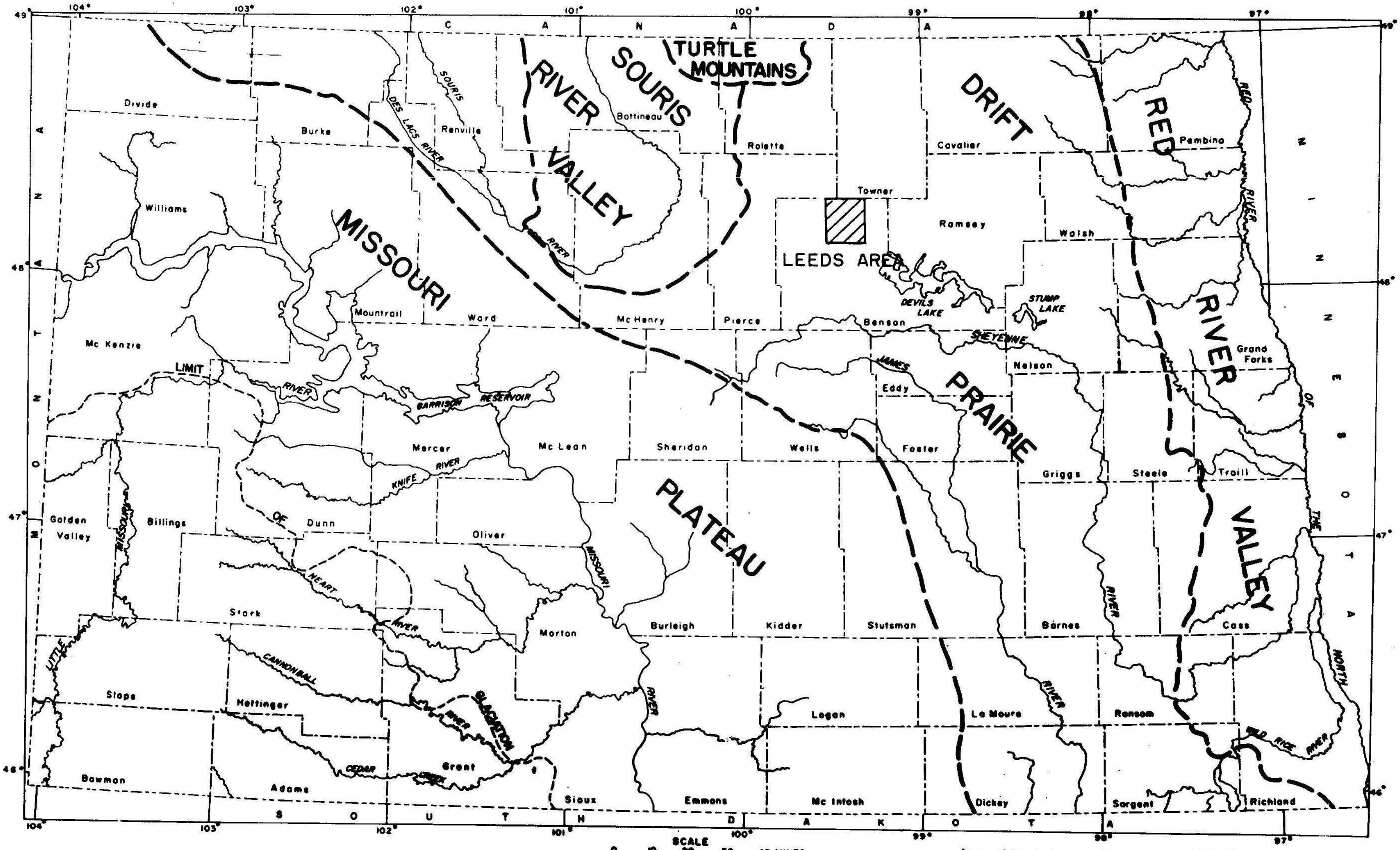
Introduction

The North Dakota State Water Conservation Commission, the North Dakota Geological Survey, and the United States Geological Survey have been making investigations of the ground-water resources available for municipal use in North Dakota as a part of a cooperative ground-water-investigations program. Relatively small areas surrounding towns that have requested aid from one of the State agencies are studied. At a later date, when adequate funds become available, more complete investigations will be made of larger areas, such as counties, and reports on these larger areal investigations will include some of the results of the municipal water-supply studies.

The present investigation was started in 1958. Its purpose was to evaluate ground-water resources near Leeds, N. Dak., with special emphasis on exploration for an aquifer suitable for a municipal water supply. Early well records and related information about ground water in the Leeds area are discussed by Simpson (1929).

Leeds is in the Drift Prairie province (Simpson, 1929, p. 7-10) in the north-central part of North Dakota, a short distance northwest of Devils Lake (fig. 1). The town is served by the main line of the Great Northern Railway, a branch line of the Northern Pacific Railway, and U.S. Highway 2. Its population was 797, according to the 1960 census.

The topography at Leeds is gently rolling, and local relief is 20 to 60 feet. Short intermittent streams connect marshy areas and shallow lakes. Ibsen Lake, about 2 miles southeast of Leeds, contains water throughout the year. Climatologic records for Leeds are available for a short period only; therefore the average annual precipitation is not known. In 1960, 17.18 inches was recorded. At the Maddock Agricultural School, 25 miles south of Leeds, the average annual precipitation is 16.55 inches, based on a 46-year record by the U.S. Weather Bureau. The average annual temperature, for the period of record, is 39.5°F.



(Modified from Simpson, 1929)

FIGURE 1--MAP SHOWING PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA AND LOCATION OF THE LEEDS AREA.

Well-Numbering System

The well-numbering system used in this report is illustrated in figure 2 and is based upon the location of the well in the Federal system of rectangular surveys of the public lands. The first numeral denotes the township north, the second numeral denotes the range west, both referred to the fifth principal meridian and base line, the third numeral denotes the section in which the well is located. The letters a, b, c, and d designate respectively the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre tracts), as shown on figure 2. Consecutive terminal numerals are added when more than one well is given in a 10-acre tract. Thus, a typical well 156-69-15daa is in the NE1/4NE1/4SE1/4 sec. 15, T. 156 N., R. 69 W.

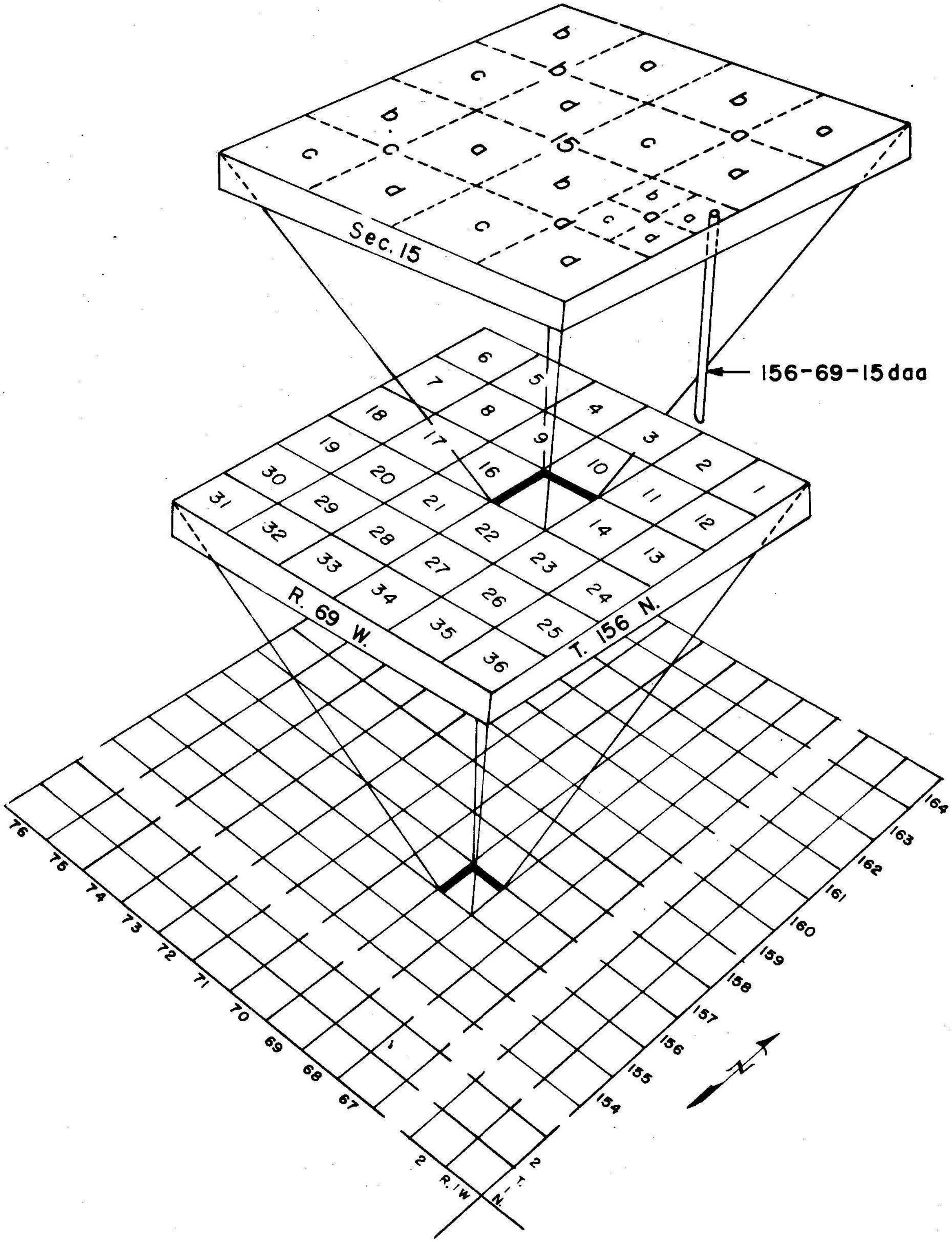


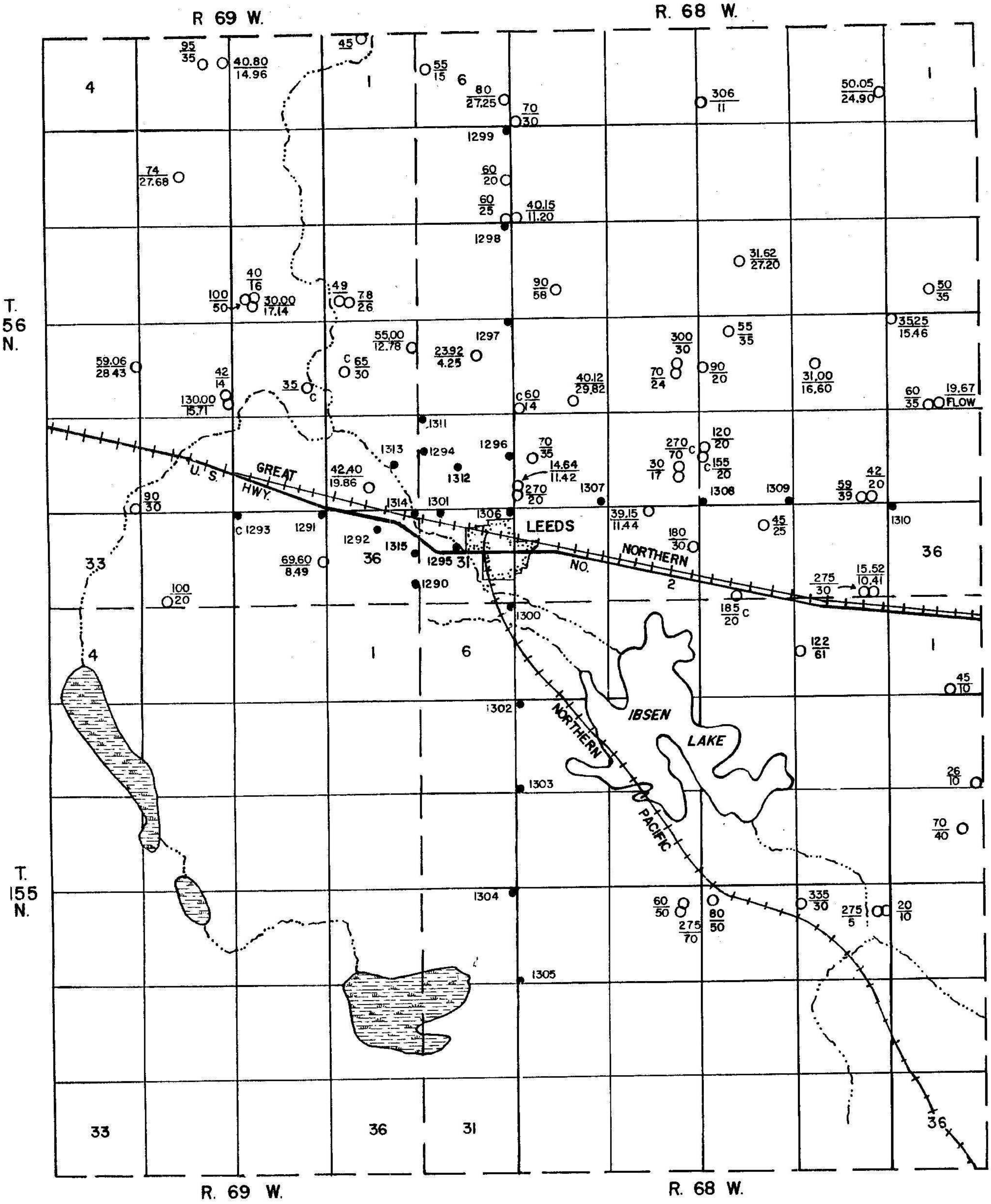
FIGURE 2-- SYSTEM OF NUMBERING WELLS AND TEST HOLES.

Ground Water in Relation to Geology

The geologic units in the area are stream and lake deposits of Recent age, glacial drift of Pleistocene age, and, underlying these deposits but not known to be exposed in the Leeds area, the bedrock formations -- of which the uppermost is the Pierre Shale of Late Cretaceous age. Recent stream and lake deposits are too thin to contain usable quantities of ground water and are not considered further in this report.

The glacial drift is derived largely from the Pierre Shale; this formation breaks down into soft brittle shale pebbles or gravel and calcareous clay. The drift may be subdivided into two distinct units: (1) till and (2) stratified drift. Till is a heterogeneous mixture of clay, silt, sand, gravel, and boulders, which is unstratified. In its uppermost 10 to 20 feet, the till is generally yellowish-brown, owing to chemical weathering. Below the zone of weathering it is bluish gray. The till itself does not yield water to wells readily; in fact it may act as a confining zone for water contained in lenses or layers of sand or gravel under or within the till.

Most wells in the Leeds area probably derive their water from relatively small bodies of sand and gravel of stratified drift that are buried in the till and are usually isolated (table 1). These deposits were laid down by glacial melt-water streams, probably in close association with the disintegrating ice sheet. In a more comprehensive ground-water investigation of the Minnewaukan area (Aronow, and others, 1953, p. 64), the following was said about the small water-bearing zones within the till, "Because the till is not entirely impermeable, these small bodies of sorted material may occur in certain areas in sufficient number to make the entire till sheet function as a weak aquifer."



EXPLANATION

WELL: ○ 70/40 C

UPPER NUMBER INDICATES DEPTH OF WELL, LOWER NUMBER INDICATES DEPTH TO WATER IN THE WELL
"C"— CHEMICAL ANALYSIS

2 MILES

● 1305 TEST HOLE

Base compiled from North Dakota State Highway Maps

FIGURE 3-- MAP OF LEEDS AREA SHOWING LOCATIONS OF WELLS AND TEST HOLES

In 1958 the North Dakota State Water Conservation Commission drilled 26 test holes (table 2) in the Leeds area to locate, if possible, a source of ground water for municipal use. The test holes ranged in depth from 147 to 220 feet and averaged 185 feet. Twenty-two test holes were drilled through the entire thickness of glacial drift and into the underlying Pierre Shale. Figure 3 shows the location of the test holes, and figure 4 shows graphic logs of selected test holes in the Leeds area. Test hole 1308 (156-68-27ccc) penetrated 25 feet of fine to medium gravel from 134 to 159 feet below the land surface. Test holes a mile east and a mile west also penetrated thin beds of gravel. Additional test drilling in the area of test hole 1308 probably would be desirable to obtain more data on the thickness and extent of the water-bearing material. A pumping test to determine whether a sufficient supply of water can be developed in this area also is desirable. In test hole 1297 (156-68-19aaa), 18 feet of sand and gravel occur between 72 and 90 feet. An electric log (fig. 4) of this test hole shows a permeable zone at about this depth, and further exploration may be warranted in this area also. Five feet of gravel was penetrated between 55 and 60 feet, and 15 feet of coarse gravel between 153 and 168 feet in test hole 1294 (156-68-30bcc). The full thickness of gravel at this site was not penetrated, but surrounding test holes penetrated little or no gravel; hence the areal extent of the gravel in this area probably is relatively small. Ground-water yields from this zone would probably not be sufficient for a lasting municipal water supply for Leeds, although additional testing may be justified short distances northwest and south of test hole 1294.

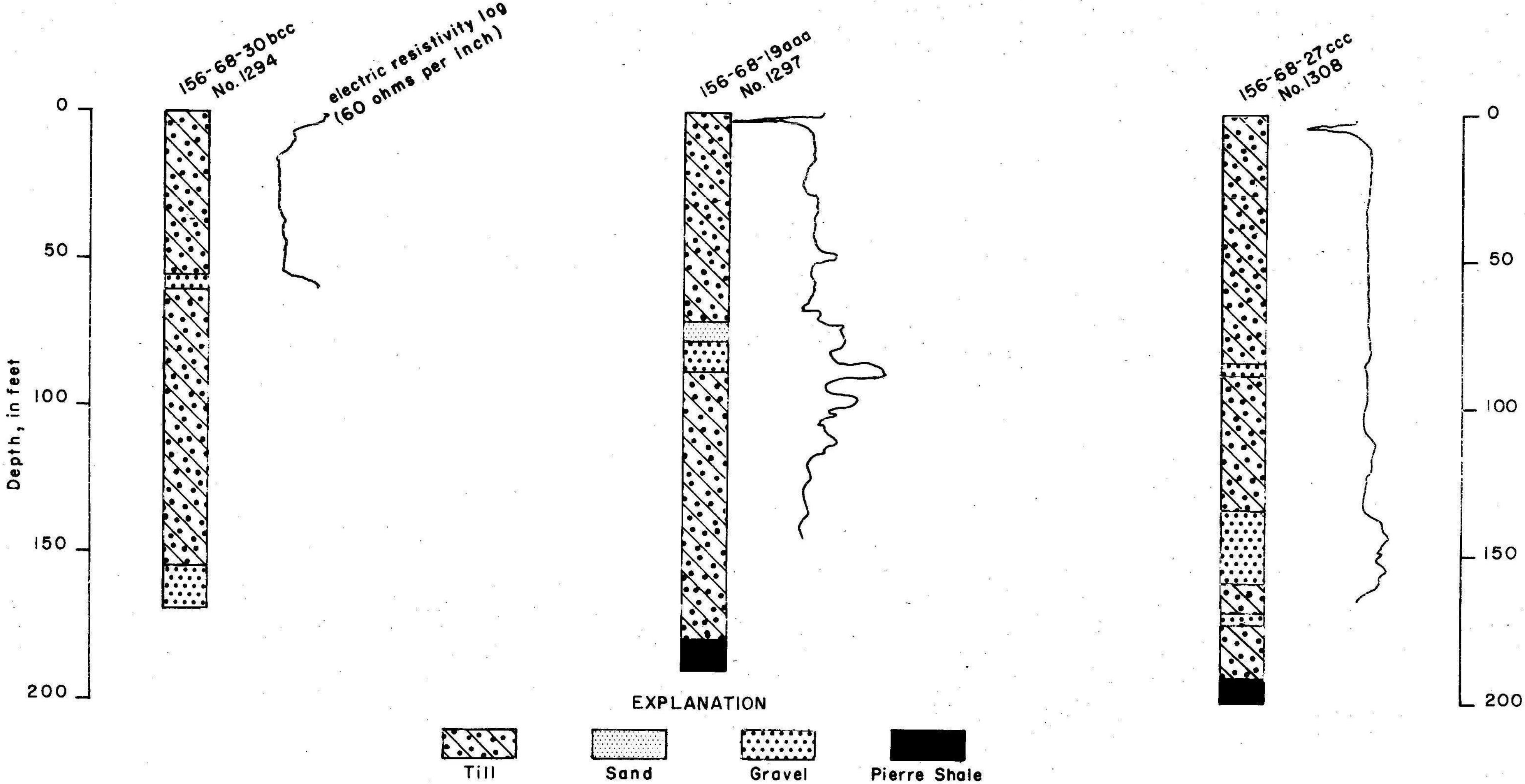


FIGURE 4--GRAPHIC LOGS AND RESISTIVITY MEASUREMENTS OF SELECTED TEST HOLES IN THE LEEDS AREA.

Chemical Quality of Ground Water

Ground water of good quality for general use is difficult to find in the Leeds area (table 3). The 7 wells sampled range in depth from 35 to 270 feet. Five of these yield water from the sand and gravel deposits in or at the bottom of the till, and two yield water from the Pierre Shale. Water from wells in most of the area is reported to be very hard and probably has a high concentration of dissolved solids. The concentration of iron exceeded the U.S. Public Health Service's recommended limits in all the samples, and sulfate exceeded the limit in four. Hardness is caused mainly by calcium and magnesium, but is also caused by dissolved iron, manganese, aluminum, and other metals. Hardness is an indication of the soap consuming power of the water. On a large scale, hardness may be decreased in water-treatment plants by the addition of slaked lime and soda ash and on a domestic or small commercial scale by passing the water through beds of zeolite charged with sodium salts. The sulfate ion is of little significance in domestic water supplies, except if the concentration is so large as to have a laxative effect.

The quality of water for public supply and domestic use commonly is evaluated in relation to standards of the U.S. Public Health Service for drinking water. The standards, adopted in 1914 to protect the health of the traveling public, were revised several times in subsequent years. The latest revisions by the U.S. Public Health Service (1962) are, in part, as follows:

Constituent	Maximum concentration ppm	
Iron (Fe)	0.3	
Manganese (Mn)	.05	
Sulfate (SO_4)	250	
Chloride (Cl)	250	
Fluoride (F)	1.7	a/
Nitrate (NO_3)	45	b/
Dissolved solids	500	c/

a/Based on annual average of maximum daily air temperature at Maddock Agricultural School.

b/In areas where the nitrate content of water exceeds 45 ppm the public should be warned of the potential dangers of using the water for infant feeding.

c/Dissolved-solids concentration of 1,000 ppm are permitted if water of better quality is not available.

The data listed in table 3 show that the recommended maximum limits for some mineral constituents are exceeded in all analyses; however, water containing more than the recommended mineral concentrations has been used in some areas, including North Dakota, for many years without reported ill effects.

Water containing large amounts of dissolved solids and sodium in excess of 50 percent of total cations, may cause soils to become less permeable. Other factors such as porosity of the soil, crop management, irrigation practices, and drainage also affect the use of water with high sodium content when applied to various soils for irrigation.

The salinity of water is determined by the dissolved salts it contains and is closely related to the specific conductance of the water. Nearly all waters that have been used successfully for a considerable time for irrigation have specific conductances of less than 2,250 micromhos per cm. Waters having higher specific conductance are used occasionally, but crop production, except in unusual situations, has not been successful (U.S. Salinity Laboratory Staff, 1954, p. 70).

Summary and Recommendations

The investigation shows that several aquifers in the report area may contain sufficient quantities of water for additional development; however, the dissolved-solids content of the water exceeds the upper limit (500 ppm) recommended by the U.S. Public Health Service (1962) and the water is very hard (minimum hardness reported was 274 ppm).

Before additional development, more information about the water-bearing deposits should be obtained. Additional test drilling in the immediate vicinity of the sand and gravel deposits (near test holes 1308, 1297, and perhaps 1294), would be helpful to determine the full areal extent and thickness of the deposits. A pumping test and additional quality-of-water testing should be made to determine whether a sufficient supply of suitable water could be obtained in these areas.

TABLE 1.--Records

Depth of well and depth to water: Measured depths are given in feet, tenths and (or) hundredths; reported depths are in feet.

Type of well: Dr, drilled; Du, dug.

Location no.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
155-68					
1dcd	Wallace Tarang	45	48	Du	....
2cbb	Ingvold Foss	122	5	Dr	1920
6aaa	Test hole 1300	178.5	5	Dr	5-58
8bbb	Test hole 1302	178.5	5	Dr	5-58
8ccc	Test hole 1303	178.5	5	Dr	5-58
12ddd	Stadness Co.	26	30	Dr	....
13adc	J. M. L. Anderson	70	30	Dr	....
19aaa	Test hole 1304	199.5	5	Dr	5-58
20ccc	Test hole 1305	147	5	Dr	5-58
21aac1	C. M. Fogelson	60	48	Du	....
21aac2	..do....	275	6	Dr	....
22bb	..do....	80	24	Dr	1957
23ada1	Mertle E. Haugen	20	24	Dr	1957
23ada2	..do....	275	5	Dr	....
23bbc	Harold Kenner Sr.	335	5	Dr	....
156-68					
2dad	....	50.05	24	Dr	....
3ccb	Bennet Medhus	306	5	Dr	1933
5ccc	Oscar Jorgenson	70	36	Dr	1952
6bc	Ole Rodland	55	...	..	1910
6dad	George Jorgenson	80	4	Dr	1911
7aaa	Test hole 1299	175	5	Dr	5-58
7daa	E. Tostenson	60	36	Dr	1916
7ddd	Mrs. Runcken	60	36	Dr	1917
8ccc	Inga Quammen	40.15	36	Dr	....
13cda	Olie Eliksmoen	50	36	Dr	1910
15bdd	John R. Coway	31.62	48	Du	....
17cad	Lewis Peiler	90	4	Dr	....
18aaa	Test hole 1298	210	5	Dr	5-58
19aaa	Test hole 1297	189	5	Dr	5-58

of wells and test holes

Use of water: D, domestic; N, none;
S, stock; T, test hole.

Remarks: Chemical analyses are in table 3;
logs are in table 2.

Depth to water below land surface (feet)	Date of measurement	Use	Aquifer	Remarks
10	....	D,S	Gravel	Supply reported adequate.
61	....	D,S	..do..	..Do....
......	....	T	......	See log.
......	....	T	......	..Do....
......	....	T	......	..Do....
10	....	D,S	Sand	Supply reported adequate.
40	....	D,S	......	..Do....
30	....	T	......	See log.
......	....	T	......	..Do....
50	....	N	..do..	Supply reported adequate.
70	....	N	Clay	..Do....
50	....	D,S	Sand	..Do....
10	....	D	Sand and gravel	..Do....
5	....	S	......	Supply reported adequate; saline.
30	....	D,S	Sand	Supply reported adequate.
24.90	4- 4-58	N	......	Abandoned.
11	....	D,S	Shale	Supply reported adequate.
30	....	D	Sand	..Do....
15	....	D,S	..do..	..Do....
27.25	4- 3-58	D,S	..do..	Supply reported inadequate.
......	....	T	......	See log.
20	....	N	......	Supply reported adequate.
25	....	N	..do..	..Do....
11.20	4- 3-58	D,S	Gravel	..Do....
35	....	D,S	Sand	..Do....
27.20	4- 4-58	D,S	......	..Do....
58	....	D,S	..do..	Supply reported inadequate.
......	....	T	......	See log.
......	....	T	......	..Do....

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
156-68 (Cont.)					
19ac	Stewert Robinson	23.92	36	Du	1943
20ccc	Chester Johnson	60	36	Du	.....
20dc	..do....	40.12	36	Du	.....
21dab1	Joe Blegen	300	6	Dr	1920
21dab2	..do....	70	30	Du	1952
22ba	Ernest Elverud	55	2	Dr	.....
22cbb	John Paulson	90	24	Du	.....
23cba	Norris Gresdahl	31.00	36	Du	.....
24bbb	Oris Norhaugen	35.25	36	Dr	.....
24cdd	Ragna Knudson	60	4	Dr	.....
24dcc	Chester Johnson	19.67	24	Dr	1947
26ddc1	Oscar Gustafson	42	24	Dr	.....
26ddc2	..do....	59	4	Dr	1956
27bcc1	Peter Blegen	120	6	Dr	1914
27bcc2	..do....	155	6	Dr	1951
27ccc	Test hole 1308	199.5	5	Dr	5-58
27ddd	Test hole 1309	147	5	Dr	5-58
28dac1	Jens Engstrom	270	4	Dr	1928
28dac2	..do....	30	36	Dr	1943
29bcd	Emil Engstrom	70	24	Dr	.....
29ccb1	Charlie Urness	270	4	Dr	1918
29ccb2	..do....	14.64	36	Du	.....
29ddd	Test hole 1307	210	5	Dr	5-58
30add	Test hole 1296	220	5	Dr	5-58
30bbb	Test hole 1311	189	5	Dr	5-58
30bcc	Test hole 1294	168	5	Dr	4-58
30caa	Test hole 1312	189	5	Dr	5-58
31aaa	Test hole 1306	199.5	5	Dr	5-58
31bba	Test hole 1301	189	5	Dr	5-58
31bdd	Test hole 1295	178.5	5	Dr	5-58
33add	Grimsrud	180	5	Dr	.....
33baa	Kenneth Fox	39.15	24	Dr	1952
34abd	J. Johnson	45	24	Dr	1936

of wells and test holes -- Continued

Depth to water below land surface (feet)	Date of measure-ment	Use	Aquifer	Remarks
4.25	4- 2-58	S	Sand	Supply reported adequate.
14	....	D,S	..do..	Supply reported adequate; chemical analysis.
29.82	4- 2-58	S	Gravel	Supply reported adequate.
30	....	S	Sand	Supply reported adequate; saline.
24	....	D	Gravel	Supply reported adequate.
35	....	D,S	......	..Do....
20	....	D,S	......	..Do....
16.60	4- 4-58	N	Sand	..Do....
15.46	4- 3-58	N	......	
35	....	D,S	..do..	..Do....
Flow	4- 2-58	S	Gravel	..Do....
20	....	S	Sand	Supply reported inadequate.
39	....	D	..do..	..Do....
20	....	S	......	..Do....
20	....	D	..do..	Supply reported inadquate; chemical analysis.
......	....	T	......	See log.
......	....	T	......	..Do....
70	....	S	Shale	Supply reported adequate; chemical analysis.
17	....	D,S	Sand	Supply reported inadequate.
35	....	D,S	Gravel	..Do....
20	....	N	Sand	Supply reported adequate.
11.42	4- 3-58	N	......	Supply reported inadequate.
......	....	T	......	See log.
......	....	T	......	..Do....
......	....	T	......	..Do....
......	....	T	......	..Do....
......	....	T	......	..Do....
......	....	T	......	..Do....
......	....	T	......	..Do....
......	....	T	......	..Do....
30	....	N	Sand	
11.44	4- 3-58	D,S	..do..	Supply reported inadequate.
25	....	D,S	..do..	Supply reported adequate.

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
156-68(Cont.)					
34cdd	Ornald Strand	185	4	Dr	10-57
35ddc1	Virgil Anderson	275	4	Dr	.....
35ddc2	..do....	15.52	36	Du	.....
36bbb	Test hole 1310	178.5	5	Dr	5-58
156-69					
1baa	Martha Straade	45	36	Du	1934
3aca	Nils Hove	95	6	Dr	1919
3ada	Fritz Hove	40.80	5	Dr	.....
10bdd	Walter Oeffer	74	36	Du	1939
13cca1	Robert Peiler	49	12	Du	.....
13cca2	..do....	78	3	Dr	1956
14cca1	George Peiler	100	5	Dr	.....
14cca2	Peter Tousrud	40	4	Dr	1950
14cca3	..do....	30	36	Dr	1938
21add	....	59.06	36	Du	.....
22dda1	Raymond L. Russell	130.00	4	Dr	1923
22dda2	..do....	42	24	Dr	1949
23dac	John Stenson	35	32	Du	1935
24ada	Oscar and Iver Crist	55.00	24	Dr	.....
24cba	Tom Stenson	65	..	Dr	1906
25cda	....	42.40	36	Du	.....
25dba	Test hole 1313	189	5	Dr	5-58
28ddd	Walter Larson	90	5	Dr	1935
34cdc	C. E. Follman	100	4	Dr	.....
35aaa	Test hole 1291	178	5	Dr	4-58
35bbb	Test hole 1293	210	5	Dr	4-58
35daa	....	69.60	48	Du	.....
36aaa	Test hole 1314	178.5	5	Dr	5-58
36abc	Test hole 1292	178.5	5	Dr	4-58
36add	Test hole 1315	178.5	5	Dr	5-58
36dda	Test hole 1290	178.5	5	Dr	4-58

of wells and test holes -- Continued

Depth to water below land surface (feet)	Date of measurement	Use	Aquifer	Remarks
20	....	D,S	Shale	Supply reported adequate; chemical analysis.
30	....	S	Sand	Supply reported adequate.
10.41	4- 3-58	D	..do..	Supply reported inadequate.
......	....	T	......	See log.
......	....	S	......	
35	....	N	Gravel	Supply reported adequate.
14.96	4- 4-58	N	......	
27.68	4- 4-58	D,S	..do..	..Do....
......	....	S	......	
26	....	D	Sand	
50	....	D,S	..do..	..Do....
16	....	D	......	
17.14	4- 4-58	S	......	
28.43	4- 4-58	N	......	
15.71	4- 4-58	D	..do..	
14	....	S	..do..	..Do....
......	....	D,S	..do..	Supply reported adequate; chemical analysis.
12.78	....	D	......	
30	....	D,S	Gravel	..Do....
19.86	4- 3-58	N	......	
......	....	T	......	See log.
30	....	D,S	Sand	Supply reported adequate.
20	....	D,S	......	..Do....
......	....	T	......	See log.
......	....	T	......	See log; chemical analysis.
8.49	4- 3-58	...	......	
......	....	T	......	See log.
......	....	T	......	..Do....
......	....	T	......	..Do....
......	....	T	......	..Do....

TABLE 2.--Logs of test holes

155-68-6aaa
Test hole 1300

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	1	1
	Till; clay, silty to sandy, yellowish-gray..............................	4	5
	Gravel, fine to coarse................	2	7
	Till; clay, gray; fine to medium gravel, shale pebbles.....................	29	36
	Gravel, fine to medium................	1	37
	Till; clay, gray, medium to coarse gravel; shale pebbles and some cobbles......	138	175
Pierre Shale:			
	Shale, gray...........................	$3\frac{1}{2}$	$178\frac{1}{2}$

155-68-8bbb
Test hole 1302

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	2	2
	Till; clay, yellowish-gray; some gravel	14	16
	Till; clay, gray; fine to coarse gravel	158	174
Pierre Shale:			
	Shale, gray...........................	$4\frac{1}{2}$	$178\frac{1}{2}$

155-68-8ccc
Test hole 1303

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, medium to coarse sand...........	2	2
	Gravel, medium to coarse..............	2	4
	Till; clay, yellow to brown; medium to coarse gravel......................	8	12
	Till; clay, gray; fine to medium gravel	49	61
	Sand, fine to medium..................	17	78
	Gravel, fine to medium................	2	80
	Till; clay, gray; medium to coarse gravel; shale pebbles...............	87	167
Pierre Shale:			
	Shale, gray; some lignite fragments...	$11\frac{1}{2}$	$178\frac{1}{2}$

TABLE 2.--Logs of test holes -- Continued

155-68-19aaa
Test hole 1304
1570

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	2	2
	Till; clay, yellowish-gray, fine gravel	19	21
	Till; clay, gray; fine to medium gravel	63	84
	Gravel, fine to medium................	2	86
	Till; clay, gray; fine to medium gravel; large concentration of boulders from 131 to 137 feet.....................	109	195
Pierre Shale:			
	Shale, gray...........................	$4\frac{1}{2}$	$199\frac{1}{2}$

155-68-20ccc
Test hole 1305
1530

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	2	2
	Till; clay, sandy, light-gray.........	4	6
	Till; clay, yellow to brown; fine to medium gravel......................	8	14
	Till; clay, gray; fine to medium gravel and shale pebbles..................	53	67
	Gravel, fine to medium................	2	69
	Till; clay, gray; fine to medium gravel and shale pebbles...........	21	90
	Till; clay, gray; fine to medium gravel and lignite fragments which become large from 131 to 147 feet..........	57	147

156-68-7aaa
Test hole 1299

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	1	1
	Till; clay, yellow to brown; medium to coarse gravel......................	14	15
	Till; clay, gray; fine to medium gravel; shale pebbles......................	40	55
	Gravel, coarse; some cobbles..........	2	57
	Till; clay, gray; fine to medium gravel and some cobbles; shale pebbles.....	118	175

TABLE 2.--Logs of test holes -- Continued

156-68-18aaa
Test hole 1298

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	1	1
	Till; clay, yellow to brown; shale pebbles............................	16	17
	Till; clay, gray; fine to medium gravel; shale pebbles......................	13	30
	Gravel, fine to coarse; shale pebbles.	6	36
	Till; clay, gray; medium to coarse gravel; shale pebbles...............	74	110
	Till; clay, gray; medium to coarse sand; shale pebbles and lignite fragments.	10	120
	Till; clay, gray; medium to coarse gravel; shale pebbles...............	70	190
	Till; clay, gray; medium to coarse sand; shale pebbles.................	12	202
Pierre Shale:			
	Shale, gray...........................	8	210

156-68-19aaa
Test hole 1297

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	2	2
	Till; clay, yellowish-brown; fine to medium gravel......................	21	23
	Till; clay, gray; fine to medium gravel; shale pebbles......................	49	72
	Sand, fine to medium, large concentrations of shale fragments...	8	80
	Gravel, fine to coarse; cobbles.......	10	90
	Till; clay, gray; fine to coarse gravel; shale pebbles, cobbles..............	91	181
Pierre Shale:			
	Shale, gray...........................	8	189

TABLE 2.--Logs of test holes -- Continued

156-68-27ccc
Test hole 1308

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	4	4
	Till; clay, yellow; coarse sand grains and pebbles; shale pebbles..........	10	14
	Till; clay, gray; fine to medium gravel; shale pebbles......................	69	83
	Gravel, fine to medium................	5	88
	Till; clay, gray; fine to medium gravel	46	134
	Gravel, fine to medium................	25	159
	Till; clay, gray; fine gravel.........	9	168
	Gravel, medium to coarse..............	5	173
	Till; clay, gray; fine to medium gravel; shale and lignite pebbles...	18	191
Pierre Shale:			
	Shale, gray...........................	8½	199½

156-68-27ddd
Test hole 1309

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	2	2
	Till; clay, yellow; coarse sand grains and some pebbles..................	19	21
	Till; clay, gray; fine to medium gravel; shale pebbles......................	114	135
	Gravel, fine, medium and coarse.......	6	141
	Till; clay, gray; fine to medium gravel; shale pebbles......................	6	147

TABLE 2.--Logs of test holes -- Continued

156-68-29ddd
Test hole 1307

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	4	4
	Till; clay, yellow to brown; carbonate pebbles...........................	12	16
	Till; clay, gray; medium to coarse gravel; shale pebbles..............	32	48
	Gravel, medium to coarse; and coarse sand...............................	3	51
	Till; clay, gray; fine to medium gravel; shale pebbles...............	38	89
	Till; clay, gray; medium to coarse sand...............................	16	105
	Gravel, medium to coarse.............	7	112
	Till; clay, gray; medium to coarse gravel; cobbles and shale pebbles...	88	200
Pierre Shale:			
	Shale, gray..........................	10	210

156-68-30add
Test hole 1296

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, clayey, black................	2	2
	Till; clay, sandy, yellow-brown.......	17	19
	Till; clay, gray; fine to medium gravel; shale pebbles......................	50	69
	Gravel, medium to coarse; shale pebbles	4	73
	Till; clay, gray; fine to medium gravel; cobbles and shale pebbles...........	136	209
Pierre Shale:			
	Shale, gray..........................	11	220

TABLE 2.--Logs of test holes -- Continued

156-68-30bbb
Test hole 1311

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Till; clay, light-gray-yellow	12	14
	Till; clay, sandy, light-gray	9	23
	Till; clay, gray; fine to medium gravel; shale pebbles	51	74
	Sand, fine to medium, clayey	9	83
	Till; clay, gray; fine to medium gravel; shale pebbles	22	105
	Till; clay, gray; fine to medium gravel; shale pebbles	74	179
Pierre Shale:			
	Shale, gray-blue	10	189

156-68-30bcc
Test hole 1294

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	1	1
	Till; clay, sandy, yellow-brown	12	13
	Clay, light-gray	5	18
	Till; clay, gray; fine to coarse gravel; cobbles and shale pebbles	37	55
	Gravel, fine to coarse; medium to coarse sand; cobbles	5	60
	Till; clay, gray; fine to coarse gravel; cobbles and shale pebbles	93	153
	Gravel, coarse; cobbles	15	168

156-68-30caa
Test hole 1312

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	1	1
	Till; clay, yellow; fine to medium gravel	11	12
	Till; clay, gray; fine to medium gravel	133	145
	Till; clay, gray; fine to medium gravel; small boulders	34	179
Pierre Shale:			
	Shale, gray	10	189

TABLE 2.--Logs of test holes -- Continued

156-68-31aaa
Test hole 1306

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	2	2
	Till; clay, yellowish-gray, fine to medium gravel......................	12	14
	Till; clay, gray; fine to medium gravel............................	29	43
	Gravel, fine.........................	2	45
	Till; clay, gray; fine to medium gravel	17	62
	Gravel, fine to medium, interbedded with gray clay.....................	13	75
	Till; clay, gray; fine and medium gravel............................	71	146
	Till; clay, gray; fine gravel.........	22	168
	Till; clay, gray; fine to medium gravel and cobbles..................	25	193
Pierre Shale:			
	Shale, gray...........................	6½	199½

156-68-31bba
Test hole 1301

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	5	5
	Till; clay, yellow to yellowish-gray; medium gravel......................	12	17
	Till; gray, clay; fine to medium gravel............................	165	182
Pierre Shale:			
	Shale, gray...........................	7	189

TABLE 2.--Logs of test holes -- Continued

156-68-31bdd
Test hole 1295

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy, black.................	1	1
	Sand, medium to coarse; granule gravel	5	6
	Clay, gray; medium to coarse gravel; cobbles............................	6	12
	Till; clay, gray; fine to medium gravel; shale pebbles...............	19	31
	Till; clay, gray; medium to coarse sand................................	53	84
	Till; clay, gray, medium to coarse gravel; cobbles....................	74	158
	Till; clay, gray; medium to coarse sand	16	174
Pierre Shale:			
	Shale, gray..........................	4½	178½

156-68-36bbb
Test hole 1310

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black.......................	2	2
	Gravel, fine to medium................	5	7
	Till; clay, yellow; some fine gravel..	11	18
	Till; clay, gray; fine to medium gravel	26	44
	Sand, fine gravel....................	19	63
	Till; clay, gray; fine to medium gravel; lignite fragments...........	106	169
Pierre Shale:			
	Shale, gray..........................	9½	178½

TABLE 2.--Logs of test holes -- Continued

156-69-25dba
Test hole 1313

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	3	3
	Till; clay, sandy, yellowish-gray; fine to medium gravel (weathered till)...	8	11
	Clay, sandy, gray; a few pebbles (sandy till?)......................	9	20
	Till; clay, sandy, gray...............	9	29
	Till; clay, gray; fine to medium gravel	152	181
Pierre Shale:			
	Shale, gray..........................	8	189

156-69-35aaa
Test hole 1291

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black.......................	1	1
	Till; clay, sandy, yellow-brown.......	14	15
	Till; clay, gray; fine to coarse gravel; cobbles; shale pebbles.............	26	41
	Gravel, fine to medium; shale pebbles.	6	47
	Till; clay, gray; fine to coarse gravel; shale pebbles...............	100	147
	Till; clay, gray; fine to coarse gravel, cobbles; shale pebbles......	27	174
Pierre Shale:			
	Shale, gray..........................	4	178

156-69-35bbb
Test hole 1293

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Till; clay, yellow to brown; fine to medium gravel	30	32
	Till; clay, gray; medium to coarse gravel	31	63
	Sand, fine to medium	10	73
	Sand, medium to coarse	11	84
	Gravel, medium to coarse	6	90
	Gravel, medium to coarse; carbonate pebbles	5	95
	Till; clay, gray, sandy; shale pebbles	5	100
	Sand, medium to coarse; shale pebbles.	5	105
	Till; clay, gray, medium to coarse gravel	5	110
	Till; clay, gray; fine to medium gravel; shale pebbles; cobbles	96	206
Pierre Shale:			
	Shale, gray	4	210

156-69-36aaa
Test hole 1314

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Till; clay, yellow; medium sand; carbonate pebbles	10	12
	Till; clay, gray; fine to medium gravel; a few coarse carbonate pebbles; shale pebbles	9	21
	Gravel, medium to coarse	2	23
	Till; clay, gray; fine to medium gravel; a few coarse carbonate pebbles; shale pebbles	16	39
	Gravel, fine to medium; coarse sand; shale pebbles	9	48
	Till; clay, gray; fine to medium gravel; shale pebbles	125	173
Pierre Shale:			
	Shale, gray-blue	5½	178½

TABLE 2.--Logs of test holes -- Continued

156-69-36abc
Test hole 1292

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	1	1
	Till; clay, yellow to brown, pebbles..	6	7
	Till; clay, gray; fine to medium gravel; shale pebbles...............	51	58
	Gravel, fine to medium................	5	63
	Till; clay, gray; medium to coarse gravel.............................	74	137
	Gravel, fine to medium................	2	139
	Till; clay, gray; medium gravel.......	19	158
	Till; clay, gray; fine gravel.........	16	174
Pierre Shale:			
	Shale, gray...........................	4½	178½

156-69-36add
Test hole 1315

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black........................	1	1
	Till; clay, yellowish-gray; gravel....	15	16
	Till; clay, gray; fine and medium gravel	26	42
	Sand, and fine gravel.................	2	44
	Till; clay, gray; fine to coarse gravel; abundant gravel in samples from 58 to 80 feet............................	129	173
Pierre Shale:			
	Shale, gray...........................	5½	178½

TABLE 2.--Logs of test holes -- Continued

156-69-36daa
Test hole 1290

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy, black	2	2
	Till; clay, gray; carbonate, and granite pebbles	4	6
	Clay, sandy, brown to gray; carbonate pebbles	4	10
	Till; clay, gray; medium to coarse gravel; shale, granite and carbonate pebbles	160	170
Pierre Shale:			
	Shale, gray	8½	178½

analyses of ground water

Analyses by State Laboratories, Bismarck

Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids a/	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH per cm
306	12.2	471	455	54	0.2	0.4	1.0	1,300	290	69	1,960	7.4
240	15.5	561	251	49	0.0	0.7	1.0	1,200	336	59	1,780	8.1
2,025	29.5	460	7	3,000	0.0	10	5.1	5,500	337	92	8,460	8.1
372	14.5	155	494	284	0.0	0.4	...	1,500	274	73	2,280	8.0
36	4.0	324	144	35	0.2	2.2	0.2	660	434	15	1,020	6.9
215	...	440	362	111	0.3	0.5	0.7	1,200	441	51	1,850	7.1
360	14.2	426	794	54	0.1	0.9	0.8	1,800	505	60	2,740	7.8

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