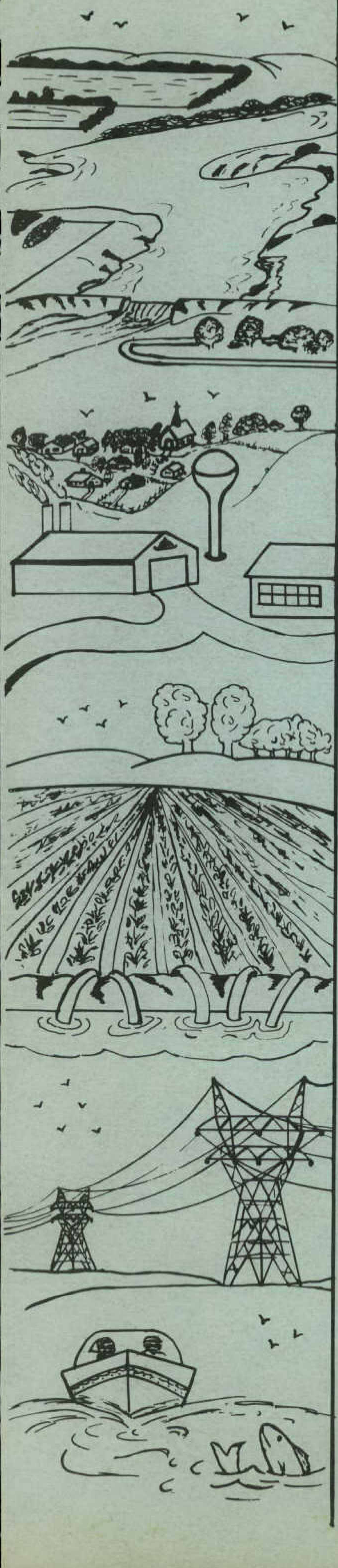


GEOLOGY AND GROUND WATER RESOURCES OF THE DRAKE AREA
McHENRY COUNTY, NORTH DAKOTA

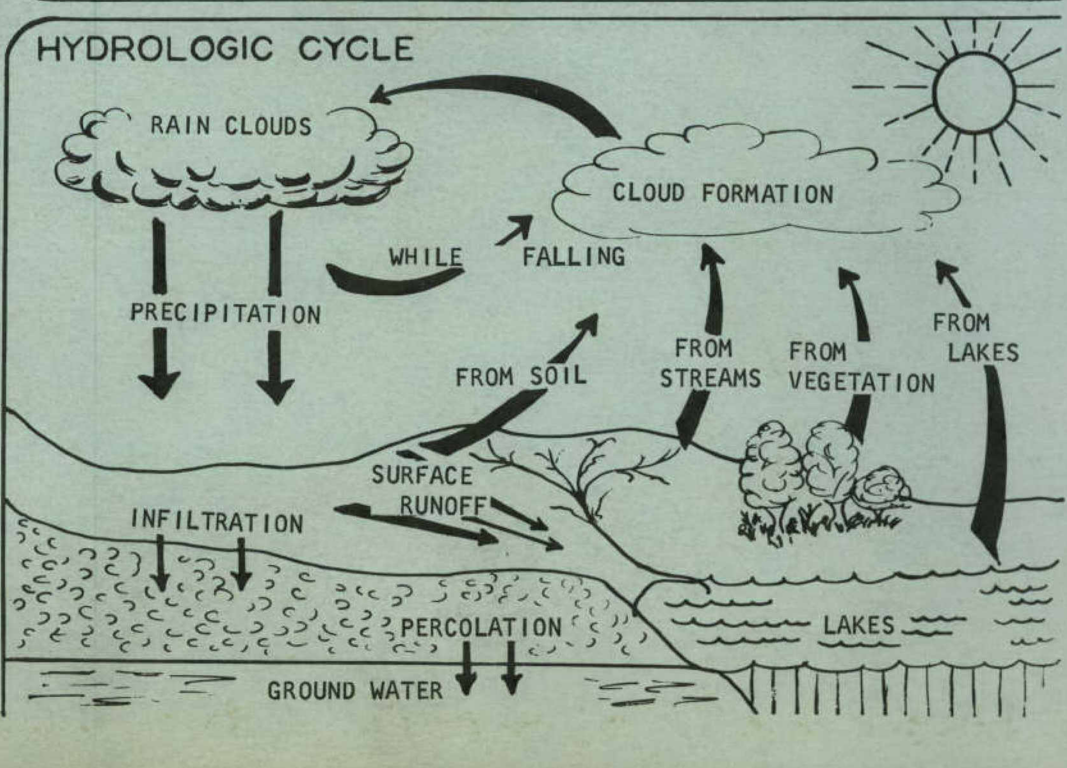
BY
D. G. ADOLPHSON
GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

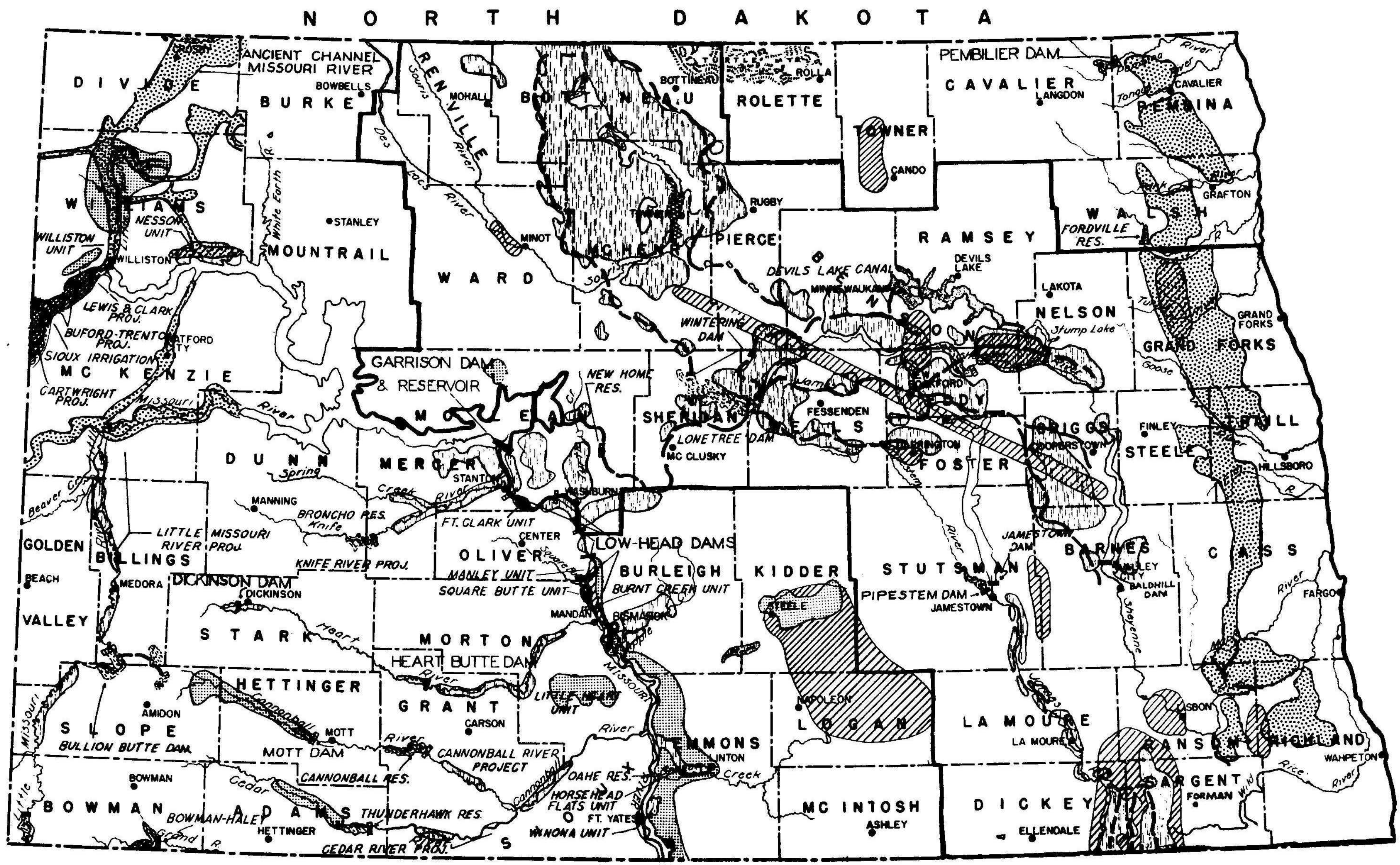
NORTH DAKOTA GROUND WATER STUDIES

NO. 31

PUBLISHED BY
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
1301 STATE CAPITOL, BISMARCK, NORTH DAKOTA
IN COOPERATION WITH
U. S. **GEOLOGICAL SURVEY**

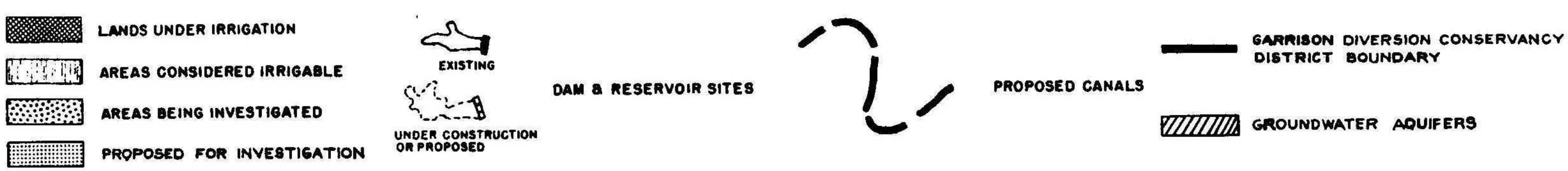
- 1961 -





NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN



Gov. William L. Guy
CHAIRMAN
EARLE F. TUCKER
VICE CHAIRMAN
MILO W. HOISVEEN
SECRETARY AND STATE ENGINEER
EINAR H. DAHL
WM W. CORWIN
A.R. WEINHANDL
MATH DAHL
OSCAR LUNSETH

GEOLOGY AND GROUND-WATER RESOURCES OF THE DRAKE AREA
McHENRY COUNTY, NORTH DAKOTA

By
D. G. Adolphson
Geological Survey
United States Department of the Interior

North Dakota Ground-Water Studies No. 31

Published By
North Dakota State Water Conservation Commission
1301 State Capitol, Bismarck, North Dakota
In Cooperation With
U. S. Geological Survey

1961

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND GROUND-WATER RESOURCES OF THE DRAKE AREA McHENRY COUNTY, NORTH DAKOTA

By
D. G. Adolphson

ABSTRACT

The Drake area includes about 192 square miles of southeastern McHenry County in north-central North Dakota.

The area was glaciated during Wisconsin time of the Pleistocene epoch. Drift from the last ice advance mantles the area except where the drift underlies thin beds of Recent alluvium and where the Cannonball member of the Fort Union formation is exposed.

The Recent alluvial deposits in the drainage system are less than 7 feet thick and do not contain usable quantities of ground water.

Deposits of the glacial drift are subdivided into the following units: (1) deposits of glacial Lake Souris, (2) outwash deposits, and (3) till and associated sand and gravel deposits. The average thickness of the glacial drift is about 90 feet; 310 feet of drift was penetrated on one test hole.

Deposits of glacial Lake Souris are present in the northeastern corner of the area. Logs of test holes drilled 5 miles north of the area show that the lake sediments range in thickness from 6 to 76 feet and average 31 feet. The drill cuttings consist of clay, silt, and very fine to medium sand. Shallow wells in the lacustrine sand and silt in the Drake area yield moderate water supplies that are adequate for farm use.

Glacial outwash deposits are found in an outwash plain and in diversion and ice-marginal channels. The channels cross the area in a southeasterly direction. Deposits of sand and gravel in the diversion and ice-marginal channels range in thickness from a few feet at the edge to 45 feet near the center. Deposits of sand and gravel in the outwash plain range in thickness

from 25 to 59 feet. An aquifer in a diversion channel west of Drake and an aquifer in an outwash plain south of Drake are sufficiently permeable and widespread to yield adequate water supplies for municipal use.

Till covers much of the Drake area; isolated water-bearing sand and gravel lenses have been found by drilling or digging wells in the till at many places. Most wells tapping these aquifers yield sufficient water for farm use. An aquifer that may be productive occurs 4 miles east of Drake in a sand and gravel deposit at the base of the glacial drift. The deposit, which is 52 feet thick, occurs at the edge of a preglacial valley that extends southeastward across central North Dakota.

The bedrock in the Drake area is the Cannonball member of the Fort Union formation of Paleocene age. Although yields from the Cannonball member are generally small to moderate, sufficient water for the present (1960) demand of the city of Drake is obtained from wells in this unit.

The Fox Hills(?) sandstone of Late Cretaceous age probably underlies the Cannonball member in the report area. Some farm wells tap a sandstone that may be the Fox Hills, but the formation is not known to yield large supplies of water.

The Pierre shale of Late Cretaceous age underlies the Cannonball member and the Fox Hills(?) sandstone in the area. No wells in the area obtain water from the Pierre.

Of the older rocks that underlie the Pierre shale, only the Dakota sandstone of Early Cretaceous age is important as a possible ground-water source. The formation is a major aquifer in some parts of the State; however, becuase of its depth and the high mineralization of its contained water, the aquifer is not presently utilized in the report area.

Ground water from glacial-drift wells in the Drake area is generally of the calcium bicarbonate or sulfate type, is hard, and varies considerably in degree of mineralization. Water from the bedrock wells is slightly hard, is relatively high in boron and is moderately to highly mineralized.

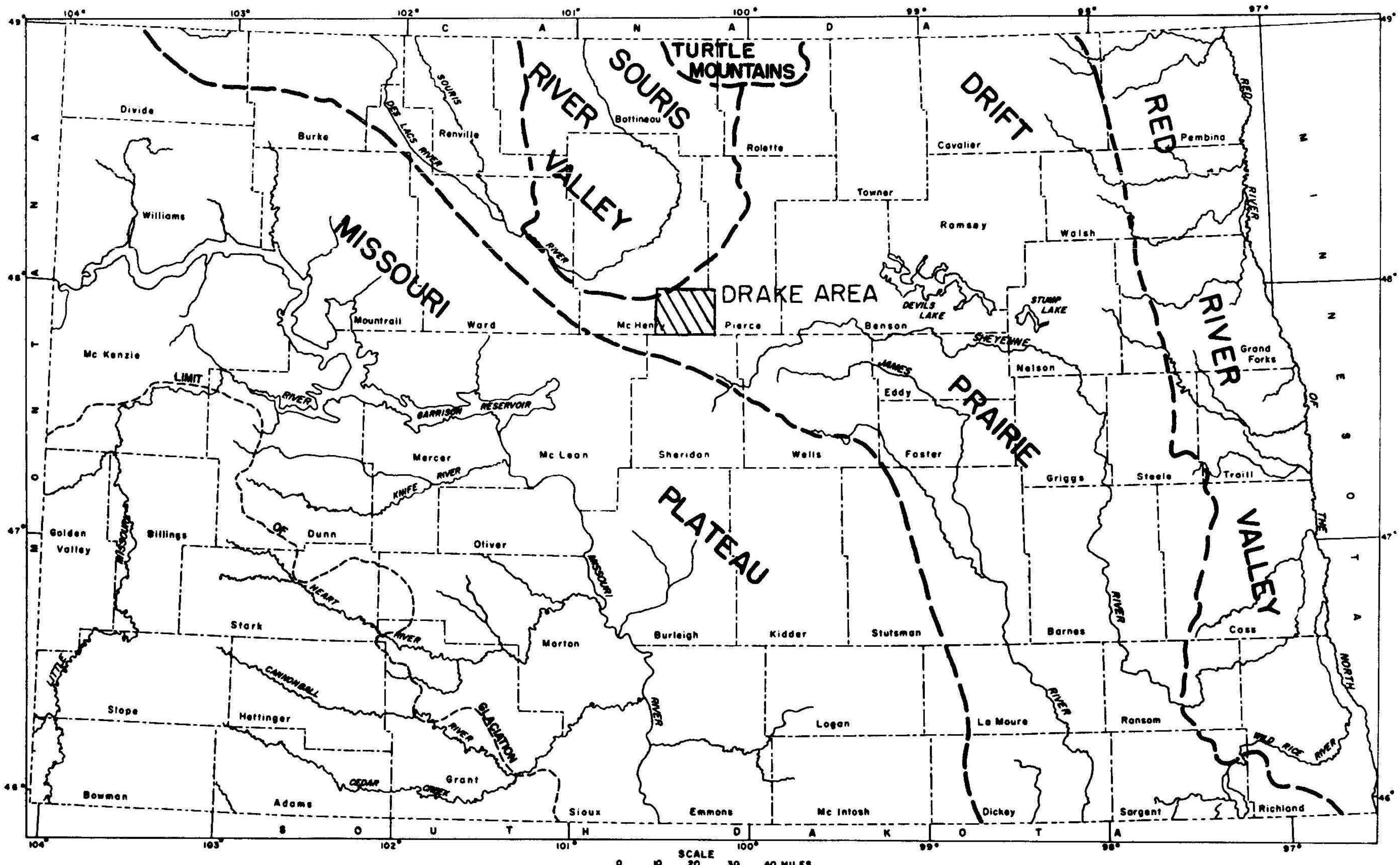


FIGURE I--PHYSIOGRAPHIC PROVINCES OF NORTH DAKOTA AND LOCATION OF THE DRAKE AREA

(MODIFIED FROM SIMPSON, 1929)

INTRODUCTION

Location and General Features of the Area

The Drake area comprises about 192 square miles of southeastern McHenry County in north-central North Dakota. The area includes all of T. 151 N., Rs. 75 and 76 W., and T. 152 N., Rs. 75 and 76 W., and parts of T. 151 N., R. 77 W., and T. 152 N., R. 77 W.

Drake, the largest municipality, is in the central part of the area and had a population of 752 in 1960. Also in the report area are the towns of Kief, Balfour, and Anamoose. The area is served by U. S. Highway 52 and State Highway 14 and by a branch line of the Minneapolis-St. Paul and Sault Ste. Marie Railroad. The main line of the Great Northern Railroad crosses the northern part of the area. Farming is the chief occupation and wheat is the main crop.

The average annual precipitation recorded by the U. S. Weather Bureau at Drake from 1929 through 1959 was 16.30 inches. The average annual temperature was 39.4° for the same period.

Purpose and Scope of the Investigation

This report describes the geology and ground-water resources of part of McHenry County, N. Dak. 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. It is one of a series being made to study the geology and ground-water resources of areas that need additional water. For example, one of North Dakota's most critical needs is for adequate perennial water supplies for many small towns and cities that are attempting to install water-supply systems or are expanding their present facilities. Because of this demand, relatively small investigations are begun in the vicinity of towns that request aid from the State Water Conservation Commission and the State Geologist, and reports thereof are released as soon as possible.

This investigation was made under the general supervision of A. N. Sayre, P. E. LaMoreaux, successive chiefs of the Ground Water Branch, U. S. Geological Survey, and under the direct supervision of the late Joseph W. Brookhart, district geologist, Grand Forks. The fieldwork was done intermittently from 1955 to 1958 and consisted of a study of the surface geology, inventory of the wells, test drilling, and collection of water samples. Chemical analyses of water samples were made by the North Dakota State Laboratories Department. The test drilling was done by a rotary drilling rig owned by the North Dakota State Water Conservation Commission.

Subsurface Data Collection

Subsurface information in the Drake area was obtained in part from a study of the cuttings from 26 test holes (samples taken of each 5-foot interval) and in part from published information. The locations of test holes drilled in the area are in figure 5, and the logs are listed on pages 45 to 56. The depths of the test holes ranged from 50 to 370 feet and averaged 124 feet. Geologic sections based upon the logs are shown on figure 6. Information concerning the deeper formations in the area was obtained from logs of oil-test holes supplied by the North Dakota Geological Survey. The logs of other wells and test holes outside the area also were available for study.

Previous Investigations and Acknowledgments

Warren Upham (1895)[1/] described the surface features of the glacial

---

1/ See references at end of report.

Lake Souris basin in the vicinity of the Drake area, and a general study of the geology and ground-water resources of McHenry County was made by Simpson (1929, p. 156-161). Chemical analyses of water samples from wells in Drake, Anamoose, and Balfour are given by Abbott and Voedisch (1938, p. 64-65).

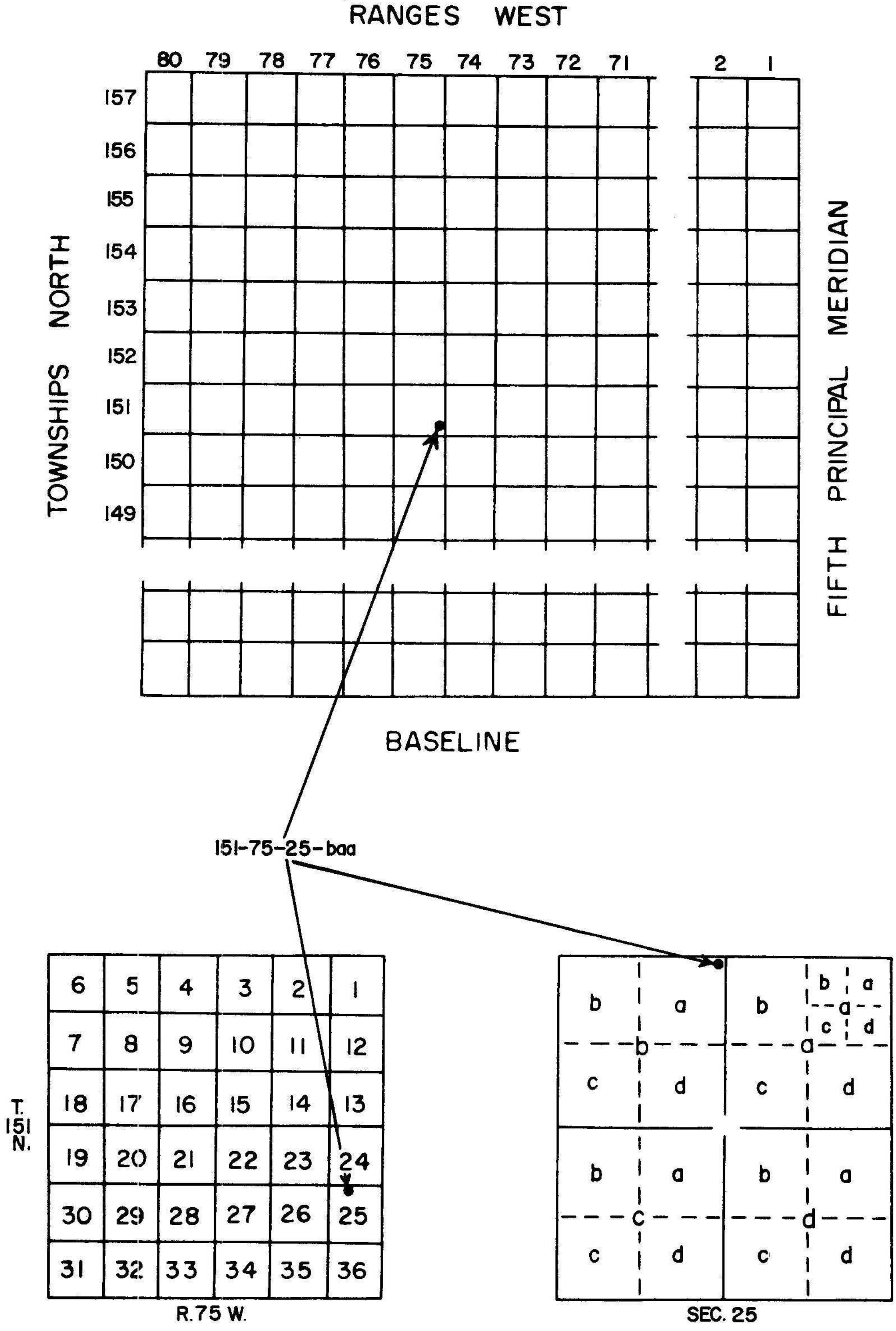


Figure 2 -- Sketch illustrating well-numbering system

Jenkinson (1950) mapped the geology of the Drake quadrangle in partial fulfillment of the requirements for a master's degree. Lemke (1960) studied the geology in northwestern and north-central North Dakota, and much of the geologic information used in this report has been taken from his work.

Well-Numbering System

The well-numbering system used in this report is illustrated in figure 2 and is based upon the location of the well within the grid established by the U. S. Bureau of Land Management's survey of the area. The first numeral denotes the township north of the base line that extends laterally across the middle of Arkansas; 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, the quarter-quarter sections, and the quarter-quarter-quarter sections (10-acre tracts). Consecutive terminal numerals are added if more than 1 well is located within a 10-acre tract. Thus, well 151-75-25baa is in the northeast quarter of the northeast quarter of the northwest quarter of section 25, T. 151 N., R. 75 W. Similarly, well 152-75-22bcb2 is the second well located in the northwest quarter of the southwest quarter of the northwest quarter of section 22, T. 152 N., R. 75 W.

Physiographic Features

The Drake area is a part of the Western Young Drift section of the Central Lowland physiographic province of Fenneman (1938, p. 559) and is in the western edge of the Drift Prairie region, as designated by Simpson (1929, p. 5, 7-8).

The report area is a gently rolling ground-moraine plain characterized by broad, shallow outwash channels, groups of well-rounded knobs and hills, and shallow depression. Numerous ponds and lakes occur throughout the area, particularly in the outwash channels of the glacial spillways. The best-developed channels (Lemke, 1958b, p. 272) are the Velva, Lake Hester, Verendrye, Antelope Valley, Kruger Lake and Alymer, which trend southeastward. Straight and narrow parallel ridges trend southeastward across the western part of the area. These ridges are probably an elongated type of drumlin (op. cit., p. 270).

The surface runoff of the area is carried by the Wintering River and its intermittent tributaries, which drain northward to the Souris River, but no integrated postglacial drainage system has been developed.

GEOLOGY AND OCCURRENCE OF GROUND WATER

Principles of Occurrence of Ground Water

Practically all ground water is derived from precipitation. Water enters the ground by direct penetration of rain or melting snow or by percolation from streams and lakes that lie above the water table. Ground water generally moves downward and then laterally from areas of recharge to areas of natural discharge.

Ground water is discharged by evaporation from lakes, ponds, and the land surface where the water table is near the land surface, by transpiration by plants, by seepage into streams, by pumping from wells and from 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 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 material, such as clay, sand, and gravel, generally is more porous than consolidated rock, such as sandstone and limestone; however, consolidated rock in some areas is highly porous.

The capacity 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 to the rock particles; the smaller the pores, the greater the proportion of water that will be held. The amount of water, expressed as a percentage of a cubic foot, that will drain by gravity from 1 cubic foot of an aquifer is called the "specific yield" of the aquifer.

If the water in an aquifer is not confined by overlying, relatively impermeable strata, the water is under water-table conditions. Under these conditions, water can be obtained from storage in the aquifer by gravity drainage--that is, by lowering the water level, as in the vicinity of a pumped well.

Water is present under artesian conditions if it is confined in the aquifer by an overlying relatively impermeable stratum. Under such conditions, hydrostatic pressure will raise the water in a well, or other conduit penetrating the aquifer, above the top of the aquifer. When water is yielded from the well, the aquifer remains saturated, and water is yielded because it expands as the aquifer is compressed and the pressure is decreased. The water-yielding capacity of an artesian aquifer is called the "coefficient of storage" and generally is very 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. The volume of water attributable to compressibility is a negligible part of the total volume of water released from or taken into storage, however, and can be disregarded. Thus, for a water-table aquifer, the coefficient of storage is practically equal to the specific yield.

The resistance to the movement of water through pore spaces that are relatively large, as in coarse gravel, is not great, and such material is said to be permeable. However, the resistance to the movement of water through small pore spaces, as in clay or shale, may be great and such 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 the ground water.

The "coefficient of transmissibility" is convenient to use in ground-water studies because it indicates a characteristic of the aquifer as a whole 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 supply is governed by its permeability, volume, and capacity to store and release water. Also recharge to the aquifer over a long period must equal the quantity pumped out and that lost by natural discharge, or the water supply may gradually diminish to the extent that it is no longer economically feasible to pump from it. Aquifers which are highly permeable but small in areal extent and which are surrounded by relatively impermeable material can be pumped dry in a comparatively short time. The rather high initial yield of a well tapping such an aquifer may give an erroneous impression that a large volume of water is available from the aquifer indefinitely. Thus, before any substantial ground-water development is made, sufficient test drilling, aquifer tests, and related studies should be undertaken to determine the capabilities and recharge conditions of the aquifer being considered.

Geologic History

Parts of the northern Great Plains were covered during much of Tertiary and Cretaceous time by vast seas in which all or some of the sediments of the Cannonball member of the Fort Union formation, Fox Hills sandstone, and Pierre shale were deposited. Parts of these formations, however, may have been deposited in terrestrial environments. All the formations are probably present in the Drake area.

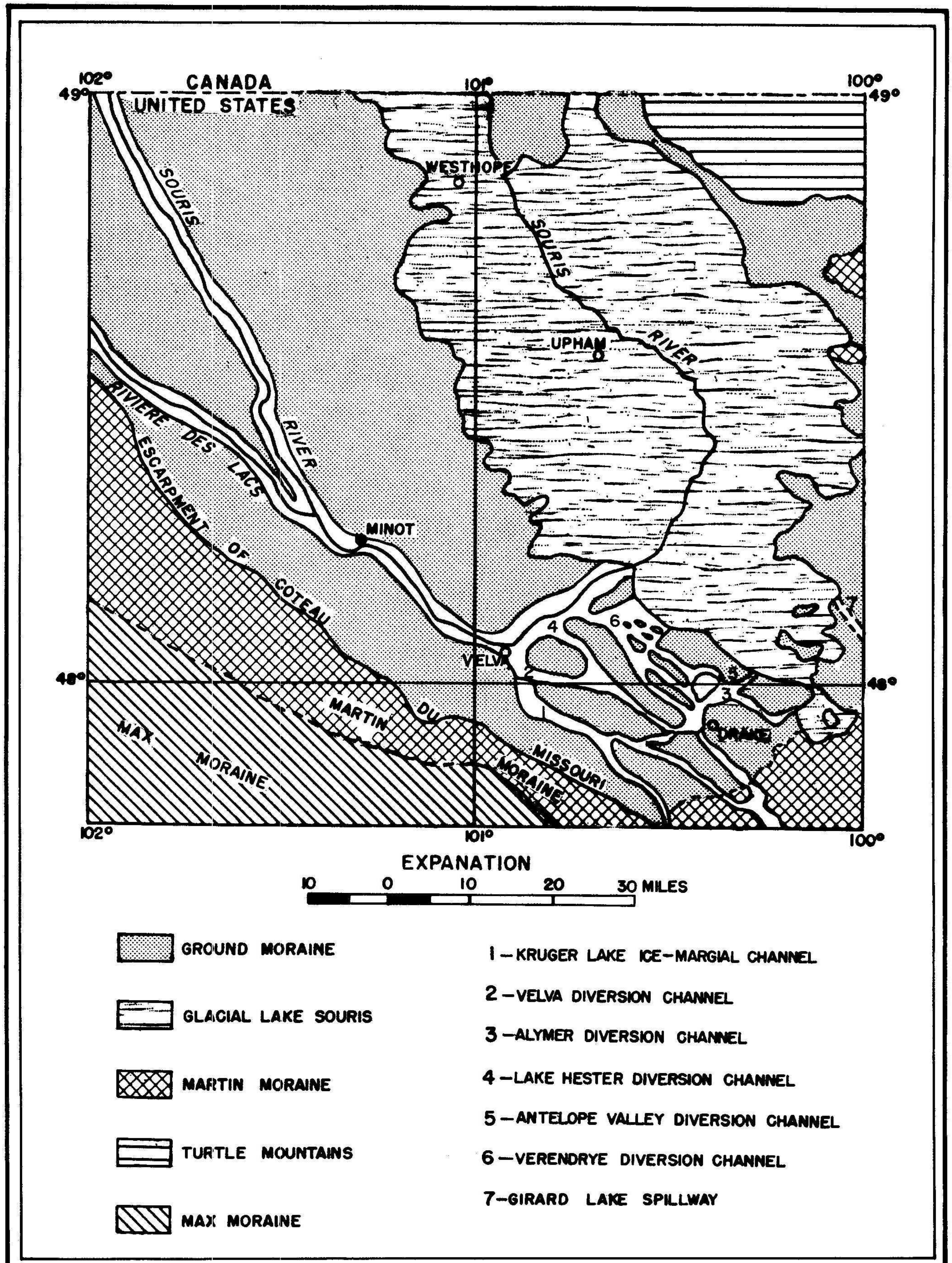
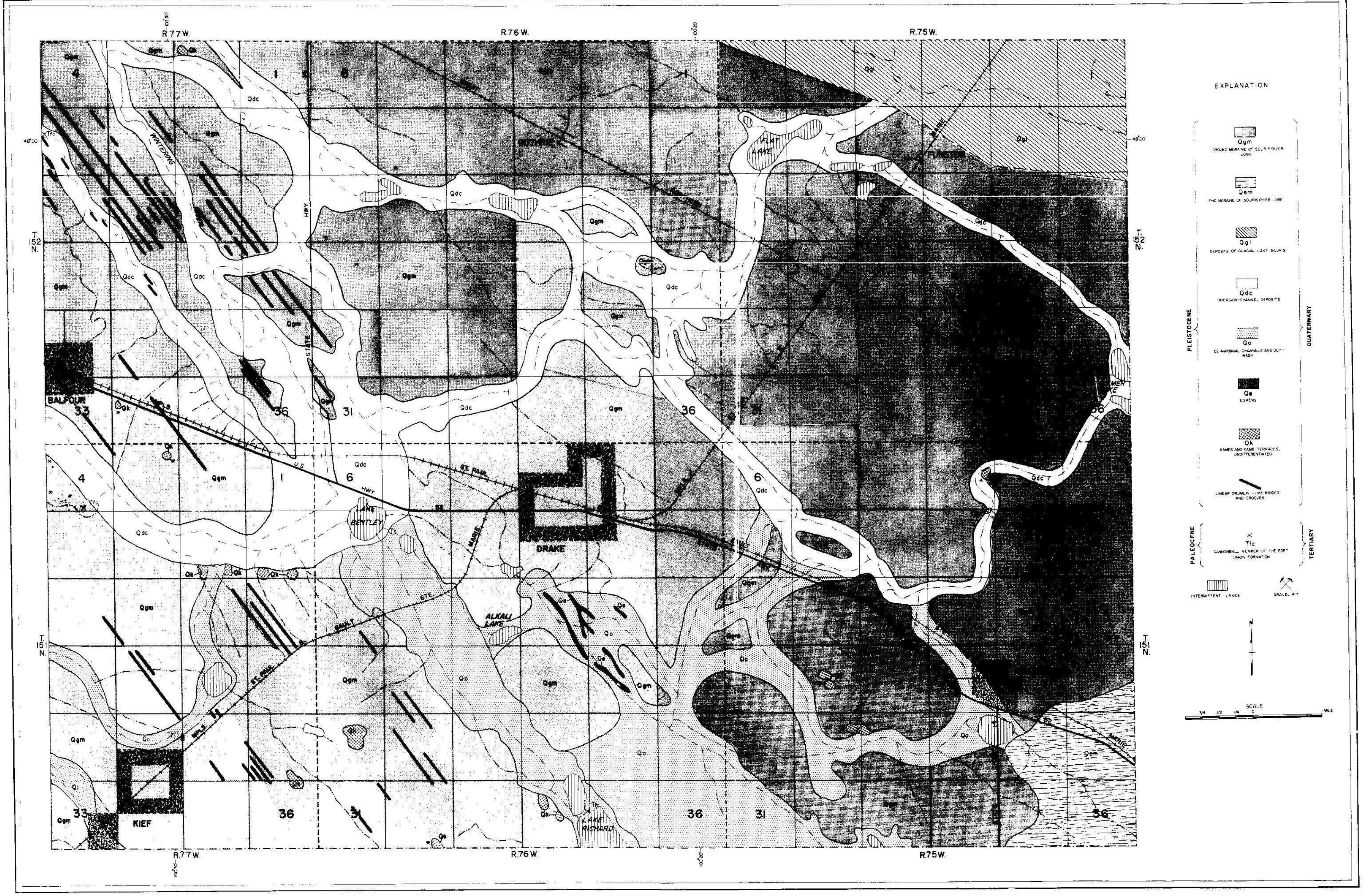


FIGURE 3—GENERALIZED GEOLOGIC AND PHYSIOGRAPHIC MAP OF NORTH-CENTRAL NORTH DAKOTA (FROM LEMKE, 1958a)

The Drake area was subjected to several advances of ice sheets during the Wisoconsin stage of the Pleistocene epoch (Lemke, 1958a, p. 86). The Souris River lobe, which was the last ice sheet to cover the area, deposited drift that conceals any evidence of prior glaciation. Southeastward movement of ice is suggested by northwest-trending linear drumlin like ridges with linear grooves between them. (See fig. 4) Also, a regional northwest concavity of the Martin moraine, which is the terminus of the Souris River lobe, indicates that this ice moved from the northwest. The moraine extends around glacial Lake Souris to the northeast and north, as is shown in the upper right corner of fig. 3.

After the initial retreat of the ice of the Souris River lobe, the melt waters were discharged through the present-day Souris and Des Lacs drainage system above Velva into the Kruger Lake spillway. This spillway cut through the Martin moraine and emptied into what is now the head of the Sheyenne River drainage system.

As the ice continued its recession, the western part of the Kruger Lake ice-marginal channel system was abandoned in favor of a lower outlet to the Velva diversion channel. The melt water was then carried through the Velva and Alymer diversion channels into glacial Lake Souris, which was developing at that time. Lake Souris was a marginal glacial lake that formed when melt water was impounded on the northward-sloping Souris River basin. The lake occupied approximately 3,000 square miles of north-central North Dakota during a late substage of the Pleistocene epoch, possibly Mankato (Upham, 1895, p. 268). At its greatest extent, the lake was approximately 175 miles long and 75 miles wide. The absence of prominent beaches and lack of evidence of wave or lake-ice action suggest that the lake was subject to only minor fluctuations of stage. During a major part of its history, the lake probably



MAP SHOWING GEOLOGY OF THE DRAKE AREA (MODIFIED FROM JENKINSON, 1950, AND LEMKE, 1960) consisted of several disconnected water bodies that contained numerous islands (Powell 1959, p. 15). Although only the northeast corner of the Drake area is included in the lake plain (see fig. 4), the geologic history of the entire region was influenced by the lake and its history.

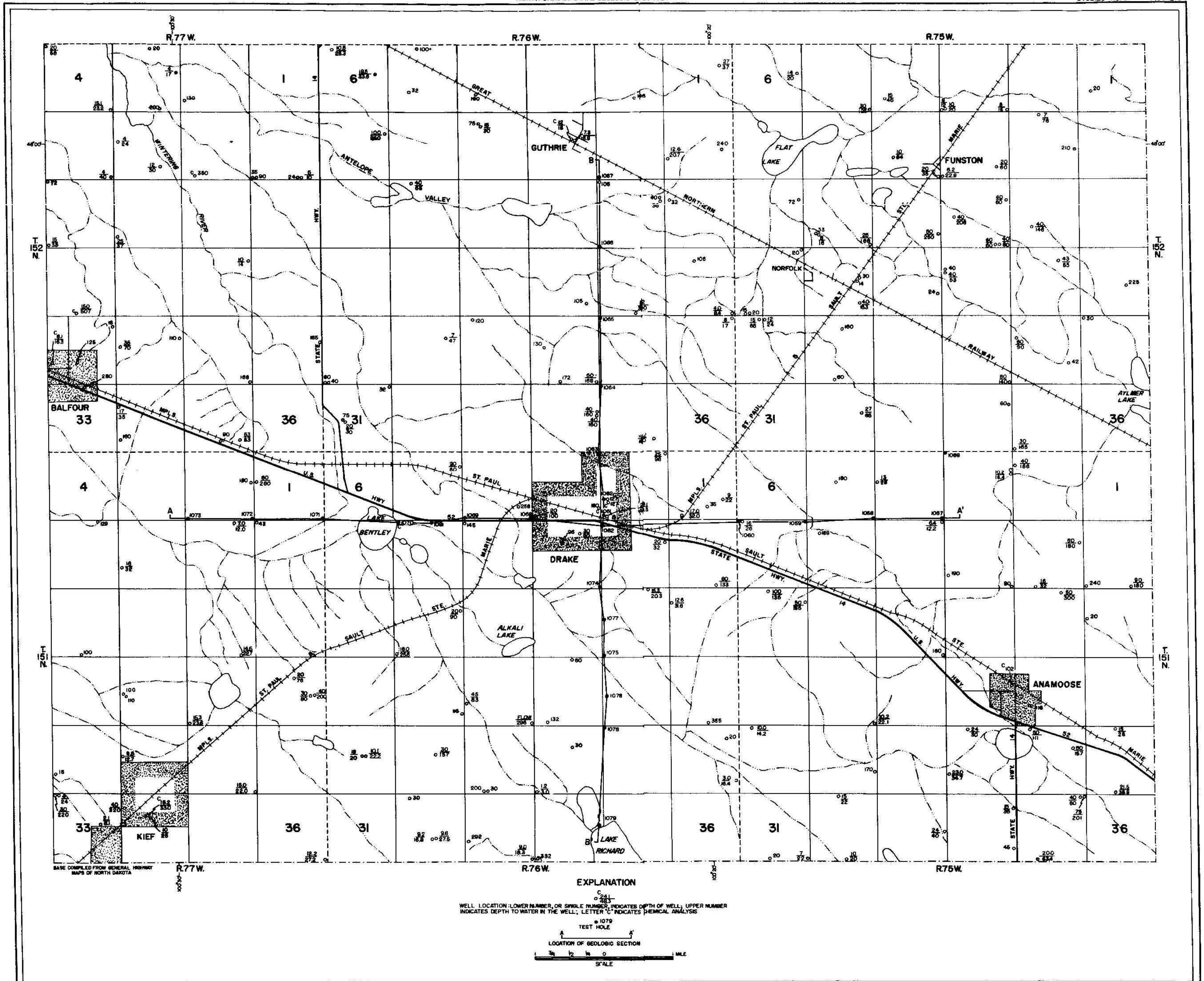
With the continued retreat of the ice, the older diversion channels were successively abandoned for the Lake Hester, Antelope Valley, and Verendrye diversion channels (see fig. 3). The youngest channel into the southern part of the glacial Lake Souris followed the present course of the Souris River. The outflow of the lake during its early stages was through the Girard Lake spillway into the Heimdal and Sheyenne diversion systems. Glacial Lake Souris expanded northward into Saskatchewan and Manitoba, Canada, and when the ice had receded north of the Turtle Mountains, the lake drained eastward into glacial Lake Agassiz via the Pembina trench (Upham, 1895, p. 268).

General Stratigraphic Relations

Following is a partial stratigraphic section of the Drake area:

Table 1.--Quaternary, Tertiary, and Cretaceous stratigraphy in the Drake area

- Cenozoic era:
  - Quaternary system
    - Recent series
      - Alluvium
    - Pleistocene series
      - Wisconsin stage
        - Deposits of glacial Lake Souris
        - Outwash deposits
        - Till and associated sand and gravel deposits
      - Pre-Wisconsin (?) stage
  - Tertiary system:
    - Paleocene series
      - Cannonball member of Fort Union formation
- Mesozoic era:
  - Cretaceous system
    - Upper Cretaceous series
      - Fox Hills (?) sandstone



MAP SHOWING LOCATIONS OF WELLS AND TEST HOLES IN THE DRAKE AREA

Pierre Shale
Niobrara formation
Benton shale equivalents
Lower Cretaceous series
Dakota sandstone

Recent Alluvium

In the Recent epoch, streams have deposited thin beds of dark-colored clay, silt, and very fine sand in the valleys of the drainage system in the Drake area. These deposits are generally less than 7 feet thick, are extremely lenticular, and do not contain aquifers.

Glacial Drift

The glacial drift comprises the surficial deposits in the Drake area except where thin beds of alluvium have been deposited over the drift and where bedrock is exposed. The drift has been divided into three types according to lithology and origin: (1) deposits of glacial Lake Souris, (2) outwash deposits, and (3) till and associated sand and gravel deposits. Ice-contact features in the area are kames, eskers, kame terraces, and linear drumlinlike ridges. The drift in the Drake area originated during the Wisconsin stage of the Pleistocene epoch. Its average thickness is about 90 feet; however, 310 feet of drift was penetrated in test hole 1088 (151-75-3bbb) and 280 feet in test hole 1057 (151-75-4ddd).

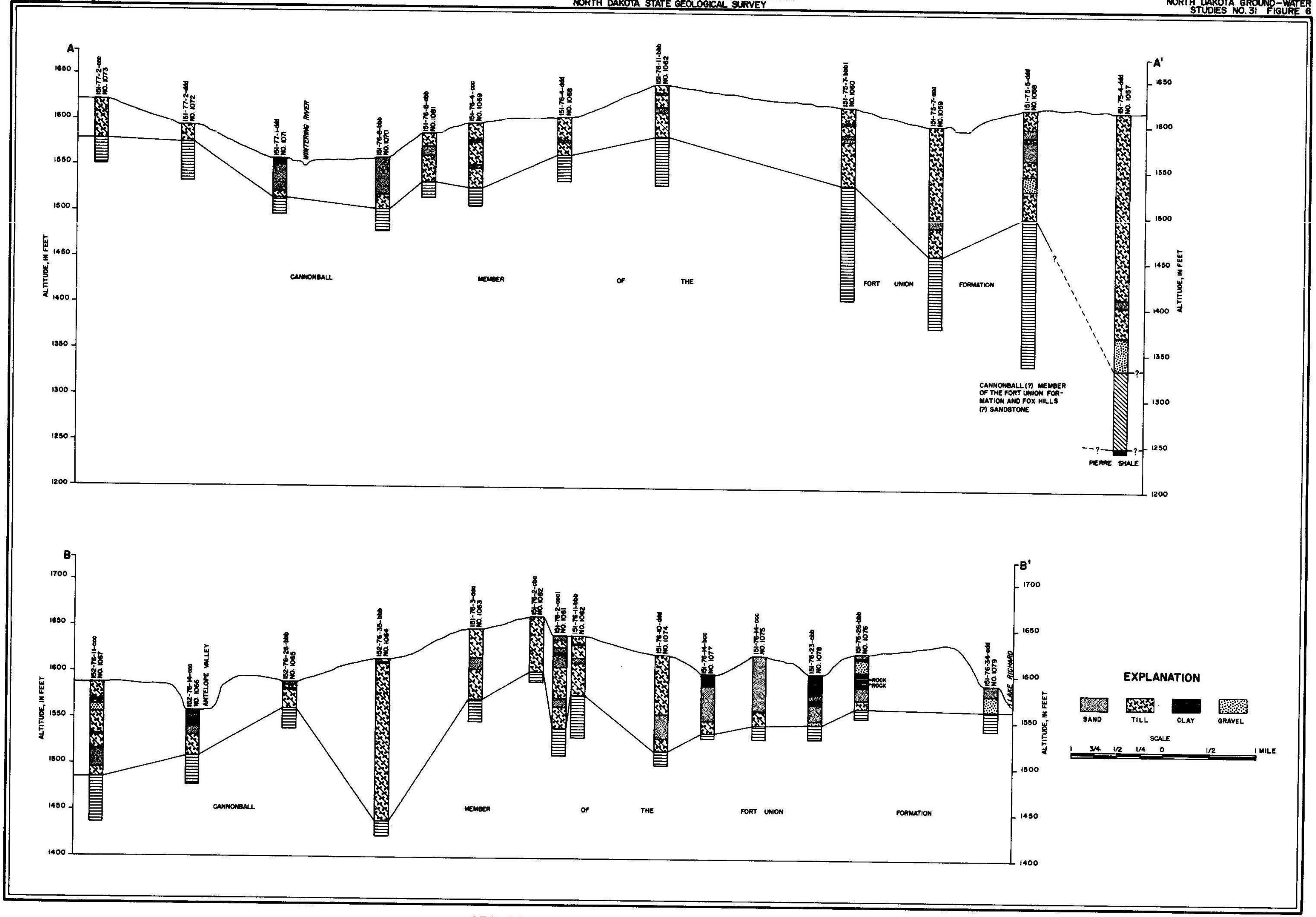
Deposits of glacial Lake Souris.--Deposits of glacial Lake Souris are present in the northeast corner of the area. Wind action since disappearance of the lake has formed eolian deposits as much as 15 feet thick for a distance of 2 miles south and west of the lake; because of the wind erosion around the lake, it is difficult to recognize the shoreline. Also, sand dunes are common throughout the lake basin.

No test drilling was done in the lake sedimemts in the area; however, logs of test holes about 5 miles north of the report area reveal that the deposits of glacial Lake Souris range from 6 to 76 feet in thickness and

UNITED STATES
GEOLOGICAL SURVEY

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
NORTH DAKOTA STATE GEOLOGICAL SURVEY

NORTH DAKOTA GROUND-WATER
STUDIES NO. 31 FIGURE 6



GEOLOGIC SECTIONS IN THE DRAKE AREA

average.about 30 feet. These deposits consist of loosely consolidated clay, silt, and very fine to medium sand. In somes test holes, coarse sand and fine gravel occur at the base of deposits.

Farm wells in the lake area generally obtain water from aquifers in the deposits of glacial Lake Souris. Most wells are less than 30 feet deep and of large diameter. Yields are generally small but adequate for farm use.

An aquifer test made at a farm well that taps the lacustrine deposits approximately 30 miles north of the Drake area showed that the coefficient of transmissibility was 1,970 gpd (gallons per day) per foot, and the coefficient of storage was 0.085 (Paulson and Powell, 1957, p. 16). The well tested is reported to be 28 feet deep and to penetrate 24 feet of sand underlying 4 feet of clay.

Outwash deposits.--Outwash deposits in the Drake area are associated with three physiographic units: diversion channels, ice-marginal channels, and a pitted outwash plain. These deposits consist of alternating layers of silt, clay, sand, and gravel.

The valleys of the diversion and ice-marginal channels are approximately ¼ mile to 2 miles wide and 15 to 30 feet deep. Test drilling west of Drake in the vicinity of Lake Bentley revealed a sizable aquifer in the outwash deposits of the valley formed by the confluence of the Velva, Lake Hester, and Verendrye channels. The aquifer extends along the diversion channels and is probably hydraulically connected with potential aquifers in other channels in the area. The deposits composing the aquifer range in thickness from 36 to 40 feet, and in test holes 1070 (151-76-8bbb) and 1071 (151-77-1ddd) they consist of fine to coarse sand and gravel.

The outwash plain south of Drake is higher topographically than the adjacent ice-marginal channels and is characterized by shallow depressions and troughs. An area containing five eskers is associated with the northern part of the plain. (See fig. 4). The eskers range from ½ mile to 2 miles in length, from 50 to 75 feet in width,and from 20 to 40 feet in height. Test holes 1075 (151-76-14ccc), 1077 (151-76-14bcc), and 1078 (151-76-23cbb) drilled in the esker area indicate the presence of an aquifer containing coarser sand and gravel deposits than those penetrated by test holes in the diversion channels west of Drake. These sand and gravel deposits range in thickness from 29 to 59 feet. Test holes 1076 (151-76-26bbb) and 1079 (151-76-34add) in the outwash plain south and east of the esker area show that the sand and gravel deposits range in thickness from 14 to 21 feet. However, the deposits in the outwash plain may be hydraulically connected with those of the eskers and may function practically as a single aquifer. Most recharge in the area is probably in the outwash deposits southeast of the eskers, and ground water moves to the northwest.

A short pumping test was made in test hole 1078. The drawdown of the water in the well was 3 feet after 6 hours of pumping at a rate of 35 to 40 gpm. The coefficients of transmissibility and storage of the aquifer were not determined because of the short duration of the testing, but the aquifer may be considered to be a potential source of municipal or industrial supply.

Till and associated sand and gravel deposits.--Deposits of glacial till and associated sand and gravel mantle approximately three-fourths of the area. Till in the Drake area is the material of the glacial drift that was deposited directly by the ice of the Souris River lobe and is shown on fig. 4 as ground and end moraine. Also, till occurs in the linear drumlinlike ridges and grooves.

The till is an unconsolidated, unstratified, heterogeneous mixture of clay, sand, gravel, and boulders that has been subjected to little or no sorting by wind or water subsequent to its deposition. It is a gray highly calcareous material consisting of about 40 per cent silt, 30 per cent sand, 25 per cent clay, and 5 per cent gravel and boulders. The gravel and boulder content of the till consists of a greater percentage of carbonate rocks than of granitic and gneissic rocks. Lignite chips and limonite blebs are found in small amounts. Oxidation extends to depths of 30 to 50 feet and little leaching extends below the B horizon of the soil (Lemke, 1958a, p. 86).

Because the till is composed of unsorted material and because the spaces between the larger particles are filled with finer materials, till does not ordinarily yield water readily to wells.

Stratified sand and gravel deposits associated with the till were formed as alluvial deposits by local melt water of glacial streams. Many of these stratified deposits in the till contain ground water and therefore constitute small, isolated aquifers. Most of the deposits are not exposed and can be detected only by drilling. Test drilling indicated that the deposits range in thickness from 0 to 52 feet in the Drake area. Many of the deposits are completely enclosed within the till; consequently, the yield of wells penetrating these sand and gravel deposits decreases as they become dewatered by pumping. Recharge is slow through the glacial till to the aquifers and therefore the pumpage of the wells should not exceed recharge.

Well inventory data (table 3) indicate that most of the farm wells obtain water from the stratified sand and gravel lenses in the till in quantities adequate for farm use at the present time (1960); during drought years, however, several wells were dry or produced inadequate supplies, according to verbal reports from local residents.

Some ice-contact features--kames and kame terraces--scattered throughout the area yield sufficient water for general farm use. For the most part these features are surrounded by ground moraine, but at a few places they occur along ice-marginal or glacial diversion channels. None of the deposits would furnish water in sufficient quantity for municipal use because the bulk of the deposits are above the water table, and only a relatively thin zone in the lower part of the deposits is saturated.

At the base of the till, a potential aquifer consisting of coarse gravel was penetrated in test holes 1057 (151-75-4ddd) and 1088 (151-75-3bbb). In test hole 1057, a deposit of coarse gravel 36 feet thick underlies 244 feet of till; in test hole 1088, a coarse gravel deposit 52 feet thick underlies 253 feet of till. This gravel section may be continuous and associated with deposits of gravel in a preglacial channel in northern Wells County. Data from previous test drilling and well inventory indicate that a buried channel trends southeastward and extends from the southeastern part of McHenry County through Wells County to the eastern part of Foster County. The channel deposits in Wells County are saturated and yield relatively large quantities of ground water. However, additional test drilling would be necessary to find out if the deposits in McHenry County are connected with the channel in Wells County.

Bedrock

Cannonball member of the Fort Union formation.--The Cannonball member of the Fort Union formation underlies central and south-central North Dakota. It ranges in thickness from 250 to 300 feet and consists of gray thin-bedded clay shale and light-brown fine-grained sand interbedded with a few thin beds of lignitic shale (Laird and Mitchell, 1942, p. 18).

The Cannonball member in the Drake area lies directly below the drift. It was identified from drill cuttings and from exposures in the NE¼SE¼ Sec. 34, T. 151 N., R. 76 W., the SW¼SE¼ Sec. 4, T. 151 N., R. 77 W., and in the SW¼NW¼ Sec. 9, T. 152 N., R. 77 W. (See fig.4). Similar exposures are found along the Souris River near the towns of Velva and Sawyer, approximately 20 miles west of the Drake area (Brown and Lemke, 1948). These exposures and those in the Drake area consist of thin-bedded brown sand and gray sandy shale. The outcrops serve as recharge areas for the Cannonball member, and the ground water moves probably toward the northeast (Paulson and Powell, 1957, p. 20). The Cannonball member yields small to moderate supplies of moderately mineralized water in central and south-central North Dakota. It is tapped by the three municipal wells in Drake and by several farm wells in the Drake area.

Fox Hills (?) sandstone.--The Fox Hills (?) sandstone probably occurs in the Drake area between the Cannonball member and the Pierre shale. Eighty-five feet of the Cannonball member of the Fort Union formation and (or) the Fox Hills (?) sandstone was penetrated in test hole 1057 (151-75-4ddd). The drill cuttings from test hole 1057 consist of gray to brown smooth clay mixed with sand at certain depths. The Fox Hills(?) sandstone is 180 to 320 feet thick in the Missouri Plateau, but in the Drift Prairie it is partly eroded or absent (Robinove, Langford, and Brookhart, 1958,p. 24).

It yields moderately mineralized water in most of the south-central and southwestern parts of the State. Some farm wells in the Drake area are reported to penetrate a sandstone that is probably the Fox Hills.

Pierre shale.--The Pierre shale is the oldest formation reached by test drilling during this investigation. It was penetrated in test hole 1057 at a depth of 365 feet below the land surface. The drill cuttings of the Pierre shale from the test hole consist of a well-indurated gray clay, shale, and siltstone. The log of the Hunt Oil Co. Peter Lenertz No. 1 well (153-77-17db), approximately 5 miles northwest of the Drake area, shows the thickness of the Pierre shale to be 990 feet and the top of the formation to be 341 feet below the land surface. The formation underlies the entire Drake area and is the bedrock directly under the drift in a large part of eastern North Dakota.

No wells in the Drake area are known to obtain water from the Pierre shale; however, in the eastern part of the State the formation yields small amounts of moderately mineralized water to wells.

Older rocks.--The Pierre shale is underlain by older Cretaceous rocks and by rocks of Jurassic, Triassic, Mississippian, Devonian, Silurian, and Ordovician ages, as shown by the log of the Peter Lenertz No. 1 well, which is 7,211 feet deep. An oil-test well drilled in McHenry County in 1959 showed Cambrian and Precambrian rocks below the Ordovician (oral communication, 1959, S. B. Anderson, North Dakota Geological Survey).

The only other Cretaceous formation in the area that may be an aquifer is the Dakota sandstone. It underlies the entire State, except at a few places in eastern North Dakota. The total thickness of the formation ranges from 150 to 450 feet (Robinove, Langford, and Brookhart, 1958, p. 16). In the Peter Lenertz well, the formation is 2,472 feet below the land surface and consists of 133 feet of medium-gray to medium-dark-gray shale with some white medium-to very coarse grained sandstone and light-gray sandy siltstone (Caldwell, 1953, p. 3). The formation yields large quantities of highly mineralized water from wells in the eastern and the south-central parts of the State (Simpson, 1929, pl. 1). Many of the wells flow. The well nearest the Drake area penetrating the Dakota sandstone is one of the city wells at Harvey, approximately 20 miles east of Drake. The well was drilled to a depth of 2,235 feet, and the original flow was 2½ gpm (gallons per minute) (Simpson, 1929, p. 264). The Harvey well does not flow at the present time (1959) owing to reduced pressure, and wells penetrating the Dakota in the Drake area probably would not flow.

QUALITY OF THE GROUND WATER

Ground water dissolves a part of the soluble mineral constituents of the rock particles as it moves toward and through an aquifer. The amount of mineral matter dissolved depends principally on the amount of soluble materials in the aquifer and on the length of time the water is in contact with them. Therefore, water from a homogeneous aquifer, that has been stored underground a long period of time or that has traveled a long distance from the recharge area is more highly mineralized than water that has been stored a short time or that is recovered relatively near the recharge area.

The chemical composition of ground water is indicated by results of the chemical analyses of ground water from 12 wells in the Drake area. (See table 2). The wells range in depth from 16.3 to 507 feet and tap aquifers in the glacial drift, the Cannonball member of the Fort Union formation, and the Fox Hills(?) sandstone. Water from the nine wells that tap glacial drift differs considerably in the degree of mineralization and in the type of the principal constituents; in this respect it is similar to water from glacial drift in other parts of North Dakota. The low calcium and magnesium and relatively high boron content of water from the Drake city wells and the two farms wells (152-77-11ccd) (152-77-21cdd) indicate that water from these wells is from the Cannonball member of the Fort Union formation and the Fox Hills(?) sandstone (Robinove, Langford, and Brookhart, 1958, p. 31). Analyses of water from these formations in surrounding areas show a high concentration of boron and a relatively low hardness.

Water samples from test holes 1070 and 1078 are similar in chemical composition, thus indicating that the aquifers tapped by the two holes may be hydraulically interconnected.

The U.S. Public Health Service has established standards for drinking water used on common carriers in interstate traffic; and these standards, as revised in 1946, have been adopted by the American Water Works Association as criteria of quality for all public supplies. The standards are soon to be revised again; but, according to Welsh and Thomas (1960), the revised standards are not likely to differ from the 1946 standards for the mineral constituents indicated below.

Chemical constituent	Recommended maximum limit (~~ppm~~) mg/l	Pahasapa water
Iron (Fe) plus manganese (Mn)	0.3	0.4
Magnesium (Mg)	125	14
Sulfate (SO_4)	250	12
Chloride (Cl)	250	2.0
Fluoride (F)	a/1.5	.4
Dissolved solids	b/500	201

a/Mandatory limit.

b/1,000 ~~ppm~~ mg/l are permitted if water of better quality is not available.

The chemical analyses of ground water in the Drake area (table 2) show that at least one of the recommended limits is exceeded in water from each of the wells sampled. However, water containing more than the recommended limits of certain chemical constituents has been used for domestic purposes for many years in some areas~~, including North Dakota,~~ without noticeable ill effects.

Iron in drinking water is objectionable mostly because of its aesthetic effects. In concentrations much greater than the recommended limit, the iron itself can be tasted. Some microorganisms thrive abundantly in water containing much iron. In some water supplies the microorganisms become so abundant that they almost completely plug water lines, and decomposition products from the microorganisms give the water a bad taste and ordor. The town of Drake has had difficulty in the past with its water supply because of the presence of such microorganisms.

Iron in solution ordinarily precipitates when the water is aerated. If aeration takes place in the vicinity of the well screen, precipitated iron salts may plug well-casing perforations and reduce the well output. If it takes place at the tap, the precipitate may cause the water to become cloudy. Iron stains porcilain fixtures and laundry and adversely effects the taste of coffee, tea, and some food products prepared with the water.

Sulfate is objectionable to industries using steam boilers if the water is also high in calcium and magnesium becuase it precipitates and forms a scale on the inside of boilers. Also, high concentrations of sulfate (more than about 500 ppm) in domestic or public water supplies has a laxative effect on human beings and certain animals.

Nearly all ground water contains at least small amounts of hardness-causing minerals. Hardness of water is caused principally by calcium and magnesium and to a lesser extent by iron, aluminum, strontium, barium, zinc, and free acid. Hardness of water is undesirable, especially if the water is used for cleaning, because it causes increased soap consumption as well as soap scum. Water having a hardness of about 100 ppm as $CaCO_3$ generally is considered to be moderately hard; water having a hardness of 200 ppm or more is considered to be very hard and should be softened to be satisfactory for most uses.

Water having a high concentration of sodium relative to the total cation concentration (high percent sodium) may be unsuitable for irrigation because it may cause soils to become relatively impermeable. The relative proportion of sodium expressed as a percentage may be calculated from the following equation:

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

where the concentrations of all cations are in equivalents per million.

The continued use of irrigation water in which the percent sodium is in excess of 50 may cause damage to the soil. However, the amount of damage depends also on other factors, such as salinity of the water, porosity of the soil, drainage, irrigation practices, and crop management. In general, the higher the percent sodium, the less suitable the water for irrigation.

Irrigating with water having 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. 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 is not given in table 2, it 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. Approximations of the specific conductance of the samples analyzed show that 5 were greater than 2,250 micromhos per centimeter. In addition, 7 samples showed a percent sodium greater than 50. Five of these obtain water from bedrock formations. Because of the low permeability of the surface deposits in the area, which consist of clay and silt, considerable caution should be used in applying water having a high percent sodium or a high salinity.

Generally, water from the glacial drift is of suitable quality for irrigation, whereas water from bedrock is unsuitable because of its high dissolved-solids content and high percent sodium. Also, boron, which is an essential plant nutrient but which is toxic in concentrations of more than 0.3 ppm to some plants, is present in relatively high concentrations in water from the bedrock.

SUMMARY OF GROUND-WATER CONDITIONS

A majority of the wells in the Drake area obtian water from aquifers in the glacial drift. Wells penetrating these aquifers supply small to moderate amounts of water adequate for individual farm and domestic users. Productive aquifers, adequate for furnishing municipal and industrial water supplies occur in the outwash deposits and in buried preglacial channels at the base of the glacial drift.

Some farm wells in the Drake area obtain water from aquifers in the Cannonball member of the Fort Union formation and the Fox Hills(?) sandstone. Wells in these aquifers yield small to moderate amounts of moderately to highly mineralized water. The city wells of Drake tap the Cannonball member of the Fort Union formation and yield a supply sufficient to support the present (1959) water demands of the city.

Deep aquifers in the Drake area are not considered good sources of ground water at the present time because they occur at depths below economical pumping lift and because the water contained in them is too highly mineralized for most uses. Newly developed methods of demineralization of water, however, may make these aquifers an important source of supply in the future.

Recharge to glacial-drift aquifers in the Drake area is derived primarily from infiltration of local precipitation through the soil and from seepage of water from streams and lakes. Recharge to bedrock aquifers is probably derived by percolation of water through the glacial-drift aquifers, by direct penetration of rainfall or melting snow and ice, and by lateral movement of water from adjacent areas.

In the region as a whole, ground water probably moves to the northeast. Locally, however, the direction of movement of ground water in the glacial drift is controlled by the bedrock surface, by channels and depressions, and by local differences in the permeability and porosity of the aquifers.

Chemical analyses of ground water in the report area indicate that the mineral content of water from different aquifers is extremely variable. Water from the glacial-drift aquifers is hard but generally suitable for domestic use and irrigation purposes. Water from the bedrock aquifers is soft but is unsuitable for irrigation. U.S. Public Health Service recommended limits were exceeded by at least one mineral constituent of water reported in each well tapping a bedrock aquifer. However, at present (1959) the water is being used without noticeable ill effects.

TABLE 2.--Chemical

Aquifer: Q, glacial drift
Tfc/Kfh: Cannonball(?) member of Fort Union formation or Fox Hills(?) sandstone
Tfc: Cannonball member of Fort Union formation

Location No.	Owner or name	Aquifer	Depth of well (feet)	Date of collection	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
151-75								
3ada	H. F. Schneets	Q	16.4	7- 9-59	1.2	77	43	40
22add	City of Anamoose	Q	102	9-22-58	.16	99	32	48
151-76								
2cbc2	City of Drake Well 2	Tfc	127	8- 1-55	.9	..	5	578
2cbc3	City of Drake Well 3	Tfc	127	8- 1-55	1	..	7	625
3dda	City of Drake Well 1	Tfc	180	8- 1-55	1.4	..	5	555
8bbb	Test hole 1070	Q	80	10-21-55	1.2	54	25	13
23cbb	Test Hole 1078	Q	70	10- 4-55	.4	46	29	60
151-77								
34bda2	Village of Kief	Q	33.0	7- 9-59	1.8	93	89	206
152-76								
10acd2	Great Northern RR.	Q	18	9-22-58	12	55	36	265
152-77								
11ccd	Carl Buri	Tfc/Kfh	350	8- 2-58	.43	2	10	1060
21cdd	Arnold Alme	Tfc/Kfh	507	9-22-58	.38	5	11	1080
28cbc	City of Balfour	Q	16.3	9-22-58	.7	186	177	710

Analyses of Ground water

Analyses by State Laboratories, Bismarck
Results in parts per million except as indicated

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$	Dissolved solids (sum of determined constituents)	Percent sodium
7	384	16	218	.....	0.2	...	0.3	374	764	19
11	339	..	162	.....	.3	0.5	.5	378	626	3
3	660	56	74	322	.4	.8	4.1	20	1,450	98
4	910	59	120	421	.4	.7	4.0	29	1,670	97
2.8	705	77	274	73	.4	1.4	3.8	20	1,410	94
1.8	216	..	34	.....	...	.4	.12	236	335	9
3.2	315	..	34	.....	...	...	.15	232	400	31
7.2	444	..	527	13	.3	...	.5	518	1,290	46
10	624	..	229	6	.2	.2	1.1	288	1,050	53
7	459	78	32	1,070	.3	1.8	3.5	46	2,540	97
8	444	40	26	1,270	.4	1.8	3.3	58	2,890	97
25	693	104	1,090	376	.3	.4	1.1	1,190	3,320	59

Depth to water: Measured water levels in feet and tenths; reported water levels in feet.

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

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
151-75					
2bbc	Henry F. Schneets	186	4	Dr	1928
3ada	do	16.4	48x48	Du	1928
3bbb	Test hole 1088	315	5	Dr	10-24-55
4bcc	H. R. Sherlock	28	48x48	Du	1926
4ddd	Test hole 1057	320	5	Dr	9- 2-55
5bdd	H. H. Priester	180	4	Dr	....
5ddd	Test hole 1058	280	5	Dr	9- 6-55
7aaa	Test hole 1059	220	5	Dr	9- 9-55
7bbb1	Test hole 1060	210	5	Dr	9-12-55
7bbb2	Max Thurow	26	36x36	Du	....
8bbd	Clarence Rademacker	188	4	Dr	1951
9aaa	Bureau of Reclamation test hole	12.2	3	Dr	....
10ccb	Otto Frueh	190	4	Dr	1947
10ddd	John Peerboom	90	2	Dr	1908
11ada	Francis Mayer	180	4	Dr	....
11cdc	Emil Schnase	32	24	Dr	....
12ccc	Carl Cuote	240	4	Dr	1926
12dcd	Joe Weninger	180	4	Dr	1926
13bcc	William Nitz	20	36x36	Du	....
14aba	Victor Mayer	300	4	Dr	....
16ddd	Cliff Frueh	160	6	Dr	....
18aad	Otto Hass	155	5	Dr	....
18baa	Walter Sherlock	185	4	Dr	1941
20ddd	Otto Hass	22.1	48x48	Du	....
22add	City of Anamoose	102	4	Dr	1950
23cbd	Albert Zuther	118	4	Dr	1950
25baa	Marcus Rudnick	28	36x36	Du	....
25cdd	Martin Hublou	38.8	36x36	Du	....
26adb	R. Rudnick	157	5	Dr	1940
26bba	do	111	5	Dr	1952
27bab	Paul Heller	30	36x36	Du	....
27cbc	D. Lykken	34.7	36x36	Du	1950
29dad	Otto Rattermaker	170	5	Dr	1947
30bba	Louis Schilling	14.2	48x48	Du	....
31cdd	Ed. Radenachener	20	36x36	Du	1948

and Test Holes

Depth of well: Measured depths in feet and tenths reported depths in feet.

Use of water: D, domestic; N, none; obs, observation PS, public supply; RR, railroad; S, stock, T, test hole.

Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Altitude of land surface (feet)	Remarks
40	8-16-55	D,S	Sand	1,600	Reported hard.
10.2	8-16-55	S	Sand	1,560	See chemical analysis.
.....	....	T	....	1,611	See log.
13	8-11-55	D,S	Sand	1,615	Reported hard.
.....	....	T	....	1,614	See log.
.....	8-11-55	D,S	....	1,620	Reported soft.
.....	....	T	....	1,616	See log.
.....	....	T	....	1,597	Do.
.....	....	T	....	1,617	Do.
16	7-28-55	D,S	....	1,617	Reported hard.
.....	8-22-55	D,S	Sand	1,600	Reported soft.
6.4	8-12-55	Obs.	....	1,614	
.....	8-12-55	D,S	Sand	1,600	Reported hard.
.....	8-16-55	D,S	....	1,610	Do.
60	8-15-55	D,S	....	1,620	Reported soft.
16	8-16-55	D,S	Gravel	1,620	Reported hard.
.....	8-16-55	D,S	....	1,626	Reported soft.
90	8-16-55	D,S	Sand	1,620	Do.
.....	8-16-55	D,S	Gravel	1,628	
50	8-15-55	D,S	....	1,626	
.....	8-12-55	D,S	....	1,620	Reported soft.
50	8-22-55	S	....	1,600	Reported soft, adequate.
100	8-22-55	D,S	Gravel	1,610	Reported soft.
10.2	8-22-55	D,S	....	1,620	Reported hard.
.....	8-17-55	PS	....	1,615	Reported soft, chemical analysis.
.....	8-17-55	D,S	....	1,615	
15	8-17-55	D,S	Gravel	1,631	Reported hard.
21.5	8-17-55	D,S	Sand	1,620	Do.
50	8-17-55	D,S	Gravel	1,619	Reported soft.
50	8-17-55	D,S	Sand	1,607	Do
24	8-18-55	D,S	Sand	1,600	Reported hard.
23.0	8-18-55	D.S	Gravel	1,620	Do.
.....	8-18-55	D,S	....	1,620	Reported soft.
10.0	8- 9-55	D,S	....	1,621	Reported hard.
.....	8- 9-55	D,S	....	1,620	Do.

TABLE 3.--Records of Wells

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
151-75 (Cont.)					
31ddd	H. L. Erlewine	22	36x36	Du	1918
32baa	E. Brown	22	36x36	Du	1931
32dcc	Ornest Wagner	20	36x36	Du	....
33daa	Sam Herman	40	48x48	Du	....
34aad	Frank Rudnick	35	36x36	Du	....
34dda	Chris Helm	45	36x36	Du	....
35aaa1	J. Rudnick	50	36x36	Du	....
35aaa2	do	201	5	Dr	1941
35cdc	Paul Stolpman	63.4	5	Dr	....
151-76					
1ccd	Frank Paulus	32.0	36x36	Du	....
1dac	O. A. Retling	22	36x36	Du	....
1dcb	Math Paulus	35	36x36	Du	....
2aaa	A. Sherlock	96	4	Dr	1900
2cbc1	Test hole 1082	70	5	Dr	10-10-55
2cbc2	City well #2	127	24	Dr	....
2cbc3	City well #3	127	24	Dr	....
2ccc1	Test hole 1061	130	5	Dr	9-13-55
2ccc2	Soo Line Railroad	48.3	144x144	Du	....
3aaa	Test hole 1063	100	5	Dr	9-15-55
3ccc	Hubert Schmidt	100	2	Dr	1910
3dda	City Well #1	180	24	Dr	....
4ccc	Test hole 1069	90	5	Dr	9-19-55
4ddb	Andrew Zezler Jr.	258	4	Dr	1950
4ddd	Test hole 1068	70	5	Dr	9-19-55
5aad	Andrew Kruger	60	4	Dr	1934
8abb	Test hole 1081	70	5	Dr	10- 8-55
8bbb	Test hole 1070	80	5	Dr	9-20-55
9bbb	Orville Kamper	145	4	Dr	1910
10abd	Dale McCarthy	80	4	Dr	....
10bda	Joe Frieson	96	4	Dr	....
10ddd	Test hole 1074	120	5	Dr	9-28-55
11ada	Jake Adams	32	36x36	Du	....
11bbb	Test hole 1062	110	5	Dr	9-15-55
12dcd	Joe Kuntz	133	5	Dr	1955
13bbc	Jake Adams	31.6	36x36	Du	....
14aba	Martin Isaak	20.3	36x36	Du	1953
14bcc	Test hole 1077	70	5	Dr	10- 4-55
14ccc	Test hole 1075	90	5	Dr	9-28-55
17ada	Loren Fenner	90	4	Dr	....
17ccc	Deserted	25.6	48x48	Du	....
20dda	C. W. Kemper	116	2	Dr	1942
21cbc	William Stock	8.3	72x72	Du	1900

Depth to water below land surface (feet)	Date of measure-ment	Use of water	Aquifer	Altitude of land surface (feet)	Remarks
7	8- 9-55	D,S	Sand	1,620	Do.
15	8- 9-55	D,S	Sand	1,620	Do.
10	8- 9-55	D,S	Sand	1,620	Do.
24	8- 18-55	D,S	Gravel	1,630	Do.
15	8- 17-55	D,S	....	1,640	Do.
.....	8-17-55	D,S	Sand	1,640	Do.
40	8-17-55	D,S	Gravel	1,630	Do.
75	8-17-55	D,S	Gravel	1,630	Do.
20.0	8-17-55	D,S	Sand	1,640	Do.
17.0	8-25-55	D,S	Sand	1,640	Do.
9	8-12-55	D,S	Gravel	1,615	Do.
.....	8-12-55	D,S	Gravel	1,640	Do.
25	8- 8-55	D,S	Gravel	1,640	Do.
.....	....	T	....	1,660	See log.
.....	8- 1-55	PS	Clay	1,680	See chemical analysis.
.....	8- 1-55	PS	Clay	1,680	Do.
.....	....	T	....	1,640	See log.
24.1	7-28-55	PS,RR	Gravel	1,650	See chemical analysis.
.....	....	T	....	1,647	See log.
20	8-12-55	D,S	Sand	1,620	Reported hard.
.....	8- 1-55	PS	....	1,680	See chemical analysis.
.....	....	T	....	1,596	See log.
.....	8- 9-55	D,S	....	1,620	Reported soft.
.....	....	T	....	1,604	See log.
20	8- 5-55	D,S	Sand	1,600	Reported hard.
.....	....	T	....	1,585	See log.
.....	....	T	....	1,558	See log; chemical analysis.
.....	8- 9-55	D,S	....	1,600	Reported soft.
30	8-22-55	D,S	....	1,620	Reported hard.
.....	8-22-55	D,S	....	1,600	Reported soft.
.....	....	T	....	1,620	See log.
20	8-22-55	D,S	Sand	1,616	Reported hard.
.....	....	T	....	1,640	See log.
60	8-19-55	D,S	....	1,620	Reported soft.
12.6	8-19-55	S	....	1,620	
15.3	8-19-55	D,S	Sand	1,620	Reported hard.
.....	....	T	....	1,600	See log.
.....	....	T	....	1,620	See log; chemical analysis.
20	8- 9-55	D,S	....	1,580	
18.0	8- 9-55	S	....	1,616	
.....	8- 9-55	S	....	1,580	Reported soft.
4.5	8- 4-55	S	Sand	1,580	Reported hard.

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date Completed
151-76 (Cont.)					
21ddd	John Kemper	296	4	Dr	....
22abb	John M. Kuntz	60	4	Dr	....
22ccd	C. W. Kemper	132	4	Dr	1927
23cbb	Test hole 1078	70	5	Dr	10- 4-55
24dcc	Louis Shelley	355	4	Dr	1920
25aac	John F. Eichhorn	20	36x36	Du	....
25dda	Ben Gange	16.4	36x36	Du	....
26bbb	Test hole 1076	70	5	Dr	9-30-55
27acb	John Kemper	30	36x36	Du	....
27ccc	William Ekrman	3.1	36x36	Du	....
28cdc1	C. Soderberg	200	4	Dr	1945
28cdc2	Do	30	36x36	Du	1952
29acc	William Stack	157	6	Dr	1945
30acc1	Ed Roder	22.2	36x36	Du	1920
30acc2	Do	20	36x36	Du	....
32bba	William Ehrman	30	36x36	Du	1920
32dbc1	Albert Erkman	27.5	36x36	Du	....
32dbc2	Do	16.8	36x36	Du	....
33cbc	Fred Blumhagen	292	4	Dr	1952
33ddd	Do	18.3	48x48	Du	....
34add	Test hole 1079	50	5	Dr	10- 6-55
34ccc	Ben Blumhagen	332	2	Dr	1926
151-77					
1bcc	Fred Steffen	260	4	Dr	1900
1ddd	Test hole 1071	60	5	Dr	9-20-55
2add	Amy Bantler	180	4	Dr	....
2ccc	Test hole 1073	70	5	Dr	9-27-55
2ddd	Test hole 1072	60	5	Dr	9-22-55
9aba	Wm. Martwickol	129	2	Dr	1926
10cbc	Emilie Pankratz	32	48x48	Du	1911
11aba	J. M. Weninger	12.0	36x36	Du	....
12bbb	V. Shink	43	4	Dr	....
14ddc	Joe Holland	22.7	2	Dr	....
16cdd	Alex Michalenko	100	4	Dr	....
22cbb1	Ed Zahopyko	110	4	Dr	....
22cbb2	Do	100	2	Dr	....
23ccc	Joe Holland	23.6	36x36	Du	....
24acb	L. M. Ross	76	4	Dr	....
24dab1	H. M. Peterson	200	4	Dr	....
24dab2	Do	80	2	Dr	....
26ddd	Roy Frankhaugen	22.0	36x36	Du	....
27bcc	Deserted	12.7	48x48	Du	....
28cbc	Ed Graham	16	2	Dr	....
33acd	Deserted	6.1	48x48	Du	....
33bbb1	Jack Peawoar	220	2	Dr	1950

and Test Holes -- Continued

Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Altitude of land surface (feet)	Remarks
Flow	8- 9-55	N	....	1,580	Reported soft.
.....	8-22-55	D,S	Sand	1,620	Do.
.....	8- 9-55	D,S	....	1,610	Do.
.....	....	T	....	1,600	See log; chemical analysis.
.....	8- 9-55	D,S	....	1,620	Reported soft.
.....	8- 9-55	N	Sand	1,610	Reported hard.
3.0	8- 9-55	S	....	1,620	Do.
.....	....	T	....	1,623	See log.
.....	8- 9-55	N	....	1,620	
1.2	8- 4-55	S	....	1,600	
.....	8- 4-55	D	....	1,620	Reported soft.
.....	8- 4-55	S	Sand	1,620	Reported hard.
30	8- 4-55	D,S	Sand	1,620	Reported soft.
10.1	8- 4-55	S	Gravel	1,630	Reported hard.
18	8- 4-55	D	Clay	1,630	Do.
.....	8- 4-55	D,S	....	1,630	Do.
9.6	8-23-55	S	Sand	1,700	Reported hard.
9.2	8-23-55	D	Sand	1,700	Do.
.....	8- 4-55	D,S	Clay	1,635	Reported soft.
9.0	8- 4-55	N	....	1,635	
.....	....	T	....	1,610	See log.
.....	8- 4-55	D,S	....	1,635	Reported soft.
80	8- 4-55	D,S	....	1,600	Do.
.....	....	T	....	1,556	See log.
.....	8- 4-55	D,S	....	1,600	Reported soft.
.....	....	T	....	1,620	See log.
.....	....	T	....	1,592	Do.
.....	8- 2-55	D,S	Sand	1,580	Reported soft.
16	8- 2-55	D,S	Clay	1,600	Reported hard.
7.0	8- 4-55	D,S	....	1,580	Do.
.....	8- 4-55	S	Clay	1,600	Do.
14.6	8- 3-55	D,S	....	1,620	
.....	8- 2-55	D,S	....	1,630	Reported soft.
.....	8- 3-55	S	Gravel	1,640	Do.
.....	8- 3-55	D	....	1,640	Reported hard.
15.3	8- 3-55	N	....	1,650	
20	8-23-55	D,S	Gravel	1,640	Reported soft.
40	8-23-55	D,S	Shale	1,640	Do.
30	8-23-55	D,S	Sand	1,640	Reported hard.
15.0	8- 3-55	D,S	....	1,640	Do.
8.6	8- 3-55	N	....	1,640	
.....	8- 3-55	D	Sand	1,660	Reported hard.
2.1	8- 3-55	S	....	1,640	
30	8- 3-55	D,S	Clay	1,660	Reported soft.

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
151-77 (Cont.)					
33bbb2	Do	24	36x36	Du	....
34bbc	Sam Kokoroy	320	2	Dr	1926
34bda1	Jake Kizima	25	36x36	Du	....
34bda2	Village of Kief	33.0	48x48	Du	....
36ddd	Fred Eichhorn	27.2	36x36	Du	1913
152-75					
1cbd	Joe Hager	20	36x36	Du	....
3ccc1	F. Zimmerman	20	36x36	Du	....
3ccc2	Do	12	36x36	Du	....
3ddd	R. Berndt	15	36x36	Du	....
4cca	Henry Schnase	45	18x18	Du	....
5ddd	Martin and George Bruner	125	4	Dr	1950
6add	Anton Bruner	20	48x48	Du	....
9cac	O. Pfirfer	64	2	Dr	1900
9ddd	E. Ruhal	35	4	Dr	1920
10ccc	Martin Samual	22.9	36x36	Du	....
10ddb	Do	60	5	Dr	1912
11baa	Ed Hoaglund	76	5	Dr	1946
11daa	Henry W. Lange	210	2	Dr	....
14cac	Robert Berndt	146	2	Dr	1920
15ada	H. Schneider	60	4	Dr	1945
15cba	Emmanual Samual	208	2	Dr	....
15ddc1	Wm. Lange	80	4	Dr	....
15ddc2	Do	60	4	Dr	....
16dda	Frank Ervert	250	2	Dr	1943
17cca1	Cliff Schnase	33	36x36	Du	....
17cca2	Do	16	36x36	Du	1955
17ddd	Melvin Schimmel	168	2	Dr	....
18ada	John Ervert	72	4	Dr	1914
19aaa	Henry Pietsch	20	4	Dr	....
19ccd1	Elmer Vollmer	20	36x36	Du	....
19ccd2	Do	15	36x36	Du	1936
20adc1	Walter Stolt	30	5	Dr	....
20adc2	Do	14	36x36	Du	....
20ddb	August Stolt	15.3	36x36	Du	....
21dad	Harry Peiler	24	4	Dr	....
22bcb1	Paul Kohlman	40	5	Dr	....
22bcb2	Do	53	4	Dr	....
23abd	Otto Wick	55	4	Dr	....
24dba	Frank Rudnick	225	2	Dr	....
25bbb	A. G. Roe	30	4	Dr	....
26bcb	Willard Peerboon	90	2	Dr	....
26dac	E. M. Roufs	42	4	Dr	1920
27ddd	Amy Berndt	140	2	Dr	1915
29abc	Wm. Pattias	160	2	Dr	1935

AND TEST HOLES -- Continued

Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Altitude of land surface (feet)	Remarks
4	8- 3-55	S	Clay	1,660	Reported hard.
40	8- 3-55	D,S	Sand	1,660	Reported soft.
10	8- 3-55	D,S	Sand	1,660	Reported hard.
18.2	8- 3-55	D	Sand	1,660	See chemical analysis.
12.2	8-23-55	D,S	....	1,660	Reported hard.
.....	8-15-55	D,S	....	.....	Do.
10	8-10-55	D	Gravel	.....	Do.
6	8-10-55	S	Sand	.....	Do.
8	8-15-55	D,S	Sand	.....	Do.
15	8-10-55	D,S	Sand	.....	Do.
30	8-10-55	D,S	Sand	.....	Reported soft.
14	8-10-55	D,S	Gravel	.....	Reported hard.
10	8-10-55	D,S	Sand	1,600	Do.
20	8-10-55	D	Gravel	1,570	
6.2	8-10-55	D,S	....	1,570	
20	8-15-55	D,S	Sand	1,580	
7	8-15-55	D,S	Sand	.....	Reported soft.
....	8-15-55	D,S	....	1,600	Do.
40	8-15-55	D,S	....	1,600	Do.
40	8-15-55	D,S	Sand	1,580	
40	8-24-55	D,S	....	1,580	Reported soft.
40	8-15-55	D,S	....	1,600	Reported hard.
40	8-15-55	S	....	1,600	Do.
50	8-10-55	D,S	....	1,600	Reported soft.
....	8-10-55	D	Sand	1,600	Do.
8	8-10-55	S	Sand	1,600	Do.
25	8-11-55	D,S	....	1,580	
....	8-10-55	D,S	Sand	1,580	Reported hard.
....	8-10-55	N	....	1,580	Do.
....	8-10-55	D	....	1,600	Do.
....	8-10-55	S	Gravel	1,600	Do.
....	8-11-55	D	....	1,600	Do.
....	8-11-55	S	....	1,600	Do.
4.0	8-11-55	D,S	Sand	1,600	Reported soft.
....	8-24-55	D,S	Gravel	1,590	
....	8-24-55	D	Sand	1,590	
40	8-24-55	S	Sand	1,590	
43	8-15-55	D,S	Gravel	1,600	Reported hard
....	8-15-55	S	....	1,600	Reported soft.
....	8-15-55	D,S	Sand	1,600	Do.
80	8-15-55	D,S	....	1,620	Do.
....	8-24-55	D,S	Gravel	1,600	Reported hard.
80	8-24-55	D,S	Clay	1,600	Do.
....	8-10-55	D,S	....	1,600	Reported soft.

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
152-75 (Cont.)					
29cdd	T. S. Rieder	60	4	Dr	1910
30baa	Carl Yahange	24	36x36	Du	....
30bab	Marvin Vollmer	65	4	Dr	1925
32adc	Hubert Spletto	65	4	Dr	1929
34ada	Herman Semechend	60	4	Dr	....
35ccc	S. Martin	165	2	Dr	....
152-76					
1abd	Frank Bruner	37	36x36	Du	....
2dcb	O. B. Olson	106	5	Dr	1915
4cac	Edward Grad	180	2	Dr	....
5baa	H. C. Knuth	100+	2	Dr	....
5cac	Joe Koble	32	18	Dr	....
6adc	Phil Schatz	33.6	36x36	Du	....
6bba	Clarence Brownley	25.3	48x48	Du	....
7ada	Jack MacNamara	250	2	Dr	1926
9bac1	Jack Kuntz	30	48x48	Du	1936
9bac2	Do	75	3	Dr	....
10acd1	Guthrie Farmers Elevator	15.9	48x48	Du	....
10acd2	Great Northern Railroad	18	36x36	Du	1942
11ccc	Test hole 1067	150	5	Dr	9-17-55
12cbc	Anton Bruner	20.7	48x48	Du	....
12dab	John Bruner, Jr.	240	2	Dr	1949
13bcb	Chris Olson	32	36x36	Du	....
14ada1	E. M. Olson	40	36x36	Du	1915
14ada2	Do	36	8	Dr	1950
14bbb	Frank Kaufman	105	5	Dr	1925
14ccc	Test hole 1066	180	5	Dr	9-17-55
17bab	Otto Matthies	65	2	Dr	....
22ddb	Joe Luduich	105	4	Dr	1945
23dcc	Wilbert Vollmer	300	2	Dr	1944
24bad	A. Stolt	105	4	Dr	1905
24ddd	Do	8.4	48x48	Du	....
25aaa	Do	17	36x36	Du	....
26bbb	Test hole 1065	50	5	Dr	9-16-55
27bcd	Gust Strege	130	2	Dr	1941
27cdd	August Fennan	172	2	Dr	1914
27ddd	Chris Merchbach	168	2	Dr	1915
28bba	Andrew Ziegler	120	2	Dr	....
29adb	Andrew Kruger	47	2	Dr	1954
30ccc1	Charles Knuth	60	36x36	Du	....
30ccc2	Do	40	36x36	Du	....
31aaa	A. K. Koble	32	36x36	Du	....
31cab1	Delmer Martnick	75	2	Dr	....
31cab2	Do	30	36x36	Du	1900

Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Altitude of land surface (feet)	Remarks
.....	8-11-55	D,S	Sand	1,620	Reported hard.
12	8-11-55	D,S	Sand	1,600	Do.
15	8-10-55	D,S	Clay	1,600	Do.
27	8-11-55	D,S	Sand	1,620	Do.
.....	8-15-55	D	Sand	1,580	
30	8-15-55	D,S	....	1,600	Reported hard.
27	8- 8-55	S	Gravel	.....	Reported hard.
.....	8- 8-55	D,S	....	.....	Do.
.....	8- 5-55	D,S	....	.....	Reported soft.
.....	8- 5-55	D,S	....	.....	Do.
.....	8- 5-55	D,S	....	.....	Reported hard.
19.5	8-26-55	D,S	Sand	.....	Reported soft.
10.5	8- 8-55	D,S	Sand	.....	
100	8- 5-55	D,S	....	.....	Reported soft.
15	8- 5-55	D,S	....	.....	Reported hard.
.....	8- 5-55	D,S	....	.....	Reported soft.
7.3	8- 8-55	N	....	.....	Reported hard.
12	8- 8-55	D	Gravel	.....	See chemical analysis.
.....	....	T	....	1,587	See log.
12.6	8-25-55	D,S	Sand	1,580	Reported hard.
.....	8-10-55	D,S	....	1,580	Reported soft.
.....	8- 8-55	D,S	....	1,580	Reported hard.
.....	8- 8-55	D,S	....	1,580	Do.
.....	8- 8-55	S	....	1,580	Do.
.....	8- 8-55	D,S	Sand	1,580	Do.
.....	....	T	....	1,557	See log.
40	8- 5-55	D,S	Sand	1,580	Reported hard.
.....	8- 8-55	D,S	....	1,580	Reported soft.
52	8- 8-55	D,S	....	1,600	Do.
.....	8- 8-55	D,S	....	1,580	
4.0	8- 8-55	N	....	1,600	
8	8- 8-55	S	....	1,600	Reported hard.
.....	....	T	....	1,588	See log.
.....	8- 8-55	D,S	Lignite	1,580	Reported soft.
.....	8- 8-55	D,S	....	1,600	Do.
60	8-25-55	D,S	Sand	1,600	Do.
.....	8- 5-55	D,S	....	1,600	Do.
7	8- 5-55	D.S	Gravel	1,610	Reported hard.
.....	8- 5-55	S	....	1,580	Reported soft.
.....	8- 5-55	D	....	1,580	Reported hard.
.....	8-26-55	D,S	....	1,590	Reported soft.
.....	8- 5-55	S	....	1,575	Do.
20	8- 5-55	D	....	1,580	Reported hard.

TABLE 3.--Records of Wells

Location No.	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed
152-76 (Cont.)					
34add1	Geo. Sendbeech	160	4	Dr	1945
34add2	Do	160	4	Dr	1949
35bbb	Test hole 1064	190	5	Dr	9-16-55
35ddb	Martin Nissen	18.0	48x48	Du	1899
152-77					
2ccb	H. E. Brunhart	130	2	Dr	1915
3abb	Albert Wiwta	20	48x48	Du	1900
3add	Do	17	48x48	Du	1954
3dcd	Mercy Hospital Farm	200	2	Dr	....
4bbb	Lloyd Redsted	68	4	Dr	....
4ddd	Ernst Struee	23.2	48x48	Du	....
9ddd	Anton Weninter	40	4	Dr	....
10bcc	Ervin Struee	24	48x48	Du	....
10dca	Evert Effestad	30	3	Dr	....
11ccd	Carl Buri	350	2	Dr	1901
12ccc1	Tius Usselmen	35	48x48	Du	1908
12ccc2	Do	90	4	Dr	....
12dcd1	Ervin Knuth	24	48x48	Du	1946
12dcd2	Do	10	48x48	Du	1936
15ccb	Mrs. M. Smith	37	36x36	Du	1915
16bbb	Mrs. Petra Skari	72	3	Dr	1917
16ccc	Leo Myxter	35	36x36	Du	1920
21cdd	Arnold Alme	507	2	Dr	1910
23aad	Arnie Martwick	14	36x36	Du	....
25add	John L. Lener	165	2	Dr	....
26ddd	W. L. Bradley	168	2	Dr	....
27ada	Carl Thompson	110	4	Dr	....
27bcc	Francis Wininder	70	2	Dr	1926
28aad	C. Stevens	18	36x36	Du	....
28cad	Balfour Hardware Store	125	2	Dr	1948
28cbc	City of Balfour	16.3	48x48	Du	....
33abb	Orvill Aanrud	280	2	Dr	....
34bcb	Anton Grinsteiner	35	36x36	Du	....
34ccb	Guy Martichol	160	2	Dr	....
35dcb	L. W. Belzer	90	3	Dr	....
35dcb	Jerold Krueger	83	2	Dr	1914

Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Altitude of land surface (feet)	Remarks
40	8- 8-55	S	Gravel	1,620	Reported soft.
40	8- 8-55	D	Gravel	1,620	Do.
.....	....	T	....	1,613	See log.
10.2	8- 8-55	D,S	....	1,620	Reported soft.
.....	8- 4-55	D,S	....	.....	Reported soft.
.....	8- 2-55	D,S	Sand	.....	Reported hard.
4	8- 2-55	D	Sand	.....	Do.
.....	8- 4-55	D,S	....	.....	Reported soft.
20	8- 2-55	D,S	Sand	.....	Reported hard.
15.1	8- 2-55	N	....	.....	
4	8- 2-55	D,S	Sand	1,575	Do.
4	8- 2-55	D,S	Sand	.....	Reported soft.
12	8- 2-55	S	Sand	1,580	Reported hard.
.....	8- 2-55	D,S	....	1,600	See chemical analysis.
.....	8- 2-55	D	....	1,575	Reported hard.
.....	8- 2-55	S	....	1,575	Reported soft.
.....	8- 2-55	D	Sand	1,560	Do.
5	8- 2-55	S	Sand	1,560	Do.
25	8- 2-55	D,S	Clay	1,575	
.....	8- 2-55	D,S	Sand	1,620	Reported soft.
15	8- 2-55	D,S	Sand	1,600	Reported hard.
150	8-23-55	D,S	Sand	1,620	See chemical analysis
10	8-26-55	D,S	Sand	1,580	
.....	8- 2-55	D,S	....	1,580	Reported soft.
.....	8-30-55	D.S	Sand	1,580	Do.
.....	8- 2-55	D,S	....	1,580	Do.
35	8- 2-55	D,S	Sand	1,600	Do.
.....	8-30-55	D,S	Sand	1,600	Reported hard.
.....	8- 4-55	D	Sand	1,600	Reported soft.
8.1	8- 4-55	D	....	1,600	See chemical analysis.
.....	8- 4-55	D,S	....	1,600	Reported soft.
17	8-30-55	D,S	....	1,600	Reported hard.
.....	8- 2-55	D,S	....	1,600	Reported soft.
.....	8- 4-55	D,S	....	1,600	Do.
63	8- 4-55	D,S	Sand	1,620	Do.

TABLE 4.--Logs of Test Holes

151-75-3bbb
Test hole 1088

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, sandy, yellow	3	3
Clay, yellow, and fine to medium gravel	13	16
Clay, gray, and fine to medium gravel	116	132
Clay, smooth, gray	10	142
Clay, sandy, gray	7	149
Clay, gray, and fine to medium gravel	104	253
Gravel, cemented, clayey; very hard drilling.	52	305
Clay, gray, and fine gravel	5	310
Cannonball member of the Fort Union formation:		
Clay, smooth, silty, gray	5	315

151-75-4ddd
Test hole 1057

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, yellow, and fine gravel	16	16
Clay, gray, and fine to medium gravel	186	202
Sand, fine to medium, silty	10	212
Clay, gray, and fine to medium gravel	32	244
Gravel, fine to medium	16	260
Gravel, fine, and coarse sand	20	280
Cannonball(?) member of the Fort Union formation and Fox Hills(?) sandstone:		
Clay, smooth, sandy, gray	85	365
Pierre shale:		
Shale, gray	5	370

151-75-5ddd
Test hole 1058

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, sandy, yellow	5	5
Clay, yellow, and fine gravel	13	18
Clay, gray, and fine gravel	3	21
Sand, fine	10	31
Clay, gray, and fine gravel	4	35
Sand, medium to coarse	21	56
Clay, gray, and fine to medium gravel	17	73
Gravel, fine, sandy	17	90
Clay, gray, and fine to medium gravel	30	120
Cannonball member of the Fort Union formation:		
Clay, sandy, silty, gray to brown	160	280

TABLE 4.--Logs of Test Holes -- Continued

151-75-7aaa
Test hole 1059

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Clay, yellow, coarse sand, and fine gravel..	9	9
	Clay, gray, and fine to medium gravel.......	24	33
	Clay, sandy, gray..........................	9	42
	Clay, gray, and fine to medium gravel.......	60	102
	Sand, fine to medium, silty.................	8	110
	Clay, sandy, green..........................	17	127
	Clay, gray, and fine to medium gravel.......	14	141
Cannonball member of the Fort Union formation:			
	Shale, lignitic.............................	3	144
	Clay, smooth, brown.........................	3	147
	Clay, sandy, silty, green...................	40	187
	Clay, lignitic, silty.......................	25	212
	Clay, smooth, gray..........................	8	220

151-75-7bbb1
Test hole 1060

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Clay, sandy, yellow.........................	11	11
	Clay, gray, and fine to medium gravel.......	7	18
	Gravel, fine to medium......................	1	19
	Clay, gray, and fine to medium gravel.......	13	32
	Sand, coarse, and fine gravel...............	3	35
	Gravel, fine to medium......................	4	39
	Clay, gray, and fine to medium gravel; lost circulation 70 to 83 feet................	47	86
Cannonball member of the Fort Union formation:			
	Clay, sandy, gray...........................	48	134
	Lignite.....................................	1	135
	Clay, smooth, brown.........................	13	148
	Clay, smooth, gray..........................	19	167
	Clay, smooth, brown.........................	30	197
	Clay, sandy, silty, gray....................	13	210

151-76-2cbc1
Test hole 1082

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Clay, sandy, yellow.........................	3	3
	Clay, yellow, and fine gravel...............	25	28
	Clay, sandy, brown..........................	26	54
	Clay, sandy, gray-green.....................	5	59
Cannonball member of the Fort Union formation:			
	Clay, silty, gray...........................	11	70

TABLE 4.--Logs of Test Holes -- Continued

151-76-2ccc1
Test hole 1061

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Sand, fine	5	5
Clay, yellow, and fine gravel	8	13
Sand, medium to coarse, and fine gravel	6	19
Clay, gray, and fine to medium gravel	1	20
Sand, medium to coarse, and fine gravel	14	34
Clay, gray, and fine to medium gravel	14	48
Clay, smooth, gray	3	51
Clay, gray, and fine to medium gravel	16	67
Sand, medium to coarse, and fine gravel	10	77
Clay, gray, and fine to medium gravel; hard drilling 98 to 100 feet	22	99
Cannonball member of the Fort Union formation:		
Clay, smooth, dark-gray	21	120
Clay, sandy, silty, gray	10	130

151-76-3aaa
Test hole 1063

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, yellow, and fine gravel	4	4
Clay, sandy, yellow	3	7
Clay, yellow, and fine to medium gravel	24	31
Sand, fine to medium	13	44
Clay, gray, and fine to medium gravel	32	76
Cannonball member of the Fort Union formation:		
Clay, smooth, dark-gray	24	100

151-76-4ccc
Test hole 1069

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, sandy, yellow	19	19
Sand, fine to medium	2	21
Clay, sandy, gray	12	33
Clay, gray, and fine to medium gravel	13	46
Sand, medium to coarse, and fine gravel	3	49
Clay, sandy, gray	7	56
Clay, gray, and fine to medium gravel	15	71
Cannonball member of the Fort Union formation:		
Clay, smooth, gray	17	88
Clay, sandy, dark-gray	2	90

151-76-4ddd
Test hole 1068

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, sandy, yellow	6	6
Clay, yellow, and fine to medium gravel	8	14
Clay, gray, and fine to medium gravel	10	24
Sand, fine to medium	2	26
Clay, gray, and fine to medium gravel	14	40
Cannonball member of the Fort Union formation:		
Clay, sandy, dark-gray	22	62
Clay, smooth, light-gray	3	65
Clay, smooth, dark-gray	5	70

151-76-8abb
Test hole 1081

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, sandy, dark-gray	4	4
Clay, sandy, yellow	10	14
Sand, clayey, yellow	7	21
Sand, fine to coarse	3	24
Clay, gray, and fine to medium gravel	29	53
Cannonball member of the Fort Union formation:		
Clay, smooth, gray	17	70

151-76-8bbb
Test hole 1070

Formation Material	Thickness (feet)	Depth (feet)
Outwash deposits:		
Sand, fine	3	3
Sand, fine to medium	2	5
Sand, medium to coarse, and fine gravel; large lignite fragments	17	22
Sand, coarse, and fine gravel	18	40
Till and associated sand and gravel deposits:		
Clay, gray, and fine to medium gravel	16	56
Cannonball member of the Fort Union formation:		
Clay, smooth, gray	19	75
Clay, smooth, light-grown	5	80

151-76-10ddd
Test hole 1074

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, silty, yellow, and coarse sand	22	22
Clay, yellow, and fine gravel	4	26
Clay, silty, gray, and fine gravel	9	35
Clay, sandy, gray	28	63
Sand, fine to coarse, and fine gravel	11	74
Sand, fine silty, gray	16	90
Clay, gray, and fine gravel	10	100
Clay, sandy, gray	4	104
Cannonball member of the Fort Union formation:		
Clay, sandy, light-gray	16	120

151-76-11bbb
Test hole 1062

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, smooth, gray	3	3
Clay, yellow, and fine gravel	5	8
Sand, medium to coarse	2	10
Clay, yellow, and fine gravel	3	13
Clay, gray, and fine to medium gravel	11	24
Sand, medium to coarse, and fine gravel	6	30
Clay, gray, and fine to medium gravel	34	64
Cannonball member of the Fort Union formation:		
Clay, smooth, gray	12	76
Clay, sandy, silty, gray	9	85
Clay, smooth, gray	25	110

151-76-14bcc
Test hole 1077

Formation Material	Thickness (feet)	Depth (feet)
Outwash deposits:		
Clay, silty, gray-brown	5	5
Clay, smooth, light-gray	2	7
Clay, yellow, and fine gravel	3	10
Clay, gray to yellow, and fine gravel; fine to coarse sand	3	13
Sand, medium to coarse, and fine gravel	2	15
Sand, fine to coarse; fairly clean	36	51
Till and associated sand and gravel deposits:		
Clay, dark-gray, and fine gravel	14	65
Cannonball member of the Fort Union formation:		
Clay, smooth, light-gray	5	70

151-76-14ccc
Test hole 1075

Formation Material	Thickness (feet)	Depth (feet)
Outwash deposits:		
Sand, fine to coarse, brown	6	6
Sand, fine to coarse, brown to yellow, and fine gravel	9	15
Sand, very fine to fine, gray, and lignite fragments	37	52
Sand, fine to coarse	3	55
Sand, fine to coarse, and fine gravel; shale pebbles	4	59
Till and associated sand and gravel deposits:		
Clay, dark-gray, and fine gravel	16	75
Cannonball member of the Fort Union formation		
Clay, silty, light-gray	15	90

151-76-23cbb
Test hole 1078

Formation Material	Thickness (feet)	Depth (feet)
Outwash deposits:		
Clay, sandy, dark-brown	3	3
Clay, yellow, and fine gravel	11	14
Clay, sandy, yellowish-brown	8	22
Sand, fine, silty	7	29
Clay, gray, and fine sand	3	32
Sand, fine to coarse, and fine gravel	11	43
Sand, coarse, and fine gravel	7	50
Gravel, fine and coarse sand	4	54
Cannonball member of the Fort Union formation:		
Clay, sandy, silty, light gray	16	70

TABLE 4.--Logs of Test Holes -- Continued

151-76-26bbb
Test hole 1076

Formation Material	Thickness (feet)	Depth (feet)
Outwash deposits:		
Sand, fine, brown, clayey, yellow...........	4	4
Clay, smooth, yellow.........................	2	6
Gravel, fine, clayey, yellow................	15	21
Clay, yellow and fine gravel................	4	25
Hard rock; difficult drilling...............	2	27
Clay, yellow to brown, and fine to medium sand....................................	4	31
Hard rock; difficult drilling...............	2	33
Clay, silty, yellow to brown, and fine to coarse sand..............................	3	36
Sand, fine to medium, gray..................	14	50
Till and associated sand and gravel deposits:		
Clay, smooth, dark-gray.....................	10	60
Cannonball member of the Fort Union formation:		
Clay, sandy, gray...........................	10	70

151-76-34add
Test hole 1079

Outwash deposits:		
Sand, clayey, dark-gray.....................	3	3
Sand, medium to coarse......................	9	12
Gravel, fine to medium......................	16	28
Cannonball member of the Fort Union formation:		
Clay, smooth, light-gray....................	3	31
Clay, sandy, silty, light-gray..............	4	35
Clay, sandy, silty, dark-gray...............	14	49

151-77-1ddd
Test hole 1071

Alluvium:		
Clay, smooth, light-gray....................	7	7
Outwash deposits:		
Sand, fine to medium........................	8	15
Sand, medium to coarse, and large lignite fragments................................	10	25
Sand, medium to coarse......................	11	36
Till and associated sand and gravel deposits:		
Clay, gray,and fine to medium gravel........	7	43
Cannonball member of the Fort Union formation:		
Clay, smooth, gray..........................	17	60

151-77-2ccc
Test hole 1073

Till and associated sand and gravel deposits:		
Clay, sandy, yellow.........................	6	6
Clay, yellow, and fine to medium gravel.....	35	41
Cannonball member of the Fort Union formation:		
Clay, sandy, gray...........................	19	60
Clay, smooth, gray..........................	10	70

151-77-2ddd
Test hole 1072

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Clay, yellow, and fine to medium gravel.......	10	10
	Clay, dark-brown and fine to medium gravel....	7	17
Cannonball member of the Fort Union formation:..........			
	Clay, sandy, dark-brown......................	20	37
	Sand, fine to medium, dark-brown.............	4	41
	Clay, sandy, dark-brown......................	6	47
	Clay, smooth, light-gray.....................	13	60

152-76-11ccc
Test hole 1067

Formation	Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:			
	Clay, sandy, brown...........................	3	3
	Clay, sandy, yellow..........................	2	5
	Clay, yellow, and fine to medium gravel.......	10	15
	Clay, gray, and fine to medium gravel.........	3	18
	Sand, medium to coarse, and fine gravel.......	2	20
	Clay, gray, and fine to medium gravel.........	3	23
	Gravel, fine, and coarse sand................	9	32
	Clay, gray, and fine to medium gravel.........	23	55
	Gravel, fine.................................	2	57
	Clay, gray, and fine to medium gravel..........	14	71
	Sand, fine to medium.........................	21	92
	Clay, gray, and fine to medium gravel.........	9	101
Cannonball member of the Fort Union formation:			
	Clay, sandy, silty, gray.....................	15	116
	Sand, medium, hard, silty, gray..............	26	142
	Clay, smooth, gray...........................	8	150

152-76-14ccc
Test hole 1066

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium:			
	Clay, sandy, gray............................	4	4
Outwash deposits:			
	Sand, fine to medium.........................	4	8
	Clay, yellow, and fine to medium gravel.......	9	17
	Sand, fine to coarse, and fine gravel.........	9	26
Till and associated sand and gravel deposits:			
	Clay, gray, and fine gravel..................	23	49
Cannonball member of the Fort Union formation:			
	Sand, fine to medium, silty, gray-green.......	13	62
	Shale, lignitic..............................	2	64
	Clay, smooth, brown..........................	9	73
	Clay, smooth, light gray.....................	2	75
	Shale, lignitic..............................	2	77
	Clay, smooth, brown..........................	2	79
	Clay, smooth, light-gray.....................	1	80

TABLE 4.--Logs of Test Holes -- Continued

152-76-26bbb
Test hole 1065

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Sand, fine, silty	3	3
Clay, smooth, light-gray	2	5
Clay, yellow, and fine to medium gravel	2	7
Sand, medium to coarse, and fine gravel	1	8
Clay, yellow, and fine to medium gravel	4	12
Clay, gray, and fine to medium gravel	9	21
Clay, sandy, dark-brown	7	28
Cannonball member of the Fort Union formation:		
Clay, smooth, light-gray	3	31
Clay, sandy, silty, gray	3	34
Clay, smooth, brown	6	40
Clay, smooth, gray	10	50

152-76-35bbb
Test hole 1064

Formation Material	Thickness (feet)	Depth (feet)
Till and associated sand and gravel deposits:		
Clay, sandy, yellow	3	3
Sand, fine to coarse, and fine gravel	1	4
Clay, yellow, and fine to medium gravel	8	12
Clay, gray, and fine to medium gravel	65	77
Clay smooth, gray	3	80
Clay, gray, and fine to medium gravel	94	174
Cannonball member of the Fort Union formation:		
Clay, smooth, sandy, gray	16	190

SELECTED REFERENCES

Abbott, G. A., and Voedisch, F. W., 1938, The municipal ground-water supplies of North Dakota: North Dakota Geol. Survey Bull. 11, 99 p.

Brown, R. W., and Lemke, R. W., 1948, Newly discovered outcrops of the Cannonball formation in North Dakota: Science, v. 107, p. 624-625.

Caldwell, J. W., 1953, Summary of the Peter Lenertz No. 1. oil-test well McHenry County, North Dakota: North Dakota Geol. Survey Circ. 24, 12 p.

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

Jenkinson, L. F., 1950, Geology of the Drake quadrangle, North Dakota; Iowa City, Iowa, Iowa State Univ., master's thesis, 87 p.

Laird, W. M., and Mitchell, R. H., 1942, The geology of the southern part of Morton County, North Dakota: North Dakota Geol. Survey Bull. 14, 42 p.

Lemke, R. W., 1958a, Glacial history of the Souris River lobe, North Dakota: North Dakota Geol. Survey Guidebook 9th Ann. Field Conf., Midwestern Friends of the Pleistocene, 1958, North Dakota Misc. Ser. No.10, p.85-92.

-------1958b, Narrow linear drumlins near Velva, North Dakota: Am. Jour. Sci., v. 256, p. 270-283, April.

-------1960, Geology of the Souris River area, North Dakota: U. S. Geol. Survey Prof. Paper 325, 138 p.

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.

Paulson, Q. F., and Powell, J. E., 1957, Geology and ground-water resources of the Upham area, McHenry County, North Dakota: North Dakota Ground-Water Studies No. 26, 66 p.

Powell, J. E., 1959, Progress report on the geology and ground-water resources of the Westhope area, Bottineau County, North Dakota: North Dakota Ground-Water Studies No. 27, 68 p.

Robinove, C. J., Langford, R. H., and Brookhart, J. W., 1958 Saline-water resources of North Dakota: U.S. Geol. Survey Water-Supply Paper 1428, 72 p.

Simpson, H. E., 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.

Upham, Warren, 1895, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25 658 p. (1896)

U. S. Public Health Service, 1946, Drinking water standards: Public Health Repts., v. 61, no. 11, p. 371-384.

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

U. S. Weather Bureau, 1960, Climatological data for North Dakota - Annual summary, 1959: v. 68, no. 13, p. 180-189.

Welsh, G. B., and Thomas J. F., 1960, Significance of chemical limits in U.S. Public Health Service drinking water standards: Am. Water Works Assoc., Jour., v. 52, no. 3, p. 289-299.