GROUND WATER IN THE MOHALL AREA BOTTINEAU AND RENVILLE COUNTIES NORTH DAKOTA

BY

P. D. AKIN
ENGINEER, GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

NORTH DAKOTA GROUND-WATER STUDIES NO. 17

PREPARED COOPERATIVELY BY THE UNITED STATES GEOLOGICAL SURVEY, THE NORTH DAKOTA STATE WATER CONSERVATION COMMISSION, AND THE NORTH NORTH DAKOTA GEOLOGICAL SURVEY

1951

GROUND WATER IN THE MOHALL AREA,

BOTTINEAU AND RENVILLE COUNTIES, NORTH DAKOTA

By

P. D. Akin
Engineer, Geological Survey
United States Department of the Interior

North Dakota Ground-Water Studies No. 17

Prepared cooperatively by the United States Geological
Survey, the North Dakota State Water
Conservation Commission, and the North
Dakota State Geological Survey.

1951

CONTENTS

ILLUSTRATIONS

GROUND WATER IN THE MOHALL AREA,

BOTTINEAU AND RENVILLE COUNTIES, NORTH DAKOTA

by

P. D. Akin

ABSTRACT

The Mohall area includes about 120 square miles in Bottineau and Renville Counties in northwestern North Dakota. Mohall, whose 1950 population was 1,073, is the only town in the area.

The area is part of the Drift Prairie section of the Central Lowland physiographic province. It is characterized by the gently undulating ground moraine plain which slopes regionally to the northeast. It is drained by several southeast-trending intermittent streams which run almost at right angles to the regional slope.

The geologic formations in the Mohall area may be conveniently grouped into three units: the alluvium or alluvial deposits, which are found in the valleys of the intermittent streams, the till and associated glaciofluvial deposits, and the bedrock formations.

Ground water of reasonably good quality is obtained in the area only from the alluvial deposits. Because of the limited areal extent of these deposits, only a small number of farms obtain water supplies from them. However, the municipal water supply of the town of Mohall is obtained from these deposits in Spring Coulee northeast of the town, and much water for rural domestic use is hauled from the Becker well southwest of the town, in Little Deep Creek.

The principal source of recharge to the alluvial deposits is seepage during the spring runoff period. Natural discharge occurs

by underflow down the stream valleys, by evaporation from open water and marshy areas, and by transpiration by plants.

The coefficient of transmissibility of the alluvium, on the basis of short pumping tests on Mohall wells 3 and 4, is indicated to be about 6,000 gallons a day per foot at well 3 and about 20,000 gallons a day per foot at well 4. The specific yield was computed as 0.25 from the pumping test on well 3. No gravel of importance was encountered in the two cross sections that were drilled across Spring Coulee near the municipal wells, and the greatest thickness of saturated alluvial deposits found was only about 10 feet.

A saturated thickness of 20 feet of sand and gravel was penetrated in test drilling along Cut Bank Creek. This is the greatest thickness of saturated alluvial deposits penetrated anywhere in the area. Ground water in storage in these alluvial deposits has been estimated to be about 150 million gallons per mile. These deposits are favorably situated to receive recharge, as Cut Bank Creek drains a rather large area and contains long stretches of open water perennially. Therefore, it is believed that the alluvial deposits of Cut Bank Creek offer the best promise for the development of moderately large perennial ground-water supplies for the present and probable future needs of the town of Mohall.

Test drilling in West Cut Bank Creek and in Little Deep Creek did not reveal alluvial deposits of such character and saturated thickness as to be considered favorable for the development of moderate to large water supplies, though some of the material encountered should yield adequate quantities for farm supplies.

The till with its associated glaciofluvial deposits is the surface formation in the area except where covered by the alluvial deposits in the stream valleys. In the Mohall area, this formation is not an important aquifer and fewer than half a dozen wells are known to obtain water from it. The glaciofluvial deposits penetrated by the test holes are not considered adequate sources for permanent municipal or industrial supplies because they are likely to have small areal extent and the overlying, relatively impermeable till makes seasonal recharge to them practically impossible.

Test drilling in the Souris River Valley about 12 miles west of Mohall penetrated as much as 58 feet of fluvial sediments, but practically all the material is clay and silt. No important aquifers were found there.

At least 50 percent of all the farm water supplies in the area are obtained from wells in the bedrock formations, which probably consist of the Fox Hills sandstone, the Cannonball formation, and the Ludlow and Tongue River members of the Fort Union formation.

Underlying these formations is approximately 2,600 feet of Cretaceous shale, which is not water bearing. Water from the "Dakota" sandstone (including the possible equivalent of the Fuson shale and Lakota sandstone) may be obtained at depths of about 3,200 to 3,300 feet. The "Dakota sandstone" probably would yield water in sufficient quantity for municipal and many industrial purposes in this area, but the water is likely to be too highly mineralized for most domestic uses.

Jurassic formations underlie the Cretaceous formations in the area. They do not constitute aquifers of importance, and any water found in them is likely to be too highly mineralized for most purposes.

In the Mohall area, by far the most suitable water for general purposes is obtained from the shallow alluvial deposits in the stream valleys. Of the seven samples of this water analyzed, the highest concentration of dissolved solids was 1,242 parts per million and the lowest, 317 parts. The iron content was higher than desirable in two samples but satisfactory in all the others. Total hardness ranged from 196 to 570, which is higher than desirable. Nitrate was present in all samples analyzed and was excessively high in two samples.

Water samples for analysis were not obtained from the till and associated glaciofluvial deposits but the water from these aquifers is likely to be more highly mineralized than the water from the alluvial deposits.

The water from the upper part of the bedrock is highly mineralized, but its mineral content varies considerably. The chloride concentration of the samples analyzed ranges from 608 to 3,740 parts per million and the bicarbonate concentration ranges from 160 to 860 parts per million. The specific conductance ranges from 3,190 to 11,120 micromhos and may represent total mineralization on the order of 1,500 to more than 6,000 parts per million in the water with high chloride and bicarbonate content.

INTRODUCTION

Scope and Purpose of the Investigation

A study of the geology and ground-water resources of Bottineau and Renville Counties, N. Dak., is being made by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the State Geological Survey as part of a series of investigations of differenct counties in the State. The purpose of these general studies is to determine the occurrence, movement, discharge, and recharge of the ground water, and the quantity and quality of such water available for all purposes, including municipal, domestic, irrigation, and industrial. At present, the most critical need is for adequate and perennial water supplies for many towns and small cities throughout the State. For this reason, the county-wide studies are being started in the vicinity of those towns requesting the help of the State Water Conservation Commission and the State Geologist in locating suitable ground-water supplies. Progress reports, such as this one, are being released before the completion of the general studies so that the data may be made available as soon as possible for use in connection with immediate problems.

The Mohall area, the subject of this report, comprises about 120 square miles in Bottineau and Renville Counties, N. Dak. The town of Mohall is approximately in the center of the area. The field work done during the present investigation was confined largely to test drilling and to the collection of a small number of water samples from shallow wells. Pumping tests were made on two of the town's shallow supply wells. Test drilling also was done in the Souris River valley (outside the Mohall area as defined above) about 12 miles west of Mohall, and the results are presented herein because they are of general interest to governmental agencies doing work in the area and are of particular interest to the town of Mohall.

The investigation was made under the general supervision of A. N. Sayre, Chief, Ground Water Branch, Water Resources Division of the U. S. Geological Survey. The test drilling and other field work were done in the fall of 1948 under the direct supervision of the writer.

Well records and logs and chemical analyses of ground water compiled by the Ground Water Branch personnel working on the Missouri Basin project were made available to the writer. Most of the data on wells and chemical analyses given in this report were obtained during that work (Waring and LaRocque, 1949).

Information in regard to the geology of the area was furnished by members of the Geologic Division of the Federal Survey and topographic maps of the area were made available by the Topographic Division.

Test drilling was done by Ray Danielson and George McMaster. Work was facilitated by the excellent cooperation of residents in the area and by the interest and assistance of the Mohall Water Commission, especially through the efforts of Mr. Page and Mr. McDonald.

Chemical analyses of 6 water samples from the area were made by the North Dakota State Department of Health and this assistance is gratefully acknowledged.

Previous Investigations

General information concerning the geology and ground-water resources of Bottineau and Renville Counties was compiled by Simpson (1929). He also made a short special investigation in 1935 for the town of Mohall in regard to the location of a municipal ground-water supply, and submitted a brief report to the Mayor and Council.

During the years 1946-49, the Federal Geological Survey made an intensive investigation of the occurrence of ground water in the Crosby-Mohall area in connection with the proposed irrigation development of the northwestern part of the State (Waring and LaRocque, 1949). Also, the area has been mapped topographically and geologically. Much of the information obtained is as yet unpublished and is not in final form. However, most of the data were available to the author and have been used extensively in the preparation of this report.

Location and General Features of the Area

The Mohall area, as described in this report, is located in northwestern North Dakota and is divided about equally between Bottineau and Renville Counties (see fig. 1). The central part of the area is about 17 miles south of the Canadian border. The area is approximately 10 by 12 miles in size and includes parts of Rs. 83, 84, and 85 W. in T. 160 N., all of Rs. 83 and 84 W. in T. 161 N., and parts of Rs. 83, and 84 W. in T. 162 N. (see fig. 2).

Mohall, in Renville County, is the only town in the area; it is on State Highway 5, 1 mile west of the Bottineau County line. The town is served by a branch line of the Great Northern Railroad. The 1950 population was 1,073.

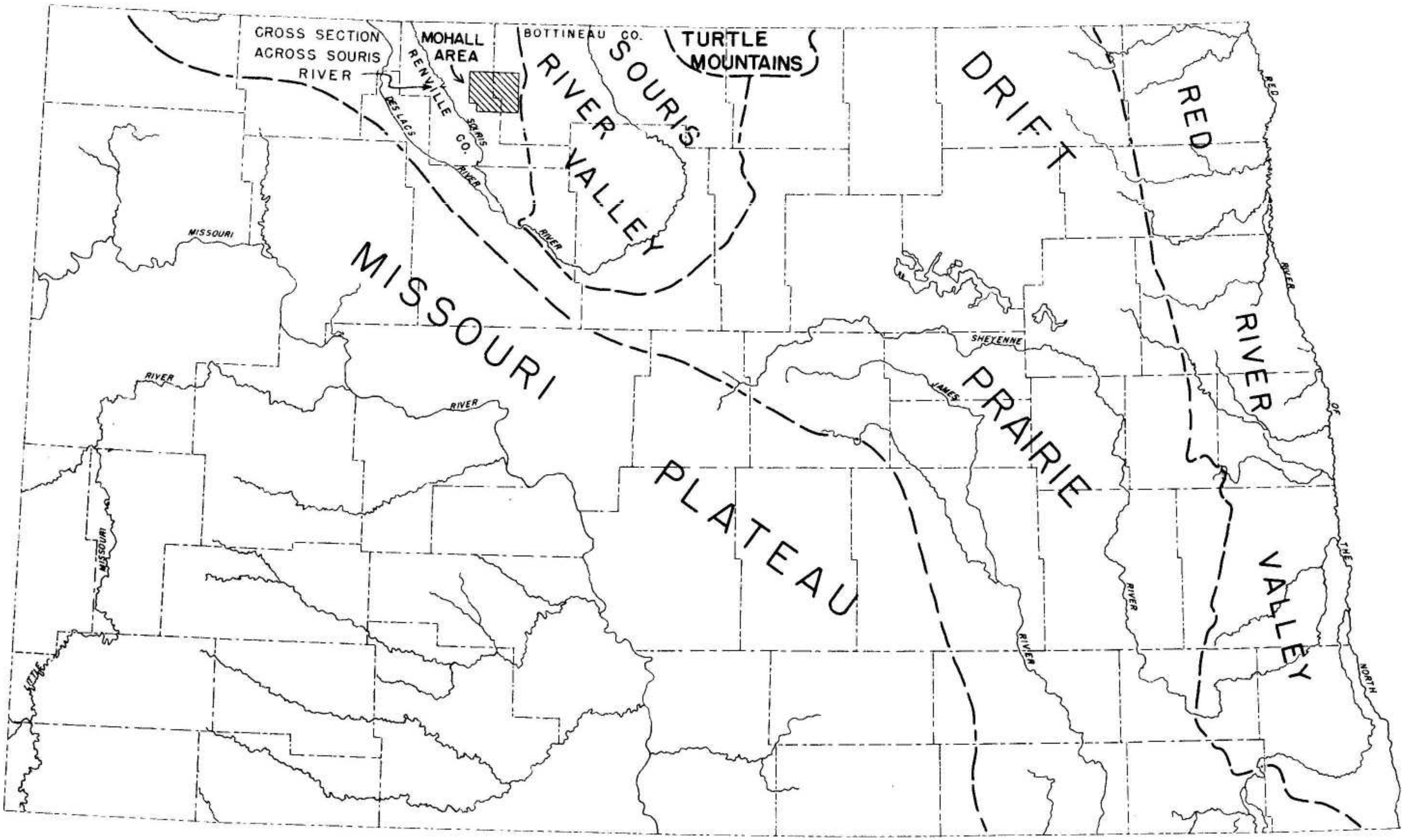

FIGURE I.—MAP SHOWING PHYSIOGRAPHIC DIVISIONS IN NORTH DAKOTA (MODIFIED AFTER SIMPSON) AND LOCATION OF MOHALL AREA

15644

Farming is the main occupation in the area, wheat being the major crop. Mohall serves as a trading and shopping center for the people living in the surrounding farm area.

The climate of the Mohall area is characterized by the hot summers and cold winters typical of this section of the United States. The highest recorded temperature at Mohall is 107°F. and the lowest, 39° below zero. These and other climatological data are taken from records of the U. S. Weather Bureau.

The average annual precipitation at Mohall is 15.19 inches, distributed by months as follows:

Month	Avg. precipitation (inches)	Month	Avg. precipitation (inches)
Jan.	.34	July	2.45
Feb.	.35	Aug.	1.91
Mar.	.71	Sept.	1.56
Apr.	.96	Oct.	1.04
May	1.98	Nov.	.54
June	2.93	Dec.	.42
		Total	15.19

The following table shows the annual precipitation at Mohall from 1894 through 1949. The greatest recorded annual precipitation was 25.87 inches in 1944 but an annual precipitation of more than 20 inches has occurred in only 9 of the 56 years of record. The driest year recorded was 1902, which had only 6.58 inches of precipitation, but only 4 years are recorded in which the precipitation was less than 10 inches. In two periods annual precipitation has been below average for three consecutive years.

Annual Precipitation at Mohall

Year	Precipitation	Year	Precipitation	Year	Precipitation
1894	13.89	1913	12.58	1932	19.80
1895	16.70	1914	15.96	1933	16.85
1896	20.06	1915	15.32	1934	9.52
1897	19.36	1916	12.01	1935	16.63
1898	15.35	1917	7.61	1936	10.93
1899	15.76	1918	13.39	1937	25.20
1900	15.73	1919	16.19	1938	----
1901	14.51	1920	10.94	1939	13.40
1902	6.58	1921	17.38	1940	19.16
1903	16.55	1922	20.58	1941	24.90
1904	15.33	1923	16.82	1942	15.04
1905	15.28	1924	18.29	1943	21.32
1906	13.75	1925	13.97	1944	25.87
1907	11.69	1926	15.54	1945	15.95
1908	18.47	1927	21.29	1946	13.11
1909	10.53	1928	16.37	1947	17.92
1910	11.15	1929	13.58	1948	23.00
1911	16.79	1930	14.90	1949	14.29 1/
1912	22.29	1931	8.05		

1/ Does not include precipitation for month of February.

In view of these data it appears likely that any ground-water supply in this area that is dependent upon seasonal precipitation for recharge should contain sufficient water in storage to supply pumpage requirements and natural discharge demands for a period of 3 to 4 years, when recharge may be below normal or entirely lacking.

The Mohall area is part of the Drift Prairie section of the Central Lowland physiographic province. It is characterized by the gently undulating ground moraine plain that slopes regionally to the northeast. The area is drained by several southeast-trending intermittent streams which run almost at right angles to the regional slope. The streams were formed as distributaries for the meltwaters from the receding front of the last ice sheet that covered the area and are connected by less developed Pleistocene spillways, which functioned at one time or another as the ice sheet melted. It is not clear whether the network of spillways ever functioned as a whole or whether various parts were used at different times. The largest and best developed of these streams is Cut Bank Creek, which crosses the northeastern part of the area. West Cut Bank Creek, a tributary, joins it about 6 miles east of Mohall. Spring Coulee trends southward from its junction with West Cut Bank Creek in the north central part of the area and crosses State Highway 5 about 1 mile east of Mohall, where it takes a more southeasterly course, paralleling the principal directional trend of the other streams. Little Deep Creek crosses the southwestern part of the area, and an unnamed tributary joins it from the north in Sec. 33, T. 161 N., R. 84 W.

Much of the area between the streams is poorly drained, no integrated drainage net having been developed there.

Present Water Supply and Future Needs

At the present time the Mohall area is almost entirely dependent upon ground water to supply all water requirements. Farm supplies from deep wells tapping the bedrock formations are in general too highly mineralized for satisfactory domestic use, and in many places, rain water is caught and stored in cisterns for such use. In addition, a considerable amount of ground water for domestic use is obtained from shallow aquifers along the intermittent streams and is hauled to many of the farms by tank truck.

The town of Mohall has municipal water-supply and sewage facilities. The present water supply is obtained from four shallow wells dug in the alluvial deposits of Spring Coulee (see fig. 2) northeast of town. The wells yield water of satisfactory quality but the supply is insufficient to meet the present demands during the summer months, especially in drier years.

The following table shows the amount of water that was metered from the water system during 1946, 1947, and part of 1948. The actual amount of water used is probably somewhat higher than is indicated in the table, but there are no data available upon which to base an estimate of water losses in the distribution system or of unmetered use.

Metered Use of Water by the Town of Mohall
(thousands of gallons)

Month	1946	1947	1948
Jan.	434	163	688
Feb.	468	624	369
Mar.	424	579	383
Apr.	418	a 1,460	414
May	514		467
June	609		690
July	488	b 1,187	583
Aug.	549		583
Sept.	532	514	559
Oct.	663	573	555
Nov.	524	430	
Dec.	404	417	
Total	6,027	5,947	

a, Total for months of April and May.
b, Total for months of June, July, and August.

The annual use of about 6 million gallons in 1946 and 1947 represents an average daily consumption of only about 16,400 gallons. The greatest monthly consumption was 690,000 gallons in June 1948, representing an average daily consumption of 23,000 gallons for the month. The least monthly use during the period tabulated is indicated as 163,000 gallons in January 1947, or an average daily consumption of only about 5,300 gallons for the month. This figure, however, seems much too low to represent fairly the minimum monthly consumption of water. The next lowest monthly use was 369,000 gallons in February 1948, representing an average daily consumption of about 12,700 gallons for the month.

There is a great need for water of satisfactory quality for farm use throughout the area. However, at the present time, the only single need for a water supply of relatively large magnitude is for the municipal and industrial requirements of Mohall. It is estimated that a dependable water supply on the order of 75,000 gallons a day would fill this need. Additional demands for water for municipal and industrial purposes may arise in the future, depending upon how the development of irrigation farming under the Missour-Souris project may affect the municipal and industrial growth in the area.

GEOLOGY AND OCCURRENCE OF GROUND WATER

Introduction

For the purpose of discussing the occurrence of ground water in the Mohall area, the geologic formations may conveniently be grouped into three types: (1) the alluvium or alluvial deposits which are found in the valleys of the intermittent streams, (2) the till and associated glaciofluvial deposits, and (3) the bedrock formations. In this report the term "alluvium" or "alluvial deposits" is used to include all the shallow-lying sorted materials found in the stream valleys, although much of these materials probably was deposited as glacial outwash in the stream channels.

The alluvial deposits and the ground moraine of till and associated glaciofluvial deposits are the only deposits exposed in the area. The bedrock formations underlie the till and associated glaciofluvial deposits and extend downward to unknown depths in this area. They are recognized in the area in the log of only one well, which was drilled to a depth of 3,872 feet but did not reach the basement complex of igneous rocks. It is believed that rocks of Paleocene, Cretaceous, and Jurassic ages were penetrated in this test hole.

Hydrologic Concepts

Essentially all ground water of economic importance is derived from precipitation. The water may either enter the ground by direct penetration of rain or melted snow or percolate to the ground-water body from streams, lakes, or ponds.

Practically all ground water is in process of movement through the ground from a place of intake or recharge to a place of disposal or discharge. The rate of movement may be different in different areas, but velocities of a few tens to a few hundreds of feet a year probably are most common under natural conditions.

Discharge of the ground water may occur by direct evaporation from the soil surface or from lakes and ponds, by transpiration of plants in areas where the ground-water level is at or near the surface, and by seepage to streams. In some places where the physical situation is suitable, water may discharge from one ground-water reservoir to another by slow percolation through the separating formations.

Any rock formation or stratum that will yield water to wells in sufficient quantity to be of importance as a source of supply is called an "aquifer" (Meinzer, 1923, p. 52). The water moving in an aquifer from recharge areas to discharge areas may be thought of as being in "transient storage" in the ground. The amount of water that can be thus stored in an aquifer is dependent upon the porosity of the material composing the aquifer and upon the volumetric dimensions of the aquifer as a whole.

The capacity of a rock to yield water by gravity drainage may be much less than would be indicated by its porosity because part of the water may be held in the pore spaces by molecular forces between the water and the rock materials. The volume of water that will drain by gravity from a unit of the saturated rock material expressed as a percentage of the volume of the rock, is called the "specific yield."

If the water in an aquifer is not confined by impermeable strata above, the water is said to occur under water-table conditions. In this case, water may be obtained from storage in the aquifer by lowering the water level, as in the vicinity of a well being pumped which results in gravity drainage.

If water is confined in the aquifer by an overlying impermeable stratum, however, so that the water in a well or other conduit penetrating the aquifer rises above the top of the aquifer under hydrostatic pressure, the water is said to occur under artesian conditions. In this case, if ideal artesian conditions prevail, water is yielded as the water level in the well is lowered, but the aquifer remains saturated and the water is yielded because of its own expansion and the compression of the aquifer due to lowered pressure, rather than by gravity drainage. The water-yielding capacity is called the "coefficient of storage" and is generally very much smaller than the specific yield of the same material when drained by gravity. The coefficient of storage is defined as the volume of water that will be released from storage in each vertical column of the aquifer having a base 1 foot square, when the artesian water level falls 1 foot.

If the pore spaces are large and interconnected, as they commonly are in sand and gravel, the water is transmitted more or less freely, and the rock is said to be permeable, but if the pore spaces are very small or not connected, as they are in clay, the water is transmitted very slowly or not at all, and the rock is said to be impermeable.

The unconsolidated alluvium such as sand and gravel is generally more permeable than consolidated rocks and, therefore, generally is more important as a ground-water reservoir. In some areas, however, the consolidated rocks are highly permeable and function as important reservoirs.

The permeability of a rock may be expressed by the "coefficient of permeability" which is defined in laboratory use as the number of gallons of water that will pass in 1 day through a cross section of the aquifer of 1 square foot under a hydraulic gradient of 100 percent at a temperature of 60°F. It also may be defined in field use as the number of gallons of water that will pass in 1 day through a strip of the aquifer 1 foot high and 1 mile wide under a hydraulic gradient of 1 foot per mile under conditions prevailing in the field.

The "coefficient of transmissibility" is convenient to use in ground-water studies because it indicates characteristics of the aquifer as a whole rather than of small sections. It is the average permeability of the aquifer multiplied by the saturated thickness.

Alluvial Deposits

The alluvial deposits in the valleys of the intermittent streams and in the connecting spillways are the only source of ground water of reasonably good quality in the Mohall area. Figure 2 shows the principal occurrences of these deposits as they have been determined from preliminary data obtained from the Geologic Division of the U. S. Geological Survey and modified to some extent on the basis of recently published topographic maps of the area and the test drilling done in the present investigation. The deposits consist of materials which range in size from clay to sand and gravel which may be present in almost any proportion. Beds of relatively clean sand and gravel occur as somewhat discontinuous lenses along the streams and are somewhat separated by less permeable materials such as silty or clayey sand or clayey silt. The thicker sand and gravel beds are the best potential aquifers. In much of the area the alluvial deposits shown on figure 2 do not have sufficient thickness to be important as sources of ground water.

The lack of continuity in the sands and gravels, both along the streams and vertically, probably is due to the varying conditions of sedimentation during late Pleistocene time. Some of the streams and spillways probably carried water away from melting blocks of ice that were more or less isolated from the main mass of the glacier. The resulting outwash deposits probably were reworked later or were covered over. In some places, ice-contact deposits may have been formed in the channels and later covered or reworked. Also, the supply of water from the melting ice probably was varied, according

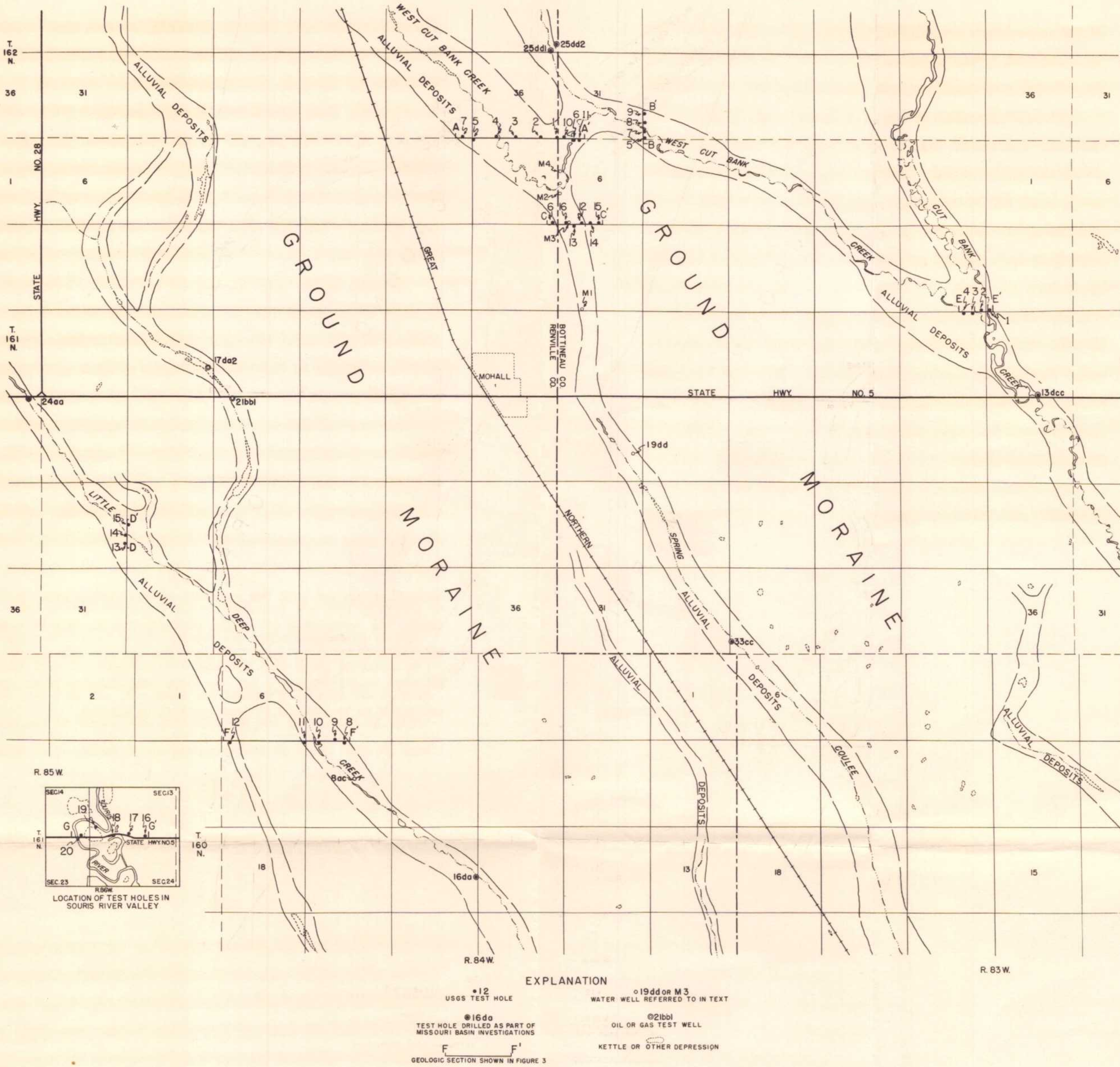

FIGURE 2.— MAP OF MOHALL AREA SHOWING GEOLOGY, TEST HOLES, AND SELECTED WELLS

to the temperatures from season to season and from year to year. This variation in the supply of water from the ice would result in the deposition of materials of variable size.

Sediment deposition in the channels probably has been continuous from late Pleistocene time to the present, taking place principally during the spring runoff. The bodies of standing water in the valleys act as small basins for lacustrine sedimentation, and the irregular profiles of the stream bottoms may constitute a series of pockets or baffles which largely prevent extensive downstream migration of the coarser materials.

Because these aquifers are not widely distributed throughout the area, only a small number of the farms obtain water supplies from them. However, the municipal water supply of the town of Mohall is obtained from these deposits and much water for rural domestic use is hauled from the Becker well, (160-84-8ac) which also is dug in the alluvial deposits.

Significant amounts of recharge to the aquifers may occur through the direct penetration of water during the heavier rains, especially in the spring or the fall when evaporation rates are low, but probably little if any water is contributed to the aquifers by light summer rains. Water is contributed to these aquifers also by lateral movement into the valleys from the till and associated glaciofluvial deposits through the processes of natural subsurface drainage of the upland areas. However, the most important recharge to these aquifers occurs during the spring runoff period when substantial surface flows may result from the melting of the accumulated winter snows. During this period much more water generally is available than can be absorbed by the aquifers and part of the surface runoff may be thought of as "rejected recharge", or water that would have been absorbed by the aquifers if they had not been saturated.

The water absorbed by the aquifers may be thought of as being in "transient storage". Natural disposal processes are constantly removing the water from the aquifers so that they would eventually dry up entirely if not replenished from time to time. Natural disposal results from downstream underflow of the water in the aquifers to lower parts of the valleys and eventually to the permanent streams. Some of the valleys contain long stretches of open water that is perennial, and a considerable amount of water is evaporated from these areas. Evaporation and transpiration also remove a considerable amount of water from marshy areas in the stream valleys.

Much of the test drilling done in the Mohall area was directed exclusively toward the determination of the character and thickness of the alluvial deposits. Geologic sections across the stream valleys at various locations in the area were prepared from the data obtained and are shown in figure 3.

Spring Coulee

The present municipal water supply for the town of Mohall is obtained from four large-diameter dug wells located in Spring Coulee near its junction with West Cut Bank Creek northeast of town (see fig. 2). The wells are connected by pipeline so that water may be pumped from wells M2, M3, and M4 to well M1, from whence it is pumped to the pressure tank in town. Well M1 does not produce much water and serves principally as a small collecting basin for the water pumped from the other wells. During October 1948, most of the water for the town was pumped from well M2 and short pumping tests were made on wells M3 and M4.

Well M3, 15 feet deep and 10 feet in diameter, was pumped about 3 hours at a rate of about 100 gallons a minute with a resultant drawdown of 5.03 feet. The water level before pumping was 6.70 feet below land surface so that the total depth of water in the well was only a little more than 8 feet.

Well M4, 16 feet deep and 10 feet in diameter, was pumped about 16 hours at an average rate of 41 gallons a minute with a resultant drawdown of 3.16 feet. The water level before pumping was 8.58 feet below land surface so that the total depth of water in the well was only about 7½ feet.

The data obtained from these tests were analyzed for the coefficient of transmissibility by the modified nonequilibrium formula (Cooper and Jacob, 1946, pp. 526-534), but it was recognized that the conditions under which the tests were made differed considerably from the ideal conditions assumed in the derivation of the formula. Corrections were made where possible but the results should be considered to reflect only the magnitude of the coefficient. On this basis, the coefficient of transmissibility for the test on well M3 was found to be about 6,000 gallons a day per foot and that for well M4 about 20,000 gallons a day per foot. The specific yield was estimated to be about 0.25 from the test on well M3.

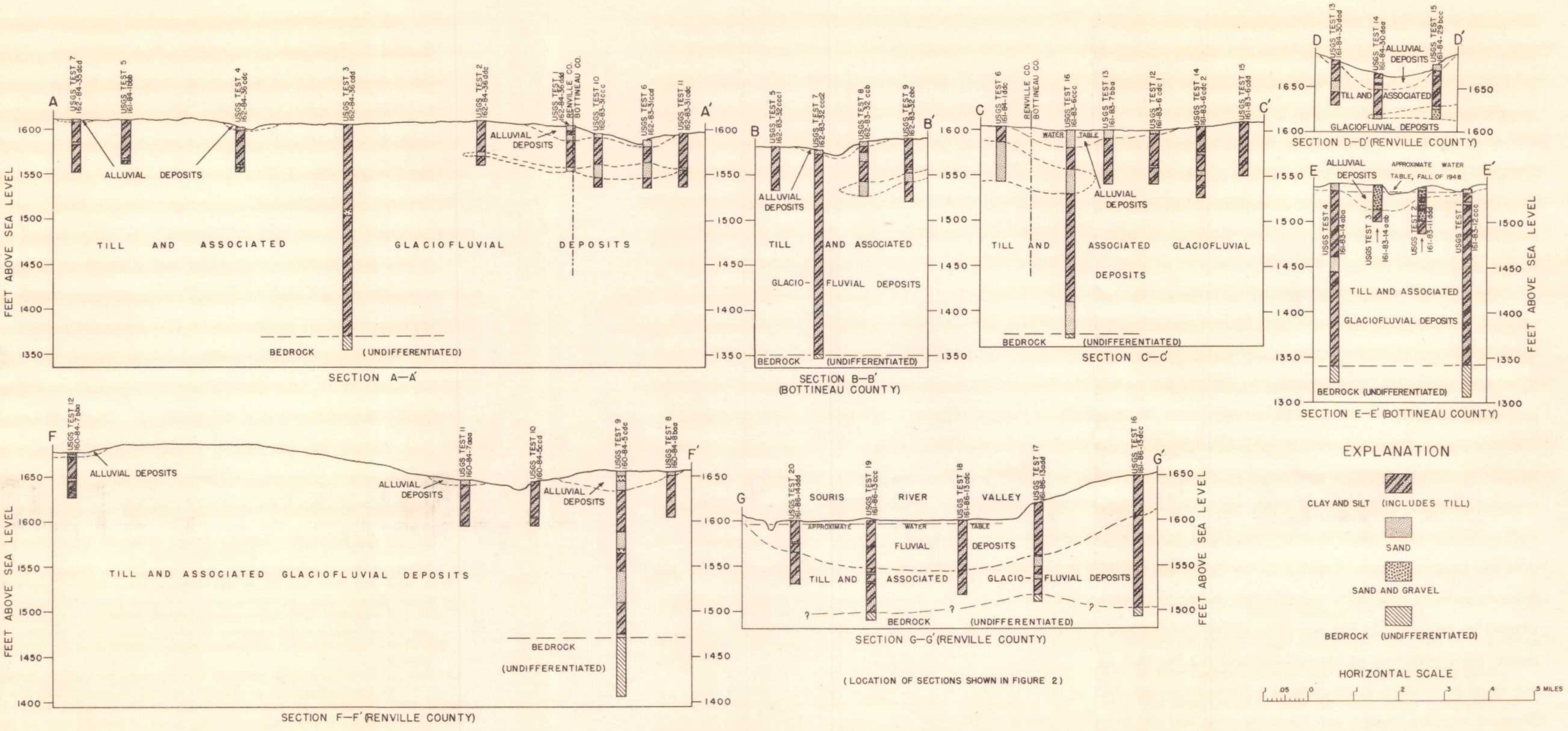

FIGURE 3.—GEOLOGIC SECTIONS IN THE MOHALL AREA AND IN THE SOURIS RIVER VALLEY WEST OF MOHALL

15644

Section A-A' was drilled across Spring Coulee and west along the section line about three-eighths of a mile north of well M4 and section C-C' was drilled across the same stream about 1 mile south along the section line by well M3 (see figs. 2 and 3). No substantial thickness of gravel was found in the alluvial deposits in these test holes. The only material in the alluvial deposits in these sections that can be considered of importance as an aquifer is the upper sand in test hole 16 (Bottineau County). The thickness of saturated material at this test hole is only about 10 feet.

The surface drainage of Spring Coulee in the vicinity of section C-C' is not well defined. There probably is a minor divide at about this location so that normal surface runoff is both to the north and to the south. However, in times of high water the drainage may be all toward the south. The direction of the underground drainage or underflow probably is similar to that of the surface drainage. During the fall of 1948 there were several stretches of open water along Spring Coulee in the vicinity of wells M2 and M4 and northward.

Cut Bank Creek

Cut Bank Creek is the major stream in the area and from most standpoints its alluvial deposits hold the most promise for the development of moderately large perennial ground-water supplies. The stream valley in some places is more than a mile wide, and its head is many miles north of the Mohall area in Canada. Much of its length in the area is occupied by stretches of open water that, according to residents, have never been dry.

The results of test drilling across this stream are shown in section E-E', figure 3. In this section USGS test 3 (Bottineau County) penetrated 27 feet of alluvial deposits of which 20 feet was saturated sand and gravel. This is the greatest thickness of these deposits found anywhere in the area, as well as the greatest saturated thickness.

The cross-sectional area of the alluvial deposits shown in section E-E' is about 15,000 square feet. The average slope of the stream floor and the water table over a length of several miles is about 2 feet per mile. Assuming an average permeability of 1,000 gallons a day per square foot for the saturated material, a cross-sectional area of 15,000 square feet and a slope of 2 feet per mile at section E-E', the underflow across this section would be $\frac{15,000}{5,280}$ X 1,000 X 2 = about 5,700 gallons a day. Assuming a specific yield of 0.25 and the section described above, the amount of water stored in a 1-mile length of stream can be computed as 15,000 X 5,280 X 7.5 X 0.25 = about 150 million gallons.

A use of 75,000 gallons a day, which it is estimated would be required for a satisfactory water supply for Mohall, would amount to about 27 million gallons a year, or only about 18 percent of the amount of water estimated to be in storage in a 1-mile length of stream.

It is believed that a water supply satisfactory for the present and probable future needs of the town of Mohall can be developed from the alluvial deposits in Cut Bank Creek. It should be apparent from the foregoing estimates that most of the water used would be taken from local storage and the perennial adequacy of such a supply would depend upon the seasonal replenishment of the water. It is probable that more than one well would be required for satisfactory operation of the water-supply system and an arrangement of several wells similar to the present well field in Spring Coulee might be desirable. Instead of wells, some type of infiltration system or collectors might be used to advantage in connection with developments in these deposits.

It should be noted that the test hole (Missouri-Souris 161-83-13dcc) drilled on the west side of the stream channel 1 mile south of section E-E' penetrated 13 feet of alluvial deposits, of which 12 feet was sand and gravel. The thickness of saturated alluvium at this location is probably about 8 or 9 feet.

West Cut Bank Creek

Four test holes were drilled across West Cut Bank Creek along the section line 1 mile east of the present Mohall town wells. The results of this drilling are shown in section B-B', figure 3. The alluvial deposits penetrated there were thin and of little or no importance as aquifers.

Two test holes (Missouri-Souris 162-84-25dd1 and 25dd2) drilled in West Cut Bank Creek, penetrated 5 feet and 6 feet of alluvial deposits, respectively.

Little Deep Creek

Two sections (D-D' and F-F') were drilled across Little Deep Creek in the southwestern part of the area and the results of this drilling are shown in figure 3. USGS test 9 (Renville County) penetrated 20 feet of alluvial deposits consisting principally of sand and gravel. However, all this material is higher than the bottom of the Creek Valley and the thickness of saturated material is probably not more than one-fourth of the total thickness. Estimates based on the thickness of saturated materials at the Becker well (160-84-8ac), located in the same deposit about one-fourth mile south of the test hole, would place the saturated thickness of these deposits at about 3 feet.

In USGS test 14 (Renville County), 17 feet of alluvial deposits were found. The material in the lower 6 feet of this hole was sand and gravel. The hole was drilled near the lowest part of the stream valley and the saturated thickness of material is probably about 10 feet. Because of its limited width and the heterogeneous character of the deposits, this aquifer is not considered suitable for the development of moderate to large supplies. However, it should be suitable for the development of individual farm supplies.

A test hole (Missouri-Souris 161-85-24aaa) drilled in Little Deep Creek along State Highway 5 penetrated 11 feet of yellow clay containing gravel and boulders (probably till) from 1 to 12 feet and then 6 feet of sand and gravel. These materials probably are till and associated glaciofluvial deposits rather than alluvial deposits.

Use of Underground Cut-Off Structures

Some consideration has been given to the possibility of utilizing cut-off structures of some type across the streams in order to stop the normal ground-water underflow along the streams and thus increase the amount of ground water that would be available to wells located upstream from the structures. A specific example that has been considered is a cut-off across Spring Coulee just south of the present Mohall supply wells with a view to increasing the supply that would be available to the wells, especially during the drier years when the water levels are lowest and water demands greatest.

Such cut-off structures would not conserve water in excess of the natural underflow along the streams. In view of the estimate of approximately 6,000 gallons a day as the probable natural underflow along Cut Bank Creek in the area east of Mohall, this probably is the maximum amount of water that possibly could be conserved by any single structure. Because the underflow along Spring Coulee and the other streams in the area is much less than along Cut Bank Creek, it is likely that not more than 2 to 3 thousand gallons a day could be conserved by cut-off structures in these streams. If a series of cut-offs were used along the same stream, it probably would not be efficient to construct them closer than about 2 miles because of the low gradients of most of the streams.

Actually, there may be a ground-water divide in Spring Coulee in the vicinity of well M1 so that normal ground water flow in this part of the stream may be to the north. If this is the case, the construction of cut-off structures in this section might diminish the supply now available to the wells to the north.

Any rise in water level that would result from the use of the cut-off structures would increase the amount of water subject to evaporation and transpiration by plants, and it is possible that the increased waste of water in this manner might offset entirely any benefits that would be expected to result from the cut-offs.

The construction of dams of sufficient capacity to catch and store the spring surface runoff would be effective on some of the streams and might provide dependable supplies. The feasibility of such structures would have to be considered in the light of construction costs, storage demand, damage to areas that would consequently be flooded or waterlogged, evaporation and other water losses, and the amount of water available for storage from surface runoff.

Till and Associated Glaciofluvial Deposits

In the Mohall area the till with its associated glaciofluvial material is the surface deposit except where it is covered by the alluvial deposits in the stream valleys.

The till is a heterogeneous mixture of materials ranging in size from clay to boulders and lacking stratification. The till in this area is not an aquifer as it is composed principally of clay and silt. Glaciofluvial deposits consisting of sorted materials are included in or are otherwise associated with the till. These deposits vary considerably in thickness, extent, and degree of sorting and thus form aquifers of varying degrees of importance. Aquifers of this type are of great economic importance as sources of stock and domestic water supplies throughout the glaciated area in North Dakota, some of them yielding several thousand gallons of water a minute to wells.

In the Mohall area the till and associated glaciofluvial deposits do not constitute an important aquifer. Fewer than half a dozen wells in the entire area are known to obtain water from these deposits.

The thickness of the till and associated glaciofluvial deposits ranged from 164 to 250 feet in 10 test holes, drilled by the U. S. Geological Survey, that completely penetrated the deposit. The log of the J. C. Fisher well (161-83-19dd), reported by Simpson, indicates a thickness of 320 feet of the deposit at that location. On the other hand, the log of the A. R. Jones Oil & Operating Co. well no. 1 (161-84-17da2) indicates a thickness of only 65 feet and the log of the Great American Gas & Oil Co. well no. 5 (161-84-21bb1) indicates a thickness of 75 feet for the deposit (see logs, pp. 58, 61-63).

Of an aggregate thickness of 3,377 feet of the deposit encountered in 35 test holes, about 12 percent consisted of sorted materials but only 2 percent contained sorted material composed predominantly of sand and gravel.

The occurrence of glaciofluvial deposits encountered during the test drilling are shown in figure 3 and more detailed information is given in the well logs.

The upper glaciofluvial deposits shown in sections A-A', B-B', and C-C' were thought to be potential sources of ground water for municipal or light industrial use because the deposits probably are connected, thus forming a rather extensive, though thin, aquifer. Also, the deposits are sufficiently near the surface to receive a significant amount of recharge through the thin till cover. However, subsequent to the Geological Survey test drilling, three other test holes were drilled near USGS test 6 (Renville County) and USGS test 16 (Bottineau County) by a private driller, who reported that water in any practical quantity could not be developed from the glaciofluvial deposits encountered. A test well was drilled also near USGS test 6 (Bottineau County, section A-A') with similar results.

Several other glaciofluvial deposits greater than 10 feet in thickness were encountered and these are shown in figure 3 or are described in the well logs. The greatest single thickness of these materials was found in USGS test 9 (Renville County, section F-F'). These occurrences are not considered potential sources of permanent municipal or industrial supplies because they are likely to be of slight areal extent and the great thicknesses of the relatively impermeable overlying till make seasonal recharge to them practically impossible. Certainly these deposits should be thoroughly explored by wells and exhaustive pumping tests before any very expensive developments are undertaken that depend upon them as sources of water.

Souris River Valley Deposits

Five test holes were drilled in the Souris River valley along State Highway 5 west of Mohall. These holes were drilled to determine whether materials similar to those composing the productive aquifer at Minot, N. Dak. (Akin, 1947), were present in the Souris River valley near Mohall. The results of this test drilling are shown in section G-G', figure 3, and the materials penetrated are described in the well logs.

As much as 58 feet of fluvial sediments was encountered in the valley but practically all the material is clay and silt. Only a few thin layers of sand or coarser material were found in the fluvial sediments and the underlying till. No indication of a deep preglacial valley or other "low" in the underlying bedrock was found. Similar conditions were found in test holes 162-86-28cc and 159-85-10ac, which were drilled in the Souris River valley as part of the Missouri Basin ground-water studies (Waring and LaRocque, 1949).

Bedrock Formations

At least 50 percent of all the farm water supplies in the Mohall area are obtained from wells in the bedrock formations underlying the till and associated glaciofluvial deposits. The shallowest occurrence of bedrock reported in the area is at the location of the A. R. Jones Oil & Operating Co. well no. 1 (161-84-17da2) where it reportedly was reached at a depth of 65 feet. In the Great American Gas & Oil well no. 5 (161-84-21bb1) bedrock reportedly was reached at a depth of 75 feet. However, the least depth to recognizable bedrock found in any of the USGS test holes in the area was 184 feet in test hole 160-84-5cdc. The greatest depth to bedrock in the USGS test holes was 250 feet in test hole 161-85-24aa, but a depth of 320 feet was reported in the J. C. Fisher well (161-83-19dd). Farm wells in the area are as much as 652 feet deep.

The bedrock in the area probably is either the Tongue River member of the Fort Union formation or the Ludlow member of the Fort Union (or its stratigraphic equivalent, the Cannonball formation). Simpson (1929, p. 201) states that the Pierre shale forms the bedrock surface in the eastern part of Renville County but this formation was not encountered in the USGS test holes drilled in the area. According to Waring and LaRocque (1949, p. 39) an "indication that the Cannonball formation underlies the Pleistocene deposits in much of the eastern part of the area (Crosby-Mohall area) is the widespread distribution of ground water containing chlorides ranging from 1,000 to 4,000 parts per million." Additionally, the Cannonball formation crops out near Velva, Sawyer, and Grano, N. Dak. "Some consideration should also be given to the possibility that the Hell Creek (Lance) formation and Fox Hills sandstone are producing aquifers within the Crosby-Mohall area."

The following table shows the formations underlying the Mohall area to a depth of 3,872 feet, as determined by Dr. Virginia H. Kline (1942, pp. 368-369) from a study of the A. R. Jones Oil & Operating Co. well no. 1 (161-84-17da2).

Formation	Thickness (feet)	Depth (feet)
Drift	65	65
Fort Union	207	272
Lance	218	490
Fox Hills	110	600
Pierre	1,820	2,420
Niobrara	180	2,600
Benton	600	3,200
Dakota	40	3,240
Fuson	30	3,270
Lakota	70	3,340
Jurassic formations, undifferentiated	532	3,872
	Total depth	3,872

All the formations above the Pierre shale are important aquifers in different areas in North Dakota. Water is yielded from sand or sandy strata and from lignite beds. A number of municipalities obtain water supplies of satisfactory quantity from these formations but, as the peremability varies greatly from one area to another, some towns have been unable to obtain sufficient water. The water from the bedrock is generally highly mineralized, as it is in the Mohall area (see table of chemical analyses). It is possible that a sufficient quantity of water to supply the town of Mohall could be obtained from one or more wells in these bedrock formations but the potential yield can be determined only by constructing a well, properly screened, gravel-packed if necessary, and making pumping tests or by making extensive permeability tests on undisturbed core samples. In any event, the water is highly mineralized and probably would not be suitable for most domestic purposes.

In the east-central part of the State, the Pierre shale yields small supplies of water to farm wells but none of these wells is known to be capable of producing more than 10 to 15 gallons a minute. Fairly good water is found in the upper parts of the shale in these areas but water encountered at depth is generally highly mineralized and unfit for domestic uses.

The Pierre shale generally is not considered to be an aquifer and it is doubtful that significant amounts of water could be obtained from this formation in the Mohall area. However, water was reported in the A. R. Jones Oil & Operating Co. well no. 1 (161-84-17da2) at depths of 815 to 820 feet and about 900 feet. The following is quoted from an unpublished report by E. J. Thomas, Field Engineer, Federal Emergency Relief Administration, to Howard E. Simpson, State Geologist:

> Mr. J. P Dougherty, a well driller who put down the water well for operating the well drilling outfit at the Jones well informs me that at a depth of 815 to 820 feet at the oil well a flow of water was obtained. The water was not salty. The information in the log does not show this to be the case.
>
> Mr. Percy Clark, who was the attorney for the Jones Company when putting down the well and was at the well many times when being put down, told me that he remembers of water being obtained at about 900 feet. The log shows nothing of this***

No wells in North Dakota are known to obtain water from the Niobrara formation or the Benton shale, and they are therefore considered to be, for all practical purposes, not water bearing.

The possible equivalents of the Fall River sandstone, the Fuson shale, and the Lakota sandstone constitute collectively the aquifer or aquifers generally referred to as the "Dakota sandstone." This formation is most widely used as a source of water supply in the south-central part of the State. A few wells in the central part, as at Devils Lake and Leeds, obtain water from the "Dakota sandstone." In the western part of the State it has been considered uneconomical to drill to it for water supplies. The water is highly mineralized everywhere in the State but is used for municipal, domestic, and stock supplies in the south-central part. At Devils Lake and Leeds the water generally is not used for domestic purposes.

The report by E. J. Thomas to Howard E. Simpson cited above gives the following statement regarding the water from the "Dakota" sandstone as encountered in the A. R. Jones Oil & Operating Co. well no. 1:

At the time of my first visit to Mohall in connection with this survey, it was reported that an abundant yield of good water was obtained at a considerable depth when putting down the Jones Oil which is $3\frac{1}{2}$ miles west of Mohall. In order to definitely determine as to what depth this water was found, the A. R. Jones Company of Kansas City were asked to send a log of the well. This log was received within a few days. The log shows that this water was encountered at a depth of 3,330 feet*** No chemical analysis of this water was made. I have interviewed Mr. J. B. Bennet and Mr. Jesse Powell who drank the water and tested the water as to softness by the use of soap. They report to me that the water was of good taste and soft. The water came up in the casing close to the surface of the ground***

At Devils Lake an average of about 350,000 to 400,000 gallons of water a day is obtained from the "Dakota sandstone" through several wells, and it is probable that sufficient water for present municipal and other needs can be obtained from this aquifer in the Mohall area.

No wells in North Dakota are known to obtain water from the Jurassic formations and nothing is known of either their water-bearing characteristics in the Mohall area or the quality of the water that might be obtained. However, considering the log of the oil test below 3,340 feet and the general unsatisfactory quality of the deeper ground water in the State, it seems unlikely that either an adequate or satisfactory water supply for municipal and domestic use could be obtained from these formations in the Mohall area.

QUALITY OF GROUND WATER IN THE MOHALL AREA

In order that the reader may more easily understand the significance of the chemical analyses, the following partial list of chemical standards recommended by the U. S. Public Health Service, for water used in interstate commerce, is given:

Chemical constituent	Maximum concentration permitted (parts per million)
Dissolved solids	500 (1,000 permitted if necessary)
Chloride (Cl)	250
Sulfate (SO_4)	250
Magnesium (Mg)	125
Fluoride (F)	1.5
Iron and manganese	.3

Presence of nitrate in ground water may indicate organic contamination. Also, water containing more than 45 parts per million of nitrate (Comly, 1945; Silverman, 1949) should not be used in the feeding of infants, because of the danger of infant cyanosis (methemoglobinemia) resulting in the so-called blue baby.

The presence of fluoride in drinking water in excess of 1.5 parts per million may cause mottling of the enamel of teeth in young children, but fluoride in concentrations less than 1 part per million is beneficial in the development of the teeth.

In the Mohall area, the most suitable water for general purposes is obtained from the shallow alluvial deposits in the stream valleys. Of the seven samples analyzed, the highest concentration of dissolved solids was 1,240 parts per million and the lowest concentration was

317 parts. The iron content was high in two samples but not objectionably high in the others. The water is somewhat harder than is desirable for domestic purposes but this objectionable feature could be overcome by treatment. Nitrate was present in all samples analyzed for this constituent and was excessively high in two samples. This may indicate organic contamination, and care should be taken to see that the water is properly sterilized before being used for drinking purposes. Sterilization would destroy any pathogenic bacteria present but would not reduce the amount of nitrate or lessen the possible harmful effects due to high-nitrate concentrations.

No water samples were taken from wells known to obtain water from the till and associated glaciofluvial deposits. The water from these aquifers is likely to be considerably more highly mineralized than the water from the alluvial deposits.

In the following table are given chemical analyses of 55 samples of water that were obtained, insofar as is known, from wells in the bedrock formations. Most of these analyses were made by the Quality of Water Branch of the U. S. Geological Survey as part of the water-resources investigation in the Missouri River basin.

Location number	Owner or name	Date of collection	Source of analysis 1/	Depth of well (feet)	Specific conductance (micromhos/cm)	Dissolved solids
160-83-4ba	Andrew Bjork	10-23-47	a	297	7,170	–
160-83-5cb	J. Tally	10-23-47	a	265	5,310	–
160-83-8cd	Emery Blowers	10-23-47	a	246	6,230	–
160-83-17bal	C. A. Gillstraph	10-23-47	a	260	6,800	–
160-83-17cc	Geo. Blowers	10-23-47	a	260	6,160	–
160-83-18aa	T. Blowers	10-23-47	a	300	4,610	–
160-83-19bb	Elden Otto	10-23-47	a	350	3,800	–
160-84-3aa	R. B. May	10-21-47	a	400	4,880	–
160-84-7cc	Murray Bros.	10-22-47	a	375	5,620	–
160-84-8ac	Becker	11-23-48	b	6	–	320
160-84-9bb	Bryan Miller	10-21-47	a	280	3,190	–
160-84-10bc	Grant May	10-22-47	a	300	3,250	–
160-84-14dc	Edward Sanders	10-21-47	a	600	3,790	–
160-84-16da	USGS test	10-24-47	a	270	6,730	–
160-84-17aa	R. McLain	10-21-47	a	400	8,740	–
160-84-21bb	Lynn Overholster	10-21-47	a	–	7,200	–
160-85-2dbl	A. H. Trutna	10-21-47	a	540	10,400	–
160-85-13bb	John Townsend	10-22-47	a	320	3,190	–
160-85-23ad	Robert Burbidge	10-21-47	a	–	5,540	–
161-83-7cdc 6cbc	Town of Mohall (Composite of wells M1 and M2)	10-20-48	b	20 and 22	–	522
161-83-6bcb	Town of Mohall (M4)	10-14-48	b	17½	4,130	764
161-83-6cbc	Town of Mohall (M2)	1921	c	22	–	359
161-83-6ccd	Town of Mohall (M3)	10-19-48	b	16	3,170	542
161-83-8cd	G. Herrigstad	7-30-47	a	350	5,960	–
161-83-9bh	Carl Crougan	7-30-47	a	375	5,440	–
161-83-9cd	A. Halvorson	7-30-47	a	360	8,380	–
161-83-13cd	J. Reed	10-23-48	b	13	6,670	1,240
161-83-14cc	Whitteman	7-30-47	a	325	9,120	–
161-83-17ad	Marrias Aune	7-30-47	a	453	10,000	–
161-83-17da	O. Solemsaus	7-30-47	a	365	7,560	–
161-83-18cc	Haugan	9-8-47	a	340	5,710	3,240
161-83-20bb	Wortz Jahansen	7-30-47	a	380	4,610	–
161-83-21ab	E. Salvey	7-30-47	a	–	5,170	–
161-83-25bb	Charles F. Adams	8-13-47	a	300	6,000	–
161-83-30bb	J. C. Fischer	7-30-47	a	417	6,910	–
161-83-33ba	Ernest Martins	7-30-47	a	350	5,250	–

1/ See footnotes at end of table.

WATER IN THE MOHALL AREA,
COUNTIES, N. DAK.
million)

Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$
-	-	-	-	98	350	-	2,330	-	-
-	-	-	-	59	215	-	1,680	-	-
-	-	-	-	98	325	-	1,920	-	-
-	-	-	-	84	335	-	2,150	-	-
-	-	-	-	80	350	-	1,900	-	-
-	-	-	-	89	573	-	1,200	-	-
-	-	-	-	128	610	-	900	-	-
-	-	-	-	69	450	-	1,460	-	-
-	-	-	-	84	395	-	1,670	-	-
0.28	42	22	12	19	203	15	6	2.2	196
-	-	-	-	20	440	-	645	-	-
-	-	-	-	79	385	-	655	-	-
-	-	-	-	89	670	-	940	-	-
-	-	-	-	0	515	-	7	-	-
-	-	-	-	59	275	-	3,100	-	-
-	-	-	-	49	330	-	2,400	-	-
-	-	-	-	74	160	-	3,660	-	-
-	-	-	-	30	370	-	608	-	-
-	-	-	-	79	465	-	1,660	-	-
.13	93	39	30	0	341	157	10	Trace	391
.05	148	49	31	0	326	311	6	4.3	570
.11	71	28	d/ 11	-	281	66	4	1.0	292
.15	84	46	-	0	276	97	10	13	397
-	-	-	-	49	480	-	1,760	-	-
-	-	-	-	16	520	-	1,590	-	-
-	-	-	-	0	420	-	2,770	-	-
.95	84	54	82	0	255	97	90	325	430
-	-	-	-	22	320	-	3,080	-	-
-	-	-	-	0	330	-	3,570	-	-
-	-	-	-	20	390	-	2,390	-	-
.15	22	5	1,220	-	470	6	1,720	5.0	75
-	-	-	-	49	660	-	1,200	-	-
-	-	-	-	16	600	-	1,460	-	-
-	-	-	-	0	635	-	1,760	-	-
-	-	-	-	0	610	-	2,100	-	-
-	-	-	-	24	640	-	1,480	-	-

Location number	Owner or name	Date of collection	Source of analysis 1/	Depth of well (feet)	Specific conductance (micromhos/cm)	Dissolved solids
161-84-3dd	Peter Nelson	6-15-47	a	343	6,050	3,380
161-84-4bb1	George Strandberg	7-3-47	a	492	11,200	-
161-84-5ab	John Newstrom	7-2-47	a	492	8,880	-
161-84-9aa	Clifford Co.	7-2-47	a	-	6,980	-
161-84-12cd	O. Witteman	7-3-47	a	-	5,680	-
161-84-12da	Frank Gehringer	7-30-47	a	294	7,410	-
161-84-13cd2	F. Paris	1934	d	343	-	2,690
161-84-14db1	George Barcus	7-30-47	a	375	5,740	-
161-84-15dd	J. Southam	7-3-47	a	270	6,040	-
161-84-16dd	John Moberg	7-3-47	a	-	7,100	-
161-84-17aa1	Lloyd Horner	8-14-47	a	500	4,850	-
161-84-18cd	Wendel Bohen	7-30-47	a	390	9,390	-
161-84-21bb2	Burduik	7-3-47	a	350	6,450	-
161-84-22aa	D. Gehringer	7-3-47	a	300	5,570	-
161-84-28dd	Swartz	7-30-47	a	300	3,970	-
161-84-29aa	LeRoy Allen	7-30-47	a	-	7,750	-
162-83-8cc	Roy Brockelsberg	10-23-48	b	16	5,240	984
162-83-26dc1	R. Sherer	8-14-47	a	385	8,250	-
162-83-32dc1	Harold Ring	7-30-47	a	-	9,120	-
162-83-35da	A. J. Skeaden	8-14-47	a	372	9,650	-
162-84-28cc	Roy Eldred	7-3-47	a	418	6,290	-
162-84-31bb1	Shoenberg	7-3-47	a	370	9,740	-
162-84-32ad1	Jesse Powell	7-3-47	a	350	9,740	-
162-84-32ba1	Albert Keup	7-3-47	a	388	7,370	-
162-84-32dd2	Alfred Newstrom	7-3-47	a	364	8,880	-
162-84-33cd	A. H. Trutna	7-3-47	a	400	11,200	-

1/ Explanation of symbols:

a, Waring, G. A., and LaRocque, G. A., Jr., Progress report on the geology and ground-water hydrology of the lower Missouri-Souris unit; Part I., Crosby-Mohall area, N. Dak.: U. S. Geol. Survey manuscript report, February 1949.

b, North Dakota State Department of Health, Bismarck, N. Dak.

c, Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, 1929.

d, Abbot, G. A., and Voedisch, F. W., The municipal ground-water supplies of North Dakota: North Dakota Geol. Survey Bull. 11, 1939.

2/ Sodium and potassium.

WATER IN THE MOHALL AREA,
COUNTIES, N. DAK.
million)

Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$
Trace	26	7	1,270	-	539	5	1,780	1.0	94
-	-	-	-	18	265	-	3,740	-	-
-	-	-	-	30	305	-	2,960	-	-
-	-	-	-	49	380	-	2,210	-	-
-	-	-	-	7	390	-	1,760	-	-
-	-	-	-	59	320	-	2,360	-	-
0.3	37	19	2/1,010	-	769	40	1,190	18	177
-	-	-	-	49	540	-	1,670	-	-
-	-	-	-	20	560	-	1,820	-	-
-	-	-	-	7	195	-	2,300	-	-
-	-	-	-	14	860	-	1,220	-	-
-	-	-	-	0	350	-	3,170	-	-
-	-	-	-	12	545	-	1,960	-	-
-	-	-	-	44	605	-	1,600	-	-
-	-	-	-	98	920	-	810	-	-
-	-	-	-	49	520	-	2,450	-	-
.5	132	49	63	0	314	150	34	217	530
-	-	-	-	0	410	-	2,760	-	-
-	-	-	-	8	260	-	3,080	-	-
-	-	-	-	0	375	-	3,420	-	-
-	-	-	-	49	460	-	1,900	-	-
-	-	-	-	22	325	-	3,160	-	-
-	-	-	-	15	280	-	3,300	-	-
-	-	-	-	26	375	-	2,260	-	-
-	-	-	-	24	315	-	2,950	-	-
-	-	-	-	14	285	-	3,710	-	-

The specific conductance may be considered as an approximate index to the total mineralization. In similarly mineralized solutions the specific conductance will be proportional to the total mineralization.

The water from the upper part of the bedrock is highly mineralized, the mineral content varying considerably. The chloride content of the samples analyzed ranges from 608 to 3,740 parts per million and the bicarbonate content, from 160 to 920 parts per million. The specific conductance ranges from 3,190 to 11,200 micromhos per centimeter and may represent total mineralization on the order of 1,500 to more than 6,000 parts per million, respectively, in the waters having high chloride and bicarbonate content.

There are no data regarding the mineralization of the deeper bedrock aquifers in the Mohall area, but the waters are likely to be very highly mineralized. It is not expected that the mineralization of the "Dakota sandstone" water in the Mohall area would be less than that found in the central part of the State, as at Devils Lake and Leeds.

Following are chemical analyses of water from the "Dakota sandstone" in North Dakota.

Chemical analyses of water from the "Dakota sandstone" in North Dakota
(parts per million)
(Analyses from Abbott and Voedisch, 1938, pp. 44-89.)

Chemical constituent	Barnes County Litchville, N. Dak. (well 1,300 ft. deep)	Benson County Leeds, N. Dak. (well 1,670 ft. deep)	Dickey County Ellendale, N. Dak. (well 1,080 ft. deep)	Ramsey County Devils Lake, N. Dak. (well 1,514 ft. deep)	Ransom County Lisbon, N. Dak. (well 920 ft. deep)	Sargent County Cogswell, N. Dak. (well 1,000 ft. deep)
Dissolved solids	2,640	4,290	2,780	3,860	2,800	2,500
Silica (SiO_2)	20	19	28	19	5	19
Alumina (Al_2O_3)	28	7	14	32	9	13
Iron (Fe)	3	1.4	0.5	0.2	0.7	0.05
Manganese (Mn)	0	0	0	0	0	0
Zinc (Zn)	4	2	0	0	2	12
Calcium (Ca)	185	44	29	29	34	26
Magnesium (Mg)	74	14	9.8	12	9.2	7.9
Sodium (Na)	541	1,480	993	1,360	908	815
Bicarbonate (HCO_3)	207	867	591	872	273	315
Sulfate (SO_4)	1,320	1,260	435	1,050	1,320	1,160
Chloride (Cl)	280	950	939	888	352	293
Fluoride (F)	1.4	3.6	3.2	4.0	3.2	4.0
Nitrate (NO_3)	22	31	6.2	1.5	.7	4.4
Total hardness (as $CaCO_3$)	779	173	114	125	136	115

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based upon the location of the well with respect to land-survey divisions. The first number of three digits is that of the township north of the base line. The second number of two digits is that of the range west of the fifth principal meridian. The third number is that of the section within the designated township. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast part of each quarter section, quarter-quarter section, or quarter-quarter-quarter section. If more than one well is within a 10-acre tract (quarter-quarter-quarter section), consecutive numbers are given to them as they are scheduled. This number follows the letters. Thus well 161-83-6cdc1 is in Township 161 North, Range 83 West, section 6. It is in the southwest quarter of the southeast quarter of the southwest quarter of that section and is the first well scheduled in that 10-acre tract. Similarly, well 162-83-32ccb (see USGS test 8, sec. B-B', fig. 3) is in the northwest quarter of the southwest quarter of the southwest quarter of sec. 32, T. 162 N., R. 83 W. Numbers for wells not accurately located within the section in the field may contain only one or two letters after the section number, indicating that the locations of such wells are accurate only to the quarter section or the quarter-quarter section, respectively.

The following diagram, showing the method of numbering the tracts within the section, may be helpful to the reader in determining locations of wells not shown in the illustrations.

<table>
<tr><td>bbb bba
(b)
bbc cbd</td><td>bab baa
(a)
bac bad</td><td>abb aba
(b)
abc abd</td><td>aab aaa
(a)
aac aad</td></tr>
<tr><td colspan="2">b</td><td colspan="2">a</td></tr>
<tr><td>bcb bca
(c)
bcc bcd</td><td>bdb bda
(d)
bdc bdd</td><td>acb aca
(c)
acc acd</td><td>adb ada
(d)
adc add</td></tr>
<tr><td>cbb cba
(b)
cbc cbd</td><td>cab caa
(a)
cac cad</td><td>dbb dba
(b)
dbc dbd</td><td>dab daa
(a)
dac dad</td></tr>
<tr><td colspan="2">c</td><td colspan="2">d</td></tr>
<tr><td>ccb cca
(c)
ccc ccd</td><td>cdb cda
(d)
dcd cdd</td><td>dcb dca
(c)
dcc dcd</td><td>ddb dda
(d)
ddc ddd</td></tr>
</table>

Type of well: B, bored; Dn, driven; Dr, drilled; Du, dug.

Depth to water: Water levels given in feet below land surface; measured water levels given to hundredths or tenths of feet; reported water levels given to feet only.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
160-83-4ba	Andrew Bjork	297	3-2	Dr	....
160-83-5cb	J. Tally	265	4	Dr	....
160-83-8cd	Emery Blowers	246	3-2	Dr	....
160-83-10bc	G. Huss	250	4	Dr	....
160-83-15dd	J. Holmes	250	4	Dr	....
160-83-17aa1	J. H. Gibbs	12	14	B	....
160-83-17aa2	.....do....	285	4	Dr	....
160-83-17ba1	C. A. Gillstraph	260	3-2	Dr	....
160-83-17ba2	.....do.........	9	15	Du	....
160-83-17cc	George Blowers	260	3-2	Dr	....
160-83-18aa	T. Blowers	300	3-2	Du	....
160-83-18cc	B. Robbins	319	...	Dr	....
160-83-19bb	Elden Otto	350	3-2	Dr	....
160-84-1cd1	R. McLain	40	24	B	....
160-84-1cd2	.....do...	20	48	Du	....
160-84-1cd3	.....do...	20	48	Du	....
160-84-2ab1	Milton Armstrong	12	36	Du	....
160-84-2ab2	.....do.........	12	1½	Dn	....
160-84-3aa	R. B. May	400	3-2	Dr	....
160-84-3da	Bascom May	11	36-1½	..	....
160-84-4aa1	Lural Keith	16	40	Du	....
160-84-4aa2	.....do....	...	24	..	....
160-84-4bb	C. Thompson	400	3	Dr	....
160-84-4dd	Clarence Kingsley	275	3-2	Dr	....
160-84-5ad	Harry Hineland	350	3-2	Dr	....
160-84-5ccd	USGS test 10 (R)	50	5	Dr	1948
160-84-5cdc	USGS test 9 (R)	249	5	Dr	1948
160-84-5cd	....	...	1½	Dn	....
160-84-5dc	....	14	40	Du	....

Use of water: D, domestic; O, observation well; P, public water supply; S, stock; T, test hole; U, unused.

Owner or name: (B) and (R) following USGS test hole nos. indicate Bottineau and Renville Counties, respectively.

Depth to water	Date of measurement	Use	Remarks
.....	....	S	See chemical analysis.
30	10-6-47	S	Aquifer reported to be sand. See chemical analysis.
13.38	10-6-47	S	Do.
24.12	10-8-47	S	
.....	....	...	Aquifer reported to be sandstone.
8.40	10-7-45	D,O	
.....	....	...	Do.
12	10-7-47	S	Aquifer reported to be sand. See chemical analysis.
.....	....	D	
.....	....	S	Do.
10	10-6-47	S	See chemical analysis.
.....	....	...	Aquifer reported to be sandstone.
45.94	10-7-47	S	See chemical analysis.
12.90	9-23-47	U	
5.92	9-23-47	U	Aquifer reported to be sand and gravel.
6.36	9-23-47	U	Do.
5.78	9-23-47	S	
.....	....	D	
30	9-23-47	S	Aquifer reported to be sand. See chemical analysis.
.....	....	S	Aquifer reported to be clay and sand.
7.77	9-22-47	S	Aquifer reported to be sand and gravel.
11.16	9-22-47	D	
.....	....	S	Aquifer reported to be sand.
.....	....	S	Do.
.....	....	S	Do.
.....	....	T	Hole filled. See log.
.....	....	T	Do.
.....	....	...	
11.78	9-18-47	S	

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
160-84-6dd	Selmer Erickson	12	$1\frac{1}{2}$	Dn	....
160-84-7aaa	USGS test 11 (R)	50	5	Dr	1948
160-84-7bba	USGS test 12 (R)	50	5	Dr	1948
160-84-7cc	Murray Bros.	375	3-2	Dr	....
160-84-7cd	Marston Fitzgerald	7	48	Du	....
160-84-8ac	Becker	6	84	Du	....
160-84-8baa	USGS test 8 (R)	50	5	Dr	1948
160-84-8da	Lynn May	11	40	Du	....
160-84-9bb	Bryan Miller	280	3-2	Dr	....
160-84-9cd1	Marvin Iverson	16	$1\frac{1}{2}$	Dn	....
160-84-9cd2	.....do.......	15	$1\frac{1}{4}$	Dn	....
160-84-10bc	Grant May	300	3	Dr	....
160-84-12ba1	R. McLain	14	36	Du	....
160-84-12ba2	.....do....	...	40	Du	....
160-84-13aa	....	265	5	Dr	....
160-84-14dc	Edward Sanders	600	3-2	Dr	....
160-84-16da	USGS Missouri-Souris test	270	4 3/4	Dr	1947
160-84-17aa	R. McLain	400	3-2	Dr	....
160-84-19aa	....	...	18	B	....
160-84-21aa1	Lee Miller	10	48	Du	....
160-84-21aa2	.....do.....	10	48	Du	....
160-84-21bb	Lynn Overholster	...	...	..	....
160-84-22bb	M. Solor	8	37	Du	....
160-84-24ab	Roy Otto	15	48	Du	....
160-85-1cd	....	...	4	Dr	....
160-85-2db1	A. H. Trutna	540	$4-2\frac{1}{2}$	Dr	....
160-85-2db2	....	380	4	Dr	....
160-85-11dd	....	...	3	Dr	....
160-85-12cc	R. S. Wright	25	24	Du	....
160-85-13bb	John Townsend	320	3-2	Dr	....
160-85-23ad	Robert Burbidge	...	...	Dr	....

Depth to water	Date of measurement	Use	Remarks
.....	....	D, S	
.....	....	T	Hole filled. See log.
.....	....	T	Do.
.....	....	S	Aquifer reported to be sand. See chemical analysis.
4.48	10-8-45	D, S, O	Aquifer reported to be clay.
3	11-23-48	D	Water distributed widely in Mohall area for domestic uses. Aquifer, gravel. See chemical analysis.
.....	....	T	Hole filled. See log.
.....	....	D, S	Aquifer reported to be gravel.
.....	....	S	Aquifer reported to be sand and gravel. See chemical analysis.
.....	....	S	
.....	....	D	Aquifer reported to be gravel.
30	9-19-47	S	Aquifer reported to be sand. See chemical analysis.
7.67	9-23-47	S	
4.95	9-23-47	D	Aquifer reported to be sand.
44.05	10-2-45	O	
80	9-23-47	S	See chemical analysis.
2.21	8-14-47	T	Hole filled. See log. See chemical analysis.
.....	....	S	See chemical analysis.
7.64	9-22-47	U	
6.20	10-2-45	S, O	Aquifer reported to be gravel.
5.55	10-2-45	S, O	Do.
.....	....	S	See chemical analysis.
6.5	9-24-47	D, S	
9.15	10-2-45	D, S, O	
.....	....	U	
70	9-18-47	S	Do.
.....	....	U	
.....	....	S	Aquifer reported to be gravel and shale.
19.40	10-2-45	D, O	
.....	....	S	Aquifer reported to be gravel and shale. See chemical analysis.
.....	....	S	See chemical analysis.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
161-83-1aa	Mrs. Tenberg	350	4	Dr	....
161-83-1bc	Mrs. Williams	450	4-1½	Dr	....
161-83-2ba	A. B. Ericson	52	24	B	....
161-83-2bb	Lacy Greek	350	4-3	Dr	....
161-83-2cc	O. Staven	46	40	Du	....
161-83-3dc	Herman Staven	323	4-3	Dr	....
161-83-4cd	Hemming Halvorson	30	40	Du	....
161-83-5bd	Carl Gilseth	380	5-3	Dr	....
161-83-6bcb	Town of Mohall (M4)	16	120	Du	1935
161-83-6cbb	Town of Mohall	20	40	Du	....
161-83-6cbc	Town of Mohall (M2)	22	216	Du	....
161-83-6ccc	USGS test 16 (B)	230	5	Dr	1948
161-83-6ccd	Town of Mohall (M3)	15	120	Du	1935
161-83-6cdc1	USGS test 12 (B)	60	5	Dr	1948
161-83-6cdc2	USGS test 14 (B)	80	5	Dr	1948
161-83-6cdd	USGS test 15 (B)	60	5	Dr	1948
161-83-7bba	USGS test 13 (B)	60	5	Dr	1948
161-83-7bd	Smith	11	48	Du	....
161-83-7cdc	Town of Mohall (M1)	20	240	Du	1916
161-83-8ba	Carl Gilseth	350	4	Dr	....
161-83-8cd	G. Herrigstad	350	5-3	Dr	....
161-83-9bb	Carl Crougan	375	3-2	Dr	....
161-83-9cd	A. Halvorson	360	3	Dr	....
161-83-9da	....	300	...	Dr	....
161-83-10ba	Oliver Staven	380	4	Dr	....
161-83-11dc1	Carl Pfefferkorn	28	40	Du	....
161-83-11dc2	......do.........	12	40	Du	....
161-83-11ddd	USGS test 2 (B)	50	5	Dr	1948
161-83-12ccc	UGSS test 1 (B)	230	5	Dr	1948
161-83-13ab	J. Reed	20	40	Du	....

Depth to water	Date of measurement	Use	Remarks
.....	....	S	
.....	....	U	
11.35	7-30-47	D	
.....	....	S	
6.98	7-29-47	U	
6.60	7-29-47	S	
10.45	7-25-47	D, S	
.....	....	S	
8.58	10-14-48	P	Reportedly went dry in drought years. Well is through sand. See chemical analysis.
4.27	7-23-47	U	
12	10-3-45	P	Reportedly went dry in drought years. Well ends in clay. See chemical analysis. See also analysis of composite sample.
.....	....	T	Hole filled. See log.
6.70	10-19-48	P	Well reportedly went dry during drought years. See chemical analysis.
.....	....	T	Hole filled. See log.
.....	....	T	Do.
.....	....	T	Do.
.....	....	T	Do.
7.55	10-3-45	D, S	
.....	....	P	Reportedly 14 feet of sand from surface. Clay rest of way. See analysis of composite sample.
22.65	7-24-47	U	
.....	....	S	See chemical analysis.
12	7-24-47	S	Do.
15	7-24-47	S	Do.
50	10-3-45	D, S	Water reported unsuitable for domestic use.
.....	....	S	
10.36	7-29-47	S	
4.15	7-29-47	U	
.....	....	T	Hole filled. See log.
.....	....	T	Do.
4.95	7-29-47	D	

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
161-83-13cd	J. Reed	13	...	Du	....
161-83-13dcc	USGS Missouri-Souris test	205	4 3/4	Dr	1947
161-83-14aab	USGS test 3 (B)	40	5	Dr	1948
161-83-14aba	USGS test 4 (B)	220	5	Dr	1948
161-83-14cc	Witteman	325	3	Dr	....
161-83-15cc1	Milton Rice	10	24	Du	....
161-83-15cc2	.....do.....	12	.	Du	....
161-83-16cd1	Roy Winder	300	4	Dr	....
161-83-16cd2	.....do.....	...	3	Dr	....
161-83-17ad	Marrias Aune	453	3-2	Dr	....
161-83-17da	O. Solemsaus	365	3-2	Dr	....
161-83-18aa	T. Haugan	380	3	Dr	....
161-83-18cc	Haugan	340	3	Dr	....
161-83-18dc	Connole	...	...	Dr	....
161-83-19ab	....	...	40	Du	....
161-83-19cc	....	...	...	Du	....
161-83-19dd	J. C. Fisher	391	2	Dr	....
161-83-20bb	Wortz Jahansen	380	4-3	Dr	....
161-83-20dc	Haugan	...	3	Dr.	....
161-83-21ab	E. Salvey	...	3	Dr	....
161-83-22ba	....	...	3	Dr	....
161-83-23dd	....	300	4	Dr	....
161-83-24ba	....	...	...	Du	....
161-83-24cd	....	...	3	Dr	....
161-83-25bb	C. F. Adams	300	4	Dr	....
161-83-26bb	....	11	60	Du	....
161-83-28cb	O. Mortenson	16	40	Du	....
161-83-30bb	J. C. Fisher	417	4-3	Dr	....
161-83-30da	Everett Thorpe	18	48	Du	....
161-83-31bb	Bernard Schraeder	350	3	Dr	....
161-83-31cc	....	400	4	Dr	....
161-83-32cd	....	380	4	Dr	....
161-83-32dd	H. A. Milleton	13	48	Du	....
161-83-33ba	Ernest Martins	350	4-3	Dr	....
161-83-33cc	USGS Missour-Souris test	240	4 3/4	Dr	1947

Depth to water	Date of measurement	Use	Remarks
.....	....	D	See chemical analysis.
3.93	8-9-47	T	Hole filled. See log.
.....	....	T	Do.
.....	....	T	Do.
19.50	7-25-47	S	See chemical analysis.
2.94	7-25-47	S	
.....	....	S	
40	7-25-47	S	
.....	....	U	
.....	....	S	Do.
25	7-24-47	S	Do.
35.34	7-23-47	U	
.....	....	U	Do.
.....	....	S	
10.00	7-24-47	D	
.....	....	U	
.....	....	...	See log.
20	7-23-47	S	See chemical analysis.
32.90	7-24-47	S	
.....	....	S	Do.
25	10-7-45	S	
30	10-7-45	D, S	Aquifer reported to be sandstone.
.....	....	...	
19.26	7-31-47	U	
21.34	7-31-47	S	See chemical analysis.
4.51	7-31-47	U	
4.85	7-24-47	D, S	
5.40	10-7-45	S	Do.
.....	....	S	
.....	....	S	
.....	....	...	
.....	....	...	
.....	....	S, O	
40	7-24-47	D, S	Do.
5.24	8-14-47	T	Hole filled. See log.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
161-84-1bbb	USGS test 5 (R)	50	5	Dr	1948
161-84-1bd	Melvin Duerre	12	2	Dn	....
161-84-1ddc	USGS test 6 (R)	60	5	Dr	1948
161-84-1dd	....	...	60	Du	....
161-84-2aa	A. D. Gilseth	12	48	Du	....
161-84-3dd	Peter Nelson	343	3-2	Dr	....
161-84-4bb1	George Strandberg	492	3-2	Dr	....
161-84-4bb2	.....do..........	12	48	Du	....
161-84-5ab	John Newstrom	492	3-2	Dr	....
161-84-5cb	G. Johnson	10	48	Du	....
161-84-5cc	.....do......	14	48	Du	....
161-84-6cb	....	...	48	Du	....
161-84-7cd	Einer Norkiel	...	...	Dr	....
161-84-9aa	Clifford Co.	...	...	Dr	....
161-84-10dd1	W. Zimmerman	7	40	Du	....
161-84-10dd2	.....do......	14	40	Du	....
161-84-11ad1	Wm. Connole	...	3	Dr	....
161-84-11ad2	.....do......	13	36	Du	....
161-84-11cd	W. Zimmerman	...	4	Dr	....
161-84-12cd	O. Witteman	...	3	Dr	....
161-84-12da	Frank Gehringer	294	3-2	Dr	....
161-84-13cd1	F. Paris	13	18	B	....
161-84-13cd2	.....do......	343	...	Dr	....
161-84-14db1	George Barcus	375	4	Dr	....
161-84-14db2	.....do......	21	40	Du	....
161-84-15dd	J. Southam	270	4-2	Dr	....
161-84-16dd	John Moberg	...	3	Dr	....
161-84-17aa1	Lloyd Horner	500	3	Dr	....
161-84-17aa2	Martin Jacobson	...	...	Dr	....
161-84-17cc	....	300	3	Dr	....
161-84-17da1	A. R. Jones Oil & Operating Co.	...	72	Du	....
161-84-17da2	A. R. Jones Oil & Operating Co. Well no. 1	3,872	...	Dr	....

Depth to water	Date of measurement	Use	Remarks
.....	....	T	Hole filled. See log.
.....	....	D, S	Aquifer reported to be sand.
.....	....	T	Hole filled. See log.
.....	....	D	
6.15	9-29-45	S, O	
15	6-17-47	S	See chemical analysis.
1.78	6-18-47	S	Do.
9.13	6-18-47	D	
.....	....	S	Do.
2.76	6-17-47	S	
.....	....	U	
8.15	9-29-45	D, S, O	
.....	....	S	
.....	....	S	Do.
.....	....	U	
5.66	6-17-47	U	
24.61	6-18-47	U	
3.59	6-18-47	U	
34.00	6-25-47	S	
22.20	6-25-47	S	Do.
.....	....	S	Aquifer reported to be shale. See chemical analysis.
11.64	7-19-40	O	
.....	....	...	Aquifer reported to be sandstone. See chemical analysis.
14	7-23-47	S	See chemical analysis.
5.34	7-23-47	D	
.....	....	S	Do.
.....	....	S	Do.
17.70	8-1-47	S	Do.
.....	....	S	
50	9-23-45	S	
16.90	9-30-45	O	Water well used in connection with drilling of oil test (161-84-17da2).
.....	....	U	See log.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
161-84-18cd	Wendel Bohen	390	4	Dr	....
161-84-18dc	Louis Erickson	...	3	Dr	....
161-84-20aa1	A. Burduik	16	...	Du	....
161-84-20aa2	.....do.....	330	4	Dr	....
161-83-20ba	Elmond Lundgreen	...	2	Dr	....
161-84-21aa	Paul Gehringer	350	3	Dr	....
161-84-21bb1	Great American Gas & Oil Co.	350	6¼	Dr	....
161-84-21bb2	Burduik	350	...	Dr	....
161-84-21bb3	.....do.....	14	40	Du	....
161-84-22aa	D. Gehringer	300	3-2	Dr	....
161-84-22bb	Henry Skordal	21	40	Du	....
161-84-23dd	....	...	36	Du	....
161-84-24ab	J. D. Taylor	15.2	48	Du	....
161-84-24cb	George Capranus	...	3	Dr	....
161-84-25cb	Palmer Asheim	...	...	Dr	....
161-84-26aa1	Mrs. A. H. Sleeper	316	3	Dr	....
161-84-26aa2	.....do...........	16	72	Du	....
161-84-28bc	....	9	72	Du	....
161-84-28dd	Swartz	300	3-2	Dr	....
161-84-29aa	LeRoy Allen	...	3	Dr	....
161-84-29bcc	USGS test 15	60	5	Dr	1948
161-84-29dc	Roy Hoke	383	4-2	Dr	....
161-84-30daa	USGS test 14 (R)	50	5	Dr	1948
161-84-30dad	USGS test 13 (R)	50	5	Dr	1948
161-84-31ad	....	...	...	Dr	....
161-84-32cc1	....	300	3	Dr	....
161-84-32cc2	Roy Hoke	363	4-2	Dr	....
161-84-33aa	....	300	3	Dr	....
161-84-36ba	R. Nelson	14	36	Du	....
161-85-24aa	USGS Missouri Souris test	260	4 3/4	Dr	1947
161-86-13add	USGS test 17 (R) (in Souris River Valley)	110	5	Dr	1948
161-86-13ccc	UGSG test 19 (R) (in Souris River Valley)	110	5	Dr	1948

Depth to water	Date of measurement	Use	Remarks
70	7-22-47	S	See chemical analysis.
.....	....	S	
1.48	6-29-47	...	
.....	....	...	Aquifer reported to be lignite and sandstone.
.....	....	U	
.....	....	S	
30	9-23-45	U	See log.
.....	....	...	See chemical analysis.
7.98	6-29-47	D	
30	9-23-45	S	Water reported not suitable for domestic use. See chemical analysis.
2.41	6-29-47	U	
.....	....	D, S	
11.04	7-19-40	O	Aquifer reported to be sand.
.....	....	...	
.....	....	S	
.....	....	S	
.....	....	D	
5.30	10-6-45	S, O	
.....	....	U	Aquifer reported to be sand. See chemical analysis.
.....	....	S	See chemical analysis.
.....	....	T	Hole filled. See log.
100	7-23-47	S	
.....	....	T	Hole filled. See log.
.....	....	T	Do.
.....	....	S	
80	10-2-45	U	
60	7-23-47	U	Aquifer reported to be shale.
80	10-2-45	D, S	Water reported unsuitable for domestic use.
6.75	10-6-45	D, S, O	
6.04	8-14-47	T	Hole filled. See log.
.....	....	T	Do.
.....	....	T	Do.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
161-86-13cdc	USGS test 18 (R) (in Souris River Valley)	83	5	Dr	1948
161-86-13dcc	USGS test 16 (R) (in Souris River Valley)	155	5	Dr	1948
161-86-14ddd	USGS test 20 (R) (in Souris River Valley)	67	5	Dr	1948
162-83-25bc	O. Ronning	400	3	Dr	....
162-83-25cb1	.....do.....	73	24	B	....
162-83-25cb2	.....do.....	32	24	B	....
162-83-26dc1	R. Sherer	385	3	Dr	....
162-83-26dc2	.....do.....	14	24	..	....
162-83-27cd	....	...	...	Dr	....
162-83-30cc1	Louis Erickson	15	60	Du	....
162-83-30cc2	.....do.....	11	48	Du	....
162-83-31ccc	USGS test 10 (B)	60	5	Dr	1948
162-83-31ccd	USGS test 6 (B)	50	5	Dr	1948
162-83-31cdc	USGS test 11 (B)	60	5	Dr	1948
162-83-32cbc	USGS test 9 (B)	70	5	Dr	1948
162-83-32ccb	USGS test 8 (B)	60	5	Dr	1948
162-83-32ccc1	USGS test 5 (B)	50	5	Dr	1948
162-83-32ccc2	USGS test 7 (B)	230	5	Dr	1948
162-83-32dc1	Harold Ring	...	3-2	Dr	....
162-83-32dc2	.....do.....	20	...	Du	....
162-83-33da	F. Rebillard	654	3	Dr	....
162-83-35ba1	....	14	14	...	....
162-83-35ba2	....	...	...	Du	....
162-83-35da	A. J. Skeaden	372	4	Dr	....
162-83-36ba	....	...	3	Dr	....
162-84-25dd1	USGS Missouri-Souris test	105	4 3/4	Dr	1947
162-84-25dd2	.....do.....	255	4 3/4	Dr	1947
162-84-26cd	Clark Kelly	9	48	Du	....
162-84-26dd	A. Crooks	400	3	Dr	....
162-84-28cc	Roy Eldred	418	3-2	Dr	....
162-84-31bb1	Shoenberg	370	2	Dr	....

Depth to water	Date of measurement	Use	Remarks
.....	....	T	Hole filled. See log.
.....	....	T	Do.
.....	....	T	Do.
21.00	7-30-47	U	
5.08	7-30-47	S	
5.55	7-30-47	U	
.....	....	S	See chemical analysis.
5.29	7-30-47	S	
.....	....	S	
9.69	7-23-47	S	
7.99	7-23-47	D	
.....	....	T	Hole filled. See log.
.....	....	T	Do.
.....	....	T	Do.
.....	....	T	Do.
.....	....	T	Do.
.....	....	T	Do.
.....	....	T	Do.
8.10	7-24-47	S	See chemical analysis.
.....	....	S	
50	10-3-45	D,S,O	See log.
.....	....	D	
.....	....	U	
20	7-30-47	S	See chemical analysis.
.....	....	U	
4.80	8-14-47	T	Hole filled. See log.
4.79	8-14-47	T	Do.
8.95	6-18-47	S	
13.17	7-18-47	U	Aquifer reported to be sand and shale.
39.79	....	S	See chemical analysis.
.....	....	S	Aquifer reported to be shale. See chemical analysis.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
162-84-31bb2	Shoenberg	...	40	Du	....
162-84-31da	....	350	3-2	Dr	....
162-84-32ad1	Jesse Powell	350	3-2	Dr	....
162-84-32ad2	.....do.....	320	3	Dr	....
162-84-32ad3	.....do.....	300	3	Dr	....
162-84-32ba1	Albert Keup	388	3-2	Dr	....
162-74-32ba2	.....do.....	10	36	Du	....
162-84-32dd1	Alfred Newstrom	15	48	Du	....
162-84-32dd2	.....do.....	364	3-2	Dr	....
162-84-33bc	Orville Witteman	325	3-2	Dr	....
162-84-33cd	A. H. Trutna	400	3-2	Dr	....
162-84-34cd	George Capranus	...	...	Dr	....
162-84-35dcd	USGS test 7 (R)	60	5	Dr	1948
162-84-35dd1	Lloyd Snyder	11	36	Du	....
162-84-35dd2	.....do.....	...	72-48	Du	....
162-84-36bb	Glenn Wade	10	48	Du	....
162-84-36cdc	USGS test 4 (R)	50	4	Dr	1948
162-84-36cdd	USGS test 3 (R)	250	5	Dr	1948
162-84-36ddc	USGS test 2 (R)	50	5	Dr	1948
162-84-36ddd	USGS test 1 (R)	50	5	Dr	1948

Depth to water	Date of measurement	Use	Remarks
2.94	6-18-47	D	
.....	....	U	Aquifer reported to be shale.
14.06	6-18-47	S	See chemical analysis.
.....	....	U	
.....	....	U	
.....	....	S	Aquifer reported to be shale. See chemical analysis.
3.00	6-18-47	D	
8.10	10-8-45	D,O	
.....	....	S	Do.
.....	....	S	Aquifer reported to be shale.
36.39	6-18-47	S	Aquifer reported to be shale. See chemical analysis.
27.31	6-18-47	U	
.....	....	T	Hole filled. See log.
.....	....	D	Aquifer reported to be gravel.
7.07	7-18-47	S	Do.
.....	....	D,S	Do.
.....	....	T	Hole filled. See log.
.....	....	T	Do.
.....	....	T	Do.
.....	....	T	Do.

160-84-5ccd
USGS test 10 - Renville County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till (weathered)		
Soil, clayey, black	1	1
Clay, light-buff; several large limestone pebbles	17	18
Till (unweathered)		
Clay, silty, pebbly, gray	21	39
Glaciofluvial deposits		
Sand, very coarse.	1	40
Till		
Clay, very sandy, gray.	10	50

160-84-5cdc
USGS test 9 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, silty, black.	1	1
Sand, coarse; gravel.	4	5
Gravel, fine and medium	5	10
Sand, very coarse, and some clay.	10	20
Till and associated glaciofluvial deposits:		
Till		
Clay, silty, gray, and some sand.	45	65
Glaciofluvial deposits		
Sand, very coarse, with abundant clay and silt	20	85
Gravel, fine, and some clay and silt.	5	90
Till		
Clay, silty, gray, and some very coarse sand	19	109
Glaciofluvial deposits		
Sand, very coarse, and some fine gravel	5	114
Sand, very coarse, and some gravel, with abundant clay and silt . .	31	145
Till ? (partly washed)		
The material at this depth appears to be gray clay and silt with abundant sand and gravel. . . .	35	180

160-84-5cdc
USGS test 9 - Renville County (Continued)

Material	Thickness (feet)	Depth (feet)
Glaciofluvial deposits		
Sand, very coarse, and some clay and silt	4	184
Bedrock (undifferentiated):		
According to drillers, a gray-green sandy clay was encountered at 184 feet. The drill cuttings when later examined appeared much like till.	65	249

160-84-7aaa
USGS test 11 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy, black.	1	1
Clay, sandy, dark-brown	1	2
Sand, medium to very coarse, light-brown.	2	4
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silt, very sandy, light-tan	46	50

160-84-7bba
USGS test 12 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy, black.	1	1
Clay, light-gray to white, highly calcareous	1	2
Sand, coarse.	3	5
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, gravelly, light olive-brown	23	28
Glaciofluvial deposits		
Sand, fine and medium	3	31
Till (unweathered)		
Clay, silty, pebbly, gray	19	50

160-84-8baa
USGS test 8 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black	1	1
Clay, gravel, buff.	1	2
Sand, medium, coarse.	2	4
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, gravelly, buff . . .	10	14
Till (unweathered)		
Clay, silty, gravelly, gray . . .	36	50

160-84-16da
USGS Missouri-Souris test

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Soil.	1	1
Clay, yellow.	4	5
Clay, sandy, yellow, with some boulders and gravel	5	10
Sand.	3	13
Clay, sandy, gray	28	41
Clay, sandy, gray, with thin strips of gravel and lignite fragments	36	77
Clay, sandy, gray, with some gravel.	30	107
Clay, sandy, gray, with thin strips of gravel and lignite fragments	24	131
Clay, sandy, gray, gravel, and fine sand in thin strips. . . .	51	182
Clay, sandy, gray, gravel, and boulders in strips.	12	194
Clay, sandy, gray, with thin strips of gravel	54	248
Bedrock (undifferentiated):		
Clay, sandy, white.	1	249
Lignite, hard	2	251
Clay, sandy, gray, white, and lignite in strips	19	270

161-83-6ccc
USGS test 16 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy, black	1	1
Sand, medium to coarse, and fine to medium gravel	10	11
Sand, coarse, silty, gravelly	9	20
Till and associated glaciofluvial deposits:		
Till		
Clay, silty, gray, and some sand and gravel	22	42
Glaciofluvial deposits		
Sand, silty, and gravel	8	50
Sand, very silty and gravelly, gray	20	70
Till (sandy)		
Clay, silty, gravelly, gray; very abundant coarse sand	25	95
Clay, gray, and some very coarse sand (samples contain nearly 50 percent sand, 50 percent clay)	95	190
Glaciofluvial deposits		
Gravel, fine, and sand, very coarse, very dirty	36	226
Bedrock (undifferentiated):		
Drillers report a brown smooth clay	4	230

161-83-6cd1
USGS test 12 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black	1	1
Clay, light-gray	1	2
Sand, coarse	2	4
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, yellowish-brown	15	19
Till (unweathered)		
Clay, silty, gray, and some coarse gravel	20	39
Glaciofluvial deposits		
Sand, coarse	2	41
Till		
Clay, silty, grayish-tan, and some fine and medium gravel	19	60

161-83-6cdc2
USGS test 14 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till (weathered)		
Soil, clayey, black	1	1
Clay, silty, gravelly, buff	23	24
Till (unweathered)		
Clay, silty, gravelly, gray	4	28
Glaciofluvial deposits		
Sand, medium to coarse	3	31
Till		
Clay, silty, gray, with some sand and gravel	18	49
Glaciofluvial deposits		
Sand, coarse, and fine, very silty gravel	7	56
Till		
Clay, silty, pebbly, gray	11	67
Glaciofluvial deposits		
Sand, medium to coarse, and fine gravel	2	69
Till		
Clay, silty, pebbly, gray	11	80

161-83-6cdd
USGS test 15 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till (weathered)		
Soil, clayey, black.	1	1
Clay, light-gray, and some coarse gravel	1	2
Clay, silty, slightly sandy, tan .	13	15
Clay, silty, light-brown	20	35
Till (unweathered)		
Clay, silty, gray.	25	60

161-83-7bba
USGS test 13 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, silty, black	1	1
Clay, light-gray	1	2
Sand, medium, light-brown.	7	9
Till and associated glaciofluvial deposits:		
Till		
Silt, pebbly, grayish-brown. . . .	51	60

161-83-11ddd
USGS test 2 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy, black	1	1
Sand, very fine, light-gray. . . .	1	2
Gravel and very coarse sand. . . .	8	10
Till and associated glaciofluvial deposits:		
Till		
Clay, silty, dark-gray	6	16
Glaciofluvial deposits		
Sand, medium to coarse	2	18
Till		
Clay, silty, pebbly, dark-gray . .	5	23
Glaciofluvial deposits		
Sand, medium to coarse	2	25
Gravel, fine to medium, clean, partly shale	12	37
Till		
Clay, sandy, dark-gray	13	50

161-83-12ccc
USGS test 1 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, silty, black	1	1
Gravel, fine to coarse, and some silty light-gray clay.	2	3
Sand, medium to coarse	2	5
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, buff, and gravel. . .	7	12
Clay, silty, pebbly, gray.	3	15
Glaciofluvial deposits		
Sand, medium to coarse	3	18
Till		
Clay, pebbly, gray	21	39
Sand, fine to coarse	1	40
Clay, silty, gray.	20	60
Clay, and abundant very coarse sand	137	197
Bedrock (undifferentiated):		
Clay, slightly sandy, dark-gray. .	8	205
Clay, dark-gray; some carbonaceous material present	15	220
Silt, light-gray	5	225
Clay, dark-gray.	5	230

161-83-13dcc
USGS Missouri-Souris test

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Soil	1	1
Sand and gravel.	12	13
Clay, sandy, gray.	37	50
Clay, sandy, gray, with some gravel and lignite fragments.	98	148
Clay, sandy, gray, and fine sand .	7	155
Clay, sandy, silty, gray	30	185
Sand and gravel.	14	199
Bedrock (undifferentiated):		
Lignite, hard.	4	203
Clay, brown.	2	205

161-83-14aab
USGS test 3 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black.	1	1
Clay, gravelly, light-gray	6	7
Sand, medium and coarse, and some fine gravel.	20	27
Till and associated glaciofluvial deposits:		
Till		
Silt and clay, pebbly, dark-gray .	13	40

161-83-14aba
USGS test 4 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black.	1	1
Clay, light-gray	2	3
Sand, medium brown, and some coarse gravel.	5	8
Till and associated glaciofluvial deposits:		
Till		
Clay, silty, pebbly, gray.	73	81
Glaciofluvial deposits		
Sand, fine to medium, quartzitic, abundant clay and silt	16	97
Till		
Clay, silty, pebbly, gray.	105	202
Bedrock (undifferentiated):		
Clay, sandy, light-gray to white	3	205
Clay, silty, brown to black.	15	220

161-83-19dd
J. C. Fisher

Glacial drift:		
Clay and sand.	320	320
Bedrock (undifferentiated):		
Sandstone.	8	328
Lignite and shale	2	330
Sandstone.	4	334
Shale.	42	376
Shale, sandy	1	377
Lignite and shale.	3	380
Shale, sandy; water.	11	391

Note: Log modified from Simpson (1929)

161-83-33cc
USGS Missouri-Souris test

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Soil	4	4
Clay, sandy, yellow and some gravel	8	12
Sand, fine	1	13
Clay, sandy, yellow	1	14
Clay, sandy, gray, and some gravel	15	29
Gravel	1	30
Clay, sandy, gray, and some gravel	7	37
Clay, sandy, gray, and thin strips of gravel	2	39
Clay, sandy, gray, and some gravel	30	69
Clay, sandy, gray, and thin strips of gravel	33	102
Clay, sandy, gray, and some some gravel and fine sand	38	140
Gravel	2	142
Clay, sandy, gray, and thin strips of gravel	66	208
Clay, sandy, gray, and thin strips of lignite fragments	3	211
Bedrock (undifferentiated):		
Clay, sandy, white	1	212
Shale, hard, white	1	213
Clay, sandy, gray	21	234
Shale, brown	1	235
Clay, sandy, brown	5	240

161-84-1bbb
USGS test 5 - Renville County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till (weathered)		
Soil, clayey, black.	1	1
Clay, pebbly, tan.	12	13
Till (unweathered)		
Clay, pebbly, gray	29	42
Glaciofluvial deposits		
Sand	1	43
Till		
Clay, pebbly, gray	7	50

161-84-1ddc
USGS test 6 - Renville County

Material	Thickness (feet)	Depth (feet)
Till and glaciofluvial deposits:		
Till		
Soil, clayey, black.	1	1
Clay, gravelly, buff	16	17
Glaciofluvial deposits		
Sand, coarse to very coarse, and some fine gravel	5	22
Sand, very coarse, with abundant clay and silt.	38	60

161-84-17da2
A. R. Jones Oil & Operating Co.
Well no. 1

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Soil, clay, and sand	65	65
Bedrock (undifferentiated):		
Shale, sandy	30	95
Sandstone, coarse	30	125
Shale and sandy shale	143	268
Limestone, thin-bedded	2	270
Shale; gas	2	272
Shale, brown and blue	23	295
Limestone, thin-bedded	1	296
Sandstone; water	19	315
Shale, with thin-bedded limestone	10	325
Lignite	5	330
Shale, sandy, gray	5	335
Shale, gray	43	378
Limestone, thin-bedded	1	379
Shale, brown	111	490
Sandy shale	110	600
Shale, gray and brown	245	845
Shale, sandy; water	5	850
Shale, gray to blue	220	1,070
Shale, black	25	1,095
Shale, gray to blue	330	1,425
Limestone, thin-bedded	1	1,426
Shale, blue	53	1,479
Limestone, thin-bedded	1	1,480
Shale, gray to brown	390	1,870
Shale, gray; trace of oil	40	1,910
Shale, black to brown	510	2,420
Shale, limy, black, trace of oil	85	2,505
Limestone, thin-bedded	5	2,510
Shale, brown, and thin-bedded limestone	90	2,600
Shale, brown	55	2,655
Shale, gray; small amount of gas	345	3,000
Shale, gray to blue	50	3,050
Sandstone; no water	10	3,060
Shale, gray	35	3,095
Limestone, thin-bedded	15	3,110
Shale, gray	90	3,200
Limestone and sandstone, broken	15	3,215
Limestone and sandstone, hard	4	3,219
Limestone, sandy	21	3,240

161-84-17da2
A. R. Jones Oil & Operating Co.
Well no. 1 (continued)

Material	Thickness (feet)	Depth (feet)
Shale, sandy	10	3,250
Shale, gray.	20	3,270
Sandstone.	20	3,290
Limestone.	10	3,300
Shale, gray.	10	3,310
Sandstone.	2	3,312
Shale, gray.	3	3,315
Sandstone; water	15	3,330
Sandstone; small amount of gas	10	3,340
Shale, gray; small amount of gas	30	3,370
Shale, sandy, gray	30	3,400
Shale, gray.	30	3,430
Limestone, gray to blue.	20	3,450
Shale, with thin-bedded limestone.	20	3,470
Limestone and shale, broken.	25	3,495
Shale, hard.	5	3,500
Limestone, sandy; water.	5	3,505
Shale, blue and gray	232	3,737
Shale, red to gray	98	3,835
Limestone, sandy	9	3,844
Sandstone.	11	3,855
Shale, hard, gray.	3	3,858
Limestone, sandy	5	3,863
Sandstone.	2	3,865
Shale, hard, gray.	7	3,872

Note: Log modified from Kline (1942)

161-84-21bb1
Great American Gas & Oil Co.
Well no. 5

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Sand and clay	75	75
Bedrock (undifferentiated):		
Shale and sandy shale	188	263
Shale and sandstone	19	282
Sandstone; gas	13	295
Sandstone and shale; water	47	342
Lignite	2	344
Sandstone and shale; water	6	350

Note: Log modified from Simpson (1929)

161-84-29bcc
USGS test 15 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy, black	1	1
Gravel	1	2
Sand, medium to coarse, light-tan; some fine gravel	5	7
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, buff	2	9
Till (unweathered)		
Clay, silty, gray, and some very coarse sand	37	46
Glaciofluvial deposits		
Sand and gravel	3	49
Sand, very coarse, with abundant clay and silt	11	60

161-84-30daa
USGS test 14 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black.	1	1
Clay, light-gray, highly calcareous	3	4
Sand, fine	1	5
Sand, coarse, silty.	5	10
Clay, gray, gravelly	1	11
Gravel, medium, and some coarse sand	6	17
Till and associated glaciofluvial deposits:		
Till		
Clay, silty, pebbly, gray.	23	40
Glaciofluvial deposits		
Sand, very coarse, and clay. . . .	10	50

161-84-30dad
USGS test 13 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy, black	1	1
Clay, light-gray, highly calcareous	3	4
Sand	1	5
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, pebbly, light-brown.	18	23
Glaciofluvial deposits.		
Sand, very fine, and clay.	12	35
Till (unweathered).		
Clay, silty, gray, and some sand .	15	50

161-85-24aa
USGS Missouri-Souris test

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Soil	1	1
Clay, sandy, yellow, with gravel and boulders	11	12
Gravel and sand, with lignite fragments	6	18
Clay, sandy, yellow	2	20
Clay, sandy, gray, with boulders	11	31
Thin beds of fine sand and gray sandy clay	5	36
Clay, sandy, gray, with thin beds of gravel and fine sand and thin beds of lignite fragments	40	76
Sand, fine	2	78
Clay, sandy, gray, and thin beds of fine sand	28	106
Gravel	1	107
Clay, sandy, gray, and thin beds of gravel and sand	14	121
Gravel and gray sandy clay in strips	19	140
Gravel and thin beds of clay	9	149
Clay and gravel, thin beds, sandy, gray	25	174
Clay, sandy, gray, and thin beds of gravel	36	210
Clay, sandy, gray, and thin beds of gravel and boulders	8	218
Boulder, granite	3	221
Clay, sandy, gray, and gravel and boulders	23	244
Clay, sandy, gray, and brown sandy clay, gravel, and boulders	6	250
Bedrock (undifferentiated):		
Clay, sandy, gray and brown	10	260

161-86-13add
USGS test 17 - Renville County
(in Souris River valley)

Material	Thickness (feet)	Depth (feet)
Fluvial deposits:		
Soil, silty, black	1	1
Clay, sandy, olive-brown	57	58
Till and associated glaciofluvial deposits:		
Glaciofluvial deposits		
Sand, very coarse, with abundant clay and silt	12	70
Till		
Clay, sandy, dark-gray	10	80
Glaciofluvial deposits		
Sand and gravel	5	85
Till		
Clay, gravelly, sandy, dark-gray	18	103
Bedrock (undifferentiated):		
Shale, light-gray	7	110

161-86-13ccc
USGS test 19 - Renville County
(in Souris River Valley)

Material	Thickness (feet)	Depth (feet)
Fluvial deposits:		
Soil, silty, black	2	2
Clay, light-tan	20	22
Silt, greenish-gray, with some shell material	7	29
Sand, very coarse	1	30
Clay and silt, light blue-gray, with some shell material	23	53
Till and associated glaciofluvial deposits:		
Till		
Clay, pebbly, gray	5	58
Sand, coarse, and gravel	2	60
Clay, pebbly, gray; drillers reported numerous rocks	8	68
Glaciofluvial deposits		
Sand, fine and medium	2	70
Clay, light-gray, with shale pebbles and coal fragments	32	102
Bedrock (undifferentiated):		
Clay, light-gray	8	110

161-86-13cdc
USGS test 18 - Renville County
(in Souris River valley)

Material	Thickness (feet)	Depth (feet)
Fluvial deposits:		
Soil, sandy, black	2	2
Clay, brown.	16	18
Clay and silt, sandy, soft, dark-gray, with some shell material .	38	56
Till and associated glaciofluvial deposits:		
Till		
Clay, gray, pebbly	27	83

161-86-13dcc
USGS test 16 - Renville County
(in Souris River valley)

Material	Thickness (feet)	Depth (feet)
Fluvial deposits:		
Soil, clayey, black.	1	1
Clay, brown.	2	3
Clay, sandy, light-gray to white .	1	4
Clay, sandy, light-brown, rather uniform in texture	36	40
Till and associated glaciofluvial deposits:		
Till		
Clay, pebbly, light-brown and gray	20	60
Clay, sandy, dark-gray	30	90
Clay, silty, sandy, dark-gray; numerous chips of soft black shale or clay.	33	123
Clay, sandy, gray, with much very coarse sand; numerous chips of soft, black shale or clay. . . .	23	146
Bedrock (undifferentiated):		
Coal and black shale cuttings. . .	9	155

161-86-14ddd
USGS test 20 - Renville County
(in Souris River Valley)

Material	Thickness (feet)	Depth (feet)
Fluvial deposits:		
Soil, sandy, black	2	2
Clay, light-gray	16	18
Silt, blue-gray; some shell material	6	24
Sand, coarse	1	25
Clay, gravelly, gray; some shell material	11	36
Till and associated glaciofluvial deposits:		
Till		
Clay, tan; gravel.	4	40
Clay, sandy, tan	10	50
Clay, sandy, blue-gray, and some smooth black clay.	17	67

162-83-31ccc
USGS test 10 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black,	1	1
Silt, light-gray	1	2
Sand, medium to coarse	2	4
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, pebbly, light-brown	12	16
Till (unweathered)		
Clay, silty, pebbly, gray.	17	33
Glaciofluvial deposits		
Sand, very coarse, and some fairly clean gravel	8	41
Sand, and gravel, very silty	5	46
Sand, coarse, and some medium very dirty gravel	4	50
Till		
Clay, silty, and gravelly, gray.	10	60

162-83-31ccd
USGS test 6 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black.	1	1
Clay, light-gray and some medium gravel	1	2
Sand, medium and coarse, and some fine and medium gravel	4	6
Till and associated glaciofluvial deposits:		
Till		
Silt, gravelly, light-brown.	4	10
Silt, sand and gravel, grayish-brown.	12	22
Glaciofluvial deposits		
Sand, medium to coarse, and some fine and medium gravel, fairly clean.	17	39
Till		
Silt, gray, and small amounts of sand and gravel.	11	50

162-83-31cdc
USGS test 11 - Bottineau County

Till and associated glaciofluvial deposits:		
Till		
Soil, clayey, black.	1	1
Clay, light-gray; cobblestones	2	3
Clay, silty, tan	17	20
Clay, silty, gray.	19	39
Glaciofluvial deposits		
Sand, medium to coarse	2	41
Till		
Clay, silty, gray; medium to coarse sand	19	60

162-83-32cbc
USGS test 9 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till (weathered)		
Soil, clayey, black.	1	1
Silt, pebbly, light-tan.	22	23
Till (unweathered)		
Silt, pebbly, gray	10	33
Glaciofluvial deposits		
Sand, very coarse, and fine gravel.	2	35
Till		
Clay, silty, gravelly, light-gray.	3	38
Glaciofluvial deposits		
Sand, medium to very coarse, and fine, fairly clean gravel, partly shale	10	48
Till		
Clay, silty, very sandy and gravelly, gray	22	70

162-83-32ccb
USGS test 8 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black.	2	2
Clay, light-gray	1	3
Sand and gravel.	1	4
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, gravelly, yellowish-brown.	6	10
Glaciofluvial deposits		
Sand, very fine; silt.	5	15
Sand, very coarse; clay.	5	20
Till (unweathered)		
Clay, silty, pebbly, gray.	23	43
Glaciofluvial deposits		
Sand, medium to coarse	2	45
Sand, medium to coarse, and fine gravel with much clay and silt .	15	60

162-83-32ccc1
USGS test 5 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till		
Soil, clayey, black.	1	1
Clay, pebbly, light-gray	1	2
Clay, silty, pebbly, highly calcareous, yellowish-brown. . .	8	10
Clay, pebbly, yellowish-brown. . .	14	24
Clay, silty, pebbly, brown	26	50

162-83-32ccc2
USGS test 7 - Bottineau County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black.	1	1
Clay, light-gray, and some sand and gravel	1	2
Sand and gravel.	2	4
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, gravelly, tan	7	11
Silt, pebbly, olive-brown.	15	26
Silt, rather sandy and gravelly, grayish-brown.	14	40
Till (unweathered)		
Clay, silty, becoming increasingly sandy and gravelly with depth, grayish-brown.	184	224
Bedrock (undifferentiated):		
Lignite coal; gray clay.	6	230

162-83-33da
F. Rebillard

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Clay and sand.	205	205
Bedrock (undifferentiated):		
Sandstone.	55	260
Shale.	8	268
Sandstone, soft.	11	279
Sandstone, hard.	9	288
Sandstone, soft.	28	316
Sandstone, hard.	37	353
Shale, sandy	17	370
Sandstone, fine.	10	380
Shale, sandy	90	470
Shale and sandstone, hard.	184	654

Note: Log modified from Simpson (1929)

162-84-25dd2
USGS Missouri-Souris test

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Soil	1	1
Sand and gravel	4	5
Clay, sandy, gray, and some gravel.	25	30
Sand, fine and gravel.	2	32
Clay, sandy, gray, and some gravel mixed.	46	78
Clay, silty, sandy, gray, and some fine gravel.	78	156
Clay, sandy, gray, and some gravel	39	195
Clay, sandy, gray, and some lignite fragments and gravel	33	228
Bedrock (undifferentiated):		
Clay, sandy, gray, and brown carbonaceous shale	27	255

162-84-25dd1
USGS Missouri-Souris test

Material	Thickness (feet)	Depth (feet)
Glacial drift:		
Soil	1	1
Clay, gray	2	3
Sand, fine, and gravel	3	6
Clay, gray, with some gravel	10	16
Clay, sandy, silty	27	43
Clay, sandy, gray, with some lignite fragments.	37	80
Clay, sandy, gray, with some gravel	25	105

162-84-35dcd
USGS test 7 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, silty, black	1	1
Sand, gravel	2	3
Till and associated glaciofluvial deposits:		
Till (weathered)		
Clay, silty, buff, and some sand and gravel	15	18
Till (unweathered)		
Clay, silty, gray, and some sand and gravel	8	26
Glaciofluvial deposits		
Sand, medium and coarse.	2	28
Till (unweathered)		
Clay, silty, gray, and some sand and gravel; coal fragments	32	60

162-84-36cdc
USGS test 4 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, clayey, black	1	1
Sand, coarse	3	4
Till and associated glaciofluvial deposits:		
Till		
Clay, silty, pebbly, gray	36	40
Glaciofluvial deposits		
Sand, medium	2	42
Till		
Clay, pebbly, gray	8	50

162-84-36cdd
USGS test 3 - Renville County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till (weathered)		
Soil, black	1	1
Silt, buff, highly calcareous	12	13
Till (unweathered)		
Silt, gray, and some cobblestones	11	24
Clay, silty, hard, gray, and gravel	44	68
Clay, gray, and fine and medium gravel	24	92
Glaciofluvial deposits		
Gravel, fine and medium	4	96
Gravel, coarse, angular, dirty	4	100
Till (unweathered)		
Clay, silty, gray, and some sand and gravel	75	175
Clay, silty, gray; approximately 30 percent sand and gravel	60	235
Bedrock (undifferentiated):		
Silt and clay, light-gray	15	250

162-84-36ddc
USGS test 2 - Renville County

Material	Thickness (feet)	Depth (feet)
Till and associated glaciofluvial deposits:		
Till		
Soil, sandy, black	2	2
Clay, silt, buff	14	16
Clay, gravelly, gray	20	36
Glaciofluvial deposits		
Sand, fine to coarse, and some fine gravel	4	40
Till		
Clay, silty, sandy, gray	10	50

162-84-36ddd
USGS test 1 - Renville County

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Soil, sandy, black	2	2
Sand, fine to medium, dark-brown .	3	5
Clay, silty, sandy, buff	4	9
Sand, very fine, light-gray. . . .	6	15
Till and associated glaciofluvial deposits:		
Till		
Clay, sandy, gray, and gravel. . .	30	45
Glaciofluvial deposits		
Sand, coarse, and fine gravel. . .	1	46
Gravel, medium, and some sand and clay	4	50

REFERENCES

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

Akin, P. D., 1947, Geology and ground-water conditions at Minot, N. Dak.: North Dakota Geol. Survey Ground-Water Studies No. 6.

Comly, H. H., 1945, Cyanosis from nitrates in well water: Am. Med. Assoc. Jour., vol. 129, pp. 112-116.

Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., vol. 27, pp. 526-534.

Kline, V. H., 1942, Stratigraphy of North Dakota: Am. Assoc. Petroleum Geologists Bull., vol. 26, pp. 368-369.

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.

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

Simpson, H. E., 1929, Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, pp. 79-88, 201-208.

Waring, G. A., and LaRocque, G. A., Jr., 1949, Progress report on the geology and ground-water hydrology of the lower Missouri-Souris unit; Part I, Crosby-Mohall area, N. Dak.: U. S. Geol. Survey manuscript report.

15644 Interior - Duplicating Section, Washington, D.C.