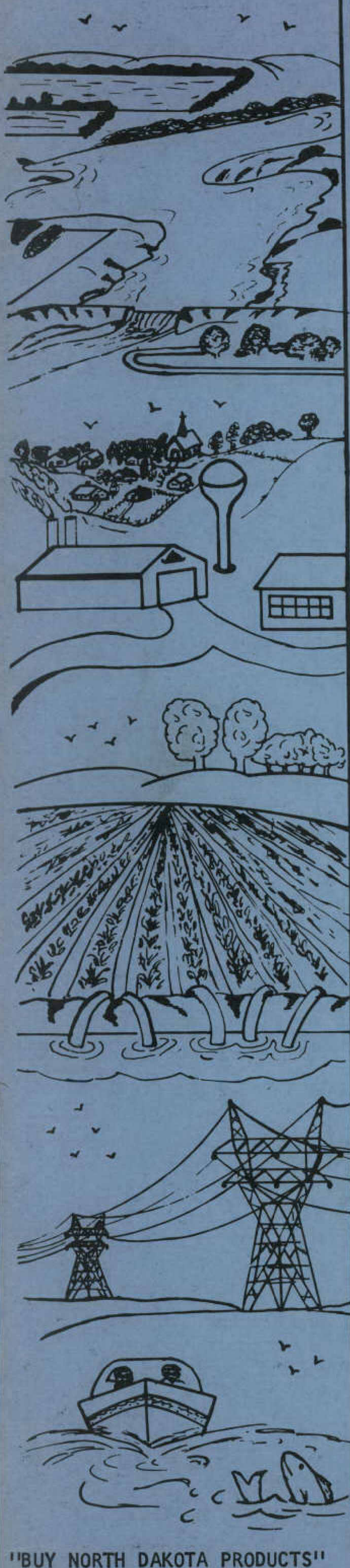


GROUND WATER RESOURCES IN THE LAKOTA AREA
NELSON COUNTY, NORTH DAKOTA

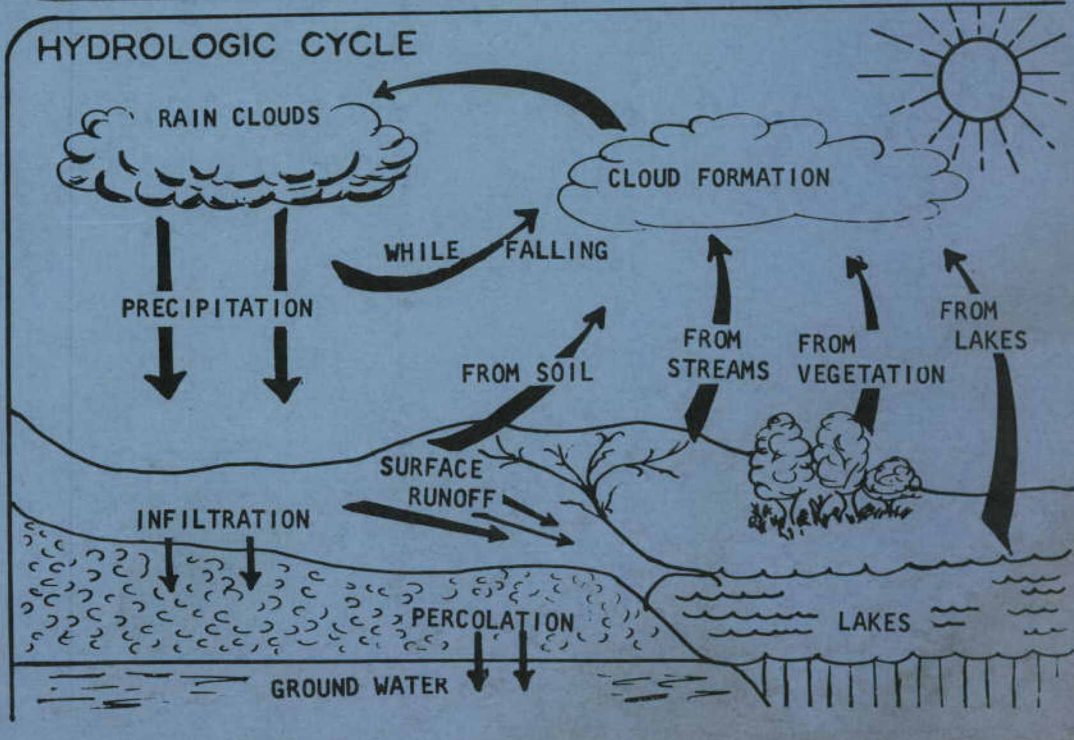
By
J. E. Powell and S. L. Jones
Geological Survey
United States Department of the Interior

NORTH DAKOTA GROUND WATER STUDIES
NO. 48

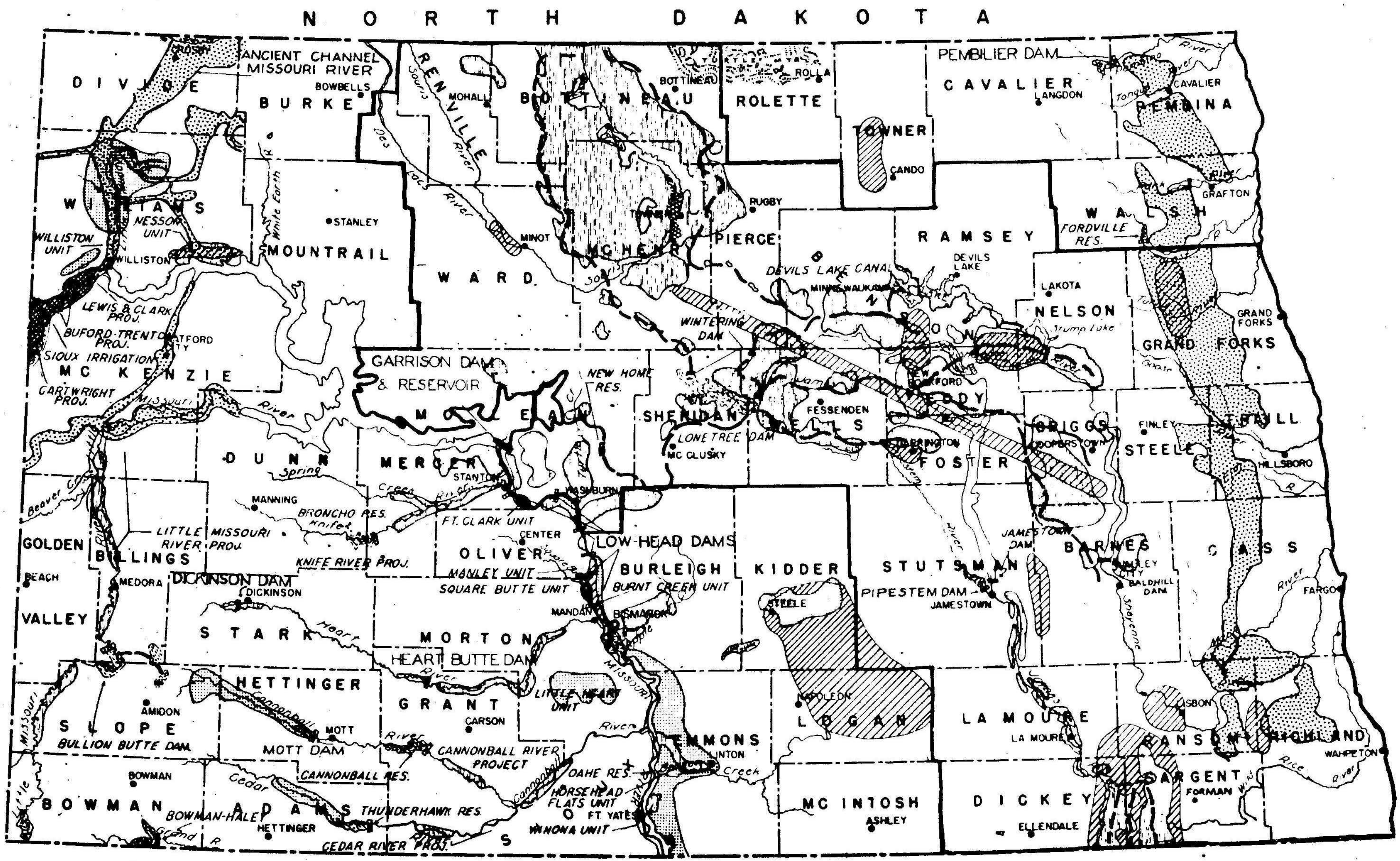
Prepared by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission, and the North Dakota Geological Survey

PUBLISHED BY
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
1301 STATE CAPITOL, BISMARCK, NORTH DAKOTA

- 1962 -



"BUY NORTH DAKOTA PRODUCTS"



NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

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

EXISTING
UNDER CONSTRUCTION OR PROPOSED
DAM & RESERVOIR SITES

PROPOSED CANALS

GARRISON DIVERSION CONSERVANCY DISTRICT BOUNDARY

GROUNDWATER AQUIFERS

Gov. William L. Guy
CHAIRMAN
OSCAR LUNSETH
VICE CHAIRMAN
MILO W. HOISVEEN
SECRETARY AND STATE ENGINEER
RICHARD P. GALLAGHER
MATH DAHL
WILLIAM W. CORWIN
EINAR H. DAHL
HENRY J. STEINBERGER

GROUND WATER RESOURCES IN THE LAKOTA AREA

NELSON COUNTY, NORTH DAKOTA

By
J. E. Powell and S. L. Jones
Geological Survey
United States Department of the Interior

North Dakota Ground-Water Studies No. 48

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

Published by
North Dakota State Water Conservation Commission
1301 State Capitol, Bismarck, North Dakota

- 1962 -

CONTENTS

CONTENTS -- Continued

ILLUSTRATIONS

TABLES

GROUND-WATER RESOURCES IN THE LAKOTA AREA
NELSON COUNTY, NORTH DAKOTA

By
J. E. Powell and S. L. Jones

ABSTRACT

The Lakota area includes 126 square miles within the Devils Lake interior drainage basin of the Drift Prairie physiographic province in Nelson County, N. Dak. The surface deposits of glacial drift are underlain by Pierre Shale, which crops out around Stump Lake in the southwestern part of the area. Gently rolling ground moraine covers most of the Lakota area but end moraine occurs locally in the north-central, southeast, and northwest. The topography consists of low relief and poorly developed drainage that results in many undrained depressions and swamps. Two glacial spillways trend southward in meandering courses across the area and drain into Stump Lake.

A buried, steep-sided channel deposit of sand and gravel about half a mile wide was discovered by test drilling east of Lakota. The channel is about 1 mile east of the city and trends southwestward for a distance of at least 1 1/4 miles. The city of Lakota has developed a producing water well, Lakota No. 6(153-60-26acb4) in this deposit; an estimated 70 gpm (gallons per minute) for a period of about 6 hours a day is pumped from the well. This well, together with Lakota well No. 2 (153-60-26acbl), a shallow dug well in an esker deposit, furnishes the water supply for the city.

The surficial deposits in the Lakota area are mostly glacial drift that was deposited during the last major ice sheet advance. Most of the drift consists of till but lenses of stratified sand and gravel enclosed within the till occur at some places. The drift also includes ice-contact deposits such as eskers and kames, spillway or channel deposits, buried valley deposits, and lake deposits. Cretaceous bedrock formations underlie the glacial drift in the report area.

Glacial drift is a source of ground water in many parts of the Lakota area. Many wells yield water from sand and gravel lenses associated with the till; some wells obtain water from ice-contact deposits. Also, it may be possible to develop ground-water sources from spillway deposits; about 2 miles east of Lakota 90 feet of saturated sand and gravel was found in a test hole. Small supplies of ground water are obtained from the wells drilled into a bedrock formation, the Pierre Shale of Late Cretaceous age. Probably the water occurs in cracks or fractures in the upper few feet of the shale. Rocks older than the Pierre Shale are not used as aquifers in the report area, but in adjacent areas, the Dakota Group of Hansen (1955) of Early Cretaceous age, yields water to wells.

A short pumping test of 24 hours and 23 minutes duration was made on a well, Lakota No. 6. The drawdown after pumping was 24.25 feet. The coefficient of transmissibility was calculated to be about 12,000 gpd/ft (gallons per day per foot) and the coefficient of storage was calculated to be 0.0007. The magnitude of the coefficient of storage indicates an artesian aquifer.

Recharge in the Lakota area is by downward percolation of rain water and water from melted snow. Shallow aquifers in the glacial drift receive recharge faster than deep aquifers; thus sand and gravel deposits at the surface in spillways or ice-contact deposits are favorable areas for recharge. Ground water is discharged by direct evapotranspiration in low areas, especially during the growing season. The regional direction of ground-water movement is probably southwestward toward Stump Lake.

Chemical analyses of ground water in the report area indicate that the dissolved-solids content is high. Recommended maximum concentrations of various constituents are exceeded in water from a number of the wells sampled.

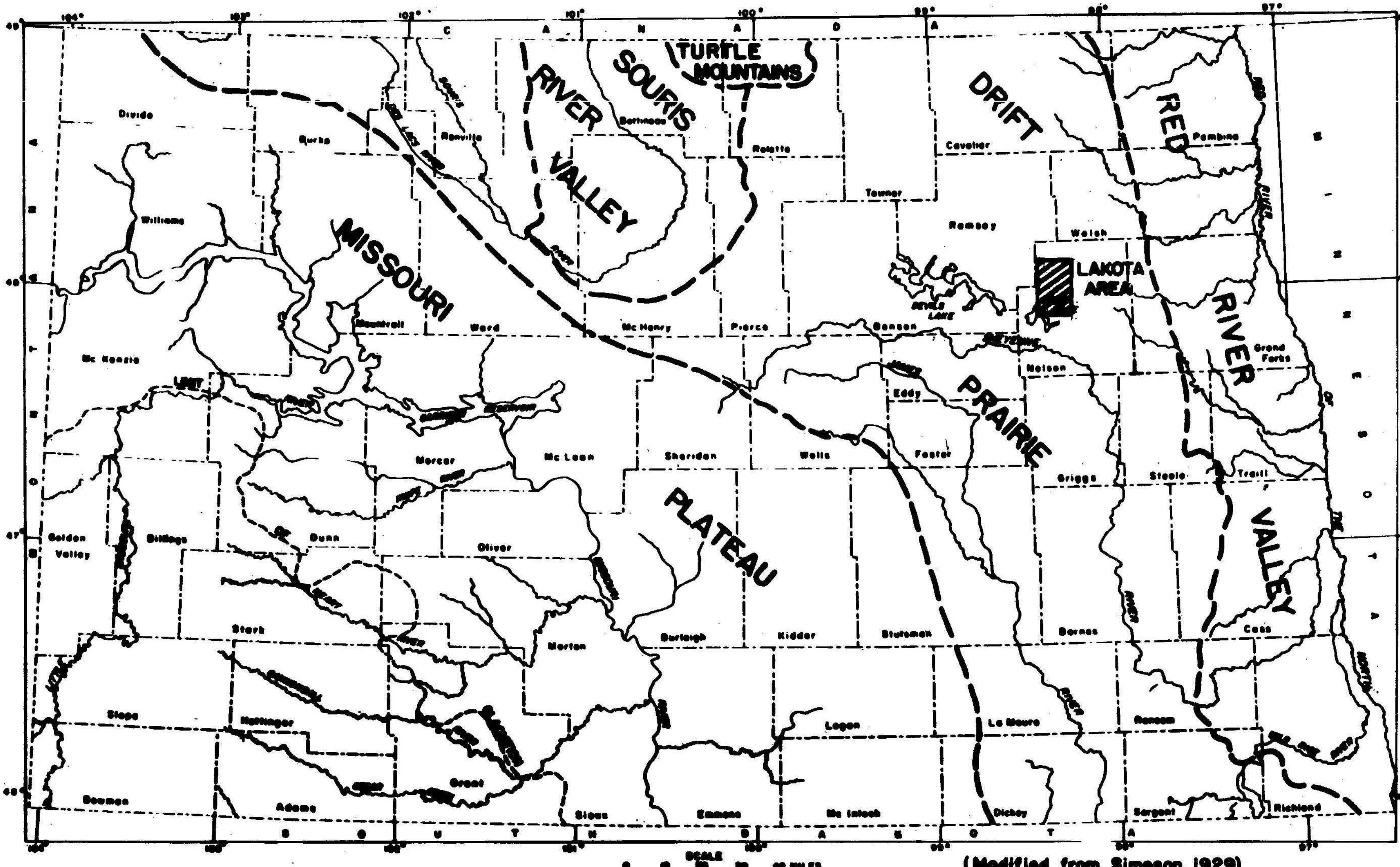
INTRODUCTION

Location and General Features of the Area

The Lakota area comprises 126 square miles in the western part of Nelson County, North Dakota (fig. 1). Lakota, population 1,066 (1960 census), located in the central part of the area, is the county seat of Nelson County and is situated at the intersection of U.S. Highway 2 and State Highway 1. Lakota is served also by the main line and a branch line of the Great Northern Railway.

According to the U.S. Weather Bureau, the temperature in the area ranges from a January average of about 2°F. to a July average of about 67°F.; however, maximum and minimum temperatures of above 100°F. and below -30°F. are common. The average annual precipitation is about 18 inches, most of which falls during the 120-day growing season.

The principal occupation in the Lakota area is farming; wheat, flax, oats, barley, and hay are the main crops, and cattle and hogs are the main livestock.



(Modified from Simpson, 1929)

FIGURE I - MAP SHOWING PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA AND LOCATION OF THE LAKOTA AREA

Purpose and Scope of the Investigation

This report presents the results of an investigation of the geology and occurrence and quality of ground-water resources in the Lakota area. The investigation was made by the U.S. Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the North Dakota Geological Survey. The purpose of the study is to evaluate the availability of ground water particularly for municipal use, but for other uses as well.

During this study, data were collected on about 300 wells including measurements of depths and water levels where possible; 33 test holes ranging in depth from 18 to 165 feet and totaling about 2,700 feet were drilled; altitudes of the test holes were determined; water samples were collected from selected wells and test holes; and a study was made of the surface geology. The test holes were drilled with a hydraulic rotary drilling rig owned by the North Dakota State Water Conservation Commission.

Physiographic Features

The Lakota area is in that part of the Central Lowland physiographic province (Fenneman, 1938, p. 559-588) that Simpson (1929, p. 4) called the Drift Prairie (fig. 1). The Drift Prairie is bordered by the Missouri Plateau on the west and by the Red River Valley on the east. The area is within the Devils Lake interior drainage basin (Babcock, 1902, p. 208), which extends from the southern part of the Turtle Mountains and the Canadian boundary southward to the drainage divide between the Sheyenne and James Rivers. The basin is bounded on the east by the edge of the Red River Valley and on the west by the Souris basin.

Drainage units within the basin are poorly integrated as a result of glaciation and consist mainly of intermittent streams, undrained depressions, small ponds and swamps, and a few lakes. Areally, the most prominent drainage units are Devils Lake and Stump Lake, both of which formerly drained southward to the Sheyenne River.

The topographic features of the area have resulted from the action of glacial ice and melt water. Gently rolling terrain called ground moraine constitutes most of the surface except for several tracts of high, rough terrain called end moraine in the northwest, southeast, and southwest corners of the area. Glacial features known as kames and eskers constitute local topographic features as do wave-cut benches around Stump Lake.

Well-Numbering System

The well-numbering system used in this report, illustrated in figure 2, 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 of the base line, the second numeral denotes the range west of the fifth principal meridian, and 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 (10-acre tracts). To distinguish between two or more wells situated within the same tract, consecutive numbers,beginning with 1, are added as a suffix to each well number. Well 153-60-26acb4, Lakota No. 5A, is the fourth well described in the NW1/4SW1/4NE1/4 sec. 26, T. 153 N., R 60 W. The method of designating the location of wells is shown on figure 2.

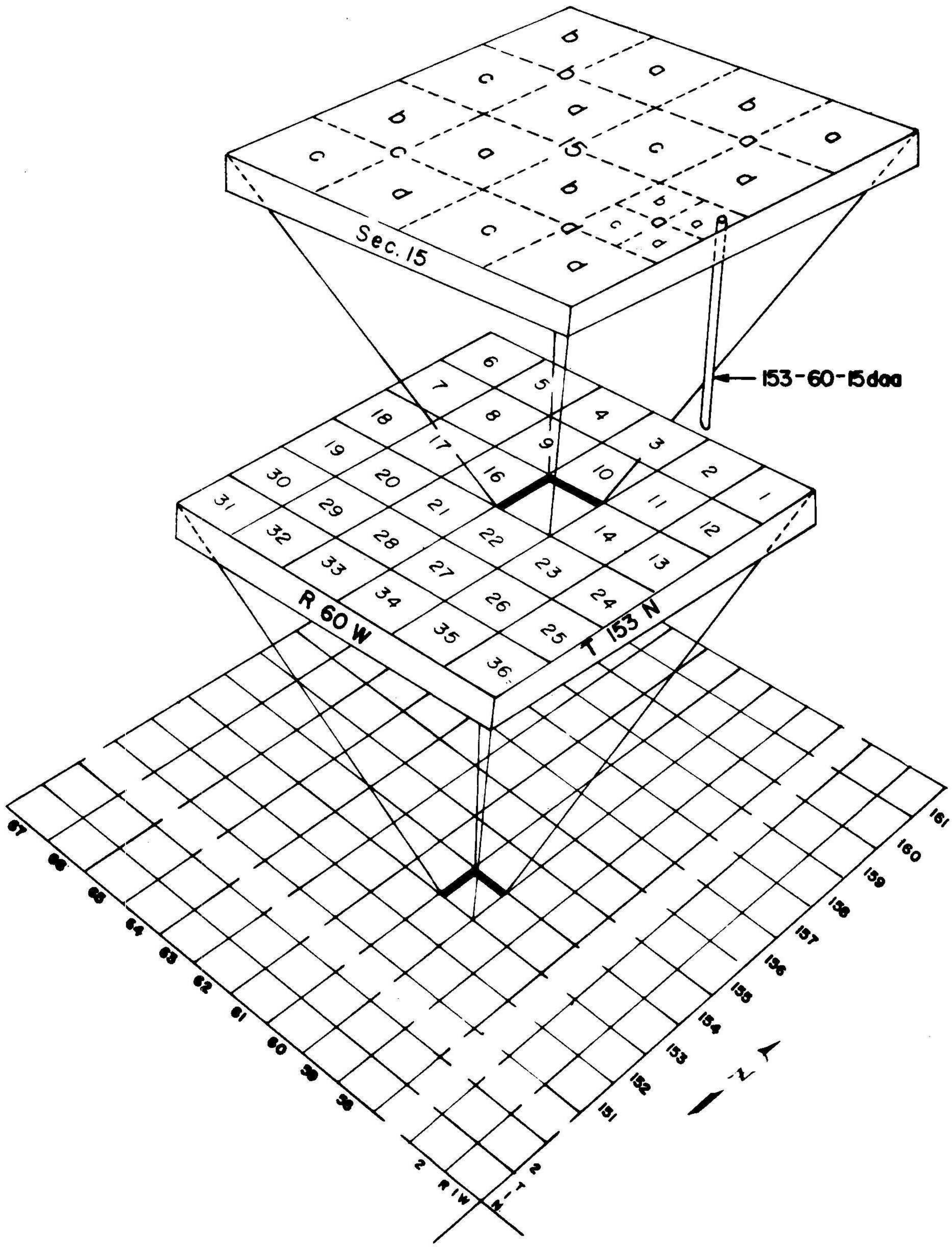


FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

Present Water Supply and Future Needs of Lakota

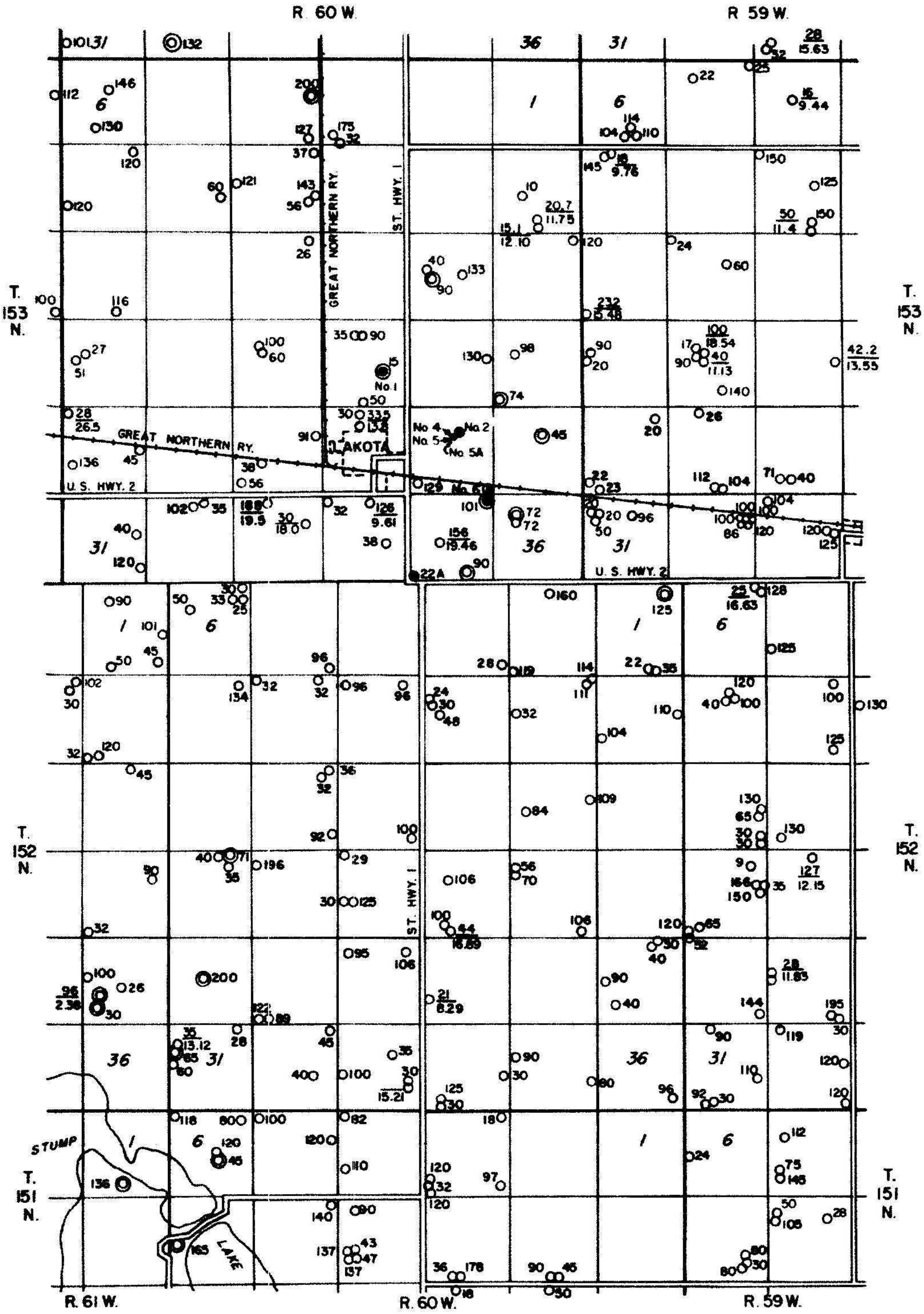
Many years ago water for domestic use in the city of Lakota was furnished by numerous privately-owned wells. In 1919, the city constructed a municipal system that consisted of two shallow wells (Lakota No. 1, 153-60-22dba, and Lakota No. 2, 153-60-26acb1), 15 and 20 feet deep and 20 and 18 feet in diameter respectively. The two wells produced hard but potable water from a deposits of glacial drift known as an esker. The wells yielded sufficient water for municipal needs except during the drought years (1930-1940).

The decline of water levels during the drought years made it necessary for the city to drill additional wells in 1937 and 1938. The wells penetrated the Pierre Shale and furnished small individual supplies (3 to 4 gpm) of water. Three of the shale wells, Lakota No. 4 (153-60-26acb2), No. 5 (153-60-26acb3), and No. 5A (153-60-26acb4), were drilled to depths of 120 feet near well No. 2. Eight additional wells in the Pierre Shale that ranged in depth from 90 to 280 feet were drilled within the city limits prior to 1949 but were not connected to the city system; however, Lakota No. 7 (153-60-27aca), No. 8 (153-60-27adc2), and No. 9 (153-60-27bcd1) were equipped with hand pumps and have been used by residents who live nearby. Lakota No. 12 (153-60-27bdd) at the swimming pool, was used to furnish part of the water necessary for the operation of the pool. Two of the shale wells, No. 10 (153-60-27bda1), and No. 11 (153-60-27bdc4) have not been used because they yielded extremely corrosive water. Chemical analyses of water from several of these wells are listed in table 1.

In the late 1940's, an increase in per capita water consumption and the resultant enlargement of the municipal water system without a corresponding increase in the available supply of water created a supply problem for the city of Lakota. Additional water to augment the city's supply was obtained from a new well (No. 6, 153-60-26ddd), which was drilled in 1952. Generally the well is pumped about 6 hours per day in the winter and 10 hours per day in the summer at a rate of about 70 gpm. The shallow east well, Lakota No. 2, pumps 15,000 gpd (gallons per day) and is used to supplement the supply from the No. 6 well.

The rate of decline of water level in Lakota No. 6 may be judged by the water-level fluctuations recorded from observation well 101 (153-60-35aaa), which is adjacent to the city well. The highest water level recorded in observation well 101 was 10.25 feet below land surface on June 12, 1951. The lowest was more than 33.00 feet below land surface on November 14, 1961. Records of water-level fluctuations in this well from 1949 to 1955 are available in the following U.S. Geological Survey Water Supply Papers: 1158, 1167, 1193, 1223, 1267, 1323, and 1406. Records for the period 1956 to present (1962) will be published in a forthcoming U.S. Geological Survey Water Supply Paper and are now available from the U.S. Geological Survey, Ground Water Branch, District Office, Grand Forks, North Dakota.

In 1961 the rate of water consumption in the city was estimated to be 60,000 gpd during the summer and 40,000 gpd during the winter. If the population increases significantly, additional wells will be needed.



EXPLANATION

○ $\frac{145}{12.34}$ DOMESTIC OR FARM WELL. UPPER NUMBER INDICATES DEPTH OF WELL. LOWER NUMBER INDICATES DEPTH TO WATER. (SEE WELL TABLES)

● No. 2 CITY OF LAKOTA SUPPLY WELL

◎ SAMPLED FOR CHEMICAL ANALYSIS

● 22A OBSERVATION WELL

(SEE FIGURE 6 FOR LOCATION OF WELLS IN LAKOTA)

SCALE

1 MI. .5 0 1 2 3 MI.

FIGURE 3.- MAP SHOWING LOCATION OF WELLS, DEPTH OF WELLS, AND DEPTH TO WATER IN WELLS IN THE LAKOTA AREA

Thirty-four wells within the city limits of Lakota range in depth from less than 10 feet to a maximum of 280 feet. Records of wells in the report area are given in table 2, and their locations are shown on figure 3 and figure 4.

Previous Investigations and Acknowledgments

Upham (1896, p. 595-598) outlined the general features of the glacial and bedrock geology and the glacial history of the Devils Lake-Stump Lake region. Babcock (1902, p. 208-250) reported on the Devils Lake area but had few references to the related Stump Lake basin. Simpson (1912, p. 109-156) presented a detailed description of the physiography of the Devils Lake-Stump Lake region and in a later report (1929, p. 177-181) included general information on the geology and ground water of Nelson County and detailed data for wells in the city of Lakota. Swenson and Colby (1955) discussed the quality of the water in Stump and Coon Lakes in relation to surface waters in the Devils Lake basin. Records of wells were obtained by the county assessors as part of a state-wide well inventory under the Works Projects Administration in 1939.

Work was facilitated by the cooperation of the townspeople and farmers in the area and particularly by L. D. Purdy, former water superintendent, and by other city officials.

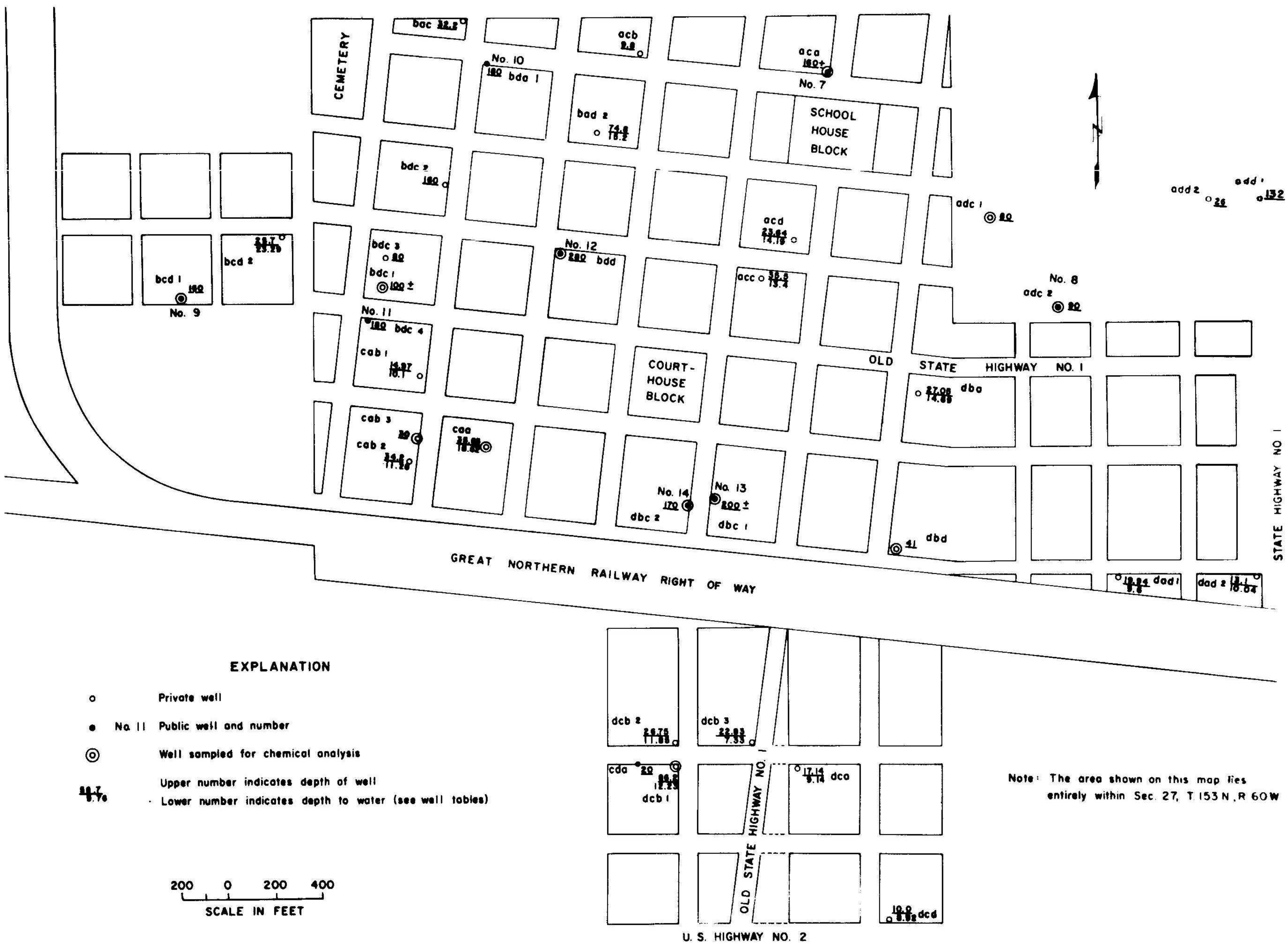


FIGURE 4--MAP SHOWING LOCATION OF WELLS IN LAKOTA

GEOLOGY

Stratigraphic Relations

The stratigraphic section for the Lakota area is summarized in the following table:

Cenozoic
- Quaternary System
  - Recent Series
    - Alluvium
  - Pleistocene Series
    - Wisconsin Glaciation
      - Mankato Stade

Mesozoic
- Cretaceous System
  - Upper Cretaceous Series
    - Pierre Shale
    - Niobrara Formation
    - Greenhorn Limestone
  - Lower Cretaceous Series
    - Dakota Group of Hansen (1955)
- Jurassic System

Paleozoic
- Silurian System
- Ordovician System

Precambrian

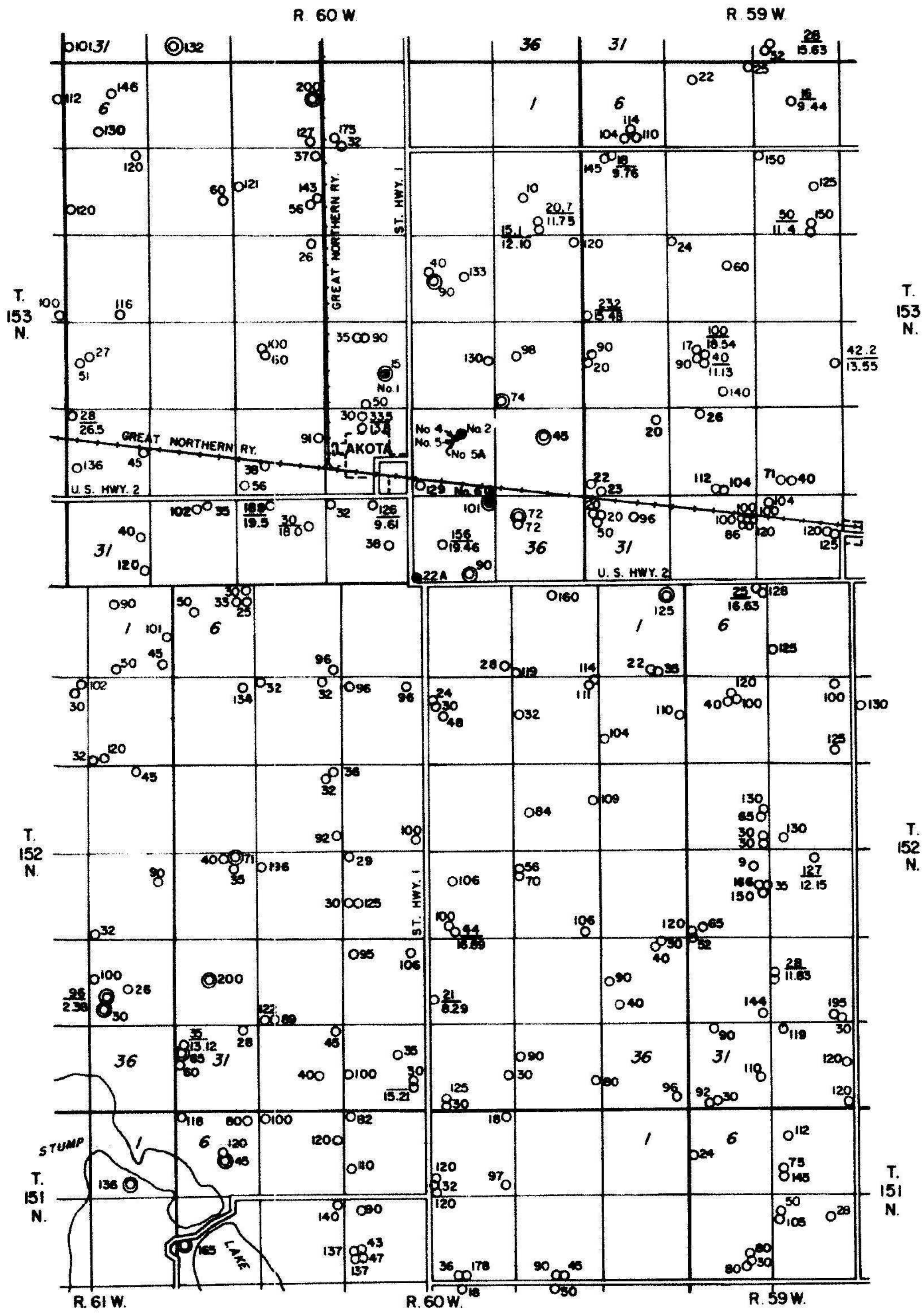
The stratigraphy of the glacial drift was determined from a study of samples from 33 test holes drilled in the area, by hand augering, and by observations at road and railway excavations.

Information concerning the depth of, occurrence, thickness, and lithology of Cretaceous and older rocks was obtained primarily from the published logs of oil-test wells. The most reliable of these logs is from the Louis and Alvina Bryl #1 well (Garske, 1958), which was drilled 2 miles south of Lakota in the NW1/4NW1/4SE1/4 sec. 5, T. 152 N., R. 60 W. Additional information on the Dakota Group of Hansen (1955) was obtained from the log of a municipal-supply well in the city of Devils Lake, 28 miles west-northwest of the city of Lakota.

Recent Deposits

The soil is composed of dark-brown to black clayey loam that is calcareous locally. The top soil is silty and clayey throughout most of the area and is generally heavy in texture.

Recent deposits of alluvium and slopewash are in the valleys of Coon Lake and East Bay spillways (fig. 5). Generally the alluvium is thin and discontinuous and is composed of varying proportions of clay, sand, and gravel.



EXPLANATION

○ $\frac{145}{12.34}$ DOMESTIC OR FARM WELL. UPPER NUMBER INDICATES DEPTH OF WELL. LOWER NUMBER INDICATES DEPTH TO WATER. (SEE WELL TABLES)

◉ No. 2 CITY OF LAKOTA SUPPLY WELL

◎ SAMPLED FOR CHEMICAL ANALYSIS

● 22A OBSERVATION WELL

(SEE FIGURE 6 FOR LOCATION OF WELLS IN LAKOTA)

SCALE

1 MI. .5 0 1 2 3 MI.

FIGURE 3.- MAP SHOWING LOCATION OF WELLS, DEPTH OF WELLS, AND DEPTH TO WATER IN WELLS IN THE LAKOTA AREA

Pleistocene Deposits

The surficial deposits are mostly glacial drift that was deposited during the last major ice sheet advance, or Wisconsin Glaciation, of the Pleistocene Epoch. Drift deposits older than the youngest or probably Mankato(?) Stade of the Wisconsin Glaciation have not been identified in the area. The Wisconsin Drift consists mainly of unstratified glacial till, but associated with the till are deposits of sand and gravel, most of which are stratified.

Deposits of glacial till cover about 97 percent of the area. The till is a heterogeneous mixture of materials that range in size from clay to boulders. It was deposited directly from the melting glacial ice or was pushed out along the margins of the advancing glacier. In either method of deposition, the till is subjected to little or no sorting or stratification and consequently voids between the larger particles are usually filled with fine materials.

Till in the Lakota area is yellowish brown where it is oxidized and gray to bluish gray where it is unoxidized. The oxidized zone ranges from as little as 1 foot to approximately 30 feet in thickness. The till is predominantly clay, together with varying amounts of sand, gravel, and coarser fragments; locally it contains small, platy crystals of gypsum. About half of the pebbles in the till are limestone or dolomite, probably derived from Silurian and Ordovician formations in Manitoba, Canada; about a quarter are Pierre Shale of local origin, and the other quarter are mainly Precambrian granite, greenstone, and gneiss (Russell, 1950). Lignite fragments were identified in the till in test holes 112 (153-60-27cdd), 114 (153-60-28cdd), 177 (153-60-26dab), and 179 (153-60-25cab), and in the sand in test hole 180 (153-60-26dda).

Morainic deposits.--Two types of glacial moraine, ground moraine and end moraine are in the report area. Both types are composed primarily of glacial till but differ in origin and topographic form. Ground moraine was deposited from the main body of the ice as it melted and in this area is characterized by gentle slopes and moderately rolling surfaces. End moraine was accumulated at the margins of the glacier by thrusting action of the active ice. In this area it is characterized by moderately steep slopes, hummocks, and closed depressions.

Ground moraine occupies about 90 percent of the Lakota area and end moraine about 7 percent (fig. 5).

Ice-contact deposits.--Ice-contact features such as eskers and kames are bodies of stratified drift that were deposited in contact with melting glacier ice. Eskers are sinuous, steep-sided, low ridges -- composed mainly of stratified sand and gravel -- that were deposited by streams of glacial melt water within or beneath the glacial ice. They are the most prevalent ice-contact features in the Lakota area; they range in length from a fraction of a mile to about 5 miles. They have low relief, ranging from 10 to 35 feet, and irregular surfaces that generally trend in a north-south direction. However, some of them, such as the esker in which wells, Lakota No. 1 and No. 2 (153-60-22dba and 153-60-26acb1) are situated, trend in an east-west direction. Most of the eskers are located on low ground and commonly have shallow depressions on one or both sides. Some of them have minor tributary branches. Their sides are steep and have slopes that approximate the angle of repose of the sand and gravel of which they are composed. The gravel, which consists mainly of igneous rock, limestone, dolomite, and shale fragments, is poorly sorted at some places and well sorted at others. Crossbedding, intermixed till, layers of silt, minor faults, and other types of deformation were observed in many of the eskers.

Kames are steep-sided hills of poorly sorted glacial debris. They were deposited by melt water at or near the margin of the glacier. Several hills in the northeastern and northwestern parts of the area (153-59-16, 153-60-17, 18, 20) have tentatively been identified as kames (fig. 5). A group of low, rounded hills in secs. 11 and 14, T. 153 N., R. 60 W. probably are tops of partially buried kames.

Buried valley deposits.--A buried valley or channel that contains sand and gravel, probably a glacial feature, was discovered by test drilling along section A-A' (figs. 5 and 6). The valley, which has no surface expression is partly filled with water-bearing sand and gravel that ranges in thickness from 25 to 82 feet. The glacial origin of this sand and gravel is indicated by its similarity to sand and gravel in East Bay spillway; both consist of approximately equal proportions of igneous, sedimentary, and metamorphic rocks. In addition, the proximity of the buried valley to East Bay and Coon Lake spillways, its parallel alignment with the spillways, and its relative altitude (fig. 6), all suggest that it has a glacial origin.

Information from test drilling indicates that the valley extends southwestward from about the center of sec. 25, T. 153 N., R. 60 W. for a known distance of 1 1/4 miles. At section A-A' it is about half a mile wide but its width south of the section is unknown. A large difference in the thickness of the drift within a relatively short distance indicates that the sides of the valley are very steep. Depth to Pierre Shale on the west boundary of the valley ranges from 31 feet in test hole 105 (153-60-35baa) to 114 feet in test hole 104 (153-60-35abb) about 0.2 mile east; on the east boundary it ranges from more than 77 feet in test hole 1A (153-60-36bbb) to 28 feet in test hole 106 (153-60-36bba) about 0.1 mile east (fig. 6). Test hole 28A (152-60-3bbc), the southernmost test hole in the buried valley, penetrated 58 feet of saturated sand and gravel. Additional test drilling will be necessary to determine the full extent of the valley.

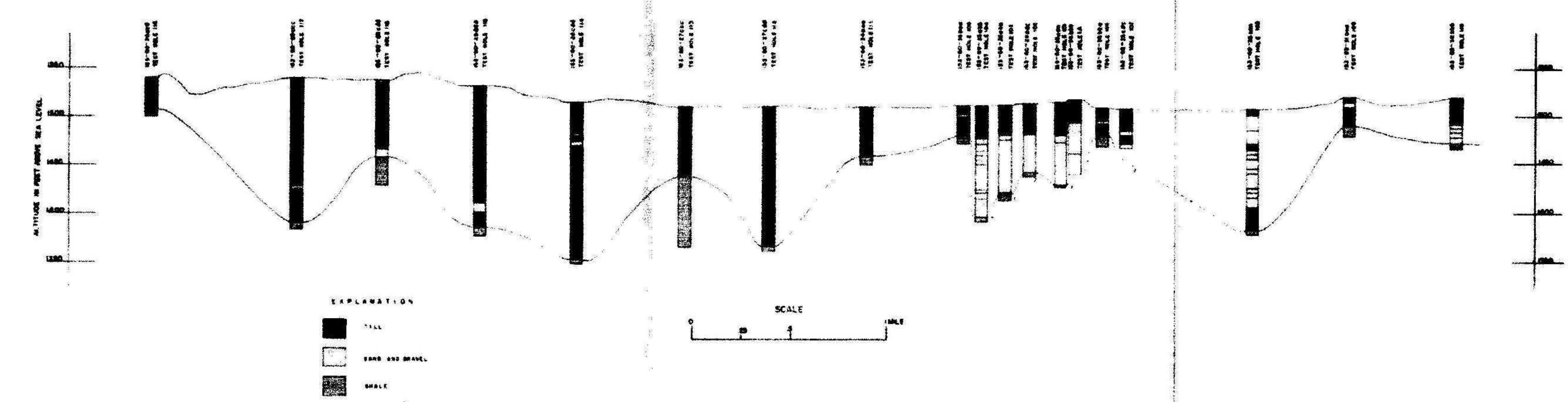


FIGURE 6.-GEOLOGIC SECTION IN THE LAKOTA AREA

In order to further investigate the distribution of sand and gravel along section A-A', the city of Lakota test-drilled in the vicinity of test hole 101 (153-60-35aaa1). One of the test holes penetrated 18 feet of till, 67 feet of sand and gravel, and 3 feet of gravelly clay. This test hole was developed as a production well and was designated Lakota No. 6 (153-60-26ddd).

Lake deposits.--Beach deposits and wave-cut benches mark the various lake levels around Stump Lake (fig. 5). The higher benches are in glacial till and the lower in Pierre Shale. The present beaches and shoreline deposits are principally sand, gravel, and shale pebbles. According to Swenson and Colby (1955, p. 48, 50) the bed sediments of Stump Lake are clayey silt.

Bedrock Formations

Tops of Cretaceous formations and pre-Cretaceous systems in feet below land surface are listed in the log of the Louis and Alvina Bryl No. 1 oil-test well (Garske, 1958) as shown in the tabulation below:

Cretaceous System	
Pierre Shale	46
Niobrara Formation	465
Greenhorn Formation	872
Dakota Group of Hansen (1955)	1,188
Jurassic System	1,514
Silurian System	1,565
Ordovician System	1,827
Precambrian System	2,743

Of the bedrock formations in the Lakota area, only the Pierre Shale and the Dakota are considered as practical sources of ground water; consequently, the other units are listed but not discussed.

Pierre Shale.--The Pierre Shale crops out only in the hills around Stump Lake where it is thinly bedded, closely jointed, and locally has iron stain on some weathered surfaces. In North Dakota, fossils in the Pierre Shale are generally poorly preserved and are not common. No fossils were found in exposures in the Lakota area, consequently identification of the shale was made on the basis of its physical characteristics rather than fossil evidence.

Dakota Group of Hansen (1955).--The Dakota Group of Hansen (1955) is 1,188 feet below land surface and 326 feet thick at the oil-test well site 2 miles south of the city of Lakota (Garske, 1958). In other test wells within a radius of about 40 miles from the one described above, the Dakota ranged from 166 to 270 feet thick. It consists of alternating layers of quartzose sand, fine-grained sandstone, dense shale, and clayey limestone.

Late Quaternary Geologic History

The number of advances and retreats of ice in the Lakota area during and prior to the Wisconsin Glaciation of the Pleistocene Epoch have not been determined. The surface drift is believed to have been deposited during the last or Mankato(?) Stade of the Wisconsin Glaciation.

The absence of a conspicuous end moraine in the area indicates that the ice had no prolonged halting place. However, the prominence of Coon Lake and East Bay spillways indicate that the ice front may have been relatively stationary to the north and northeast for a prolonged period during the latter part of the Mankato(?) Stade.

Stump Lake in the report area and Devils Lake just west of the area occupy a partly filled pre-glacial valley that trends southeastward (Simpson, 1929, p. 178). As the ice retreated, the lakes were formed and melt water began to overflow from Devils Lake to Stump Lake and from Stump Lake south to the Sheyenne River. Flow from Stump Lake to the Sheyenne River ceased when the lake level fell below 1,460 feet below sea level. The lake levels were first recorded in 1867; prior to that time, when the level of Devils Lake declined to 1,450 feet below sea level, it ceased to drain into Stump Lake.

GROUND-WATER RESOURCES

Occurrence of Ground Water

General Principles

Practically all ground water is derived from precipitation. Rain and melt water from snow enter the ground by direct percolation or by percolation from streams and lakes that lie above the general water table. Ground water generally moves downward and laterally from areas of recharge to areas of natural discharge.

Ground water is discharged through transpiration by plants and evaporation from the soil in areas where the ground-water level is near the land surface, by seepage into surface-water bodies, by pumping from wells, and by springs.

Any rock formation or stratum that will yield water in sufficient quantity to be important as a source of supply is called an aquifer (Meinzer, 1923, p. 52). Water moving in an aquifer from recharge areas to discharge areas may be considered to be in transient storage.

The amount of water that a rock can hold is determined by its porosity. Unconsolidated materials, such as clay, sand, and gravel, generally are more porous than consolidated rocks, such as sandstone and limestone; however, some consolidated rocks are very porous.

The ability of an aquifer to yield water by gravity drainage may be much less than is indicated by its porosity because part of the water is held in the pore spaces by molecular attraction between the water and the rock particles; the smaller the pores, the greater the proportion of the water that will be held. The amount of water, expressed as a fraction of a cubic foot, that will drain by gravity from 1 cubic foot of an aquifer, is called the specific yield of an aquifer.

If the water in an aquifer is not confined by an overlying impermeable stratum, the water is said to be under water-table conditions. Under these conditions, the water can be obtained from the aquifer by gravity drainage -- that is, by lowering the water level, as by pumping from a well.

Water is said to be under artesian conditions if it is confined in the aquifer by an overlying impermeable stratum. Under artesian conditions, hydrostatic pressure will raise the water in a well, or other conduit that penetrates the aquifer, above the top of the aquifer, and water is yielded by the aquifer as the water level in the well is lowered. However, the aquifer remains saturated as the water is yielded because the water expands and because the aquifer is compressed and the head is decreased. Gravity drainage does not occur under normal artesian conditions. The water-yielding ability of an artesian aquifer is called the coefficient of storage, and is generally much smaller than the specific yield of the same material under water-table conditions. The coefficient of storage of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

The water released from or taken into storage in a water-table aquifer in response to a change in head is attributed partly to gravity drainage or refilling of the zone through which the water moves, and partly to compressibility of the water and of the material in the saturated zone. However, the volume of water attributable to compressibility is a negligible part of the total volume of water released from or taken into storage and can be disregarded. Thus, for a water-table aquifer, the coefficient of storage is essentially equal to the specific yield.

The frictional resistance to the movement of water through pore spaces that are relatively large, such as those in coarse gravel, is not great and the material is said to be highly permeable. However, the resistance to the movement of water through small pore spaces, such as those in clay or shale, may be very great and the material is said to be relatively impermeable or to have low permeability. The coefficient of permeability is expressed quantitatively for field use as the number of gallons of water per day that will pass through a cross-sectional area of 1 square foot under unit hydraulic gradient at the local temperature of ground water

The coefficient of transmissibility is convenient to use in ground-water studies because it indicates a characteristic of the whole aquifer rather than of a small part. It is the average field permeability of the aquifer multiplied by its thickness, in feet.

The suitability of an aquifer as a source of water is governed by its permeability, its volume, and its capacity to store and ability to release water. Recharge to the aquifer must be adequate if the water-supply development is to continue indefinitely, because even a small rate of withdrawal will ultimately deplete the water in storage unless there is equal or greater recharge. Aquifers that are highly permeable but small in areal extent, and surrounded by relatively impermeable material such as glacial till, can be pumped dry in a comparatively short time. The high initial yield of a well may give the erroneous impression that a large volume of water is available indefinitely from the aquifer. Thus, before any substantial ground-water development is made, sufficient test drilling, aquifer tests, and related studies should be made to determine the physical characteristics of, and the available recharge to, the aquifer.

Water-bearing Characteristics of Aquifers

Sand and gravel deposits enclosed in glacial till.--Many wells in the area produce water from sand and gravel lenses that are completely surrounded by till. Generally these aquifers have no surface expression and can be located only by subsurface exploration, ordinarily test drilling. The yields of wells that penetrate these deposits depend upon the permeability of the surrounding till and upon the areal extent of the aquifers. Initially the yield of a well that produces from a sand and gravel lens may be large, giving an erroneous impression of abundant water. However, recharge to such aquifers from the surrounding till is usually slow and the aquifers may be rapidly dewatered by sustained pumping. Before large investments are made in wells that produce from sand lenses in the till, aquifer tests should be made to determine the aquifer characteristics.

A total of 99 wells in the area are known to tap aquifers in the glacial till; many others for which exact information is lacking are presumed to do so. The wells range from 15 to 200 feet in depth; their locations and other information may be found on fig. 3.

Ice-contact deposits.--The principal water supply for the city of Lakota for many years was obtained from two wells, Lakota Nos. 1 and 2, which were completed in an esker deposit. Lakota No. 1 penetrates 12 feet of sand and gravel; Lakota No. 2 penetrates 18 feet of sand and gravel. Test hole 24A (153-60-22acc) and 177 (153-60-26adb) also penetrated esker deposits of sand and gravel. The material in test hole 24A was 16 feet of fairly clean very coarse sand, and in test hole 177 it was 19 feet of clean sandy gravel.

Ten farm wells in the area obtain their water from ice-contact deposits. All are dug wells and about half of them were dug prior to 1920; many others have been abandoned.

Most of the ice-contact deposits in the report area -- including those penetrated by Lakota city wells Nos. 1 and 2 -- are above the water table or have relatively thin saturated zones. Aquifers in the deposits are drained when the water table is lowered naturally; therefore, the aquifers are not ordinarily good permanent sources of water.

Spillway deposits.--Aquifers in spillway deposits, though not used extensively at present (1962), are potentially productive aquifers in the Lakota area. In the East Bay spillway about 2 miles east of the city, test hole 108 (153-60-36aaa) was drilled through 90 feet of saturated sand and gravel. No test holes were drilled into the surface spillways elsewhere in the area but it is probable that they contain saturated sand and gravel at other locations.

Buried valley deposits.--The sand and gravel deposit contained in the buried valley discovered by test drilling during this investigation is the largest known aquifer in the area. It was penetrated by five test holes along section A-A' (fig. 5) and is used by Lakota city well No. 6. On August 29, 1952, a short pumping or aquifer test was made at Lakota city well No. 6. When the test began the static water level was 16.31 feet below land surface. After pumping at a rate of 150 gpm for 24 hours and 23 minutes, the water level was 40.56 feet below land surface (a drawdown of 24.25 feet). Recovery of the water level was almost complete by 1:00 p.m., September 3. The coefficient of transmissibility of the aquifer was calculated to be 12,260 gallons per day per foot and the coefficient of storage was calculated to be .0007. The magnitude of the coefficient of storage indicates that water in the aquifer occurs under artesian conditions. This is confirmed by test drilling and water-level measurements.

There is a possibility that the lower sand and gravel deposit (40 to 100 feet below the surface) penetrated in test hole No. 108 (153-60-36aaa) may be hydraulically connected to the aquifer tapped by city well No. 6. Additional test holes between test hole 107 (153-60-25cdc) and test hole 108, and pumping tests are necessary to establish whether or not such a connection exists.

Pierre Shale.--The Pierre Shale is a source of water in the report area. However, the hydrologic characteristics of the aquifers in the Pierre have not been determined. Simpson (1929, p. 30) suggests that the aquifers are in weathered or creviced parts of the shale or in interbedded sandstone layers. The possibility of percolation of water through fractures is suggested by the appearance of the shale in exposures near the Sheyenne River and near Stump Lake. Here, in addition to horizontal breaks along bedding and lamination planes, the weathered surfaces have numerous vertical joints that approximate polygonal patterns. Where a supply of water is not available from overlying rocks, well drillers in the Lakota area and in other parts of North Dakota, occasionally complete wells in the upper few feet of the Pierre Shale. At these locations, systems of cracks, fractures, and joints are probably interconnected and function as aquifers.

A total of 86 wells in the Lakota area for which records were obtained during this investigation produce small supplies of water from the Pierre Shale. The wells range from 32 to 280 feet in depth.

Older rocks.--Rocks older than the Pierre Shale are not used as aquifers in the Lakota area. However, some information is available on the water-bearing characteristics of the Dakota Group of Hansen (1955) at the city of Devils Lake, 28 miles northwest of Lakota. Three municipal wells in Devils Lake tap the Dakota and are pumped at a rate of about 300 gpm; the wells flow when they are not pumped. According to Simpson (1929, pl. 1) wells to the Dakota would flow in approximately the southwestern one-quarter of the Lakota area. However, because water is usually available from the glacial drift or the Pierre Shale, the great depth to the Dakota renders its use for individual farm and ranch supplies impractical.

Some of the Mesozoic and Paleozoic formations between the Dakota Group of Hansen (1955) and the Precambrian basement rocks may be sufficiently permeable to yield considerable quantities of highly mineralized water to wells. However, the formations are too deep to be considered as sources of supply in the Lakota area.

Recharge

Recharge to the various aquifers in the glacial drift is principally by downward percolation of rain water and water from melted snow. To a much lesser extent recharge is accomplished by lateral migration of ground water from adjacent areas.

The configuration of the land surface directly influences the amount of recharge available to underlying aquifers. In poorly drained areas such as those occupied by kettles, potholes, or other depressions, water remains ponded and is available for recharge. In well drained areas, runoff is rapid and very little water is available for recharge unless the soil and subsoil zones are very permeable.

The shallow sand and gravel deposits in the glacial spillways are the best situated aquifers in the area to receive recharge by direct penetration of precipitation. In years of heavy snowfall, a considerable amount of water runs into the spillways from adjacent areas when the accumulated snow melts in the spring. This runoff water produces large surface flows in the spillways, part of which percolates underground into the spillway deposits.

The aquifers that receive the least recharge are those that are surrounded by glacial till. Water that recharges these aquifers must percolate downward and laterally through a till cover of low permeability. Consequently the movement of water into the aquifers is very slow.

Shallow aquifers in the till receive recharge faster than the deep aquifers. The water level in wells that penetrate shallow till aquifers rises sharply in the spring in response to the infiltration of melted snow. Water levels also rise after rains in the fall, but they generally decline during the winter months when the ground is frozen.

Water levels in deep till aquifers show little indication of the immediate effects of recharge from spring snowmelt; generally the water level is lowest in late fall and rises during the winter. The rise in the water level continues until spring or early summer, after which it declines until late fall. The small magnitude of the changes in water level probably indicate a slow rate of recharge to the deep till aquifers.

Evapotranspiration has an important effect upon ground-water recharge. During the summer and early fall, evapotranspiration rates are high and water that enters the ground from light rains probably is used by vegetation before it can contribute to ground-water storage. In the late fall and early spring, evapotranspiration losses are considerably lower and rains contribute significantly to ground-water storage. Heavy or sustained rains may contribute to ground-water storage at any season of the year. Most of the precipitation in the area occurs as rain during the late spring and early summer months when evapotranspiration rates are low. Therefore, most of the water that percolates into the ground is available for recharge to the glacial drift aquifers.

Discharge

The mechanics of ground-water discharge in the area cannot be fully understood until the nature of the relationship between the various glacial-drift aquifers is known. However, it is possible that in places the aquifers are hydraulically connected. The ice-contact deposits, for example, may intersect, overlie, or otherwise contact sand and gravel deposits of different origin in the till, which in turn overlie fractured zones in the Pierre Shale. At 9 of the 35 test holes, sand and gravel deposits are in contact with the Pierre. These contacts could permit relatively free movement of water between the aquifers so that all would function essentially as a unit. Even where two bodies of sand and gravel are separated by till, there may be a significant movement of water between them, especially where the intervening till is thin or somewhat permeable.

The regional direction of ground-water movement probably is to the southwest toward Stump Lake. Sand and gravel deposits in the glacial spillways form relatively permeable, though shallow troughs, through which water percolates readily. Ground water moves laterally from adjacent areas to the spillways, where a considerable part of it is probably returned to the atmosphere by evapotranspiration. The balance presumably percolates slowly downslope toward Stump Lake through the lower sandy lenses of the drift that overlie the Pierre Shale.

Discharge from aquifers in the Pierre Shale in the Lakota area is by pumping from wells. The fractured and cracked zones in the upper surface of the shale are probably confined to scattered local areas and it is doubtful that they contribute significantly to regional ground-water migration. In general, the surface of the Pierre is an impermeable barrier along which ground water migrates to areas of natural discharge.

A large amount of water is probably stored in aquifers in the glacial drift in the Lakota area. However, the quantitative data necessary to make an accurate estimate of the storage are not available.

QUALITY OF THE GROUND WATER

Water dissolves part of the mineral constituents of the rock through which it moves. The amount of mineral constituents dissolved depends on the chemical changes which the water undergoes as it percolates through the carbon dioxide-rich soil, on the characteristics of the rocks through which water percolates toward the aquifer, and on the characteristics of the minerals in the aquifer and the length of time that the water is in contact with them. Therefore, in a homogeneous aquifer that has a homogeneous recharge area, water that has been stored underground a long time or has traveled a long distance from the recharge area is more highly mineralized than water that has been stored a short time and recovered relatively near the recharge area.

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 (1961), approved by the Secretary of Health, Education, and Welfare, 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	
Dissolved solids	500	b/

a/Based on annual average of maximum daily air temperature at Petersburg.

b/Dissolved solids of 1,000 ppm permitted if water of better quality is not available.

The chemical quality of the ground water was determined from the analyses of water from 35 wells in the Lakota area. Fifteen of the wells produce water from the Pierre Shale and 20 produce from the glacial drift. Results of the chemical analyses are shown in table 1.

The chemical analyses show that the ground water in the report area contains a high dissolved-solids content. Recommended maximum concentrations of chloride and nitrate are exceeded in water from some of the wells sampled; of iron and sulfate in water from most of the wells sampled; and of total dissolved solids in water from all of the wells sampled. However, water that contains more than the recommended limits of certain chemical constituents has been used in some areas of North Dakota for many years without reported ill effects.

Nearly all ground water contains some hardness-causing constituents. Hardness of water is caused principally by calcium and magnesium and to a lesser extent by iron, aluminum, strontium, barium, zinc, and free acid. Hard water is undesirable, especially if the water is used for laundering because it causes increased soap consumption as well as soap scum. Water that has a hardness of 100 ppm as $CaCO_3$ is generally considered to be moderately hard; water that has a hardness of 200 ppm or more is considered very hard. Water from nearly all the wells listed in table 1 is very hard and would require softening to be satisfactory for many uses. Hardness of water from most of the wells sampled ranged from 200 to 1,600 ppm as $CaCO_3$; that of water from one well, however, was 2,000 ppm. The average hardness of water from the Pierre Shale was 541 ppm and that of water from the glacial drift was 678 ppm.

High concentrations of nitrate in well water may be due to decaying organic matter and may, therefore, indicate that the water is being polluted. High concentrations may also be due to nitrates derived from high-analysis or concentrated commercial fertilizers. Water that contains more than about 44 ppm of nitrate may cause cyanosis in infants when used in feeding formulas and for drinking (Comly, 1945; Silverman, 1949). Water from three of the wells sampled contained concentrations of nitrate in excess of 44 ppm.(See table 1.)

The consumption of water that contains fluoride in concentrations of about 1 ppm by children during calcification of teeth, reportedly lessens the incidence of tooth decay. However, the consumption of water that contains concentrations higher than about 1.5 ppm (probably about 1.7 in the report area) may cause mottling of tooth enamel (Dean, 1936). Fluoride in excess of the recommended limit was not present in water from any of the wells that were sampled.

In general, ground water in the report area may be used for most domestic needs but would require softening to avoid excessive soap consumption when used for laundering. However, samples of water from new or unused wells should be submitted to the State Department of Health for analysis before the water is used for drinking.

Water that is satisfactory for certain domestic and industrial uses such as laundering, may be unsatisfactory for irrigating crops. Irrigating with water that has a high dissolved-solids content may cause salts to accumulate in the root zone of the soil and may eventually cause the soil to become unproductive. The specific conductance of water is dependent on the dissolved-solids content of the water and is a measure of the soluble salts that the water contains. According to the U.S. Salinity Laboratory Staff, 1954, p. 70, "Nearly all irrigation waters that have been used successfully for a considerable time have conductivity values (specific conductance) of less than 2,250 micromhos per centimeter (equivalent to a dissolved-solids content of about 1,500 ppm). Waters of higher conductivity are used occasionally, but crop production, except in unusual situations, has not been satisfactory." Although the specific conductance of the samples are not given in table 1, the conductance can be approximated by dividing the dissolved-solids content by 0.65. For most of the samples the approximation probably would be accurate within 10 percent.

On the basis of the above approximation the average specific conductance of water from wells that were sampled in the report area is about 3,700 micromhos per centimeter.

Irrigating with water that has a high percent sodium may cause the soil to become impermeable. The percent sodium is calculated as follows:

$$\text{Percent sodium} = \frac{Na \times 100}{Ca + Mg + Na + K}$$

where all concentrations are in equivalents per million. The continued use of irrigation water in which the percent sodium is in excess of 50 may cause the soil to become less productive. However, the extent of productivity loss that will result from the continued use of a particular type of water also depends on other factors, such as salinity of the water, porosity and permeability of the soil, drainage, irrigation practices, and crop management. In general, the higher the percent sodium, the less suitable the water is for irrigation.

The chemical analyses indicate that water from most of the wells sampled is of unsuitable quality for irrigation because the percent sodium was greater than 50 and the specific conductance (computed) was greater than 2,250 micromhos per centimeter.

SUMMARY OF GROUND-WATER CONDITIONS

Small supplies of ground water sufficient for domestic and farm use can usually be found in the report area. When drilling for individual farm and ranch supplies, an attempt is usually made by the well contractor to obtain a water supply from the glacial drift. However, many residents prefer wells in the Pierre Shale because the water is somewhat softer and because the wells do not go dry after long droughts. In some instances, rural residents find it necessary to construct two wells, one in the Pierre Shale and one in the glacial drift, or two in either formation, in order to obtain sufficient water.

The most productive aquifer that is known in the area was discovered by drilling test holes along section A-A' east of the city of Lakota. The aquifer is in a buried valley that is probably glacial in origin. The valley is partly filled with saturated sand and gravel that ranges in thickness from 25 to 82 feet. Along section A-A', the center of the aquifer is about one-quarter of a mile west of the southeast corner of sec. 26, T. 153 N., R. 60. It extends southwestward for a distance of at least 1 1/4 miles to a point where it contains 58 feet of saturated sand and gravel. Lakota city well No. 6 penetrates this aquifer and furnishes most of the municipal supply. The aquifer is capable of supporting additional wells but should be investigated further by test drilling and aquifer tests before permanent well sites are chosen.

Additional water for municipal and (or) other use probably is available two miles east of Lakota where test hole 108 (153-60-36aaa) was drilled through 90 feet of sand and gravel. However, this aquifer should also be explored by test drilling and aquifer tests prior to construction of permanent wells.

Ground water from wells in the Lakota area has a high dissolved-solids content. Recommended maximum limits of one or more constituents are exceeded in the wells sampled during this investigation.

Abbreviations: G, gravel; S, sand; Sh, Pierre Shale; T, glacial till

Analyses made by the North Dakota State Department of Health, Bismarck, North Dakota

Location No.	Owner or name	Date of collection	Aquifer	Depth of well (feet)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)
151-60							
6dbb	Jake Geritz	9-24-49	Sh	45	1.4	48	20
7cbb	Wishart Sisters	9-24-49	Sh	165	.3	184	66
9cbc1	Mrs. H. Durnell	9-20-49	..	137	1.4	57	67
151-61							
1cda	Orville Engel	9-26-49	G	136	.4	7	2
152-60							
1aab	W. W. Brooker	9-19-49	Sh	125	1.5	26	12
19aba1	William Winer	9-21-49	G	71	3.8	140	94
30bdd	Karl Jonson	9-28-49	Sh	200	1.1	400	228
31bcb	Harry Saunders	9- 5-49	..	65	...	25	12
152-61							
25cbd1	William Saunders	9- 5-49	..	30	.6	128	89
25cbd2	..do....	9- 5-49	..	96	1	77	46
153-60							
4add	J. W. Rainsberry	9-19-49	S	200	.4	101	65
14bcd2	Wesley Davidson	9-27-49	S	90	.9	48	41
22dba	Lakota No. 1	9- 9-49	S,G	15	.2	120	89
24ccc	Ed Bjorge	9-15-49	...	74	1.9	305	160
25acb	Martin Sitar	9-15-49	G	45	...	326	190
25cab	Test hole 179	....	S,G	100	3.3	274	182
26acb1	Lakota No. 2	9- 9-49	S,G	20.6	...	94	40
27aca	Lakota No. 7	9-15-49	Sh	160	4.4	43	48
27adc1	E. J. Duchesneau	9-25-49	S	80	.3	14	4
27adc2	Lakota No. 8	9-15-49	Sh	90	.7	38	61
27bcd1	Lakota No. 9	....	Sh	160	5	208	52
27bdc1	The Grant House	9-25-49	Sh	100	2.5	15	8
27bdd	Lakota No. 12	9- 9-49	Sh	280	3	144	133
27caa	Lester Purdy	9-25-49	S,G	35.6	1.1	252	83
27cab4	A. H. Kaufman	9-25-49	S,G	30	1.3	52	20
27dbc1	Lakota No. 13	9- 9-49	Sh	200	1	19	6
27dbc2	Lakota No. 14	9-15-49	Sh	170	.3	48	64
27dbd	Lakota Creamery	9-27-49	S	41	.3	248	39
27dcb1	Alfred Howen	9-25-49	S,G	86.2	1.2	160	46
35aaa	Test hole 101	....	S,G	87	.8	242	47
35abb	Test hole 104	....	S,G	120	4.7	248	93
35dcd	Charles Stein	....	G	90	4.7	176	56
36bac1	George McHugh	9- 9-49	S	72	.5	42	146
154-60							
32cdb	Charles Turner	9-20-49	Sh	132	.2	55	118

analyses of ground water

Results in parts per million except as indicated

Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated)	Hardness as $CaCO_3$	Percent sodium
741	545	..	1,298	50	..	2.1	2,705	200	89
313	478	..	935	32	..	....	2,008	730	48
615	689	34	458	510	..	8.6	2,448	417	75
749	945	..	665	135	.2	4.3	2.508	28	98
1,210	766	..	.....	1,310	.2	122	2,447	100	95
347	495	..	1,118	27	..	....	2,224	735	48
.....	547	..	140	372	.2	3,040	4,728	2,000	..
746	277	..	1,669	192	..	86.7	3,233	635	93
228	420	..	708	65	..	2.1	1,641	686	42
290	316	..	670	38	.2	....	1,438	380	61
568	439	..	1,215	91	..	6.5	2,486	519	70
19	573	..	117	78	..	4.3	881	287	12
324	339	..	600	20	..	....	1,501	688	51
270	512	..	1,480	34	..	4.3	2,767	1,424	29
99	596	..	1,110	107	..	17.3	2,444	1,596	1
723	532	..	2,475	38	.4	4.3	4,232	1,440	51
17	324	..	146	14	..	8.7	643	399	8
543	659	29	754	32	..	4.3	2,116	314	75
440	570	..	499	15	.1	....	1,542	52	95
575	683	..	865	124	.2	....	2,347	346	78
207	585	49	642	20	.7	....	1,718	736	35
745	557	..	1,118	53	.2	....	2,499	72	93
1,535	765	..	8	3,000	..	....	5,589	915	78
665	499	..	1,719	157	..	....	2,778	972	59
659	675	..	724	236	..	4.4	2,370	212	86
646	710	..	505	269	.2	6.5	2,163	73	94
633	618	36	964	134	.3	4.3	2,502	384	78
815	508	..	1,641	261	.2	26	3,539	810	69
314	490	..	754	60	..	....	1,897	590	53
127	384	..	696	27	..	39	1,563	800	25
236	432	..	1,013	76	..	....	2,102	1,000	32
256	495	..	726	52	..	....	1,766	700	42
401	209	..	1,262	63	..	....	2,123	703	55
1,175	877	..	.....	1,750	.2	6.5	3,996	622	80

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

Type: Dr, drilled; Du, dug.

Geologic source: Qg, gravel; Qs, sand; Kp, Pierre Shale; Qt; glacial till.

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

Use: D, domestic; M, municipal; O, observation, S, stock; T, test hole; U, unused.

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
151-59					
5c1	Martin Flom	75	24	Dr	1900
5c2	P. M. Severson	145	6	Dr	1913
5bcd	H. Miller	112	5½	Dr	1949
6cbb	Wm. Franzen	24	24 x 24	Du	1900
7dbd	Charles Wolford	80	5	Dr	1946
7dca1	..do....	30	24	Dr	1928
7dca2	..do....	80	...	..	....
8abd	Olaf Sieverson	28	36 x 36	Du	a1890
8b	Mrs. A. Lier	50	6	Dr	....
8bcb	Frank Franzen	105	6	Dr	1920
151-60					
3a	G. Ensrud	18	4	Du	1935
3c1	A. I. Ferry	120	6	Dr	1934
3c2	..do....	32	24	Dr	1894
3ccb	..do....	120	6	Dr	1945
3d	S. W. Ludburgh	97	5	Dr	1937
4b	M. Rogness	82	5	Dr	1937
4cbc	Lawrence Johnson	110	6	Dr	1920
5ada	Mrs. Hattie Durnell	120	6	Dr	1920
5b	Federal Land Bank	100	6	Dr	1917
6a	Merchants Bank	80	6	Dr	1906
6acc	Jake Geritz	120	5	Dr	1917
6b	Merchants Bank	118	6	Dr	1918
6dbb	Jake Geritz	45	8	Dr	1890

and test holes

Remarks: C, see chemical analysis in table 1; L, test hole refilled; log in Table 3; Wad, water supply reported to be adequate; Wal, water reported to have alkaline taste; Wc, water reported to be corrosive; Wh, water reported to be hard; Wi, water reported to contain iron; Win, water supply reported to be inadequate; Wio, water reported to contain iodine; Ws, water reported to be soft; Wst, water reported to have salty taste; Wu, water unfit for domestic use; Sh-90, shale at 90 feet (number indicates depth at which shale was penetrated).

Year completed or measured: a, approximate.

Geologic Source	Depth to water below land surface (feet)	Year measured	Use	Remarks
...	....	....	....	
Qs	45	1938	S	
Kp	....	....	D	Ws
Qg	15	1949	D,S	
...	20	1946	D	Wi
...	10	1949	S	Ws
...	....	....	U	Ws, Wst
Qs	23	1949	D,S	Wh, Wi
...	....	....	D,S	
Kp	15	1920	D,S	Ws
...	2	1938	S	
...	20	1938	D,S	
...	25	1938	S	
Kp	....	1945	D,S	Ws
...	47	1938	D,S	
Kp	20	1938	S	
Kp	80	1949	D,S	Wh
...	70	1939	S	Ws
Qs,Qg	25	1938	D	
Qg	25	1938	D	
Kp	30	1949	S	Wh, Wio, Wst
Kp	120	1938	S	
...	35	....	D	C

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
151-60 (Continued)					
7cbb	Wishart Sisters	165	..	Dr	....
8aaa	Lawrence Johnson	140	6	Dr	1946
9b	L. Foster	90	6	Dr	1916
9cbc1	Mrs. Hattie Durnell	137	4	Dr	1949
9cbc2	..do....	137	6	Dr	a1915
9cbd1	..do....	47	26	Dr	....
9cbd2	..do....	43	26	Dr	1901
10cdc	Close Bros.	36	24 x 24	Du	1948
10cdd	..do....	178	6	Dr	1915
11cdd1	Wm. Robson	90	6	Dr	1918
11cdd2	..do....	45	36 x 36	Du	1941
14baa	..do....	50	36	Dr	1912
15bab	Close Bros.	18	24	Du	....
17baa	Bruce and Sidney Unglesbee	65	..	Dr	a1925
151-61					
1cda	Orville Engel	136	6	Dr	1926
152-59					
5cbc	Albert Olson	125	6	Dr	1917
6aaa1	Myron Ensrud	128	6	Dr	1918
6aaa2	..do....	25	16	Du	1912
7abc1	Ed Nelson	120	6	Dr	1938
7abc2	..do....	100	6	Dr	1947
7abc3	..do....	40	16	Du	1938
8aab	Hans Moberg	100	6	Dr	1919
8d	K. Elvick, Jr.	125	6	Dr	1915
9bcb	Tony Foley	130	6	Dr	1940
17c	Axel Anderson	130	..	Dr	1909
18d1	..do....	30	18	Dr	1908
18d2	..do....	30	18	Dr	1934
18daa1	..do....	130	5	Dr	1940
18daa2	..do....	65	18	Dr	1938
19a	John Tierney, Jr.	9	144 x 96	Du	....
19add1	John Tierney	166	7	Dr	1928
19add2	..do....	150	4	Dr	1908

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
Kp	....	....	D,S	C
Kp	20	1946	S	Wh
Qg,Kp	50	1938	D,S	
Kp	70	1949	D,S	C
Kp	40	1938	D	Wh
....	....	....	U	Wh, Win
....	....	....	U	Wh, Win
....	25	....	D	Wh
Qs	30	....	D,S	Ws
....	....	....	U	
....	....	....	U	Wh
Kp	....	....	U	
Qg	16	....	S	Wh
....	25	1949	D,S	Ws, Wst
Qg	50	1949	D,S	C
Kp	25	1938	D,S	Ws, Wu
Kp	20	1947	D,S	Ws
Kp	16.63	1948	U	
Kp	20	....	S	Ws
Kp	20	1947	D	Ws
Kp	10	1938	U	Wh
Kp	18	1949	D,S	Wal, Ws, Wst
Kp	25	1938	S	Sh - 90
....	75	1949	D,S	Wio, Ws, Wst
....	....	....	D,S	Win
Qt	6	1938	S	
Qt	24	1938	D,S	
Kp	15	1947	D,S	Sh-25, Ws
Qs	20	1949	D,S	Wh
....	5	1938	S	
Kp	50	1949	S	Ws
Kp	50	1949	S	Ws, Wst

Location	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
152-59 (Continued)					
19add3	John Tierney	35	18	Dr	1904
19c	Pete Schuh	65	18	Dr	1934
19ccc1	..do....	52	48	Du	1910
19ccc2	..do....	120	6	Dr	1940
20abb	E. Elvick, Jr.	127	6	Dr	1914
29bcc1	Wm. Faahey	28	48 x 48	Du	1946
29bcc2	..do....	42	48 x 48	Du	1938
29ddc1	J. E. Burgees	195	..	Dr	1947
29ddc2	..do....	30	48 x 48	Du	1900
30d	W. H. Johnson	144	6	Dr	1913
31bab	Hans Severson	90	6	Dr	1920
31cdc1	Paul Franzen	92	6	Dr	1944
31cdc2	..do....	30	36 x 36	..	....
31da	Clifford Sateren	110	5	Dr	1952
32add	Sever Klaragard	120	..	Dr	1912
32bba	John Faahey	119	6	Dr	1920
32ddd	Iver Hanson	120	6	Dr	1915
152-60					
1aab	W. W. Brooker	125	6	Dr	1909
1dcc1	Joseph Schuh	22	40 x 40	Du	1948
1dcc2	..do....	35	42 x 42	Du	1919
2baa	C. Loften	160	4	Dr	1937
2ccc	Andrew Bolken	119	6	Dr	1923
3bbc	Test hole 28A	110	5	Dr	1948
3ddd	Andrew Bolken	28	36 x 36	Du	1915
5ddd	Miles Schindele	96	6	Dr	....
6a1	National Life Ins. Co.	33	12	Dr	....
6a2	..do....	25	36 x 36	Du	....
6aaa	Jacob Beck	30	40 x 40	Du	1938
6b	John Kutzman	50	..	Dr	1933
7aab	P. A. Pogatshnik	134	4	Dr	1927
8aab	Richard J. Harper	32	18	Dr	1898
8bbb	Henry Geritz	32	24	Du	1918
9aaa	Josepth Ettl	96	6	Dr	1928
9bbb	D. C. Keisacker	96	6	Dr	1909
10bcb1	Carl Noss	24	24	Dr	1919
10bcb2	..do....	30	48 x 48	Du	1936

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
Qg	30	1938	D	Wh, Wi
Qt	25	1934	D,S	Win
Qt	40	1949	D,S	Wal, Wh
....	40	1949	U	Ws, Wst
Kp	12.15	1949	U	
Qt	11.83	1949	D	Wh, Wu
....	15	1949	U	Wh
....	....	....	S	Wst
Qt	30	1938	S	Win
Kp	80	1938	S	
Qs	20	1949	D,S	Win, Ws, Wst
Kp	....	....	D,S	Ws
....	....	....	U	Ws, Wu
Qs,Qg	....	....	D,S	Wh
....	....	....	D,S	Ws,Wst
Kp	45	1938	D,S	Ws,Wst
Kp	40	1949	D,S	Ws,Wst
Kp	6	1946	S	C
Qs	15	1949	D,S	Wh
Qt	33	1938	U	Win
Kp	20	1938	D,S	Wio, Wh, Wst
Kp	40	1949	S	Ws
....	....	....	U	L
....	26	1938	S	Wh
Kp	70	1938	D	Wi, Ws
Qs	30	....	D,S	Win
Qt	22	1938	D,S	Win
....	....	....	D,S	Wh, Wi
Kp	30	1938	...	
Kp	5	1949	D,S	Wh, Wi
Qs	29	1949	D,S	Wh
Qs,Qg	20	1938	D,S	Wh, Wi
Kp	80	1938	D,S	Wal, Ws
....	7	1948	D,S	Wh, Wi
Qg	20	1938	D	
Qs	26	1938	D,S	

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
152-60 (Continued)					
10bcd	Carl Noss	48	18	Dr	1945
11aaa1	Ed Nelson	111	6	Dr	....
11aaa2	..do....	114	6	Dr	1949
11b	Ollie Kiesacker	32	48 x 48	Du	....
12add	Chas. Bazal	110	6	Dr	1937
12cbc	R. W. Dougherty	104	6	Dr	1922
14add	Claude Arneson	109	6	Dr	1935
14cba	Leo Welch	84	6	Dr	1927
16ddd	Eddie Rosenberger	100	6	Dr	....
17a	Albert Schindele	32	36 x 36	Du	....
17aaa	..do....	36	48 x 48	Du	1905
17dda	D. Durnell	92	6	Dr	1915
19aba1	Wm. Winer	71	6	Dr	1943
19aba2	..do....	40	48 x 48	Du	1929
19aba3	..do....	35	..	Dr	....
20bbc	Harold Anseth	196	5	Dr	1926
21bbb1	Harold Johnson	29	24	Dr	1948
21c1	Jake Geritz	125	6	Dr	1916
21c2	..do....	30	60 x 60	Du	1903
22bdb	E. D. Beckman	106	6	Dr	....
22cdd1	Katherine Schuh	100	6	Dr	1941
22cdd2	..do....	44	28 x 28	Du	1903
23b	Jake Geritz	56	6	Dr	1905
23bcb	..do....	70	5	Dr	1916
23ddc	Henry Fossen	106	6	Dr	1920
25aba1	Hugh Anderson	30	36	Dr	....
25aba2	..do....	40	48 x 48	Du	1913
25c	Wm. McFadden	40	48 x 48	Du	1935
25cb	Bill Saunders	90	5	Dr	1934
27cbc	Gertrude Carlson	21	18	Dr	1924
28a	Bert Sturtevant	106	5	Dr	1915
28b	..do....	95	5	Dr	....
29ccc	Fantus Olson	122	2	Du,Dr	a1890
29ccd	..do....	89	6	Du	1925
30bdd	Karl Jonson	200	6	Dr	1931
31aab	Fantus Olson	28	36 x 36	Du	1904
31bbc	Harry Saunders	35	36	Dr	1908
31bcb	..do....	65	6	Dr	1949
31bcc	..do....	60	..	Dr	1944

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
Qs,Qg	32	1949	D,S	Wal, Wh
Kp	30	1938	D,S	Ws
Kp	....	....	D	Ws
Qs	28	1938	D,S	
Kp	22	1938	D,S	Ws, Wst
Kp	40	1949	D,S	Ws
Kp	15	1935	D,S	Ws
Kp	85	1949	D,S	Ws
....	20	1948	D,S	Ws
Qg	....	....	...	Win
Qs,Qg	25	1949	D,S	Wh, Wi
Kp	25	1938	D,S	Ws, Wst
Qs	21	1943	D,S	C
Qt	17	1949	U	Wh
Qg	33	1938	D	Win
Kp	30	1938	S	Wio, Ws, Wst, Wu
Qs	....	....	D,S	Wh
Kp	40	1938	D,S	
Qg	25	1938	D	
Kp	....	....	D,S	Ws
....	....	....	D,S	Ws
....	16.89	1948	U	Wh
....	5	1938	D,S	
....	5	1949	D,S	Ws
Kp	40	1938	D,S	Ws, Wst
....	....	....	D,S	Wh
....	7	1938	...	
....	29	1938	D,S	
Qs,Qg	Flow	1952	S	Wh
Qs,Qg	8.29	1948	S	Wh
Kp	60	1938	D,S	Win
Kp	60	1938	D,S	Win
Kp	38	....	D,S	Wh
Qt	20	1938	D,S	Wal, Wh
Kp	8	1931	D,S	C
Qg	....	....	S	Wh
Kp	13.12	1949	U	Wal, Wh, Wi
Kp	20	1949	D,S	C, Sh-16
Qs	20	1944	U	Ws

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
152-60 (Continued)					
32a	Fred Reimer	45	48 x 48	Du	1900
32dba	Jacob Geritz	40	24	Dr	1925
33acd	M. L. Munson	35	48 x 48	Du	1937
33cbb	Harold Gutting	100	6	Dr	....
33dac1	Harry Belyea	30	48 x 48	Du	1936
33dac2	..do....	...	30 x 30	Du	....
34c	Federal Land Bank	30	24	Du	....
34cca	M. L. Munson	125	5	Dr	1939
34d	Hans Lien	30	48	Du	1936
35bcc	Winford Close	90	8	Dr	1918
35dad	Sever Klaragard	80	6	Dr	a1910
36d	Gronna Investment	96	6	Dr	....
152-61					
1bac	Jess Keitzman	90	18	Dr	1900
1cdc	Henry Bagne	50	30	Dr	....
1d	R. H. Carlson	45	14	Dr	....
1daa	B. W. Kietzman	101	5	Dr	1915
11a	H. T. Metcalf	30	24	Dr	1905
11aaa	..do....	102	5	Dr	1912
12cc	F. Dick	32	36	Du	1895
12ccd	S. B. Bagne	120	5	Dr	a1930
13abb	John Beck	45	36	Dr	....
24adb	Harold Alwin	90	5	Dr	1930
24ccc	H. Saunder	32	32	Dr	....
25bcc	E. F. Groves	100	5	Dr	1934
25caa	..do....	26	36 x 36	Du	1934
25cbd1	Wm. Saunders	30	36	Dr	a1910
25cbd2	..do....	96	6	Dr	1934
153-59					
4bdd	Wm. Laity	16	36 x 36	Du	....
5aaa	Alex Hatula	25	18	Du	1914
5bac	Ing Orseth	22	36 x 36	Du	1890
6dcc1	A. J. Miller	114	6	Dr	1934
6dcc2	..do....	110	..	Dr	....
6dcc3	..do....	104	..	Dr	1922
7bab1	S. B. Bagne	18	30 x 30	Du	1908
7bab2	..do....	145	6	Dr	1920

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
Qt	42	1938	D,S	Win
....	....	....	U	Wh, Wi
....	20	1949	D,S	Wh
....	....	....	U	Ws
....	28	1938	D,S	Wh
....	15.21	1948	U	
Qs	28	1938	D,S	Win
Qs	....	....	D	Wh
Qg	25	1938	D,S	
Kp	14	1938	D,S	Wh
....	30	1938	D,S	Wal, Wh
Kp	30	1938	D,S	
....	40	1949	D,S	Ws
....	20	....	D,S	Wh, Wi
Qt	20	1938	D,S	
....	20	....	D,S	Wal, Ws
....	18	1938	S	
....	30	1938	D,S	Wal, Ws
Qt	30	1938	D,S	
....	....	....	D,S	Ws
Qt	28	....	D,S	Wal, Wh, Wi
Kp	40	1949	D,S	Wh, Wi
Qt	26	1938	U	
Qs	30	1938	D,S	Wal, Wh, Wi
Qs,Qg	12	....	U	Wh
Qt	....	....	D,S	C
Kp	+ 2.38	1949	U	C
....	9.44	1949	S	Wh, Wst
Qg	....	....	S	Wh
Qs,Qg	12	1938	D,S	Wh
....	25	1938	D	Ws, Wst
Qs	....	....	S	Ws, Wst
....	50	1938	D,S	Win
Qs	9.76	1949	D,S	Wh
....	....	....	S	Ws, Wst

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
153-59 (Continued)					
9acd	Marcus Schmidt	125	5	Dr	a1930
9b	John McHugh	150	6	Dr	1917
9dcc1	Floyd Fisk	150	..	Dr	1944
9dcc2	..do....	50	30	Dr	1908
17a	North, Corp.	60	6	Dr	1915
17b	..do....	24	..	Du	1890
18ccc	Olaf Thorsen	23	48 x 48	Du	1890
19bcc1	Orville Davidson	90	6	Dr	1939
19bcc2	..do....	20	30 x 30	Du	1906
20bdd1	Iland Olson	100	6	Dr	a1935
20bdd2	..do....	40	24 x 24	Du	....
20bdd3	..do....	17	36	Du	1890
20bdd4	..do....	90	6	Dr	1918
20dcb	Leland Steinman	140	6	Dr	1930
21add	....	42.2	5	Dr	....
28c1	George Noble	40	..	Du	1906
28c2	..do....	71	..	Dr	1923
29baa	Iland Olson	26	36	Du	1930
29dcc1	Arthur Estvold	104	4	Dr	1949
29dcc2	..do....	112	5	Dr	1921
30aab	John Korstad	20	18	Du	1918
30c1	J. O. Asser	23	24	Dr	1910
30c2	A. Korolate	22	..	Du	1908
31abc	Uriell Bros.	96	6	Dr	1913
31b	Mrs. May E. Milk	20	48 x 36	Du	1922
31baa	Test hole 109	40	5	Dr	1949
31bbd1	Ed Ludtke	20	6	Dr	1947
31bbd2	..do....	50	..	Du	1920
32ada1	Clarence Sateren	100	5	Dr	1948
32ada2	..do....	100	5	Dr	1925
32ada3	..do....	120	5	..	....
32ada4	..do....	86	6	Dr	1918
32ada5	..do....	100	..	Dr	1920
32bbb	Test hole 110	50	5	Dr	1949
32ddd	Test hole 20A	45	5	Dr	1948
33add1	Martin Fuchs	125	6	Dr	1943
33add2	..do....	120	6	Dr	....
33bb	Clarence Sateren	104	5	Dr	1952

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
....	....	....	S	Wi, Wst, Wu
....	20	1938	D,S	
....	....	....	D,S	Ws
....	11.4	1949	U	
....	....	....	S	
....	24	1938	D,S	Win
....	15.48	1949	D,S	Wh
....	20	....	D,S	Wh, Wst
....	....	1948	U	Wh
....	18.54	1949	D	Ws
....	11.13	1949	S	Wal, Wh, Wi
....	....	....	S	
....	....	....	D	Win
Qg	....	....	D,S	Wh
....	13.55	1949	U	
....	....	....	S	
....	....	....	D,S	
....	16	1938	U	Ws
....	14	1949	D	Ws, Wst
Kp	40	1938	S	Wh, Wst
....	18	1949	D,S	Wh
....	....	....	S	
....	20	1938	D,S	
Qs	20	1949	D,S	Wh
....	18	1938	...	
....	....	....	T	L
Qs,Qg	....	....	D	Ws
....	....	....	S	Ws
Kp	20	1948	D	Ws
....	20	....	S	Ws
....	....	....	U	Ws
....	25	1938	D,S	
....	50	1938	D,S	
....	....	....	T	L
....	....	....	T	L
....	25	....	D,S	Ws
....	20	....	S	Ws
Kp	....	....	S	Wh

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
153-60					
3c	Mr. Sheets	175	4	Dr	....
3ccd	Walter Larson	32	30 x 33	Du	1921
4add	John W. Rainsberry	200	6	Dr	a1914
4d	Minn. Fire Ins.	127	6	Dr	1906
6acc	Vic Thorstenson	146	4	Dr	a1920
6c	J. W. Murphy	130	..	Dr	....
7aaa	Art Goldammer	120	5	Dr	1928
7cbc	S. B. Bagne	120	6	Dr	....
8daa	Cecelia Feeney	60	18	Dr	a1930
9a	State Land Dept.	37	48	Du	1937
9bcc	Cecelia Feeney	121	5	Dr	1934
9daa1	James Fahey	143	6	Dr	1931
9daa2	..do....	56	40	Du	1937
12cab	Walter Kaliff	10	..	Du	1944
12cdd1	..do....	20.7	22	Dr	1937
12cdd2	..do....	15.1	36	Du	1900
13a	Federal Land Bank	120	48	Dr	1937
14acc	Ed Ritteman	133	4	Dr	1938
14bcd1	Wesley Davidson	40	36	Du	1900
14bcd2	..do....	90	5	Dr	1937
16a	R. J. Goodheart	26	..	Du	....
18dcc	Wm. Thompson	116	6	Dr	....
19bcd1	..do....	27	24	Dr	1940
19bcd2	..do....	51	24	Dr	....
21bdb1	Ernest Rainsberry	100	6	Dr	1948
21bdb2	..do....	60	48 x 48	Du	1908
22acb	Test hole 25A	18	5	Dr	1948
22acc	Test hole 24A	35	5	Dr	1948
22bad1	Art Schroeder	35	36	Dr	1937
22bad2	..do....	90	18	Dr	1936
22bda	Test hole 26A	30	5	Dr	1948
22cdd	E. R. Ferguson	50	36	Du,Dr	1917
22dba	City of Lakota No. 1	15	240	Du	1919
22ddd	Test hole 23A	37	5	Dr	1948
23add	Albert Bjorge	130	4	Dr	1935
24bcd	Clarence McHugh	98	5	Dr	1937
24ccc	Ed. Bjorge	74	6	Dr	1918
25acb	Martin Sitar	45	36	Dr	1935

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
....	....	....	D	
Qg	12	1949	D,S	Wi
Qs	20	....	D,S	C
....	37	1906	...	
....	40	1942	D,S	Wio, Ws
....	....	....	...	
....	....	....	D,S	Ws, Wst
Kp	40	....	D,S	Wal, Ws, Wst
....	....	....	D	Wal, Ws
....	30	1938	D,S	
....	....	....	S	Wh
Kp	18	1944	D	Ws
Kp	40	....	S	Wal, Wh
....	....	....	S	Wal, Wh
Qg	11.75	1949	D,S	Wal, Wh
Qg	12.10	1949	U	Wal, Wh
....	....	....	D,S	
....	....	....	D,S	Ws, Wst
Qs	15	....	S	Wh
Qs	15	1949	D	C
....	33	1938	...	
....	....	....	U	Ws, Wst
....	8	1949	S	Wh, Wi
....	....	....	S	Wh, Wi
Qt	20	1948	D	Ws
....	20	....	S	Wh, Wi
....	....	....	T	L
....	....	....	T	L
....	21	1937	D	Wh, Wi
....	5	1936	S	Ws, Wst, Wu
....	....	....	T	L
....	40	1938	D,S	Wal, Wh
Qs,Qg	8.2	1949	M	C,L
....	....	....	T	L
Qs	20	....	D,S	Ws, Wst
Kp	17	1949	D,S	Wh, Wi
Qs,Qg	....	....	U	C
Qg	15	....	D,S	C

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
153-60 (Continued)					
25cab	Test hole 179	100	5	Dr	1949
25cbb	Test hole 178	58	5	Dr	1949
25cdc	Test hole 107	40	5	Dr	1949
26acb1	City of Lakota No. 2	20.65	216	Du	....
26acb2	City of Lakota No. 4	120	5	Dr	1937
26acb3	City of Lakota No. 5	120	5	Dr	1937
26acb4	City of Lakota No. 5A	120	5	Dr	1937
26ccc	J. B. Gunderson	129	6	Dr	1946
26dab	Test hole 177	85	5	Dr	1949
26dda	Test hole 180	120	5	Dr	1949
26ddc	Test hole 102	75	5	Dr	1949
26ddd	City of Lakota No. 6	85	10	Dr	1952
27aca 1/	City of Lakota No. 7	160	5	Dr	a1937
27acb 1/	Jake Debing	9.8	8	..	....
27acc 1/	A. F. Goldammer	35.5	30 to 18	..	....
27acd 1/	H. J. Byrne	23.6	10	..	....
27adc1 1/	E. J. Duchesneau	80	5	Dr	1946
27adc2 1/	City of Lakota No. 8	90	5	Dr	a1937
27add1 1/	E. O. Kleven	132	6	Dr	1949
27add2 1/	..do....	26	12	Dr	1945
27baa	Frances Johnson	30	5	Dr	....
27bac 1/	Frank Dykhoff	32.2	..	Dr	1949
27bad 1/	Oscar Olson	33.5	12	Dr	....
27bcd1 1/	City of Lakota No. 9	160	5	Dr	a1937
27bcd2 1/	Bill Simmons	25.7	12 to 6	..	....
27bda1 1/	City of Lakota No. 10	180	5	Dr	a1937
27bda2 1/	Jim Murphy	74.8	24	Dr	....
27bdc1 1/	The Grant House	100	6	..	1900
27bdc2 1/	Joe Barrett	160	8	Dr	1914
27bdc3 1/	Mrs. Hughes	80	6	Dr	....
27bdc4 1/	City of Lakota No. 11	180	5	Dr	1937
27bdd 1/	City of Lakota No. 12	280	6	Dr	a1937
27caa 1/	Lester Purdy	35.6	18	Dr	....
27cab1 1/	Oscar Lundgren	14.9	24	..	....
27cab2 1/	Jim Solberg	34.2	12	Dr	1919
27cab3 1/	A. H. Kaufman	30	2	Dr	1929
27ccc 1/	Test hole 113	145	5	Dr	1949
27cda 1/	Charles Hauser	20.8	..	..	....

1/ See figure 4.

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
....	....	....	T	C, L
....	....	....	T	L
....	....	....	T	L
Qs,Qg	16.85	....	M	C, L
Kp	....	....	U	
Kp	....	....	U	
Kp	....	....	U	
Qs	15	1946	D,S	Ws, Wst
....	....	....	T	L
....	....	....	T	L
....	....	....	T	L
Qg	....	....	M	
Kp	23	1937	U	C
....	....	....	U	
....	13.4	1949	U	Wh
....	14.19	1949	U	
Qs	20	1946	D	C
Kp	....	....	U	C
....	10	1949	D	Ws
....	....	....	D	Wh
....	25	....	S	Wh, Wu
Kp	31	1949	U	Wh, Win, Wu
....	13.8	1949	D,S	Wh
Kp	23	1937	U	C
....	23.29	1949	U	
Kp	23	1937	U	Ws
....	15.2	1949	U	
Kp	75	1949	D	C
....	....	....	U	Ws, Wst
....	....	....	D	Ws, Wst
Kp	23	1937	U	Wc, Ws
Kp	23	1937	M	C
Qs,Qg	18.62	1949	D	C
....	10.1	1949	D	
....	11.28	1949	U	
Qs,Qg	....	....	D	C
....	....	....	U	L
....	....	....	D	Wal, Wc, Wh, Wu

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
153-60 (Continued)					
27cdd 1/	Test hole 112	149	5	Dr	1949
27dad1 1/	Alfred Kleven	19.9	14	..	....
27dad2 1/	....	13.1	8	..	....
27dba 1/	Chas. Travnicek	27.05	14	Du	a1910
27dbc1 1/	City of Lakota No. 13	200	5	Dr	1937
27dbc2 1/	City of Lakota No. 14	170	5	Dr	1937
27dbd 1/	Lakota Creamery	41	72 x 72	Du	....
27dca 1/	Hugh Reynolds	17.4	12	Dr	1938
27dcb1 1/	Alfred Howen	86.2	5	Dr	1900
27dcb2 1/	A. H. Swanson	26.75	12	..	1918
27dcb3 1/	Walter Mootz	22.83	24	..	....
27dcd 1/	C. A. Ludtke	10.0	20	Du	1937
28ada	Leif Johnson	91	5	Dr	....
28c	J. H. Bealey	56	48	Du	1884
28caa	Oscar Bakken	38	24	Dr	....
28cdd	Test hole 114	165	5	Dr	1949
29ccc	Test hole 117	155	5	Dr	1949
29cdd	Test hole 116	108	5	Dr	1949
29ddd	Test hole 115	155	5	Dr	1949
30b	Mr. Barnett	28	48	Du	1932
30cbc	Harvey Appeman	136	6	Dr	1923
30ccd	Test hole 118	40	5	Dr	1949
30daa	Christien Beck	45	6	Dr	....
31add	James Randle	40	24	Dr	....
31dda	Jess Keitzman	120	6	Dr	1925
32abb1	Art Goldammer	102	5	Dr	a1920
32abb2	..do....	35	..	Du	a1890
33adb	R. A. Alwin	30	36 x 36	Du	....
33b	J. C. Bealey	188	6	Dr	1928
34aaa	Test hole 111	60	5	Dr	1949
34abb	....	126.2	5	Dr	....
34b	Wm. Fahey	32	48	Du	1937
34dab	Geo. Holicky	38	48	Du	1936
35aaa	Test hole 101	87	$1\frac{1}{4}$	Dr	1949
35aba	Test hole 103	97	5	Dr	1949
35abb	Test hole 104	120	5	Dr	1949
35baa	Test hole 105	40	5	Dr	1949

1/ See figure 4.

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
....	....	....	U	L
....	9.6	....	D	Wh, Wu
....	10.04	1949	U	
....	14.69	1949	D	Wh, Wst
Kp	23	1937	U	C
Kp	23	1937	U	C
Qs	....	....	U	C
Qs,Qg	9.14	1949	S	Wh, Wu
Qs,Qg	12.23	1949	D	C
....	11.85	1949	D	Wh, Wi
....	7.33	1949	U	Wu
....	8.92	1949	D	Wh, Wu
....	86	1947	D,S	Ws, Wst
....	53	1938	D,S	
....	16	1949	D,S	Wh
....	....	....	T	L
....	....	....	T	L
....	....	....	T	L
....	....	....	T	L
Qt	26.5	1938	D,S	Win
....	20	1923	D,S	Ws, Wst
....	....	....	T	L
Qs	28	....	D,S	Wh, Wi
....	....	....	S	Wal, Wh, Wu
Kp	40	....	D,S	Wh, Win
....	....	....	D	Wh, Wi, Wst, Wu
....	....	....	U	Wh
....	18.0	1949	S	Wh, Wu
....	19.5	1938	D,S	
....	....	....	T	L
....	9.61	1949	U	
Qt	27	1938	D,S	
Qt	15	1949	D,S	Wh, Wi
Qs,Qg	....	....	T,O	C, L
Qs,Qg	....	....	T	L
Qs,Qg	....	....	T	C, L
....	....	....	T	L

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Year completed
153-60 (Continued)					
35caa	M. H. Altermatt	156	5	Dr	1936
35ccb	Test hole 27A	160	5	Dr	1948
35ccc	Test hole 22A	100	$1\frac{1}{4}$	Dr	1948
35ccd	Test hole 29	38	4	Dr	1948
35dcd	Charles Stein	90	5	Dr	1920
36aaa	Test hole 108	130	5	Dr	1949
36bac1	George McHugh	72	4	Dr	1947
36bac2	..do....	72	4	Dr	....
36bba	Test hole 106	40	5	Dr	1949
36bbb	Test hole 1A	77	5	Dr	1948
36ddd	Test hole 21A	40	5	Dr	1948
153-61					
1add	Herb Westensee	112	4	Dr	1925
13ddd	Raymond Thompson	100	6	Dr	a1930
154-59					
33ccc1	Alex Hatula	28	40 x 40	Du	1916
33ccc2	..do....	32	40 x 40	Du	1919
154-60					
31ccb	Anton Johnson	101	5	Dr	1928
32cdb	Charles Turner	132	$4\frac{1}{2}$	Dr	1938

and test holes -- Continued

Geologic source	Depth to water below land surface (feet)	Year measured	Use	Remarks
Qs	19.46	1948	S	Ws, Wst
....	....	....	T	L
Qs,Qg	....	....	T,O	L
Qs,Qg	....	....	T	L
Qg	....	....	D,S	C
Qs,Qg	....	....	T	L
Qs	17	1947	U	C
....	....	....	S	Wh, Wi
....	....	....	T	L
....	....	....	T	L
....	....	....	T	L
Qs	....	....	D,S	Ws, Wst
....	....	....	D,S	Ws, Wst, Wu
Qg	15.63	1949	D	Wh
Qg	20	1938	S	Wh
Kp	18	1948	D,S	Ws
Kp	25	1938	D,S	C, Wal, Wio, Ws, Wst

TABLE 3.--Logs of test holes and wells

"Till" in the following logs refers to unsorted, unconsolidated sediments consisting largely of clay and silt particles but containing also larger-sized rock particles.

Test hole 28A
152-60-3bbc
Altitude: 1,510 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	2	2
	Till, brown, noncalcareous	3	5
	Till, tan	7	12
	Till, gray	37	49
	Gravel, fine; coarse sand	11	60
	Gravel, fine to coarse	47	107
Pierre Shale:			
	Shale, gray	3	110

Test hole 109
153-59-31baa
Altitude: 1,520 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	2	2
	Till, dark-brown, noncalcareous	2	4
	Sand, fine to very coarse, brown	6	10
	Till, brownish-gray	5	15
	Till, light-gray	10	25
	Till, light-gray, noncalcareous	4	29
Pierre Shale:			
	Shale, bluish-gray, noncalcareous; limestone pebbles	11	40

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 110
153-59-32bbb
Altitude: 1,517 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, buff	3	4
	Sand, medium to coarse; fine gravel and shale pebbles	3	7
	Till, yellowish-brown	5	12
	Till, grayish-brown	14	26
	Gravel	4	30
	Sand, coarse to very coarse	5	35
	Gravel	5	40
	Sand, coarse to very coarse	6	46
Pierre Shale:			
	Shale, light-gray, noncalcareous; angular chips, limestone pebbles	4	50

Test hole 20A
153-59-32ddd
Altitude: 1,525 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellow	13	14
	Till, gray	24	38
Pierre Shale:			
	Shale, gray	7	45

TABLE 3.--Logs of test holes and wells (Continued)

Test hole 25A
153-60-22acb
Altitude: 1,504 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, grayish-tan	3	4
	Sand, fine to coarse; fine gravel	2	6
	Till, grayish-tan	2	8
	Till, gray; shale pebbles	10	18

Test hole 24A
153-60-22acc
Altitude: 1,505 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	2	2
	Sand, very coarse; medium gravel	8	10
	Sand, very coarse, clayey, gray	6	16
	Till, gray	6	22
	Till, gray; shale pebbles	2	24
Pierre Shale:			
	Shale, gray	11	35

Test hole 26A
153-60-22bda
Altitude: 1,504 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Sand, medium to coarse; fine gravel	7	8
	Till, gray	16	24
Pierre Shale:			
	Shale, gray	6	30

City of Lakota (No. 1)
153-60-22dba
Altitude: 1,505 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Sand and gravel	12	12
	Till	3	15

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 23A
153-60-22ddd
Altitude: 1,521 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Till, buff	16	16
	Till, gray	12	28
	Gravel, gray; shale pebbles	2	30
	Till, grayish-tan	5	35
	Sand, very coarse; fine gravel	2	37

Test hole 179
153-60-25cab
Altitude: 1,507 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, white, highly calcareous	2	3
	Till, yellow	2	5
	Sand, medium to coarse	3	8
	Till, gray	5	13
	Sand, very fine to coarse; shale pebbles	2	15
	Till, bluish-gray; coal fragments	15	30
	Till, bluish-gray; shale pebbles	11	41
	Gravel, rounded	9	50
	Sand; shale pebbles	15	65
	Gravel; sand	32	97
Pierre (?) Shale:			
	Clay, sandy, gray	3	100

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 178
153-60-25cbb
Altitude: 1,509 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, grayish-tan	3	4
	Sand, fine to coarse; gravel and shale pebbles	1	5
	Till, yellowish-brown	4	9
	Till, gray	16	25
	Sand, medium to coarse; gravel and shale pebbles	2	27
	Till, gray	3	30
	Till, greenish-gray	7	37
Pierre Shale:			
	Shale, bluish-gray	21	58

Test hole 107
153-60-25cdc
Altitude: 1,508 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellowish-brown	8	9
	Till, gray	7	16
	Gravel, fine to medium; shale pebbles	2	18
	Till, gray	3	21
	Sand, medium to very coarse	6	27
	Till, gray	9	36

City of Lakota (No. 2)
153-60-26acb1
Altitude: 1,514 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Sand and gravel	18	18
	Clay	3	21

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 177
153-60-26dab
Altitude: 1,521 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black; coarse gravel	1	1
	Sand and gravel	4	5
	Gravel	14	19
	Till, yellow	2	21
	Till, gray; rock from 46 to 47 feet	26	47
	Till, greenish-gray; lignite fragments	20	67
	Till, gray	9	76
	Gravel and boulders	1	77
Pierre Shale:			
	Shale, bluish-gray	8	85

Test hole 180
153-60-26dda
Altitude: 1,506 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, tan, highly calcareous	2	3
	Till, yellowish-brown, highly calcareous	10	13
	Sand, gray	5	18
	Till, gray	12	30
	Sand, gray; lignite fragments	10	40
	Till, bluish-gray; shale pebbles	15	55
	Till, bluish-gray	20	75
	Sand, gray	10	85
	Gravel	35	120

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 102
153-60-26ddc
Altitude: 1,513 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, tan	9	10
	Till, yellowish-brown	5	15
	Till, brownish-gray	5	20
	Till, light-gray	10	30
	Gravel	40	70
Pierre(?) Shale:			
	Shale, gray, angular chips, clayey, sandy, slightly calcareous; sand and fine gravel	5	75

City of Lakota (No. 6)
153-60-26ddd

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Till	18	18
	Sand and gravel	67	85
	Clay, gravelly	3	88

Test hole 113
153-60-27ccc
Altitude: 1,510 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, buff	12	13
	Till, gray	9	22
	Sand, coarse; fine to medium gravel	1	23
	Till, gray	10	33
	Gravel, fine to medium; shale pebbles	2	35
	Till, gray	37	72
Pierre Shale:			
	Shale, bluish-gray, noncalcareous	58	130
	Shale, gray, calcareous; fine gravel and whitish clay	10	140
	Shale, bluish-gray, noncalcareous	5	145

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 112
153-60-27cdd
Altitude: 1,510 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellowish-brown	12	13
	Till, gray; lignite fragments from 30 to 40 feet	27	40
	Till, gravel; lignite fragments	30	70
	Till, light-gray	35	105
	Till, bluish-gray; shale pebbles	40	145
Pierre Shale:			
	Shale, bluish-gray	4	149

Test hole 114
153-60-28cdd
Altitude: 1,515 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellowish-brown	12	13
	Till, gray	10	23
	Sand, coarse; fine gravel and shale pebbles	1	24
	Till, gray	8	32
	Sand, coarse; fine to medium gravel and shale pebbles	2	34
	Till, gray; lignite fragments	6	40
	Sand and gravel	5	45
	Till, gray; lignite fragments	80	125
	Till, gray	37	162
Pierre Shale:			
	Shale, gray	3	165

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 117
153-60-29ccc
Altitude: 1,538 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellowish-brown	28	29
	Till, gray	17	46
	Gravel, fine to medium; shale pebbles	3	49
	Till, gray	61	110
	Gravel	5	115
	Till, gray, slightly calcareous	30	145
	Till, bluish-gray	4	149
Pierre Shale:			
	Shale, bluish-gray, noncalcareous	6	155

Test hole 116
153-60-29cdd
Altitude: 1,536 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Sand and gravel	2	3
	Till, tannish-brown	21	24
	Till, brownish-gray	21	45
	Till, gray	25	70
	Gravel and sand; shale pebbles	10	80
Pierre Shale:			
	Shale, bluish-gray; noncalcareous	28	108

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 115
153-60-29ddd
Altitude: 1,531 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellowish-brown	21	22
	Till, gray	98	120
	Sand and gravel; shale pebbles	10	130
	Till, gray	15	145
Pierre Shale:			
	Shale, gray, noncalcareous	10	155

Test hole 118
153-60-30ccd
Altitude: 1,540 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellowish-brown	24	25
	Till, gray	9	34
Pierre Shale:			
	Shale, bluish-gray, noncalcareous	6	40

Test hole 111
153-60-34aaa
Altitude: 1,510 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, whitish-gray	1	2
	Till, yellowish-brown	12	14
	Till, gray	5	19
	Sand, medium to coarse; fine gravel and shale pebbles	1	20
	Till, gray	10	30
	Sand, gray	2	32
	Till, gray; shale pebbles	19	51
Pierre Shale:			
	Shale, light-gray to bluish-gray, angular chips, noncalcareous	9	60

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 101
153-60-35aaa
Altitude: 1,514 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, yellowish-brown	15	16
	Till, gray	17	33
	Sand, medium to very coarse	7	40
	Gravel	45	85
Pierre(?) Shale:			
	Shale, gray, calcareous; sand and gravel	2	87

Test hole 103
153-60-35aba
Altitude: 1,511 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, tannish-brown	4	5
	Till, yellowish-brown	10	15
	Till, gray	15	30
	Sand, medium to very coarse	5	35
	Gravel	15	50
	Gravel, silt	40	90
	Sand, coarse to very coarse	2	92
Pierre(?) Shale:			
	Shale, gray, calcareous; sand and gravel	5	97

Test hole 104
153-60-35abb
Altitude: 1,510 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, tannish-brown	4	5
	Till, yellowish-brown	10	15
	Till, light-gray to bluish-gray; shale pebbles	17	32
	Gravel; shale pebbles	6	38
	Sand, medium to very coarse	7	45
	Gravel	5	50
	Sand, coarse to very coarse	5	55
	Gravel	4	59
	Sand	11	70
	Sand, coarse to very coarse	15	85
	Gravel	5	90
	Sand, coarse to very coarse	5	95
	Gravel	5	100
	Sand, coarse to very coarse	14	114
Pierre(?) Shale:			
	Shale, gray, calcareous; limestone pebbles	6	120

Test hole 105
153-60-35baa
Altitude: 1,511 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, tannish-brown	3	4
	Till, yellowish-brown	5	9
	Sand, medium to coarse; fine to medium gravel and shale pebbles	1	10
	Till, yellowish-brown	6	16
	Till, grayish-brown	6	22
	Sand, medium to very coarse	3	25
	Till, gray	6	31
Pierre Shale:			
	Shale, bluish-gray, noncalcareous; limestone pebbles	9	40

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 27A
153-60-35ccb
Altitude: 1,506 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, buff	16	17
	Till, gray	3	20
	Sand, medium to coarse; shale pebbles	10	30
	Till, gray	126	156
Pierre Shale:			
	Shale, gray	4	160

Test hole 22A
153-60-35ccc
Altitude: 1,511 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, light-tan	18	19
	Till, gray	19	38
	Sand, very coarse; fine gravel	7	45
	Gravel, fine; coarse sand	25	70
	Gravel, medium to coarse	15	85
	Gravel, coarse	5	90
	Gravel, coarse; coarse sand	4	94
Pierre Shale:			
	Shale, gray	6	100

Test hole 29
153-60-35ccd
Altitude: 1,503 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Till, buff	8	8
	Sand, very coarse; fine gravel	12	20
	Sand and gravel, clayey	5	25
	Gravel, fine to coarse	8	33
Pierre Shale:			
	Shale, gray	5	38

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 108
153-60-36aaa
Altitude: 1,507 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, whitish-gray	4	5
	Sand, yellowish-brown	10	15
	Sand, medium to very coarse	5	20
	Gravel	15	35
	Till, tannish-gray	5	40
	Gravel, gray	5	45
	Sand, gray	5	50
	Gravel, gray	10	60
	Sand, coarse to very coarse	5	65
	Gravel, gray	15	80
	Sand, gray	5	85
	Gravel, gray	5	90
	Sand, gray	10	100
	Till, gray; shale pebbles	15	115
	Till, gray; shale pebbles, noncalcareous	9	124
Pierre Shale:			
	Shale, bluish-gray, noncalcareous; limestone pebbles	6	130

Test hole 106
153-60-36bba
Altitude: 1,509 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Topsoil, black	1	1
	Till, tan to yellowish-brown	6	7
	Sand, coarse; fine gravel and shale pebbles	1	8
	Till, yellowish-brown	5	13
	Sand, medium to very coarse	3	16
	Till, gray; shale pebbles	12	28
Pierre Shale:			
	Shale, bluish-gray, noncalcareous; limestone pebbles	12	40

TABLE 3.--Logs of test holes and wells -- Continued

Test hole 1A
153-60-36bbb
Altitude: 1,517 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Till, bluish-gray, highly calcareous	3	3
	Till, tan	13	16
	Sand, medium to very coarse; fine gravel and shale pebbles	2	18
	Till, light-gray	3	21
	Sand, medium to coarse; fine to medium gravel and shale pebbles	4	25
	Sand, coarse; fine gravel	5	30
	Sand, fine to medium	15	45
	Sand, coarse	10	55
	Gravel, fine to coarse; coarse sand	22	77

Test hole 21A
153-60-36ddd
Altitude: 1,508 ft

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Sand, fine to coarse	22	22
	Gravel, fine to medium; coarse sand	16	38
Pierre(?) Shale:			
	Shale, gray, coarse sand	2	40

REFERENCES

Babcock, E. J., 1902, Water resources of the Devils Lake region: North Dakota Geol. Survey Second Bienn. Rept., p. 208-250.

Comly, H. H., 1945, Cyanosis in infants caused by nitrates in well water: Am. Med. Assoc. Jour., v. 129, p. 112-116.

Dean, H. T., 1936, Chronic endemic dental fluorosis: Am. Med. Assoc. Jour., v. 107, p. 1269-1272.

Fenneman, N. M., 1938, Physiography of eastern United States: New York, McGraw-Hill, 599 p.

Garske, J., 1958, Summary of the Reelfoot Development Co., Inc.- Louis and Alvina Bryl No. 1, Nelson County, North Dakota: North Dakota Geol. Survey Circ. 207.

Hansen, D. E., 1955, Subsurface correlations of the Cretaceous Greenhorn - Lakota interval in North Dakota: N. Dak. Geol. Survey Bull. 29, 46 p.

____________, 1956, Summary of Oil Exploration Co. - Joe W. Lamb No. 1, Nelson County, North Dakota: North Dakota Geol. Survey Circ. 143.

Laird, W. M., 1948, Ground water in the Zeeland area, North Dakota: North Dakota Ground Water Studies 12, 38 p., 8 figs., 2 tables.

Meinzer, O. E., 1923, The occurrence of ground water in the United States with a discussion of principles: U.S. Geol. Survey Water-Supply paper 489, 321 p.

Russell, A. E., 1950, Pebbles in the glacial till of eastern North Dakota: A thesis submitted to the graduate faculty of the Univ. of North Dakota.

Silverman, L. B., 1949, Methemoglobinemia: Report of two cases and clinical review: Journal-Lancet, v. 69, p. 94-97.

Simpson, H. E., 1912, The physiography of the Devils-Stump Lake region, North Dakota: North Dakota Geol. Survey Sixth Bienn. Rept., p. 101-157.

____________, 1929, Geology and ground-water resources of North Dakota with a discussion of the chemical character of the water by H. B. Riffenburg: U.S. Geol. Survey Water-Supply Paper 598, 312 p.

____________, 1932, The ground waters of North Dakota: North Dakota Geol. Survey Bull. 7, Artesian Water Paper 5, 26 p.

Swenson, H. A., and Colby, B. R., 1955, Chemical quality of surface waters in Devils Lake basin, North Dakota: U.S. Geol. Survey Water-Supply Paper 1295, 82 p., 24 figs., 19 tables, 4 pls.

Upham, Warren, 1896, The glacial Lake Agassiz: U.S. Geol. Survey Mon. 25, 658 p., 38 pls.

U.S. Public Health Service, 1961, Drinking water standards: Am. Water Works Assoc. Jour., v. 53, no. 8, p. 935-945.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture, Agric. Handb. 60, 160 p.

U.S. Weather Bureau, 1961, Climatological data for North Dakota, Annual Summary, v. 70, no. 13, p. 188-197.