GROUND WATER IN THE LITCHVILLE AREA BARNES COUNTY, NORTH DAKOTA

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NORTH DAKOTA GROUND-WATER STUDIES NO. 18

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

ILLUSTRATIONS

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ABSTRACT

Except for thin deposits of alluvium found in most of the intermittent stream valleys, the surface deposits in the Litchville area are the glacial drift of Pleistocene age, consisting of ground moraine, end moraine, and outwash-channel deposits. In the moraine areas, the drift consists essentially of relatively impermeable till, but locally bodies of water-sorted sand or gravel lie within or adjacent to the till.

The glacial drift is underlain by Cretaceous shale to a depth of approximately 1,000 feet. The stratigraphic units include the Pierre shale, the Niobrara formation, and the Benton shale. Below the shale, a sequence of sandstones and shales, referred to by Simpson as the "Dakota sandstone", is encountered at depths of 1,000 to 1,300 feet in the Litchville area. Formations below the "Dakota sandstone" have not been drilled in the area but it is not unlikely that sedimentary rocks of early Mesozoic or Paleozoic age are present above the pre-Cambrian crystalline basement complex.

Except for a few stock wells in Stoney Slough in the northeastern part of the area, no wells are known to obtain water from the outwash-channel deposits and alluvium. However, because of their presence in the valleys of the intermittent streams, these deposits are the best adapted of any aquifers found in the area to

receive substantial amounts of recharge from precipitation and runoff. It is estimated that about 20,000 to 35,000 gallons of water a day per mile could be developed in the south-trending stream channel in the western part of the area. Substantial ground-water developments also may be possible in Stoney Slough where a maximum thickness of 40 feet of sand and gravel was found.

Most of the wells for stock and domestic water supplies in the area obtain water from the glaciofluvial deposits associated with the till. During the test drilling numerous thin deposits of glaciofluvial materials associated with the till were penetrated but in only two test holes (USGS tests 5 and 11) were such deposits found in thicknesses of 10 feet or more. The aquifers do not appear to be sufficiently thick and extensive to provide an adequate water supply for the town of Litchville. However, the thicker aquifers may be suitable for developments of 5,000 to 10,000 gallons a day.

Only two wells in the area are known to obtain water from the Pierre shale, although some of the other deeper wells in the area may enter this formation. Only small yields can be obtained from the Pierre shale in this area and the water is highly mineralized. The Niobrara formation and the Benton shale are not aquifers in North Dakota.

About a dozen wells obtain water from the "Dakota sandstone" at depths of 1,000 to 1,300 feet in the Litchville area. Large volumes of water are available from this aquifer and can be withdrawn by pumping.

The water from the glacial drift and alluvium varies considerably in chemical quality. In 15 water samples, dissolved solids ranged from 334 to 6,290 parts per million. One sample of water from the Pierre shale contained 7,020 parts per million dissolved solids with high percentages of calcium, sodium, and sulfate. Analyses of two samples of water from the "Dakota sandstone" are given in the table. One of the samples contained 2,580 parts per million dissolved solids, including excessive amounts of sodium and sulfate.

INTRODUCTION

Scope and Purpose of the Investigation

This is a progress report on the results of a part of the study of the geology and ground-water resources of Barnes County, N. Dak., that is being made by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the State Geological Survey. It is one of a series of cooperative investigations of different counties in the State, 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. The most critical need, at present, is for adequate 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, are being released before the completion of the general studies so that the data may be available for use in solving immediate problems.

The investigation was under the general supervision of A. N. Sayre, chief of the Ground Water Branch, Water Resources Division, of the Federal Geological Survey. The test drilling and other field work were under the direct supervision of P. E. Dennis, district geologist, and the writer in 1947 and 1948. The well inventory was made by Gordon E. Andreason and Quentin F. Paulson; the test drilling was done by Ray Danielson and George McMaster.

Most of the chemical analyses of water samples given in this report were made by the North Dakota State Department of Health.

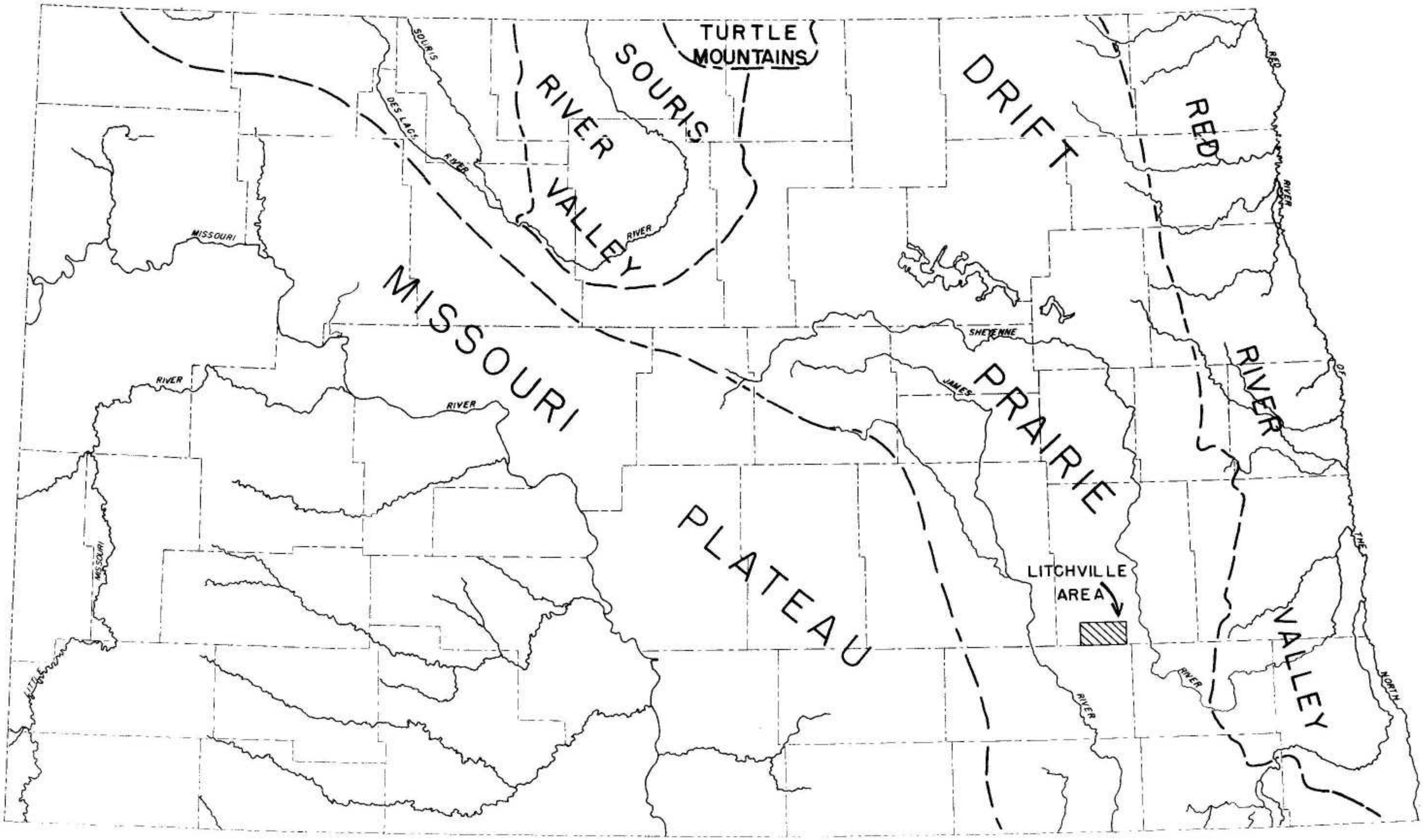

FIGURE I.—MAP SHOWING PHYSIOGRAPHIC DIVISIONS IN NORTH DAKOTA (MODIFIED AFTER SIMPSON) AND LOCATION OF LITCHVILLE AREA.

23759

Previous Investigations

Probably the first investigation of the general geology of the Litchville area was made by Upham (1896, pp. 143-144) during his study of glacial Lake Agassiz. He described and mapped some of the moraines found in the area.

In 1903-04, Willard (1909) investigated the general geology of the Litchville area and obtained data from existing wells and showed the areas in which flowing wells could be obtained from the "Dakota sandstone". Geological maps of the area were also prepared.

Brief general information concerning the geology and ground-water resources of Barnes County is found in a report by Simpson (1929, pp. 65-70). Little specific information concerning the Litchville area is given, however.

In 1937-38 an investigation of the water supply of the "Dakota sandstone" in the Ellendale-Jamestown area, which includes the Litchville area of the present report, was made by Wenzel and Sand (1942). Little or no information regarding the shallow ground-water resources of the area is given in that report.

Location and General Features of the Area

The Litchville area as described in this report is in southeastern North Dakota in the southwestern part of Barnes County (fig. 1). The area is approximately 6 by 12 miles in size and includes T. 137 N., Rs. 59 and 60 W. The area is served by State highways 1 and 46, by good graded county roads, and by a branch line of the Northern Pacific Railway.

The only communities in the area are Litchville (1950 population, 430) and Hastings (1950 population, 150). Dry-farming is the main occupation in the area, wheat being the major crop. The communities serve as shopping and trading centers for the surrounding farm area.

The climate of the area is one of extremes, as is typical in this section of the Great Plains. During the summer the temperatures may reach 100° F. and higher, and during the winter temperatures of 30° F. or more below zero are not uncommon. According to Weather Bureau records the mean annual temperature at Valley City, about 26 miles northeast of Litchville, is 40.8° F. The average annual precipitation is 19.61 inches, of which approximately 80 percent occurs as rain during the months of April through September.

The area is part of the Drift Prairie section of the Central Lowland physiographic province. It is poorly drained by intermittent streams, the channels of which were developed as distributaries or spillways for the meltwaters from the front of the last ice sheet during its withdrawal from the area. The largest of these stream channels is Stoney Slough, which crosses the northeastern part of the area and empties into the Sheyenne River. Another prominent (unnamed) stream channel crosses the western part of the area from north to south. This latter channel extends south-southeastward to join Bear Creek, which drains into the James River. Several less prominent channels head in the central and southern part of the area. They trend southeastward and eastward and drain into the basin of glacial Sand Prairie Lake. The basin of Sand Prairie Lake is drained partly by the Sheyenne River, tributary to the Hudson Bay drainage, and partly by Bear Creek which is tributary to the Missouri River drainage.

The topography of the area consists largely of low hills and intervening shallow depressions typical of ground moraine. However, in the western part and along the eastern edge, end moraines having more rugged topography trend north and northeast across the area.

Present Water Supply and Future Needs

The Litchville area is almost entirely dependent upon ground water for all its water supplies. The only other source of water is precipitation that may be caught and stored in cisterns. The most widespread use of water is for relatively small domestic and stock water supplies on farms. Most of these supplies are obtained from wells less than 100 feet in depth, which tap aquifers in the glacial drift. Only two wells in the area are reported to obtain water from the Pierre shale, which immediately underlies the glacial drift, and only about a dozen wells obtain water from the "Dakota sandstone" at depths ranging from 1,000 to 1,300 feet.

Neither Litchville nor Hastings had modern municipal water-supply and sewage facilities. At the time the field work for the present investigation was done, Litchville had one deep artesian well which overflowed into an underground reservoir where the water was available for fire-protection needs. Domestic supplies were obtained from individual private wells in the glacial drift. A considerable amount of water for domestic use was hauled by tank truck from springs or shallow wells in the deposits of the former glacial Sand Prairie Lake, east of the Litchville area, and was sold to residents. Also, some water for domestic use was obtained by catching rain and storing it in cisterns.

In addition to private wells and cisterns, Hastings had one shallow community well equipped with a hand pump, from which residents could haul or carry water to their homes for domestic use.

The only requirement for a water supply of relatively large magnitude in the area at the present time is for the municipal and industrial needs of Litchville. It is estimated that 40,000 to 50,000 gallons a day would be required to fill this need. If Hastings should construct modern water-supply and sewage facilities an additional 10,000 to 20,000 gallons a day might be required.

GEOLOGY AND OCCURRENCE OF GROUND WATER

Introduction

Except for thin deposits of alluvium in most of the stream valleys, the surface rock in the Litchville area is glacial drift of Pleistocene age. The glacial geology of the area shown in figure 2 has been adapted from Willard (1909), his work being modified as appeared desirable from comparison with aerial photographs. No geologic mapping in the field was undertaken during the present investigation.

The major part of the area is characterized by the gently rolling ground moraine deposited during the latest or Wisconsin stage of glaciation. Several end moraines are present, whose topography is somewhat more rugged. The largest of the end moraines is the "Waconia" moraine in the eastern part of the area. This moraine was mapped and described by both Willard (1909, p. 3) and Upham (1896, p. 143). The "Keister" moraine, which is found in the very southwest corner of the area, also was described by Willard. The moraine trending southwest through T. 137 N., R. 60 W. and the small isolated morainal patch just south of this moraine have been included principally on the basis of the topography indicated by the aerial photographs. These moraines are unnamed and it is not certain to what general morainic system they belong.

A group of kames, the only ice-contact features in the area that have been mapped or described, are shown by Willard to be in secs. 8 and 17, T. 137 N., R. 60 W. These features could not be identified in the aerial photographs and so are omitted from figure 2. The features are not mentioned in Willard's description of the area.

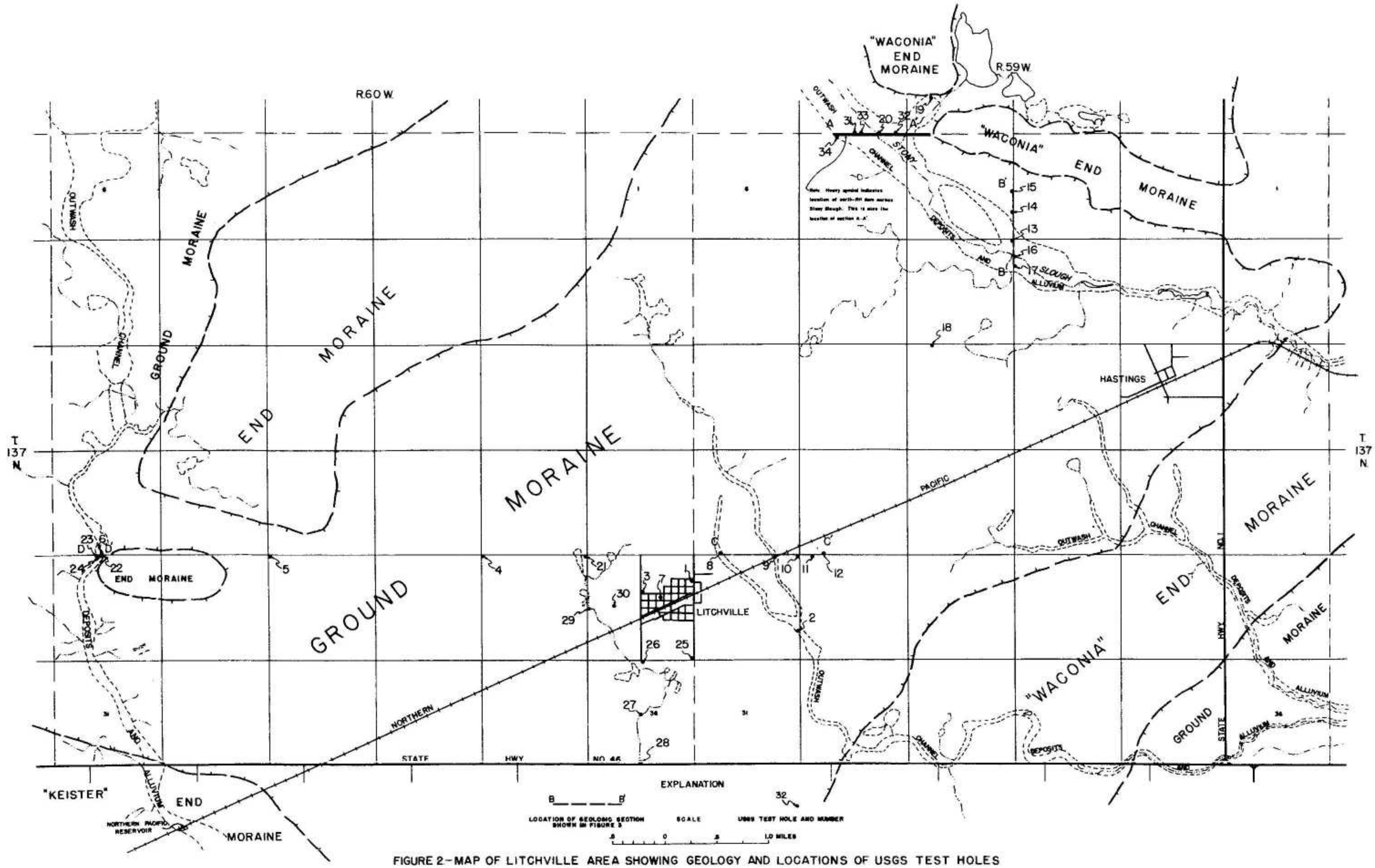

FIGURE 2—MAP OF LITCHVILLE AREA SHOWING GEOLOGY AND LOCATIONS OF USGS TEST HOLES

(GEOLOGY AFTER WILLARD AS REVISED FROM AERIAL PHOTOGRAPHS)

Willard also indicated that the deposits of glacial Sand Prairie Lake extend into the very southeast corner of the Litchville area. These deposits, however, cannot be distinguished in the areial photographs, and they are omitted from figure 2.

The intermittent streams in the area were developed as spillways or distributaries for the water released from the receding ice sheet. The valleys of these streams may contain glacial-outwash deposits and a relatively thin cover of Recent alluvium. Their locations and widths as shown in figure 2 were determined from aerial photographs and are considerably different in some places than as shown on Willard's map.

The glacial drift in the ground and end moraines consists essentially of till, but included or otherwise associated with it are deposits of sorted sand, gravel, and other materials of glaciofluvial origin. The till itself is a heterogeneous mixture of clay, silt, sand, gravel, and boulders, a relatively impermeable material, which does not yield water in sufficient quantities for most purposes. The glaciofluvial materials, however, yield significant amounts of water when encountered in sufficient thickness below the water table and, where they are relatively extensive and very permeable, may form important sources of municipal, industrial, and other supplies.

For the purpose of discussing the occurrence of ground water in the Litchville area, therefore, the glacial-drift deposits and alluvium may be divided conveniently into two groups: the deposits in the stream valleys, which here are called outwash-channel deposits and alluvium, and the till and associated glaciofluvial deposits.

The glacial-drift deposits are underlain by shales of Cretaceous age to a depth of approximately 1,000 feet. In descending stratigraphic order these include the Pierre shale, the Niobrara formation, and the Benton shale. The "Dakota sandstone" underlies the shales of Cretaceous age and has been penetrated by wells at depths of 1,000 to 1,300 feet in the Litchville area.

Formations below the "Dakota sandstone" have not been drilled in the Litchville area but it is not unlikely that rocks of earlier Mesozoic or Paleozoic age would be found above the pre-Cambrian crystalline basement complex.

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 of economic importance 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 vary considerably from one area to another 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, expressed as a percentage of a cubic foot, that will drain by gravity from one cubic foot of the saturated rock material is called its "specific yield."

If the water in an aquifer is not confined by impervious 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 causing a lowering of the water level, as in the vicinity of a pumping well, which results in gravity drainage.

If the 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, 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 pressure 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 such as sandstone and limestone and, therefore, is more important generally as a ground-water reservoir. In some areas, however, the consolidated rocks are highly porous 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 for 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 prevailing conditions.

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.

Outwash -Channel Deposits and Alluvium

Outwash-channel deposits of Pleistocene age generally covered by relatively thin Recent alluvial deposits occur in the valleys of the intermittent streams in the Litchville area. These deposits consist of sorted materials that range in size from clay to sand and gravel, which may be present in almost any proportion. Deposits of relatively clean sand and gravel probably occur as somewhat discontinuous lenses along the streams and may be more or less separated by less permeable materials such as silty or clayey sand or clayey silt. The thicker deposits of sand and gravel may be important as sources of ground water.

Only in Stoney Slough and in the south-trending stream channel in the extreme western part of the area do the deposits occur in sufficient thickness to be of potential importance as sources of ground water. In all the other stream channels in the area the deposits are only a few feet thick. Only a few stock wells, located in Stoney Slough in the northeastern part of the area, are known to obtain water from these deposits.

The largest water-supply development from these deposits has been made by the Northern Pacific Railway Co. in sec. 1, T. 136 N., R. 61 W. just south of the western part of the Litchville area. Here the railway company has constructed a shallow reservoir or open pit across the south-trending stream channel which crosses the extreme western part of the area. The reservoir was constructed simply by dredging out the materials in the stream valley to some distance below the water table. The pit is 420 feet long and 80 feet wide. 1/ In the past, only about 100,000 gallons of water per month on the average has been used from the pit and in recent years the amount probably has been considerably less because of the increased use of diesel locomotives.

Because of their occurrence in the stream valleys where they can absorb runoff water from the upland areas, the outwash-channel deposits and alluvium are the aquifers in the Litchville area most likely to receive substantial amounts of recharge. Significant amounts of recharge may reach the aquifers by direct penetration during heavy rains in the spring or fall when evaporation rates are low. Light summer rains probably contribute little if any water to the aquifers. They may supply the needs of certain types of vegetation, however, and thereby, reduce the draft on ground water in storage to some extent. Some water also is contributed to these aquifers from the till and associated glaciofluvial deposits by lateral subsurface drainage of the upland areas. However, the most significant amount of recharge to these aquifers occurs during the spring runoff period when substantial surface flows may result from the melting of the accumulated winter snows.

The water absorbed by these aquifers may be thought of as being in "transient" storage. Natural disposal processes are constantly removing water from the aquifers, and they would eventually dry up entirely if not replenished from time to time. Natural discharge results from downstream underflow of the water in the aquifers to lower parts of the valleys and eventually to the permanent streams,

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1/ Schudlich, H. M., 1948, Engineer of water service, Northern Pacific Railway Co., Personal communication, Sept. 15, 1948.

Much water is discharged by evaporation from marshy areas or from open water areas that may exist when the water level is high, as in the spring. Much water is discharged, also, by transpiration of vegetation in the valleys.

In addition to the necessity of receiving recharge from time to time, the adequacy of these deposits as sources of supply for municipal or industrial purposes depends upon: (1) the amount of water available from storage, and (2) a sufficiently high transmissibility to sustain adequate development.

A section across the south-trending stream channel in the western part of the area about 5 miles west of Litchville is shown as D-D' in figure 3. In this section USGS test 6 penetrated 24 feet of outwash-channel deposits and alluvium, 19 feet of which was sand and gravel, containing little clay. At the time this test hole was drilled, in October 1948, the water level was approximately 4 feet below the land surface. From the above data it is estimated that at this section approximately 5,500 square feet of the outwash-channel deposits was saturated when USGS test 6 was drilled. Assuming this to be an average section having an average effective porosity of 20 percent, 43,500,000 gallons of water would be stored in each mile of the stream. Not all this water could be recovered through wells and, of course, a considerable amount would be removed through natural discharge processes. Pumping from wells in the channel would lower the water table and reduce or reverse natural hydraulic gradients south of the wells. These results would tend to lessen the amount of water being removed through natural discharge processes and the water so salvaged would become available for

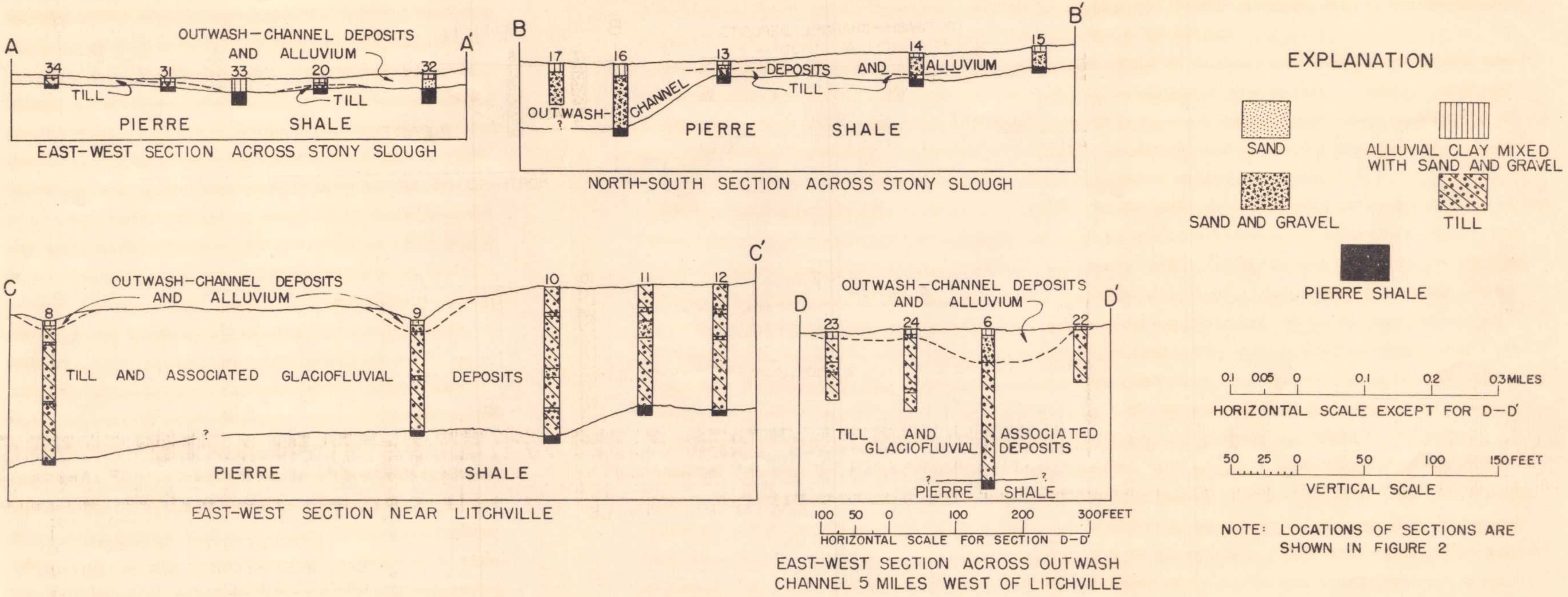

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FIGURE 3.-DIAGRAMMATIC CROSS SECTIONS IN THE LITCHVILLE AREA

pumping from the wells.

Considering the need of Litchville for a municipal water supply of 50,000 gallons a day, or approximately 18,250,000 gallons a year, this would amount to almost half the water in storage in 1 mile of the stream when the aquifer is almost totally saturated. It seems unlikely that more water could be salvaged through wells, especially in dry years when little or no recharge would occur. Also, although the transmissibility is not known, the natural underflow probably is not more than 5 to 10 percent of the required 50,000 gallons a day, so that little water would be contributed by natural underflow from upstream. This would mean that most of the water used would be derived from storage very near the development and annual or more frequent replenishment of the aquifer would be required to support it.

Because of the possibility of having two consecutive years, or more, of deficient precipitation it would appear undesirable to construct developments requiring more water than could be supplied from storage over at least 2 years, and preferably 3 years, without substantial replenishment. If 60 percent of the water in storage when the aquifer is full would be available for withdrawal, then approximately 12½ million gallons a year per mile could be obtained over a 2-year period without replenishment, and about 8-1/3 million gallons a year per mile over a 3-year period. These would be equivalent to approximately 34,000 and 23,000 gallons a day, respectively, per mile of stream.

It seems likely, therefore, that a sufficient water supply for the town of Litchville could be developed from the outwash-channel deposits in this stream but that such a development would need to be spread over a length of stream of $1\frac{1}{2}$ to 2 miles, with perhaps three or four wells involved to insure proper capacity and permanence. Underground infiltration systems or collector type wells might be preferable to drilled or dug wells in this area.

In the foregoing discussion, it has been assumed that, on the average, there would be sufficient recharge to the outwash-channel deposits to replenish the water that would be pumped from them and to supply the water removed through natural discharge processes. Although there are no stream-flow or water-level measurements from this area upon which to base an accurate estimate of water normally available for recharging the aquifer, the following discussion will give some idea as to the magnitude of the quantities involved.

The width of the valley floor which is occupied by the alluvium and outwash-channel deposits varies considerably along the valley. At section D-D', these deposits occupy a width of about 450 feet in the channel floor and this would be the width of channel in which water for recharging the aquifer would be most readily absorbed. In fact, only the precipitation occurring on this part of the valley would produce recharge to the aquifer by direct downward percolation. This fact would be important in determining the recharge that would occur from light rains which would not cause runoff from the upland areas.

However, the greatest amount of recharge to the aquifer probably occurs by infiltration of water during the spring break-up, generally during the last part of March or the first part of April when the accumulated winter snows melt. During this time, water from the valley sides will run off to the flat channel bottoms almost as soon as the snow is melted. The junction between the valley sides and the true upland areas, marking the division between the relatively well-drained and poorly-drained land, is indistinct on the ground and the division line can be determined only approximately from aerial photographs. In this sense, the width of the valley varies considerably but probably ranges from somewhat less than half a mile to a little more than a mile in the length of stream near section D-D'. If it is assumed that the width of the well-drained area will average half a mile, then the area from which spring runoff can effectively contribute recharge to the outwash-channel deposits would be 5,280 x 2,640 = 13,939,200 square feet per mile of channel. If 18,250,000 gallons = 2,444,000 cubic feet of water were taken annually from a $1\frac{1}{2}$ mile length of channel, this would require a depth of water of $\frac{2,444,000}{13,939,200}$ feet = 0.175 feet = 2.10 inches to be contributed from the well-drained area. This amount of water is equivalent to $\frac{2.10}{19.61} \times 100 = 10.7$ percent of the average annual precipitation. 1/

The water in the accumulated snows that would generally be released during the spring runoff would amount roughly to the precipitation from November through March, both inclusive, less any moisture that would be lost through sublimation during those months. The average November-March precipitation at Valley City is 3.18 inches or a little more than 50 percent more than the 2.10 inches estimated above as being required for recharge.

Additionally, there would be an undetermined amount of recharge to the outwash-channel deposits from lateral flow of ground water from adjacent upland areas. Also, the valley extends approximately 8 miles

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1/ Precipitation taken to be equivalent to that at Valley City.

north of section D-D' and a considerable portion of the runoff water in this upper stretch of the valley probably normally would be available for recharging the aquifer in the vicinity of section D-D' if no other large ground-water developments were undertaken in the up-stream stretch of the valley.

Although, because of the unknown factors involved, it is impossible to make a conclusive estimate of the actual amount of water that would be available for recharging the outwash-channel deposits in the vicinity of any development, it appears likely that there would be sufficient recharge, on the average, to satisfy the demand of 50,000 gallons a day for Litchville.

Sections A-A' and B-B' in figure 3 are sections across Stoney Slough in the northeastern part of the area approximately 5 miles northeast of Litchville. Along section A-A', only a relatively thin section of the outwash-channel deposits and alluvium was found. The deposits found in this section are too thin and impermeable to be considered practical sources of municipal or industrial supplies.

Along section B-B', however, 40 feet of sand and gravel were penetrated in USGS test hole 16. Because these deposits were not penetrated in section A-A', it is not known whether they are part of the outwash-channel deposits as considered here or whether they more properly belong to the glaciofluvial deposits associated with the till. It is quite possible that these deposits occupy a preglacial valley in the Pierre shale and, if so, they may be expected to have considerable linear extent. Little can be said, on the basis of present information, in regard to the amount of water stored in them or their probable permanence as a source of water supply. However, it is apparent that if they have any considerable linear extent and continuity, these deposits would furnish much more water and would be a much more desirable source for large water-supply developments than any other shallow aquifer that has been found in the area.

It should be emphasized that if a substantial water-supply development from the aquifer penetrated in USGS tests 16 and 17 is considered, additional test drilling should be done to determine whether the aquifer has considerable linear extent and continuity or whether it may be a rather limited deposit occurring in a pocket between the Pierre shale and the till and associated glaciofluvial deposits.

The U. S. Fish and Wildlife service has constructed a dam across Stoney Slough at the site of section A-A' to intercept the spring runoff in Stoney Slough. The runoff is shunted through a canal northeastward to natural lakes in order to maintain them as refuges for ducks and geese. Some of the water thus intercepted, of course, is water that would be available for recharging the aquifer penetrated in test holes 16 and 17 if withdrawal works were built and the water level lowered. Therefore, the only runoff water available to recharge the aquifer at the present time is that which accumulates below the dam or which may be released from the dam after the water demands for the refuge have been satisfied. The amount of this water would be considerable in the wet years but probably would be small in normal or dry years.

In section B-B', figure 3, outwash-channel deposits and alluvium are indicated as occurring in USGS test holes 14 and 15. As shown in figure 2, these test holes are somewhat outside the area of the stream deposits. It is possible, therefore, that the materials found in test holes 14 and 15 are outwash deposits derived from the end moraine to the north rather than channel deposits as indicated. The distinction is rather difficult to make on the basis of present information.

Till and Associated Glaciofluvial Deposits

Except in the stream valleys, the till and associated glaciofluvial deposits constitute the surface formation in the Litchville area.

The till itself is a heterogeneous mixture of materials ranging in size from clay to boulders and lacking stratification in any degree. In this area, the till is not an aquifer because of its high clay and silt content. However, 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 usefulness. Such aquifers are good sources of stock and domestic water supplies throughout the glaciated area in North Dakota and some of them yield several thousand gallons of water a minute to wells for industrial and municipal uses. The water found in these deposits is of great importance to the economy of the State. Most of the wells for stock and domestic water supplies in the Litchville area tap these deposits.

In the 29 USGS test holes in the Litchville area that were drilled to the underlying Pierre shale, the thickness of the till and associated glaciofluvial deposits ranged from almost nothing in test holes in Stoney Slough (see secs. A-A' and B-B', fig. 3) in the northeastern part of the area to 141 feet in USGS test 4 about 1½ miles west of Litchville. Most of the wells in the area that obtain water from the glaciofluvial deposits in the till are 100 feet or less in depth, the average being about 50 feet. Aside from the deep artesian wells, records of only four wells deeper than 100 feet were obtained. It is known that one of these wells obtains water from the underlying Pierre shale and it is quite likely that some or all of the others also do.

In the test drilling, many thin aquifers which probably would yield satisfactory farm supplies were penetrated in the till and associated glaciofluvial deposits (see logs and sections in fig. 3). However, only three occurrences of these deposits were found in thicknesses of 10 feet or more: one in USGS test 11, about 1 mile east of Litchville, and two in USGS test 5, nearly 4 miles west of Litchville. In USGS test 11, 13 feet of relatively clean sand and gravel was penetrated between 27 and 40 feet. In USGS test 5, 11 feet of gravel was penetrated between 40 and 51 feet, and 6 feet of clayey gravel above. In this same hole 10 feet of clayey gravel was found between 93 and 103 feet.

The aquifers in the till in the Litchville area probably are discontinuous and of small areal extent. Where the deposits occur in sufficient numbers and complexity they may be interconnected to such a degree as to make the entire formation a weak aquifer; this may be especially true where a rather thick, long, or widespread deposit of sand and gravel occurs in such a way that many of the smaller glaciofluvial bodies are intercepted on its edges.

Recharge to the aquifers in the till is principally through downward percolation of precipitation on the land surface in the immediate vicinity of the aquifers and from the water that may move laterally through the till from adjacent areas. The amount of recharge that may be received by the aquifers individually is dependent upon surface conditions unfavorable for runoff (so that water will have ample opportunity to percolate downward), upon the peremability of the overlying or surrounding till, and upon other factors. It is impossible to determine just how much recharge can reach a given aquifer without records of water-level fluctuations over a considerable length of time and under conditions such that possible recharge would not be rejected because of high water levels. However, the opportunity for receiving recharge will be greater for the larger aquifers and for those nearer the land surface.

None of the aquifers encountered in the till during the test drilling appears to be sufficiently thick and extensive to warrant development of 40,000 to 50,000 gallons of water a day from any one. However, each of the thicker aquifers encountered may yield supplies on the order of 5,000 to 10,000 gallons a day, or more.

Bedrock Formations

Cretaceous Shales

In the Litchville area, the till and associated glaciofluvial deposits are underlain by the Pierre shale of Upper Cretaceous age. In Stoney Slough, in the northeastern part of the area, the shale occurs at a depth of 7 feet in USGS tests 31 and 34. The greatest depth at which shale was encountered in the test drilling was 141 feet in USGS test 4, about 1½ miles west of Litchville.

In the east-central part of the State, the Pierre shale yields small supplies of water to farm wells but none of the wells is known to produce more than 10 to 15 gallons a minute. Water of fairly good quality is found in the upper parts of the shale, but water found at depth is generally too highly mineralized for domestic use.

In the Litchville area only two wells (137-59-20aac and 31bbb) are reported to obtain water from the shale. There are a few other wells in the area more than 100 feet deep and it is possible that some or all of them may obtain water from the shale. Water from well 137-59-20aac is highly mineralized and is used only for stock. It is reported that the well may easily be pumped dry with a pump jack and motor that will discharge at a rate of not more than 10 to 15 gallons a minute. The other wells that may end in the shale are generally reported to be unsatisfactory as regards both quantity and quality of the water.

The Pierre shale is underlain by the Niobrara formation, which in turn is underlain by the Benton shale, all of Cretaceous age. In the Litchville area the Cretaceous shales extend downward to depths of about 1,000 feet.

The Niobrara and Benton formations for all practical purposes are not water bearing and no wells in North Dakota are known to obtain water from them.

"Dakota Sandstone"

The "Dakota sandstone" is a widespread formation and, as far as is known, underlies the entire State of North Dakota except for portions of the extreme eastern part, where it has been removed by erosion prior to glaciation. In the Litchville area, about a dozen wells ranging in depth from 1,000 to 1,300 feet obtain water from the "Dakota sandstone".

The following discussion of the "Dakota sandstone" and its contained waters is taken from Wenzel and Sand (1942, pp. 14-17). The discussion applies to the Ellendale-Jamestown area, N. Dak., which includes the Litchville area of the present report.

> The Dakota sandstone is found almost everywhere in the area below Benton shale or, where that is absent, below the younger formations. Its texture and composition are known only from drilling because the sandstone does not crop out. The formation consists of a gray ferruginous sandstone, poorly cemented and interbedded with layers of clay and shale. In places it includes beds of fine loose sand***
>
> Two or more sandstone beds, separated by shale layers, are recognized by most drillers; and all these strata are generally assigned to the Dakota, although it is commonly recognized that the lower sediments may belong to other formations. The aggregate thickness of the sandstone and shale beds ranges from less than a hundred feet to a few hundred feet. As the artesian head and the chemical character of the water from the various beds usually differ considerably, the beds are commonly classified as distinct artesian horizons. Correlating the horizons from place to place, however, is difficult, and the precise horizon that a well taps is not generally known with certainty. According to Hard, as many as seven successive flows have been obtained in drilling one well, the water-bearing beds being separated by shale or dense sandstone.
>
> The chemical character of the water probably provides as good a basis as any for differentiating between the several flow horizons. The water from the upper part of the sandstone is generally soft but

somewhat salty and is often assigned to the 'first flow.' The waters from the sandstone at greater depths are usually much harder but lower in chloride and are commonly regarded as 'second flow' waters. However, a water of very high mineral content but apparently of no consistent chemical character is encountered in some places in the deepest sandstone beds; it is designated by some drillers as 'third flow' water***

Most of the water from the Dakota artesian basin in southeastern North Dakota is highly mineralized and at many places is unsuited for general use, especially for household purposes. Nevertheless, the water is used extensively over the area, chiefly because adequate supplies of more potable water are not available. Water from the surface deposits and Pierre shale is generally utilized wherever possible.

The water from the Dakota artesian basin is used for cooking and washing, although it commonly turns some vegetables dark and stains clothes. The water of the first flow is soft, in contrast with the waters of the second and third flows, which are hard and is therefore the water most desirable for washing purposes. The water is regarded as excellent for stock and is used extensively for this purpose. Because the temperature of the Dakota water is higher than the temperature of the drift and shale water, cows will drink more Dakota water during the cold winter months, and as a result the production of milk and cream is said to be increased.

Very little of the water is used for irrigation because of its high mineral content. A small vegetable garden was irrigated during the recent years of drought from a well on the farm of A. L. Stevens in the SE¼ sec. 7, T. 131 N., R. 63 W. Mr. Stevens reported that the minerals left by evaporation of the water caused the soil to become hard and lumpy and that the plants grew very poorly. However, a hedge on the farm was watered sparingly with the artesian water with fair success. In many places in the area almost all the vegetation has been killed along pools and ditches into which waste artesian water has been drained.

Some of the uses to which the water from the Dakota basin was originally put are not now generally possible. When the artesian pressure was high the water furnished fire protection for individual farm homes without pumping and furnished power to operate dynamos and other mechanical devices. The water was originally piped about the farms to convenient taps and into farm houses where it served as a general

> supply. For public supplies the wells were connected directly to the mains and the artesian pressure was sufficient to operate the system without pumping. At one time the operating of small electric light plants, feed mills, blowers in blacksmith shops, and washing machines by artesian water power was common.

Because the "Dakota sandstone" is deeply buried and covered with thick shale formations in the Litchville area, it cannot receive recharge locally from precipitation or other sources. The water so far taken from the formation in this area has been derived from local storage through compression of the aquifers and expansion of the water caused by the lowering of the artesian pressure. Wenzel and Sand (p. 1) indicate that this lowering in pressure has amounted to as much as 330 feet of water in some places. In the Litchville area, the artesian pressure has declined to such an extent that present wells in the area flow only under very low pressures or not at all. Nevertheless, large volumes of water are still available from the aquifer and can be withdrawn by pumping.

It has been estimated (Wenzel and Sand, pp. 40-45) that the transmissibility of the "Dakota sandstone" is on the order of 12,000 gallons a day per foot and that the coefficient of storage is on the order of 0.0011. These figures were not derived from pumping tests but were obtained by calculations involving estimates based on relatively uncertain information. The figures cannot be applied with certainty to any particular area. In the absence of better data, the above figures have been used in calculating the drawdown to be expected at a distance of 1,000 feet from a well in an areally extensive formation producing water at various rates and without interference effects caused by other wells in the formation. The results of the calculations are shown graphically in figure 4.

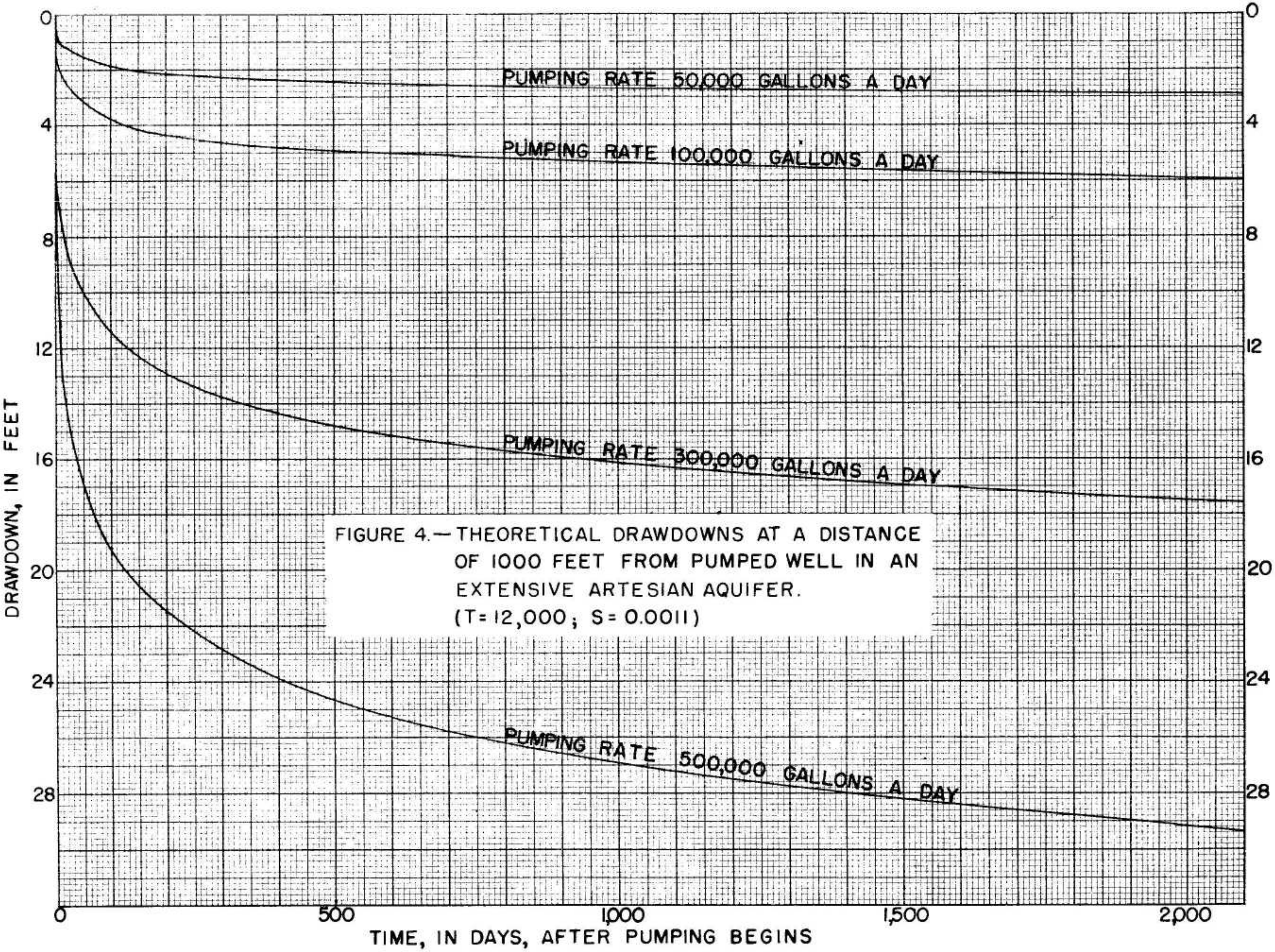

FIGURE 4.—THEORETICAL DRAWDOWNS AT A DISTANCE OF 1000 FEET FROM PUMPED WELL IN AN EXTENSIVE ARTESIAN AQUIFER. (T= 12,000; S= 0.0011)

QUALITY OF GROUND WATER

In order that the reader may more easily understand the significance of the chemical analyses, the following partial list of chemical standards promulgated by the U. S. Public Health Service, for water used for domestic purposes 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	0.3

Presence of nitrate in ground water may indicate organic contamination. Also, water containing more than about 45 parts per million nitrate (Comly, 1945, Silverman, 1949) may be injurious to infants. The presence of fluoride in drinking water in excess of 1.5 parts per million may cause mottling of the enamel of the teeth in growing children, but fluoride in lesser concentrations may be beneficial in preventing tooth decay.

Nearly all the waters in this area are more highly mineralized and harder than is generally desired for most domestic uses. However, in areas where water of the better classification cannot be obtained with reasonable economy, the acceptability of the more mineralized water will depend largely upon the tolerance of the local users. The users may become accustomed to the poorer waters and find them quite acceptable for general purposes.

In the table on pages 32a and 32b, 19 chemical analyses of ground water from the Litchville area are presented. Of these analyses, 3 are of water from the outwash-channel deposits and alluvium, 12 are of water from glaciofluvial aquifers associated with the till, 1 is of water from the Pierre shale, 1 (137-60-4bab) is of water that may be from either a glaciofluvial aquifer or the Pierre shale, and 2 are of water from the "Dakota sandstone" obtained from the Litchville well.

The water from the drift, including the outwash-channel deposits, varies considerably in mineral content. The least mineralized sample of water was that from the Northern Pacific pit in sec. 1, T. 136 N., R. 61 W., which had only 334 parts per million dissolved solids. The next least mineralized sample of water was from well 137-60-19ddd which had 578 parts per million dissolved solids. With the exception of these two, all wells in the area yielded water containing more than 1,000 parts per million of dissolved solids. The most mineralized water sampled from the glaciofluvial aquifers was from the Hastings well (137-59-14dcd), which had 6,290 parts per million dissolved solids.

The only sample of water that is known to be obtained from the Pierre shale was from well 137-59-20aac, and it contained 7,020 parts per million dissolved solids. The water contains excessive amounts of calcium, sodium, and sulfate.

The sample taken in 1949 from the "Dakota sandstone" obtained from the Litchville well contained 2,580 parts per million dissolved solids. The water contains excessive amounts of sodium and sulfate and is very hard.

CHEMICAL ANALYSES OF GROUND WATERS

(parts per

Source of analysis: a, North Dakota State Department of Health, Bismarck, North Dakota

b, Wenzel, L. K., and Sand, H. H., Water supply of the Dakota sandstone in the Ellendale-Jamestown area, N. Dak.: U. S. Geol. Survey Water-Supply Paper 889-A, p. 20, 1942.

Location number	Owner	Source of Analysis	Date of Analysis	Depth of well (feet)	Aquifer	Iron (Fe)	Calcium (Ca)
136-61-1da	Northern Pac. R.R.	a	2- 8-49	Pit	O	.7	50
137-59-9aad	Wm. Carlson	a	1-13-49	20	O	.9	135
137-59-10bcb	Wm. Carlson	a	1-13-49	11	O	4.4	154
137-59-10bcc	Wm. Carlson	a	1- 8-49	31	G	.7	147
137-59-14bdb	Spring Creek Twp.	a	1-10-49	35	G	.2	311
137-59-14cab	Robert Olafson	a	2-26-49	45	G	2.6	12
137-59-14dcd1	Hastings	a	2- 8-49	39	G	3.0	642
137-59-19dcc	R. Klevers	a	1-13-49	80	G	3.5	340
137-59-20aac	Russell Fewell	a	2-26-49	200	P	.1	604
137-59-29bbb	USGS Test 11	a	1-13-49	1/97	G	5.6	142
137-59-30aaa	USGS Test 10	a	1-10-49	2/112	G	3.1	27
137-59-30bcb	Lutheran Church	a	2-26-49	35	G	1.1	547
137-60-4bab	J. S. Dykstra	a	1-13-49	160	G	1.4	540
137-60-19ddd	G. Gudmestad	a	1-10-49	42	G	.8	92
137-60-25a	Litchville	a	2- 8-49	1,300	D	1.5	190
137-60-25a	....do....	b	1937	1,300	D	3.0	184
137-60-25acd	T. Strinden	a	1-13-49	87	G	1.0	104
137-60-25aca	H. Tempas	a	1-10-49	90	G	.3	888
137-60-30baa1	USGS Test 22	a	1-10-49	44	G	.6	196

1/ Aquifer from 27 to 40 feet.
2/ Aquifer from 59 to 66 feet.

FROM THE LITCHVILLE AREA, N. DAK.

million)

Aquifer: D, "Dakota Sandstone"
G, till and associated glaciofluvial deposits
O, outwash-channel deposits and alluvium
P, Pierre shale

Magnesium (Mg)	Sodium (Na)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Nitrate (NO_3)	Dissolved Solids	Total Hardness (as $CaCO_3$)
21	6	13	159	53	11	0	0	334	211
34	610	0	0	775	705	.1	0	2,210	475
51	277	0	478	783	218	0	13	1,840	545
75	54	0	321	458	121	.1	17	1,150	677
110	70	0	451	790	106	0	48	1,880	1,230
14	380	65	342	507	118	.6	7	1,450	88
480	459	0	399	3,790	206	0	52	6,290	3,580
73	195	0	178	1,080	320	.1	217	2,190	1,150
74	1,220	0	330	3,690	667	0	434	7,020	.....
63	378	0	218	884	240	.1	0	1,900	665
15	417	36	309	48	488	0	0	1,500	130
242	110	0	164	2,080	50	0	26	2,820	2,370
346	531	0	488	2,920	290	0	30	5,650	2,780
12	100	0	277	155	78	.2	2	578	280
48	563	0	152	1,330	270	.8	9	2,580	669
74	541	0	207	1,320	280	1.4	22	2,640	779
37	379	0	344	452	342	0	2	1,680	410
260	184	0	494	748	1,780	0	4	4,650	329
51	104	0	398	475	78	0	0	1,120	700

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based upon the location of the well with respect to the land-survey divisions used in North Dakota. The first group of three numbers is that of the township north of the base line. The second group of two numbers is that of the range west of the fifth principal meridian. The third group of one or two numbers is that of the section within the designated township. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections and quarter-quarter-quarter sections depending on their position in the well number. If more than one well occurs 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 137-59-8ddc1 is in Township 137 North, Range 59 West, section 8. It is in the southwest quarter of the southwest quarter of the southeast quarter of that section and was the first well scheduled in that 10-acre tract. Similarly, well 137-60-25bdc (see USGS test 30, fig. 2) is in the SW¼SE¼NW¼ sec. 25, T. 137 N., R. 60 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 location of such wells is 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.

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

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

Depth to water: Measurements given to hundredths or tenths are measured water levels. Those given in whole numbers are reported.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
137-59-1cbd	A. G. Velure	48	.....	Du	....
137-59-1adc	Roy Sorenson	24	.....	Du	....
137-59-2cca	H. J. Verdnin	30	.....	B	....
137-59-4baa	Clarence Olson	30-35	.....	Du	....
137-59-4daa	USGS test 15	20	5	Dr	9- 4-48
137-59-4dad	USGS test 14	25	5	Dr	9- 3-48
137-59-5bab	USGS test 34	10	5	Dr	9-24-48
137-59-8bbb	Glen Peterson	85	.....	B	....
137-59-8dcc1	Wilford Jefferson	40	.....	Du	....
137-59-8dcc2	........do........	80	.....	B	....
137-59-9aaa	USGS test 13	15	5	Dr	9- 3-48
137-59-9aad	William Carlson	20	30	Du	1925
137-59-9c 1/	L. Platon	1,000	1½	Dr	....
137-59-10aad	Carl J. Johnson	25	.....	Du	1919
137-59-10bbc1	USGS test 17	30	5	Dr	9- 8-48
137-59-10bbc2	USGS test 16	53	5	Dr	9- 6-48
137-59-10bcb	William Carlson	11	.....	Du	1915
137-59-10bcc	........do.......	31	24	B	7- 7-48
137-59-10bcd	........do.......	30	.....	Du	....
137-59-10dab1	Anna Stoneberg	.....	.....	Dr	....
137-59-10dab2	......do......	14	.....	Du	....
137-59-11d 1/	H. Stoneberg	1,050	1¼	Dr	....
137-59-12aad	Andrew Aggen	55	.....	B	....
137-59-12ccc	Adolf Strum	40	.....	Du	....
137-59-14bdb	Spring Creek Twp.	35-40	24	B	1908
137-59-14bdc1	Community Well	39	.....	Du	1935

Use of water: D, domestic; S, stock; T, test holes; U, unused.

Date of measurement: For measured depths to water, this is date of measurement. For reported measurements, this is date of report, not date of measurement by reporter.

Depth to water(feet)	Date of Measurement	Use	Remarks
......	....	D,S	Pumps sand. Supplies water to 25 head of cattle..
......	....	D,S	Pumped continuously for 2 weeks.
......	....	D,S	Supplies water to 35 head of cattle.
......	....	D,S	Pumps sand.
......	....	T	Hole destroyed. See log.
......	....	T	Do.
......	....	T	Do.
35	9-17-47	S	Poor quality reported.
......	....	D,S	Do.
......	....	S	Easily pumped dry.
......	....	T	Hole destroyed. See log.
8.92	9-21-48	S	Gravel aquifer. See chemical analysis.
Flow	7-25-28	...	
13.55	9-16-47	D,S	
......	....	T	Hole destroyed. See log.
......	....	T	Do.
6.7	9-21-48	S	Well is 48x48 inches square. Reported adequate. See chemical analysis.
20.8	9-21-48	D	See chemical analysis.
......	....	D	Poor quality. Becomes cloudy after standing.
......	....	S	Artesian well. Water level is near land surface.
......	....	D	Good quality reported. Easily pumped dry.
Flow	7-25-28	...	
......	....	D,S	Becomes cloudy after standing.
......	....	S	Supplies water to 30 head of cattle.
10	1948	D	Reported good quality but inadequate quantity. See chemical analysis.
11.11	9-22-48	U	Reported inadequate and poor quality.

(See footnotes at end of table)

Location number	Owner or name	Depth of well(feet)	Diameter (inches)	Type	Date completed
137-59-14bdc2	Sophia Elm	35	.....	Du	1923
137-59-14cab	Bob Olafson	45	30	B	1917
137-59-14dcd1	Hastings	39	.....	Du	....
137-59-14dcd2	Elleas Johnson	40	.....	B	....
137-59-16bba	USGS test 18	50	5	Dr	9- 9-48
137-59-16dcc	Ernest Johnson	60	.....	B	....
137-59-17ddd	Frank Sorenson	30	.....	B.	....
137-59-18add	L. A. Larson	40	.....	Du	1897
137-59-18ccc	John Fewell	1,180	.....	Dr	1907
137-59-19bcb	P. E. Berg	57	.....	B	....
137-59-19cdc	USGS test 8	107	5	Dr	8-27-48
137-59-19dcc	Ralph Kluvers	80	30	B	....
137-59-20aac	Russell Fewell	200	4½	Dr	....
137-59-20cdd	USGS test 12	98	5	Dr	9- 2-48
137-59-20ddd	Alvin Rodin	.....	.....	B	....
137-59-22aab	Emil Anderson	.....	.....	B	....
137-59-22cdd	Algel Larson	65	.....	B	....
137-59-22dcc	B. O. Kjelland	35	.....	Du	....
137-59-24bbc	Ellers Johnson	40	.....	B	....
137-59-24ccb	Carl Bjerky	36	20	Du	....
137-59-26a 1/	K. Olson	1,100	2	Dr	....
137-59-26aba	Claudine Olson	28	.....	Du	....
137-59-26b 2/	John Norberg	1,060	1¼	Dr	....
137-59-26ccd	Andrew Bergan	25	.....	Du	....
137-59-26dcc	Handry Rosvig	50	.....	Du	....
137-59-29bbb	USGS test 11	97	5	Dr	9- 1-48
137-59-29cdc	Herbert Peterson	53	.....	B	....

LITCHVILLE AREA, N. DAK. - - Continued

Depth to water(feet)	Date of Measurement	Use	Remarks
......	....	S	Well is 48 by 60 inches.
10	9-22-48	D	Soft, good-tasting. See chemical analysis.
......	....	U	See chemical analysis. Unused public well.
......	....	D, S	Reported good quality, but inadequate.
......	....	T	Hole destroyed. See log.
......	....	D, S	Supplies water to 40 head of cattle.
......	....	D, S	Easily pumped dry.
30	9-17-47	D, S	
15	9-17-47	S	Artesian in Dakota sandstone.
......	....	S	Reported poor quality and inadequate.
......	....	T	Hole destroyed. See log.
......	....	D, S	See chemical analysis.
......	....	S	In shale 112 to 200 feet. Easily pumped dry. See chemical analysis.
......	....	T	Hole destroyed. See log.
......	....	D, S	Reported inadequate, salty, high in iron.
......	....	D, S	Reported good quality; adequate.
1	9-16-47	S	Reported poor quality.
14.01	9-16-47	D, S	Used during the years of drought.
14.36	9-16-47	S	Reported bad-tasting water; inadequate.
22.98	9-16-47	S	Gravel in blue clay.
Flow	7-25-28	...	
20.69	9-16-47	D, S	Reported adequate.
Flow	....	...	
13	9-17-47	D, S	
......	....	S	Reported poor quality.
......	....	T	Hole destroyed. See log. See chemical analysis.
......	....	D	Easily pumped dry.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
137-59-30aaa	USGS test 10	115	5	Dr	8-30-48
137-59-30aab	USGS test 9	85	5	Dr	8-27-48
137-59-30bac	Hans Justesen	30	.....	B	....
137-59-30bcb	Lutheran Church	35	.....	Du	....
137-59-30ccc	Leo N. Schall	75	36	B	....
137-59-30dad	USGS test 2	110	5	Dr	....
137-59-30dbd	B. Kluvers	55	.....	B	1909
137-59-31abb	Mrs. Sophie Eilts	75	.....	B	1917
137-59-31bbb	Robert Froemke	90	.....	B	1939
137-59-32bab	Albert Sonsthagen	60	.....	B	1890
137-59-32d	D. Vikstrom	1,050	1¼	Dr	1903
137-59-33a 1/	C. Salberg	1,150	1¼	Dr	....
137-59-34aab	P. Tweit	22	.....	Du	1943
137-59-34cad	Fred Rodin	27	.....	Dr	....
137-59-34cdc	Oscar Salberg	82	.....	B	1919
137-59-34cdd	.....do.....	30	.....	Du	....
137-60-1adc	G. H. Van Bruggen	75	.....	B	....
137-60-3aca1	A. G. Pavluk	1,200	3 to 1	Dr	1942
137-60-3aca2	.....do.....	40	30	Du	....
137-60-4bab	J. S. Dykstra	160	.....	Dr	....
137-60-4ddc	George Person	59	24	B	1935
137-60-5dca	Toruel Knutson	64	24	B	1910
137-60-6dad	Spencer Brandt	1,130	.....	Dr	1936
137-60-8baa	....	60	36	...	....
137-60-8bbc	Lars Billings	1,118	.....	Dr	1946
137-60-8dba1	John Nordahl	64	.....	Du	1938
137-60-8dba2	.....do.....	30	.....	Du	1898

Depth to water(feet)	Date of Measurement	Use	Remarks
......	....	T	Hole destroyed. See log. See chemical analysis.
......	....	T	Hole destroyed. See log.
......	....	D, S	Easily pumped dry.
......	....	D, S	See chemical analysis. Reported inadequate.
......	....	D, S	Fine sand in blue clay.
......	....	T	Hole destroyed. See log.
......	....	D, S	Very good quality reported. Sufficient water for 65 pigs and 18 head of cattle.
......	....	D, S	Reported adequate.
......	....	D	Shale aquifer.
......	....	D, S	Adequate supply for 35 head of cattle and 100 pigs. Good quality reported.
......	7-25-28	...	Non-flowing artesian.
flow	7-25-28	...	
......	....	D, S	Reported adequate.
......	....	S	
......	....	S	
15	9-18-47	D	Do.
55	9-17-47	S	Fairly adequate.
6	9- 3-48	D, S	Artesian well; adequate; reported rather soft water.
7.50	9- 3-48	D, S	
......	....	...	Bitter-tasting. See chemical analysis.
35.42	9- 3-48	...	Reported adequate.
19.07	9- 3-48	D, S	Never pumped dry.
......	....	D, S	Flowing artesian well. Bitter-tasting water.
11.4	9- 2-48	U	Well along sec. road.
......	....	S	Artesian well. Suitable for stock.
28.14	9- 2-48	D, S	
20.8	9- 2-48	S	

(See footnotes at end of table)

Location number	Owner or name	Depth of well(feet)	Diameter (inches)	Type	Date completed
137-60-9bbc	Clarence Tenant	29	24	B	1918
137-60-10bcc	R. B. Monson	32	24	B	1902
137-60-10cbb1	John Formo	40	.....	Dr	....
137-60-10cbb2	....do....	35	.....	Dr	....
137-60-11dda	George Miller	58	.....	B	....
137-60-12cca	.....do......	41	.....	B	....
137-60-12daa	Leonard Boom	35	.....	Du	....
137-60-13ccd	Oscar Sather	46	36	B	9- -47
137-60-14baa	Harvey Faber	65	.....	B	....
137-60-14dad1	H. Vaders, Jr.	30	24	Du	....
137-60-14dad2	.......do......	130	72	Du	1929
137-60-15bcd	L. L. McCarthy	53	30	B	....
137-60-15dda1	A. G. Anderson	90	.....	Dr	....
137-60-15dda2	......do.......	48	.....	B	....
137-60-18cbb1	R. E. Hurley	65	30	B	1936
137-60-18cbb2	.....do......	35	30	B	1908
137-60-19cdc	Jim Hurley	30	18	B	....
137-60-19ddd	George Gudmestad	42	24	B	1923
137-60-20add	E. Norum	18	.....	Du	....
137-60-20bbb	Alfred Sandness	30	.....	Du	9- -47
137-60-21add	....	...	.....	Du	....
137-60-21dda	Frank W. Satterlee	33	30	B	1917
137-60-23ccc1	E. Vietzke	63	.....	B	....
137-60-23ccc2	....do....	58	.....	B	....
137-60-25a 1/	Litchville	1,300	3	Dr	....

LITCHVILLE AREA, N. DAK. - - Continued

Depth to water(feet)	Date of Measurement	Use	Remarks
......	....	D,S	Reported to contain epsom salts.
15	1946	D,S	Reported adequate.
23.4	9- 2-48	D,S	
23.2	9- 2-48	U	Unfit for use because of high iron content
......	....	S	Reported adequate.
......	....	D,S	Blue clay down to 20 feet; sand and gravel below 20 feet.
......	....	S	Reported adequate.
26.00	9-18-47	D,S	New well; reported adequate.
......	....	D,S	
14.7	9- 2-48	D	Reported adequate.
15.15	9- 2-48	S	
20	1947	D,S	Reported to be a very good well. Topsoil, 20 feet yellow clay, 5 feet blue clay, about 25 feet sand and gravel.
......	....	S	Adequate for stock.
......	....	D	Adequate for domestic use.
18.2	9- 2-48	D	Good quality. Gravel aquifer.
14.1	9- 2-48	...	Reported inadequate.
17.4	....	...	
24.97	9- 1-48	D,S	Reported adequate. See chemical analysis.
......	....	D,S	Reported adequate.
13.5	....	D,S	Reported adequate.
17.00	9- 2-48	U	
......	....	D,S	Coarse sand aquifer. Reported to have supplied water for steam engines during early days.
......	....	D,S	Reported adequate.
......	....	D	Reported good quality water. Used by town of Litchville.
Flow	7-26-28	M	Deepened from 1,115 to 1,300 feet in 1925. See chemical analysis.

(See footnotes at end of table)

Location number	Owner or name	Depth of well(feet)	Diameter (inches)	Type	Date completed
137-60-25aac1	J. Reihner	100	.....	B	....
137-60-25aac2	.....do.....	75-80	.....	B	....
137-60-25aad1	T. Strinden	87	.....	B	1927
137-60-25aad2	USGS test 1	135	5	Dr	10- 1-47
137-60-25aca	Henry Wezpas	90	24	B	....
137-60-25aca	A. Nygaard	76	.....	B	....
137-60-25acb	USGS test 3	133	5	Dr	10- 4-47
137-60-25acd	USGS test 7	134	5	Dr	10-10-47
137-60-25ada	E. Bjerke	70	.....	B	....
137-60-25ada	School well	160-180	.....	Dr	....
137-60-25adb	Ordean Dahl	90	24	B	9- -48
137-60-25bdc	USGS test 30	125	5	Dr	9-22-48
137-60-25cbb	USGS test 29	130	5	Dr	9-21-48
137-60-25dab	Mrs. M. Eggen	43	20	B	1915
137-60-25ddd	USGS test 25	125	5	Dr	9-15-48
137-60-26aaa	USGS test 21	127	5	Dr	9-10-48
137-60-26bab	Axel Formo	66	.....	B	....
137-60-26bbb	USGS test 4	149	5	Dr	10- 6-47
137-60-27aaa	Peter Verduin	50	.....	B	1922
137-60-27cdc	Clarence Hanson	75	60	B	....
137-60-28bbb	USGS test 5	155	5	Dr	10- 8-47
137-60-30acc	H. Uprud	55	.....	Du	....
137-60-30baa1	USGS test 22	44	5	Dr	9-14-48
137-60-30baa2	USGS test 6	117	5	Dr	10- 9-47
137-60-30bab1	USGS test 23	50	5	Dr	9-14-48
137-60-30bab2	USGS test 24	60	5	Dr	9-15-48
137-60-30dda	P. F. Satterlee	55	.....	B	....

LITCHVILLE AREA, N. DAK. - - Continued

Depth to water(feet)	Date of Measurement	Use	Remarks
31.6	9-16-47	U	Reported contaminated.
......	....	S	Contaminated and not used for drinking.
......	....	D	See chemical analysis.
......	....	T	Hole destroyed. See log.
......	....	S	Reported contaminated. See chemical analysis.
......	....	D	Easily pumped dry.
......	....	T	Hole destroyed. See log.
......	....	T	Do.
......	....	U	Reported inadequate.
......	....	U	Do.
20	9-22-48	D	0-30 feet yellow till, 30-90 feet gray till, 90-93 feet blue quicksand (aquifer)
......	....	T	Hole destroyed. See log.
......	....	T	Do.
6.73	9- 1-48	U	Formerly used for watering stock.
......	....	T	Hole destroyed. See log.
......	....	T	Do.
......	....	S	Reported adequate.
......	....	T	Hole destroyed. See log.
......	....	D, S	Adequate. Reported to be a good well.
......	....	D, S	Easily pumped dry.
......	....	T	Hole destroyed. See log.
37.7	9- 1-48	D, S	Well is 48x48 inches square.
......	....	T	Hole destroyed. See log. See chemical analysis.
......	....	T	Hole destroyed. See log.
......	....	T	Do.
......	....	T	Do.
......	....	D, S	Reported adequate.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
137-60-31dda	C. F. Anderson	30	.....	Du	....
137-60-32bcc	C. P. Sandness	40	.....	Du	1907
137-60-33aab	Peter Van Bruggen	40	.....	B	....
137-60-33baa	Albert Koppa	40	.....	B	....
137-60-34cdd	H. Arends	35	.....	B	....
137-60-34ddd	R. Lenssen	65	.....	Dr	....
137-60-35bab	E. Murphy	65	.....	B	....
137-60-36abb	USGS test 26	127	5	Dr	9-16-48
137-60-36cdd	USGS test 28	135	5	Dr	9-20-48
137-60-36dbb	USGS test 27	130	5	Dr	9-17-48
138-59-32dcc1	USGS test 31	10	5	Dr	9-23-48
138-59-32dcc2	USGS test 33	20	5	Dr	9-23-48
138-59-32dcd	USGS test 20	11	5	Dr	9- 9-48
138-59-32ddd	USGS test 32	20	5	Dr	9-23-48
138-59-33cbd	USGS test 19	20	5	Dr	9- 9-48

LITCHVILLE AREA, N. DAK. -- Continued

Depth to water(feet)	Date of Measurement	Use	Remarks
......	....	D, S	Reported adequate.
......	....	D, S	Easily pumped dry.
......	....	D, S	Fairly adequate.
......	....	D, S	Reported inadequate.
......	....	S	Do.
......	....	S	Reported adequate.
......	....	D, S	Fairly adequate.
......	....	T	Hole destroyed. See log.
......	....	T	Do.
......	....	T	Do.
......	....	T	Do.
......	....	T	Do.
......	....	T	Do.
......	....	T	Do.
......	....	T	Do.

1/ Data from Wenzel, L. K., and Sand, H. H., Water supply of the Dakota sandstone in the Ellendale-Jamestown area, N. Dak.: U. S. Geol. Survey Water-Supply Paper 889-A, p. 79, 1942.

2/ Data from Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 69, 1929.

137-59-4daa
USGS test 15

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Sand and gravel, gray, very clayey.	2	3
Sand and gravel, upper part buff, lower part gray . .	13	16
Pierre shale, gray.	4	20

137-59-4dad
USGS test 14

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Clay and gravel, light-brown.	1	2
Sand and gravel, upper part light-brown, lower part gray.	15	17
Till, gray.	2	19
Pierre shale, gray.	6	25

137-59-5bab
USGS test 34

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	2	2
Alluvial slopewash, clay with sand and gravel	2	4
Till, tan	3	7
Pierre shale, gray.	3	10

137-59-9aaa
USGS test 13

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Clay and gravel, gray	1	2
Sand, tan	3	5
Till, gray.	4	9
Pierre shale, gray.	6	15

137-59-10bbc1
USGS test 17

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Clay and gravel, gray	2	3
Clay and gravel, brown.	2	5
Clay and gravel, gray	2	7
Sand and gravel, gray	23	30

137-59-10bbc2
USGS test 16

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Clay and sand, gray	2	3
Clay and sand, light-brown.	3	6
Clay and sand, gray	2	8
Sand and gravel, gray	40	48
Pierre shale, gray.	5	53

137-59-16bba
USGS test 18

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Till, light-tan	4	5
Sand and gravel, light-tan.	2	7
Till, gray.	9	16
Sand and gravel, gray	3	19
Till, gray.	19	38
Pierre shale, gray.	12	50

137-59-19cdc
USGS test 8

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Alluvial slopewash, clay with sand and gravel, yellow-brown	1	2
Sand and gravel, yellow-brown	2	4
Till, yellow-brown.	12	16
Sand and gravel, yellow-brown	2	18
Till, gray.	40	58
Shale gravel, gray.	1	59
Till, gray.	45	104
Pierre shale, gray.	3	107

LOGS OF TEST HOLES IN THE LITCHVILLE AREA, N. DAK. -- Continued

137-59-20cdd
USGS test 12

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Till, light-tan	17	18
Sand and gravel, clayey, gray, some rocks	3	21
Till, gray.	17	38
Sand and gravel, clayey, gray	1	39
Till, gray.	54	93
Pierre shale, gray.	5	98

137-59-29bbb
USGS test 11

Topsoil, black.	1	1
Till, light-tan	17	18
Gravel, tan	2	20
Till, light-tan	4	24
Till, gray.	3	27
Sand and gravel, clayey, gray	13	40
Till, gray.	51	91
Pierre shale, gray.	6	97

137-59-30aaa
USGS test 10

Topsoil, black.	1	1
Till, gray.	2	3
Till, tan	15	18
Gravel, gray.	2	20
Till, gray.	39	59
Sand and gravel, gray	7	66
Till, gray.	23	89
Gravel, gray.	1	90
Till, gray, numerous small rocks near bottom.	20	110
Pierre shale, gray.	5	115

137-59-30aab
USGS test 9

Material	Thickness (feet)	Depth (feet)
Topsoil, black	1	1
Alluvial slopewash, clay with sand and gravel, light-gray	1	2
Sand and gravel, yellow-tan	2	4
Till, yellow-tan	4	8
Till, gray	33	41
Sand and gravel, clayey, gray	3	44
Till, gray	38	82
Pierre shale, gray	3	85

137-59-30dad
USGS test 2

Material	Thickness (feet)	Depth (feet)
Topsoil, black	1	1
Till, yellow	7	8
Till, gray	20	28
Shale gravel, clayey, gray	5	33
Till, gray	61	94
Pierre shale, gray	16	110

137-60-25aad2
USGS test 1

Material	Thickness (feet)	Depth (feet)
Topsoil, black	1	1
Till, yellow	28	29
Till, gray	51	80
Till, blue-gray 1/	48	128
Pierre shale, gray	7	135

1/ Core taken of till, 105 to 107 feet. Till is well indurated and difficult to break with a hammer. It is highly calcareous and may be partly cemented as well as compacted.

137-60-25acb
USGS test 3

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Till, yellow.	18	19
Till, gray.	7	26
Sand and gravel, clayey, gray	2	28
Till, gray.	94	122
Pierre shale, gray.	11	133

137-60-25acd
USGS test 7

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	2	2
Till, yellow.	18	20
Till, gray.	7	27
Gravel, clayey, gray.	1	28
Till, gray 1/	97	125
Pierre shale, gray 2/	9	134

1/ Core of till taken 70 to 80 feet. Very hard "shaly" till which contained pebbles of dark-colored limestone and shale.

2/ A shale core between 130 and 134 feet yielded very hard shale.

137-60-25bdc
USGS test 30

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Till, tan	25	26
Till, gray.	14	40
Sand and gravel, gray	1	41
Till, gray.	76	117
Pierre shale, gray.	8	125

137-60-25cbb
USGS test 29

Material	Thickness (feet)	Depth (feet)
Topsoil, black	2	2
Till, gray	1	3
Till, tan	14	17
Till, gray	65	82
Sand and gravel, gray	2	84
Till, gray	41	125
Pierre shale, gray	5	130

137-60-25ddd
USGS test 25

Material	Thickness (feet)	Depth (feet)
Topsoil, black	2	2
Till, gray	2	4
Till, yellow-brown	9	13
Till, gray	39	52
Sand and gravel, gray	4	56
Till, gray	62	118
Pierre shale, gray	7	125

137-60-26aaa
USGS test 21

Material	Thickness (feet)	Depth (feet)
Topsoil, black	2	2
Till, tan	18	20
Sand and gravel, tan	1	21
Till, gray	15	36
Sand and gravel, gray	1	37
Till, gray	47	84
Sand and gravel, shaly, gray	6	90
Till, gray	28	118
Sand and gravel, gray	3	121
Pierre shale, gray	6	127

137-60-26bbb
USGS test 4

Material	Thickness (feet)	Depth (feet)
Topsoil, black	1	1
Till, yellow	20	21
Till, gray	49	70
Till, blue-gray	71	141
Pierre shale, gray 1/	8	149

1/ Core taken 147 to 149 feet. Shale was hard and had poor fissility. Contained a bivalve shell, some foraminifera and possibly plant fragments.

137-60-28bbb
USGS test 5

Material	Thickness (feet)	Depth (feet)
Topsoil, black	2	2
Till, buff	18	20
Till, gray	14	34
Gravel, clayey, gray	6	40
Gravel, gray	11	51
Till, gravelly, gray	42	93
Shale gravel, very clayey, gray	10	103
Till, gray	36	139
Pierre shale, gray 1/	16	155

1/ Core taken from 150 to 155 feet. Shale contained veinlets of secondary calcium carbonate which may have been aragonite. Shale was otherwise non-calcareous.

137-60-30baa1
USGS test 22

Material	Thickness (feet)	Depth (feet)
Topsoil, black	1	1
Alluvial slopewash, clay with sand and gravel, gray	3	4
Till, tan	5	9
Sand and gravel, tan	1	10
Till, gray	34	44

137-60-30baa2
USGS test 6

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	2	2
Alluvial slopewash, clay mixed with sand and gravel, yellow-brown.	3	5
Sand and gravel, gray	19	24
Till, gray.	88	112
Pierre shale, gray.	5	117

137-60-30bab1
USGS test 23

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Alluvial slopewash, clay mixed with sand and gravel, gray.	3	4
Till, tan	6	10
Till, gray.	11	21
Sand and gravel, gray	8	29
Till, gray.	21	50

137-60-30bab2
USGS test 24

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	2	2
Alluvial slopewash, clay mixed with sand and gravel, gray.	2	4
Sand and gravel, brown.	1	5
Till, gray.	11	16
Till or clayey sand, gray	11	27
Till, gray.	16	43
Sand and gravel, gray	3	46
Till, gray.	14	60

LOGS OF TEST HOLES IN THE LITCHVILLE AREA, N. DAK. -- Continued

137-60-36abb
USGS test 26

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Till, yellow-brown.	15	16
Till, gray.	29	45
Sand and gravel, gray	3	48
Till, gray.	56	104
Sand and gravel, gray	1	105
Till, gray.	16	121
Pierre shale, gray.	6	127

137-60-36cdd
USGS test 28

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Sand, light-brown, clayey	11	12
Till, gray.	87	99
Sand, clayey, gray.	3	102
Till, gray.	33	135

137-60-36dbb
USGS test 27

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Clay and sand, light-brown.	2	3
Sand, light-brown	3	6
Alluvium, clay mixed with sand and gravel, light-brown	5	11
Sand and gravel, gray	4	15
Till, gray.	88	103
Sand and gravel, gray	2	105
Till, gray.	21	126
Pierre shale, gray.	4	130

138-59-32dcc1
USGS test 31

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Clay, sand and gravel, gray	2	3
Till, yellow-brown.	4	7
Pierre shale, gray.	3	10

138-59-32dcc2
USGS test 33

Material	Thickness (feet)	Depth (feet)
Clay and rocks, gray.	1	1
Alluvial slopewash, clay mixed with sand and gravel, yellow-brown.	3	4
Alluvium, clay with sand and gravel	6	10
Pierre shale, gray.	10	20

138-59-32dcd
USGS test 20

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Alluvial slopewash, clay mixed with sand and gravel, gray calcareous	1	2
Alluvial slopewash, clay mixed with sand and gravel, tan	1	3
Sand and gravel, clayey, tan.	2	5
Till, tan	3	8
Pierre shale, gray.	3	11

138-59-32ddd
USGS test 32

Material	Thickness (feet)	Depth (feet)
Sand and clay, gray	3	3
Sand, gray-brown.	8	11
Pierre shale, gray.	9	20

138-59-33cbd
USGS test 19

Material	Thickness (feet)	Depth (feet)
Topsoil, black.	1	1
Alluvial slopewash, clay mixed with sand and gravel, gray, highly calcareous	2	3
Alluvial slopewash, clay mixed with sand and gravel, tan	5	8
Till, gray.	5	13
Sand and gravel, clayey, gray	2	15
Pierre shale, gray.	5	20

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