UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGY AND GROUND-WATER RESOURCES OF NORTH DAKOTA

Prepared in cooperation with the
STATE GEOLOGICAL SURVEY OF NORTH DAKOTA

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Water-Supply Paper

GEOLOGY AND GROUND-WATER RESOURCES OF NORTH DAKOTA

BY

HOWARD E. SIMPSON

WITH A DISCUSSION OF THE CHEMICAL CHARACTER OF THE WATER

BY

HARRY B. RIFFENBURG

Prepared in cooperation with the
STATE GEOLOGICAL SURVEY OF NORTH DAKOTA
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CONTENTS

ILLUSTRATIONS

GEOLOGY AND GROUND-WATER RESOURCES OF NORTH DAKOTA

By Howard E. Simpson

INTRODUCTION

HISTORY OF THE INVESTIGATION

Water is the most valuable of the mineral resources. The study of ground waters is therefore clearly within the field of economic geology and constitutes an important part of the work of the geological surveys, both State and national, as defined by law. In the spring of 1911 the investigation of the ground waters of North Dakota was begun by the North Dakota Geological Survey, and the work was assigned to the author of this paper. During each of the three summers 1911, 1912, and 1913 several weeks were devoted by the author to the field work of a general survey. A report on the ground waters of the State was then prepared by him and was transmitted by the director of the North Dakota Geological Survey to the State printing commission for publication. However, owing to lack of available funds the report was not published.

A portion of the summer of 1914 was given to a study of artesian conditions in the Souris River Basin. Since that time considerable work has been done in connection with detailed surveys made for a number of cities and villages in an effort to obtain the best available supply of water for public use.

During the summer of 1920 arrangements were made by the United States Geological Survey with the North Dakota Geological Survey whereby the author completed the work as fully as possible by correspondence and brought the report up to date.

In the spring of 1921 samples of water from 196 sources were collected by the author and J. H. Buchanan and were sent to the United States Geological Survey for analysis. Most of these samples were analyzed by H. B. Riffenburg, who has used the analyses for a description of the chemical character of ground waters in the State. In addition to the analyses of samples collected in connection with the preparation of this report, over 700 partial analyses from different sources were examined. These analyses are not given in this paper, because the location of many of the wells was not stated definitely, and most of the analyses were incomplete. They were useful, however, in confirming the conclusions based on the analyses that are printed, particularly for counties where only a few samples were collected for this report.

SOURCES OF INFORMATION

In the portions of this report that deal with the shallow waters the county is made the areal unit, and practically every county has been visited and studied. In all towns that have a municipal water supply the city officials were asked to contribute the data regarding such supply.

The well drillers of the different localities have supplied the facts regarding the kinds of wells in common use, the depth of the wells, the material passed through in drilling, and the sources from which the waters come. Much information has also been gathered from private individuals who were interested in the work.

The time spent in each county was necessarily too brief for the desired results. Throughout much of the western part of the State the North Dakota Geological Survey has already carried forward the study of the coal resources and at the same time procured a large amount of material in regard to the geologic conditions that control the distribution of the ground waters. The reports of the State survey and of the Federal survey, including the very valuable report by N. H. Darton [1] on the underground waters of the Dakota artesian basin, and the paper on the underground water resources of Iowa by Norton and others,[2] have been freely used. From the Iowa report the writer has drawn much that relates to the occurrence and geologic relations of ground waters, particularly to the artesian phenomena, and he here acknowledges his indebtedness to Prof. W. H. Norton, the senior author of that report.

PURPOSE OF THE INVESTIGATION

The purpose of this investigation was to determine to the fullest extent, with the time and funds available, the significant facts regarding ground water in North Dakota. These facts include a knowledge of the geologic formations of the State, the conditions under which water occurs in them, and the quality of the water. This study applies both to the shallow subsurface waters found almost everywhere and to the deeper artesian waters that underlie large portions of the State.

NEED OF THE INVESTIGATION

The need of a scientific investigation of the ground-water resources of North Dakota is evident to all who consider the matter. A larger number of waterworks are being built than ever before, many towns

[1] Darton, N. H., Preliminary Report on Artesian Waters of a Portion of the Dakotas: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, pp. 603-694, 1896.

[2] Norton, W. H., Hendrixson, W. S., Simpson, H. E., Meinzer, O. E., and others, Underground Water Resources of Iowa: U. S. Geol. Survey Water-Supply Paper 293, 1912.

are considering their installation, and still others are seeking better and more adequate supplies. The deep water-bearing beds lie far below the sources that supply the common wells. The local well driller can not be expected to know either the quantity or quality of the water of these deeper beds, the depth at which the beds may be reached, or whether they may be reached at all. In some parts of the State there are serious difficulties in obtaining a suitable supply. The problems that arise in this connection are numerous. They are not the same for any two communities, and many serious mistakes are made in their solution. Many towns proceed without expert advice, and thousands of dollars have been wasted in unwise and fruitless search for artesian water. Deep drillings have been made at other points where careful study of conditions proves that suitable supplies will be found at shallow depths or not at all. Other communities rely on very unsatisfactory supplies, though better may be had at greater depths. Careful interpretation of data from wide areas, a knowledge of the geologic structure, and an acquaintance with the occurrence, distribution, and movement of ground waters are necessary for the best solution of such problems. The statement of the facts and the discussion of the conditions as presented in this paper should be of particular value to the municipalities of the State, though it is far from complete. More detailed studies of noteworthy localities, local artesian basins, areas of insufficient supply, and formations that yield strongly mineralized waters are greatly needed, and these will undoubtedly follow this general preliminary report as fast as appropriations warrant.

ACKNOWLEDGMENTS

The writer is indebted to many well drillers for courtesies extended in giving well logs and other information. Valuable information has been received from so many that individual mention is impossible.

The cooperation and assistance of the officers and members of the North Dakota Well Drillers' Association has been of especial value and indicates the possibilities that lie in cooperation between organized drillers and the State geological survey. This organization was formed in 1915 for bettering the work of well drilling in the State through increased knowledge of the occurrence and character of the ground waters and through better methods of recovering them.

Most of the valuable artesian records were made several years ago, when standard rigs were used. In recent years, owing to the ease with which wells are put down in the soft rocks in this State, the jetting process has been used almost exclusively. With this process a good log can not be obtained, though much may be inferred by the experienced driller as to the character of the strata in which the drill is working. Few written records are kept except as to depth, but the

information is of considerable value when analyzed by one familiar with the geologic formations present and the modes of occurrence of water within them.

PHYSIOGRAPHY

RELIEF

The surface of North Dakota, although considerably diversified, consists essentially of plains which rise steplike from an altitude of about 800 feet in the Red River Valley in the northeastern part to a general altitude of about 2,800 feet in the southwest corner of the State. The total relief, however, is somewhat greater, as measured from Pembina, at an altitude of 798 feet, at the point where Red River crosses the Canadian boundary, to the crest of Black Butte, in Slope County, at 3,468 feet. The relief, as shown by these figures, is slightly more than half a mile—a very moderate range for an area of 72,000 square miles.

PROVINCES

GENERAL FEATURES

North Dakota consists entirely of plains and lies in what physiographers generally regard as the Interior Plains—one of the major divisions of the continent. As the eastern part of the Interior Plains is much lower than the western part and as it has been generally modified by glaciation the major division has been divided into two fairly distinct provinces. (See fig. 1.) The province on the east is called the Central Lowland and the one on the west the Great Plains. The line that separates these provinces passes nearly through the middle of North Dakota, along the base of the eastern escarpment of the Great Plains. This line enters the State from the south on the meridian of 98° 50′, passes just west of the towns of Jamestown and Minot, and crosses into Canada on the meridian of 102° 45′.

CENTRAL LOWLAND

DIVISIONS

That part of the Central Lowland which lies within the State of North Dakota consists of two distinct areas of well-marked topographic features. One of these areas, which embraces the easternmost part of the State, is the Red River Valley, and the next one to the west is generally known in this region as the Drift Prairie.

RED RIVER VALLEY

Character and origin.—The Red River Valley takes its name from the river which drains it. However, it is not a true river valley of erosion but an ancient lake plain. That portion which lies within the State has a breadth of 35 to 40 miles, except at the south end, where it narrows to 10 miles. It has an altitude of about 800 feet in the north and rises to almost 1,000 feet at the south end.

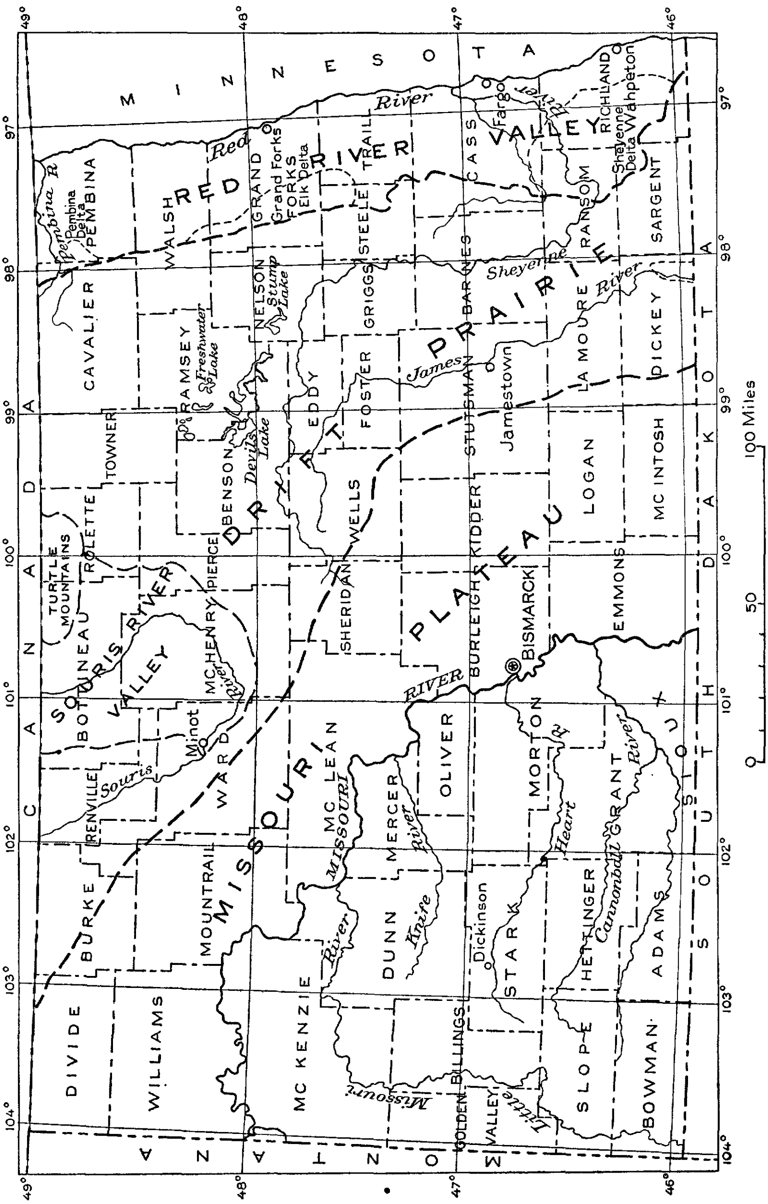

FIGURE 1.—Map showing the physiographic regions of North Dakota

There is no bedrock exposed in this region, for the surface is deeply covered with fine silt that overlies a thick layer of glacial drift horizontally bedded.

Native trees grow only along Red River and its tributaries, and here they are usually confined to the terraces of these streams.

The Red River plain is a bed of a former lake known to geologists as Lake Agassiz.[3] During the glacial epoch the entire plain and the region far to the south was covered by a great sheet of ice. The ice front was melted back northward at the end of the epoch. After retreating across the high land that forms the Continental Divide between the streams that flow to Hudson Bay and those that flow to the Gulf of Mexico, the water from the melting ice front was held in between this divide on the south, the wall of ice on the north, and the high land on each side. This ponded water formed the lake that is now, thousands of years after its disappearance, known as glacial Lake Agassiz.

The water of the lake soon overflowed at the lowest point in the highland rim, cut the depression now occupied by Lake Traverse and Big Stone Lake, and found its way into Mississippi River by the present valley of Minnesota River.

The streams that flowed into Lake Agassiz carried large quantities of fine sediment, which settled evenly over the bottom, forming a level floor. In time the ice melted so far back that the water could flow northward, thus draining the lake and leaving a level plain. The streams that flowed into the lake from the sides extended their courses across the plain as the lake retreated and united in the middle, forming Red River. This river still flows northward to Lake Winnipeg, a remnant of glacial Lake Agassiz. The Red River Valley lies therefore in the Nelson River drainage basin.

Surface features.—The plain on both sides of Red River is remarkably level. Few features of the relief are large enough to be noticeable to the eye. The groves planted by the early settlers to act as windbreaks stand above the horizon in every direction. The northward slope averages not more than 1½ feet to the mile. The rise to the west is more marked but does not exceed 4 or 5 feet to the mile near the axis of the valley.

A series of well-defined gravel ridges marks the western margin of the plain. These are old beach ridges formed on the shore of the ancient lake. The highest marks the westernmost shore line of this remarkable glacial lake; the lower beaches represent the different stages in the lowering of the lake level.

Other characteristic shore forms are the three large deltas that were built on the western margin of the lake by the inflowing rivers. These are the Pembina delta at the north, on which stands the town of Walhalla; the Sheyenne delta at the south, a few miles east of Lisbon; and the Elk River delta, in the center of which stands

[3] Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1895.

Larimore. The Elk River delta was formed by a glacial river that flowed down the Elk Valley from the ice front but is now extinct.

Drainage.—So little has the surface of this plain been carved by streams and so few are the drainage channels that the run-off of rain water is exceedingly slow. Much of it sinks into the soil or is evaporated from standing pools. There are but few permanent streams, and these have few tributaries. All flow in narrow, shallow trenches, and their courses are very winding. The plain is therefore still in the stage of early youth.

Red River is the master stream of the region. Through its tributaries, Bois de Sioux, Wild Rice, Sheyenne, Goose, Turtle, Forest, Park, and Pembina Rivers, it drains the entire area and a considerable part of the Drift Prairie on the west. The gradient on Red River does not exceed 1 foot to the mile for much of its length, and owing to this very gentle gradient it is one of the most winding rivers in the world.

The retreat of the lake from this region left extensive marshy areas that still exist in considerable part, especially in the northern portion of the valley. Considerable areas of "alkali" and salty marshland occur in Pembina, Walsh, and Grand Forks Counties. Much has been done by means of ditches to reduce the ground-water level in these lands and to provide adequate drainage, but much still remains to be done.

Soil and cultivation.—The soil of Red River Valley is exceedingly fertile. The region is particularly well adapted to farming on a large scale. The settlement of this plain was rapid as soon as railroads brought access to markets. Wheat and flax were long the only products, but the farms are now being reduced in size, the variety of crops is increasing, and livestock is being generally introduced. Agriculture, the prevailing occupation, is being rapidly diversified.

DRIFT PRAIRIE

EASTERN BOUNDARY

The boundary between Red River Valley and the Drift Prairie is a well-defined rise of land amounting to 300 or 400 feet, extending entirely across North Dakota from north to south. In its southern portion it is gentle and somewhat inconspicuous and merges into the Coteau des Prairies in South Dakota. In the north it is abrupt, and the region to the west is so rugged as to receive the name Pembina Mountains. This feature is not a true mountain range but the edge of a plateau deeply eroded by the streams as they flow eastward from the higher to the lower country. For convenience, the border of the Red River Valley within the State is referred to as the Pembina escarpment.

SURFACE FEATURES

General character.—The Drift Prairie is a gently rolling or hilly area, characteristic of a drift region in early youth. The bedrock is so soft and shaly that it does not influence the surface form to any marked extent. Here and there groups of low, well-rounded hills or ridges rise above the prairie, but these are so deeply covered with drift that only their form reveals the fact that they are composed of bedrock. The best known hills of this kind are Mauvaise Butte, Sullys Hill, Devils Heart, and Pilot Knob. These hills are remnants of formations which are higher in the geologic column than those that underlie the prairies and which were largely eroded before the coming of the ice sheet, which passed over them and covered them with glacial drift. More numerous are the long lines of knobby hills and ridges that stretch across the prairies from northwest to southeast. These hills are the recessional moraines and were formed at the front of the ice during pauses in its retreat. Hills or ridges of this type are particularly well shown between Devils and Stump Lakes and Sheyenne River.

The prairie between these hilly belts is a gently rolling till plain with here and there level floors of old glacial lakes. In this region the irregularities of an old plain have been largely modified by an ice sheet. The old valleys have been filled, the hills smoothed down, and a mantle of glacial drift spread over all.

Three features of especial interest lie within the Drift Prairie—the Devils Lake Basin, the Turtle Mountains, and the Souris River Valley. The resemblance of the Turtle Mountains to the Missouri Plateau and of the Souris River Valley to the Red River Valley emphasizes the transitional character of this middle plain.

Turtle Mountains.—The Turtle Mountains consist of a rough moraine-covered tableland that lies midway on the Canadian boundary line of North Dakota. They cover an area of 600 to 800 square miles and rise 400 to 600 feet above the surrounding plain, their margin forming a gentle though conspicuous escarpment on all sides. The mountainous character is suggested not only by the height of this plateau above the plain but also by the very rough character of the surface. Lakes abound, and the upland is, on the whole, well timbered and well watered but very poorly drained. The Turtle Mountains are the most conspicuous illustration of that group of solated areas scattered here and there over the western portion of the Drift Prairie which are underlain by remnants of younger horizontal strata that elsewhere have been eroded back to the Missouri Plateau, of which they may be considered outliers.

Souris River Valley.—The Souris River Valley is a glacial marginal lake plain, similar to the Red River Valley. Its floor was formerly covered by the water of Lake Souris. This plain lies between 1,100 and 1,600 feet above sea level. Like the Red River Valley, it also is drained northward, through the eastern portion of the "loop" of Souris River. The position of this low, flat lake plain between the Missouri Plateau and its eastern outlier, the Turtle Mountains, accentuates the separation of these two features, which were formerly united, and shows by strong contrast the relative amount of work performed in this region by the agents of erosion in preglacial time as compared with the meager work done since the glacial epoch.

DRAINAGE

James and Sheyenne Rivers have deep, wide valleys cut by the water that flowed from the front of the ice sheet. Besides these well-marked valleys the plain is cut by many shallow, irregularly winding coulees and dotted by thousands of small lakes, ponds, and marshy areas that show the undeveloped character of the drainage. The time since the completion of the work of the ice has been insufficient for anything save the slightest beginning of the work of erosion.

Numerous lakes occur throughout this area, particularly in the rougher morainal portions. A few of the larger lakes occupy old preglacial valleys, which were partly filled with glacial drift, as Devils and Stump Lakes; others occupy the deep channels cut by the water that flowed from the front of the ice sheet, as Des Lacs and Eckelson Lakes; and the great majority of the smaller lakes occupy shallow basins left in the irregular surface of the morainal deposit, as Sweetwater Lake[3a] and Lac aux Mortes. A few of these lakes are of considerable size, and the largest is Devils Lake, which is described below. Some of these lakes, including Metigoshe and Fish Lakes of the Turtle Mountains, Devils Lake, and Spiritwood Lake, farther south, have become popular summer resorts, and all are valuable hunting grounds for waterfowl in the game season.

DEVILS LAKE BASIN

Devils and Stump Lakes lie just within the southern border of the large interior drainage basin to which Devils Lake, the largest body of water in the State, has given its name. This basin extends from the southern slopes of the Turtle Mountains and the Canadian boundary southward to a series of prominent hills that lie between Devils and Stump Lakes and Sheyenne River. The eastern and western boundaries are more vague and indistinct, but the area of the entire drainage basin is estimated at about 3,500 square miles. There is a gradual southward slope throughout the basin to these two lakes; the gradient is so slight, however, and the surface so irregular that the drainage is very imperfectly developed. Small lakes and ponds abound, especially in the southern part.

[3a] Shown on Plate 1 and Figure 1 as Freshwater Lake.

Coulees are few and very shallow and rarely contain running water except in wet seasons. Formerly these coulees and the chains of lakes connected by them emptied considerable water into Devils Lake through Mauvais Coulee and by several converging coulees into both the eastern and western arms of Stump Lake. Mauvais Coulee was the largest drainage line of the entire basin. Its headwaters were gathered north of the international boundary line, and in its course southward it drained the Sweetwater chain of lakes by Lake Irvine, through which it passed, and entered Mauvaise Bay of Devils Lake as a large and permanent stream. To-day no surface streams flow except during rapid thaws and after excessive falls of rain. Both lakes, however, undoubtedly receive extensive underground seepage from the glacial drift cover of the large drainage basin, the waters of which move slowly down the slope from the north over the impervious floor of Pierre shale and through the lower sandy portions of the drift. Little of the surface drainage of this inland basin ever reaches either of these lakes. In fact, but a very small, almost negligible, fraction of the rain that falls in the basin reaches the lakes by running off over the surface. The amount that reaches the lakes and Sheyenne River by underground seepage is no doubt greater, but this amount can not be satisfactorily estimated.

SOILS

In the Drift Prairie the wide areas of rolling prairie owe their fertility largely to the work of the ice. The rich soil is composed chiefly of ground-up rock mixed with sand and gravel. Though the depressions are commonly alkaline the rolling land is well drained. The region is therefore largely devoted to growing wheat, though a number of other crops are now being raised. Grazing and dairying are both extensive industries, particularly in the northwestern part.

GREAT PLAINS

MISSOURI PLATEAU

General features.—On the western border of the Drift Prairie rises an escarpment which is even more abrupt than that which bounds the prairie on the east. This feature is the eastern edge of the Missouri Plateau and is known as the Missouri escarpment. This escarpment trends northwest and passes near and to the west of Crosby, Kenmare, Minot, Carrington, and Jamestown. It is in general 500 to 600 feet above the lower plain to the east. The plateau, which stretches westward from this escarpment to and beyond the western border of the State, occupies fully half of the State and is a characteristic portion of the Great Plains. Its irregular surface ranges in altitude from 1,800 to 2,800 feet above sea level, and the relief in some localities is strongly marked. Only in the eastern part, where the Altamont moraine, the terminal moraine of the last advance of the Dakota lobe of the great North American ice sheets, forms a broad hilly belt, is the surface form the result of ice action. Elsewhere the broken character of the plateau is due to the erosion of the nearly horizontal beds of shale and sandstone of different composition and hardness, in part of the area slightly modified by deposits of older glacial drift. That portion of the plateau between the Missouri escarpment and Missouri River is known as the Coteau du Missouri, and the portion west of the river is known locally as the Missouri slope.

Above the general level of the plateau stand many buttes and mesas, remnants of the higher formations. Among these buttes are Sentinel Butte and Black Butte, and the latter, which rises 3,468 feet above sea level, is the highest point in the State.

The most striking part of the Missouri slope is the famous badlands of the Little Missouri. Here the soft clay and sandstone have been carved by running water into a perfect maze of buttes and mesas, all etched into most fantastic forms. Although these badlands are hard to travel through, they are, because of running water and good cover, an excellent cattle country.

Drainage.—The plateau is drained by Missouri River, which occupies a great trenchlike valley 200 to 600 feet deep and 1 to 3 miles wide. Its tributaries are numerous, and they thoroughly drain that part of the plateau which lies west of the river. Chief among these tributaries are Little Missouri, Knife, Heart, and Cannonball Rivers. So deeply have they carved the plain that it may be said to have reached the stage of early maturity over wide areas.

A large number of small lakes and marshes are scattered throughout the morainic portion of the Coteau du Missouri. These lakes almost without exception occupy basins left in the irregular surface of the glacial deposits. On the General Land Office map of McLean County, which was compiled from the original survey, appear 465 of these lakes and marshes. Of these but 10 are of sufficient size to bear names, and many of them are undoubtedly alkali flats during dry seasons.

Soil and cultivation.—The Missouri Plateau, which was formerly a stock-raising country, is rapidly coming to have agriculture associated with grazing. Dairy cattle are increasing. The soils of the valley floors and of many of the uplands are of such character that large areas are being rapidly turned into farms. On the uplands systematic dry-farming methods assist materially in the growing of the crops, especially forage crops for the winter feed of the cattle and horses of the ranches.

GROUND-WATER RELATIONS

The topographic character of the State favors the absorption of rain by the soil or evaporation into the air and causes the ground water to stand near the surface and to be within easy reach of wells, particularly in the very flat Red River Valley.

The gently rolling character of the Drift Prairie insures good drainage on the slopes but permits stagnation in the depressions. For this reason many spots of "alkali" and "gumbo" are found in a region of generally good soils. The sandy character of the drift soils also favors absorption and decreases the run-off.

The maturely dissected parts of the Missouri Plateau, on the other hand favor a rapid run-off with slight absorption or evaporation. As the total annual run-off as found at river stations in this State is rarely more than 2 inches and often only a small fraction of 1 inch,[4] the run-off in the more populous portions of the State is obviously of small importance as compared with that which soaks in and dries up.

CLIMATE

GENERAL CONDITIONS

North Dakota lies in a region of temperate climate and moderate rainfall. Its location at the center of the great interior plain of North America gives to the State a climate that is continental in its character, and the absence of strongly marked physical features permits geographic uniformity in temperature at least. As the State lies mainly between the parallels of 46° and 49° it is within that part of the Temperate Zone that has cold winters and warm summers. Its position in the belt of prevailing westerly winds and in the most frequented northern path of the eddying cyclones that move eastward in this belt gives a marked variety to the direction and velocity of the winds and almost wholly determines the variations of its weather.

TEMPERATURE

One of the chief characteristics of the continental climate is the wide difference in temperature between the summer and the winter. Temperatures of 90° to 95° F. are not uncommon in the summer, whereas 30° to 35° below zero is not infrequently recorded in the winter. Owing to the low relative humidity of the atmosphere, however, these extremes are not so keenly felt as the much more moderate extremes in regions where the atmosphere is moister. The annual mean temperature for the entire State is 39° F. The northern

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[4] Chandler, E. F., Surface Water Supply of the United States, 1907–8, Pt. V: U. S. Geol. Survey Water-Supply Paper 245, p. 51, 1910.

part of the State is colder than the southern, and the eastern part is slightly colder than the western, but the range in the average annual temperatures between the two extremes is only about 6°. The highest maximum ever recorded within the borders of the State is 124° F., at Medora, Billings County, September 3, 1912, and the lowest minimum ever recorded is −56° F., at Goodall, McKenzie County, January 12, 1916. This record gives the rather remarkable range of 180° between the highest and lowest observed temperatures.

The table below gives the monthly, seasonal, and average annual temperatures as recorded at 14 climatologic stations of the United States Weather Bureau in North Dakota and one at Moorhead, Minn. The distribution of these stations represents well the climatic conditions of all parts of the State. To these temperatures are added for comparison the corresponding mean temperatures for the State as a whole.

The winters are long and severe and the summers comparatively short. The growing season, or the period between the latest and the earliest killing frosts, ranges from 110 to 120 days. The number of days embraced in this period is few, yet because of the long periods of sunlight which at the maximum, about June 21, reach 16 hours a day in the northern part of the State, the growth of vegetation is very rapid. Again growth is favored by the high percentage of clear sky during the growing season. Owing to these very favorable conditions wheat and other hardier cereals seldom fail to reach maturity.

The streams are closed by ice for about four months, and the surface of the ground is sufficiently frozen to prevent ready absorption of moisture for about six months of the year. During the other six months the soil is in condition to absorb the rain, which then largely goes to increase the ground-water supply.

The relations of temperature to ground water are very complex. They include the immediate and direct relations that govern the amount, rate, and form of the precipitation; those that determine the proportionate parts of the rain and snow that evaporate, run off, or are absorbed, as affected by the evaporativity of the atmosphere and by the freezing, baking, etc., of the surface; and those that govern the movements of ground water. The last item is commonly overlooked, but its importance may be suggested by the fact that water at 100° F. has a viscosity only a little more than half that of water at 50° F. and hence percolates nearly twice as rapidly through sand of a given texture as water at 50°; both absorption and flow therefore vary greatly with the temperature.

Average monthly, seasonal, and annual temperatures of North Dakota [a]

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Winter	Spring	Summer	Autumn	Annual
Ashley	7.5	7.8	22.0	42.5	52.7	62.0	68.4	65.9	57.3	43.7	27.7	13.5	9.6	39.1	65.4	42.9	39.2
Bismarck	7.8	8.3	24.3	42.3	54.9	63.7	69.7	67.3	58.1	44.9	28.5	14.7	10.3	40.5	66.9	43.8	40.3
Crosby	1.7	7.1	22.0	40.6	50.4	60.6	65.9	63.7	53.7	41.5	27.8	12.3	7.0	37.7	63.4	41.0	37.3
Devils Lake	.3	4.5	18.5	38.2	52.7	62.6	68.1	65.1	55.6	40.5	22.6	8.0	4.3	36.5	65.3	39.6	37.5
Dunn Center	15.0	13.0	24.1	42.6	51.9	61.9	68.0	66.6	57.1	45.6	28.4	20.5	16.2	39.5	65.5	43.7	41.2
Garrison	6.5	8.4	21.7	42.6	52.6	62.2	68.1	65.7	56.8	43.8	27.0	13.6	9.5	39.1	65.3	42.5	39.1
Grand Forks	3.6	6.5	22.4	42.0	53.4	62.9	67.4	64.9	56.2	43.5	26.1	10.6	6.9	39.3	65.2	41.9	38.3
Jamestown	6.5	7.9	22.6	42.5	53.5	63.1	68.5	66.2	56.7	44.8	27.6	13.6	9.3	39.5	65.9	43.0	39.5
Langdon	[b]−2.7	3.0	[b]19.0	38.1	50.8	59.7	64.5	61.7	53.5	40.4	25.5	7.3	2.5	36.0	62.0	39.8	35.1
Manfred	4.0	6.8	23.1	41.8	51.6	61.5	66.9	64.3	55.9	43.3	29.0	11.3	7.3	46.2	64.2	42.7	38.3
McKinney	3.2	5.1	19.2	41.0	52.0	60.7	66.0	63.5	54.1	41.9	24.6	10.7	6.3	37.4	63.4	40.2	36.8
Moorhead, Minn	2.7	8.1	22.7	40.6	55.1	64.4	68.1	66.1	58.2	44.5	27.1	11.5	7.4	39.5	66.2	43.3	39.0
New England	13.3	12.1	24.4	43.1	51.6	62.0	68.5	66.7	55.8	43.7	30.2	17.4	14.3	39.7	65.7	43.2	40.7
Pembina	−2.9	1.4	16.0	37.9	52.5	62.6	67.7	64.1	53.8	40.9	22.7	6.0	1.5	35.5	64.8	39.1	35.2
Wahpeton	7.8	9.9	26.2	44.3	55.3	64.8	69.3	66.9	58.6	45.9	28.3	14.7	10.8	41.9	67.0	44.3	41.0
Williston	6.5	8.1	22.9	42.0	54.0	62.7	69.1	66.1	56.6	43.4	27.2	13.8	9.5	39.6	66.0	42.4	39.1
Willow City	.3	2.7	18.3	40.2	51.5	61.0	65.4	63.5	54.3	41.7	22.1	8.5	3.8	36.7	63.3	39.4	35.8
Average for the State	4.9	7.9	22.6	41.7	52.6	62.8	67.5	65.4	56.4	43.8	26.6	13.0	8.6	39.0	65.2	42.3	38.8

[a] Compiled from U. S. Weather Bur. Climatological Data, North Dakota section, 1923, except as noted.
[b] U. S. Weather Bur. Climatological Data, North Dakota section, 1922.

PRECIPITATION

CONTROLLING CONDITIONS

The moisture that falls as rain or snow over North Dakota comes chiefly from the Gulf of Mexico and the Atlantic Ocean. As the areas of low pressure, technically called cyclones, with their eddying winds move eastward across the continent with the prevailing westerly winds, the warm, moist air from the south and southeast is drawn into the eddies and causes southerly winds and mild temperature. Because this air is passing from warm to cooler regions and ascends it is cooled, and a portion of its vapor is condensed into clouds, from which rain or snow is precipitated. With the passing of the stormy area the winds become northwesterly, and cold air flows in with considerable force; the sky clears, and the temperature falls. These cyclonic storms are large in area, moderate in force, and beneficial in effect. They should not be confused with the violent rotating storms of small diameter properly called tornadoes, which occasionally occur in the middle and eastern parts of the United States, though seldom in North Dakota. These tornadoes have narrow tracks and extend over small areas.

The precipitation of the State is directly cyclonic in winter and indirectly cyclonic in summer. During summer it occurs chiefly in the form of local showers and thunderstorms in the southeast quadrant of the low-pressure areas. On the whole and in all seasons of the year this State has a large majority of clear days with bright sunshine.

GEOGRAPHIC DISTRIBUTION

The average annual precipitation for the entire State is about 18 inches. The difference in precipitation between different portions of the State is greater than that of any other climatic factor. The highest average precipitation, about 22 inches, occurs in the upper Red River Valley, in the southeast corner of the State; the lowest average, about 14 inches, occurs on the uplands in the southwest corner of the State. (See fig. 2.) As most of the rain comes in local summer showers there is frequently a very decided variation between stations located close together, as well as a very great range between the amounts that fall at the same place in different years.

The highest annual mean for any of the United States Weather Bureau stations in the State that has a record of 10 years or over is 22 inches, which occurred at Wahpeton, in the southeast corner of the State, and the lowest annual mean is 14 inches, at New England, in the southwestern part. These amounts confirm the general relations above stated and give a range of 10 inches in the average annual precipitation as recorded at the different stations of the State.

The precipitation is greatest in the southeastern corner of the State and decreases in general toward the north and west. (See

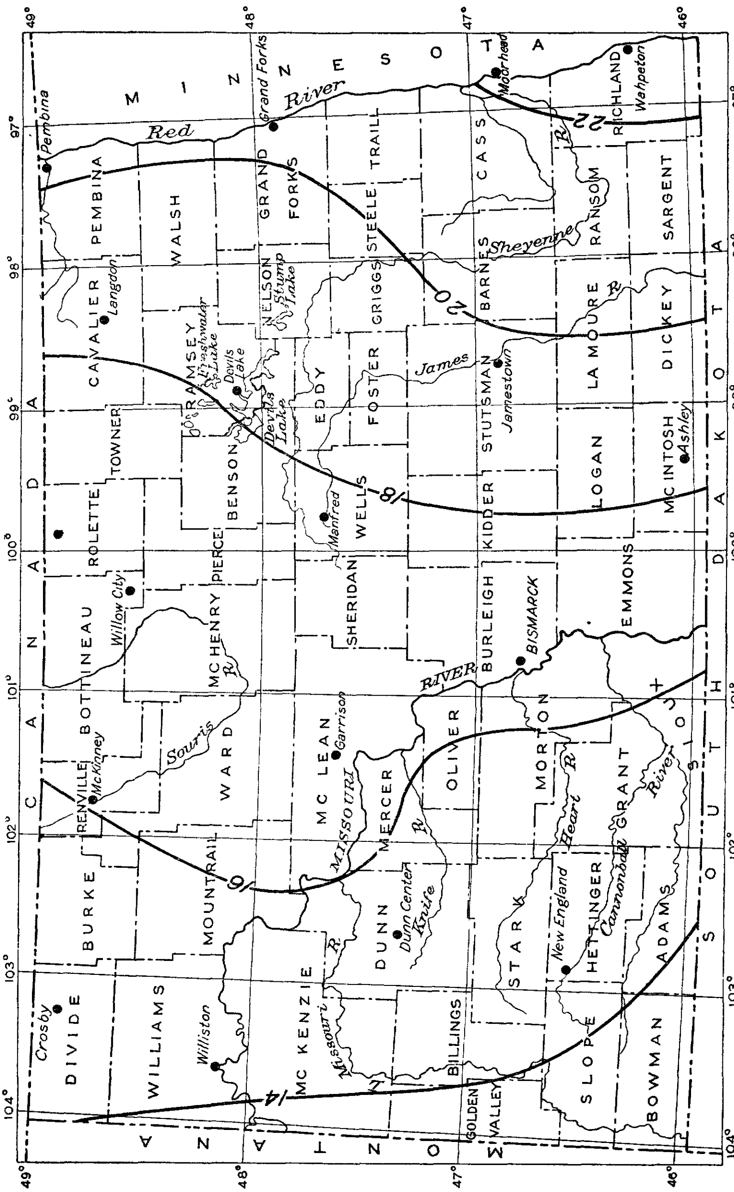

FIGURE 2.—Map of North Dakota showing precipitation. Compiled from observations and records of the United States Weather Bureau. Black dots show weather stations whose records were used in this report. Lines show annual precipitation in inches.

fig. 2.) This condition may indicate that the distribution of the precipitation depends primarily on proximity to the source of moisture.

SEASONAL DISTRIBUTION

To give a clear idea of the relation of rainfall to ground water the records should show not only the amount of precipitation but the rate of fall, the condition of the land surface at the time, the cloudiness, and the direction and velocity of the wind that follows the rain. A slow rate of fall, if long continued, permits a large amount of the water to soak in, whereas a rapid fall of brief duration saturates only a thin surface layer and compels much to run off. Rain which falls on a moderately dry surface is absorbed more rapidly than that which falls on hard-baked soil and still more rapidly than that which falls on a frozen surface. Into the frozen soil it is scarcely absorbed at all, and even the snow melts in spring before the ground is thawed out and runs off over the frozen surface. The precipitation of winter and early spring is of little value as compared with that of summer. The snow is commonly about 6 inches to 1 foot deep from December to March and rarely attains a depth of 2 feet or more. Snow may fall, however, at any time from September to May.

The monthly, seasonal, and annual precipitation for several Weather Bureau stations in North Dakota and the one at Moorhead, Minn., is given in the accompanying table.

Most of the precipitation occurs in well-distributed showers during the late spring and the summer. The approximate percentages for the seasons are for winter 8.3 per cent, spring 27.1 per cent, summer 46.6 per cent, and autumn 18 per cent. Only a small part of the total precipitation occurs during the season when the ground is frozen and absorption is least, and a very large proportion, probably 75 per cent, occurs when absorption is greatest. The relative increase of the precipitation of spring and summer over that of winter becomes more marked as the total precipitation decreases from Red River westward, thus compensating to a considerable degree for the differences in the total precipitation. The diminution of precipitation during the winter may also be noted in the light snowfall.

The winds that sweep across the almost level plains with great force blow the snow about and heap it in drifts where obstacles are found and cause a marked evaporation directly into the air without melting.

Average monthly, seasonal, and annual precipitation of North Dakota [a]

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Winter	Spring	Summer	Autumn	Annual
Ashley	0.55	0.47	1.19	1.97	2.46	3.49	2.66	2.20	1.02	1.06	0.54	0.51	1.53	5.62	8.35	2.62	18.12
Bismarck	.54	.50	1.04	1.88	2.50	3.54	2.14	1.98	1.19	1.03	.68	.62	1.66	5.42	7.66	2.90	17.64
Crosby	.55	.26	.66	1.02	2.02	2.96	1.98	2.21	1.24	.76	.76	.51	1.32	3.70	7.15	2.76	14.93
Devils Lake	.60	.53	1.01	2.03	2.20	3.53	3.78	2.76	1.39	1.23	.71	.39	1.52	5.24	10.07	3.33	20.16
Dunn Center	.51	.56	1.11	1.32	2.54	4.30	2.05	1.57	1.12	.63	.62	.56	1.63	4.79	7.92	2.37	16.89
Garrison	.43	.53	1.04	1.20	2.17	3.32	2.10	2.00	1.36	.90	.58	.57	1.53	4.46	7.42	2.84	16.20
Grand Forks	.58	.53	.71	1.93	2.54	3.39	2.75	2.46	1.86	1.16	.70	.63	1.74	5.18	8.60	3.72	19.24
Jamestown	[b].64	.58	1.00	1.74	2.69	3.78	2.75	2.74	1.53	.93	.73	.75	1.97	5.43	9.27	3.19	19.86
Langdon	.65	.65	[b].84	1.33	2.25	3.50	2.56	2.65	1.99	.94	.70	.73	2.03	4.42	8.71	3.63	18.79
Manfred	.65	.43	.78	1.27	2.36	3.58	2.30	2.46	1.35	.81	.74	.76	1.84	4.41	8.34	2.90	17.49
McKinney	.37	.28	.73	.89	1.96	3.22	2.06	1.79	1.43	.84	.59	.44	1.09	3.58	7.07	2.86	14.60
Moorhead, Minn	.71	.73	1.14	2.33	2.95	4.13	3.74	3.10	2.30	2.07	.98	.74	2.18	6.42	10.97	5.35	24.92
New England	.42	.54	.87	1.02	2.15	2.69	2.01	1.77	1.12	.65	.49	.41	1.37	4.04	6.47	2.26	14.14
Pembina	.64	.71	.90	1.41	2.22	3.28	2.38	2.13	1.69	1.34	.68	.76	2.11	4.53	7.79	3.71	18.14
Wahpeton	.51	.53	.91	2.23	2.81	3.95	3.80	2.90	2.22	1.51	.69	.45	1.49	5.95	10.65	4.42	22.51
Williston	.58	.47	.68	1.23	2.26	3.57	2.03	1.31	.91	.77	.60	.66	1.71	4.17	6.91	2.28	15.07
Willow City	.58	.46	.73	.95	1.92	3.18	2.09	2.08	[b]1.55	.70	.51	.54	1.58	3.60	7.35	2.76	15.29
Average for the State	.54	.49	.83	1.38	2.55	3.50	2.61	2.28	1.64	1.00	.58	.54	1.57	4.76	8.39	3.22	17.94

[a] Compiled from U. S. Weather Bur. Climatological Data, North Dakota section, 1923, except as noted.
[b] U. S. Weather Bur. Climatological Data, North Dakota section, 1922.

VARIATIONS

Severe general midsummer droughts occur at irregular intervals, although during such droughts many small areas have practically normal precipitation. The table below shows the variations in annual precipitation since the North Dakota climatologic service of the Weather Bureau was established in 1892. The lowest average for the whole State for a single year was 10.92 inches in 1917 and the highest was 23.57 inches in 1896. These two extremes show a marked variability, but the tendency to one extreme is frequently followed by a tendency to the other, as illustrated in the wet year of 1916 and the dry year of 1917. The general average, with a few exceptions, has been well maintained through all the period of the record.

Yearly variation of precipitation in North Dakota, 1892–1923

Year	Average precipitation (inches)	Departure from normal (inches)	Year	Average precipitation (inches)	Departure from normal (inches)	Year	Average precipitation (inches)	Departure from normal (inches)
1892	18.34	+0.40	1903	19.25	+1.31	1914	19.16	+1.22
1893	15.91	−2.03	1904	19.02	+1.08	1915	19.42	+1.48
1894	15.64	−2.30	1905	19.96	+2.02	1916	20.50	+2.56
1895	17.32	−.62	1906	19.72	+1.78	1917	10.92	−7.02
1896	23.57	+5.63	1907	14.41	−3.53	1918	16.02	−1.92
1897	15.88	−2.06	1908	18.64	+.70	1919	15.76	−2.18
1898	15.17	−2.77	1909	17.73	−.21	1920	15.34	−2.60
1899	17.67	−.27	1910	12.19	−5.75	1921	19.59	+1.65
1900	18.96	+1.02	1911	19.40	+1.46	1922	19.75	+1.81
1901	19.48	+1.54	1912	20.34	+2.40	1923	17.76	−.18
1902	19.34	+1.40	1913	14.69	−3.25			

RELATION TO WATER TABLE

The influence of meteorologic conditions upon the ground-water supply is best seen in the fluctuations of the water level in shallow wells and of the flow of streams.

Deficiency of summer rainfall sometimes causes droughts, the effect of which is marked on the streams, springs, and shallow-drift wells, producing scarcity of water for stock and domestic use. Heavy drains for stock are made on the deeper wells when streams are low, and as these wells are of small bore they are sometimes temporarily exhausted.

The most severe drought on record is that of 1917. During this season occurred the most unfavorable weather conditions ever known in North Dakota. The average temperature recorded was exceedingly high, the precipitation was the least ever recorded in the State, and there was an unusual amount of sunshine. Hot, dry winds also prevailed during critical periods of summer, thus greatly increasing the possibilities of evaporation. So far was the ground-water level lowered under these adverse conditions that the normal was not reestablished for several years.

During the early summer, when rainfall is heaviest, the water table stands highest and all wells contain water. As the rainfall decreases in the late summer and early autumn, evaporation from the soil and through vegetation rapidly lowers the water level below the bottoms of many of the wells, and they go dry. Water may then be generally procured by digging until the water level is reached.

In autumn, owing to lessening evaporation, the water table may rise and the water may again enter the wells and dry stream beds, even though the rainfall continues to diminish.

With the long winter, during which the precipitation occurs in the form of snow and the percolating surface is frozen into an impervious cover, a second period of drying up of wells comes on, owing to the loss of water through underground drainage, to seepage into streams, and in small degree to pumping without chance of replenishment except by lateral movements, which are very slow. In some wells the first period passes into the second without renewal of supply until the frost leaves the ground in the following spring.

The influence of meteorologic conditions on the deeper wells is less evident, owing to the fact that in the deeper formations the movements of water are slower, replenishment comes from greater distances, and the water is under greater hydrostatic pressure. Under such conditions local changes in temperature and rainfall have little effect, and that only after a long period of time.

VEGETATION IN RELATION TO CLIMATE AND GROUND WATER

North Dakota is almost exclusively a prairie State. The conditions of rainfall and drainage combined with those of evaporation as determined by temperature, wind, and topography fully account for its treeless expanse, covered only, so far as native vegetation is concerned, with a typical prairie flora.

Timber grows on the terraces of the Red, Missouri, Sheyenne, Little Missouri, Souris, Pembina, and a few of the minor rivers of the State. It is also found in fine groves among the hills about Devils Lake and in a few of the rougher portions of the State, such as the Turtle Mountains, the Pembina Mountains, and some portions of the bad lands. The presence of timber in the valleys is largely due to the increased amount of moisture in the soil of these lowlands. In the areas of broken relief it is found only upon the slopes least exposed to sun and wind, where evaporation is least. The principal trees are elm, ash, oak, basswood, and box elder in the northern and eastern parts of the State and cottonwood and other poplars in the Missouri Valley. Many varieties of shrubs and vines also grow in the timbered regions. The prairies produce more than a hundred species of grasses and forage plants.

Timber and brushwood are valuable agents in the conservation of ground water. The thick forest litter and humus soil retain moisture that falls as rain or snow, and the shade of the woods retards evaporation. The run-off is therefore reduced, and a larger quantity of water sinks directly into the ground. Timberlands act as reservoirs of rainfall, gradually feeding it into the ground, and thus not only equalize but increase the ground-water supply and cause the ground-water surface to stand relatively high.

The prairie grasses, on the other hand, form with their rootlets a thick matted sod, which is to a large degree impervious to water, thus preventing much of it from soaking in and increasing the run-off from heavy showers. This sod holds the water from light rainfalls on the surface, where it is quickly evaporated. The prairie is thus a region of rapid run-off and little absorption and therefore of relatively low ground-water level. The sod does, however, tend to conserve the water that enters the ground by restricting evaporation from the soil.

The water table of the prairie has been further lowered by cultivation since the settlement of the region. The tough impermeable sod has been broken up and destroyed, and mellow cultivated fields have taken its place. Run-off is retarded, and rainfall is rapidly absorbed, but evaporation from the cultivated soil is rapid, providing the fields are not frequently worked, owing to its porous character, and the new vegetation makes an almost insatiable demand upon the ground water. The result is lowered ground-water level, drying springs and streams, and a need for deeper wells. This condition continues in a diminishing ratio until a new equilibrium is established, following a second or third set of successively deeper wells which draw their supplies largely from the deeper beds. The demand for deeper supplies is also hastened by the demand for larger and more permanent supplies owing to the stocking of the farms and the development of the more populous industrial centers.

OCCURRENCE OF GROUND WATER

In North Dakota, as in other regions of the plains type, the permanent ground-water level may lie at no great distance below the surface, and water for domestic, farm, and village supplies may generally be obtained from shallow wells. Such shallow waters are in many places too meager to meet the needs of larger industrial plants and of towns and cities. Where larger supplies are required and where river waters are not available it has been necessary to resort to the deeper beds, hundreds of feet below the surface. In many of the stream valleys, however, large supplies are obtained from alluvial gravel and sand.

The ground waters of the State fall, by popular classification at least, into three groups. One group comprises the shallow waters used for home, farm, and village supplies, which commonly lie within 15 to 50 feet of the surface. These waters are obtained from dug, bored, and driven wells and only rarely from drilled wells. In a few districts, where the valleys are cut deeply below the water table, the waters flow directly from springs. These shallow waters are local, as they are fed directly by local rainfall absorbed through the surface soils. Wells that draw their supply from these shallow sources penetrate only the drift or other superficial deposits and rarely enter the bedrock that immediately underlies these deposits.

A second group of waters comprises those that belong to the bedrock which lies immediately below the surface deposits. These waters occur at depths ranging from 100 to 500 feet and are reached by drilled wells. Because of the small drill hole and the casing usually inserted the wells that draw upon these waters are sometimes termed tubular wells. The waters are found in porous sandy layers of shale, in sandstone, and in lignite. They are in many places scanty and in some places absent. They usually enter the formation at some distance from the point of recovery and gradually move down through the pervious beds under slight pressure to lower levels.

The waters of the third group occur in beds that are deeply buried and circulate through the more permeable layers under greater or less pressure. They are termed artesian waters, and wells that derive their supply from such waters are artesian wells, whether they flow out at the surface or not. Many farms, several cities, and some industrial plants use these waters.

The lines of demarcation between the shallow waters, the bedrock waters, and the deeper artesian waters can not be sharply drawn. In the eastern margin of the artesian basin, along the Pembina escarpment, the waters of the deep artesian system rise and approach the surface through a narrow belt, and practically all drilled wells are of the artesian class, though not more than 300 to 600 feet in depth. In the nonglaciated area in the southwestern part of the State the superficial deposits are so thin that the shallow waters are very scanty and the deeper zones of artesian pressure are far beyond the reach of the drill. Most all waters in this area belong to the bedrock group, though they range in depth from only a few feet on the upland farms to several hundred feet in the deep wells put down at Medora, Mandan, Dickinson, and Bismarck.

Flowing wells are also sometimes obtained from both the drift and the bedrock immediately under the drift at the comparatively shallow depths of 40 to 400 feet, but the pressure is not strong and the flow is comparatively slight.

WATER-BEARING FORMATIONS

WATERS OF THE UNCONSOLIDATED DEPOSITS OF QUATERNARY AGE

The water-bearing beds of the Quaternary system are numerous, and their positions are extremely variable. Nevertheless, many localities have what the drillers recognize as the "first water bed" and the "second water bed" and in some places even the "third water bed" above the bedrock. These beds are generally sandy or gravelly layers of the drift, but they vary greatly with locality and in places are absent.

The Quaternary water-bearing beds most frequently recognized and reported are the sand and silt of the ancient Lake Agassiz and other glacial lakes, the Wisconsin till and other morainal deposits, the alluvial outwash deposits of Wisconsin age, the till and gravel of pre-Wisconsin age; and the residual soil.

The glacial drift of North Dakota includes the deposits of two or more glacial stages, the Wisconsin and at least one stage of pre-Wisconsin age. It also consists of two classes of material, the stony clay or till, which was deposited directly by the ice, and the assorted beds of silt, sand, and gravel, which were laid down by the waters of the melting ice. No deposits of an interglacial stage, such as old soils and marsh and foreset beds, have yet been definitely recognized and described.

WISCONSIN DRIFT

LACUSTRINE DEPOSITS

Silts.—Lacustrine clayey silt occupies the central part of the Red River Valley plain from Wahpeton to Pembina (see p. 5) and is interrupted only by belts of till several miles in width where the combined Fergus Falls and Leaf Hills moraines of Upham cross Red River at Caledonia, forming the Goose Rapids. Westward this belt divides, and the Fergus Falls moraine passes northward through Cummings and Arvilla, and the Leaf Hills moraine passes southward through Hillsboro and Blanchard. This morainic belt is marked by many small inequalities of surface, few of them as much as 10 feet in relief, and by a plentiful supply of boulders and gravel on its surface. The fine silt was brought into the lake by the tributary streams, was washed from the wall of ice that formed the northern boundary, was worn by the erosive action of the waves on the shore, and was laid down in the quiet waters over the lake bottom. To this silt has been added in the lower part of the basin and along the present river courses much similar clayey material in the form of alluvial silt brought in by the rivers and smaller streams after the retreat of the lake. In many places these stream deposits have greater thickness than the lacustrine silt, from which they are almost indistinguishable.

The lacustrine silt makes a somewhat porous soil that is composed mostly of fine sand and rock flour, ground and pulverized by the great ice sheet, and is less coherent than the clay, which was formed by the chemical decomposition of rocks. It is therefore similar to the till from which it was formed, except that the coarser materials have all been removed through the remarkable sorting power of water. It also has a lower percentage of soluble alkaline salts, which in the process of aqueous deposition of the beds were partly removed by the waters and carried away to the sea. The lower lake silt that was deposited in the quiet waters of the lake shows little evidence of stratification, so uniform were the conditions of deposition. The upper silt, in the formation of which the streams took an active part, reveals considerable stratification of a very perfect character and commonly contains traces of old soil and remains of plants and animals.

The thickness of the deposit ranges from a feather edge on the margins to 100 feet in places along the axis of the valley, and commonly it is 20 or 30 feet.

Similar deposits are found on the floor of Lake Souris, now known as the Souris River Valley, though they are neither so extensive nor so deep, and on the floors of many smaller glacial lakes, but these are generally insignificant as sources of ground water.

Although wells in lacustrine silt are very numerous, they yield but a small quantity of water, which is largely supplied by seepage of surface waters. Where the silt forms the soil it contains large quantities of water, but the pore spaces are so small that water soaks out of it very slowly. Considerable amounts generally come from more or less sandy layers in the overlying alluvial silt, which not only holds but yields the water in great quantity during the wet seasons, in which it is practically saturated almost to the surface.

The wells are generally shallow, and most of them range in depth from 10 to 30 feet, though a few are as much as 50 feet, and they are of large diameter in order to insure ample storage capacity. All are either dug or bored and are, unfortunately, curbed with wood, owing to the high cost of stone or brick. Such wells should now be curbed with cement or tile, carefully sealed near the top, and covered and protected from all sources of pollution.

Beach sand and gravel.—Along the western margin of the Red River Valley plain stands a series of well-marked, smoothly rounded ridges, which indicate the successive shore lines of the ancient lake. These ridges are composed of sand and gravel, with a little clay intermingled, and have a general northward trend. The most typical of them are continuous and are remarkably uniform for many miles. They have a height of 10 to 25 feet and a total width of 100 to 250 feet. The eastern slope or front of each of the beaches is usually higher, yet more gentle, than the western or back slope, and an undrained and marshy strip commonly lies immediately behind the ridge. This marshy strip is in many places a remnant of an old lagoon formed by the building of the reef offshore in the shallow waters of the lake; in other places it is due simply to the cutting off of drainage to lower levels by the beach ridge.

These beautifully rounded ridges have been selected, as far as possible, as sites for farm homes, not only because of the advantageous outlook they afford but because of the drainage facilities and the opportunities for excellent water supplies for home and stock. Houses located on the crests of these ridges have dry cellars, the barns are surrounded by clean dry yards, and the wells, which pass down through the sand and gravel, are generally supplied with an abundance of water immediately above the impervious till at the base.

The beach deposits are very porous. There is a large amount of open space between the grains, which allows the free passage of water to the till beneath, where its downward flow is checked, and it stands there, saturating the gravel to a considerable height. The water is of good quality, though hard because of the presence of the bicarbonates of lime and magnesia dissolved from the gravel and sand, which contain much limestone that was brought by the glacial ice from the Winnipeg region in Canada. The water is usually free from alkaline material and sulphates, which are common in the waters of the till and bedrock, as it has not passed through these formations but has fallen directly on the surface gravel as rain or entered it from the melting snows of spring.

Wells in these deposits are of course shallow and are very generally open, dug, or bored wells. A few of the newer wells in some places are driven, and this is the type of well which is to be commended as the cheapest and best for these areas. They can be sunk quickly and at slight cost and can be moved almost at pleasure. The drive point should carry a screen to exclude the sand, which would otherwise clog the pipe and ruin the pump, unless the gravel is coarse. Where the deposit includes considerable gravel very satisfactory wells could doubtless be made by sinking perforated casings, about 6 inches in diameter, without screens, and pumping vigorously until all the fine sand near the intakes of the wells is removed and natural gravel screens are developed. Only where the beach is low and the supply is scanty is it necessary to dig a large open well, and this should be continued far enough into the till beneath to insure ample storage capacity.

The ready movement of water through fine sand provides a natural filtration, and water polluted at the surface is commonly purified below. In coarser sand and gravel there is less purification by filtration and therefore greater danger from surface pollution. It is therefore essential that wells of this character, if they are comparatively shallow, and especially if they are open wells, be placed a considerable distance from barns, stockyards, cesspools, and all possible sources of pollution.

Delta sand and gravel.—Extensive sand plains occur along the western side of the Red River Valley and rise with rather abrupt fronts above the lacustrine silt on the east. These plains are deltas composed of modified drift materials that were brought from the front of the melting ice sheet and built by the tributary streams in the western margin of the lake. Such deltas were formed by Pembina and Sheyenne Rivers, and another, which extends southward from the mouth of Elk Valley, was deposited by a large river, known as glacial Elk River, that flowed down the valley where no river now flows. These deltas are flat or gently undulating plains, built up to or slightly above the level of the lake at the time of the accumulation. The front of the Pembina delta, is a conspicuous wooded bluff 100 to 200 feet high, and the Sheyenne delta rises 60 to 75 feet above the lake floor. The Elk Valley delta is lower and has a more gentle slope.

The deposits are composed chiefly of well-stratified sand, mixed with small fragments of shale and here and there layers of fine gravel. There is a small admixture of clay in layers, and this clay, on the southern and eastern margins of the Elk Valley delta, becomes so abundant that it forms a fine sandy clay loam of exceptional fertility.

The winds have blown up the sand of large areas of the Sheyenne delta into dunes and irregular hills 5 to 50 feet or more high, which present a topography in sharp contrast to that of the level plain of Red River. These deposits, like those of the beaches, contain little alkaline matter, and the soil, where fine, is exceedingly fertile, though large areas of the coarser waste in the dune regions are of little worth for agriculture. The porous subsoil that underlies all the delta areas insures excellent drainage.

Wells in the deltas yield waters of exceptionally good quality, though at different depths, according to the thickness of the formations. Bored wells 10 to 20 feet deep are common on the Elk Valley delta, but those on the Pembina delta may be 100 feet deep if porous sand and gravel are penetrated before the zone of saturation in the basal portion is reached. One well cited by Upham [5] reached a depth of 175 feet without obtaining any water. The beds that it penetrated were all sand and gravel, and some layers carried pebbles as large as 3 or 4 inches in diameter, but most of the material was sand.

[5] Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, p. 549, 1895.

Owing to the depth and character of the deposits there is comparatively little danger of pollution, except from the surface through open wells. Tubular wells are recommended for this reason as well as for cheapness.

Springs are common along the foot of the frontal slopes of all these deltas and in the banks of the streams that have eroded deep gorgelike valleys in the delta deposits. The ready absorption of the water, its rapid percolation downward to the basal beds of impervious till and clay, and the ease with which it moves laterally through the gravel and over the clay floor make for large springs, and many of the finest and strongest of the State are found in these localities. Some of the springs of this type on the front of the Sheyenne delta near the village of Leonard have been termed "traveling springs," because they have formed deep coulees by eroding back into the delta as a result of the action of their own waters in carrying away the materials out of which they emerge. A spring half a mile west of the village is said to have eroded a gorge 2 miles in length that has a maximum depth of 70 feet.[6]

Considerable areas of the old lake floor in front of these deltas are turned into boggy marshes by the outflow from these springs and by the rising of the ground-water level under the lower plain, through the hydrostatic pressure of the waters in the higher levels of the delta.

The chemical character of the waters from the deposits of Lake Agassiz is indicated by nine analyses given on pages 276–307. The maximum, minimum, and average results are given in the table below. The waters differ considerably in mineral content, but the predominating constituents in nearly all of them are calcium and bicarbonate, and all the waters are decidedly hard. Six of the nine waters analyzed contain less than 900 parts per million of dissolved solids, but many sources from which samples were not taken are reported to yield water that is too highly mineralized to be used. The analyses, therefore, represent the better waters from the deposits of Lake Agassiz. In some parts of the area covered by the deposits small quantities of water that has a low or moderate mineral content are obtained from shallow wells, whereas the water from deeper wells in the sand and gravel that overlie the bedrock is not usable. In such places the bedrock is commonly drawn upon for larger supplies.

Analyses of water from deposits of Lake Agassiz [a]

[Parts per million]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	2,092	36	1.6	303	201	212	703	412	304	400	1,240
Minimum	250	15	Trace.	56	18	7.0	232	24	2.0	Trace.	214
Average	956	29	.33	151	77	69	453	190	90	116	692

[a] Based on analyses 35, 64, 67, 116, 117, 130, 167, 168, 173. (See pp. 276-307.) [b] Calculated.

[6] Willard, D. E., U. S. Geol. Survey Geol. Atlas, Casselton-Fargo folio (No. 117), p. 3, 1905.

TILL AND ASSOCIATED SAND AND GRAVEL

The Wisconsin drift consists chiefly of a compact clay through which are mixed sand, gravel, and boulders. This material is in part derived from the bedrock of the area and in part entirely foreign, for it contains many fragments of limestone and crystalline rock that were brought by the glacier from Canada. This till contains in places thin layers of sand and gravel, rudely stratified and discontinuous.

The till is generally 30 to 60 feet deep and is in many places very much deeper. The maximum depth reported is 500 feet in a 520-foot well in the SW. ¼ sec. 28, T. 147 N., R. 73 W., in Wells County. It is continuous over all that part of North Dakota north and east of the Altamont moraine, a conspicuous line of hills that runs from northwest to southeast across the State about 50 miles east of Missouri River. This till therefore covers about three-fifths of the entire State but is covered in turn by lacustrine silt to a greater or less depth throughout the Red River Valley and Souris River Valley plains. The topography of the bedrock has been entirely concealed, except in the higher ridges and deeper valleys, and even here it has been greatly modified. The till plain between the moraines is of a gently rolling type of topography, with irregular, shallow, winding coulees and a few deeply trenched valleys that were carved by the great glacial rivers of the past. The present streams are small, winding, and deeply intrenched on the valley floors.

The morainal drift has the form of irregular ridges and confused groups of hills that rise from 15 to 150 feet above the till plain. These deposits were formed at the front edge of the ice, and the succession of looped hilly ridges marks the stages in retreat of the ice front northward. They are composed of till together with numerous pockets, lenses, and beds of stratified sand and gravel, commonly much distorted and disturbed. It is therefore much more open and porous in character than the till proper.

The great thickness of the younger or Wisconsin drift over a large part of the State necessitates its utilization as a source of water for domestic and farm wells, and it probably supplies more wells than any other formation in the State. As the drift lies at the surface, except where it is now covered by the lacustrine deposits, it must receive most of its waters from the rainfall. The surface drainage is so imperfect that a large proportion of the rainfall is absorbed, particularly where the till is overlain by morainic and outwash deposits. Only where the drift fills preglacial valleys and comes into contact with the eroded edges of the bedrock on the valley sides does it receive any considerable amount of water from the rock.

The most useful water-bearing bed in the drift is the gravelly and sandy portion at the base and at no great distance above the bedrock. The water from this bed is relatively pure, wholesome, and abundant. Many other wells are supplied by small sandy layers, lenses, and "veins," scattered through the denser till, and neighboring wells differ greatly in both quality of water and yield. These wells are so shallow and depend so largely on surface waters that they are generally affected by droughts. Wells of this sort must have so large a diameter that a large surface for the slow yet fairly constant seepage and an ample reservoir for storage are obtained. In such wells there is grave danger from surface and subsoil contamination unless care is taken to prevent it by locating the wells at a safe distance from all sources of impurity and by proper curbing and sealing at the surface. Large tubular or bored wells have quite generally superseded the dug wells over extensive areas.

The waters of the sandy layers of the drift are in many places under artesian pressure, particularly in the Red River Valley, where the head is derived from the uplap of these water-bearing layers over the Pembina escarpment to the west. The till itself is relatively impervious and thus forms the retaining beds.

OUTWASH

Along the south and west sides of the morainal belts in many places lie plains underlain by gravel, sand, and silt, which descend from the moraines in graceful slopes. These plains were formed at the time of the building of the moraines by the abundant waters that flowed away from the front of the ice and carried large quantities of the glacial débris. This material, which was deposited over large, gently sloping areas, is frequently used for gravel in ballasting railroads, as near Dunseith and Tolna. In a considerable area south and west of Hamar, Tolna, Pekin, McVille, and Kloten the thick deposits of outwash provide most excellent water for driven wells at comparatively shallow depths.

QUALITY OF GROUND WATER FROM THE DRIFT

Analyses of 71 waters from the drift are given on pages 276–307. The maximum, minimum, and average results are set forth in the table below. These analyses indicate that the waters are entirely of meteoric origin and have derived their mineral content from the soils and rocks with which they have been in contact. These waters, nearly all of which are hard, fall naturally into two classes. One class comprises those typical of ordinary ground water, in which calcium, magnesium, and bicarbonate are the predominating radicles. The other class includes those concentrated by evaporation or evaporation together with reduction and double decomposition between the carbonates and sulphates. In these waters sodium and sulphate are generally the predominating radicles, though in a few calcium, magnesium, and sulphate predominate. Carbon dioxide occurs entirely in the form of bicarbonate, because carbonate is changed to bicarbonate in the presence of air and carbon dioxide.

In general, waters from the drift are suitable for all ordinary uses, although those that have been concentrated contain so much dissolved mineral matter that they can not be used. Of the 71 waters analyzed 38 contain less than 1,000 parts per million of dissolved solids and only 16 contain more than 1,500 parts. Waters from different depths in the drift at any place may differ greatly in mineral content, and waters from the same depth in different localities may also contain different amounts of mineral matter.

Analyses of water from drift [a]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	3,660	38	11	500	187	880	883	1,600	930	250	1,972
Minimum	223	14	Trace.	20	9.0	4.0	95	12	1.0	Trace.	88
Average	1,178	30	1.0	141	54	168	421	417	106	14	574

[a] Based on analyses 3, 8, 9, 12, 13, 14, 19, 24, 30, 31, 34, 36, 37, 38, 39, 44, 46, 51, 55, 56, 57, 58, 59, 68, 70, 71, 78, 83, 84, 85, 86, 87, 89, 90, 94, 95, 109, 111, 118, 121, 126, 127, 128, 129, 131, 132, 133, 135, 137, 138, 139, 140, 144, 146, 156, 157, 158, 159, 160, 164, 169, 172, 176, 178, 183, 185, 187, 188, 189, 190, 196. (See pp. 276–307.)

[b] Calculated.

VALLEY ALLUVIUM

Alluvium is found in practically all the larger valleys of the State, and many of the smaller streams show considerable patches of alluvial land in favorable locations. The most extensive alluvial deposits are those of Missouri, Little Missouri, Heart, Knife, and Cannonball Rivers in the southwest, and Sheyenne, James, and Souris Rivers in the central part. Red River flows in a young, narrow valley carved in lacustrine silt in very recent time and has therefore no clearly distinguishable alluvium. The deposits are composed of roughly assorted gravel, sand, and silt, chiefly the reworked and modified drift that was brought directly from the front of the melting ice sheet and deposited by the overloaded streams in the valleys until it filled them many feet above the present river levels. When the ice retreated the streams ceased to bring down their load of débris.

Nowhere are these deposits better shown than in the Sheyenne River Valley at Valley City, where the deep, wide valley deposits of coarse glacial gravel and sand rise terrace on terrace to a height of 150 feet above the broad bottom of the valley, on which the river now meanders. The recent alluvium is shown by wells and other artificial excavations to have a depth of 10 to 12 feet. The deposit ranges from fine silt to coarse sand, well stratified throughout. The silt is black owing to the large amount of decomposed organic matter present. In general it overlies coarser gravel and sand, but in some places it rests directly on the shale of the bedrock. With changes of outflow from the ice front the waters in these streams diminished to but a fraction of their former volume and became for a time actively eroding agents, excavating narrow portions of the valleys in some places far below their present floors and leaving many well-developed terraces of the coarse glacial gravel interbedded with sand. The valleys have since been partly refilled with the fine sand and silt brought in by their tributaries in time of flood and spread down on the flood plain. The "first bottom" is therefore the true flood plain of the river during its present stage, upon which a thin veneer of the fine alluvium of the present stage has been laid down. Each flood adds a little, often only a fraction of an inch, but this material helps to build up the flood plain. In the nonglaciated region of the southwestern part of the State, particularly along the western tributaries of the Missouri, the valley débris is composed largely of the residual soil and the disintegrated shale and sandstone of the country rock.

The deposits in the valley of the Missouri are most extensive; they have a maximum width of 3½ miles and an average width of about 2½ miles. The depth of stream deposits, as revealed by numerous drill holes made by the Northern Pacific Railway prior to the building of the bridge across the river at Bismarck, is from 50 to 125 feet on the east side of the valley, where the borings were made, and it is quite probable that they may extend to a greater depth near the middle of the valley, toward which the deposits rapidly thicken. Most of this material is believed to have been deposited by streams swollen by the drainage from melting ice and loaded with the débris from the ice front, but much of the finer alluvium in the lower terraces and on the valley floor is of recent formation.

Owing to the difficulty of distinguishing between the glacial débris of the valley trains and the more recent alluvial deposits, all will be considered together.

The valley alluvium, which consists of unconsolidated materials, has a large amount of open space available for water storage and transmission, especially the coarser sand and gravel in the deeper parts. In the river bottoms the water table is near the surface, and water may therefore be obtained through shallow wells with ease.

Much of the recent alluvium is, however, composed of mud and fine sand. The available water in this material is small and generally turbid or roily and of bad taste, owing to the large amount of decomposed organic matter present. It is therefore advisable to go into the coarser sand and gravel beds, which generally lie underneath, in order to get a more satisfactory supply.

The water in the alluvial deposits is in part absorbed directly from the rainfall, owing to the porous character and flat surface. In part it is obtained through seepage from the uplands on each side, where the water table stands higher than in the valley, which results in a gradual flow from the subsoil and bedrock of the uplands into the valley deposits.

Water is generally obtained in the alluvium at slight cost by means of open and driven wells and collecting galleries. These deposits furnish the chief supply for several of the larger cities of the State, notably Jamestown, Valley City, Minot, Williston, Harvey, Oakes, and La Moure.

The waters immediately beneath the towns and cities or downstream from them are generally contaminated from the surface or through cesspools. The public supply should be taken at some point above the city, and private wells should be closed. All such waters when used for domestic supplies should be frequently tested and carefully guarded.

Analyses of 16 waters from alluvial deposits are given on pages 276–307. Maximum, minimum, and average results are shown in the table below. The analyses indicate that hard water of low or moderate mineral content is obtained from the alluvial deposits. The waters from these deposits are on the whole better than those from the other formations in the State, and are nearly all satisfactory for general use. In places where the drainage is poor or in stream beds that are now dry the alluvial deposits may yield water that is too highly mineralized to be used. Ten of the 16 samples analyzed contained from 321 to 789 parts per million of dissolved solids, appreciably less than the average of 877 parts per million. Calcium and bicarbonate are the chief constituents of most of the waters from the alluvial deposits.

Analyses of water from alluvial deposits [a]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	2,206	38	4.1	436	126	417	625	1,020	996	144	1,607
Minimum	321	13	Trace.	15	1.0	14	190	27	2.0	Trace.	78
Average	877	26	.77	124	42	110	438	196	120	18	508

[a] Based on analyses 5, 47, 48, 81, 97, 98, 99, 100, 104, 123, 147, 161, 162, 171, 184, 186. (See pp. 276-307.)
[b] Calculated.

PRE-WISCONSIN DRIFT

In a broad belt immediately outside the Altamont moraine, which marks the limits of the Dakota lobe of the Wisconsin ice sheet, occurs an old and deeply eroded drift that is believed to be of pre-Wisconsin age. This belt is 100 to 150 miles in width and is about equally divided along its axis by Missouri River. On the west side of the river the drift is represented chiefly by scattered boulders and gravel and patches of till that crown some of the hills or occur as filling in valleys. East of the river it is more nearly continuous, but even here it is in many places thin and merely a veneer a few feet in thickness. In the areas east of the river and between the river and the Altamont moraine also occur outwash deposits and other forms of stratified drift deposited by waters that flowed from the front of the Wisconsin glacier at its maximum stage along the Altamont moraine.

So thin and scattering are the deposits of pre-Wisconsin age west of the Missouri that they are of little use as sources of ground water, particularly as they occur chiefly on the higher portions of the area. On the larger areas of the higher lands east of the river, however, sandy and gravelly beds are drawn upon by shallow wells for water for the upland farms. The outwash gravel and valley trains of the Wisconsin stage that occur in the lowlands of this region form one of the most valuable sources of water supply.

RESIDUAL SOIL

Residual soil occurs throughout the nonglaciated area of the southwestern part of the State and elsewhere may immediately overlie the bedrock beneath the drift. That beneath the drift is so thin and patchy, owing to its general erosion by the ice, that it is rarely recognized. In such positions it merges into the overlying drift, which is generally more or less gravelly and sandy.

In the driftless region, however, and over the area of the pre-Wisconsin drift, where the remnants of the drift are sparse, the residual soil forms a valuable source of supply for the shallow wells on the broad rolling uplands. In its altitude and relation to bedrock it takes the place of the drift to a degree, but the supply is generally very scanty and uncertain.

WATERS OF THE ROCK FORMATIONS

Many wells draw their supplies from the bedrock. Many of the bedrock waters are under hydrostatic pressure and produce flowing wells, some of which obtain their supplies from formations that do not come to the surface in this State. A study of the well records and drillings and of the outcrops elsewhere, however, has determined the value and importance of the water-bearing beds of the different formations. The formations which crop out in the State, together with those which do not crop out but have been reached by the drill, are briefly described to indicate their general character and value as water bearers. All the bedrock formations of this region consist of sedimentary beds, except the basement granite, which is reached only by the deepest wells in the eastern part of the State.

TYPES OF SEDIMENTARY ROCKS

Four types of sedimentary rocks are recognized—shale, sandstone, limestone, and lignite. Shale is composed of particles of clay pressed and cemented together into a compact mass, forming a soft, fine-grained rock which tends to split into thin fragments. This is often improperly called "slate" or "soapstone," both of which are metamorphic rocks and are not found in this region. Shale is a very poor water bearer because its particles are so small and its pore spaces so minute that little water can percolate through it, and therefore it is one of the most impervious of rocks. Because of the fineness of the material and the relatively large amount of mineral matter with which the water comes into contact, the waters in shale are in many places strongly mineralized. Shale is the chief rock formation of the region, and most of the State is underlain by hundreds or thousands of feet of this rock.

Sandstone is consolidated sand, the grains of which are cemented with siliceous, calcareous, or ferruginous material deposited from percolating waters. Sandstone is one of the best water bearers among the consolidated rocks. Under favorable conditions it is saturated throughout its extent below ground-water level, and because of the open character of its pores it yields this water freely when tapped by the drill. The water from sandstone is rarely polluted, owing to the natural filtration, but in the deeper beds it may be strongly mineralized. The Dakota sandstone is the source of many deep artesian wells in the eastern part of North Dakota. Sandstones of the Fort Union and Lance formations lie near the surface in the western part of the State and are the chief sources of water supply in the Missouri Plateau outside of the area covered by heavy drift. They yield flowing wells in the deeper valleys, such as that of the Little Missouri.

Limestone is formed from consolidated beds of calcareous animal remains. It is composed chiefly of calcium carbonate and can be readily identified by the effervescence which takes place when it is moistened with acid. Limestones commonly contain much sand, clay, and other impurities. Water occurs in limestone mainly in crevices and in open channels dissolved out by the water itself. The waters of limestone are generally hard, and when they occur near the surface they are liable to contamination, owing to the easy entrance of polluted surface wash. Limestone is rare and contains little water in North Dakota.

Lignite is vegetable matter in the stage between peat and bituminous coal. It is also called brown coal. Coal beds are generally water bearing below the water level owing to the large number of shrinkage cracks, but the water is commonly brown and generally unpleasant to the taste, owing to the large amount of organic matter present.

WATERS OF THE TERTIARY ROCKS

WHITE RIVER FORMATION

The youngest bedrock formation of the State is the White River formation, of Oligocene age. This formation is found only in a few elevated areas in the southwest corner of the State, notably on top of Sentinel Butte, Black Butte, the White Buttes, and the Killdeer Mountains. It is composed of calcareous clay, coarse sandstone, and limestone. Owing to their small area and exposed position, these beds have no value as water bearers.

FORT UNION FORMATION

The Fort Union formation is widespread in western North Dakota and is excellently shown in the badlands of the Little Missouri. It is composed of light-colored clay shale which alternates with soft sandstone and contains many beds of lignite together with some very pure plastic clay. The clay is highly valuable for the manufacture of brick and pottery, and the lignite constitutes the most valuable mineral resource of the State except water and soil.

The formation underlies practically all of the Missouri Plateau except the southeastern part, in and east of Morton and Sioux Counties, and a small area in the extreme southwest corner of Bowman County. It also has an outlier which caps the Turtle Mountains. The maximum thickness is about 1,300 feet, but in most of the area it is very much eroded.

The rather numerous sandstone layers of the Fort Union are the chief source of potable water on the uplands of the Missouri Plateau west of the Altamont moraine. Water is commonly found in beds of lignite below the ground-water level, but this water is generally brown and has a disagreeable taste, owing to the presence of organic matter. The numerous beds of shale, which are well distributed throughout the formation, largely prevent the vertical circulation of the waters. The shale beds are so compact and close-grained that circulation of water through them is inconsiderable. In the sandstone the circulation is more free, both through the pores of the rock and through the many crevices. In the lignite the water freely circulates through the crevices and bedding planes. In both it is confined by the shale to a single bed or an adjacent bed. Many of the sandstones are inclosed lenses and therefore do not yield much water.

The wells that enter the bedrock find fair supplies in the sandstone, poor water in the lignite, and none in the shale. Throughout the large area of the Missouri Plateau that is underlain by the Fort Union many wells end in the surface deposits.

Analyses of 37 waters from different depths in the Fort Union formation are given on pages 276–307. Maximum, minimum, and average results of 35 of these analyses are given in the table below. One analysis, No. 155, was omitted because it contained an excessive quantity of dissolved mineral matter and another because it was only a partial analysis.

The waters from the Fort Union formation may be divided into two classes. One class comprises the waters from wells less than 100 feet deep, which are hard and contain calcium, magnesium, and bicarbonate as the predominating radicles. These waters are very similar to the waters from the drift, alluvial deposits, and other overlying deposits. The second class comprises waters from wells more than 100 feet deep, which are soft and contain sodium and bicarbonate or sodium and sulphate as the predominating radicles. The soft waters have apparently undergone marked alteration in chemical character by the precipitation of calcium, magnesium, and carbonate or sulphate from solution, by the formation of bicarbonates through reaction between lignite, carbonaceous material, or natural gas and the sulphate originally present, or by base exchange, where the waters have given up calcium and magnesium in exchange for sodium. Some of the waters may have dissolved sodium sulphate directly from the rocks with which they came in contact.

Most of the waters analyzed are suitable for general use; 17 of the 36 contain less than 1,000 parts per million of dissolved mineral matter and only a few of the others are too highly mineralized to be used.

Analyses of water from Fort Union formation [a]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	4,386	36	3.0	186	78	1,499	2,152	2,185	1,135	181	690
Minimum	274	8.6	Trace.	4.0	1.0	8.0	303	3.0	1.0	Trace.	14
Average	1,281	19	.65	37	20	417	851	256	81	7.4	171

[a] Based on analyses 1, 2, 16, 17, 18, 20, 21, 22, 23, 25, 50, 52, 53, 54, 60, 61, 62, 63, 72, 73, 91, 92, 93, 96, 101, 102, 107, 151, 152, 153, 154, 179, 180, 182, 194. (See pp. 276-307.)
[b] Calculated.

WATERS OF THE TERTIARY (?) ROCKS

LANCE FORMATION

The Lance formation underlies the Fort Union, and the question is still debated whether it is of Tertiary or Cretaceous age. It lies at the surface in two areas in the State, one in the south-central part about Bismarck and southwestward through Morton and Sioux Counties and southeastward through Burleigh and Emmons Counties and the other a small area near Marmarth, in the western part of Bowman County. The relations of these areas indicate that a very considerable portion of the Missouri Plateau is underlain by this formation. It is composed of massive gray sandstone and shale and thin beds of lignite. The maximum thickness is probably not over 900 feet. The basal Cannonball marine member, which is exposed in the valleys of Cannonball and Heart Rivers and along the Missouri as far north as Price, is the youngest marine deposit in the State.

The heavy sandstones supply a small amount of water where they lie sufficiently near the surface. The formation, however, has little value as a source of water.

Analyses of seven waters from the Lance formation are given on pages 276–307, and maximum, minimum, and average results are given in the table below. Waters from this formation are similar to water from the lower water-bearing beds of the Fort Union formation. They are all soft and contain over 1,000 parts per million of dissolved solids. Sodium and bicarbonate are the predominating constituents, and therefore the waters are more satisfactory for general use than waters that contain equivalent quantities of sodium sulphate or chloride.

Analyses of water from Lance formation [a]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	2,124	39	0.69	18	7.6	892	1,674	145	533	4.0	76
Minimum	1,272	11	.07	4.0	2.6	520	1,200	4.9	56	Trace.	23
Average	1,714	20	.33	8.0	4.0	685	1,387	30	233	1.2	36

[a] Based on analyses 103, 105, 106, 112, 113, 192, 195. (See pp. 276–307.) [b] Calculated.

WATERS OF THE CRETACEOUS ROCKS

FOX HILLS SANDSTONE

The uppermost formation of known Cretaceous age in North Dakota is the Fox Hills sandstone. It is a soft yet massive yellow to gray sandstone and is exposed only in the banks of the Missouri south of Bismarck, in the valleys of the immediate tributaries of the Missouri, and in a small area on Little Beaver Creek in Bowman County. It is characterized by large numbers of ferruginous concretions of remarkable size and form, which gives the name to Cannonball River. This formation does not exceed 125 feet in thickness and underlies the Lance formation under a considerable portion of the southern part of the Missouri Plateau. The Fox Hills sandstone yields an abundant supply of water in that part of the Missouri Plateau in which it may be reached at not too great depth.

Analyses of 11 waters from the Fox Hills sandstone are given on pages 276–307. Maximum, minimum, and average results from 10 analyses are given in the table below. One water from this formation

(No. 29, pp. 280–281) contains so much dissolved mineral matter that it is not usable, and its analysis was therefore not considered in the summary. Some other highly mineralized waters are found in this formation, but most of the waters are within the range of composition shown in the table. They are of moderate or high mineral content, and the predominating constituents are sodium and bicarbonate except in the highly mineralized waters, which contain large quantities of sulphate. Some of the waters are soft and others are hard without any relation between the hardness and the total quantity of dissolved solids. Most of these waters are similar to those from the Fort Union formation.

Analyses of water from Fox Hills sandstone [a]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	2,441	46	0.80	193	65	951	1,174	848	824	24	749
Minimum	592	13	Trace.	7.4	23	55	500	5.9	4.0	Trace.	28
Average	1,439	28	.36	67	28	422	853	329	114	4.9	280

[a] Based on analyses 26, 27, 28, 74, 75, 82, 88, 148, 149, 150. (See pp. 276–307.)
[b] Calculated.

PIERRE SHALE

The Pierre shale probably underlies the entire State except the Red River Valley and occurs immediately below the drift throughout the Drift Prairie except in the Turtle Mountains, which are capped by an outlier of the Fort Union formation. West of the Missouri escarpment it is generally heavily covered with younger sedimentary rocks and comes to the surface only in two small areas—one along the Missouri near the place where the river leaves the State and the other in the valley of Little Beaver Creek near the southwest corner of the State.

Though the Pierre shale immediately underlies the glacial deposits in a large portion of the State the drift is so thick that few good exposures occur. Outcrops are present in the small stream valleys that cut the face of the Pembina escarpment, particularly in the Pembina Mountains and in the lower valley sides of the Pembina, Sheyenne, and other streams in which there has been a large amount of postglacial cutting.

The Pierre shale is generally dark blue-gray and is composed of thin layers of very uniform character. It is estimated to have a maximum thickness of 1,100 feet in this State. In the outcrops where the shale is exposed to the air it is well jointed and readily weathers into small flaky fragments that have little yellow spots or blotches caused by the iron oxide which they contain. They also occasionally contain small brownish-yellow limonitic concretions.

The water in the shale is held in microscopic openings between the tiny particles of compressed clay and is held very tenaciously. Adhesion to the walls of the pores makes the water of the shale practically stationary. It is not improbable that some of it has remained in the shale since it was first deposited as mud in some quiet area on a shallow sea floor. Many wells have passed through 1,000 feet of this and underlying shale formations without getting any appreciable amount of water. Some wells, however, have found small supplies in weathered or jointed parts of the shale or in the interbedded sandstone.

It is not recommended that drilling be continued far into this shale unless it is intended to reach the Dakota sandstone, and this should be attempted only where this sandstone lies within feasible drilling depth.

Analyses of 11 waters from the Pierre shale are given on pages 276–307, and maximum, minimum, and average results are given in the table below. The water that contains the minimum amount of total solids is the only one that has less than 1,000 parts per million. Most of the waters from the Pierre shale are unsatisfactory for general use, but at some places where fairly thick layers of sandstone occur near the top of the formation soft water suitable for ordinary use can be obtained.

Analyses of water from Pierre shale [a]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	3,088	33	3.0	163	77	1,050	1,000	782	1,048	--------	683
Minimum	967	13	Trace.	8.4	4.7	30	500	2.8	20	--------	40
Average	1,760	26	.48	64	24	539	690	432	292	--------	268

[a] Based on analyses 6, 10, 11, 15, 40, 69, 76, 108, 110, 120, 165. (See pp. 276–307.)
[b] Calculated.

NIOBRARA AND BENTON SHALES

The Niobrara and Benton shales underlie the Pierre in a large portion of the State. Though they have been penetrated by the drill in many wells they are rarely differentiated by the driller, and logs that show 1,000 feet or more of shale generally include all three formations. These two formations have been recognized with certainty only in outcrops in the Pembina Mountain escarpment along Pembina River, and in the Sheyenne Valley near Valley City.

The Niobrara is a moderately hard calcareous shale, bluish gray and somewhat lighter in color than either of the other associated shales. It is generally mottled with white specks and blotches of lime carbonate. Some layers have the composition of a natural cement, for the manufacture of which it has been used. The Niobrara probably exceeds 400 feet in maximum thickness, as shown by the Des Lacs test hole. (See p. 252.)

The Benton shale is considerably darker than either the Pierre or Niobrara. It is generally dark gray, in places almost jet-black from carbonaceous matter, and not uncommonly contains nodules of pyrite and crystals of gypsum. It is soft and readily breaks into thin flakes and occasionally has a strong odor of petroleum. At the mouth of Little Pembina River it weathers to a plastic clay and is used in the making of brick. Well sections commonly indicate a thickness of less than 500 feet, though at Des Lacs over 1,000 feet has been penetrated.

These Niobrara and Benton shales are not a possible source of water supply. Not a single well is known which obtains its waters from either formation. They lie deeply buried beneath the Pierre shale, and no well should penetrate them unless it is intended to pass through into the underlying Dakota sandstone in the effort to obtain an artesian flow. These shales, however, serve a useful function in connection with the ground waters in maintaining the head of the water in the Dakota sandstone by forming the overlying impermeable stratum and preventing upward leakage. In this way they play a part in the Dakota artesian system second only to that of the porous sandstone itself.

DAKOTA SANDSTONE

The Dakota sandstone lies below the Benton shale. It does not crop out at any point in the State, though at its extreme eastern margin it rises within 200 or 300 feet of the surface along the western edge of the Red River Valley. Throughout the Drift Prairie its location at depths of 500 to 2,000 feet is widely known, for it is the source of water in all the deep artesian wells of the southeastern portion of the State. West of the Missouri escarpment it lies too far below the surface to be reached by the drill, but it probably underlies all of the State except parts of the Red River Valley. In the absence of outcrops it is not possible to correlate the deep strata precisely. For convenience in this report the entire group of water-bearing sandstone beds below the Benton, with the intervening shaly or calcareous beds, is called the Dakota sandstone, though it may include earlier Cretaceous rocks, especially in the western part of the State. Its thickness differs greatly in different places, for in some places it has been reported as very thin, whereas the maximum thickness is believed to be nearly 500 feet.

The texture and composition of the Dakota is well known from the records of drillings and samples and from outcrops in other regions. It consists of a gray ferruginous sandstone, very poorly cemented and interbedded with thin layers of clay and shale. In places it includes beds of fine incoherent nearly white sand. At the base of the formation in some places the sandstone passes into a conglomerate.

The Dakota sandstone yields water under great artesian pressure, but the water is commonly highly mineralized. In pumped wells the very fine incoherent white sand that enters the wells cements itself in the screens and wears out the pumps. In the southern part of the State less difficulty of this sort has been reported than in the northern part.

Owing to the presence of the clayey and shaly layers the formation is subdivided into several portions, and first, second, and even third flows are frequently recognized throughout a large part of the artesian basin.

The Dakota sandstone is the best water bearer in the bedrock in North Dakota and is in fact one of the best-known aquifers of the world because of its wide extent, its high economic value, and particularly because of the reputation of its artesian wells for high head and strong pressure.

Analyses of 29 waters from the Dakota sandstone are given on pages 276–307, and maximum, minimum, and average results from 27 analyses are given in the table below. The waters from different localities in the artesian basin have the same general character chemically, but those from the upper and lower sands differ considerably. Waters from the first sand are generally soft and high in chloride, and those from the lower sands are hard and generally contain relatively small amounts of chloride. All waters from the second sand and many of those from the first sand contain moderate to large quantities of sulphate, though it may have been reduced in some of them. The analyses of waters in the deeper sands indicate that they are of meteoric origin and have dissolved their load of mineral matter from the rocks with which they have come in contact. The character of the waters of the first sand indicate that the waters of sedimentation have not been entirely replaced by the meteoric waters as they have in the lower sands.

Many of these waters are too highly mineralized for satisfactory domestic supplies. Their main use is for livestock and protection from fire. A few of the towns, however, depend entirely on these waters for their supply.

Analyses of water from Dakota sandstone [a]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ [b]
Maximum	4,799	33	9.9	204	70	1,710	1,025	1,989	1,832	15	772
Minimum	1,056	7.6	Trace.	5.6	24	320	171	64	70	Trace.	22
Average	3,017	19	1.9	53	18	991	473	981	670	2.9	206

[a] Based on analyses 4, 7, 32, 41, 42, 43, 45, 49, 77, 79, 80, 119, 122, 124, 125, 134, 136, 141, 142, 143, 145, 163, 166, 170, 175, 177, 191. (See pp. 276–307.)

[b] Calculated.

WATERS OF THE EARLY PALEOZOIC ROCKS

Great thicknesses of sedimentary rocks of early Paleozoic age are widespread throughout the upper Mississippi Valley. They are older than the Cretaceous formations and rest unconformably on the uneven floor of the still older crystalline rocks. These Paleozoic rocks consist of beds of sandstone, limestone, and shale, repeated in varying order. They do not crop out in North Dakota, and nothing is known regarding their presence here except in a few deep wells in the eastern part of the State. In the Red River Valley Paleozoic rocks that apparently belong to the Cambrian and Ordovician systems lie directly beneath the drift. West of the Pembina escarpment they lie below the Dakota sandstone. In both areas they rest unconformably upon gneiss or granite or the greenish residual clay of these crystalline rocks.

The Grafton well passes through several hundred feet of these Paleozoic sedimentary rocks, including chiefly limestone, sandstone, and some shale, interpreted by Upham as including formations that range from the "Galena-Trenton limestone" of the Ordovician system to the Dresbach sandstone of the Cambrian, which, according to Upham, overlies the granite. Water was found in the sandstone between 425 and 450 feet below the surface (identified by Upham as the St. Peter), and a brine in the formation between 903 and 908 feet (identified by Upham as Dresbach sandstone). Two other formations were reported by Upham as the Jordan sandstone and the St. Lawrence formation, both of which are water bearers elsewhere. This log shows an abundance of water-bearing beds in this part of the valley, but unfortunately the water in all of them is strongly mineralized. This fact was further attested in the Hamilton well, of which the log is not so definite but which penetrated the granite several hundred feet and found very saline water. The Hamilton well was recently cleaned to a depth of 270 feet, the casing having been filled to the top. The filling was found to consist of pure crystals of gypsum, evidently precipitated from a saturated solution. Further drilling to these beds can not therefore be recommended unless the water is to be used for fire protection only.

The limestone reported in the log of the La Moure well at a depth between 1,300 and 1,328 feet is fortunately known through an excellent sample procured by means of a core drill. It is a very compact, semi-crystalline pinkish-yellow to buff limestone. This limestone has been tentatively referred to the Ordovician, chiefly on account of physical characteristics and probable relations to limestone formations of this age in the vicinity of Winnipeg. At Jamestown 19 feet of "limestone (Carboniferous?)" is reported at a depth of 1,505 feet. To judge from a number of samples, obtained elsewhere, of a very hard carbonaceous shaly limestone, which contained leaf impressions in the shaly portions, this bed is of Cretaceous age.

Although ordinary limestone transmits water very freely through many small cavities and where near the surface through a large number of joints, cracks, bedding planes, and open crevices formed by solution, this rock lies so far below the surface and is so compact and crystalline that it is not recognized as a water bearer in any one of the few wells that penetrate it.

WATERS OF THE PRE-CAMBRIAN GRANITE

The basement rocks have been reached by wells at a number of places in the Red River Valley and by a few of the deeper artesian wells in several localities in the southeastern part of the State west of the valley. Knowledge is limited, however, to the few wells from which cores were obtained, for these rocks do not crop out in North Dakota. They do, however, crop out in western Minnesota, South Dakota, and Manitoba, from which they dip westward and this dip, together with the rise of the land surface in that direction, causes the basement rocks to lie beyond the depth of the ordinary deep-well drill and beyond the depth from which water will rise to the surface or even within pumping distance of the surface. No artesian wells belonging to this basin have ever been obtained west of the Missouri escarpment in North Dakota.

In the vicinity of Big Stone Lake, along the Minnesota Valley, the granite crops out, and in several wells in the southeastern part of the State "granite" is reported to have been reached. The nature of the rock has not been generally recognized by the drillers, but the term "granite" has been used to cover any "very hard" rock reached below the Dakota sandstone without regard to its character. A few samples of drillings or cores have been submitted to persons qualified to determine their petrographic nature, but more often we have only the judgment of the well drillers, and their judgment has been open to question when the core drill is not used, for granite pebbles from the drift sometimes get into the hole and are ground to pieces by the bit.

In the soldiers' home well at Lisbon a good sample was procured at a depth of 785 feet by means of a core drill. This sample is a good firm piece of biotite-hornblende granite, dark gray and of medium coarse texture. The occurrence of white and green varicolored clays above the granite at Moorhead, Minn., at Wahpeton, and in other places in the southeastern part of the State has been taken to indicate that the granite had been altered and decomposed by long exposure to atmospheric weathering before the submergence of the old land surface and the deposition of the overlying sedimentary rocks. The granite is of great though unknown thickness. In the Moorhead well

"Dakota" area.—Area in which Cretaceous sandstones will probably yield flowing wells with light to heavy pressure. (This area has been considerably constricted on all margins owing to loss of pressure and head.) The depth ranges from 300 or 400 feet on the eastern margin to 1,500 to 2,100 feet on the western margin. Between 4,000 and 5,000 flowing wells have been drilled in this area.

Red River Valley area.—Area in which either glacial drift or Dakota sandstones or both will probably yield flowing wells with light to moderate pressure. The depth ranges from 150 to 500 feet. More than 2,000 flowing wells have been drilled in this area.

Maple River Valley area.—A small area in which both glacial drift and Dakota sandstone will yield flowing wells, the glacial drift with very light pressure, though the wells are few. The depth of the glacial drift is 25 to 50 feet and of the Dakota sandstone 600 to 700 feet.

Little Missouri Valley area.—Area in which sandstones and lignites of Fort Union, Lance, and Fox Hills formations may yield flowing wells with light pressure. The depth ranges from 50 to 1,000 feet, and the number now exceeds 300.

Crosby artesian area.—Area in which glacial gravel and Fort Union sandstones and lignites may yield flowing wells with light pressure. The depth ranges from 150 to 500 feet. There are about 40 flowing wells in this small area.

Des Lacs artesian area.—Area in which Fort Union sandstones and lignites may yield flowing wells with light pressure. The depth ranges from 100 to 300 feet, and the number of wells is only about 35.

Antler artesian area.—Area in which glacial drift and Fort Union sandstones yield a few flowing wells with very light pressure. The depth ranges from 100 to 250 feet.

Souris River gas-artesian area.—Area in which Fort Union sands or sandstones will yield an intermittent flow of water in many wells due to gas pressure. The depth ranges from 100 to 300 feet.

NOTE.—Numerous small areas of artesian flow in the western part of the State, which are due chiefly to narrow-valley or escarpment artesian conditions, are not shown on the map.

MAP OF NORTH DAKOTA SHOWING ORIGINAL AREAS OF ARTESIAN FLOW

1,426 feet of it was penetrated, and the drill stopped at a depth of 1,901 feet below the surface. It has been reached at depths that range from 255 feet near Fargo and 450 feet near Casselton to 785 feet at Lisbon. Comparison of the borings, however, shows the surface to be uneven, though generally it shows a westward slope.

It should be clearly understood that the drilling of deep wells into the granite basement is not only difficult and costly but also futile. In no place in the State can it be encouraged. When the drill reaches the crystalline rocks, the work should cease. But the question whether the crystalline rocks have really been reached can not be left to either the workman or to the layman untrained in the determination of rocks. It must be decided by an experienced geologist. For this purpose the washings from the ordinary jetting process are very misleading, for they may contain fragments of every overlying formation, including the drift, with its pebbles of foreign granite. Chippings from the rock itself obtained by means of the churn drill are satisfactory, but the only unquestionable evidence is that afforded by the core obtained by one of the rotary processes. This core furnishes evidence that is positive and final. Any geologist can readily identify such rock on receipt of a sample of the core.

The granite yields small quantities of water. At Moorhead a little salt water was reported at 1,300 feet below the top of the granite, but the possibility of getting small supplies from such depths does not warrant deep drilling through the hard rock.

GROUND-WATER PROVINCES

North Dakota may be divided into three ground-water provinces, which correspond nearly to the three physiographic provinces already defined—the Red River Valley, the Drift Prairie, and the Missouri Plateau.

RED RIVER VALLEY

In the Red River Valley water is obtained from shallow wells in the beach and delta deposits and in the lake silt and from deeper wells in the Wisconsin drift and the sedimentary bedrock beneath. Much of the water in the sandy layers of the drift and the bedrock is under sufficient artesian pressure to produce flows in wells of moderate depths. The lake silt supplies some shallow wells with a small amount of water, much of which is "alkaline," and the sandy beaches and deltas on the western margin yield to shallow wells some of the best water in the State. The deeper artesian waters are generally highly mineralized, especially those that come from the bedrock.

DRIFT PRAIRIE

In the Drift Prairie water is obtained from the alluvium in the valleys, from the glacial drift, and from the underlying rock. The drift is so thick that it is the most generally utilized formation in the State. The sand and gravel at the base of the drift, immediately above the shale, form a common source of supply.

The deposits of sand and gravel under the broad floors of the principal valleys, particularly those of the Sheyenne and the James, yield ample supplies for cities of several thousand people. The waters are commonly obtained by wells fitted with drive points and strainers.

Many wells penetrate the shale that underlies the drift and draw from the few sandy layers found in it a moderate supply of slightly mineralized water.

In the southern parts of this province many wells are drilled to the Dakota sandstone and obtain strong flows of higher mineral character. The area of artesian flow of this sandstone constitutes an important subdivision of the Drift Prairie province and occupies all of its southern and central portion.

MISSOURI PLATEAU

In the glaciated part of the Missouri Plateau the water is commonly obtained from the drift, as in the Drift Prairie province. In the non-glaciated part the water is obtained from the alluvium of the valleys, the residual soils that cover the surface to considerable depths on the uplands, and the layers of lignite and sandstone in the upper part of the bedrock. In some of the larger valleys shallow wells draw an abundance of good water from the alluvial gravel and sand. These materials were largely washed out from the front of the Wisconsin ice sheet when it occupied its most advanced position along the Altamont moraine. In this region springs from the lignite and other outcropping rocks of the valley sides are so numerous that they greatly decrease the number of wells necessary. All the deeper wells enter the bedrock sandstone and lignite, and some that are located in the deeper valleys yield weak flows.

ARTESIAN WATER

DEFINITION

The term "artesian" is derived from Artesium, the Latin equivalent of Artois, the name of an ancient Province in northern France, where there are some of the most ancient of flowing wells. One of these wells in an old convent at Lillers, has flowed steadily since the year 1126.[7]

The term artesian at first included in its meaning little more than the superficial phenomena of flowing wells. With the investigation of the physical and geologic conditions of these wells the emphasis of

[7] Norton, W. H., Artesian Wells of Iowa: Iowa Geol. Survey, vol. 6, p. 122, 1897.

the definition naturally shifted from the mere fact of the artificial fountain to the structural and dynamic relations that condition it. The mere fact of overflow is now considered unessential. An artesian well is, therefore, a well in which the water rises considerably above the ground-water table by natural hydrostatic pressure, which is a result of certain structural conditions. These wells are usually of small diameter, ranging from 1 to 16 inches, and of considerable depth. There are many 1-inch wells in southeastern North Dakota, and the Casselton city well is 16 inches in diameter throughout. The Harvey artesian well is 2,235 feet deep, whereas the 4-inch well of J. J. Scully, in the SW. ¼ sec. 15, T. 162 N., R. 75 W., Bottineau County, is only 14 feet deep and has a large flow of water with a temperature of 42°. Depth and diameter are not an essential part of the definition, for although many deep wells of the world are artesian in character, yet many shallow wells are as truly artesian as those whose waters rise from strata thousands of feet beneath the surface. The term "flowing well" is now generally used to designate that type of well whose waters overflow, and the others are generally termed "nonflowing wells." The distinction is of little scientific value but is very important to the owners of the wells.

REQUISITE CONDITIONS

The theory of artesian wells is well known and generally accepted. Little has been added since 1729, when Belidor in his "Science of engineering" stated the views then held as follows:

> It would be desirable to make such wells in all sorts of places, which appears impossible, since conditions of the terrane are requisite that are not everywhere found, for as these wells are caused by waters which, proceeding from neighboring mountains, make a subterranean channel to a certain point where they are retained by beds of clay or rock which prevent their escape, it is necessary that these beds be pierced by drills and that the water which is beneath should be capable of ascending in a vertical tube to the surface of the earth.[8]

The conditions have, however, been ably restated by a number of American writers, notably by Chamberlin [9] and Fuller.[10]

The fundamental principle is very simple but the problem presented through the combination of varying conditions is commonly complex. Artesian water follows the common law of flow and appears to rise against gravity only because we see but a part of the stream. It rises because a great portion of the same stream is pressing down. The greater descending portion is concealed deep within the earth's crust and rises to higher altitudes perhaps hundreds of miles away.

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[8] Norton, W. H., Artesian Wells of Iowa: Iowa Geol. Survey, vol. 6, p. 128, 1897.

[9] Chamberlin, T. C., The Requisite and Qualifying Conditions of Artesian Wells: U. S. Geol. Survey Fifth Ann. Rept., pp. 125–173, 1884.

[10] Fuller, M. L., Summary of the Controlling Factors of Artesian Flows: U. S. Geol. Bull. 319, 1908.

To understand the simplest and most common types of artesian wells, one should imagine a pervious stratum, a bed that will absorb water freely, such as sand or sandstone, through which water can readily pass, that lies between two impervious beds, such as clay or shale, so that water may not escape either upward or downward, and the edges of these beds should rise to the surface in some high region and be covered only with soil or loose surficial material that will permit percolation. In the opposite direction they may dip down into the earth and either rise again to the surface, thus forming a basin, or the water-bearing stratum may wedge out or become so changed in character as to be impervious. Rain that falls on the surface and stream waters that pass over the upturned edge of the pervious bed will be absorbed into it and will fill it, if sufficient in quantity, to saturation. Ordinary wells that enter such a bed in the region of the outcrop find abundant water in it at slight depth. If a well enters this water-bearing bed at some place considerably below the level of the outcrop, the water rises in it and flows out at the surface because of the pressure of the mass of water in the higher portion of the bed. If surface water enters the outcropping edge of the bed as fast as the artesian water is drawn off below a constantly flowing well is obtained.

The requisite conditions upon which artesian flows depend are stated by Chamberlin [11] as follows:

1. A pervious stratum to permit the entrance and the passage of the water.
2. A water-tight bed below to prevent the escape of the water downward.
3. A like impervious bed above to prevent escape upward, for the water, being under pressure from the fountainhead, would otherwise find relief in that direction.
4. An inclination of these beds, so that the edge at which the water enters will be higher than the surface at the well.
5. A suitable exposure of the edge of the porous stratum, so that it may take in a sufficient supply of water.
6. An adequate rainfall to furnish this supply.
7. An absence of any escape for the water at a lower level than the surface at the well.

These requisites have been generally accepted by all writers on this subject. Fuller objects to them, however, on the ground that they apply to a single class of flow—those from stratified rocks—and neglect all flows from other varieties of rock and even types of flow from the same rock. He also calls attention to many exceptions to the limitations mentioned and suggests new and more comprehensive essential conditions as follows: [12]

1. An adequate source of water supply.
2. A retaining agent offering more resistance to the passage of water than the well or other opening.
3. An adequate source of pressure.

[11] Chamberlin, T. C., The Requisite and Qualifying Conditions of Artesian Wells: U. S. Geol. Survey Fifth Ann. Rept., pp. 134–135, 1884.

[12] Fuller, M. L., Summary of the Controlling Factors of Artesian Flows: U. S. Geol. Survey Bull. 319, p. 34, 1908.

He does not make the source specific because artesian waters may not be derived from a single source but from many different sources. The retaining agent may be a stratum, a vein, a joint, or even a water layer, and the pressure, although due to the variations in level, may be transmitted in many ways and modified by many factors.

A homely illustration of the more necessary conditions in the simple basin type of artesian system may be made by placing a small bucket within a large one and filling the space between them with coarse sand. If water is poured upon the sand until it is saturated and a small hole is punched through the bottom of the smaller bucket the water will rise into it in a small fountain, exactly as water rises in an artesian well. The sand represents the permeable water-bearing stratum, or aquifer, and the two buckets represent the two impermeable layers that prevent the escape of the water from the aquifer. The water gushes through the hole in the inner bucket owing to the pressure of the water held in the sand at a higher level.

In a larger way, we have an illustration in every system of waterworks that uses a gravity method of distribution. Water is supplied by the pumps to the elevated tank, from which it flows down and out through the mains to the delivery pipes, and through them it rises under a pressure proportional to the relative height of the water in the tank. The form and size of the receiving portion of the plant is immaterial, as shown by the fact that a reservoir or a standpipe produces the same results as an elevated tank or a simple pipe. In the artesian system the water-bearing stratum is both reservoir and conduit, and in North Dakota, it usually consists of a bed of sand or sandstone.

The region between Lansford and Westhope, in Bottineau County, contains a number of wells that yield gas in considerable quantities. Of these a few have an intermittent flow of water mingled with gas, and the flow of water is undoubtedly due to the pressure of the gas, which works on the principle of the air lift. Such wells are easily distinguished by the unsteady jetting character of their flow and are referred to in this report as gas lifts.

Thus we see that there is nothing mysterious about artesian water. The reason for its flow is as easily understood as that of the water from a tap or fire hydrant connected with the village waterworks, because the principle is the same. If all taps and hydrants in the village system were allowed to stand open, the supply in the reservoir would very soon be exhausted and then only a few of the lowest taps in the village would flow, since a few open taps can drain away the water as fast as it is pumped into the system. The same is true of an artesian system; if all wells are left wide open to flow to waste, the reservoir of sand or sandstone is soon drained and the wells, except perhaps those on very low ground, cease to flow. A few wells may waste all the water which enters the artesian reservoir from rainfall.[13]

[13] Simpson, H. E., Artesian Conditions in North Dakota: North Dakota Geol. Survey Bull. 2, p. 4, 1923.

TYPES OF ARTESIAN SYSTEMS IN NORTH DAKOTA

There are several types of artesian systems that differ from one another in geologic structure and origin. Of these types at least four are found in North Dakota.

The artesian basin (fig. 3) was the earliest known and is still the most commonly figured type, but the true basin is much less common than the artesian slope (fig. 5). The artesian basin is formed where alternating permeable and impermeable layers are laid down on a basin-shaped floor so that they slope from all sides toward the center.

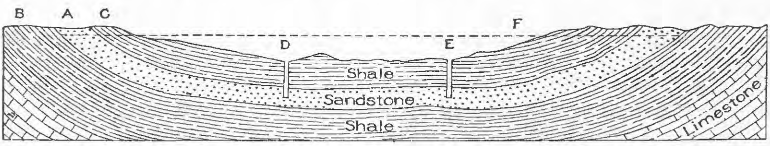

FIGURE 3.—Diagrammatic section of an artesian basin or syncline. A, Permeable stratum; B, C, impervious strata below and above A, acting as confining beds; D, E, flowing wells supplied by the permeable water-filled bed A. The broken line (F) shows the height to which the water will rise by artesian pressure. (After Chamberlin)

This type is common in old lake beds, where the earlier deposits of sand on the concave floor are covered, except on the outer margins, with an impervious layer of fine silt. Wells driven into the sandy layer in the lower portions of the basin yield waters received on the margins. Perhaps the best-known American basin of this type is that of the San Luis Valley of Colorado, in which there are thousands of artesian wells.

Some artesian basins have a trough-shaped floor so that they slope from the sides toward the axis, and these are known as artesian synclines. Both basins and synclines may be produced by warping.

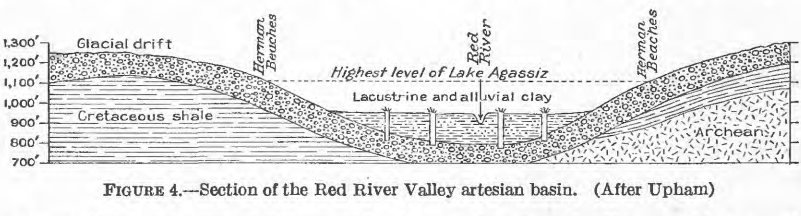

FIGURE 4.—Section of the Red River Valley artesian basin. (After Upham)

A modification of this type is found in the shallow drift artesian basin of the Red River Valley. (See fig. 4.) Here the central depression is an old river valley that opens toward the north, over which was spread a thick layer of glacial drift and later a thick bed of lake silt. In both these deposits occur beds and layers of sand that slope from the margin toward the axial line along which now flows Red River. This valley is spoken of as a modified form of the basin because it slopes toward the north, on which side the basin rim is wanting, and thus, as a pitching syncline, it also resembles a slope. The Red River Valley is therefore a combination of the synclinal basin and slope types.

More common and of vastly greater extent than the artesian basins are the artesian slopes. (See fig. 5.) Here the water-bearing formation dips gently from the higher outcropping area toward a lower land area, owing to the fact that the formations were laid down on the margin of an old sea floor, now uplifted into sloping plains. Many of these slopes are therefore of vast extent, and their beds are of great thickness. Of this type are all three of the great artesian systems of the United States—the Atlantic coastal plain system, which extends from Long Island to Texas, and is about 100 miles in width; the upper Mississippi Valley system, which crops out in central Wisconsin and dips southward under Iowa, Illinois, Indiana, and Ohio; the Dakota system, which crops out in the Black Hills and eastern foothills of the Rocky Mountains and underlies North Dakota, South Dakota, Nebraska, and Kansas. The Dakota artesian area, which includes the southern portion of the Drift Prairie in North Dakota

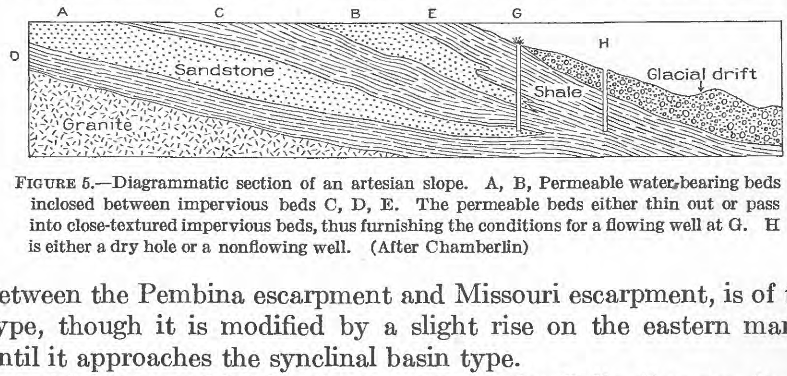

FIGURE 5.—Diagrammatic section of an artesian slope. A, B, Permeable water-bearing beds inclosed between impervious beds C, D, E. The permeable beds either thin out or pass into close-textured impervious beds, thus furnishing the conditions for a flowing well at G. H is either a dry hole or a nonflowing well. (After Chamberlin)

between the Pembina escarpment and Missouri escarpment, is of this type, though it is modified by a slight rise on the eastern margin until it approaches the synclinal basin type.

A third type, which has been suggested by Fuller,[14] occurs in the plateau region, where deep valleys extend below the general ground-water level and dissect nearly horizontal strata underlying the glacial drift. In these valleys the more permeable horizontal beds may yield springs and the water-bearing formations beneath the valley floor may yield weak artesian flows. The water rises in these wells more easily and with less friction than through the relatively impervious strata. The water-bearing formations are replenished by slow downward percolation through the overlying strata. This type may be referred to as the "narrow-valley type of artesian systems." (See fig. 6.) It is well illustrated in the many flowing wells of the valleys of Little Missouri River and its tributaries and also in the valley of Des Lacs River at Kenmare. Probably the slope conditions may also strongly influence the wells of the Little Missouri Valley.

[14] Fuller, M. L., Summary of the Controlling Factors of Artesian Wells: U. S. Geol. Survey Bull. 319, p. 39, 1908.

The fourth type of artesian systems found in North Dakota has not heretofore been definitely described. It may be referred to as the "escarpment type." (See fig. 7.) This type occurs in a rather narrow belt that extends across the State in front of the Missouri escarpment and about the foothills of the Turtle Mountains. The

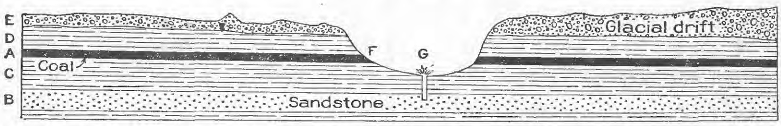

FIGURE 6.—Diagrammatic section showing an artesian system of the narrow-valley type. The permeable sandstone (B) beneath less permeable beds (C, D, E) yields weak artesian flows to wells in the valley (G). The coal bed (A) is water bearing and yields springs at its outcrop (F). (After Fuller)

formations beneath the escarpment are composed of soft shale, which in places contains sandy layers not clearly differentiated from it. Wells that penetrate these beds on the lowlands in front of the escarpment to depths as great as 500 feet find water in the sandy layers. The water, which rises in wells to the surface in small weak

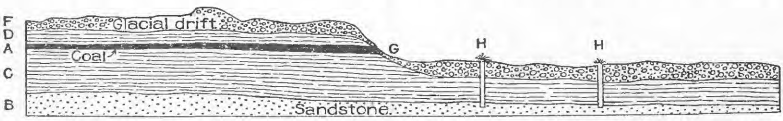

FIGURE 7.—Diagrammatic section showing an artesian system of the escarpment type. The permeable sandstone (B) beneath less permeable beds (C, D, F) may yield weak flows to wells on the lowland (H). The coal bed (A) is water bearing and yields springs at its outcrop (G)

flows, seems to derive its hydrostatic pressure more from the higher ground-water level beneath the escarpment, which causes a slow general downward percolation of the water, than from the elevation of water in the bed that is tapped. Of this type are the wells on the uplands in front of the escarpment southwest of Kenmare and Minot and south of the Turtle Mountains.

ARTESIAN SYSTEM OF THE DAKOTA SANDSTONE IN NORTH DAKOTA

GENERAL FEATURES

The artesian system formed by the Dakota sandstone is already well known through the work of Darton,[15] Nettleton,[16] Todd,[17] and others. It includes not only a large area in North Dakota but also large areas in South Dakota, Nebraska, Kansas, and adjacent States. It yields flowing wells throughout large areas in North Dakota and South Dakota and in smaller areas in several other States.

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[15] Darton, N. H., Preliminary Report on Artesian Waters of a Portion of the Dakotas: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 609, 1896.

[16] Nettleton, R. C., Artesian and Underflow Investigation: 52d Cong., 1st sess., S. Ex. Doc. 41, pt. 2, 1892.

[17] Todd, J. E., Geology and Water Resources of a Portion of Southeastern South Dakota: U. S. Geol. Survey Water-Supply Paper 34, 1900.

The Dakota sandstone and the overlying dense plastic shales form the most remarkable artesian basin in the United States with respect to its great extent, the long distances through which its water has percolated from the outcrops of the sandstone in the western mountains to the areas of artesian flow, and especially the tremendous pressure under which the water in the sandstone was originally held by its thick and continuous cover of impermeable shale.[18]

The accompanying map (pl. 1) indicates the general limits of the original areas of artesian flow and the location and depths of the more significant wells studied. There are probably 6,000 flowing wells that belong to this system in the State.

These waters have pressures at the surface that range from zero to the original pressure of 197 pounds to the square inch, in the well at Ellendale, which is used directly for fire protection and which obtains its water from the third horizon. Repeated tests on different gages showed an original pressure of 245 pounds to the square inch in a well 1,150 feet deep about 6 miles northwest of Page, Cass County, in the SW. ¼ sec. 20, T. 143 N., R. 55 W., according to the North Dakota Artesian Well Co., driller, and D. C. Moug, the owner.

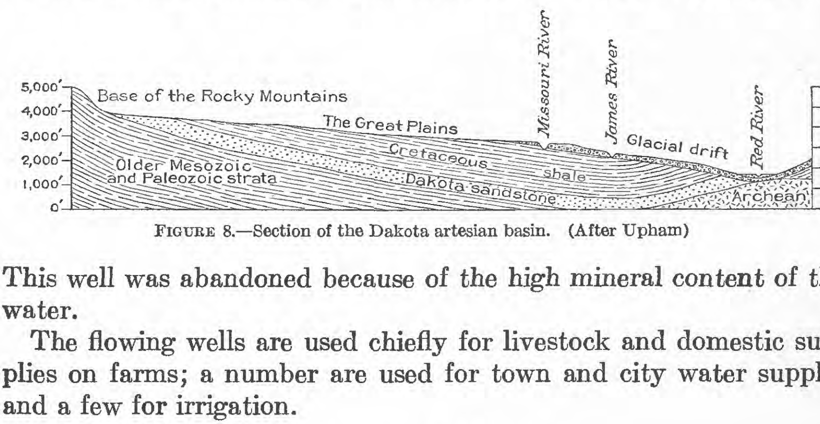

FIGURE 8.—Section of the Dakota artesian basin. (After Upham)

This well was abandoned because of the high mineral content of the water.

The flowing wells are used chiefly for livestock and domestic supplies on farms; a number are used for town and city water supply, and a few for irrigation.

GEOLOGIC RELATIONS

The geologic relations of the formations of North Dakota will be briefly reviewed because an understanding of them is necessary to a consideration of the artesian system. (See fig. 8.)

Between the Red River Valley and the Altamont moraine, near the Missouri, the surface formation consists of glacial drift, which in some places attains a thickness of more than 400 feet and is so continuous that exposures of underlying formations are few. Beneath the drift lies bedrock composed of Cretaceous shales, which have a thickness east of the Missouri escarpment of 1,000 to 2,000 feet but which thin

[18] Meinzer, O. E., and Hard, H. A., The Artesian-Water Supply of the Dakota Sandstone in North Dakota, with Special Reference to the Edgeley Quadrangle: U. S. Geol. Survey Water-Supply Paper 520, p. 73, 1925.

out eastward toward the Red River Valley. The lower shale beds are known as the Benton shale and are separated from the thick overlying beds of Pierre shale by a more or less calcareous formation known as the Niobrara shale. West of the Missouri escarpment these formations are overlain by a younger series of shale and sandstone of Tertiary age.

Beneath the Cretaceous shales lies a relatively thin but very widespread sheet of sand or soft sandstone that contains thin irregular bands of clay. This bed is the Dakota sandstone, the great water-bearing formation that underlies wide areas of the Great Plains. On the east this formation is buried under the thin margins of Cretaceous shales or in the extreme east perhaps by a thin cover of drift and lake sediments. It dips gently westward as the overlying younger sediments thicken, but still farther west it is brought to the surface by uplifts, such as the Black Hills in South Dakota and some of the mountain ranges in Wyoming and Montana, including the great anticlines of the Big Horn Mountains and the Front Range of the Rocky Mountains.

Beneath the Dakota sandstone in the western mountains lies a thick mass of sandstone, shale, and limestone, and these in turn rest upon granite and schist. Over wide areas in the eastern part of North Dakota the sandstone appears to rest directly on the granite, though in the La Moure well a core cut by the drill shows that a compact pinkish-buff limestone underlies the sandstone for at least 28 feet, and in the Grafton and Hamilton wells, where the Dakota is absent, a few hundred feet of these beds overlies the basement of igneous rock.

The westward dip of the sandstone and the rise of the surface in that direction carries the formation below the depth to which it is feasible to drill for water. The Dakota formation is not even reached by the 2,000-foot boring at Mandan or the 2,400-foot well at Max, and there are some doubts regarding the correctness of the identification of the white sand in the 1,800-foot hole drilled for gas near Westhope as belonging to the Dakota formation. The transition beds between the Benton shale and the Dakota sandstone appear to be reached near the bottom of the 3,965-foot oil test hole at Des Lacs. Throughout the western part of the State there appears to be no prospect for utilizing the water from the Dakota sandstone. The area is undoubtedly underlain by this formation, which contains large volumes of water, but it lies too deep to be recovered, and moreover the pressure is not sufficient to carry it to the surface in the plateau region west of the Missouri escarpment.

The Missouri escarpment forms the western boundary of the area of artesian flow. On the east the frayed edge of the sandstone passes underneath the silt of Lake Agassiz and the saline waters of the Dakota are mingled with the fresher waters of the drift in the Red River Valley artesian system. The northern boundary is an indefinite line where the altitude becomes so great that flows may not be obtained. Originally it approximated the line of the Great Northern Railway.

AREA OF INTAKE

Geologists agree that the chief artesian supply of the Dakota sandstone is derived from the outcrops of this formation in the high regions about the base of the Black Hills and upon the eastern foothills of the Rocky Mountains. In these regions the Dakota sandstone or equivalent beds are upturned and reach the surface over areas of greater or less width, together with the underlying sedimentary formations that lie on the surface of granite or other crystalline rocks. The sedimentary rocks are more or less permeable to water, which is free to pass eastward under the plains region. Not only are there extensive areas in which more or less of the rainfall may sink directly, but the outcrops are crossed by streams of greater or less size, and some of the flow, it is thought, sinks into permeable sedimentary beds. This condition is reported to occur on Missouri River at Great Falls and on Big Horn River on the north flank of the Big Horn Mountains. The altitude of these tributary catchment areas ranges from 3,200 to 7,000 feet above sea level, whereas that of the areas where flows are obtained in North Dakota is 1,100 to 1,300 feet.

PERMEABLE BED

The chief water-bearing bed of the basin is the Dakota sandstone. This formation consists of fine light-gray to white sand and sandstone, with interstratified beds of clay, shale, and limestone. Pyrite and ironstone concretions are common and make drilling with light hydraulic rigs difficult in places. Although the texture and therefore the capacity to hold and transmit water differs greatly, water is almost invariably found in the white sandstone, and in many places two or even three beds yielding flows are found, separated by shaly layers of more compact sandstone or rarely by limestone.

The gathering ground of artesian waters consists of the area of outcrop of the permeable water-bearing formation. The formation itself, above the highest level of flow from the artesian wells, constitutes the artesian reservoir. In regard to this reservoir there are many and strong popular misconceptions. Frequently the reservoir of an artesian well or basin is supposed to be in some lake. Because of the salty water in many wells in the southeastern part of North Dakota the water is thought to have its source in Devils Lake, but the water from some of these wells rises above the level of the lake, and the history of the lake and the conditions of its existence show that it can not be a reservoir of artesian water. The lake is underlain by hundreds of feet of relatively impervious clay shale. The sandy beaches afford no subterranean outlet, and the surface of the lake, which represents the exposed ground-water level, is being constantly replenished from the outseeping ground waters as the water from the surface evaporates. The lake is receiving rather than delivering supplies of ground water. Rivers contribute to the artesian supply only in the areas of outcrop of the permeable beds. Many believe the artesian reservoir to be a subterranean lake or pool. That of the Dakotas has been spoken of as "an underlying sea of water reaching from the British possessions to Texas" or "from the Atlantic to the Pacific." Nothing could be more erroneous. Small subterranean pools and streams undoubtedly exist in limestone regions, but in the Dakota sandstone the water is stored in the interstices, cracks, and crevices of the water-bearing rock.

The value of any rock as a water-bearing layer depends on its permeability rather than on its porosity. Permeability is that property by which it permits water to pass through it and depends not only on the amount of pore space but also on the size of the pores. Clay absorbs water in large quantities but transmits none. Many sandstones absorb and transmit water in large quantities. A loose quartz sand or sandstone, if sufficiently coarse, like the Dakota sandstone, makes a good water-bearing formation. A slight admixture of clay or lime, although it may but slightly lessen the amount of water which a rock will hold, will decidedly impair the power to transmit water. This fact is well illustrated in the Dakota sandstone, in the shaly and limy layers which commonly divide the formation into several portions known to the drillers as first water, second water, and third water. The fact that these water-bearing layers are clearly separated is shown by the very different quality of the waters at different depths.[19]

The capacity of porous rocks as reservoirs is further increased by the numerous planes of stratification and the joints which divide the beds into rhombic blocks. These blocks are in many places broken by many small cracks and fissures, especially near the surface. Water readily percolates through all these openings below the water level and collects in them in large quantities. The capacity of these natural underground waterways is very great. The reservoir sandstones of the Dakota formation probably absorb a quantity of water that amounts on an average to at least 10 per cent of their volume. Many layers can undoubtedly absorb 20 per cent of their volume.

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[19] Hall, C. W., Meinzer, O. E., and Fuller, M. L., Geology and Underground Waters of Southern Minnesota: U. S. Geol. Survey Water-Supply Paper 256, pp. 68–74, 1911. Shepard, J. H., The Artesian Waters of South Dakota: South Dakota Agr. Coll. and Exper. Sta. Bull. 41, 1895.

CONFINING BEDS

In order that water transmitted from the reservoir may rise in the well above the water table it must be confined within the water-bearing bed. This confinement is effected by layers of impervious rock or their equivalent, both above and below the water-bearing bed. The best confining strata consist of heavy clay, for it is practically impermeable, but shale, shaly limestone, and most crystalline rocks are also effective. The Dakota sandstone lies below many hundred feet of dense plastic shale, which is effective in preventing upward leakage. Within these formations the pervious layers are saturated with water but the impervious layers yield no water to the drill.

MEASUREMENT OF PRESSURE

The pressure may be measured at the well mouth in pounds to the square inch by means of an ordinary gage. From this gage the head, which is of more significance, may be calculated by multiplying the pressure in pounds to the square inch by 2.3 feet, the number of feet to which a pressure of 1 pound will lift a column of water 1 inch square. By adding the altitude above sea level of the well curb a convenient plane of comparison may be had.

The head may also be measured by coupling on water-tight tubing and carrying this up until water stands at the top but does not overflow. The size of the tube is immaterial, and the test is easily made with a rubber hose on the well-rig ladder or in a near-by building or tree.

FACTORS THAT AFFECT PRESSURE

ALTITUDE OF INTAKE AREA

The question whether a given well will flow or not depends on several conditions, chiefly the altitude of the intake area. The greater the altitude of the intake of the reservoir above the region of the wells the stronger is the hydrostatic pressure and the heavier the flow.

In the southwestern part of the Red River Valley the Dakota sandstone is so thinly covered and so much of the cover is composed of the unconsolidated lake silt and glacial drift that the heavy artesian pressure causes the water to burst out around the casings of wells in such a way that it occasionally gets beyond control and does serious damage to farm land.

ALTITUDE OF WELL MOUTH

The highest head, relative to the top of the well, is found where the altitude of the well mouth above sea level is least. Wells in the deeper valleys show stronger pressure than wells on the adjacent uplands. The oldest well in Valley City had an initial pressure of 56 pounds at the curb, but the pressure had decreased to 40 pounds in 1921. On the upland just east of the city flows are very weak, and it is doubtful whether they can be obtained on the highest points. Thus one of two wells may overflow and the other may not, although they may be exactly alike in all respects except that one is drilled on higher ground than the other, and both may tap the same water-bearing rock.

Other factors may produce changes in the head of a well or group of wells, such as leaks in the casings and the drilling of other wells to the same horizon. Wells drilled on low ground commonly cause those on higher ground to cease to flow. All these factors should be considered in plans to utilize the pressure for protection against fire, for power, or for manufacturing.

YIELD OF ARTESIAN WELLS

Accurate measurement of the yield of artesian wells is seldom made. The reported flow is generally but a loose estimate. For pumped wells the amount delivered by the pumps can be calculated with considerable accuracy.

The yield of a flowing well is generally determined in one of three ways—by noting the time necessary to fill a receptacle of known capacity, the larger the receptacle the better; by measuring the flow over a weir; or by recording the flow by means of a current meter set in the pipes.

The maximum yields reported in North Dakota are 1,000 gallons a minute from the Minneapolis, St. Paul & Sault Ste. Marie Railway well at Enderlin and 800 gallons a minute from the city well at Ellendale. In 1923 the flow of about 400 artesian wells, 1 to 2 inches in diameter, averaged about 3 gallons a minute.

USES OF ARTESIAN WATER

Domestic supply.—Artesian waters are commonly used in North Dakota as a general supply for home and farm. In the southeastern part of the State many hundreds of farms utilize these waters for all purposes, or for all purposes except drinking and cooking, for which shallow waters from the drift are largely used. As the waters grow more saline toward the north their use for domestic purposes decreases, though they are generally used for stock.

Fire protection.—Wherever pressure and flow are sufficient the artesian wells are connected directly with the mains, and the natural pressure of the water is used for protection against fire. (See pl. 3, *B.*)

Irrigation.—The use of artesian wells for irrigation has not been general in North Dakota, owing to the large mineral content of the water. In South Dakota the waters are less strongly mineralized and have been more extensively used for this purpose, especially for gardens.

Power.—Many of the artesian wells formerly yielded water under sufficient pressure to furnish power for minor mechanical operations. Among the uses to which the water has been put in North Dakota are the running of dynamos for small electric-lighting plants, the operation of grist and feed mills, the operation of lathes and blowers in blacksmith shops, and many minor uses about the farms. The use of the flowing water for power has largely been discontinued owing to decrease of pressure and resulting loss of power.

CONSERVATION OF ARTESIAN WATER

The popular theory of unlimited natural resources in ground water and particularly in artesian waters[20] which prevailed when the early wells in this basin revealed such astonishing pressures and flows has in less than 40 years proved false. (See fig. 9.) Owing to careless

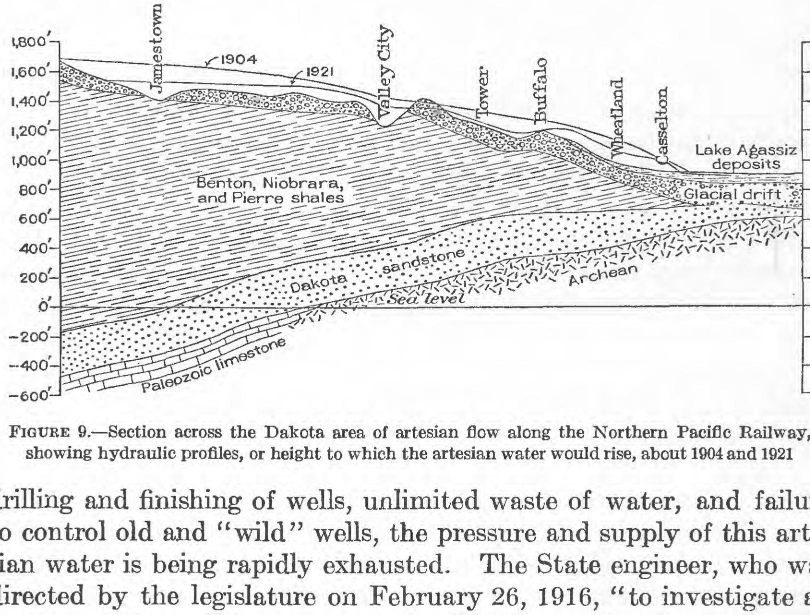

FIGURE 9.—Section across the Dakota area of artesian flow along the Northern Pacific Railway, showing hydraulic profiles, or height to which the artesian water would rise, about 1904 and 1921

drilling and finishing of wells, unlimited waste of water, and failure to control old and "wild" wells, the pressure and supply of this artesian water is being rapidly exhausted. The State engineer, who was directed by the legislature on February 26, 1916, "to investigate all matters and conditions connected with the construction, use, and maintenance of our artesian wells in the State of North Dakota," called attention in his manuscript report to the governor, dated November 1, 1919, to the fact that throughout a considerable portion of the Dakota artesian basin the head had been so reduced that "a large proportion of the wells where the original pressure is known has ceased to flow, and in all cases the flow has been greatly reduced." A report by the State engineer of South Dakota to the governor of that State, which was submitted in the same year, reveals a similar situation throughout that part of the Dakota artesian basin, in which he

[20] McClure, P. F. (compiler), Resources of Dakota, Pierre, 1887.

estimates that 10,000 artesian wells have been drilled. In his general considerations of the conditions in South Dakota,[21] the State engineer says:

"There was a time when we did not know but that the artesian water supply was inexhaustible; later we began to surmise that it was failing; and to-day we know that it is failing at such a rapid rate that if the present waste continues to be tolerated in connection with the sinking of new wells it will only be a few years until there will not be remaining a single flowing artesian well in the State of South Dakota. True, the water supply in the Dakota sandstone can never be exhausted, but when the last well in the valleys of the James and Missouri Rivers quits flowing, it will be a sad day for the farmers in counties like Sully, where there are no running streams or surface wells to be had, and very deep pumping will have to be resorted to.

That this condition is due to the general falling off of the artesian head may be seen from the fact that new wells do not obtain the same flow and pressure that the original wells obtained.

From the facts shown in these reports of official investigations of the State engineers of both North Dakota and South Dakota, it will be seen that unless this waste of artesian water is checked the greater part of the Dakota artesian area in North Dakota will cease to yield flowing water, and another valuable natural resource will have been dissipated. This situation is alarming to those who depend upon this source of supply for home and stock as well as to those interested in the preservation of our natural resources for the use of future generations on these prairies.

Next to soil, ground water is the most valuable natural resource of North Dakota. Next to natural springs, artesian wells are the most economic means of recovery of ground water for man's use. They are of especial value to stock interests in both grazing and diversified farming, on account of the unpumped flow of an unpolluted stream, cool in summer and warm in winter. The saving in pumps and windmills, or engines and gasoline, and in tank heaters and fuel amounts to thousands of dollars on every stock farm in the course of a few years, to say nothing of the still greater value in better form and flesh on the horses, increase in beef, pork, and mutton on the meat animals and best of all in amount of milk, cream, and butter produced from the dairy cows.[22]

Conservation should be enforced by eliminating the waste of water though permitting its unlimited use.

METHODS OF REDUCING THE FLOW OF ARTESIAN WELLS[23]

Many methods of limiting the flow of artesian wells have been tried because of the need arising from the superabundance of water, lack of good drainage, and damage to land and highways. Now

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[21] Derr, H. M., Sixth Biennial Report of the State Engineer to the Governor of South Dakota, p. 150, Pierre, 1916.

[22] Simpson, H. E., Artesian Water Conditions in North Dakota: North Dakota Geol. Survey Bull. 2, p. 5, 1923.

[23] Simpson, H. E., Methods of Reducing the Flow of Artesian Wells: North Dakota Geol. Survey Bull. 3, 1924.

that a still greater need is recognized in the conservation of the water—the saving of it for future use—more effective methods are being used than formerly. The methods now in use in the Dakota artesian area in North Dakota are here reviewed.

VALVES

A method of control of a flowing well in general use is by means of a valve set below frost and operated by means of a handle reaching to the surface. Drainage of the pipe above the valve is necessary to prevent freezing when the valve is entirely closed. By this method the flow of water may be controlled by the owner and may be cut off entirely when not in use as in a city water system.

The valve may also be placed on the pipe above the surface of the ground, which makes it easier of access, but in this event a certain amount of water must be permitted to flow in winter in order to prevent freezing.

Two types of valves are in common use—the globe valve and the gate valve. In the globe valve a globular surface fits into a hemispherical cup, which when open presents a large surface to the flowing water and the wear is correspondingly slight. In the gate valve two surfaces that resemble the edges of a pair of circular shears close upon one another in such a way as to permit more rapid wear upon the valve.

Besides easily getting out of order through wear and rust, valves are so easily turned and put out of adjustment by children and irresponsible persons as to render them unsatisfactory unless they are permanently chained and padlocked, and a padlock exposed to the action of spattering water frequently becomes so rusted that it can not be unlocked. In the valve also lies a certain amount of danger from wells drawing their supply from a bed of soft or "muddy" sand. There is under ordinary conditions no danger from reducing the flow of an artesian well, especially if it is done slowly. But caving is liable to occur in the water-bearing formations from sudden shock or jar when the valve is opened suddenly and the back pressure is released. The water then becomes roily or sandy, and the well may even become plugged with sand or mud and the flow stopped entirely. This condition necessitates cleaning out the well at considerable expense.

REDUCERS

For the reasons above mentioned a reducer is recommended. This device permits the uniform flow of a small quantity of water and avoids all danger of roiling or sanding due to sudden turning off and on at the well by inexperienced hands. It can, however, be removed in a few moments in an emergency by the aid of a pipe wrench.

The standard form of reducer, however, which screws into the pipe, can not be obtained in size sufficiently small, and it presents so small a surface to the action of the water that it does not greatly reduce the flow, and the orifice rapidly wears larger.

The same objection holds in the common use of a standard plug through the center of which a hole has been drilled, except that this hole may be made small enough; but the pressure remains high and the orifice is liable to be closed with small pieces of sediment carried up by the water.

Better than these is a nipple filled with Babbitt metal through which a small hole is bored; one-eighth of an inch is usually sufficient to yield a gallon of water a minute under the normal pressure of several pounds. For light pressures a larger hole may be used. Owing to the softness of Babbitt, it will occasionally have to be replaced and rebored.

In emergency and as a temporary expedient even a hardwood plug notched in the sides or with hole bored through the center may

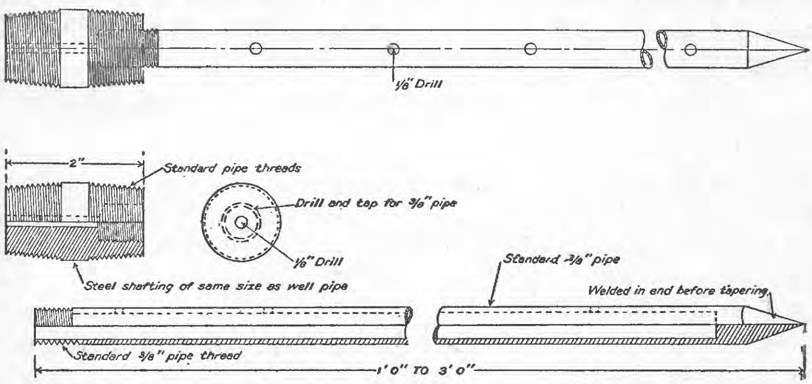

FIGURE 10.—Inside reducer recommended for use in flowing wells in North Dakota

be fitted into the end of the pipe. The plug after being bored should be sharpened like a lead pencil and the pointed end inserted in the pipe. This method tends to avoid the clogging of the hole. The swelling of the wood as it becomes water soaked should, however, be anticipated.

The most satisfactory reducer in use in the Dakota artesian area, one introduced and long recommended and used by the North Dakota Artesian Well Co., is known in the field simply as the inside reducer. This reducer is not patented and may be purchased from the company mentioned in 1¼, 1½, and 2-inch sizes or made by a blacksmith in size to fit any well pipe at a cost of $1.50 to $4 apiece. The accompanying figure illustrates this reducer and furnishes sufficient instructions for making it. (See fig. 10.)

A cylindrical piece of steel shafting 2 inches or more in length and of the same diameter as the well to be fitted, is threaded with standard threads on each end, leaving about half an inch in the middle not threaded. A ⅛-inch hole is drilled through the center of the shafting, and one end is drilled and tapped to insert a ⅜-inch pipe.

A piece of standard ⅜-inch pipe about 1 foot or more in length is welded and tapered at one end. On the other end is cut a standard ⅜-inch pipe thread, and a dozen or more ⅛-inch holes are drilled through the side of the pipe at well-spaced intervals, or an equal number of slots may be cut with a hack saw. The pipe is then screwed into the shafting, and the reducer is complete.

This reducer may be fitted into the pipe leading from the well either vertically or horizontally. The tapered end of the pipe is inserted first and the inner end of the reducer used as a plug. Additional lengths of well pipe may be screwed to the outer end of the reducer. The reducer thus becomes an inside union in the well pipe. By this method the flow is greatly reduced; the pressure is also reduced through friction on the walls of the small holes and any particle of sand or gravel which enters the reducer may pass entirely through it and out without danger of clogging.

RESULTS OF REDUCTION

The flow from a well thus reduced is constant and without great force. In an emergency the reducer may be removed by a small pipe wrench and again replaced when the emergency is passed, but it can not be tampered with by children and irresponsible strangers. The flow is kept open to prevent freezing and gives an amount of water sufficient for the stock of an ordinary farm if used with an ample storage tank, and if the reducer is placed at the tank outlet of a looped line of pipe passing through the house, as is a common custom, it will maintain sufficient back pressure to give a good strong flow at the house tap. If all lead pipes are properly buried 1 foot underground and the exposed loops covered in winter, there will be ample flow to prevent freezing through a considerable line of pipe, and abundant water may be furnished to both house and stock, cool in summer and moderately warm in winter.

Above all, the waste of water will be largely stopped, artesian flow and pressure will be conserved, and flooding of many acres of valuable land and much damage to highways will be avoided. In this way it is hoped to save this most valuable natural resource not only for our own use, but for many future generations.

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ADAMS COUNTY

TOPOGRAPHY

Adams County, which is situated on the southern boundary of the State, midway between Missouri River and the Montana line, is a typical part of the Missouri Plateau. The region is characterized by high, rolling uplands capped here and there with flat-topped buttes and cut by the broad, deep valleys of numerous streams that flow southeastward.

Chief among these streams is South Fork of Cannonball River, or Cedar Creek, which, with its tributaries, has thoroughly drained the area and brought it to a state of maturity. Other streams that drain the southwest corner flow across the boundary into Green River of South Dakota.

GEOLOGY AND GROUND WATER

The surface mantle here consists of residual material from the decay of the underlying rocks, the waste and wash that is moving down the slope from the residual deposits to the stream valleys, and the alluvium that deeply covers the broad floors of the stream valleys and lies in flat tracts as terraces along the sides. The underlying bedrock is the Fort Union formation, except in the southeast corner, where this has been removed by erosion and beds of the Lance formation have been brought to the surface. Both these formations consist largely of soft clays and sandstones. Some of the sandstone layers hold large quantities of water. They include also thick beds of lignite which permit the passage of water freely, and are therefore the source of many springs on the valley sides and of the water supply for most of the upland wells that enter the bedrock. Dry holes are very uncommon, even on the uplands of this region, and below the ground-water level the yield of wells generally increases with their depth. Most wells, however, are located in the lower lands and in the valleys, where water can generally be obtained at slight depths in the alluvial deposits of sand and silt. On failure to obtain enough water in the alluvium or upper layers of the bedrock the drill should be sunk deeper for adequate supplies. Beneath the Lance lies the Pierre shale, unless perhaps there are intervening beds of the Fox Hills sandstone. The Pierre shale is a very uniform soft dark blue-gray rock, almost without a trace of sand or grit except in a few thin layers, which contain very fine sand. This shale passes below into other shales, in all several hundred feet in thickness. These shales are all very unpromising for water supplies, and the formations below, which contain sandstone, are deeply buried, and moreover would probably not yield artesian flows. It is advisable, therefore, to stop all drilling for water at the top of the Pierre formation, which is easily recognized because of the uniform dark bluish-gray mud obtained by the drill.

Many springs occur in the deeper valleys of Cedar Creek (South Fork of Cannonball River), Hidden Wood Creek, and other streams where they have cut through lignite and porous sandstone. Where the flow is sufficient, these springs form valuable water supplies for stock.

QUALITY OF GROUND WATER

Most of the wells in Adams County are shallow dug or bored wells in the Pleistocene, Fort Union, or Lance formations and yield hard water. (See analysis 2.) Softer water, some of which may, however, be more highly mineralized, is obtained from deeper drilled wells that enter the lower beds of the Fort Union formation or the Lance formation. (See analysis 1.) Highly mineralized waters, which appear to be due to local concentration, have been obtained from a few wells in the county.

Typical wells of Adams County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Ben Oehler	SW. ¼ sec. 10, T. 132, R. 98.	185	4½	Coal	15	
Roy White	SE. ¼ sec. 15, T. 132, R. 95.	51	2⅗	Sand	12	
Edgar Anderson	NE. ¼ sec. 26, T. 131, R. 98.	135	4½	Quicksand	35	Abundant.
Conrad Davis	SW. ¼ sec. 4, T. 131, R. 96.	92	2			No water.
George Corbett	SW. ¼ sec. 9, T. 131, R. 96.	46		Sand		
W. M. Atkins	W. ½ sec. 4, T. 130, R. 98.	176	4½	Brown sand	22	Abundant.
A. F. Atkins	Reeder	165	4½	Sand	60	Brown water.
C. M. Cleveland	SE. ¼ sec. 15, T. 130, R. 98.	176	4½	Coal	22	Abundant.
Village	Reeder	86	4½	Sand	65	
T. J. Mather	do	173	4½	do	63	Brown water of good taste; unused for washing.
C. R. Krause	SW. ¼ sec. 6, T. 130, R. 97.	220	4½	do	70	In clear fine sand.
Joe Ludwig	5 miles south of Reeder.	135	4½	do		Slightly brown color.
Benj. Stuart	Bucyrus	120	4½			Water at 20, 42, and 120 feet, all alkaline. Abandoned.
Joe Skogen	SW. ¼ sec. 12, T. 130, R. 96.	65	2	do	17	
George P. Woller	NE. ¼ sec. 13, T. 130, R. 96.	89	2	do	35	Poor water.
Anna Hoadge	NW. ¼ sec. 24, T. 130, R. 96.	112	2	do	4	
S. Thompson	SW. ¼ sec. 1, T. 130, R. 96.	106	2	do	10	
Herbert Gentry	SE. ¼ sec. 6, T. 130, R. 95.	51		do	15	
C. R. Purtergost	SW. ¼ sec. 35, T. 130, R. 96.	57	2	do	14	
Oscar Melby	SE. ¼ sec. 24, T. 129, R. 98.	177	5	Brown sand	27	Good, soft, brown water.
Jacob Knoff	SE. ¼ sec. 10, T. 129, R. 98.	65	5	Blue sand	35	Do.
George Becker	Hettinger	50	2	Sand	8	
City	do	400	6	do	150	Water-bearing sandstone at 235-260 feet, 370-390 feet, and main bed at 395-400 feet. Consumption, 10,000 gallons daily.
Henry Moen	do	51	2	do	10	
G. L. Thompson	do	25	2	do	8	
Prof. Sturch	do	56	2	do	10	
O. T. Peterson[a]	NW. ¼ sec. 12, T. 129, R. 96.	30	36	do	22	Wood curb, hand pump; pumps dry.
George Oeneson	SE. ¼ sec. 9, T. 129, R. 96.	56	2	do	15	
P. D. Norton	SW. ¼ sec. 12, T. 129, R. 96.	46	2	do	120	

[a] See table of analyses.

Water supplies of towns in Adams County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bucyrus	113	Bored	15	150		Clay	Sand, coal	Some good springs.
Haynes	113	Dug, bored			15–25	Gravel		
Hettinger	817	Dug, bored, drilled.	25	400	55	Sand, coal	Sandstone, coal.	Wells reported satisfactory. Mill well 1,200 feet deep.
Reeder	258	do	60	175	65–170	Coal	Sand in blue shale.	Many drilled wells; some yield soft brown water.

BARNES COUNTY

TOPOGRAPHY

Barnes County lies entirely within the drift-covered prairie toward the southeast corner of the State. Its surface shows the characteristic morainal features of a glaciated plain and is on the whole gently undulating, though in places nearly flat. The chief modifying feature of this topography is the deeply excavated valley of Sheyenne River, which divides the county into east and west halves. This valley is a steep-sided trench about 200 feet deep and half a mile in width and is out of all proportion to the stream which now occupies it. It was carved by the heavily loaded waters that flowed southward from the front of the melting ice sheet when it lay in the vicinity of Devils Lake. With the weakening of the flow large loads of débris were deposited in the form of a valley train of coarse gravel and sand, which were later deeply trenched by clearer waters after the ice had retreated so far northward that its débris was no longer carried into this valley. Thus we have the remarkable terraced valley, gravel-walled within, whereas on the present flood plain the small stream of the present day meanders widely and has barely sufficient water to flow during the summer season.

Between the hills of rough and irregular outline formed of morainal débris from the great ice sheet lie many small lakes without outlet and undrained sloughs. Largest of these lakes are Eckelson and Fox Lakes, which lie west of Valley City, high on the plateaulike divide between James and Sheyenne Rivers and therefore between the drainage of Hudson Bay and the Gulf of Mexico. These basins are portions of the deep, broad troughs of ancient glacial waterways that led from the ice front into the valleys of Sheyenne and James Rivers. These channels in many places cross the great continental watershed and other divides and in no adequate way drain the areas which they cross. In fact, a large part of the county has no surface drainage whatsoever, and the rainfall is largely absorbed or evaporated. Several broad, deep valleys enter the valley of the Sheyenne from the west, each of them occupied only by an intermittent stream insignificant in size even after heavy rains, and the only land that is truly drained is that in these short, deep gorges, which broaden rapidly toward the Sheyenne and deploy upon its flood plain. Another system of ancient channels along the eastern edge of the county is occupied by tributaries of Maple River that are very temporary in their flow.

GEOLOGY

The surface of Barnes County is thickly mantled with glacial drift, except in the lower parts of the deep valley of Sheyenne River. Beneath this drift lies the soft blue-gray Pierre shale. Outcrops occur in the side slopes of the Sheyenne Valley, which has been eroded into the Pierre shale to a depth of 50 or 100 feet. Beneath the Pierre shale and at the base of the valley sides, immediately above and for some miles below Valley City, occur some of the few outcrops of the Niobrara shale in North Dakota. This shale is of a lighter color than the Pierre—almost cream-colored, in fact—and it reacts readily with acid, which shows the presence of considerable lime. Deep wells at Valley City and elsewhere have also penetrated the Benton shale, which underlies the Niobrara, and have reached the Dakota sandstone, the lowest known formation of the Cretaceous system that is present in this region.

A more complete review of the geology and water resources of Barnes County is given in the Jamestown-Tower folio, to which the author is indebted for some of the material here presented.[24]

GROUND WATER

The ground waters of Barnes County are obtained from several beds that are not everywhere easily distinguished except in the deeper wells. Among these beds are the alluvium and valley-train gravel of the Sheyenne Valley, the gravelly and sandy portions of the drift, the porous sandy layers of the Pierre shale, and the Dakota sandstone. On the floor of the Sheyenne Valley proper and on the higher gravel or sand terraces, such as the Lanona Plain east of Valley City and the Sand Prairie on the west side of the river, where it passes out of the county, and on the outwash plain along the foot of the morainal ridge that runs northward through Alberta, shallow wells 10 to 20 feet in depth yield an abundance of water for domestic and farm use. Many of these wells are simple driven wells to which a suction pump may be attached. The supply is generally of good quality. Elsewhere water may generally be found in shallow wells, which draw their supplies from the gravel and sandy layers and lenses of the drift, especially from the base of the glacial drift in its contact with the underlying shale. These deposits range from coarse gravel to finest quicksand. Where the topography is such that the surface waters can not escape except by evaporation or percolation, and the material is such as not to afford good underdrainage, the waters are generally strongly alkaline and of very poor quality.

A considerable number of wells penetrate the Pierre shale beneath the drift and are meagerly supplied by thin porous sandy layers. The line of demarcation between the blue gravelly clay of the drift and the more compact blue shale is not everywhere easily distinguished, so that the relative use of the two terms is uncertain. In some localities the drillers claim that no water may be obtained after the shale, or "soapstone," as they frequently term it, is reached, and this is undoubtedly true. Unless a considerable amount is found in sand within the shale formation the water is brackish and very disagreeable to the taste.

In some places the waters of wells supplied by small aquifers in the drift rise so near the surface that they flow into reservoirs excavated for them. Other beds, in the deeper valleys, yield weak flows because of conditions determined by local topography. These waters are, however, rare and of little use. The entire county is underlain by the Dakota sandstone, which contains a large volume of water under considerable pressure. This sandstone has not been entirely penetrated in this county but is known to dip westward and to be 200 to

[24] Willard, D. E., U. S. Geol. Survey Geol. Atlas, Jamestown-Tower folio (No. 168), 1909.

300 feet thick. It is overlain by a thick bed of shale and is reached at depths of about 800 feet at the eastern margin of the county. Owing to the western dip and the rise of the land surface in that direction the depth gradually increases to 1,200 or 1,300 feet along the western margin. The head of the water is sufficient to afford a flow in all the region except on the higher portions of the Alta Ridge east of Valley City and the higher morainal region about Moon and St. Mary's Lakes, several miles southwest of the same city. Many wells from 800 to 1,200 feet in depth have been sunk in the eastern and southern portions of the county, and nearly all obtained flows that ranged originally from 20 to 300 gallons a minute, depending on the size of the well and local pressure. The pressure has in a few places been used to develop from 1 to 5 horsepower for the operation of machinery. This use has, however, been generally discontinued as the pressure has decreased. The water is slightly saline, and this characteristic increases with the depth from which the water comes, the water of the second horizon being harder and higher in mineral content than the first. As the water-bearing sandstones appear to lie in widely extended sheets separated by deposits of shale, two or more distinct horizons are recognized. In each of the Valley City wells the second artesian horizon lies more than 300 feet below the first.

Log of artesian well at Nome, N. Dak., in the SE. ¼ sec. 13, T. 137 N., R. 57 W.

	Feet
Soil, sand, and clay	40
Yellow clay	20
Bluish gravelly clay	48
Tough bluish clay	162
"Iron ore"	1
Blue clay, with thin layer of "iron ore" at 356 feet	128
"Iron ore," softer below	5
Blue clay with fine sand	300
Hard clay	10
Sand and clay mixed; first flow	42
Hard "iron layer"	½
Clay, with thin hard layer at base	27½
Clay and fine sand	46
Sand and clay, alternating; thin layer of "iron ore"; second flow at top	35
Clay and sand; third flow at top	22
Sand with main flow	1
	888

The decline in pressure and flow of the artesian wells in Valley City as hereafter related is the history of all flowing wells in Barnes County. In fact a considerable number near the former margin of the areas of flow have ceased to flow. It is hoped that the steps now being taken to save the waste of this water and conserve the supply will result in checking the further decline of the wells.

Springs occur along both sides of the Sheyenne Valley and its larger tributaries, commonly at the line of contact of the drift with the shale. They are used on the valley farms for domestic and stock use in a few places, but most of them are entirely inadequate for such use. As they are available only to the few who live in the valleys they do not yield a large part of the ground-water supply of the region. The water is, however, generally good and the farmer fortunate who possesses one.

QUALITY OF GROUND WATER

Analyses of typical ground waters from Barnes County indicate that waters of widely differing composition are obtained in Barnes County. Shallow wells in the alluvial deposits nearly all yield hard, moderately mineralized water that is satisfactory for domestic and other uses. (See analysis 5.) The drift is penetrated by deeper wells which yield similar water, although some of it may be more highly mineralized. (See analysis 3.) The Pierre shale is a poor water-bearing formation, but thin sandy layers yield small amounts of highly mineralized water of variable hardness. Deep wells in the Dakota sandstone yield water which is highly mineralized but usually soft. (See analysis 4.) Where the less highly mineralized water from shallow wells can be obtained in sufficient quantity the water from the Dakota sandstone is not used for domestic supplies.

WATER SUPPLIES AT VALLEY CITY

There are two water-bearing beds beneath Valley City—the alluvial gravel of the Sheyenne Valley and the Dakota sandstone.

The water from the alluvial gravel is now being used for the public supply. This water does not, as many believe, come from the river but is the underflow of the river valley, fed by rainfall upon the uplands through seepage into the valley gravel. Except in seasons of heavy rainfall the underflow is itself the source of the water that flows away in the river.

The Dakota sandstone formerly furnished a public supply to a well 1,557 feet in depth and 4½ inches in diameter. This well had an initial pressure of 70 pounds, yielded 200 gallons a minute, and furnished direct pressure for protection against fire, but it was abandoned because of the loss of pressure and yield and because the high mineral content of the water rendered it unsuitable for domestic use.

The well of P. G. Davidson, 985 feet in depth and 4½ and 3 inches in diameter, which had an early pressure of 56 pounds to the square inch and a yield of 320 gallons a minute, had in 1922 a pressure of 40 pounds and was leased by the city for supplying water to sprinkle the streets.

These artesian wells may still furnish a large industrial supply through the use of a pump or an air lift.

The alluvial gravel furnishes a very satisfactory source of supply, both in quantity and quality. The present city well is 15½ feet in diameter and 30 feet in depth. It is curbed with cement blocks and has 12-inch strainers set at least 9 feet in gravel beneath the main well. The well is about 1,200 feet from the river, and no treatment of the water is required. This well is pumped by electric centrifugal pumps of a capacity of 800 gallons a minute, set in a pumping pit, which draws from 12-inch screens set into the gravel below. About 265,000 gallons is consumed daily. The present plant is capable of yielding half a million gallons daily. Additional yields can be procured by the installation of other wells in the vicinity of the plant.

Typical wells of Barnes County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
F. Grahm	SW. ¼ sec. 10, T. 143, R. 61	301	2	Shale		Abundant but salty.
A. Felohn	S. ½ sec. 21, T. 143, R. 61	60	5	Gravel		Abundant.
Julius Halvorson	SW. ¼ sec. 4, T. 143, R. 60	50	5	Sand		
Herman Pyrn	W. ½ sec. 22, T. 143, R. 59	170	3	Fine sand		
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Wimbledon	1,557	8	Sandstone	Flow.	Formerly 400 gallons a minute. Used for pressure for fighting fires.
H. W. Green	Leal	1,380	2		Flow.	
Hugh McDonald	2 miles northeast of Rogers	1,485	2	Sandstone		Slightly salty.
	SE. ¼ sec. 4, T. 142, R. 58	1,340		do	11	
Northern Pacific Ry	Rogers	20	92			Brick curb.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	24	106	Gravel		Formerly 150 gallons a minute.
W. R. Barnes	NW. ¼ sec. 17, T. 141, R. 59	1,304		Sandstone	Flow.	
Jacob Shaefer	SE. ¼ sec. 14, T. 141, R. 59	1,255	1¼	do	do	
Northern Pacific Ry	Eckelson	70	12	Gravel	35	
Sacred Heart Church	Sanborn	40	18	Sand	25	
Northern Pacific Ry	do	24	240			Brick curb.
S. Granger	NW. ¼ sec. 27, T. 140, R. 58	1,191	3–1¼	Sandstone	Flow.	50 gallons a minute.
Nels Jorgenson	SE. ¼ sec. 20, T. 140, R. 58	1,285	3–1¼	do	Flow.	Shale at 1,180 feet, reddish sandstone at 1,220 feet.
L. S. Platou	SW. ¼ sec. 34, T. 140, R. 58	894	2½–2½	do		
E. A. Pray	Valley City	1,120		do	Flow.	First flow at 836 feet.
County hospital	do	1,124	1¼	do	Flow.	
Hugh McDonald	do	1,278	1¼	do	Flow.	
P. G. Davidson	do	985	4½–3	do	Flow.	320 gallons a minute. Pressure 40 pounds to the square inch; original pressure 56 pounds.
City[a]	do	30	186	Gravel	28	City water supply.
F. Winkler	NW. ¼ sec. 35, T. 140, R. 57	1,196		Sandstone	Flow.	First flow at 900 feet.
Matt. Murphy	NW. ¼ sec. 35, T. 139, R. 61	118	12	Sand	98	
L. S. Platou	NW. ¼ sec. 35, T. 139, R. 59	1,200	2	Sandstone		
S. J. Aandahl	SW. ¼ sec. 28, T. 138, R. 60				Flow.	
S. Thompson	SW. ¼ sec. 32, T. 138, R. 59	1,274	1¼	Sandstone	Flow.	
John Reimeke	SW. ¼ sec. 18, T. 138, R. 59	1,140		do	Flow.	
B. N. Opsahl	NE. ¼ sec. 26, T. 138, R. 58	1,123	1½	do	Flow.	
Martin Thoreson	NW. ¼ sec. 24, T. 138, R. 58	1,150	2	do	Flow.	Pressure formerly 60 pounds to the square inch.
J. J. Peterson	SW. ¼ sec. 23, T. 138, R. 57	1,130	3	do	Flow.	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Fengal	15	96	Gravel		
City	Litchville	150	12	Drift		No water.
John Norberg	NW. ¼ sec. 26, T. 137, R. 59	1,060	1¼	Sandstone	Flow.	
M. O. Baarstad	SW. ¼ sec. 35, T. 137, R. 57	1,265		do	Flow.	
Northern Pacific Ry	Kathryn	25	180	do		Brick curb; near Sheyenne River.
Village	Nome	1,089	3	Sandstone	Flow.	180 gallons a minute.
J. Jans	NW. ¼ sec. 13, T. 137, R. 56	44	24	Drift	420	Wood curb, yield small.

[a] See table of analyses.

Water supplies of towns in Barnes County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing material		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Dazey	293	Dug, drilled	10	175	25	Gravel or clay	Sand	Dakota artesian horizon about 900 feet below the surface.
Eckelson		Bored, drilled	40	70		Drift		Dakota artesian horizon about 1,300 feet below the surface.
Fingal		Dug, drilled	10	1,100		Sand, gravel	Sandstone	Shallow water hard; deep water salty.
Kathryn	289	Bored, drilled	25	1,000		Alluvium, drift	do	First artesian horizon about 900 feet below the surface.
Leal	88	Dug, drilled	20	1,380	22	Clay	do	Rather hard water; artesian water salty.
Litchville	528	Bored, drilled	20	40	30	Clay, sand	do	Shallow water alkaline. Artesian water salty.
Nome	267	do	25	1,200	70	Drift	do	Artesian water salty. Water used for public supply.
Oriska	300	Drilled	20	1,200			do	First artesian horizon about 860 feet below the surface.
Rogers	173	do	20	1,485	20	Drift	do	Artesian water slightly salty.
Sanborn	391	Bored	16	1,285	25	do	do	A few strong springs.
Valley City	4,686	Driven, bored, drilled	30	1,550		Alluvium drift	do	Deep artesian wells yield moderate flows.
Wimbledon	521	Dug, drilled	10	1,557		Sand, gravel	do	Water in shallow wells "alkaline" and in deeper wells soft but salty.

BENSON COUNTY

TOPOGRAPHY

Benson County, which includes the Devils Lake Indian Reservation, is topographically the most varied area within the Drift Prairie. It is strikingly morainal, as it is crossed by at least five of the recessional moraines which the Wisconsin ice sheet formed within the borders of North Dakota.

Probably in no other region of the State, if indeed anywhere else in the United States, is morainal topography of the knob and kettle type better shown than in this region, particularly in the area south of Devils Lake that was formerly included within the Sioux Indian Reservation. The confused masses of hills that have resulted from the compounding of moraines in this area are thus described by Upham:[25]

> Along the entire south side of Devils Lake, extending more than 30 miles from Jerusalem to Minnewaukan, this compound morainic belt is magnificently developed, in many portions forming hills, knobs, and ridges of till, very rough in outline and bristling with multitudes of boulders of all sizes up to 10 feet in diameter, on a width that varies from 1 to 5 miles. Most of these hills rise 50 to 100 feet above the lake and appear by their small area and glacial features to consist wholly of drift.

Remarkable outwash plains occur in several parts of the county, on the south and west sides of the greater moraines. The Antelope Valley about Oberon is a good illustration, and the valley near Fort Totten that extends eastward to Tokio, Warwick, Hamar, and on into Nelson County is one of the largest and most remarkable in the State.

In the western part of the county the long irregular ridges of knobs with kettle-like depressions between them is more pronounced and long loops of these extend across the region to the northwest. The prairie between these hilly tracts is a rather gently rolling drift plain which is dotted with many panlike depressions that contain meadows, marshes, ponds, and lakes and which in the south is also deeply cut by the valleys of the Sheyenne and its tributaries.

The soft shaly country rock throughout the Drift Prairie does not influence the surface topography to a marked extent and is generally fully masked by the morainal features. In Benson County, however, several well-rounded hills and full-bodied ridges rise above the general level of the plain and make striking features in the landscape. Most conspicuous of these hills are Devils Heart, Sullys Hill, Crow Peak, and Mauvaise Butte, all of which rise 200 or 300 feet above the plain and are mesalike remnants of older and once continuous formations now elsewhere removed by erosion. These hills are so veneered with drift that their origin is only revealed by their form.

Second in interest in bedrock topography to these hills is the valley of the preglacial stream now partly filled with glacial drift, in which lie Devils and Stump Lakes. This valley probably extends northward and includes the depressions in which lie Ibsen, Hurricane, Grand, and Long Lakes. Deep wells that penetrate 300 feet of drift, including many feet of quicksand, about 4 miles north and west of Pleasant Lake indicate a preglacial channel probably tributary to this valley. The large hills just mentioned probably formed a series of buttes on the divide to the south and west of this valley. The south side of the old valley trough is in general the south margin of Devils Lake, as indicated by the bedrock that crops out at the west entrance of Fort Totten Bay and elsewhere and by the form, character, and arrangement of the hills just mentioned. The form and altitude of the secondary bays, as Fort Totten, Mission, and Black Tiger, indicate that

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[25] Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 24, p. 169, 1894.

they were tributaries of the main valley. Minnewaukan or West Bay of Devils Lake lies entirely within Benson County. This bay was formerly navigable to Minnewaukan, but now only boats or launches drawing less than 18 inches of water may enter the narrows at La Rose Ferry, and the western half is practically dry and covered with grass. A small channel that extends up to the mouth of Mauvaise Bay is the only remnant of this recently broad expanse of water.

Because of its legendary and historic associations and its interesting scenery Sullys Hill has been set aside as a national park.

GEOLOGY AND GROUND WATER

As may be inferred from the account of the topography of the county, the drift presents many varied conditions of water supply. The deposits of sand and gravel in the morainal ridges, the great expanse of outwash plain, the gravel terraces on the sides of the Sheyenne Valley, the alluvium on its floor, and even the till sheet itself furnish valuable water supplies. So far as known, the glacial drift is everywhere underlain by the Pierre shale. Outcrops of the Pierre occur at several points in this region, notably just beneath a long shale beach at the west side of the entrance to Fort Totten Bay, near the south end of Mission Bay, and in the valley walls of the Sheyenne. It has also been exposed in the deepest cuts of the new highway that runs along the base of the Sully Hill Range and along the south shore of the lake. All the outcrops reveal the characteristic fissile blue-gray shale of the Pierre formation.

The alluvium and the valley-train gravel of the Sheyenne Valley, the other outwash gravel and sand, the gravelly and sandy layers in the till, and the sandy layers of the Pierre shale all yield supplies of water in this region, and the Dakota sandstone is reached by the deep well at Leeds.

The gravel of the Sheyenne Valley and other alluvial deposits furnish water supplies to shallow driven and dug wells on the farms located in this valley.

The drift gravel is so widely distributed and in general yields so much water that it forms an abundant source of supply. Villages and farms upon the outwash plains are particularly fortunate in having an abundant supply of good water in this gravel that overlies the till. The morainal deposits are more irregular and uncertain as to water supplies.

Throughout the county the till sheet with its interbedded sandy and gravelly layers forms perhaps the most useful single source on account of its extent and thickness. The waters differ in character and are in many places not so good as those of the surface gravel on account of the mineral salts dissolved from the boulder clay, with the fine particles of which the waters come into close contact.

Many of the deeper drilled wells enter the Pierre shale. These wells are likely to be dry or to yield water that is strongly mineralized, but good water may be found here and there in sandy layers at depths of 150 to 250 feet.

Small artesian flows have been obtained from drift gravel in a few places on lowlands. On the margin of the lowlands in the NE. ¼ sec. 9, T. 155 N., R. 69 E., about 5 miles southwest of Leeds, a drilled well 100 feet deep yields a weak flow of this type. About 2 miles south of York are the flowing wells of Bruce Anderson and Len Olson, which have heads of 8 or 9 feet and are supplied from gravel beds found at depths of 65 and 135 feet. Two wells in T. 156 N., R. 70 E., east of Knox, yield small flows. One of these, in the NW. ¼ sec. 21, is 100 feet deep, and the other, in the NE. ¼ sec. 9, is only 30 feet deep. A good flow of 20 gallons a minute with an 18-foot head was procured by W. J. Maddock in the SW. ¼ sec. 23, T. 152 N., R. 69 W., at a depth of 155 feet in drift sand. On the insertion of a sand point the flow was reduced to 1⅔ gallons a minute and it has decreased somewhat since.

The only deep artesian well in Benson County was drilled by the city of Leeds in 1907, in order to obtain a city supply from the Dakota sandstone. This well proved that Leeds is in the area of flow of this artesian basin, though the well was for a time thought to be unsuccessful. The well was put down to the depth of 2,110 feet, the second deepest drill hole in the State, and the sandstone was reported by the drillers to lie at 1,637 feet. A 6-inch bit was used to start the hole and a 1½-inch bit was being used when the drilling stopped. The principal water bed was reported at 1,750 feet in the Dakota sandstone, and although minor water beds were found this is the only bed which produced a flow. Perforations were placed opposite sandstone formations at 1,737 to 1,792 feet, 1,822 to 1,832 feet, 1,835 to 1,860 feet, and 1,890 to 2,110 feet. The yield was only about 3 gallons a minute at first, but this decreased in 6 months to half a gallon and later the water ceased to flow and stood in the casing just at the ground level. That the well was not strong was also shown by the fact that 15 or 20 minutes of pumping would lower the water 400 feet, and a withdrawal of 2½ to 3 gallons a minute would hold the head there, though the natural head was reported to be 6 feet above the curb. Owing to the weakness of the flow obtained and the high mineral content of the water no use was made of it at the time. The well was pumped with a 3-inch cylinder and gave the full capacity of the pump, 25 gallons a minute, before the seal between the 6-inch and 4½-inch casing was put in place. After the seal was placed the well would yield 10 gallons a minute. The well remained unused for several years, when it was shot at a depth of approximately 1,650 feet with a charge of nitroglycerine, and a flow of 125 gallons a minute was procured. This flow had decreased to 100 gallons a minute in 1923. The water is used only for sprinkling and fire protection. (See table of analyses and pl. 2, *A*.) The Leeds artesian well is the northernmost well in the Dakota artesian area in North Dakota. The driller's log is as follows:

Log of Leeds artesian well

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Drift	100	100	Sandstone, good	10	1,832
Hard shale and streaks of limestone	1,637	1,737	Shale	3	1,835
Sandrock streaks in shale	55	1,792	Sandstone	25	1,860
Shale	30	1,822	Soft sand and shale	30	1,890
			Streaky sandstone	220	2,110

The geologic interpretation of the log is given below:

	Feet
Pleistocene drift	100
Pierre, Niobrara, and Benton shales (Upper Cretaceous)	1,637
Dakota sandstone (basal Upper Cretaceous) and other beds	373
	2,110

A number of fine springs emerge along the south side of Devils Lake and in the Sheyenne Valley, from the beds at the base of the drift and immediately over the impervious shale. Elsewhere springs are but seepages from more porous layers of the drift. The spring owned by J. M. Reynolds 1 mile north of Tokio, which has been walled up and the water carried to a good cemented reservoir through a 6-inch pipe; that of S. J. Dean in the SE. ¼ sec. 34, T. 152 N., R. 63 W., which is piped to a tank for the use of stock; and that of V. W. Matthews in the SE. ¼ sec. 34, T. 152 N., R. 64 W., where a 6-inch stream emerges from a bed of sand at the base of a hillside and forms a considerable lake—all flow from the beds at the base of the drift. Others emerge in lot 1, sec. 10, T. 152 N.,

R. 63 W., owned by J. E. Johnson on the south shore of Devils Lake, where a flow of 25 gallons a minute from drift sand is maintained, and in lot 1, sec 24 and sec. 12 of the same township. All these springs yield excellent water for stock and for threshing engines, for which they are chiefly used. A very fine group of springs, known as the Pleasant Lake Springs, is owned by C. Geibel, in the SW. ¼ sec. 4, T. 156 N., R. 71 W. The location in a beautiful grove on the Roosevelt Trail just north of the lake and near the village, makes this group well known to tourists and picnickers. The waters are also collected by the Great Northern Railway in a spring well 12 by 34 by 10 feet in dimensions and used for boilers. The capacity of this well is 100,000 gallons a day. The yield of 20 gallons a minute by one of these springs represents but a portion of the outflow.

QUALITY OF GROUND WATER

Analyses of 10 typical waters from Benson County are given in the table (Nos. 6–15). The drift yields hard water that contains a moderate amount of dissolved constituents. (See analyses 8, 9, 12, 13, and 14.) Most of it is satisfactory for general use, though a few wells in the drift yield water too highly mineralized to be used except for protection against fire or similar uses which are not affected by the quality of the water. The Pierre shale is a poor water-bearing formation; only the thin sandy layers in the shale yield water and the comparatively small quantity obtained is highly mineralized and usually hard. (See analyses 6, 10, 11, and 15.) Much of the water can be used, though it may be objectionable for drinking or other domestic use. The Dakota sandstone here as elsewhere in the artesian basin, yields highly mineralized waters of different degrees of hardness, most of which is unsatisfactory for domestic use. (See analysis 7.).

WATER SUPPLIES AT MADDOCK

A special survey was made by the author, for the village of Maddock, and parts of his report are given in substance below.

There are four formations from which water might be procured in Maddock—the shallow drift, the deeper drift, the shale, and the Dakota sandstone.

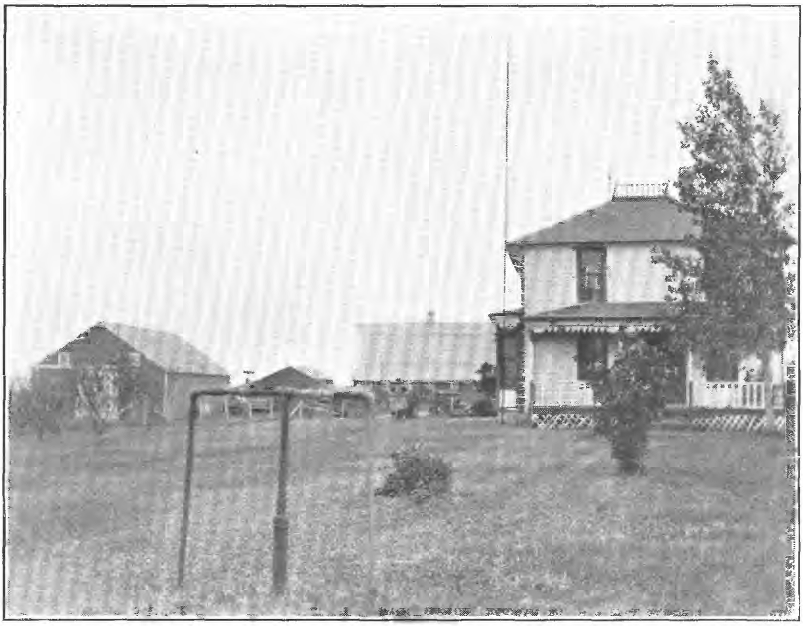
The shallow-drift waters are well known because of the easy access to them and because they have been in general use since the settlement of the region Most of the wells that draw their supplies from these shallow sources have been found unsatisfactory because of the frequency with which they are polluted from the surface and because of the high content of mineral matter in solution in the waters, which renders them unpalatable. Many wells have been dug to depths of 10 to 30 feet, but few remain in use. Those now being used are above the average in quality and quantity and draw their supply from thin gravel layers of the upper drift. These would probably not yield enough water for a public supply.

The most commonly used waters are those that come from the deeper portions of the drift, generally from gravel and sand at or near the base of the drift and immediately above the bedrock. These waters are less liable to contamination from the surface, are more permanent, and, in many places, are much less strongly mineralized than those of the shallower drift. They are only moderately hard, but some contain too much iron for use in laundries. (See analysis 10.)

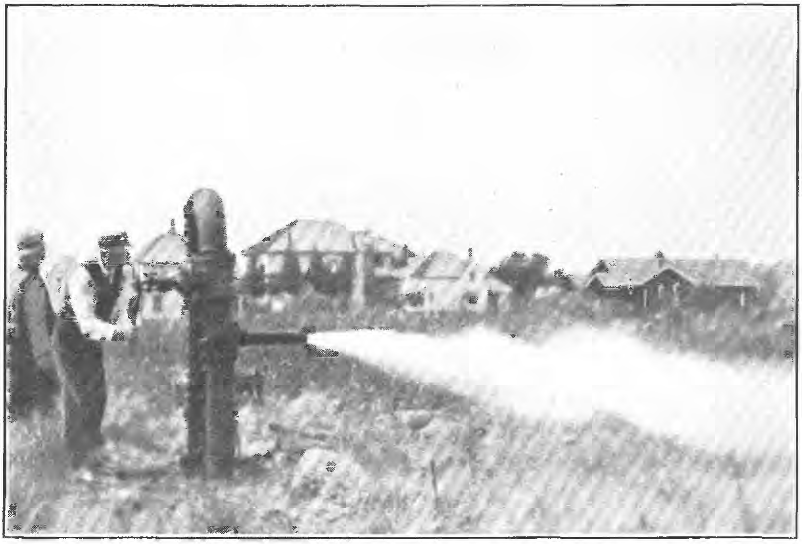
Many of the more permanent farm and stock wells draw their supply from sandy layers of Pierre shale, which immediately underlies the drift. These waters contain sufficient mineral matter to give them a rather strong mineral taste, but the water would be good for laundry use. (See analysis 11.)

Maddock lies well within the Dakota artesian basin, and a flowing well could probably be obtained at a depth of about 2,000 feet. It is probable that the water would be abundant, but it would be highly mineralized.

A. WATERWORKS AT LEEDS, N. DAK., SHOWING TYPICAL ARTESIAN WELL USED FOR PUBLIC SUPPLY

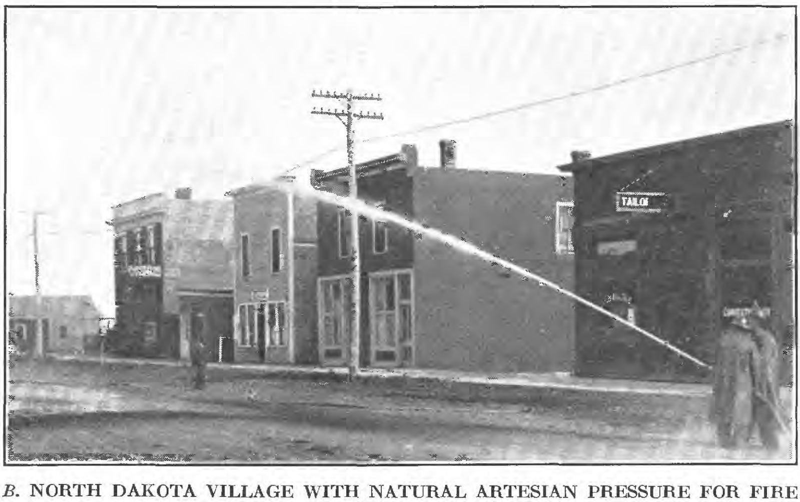


B. A NORTH DAKOTA FARM HOME WITH ARTESIAN WELL FROM WHICH WATER IS PIPED TO HOUSE, BARN, AND PASTURE



A. ARTESIAN WELL AT ELLENDALE, N. DAK.

This well had an original pressure of 196 pounds to the square inch



B. NORTH DAKOTA VILLAGE WITH NATURAL ARTESIAN PRESSURE FOR FIRE PROTECTION

Outside the town about 3 miles to the east and to the west stretch coulees, the beds and banks of which consist of heavy deposits of glacial gravel that were laid down by the southward-flowing waters from the retreating ice front in the closing stage of the glacial epoch. This gravel contains waters which are less strongly mineralized than any others in the vicinity, as the supplies come from water which has recently fallen as rain over the areas of the drainage basins. These waters are recommended for public use wherever it is possible to obtain them uncontaminated and in sufficient quantity. (See analysis 8.) The Northern Pacific Railway well 3 miles east of Maddock and the West Coulee well about the same distance west of the town are typical wells that yield these waters. Both waters are good, though the water of the West Coulee well is preferred for chemical reasons.

Typical wells of Benson County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
C. Giebel [a]	NE. ¼ sec. 27, T. 156, R. 71.					Spring flows 20 gallons a minute to Great Northern Ry. well.
Great Northern Ry.	NE. ¼ sec. 27, T. 156, R. 71.					Spring well, 12 by 34 by 10 feet, capacity 100,000 gallons a day.
Sam Maddess	NW. ¼ sec. 1, T. 156, R. 71.	110		Gravel		Strong well.
R. L. Jones	Sec. 23, T. 156, R. 70.	280		Shale		Drift to 130 feet. Small yield.
Do	do	86			1	
H. A. Jones	SW. ¼ sec. 27, T. 156, R. 70.	160			3	
Wirtz Bros	NW. ¼ sec. 13, T. 156, R. 70.	145		Sand	12	Shale at 85 feet.
Bruce Anderson	½ mile southwest of Knox.	65			Flow.	
Len Olsen	SE. ¼ sec. 26, T. 156, R. 70.	135			Flow.	
Village	Knox	125	6–2	Shale	6	Strong; first water in shale.
Great Northern Ry.	do					12 by 24 by 62 feet; capacity 100,000 gallons a day.
Northern Pacific Ry.	do		16	Drift		Shallow well; large supply of poor water.
School District No. 8.[a]	do	100	6	do		
Bank of York	do	100	30	do		
City [a]	Leeds	2,110	6	Dakota sandstone.	Flow.	Original flow after shooting at 1,650 feet was 1,259 gallons a minute. 100 gallons in 1923.
H. A. Jones	NW. ¼ sec. 33, T. 156, R. 68.	150	36			Pumps down to 85 feet below surface.
Anton Johnson	SW. ¼ sec. 2, T. 156, R. 68.	80				
Wirtz Bros	Leeds; T. 156, R. 68.	225	4	Sand	118	Salty; shale at 165 feet.
Thomas Erglehorn.	N. ½ sec. 25, T. 156, R. 67.	87				
J. Cassidy	SW. ¼ sec. 27, T. 156, R. 69.	100		Gravel		Bored to shale.
Mrs. Corey	York	110		Sandy shale	18	Strong well.
Tom Allen	E. ½ sec. 33, T. 155, R. 70.	156			20	Strong well. First water at 80 feet; hard.
Chris Solberg	6 miles southwest of York, in sec. 4, T. 155, R. 70.	140				
Thomas Webster	6 miles southwest of Knox.	125				
Alf Solberg	12 miles west of York; T. 155, R. 70.	245		Sand		Quicksand at 125 and 250 feet.
Do	NW. ¼ sec. 34, T. 155, R. 70.	80		do		Abundant supply in sand above shale.
Samuel Reauch	S. ½ sec. 10, T. 155, R. 70.	365		Coal		No water below 80 feet.
L. L. Ellstad	E. ½ sec. 4, T. 155, R. 69.	100			Flow.	Weak flow in drilled well at edge of lowland.
Carl Peterson	SE. ¼ sec. 4, T. 155, R. 69.	106			Flow.	

[a] See table of analyses.

Typical wells of Benson County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Fillmore	50		Gravel		30 feet dug and several 4-inch sand screens driven 20 feet deeper.
Peter Nelson	7 miles east of Fillmore, T. 154, R. 70.	140			60	Strong well.
Do	do	35				Drift to 20 feet.
A. Adolph	SE. ¼ sec. 14, T. 154, R. 70.	140		Sand	17	Quicksand below shale.
Chris Solberg	N. ½ sec. 11, T. 154, R. 70.	140		do		Do.
D. A. Hill	SE. ¼ sec. 23, T. 152, R. 70.	26	36, 2	do	12	14-foot driven points in open well.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Comstock	35		do		70 gallons a minute.
W. J. Maddock	SW. ¼ sec. 23, T. 152, R. 69.	155	2	do	Flow.	¾ gallon a minute in 1916.
Public School [a]	Maddock	62	6	Shale		Dug 6 feet; drilled 56 feet.
H. S. Rice [a]	NW. ¼ sec. 29, T. 152, R. 69.	153	4	do	25	Not a strong well.
Northern Pacific Ry.	Maddock	12	384	Fine sand		In depression. Brick curb.
H. A. Nicholson	NW. ¼ sec. 14, T. 152, R. 63.	156			50	
H. Gilbertson	NW. ¼ sec. 10, T. 151, R. 69.				Flow.	
Elan Hill	SW. ¼ sec. 3, T. 151, R. 67.	225	5		30	Hard shale, 20 feet; sandy clay, 30 feet; blue clay, 40 feet; hard shale, 100 feet; salty water at 130 feet. Gas at 117 feet. Cased off gas and water and found dry hole. Drew casing to 116 feet.
Abraham Baldwin.[a]	SW. ¼ sec. 10, T. 151, R. 67.	21	30	Gravel		Cement casing.
Northern Pacific Ry.	N. Oberon; T. 151, R. 67.	30	192	do	24	Salty water. Pumps dry.
Great Northern Ry.	Tokio	12	144			50,000 gallons a day.
Do	Warwick	24	196			108,000 gallons a day.

[a] See table of analyses.

Water supplies of towns in Benson County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Brinsmade	191	Bored			150			Cisterns common because of poor quality of water.
Esmond	343	Dug, bored	25	60	35	Drift	Drift	
Flora	50	Dug	25	40	32	Drift sand		Water hard and mineralized.
Hamar	225	Dug, driven	7	14	10	Gravel	Gravel	Abundant supply.
Knox	173	Drilled	65	150	85	Drift	Shale	Shale at 60 feet. A few small springs.
Leeds	704	Dug, drilled	30	250		do	do	Flowing well 2,110 feet deep. Two flowing wells 4 miles southwest.
Maddock	557	do	20	160	28	Quicksand	Quicksand	Small springs. Water hauled in from springs.
Minnewaukan.	564	Bored, drilled	20		40	Drift	Shale	
Oberon	450	Dug, driven	14	225	30	Sand	Drift	
Pleasant Lake	100	Springs, wells	20	90		do	Sand	Large springs.
Warwick	290	Bored	12	25	15			

BILLINGS COUNTY

TOPOGRAPHY

Billings County is most remarkable topographically for the badlands of the Little Missouri. This river crosses the county from south to north and forms the axis of the belt of badlands, in some respects among the most remarkable formations of the kind in the world. This belt is from 10 to 30 miles in width along either side of the Little Missouri and its many tributaries and creeks. Here the soft clay and sandstone have been carved by running water into a perfect chaos of buttes and mesas and etched into very picturesque forms. The dull color of these beds is banded with the black of lignite seams and for considerable thicknesses over large areas has been altered to reds, pinks, and purples as a result of the burning out of some of the coal beds, forming scoria from the clay and shale. The stumps of petrified trees that stand in place or lie on the slopes add charm to this remarkable landscape. As seen from a distance many of the buttes and mesas of the badlands rise nearly to a uniform height, level with the broad rolling surface of the plateau on either side, and above this level rise a higher series of buttes upon the crests of the divides on either side of the valley. Among these buttes in Billings County are Bullion Butte and White Butte.

The valleys of the larger streams are deep, steep-sided, U-shaped troughs. That of the Little Missouri averages three-fourths of a mile in width and 300 to 400 feet in depth and has walls so steep that in many places they may be climbed only by a circuitous route through some gorge. The erosion of this maze of valleys that forms the badlands is primarily the work of the streams upon horizontally bedded soft materials, of rather uniformly fine texture, in an arid region, where the rainfall is largely torrential in character. Wind and fire also play a part, the wind on the dry flats and slopes between times of irregular rainfall and fire continuously over long periods of time in burning lignite beds.

GEOLOGY AND GROUND WATER

Billings County lies outside the area that was invaded by glacial ice, as implied by the topography. The surficial deposits consist of residual soils on the uplands and wash and alluvium in the valleys. The outcropping rock formations include the sandy White River formation, of Oligocene age; the shale, sandstone, and lignite of the Fort Union formation; and the shale and sandstone of the Lance formation. The White River is the youngest formation represented in the country rock of North Dakota, but it occurs in only a few isolated remnants in several of the buttes of this portion of the State. The largest and most prominent of these buttes is White Butte, in the southeastern part of the county. Owing to its small area and high position this formation is of no value for yielding ground water. The Fort Union formation lies at or near the surface throughout the greater part of the county. The beds of sandstone and lignite bear a considerable quantity of water, and the lignite beds at their outcrops in the valley walls yield numerous strong springs.

The Lance beds occur in the upper part of the Little Missouri Basin in the southwest corner of the county, where the Fort Union is cut through largely as a result of a gentle anticline, the axis of which enters the State from the west along Little Beaver Creek. These beds contain less sandstone than the Fort Union, but this rock undoubtedly contains water, where it lies well below the groundwater level.

Much drilling has been done in recent years to supplement the supplies which were formerly derived from springs on the valley sides and shallow dug or bored wells in the alluvium. The water from both sources is somewhat brackish, owing to the presence of a large amount of mineral salts in the bedrock.

Many wells in the valleys of the Little Missouri and its tributaries yield artesian flows from different layers of sandstone and lignite in the Fort Union and Lance formations. The flows are not generally strong and are of the narrow-valley type. The higher ground-water level in the adjacent uplands gives sufficient head to bring the water above the surface of the lowlands. It is possible also that an artesian slope is also present. The most successful of these wells are those put down by the Northern Pacific Railway Co. at Medora, the deepest of which is 941 feet deep and probably passed through the Fort Union formation into the Lance beds. The log of this well is as follows:

Log of Northern Pacific Railway well at Medora, N. Dak.

	Thickness (feet)	Depth (feet)
Sand	30	30
Coal	1	31
Soapstone	44	75
Coal	½	75½
Soapstone and sand	47½	123
Coal	23½	146½
Soapstone and sand	39½	186
Quicksand	85	271
Soapstone	5	276
Coal	2½	278½
Soapstone and sandstone	85½	364
Coal	7½	393½
Sandstone and shale	22½	416
Coal	2	418
Soapstone and sandstone	18	436
Hard sandrock	5	441
Soapstone	24	465
Coal	3	468
Soapstone	38	506
Coal	2	508
Soapstone	12	520
Coal	2	522
Soapstone	14	536
Hard sandrock	5	541
Fossil shells, soapstone, and sandstone	50	591
Quicksand	35	626
Coal	2	628
Soapstone	3	631
Coal	5	636
Soapstone	55	691
Soapstone with fossil	2	693
Quicksand	18	711
Soapstone	50	761
Coal	5	766
Soapstone	78	844
Coal	3	847
Soapstone	35	882
Coal	1	883
Soapstone and sandstone	32	915
Coal	1	916
Coarse soft sand	15	931
Sand and gravel	10	941

Two flows were obtained. The first flow had a head of 45 feet above curb and the second over 100 feet. The second flow yielded a good supply within 30 feet of the bottom at a depth corresponding to 1,315 feet above sea level. The head in 1912 was 34½ feet and the yield about 33 gallons a minute.

The Northern Pacific Railway Co. also drilled a well 631 feet in depth at Sully Springs but did not find satisfactory water. The log of the Sully Springs well follows:

Log of Northern Pacific Railway well at Sully Springs

	Feet
Shale	56
Coal	1
Shale	29
Coal	12
Shale	148
Rock	3
Shale	64
Coal	9
Shale	99
Sand and shale	135
Shale	24
Rock	6
Sand and shale	45

The deeply trenched valleys of the Little Missouri and its many tributaries extend into most parts of this county. Many porous beds of sandstone and lignite crop out on the sides and floors of these valleys, and wherever the outcrop is below the general ground-water level springs occur. These springs are of especial value in this county, which is largely used for grazing cattle and horses, and they generally supply the stock without recourse to wells, except during the winter, when they are now supplemented by artesian wells. The constant flow of relatively warm soft water during the severe cold of winter, whether from springs or artesian wells, is a great aid in keeping the stock in good condition. The rolling uplands on each side of the Little Missouri Valley provide an unequaled range for stock in summer but are too open to furnish proper protection in winter. In order to obtain shelter from the driving storms and to procure water for the cattle and horses, many of the ranches that are established in the open uplands in summer are moved to the "breaks" in winter.

QUALITY OF GROUND WATER

The waters in Billings County do not differ a great deal aside from being hard or soft. Along the river valleys the alluvial deposits yield hard, moderately mineralized water, suitable for general use. The beds of sandstone and lignite of the Fort Union formation supply the wells on the upland and the springs of the valleys with soft, moderately mineralized water, acceptable for most uses. (See analyses 16 and 17.) However, some of the spring water is less highly mineralized, because of the leaching and washing of the rocks in former times and the greater movement of the water at present. The Lance formation has not been reached in many places in the county but would yield water similar to that from the Fort Union. (See p. 36.)

Typical wells of Billings County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
L. E. Putney	1 mile south of Richland Center.	105	6	Coal	80	
Ben Gussie	3 miles east of Richland Center.	160	6	do	40	
Paul Schultz	3 miles northwest of Richland Center.	101	6	do	56	
A. B. Sletto	2½ miles northwest of Richland Center.	205	6	do	62	
Myrtle Walcot	6 miles north of Richland Center.	117	4	do	30	Ample supply of brackish and hard water.
Northern Pacific Ry.	Medora	1,050			Flow.	Originally flowed 50 gallons a minute.
Do	do	505	4	Sand	Flow.	Originally flowed 48 gallons a minute; in 1921, 1½ gallons a minute.
G. R. Osterhout	NE. ¼ sec. 7, T. 140, R. 102.	300	1¼	do	Flow.	2½ gallons a minute.
Northern Pacific Ry.	Sully Springs	600	8		185	"Scum of oil" and strong smell. Filled with sand. Abandoned.
Ed. Tittsun	E. ½ sec. 30, T. 137, R. 1-2.	352	2		Flow.	

BOTTINEAU COUNTY

TOPOGRAPHY

Bottineau County lies chiefly on the level plain formerly occupied by Lake Souris and now known as the Souris River Valley. The Turtle Mountains occupy the northeast corner of the county, and this outlier of the Missouri Plateau, with its abrupt slope and mesalike top crowned with rough forested moraines presents a striking contrast to the level lake floor. The eastern margin of the plain shows much of the undulating topography of the drift, somewhat modified by the cutting action of the waves and the building action of waves and currents. The result is the characteristic topography of a wave-washed receding shore. Gravel and sand ridges and large, irregular sandy tracts are associated with marshy patches and areas of fine lake silts, which show that this is an area of reworked drift and lacustrine deposits, depending on the configuration of the shore. The plain to the west of this marginal belt is a great tract of featureless lake floor. In some places large marshes occupy slightly lower parts of the surface. Souris River flows across the middle of the county in passing north on its return into Canada after making its great loop into the United States. Its true valley is a broad, shallow marshy flat, which is overflowed in every season of high water. Many beautiful morainal lakes nestle among the hills of the Turtle Mountains, chief of which is Lake Metigoshe. These lakes yield excellent fish to the sportsman's rod, and the entire county abounds in game, particularly wild fowl. Formerly the plain was one of the richest grazing grounds for buffalo in the State.

GEOLOGY

The geologic history of the Souris River Valley has not yet been fully worked out, but the broad depression that separates the Turtle Mountain outlier from the Missouri Plateau undoubtedly was an extensive river basin previous to the glacial epoch. The glacial ice disorganized the drainage and deposited a thick mantle of drift over plateau and valley alike. Upon this drift was afterwards laid down the lacustrine and alluvial silts on the floor of the valley. The country rock of the lowland is the blue-gray Pierre shale, whereas the sandstones and shales of the Fort Union formation undoubtedly underlie the drift mantle of the mountains. The deep drilling by the North Dakota Gas Co., 9 miles south of Westhope, affords considerable information regarding the deeper geologic formations in spite of the fact that no samples of drillings were preserved and only a fragmentary record. The hole was put down to a depth of 1,980 feet in 1908–1910 in the hope of striking a good supply of gas in the Cretaceous formations, particularly the Dakota sandstone, which in some regions in Canada contains much gas. An oil-well rig of the usual American type was used and the boiler fired with gas from a near-by well about 175 feet in depth. The gas in this well came from porous gravel and sand in or beneath the base of the drift and immediately overlying Pierre shale. The log is as follows:

Log of Westhope gas well

	Ft.	in.
Soil	2	
Clay, yellow and gravel	30	
Clay, blue	122	
Gravel, with sand below; no flow of gas	16	
Slate, white	35	
Sandstone, black	3	
Shale, soft blue covering	242	
Slate, black	50	
Rock, yellow, hard limestone		5
Shale, blue covering	205	
Shale, blue	145	
Shale, sandy	10	
Shale, blue	510	
	1,370	5

The drilling ceased here in 1908 but was continued in 1910 to the depth of 1,980 feet and ended in a formation claimed by the drillers to be the Dakota sandstone and to contain some gas. There are, however, doubts regarding the correctness of this identification. Caving of a soft calcareous clay 30 feet above the sandstone, however, caused the abandonment of the work. Another hole drilled to a depth of 391 feet for the village of Willow City is of interest as showing the possible occurrence of Fort Union sandstone about the margin of the Turtle Mountains. The log is as follows:

Log of Willow City well

	Feet
Surface soil	2
Yellow clay mixed with sand	15
Black joint clay	34
"Hardpan"	43
Fort Union sandstone	23
Bluish-gray clay, no grit	60
Black sandy clay (?); 8-inch layer of rock at 274 feet	149
Hard material (as shown in the sample)	65
	391

GROUND WATER

Bottineau County is plentifully supplied with both surface and ground water. Throughout the lake plain which constitutes almost seven-eighths of the county the ground-water level stands high. Although very shallow wells in lake sediments or drift are the general rule, deeper drilled wells in places pass to the bottom of the drift at depths ranging from 100 to 200 feet and draw a better supply from the basal gravel and sand that overlie the shale. The sandy layers of the shale also yield water, but it is generally salty and somewhat bitter. In the mountains the bedrock is seldom if ever tapped by wells. The drift cover is morainal in character and contains much gravel that yields an abundance of good water at slight depths nearly everywhere in this part of the county.

Flowing wells of three very distinct types occur in Bottineau County, though none yield large quantities. (See pl. 1.) About the margins of the Turtle Mountains flowing wells of slight head may be obtained in a number of places at depths of about 150 feet. The head is probably due to the higher ground-water level in the adjacent "mountains," and the water comes either from coal or sandstone in the formation that overlies the Pierre shale. The wells are of the escarpment type of artesian flows. The occurrence of a few weak flowing wells between Antler and Hurd suggests the presence of a very gentle syncline within the broad curving anticline of the Souris River gas field. If a syncline is present it begins at a point about 5 miles north of Hurd and west of Maxbass and runs slightly west of north across the international boundary near Antler. Within a broad irregular V which has its point near Deering and its sides extending to the international boundary at Westhope and Sherwood, and which therefore incloses the syncline just mentioned, occurs a very different type of flowing well. In these wells the flow is of a jetting or sputtering character and is caused by the rise of gas in the well. Because of the resemblance of this phenomenon to that of the air lift, these are termed gas lifts. In some wells the pulsations are permanent, regular, and of several seconds' duration. The amount of gas in the well ranges from a trace which may only show bubbles in the water pumped to gas under many pounds of pressure that comes from a dry well. In some places the gas simply interferes with the working of the cylinder-piston in the pump; in others it has been known to blow the entire string of drilling tools out of the well.

Wells are not numerous in the Turtle Mountains, for settlers are few and the large number of fine springs that flow from the margins of the hills and into the numerous stream valleys that head up into the hills make the digging of wells almost unnecessary. In the earlier days, before the forest cover had been so largely removed, the flow from some of these springs was considerable. The waters of Willow Creek flowed all the year round, and where the tributary of this creek flows from the hills northeast of Bottineau Mr. Woodward established the first gristmill in the region. This location has since been abandoned on account of the diminished flow of water. The head-waters of Oak Creek, which flow through Bottineau from the northeast, are supplied by springs that flow from the southwestern side of the "mountains." These spring waters are high in mineral content, and much of the material in solution is deposited on exposure to the air and in contact with the vegetable matter that grows profusely in the flowing waters. This deposit forms a long series of tufa terraces in the heads of the valleys on the hillsides. These terraces are now in part heavily overgrown by vegetation, probably on account of the decreased building activity that has resulted from the lessening of the permanent flow of waters from the hills since the partial removal of the forest cover. These springs are now a source of public water supply for the city of Bottineau.

QUALITY OF GROUND WATER

Hard and soft waters that differ in mineral content are obtainable in Bottineau County, as indicated by analyses 18–21; analyses 126, 137, and 128 represent waters from neighboring counties. Wells that draw either from the surface sand (see analysis 126) or from the gravel at the base of the drift (see analyses 137 and 128) yield hard water, most of which is moderately mineralized and suitable for general use. Some of it is very highly mineralized and can be used only for protection against fire or for stock. (See analysis 19.) Deeper wells that enter bedrock below the drift yield soft water that carries considerable amounts of dissolved constituents, but most of it is acceptable for domestic and other uses. (See analyses 18, 20, and 21.)

Typical wells of Bottineau County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Ralph Henning	NW. ¼ sec. 31, T. 164, R. 6.	140		Fine sand	6	Clay, 80 feet; shale, 60 feet; fine sand, 10 inches.
J. T. MacCampbell.	SE. ¼ sec. 31, T. 163, R. 83.	256		Drift	Flow.	In valley of Cub Bank Creek. Flowed 4 gallons a minute. Pressure very light.
Robert Larter	NW. ¼ sec. 28, T. 163, R. 81.	220	2	Gravel		On low ground near marsh and coulee. Boulder clay to 215 feet; gravel 5 feet. Gas.
Alf Ryder	SE. ¼ sec. 13, T. 163, R. 80.	70	12	Drift sand	Flow.	Bored; tile curb.
C. L. Larson	SE. ¼ sec. 15, T. 163, R. 79.	750		Shale		Dry; 50 feet to shale.
Mr. Matson	Landa	60			48	
Synod Church	do	80			22	Bored 18 feet; drilled below.
Village	do	23			8	Shallow well in draw, used by village.
J. M. Daly	Roth	90	12			Pumped dry daily in summer for stock.
Elevators	do	80	14		30	Notable taste and smell.
T. Aasheim	SE. ¼ sec. 25, T. 163, R. 77.	90			16	
Village	Souris	54	12			Bored. Pumps dry.
T. A. Yearn	SW. ¼ sec. 31, T. 163, R. 77.	300				Dry. Gas present.
L. G. Glomseth	NW. ¼ sec. 33, T. 163, R. 76.	138		Sand	16	Clay, 110 feet; shale, 27 feet; sand, 1 foot.
W. W. Smith	Sec. 2, T. 162, R. 85.	345	3	Coarse sand	50	Small flow in drift at 315 feet.

Typical wells of Bottineau County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
G. A. Durnin	SW. ¼ sec. 2, T. 62, R. 83.	344				Sandy clay to 240 feet, muddy sand at 250 feet, fine gravel at 262 feet, shale with hard layer at 285 feet, fine gray sand at 296 feet, sandy rock with hard layer at 314 feet.
Mrs. Della Van Wort.	NE. ¼ sec. 4, T. 162, R. 83.	312				Gas at 222 feet, hard layer at 258 feet, shale with hard layer at 270 feet, little sand and gravel, hard layer at 278 feet.
J. W. Lewis	SE. ¼ sec. 6, T. 162, R. 83.				Flow.	
A. Witteman	SE. ¼ sec. 28, T. 162, R. 83.	712				A little gas at 350 feet, a little water at 400 feet.
J. C. McKechnie	SE. ¼ sec. 32, T. 162, R. 83.	312	3			30 gallons a minute. Blows gas whenever pumped down.
F. Rebillard	SE. ¼ sec. 33, T. 162, R. 83.	654				Rock at 205 feet, shale at 260 feet, sand at 268 feet, hard layer at 279 feet, sand at 288 feet, hard layer at 316 feet, sandy shale with little gravel at 353 feet, little sand 370 feet, white sandy shale at 380 feet, hard layer at 470 feet.
A. J. Skaden	NE. ¼ sec. 35, T. 162, R. 83.	372		Sand		Dry sandrock at 230 feet, shale at 240 feet, sand at 322 feet.
G. Tennyson	NE. ¼ sec. 6, T. 162, R. 82.	300				
G. G. Feeland	NW. ¼ sec. 8, T. 162, R. 82.	482				Sand at 94 feet, gravel and sand at 145 feet, white sandy shale at 250 feet, sandy shale at 260 feet, hard shale at 275 feet and lower.
Mr. Swaringen	NE. ¼ sec. 10, T. 162, R. 82.	340	4		30	
C. M. Price	SE. ¼ sec. 22, T. 162, R. 82.	433½	3			Gravel at 220 feet, sand at 224 feet, shale at 232 feet, sand at 242 feet, shale at 246 feet; sand, gravel, 270 feet; shale, 3 feet, at 278 feet; blue sand at 280 feet; shale; coarse gray sand at 392 feet; hard layer with sand at 418 feet. Gas sufficient to burn at probably 270 feet. Highly mineralized.
Walker Bros.	SW. ¼ sec. 26, T. 162, R. 82.	245		Coarse sand	Flow.	
Charley Twar	NW. ¼ sec. 30, T. 162, R. 82.	413		Sand		2 feet of sand at 30 feet, 1 foot of sand at 40 feet, 3 feet of coarse sand at 60 feet, blue clay to 250 feet, shale at 250 feet, sand at 300 feet, 1½ feet of coal at 350 feet, sticky shale to 361 feet, sand at 361 feet.
Z. Frazier	SE. ¼ sec. 35, T. 162, R. 82.	300			Flow.	Former flow, probably on low ground near coulee.
F. G. McCarm	W. ½ sec. 12, T. 162, R. 81.	1,105	6	Shale		Dry hole. Blue boulder clay, 200 feet; blue-gray shale with hard shale and limestone (Fort Union), 20 feet; hard dark shale (Pierre), 885 feet.

Typical wells of Bottineau County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Thomas Staed	SW. ¼ sec. 15, T. 162, R. 81.	359	3	Fine light gray sand.	Flow.	5 gallons a minute. Drilled in 1907. In 1916 flow was 2 gallons a minute, head 3 feet, and temperature 47° F. Drift 200 feet, light-bluish shale 100 feet, shale with layers containing pyrite 20 to 50 feet, blue-gray water-bearing sand.
John Reep	SE. ¼ sec. 8, T. 162, R. 80.	176	4	Sand	50	Gas flows strongly when water is pumped. Drift 155 feet, shale 15 feet, sand 60 feet.
G. W. Finkham	SW. ¼ sec. 24, T. 162, R. 81.	64	2	Gravel	52	Draws in air; a "sucking well."
W. B. Parker	S. ½ sec. 10, T. 161, R. 80.	1,900	10½, 3½			Prospect hole for gas and oil. Abandoned.
R. F. Armour	SW. ¼ sec. 17, T. 162, R. 80.	400	4	Shale		Dry.
W. W. Link	NW. ¼ sec. 35, T. 162, R. 80.	145				Water well. A gas well on farm also.
G. A. Durrin	Sec. 36, T. 162, R. 80.	150	3	Fine sand	50	Sand plugs well.
Do	do	205		Shale		
Ole Crogan	NE. ¼ sec. 5, T. 162, R. 76.			Sand		Boulder clay 70 feet, soapstone 88 feet, sand 2 feet.
Ralph Henning	NW. ¼ sec. 31, T. 164, R. 76.	140		Fine sand	6	Clay 80 feet, shale 60 feet, fine sand 10 inches.
J. J. Scully [a]	SW. ¼ sec. 15, T. 162, R. 75.	14	4	Gravel	Flow.	25 gallons a minute. Temperature 42° F.
F. M. Woodward.[a]	Bottineau	135	2½	Black sand	60	30 gallons per hour.
Bottineau	do	170		Sand		Fine blue sand.
G. K. Vikan	do	250				Pulled casing to 135 feet.
State School of Forestry.[a]	do	150	2½		8	
W. R. McIntosh	do	175	2	Sand	14	Pumped white sand for a time.
Doctor McKay	do	165	4			Salty.
Do	do	106	4	Sand		
Daniel White	do	165	2½	do	20	Cased 106 feet to shale. Water from 1-foot sand bed in shale. Not enough. Flowed 2 hours; gas burned.
J. N. Gruss	do	160		Blue sand	10	
C. W. Beyer	NW. ¼ sec. 5, T. 162, R. 75.	350				Water at several depths. Some gas.
Charles Beaver	NE. ¼ sec. 16, T. 162, R. 75.	150	2½	Fine sand and coal.	Flow.	2 gallons a minute.
Do	do	115	2½	Fine sand	Flow.	8 gallons a minute. Drift 100 feet, shale 15 feet, sand, coal.
Jens Anderson	SE. ¼ sec. 17, T. 162, R. 75.	154	2½	do	Flow.	2 gallons a minute. Drift 100 feet, "boulder" 25 feet, shale 41 feet, sand 1 foot.
V. B. Noble	NE. ¼ sec. 19, T. 162, R. 75.	116	2½	do	Flow.	½ gallon a minute. Flow at 109 feet. Drift 80 feet, blue-gray shale 28 feet, fine blue sand 2 feet, shale 6 feet.
James Jackson	E. ½ sec. 21, T. 162, R. 75.	118	2½		Flow.	2 gallons a minute. Bad taste. Drift 100 feet, coal 1 foot, shale 16 feet, sand 2 feet.
Peter Moe	NW. ¼ sec. 21, T. 162, R. 75.	130	1½		Flow.	¾ gallon a minute.
Public school	do	115	2½	Fine sand	Flow.	Drift 98 feet, shale 17 feet, fine blue sand.
George Longevin	SE. ¼ sec. 22, T. 162, R. 75.	115		do	Flow.	25 gallons a minute at first. Temperature 42° F.
Erma Des Champs.	S. ½ sec. 24, T. 162, R. 75.	100		Fine blue sand.	Flow.	½ gallon a minute. Roily.

[a] See table of analyses.

Typical wells of Bottineau County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Joe Croisettier	SW. ¼ sec. 25, T. 162, R. 75.	100	3		Flow.	
Joe Destaller	NE. ¼ sec. 25, T. 162, R. 75.	135	2½	Sand	Flow.	
Joe Seymour	S. ½ sec. 26, T. 162, R. 75.	140	2½	Fine sand		
John Hayes	NW. ¼ sec. 27, T. 162, R. 75.				Flow.	Flowed in drops only.
Trent Bros	NE. ¼ sec. 33, T. 162, R. 75.	60	2½	Fine sand	Flow.	
E. A. Juneau	SE. ¼ sec. 30, T. 162, R. 74.	140	4	Sand	Flow.	3 gallons a minute.
August Gagner	NE. ¼ sec. 32, T. 162, R. 74.	84			Flow.	½ gallon a minute.
H. Williams	NW. ¼ sec. 1, T. 161, R. 83.	340		Sandy shale		Trace of gas. Sand at 280 feet, coal at 318 feet, fine sandy shale.
H. Staven	SE. ¼ sec. 3, T. 161, R. 83.	110	3	Gravel	18	
Do	NW. ¼ sec. 11, T. 161, R. 83.	384	2½	Fine sand	Flow.	Temperature 44° F. Bedrock at 376 feet.
John Kraach	SE. ¼ sec. 12, T. 161, R. 83.	300				Gas.
J. B. Wander	S. ½ sec. 16, T. 161, R. 83.					Gas.
Nels Land	NE. ¼ sec. 18, T. 161, R. 83.	430	3	Sand		Much gas and water in blue-gray sand among hard layers.
J. C. Fisher	SE. ¼ sec. 19, T. 161, R. 83.	391	2	Sandy shale		Sand at 320 feet, shale and coal at 328 feet, sand at 330 feet, shale at 334 feet, sandy shale at 376 feet, shale and coal at 377 feet, sandy shale at 380 feet.
U. G. Henton	NW. ¼ sec. 31, T. 161, R. 83.				Gas lift.	Intermittent gas flow.
O. A. Lofthus	W. ½ sec. 7, T. 161, R. 82.	285				Gas at 278 feet. Blew water 30 days and was then capped and made into water well.
W. W. Nicholson	NW. ¼ sec. 18, T. 161, R. 82.	278	3	Sand		Gas at 245 feet in 5 feet of sand.
O. J. Gilbertsen	SE. ¼ sec. 18, T. 161, R. 82.					Gas from this well used to heat and light house.
C. VanNewkirk	NW. ¼ sec. 21, T. 161, R. 82.	345		Sand		Coarse blue sand.
M. Booth	SE. ¼ sec. 23, T. 161, R. 82.				Flow.	
W. T. Painter	NE. ¼ sec. 27, T. 161, R. 82.	268	3		Gas lift.	Gas and water in sand.
John Daumen	SW. ¼ sec. 32, T. 161, R. 82.				Gas lift.	Intermittent flow due to gas.
C. A. Stratton	SW. ¼ sec. 36, T. 161, R. 82.	300	3	Sandy shale		Flows slightly at times. Drift probably 200 feet, below which is shale and sandy shale.
State bank	Maxbass	9	3		6	Freezes dry in spring.
Village	do	260	3	Sand	10	Little gas. First vein at 150 feet in clay. A little water in sand at 260 feet.
E. A. Schultheis	NE. ¼ sec. 3, T. 161, R. 81.	180				
Ed. Hopwood	NW. ¼ sec. 7, T. 161, R. 81.	265	4	Coal and sand.	Flow.	Flows at times.
J. E. Hopwood	do	168	3		Gas lift.	
Abe McCaslin	SW. ¼ sec. 14, T. 161, R. 81.	180		Sand	Flow.	Filled with sand.
R. H. Flemming	NE. ¼ sec. 24, T. 161, R. 81.	215		do	30, gas lift.	Gas in sand at 180 feet.
Edson Brown	NE. ¼ sec. 31, T. 161, R. 81.	278	3	do	Flow.	Clay and sand to bottom. Water carries fine yellow sand. Slight flow.
Ole Bjorgo	SW. ¼ sec. 31, T. 161, R. 81.	270	3	do	Flow.	Slight flow. Some gas when pumping. Blue clay, sand, black shale, sand.

Typical wells of Bottineau County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
W. A. McKaney	NW. ¼ sec. 3, T. 161, R. 80.	190	4	Green sand		Cased to 160 feet. Hole below filled with mud to seal gas of 65 pounds pressure and form water well. Very hard layer at 165 feet overlies green gas sand.
Do	do	420				Drilled for water. No water and no gas.
Do	do	175				
C. E. Fees	SW. ¼ sec. 6, T. 161, R. 80.	200	3		Gas lift.	Flows intermittently from gas pressure.
A. T. Thompson	SE. ¼ sec. 8, T. 161, R. 80.	212		Blue sand	Gas lift.	Gas pressure, 40 pounds. Gas occurs in 25 or 30 feet of fine blue sand beneath a hard shell, passes into lighter and coarser water sand below overlying light gray shale, probably Pierre.
Charles Brander	NE. ¼ sec. 9, T. 161, R. 80.	179	6	Sand		Gas occurs in fine green sand just below hard layer with water and sand overlying.
Do	do	180	4	do		Dry gas found in sand but without hard layer. After 1 month water entered, filled casing 100 feet. Gas appears as strong as ever when water is pumped out.
Do	do	1,100	6			No gas and no water.
W. B. Parker	SE. ¼ sec. 10, T. 161, R. 80.	178		Sand		"Original well." In drilling for water a sand vein was encountered somewhat below 178 feet. Gas, water, and mud were blown out and over the farm buildings. Casing pulled and abandoned.
W. B. Parker Co., well No. 1.	do	182	6	do		Great Northern Oil & Gas Pipe Line Co.; 100 feet north of original well; produced gas. Soil 5 feet, yellow clay and gravel 41 feet, blue clay 34 feet, gravel 6 feet, sand 3 feet, blue clay 48 feet, shale 2 feet, gas sand 12 feet, total 170 feet.
W. B. Parker Co., well No. 2.	do	178		do		Water and gas in sand.
Joe Poisson	NW. ¼ sec. 19, T. 161, R. 80.	300			Gas lift.	
H. Brosseau	N. ½ sec. 19, T. 161, R. 80.	185	2½	Sand	Gas lift.	
Nels J. Dahl	SE. ¼ sec. 22, T. 161, R. 80.	176				Trace of gas in water well.
Andrew Aurew	NW. ¼ sec. 26, T. 161, R. 80.	192	3	Sand	Gas lift.	Gas with water in fine dark-blne sand.
W. H. Hamel	NE. ¼ sec. 32, T. 161, R. 80.	300			Gas lift.	
A. V. Walters	SW. ¼ sec. 21, T. 161, R. 78.	114		Sand		Much gas in fine white sand with much water.
John Lee	SW. ¼ sec. 5, T. 160, R. 83.	260				Gas with water.
R. Blowers	SW. ¼ sec. 8, T. 160, R. 83.	265				Some gas and a little water.
N. Nelson	NW. ¼ sec. 10, T. 160, R. 83.	311	3	Fine sand	25	
R. Runels	NW. ¼ sec. 11, T. 160, R. 83.	202	4	Gravel	13	
Walter Norris	SW. ¼ sec. 13, T. 160, R. 83.	235				Abandoned on account of gas.

Typical wells of Bottineau County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Walter Waul	N. ½ sec. 15, T. 160, R. 83.	+417		Sand		No water. Gas at 240 feet.
M. J. Murray	SE. ¼ sec. 15, T. 160, R. 83.	349				Gas near 260 feet.
J. H. Gibbs	NE. ¼ sec. 17, T. 160, R. 83.	285				Some gas.
Brent Robbins	SW. ¼ sec. 18, T. 160, R. 83.	319		Sand		Hard sandy shale at 247 feet. Strong gas in 3-foot layer, fine dark sand below.
Charles Short	NE. ¼ sec. 2, T. 160, R. 82.	258	3	Gravel	Flow.	Steady flow, 1¼ gallons a minute. Clay and gravel to bottom.
Will Underwood	SE. ¼ sec. 8, T. 160, R. 82.	180	5	Sand	Gas lift.	Sand and lignite at bottom.
O. S. Svee	NE. ¼ sec. 11, T. 160, R. 82.					Gas present.
A. Schoening	NW. ¼ sec. 17, T. 160, R. 82.	355	4	Sand	3½	Gas. Sand causes trouble by filling. Some coal.
Robert McLean	SE. ¼ sec. 17, T. 160, R. 82.	185	4	White sand	Flow.	Yields 2½ gallons a minute. Some gas.
F. M. Tyler	NE. ¼ sec. 20, T. 160, R. 82.	250	4		Flow.	Less than 1 gallon a minute.
William Martin	SW. ¼ sec. 22, T. 160, R. 83.	357	3	Fine sand	25	
Bert King	SW. ¼ sec. 26, T. 160, R. 82.	185	5			Gas cased off and water well formed.
Do	do					Gas well. Pressure 65 pounds. Gas used 1 year until bluish mud filled well. Water is bitter.
J. C. Cunningham.	NE. ¼ sec. 26, T. 160, R. 82.	217	4	Blue sand	50	Slightly salty.
J. D. Bales	SW. ¼ sec. 28, T. 160, R. 82.	225	5	Sand		Gas well.
H. D. Convis	SE. ¼ sec. 29, T. 160, R. 82.	217	4	do	25	Water with small amount of gas at first.
John Danberg	NW. ¼ sec. 33, T. 160, R. 82.	210	4	do		Gas pressure reported 100 pounds.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Eckman	263	10	Clay		No water.
Public school	Russell	90	18	Sand		
Dr. H. T. Irwin	do	110	18			
Village	do	170				No water.
George LaPorte	do	85	18	Sand	10	
Stephens & Stephens.	do	20				
George LaPorte	SE. ¼ sec. 2, T. 160, R. 79.	300	4			Gas at 200 feet. Dry hole.
Village	Newburg	108	3½		31	Fine blue-gray sand.
Railway stock-yard.	do	101	6		28	
Albert Aerschlip	SE. ¼ sec. 28, T. 160, R. 79.	540				No water.
Gus Schwarke	Kramer	106		Coarse gravel	12	
Village	Omemee	47		Sand	12	Sandstone at base of drift.
S. Perrault	Overly, 160-74	172		Sand in shale		Water with bad taste at 100 feet in quicksand.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	125	10	Clay		Very little water.
R. E. Schoonover	do				20	Bad taste.
P. S. Svingen	NW. ¼ sec. 13, T. 160, R. 74.	50		Quicksand	45	Water used generally in town.
Joe Senechal	SW. ¼ sec. 23, T. 160, R. 74.	110	4½		30	
Milling Co.	Lansford	245	2	Sand and gravel.	20	Water in blue-gray sand above shale.
City [a]	do	254	4	do	20	Gas and water.
Joe Martineson	N. ½ sec. 9, T. 159, R. 83.	16	4			Hauled to town for drinking water. Generally used.
Ekern Bros.	Lansford	26	14			Small yield.
E. P. Keefe	SE. ¼ sec. 11, T. 159, R. 82.	219		Sand	45	Gas and water.

[a] See table of analyses.

Typical wells of Bottineau County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. B. Simomege	NW. ¼ sec. 14, T. 159, R. 82.	230	4	Gravel		Gas and water. First water at 186 feet in coal; second water at 219 feet; and third water at 320 feet in 2 feet of coarse gravel.
Goldberg Bros	NW. ¼ sec. 25, T. 159, R. 82.	200				Gas.
Nels Mikkleson	SE. ¼ sec. 22, T. 159, R. 81.	290				Water and also gas.
Ed. Simpkins	NE. ¼ sec. 28, T. 159, R. 81.	357	3	Sand	12	White shale at 180 feet. Gas at 210 feet and 300 feet. Shale below 300 feet. Water at 357 feet.
Do	do	60	24	Drift	Flow	Flowed for a time as much as a 6-inch pipe could carry.
A. Aitkin	SW. ¼ sec. 31, T. 159, R. 81.	297	4		Gas lift.	Sometimes gas jets from pump after pumping.
Ed. Brace	SE. ¼ sec. 33, T. 159, R. 81.	200		Sand	Gas lift.	Gas burns at pump. Gushes water, which freezes about pump in winter.
Great Northern Ry.	Willow City	10	96	do		6 drive points 2 inches in diameter driven 20 feet in bottom of well.
City	do	391				

Water supplies of towns in Bottineau County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Antler	265	Dug	8	36	12	Clay and gravel.		Small springs.
Bottineau	1,172	Drilled					Sand	Best water reported at 125 to 135 feet.
Eckman	64	Dug	12		15	Sand		
Gardena	99	Bored, drilled.	26	78	30	Clay		Hard salty water reported in shallow and softer in deep wells.
Hurd	125	Driven, bored.	8	220	12	Sand		
Kramer	172	Bored	50	85	65	Drift		
Landa	250	Bored, drilled.	15	175				Small springs. Wells mostly in gravel over shale.
Landsford	337		50	300				All wells have some gas.
Maxbass	147	Dug, bored, driven, drilled.	8	260	12	Sand and silt.		Little gas in deeper wells. Very shallow wells yield abundant water from lake sands.
Newburg	110							Best wells at 250 feet.
Omemee	222	Bored, drilled.	40	150	50			
Overly	193	Dug, bored, drilled.	20	150	30			Mostly bored, few drilled.
Roth		Bored	80	100				
Russell	119							Village well 170 feet deep; bored 18 feet.
Souris	267	Bored	50	60		Drift	Shale.	
Westhope	439	Dug, drilled.	12	100	15			
Willow City	559	Dug, driven.	15	30	20	Sand		Most wells driven, only a few drilled.

BOWMAN COUNTY

TOPOGRAPHY

Bowman County, in the extreme southwest corner of the State, lies entirely outside the drift area, and its surface is characterized by the broad, gently rolling topography of the plateau province. Above the general level rise the Twin Buttes on the divide that separates Deep Creek, a tributary of the Little Missouri, and the southeastward-flowing Grand River. The Little Missouri crosses the county from south to north in the western half. Its valley is a deep, broad, steep-sided trench, which is bordered on each side by a narrow belt of rounded buttes and mesas that approach the general level of the upland from which they were carved by stream erosion.

GEOLOGY AND GROUND WATER

The surficial deposits consist of residual soil on the upland and alluvium in the valley floors. The alluvium yields a considerable amount of fair water to shallow wells. The bedrock in the eastern two-thirds of the county belongs to the Fort Union formation and consists of clay, sandstone, and lignite. In the western third a broad, gentle anticline has its axis along the valley of Little Beaver Creek. The beds of the Fort Union have here been eroded away, and the Lance formation rises to the surface. Near the creek the Lance also is cut through, and the Fox Hills sandstone and Pierre shale each in turn crop out on the valley sides. On the broad uplands the sandstone and lignite of the Fort Union furnish the chief water supply for wells and yield springs in the valley walls. Flowing wells with slight pressure are obtained in the valley of the Little Missouri and its tributaries in the extreme northwest corner of the county. The water comes from the sandstone beds of the Lance formation. In these valleys the well curbs are somewhat below the ground-water level of the uplands.

The valleys of the Little Missouri and its many tributaries in the western end of this county are so deeply intrenched in soft clays and sandstone that springs are found on the valley sides wherever the outcrops of soft porous sandstone and the local lignite beds occur.

The streams in the southern and eastern portions of the county, which drain chiefly into Grand River of South Dakota, are not so deeply carved, yet fair springs flow in many places in these valleys. The county as a whole is therefore well suited for grazing cattle and horses.

QUALITY OF GROUND WATER

Two kinds of water are obtained in Bowman County—hard water that contains a moderate amount of mineral matter and soft but more highly mineralized water. The hard water, which is represented by analyses 22 and 23, is generally satisfactory for most uses. It is obtained from shallow wells in the alluvium of the valleys or in the soils and upper sandstone and lignite beds of the Fort Union formation on the uplands, and also from the springs in this formation in the river valleys. The soft water (see analysis 151, Slope County) is drawn from the lower beds of the Fort Union formation and from the Lance formation. This water is commonly so highly mineralized that it is objectionable for domestic use and is used only for stock.

Typical wells of Bowman County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
A. S. Kelly	NW. ¼ sec. 12, T. 132, R. 105.	156	6	Sand	130	
W. B. Shaw	Rhame	140	2	Quicksand	120	
Rhame Hotel	do	25				Bored.
Robert Rosenbaum.	Sec. 25, T. 132, R. 102.	135	18	Sand	10	Bored on east slope of Butler Creek. Water can not be greatly drawn down with gas engine.
J. E. Carter	Stillwater	43		Gravel		
Hotel	do	100				Abundant supply.
H. A. Shoehern	SW. ¼ sec. 27, T. 132, R. 100.	195	4	Coal	110	
Glen Howe	NE. ¼ sec. 35, T. 132, R. 100.	285	4		85	Carried fine sand.
Do	do	165			100	On flat.
Village [a]	Bowman	48	192	Sand	36	Water-bearing sand 3 inches thick at 34 feet.
Cemetery	do	135	18	do	95	
George Seebart [a]	do	10	36	do	7	On lowland.
John Vandepass	SW. ¼ sec. 18, T. 131, R. 101.	140	18		90	
Fredric Garling	NE. ¼ sec. 2, T. 131, R. 100.	115	4	Sand	60	
Mr. Fraymiller	NE. ¼ sec. 11, T. 131, R. 100.	110	4	Coal	60	
Scranton Lumber Co.	Scranton			do	Flow.	1½ gallons a minute; brownish water.
A. Peterson	SW. ¼ sec. 15, T. 130, R. 102.	100	2	Sand	Flow.	

[a] See table of analyses.

Water supplies of towns in Bowman County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bowman	767	Dug, drilled	20	150		Sand	Sandstone	Public supply from two 24-inch bored wells, 48 and 60 feet deep.
Gascoyne	60	Bored	12	44	20	do	Sand	
Rhame	302	Drilled	40	156	75	do	Shale	Spring which yields 200 gallons a minute.
Scranton	353	Driven, drilled	16	150	35	do	Sand, coal	In valley of Buffalo Creek. Water from brown coal.

BURKE COUNTY

TOPOGRAPHY

The Missouri escarpment divides Burke County into a northeastern or prairie area and a southwestern or plateau area, though the distinction is not so great here as in the southern part of the State, owing to the elevated and transitional character of the Drift Prairie. The Altamont moraine lies upon the coteau and practically covers the plateau portion with grassy rolling hills and hollows. The chief topographic feature of the Drift Prairie in the county is the long valley of upper Des Lacs Lake, an old glacial waterway of considerable depth and slight breadth, the floor of which is filled by this riverlike lake. In the extreme southwest corner a small area of the drift is drained by the headwaters of White Earth Creek.

GEOLOGY AND GROUND WATER

The drift in Burke County is underlain beneath the plateau and the prairie by the Fort Union formation, in which lignite and sandstone, interbedded with shale, yield water to many relatively shallow drilled wells. The drift is everywhere a source of supply for small amounts of water for domestic use and for the farm. Shallow wells obtain a small supply from layers of gravel and sand in and at the base of the drift, just above the bedrock. Springs are numerous in the sides of the Des Lacs Valley and keep a good supply of water in the lake at all seasons of the year, and many also emerge in the draws and coulees that cut into the face of the escarpment.

Flowing wells with slight head may be obtained on the prairie near the foot of the escarpment, the head of which is due to the higher ground-water level in the upland to the west. These wells range in depth from 70 to 500 feet and draw their supply from a sandy layer at the base of the drift or from the porous layers of the bedrock.

Many small springs issue from the foothills of the Missouri escarpment. About 10 miles southwest of Bowbells and 6 to 8 miles south of Lignite, Stampede, and Larson these springs are especially numerous. Other smaller springs are found throughout the morainal hills in the southwestern part of the county about Powers Lake and the headwaters of White Earth Creek.

QUALITY OF GROUND WATER

Analysis of samples from Burke and adjoining counties indicate that the water in Burke County ranges in quality from some that is equal to the best in the State to some that is very poor. Shallow dug wells in the drift furnish hard water, most of which is not too highly mineralized for general use. (See analyses 25 and 51.) Deeper wells that draw on the upper beds of the Fort Union formation yield mainly soft water of different mineral content, as represented by analysis 25. The larger part of it is moderately to highly mineralized, and some is unfit for general use. (See analysis 50.) Good water is scarce in parts of the county where the drainage is poor. The springs that flow from shallow drift gravel yield some of the best water in the county.

Typical wells of Burke County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
R. J. Mamer	Portal	248	6		65	
Electric Light Co.	do	240	8		150	Fine white sand.
Village	do	320	10		150	Small yield.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	353	10	Fine sand		Roils before storm. Yields 35 gallons a minute to pump.
Frederic Wheeler	N. ½ sec. 36, T. 164, R. 91.	248	2	Sand and gravel.	80	Yellow clay, blue clay, sand and gravel. All glacial drift. Seven holes tried; many boulders interfered.
C. A. Merrill	SE. ¼ sec. 23, T. 164, R. 90.	85	78	Sand	28	Sand under shale.
Great Northern Ry.	SE. ¼ sec. 30, T. 164, R. 89.	325		Coal		Pumps fine sand.
B. W. Lowend	Northgate	152	5	Sand	67	Drift well.

Typical wells of Burke County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Knute Overby	SW. ¼ sec. 19, T. 163, R. 95.	120	2	Shale		
C. Koestler	T. 163, R. 94	180			80	Bored.
Charles Ayers	Sec. 4, T. 163, R. 94	150	5		5	Good strong well.
Lars Horntvedt	SW. ¼ sec. 22, T. 163, R. 94.	135				
Village	Columbus	275	2	Coal	30	
George Kemp	do	30	12	Gravel		Bored.
John Salverson	SW. ¼ sec. 17, T. 163, R. 93.	281		Coal	64	
Thomas Ely	SE. ¼ sec. 19, T. 163, R. 93.					Blue clay and gravel. Coal bed at 168 feet.
Lea Powell	SW. ¼ sec. 30, T. 163, R. 93.	320	2	Brown sand	100	
Farmers' State Bank.	NW. ¼ sec. 32, T. 163, R. 93.	160	3	Coal	60	Drift, white clay, coal.
Jack Rumble	2½ miles south of Portal.	314	5	Sand		Sand and coal. Ample supply.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Flaxton	18	120			Small supply in dry seasons.
J. P. Smith	S. ½ sec. 11, T. 163, R. 91.	349		Sand		
D. Hodge	E. ½ sec. 19, T. 163, R. 91.	233	5	Coal	73	Drift, sand, and coal.
A. S. Hodge	NW. ¼ sec. 19, T. 163, R. 91.	60		Coarse sand	20	Drift.
R. A. Christianson.	SE. ¼ sec. 17, T. 163, R. 90.	120		Fine sand		
Peter Morgenson	3 miles northeast of Flaxton.	280	2	Sand	80	
Village	Flaxton	217	4		75	Roily after pumping. Clogs strainer. Gas engine.
Do	do	400	2		80	Strong well. Gas engine.
C. J. Schultz	do	500				At north edge of town.
Tony Hagan	SW. ¼ sec. 26, T. 163, R. 88.	125	3		Flow.	Near Des Lacs Ferry. Threw water 40 feet after capping and reducing to 1 inch.
Gus Bjorkmon	NE. ¼ sec. 3, T. 162, R. 93.	42	18			Little water.
Hans Runsingen	Stampede	42	18			
Truax Coal Co.	NW. ¼ sec. 17, T. 162, R. 93.	167	3	Shale and coal		
A. O. Ness	SW. ¼ sec. 26, T. 162, R. 93.	265	2		75	
Otto Aas	NE. ¼ sec. 27, T. 162, R. 93.	160	2			
A. Rud	SW. ¼ sec. 34, T. 162, R. 93.	105	2			
A. M. Brunsven	NW. ¼ sec. 34, T. 162, R. 93.			Drift	Flow.	At foot of escarpment.
Do	SE. ¼ sec. 34, T. 162, R. 93.	140	2			
M. M. Ronsinger.	SE. ¼ sec. 35, T. 162, R. 93.	40	18	Drift	Flow.	Do.
Do	SE. ¼ sec. 35, T. 162, R. 93.	105	2		Flow.	Bored well.
Great Northern Ry.	Lignite					Size, 12 by 24 by 44 feet. Capacity 75,000 gallons a day.
Village	Woburn	72	6	Coal	6	Bored. Brown water.
Frederic Coslead	5 miles southwest of Flaxton.	284	2	do	80	Yellow clay with water to 30 feet. Blue clay with layers of sand; white clay at 233 feet. Good water in 9-foot bed of coal.
Thomas Jacobson.	6 miles southwest of Flaxton.	348		Fine sand	100	Sand and blue clay.
Harry Bird	NE. ¼ sec. 3, T. 162, R. 91.	80	3	Drift sand	45	Not a strong well.
John Fossum	SE. ¼ sec. 3, T. 162, R. 91.	365		Sand in shale	150	Water in fine blue sand interbedded with shale.
William Holte	SE. ¼ sec. 5, T. 162, R. 91.	68		Sand		

Typical wells of Burke County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Peter Johnson	NW. ¼ sec. 25, T. 162, R. 91.	100	2	Coal	50	In thick bed of coal.
O. A. Cropper	SE. ¼ sec. 13, T. 162, R. 90.	212	2	do	4	Flows into pump pit.
Jud Kellog	NW. ¼ sec. 14, T. 162, R. 90.	155		Sand		Sand beneath blue clay.
O. C. Tucker	NE. ¼ sec. 24, T. 162, R. 90.	198	3	Coal	16	
Mr. Ingals	7 miles northeast of Bowbells.	400				"Soapy white water."
D. F. Clothland	5 miles northeast of Bowbells.	175				Yellow, black, and white clay and sand.
P. C. Lunstad	S. ½ sec. 9, T. 161, R. 93.	365	2			
A. M. Brunsven	NW. ¼ sec. 6, T. 161, R. 92.	135			Flow.	On bank of coulee.
M. Mansen	SW. ¼ sec. 7, T. 161, R. 92.	60	24	Coal	Flow.	Weak flow at night after pumping by day.
A. Garlic	NW. ¼ sec. 32, T. 161, R. 92.				Flow.	
George Gangley	8 miles west of Coteau.	120	5	Coal	Flow.	On level prairie in front of foothills of escarpment. Drift and coal.
James Upham	S. ½ sec. 14, T. 161, R. 91.	200		do	60	
A. C. Wiper	SE. ¼ sec. 16, T. 161, R. 91.	120	6		Flow.	
John Stenson	N. ½ sec. 33, T. 161, R. 91.				Flow.	Slight flow. In foothills of escarpment.
Lew Rouse	S. ½ sec. 24, T. 161, R. 90.	416	2	Sand	75	
O. M. Peterson	NW. ¼ sec. 27, T. 161, R. 90.			Coal		Coal at 140 and 170 feet.
Ben Hinds	Bowbells	280	2	do	50	
Jens Peterson	do	84	2	do	40	
City	do	543	6	do	20	Water in sandstone at 40 feet; also water at 150 feet. No supply below. Pumped by gas engine. Weak.
N. C. Aukerman.[a]	do	12	60	Gravel	7	Sold for domestic use in Bowbells.
R. E. Knowlton	do			Coal		Yellow clay, blue clay, smooth white clay; coal with water.
A. C. Wiper	do	90		do	30	
John Holter	N. ½ sec. 17, T. 160, R. 94.	371	1¼	Fine sand	120	
Great Northern Ry.	Powers Lake					12 by 29 by 26 feet. Capacity 150,000 gallons daily.
C. H. Tibbets	SE. ¼ sec. 5, T. 159, R. 93.	343	5	Sand	168	Clay and sand to 128 feet, blue clay to 202 feet, all sand below 202 feet.
Charles Olson	SW. ¼ sec. 6, T. 159, R. 93.	148	5	Lignite	105	Poor water. All clay and coal.
John Van Beckom	NW. ¼ sec. 24, T. 159, R 93.	168	5	Clay	108	Poor water. All blue clay.
Ole Breding	E. ½ sec. 34, T. 159, R. 93.	248	5	Lignite	84	Soft.

[a] See table of analyses.

Water supplies of towns in Burke County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bowbells	643		100	300		Sand	Coal	Water sold from Ackerman's spring. Many springs in foothills 10 miles west of city.
Columbus	332	Bored, drilled.	25	260	45	Drift	Drift	Few have good water. Cisterns generally used. 2 or 3 flowing wells close to foothills.
Coteau		Dug, drilled	20	90		Sand	Coal	
Flaxton	374	do	20	457		do	Coal, sand	
Larson	114	Bored, drilled.	18	180	30	Gravel	Sand	Water hard and salty. Water level close to surface.
Lignite	214	Dug, bored	45	55	50			
Portal	454	Dug, drilled	25	300				Village water from deep well.
Powers Lake	251	Bored, drilled	15	100	25	Sand	Sand	
Stampede		do	50	165		Drift	Coal	Water level generally about 40 feet below surface.

BURLEIGH COUNTY

TOPOGRAPHY

Burleigh County lies in south-central North Dakota and is bordered on the west by Missouri River. It is included in the Missouri Plateau. The eastern third of the county has the irregular knob and kettle topography of the great broad terminal moraine (Altamont moraine) that marks the extreme western limit of the advance of the Dakota lobe of the Wisconsin ice sheet. In the central third the topography is of the rolling plateau type, but toward Missouri River this type merges within a short distance into a more dissected type, in which deep and broad stream valleys open out upon the level valley lowlands of the master river. So thoroughly have the streams done their work of erosion in the western portion that but few remnants of the plateau remain as broken uplands 2,000 to 2,200 feet above sea level.

The valley of Missouri River is a rather remarkable lowland separated from the upland for the most part by steep slopes or abrupt bluffs. The valley trench is 400 to 600 feet in depth and 2 to 3 miles wide. The flood plain lies 12 to 15 feet above the normal stage of the river and is generally covered with meadow or with thick growth of brush and cottonwood timber. The valley sides are well terraced, and the chief terrace is about 30 feet above the flood plain. Upon this terrace Fort Lincoln and part of the city of Bismarck are built.

Drainage in the morainic eastern portion of the county is almost entirely undeveloped. Lakes, marshes, and undrained meadow lands abound among the irregular hills, and grassy coulees lead into but rarely out of these areas except the largest—Long Lake—which has an outlet southward through Beaver Creek. The remainder of the county is thoroughly drained by the Missouri and its tributaries, chief of which are Apple, Burleigh, Burnt, and Painted Woods Creeks. Apple Creek is the largest and has a valley entirely disproportionate to its size, in which it meanders widely.

GEOLOGY

The bedrock of Burleigh County includes both the Lance and the Fort Union formations. The Lance underlies all the southern and western parts of the county and is overlain by the Fort Union on the uplands of the northeastern parts. The Lance formation is composed chiefly of dark-gray and brown shales that locally contain sandstones of similar color and thin seams of lignite. The Fort Union is distinctly lighter in color and consists of ash-gray and yellow shales and sandstones together with thicker beds of lignite. In the western portion of the area in front of the Altamont moraine the uplands are capped with an ancient till of pre-Wisconsin age.

The Wisconsin sheet has left a heavy mantle of morainic drift over all bedrock in the eastern part of the county, and its outwash has been carried far westward, spreading over the uplands, filling the valleys such as that of Apple Creek with valley trains, and undoubtedly contributing largely to the very thick deposits of alluvial gravel with which the bottom of the Missouri Valley is deeply covered.

A more complete account of the geology and water resources of southwestern Burleigh County is given in the Bismarck folio,[26] from which the author has taken much material for the report on this county.

GROUND WATER

The alluvial gravel of the Missouri Valley contains a very large supply of water at depths that in few places exceed 15 or 20 feet. Water may also be found in the outwash gravel that extends from the front of the Altamont moraine and in the valley trains which have been accumulated in most of the creek valleys that lead down to the Missouri, especially in the valley of Apple Creek. The drift cover in the area occupied by the Wisconsin ice contains a small supply of water of variable quality which depends on the presence of gravel beds in the drift and the lack of drainage.

In other areas an abundant supply of soft water may generally be found in the sandstone beds of the Fort Union and Lance formations, for the porous character of the sandstone permits a fairly rapid lateral movement of the waters, thus insuring a good quantity and preventing impregnation with the mineral salts that so commonly occur in shale and clay. Few of these wells exceed 200 feet in depth, for several beds of sandstone generally occur within that distance of the surface.

Something of the relation of ground water to beds of lignite may be seen in the Washburn mine, 1 mile southeast of Wilton, where about 10,000 gallons of water a day is pumped from the mine, into which it flows from the thick bed of lignite here mined.

Section at Washburn mine at Wilton, N. Dak.

	Feet
Drift	8
Clay and sand	52
Lignite	8–13
Clay	½–1½
Lignite	½–2

A well was drilled for the McKenzie Hotel Co. to a depth of 600 feet. This well passed for the most part through shale that contained a few thin beds of sandstone. This boring was probably not sufficiently deep by at least 1,500 feet to reach the Dakota sandstone. This well yielded a flow of 2 gallons a minute and gave a trace of natural gas. A few small artesian flows from shallow drilled wells occur in the vicinity of Long Lake and in other lowlands in front of the Altamont moraine and are caused by local conditions.

[26] Leonard, A. G., U. S. Geol. Survey Geol. Atlas, Bismarck folio (No. 181), 1912.

Springs are not common in Burleigh County, even in the deep valley of the Missouri and its tributary creeks, chiefly, perhaps, because of the heavy filling of glacial débris which was washed into these valleys and which forms the heavy terraces that mantle their sides.

QUALITY OF GROUND WATER

The waters of Burleigh County differ in quality within wide limits. Shallow wells in the drift, alluvium, and outwash yield hard water, which is generally satisfactory for domestic supplies. Analyses 100 and 104, of waters from Morton County are typical of these waters. Where the drainage is poor the water is too highly mineralized for most uses. The deeper wells that draw on the Fort Union and Lance formations and the Fox Hills sandstone usually yield soft water that is usable, although much of it contains considerable dissolved mineral matter, as shown by analyses 26, 27, and 28. Most of the shallower wells in these beds yield hard water. The shallower wells in low places where the drainage is poor yield highly mineralized waters. The high mineral content in these waters is the result of concentration by evaporation. Analysis 29 represents a good example of water from a well in a poorly drained area.

WATER SUPPLIES AT BISMARCK

Because of the abundance, the good chemical quality, and the ease of treatment, the city of Bismarck procures its public water supply from Missouri River. Considerable water, however, is obtained from wells drilled into the sandy beds of the Fort Union and Lance formations, which underlie the surficial deposits beneath the city. A study of the available logs and depths of successful wells indicates that good wells may be obtained at depths in the main part of the city of about 75 to 100 feet, 140 to 175 feet, 190 to 235 feet, and 415 to 600 feet. At the depth last mentioned several thin beds alternate with layers of hard rock and thin layers of lignite. It is not advisable to drill much deeper than 600 feet, for a little deeper the Pierre shale would be encountered. This shale is underlain by the Niobrara and Benton shales, in all at least 1,500 feet of shale, which is not water bearing, before the next sandstone formation, the Dakota, would be reached.

A well was drilled for the St. Alexius Hospital, in Bismarck, to a depth of 590 feet and was finished at 244 feet with a 40-foot strainer. The water-bearing bed is said to extend from the depth of 190 feet to 230 feet. The water level in the well is 70 feet below the surface.

Log of St. Alexius Hospital well, Bismarck, N. Dak.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Yellow clay	80	80	Sand, water bearing	40	230
Fine sand, water bearing	30	110	Blue clay	55	285
Blue clay	30	140	Fine sand, water bearing	125	410
Sand, water bearing	30	170	Clay with layers of hard rock and thin layers of coal	125	[a] 535
Blue clay	20	190			

[a] Total depth reported to be 590 feet.

Information in regard to several other wells in Bismarck is given on pages 280–281.

Typical wells of Burleigh County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
William Broron	W. ½ sec. 8, T. 142, R. 80.	110	2		105	Bored.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Baldwin	22	120			By Burnt Creek; small supply.
H. W. Rupp	SE. ¼ sec. 4, T. 141, R. 79.	600				
W. L. Watson	McKenzie	360	3	Sand	6	Soft and salty. Drift 75 feet, water-bearing quicksand 35 feet, hard gray shale 58 feet, coarse sand at 168 feet, water-bearing sand at bottom.
H. Turner [a]	do	125	2½		40	
W. L. Watson	do	168		Coarse sand	6	
Creamery Co	do	65	3	Coarse gravel		
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Britten	294	10	Sandstone	14	Water-bearing bed at 280 feet.
McKenzie Hotel Co.	Bismarck	600		Sandstone		2 gallons a minute and trace of gas.
Grand Pacific Hotel Co. [a]	do	200				
Capitol Steam Laundry. [a]	do	400	6, 3	Gravel		8 gallons a minute.
George Gussner	NW ¼ sec. 4, T. 138, R. 80.	75	3			

[a] See table of analyses.

Water supplies of cities and villages in Burleigh County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bismarck	7,122	Drilled	75	600		Sand	Sandstone	City uses treated Missouri River water.
Driscoll		do					Sand	Best wells 100 to 150 feet deep.
McKenzie		Dug, drilled	40	300	{ 40 150	}Drift	Sandstone	{Formerly dug wells about 40 feet deep, drilled 150 feet.
Moffitt		Dug, bored	15	150	22	Gravel	Gravel	Northern Pacific Ry. spring yields 10 gallons a minute.
Regan	202	Bored, drilled	20	300	50-75			Shallow waters hard, deeper waters soft.
Sterling	137	do	50	250	100	Sand		Do.

CASS COUNTY

TOPOGRAPHY

The greater part of Cass County lies in the Red River Valley, and less than one-third lies on the upland of the Drift Prairie west of the Pembina escarpment. The topography of the valley portion is exceedingly simple, as it is formed by the very level lake bed of Lake Agassiz, which is as yet scarcely eroded and is therefore still in its youth. Near the axis of the valley the slope is not over 1 or 2 feet to the mile eastward, but this slope increases farther west as the escarpment is approached to 4 to 6 feet to the mile. On the western border of the valley the surface is slightly broken by a series of northward-trending ridges of gravel and sand. These ridges are the beaches that mark the several levels of the lake and are well shown in the vicinity of Wheatland and Magnolia. At the southern margin of the county, from the vicinity of Leonard westward to the escarpment, lies the edge of a sand plain that stands somewhat above the level of the lake floor and is almost as level as the floor itself. This plain is deeply trenched by Maple River, and its sandy surface is in places blown into low dunes. This deposit of sand is clearly the débris from the ice front which Sheyenne and Maple Rivers brought down and deposited at the margin of Lake Agassiz in the form of deltas. The Pembina escarpment, which limits the valley on the west, rises about 200 feet in 5 miles and passes into the rolling prairie, marked by many irregular low hills and shallow hollows, that is typical of the drift-covered region.

In spite of the level character of its surface Cass County is fairly well drained, for Red River flows along its eastern border, Maple River crosses the entire length of the western upland portion, and Sheyenne, Maple, and Wild Rice Rivers pass across the southern half of the area. Between these rivers there are no permanent streams, but shallow grassy coulees carry off much of the water during the melting of the snow in spring and after excessive rains.

GEOLOGY

The general geology of Cass County is as simple as its topography, to which it is closely related. The surface of the valley floor is composed of lacustrine and alluvial silts except where it is overlain in the southwest corner by the sandy deposits of the Sheyenne-Maple delta. Beneath these lake deposits and at the surface throughout the western upland lies a thick bed of glacial drift, mainly till. The bedrock of the upland is Pierre shale (Cretaceous), which terminates in the escarpment formed by the erosion of the valley on the east in preglacial times. The valley floor is underlain on the west by the attenuated beds of older Cretaceous formations, which consist of Benton shale and Dakota sandstone. In the eastern part many borings appear to pass directly from the till into granite, though the logs of others indicate that a few feet of shale, presumably Cretaceous overlies this basement. The granite is distinctly gneissic in character, and the occurrence of white and green clays, in some places distinctly micaceous, shows that its upper portion is thoroughly decomposed.

The geology and ground-water resources of Cass County are described in more detail in the Casselton-Fargo folio,[27] from which the author has taken much of the material here presented.

GROUND WATER

Ground water is abundant in Cass County. Over considerable areas artesian flows can be obtained from shallow depths and large supplies of water can be obtained with but little lift in pumping. These waters are derived from several distinct beds, including the lacustrine and alluvial silt, beach and delta gravel and sand, sand and gravel beds of the drift, and the Dakota sandstone.

The shallow wells in the clay laid down in the lakes and rivers find a scanty supply, which is generally unsatisfactory for domestic use. The water from these wells, however, differs greatly in quality, even where the wells are separated by very short distances and differ little in depth. This condition prevails par-

[27] Hall, C. M., and Willard, D. E., U. S. Geol. Survey Geol. Atlas, Casselton-Fargo folio (No. 117), 1905.

ticularly in the eastern margin of the county, where the alluvial deposits overlie the lacustrine deposits for considerable depths.

Undoubtedly the best water of the county is found in shallow wells in the beach and delta deposits. On these sandy tracts the surface wells are 12 to 20 feet deep and furnish satisfactory supplies of water. The water is usually obtained in sand or fine gravel that immediately overlies the boulder clay at the base of the sand formation. The water falls upon the surface of these deposits of sand as rain or snow and percolates slowly downward as through a sand filter, to the impervious clay beneath. Owing to the slight slope of the surface of the underlying drift the water is held at the base of the sand as in a reservoir. These shore sands, both of the beaches and of the delta, were effectually washed by the waters of the lake during the time of their deposition, and thus lost the soluble salts which generally impregnate the drift and lacustrine deposits. This rinsing process has been continued by the infiltration of waters ever since the retreat of the lake from these shores, thus leaving the sand free from undesirable salts.

The drift waters are exceedingly variable in both quality and quantity. Those of the till are scanty and strongly alkaline. Most wells in the county are supplied from layers of gravel and sand at the base of the till and immediately overlying bedrock, or from similar lenses within the till sheet. Thus the water-bearing beds are overlain by layers of compact impermeable clay, the penetration of which allows the water to rise in the well, which it commonly does with considerable force. Such wells yield much water and can rarely be lowered to any considerable extent, even with persistent pumping. Most of these wells have been bored by augurs and are known as tubular wells. They rarely exceed 200 feet, and most of them are about 20 to 50 feet in depth. They are therefore the most common type of wells in the region.

Two artesian horizons are found in Cass County—one in the drift gravel just referred to, which belongs to the Red River Valley, and the other in the Cretaceous sandstone of the greater Dakota artesian basin.

The waters of the gravel layers and lenses of the drift are under artesian pressure in many places in this portion of the Red River Valley. Every gradation in head is found from wells in which the water rises very little in the tube to those in which there is a fairly strong flow. The pressure in these wells is not strong, however, and the flow is subject to variation. In some wells the flow has ceased entirely, and these wells have to be pumped. In many wells the flow may cease because of the failure of the casing or because of the choking of the well with sand, but in others, and commonly where the flow is short lived, it is due to the lens-like character of the aquifer and its ready exhaustion. These drift artesian wells are generally obtained at depths of 50 to 150 feet, though extremes of 37 and 200 feet are reported. One well in sec. 28, T. 173 N., R. 51 W., at a depth of 80 feet yielded a strong flow of nearly 1,000 barrels a day when first drilled, whereas another well in the same section 120 feet deep yields only a weak flow, and one 87 feet deep has ceased to flow. These wells vary also in the quality of their water. In most of them the water is hard, though fairly good for general uses. In none of them is found the characteristic saltiness which is uniformly present in the deeper artesian wells that obtain their supply from the Dakota sandstone. The water in these shallow artesian wells like that in a large number of nonflowing wells in the valley, is obtained from beds of gravel and sand in the glacial drift. The great variation in depth and in quality and quantity of the waters of these wells indicates that the water-bearing beds lie not only at different depths but also in comparatively narrow belts rather than in widely extended sheets. Wells are reported to range in depth from 40 to 134 feet within a distance of less than 2 miles. Wells so variable are undoubtedly supplied by distinct reservoirs which are not continuous but thin out within short distances. The fact, however, that so many of the wells have sufficient head to flow abundantly at the surface indicates that the beds are not truly lens-shaped but extend for considerable distances in some direction. This direction is probably that parallel to the ice front on its advance and retreat or in a general upward direction. The upland to the west of the valley is covered with a thick mantle of drift and contains many sandy gravelly tracts on the surface and lenses and beds within, as is characteristic of the drift, particularly in a morainal region. This area appears to be the gathering ground where the rain water penetrates the porous soil and is conducted through the sandy and gravelly beds to lower levels in the valley, for the drift is continuous over the escarpment that separates the upland prairie from the valley. The water is held in these porous beds as in underground reservoirs under the pressure or head of the water that enters the conducting channels at the higher levels, as the drift of the valley is overlain by the impermeable silts that were deposited on the old lake floor. A boring that passes through this compact clay into the saturated sands and gravel releases some of the water with considerable force.

A few wells have penetrated all the formations, including the drift, to the granite without striking any water-bearing beds. This fact is explained by the small area of these beds, the wells not having penetrated any layers of gravel or sand of sufficient extent to contain any large amount of water. Where the flow is strong at first but soon weakens or ceases a comparatively small reservoir seems to have been tapped and is soon exhausted because the outflow greatly exceeds the intake.

The western half of Cass County lies within the Dakota artesian basin. In this portion of the county strong flows are obtained at depths that range from 250 to more than 500 feet. The water is obtained in all the wells from a fine-grained loose sand that belongs to the Dakota formation. The water in these wells is generally salt, though it is used for stock, and many like it even for drinking. It is also commonly reported to be much softer than the shallower waters of the drift and lacustrine silt. Owing to the occurrence of alternating layers of shale with the soft sandstone the wells differ considerably in depth within short distances. In some wells sufficient flow is obtained from the first layer of sand reached, in other wells from the second, and commonly more than one water-bearing bed is struck in the same boring. At times the flow from two or even three beds is combined in one well by perforations in the pipe at the levels of the different beds. At Chaffee two flowing wells about 40 rods apart are 265 and 440 feet in depth. A few miles southwest, within a radius of 1 mile, are five flowing wells that obtain water at depths of 240, 414, 430, 434, and 460 feet.

A number of wells in the eastern half of the county have been drilled to granite at depths of 400 to 475 feet without finding the characteristic water-bearing sandstone, and little if any water was obtained. This fact indicates that the margin of the Dakota sandstone lies not far east of Casselton, so that the western half of the county lies within the basin and the eastern half without.

The pressure of the water in the Dakota sandstone increases toward the west. In the few wells along the eastern margin of the basin that have a depth of 200 or 300 feet, the pressure at the surface is slight and the water does not rise more than 5 or 6 feet above the surface. As the depth of the water-bearing beds increases westward the pressure increases, notwithstanding the fact that the land rises also. At the western margin of the county the calculated height to which the water originally rose was between 50 and 100 feet, though the elevation is 200 to 300 feet above that of the eastern margin of the basin at Casselton. This head and the resulting flow have declined rather rapidly during the last few years, and in many places in northern and eastern Cass County which were formerly in the area of artesian flow and where many of the better farms had flowing wells none can now be obtained. Fortunately in most of these places good pump wells may be obtained at moderate depths.

Log of Northern Pacific Railway well at Tower City, N. Dak.

[Altitude of surface, 1,172 feet]

	Feet
Soil	50
Clay	375
Soft sandstone	25
Very soft clay	115
Mud	100
"Hardpan" (gravel and rock)	51
	716

Flow 25 gallons a minute. Pressure, 50 pounds.

An interesting example of one small shallow artesian basin superimposed upon another occurs in T. 139 and 140 N., R. 55 W., where within the area of flow from the Dakota sandstone, which lies between 600 and 700 feet below the surface, the Quaternary drift yields flowing wells at depths of 25 to 150 feet. These wells are all in the valley of Maple River, and the artesian conditions are determined by local topography. Under these conditions several farmers have two flowing wells each. One of these wells on the upland and near the house and barns is 600 to 700 feet in depth and obtains from the Dakota sandstone large amounts of highly mineralized water under pressures of 20 to 30 pounds to the square inch and at temperatures of 52° to 55°. The other a few hundred feet away and 20 to 30 feet lower, on the valley bottom of Maple River, is 40 to 100 feet deep and yields 1 quart to 5 gallons of satisfactory water a minute under a pressure of 1 to 5 pounds to the square inch at a temperature of 42° to 45° F.

Springs are exceedingly rare in the Red River Valley, and those that are found in the sides of the deeper valleys are but small seepages. However, there is one area in Cass County in which springs of considerable size occur. This area lies about the margin of the Sheyenne delta, just northeast of Leonard, where the water bed at the base of the delta sand and immediately above the clay comes to the surface. The flow is due to the eastward slope of the impervious clay, on account of which rain water penetrates the sandy soil and flows through the base of the formation upon the impermeable clay to the edge of the delta, where it is brought to the surface.

QUALITY OF GROUND WATER

Nine waters from Cass County (see analyses 30–38) and others indicate that different types of water are obtained in Cass County. Shallow wells that pierce the lacustrine and alluvial silts and the beach and delta sands yield hard water which contains different amounts of dissolved mineral constituents. Water from the silts, of which analysis 35 is typical, is used to some extent but is not as good as the water from the beach and delta sands, which is generally satisfactory for most uses. Wells that enter the lower water-bearing layers of the drift just above bedrock yield hard water, moderately to highly mineralized, as represented by analyses 30, 31, 34, 36, and 37. Such water is used where better water is not obtainable, although much of it is objectionable for drinking and other domestic uses. The Dakota sandstone in the western part of the county yields soft, highly mineralized water like that represented by analysis 32, which is used, even though it is far from satisfactory.

WATER SUPPLIES AT FARGO

The municipal water supply in Fargo is taken from Red River, but ground water may be procured in Fargo from three horizons—the alluvial and lacustrine clay, the sand and gravel beds of the drift, and the Dakota sandstone.

Shallow wells in the alluvial and lacustrine clays find a scanty supply, which is generally unsatisfactory for domestic use owing to its high mineral content and unpleasant taste. These wells, though few of them are 50 feet in depth, differ greatly in the quality of their water, even when separated by very short distances. A typical example of these shallow wells is that of S. B. Steeves, 1316 Eighth Avenue north, in the NW. ¼ sec. 6, T. 139 N., R. 48 N. The well is 22½ feet deep and 16 inches in diameter and penetrates only sandy clay. It is curbed with tile and pumped by hand. The water stands normally about 12½ feet below the surface and yields but 2 barrels at a pumping but refills to the former level overnight.

The waters of the drift are also exceedingly variable in both quality and quantity. Those in the boulder clay are scanty in yield. Most of the wells in the drift, however, are supplied from layers of sand and gravel at the base of the drift and just above the bedrock or from lenses of similar material within the boulder clay. These water-bearing beds are overlain by layers of compact, impermeable clay, and many of them are under artesian pressure, which causes the water to rise in the well nearly to the surface. Such wells yield much water and can rarely be lowered to any considerable extent, even with persistent pumping. Wells of this class are either made to flow into underground reservoirs or are pumped directly. These drift wells are obtained at from 100 to 200 feet in depth. The great variation in depth, as in quantity and quality of the waters, indicates that the water-bearing beds lie at different depths and are not continuous sheets. Those beds that extend westward and lie upon the upland in that direction receive the rain water that penetrates the porous overlying soil, and by conducting it to the lower levels the water is held in these porous beds as in underground reservoirs under the pressure or head of the waters entering the beds at higher levels. Since the drift of the valley is overlain by the impermeable clayey silts deposited on the old lake floor, a well drilled through this clay into the saturated sand and gravel permits the water to rise in the well nearly to the surface. A few wells are known to have penetrated all the formations to the granite without striking any water-bearing drift beds. This fact is explained by the small area of some of these beds, and by the wells not peneterating any layer of gravel or sand of sufficient extent to contain any large amount of water. A good type of the drift waters is furnished by the well of H. A. Oder, 203 Sixteenth Street south. This well is drilled to a depth of 175 feet 4 inches in diameter at the top and 2½ inches at the bottom. The supply comes from a bed of about 20 feet of sand at the bottom. The well is cased with 4-inch galvanized-iron pipe to a depth of 118 feet and 2½-inch pipe for the remainder. It is finished with a 6-foot screen of No. 80 mesh at the lower end of the pipe. The water formerly flowed into a cistern, 9 by 14 feet in diameter, at a point 8 feet below the surface, and 67 tanks a day have been drawn from this cistern and sold. Ordinarily 800 gallons a day was sold and used for all purposes. The well is now pumped directly for domestic use and for stock by a common cylinder pump, and the cistern has been abandoned and filled since the well ceased to flow into it. An older well, 225 feet deep, with a head of 1½ feet below the surface and a strong flow into the cistern at a depth of 8 feet below the surface, was previously used on this place. This well was abandoned after it became filled with sand.

That sandstone of Cretaceous age underlies the city of Fargo is indicated by many wells. In the old city well, which had a depth of 209½ feet, water was obtained from 50 feet of sand, that overlay white chalky rock at the bottom. The chalky rock was penetrated to a depth of only 3½ feet. The water from this well was reported to be softer than that of the wells of the overlying drift. Especially was it less hard than that from a bed which was struck in this boring below "hardpan" at 96 feet, and which was undoubtedly in drift. The sand was interpreted by Hall and Willard to be the same as that from which flowing wells are obtained farther west, in the district of the Cretaceous artesian wells. The water in this well rose nearly to the surface, and the well was estimated to yield 1,000 barrels a day. The water was long pumped and hauled away in wagons to be delivered about the city to consumers for domestic use. An incomplete log of this well follows:

Log of old city well, Fargo, N. Dak.

	Feet
Not reported	0–96
Hardpan with small bed yielding water at	96
Not reported	96–156
Sand	156–206
White chalky rock	206–209½

Test holes drilled by the Northern Pacific Railway Co. near the location of the old roundhouse (between Front Street and First Avenue near Sixth Street) showed the following results:

Test hole No. 1 (midway between Front Street and First Avenue, on eastern edge of coulee) was drilled to a depth of 207 feet and "struck some water at this depth, but not enough for a supply." Test hole No. 2 (about 200 feet southwest of corner of First Avenue and Sixteenth Street) was drilled to a depth of 360 feet in June, 1904. A little water was struck 160 feet from the surface. Hole is cased to granite at 240 feet. The log of this hole follows:

Log of Northern Pacific Railway test well No. 2, Fargo

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil and clay	93	93	Hard granite	33	360
Sand and gravel	57	150	Geologic formations:		
Soft sand and gravel, some water at 160 feet	90	240	Lake Agassiz silt	93	93
Hard granite	19	259	Glacial drift	57	150
Soft granite	68	327	Cretaceous	90	240
			Archean granite	120	360

Test hole No. 3 (north side Northern Pacific right of way near Twentieth Street) was drilled to a depth of 252 feet in August, 1904, and gave the following log:

Log of Northern Pacific Railway test well No. 3, Fargo

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil and clay	89	89	Granite	2	252
Sand and boulders	47	136	Geologic formations:		
Gravel and sand	20	156	Lake Agassiz silt	89	89
Sand and soapstone with some water	11	167	Glacial drift	67	156
Soft sandstone	13	180	Cretaceous sand and shale	94	250
Sand	70	250	Archean granite	2	252

Some water was struck at 160 feet from the surface, but did not flow fast enough to supply the pump.

Another well is that of the Blue Island Creamery Co. on First Avenue between Tenth and Eleventh Streets, which was drilled by Albert Hulberg in September, 1923. It is 6 inches in diameter to a depth of 403 feet 8 inches. The driller's log follows:

Log of well of Blue Island Creamery Co., Fargo

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, yellow clay, blue clay	105	105	Gray sandstone (?)	3	403
Sand	55	106	Geologic formations:		
Sand and gravel, water-bearing	20	180	Lake Agassiz silt	105	105
Clay and sand	100	280	Glacial drift	75	180
Green sandstone (?)	115	395	Cretaceous sand and shale	100	280
Red sandstone (?)	5	400	Archean granite (?)	123	403

The colored sandstones mentioned in the log are probably more or less decomposed granite, which passes into hard granite below. The well was cased 403 feet 8 inches, but as the water supply was insufficient the pipe was dynamited at 180 feet, and a yield to the driller's pump was obtained of about 35 gallons a minute for 6 or 7 hours. The well has not been used, however, as the supply was still considered insufficient, and the well casing was capped. On August 13, 1924, the water stood in the casing 9 feet below the ground-water level.

The well drilled for the Fairmount Creamery Co. in the northwest corner of block 18, Reeves addition, corner of Second Avenue and Sixteenth Street, gave the following driller's log:

Log of well of Fairmount Creamery Co., Fargo

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Yellow clay	20	20	Blue clay	37	227
Blue clay	105	125	Sand and gravel	19	246
Gray clay	65	190	Clay	4	250

This well was 12 inches in diameter, the water rose to a depth of 30 feet below the surface, and the yield was 50 gallons a minute, according to the driller's report.

The bed of sand and gravel at or near the base of the drift yields a large supply in the deepest part of the old preglacial valley, which was first partly filled with glacial drift and then with the clay deposited on the floor of Lake Agassiz. According to all the evidence available the axis of that valley is located somewhat to the east of the present river, between the cities of Fargo and Moorhead, and the thick deposit of coarse gravel formed therein is tapped by the city wells of Moorhead and the new Fairmount Creamery well. The test well in Moorhead, which was drilled in 1923, was found to lie east of these main gravel beds, as all deep wells in Fargo are found to lie on the west slope of this old valley. Large yields of relatively fresh water have as yet not been procured in Fargo and may be looked for only near the eastern edge of the city, especially in the Oak Grove section. If found, these valley gravels will be coarse and relatively thick and will contain much good water. They should yield in large wells properly screened, from 100 to 500 gallons a minute, with head perhaps higher at first but will pump down to a level between 100 and 130 feet below the surface.

They probably lie between 150 and 200 feet below the surface and should be 20 to 60 feet thick. In the central and western parts of the city these gravel beds thin to layers from 3 to 15 feet in thickness. They consist of fine to coarse sand and a small amount of fine gravel and lie from 80 to 150 feet beneath the surface. They may be expected to yield from 20 to 50 gallons a minute to wells provided with ordinary strainers.

The Cretaceous sandstone lies underneath the drift and above the granite in beds 10 to 90 feet in thickness and at depths of 150 to 250 feet below the surface. The yields are small, owing to the very fine texture of the sandstone, and the wells frequently fill with sand. The first yield may be 25 to 50 gallons a minute, but this is soon reduced by inflow of sand and many of the wells are abandoned. These waters are invariably highly mineralized. In many wells the drift and Dakota sandstone are not clearly distinguished, and no doubt in many wells both are drawn upon as from a single bed; particularly because the water in the underlying Dakota sandstone is under moderate pressure, so that it rises through the drift gravel and mingles with the water of the drift, making it rather distinctly mineral in character.

In a region in which granite is reached some distance below the surface, as in the vicinity of Fargo, it is well known that there is no water supply in granite. Such small amounts as are found are very highly mineralized and unfit for use.

WATER SUPPLIES AT CASSELTON

Two types of wells are common in Casselton. The first type consists of large open wells that draw their supply from sandy or gravelly layers in the drift. The second type consists of artesian wells that range in depth from 250 to 385 feet. The shallower of these artesian wells probably draw their waters from deposits of sand or gravel in the base of the drift, but these waters probably rise into these deposits under pressure from the sandstone below. The deeper artesian wells are supplied directly by the Dakota sandstone and are located in the extreme eastern edge of the area of artesian flow from this basin. All the available waters are relatively high in mineral content. Though the shallower waters are very superior to the artesian for household use owing to their low content of sulphates, they are inferior to the artesian waters for use in boilers because of their greater hardness. A good type of the waters of the drift is found in the public school well, which, however, gives little indication of a considerable supply. The supply might be increased somewhat by the use of 2-inch sand points driven outward and downward from the bottom of the well.

The waters from the artesian wells are less hard than the shallow well waters, but they contain a large amount of mineral matter in solution, especially sulphates. These wells, however, give greater supply than do the shallow wells. Most of these wells have ceased to flow. The old roller-mill well owned by Mrs. Grovener and located in the NE. ¼ sec. 35, T. 140 N., R. 52 W., in the east edge of town, is perhaps to-day the best of this earlier group of wells. It is 430 feet deep, 2 inches in diameter, and had an original flow of 22½ gallons a minute under a pressure of 8½ pounds. In 1922 it was flowing 1 gallon a minute at a temperature of 46° F. Pressure could not be determined on account of leakage. (See analysis 32.) The water was formerly used for industrial supplies but is now used for domestic supplies only. The history of this well led the city recently to put down a new well only a few feet distant from this one, which it approximately duplicates except that it has a 16-inch casing from top to bottom. This new well will be used to supply the public system now being installed.

The drillers' log of the Great Northern Railway well at Casselton, which was put down in 1908, gives perhaps the most complete record known of the formations of this vicinity.

Log of Great Northern Railway well, Casselton

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Filling	4	4	Gray shale	26	350
Black soil	1	5	White sand	1	351
Yellow clay	10	15	White shale	19	370
Blue clay	75	90	Red shale	40	410
Sandy clay	15	105	Granite formation	4	414
Blue clay	138	243	Green shale	41	455
Boulders and clay	3	246	Granite formation	76	531
Blue clay	78	324			

Typical wells of Cass County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Great Northern Ry.	Page	12	96			75,000 gallons a day.
Henry Shuman	SE. ¼ sec. 35, T. 154, R. 52.	388			Flow.	
Village [a]	Grandin	230	2	Sand		4-foot wooden curb dug 10 feet deep and 2-inch well to 230 feet.
Great Northern Ry.	Bedford	10				73,000 gallons a day.
A. E. Sommerfield.	NE. ¼ sec. 35, T. 142, R. 52.	134	5	Gravel	32	
J. R. Belsy	Sec. 9, T. 142, R. 51.	408	1¼	Sand		
J. E. Fitzsimmons.	NW. ¼ sec. 21, T. 142, R. 51.	186	2	do		
A. E. Cook	NE. ¼ sec. 2, T. 142, R. 50.	195	2	Gravel		Roily before storm.
R. A. Sterling	do	147	2	do		Alkaline. Decreases in supply. Bedrock at 102 feet.
Village [a]	Gardner	135	2		Flow.	⅙ gallon a minute.
J. J. Larson	SE. ¼ sec. 14, T. 142, R. 50.	204	2	Gravel and sand.		
Joseph Marshall	NE. ¼ sec. 27, T. 141, R. 54.	640	1¼		Flow.	
W. Hocking	E. ½ sec. 34, T. 151, ¾ R. 53.	364			26	Water at 150, 250, and 364 feet. Gas.
Great Northern Ry.	Vance	302	2	Gravel		Gravel at base of drift. capacity 200 barrels a day.
Herman Geske	NE. ¼ sec. 32, T. 141, R. 51.	190	2	do	Flow.	
Daniel Wilston	NE. ¼ sec. 15, T. 141, R. 49.	150	2		3	
Village [a]	Argusville	149	2			Formerly flowed into reservoir.
	Sec. 36, T. 141, R. 48.	352				Clay 108 feet, drift 17 feet, boulders 5 feet, sand and gravel 120 feet (Cretaceous?), decayed granite 5 feet, granite 97 feet.
Do	Tower City	716	4½	Sandstone	Flow.	Salty. Drift 163 feet, shale 502 feet, quicksand ½ foot.
John Schmitz	NE. ¼ sec. 8, T. 140, R. 55.	595½	1½	Sand	Flow.	Soft but salty; 300 feet to bedrock.
John Peterson	S. ½ sec. 2, T. 140, R. 55.	485	3-4		Flow.	
Staples well	Sec. 12, T. 140, R. 54.	514	1¼	Sandstone	Flow.	First water at 180 feet. First flow at 500 feet. "Rock" at bottom.
	Sec. 19, T. 140, R. 54.	743		do	Flow.	Top of Dakota sandstone at 610 feet.
Public school [a]	Casselton	70	4	Drift		Former flow.
City	do	430			Flow.	

[a] See table of analyses.

Typical wells of Cass County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Mrs. Grovenor (roller mill) [a].	Casselton	430	2	Sandstone	Flow.	½ gallon a minute in 1922.
Great Northern Ry.	Prosper	26	72			
W. B. Duglas	Sec. 9, T. 140, R. 50.	411		Sand		Clay 60 feet, quicksand and water 10 feet, clay and sand 60 feet, coarse sand 1 foot, clay 130 feet, coarse sand 2 feet, clay 50 feet, gravel 1 foot, clay 97 feet, sand. Granite at bottom.
	Sec. 34, T. 140, R. 47.			Drift gravel	20	Clay 100 feet, gravel 40 feet.
Henry Baron	SW. ¼ sec. 9, T. 139, R. 53.	510	1¼	Sand	Flow.	
Frank Weber	SW. ¼ sec. 24, T. 139, R. 53.	390	2	Coal and sand.	Flow.	
G. Weber	SE. ¼ sec. 10, T. 139, R. 52.	405	2	Gravel and sand.	Flow.	
John Reily	SW. ¼ sec. 12, T. 139, R. 52.	415	2	Coarse sand	Flow.	
Julius Weber	SE. ¼ sec. 22, T. 139, R. 52.	480	2	do	Flow.	
August Muller	NW. ¼ sec. 30, T. 139, R. 51.	240	2	Gravel and sand.	Flow.	
Northern Pacific Ry.	Haggart	124	4			
H. A. Alder [a]	Fargo	175	4	Sand	8 (?)	
City, first well	do	209		do		Sand overlying chalky rock at bottom.
City, second well	do	216		Gravel		Soil 7 feet, clay 15 feet, quicksand 4 feet (contains alkali water), not reported 121 feet, sand and stones 69 feet; water in gravel at 147 feet.
S. B. Stevens [a]	do	22½	16	Sandy clay	12	Tile curb, slight yield.
Northern Pacific Ry.	Alice	23	192			Brick curb.
William Gerdes	NW. ¼ sec. 34, T. 138, R. 51.	170	3	Quicksand	22	Yield 50 barrels an hour.
	Sec. 29, T. 138, R. 48.					Not reported 162 feet, white clay 22 feet, green chalky shale or clay 102 feet. Granite at bottom.
	Sec. 34, T. 138, R. 47.					Clay 97 feet, sand and clay 103 feet, clay 40 feet, greenish sand and shale 25 feet.
	Sec. 15, T. 138, R. 47.			Drift		Lake clay 70 feet, gravel and clay 50 feet, clay 60 feet, gravel and clay 2 feet, clay 30 feet, gravel and sand 2 feet, clay 23 feet. Gravel at bottom.
Henry Huer	NE. ¼ sec. 9, T. 137, R. 52.	286	2	Coarse gravel	Flow.	
Do	NE. ¼ sec. 16, T. 137, R. 52.	180	2	Gravel rock	Flow.	
Mick Toussaint	SW. ¼ sec. 15, T. 137, R. 52.	150	2	Gravel	Flow.	
John Johnson	SE. ¼ sec. 17, T. 137, R. 50.	140	4	Gray sand	35	22 barrels an hour.
Oluf H. Tryhus	NW. ¼ sec. 31, T. 137, R. 49.	80	4	Gravel	16	16 barrels an hour.
Village [a]	Hickson	80	3		15	Drinking water for village.

[a] See table of analyses.

Water supplies of towns in Cass County

Town	Population in 1920	Kind of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Alice	150	Drilled	15	450		Clay	Sandstone	Flowing wells.
Amenia	300	do	300	350				Small flows.
Arthur	225	Bored	12	400	30	Gravel	Gravel	Deep wells flow.
Ayr	275	Bored, dug, driven	17	65	20	Sand	Sand	
Buffalo	268	Dug, bored, drilled	15	750	20 700	do	Sandstone	Flowing wells.
Casselton	1,538	Dug, drilled	26	450		Drift	do	At eastern edge of Dakota artesian basin.
Chaffee	150	Drilled	25	300		Sand, gravel	Sand, gravel	
Davenport	214	do	75	200	75	Sand	Sand	Flowing wells.
Erie	200	Dug, drilled	19	60	25 60	do	do	
Fargo	21,961	Drilled					do	See p. 102.
Gardner	150	do	150	225			do	Flowing wells.
Grandin	150	do	80	300	200	Gravel		Do.
Hardwood	70	do			115 135			
Hickson	100	do	60	175		Sand	Sand	
Horace	275	Bored	15	75	25	do	Clay	
Hunter	424	Dug, drilled	12	550	35 550	do	Sand	Water in deep wells flows. Shallow dug wells used for households. Small springs.
Kindred	334	Bored, drilled	8	300	10–25	Drift	Sandstone	Flowing wells west of town.
Leonard	204	Driven	15	25		Clay, sand	Clay, sand	Spring in Buffalo Coulee.
Mapleton	198	Drilled	15	320	60	Silt	Sand	Some flowing wells.
Tower City	447	do						Flowing wells 500 to 700 feet deep.
Wheatland	400	Dug, drilled	10	400	20	Sand	Sand	Some flowing wells.

CAVALIER COUNTY

TOPOGRAPHY

Cavalier is the northeasternmost county of the Drift Prairie. It lies on the upland that stretches westward from the Pembina escarpment along the international boundary. The last line of the Itasca moraine (of Upham) in North Dakota crosses the county from northwest to southeast and an earlier line crosses the southwest corner. Much of the topography outside of these well-marked ridges of hills is quite morainal. The sags and swells are accentuated and depressions filled with marshes, ponds, and lakes are very common. Rush Lake, south of Hannah, is the largest, and this lake formerly drained by both West and East Snowflake Creeks into Pembina River. The eastern half of the county is drained by Pembina, Tongue, and Park Rivers across the escarpment to Red River, whereas the western half lies in the interior drainage basin of Devils and Stump Lakes. In the western area there is little run-off to-day, and the shallow winding beds of the coulees are grassed over and dry except during the spring thaws or after heavy rains.

GEOLOGY

The geology of Cavalier County is simple; the county is mantled with a cover of glacial drift that ranges from 20 to 60 feet in thickness and overlies the Pierre shale. Only in the Pembina Valley and on the face of the Pembina escarpment in the extreme northeastern margin of the county is the bedrock exposed. Here a section several hundred feet in thickness shows outcrops of the Niobrara and Benton shales beneath the Pierre shale.

The western margin of the Pembina delta lies within this county, so that a very narrow strip in the eastern edge of the county has the topography and geology of the area described in Pembina County.

GROUND WATER

Almost all the wells of Cavalier County are shallow and draw their water directly from the drift, the largest supply coming from the sandy base of the drift immediately above the shale. These waters are hard and slightly alkaline.

In the better-drained eastern portion of the county the wells are deeper, as much as 100 and even 200 feet in depth. These wells enter the Pierre shale and obtain a slightly saline supply from the porous sandy layers in the upper portion. No wells have been sunk to deeper beds nor is it advisable for, owing to the altitude of the region, deeper flowing wells are not to be had and the waters are too strongly mineralized and the expense of pumping too great to warrant any drilling over 500 feet. In fact, few good wells have been obtained below 250 feet; the water is increasingly saline and the danger of dry holes great. On the portion of the Pembina delta which lies within this county it is necessary to go to considerable depths through the coarse sand and gravel, commonly 100 or 200 feet before the water level is reached. The water, however, is generally good when found.

The log of the well drilled for Geiske Bros., 1 mile west of Loma, in the SE. ¼ sec. 31, T. 160 N., R. 61 W., gives an indication of the character of the Pierre shale, which underlies the drift. The drift is here evidently 170 feet thick, and the shale was drilled into for 330 feet without finding a suitable water supply. On moving the drill about 200 yards a well was obtained at a depth of 88 feet, the shale being reached at a depth of 40 feet. This indicates something of the irregular character of the surface of the bedrock beneath the drift.

Log of well of Geiske Bros., 1 mile west of Loma

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Yellow and blue clay	30	30	Soft shale	2	220
Boulder clay	15	45	Limestone	½	220½
Clay, with gravel and sand	125	170	Shale, hard	29½	250
Hard shale	5	175	Shale, hard and soft layers	140	390
Soft shale	4	179	Shale, with small gravel	10	400
Limestone	2	181	Shale, soft, with harder layers 1 to 2 feet thick	100	500
Shale, hard	37	218			

Springs are not common in Cavalier County because of the rolling upland type of most of the topography and the shallowness of the stream valleys. The valley of Pembina River and the Pembina Mountain escarpment, which faces the eastern boundary of the county, contain exceptions, however. Around McLean there is a district that is copiously furnished with springs of pure sparkling water. These springs issue at the contact of the drift with the underlying Niobrara shale, which is hard, compact, and impervious, so that the water moves along the upper surface of this gently eastward-sloping formation. From McLean northward to the international boundary line the many watercourses which lead up through the several gravel beaches that border the old lake floor and into the Pembina escarpment are characterized by numbers of seeps and springs, both small and large.

QUALITY OF GROUND WATER

The two principal sources of water supply in Cavalier County are glacial drift and Pierre shale. The drift yields hard waters that differ in mineral content. Analysis 39 shows that some of it contains less than 500 parts per million of total solids and may be regarded as fair water. Most of the water from the drift is acceptable for general use. The Pierre shale yields highly mineralized water, most of which is objectionable for drinking, though it may be used for other domestic purposes when a sufficient quantity of better water can not be obtained. At some places where only a small quantity of rain water or water from the drift can be obtained this water serves for domestic use, and water from the Pierre shale is used for stock.

WATER SUPPLIES AT LANGDON

The public supply of Langdon is taken from an open well 36 feet in depth and 13 feet in diameter located on a slight rise of land in the northwestern part of the city. This well was dug in August, 1917, and entered the Pierre shale at depth of 7 feet. It is curbed with brick to a depth of 20 feet and covered with the pump house, in which is installed an electrically driven centrifugal pump that raises 35 gallons a minute. The water supply comes from the open joints and cracks in the upper portion of the shale and stands between 20 and 30 feet from the surface of the ground, the altitude varying with the seasons. This water, though pumped from the Pierre shale, comes largely from the sand and gravel at the base of the drift immediatley above the shale, and the well yields water to the pump at the rate of 80 gallons a minute. About 37,000 gallons is used daily for all domestic purposes. (See analysis 139.)

Wells in both the drift and the shale are used by residents in the city. The wells in the shale draw mineralized waters from their sandy layers, within a few hundred feet of the surface. It is not advisable to go at most below 300 to 500 feet for these supplies, as the water becomes more strongly mineralized and is obtained in smaller amounts as drilling goes deeper. It is inadvisable to attempt to penetrate the several hundred feet of shale, as the Dakota sandstone, if reached at a depth of more than 1,000 feet, would not yield artesian flows.

Typical wells of Cavalier County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
First National Bank of Hansboro.	NW. ¼ sec. 1, T. 164, R. 68.	90	12	Shale	Flow.	Good supply.
E. J. Donovan	NE. ¼ sec. 32, T. 164, R. 61.	50		Sand		Clay 35 feet, sand and gravel 15 feet, quicksand.
Do	S. ½ sec. 36, T. 164, R. 61.	105			20	Chiefly yellow clay, blue clay, and shale. Strong well.
A. Dris	S. ½ sec. 1, T. 163, R. 66.	85	12	Shale	Flow.	
Barker farm	SE. ½ sec. 2, T. 163, R. 66.	114	12	do	Flow.	
Paul Higgins	NE. ½ sec. 25, T. 163, R. 66.	109	4	do	Flow.	
A. Ackwood	W. ½ sec. 7, T. 163, R. 64.	157	4½	do	Flow.	
C. L. Day	SW. ¼ sec. 15, T. 163, R. 64.	165	4	do	Flow.	
J. C. Huntley	1 mile northeast of Sarles.	192	4	do	35	Water at 60 feet alkaline; plenty of soft water at 170 feet.
Great Northern Ry.	Sarles	34				12 by 24 feet. 6,000 gallons a day.
H. A. Grimshaw	do	105	4	Shale		Pumped by gasoline engine.
John Mann	N. ½ sec. 6, T. 163, R. 61.	200	2			Drift, boulders, and quicksand.
Edward Riche	4 miles west of Walhalla.	200	4		Flow.	
Bert Thomas	SW. ¼ sec. 5, T. 162, R. 67.	117	12	Black clay		Very little water.
Armour	NE. ¼ sec. 7, T. 162, R. 67.	105	12	Quicksand		
Duncan Sellars	NE. ¼ sec. 2, T. 162, R. 65.	304	45	Shale	Flow.	Fair supply.
Lena Schafter	NE. ¼ sec. 9, T. 162, R. 64.	139	4	Hard shale	20	Salty. Shale at 80 feet.
C. E. Clopper	NE. ¼ sec. 17, T. 161, R. 64.	265		Shale	40	Salty.
Do	do	265	4	do		Do.
E. H. Durbin	E. ½ sec. 36, T. 161, R. 64.	136	4½	Gravel	Flow.	
Charles Mickland.	NW. ¼ sec. 26, T. 161, R. 63.	98	4½	Shale		
Langdon Com. Co.	SW. ¼ sec. 21, T. 161, R. 61.	150	6	do	6	Shale at 65 feet.
Experiment farm	Langdon	179	4	do		Shale at 35 feet.
City [a]	do	36	156	do	25	Shale at 6 feet. City supply.
Thomas Sherban	do	80	2	do		
C. J. Bone [a]	do	75	6	do	45	Shale at 8 feet.
Joseph Power	do	97	2	Gravel	50	
Joseph Goeser	N. ½ sec. 6, T. 160, R. 64.	220				
Peter Goeser	S. ½ sec. 6, T. 160, R. 64.	229	2		25	Drift 25 feet, blue clay 61 feet, clay 94 feet, shale 54 feet. Strong well.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Calio	50	120			20 gallons a minute.
D. J. Enns	Munich	145	4½	Gravel		Used for steam engine.
Great Northern Ry.	do	34	36			10,000 gallons a day.
Ed. Saunders	do	126	4	Sand		Roily on pumping. 20 feet to bedrock.
Joes Carey Hotel	do	162				
Public school	do	150	6		20	
Frank Fast	6 miles northeast of Munich.	145		Gravel	20	10 gallons a minute. 140 feet to shale.

[a] See table of analyses.

Typical wells of Cavalier County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. B. Friesen	Munich	165		Shale	11	
A. C. Wuesky	Alsen	50	18	Gravel	25	Gravel at 45 feet.
Christ Rappel	1 mile north of Alsen.	90	4½	do	20	Drift 60 feet.
F. D. Fast	NE. ¼ sec. 5, T. 160, R. 62.	145	4½	Shale	25	Drift to 140 feet; shale.
Peter A. Wieus	8 miles northwest of Alsen.	87	4½	Gravel	16	Drift to 50 feet.
H. A. Reimer	SE. ¼ sec. 19, T. 160, R. 62.	99	4½		20	Shale at 60 feet.
Jacob Hebut	8 miles northeast of Alsen.	57	18	Shale	32	Shale at 36 feet.
G. Grimson	SE. ¼ sec. 20, T. 160, R. 62.	51	18		6	
Peterson Bros	S. ½ sec. 34, T. 160, R. 62.	36	18	Shale	18	Shale at 26 feet.
Thompson Realty Co.	Sec. 7, T. 159, R. 64.	170				
J. T. Wells	SE. ¼ sec. 15, T. 159, R. 64.	96	4	Shale	8	
W. C. Fawcett	SE. ¼ sec. 22, T. 159, R. 64.	367	6, 4	do	150	Shale at 260 feet.
Peter Hamm	NE. ¼ sec. 6, T. 159, R. 62.	118	2	do	30	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Nekoma	282	10			10 gallons a minute.
Steen Taby	7 miles southwest of Milton.	160	2	Shale		Turbid before storms.
Mrs. E. L. Meling.	7½ miles southwest of Milton.	120	2	do	20	Soil 3 feet, clay 9 feet, shale 108 feet.
Village	Milton	430				
Andrew Hulkstrand.	9 miles northeast of Milton.	230	2	Quicksand	16	Soil 3 feet, drift 50 feet, quicksand 4 feet, shale 173 feet.

Water supplies of towns in Cavalier County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Calio	132	Drilled	75	175	100			Deep wells yield soft and salty water, shallow wells hard water.
Calvin	525	Dug, drilled	25	200	175	Drift	Sand	
Clyde	375	do	22	178	40	do	Shale	
Hannah	500	Bored, drilled	25	150	75	do	do	
Langdon	1,228	Dug, drilled	20	150	25	do	do	Drift water of fair quality but slightly alkaline. Shale water increases in salinity with depth.
Loma	375	Bored, drilled	25	70	30	do	do	Cisterns common. Shallow well water hard and salty; deep wells soft but otherwise mineralized.
Milton	393	Dug	12	40	25	do	do	Wells mostly to shale.
Munich	248	Bored, drilled	15	125	20	Sand	do	Best water from sand bed at base of drift.
Nekoma	189	do	25	384	40	Shale or gravel.	do	Water of deep wells mostly salty.
Olga	250	Dug	20	75	25	Drift		
Osnabrock	310	Dug drilled	30	90	35	do	Shale	Shallow drift wells preferred to saline waters in shale.
Sarles	348	Drilled	37	150	50	Sand	do	
Wales			20	80				

DICKEY COUNTY

TOPOGRAPHY

Dickey County presents a considerable variety of topographic features. The western part is crossed by the Missouri escarpment, and thus almost one-fourth of its area lies on the Missouri Plateau, whereas the major part is on the Drift Prairie. The entire area lies within the region covered by the later invasion of the ice sheet, the terminal moraine of which crosses the southwestern part of the county and gives a very rough, rolling topography to that corner, because here the coteau hills and the moraine largely coincide. The lower Drift Prairie has the topography of the ground moraine deeply trenched by the valley of James River, which enters from the north and about Oakes broadens into the bed of glacial Lake Dakota. This lake plain resembles the Red River and Souris River Valleys in miniature, as it is but 6 to 10 miles wide and its length within this State is but 15 miles. Its origin is glacial in that it was formed by a morainal dam left across the course of James River in South Dakota, thus ponding the waters back as far as Oakes. The floor is very level and covered with a deposit of lake sand and silt which is so thin that it contains comparatively small supplies of ground water.

GEOLOGY

The youngest formations of the county are the alluvium of the James Valley and the silt and sand of glacial Lake Dakota. Beneath these deposits lie the deposits of glacial drift, which elsewhere form the surficial mantle of the region. The drift is everywhere, so far as known, underlain by the Pierre shale, which is in turn underlain by Niobrara and Benton shales, rarely differentiated in any of the many wells, and below these lies the Dakota sandstone, which carries a large amount of water under considerable artesian pressure.

GROUND WATER

In Dickey County water is drawn from the alluvium and lacustrine silt, the drift, the Pierre formation, and the Dakota sandstone.

Alluvium in quantity sufficient to form a water-bearing bed is limited to the valley of James River, which is not more than one-half to three-fourths of a mile in width. The small amount of gravel and sand in the valley deposits make this bed a relatively small source of supply, except for the farm lands in the valley. The lake silt is also so thin that it is of comparatively little value; its supply is meager and is drawn upon by only a few of the shallowest wells.

The drift supplies the great majority of shallow bored and dug wells. Most of these draw their supplies from the sandy layers within the drift, but many reach the more porous layer at the base, immediately above the Pierre shale.

Some wells that pass through the drift find a moderate supply of somewhat brackish water in the porous sandy layers of the Pierre shale at depths that range from 100 to 300 feet, but most wells that go below the drift are carried through the thick shale beds to the underlying artesian water.

The prairie portion of Dickey County lies within the area of artesian flow supplied by the Dakota sandstone. The entire county is underlain by this remarkable sandstone, but as it dips westward and the land rises in the same direction the pressure is not sufficient to raise the water above the surface in the plateau country west of the Missouri escarpment or even upon the face of the escarpment. The Dakota sandstone consists of alternating beds of shale and sandstone. It averages 250 to 300 feet in thickness and is overlain by a great thickness of shale, which effectually prevents the escape of the imprisoned waters to the surface. The depth of the sandstone is about 900 feet along the eastern border and about 1,500 feet at the western margin of the basin at the foot of the escarpment. A large number of wells have been drilled to this formation in the eastern portion of the county. The first well drilled into this basin in North Dakota was at Ellendale, in this county. (See p. 115.) This well was typical of hundreds of wells drilled during the next decade. High pressure and strong flows were the rule, and extravagant theories as to the quantity of artesian water and possibilities of its use for power and irrigation were spread broadcast. Soon, however, a decline in the artesian head began, though both pressure and flow were so large that little attention was paid to the symptoms of decline. Recent surveys show that the artesian pressure has largely been dissipated and that many of the wells, especially along the western margin of the area of flow in this county, have ceased to flow. This is true in a broad zone about 10 to 15 miles in width that extends from Forbes through Merricourt to the northern border of the county. The story of the wells at Ellendale that end in the upper strata of sandstone is typical. In these wells a pressure of at least 335 feet above the surface and a yield of 600 gallons a minute have been entirely dissipated. The boundary of the area of artesian flow is rapidly receding eastward in this county and will continue to do so until adequate measures of conservation are enforced. The waste should cease in order that these waters may be conserved for use.

Log of Ellendale city well No. 1

[Altitude of surface, 1,449 feet; diameter, 3¾ inches; flow, 700 gallons a minute; pressure, 115 pounds]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Yellow clay	25	25	Hard sandstone	7	1,042
Blue clay	85	110	Soft sandstone	45	1,087
Shales	925	1,035			

Log of Oakes city well

[Altitude of surface, 1,313 feet; flow, 817 gallons a minute; pressure 125 pounds]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, sand, and gravel	65	65	Limestone with breaks of pyrite	5	880
Boulder clay	15	80	White sandrock with limestone, pyrite, and shale	62	942
Blue clay	65	145	White sand	10	952
Shale streaked with lime and sand	710	855	Limestone and sand	25	977
Hard sandrock	20	875			

Several fine springs flow from the foot of the Missouri escarpment, which extends across the west end of Dickey County from north to south. These springs are particularly numerous in the vicinity of Forbes and contribute to the headwaters of Elm River, which rises in this region. A few springs also flow from the valley sides of James River, one of which is on the farm of John Lillibridge near Oakes. The flow of all these springs is constant, and when kept clear and clean they are excellent sources of water for stock.

QUALITY OF GROUND WATER

Analyses 41–49 and others in the table are typical of the many kinds of water obtainable in Dickey County. Shallow wells in the surface deposits furnish hard water which differs in mineral content, though most of it is suitable for general use. (See analyses 44, 46, 47, and 48.) A few wells draw on the sandy lenses of the Pierre shale but furnish poor water. Most of the artesian wells that end in the Dakota sandstone yield water that is soft but highly mineralized. (See analyses 41, 42, and 43.) Although somewhat salty it is widely used. A few of the deeper artesian wells yield hard water, and some yield water too highly mineralized for ordinary use. (See analysis 49.)

WATER SUPPLIES AT ELLENDALE

The people of Ellendale at first drew their supplies of water from shallow dug wells in the drift and from drilled wells in the deeper gravelly portions of the drift and the thin sandy layers in the upper part of the Pierre shale. Because these waters are less highly mineralized than the deeper waters, these beds are still used to some extent for private supplies in the city and on farms where there is little stock. The amount available is very small at either horizon.

The first flowing well in the Dakota artesian area in North Dakota was drilled by the city of Ellendale and was completed April 6, 1886. This well was 1,087 feet in depth and 3¾ inches in diameter at the bottom. Its unrestricted yield was 600 gallons a minute under pressure variously reported but probably 145 pounds to the square inch, at least, which would give it a head of 335 feet at the surface. The temperature of the water was 65° F. This supply of water came from what is known locally as the "second flow" or "soft-water flow." The "first flow," which was reached at approximately 1,000 feet, could not be cleared and was therefore cased off. It is commonly known as the mud flow. This well, which is still in use and known as the "soft-water well," was put down for a public supply, and though it can not be generally used for drinking, the water is good for protection against fire and laundry use and has been utilized to some extent for irrigating lawns and gardens. In 1901 this well was reported by Nettleton to have a pressure of 115 pounds or a head of 265 feet.

In 1907 or 1908, owing to the loss of several buildings by fire in the fall of 1907, a second well was drilled to the same horizon as well No. 1, and this well had a pressure of only 85 pounds, the same as No. 1 at this time. A higher pressure had been desired by the city and guaranteed by the driller. Well No. 2 was therefore declared a failure. This well proved that the loss of pressure was not due to defects in the first well but to decrease of pressure in the artesian reservoir. In 1911 the city records showed a pressure test of but 7 pounds, with head of 16 feet above curb.

As the third well to the "soft-water flow," drilled in 1908, failed to get better results than well No. 2, a fourth well, popularly known as the "hard-water well," was drilled to the "third flow" during the same year. This well is 1,363 feet in depth and finished with 3-inch casing. The original pressure was 196 pounds and the yield 800 gallons a minute. This is probably the largest well completed in North Dakota, pressure and flow both considered. It was connected directly to the mains to supplement the "soft-water well" for fighting fires, but as the water is hard it is unfit for laundry use, and as it is strongly mineralized it is unsuited to domestic use. A peculiarity of this water is its strong odor of hydrogen sulphide. It has a temperature of 72° F. By 1923 the pressure from this well had decreased from 197 pounds to not more than 60 pounds, according to the chief of the fire department of the city, and for this reason the new well, No. 6, which has a depth of 1,083 feet and a diameter of 10 inches, was drilled in the "soft-water vein." This well, when completed on December 23, 1923, yielded no flow, but the water stands flush with the surface after a period of rest after pumping. (See pl. 3, *A*.)

After a period of 38 years the entire pressure of 145 pounds in wells drilled into the "second" or "soft-water flow" at Ellendale has disappeared. The yield of water to the pump may, however, be considered permanent.

WATER SUPPLIES AT OAKES

The earliest supplies of water for Oakes and vicinity came from shallow dug wells in the alluvium of the James River Valley and the drift from drilled wells in the Pierre shale below the drift. These wells were largely replaced by others that extend to the Dakota sandstone, several of which were used as a city supply and furnished water under natural pressure to the mains in such amounts as to be satisfactory for protection against fire. The rapid decrease in head during the last few years and the highly mineralized character of the water caused the abandonment of this source and the use of the shallow waters of the alluvium and drift in the James River Valley. Eighteen 3-inch driven wells were put down to depths of 20 to 48 feet and yield over 500 gallons a minute to electrically driven duplex pumps.

Typical wells of Dickey County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
John Flegal	NW. ¼ sec. 18, T. 133, R. 66.	224	3	Sand	80	Adequate supply.
J. Haggarty	2 miles south of Merricourt.	1,360	2	Sandstone	Flow.	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Merricourt	23	120			20 gallons a minute.
G. G. Chambur	N. ½ sec. 6, T. 132, R. 64.	1,380	1½			
W. H. Leonard	S. ½ sec. 11, T. 132, R. 63.	1,202		Sandstone	Flow.	
N. E. Cox	NW. ¼ sec. 32, T. 132, R. 62.	1,130	2½–1¼		Flow.	Perforated 28 feet.
Anderson Bros	SW. ¼ sec. 7, T. 132, R. 62.	1,145	2½–1¼	Sandstone	Flow.	Do.
J. H. Collins	SW. ¼ sec. 27, T. 132, R. 61.	1,062	2½	do	Flow.	Perforated 18 feet at bottom.
H. H. Hanson	SW. ¼ sec. 22, T. 132, R. 59.	1,150	2	do		Blue-gray sandstone at 750 feet.
	Glover	1,000	2		Flow.	
H. C. Peek	NE. ¼ sec. 7, T. 131, R. 64.	200	4		Flow.	
Do	N. ½ sec. 4, T. 131, R. 65.	158	4		Flow.	
W. A. Caldwell	NW. ¼ sec. 24, T. 131, R. 64.	1,220	1¼	Sandstone	Flow.	Second flow.
Village [a]	Monango	1,220	4, 2½	do	Flow.	Second flow. Early pressure 67 pounds to the square inch; less than 10 pounds in 1921.
Public school [a]	do	38	34	Drift gravel	16	Tile curb; electric rotary automatic pump.
Thomas Northrup.	Sec. 22, T. 131, R. 63.	1,190	1¼	Sandstone	Flow.	Second flow.
Bruce Scott	SW. ¼ sec. 5, T. 131, R. 63.	1,225	2½–1¼	do	Flow.	Perforated 30 feet at bottom.
Conrad Jenswald	NE. ¼ sec. 18, T. 131, R. 63.	1,240	2½–1¼	do	Flow.	Perforated 10 feet at bottom.
J. J. Champlin	Fullerton	1,167	2½–1¼			Perforated 19 inches at second flow.
O. Christianson	SE. ¼ sec. 27, T. 131, R. 60.	1,080	1¼	Sandstone	Flow.	Perforated 18 feet at bottom.
M. J. Morgan [a]	SE. ¼ sec. 18, T. 131, R. 60.	950	2–¼	do		
Henry Gemeer [a]	SW. ¼ sec. 8, T. 131, R. 59.	1,145	3, 2¼	do	Flow.	Used for stock only.

[a] See table of analyses.

Typical wells of Dickey County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
N. J. Nelson	Oakes	920	3	Sandstone	Flow.	
Do	do	977			Flow.	
City	do	963	3	Sandstone	Flow.	
Do	do	1,232		do	Flow.	Into granite 2 or 3 feet.
Do	do	906	1½	do	Flow.	
Do	do	1,225		do	Flow.	190 feet to bedrock.
Do	do	870	3¼	do	Flow.	Small flow at 100 feet.
Do. [a]	do	40-48	1½-3	Alluvium	Flow.	Series of driven points for city supply.
Dr. H. P. Boardman.	do	870	1¼	do	Flow.	200 feet to bedrock.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	14	2	Sand		6 driven points in sand. 50 gallons a minute.
George Hassinger	NE. ¼ sec. 21, T. 130, R. 65.	1,455	1¾	Sandstone	30	
Ed. Byers	SW. ¼ sec. 15, T. 130, R. 63.	1,200	1¼	do	Flow.	
J. A. Snow	SE. ¼ sec. 4, T. 130, R. 60.	1,108	1½			
City [a]	Ellendale	1,363	3	Sandstone	Flow.	Original flow 800 gallons a minute. Original pressure 197 pounds to the square inch.
W. H. Jones	do	860	3		Flow.	Abandoned.
City [a]	do	1,087	3¾	Sandstone	Flow.	Original yield 700 gallons a minute. Original pressure 145 pounds to the square inch.
Do	do	1,036	1	do	Flow.	
Do	do	1,083	10	do	0	Drilled in 1923.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	1,087	6	do	Flow.	Original pressure 175 pounds to the square inch.
D. E. Greer [a]	do	22	24	Drift		Tile curb.
Daniel Niemi	SW. ¼ sec. 24, T. 129, R. 62.	1,065		Sandstone		Perforated 8 feet at bottom.
Northwestern Land Co.	Silver Leaf	960	1¼	do	Flow.	
Village	Ludden	920	1¼	do	Flow.	Perforated for 28 feet at 865 feet and 8 feet at bottom.
Great Northern Ry.	Newton	58	4			
Minneapolis, St. Paul & Sault Ste. Marie Ry	Ludden	1,050	2, 1¼	Sandstone	Flow.	

[a] See table of analyses.

Water supplies of towns in Dickey County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Forbes	293	Drilled	15	1,500		Drift	Sandstone	Most farm wells artesian. Second flow at about 1,100 feet.
Fullerton	202	Bored, drilled	20	1,200	30	do	do	Water hard in shallow and soft in deep wells.
Ludden	132	Driven, drilled	10	1,000	15	Sand	Sand	
Merricourt	70		15	158		Clay, gravel	Shale	
Monango	231	Drilled	25	1,280		Drift	Sandstone	Do.

DIVIDE COUNTY

TOPOGRAPHY

Divide County, in the northwest corner of the State, is distinctly an upland county of the drift-covered plateau type. It is crossed in the western and southern portions by the Altamont moraine, which marks the farthest advance of the Dakota lobe of the later or Wisconsin ice invasion. This moraine consists of a belt of irregular rolling hills with intervening hollows, 10 to 12 miles in width, the edge paralleling the Missouri escarpment, which here cuts off the northeast corner of the county, thus placing that tract in the Drift Prairie province. That portion of the county southwest of the Altamont moraine is moderately well covered with the older drift, which, owing to its high position on the broad plateau and distance from master streams, is but slightly dissected. This area represents probably the youngest stage of topography to be found in the older drift region of the State. Old lake beds, marshes, and undrained areas are common, and few streams have well-defined valleys. The grassy coulees carry water only in the season of melting snows and abnormal rainfall.

GEOLOGY AND GROUND WATER

Owing to the recent advent of railroads this county is but newly settled. Dug wells that draw their waters from the sandy and gravelly deposits in the drift are characteristic of the later drift, whereas similar wells in the earlier drift generally penetrate to the base and rely on the gravelly and sandy layers that lie immediately above the bedrock. The bedrock is everywhere the Fort Union formation, the sandstone and lignite of which carry water at no great distance below the surface. The shales do not yield water. There are very few springs in this region, as few valleys reach bedrock. In the northeast corner, however, springs are not uncommon at the head of the draws that lead up into the escarpment, owing to the cutting through of the layers of sandstone and lignite.

A considerable number of flowing wells occur in T. 163 N., Rs. 97, 98, and 99 W., and the fractional townships to the north, and the area of flowing wells extends also across the international boundary line into Canada. These artesian wells are divided into two groups, for some of them draw their supply from the sandy layers of the bedrock and some from the coarse glacial gravel at the base of the drift. The water from wells in bedrock is strongly mineralized and the flow is scanty, owing to the very slow movement of the artesian waters through the thin sandy layers of the shale, which constitutes the larger portion of the bedrock in this vicinity. The city artesian well and the mill well, both in Crosby, are of this type and show the limitation of these wells. The larger number of the flowing wells in the surrounding country also yield water of the same class. The artesian wells of the other group are stronger, for they draw their supply from the coarse gravel and sand at the base of the drift and above the surface of the bedrock shale. These coarse gravel deposits probably occur in old valleys which have been filled by the glacial drift and so deeply buried that their location can not be determined except as they are reached by wells. The number of these wells is as yet insufficient to predict with any degree of accuracy the lines on which other borings would strike the same beds. These wells yield remarkably good artesian waters, and though relatively high in mineral content are very satisfactory for stock farms.

The weak artesian flows of the first group found here probably owe their head to the pressure developed in the higher land of the escarpment to the west and south—a slight pressure that is due more to the higher ground-water level beneath the upland than to the outcrop of porous beds. These wells belong in what is termed the escarpment type of artesian area. They occur in a very narrow strip along the foot of the Missouri and other escarpments in the State and are most common in the drift, though a few reach the soft porous sandstone and lignite of the Fort Union at depths of a few hundred feet.

The artesian wells of the second group draw water from old valley deposits, possibly of the preglacial Missouri, or of whatever stream was flowing north through the gap in the escarpment which lies almost south of Crosby. One of the strongest drift flows in North Dakota is the well of Robert Brevis, in the SE. ¼ sec. T. 163 N., R. 97 W., 254 feet deep, 5 inches in diameter, which draws water from a coarse drift gravel and has the strongest flow in the Crosby Basin. When struck, the water mounted 4 feet above the curb and threw out glaciated limestone cobbles, pieces of fossil wood, and chunks of lignite, some of the fragments as much as 3 or 4 inches in diameter. The well log shows drift throughout until the gravel was reached at 254 feet, when the water came up with a rush, carrying the coarse gravel as described. There was a little water and sand at 224 feet, which was cased off. Natural pressure forces the water to the house, barn, and dairy house. When visited in 1916 the well had a pressure of 11 pounds and yielded 36 gallons a minute through a 1¼-inch pipe. The temperature was 48°. The owner reports that the water is roily every few days, probably owing to change in atmospheric pressure.

QUALITY OF GROUND WATER

The two sources of ground-water supply in Divide County are the drift and the Fort Union formation. Shallow dug wells in the drift furnish moderately to highly mineralized hard water, of which analysis 51 is fairly representative. Deep wells that draw on the lignite and sandstone beds of the Fort Union formation yield soft water that differs in mineral content in different places. Most of the water from the deep wells is similar to that shown in analyses 50 and 52 which represent waters that are used for domestic supplies but are not entirely satisfactory. In many parts of the county the bedrock is close to the surface, and it is necessary to draw on the lignite and sandstone beds for an adequate water supply. This water is generally intermediate in quality between the water from the drift and that from the deeper horizons of the Fort Union formation.

WATER SUPPLIES AT CROSBY

The ground waters in the vicinity of Crosby fall into two groups—the shallow waters of the drift, and the deeper artesian waters. The shallow waters of the drift are well known because of their easy access and because they have been very generally in use since the founding of the city. Most of the wells that draw their supplies from these shallow waters have been found unsatisfactory because of the ease with which they are polluted from the surface and because of the high content of mineral matter in solution in the water. Many of these wells have been dug, but comparatively few remain in use to-day, and these are therefore probably well above the average in quality. A second group of shallow wells about a mile or two west of the city are much less strongly mineralized because they draw their supply from the base of a heavy deposit of glacial gravel and sand which forms a considerable portion at least of the long northwestward-trending ridge on which several gravel pits are located. The water in this formation has largely fallen as rain on the surface of this ridge and over the area drained by the depressions on either side. This rain water finds its way readily down through this gravel and sand formation to the surface of the underlying clay, over which it flows gradually down the slope of the clay surface, probably southeastward, in the direction of the surface drainage. The waters of the drift gravel represented by these wells are unquestionably the best waters in this vicinity, not only for domestic use but, everything considered, for city supply. The old well on the Great Northern Railway right of way at the point where it crosses Main Street yields a water similar in many respects to that of the wells west of Crosby, but its location within the city prevents its use for city supply owing to danger of pollution. Besides, the indications of the surface are that the quantity of water which could be obtained here might be rather small.

Crosby is within the artesian basin that receives its name from the city. The present public supply is furnished by an artesian well 622 feet deep and 5 inches in diameter at the top and 1¼ inches at the bottom. Its water flows from a sandy layer of the Fort Union formation. In this well 260 feet of drift is underlain by shaly material chiefly to a depth of 465 feet, where the small flow was stuck in a sandy layer. The well was continued beyond 600 feet in the hope of procuring a larger flow without success. The natural flow of the well was only about 1 gallon a minute, but this is diverted below the surface into a cistern, from which it is pumped to an elevated tank by a gas engine. The water is roily at times, especially in periods of low barometric pressure, and is rather strongly mineralized.

The artesian wells in the Crosby area that obtain water from the drift gravel yield a much more satisfactory water and the largest supply which may be obtained in this region, but the distance the water would have to be carried through pipes to reach the city mains would make the cost excessive unless a supply could be developed that could be brought into the city by gravity and thus reduce the cost of maintenance to a minimum.

Typical wells of Divide County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
T. Moen	NE. ¼ sec. 35, T. 164, R. 99.	475		Fine sand		Supply at 452 feet.
Hans Sorenson	NE. ¼ sec. 31, T. 164, R. 97.	201	5	Drift	Flow.	On prairie. 3 gallons a minute; formerly much stronger; temperature, 44° F. Coarse sand and gravel.
	3 miles south of Fortuna.	530				Dry hole.
Mr. Asleson	Fortuna	611		Sand		
Village	Ambrose	492	3	Sandstone	Flow.	Slight flow; caved and abandoned.
S. W. Adamson	NW. ¼ sec. 9, T. 163, R. 99.	229	4	Light-gray sand.	Flow.	Only 8 barrels in 10 hours. Now pumped.
Do	do	325		Sand	Flow.	1,060 feet from first well; found same water-bearing bed but none deeper.
Roy Arnold	SW. ¼ sec. 1, T. 163, R. 99.	383	3	Fine sand	Flow.	Formerly 8 gallons a minute, now only 1 quart. Temperature 44½° F.
Ole Naastad	SW. ¼ sec. 10, T. 163, R. 99.	209	51	Reddish sand	Flow.	Bedrock at 202 feet. Very slight flow. Now pumped.
R. O. Storlie	SE. ¼ sec. 10, T. 163, R. 99.	236	6	Fine gravel	Flow.	1 pint a minute of brown water.
Village	Ambrose	375	3	Sand	Flow.	4 gallons a minute reduced to 1½ gallons. Comes from brown sand. Pumped.

Typical wells of Divide County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
V. L. Gilbert	NE. 1/4 sec. 13, T. 163, R. 99.	256	5	Coal	Flow.	First flow at 150 feet in quicksand. Drilled to 200 feet and water stood at surface for two years. Redrilled and flow obtained in 8-foot bed of coal. Flows 3 gallons a minute through 1 1/4-inch pipe. Gas. Slightly brown color. Temperature 44° F.
A. Nordby	NW. 1/4 sec. 15, T. 163, R. 99.	214	5			
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Crosby	15	144			Dry hole.
J. H. Stewart	SW. 1/4 sec. 34, T. 163, R. 98.	240	5	Gravel and sand.	Flow.	3 quarts a minute from gravel and sand at base of drift. Temperature 48° F. Bedrock at 240 feet.
Ed. O. Huss	NE. 1/4 sec. 1, T. 163, R. 98.		5		Flow.	On prairie. Pressure 15 pounds. Flow only 1 quart a minute; probably from sandstone. Temperature 46° F.
Peter Hagen	NE. 1/4 sec. 10, T. 163, R. 98.	198	6	Coal	Flow.	1 quart a minute of soft brown water. Yellow and blue clay; sand at 110 feet; blue clay; coal at 148 feet; blue shale; coal at 198 feet.
T. O. Huss	SE. 1/4 sec. 23, T. 163, R. 98.	312	5	Blue sand	Flow.	On prairie. 1 quart a minute. Temperature 46° F. Boulder clay to 64 feet, white sand to 67 feet, blue clay and gravel to 280 feet, hard shale to 312 feet, fine blue sand, water.
Ella Beathka	SW. 1/4 sec. 26, T. 163, R. 98.	272	5	Drift sand	Flow.	On prairie. 140 gallons a minute from 2-inch pipe. Temperature 46° F.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Crosby	20				70 gallons a minute.
City [a]	do	30	36	Drift gravel		
Do.[a]	do	622	1 1/4	Sandy shale	Flow.	Flows into cistern and pumped by gas engine. Roily. Boulder clay 260 feet, gray shale 175 feet, shale 30 feet, hard gray shale 135 feet, hardpan 12 feet, hard shale 4 feet. Small flow in sandy layer at 465 feet.
Henry Hanson	SE. 1/4 sec. 7, T. 163, R. 97.	171	2	Sand	Flow.	On prairie. Flowed 150 gallons a minute, now 6 gallons. Temperature 44° F. Water soft and slightly brown. First light flow at 106 feet. Boulders with gravel at 107 feet, blue clay with boulders at 150 feet, seep at 155 feet, shale 1 foot. Sand and gravel.
Great Northern Ry.	Crosby	23	48			Supplies town with much of its drinking water.
Minneapolis, St. Paul & Sault Ste Marie Ry.	Imperial	329	10	Clay		Small yield.

[a] See table of analyses.

Typical wells of Divide County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Dr. E. O. Halvorson.	SW. ¼ sec. 5, T. 163, R. 97.	217	5	Blue sand	Flow.	On prairie. 3 quarts a minute. Temperature 46° F. Blue clay, shale, fine blue sand.
Do	do	164			Flow.	A weak flow, and quickly pumped down.
Robert Brewis [a]	SE. ¼ sec. 6, T. 163, R. 97.	254	6	Coarse drift gravel.	Flow.	The strongest flow in the Crosby artesian basin. When struck the water mounted 4 feet above curb, threw out limestone cobbles, fossil wood, and chunks of lignite as much as 4 inches in diameter. Boulder clay, sand, and gravel, with coarse gravel at bottom. A little water in sand at 224 feet. In 1916 pressure was 11 pounds, and flow 36 gallons a minute through 1¼-inch pipe at 10 feet above curb. Temperature about 48° F.
Hans I. Larson	SE. ¼ sec. 6, T. 163, R. 97.	243	3½	Coarse blue sand.	Flow.	Original flow 4 gallons a minute. 1 gallon now. Temperature 49° F. Slightly brown.
R. H. Point	SW. ¼ sec. 4, T. 163, R. 97.	281	4, 5	Sand and coal	Flow.	Steady flow with bubbles of gas at times.
Joseph Elsbernd	SE. ¼ sec. 17, T. 163, R. 97.	307	5	Fine blue sand in shale.	Flow.	Very weak flow of soft brown water. Blue clay, gravel, and sand at 90 feet; blue clay, sand and gravel, and boulder clay at 247 feet; shale at 204 feet; fine sandy shale at 307 feet.
Peter Semingson	SE. ¼ sec. 19, T. 163, R. 97.	174	4	Sand	Flow.	A good flow, but stopped after 8 months. Yellow sand and clay 45 feet, gravel and a little water 3 feet, blue boulder clay 112 feet, shale 10 feet, sand and fine gravel 5 feet, hard shale.
Martin Vanderpan.	SW. ¼ sec. 19, T. 163, R. 97.	44	12	Gravel and sand.	20	Bored in drift.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	T. 163, R. 97		144 by 192	Drift gravel		Shallow well in head of double draw. Much water.
Frank Halbrook	NW. ¼ sec. 27, T. 163, R. 97.	168		Sand		Drift 148 feet, fine white sand 20 feet, gravel at bottom.
City	Crosby	13	96	Drift gravel	10	Dug and bored, tile curb. Much water.
Lee	SW. ¼ sec. 29, T. 163, R. 97.	38		Gravelly clay		Water at 18 feet in gravelly clay.
Crosby Milling Co.	Crosby	655	4	Sandstone	Flow.	First drilling to 335 feet dry. Abandoned. Blue boulder clay 41 feet, coarse gray sand 1 foot, clay with small gravel 20 feet, soapy blue clay at 284 feet, very fine sand, soft shale at 335 feet. Redrilled, starting in blue clay and sand and continuing through shale, clay, sand, and lignite to 655 feet. The principal supplies occur in soft, white sandstone at 575 feet. Flow about 1 quart a minute. Trace of gas.

[a] See table of analyses.

Typical wells of Divide County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Minneapolis, St. Paul & Sault Ste. Marie Ry.	NE. ¼ sec. 30, T. 163, R. 97.	20	12	Sand		70 gallons a minute.
Thompson Bros.	NW. ¼ sec. 31, T. 163, R. 97.	251	2	Sandy shale	Flow.	On prairie. Weak flow of roily water from brown sandy shale. Yellow clay and gravel 36 feet, blue clay and gravel 148 feet, grayish sticky clay 54 feet, blue gray shale 2 feet, whitish sand 11 feet.
Great Northern Ry.	Paulson					12 by 24 by 18 feet.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Bounty	300	10			
Lars Hanson	Kermit	65				Adequate supply.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	16	120			
C. Anderson	SE. ¼ sec. 33, T. 163, R. 95.	130	3	Shale	Flow.	
Frederick Dahl	SW. ¼ sec. 18, T. 162, R. 99.					
Al Reckner	Sec. —, T. 162, R. 98.	172		Coal	6	Blue clay to coal.
C. L. Poling	NW. ¼ sec. 1, T. 162, R. 98.	231	5		Flow.	Pressure 11½ pounds to the square inch. Flow 50 gallons a minute. Temperature 46° F.
Knute Unhjem	S. ½ sec. 4, T. 162, R. 98.	150	6	Sand	44	Yellow clay 55 feet, blue clay 38 feet, sand 9 feet.
William Woodward.	NE. ¼ sec. 22, T. 162, R. 98.	150	6	do	Flow.	On high hill. Flowed 3 gallons a minute.
H. H. Bardsley	NE. ¼ sec. 24, T. 162, R. 98.	320	3	Sand and gravel.	Flow.	On slope. Said to be next to strongest flow in Crosby Basin. Water soft and brown. In 1916 pressure was 7 pounds, flow 11¼ gallons, and temperature 46° F. Bedrock at 300 feet.
T. Poirier	E. ½ sec. 28, T. 162, R. 98.	622				No water.
A. C. Lindsey	SW. ¼ sec. 35, T. 162, R. 98.					Gas in dry hole. Gas would not burn.
Bilsted Bros.	NE. ¼ sec. 14, T. 162, R. 97.	279	5	Coarse gravel	Flow.	On prairie near foot of Missouri escarpment. Original head 53 feet, original flow 150 gallons a minute. Flow later only 1½ quarts a minute. Blue boulder clay 266 feet, fine blue sand 3 feet, conglomerate with iron cement 2 feet, coarse water-bearing gravel 8 feet.
Adolph Holte	Noonan	300			270	Not much water.
Coal company	do	35	2			Bored. Domestic and oiler use.
E. M. Truax	SW. ¼ sec. 3, T. 162, R. 95.	240	6	Coarse sand	80	A strong well. Coal at 30 feet, coarse sand at 200 feet.
Village	Noonan	280	5	Sand	50	Fine white sand in bedrock.
William Noonan	N. ½ sec. 6, T. 162, R. 95.	400	6			Poor water.
Jacob Kakes	SW. ¼ sec. 10, T. 162, R. 95.	295		Sand	50	75 feet of water-bearing sand.
William Fenster	SE. ¼ sec. 18, T. 162, R. 95.				Flow.	In depression on plateau.

Typical wells of Divide County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Joe Rollefson	NE. ¼ sec. 15, T. 161, R. 98.	527	6	Coal	30	Yellow clay to 40 feet, blue clay to 100 feet, shale to 160 feet, blue sandstone to 415 feet, shale to hard cap at 496 feet, gray sandy shale, coal containing water.
J. McLaughlin	NE. ¼ sec. 24, T. 161, R. 98.	40			Flow.	Bored well in foothills of escarpment.
W. C. Martin	NW. ¼ sec. 30, T. 161, R. 97.	300				Strong flow of gas. No water. Abandoned.
A. F. Glover	S. ½ sec. 24, T. 161, R. 96.	720		Sand	75	Water at 360 feet.
Dan Schulke	7 miles west of Wildrose.	210	18			Bored in drift. No water.
C. Ytrehus	NW. ¼ sec. 21, T. 160, R. 97.	202	2	Gravel	60	Water and a little gas.
Erick Johnson	SE. ¼ sec. 33, T. 160, R. 95.	218	5	Sand	128	All clay to sand.
John Bergermoen	SE. ¼ sec. 35, T. 160, R. 95.	186	5	Coal	106	Quicksand at 170 feet; otherwise clay to coal.

Water supplies of towns in Divide County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Ambrose	389	Bored, drilled	([a])	400	([a])		Sand	See table of typical wells.
Crosby	1,147	Dug, drilled	20	600		Sand, gravel	do	Do.
Kermit	37	Drilled	12			Drift		A 12-foot shallow well at head of creek east of town.
Noonan	376	do	200	400		do		Town well 150 feet deep. Gas engine and tank.

[a] Shallow.

DUNN COUNTY

TOPOGRAPHY

Dunn County has a variety of topography, but the most striking feature is the broad, rolling high plateau above which rises the Killdeer Mountain mesa in in the northwest corner. Little Missouri River flows through a deep valley in the plateau to the Missouri at the northeast boundary of the area. The topography of the county is divisible into two general types, the older drift type and the driftless type. The areas that represent these two types are separated in general by a north and south line that passes just east of the Killdeer Mountains. The drainage systems are maturely developed, even in the eastern area, and the drift has been to a large degree removed, yet the results of ice action are everywhere apparent in the subdued character of the relief as compared with the erosion topography of the nonglaciated portion on the west. The glaciated area is about equally divided between low hills of irregular shape and rather wide basin-shaped valleys. The nonglaciated area is a broad rolling plain of great extent. Scattered over this plain are low mounds, remnants of a former higher plain. Above this broad upland rise also the Killdeer Mountains, massive steep-walled mesas, to a height of over 600 feet above the plain. In the upland the Little Missouri has carved its valley to a depth of 600 feet.

GEOLOGY AND GROUND WATER

The Fort Union formation forms the bedrock throughout Dunn County, except in the Killdeer Mountains, which are capped with the White River formation. Lignite is common in the Fort Union, in beds that range from a few inches to many feet in thickness, and associated with the lignite beds are porous sandstone and thicker beds of soft gray clay. Such conditions are ideal for the development of springs in the deeply carved valleys, particularly in the western nonglaciated portion. The early ranchmen located their homes in the valleys with reference to watering places for stock and domestic use. Springs, therefore, played a notable part in determining the location of settlements in this region. Shallow wells dug into the sandy or gravelly alluvial deposits in the valleys also afford satisfactory water supplies. Besides, the lower portions of the uplands draw a meager supply of water from the base of the superficial deposits, particularly in the area occupied by drift.

In the deeply trenched valleys of Little Missouri River and its tributaries, Charlie Bob and Jim Creeks, and in the broader, shallower valley of Spring Creek a number of wells yield flows. These flows, especially those of Spring Creek, about Killdeer, Dunn Center, and Wenner, are not strong, but they are of great value to the stock interests of this country. These wells are examples of the narrow-valley type of artesian well, caused by the higher ground-water level in the adjacent uplands, which gives sufficient head to bring the water above the surface of the lowlands. Possibly artesian slope conditions are also present in the Fort Union formation, from which the water comes.

The artesian wells of the Little Missouri Valley are represented by the well on the W. L. Richards ranch, on the south terrace of the river, 18 miles north of Killdeer, in the NW. ¼ sec. 3, T. 147 N., R. 95 W. This well was drilled in 1913 to a depth of 360 feet and finished in a soft sandstone at 1¼ inches in diameter. The water-bearing beds were found at depths of 300 and 360 feet. Bedrock was reached below alluvium at 35 feet, and from this point to the water-bearing bed lay an irregularly alternating series of shale, sandstone, and lignite. The yield in 1922 was 8¼ gallons a minute under a pressure of 13½ pounds, which was measured in the house, 14 feet above the curb. The water is used for stock, as many as 2,000 head being carried on the ranch at times, and is piped through the house for all domestic uses, both hot and cold. The well becomes roily and perhaps slightly increases its flow during periods of low amospheric pressure.

The larger streams of Dunn County, including Little Missouri River, Spring Creek, and Knife River, are all fed perennially by springs, which issue abundantly from outcrops of lignite beds upon the valley sides. Excellent illustrations may be found at Sam Juel's place in sec. 4, T. 145 N., R. 92 W., where a large peat bog has accumulated over a coal bed that is the source of some very large springs. Mr. Juel uses these springs to irrigate his garden. At Anderson's ranch, 6 miles south of Halliday, a large spring, which also issues from a coal bed, is used by Mr. Anderson to irrigate his garden. Good springs issue from coal beds in the valley of Little Knife River west of Fayette. An excellent spring in the headwaters of Jims Creek flowing from a lignite bed that crops out on the east side of Killdeer Mountains has probably determined the location of the ranch and village of Oakdale, in the SW. ¼ sec. 23, T. 146 N., R. 96 W. This spring has three outlets, the water from one of which is piped through the house of the owner, Mr. M. S. Cuskeller, and gives an excellent water system for the house, and that from another, which yields 14 gallons a minute at a temperature of 44°, is piped to a stock tank. So characteristic is the relation of coal outcrops and springs that the springs are found very useful in prospecting for coal. In places where there is a slight inclination of the coal seams the springs occur on the side of the valley toward which the formations dip, whereas the other side of the creek is free from springs except small seepages. Another excellent spring in this vicinity is of historic interest, for it was about this spring that a band of Sioux Indians were encamped on July 28, 1864, when attacked by Gen. Albert H. Sully, and the ensuing engagement is known as the Battle of the Killdeer Mountains. This spring is on the Diamond C ranch, owned by W. L. Richards, in sec. 33, T. 146 N., R. 96 W., at the foot of the south end of the Killdeer Mountains, where it flows from a bed of lignite. The temperature is 47°. A flow of 15 gallons a minute was measured, and the waste probably doubles that amount. The spring waters are gathered by a concrete dam 7 feet high, from which they are led to a spring house back of the ranch home and thence to tanks in the stockyards beyond. They are being used for all domestic purposes, for watering the extensive herds of stock on the ranch, and for irrigation.

QUALITY OF GROUND WATER

The water of Dunn County differs in different places both in hardness and mineral content. Supplies of hard moderately mineralized water satisfactory for general use are obtained from the sandy or gravelly alluvial deposits of the valley and the surface deposits of the upland. The shallow sandstone and lignite beds of the Fort Union formation furnish fairly soft water to the springs of the valleys and to the deeper wells of the uplands. These waters range in mineral content from about 250 to about 1,000 parts per million of dissolved solids. (See analyses 53 and 54.) A few waters both from the shallow and from the deep wells are too highly mineralized for general use. The lower beds of the Fort Union yield soft moderately to highly mineralized water. (See p. 36.)

Typical wells of Dunn County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Mr. Miller	SE. ¼ sec. 6, T. 146, R. 95.	25	6	Coal	20	Brown, not fit for stock.
C. Morrison	SE. ¼ sec. 2, T. 146, R. 94.	412	2	Clay		Dry hole.
A. S. Thompson	E. ½ sec. 3, T. 146, R. 34.	100	6	Coal		Clear hard water.
Peter Knudsvig	Sec. 34, T. 146, R. 94.	84		Gravel	79	Water roily at times. A "blowing and sucking well." Air moves in on some days and out on others.
Fred Frels	NE. sec. 26, T. 146, R. 93.	78	6	Sand	60	
Motor Inn[a]	NW. ¼ sec. 23, T. 145, R. 95.	73	6	do	50	
Fred Brendemuhl.	Dunn Center	112	4	Coal	Flow.	Soft and brown.
Creamery	Werner	140	3	do	15	Do.
P. Vuntz	4 miles south of Loring.	130	4	Sand	50	Slightly roily.
C. Scott	Manning	76		Coal		

[a] See table of analyses

Water supplies of towns in Dunn County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Dodge	172	Bored	20	130	50			
Killdeer	512	Dug, drilled	15	75	25-50	Sand	Sandstone and coal.	
Manning	225	Bored	50	70		Coal	Coal	
Werner	198		20	100	50	do	Sandstone, coal.	Shallow flowing wells are common.

EDDY COUNTY

TOPOGRAPHY

The topography of Eddy County is that of a gently rolling drift plain almost unmodified by stream action, save that of the Sheyenne and its immediate tributaries and the James. The work of these streams was largely accomplished during their early history, while the ice sheet stood with its front along the great morainal divide just south of Devils Lake, and these streams drained southward the flood of melting waters. So early did the Sheyenne capture the waters that were flowing into the James that the James did not long survive as a large river. It remained for the Sheyenne to carry the waters for a longer period and thus carve out a great valley, which it then partly filled with the gravels and sands of a glacial valley train. When relieved of its load as the ice retreated farther north and left it a clear stream the Sheyenne began the recarving of its valley, until it has not only cut through the great gravel deposit, leaving a series of terraces on either side of the valley, but has carved the inner valley deep into the bedrock and spread a thick mantle of alluvium on its floor through which the small stream now meanders. One broad morainal ridge of hills crosses the county from northwest to southeast and forms the main divide between the two river systems and therefore the Continental Divide that separates the run-off to Hudson Bay from that to the Gulf of Mexico. Elsewhere the chief topographic features of the upland drift plain are but rolling sags and swells, with scattered pans that contain marshes or ponds and the broad, shallow winding coulees that have no apparent trend.

GEOLOGY

The geology is even simpler than the topography. The region has everywhere a thick drift cover which overlies the blue-gray Pierre shale. Probably the only exposures of this shale occur in the inner valley sides of Sheyenne River and its immediate tributaries, where the streams have cut through the till sheet into the bedrock.

GROUND WATER

All ground waters of Eddy County are obtained from the alluvium in the valleys or the drift sheet on the uplands, or, if these fail, from the shale beneath.

The alluvium and gravel of the valley train that were deposited in the valleys by the streams that flowed directly from the ice front are found chiefly in the Sheyenne, the James having lost its larger flow of waters to the Sheyenne during the stage of rapid cutting. Boulders almost cover the James Valley floor as a pavement in the vicinity of New Rockford, but no notable deposits of gravel or alluvium occur. In the Sheyenne bottom driven and dug wells obtain an abundance of water in coarse sand and gravel beneath the alluvial clays. Large areas of upland are covered with outwash sand and gravel, and gravel kames are common in the moraines. At the base of all these deposits water is found, usually in sufficient quantity for ordinary farm supplies. At Hamar abundant supplies are obtained from shallow dug and driven wells that end in sand of the outwash plain.

Drift wells in general reach sandy and gravelly layers known as "veins" and seeps in the till, and at the base, immediately above the shale, lies a better and generally larger supply. The quality of the water in the till is variable, but it is generally poor, owing to the mineral content.

Drilled wells in shale procure considerable water, generally in sandy and gravelly layers at depths in most places not greater than 250 feet, but the water is both saline and bitter, owing to the high mineral content of the shale. It is a fair water for stock but can not be recommended for household use.

Eddy County undoubtedly lies within the area of artesian flow supplied by the Dakota sandstone, but no attempt has been made to obtain a flow from this sandstone on account of the expense of the deep drilling and the probable saline character of the water. An interesting group of flowing wells is reported from Rosefield Township (T. 148 N., R. 67 W.) in the extreme southwest corner of this county, where several wells that range from 48 to 70 feet in depth yield water from drift gravel. The water rises a few feet above the surface and flows at the rate of several gallons a minute. One of these wells is reported to have yielded 40 gallons a minute. The artesian conditions are undoubtedly due to local conditions in which a gravel layer in the drift that lies on the eastward facing slope of the Missouri escarpment bears water under slight artesian pressure.

A few excellent springs emerge among the morainic hills in the northeastern part of Eddy County, in the vicinity of Hamar. Others flow from the valley slopes of Sheyenne and James Rivers, both of which cut deep valleys across this county. One of the finest springs of this type is the Nivens Spring, 2 miles east of New Rockford, on the side of the James Valley. It receives its supply from the gravel ridge which lies north of the river and here comes to the edge of the valley. Extensive seepage from the gravel causes a considerable marsh in the valley. The spring yields about 2 gallons a minute, but this indicates only to a small degree the possibilities of this source, if a collecting gallery were constructed and all the waters which go into the river through the marsh were conserved.

QUALITY OF GROUND WATER

Waters that differ widely in quality are obtained from different wells in Eddy County. Hard water is obtained from the wells that draw on valley alluvium or drift sheets of the upland. (See analysis 55.) The waters from many of these wells contain only small quantities of mineral matter, as represented by analysis 56, and can be classed as good, whereas the water from some other wells is too highly mineralized for most uses. The Pierre shale is a very inferior aquifer, and where wells are drilled to the sandy lenses the water obtained is highly mineralized and usually hard. Though this water is used in many places it is not satisfactory for drinking and other domestic uses.

WATER SUPPLIES AT NEW ROCKFORD

There are several horizons from which ground waters may be obtained at New Rockford. The city lies within the area of artesian flow of the Dakota basin, and waters from this horizon may be obtained at a depth of approximately 1,900 feet. It would, however, be so highly mineralized as to be unsuitable for public supply and would also require an air lift to bring it to the surface in sufficient quantity.

Drilled wells that penetrate the bedrock, the Pierre shale, procure small quantities in sandy layers at depths of 100 to 300 feet. This water is rather highly mineralized, though less so than that of the deeper artesian wells and because of its relative abundance in this particular locality it has been used for the public supply.

Beds of sand and gravel within the drift yield variable and generally large quantities of water. Numerous wells that extend to depths of 60 to 90 feet draw their waters from this source. Among these deposits of drift gravel those that yield the best water are the coarse deposits found near the surface. The water that flows from the Nivens Spring 2 miles east of the city is an excellent illustration of this type. The city supply is drawn from one 140-foot well and three 90-foot wells drilled in 1915. The deeper well drew its supply from the sandy layers of the Pierre shale, but the shallower wells undoubtedly procure their supply from the better waters found in the gravels at the base of the drift. These waters stand about 14 feet below the surface and are pumped by an electric centrifugal pump of 5 horsepower and a capacity of 250 gallons a minute. The city uses approximately 66,000 gallons a day.

EMMONS COUNTY

TOPOGRAPHY

Emmons County lies midway on the southern boundary of the State and is bordered on the west by Missouri River. It is part of the Missouri Plateau, which lies entirely in front of the Altamont moraine, and its topography is more mature than is common to the counties east of Missouri River. Although not overridden by the ice of the last invasion except perhaps a few square miles in the extreme northeast corner, it was covered by the earlier invasion and mantled with a layer of the older drift. But so long a time has elapsed since the glacial epoch that there has been much stream erosion, and the topography has become mature.

The larger portion of the county is of the characteristic plateau type with deep, broad valleys, which become deeper and more numerous toward Missouri River, until a rough and thoroughly dissected topography borders the great troughlike valley of that stream. The Missouri Valley is a remarkable lowland that is separated from the upland to the east by abrupt bluffs or steep slopes so that the flood plain forms the flat bottom of a trench 200 to 300 feet in depth and 2 to 3 miles in width. This flood plain lies but a few feet above normal water level and is bordered by grassed terraces, the principal one of which is about 40 to 45 feet above the river. Only upon the flood plain is there timber, and this grows only in strips and patches, leaving the greater part of the valley floor covered with grassy meadows.

Drainage is fully developed, and Beaver Creek has sunk its deep valley across the middle of the county from east to west and sent out a large number of tributaries which have dissected the upland on either side. Cattail Creek in the southern half and Long Lake and Horsehead Creeks in the northern half have performed similar work upon a much smaller scale.

GEOLOGY

The older drift lies over the uplands of Emmons County, and this in turn is extensively overlain in the northeast corner by outwash deposits from the ice front of the Wisconsin glacier. These deposits extend far westward in the lowlands in the form of valley trains. The bedrock of Emmons County includes the Pierre shale, the Fox Hills sandstone, and the Lance formation. The Lance ormation underlies the surficial deposits throughout the county except in the valley of Missouri River and its immediate tributaries. In the Missouri River Valley the Lance has been entirely removed by erosion, and the underlying Fox Hills is exposed. From the mouth of Beaver Creek southward the Fox Hills is in turn eroded away and the Pierre shale crops out in the sides of the main valley and adjacent parts of its tributaries.

GROUND WATER

The alluvial gravel of the Missouri Valley contains a large supply of water at slight depths. Water may also be found in the outwash and valley-train gravel of the northeastern part of the county. The old drift is not a very good water bearer, but wells that penetrate the bedrock generally find a good supply in the soft sandstone layers of the Fox Hills sandstone or the Lance formation. The Northern Pacific Railway well at Hazelton, 120 feet deep and 8 inches in diameter, passes first through 75 feet of blue clay, then through 45 feet of blue sandstone. Its water level is 70 feet below the surface, and it is pumped at 75 gallons a minute.

Though Emmons County is deeply trenched by the great valley of Missouri River and a number of tributary creeks from the east, all these streams are so filled with glacial débris that the outcrops of porous sandstone are largely masked by drift. A few good springs, however, occur on Big Basin Creek and its tributaries in the neighborhood of Linton and Lenwick, and some large alkaline springs are reported near Glencoe.

QUALITY OF GROUND WATER

Shallow wells in the alluvium and valley train in Emmons County yield moderately mineralized hard water, suitable for general use. Analysis 81 of a water from Logan County is fairly representative of this type of water. Deeper wells which draw on sandstone layers of the Fox Hills and Lance formations (see analysis 82) yield soft water varying in mineral content but usually satisfactory for ordinary use. Some deep wells reach the Pierre shale, which does not yield as good water as the overlying formations. The public water supply at Linton is obtained from two wells, 60 feet deep, which are pumped at the rate of 120 gallons a minute and furnish about 25,000 gallons a day to the city waterworks.

Water supplies of towns in Emmons County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Fenwick	250	Drilled	80	240	150	Drift		Many strong springs yielding good water.
Glencoe		Dug, drilled	30	180	40-90	Quicksand	Gravel	Deep wells yield soft water; springs both large and small.
Hague	315	Dug, bored	12	140	20	Sand	Sand	Small springs.
Kintyre		Driven, drilled	15	205	20-65	do	Clay	Do.
Linton	1,011	Bored, drilled	21	90	35	Gravel	Drift	
Strasburg	653	Bored	70	95				Many cisterns used because of poor well water.
Hazelton	382	Drilled			90-180		Sand and sandstone.	Shallow water hard; deeper water soft.

FOSTER COUNTY

TOPOGRAPHY

Foster County lies in the high part of the Drift Prairie, which stretches eastward from the foot of the Missouri escarpment. The Hawks Nest, a striking bit of the escarpment lies just outside the southwest corner, in Wells County. The eastern half of the county is crossed from north to south by two morainal ridges, but these are not so strongly marked as they are farther north toward Devils Lake; in fact they are little more than belts of rolling hills between which lie broader belts of gentler topography of the sag and swell type. The western part is more level, for there are no morainal ridges and the very gently rolling topography fades into an almost level, gently sloping plain about 1,600 to 1,700 feet in altitude about Carrington.

James River flows southward through the middle of the county in a trenchlike valley that was cut by the greater stream of late glacial times, which carried the drainage from the front of the ice after it retreated past this area to the moraines on the east and north and before it was diverted to Sheyenne River by still further retreat. It was for a comparatively short time a large river which cut its valley and carried away all the débris fed to it save the largest boulders, which are a characteristic feature of its bed and banks to-day. The waters were diverted so suddenly that it had no time to lay down an extensive valley train of gravel and sand during its waning, thus leaving few gravel deposits and little alluvium in its valley. The boulders form numerous riffles, and over them the small stream of summer trickles between the many detached pools and lakes that fill the lower depressions in the valley floor. Ice in winter has acted upon these boulders in the lake beds in such a way as to shove them up into low, massive boulder walls covered over with much marsh and grass. Several deep coulees, the abandoned courses of glacial streams, in which now only small streams and marshes remain, pass across the western part of the county southeastward to the James Valley.

GEOLOGY

The drift mantle is heavy throughout Foster County, and although composed mostly of till it contains much water-laid gravel and sand in the morainal region and in the coulees once occupied by glacial streams. Little is found, however in the James River Valley for the reasons mentioned above. Below the drift, of Foster County lies the blue-gray fissile Pierre shale. This formation contains a few porous sandy layers within a few hundred feet of the surface.

GROUND WATER

The drift wells form the most common type in Foster County. Most of these wells are shallow, and few are over 40 feet in depth. Excellent supplies of water are found in the gravel of the morainal areas and in the coulees, which once served as glacial spillways. A typical water from the coulees is the new supply for the city of Carrington, which is obtained from Big Slough, about 3 miles north of the city. Considerable quantities of water are obtained from sand and gravel layers at the base of the drift. Small supplies of highly mineralized water are found in porous sandy layers in the Pierre shale, but the quality and quantity both differ according to the texture and thickness of the porous layer.

The Carrington artesian well, with a depth of 1,947 feet, is the only well which has penetrated the shale to any great depth, and it draws its supply from the Dakota sandstone. Two water-bearing beds were found, the first at a depth of 1,847 feet, which yielded soft water that stood 100 feet below the surface, and the second at 1,927 feet, which yielded a flow of hard water. Both beds are in the friable white sandstone of the Dakota. The natural flow of this well was only 10 gallons a minute, owing probably to the sand that filled the casing, and an air lift was used in order to obtain a sufficient supply for the city. This well proved unsatisfactory on account of the saline character of the water, the large amount of fine sand that was pumped, and its tendency to fill up and choke with sand. It was abandoned about 1910.

Springs are rare in Foster County. They occur at but few points in the deeper valleys and generally yield but a small flow. Notable exceptions to this rule are the springs that rise from the coarse gravel and sand in the bottom of the Big Slough on C. W. Richard's farm 3½ miles north of Carrington. A permanent flow of water through the middle of the coulee below this point and open pools throughout the winter indicate a large rise of water there. The investigation of these springs led to the selection of this gravel, some distance nearer the city, as the new source of city supply. A concrete well curb 20 feet in diameter was sunk to a total depth of 31 feet, 11 feet in alluvium and 20 feet in the bed of gravel and sand that forms the bottom of this coulee. Water stands within 5½ feet of the top and is pumped into the city's system through a 6-inch main by a gasoline pump that has a capacity of 12,000 gallons an hour. This well is located half a mile above the spring but draws from the same source, which by analysis and use is proved to be an excellent supply. Other springs emerge in the valley of James River as it crosses the middle of the county from north to south, and some fine springs occur among the foothills of the Missouri escarpment in the extreme southwestern part of the county.

QUALITY OF GROUND WATER

Both the drift and the bedrock in Foster County yield waters of variable quality. Shallow wells in the upper layers of sand and gravel of the drift yield hard water, as shown in analyses 58 and 59. Other waters contain from 250 parts per million of total solids up to several thousand parts, which makes them too highly mineralized for most uses. Deeper wells draw on the sand and gravel at the bottom of the drift that overlies bedrock and yield a variety of hard waters. Some of these waters are suitable for all ordinary uses (analysis 57), whereas others contain so much dissolved mineral matter that they are not usable. A few wells that draw from the sandy lenses of the Pierre shale yield hard, highly mineralized water that is generally unsatisfactory for domestic use. A few deep wells in the Dakota sandstone in this region yield highly mineralized water, which at some places is soft and at others is hard. This water from the wells in the area of artesian flow is not as satisfactory for domestic use as water from many of the shallow wells.

Typical wells of Foster County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Northern Pacific Ry.	Guptill	14	192			
Great Northern Ry.	Grace City	21	72			Very little water.
Northern Pacific Ry.	McHenry	25	192			Brick curb; poor water.
Paul Christenson	NW. ¼ sec. 32, T. 147, R. 62.	265	4	Shale	40	Soft, salty water. Used for laundry and stock. 100 feet to bedrock.

Typical wells of Foster County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. H. Hancher [a]	McHenry	14	3	Gravel and sand.	12	
Andrew Nerley	SE. ¼ sec. 2, T. 147, R. 62.	52				
E. P. Eide [a]	SE. ¼ sec. 5, T. 147, R. 62.	16	4	Sand and gravel.	11	
John Geiger	Carrington	270				No water.
James McCoy	do	300				Do.
Electric Light Co.	do	50	288	Drift		
Northern Pacific Ry.	SW. ¼ sec. 7, T. 146, R. 66.	18	120	Quicksand		In Big Slough. 12½ feet of water.
City [a]	Carrington	31	240	Sand and gravel.		Concrete curb sunk in valley gravel of Big Slough 3½ miles north of city. Pumps 300 gallons a minute.
Do	do	1,947	2	Sandstone	Flow.	10 gallons a minute. Pressure 85 pounds. Salty. Abandoned on account of sand filling and salinity.
Chris. S. Blocher	SW. ¼ sec. 28, T. 146, R. 64.	92	5	Sand	15	Water at 35 and 75 feet.
Frank Ayers	NW. ¼ sec. 24, T. 146, R. 64.	130	3	do	40	
Louis Bradford	SE. ¼ sec. 34, T. 146, R. 62.	218		Shale	25	Slightly salty. Quicksand at 145 feet.
Tom North	NE. ¼ sec. 18, T. 145, R. 63.	186	3	do	10	
E. A. Roach	SW. ¼ sec. 9, T. 145, R. 65.	18	4½	Sand and gravel.	16	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Bordulac	80	134			
A. L. Ede	SE. ¼ sec. 26, T. 145, R. 62.	315	5			No water. 100 feet to bedrock.

[a] See table of analyses.

Water supplies of towns in Foster County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Barlow	100	Drilled	20	125		Drift		Water reported somewhat "alkaline."
Bordulac	180	Dug, bored	8	20	15	do	Drift	Hard water.
Carrington	1,420	Dug, bored, artesian.	15	45	20	do	Sandstone	See description of shallow and deep city wells, p. 131.
McHenry	299	Dug, bored	8	20	15	do	Drift	Hard water.
Melville	200	do	30	35		do	do	Water reported "alkaline."

GOLDEN VALLEY COUNTY

TOPOGRAPHY

Golden Valley County includes a broad belt of rolling upland between Little Missouri River and the Montana line. It lies entirely within the nonglaciated part of the State, and except on its western edge, where it borders the badlands, it is relatively undissected. However, several striking buttes rise above the general plateau level as remnants of higher formations now nearly removed by erosion. Chief among these features is Sentinel Butte, whose broad, flat sandstone top is capped with a low dome of limestone and clay that rises to a height of 3,350 feet. Beaver Creek drains the northern half of the county and Andrews, Garner, and Bullion Creeks the southern half, all of them tributary to Little Missouri River.

GEOLOGY AND GROUND WATER

The low knoll of limestone and clay on the crest of Sentinel Butte belongs to the White River formation, of Oligocene age. The rocks at the surface in the rest of Golden Valley County belong to the Fort Union formation. A well drilled by the Northern Pacific Railway Co. at Beach, 1,030 feet deep, is of interest as showing something of the character of the formations.

Log of Northern Pacific Railway well at Beach

	Feet		Feet
Clay	25	Shale	18
Sand	10	Rock	2
Blue clay	25	Shale	33
White clay	75	Rock	3
Coal	40	Sand and shale	48
Shale	50	Shale	692
Limerock	3		
Shale	7		1,038
Coal	7		

The residual sandy soils of the uplands and alluvium of the valleys yield considerable water to many shallow wells. Recently a number of wells have been drilled into bedrock and draw supplies from the sandstone and lignite beds of the Fort Union formation. In the town of Beach there are drilled wells 30 to 50 feet deep and in the surrounding country some that are 100 to 200 feet deep. The deep railroad well at Beach failed to get water at the deeper levels. The railroad supply in that town is now obtained from four shallow wells that yield an adequate supply of hard water.

Springs are not uncommon in Golden Valley County in the valley walls and sides of the buttes. Shallow wells sunk into the beds of coulees are frequently termed springs but are not springs in the true sense unless water flows from them. The water of these wells may, however, closely resemble that of spring waters, for it comes from the water-washed gravel, but special care should be taken to keep it pure and free from pollution by organic matter, as it is practically stagnant. An example of this type of well is that commonly known as the Gilbertson "spring" just southwest of Sentinel Butte, which is satisfactory for household use as far as its chemical composition is concerned. On Sentinel Butte there are two rather remarkable springs. One on the north side flows from a crevice in a thick bed of coal 120 feet above the well-known 20-foot coal bed at the base. The flow is about 1½ gallons a minute of amber-colored water, which is unpleasant to the taste. On the opposite side of the butte and about 250 feet below the top another small spring issues from a coarse gray sandstone, clear, cold, and sweet. This spring has a flow of somewhat less than 1 gallon a minute, but it is the purest water known to the writer in North Dakota, and the chemist pronounced it an "ideal drinking water." The contrast in these two waters is of interest. Both originate in rainfall on the broad, flat top of Sentinel Butte. The clear, sweet water passes but a short distance downward through sedimentary rocks, chiefly sandstone, which acts as a natural filter and yields but little mineral matter in solution. The same water in passing downward through other sediments, including the thick bed of lignite, gathers impurities and has an unpleasant color and taste from the lignite.

QUALITY OF GROUND WATER

Analyses 60–63 of waters from Golden Valley County and others in the table indicate that water satisfactory for general use can be obtained almost anywhere in the county. Shallow dug wells that draw on the surface material or extend into the upper beds of the Fort Union formation yield hard water of low or moderate mineral content similar to those represented by analyses 60 and 61. Deeper wells in the sandstone and lignite beds of the Fort Union formation yield moderately highly mineralized but soft waters similar to those represented by analyses 16, 17, and 151. Some waters from both the deep and the shallow wells, however, are so highly mineralized that they are used only for extinguishing fires.

Typical wells of Golden Valley County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Henry Kuhn	4 miles north of Beach.	220	4½	Sandy shale	70	Slightly colored from coal.
Northern Pacific Ry.	Beach	1,038				No deep water. 4 shallow wells yield freely.
City [a]	do	110	20	Gravel	25	
Do	do	120	6	Sand	45	Yellow clay, clay, sand, solid blue rock.
J. H. Schroeder [a]	do	26	6	Blue-gray shale.	16	
D. J. Steiner	N.½ sec. 29, T. 140, R. 105.	100	5		30	
A. L. Martin	Sec. 35, T. 140, R. 105.	242	5		62	
Village	Sentinel Butte		24			Bored well.
C. K. Barrett	do	136	6	Sandy shale	66	Yields 80 barrels a day. Poor water at 35 and 60 feet stood about 20 feet below surface.
L. M. Crawford	do	38		Sand		Dug well on north slope of town.
G. E. Ward	do	38	2	do	20	Bored 25 feet to sand. Hard blue shale at bottom.
A. L. Martin	do	210				
L. M. Crawford	1 mile southwest of Sentinel Butte.	15	4		10	Well in a draw known as Gilbertson Spring.
N. W. Runion	East of Sentinel Butte.	200				
Northern Pacific Ry.	De Mores	16	60	Alluvium		Brick curb near Andrews Creek.
B. H. Moulton	12 miles south of Beach.	165			Flow.	
R. J. Sliehl		450				No water.

[a] See table of analyses.

GRAND FORKS COUNTY

TOPOGRAPHY

The southern extension of the Pembina escarpment separates Grand Forks County into two unequal parts—the larger eastern part, which belongs to the Red River Valley, and the smaller western part, which belongs to the Drift Prairie. The valley area may also be separated into two divisions—one the part covered by lacustrine and alluvial silt in the axis of the valley near the river and the other the Elk Valley delta in the margin of the old lake bed.

These three topographic divisions cross the county from north to south. The lacustrine silt covers about three-fifths of the area, and the delta deposits and Drift Prairie each one-fifth. The silt-covered portion is extremely flat. Near the river it has an eastward slope that does not exceed 1 foot to the mile, but this slope increases westward to 4 to 6 feet near the middle of the county. From this area westward to the margin of the delta occur several well-defined beach ridges of gravel and sand that were formed by the work of the waves and currents of the lake upon the glacial till. The finer material was carried into the lake, forming the silt, and the coarser material was thrown up in these ridges, which in places attain an altitude of 20 to 30 feet above the plains. In the rear of the beach ridges in many places occur shallow alkaline swales that are due to the obstruction to the flow of water down the natural slope of the land surface. Here and there groups of boulders scattered over this part of the lake floor attest the absence of any heavy deposit of silt in this region, and the till is practically at the surface.

The delta is a gently rolling plain that is slightly higher than the silt floor to the east. It has a decided slope of several feet to a mile from the northwest, whence came the stream that deposited this material in the lake. The surface of the delta is somewhat uneven in its upper portion, owing to the unequal deposition and erosion of the distributing streams. In places also the fine sandy soil is blown into low dunes, but nothing approaching the rough topography of the Sheyenne delta is seen here, owing to the fact that the material is much finer and mingled with a large amount of silt, so that it forms a sandy loam which is exceedingly fertile, except in the dune areas.

The Drift Prairie on the western uplands is typically morainal. Hills and kettle holes mingle in monotonous profusion, with local ridges, all of which belong to the Itasca moraine, formed during the last halt of the ice sheet in North Dakota. Many glacial boulders, both small and large, are scattered about over these hills, and some stream courses in the margin of the plain above the escarpment are almost paved with them.

The escarpment appears as a conspicuous rise of the land surface when viewed from the east, in spite of the fact that it is lower and much more gentle in slope here than in the Pembina Mountain region to the north. Its rise is about 200 or 300 feet in 8 or 10 miles. It is deeply channeled by stream courses, mostly ancient, which open out upon the delta floor of the old lake basin. On the face of the escarpment lies the heavy gravel ridge known as the upper Herman beach. This beach marks the western limit of the lake at its highest stage.

Another conspicuous ridge parallels the escarpment and the delta deposits on the east in the northern part of the county. "The Ridge," as this feature is called, is the moraine formed between the two great lobes into which the later ice sheet was divided by the deflecting influence of the escarpment and was produced much as a medial moraine on an alpine glacier of to-day.

Northward in Walsh County the broad valley between The Ridge and the escarpment was filled during the closing period of the ice retreat by a large river that drained the margins of the two glacial lobes into Lake Agassiz, which it entered in the northwest corner of this county. This river was the glacial Elk River, which formed the Elk Valley delta.

The multitude of coulees that open down through the escarpment form the headwaters of Goose River, which flows to the south, and the Turtle and Forest, which flow to the northeast across the county. All three of these streams have deeply trenched the delta and wind in shallow valleys that extend across the old lake floor, yet they do not drain the region through which they flow. The drainage is immature. Kettle holes and shallow pans abound in the western upland, and shallow swales and marshes are common throughout the valley area. Some of the marshes in the northern portion are brackish, a condition which increases to distinct salinity farther north in the valley.

GEOLOGY

The surficial deposit on the valley floor is a thick layer of yellow and blue clay, the silt and mud deposited in the quiet waters on the lake. The well-defined ridges of beach gravel and sand that parallel the western margin and the sand and sandy silt of the Elk Valley delta are all varying phases of the lacustrine deposits. Beneath these deposits on the western uplands lies a heavy mantle of drift, chiefly yellow clay, that contains sand, gravel, and boulders in confused mixture above, passing into compact blue boulder clay below. The yellow and blue clays represent two phases of the same drift. The yellow clay is colored by oxidized iron compounds, but the blue clay is unoxidized and unaltered, as it has not been exposed to the action of the air.

The blue-gray Pierre shale underlies the till in the Drift Prairie, and in the escarpment this shale undoubtedly is underlain by Niobrara shale and probably by Benton shale, but these formations occur only in very narrow strips immediately beneath the drift and are not differentiated.

In the eastern part of the county a thin series of soft sandstone and shale, probably of Cretaceous age, underlies the drift and rests directly on the granite, which is reached at a depth of 385 feet in one of the wells at Grand Forks.

GROUND WATER

Water is supplied to the wells of Grand Forks County by a number of distinct materials—the delta and beach deposits, the lacustrine and alluvial silt, the drift, and the Pierre shale.

The sandy deposits of the delta and beaches in the western part of the valley undoubtedly yield the best water. It is reached by very shallow dug or bored wells at depths of 10 to 25 feet. It originates in the rainfall on the surface, which enters as through a sand filter until it reaches the impervious clay floor, where, owing to the very gentle slope of this surface, it is held as in a reservoir. There is sufficient movement down the slope to insure freshness and to yield seepage and small springs about the margin of the delta.

The waters of the lacustrine silt are also obtained, though in meager amounts, by shallow wells and may increase to moderate amounts in some sandy lenses or layers, particularly at the base immediately above the sheet of till. These waters are generally unpleasant to the taste because of the mineral matter dissolved out of the clay through long standing.

The drift is the most valuable water bearer in the area. On the western uplands there is much outwash and some gravel on or near the surface, and these materials commonly contain a good supply for shallow wells. Many sand and gravel layers and lenses occur in the body of the till sheet, and the base immediately above the bedrock almost everywhere contains a porous stratum. In these layers a considerable amount of water may be obtained, but it is generally brackish, probably from the seepage and rise of the waters from the edge of the Cretaceous beds that crop out in the escarpment.

In a belt about 30 miles in width that parallels Red River in the east side of Grand Forks County occur many flowing wells of the Red River Valley artesian system. These wells range in depth from some of 10 or 15 feet, which are little more than artificial springs, to some reaching nearly 500 feet. The wells less than 80 feet in depth are commonly supplied from sandy phases of the lake silt; those 80 to 285 feet in depth are commonly supplied from sand and gravel layers or beds in the glacial drift. These depths differ, however, in different places, owing to the very unequal depths to the floor of the old preglacial valley in which these glacial and lake deposits were laid down. The head of the water in both of these formations may be due to the fact that they lie on the west side of the very gently synclinal trough formed by this ancient valley, which opened to the north, and therefore receive pressure from the portions of the sandy or gravelly beds that lie higher in the valley to the south, especially from those that lie higher on the western slope or even on the uplands of the Pembina escarpment. Further pressure may be added from the seepage and rise of waters from the eroded edges of the Cretaceous beds, notably the Dakota sandstone, beneath the drift on the eastern slope of the escarpment, and even extending some distance out beneath the valley floor.

A few wells 280 feet or more in depth pass through the drift and obtain their supply from the underlying bedrock. The deepest of these wells in Grand Forks County was a hole reported to be 1,100 feet in depth, which was put down many years ago at the flour mill now owned by the Russell-Miller Milling Co. opposite the Great Northern Railway station in Grand Forks. The only information obtainable about this drilling is that no flow of water at the surface was procured. The next deepest well on record is that of Hans Tinglestad, in the N. ½ sec. 19, T. 149 N., R. 54 W., whose 606-foot well is finished in a white medium sand and yields a slightly salty water that heads 75 feet below the surface. The driller reported the formations in this well to consist of soil 3 feet, yellow clay 15 feet, glacial drift 82 feet, shale 156 feet, followed by blue and gray shale with harder and softer streaks, and at the bottom the white medium-fine sand. In this location near the face of the Pembina escarpment the thick bed of shale is probably of Cretaceous age, and the fine white sand is the Dakota.

The deepest flowing well recorded is that of Louis Larson, in Thompson, whose 488-foot well is reported to be in gravel with silt and drift to the bottom, which must indicate, if the report is correct, that the well is in the axis of the preglacial valley or a major tributary of this valley. The flow is so slight as to come practically in drops. The third deepest well on record in this county, that of the University of North Dakota, on the bank of English Coulee opposite the main building on the campus, reached brick-red granite at 425 feet. The casing was pulled back to 200 feet to obtain the flow, which is salty. This well is reported to have been drilled in 1885.

QUALITY OF GROUND WATER

Analyses 64–67 show that the waters of Grand Forks County differ greatly in quality. The deltas and beaches yield hard water that carries from 250 to 2,000 parts per million of dissolved solids (see analyses 64, 67, 167, and 173), but most of the waters are suitable for general use. The drift yields similar water on the uplands (see analysis 111) and hard highly mineralized water in the lowlands (see analyses 156, 157, and 172). Some waters from the drift are objectionable for drinking but are used for other purposes, including general domestic use. In the upland area a few wells obtain water from the sandy lenses of the Pierre shale. Much of this water is acceptable for general use. Where the water is too highly mineralized for drinking it can generally be used for stock, and rain water can be collected for drinking and other domestic use.

WATER SUPPLIES AT GRAND FORKS

The city of Grand Forks uses the water of Red Lake River, which enters Red River opposite the city, the confluence of the two streams giving the name to the city. Because of the abundance and good quality of this water after purification and softening, little has been done to develop ground water within the city. The conditions are in general the same as those throughout the eastern portion of the county above described, except that no flowing wells have been obtained. In the early history of the city the shallow waters of the lake silt afforded small domestic supplies. Later boring and drilling into the drift beneath yielded larger amounts of water, but neither the character nor the amount procured have been highly satisfactory, except for industrial plants where water for cooling was desired. The temperature of 45° to 47° makes ground water much more satisfactory than river water for this purpose.

Typical wells of Grand Forks County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Great Northern Ry.	Inkster					12 by 24 by 20 feet; 30,000 gallons a day.
M. D. Miller	SW. ¼ sec. 9, T. 154, R. 53.	207	2			Plenty but very salty.
Mr. Money	1 mile northeast of Orr.	410				
Mrs. Ruthford	NE. ¼ sec. 15, T. 153, R. 54.	88				Satisfactory.
W. I. Forbes	N. ½ sec. 34, T. 153, R. 54.	53	28	Clay		No water.
Mr. Beans	Honeyford	230		Sand	Flow.	Sand 20 feet, lake silts and hardpan 130 feet, sticky blue clay 80 feet, coarse white sand. Water slightly salty.
Village	Gilby	204	2	Gravel	Flow.	
Charles Harshman.	NW. ¼ sec. 4, T. 153, R. 53.	193	3	Sand	Flow.	
J. W. Scott	NE. ¼ sec. 9, T. 153, R. 53.	170	2		Flow.	
C. Peiski	NW. ¼ sec. 5, T. 153, R. 53.	28	42		Flow.	Plenty but very bitter.
D. P. Bjerkly	W. ½ sec. 11, T. 153, R. 53.	111	2	Gravel	Flow.	Plenty but salty.
Mrs. Ruthford	NW. ¼ sec. 18, T. 153, R. 53.	260	2	White sand	Flow.	Salty.
E. Abbey	SW. ¼ sec. 23, T. 153, R. 53.	35	28			
P. S. Peterson	N. ½ sec. 36, T. 153, R. 52.	248	2	Sand		Somewhat salty water. In fine white sand.
Harry Bushaw	SE. ¼ sec. 15, T. 153, R. 51.	14	2	Gravel	8	
S. Blair	SW. ¼ sec. 3, T. 152, R. 52.	172	2	Sand	Flow.	1 barrel a minute of salty water. Soil and yellow clay, blue clay, hard sandy clay, hardpan and boulders, soft material, fine white sand with pieces of lignite.
Louis Johnson	2 miles north of Kellys.	200	2	White sand	Flow.	Salty.
Louis Oleson	N. ½ sec. 8, T. 152, R. 51.	230	2	Sand		Small yield of salty water from fine white sand.
George Summier	W. ½ sec. 33, T. 152, R. 51.	98	2	White sand	Flow.	1,500 gallons a day.
City [a]	Larimore	28	12	Beach sand	24	
Great Northern Ry.	Park River					6 by 8 by 20 feet. Near Park River.
Do	Larimore					16 by 36 by 24 feet; 50,000 gallons a day.
Chris Bintz	SW. ¼ sec. 23, T. 151, R. 51.	398	2	White sand	Flow.	300 gallons a day of very salty water. Soil, yellow clay, blue clay, limestone (?), light-blue clay, white sand.
University of North Dakota.	University	425			Flow.	425 feet to reddish granite. Pulled back 200 feet to flow. Very salty.
Richards dairy farm.	1 mile west of University.	175	1¼	Sand	Flow.	Clay 120 feet, sand and gravel 35 feet, gravelly boulder clay 20 feet.
Harry Richards	University	248	2	Gravel	Flow.	Clay 125 feet; boulders, gravel, sand, and clay 50 feet; gravel and sand with water. Small flow.

[a] See table of analyses.

Typical wells of Grand Forks County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Ole Hippe [a]	NW. ¼ sec. 3, T. 151, R. 50.	26	4		19	
R. B. Griffith [a]	NW. ¼ sec. 15, T. 151, R. 50.	350	3½	Sand	6	Salty water in fine white sand. Boulder bed at about 140 feet, clay to 263 feet, hard and soft layers of fine white sand.
O'Connor Bros	NE. ¼ sec. 22, T. 151, R. 50.	135	2	do	Flow.	Water in fine white sand.
Hans Tinglestad	N. ½ sec. 19, T. 149, R. 54.	606		do	75	Till underlain by shale. At bottom fine white sand, water slightly salty.
Louis Larson	Thompson	488	3	Gravel	Flow.	Clay 125 feet. Very small flow. Gravel at bottom.
L. Wester	SE. ¼ sec. 29, T. 149, R. 50.	190	2	Sand	Flow.	Water somewhat salty.

[a] See table of analyses.

Water supplies of towns in Grand Forks County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Deep	Shallow	Most common	Shallow	Deep	
Arvilla	60		20	300	125	Gravel	Sand	Springs in sand hills form head of Hazen Brook.
Emerado	125		16	500		Clay	do	Most wells less than 100 feet deep.
Gilby	200	Dug, bored, drilled.	20	325	20–40	Sand	do	Artesian wells 210 to 325 feet deep. No flows beyond 1 mile west of town.
Inkster	368		10	25	15	Shale	do	
Larimore	1,089	Dug, bored	12	30	20	Sand	do	Much water in delta sand.
Manvel	200	Dug, drilled	10	165	15	Clay	Sand, gravel	The shallow wells yield hard water and alkaline; the deeper wells salty water.
Mekinock	300	Bored	16		30	Sand	Sand	A few weak flows.
Niagara	199		15	40	35–40	Drift		Small springs.
Northwood	935	Bored	14	25	20			Water reported satisfactory.
Orr	225		10	300				Small springs.
Reynolds	389	Dug, drilled	12		15	Gravel	Sand	Deep wells yield salty water.
Thompson	350	Drilled	15	250	20	Clay		Several wells more than 200 feet deep.

GRANT COUNTY

TOPOGRAPHY

Grant County includes a large irregular area in the south-central part of the Missouri Plateau. The upland is a rolling plain cut deeply and in many places by the valleys of Heart and Cannonball Rivers, which cross this county in the northern and the southern parts, respectively, and by their numerous tributaries, particularly Antelope and Louise Creeks, which drain much of the territory between the master streams, and by Cedar Creek, which with its master stream, Cannonball River, forms the southern boundary of the county. The drainage system is quite mature, yet the plateau itself appears to be in the old age of a previous cycle of erosion, as is evident from the fact that above it here and there rise the remnants of the higher formations as buttes and steep-sided hills.

GEOLOGY AND GROUND WATER

Grant County lies entirely within the area occupied by the earlier drift, except its southwestern portion. This drift sheet, though it has modified the topography of the upland to some extent, has so far been removed by erosion that drainage is completely developed and the bedrock is commonly exposed in the valley walls and on the steeper slopes of the hills. Over a considerable part of the area the drift is represented only by scattered boulders and is therefore not a valuable source of ground water. The alluvial deposits in the valleys yield considerable water, and the residual and wash material on the low slopes of the upland also yield small amounts to shallow wells. Over most of the northern and western portion of the county the Fort Union formation lies beneath the unconsolidated surficial deposits, and its beds of sandstone and lignite yield a considerable supply of water to relatively shallow drilled wells. In the southeastern half of the county and thence westward in the deeper valleys the sandstone, shale, and local beds of lignite of the Lance formation crop out, because here the overlying Fort Union formation has been entirely removed by erosion, and considerable quantities of water occur in some of the porous beds of this formation. It is rarely ever necessary to go as much as 300 feet in depth for water, although in some places water-bearing beds are not found and dry holes result.

Springs flow from the sandstone and lignite beds of both the Fort Union and Lance formations in many places where they crop out along the sides of the deep valleys. The flow is commonly sufficient from these beds to form valuable water supplies for stock, and many of these springs have been the determining factor in the location of the homes of the ranchers and early settlers.

QUALITY OF GROUND WATER

Shallow wells in the alluvial deposits of the valleys and in the surface deposits of the uplands yield hard water that contains small or moderate amounts of mineral matter. Analysis 100, which represents the composition of a water of Morton County, is typical of the better waters. Where the drainage is poor the ground water is too highly mineralized for ordinary use. Deep wells draw mostly on Fort Union sandstones and lignite beds and yield waters that are soft but moderately to highly mineralized, though generally usable. Analysis 73, which represents a water of Hettinger County, and analysis 101, which represents a water of Morton County, are fairly representative of the waters from deep wells in Grant County. If the Lance beds are reached, water similar to that in the Fort Union may be expected. A few wells which draw on the upper layers of sandstone of the Fort Union formation yield hard water similar to that represented by analysis 72. The springs of the valley walls seep from the Fort Union water-bearing beds, and the water is the same as that in the deep wells of the upland.

Typical wells of Grant County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Steve Dietrich	W. ½ sec. 1, T. 137, R. 88.	150	5		8	Good water in sand below shale.
L. E. Randall	Sec. 27, T. 135, R. 85.	243	2½	Blue sand	8	Soft water.
Do	do	340	2½	do		Never pumped dry; good water.
Lewis Bros	New Leipzig	72		Fine sand	9	
Northern Pacific Ry.	Carson	34	288		14	Water at 20 feet. Pumps 45,000 gallons in 6 hours.
C. Carlson	W. ½ sec. 32, T. 133, R. 83.	70	24	Clay	60	Soft water.
Mike Brown	Sec. 17, T. 132, R. 84.	145	4	Blue sand		Never pumped dry; good water.
W. L. Belden	E. ½ sec. 25, T. 132, R. 84.	45	20	Gravel		Soft water.

Water supplies of towns in Grant County

Town	Population in 1920	Kind of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Carson	277	Bored	23	40	30	Sand	Blue sand	Water hard.
Elgin	429	do		40				Do.
New Leipzig	378		70	280	80–100		Coal	Small springs yield good water. Shallow water "alkaline," deep water brown.
Shields	75		50	150				
Leith	150	Dug, drilled	18	90	50			

GRIGGS COUNTY

TOPOGRAPHY

Griggs County is centrally located in the Drift Prairie, and although it is characterized by gently rolling topography heavy morainic areas are not uncommon in the western and northwestern parts. The most striking modification of the general features is the broad, deep valley cut by Sheyenne River from north to south across the eastern edge of the county. Smaller depressions lead into this valley from the northwest. Several small lakes occupy the depressions in the morainic region, among which are Norway, Sibley, Jessie, Addie, and Red Willow Lakes.

GEOLOGY

The Wisconsin drift is spread thickly over the entire county, except where it has been cut through in the deep valley of the Sheyenne. It rests everywhere immediately upon the flaky blue-gray Pierre shale, which is well exposed in places on the bottom and lower sides of the inner Sheyenne Valley. No wells have completely penetrated the shale within this county, and in fact comparatively few have even entered the shale.

GROUND WATER

Nearly all the water used in Griggs County is derived from the drift, which is a fairly homogeneous boulder clay that averages 30 to 50 feet in thickness. Water in small quantities is generally found within a few feet of the surface, in small sand pockets, veins, or seeps and in larger quantities in sand or gravel layers at the base of the drift, where it rests on shale.

In the valley of the Sheyenne lies a belt of alluvial gravel in which water may be procured by sand points driven but a few feet into the ground.

The Pierre formation is composed chiefly of shale, which yields little water. A few thin porous sandy layers supply farm wells with a moderate amount of water of variable quality though generally mineralized. A number of the deeper holes have found insufficient water. The well of Edgar Gutormson, about 7 miles southwest of Aneta, in the W. ½ sec. 28, T. 148 N., R. 58 W., reached shale at 40 feet and penetrated to the depth of 744 feet without finding water.

Griggs County, with the possible exception of the extreme northeast corner, probably lies entirely within the area of artesian flow of the Dakota sandstone. No wells have yet been drilled to this formation, which lies from 1,400 to 1,600 feet beneath the surface. The water from the Dakota sandstone is so highly mineralized that it is not advisable to drill to this depth, provided good water can be obtained nearer the surface. It would be satisfactory, however, for putting out fires in the villages and for water for stock on the farms.

Small springs occur along both sides of Sheyenne River and its tributaries, most commonly along the line of contact between the drift and the underlying shale. Their chief use is in the pastures of the farms that extend into the valley, where they are valuable for watering the stock. Though few in number, the farmer is fortunate who can procure water for his pasture from one of them.

QUALITY OF GROUND WATER

The few wells that draw from the alluvium of the river valleys in Griggs County yield hard water that is moderately to highly mineralized, though most of it is usable. Water from the drift is hard and differs widely in quantity of dissolved mineral matter, as shown by analyses 68, 70, and 71, but nearly all of it is suitable for general use. The few wells that draw from the shale yield hard and highly mineralized water. (See analysis 69.) The Dakota sandstone would yield larger quantities of water, but the quality probably would be poorer. (See p. 41.)

WATER SUPPLIES AT COOPERSTOWN

Water supplies can be obtained in the vicinity of Cooperstown from three formations—the drift, the Pierre shale, and the Dakota sandstone.

The shallow waters of the drift have been found most satisfactory, for a rather large quantity can be drawn from shallow gravel, and these waters have a smaller mineral content than any others in this vicinity. This source is used by the city, which has developed a public supply from a well 21 feet deep and 8 feet in diameter, in which the water-bearing gravel bed lies between 18 and 21 feet beneath the surface and the water stands at 15 feet. The well is curbed with brick and has a concrete top. It is pumped by an electrically driven centrifugal pump and furnishes about 35,000 gallons a day to the waterworks. (See analysis 68.)

The Pierre formation consists chiefly of a blue-gray shale, but has thin sandy layers in the upper portion which yield somewhat mineralized water that is very generally used through this region as a supply for farms and stock. An example of this water is that of the 42-foot well of Louis Berg, in the SW. ¼ sec. 24, T. 146 N., R. 59 W., in which the shale was reached at 8 feet. This well is 3½ feet in diameter and has a concrete curb. The water stands 12 feet below the surface but pumps down rapidly. (See analysis 69.)

Artesian water from the Dakota sandstone could undoubtedly be obtained in Cooperstown at a depth of about 1,400 feet. The water would, however, be unsatisfactory for public use, as it is strongly mineralized.

Typical wells of Griggs County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Northern Pacific Ry.	Binford	34	240			Brick curb.
Fred Walbridge	Cooperstown	16		Sand, gravel	7	Sold for drinking and washing.
Louis Berg [a]	SW. ¼ sec. 24, T. 146, R. 59.	42	3½	Blue shale	12	
R. C. Cooper	do	26		Gravel		Pumped by gas engine.
Cargset Elevator Co.	do	370				
Boostrown farm	2½ miles northeast of Cooperstown.	511				Very small supply. Bedrock at 30 feet.
City [a]	Cooperstown	21	8	Gravel	15	
Mr. Bostrom	SW. ¼ sec. 11, T. 146, R. 58.	537	4			Dry hole.
Great Northern Ry.	Sutton	18	216			
Do	do	94		Drift gravel	25	
Northern Pacific Ry.	Hannaford	8	72			Brick curb.
Great Northern Ry.	do	24	144			Near Baldhill Creek.
S. H. Berg	SW. ¼ sec. 5, T. 144, R. 59.	68	6	Gravel	40	Good supply.
Hannaford Hotel. [a]	NW. ¼ sec. 8, T. 144, R. 59.	100	5	do		
Mrs. Mabel Thorson. [a]	SW. ¼ sec. 5, T. 144, R. 55.	80	6	do		

[a] See table of analyses.

Water supplies of towns in Griggs County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Binford	393	Dug, bored			25-45	Drift, sand		
Cooperstown	1,112	Dug, bored, drilled.	15	200	35	Sand		Numerous cisterns.
Hannaford	431	Bored	25	100	90	Drift	Drift	Railway uses creek water.
Walum	40	Dug, bored			25-40	do		

HETTINGER COUNTY

TOPOGRAPHY

Hettinger County lies in the south-central part of the Missouri Plateau, popularly known as the Missouri slope. The topography is of the rolling plateau type, marked by a few high buttes and many low ones that correspond in elevation to the most elevated of the plateaus of which they are plainly remnants and by extensive nearly level stretches in the valleys of the larger streams. The drainage system is fully mature. The North Fork of Cannonball River crosses the county diagonally from the northwest and is joined at the eastern margin by its chief tributary, Thirtymile Creek, which drains the northeast half of the county, whereas tributaries of the South Fork drain the southwest half.

GEOLOGY AND GROUND WATER

The county was untouched by glacial ice and the drift is therefore absent. The superficial deposits consist of residual soil on the uplands and alluvium in the valleys, both of which are quite extensive. Beneath these deposits the Fort Union formation, which consists of clay, sandstone, and lignite, is everywhere present and crops out along the upper slopes of every stream valley and in the steeper slopes of the buttes and mesas. The storage and movement of ground water are highly favored in the lignite beds and heavy layers of sandstone, so that where these crop out, as they do in all valley sides, springs and seeps are common. Large springs issue from talus on the valley sides and are considered certain evidence of the presence of thick beds of lignite by prospectors in this region.

The beds of rock that give rise to springs in the valleys supply water to the deeper wells on the uplands. Until recently, however, the shallow waters in superficial deposits, particularly in the alluvium and wash of the valleys, were generally sufficient for the settlers, but as the uplands are now being farmed, drilled wells are coming into use.

The log of the 225-foot well of the Rex Live Stock Co., 7 miles east and 6½ miles south from Mott, in the NE. ¼ sec. 9, T. 132 N., R. 92 W., is so carefully preserved that it is presented in full as given by Mr. J. R. Chalmers, of Mott, the driller. This well is 4 inches in diameter and is pumped at the rate of 8 barrels an hour. The water stands 120 feet below the surface and is clear and soft.

Log of Rex Live Stock Co. well southeast of Mott

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Chocolate-colored silt-loam	1	1	Rock	1	119
Yellow clay	5	6	Blue clay	13	132
Coal, slacked or rotten	3	9	Coal	1	133
Blue clay	28	37	Blue clay	19	152
Rock	1	38	Soft rock	1	153
Blue clay	22	60	Blue clay with strata of shells and coal flakes	9	162
Black clay	5	65	Coal	2	164
Coal	1	66	Dark clay and very fine sand	16	180
Whitish blue clay	29	95	Fine white sand, supplied 1 gallon a minute	10	190
Blue sand, no water	2	97	Blue clay	12	202
Coal	8	105	Soft sandrock and water	23	225
Black clay	1	106			
Coal	2	108			
Blue clay	10	118			

On the lowlands, notably in the valley of Cannonball River, about Mott, the rock yields flowing artesian water to wells at depths of 120 to 150 feet.

Springs in Hettinger County occur chiefly in the valley slopes of the North Branch of Cannonball River and its tributary Thirtymile Creek. These streams are fed perennially by springs which issue abundantly from the beds of lignite. Evaporation stops most of the flow in summer, so that the water stands in the creek channels only in pools. The streams begin to flow in the fall, even though no rain may have fallen. They gradually increase until their volume is considerable, though the supply comes entirely from ground-water seepage and the flow of springs. In places they flow from the outcropping lignite and sandstone on the sides of one of the larger buttes. Such as are of sufficient size are valuable in supplying the farms and ranches with water for stock.

QUALITY OF GROUND WATER

The shallow wells in Hettinger County obtain hard water that carries small to moderate amounts of mineral matter both from the alluvium of the valleys and from the residual soils and the upper sandstone and lignite beds of the Fort Union formation on the uplands. Analysis 72 is representative of most of these waters, but a few contain too much dissolved mineral matter for general use. Deep wells that enter the lower sandstone and lignite beds of the Fort Union formation yield soft, moderately to highly mineralized water, most of which is usable. (See analysis 73.) Some of the water from the lignite is colored but not enough to make it objectionable for general use.

WATER SUPPLIES AT MOTT

There are two sources of ground water in Mott—the alluvial deposits of the valley floor and the sandstone and lignite of the Fort Union formation.

On the valley floor numerous wells, 18 to 25 feet in depth, draw water from the sand that lies at the base of the alluvium. This sand was deposited on the floor of the valley at a time when it was deeper than at present, probably during the glacial epoch, when the run-off was much greater. It was laid down in a thick bed, the coarser sand at the bottom, and upon this deposit the fine sandy alluvium of the surface was laid down to a thickness of 10 to 20 feet. Wells that pass through the silt draw water from the sand but as a rule do not penetrate it to a great depth, for it is so fine that it flows readily with the water. A considerable supply for domestic use, however, is obtained from these wells, and much larger quantities could probably be procured by packing the wells with coarse sand or gravel. They afford undoubtedly the best supply of water for public use if a sufficient quantity could be obtained in a way that would insure the sanitary character of the water. Water is found in considerable abundance in the beds of sand and lignite that alternate with the shale of the Fort Union formation. These waters are light brown and so strongly mineralized that they are not entirely satisfactory for domestic uses. Practically all the wells of this bed on the valley floor flow from 1 to 4 gallons a minute. So slight is the head, however, that the wells up on the valley sides must be pumped.

A well of each type is owned by the Brown Hotel. The shallow well is 21 feet in depth, 3 feet in diameter, and curbed with tile. It is the more satisfactory for drinking water. The deeper well, which is 177 feet deep and 3 inches in diameter, draws its water from a lignite bed and yields 26 gallons a minute of a brown water that is more suitable for laundry use. (See analyses 72 and 73.)

The flowing well at the Stewart mill, 123 feet deep and 4 inches in diameter, ends in coarse blue sand and formerly flowed 5 gallons a minute of light-brown water of satisfactory quality. The following log was reported for this well.

Log of well at Stewart mill at Mott

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand and gravel	25	25	Coal	4	97
Blue clay	5	30	Coarse blue sand	26	123
Gray-blue rock	2	32	Blue shale (not penetrated).		
Shale	61	93			

Typical wells of Hettinger County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Alf White	Sec. 7, T. 136, R. 98.	125	6	Gravel		
Ole Gullickson	SW. ¼ sec. 26, T. 136, R. 98.	66	5	Sand		
J. E. Edens	SW. ¼ sec. 20, T. 136, R. 97.	123	6	do	48	
Otto Werner	NE. ¼ sec. 26, T. 136, R. 97	303.	4	Coal	286	
Harry Fink	NE. ¼ sec. 28, T. 136, R. 97.	57	6	do	21	
Robert Zempel	SE. ¼ sec. 28, T. 135, R. 97.	202	5	Sand	93	
W. J. Peters	NE. ¼ sec. 32, T. 135, R. 97.	170	5	Coal		
Matthew Thiel	NE. ¼ sec. 35, T. 135, R. 97.	212	5	do	126	
J. W. Stribbling	New England	84	6	Sand	20	
Otto Fresonke	NW. ¼ sec. 8, T. 134, R. 97.	101	6	Coal	14	Colored water.
S. J. Kaloen	S. ½ sec. 10, T. 134, R. 97.	136	5	Quicksand	116	Blue water.
C. J. Prior	NE. ¼ sec. 18, T. 134, R. 97.	137	5	Sand	42	
John Buck	SE. ¼ sec. 18, T. 143, R. 97.	129	6	do	30	Yellow water.
Alfred Strehlow	Sec. 21, T. 134, R. 97.	167	6	Coal	60	Colored water.
Bert Wear	SW. ¼ sec. 32, T. 134, R. 94.	240	3	Brown sand		Brown water.
Emanuel Barth	Mott			Sand	Flow.	Now flows only into basement.
Barth Mercantile Co.	do		6		Flow.	4 gallons a minute.
First National Bank.	do	125	4	Sand	Flow.	Pumped.
J. J. Lee	do	66	6		41	Light brown.
H. K. Sampson	do				Flow.	2½ gallons a minute.
Joseph Aner	do	151	4		40	On hill.
A. B. Egeland	do	140	4		40	
Rivel Bros	do	136	6		Flow.	Pressure 2 pounds to the square inch. Pumped.
N. A. Moyin	do	161			35	On hill.
Kaspee Jauner	do	145	2	Sand	Flow.	West side of Cannonball River.
Paul Bohn	do	132	6		Flow.	Pumped.
Josephine Steake	do	117	4	Coal	Flow.	1 gallon a minute. Coal at 94 to 97 and 112 to 115 feet.
Simon Kuhn	do	245	4		100	Brown water.
Jacob Barth, sr	do	140	2		Flow.	West side. 2½ gallons a minute.
Jacob Barth, jr	do	126	4		Flow.	First flow on west side.
O. V. Haum	NE. ¼ sec. 4, T. 134, R. 93.	335	3	Brown sand	115	Soft brown water.
E. H. Trousdale	W. ½ sec. 13, T. 134, R. 93.	345	2	do		Do.
E. Barth	E. ½ sec. 33, T. 134, R. 93.	202	2	do		Do.
Paul Bowen	3½ miles northeast of Mott.	300	6	Sand	90	
W. H. Brown Co.	4 miles north of Mott.	360	3	do	100	Bown color.
William Stiles	2 miles north of Mott.	194	4	do	90	
Marie Eberdt	Mott	130	2	do	Flow.	Water at 22 feet, at 52 feet (in 2 feet of gravel and sand), at 90 feet, at 115 feet (in coal), and at 115 to 130 feet (in sand).
Joe Kolkema	E. ½ sec. 5, T. 133, R. 92.	408	2		60	
Paul Schultz	NW. ¼ sec. 7, T. 133, R. 92.	131		Sand	90	Small yield.

Water supplies of towns in Hettinger County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bentley	90	Bored	40	140	80	Coal	Coal, sandstone.	Few wells 120 feet deep. Flow at 140 feet.
Havelock	58		75	110		Sand	Coal	
New England	613	Bored, drilled	50	140	60	Coal	do	Small springs.
Regent	262	Drilled	25	100	60-90	Clay	do	Water in shallow wells is alkaline, in deep wells is soft. Flowing wells at depth of 100 feet. Brown water from coal.

KIDDER COUNTY

TOPOGRAPHY

Kidder County is a typical drift-covered portion of the Missouri Plateau. It is situated high on the divide between Missouri River and its prairie tributary, James River, just back from the edge of the escarpment. It is without a single valley of note, and is all plateau. It also lies wholly within the area covered by the last invasion of glacial ice and is therefore entirely covered with drift. Much of it is within the broad belt of the terminal (Altamont) moraine of the Wisconsin ice sheet and it is therefore very strongly morainic in character. Rolling hills, separated by irregular depressions, filled with remnants of alkaline lakes and marshes, characterize the landscape, and the only drainage worthy of mention is that through a series of grass-grown coulees which mark the lines of ancient glacial spillways leading to Long Lake on the southwestern boundary and thence toward the Missouri.

GEOLOGY

The accumulation of glacial débris spread over the upland and heaped into moraines is so great that all bedrock is deeply buried beneath this mantle. So little is known of the underlying rock in fact that it is uncertain whether the entire county is underlain by Pierre shale or whether the Fort Union formation extends into or across the county from the northwest and the Lance formation enters the southwest corner. At any rate the representatives of the latter formations must be comparatively thin, and the few wells that have entered the bedrock have been largely in the blue-gray Pierre shale, but the Fox Hills sandstone which overlies the Pierre, probably supplies wells at Steele.

GROUND WATER

Practically all wells in Kidder County are drift wells, and few exceed 150 feet in depth. The most productive water bearer is probably a thick sand bed that overlies the bedrock, though a few wells have passed through the drift into bedrock. Many wells find water in sand and gravel lenses and layers within the boulder clay, and many others utilize the rather uncertain waters of the surface glacial gravel, which is fairly common though very irregular in distribution.

This county is probably everywhere underlain by the Dakota sandstone at depths of 2,000 to 3,000 feet, but it lies west of the area of artesian flow. Flowing wells could therefore not be obtained from this formation, and the pressure would be insufficient to bring the water near the surface. The cost of the well and the cost of pumping would therefore both be prohibitive and, besides, the water would be highly mineralized. A few small flows are obtained from the drift in the southern part of the county among the hills and lakes of the Altamont moraine. These wells are shallow and the flows are the result of very local conditions, but they are valuable sources of water for stock.

Among the high morainal hills of Kidder County there are many large gravel deposits from which water issues in a few places in the form of springs which feed lakes that have no outlets. Several of these springs, particularly in the Tappan region, are sufficiently large to supply large herds of stock.

QUALITY OF GROUND WATER

The drift in Kidder County yields hard water that ranges in mineral content from about 250 to several thousand parts per million. Analysis 146 is fairly representative of waters from the drift in Kidder County. Wells sunk to the coarse gravel that overlies the bedrock generally yield usable water. Deeper wells that draw on the sandstones of the bedrock may yield soft water that differs greatly in composition, as shown in analyses 29, 74, and 75. Most of this water is suitable for general use.

Typical wells of Kidder County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Mr. Herkit	3 miles south of Wallace.	205	2	Sand	8	Drift 180 feet, sand 25 feet.
John Shoemaker		245		do	5	Blue clay 235 feet, sand 10 feet.
Northern Pacific Ry.	Dawson	25	288			Brick curb.
Do	do	135	10		40	
Do	do	140	10		84	Abundant water.
Do	Crystal Springs	23	240			Wood curb.
R. L. Phelps [a]	SE. ¼ sec. 17, T. 139, R. 73.	120	4	Brown sandstone.	60	
City [a]	Steele	110	2½			

[a] See table of analyses.

Water supplies of towns in Kidder County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Dawson	293	Dug, bored, drilled.	10	150	20	Drift		Northern Pacific Ry. reports water best west of Jamestown.
Steele	550	Drilled	65	150	100	do	Sand, gravel	Small springs.
Tappen	182	Dug, bored, driven.	10	25		Gravel		

LA MOURE COUNTY

TOPOGRAPHY

The Missouri escarpment crosses La Moure County from north to south near the western border. The larger portion of the area therefore lies within the Drift Prairie; the smaller western portion is on the Missouri Plateau. The step between the plain on each side of the escarpment is here between 300 and 400 feet high, and, though gentle to the north, it becomes steeper to the south. The entire county lies well within the area covered by the last invasion of glacial ice and therefore presents the features characteristic of a drift-colored region.

The prairie portion of the county is a gently rolling plain crossed by James River, which parallels the escarpment at a distance of about 20 miles. The valley of the James is a rather steep-sided, flat-bottomed trough about a mile in width. Even the casual observer can see that it must have been formed by a river much larger than the sluggish, meandering, vegetation-choked stream of the present day. The studies of the glacial geology of the State show that this valley was excavated by the waters that flowed from the front of the melting ice sheet when it stood to the north and east of the James Valley. The James Valley contains no great valley train of gravel and sand, such as that of the Sheyenne, but the floor is paved in places with large boulders, which the great river left in its bed. On these materials lies a rather thick layer of recent alluvium, through which the present stream meanders widely when it carries sufficient water to flow at all. During the summer the bed contains many detached pools, separated by areas grown to coarse grass.

The upland is broken by a few streams, of which only Bone Hill and Cottonwood Creeks on the west are worthy of note. Elsewhere it is a broad, gently rolling plain. The margin of the Missouri Plateau is broken by numerous deep, dry coulees, carved chiefly by streams that flowed in times long past, which give the landscape a somewhat rugged appearance. On the more level portions of both plains surface drainage is almost absent. In a deep channel of a former glacial stream that parallels the James Valley northeast of La Moure lie the Twin Lakes, the largest of the several glacial lakes of the county.

GEOLOGY

La Moure County is underlain by a thick deposit of glacial drift of the ground moraine. The valley of James River is underlain by a thin layer of alluvium underneath which is the blue-gray Pierre shale. Beneath the Pierre are the Niobrara and Benton shales, which overlie the Dakota sandstone. The Dakota is the valuable artesian aquifer of this region, and its character is well known from the records and drillings of many wells that have penetrated it. In the La Moure well, beneath this sandstone, at 1,300 to 1,328 feet, was encountered light purplish and buff compact limestone.

GROUND WATER

Four distinct water-bearing formations supply the wells of La Moure County—the alluvium, the glacial drift, the Pierre shale, and the Dakota sandstone. The alluvium of the James River Valley yields in places a considerable amount of water to sand points or driven wells, but owing to the small area of the valley floor this deposit is not a valuable water bearer.

Most of the wells draw their supply from the drift, and as this deposit is of the ground-moraine type the supply comes from layers of sand and gravel in the body of the boulder clay or from a porous layer that immediately overlies the shale. The water from these shallow wells is fairly satisfactory, but the supply is not very great.

A few wells penetrate the shale beneath the drift and find rather brackish water in the porous sandy layers of the Pierre. These wells are not very common, however, for farmers who desire a larger supply than is found in the drift generally seek the artesian water.

La Moure County is entirely underlain by the Dakota sandstone, which contains water under artesian pressure. This formation, which averages 300 feet or more in thickness, is overlain by a thick body of shale. The depth of the sandstone is about 900 feet along the eastern border, but, owing to the westerly dip of the formation and the rise of the surface in the same direction, the depth gradually increases to the foot of the escarpment, where the sandstone lies 1,500 to 1,700 feet below the surface, or practically at sea level. The head of the water is sufficient to afford flows throughout all the Drift Prairie, but on the escarpment and the higher plateau to the west the pressure is insufficient to bring the water to the surface. Many flowing wells that range in depth from 900 to 1,350 feet have been drilled. One of the earliest wells drilled in the Dakota artesian basin in North Dakota was located at Edgeley and reached a depth of 1,354 feet. This well obtained a yield of 500 gallons a minute together with a considerable amount of gas at a pressure of 60 pounds to the square inch. High pressures and strong flows were the rule in the wells that were first drilled. Soon, however, began the decline, in both pressure and flow, which has continued to the present time. Along the western border of the area of artesian flow lies a belt 10 to 15 miles in width in which all artesian wells have ceased to flow. This belt passes entirely across the county, through Edgeley and Nortonville. An area of about 300 square miles in this county in which almost every prosperous farmer owned a flowing well is now outside of the area of flow. It is hoped to check the eastward recession of the boundary of the area of artesian flow through careful conservation of the artesian waters without interfering with any necessary use.

Good springs are common in La Moure County, particularly in the belt of hills at the foot of the Missouri escarpment, which extends across the western end of the county from Alfred to a point about 10 miles west of Edgeley.

A few springs also flow from the sides of the valleys of James River and the creeks immediately tributary to it. Such springs are of great value on the stock farm because of the constant supply of fresh water which is relatively cool in summer and warm in winter.

QUALITY OF GROUND WATER

Analyses 76–80 represent waters from three of the four sources of water supply in La Moure County. The alluvium of the river valley yields hard, moderately to highly mineralized water, which is fairly well represented by analyses 47 and 48. The drift yields hard water which differs considerably in mineral content in different places, but most of this water is satisfactory for general use. (See analysis 78.) Wells that enter the Pierre shale yield moderately to highly mineralized water with varying amounts of hardness. Analysis 76 is representative of the better waters from the shale and indicates that some of them are satisfactory for general use. The Dakota sandstone in this county yields to flowing wells highly mineralized waters that differ in hardness. (See analyses 49, 77, 79, and 80.) Some waters from the Dakota sandstone in this area are so highly mineralized as to be unfit for domestic use.

WATER SUPPLIES AT EDGELEY

The city of Edgeley formerly obtained a public water supply from a 6-inch artesian well that was drilled in 1892 to a depth of 1,354 feet. A bed of the Dakota sandstone was penetrated between 1,300 and 1,350 feet. The original pressure was 60 pounds, which gave a head of 138 feet above the surface and a flow of 500 gallons a minute. The water was strongly mineralized and contained a considerable amount of gas, which was at one time drawn off and used to some extent for lighting in the city.

The rapid fall of the artesian head in this region in recent years is indicated by the fall of 18 feet in this well in three years of record, or 6 feet a year. In 1916 the well was reported as flowing with a head of 3 feet; in 1917 it was reported as flush with the surface; and in 1919 the static head was reported as 15 feet below the curb. The well is now plugged at the top, and the floor of the present city electric light and pumping plant is laid over it. In 1907, when it was recased, the pressure was 15 pounds, giving a head of 35 feet; in 1912 it was about 5 pounds, or 12 feet.

The well originally flowed directly into the mains and gave direct fire and domestic pressure for the city; later, as pressure decreased, it was turned into a reservoir and pumped into the mains. During this period it was noted that the well showed the effect of storms, becoming roily and throwing a little sand every few days before stormy weather and when the barometer was low.

On account of its high mineral content the water was used chiefly for fighting fires, and to some extent for stock and boilers. However, it corroded the boilers so badly that this use was early abandoned. Since the abandonment of the artesian supply, a shallow well in the glacial drift pumped by steam into reservoir and mains supplies the city with water.

About town there were formerly many dug wells 15 to 40 feet in depth, but on account of the alkaline character of the water drilled wells 3 to 4 inches in diameter and 70 to 130 feet in depth have replaced them. These wells pass 20 to 60 feet into bedrock shale. The water is satisfactory for most purposes. Deeper wells yield salty water and are therefore avoided, except where large amounts are necessary for stock farms, when it may be necessary to pump the former artesian wells that are between 1,300 and 1,400 feet in depth.

Typical wells of La Moure County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Northern Pacific Ry.	Alfred	26	192			
Fred Steel	SW. ¼ sec. 10, T. 136, R. 65.	185	4	Sand	60	
Julius Barnick	NW. ¼ sec. 11, T. 136, R. 65.	1,615	2	Sandstone	Flow.	1½ gallons a minute salty water. Gas present in second flow. No gas in "first" flow.
Carl Kuennings	NW. ¼ sec. 34, T. 136, R. 65.	308	4	Sand	90	
Ole Edstrom	NW. ¼ sec. 35, T. 136, R. 65.	108	24	Gravel	9	
O. J. Cripe	N. ½ sec. 15, T. 136, R. 64.	148	1	Sand	40	Good yield from sand in shale.
Dave Savage	7 miles north and 5 miles east of Jud.	1,436	2			Just east of foothills. Original pressure 35 pounds; 16 gallons a minute second flow.
Northern Pacific Ry.	Adrian	25	192			Brick curb.
L. S. Platon	SE. ¼ sec. 3, T. 136, R. 59.	800	1½	Sandstone		

Typical wells of La Moure County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
John Tebrugge	SE. ¼ sec. 2, T. 135, R. 66.	138	24	Gravel	130	"Good water." Yellow clay 34 feet, blue clay 104 feet. Gravel at bottom.
Will Neal	SW. ¼ sec. 6, T. 135, R. 66.	92	24	Sand	52	"Good water." Yellow clay 30 feet, blue sand 62 feet.
T. J. Cline	SE. ¼ sec. 11, T. 135, R. 66.	172	24	do	90	"Good water." Yellow clay 35 feet, blue clay 132 feet, sand 5 feet.
G. F. Podoll	N. ½ sec. 14, T. 135, R. 66.	134	24	do	80	"Good water." Yellow clay 42 feet, blue clay, 97 feet, sand.
H. A. Podoll	N. ½ sec. 22, T. 135, R. 66.	104	24	Fine sand	30	"Good water." Yellow clay 35 feet, blue clay 69 feet, sand.
Sam Gilbertson	SW. ¼ sec. 35, T. 135, R. 64.	115	4	Sand	40	"Good water; plenty."
A. Ness	E. ½ sec. 35, T. 135, R. 62.	1,110	1¼	Sandstone		
E. L. Orness	W. ½ sec. 35, T. 135, R. 62.	1,117	1¼	do		
A. L. Forkert	W. ½ sec. 3, T. 135, R. 59.	928	2½	do		30 gallons a minute. Perforated 7 feet at bottom.
C. Beebe	4 miles southwest of Diesem.	130	24	Fine sand	4	Difficulty in finishing well due to sand.
Ernest Dallman	Diesem	160	4		40	Strong well.
Louise Bethka	S. ½ sec. 14, T. 134, R. 64.	313	4	Shale	65	Salty; some gas.
R. R. Davis	SE. ¼ sec. 24, T. 134, R. 64.	1,286	1¼		Flow.	
H. M. Studebaker	SW. ¼ sec. 27, T. 134, R. 63.	1,260	1		Flow.	
William Frohm	NW. ¼ sec. 30, T. 134, R. 63.	1,300	1			Not used on account of gas.
Levi French	SW. ¼ sec. 5, T. 134, R. 62.	1,110	1	Sandstone	Flow.	
Henry Pickford	W. ½ sec. 5, T. 134, R. 62.	400	4			No water. Soft shale at 178 feet.
Schockman Bros.	N. ½ sec. 17, T. 134, R. 62.	1,165	1½	Sandstone		
M. K. Frosland	S. ½ sec. 19, T. 134, R. 62.	1,170	1	do		
H. M. Studebaker	1 mile east, 1 mile north of Medbury.	1,240	1	do	Flow.	
Ole Horsager	SW. ¼ sec. 30, T. 134, R. 62.	1,175	1½	do		
John Young	S. ½ sec. 33, T. 134, R. 62.	1,175	1¼	do	Flow.	Salty, soft.
Paul Schockman	N. ½ sec. 35, T. 134, R. 2.	1,155	1¼	do	Flow.	
J. A. Johnson	NW. ¼ sec. 21, T. 134, R. 61.	1,055	1¼	do	Flow.	
Do	NE. ¼ sec. 29, T. 134, R. 61.	1,060	1¼	do		
G. G. Downing	NW. ¼ sec. 33, T. 134, R. 60.	980	1¼	do		
Charles Punz	Kulm	293	4	Sand	60	Slightly hard but good.
G. J. Dobler	do	300	2	Blue sand	100	
Kulm Electric Co	do	288	2½	Sand	60	Good.
Minneapolis, St. Paul & Sault Ste. Marie	do	314	10	do		Insufficient. Supply now pumped from 250 feet.
City	Edgeley	1,354	6	Sandstone	Flow.	
J. F. Curtis	do	1,360	2	do	Flow.	Salty water with gas. Formerly used to light Hotel Northern.
Chicago, Milwaukee & St. Paul Ry.	do	26				Unfit for boiler use.
Otto Bailey	NE. ¼ sec. 1, T. 133, R. 63.	1,190	¾	Sandstone		
Lee R. Herring	NE. ¼ sec. 26, T. 133, R. 63.	400	4			Clay to 107 feet; shale. No water.
J. R. Thompson	S. ½ sec. 5, T. 133, R. 62.	1,155	1	Sandstone		

Typical wells of La Moure County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Ole Nelson	NE. ¼ sec. 6, T. 133, R. 62.	1,162	1	Sandstone		
Nick Linden	NE. ¼ sec. 30, T. 133, R. 62.	1,160	1	do		
John McDonald	NW. ¼ sec. 31, T. 133, R. 62.	1,160	1¼	do		
H. O. Gordon	NW. ¼ sec. 34, T. 133, R. 62.	1,150	1	do		
City	La Moure	800	3–2	do		
Northern Pacific Ry.	do	19	192	do		Brick curb; "good water."
John Downing	do	970	1¼	do	Flow.	First flow, 5 gallons a minute at 845 feet; second flow, 35 gallons at 955 feet.
John Fryberger	NE. ¼ sec. 6, T. 133, R. 61.	1,055	1¼	do		
City [a]	La Moure	1,440	3	do	Flow.	
Do.[a]	do	20	16	Gravel	17	
Do.[a]	do	875	2½	Sandstone	Flow.	
City [a]	Verona	1,100	1½	do	Flow.	
Charles White	NW. ¼ sec. 1, T. 133, R. 59.	950	1½	do	Flow.	
Wm. Brandemeyer.	SE. ¼ sec. 36, T. 133, R. 59.	928	2½–1¼		Flow.	Perforated 25 feet at bottom.
J. F. Leiger	Verona	1,078				Finished at 988 feet in second flow; first flow at 958 feet, roily and did not clear. Between 988 and 1,078 feet two distinct flows.

[a] See table of analyses.

Water supplies of towns in La Moure County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Alfred	250	Bored	12	300	30	Sand	Sand	Public spring yields 10 gallons a minute. Satisfactory water.
Berlin	130	Bored, drilled			1,200	Gravel	Sandstone	Artesian water, soft and salty.
Dickey	190		50	1,200	50–60	Shale	do	Village well, flows but not much pressure.
Grand Rapids	100	Driven	20	160	25	Sand	Sand	
Jud	178	Bored	90	120	100	do	do	Large spring.
Kulm	725	Dug, bored, drilled.	20	300		do	Sand, gravel	Abundant water at 280 to 300 feet. No wells reach bedrock.
La Moure	1,014	Driven, bored, drilled.	20	1,300		Gravel	Sandstone	
Marion	294	Dug, driven	20	30		do		
Verona	258	Dug, drilled	30	950			Sandstone	Shallow wells yield "alkaline" water; deeper artesian wells yield salty water.

LOGAN COUNTY

TOPOGRAPHY

Logan County is on the eastern margin of the Missouri Plateau, high on the broad, flat divide between the eastward-facing Missouri escarpment and the westward slope to Missouri River. It is therefore truly plateaulike, though its minor topographic features are those of a recently glaciated region, except in the southwest corner. The broad belt of heavily rolling hills and hollows that constitutes the Altamont moraine of the Wisconsin glacier crosses it from northwest to southeast and occupies almost the entire county with its confusion of hills and undrained depressions. Only in the southwest corner, in the area drained by Beaver Creek and its tributaries, is there a contrast in topography. There the deep, broad valleys and the darker weathered drift suggest the older or pre-Wisconsin drift sheet, but even these valleys are so filled with valley trains that lead westward from the Altamont moraine and the uplands are so covered with outwash gravel that the surface shows little of the older glacial topography, and outcrops of the country rock are practically absent.

GEOLOGY

The entire county is underlain by Pierre shale, but in the western part there is a considerable thickness of the Lance formation between the Pierre and the drift. The entire region is so masked with drift, however, that little is known with certainty regarding the underlying rocks.

GROUND WATER

The wells of Logan County practically all draw their supply from the drift. The best waters occur undoubtedly in the shallow gravel and sand beds of the outwash plain that passes through Napoleon, on which the Minneapolis, St. Paul & Sault Ste. Marie Railway is built, and in the valley trains in the southwestern part of the county. Where the gravel does not occur lenses and irregular deposits of sand and gravel in the kames and in the body of the drift or at a deeper horizon, at the base of the drift and immediately above bedrock, usually offer a sufficient quantity.

A number of wells, 150 to 250 feet in depth, south of Gackle, at the foot of the escarpment, enter bedrock and draw copious supplies from sandstone or sandy layers interbedded with the shale. The water in these beds is under pressure from the higher ground water to the west and rises 5 to 10 feet above the surface.

Logan County is largely covered with hills of the Altamont moraine with undrained depressions between. The drift in this county contains extensive deposits of gravel that yield many small and a few fairly large springs. Springs are also quite numerous in the stream valleys that head into the escarpment on the eastern edge of the county. Their location is determined by the contact of the drift with underlying shale or by outcrop of some of the sandy layers. A few emerge in the valleys that have been cut by the headwaters of Beaver Creek about Burnstad and in the southwestern part of the county. These springs are of great value to the ranchmen and stock farmers of this region because of the permanent flow of clear fresh water and particularly because of the abundant supply of warm water in the winter.

QUALITY OF GROUND WATER

Most of the water from the alluvium of the valleys in Logan County is hard and contains small amounts of dissolved solids, as represented by analysis 81. Shallow wells in the drift yield hard water that differs widely in the amount of of its content of dissolved mineral matter. Analysis 87 represents the lower limits of dissolved mineral matter, and analyses 83, 86, 89, and 90 represent the more highly mineralized waters. Samples of the very highly mineralized waters were not collected. Wells that draw on the sandy layers of the bedrock yield hard moderately to highly mineralized waters, most of which can be used for domestic purposes. (See analysis 82.) Waters from the deeper wells in the bedrock would be soft.

Typical wells of Logan County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Napoleon	21	132			Near creek. Yield 100 gallons a minute. Satisfactory water.
Mrs. Roth [a]	SW. ¼ sec. 29, T. 134, R. 71.	12	60	Alluvium	9	
C. P. Burnstad [a]	SE. ¼ sec. 29, T. 134, R. 71.	132	2		30	
A. Schodler	NE. ¼ sec. 4, T. 134, R. 67.	448	3	Shale	Flow.	Plenty but salty.
J. Heller	SE. ¼ sec. 14, T. 134, R. 67.	440	3	do	Flow.	30 gallons a minute.
A. Kingler	E. ½ sec. 1, T. 133, R. 67.	93	3	Sand	40	Satisfactory.
C. Eszlinger	S. ½ sec. 10, T. 144, R. 67.	105	3	do		Do.
P. Schoot	N. ½ sec. 36, T. 133, R. 67.	320	3	Gravel	30	Do.

[a] See table of analyses.

Water supplies of towns in Logan County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Burnstad	150	Drilled	20	200	100	Gravel		Good hard water.
Fredonia	296	do	90	120	100			
Gackle	424	Bored, drilled	20	400		Sand	Sand	Few flowing wells with slight head. Small springs yield 20 to 50 gallons a minute. Good water.
Napoleon	554	Driven	10	25		Gravel	Gravel	Small springs in gravel.

McHENRY COUNTY

TOPOGRAPHY

McHenry County shares the Souris River Valley with Bottineau County. Fully three-fourths of the county is contained in the level plain that once formed the bed of Lake Souris. The southern fourth has rather strongly accentuated topography, particularly in its southeastern portion, caused by heavy deposition of morainal débris and trenching of the waters that flowed out from the ice front.

The drainage of the heavier morainal portion in the southeast is very imperfect, and a number of lakes still occupy the depressions left in the drift. Over the lower parts of the valley marshes occupy shallow depressions of the old lake bed. Practically all the drainage of the county enters Souris River, which reaches the southernmost point of its great loop at Velva and swings northward in a curve past Towner on its return to the Canadian line through central Bottineau County. The true valley of Souris River is broad and shallow and is subject to frequent overflow during the seasons of melting snow or heavy rainfall.

GEOLOGY

The heavy mantle of drift, which everywhere overspreads the county, is in turn covered with lacustrine silt and sand in the area of the old lake bed. In the region north and east of Towner the sand of the lake margin has drifted extensively, forming dunes. In the southwest corner of the county the beds of the Fort Union formation occur, but elsewhere the drift rests directly upon the Pierre shale. The character of the bedrock may be seen from the following incomplete log of the well drilled by the Great Northern Railway Co. at Genoa:

Log of Great Northern Railway well at Genoa

	Feet
Sticky blue clay	100
Gray clay	160
Hardpan with gravel mixed	181
Clay	200
Fine sand, some water	225
Black hardpan	228
Red sandy clay	235
Clay	420
White sandy clay	485
White shale	489
Sticky blue clay	583
Gray clay	623
Soft slate	674
Slate	720
Black slate	840

Geologic interpretation of the log:

Drift	0–225
Fort Union formation	225–489
Pierre shale	489–840

The only water encountered was a very small amount in the fine sand between 200 and 225 feet at the base of the drift. The Dakota sandstone undoubtedly lies more than 1,200 feet below the bottom of this hole.

GROUND WATER

Throughout the Souris River plain the ground water stands so high that an abundance of water is procured near the surface in shallow wells. These wells for the most part are in the lacustrine sand and silt immediately above the drift. Where clays predominate and drainage is poor these shallow waters are strongly alkaline, but where sands predominate and the subsurface drainage is good the water is good, as in the shallow city well at Towner.

Deeper bored wells obtain a better supply in the sandy lenses in the drift or a gravelly layer at the base of the till immediately above the bedrock. This water is probably the best in the region both in quantity and quality. This same bed in many places yields a small amount of natural gas, which has little economic value because of the small quantity and slight pressure.

In the southern part of the country shallow wells in the drift are commonly used, but the deeper bed at the base affords the best supply. That gas is present in some places is shown by a bored well owned by H. Thorson, at Drake, which is open at the top and well curbed and emits gas that may be exploded every few hours. Very few wells as yet have been drilled into the shale.

Considerable quantities of gas are found in the immediate vicinity of Deering and northeastward. Practically all wells here more than 100 feet in depth show traces of gas. In some wells the gas has interfered with the working of the cylinder of the pump, and in one or two places the gas pressure released in drilling has blown water and even tools from the well. This pressure is maintained for only a short time, however, and gas in sufficient quantities for economic use has not been found. This locality marks the end of the Mohall anticline mentioned under Renville County.

Springs are common in the broken ground in the southwest corner of this county. The flow comes from the edges of the horizontally bedded sandstone layers of the Fort Union formation, which in this area is but thinly mantled with drift. Another type occurs along the sides of the Souris River Valley, particularly where they are flanked by the morainal hills south of Velva. The sand and outwash gravel yield small amounts of excellent water at points where the underlying till crops out on hillsides. The supply of Velva comes from such a source through a collecting gallery that is sunk into the hillside above a former seepage spring. The Minneapolis, St. Paul & Sault Ste. Marie Railway utilizes practically the same source by means of a reservoir and dam in the creek valley bottom. John Penroy has also a spring of water at Balfour.

QUALITY OF GROUND WATER

The drift in McHenry County yields hard water that is generally rather low in total solids. Most of the water is suitable for general use, and some of it, as represented by analyses 84 and 85 has less than 400 parts per million of total solids. Some wells yield water so highly mineralized that it is objectionable for most uses. Wells drilled to the sandstone and lignite beds of the Fort Union formation yield soft but rather highly mineralized waters, most of which are acceptable for ordinary use. (See analysis 182.)

Typical wells of McHenry County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. Nussbaum	NE. ¼ sec. 31, T. 159, R. 80.	214	3	Sandy shale	28	Weak water well. Gas burned 2 feet above curb. Clay to 160 feet, shale to 214 feet.
Village	Upham	145	6-4	Coarse sand	18	Hard blue clay, gravel, and sand. Water "good and plenty."
John Loney	SE. ¼ sec. 20, T. 158, R. 80.	275				Gas will light after pumping. Salty water.
Ezra Moore	NW. ¼ sec. 23, T. 158, R. 80.	187	4		11	Drift to 120 feet, shale to 179 feet, sandy shale. Gas threw out bucket in slushing.
Robert Johnson	SE. ¼ sec. 36, T. 158, R. 80.	235	5		30	Gas enough to light.

Typical wells of McHenry County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Julius Erickson	NW. ¼ sec. 36, T. 158, R. 80.	193	3		14	Drift 127 feet, blue sandy shale at 187 feet. Gas interferes with pumping and will burn at pump top.
C. A. Johnson	SW. ¼ sec. 32, T. 158, R. 79.	210	5	Sand		Dry gas at 185 feet. Pressure 75 pounds at 190 feet. Well filled with water and sand. Drove through to 197 feet. Drilled deeper to stronger vein of water with gas, which blows water out after pumping down. Drift 125 feet, followed by shale and sand.
A. D. Whitney	NW. ¼ sec. 33, T. 158, R. 79.	114	6	Black sand	20	Affected by weather.
John Anderson	Sec. 7, T. 158, R. 78.	159	3	Sand	7	Trace of gas. Water slightly salty. Drift 142 feet, shale, blue sand.
Henry Jones	NE. ¼ sec. 35, T. 158, R. 78.	100			Flow.	Called a "night flow." Flows about 6 gallons each night.
E. J. Ahern	W. ½ sec. 5, T. 157, R. 79.	190	5			Muddy water. Gas enough to burn.
S. E. Brady	SW. ¼ sec. 8, T. 157, R. 79.	142	6	Gravel	20	Salty, soft; small gas bubbles render water turbid when pumped. Gas may be lit.
B. Fast	S. ½ sec. 16, T. 157, R. 80.					Gas enough to light.
C. S. Allen	SE. ¼ sec. 30, T. 157, R. 80.	168				Water in sand under hard shale. Gas burns after pumping.
Ed McClusky	7 miles northeast of Norwich.	129	4	Sand	30	Soft water, 30 barrels an hour.
George Good	SE. ¼ sec. 24, T. 156, R. 80.	137	4		Flow.	Water from a brownish-black deposit.
John Nelson	SE. ¼ sec. 35, T. 156, R. 80.	157	4	Shale	30	20 barrels an hour.
C. A. Stubbins	S. ½ sec. 16, T. 156, R. 79.	124	4	Sand	20	Sand 78 feet, shale 44 feet, water sand 2 feet.
Do	SE. ¼ sec. 28, T. 156, R. 79.	110	4	do	3	Gravel at 24 feet, coal at 93 feet, water from sand under coal.
City [a]	Towner	18	25	Coarse gravel	14	To blue clay.
Village	Berwick	204		Sandstone	Flow.	Slight flow when drilling. Ceased when finished. Drift 125 feet.
Henry Paul	do	1,302	2			Yellow and blue clay 100 feet; blue clay at 289 feet, shale with bands of light-colored limestone at 423, 430, 440, and 511 feet; soft dark shale at 609 feet, smoky-colored clay at 1,202 feet. Abandoned.
Village	do	200	5			Pipe filled with quicksand that prevented pumping.
E. N. Fylbren	SW. ¼ sec. 11, T. 156, R. 75.		3	Sand	Flow.	Soft water.
Do	NW. ¼ sec. 11, T. 156, R. 75.	80	3	do	Flow.	
John O. Fjarli	NW. ¼ sec. 13, T. 156, R. 75.	110	3			No water.
Otto Hilman	E. ¼ sec. 13, T. 156, R. 75.	140	2		Flow.	Soft water.
Til Fylbren	W. ½ sec. 26, T. 156, R. 75.	70	3			"Plenty of water; almost a flow."
Walter Bond	E. ½ sec. 13, T. 155, R. 82.	319	3	Sand	90	Soft water

[a] See table of analyses.

Typical wells of McHenry County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
W. W. Warner	W. ½ sec. 13, T. 155, R. 81.	180	4	Sand	30	Soft water.
Frank Lenton	S. ½ sec. 13, T. 155, R. 81.	207	3½	do	30	30 barrels an hour. Soft water.
Great Northern Railway.	Genoa	84	2	Gravel	27	
Village	Norwich	146	4	Shale	30	12 barrels an hour.
Public school	do	128	4	Sand	25	30 barrels an hour.
O. Hestekind	S. ½ sec. 5, T. 155, R. 80.	210	4	Coarse sand	30	10 barrels an hour.
Mr. Buffham	1 mile southeast of Norwich.	184	4	Shale	30	15 barrels an hour.
Charles Shipman	7 miles southeast of Norwich.	145	4	Sand	25	Soft water.
E. A. Carpenter	W. ½ sec. 20, T. 155, R. 80.	143			33	
John Stille	SE. ¼ sec. 21, T. 155, R. 80.	178	4	Shale	30	20 barrels an hour. Shale at 128 feet.
J. E. Shirxey	N. ½ sec. 23, T. 155, R. 80.	236	4	do	30	20 barrels an hour. Soft water. Shale at 157 feet.
Sam Elston	SE. ¼ sec. 26, T. 155, R. 80.	196	4	do	30	20 barrels an hour. Shale at 90 feet.
Joseph Sitter	NE. ¼ sec. 10, T. 155, R. 75.	300	2	Sandstone	30	Water at 80, 100, and 120 feet and at bottom.
H. L. Finneseth	NE. ¼ sec. 7, T. 154, R. 80.	227	2	Sand	50	Soft water.
Thomas Histed	Sec. 16, T. 154, R. 80.	265	2	do	115	Do.
Great Northern Railway.	Semcoe	81		Drift gravel	20	
Julius Kuntz	SW. ¼ sec. 32, T. 154, R. 75.	100				
City [a]	Velva	10	9	Sand		
Hugh McCuster	E. ½ sec. 24, T. 153, R. 80.	135	2	do	10	Soft water.
Nels Sjoholm	SW. ¼ sec. 21, T. 153, R. 79.	227		do		
John Klein	SW. ¼ sec. 24, T. 153, R. 78.	80	3	Gravel	10	
Great Northern Railway.	Karlsruhe					12 by 24 by 25 feet. Yield 50,000 gallons a day. Soft water.
N. Nelo	SE. ¼ sec. 8, T. 152, R. 80.	247	2	Sand	57	Soft water.
H. Hemzerling	NW. ¼ sec. 26, T. 152, R. 79.	150	3	Sandstone	40	Do.
William Hublon	N. ½ sec. 34, T. 152, R. 77.	65	3	Soft sandstone.	30	Do.
H. Thorson	SW. ¼ sec. 21, T. 152, R. 76.	276			80	Strong well. Hardpan, shale, sand.
Rudolph Berndt	S. ½ sec. 27, T. 152, R. 75.	185	2	Gravel	20	Probably drift well.
Great Northern Railway.	Guthrie					12 by 24 by 25 feet; 32,000 gallons a day.
H. Berg	NW. ¼ sec. 9, T. 151, R. 77.	80	3	Gravel	Flow.	
Ole Skair	NW. ¼ sec. 30, T. 151, R. 77.	337	3	Sandstone	50	Soft water.
H. Thorson	Drake	30	2			Gas bubbles in water. Explodes on ignition.
Minneapolis, St. Paul & Sault Ste. Marie roundhouse.	do	256	4			
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	275		Sand		Good supply.
Do	do	256	4	Sandy clay	60	109 gallons a minute.
Do	do	208	10	Clay		
Milling company	do	250	4	Gravel	70	"Good soft boiler water."
Electric company	do	252	6	Quicksand	30	Drift 100 feet; blue hardpan, shale 100 feet; coarse sand and gravel, hard sandstone 3 feet; quicksand 20 feet.

[a] See table of analyses.

Typical wells of McHenry County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
City	Drake	110	24	Drift		Bored. Water at 97 feet in fine sand, clay 40 feet, sand and pieces of coal 20 feet, blue shale 37 feet, fine gray sand, boulders.
Minneapolis, St. Paul & Sault Ste. Marie Railway.	Anamoose	253	10	Sand	25	75 gallons a minute.
John Stephens	4 miles northwest of Anamoose.	90	2	Gravel		Drift well.
Len Harmes	5 miles north of Anamoose.	130	2	Sandstone	35	5 gallons a minute.
John Schafer	NE. ¼ sec. 9, T. 149, R. 76.	424	3		50	Soft water.

Water supplies of towns in McHenry County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Anamoose	563	Dug	15	120	50	Drift		
Balfour	322	Bored, drilled	15	320	25	do		
Bantry	475	Dug, driven	10		20	Sand		Water from shale, is salty.
Bergen	307	Bored, drilled	15	20		do		
Berwick		Dug, drilled				Drift	Sand, shale	Many wells 100 to 500 feet. Town well of 204 feet in sand interbedded with shale. Head 1 foot.
Deering	142	do	10	300		do	Shale	Deep wells yield salty water; shallow wells, hard water.
Denbigh	425	Driven	10	25	15	Sand		Plenty of good soft water. Small springs.
Drake	517	Dug	40	300	50	Drift	Sand	Good springs.
Granville	394	do	15	40	20			
Kief	307	Driven, drilled	15	35		Drift	Gravel	
Norwich	325	Drilled	145	295	200			Deep well water is soft. Small spring.
Towner	610		5	25	15	Sand		
Upham	196	Drilled			75			A number of good springs. Water from city spring is generally used.
Velva	836	do			75			

McINTOSH COUNTY

TOPOGRAPHY

McIntosh County is on the south border of the State, in the eastern margin of the Missouri Plateau, between the eastward-facing escarpment and the westward-facing slope to Missouri River. The eastern half lies in the belt of the terminal moraine of the Wisconsin glacier and is therefore hilly and rolling. The western half has the topography of the older drift and is dissected by the south branch of Beaver Creek. The older topography is, however, considerably modified by the valley train and outwash gravel that was carried far out in front of the terminal moraine by the water that flowed from the front of the Wisconsin ice at its maximum stage.

GEOLOGY

The bedrock geology of McIntosh County is as yet little known. The Pierre shale undoubtedly underlies the whole area, but it is probably overlain in the western half of the county by the Lance formation. Two wells reach bedrock, and in these the drillers have been unable to distinguish the formations mentioned, all of which are largely composed of shale. A well at Venturia, 146 feet deep, draws its supply from the Fox Hills sandstone, which underlies the Lance formation.

GROUND WATER

A fair supply of water is obtained throughout the county from the gravel and sand of the drift. In the broad belt of outwash gravel that extends through Wishek and Ashley a good supply of water is found at a very shallow depth. Where surface gravel is not found beds and layers of sand and gravel in the drift, and particularly the bed at the base of the drift and above the bedrock, furnish the supply.

Throughout the morainal hills small springs flow from the gravel deposits of the drift, where they deeply overlie the gravelly clay. Few valleys have been cut into the drift except in the northwest corner of the county, where the headwaters of Beaver Creek rise. Therefore few large springs are found, though small hillside springs are common.

QUALITY OF GROUND WATER

The drift, which is the principal source of ground water in McIntosh County, yields hard water of different mineral content. Most of this water is acceptable for general use, as indicated by analyses 86, 87, 89, and 90. Wells located where the drainage is not good may yield water that contains enough dissolved mineral matter to make it unfit for use. Soft water that is highly mineralized but usable is obtained from the underlying rocks. (See analysis 88.) In some places this water is preferable to the water of the drift.

Typical wells of McIntosh County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Wishek			Sand		12 by 10 by 21 feet. 100 gallons a minute.
Do	do	23	120			
Do	do	19	102			
Adam Nagel, jr.	Lehr	100	36	Sand	1	
John Sempel	Sec. 5, T. 132, R. 67	147	3	do	30	"Plenty of good water."
Jacob Frederick	SE. ¼ sec. 10, T. 132, R. 67.	99	3	Fine sand.	30	Do.
John Fregian	W. ½ sec. 21, T. 132, R. 67.	283	3	Gravel	80	"Plenty of fair water."
City	Ashley	80	24	Clay	10	"Water hard and alkaline."
Jacob Doerr [a]	W. ½ sec. 31, T. 130, R. 69.	70	24		50	
Reinhold Schaber [a]	do	30	24		22	
A. A. Sayler [a]	NE. ¼ sec. 15, T. 129, R. 71.	146	24		122	
August Dockler [a]	SE. ¼ sec. 3, T. 129, R. 71.	80	24		Flow.	
Jacob Schleipp [a]	NE. ¼ sec. 15, T. 129, R. 71.	23	24		11	

[a] See table of analyses.

Water supplies of towns in McIntosh County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Ashley	1,009	Dug, bored	30	90		Sand	Sand	Springs.
Lehr	362		15	70		Drift	Drift	Small springs.
Venturia	207							Chiefly 2½-inch wells, 130 to 150 feet deep. Low head; small yield.
Wishek	1,003	Bored, dug	20	30				Small springs.
Zeeland	323	Bored	40	160	60			

McKENZIE COUNTY

TOPOGRAPHY

McKenzie County lies largely within the area covered by the earlier drift sheet. The southern portion, which is drained by the Little Missouri, is outside of the drift margin, and the county has therefore two quite different types of topography. Most of the area is a great rolling upland, the slight slope of which is eastward to the Missouri. Missouri River meanders in a broad, flat-bottomed valley about 2 miles in width, bordered by bluffs about 200 to 400 feet in height. The surface for a distance of 5 to 8 miles on each side of the valley is dissected into the well-known "breaks," and beyond it merges into the rolling plateau. In the southern part of the county occur the badlands of the Little Missouri. Here the valley of this river is the dominant topographic feature. The stream has carved a deep, broad trough 500 feet below the upland. The valley is bordered by steep bluffs which rise to a wider outer valley that consists of broad flats or terraces 200 to 300 feet above the flood plain. These flats are bordered by bluffs that rise 150 to 220 feet higher or between 400 and 500 feet above the river. These flats undoubtedly represent a flood plain in an earlier stage of the river's history, on which the stream meandered at grade.

GEOLOGY

McKenzie County has three types of surficial deposits. The northern and western portions carry a thin patchy covering of the older glacial drift, now quite maturely dissected and cut through in the valleys of all the larger streams. The badland region is in part driftless, and its surficial deposits form the residual soils of the uplands and the deep accumulation of alluvium in the valleys. The rocks below the surficial deposits consists of the shale, sandstone, and lignite of the Fort Union formation.

GROUND WATER

The early settlers of the region settled in the valleys, where water was found in springs that come from the lignite seams and beds of sandstone in the walls of the valleys. Water was also obtained there from shallow wells in the alluvium. On the uplands an uncertain supply could generally be obtained at the base of the drift or sandy residual soils. Recently, however, in order to procure a larger and more permanent supply, many wells are being drilled to the sandstone layers of the Fort Union.

Some of the wells in the bottoms of the deeper valleys overflow with small heads. These wells are of the narrow-valley artesian type and probably owe their flow in part to the slight dip of the beds in this region. The flowing wells are most numerous in the deepest valleys, notably those of Missouri, Yellowstone, and Little Missouri Rivers and Cherry Creek, where they range in depth from 300 to 700 feet. There are several flowing wells at the mouth of Cherry Creek, and these range from 600 to 700 feet in depth, but the deepest reported is at the mouth of Boland Creek, where a weak flow was procured from a water bed at a depth of 680 feet in a well 730 feet deep. All these wells end in fine sandy material.

Springs yield a noteworthy supply for stock on many of the valley farms and ranches. The best known are the Shafer Springs, just south of Schafer, on the west side of Cherry Creek, in the SE. ¼ sec. 23, T. 150 N., R. 98 W., owned by Mr. Charles Shafer. The upper spring yields 35 gallons a minute, and the lower spring 17 gallons a minute, both at a temperature of 47° F. The combined flow of over 3,100 gallons an hour or 77,000 gallons a day comes from the base of a coal bed near the foot of a bluff. The water is used for all domestic purposes and to a small extent for irrigation on the Twin Springs ranch. These springs afford an interesting illustration of the influence of springs on the settlement and development of western North Dakota. Mr. Charles Shafer settled here in 1884 because of the excellent water supply afforded by these springs and named his ranch the Twin Springs ranch. In summer the cattle are now grazed in the breaks of Cherry Creek and the Little Missouri, where plenty of running water is found in the beds of the spring-fed streams, and in winter they are fed and sheltered at the ranch, where the springs supply an abundance of flowing water at a moderate temperature. The village of Schafer grew up near this ranch home, received its name from the pioneer settler, and because of its central location became the county seat of McKenzie County, thus showing the persistent influence of a good water supply. Another excellent spring is found at the X ranch, on the head of Squaw Creek. It probably flows from a bed of coal that measures 35 feet in thickness at some outcrops in the region.

QUALITY OF GROUND WATER

The quality of water obtained in McKenzie County ranges over wide limits, depending on its source. The alluvium of the valleys yields hard water, generally rather low in mineral content. The surface deposits of the upland yield similar water, except that some of it is more highly mineralized, though usually not sufficiently to make it unfit for domestic use. Hard water that contains small to moderate amounts of dissolved mineral matter is obtained from wells in the upper sandstone and lignite beds of the Fort Union formation. (See analysis 53.) Similar water is obtained from springs in the valleys. (See analyses 91 and 92.) Deep wells on the upland and some springs in the river valleys that draw on the lower beds of the Fort Union formation or on underlying formations yield soft water that is moderately to highly mineralized.

Typical wells of McKenzie County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Moorehead & Kennedy.	S. ½ sec. 27, T. 152, R. 102.	100	24			In quicksand and coal.
Thor L. Thorson	NE. ¼ sec. 13, T. 151, R. 164.	176	3	Sandstone		"Plenty of good water."
Public school	Sec. 16, T. 151, R. 103.	80	5½	do		Do.
Roy N. Johnson	SE. ¼ sec. 4, T. 151, R. 102.	117	4	Gravel		Do.
John Shaide	Sec. 7, T. 151, R. 102.	109	24	Blue sand		Gravel 20 feet, clay and sand 80 feet, rock 3 feet, blue sand 6 feet.
Mr. Siemonaig	Sec. 11, T. 151, R. 102.	127	24	Coal		
Levi Aeschliman	Sec. 20, T. 151, R. 102.	162	24	do		
Tom Deane	do	165	24	Quicksand		Sandy soil 1 foot, light loose yellow sand 20 feet, moist coarse gravel 10 feet, loose yellow sand to bottom. Water in quicksand and coal.
Thomas Spellman.	SW. ¼ sec. 21, T. 150, R. 104.	42	4	Gravel		"Plenty of good water." Near Yellowstone River.
A. Stenjhem	NW. ¼ sec. 31, T. 150, R. 99.	100	24	Blue sandstone.		Soil 4 feet, clay and gravel 20 feet, hard blue sand (dry) 36 feet, hard till, tough sandstone, hard blue sand.
C. C. Converse	Schafer	65	4	Coal	18	
J. F. Stevens	do	16	6	Gravel, sand		
F. Palmer	NE. ¼ sec. 21, T. 150, R. 98.	83	6	Gravel	32	Good well.
A. C. Richardson	NE. ¼ sec. 22, T. 150, R. 96.	92	120	Sandstone	70	Bored well.
C. Ludington	NW. ¼ sec. 34, T. 149, R. 101.	88	6	Coal		Poor water.
Ernest Simpson	Sec. 36, T. 149, R. 100.	130	24	Blue sand		Mixture of clay and gravel 20 feet, light loose clay mixed with sand 100 feet, blue sand 6 feet. Gas.
Mr. Dudley	Sec. 30, T. 149, R. 99.	51	24	Shale		Soil 3 feet, blue shale 48 feet.
Philips & Bateman.	Sec. 31, T. 149, R. 99.	37	24	Gravel	26	
Wenzel Neubaum	NE. ¼ sec. 15, T. 149, R. 98.	141	6	Sandstone	30	
J. E. Williams	S. ½ sec. 5, T. 149, R. 95.	47	6	Coal		Went dry in 3 months.

Water supplies of towns in McKenzie County

Town	Population in 1920	Common range in depth of wells (feet)			Water-bearing materials		Remarks
		Shallow	Deep	Most common	Shallow	Deep	
Alexander	274	30	470	100	Coal, sand	Coal, sand	Spring water piped to town.
Ellsworth		300	700				Flowing wells common in lowlands.
Schafer	757	15	60		Sand	Sand	Good springs.

McLEAN COUNTY

TOPOGRAPHY

McLean County is approximately a right-angled triangle, the longer southwest side of which is formed by Missouri River. Across the extreme northeast edge of the county runs the escarpment that separates the Drift Prairie from the Missouri Plateau. Dogden Butte, a well-known landmark in the northeast corner, is a partly detached portion of the plateau. The county lies chiefly on the broad, nearly level eastern portion of the plateau, which slopes gently westward and southward to the Missouri. The Altamont moraine, which was deposited by the Wisconsin ice sheet, also stretches across the county from northwest to southeast and covers a belt 15 to 30 miles in width with its rough and hilly topography. Many lakes, sloughs, and undrained areas abound in the morainal region, chief of which is Turtle Lake. To the south and west of the Altamont moraine lies the earlier drift sheet which covers the entire area to Missouri River with a broken mantle of boulder clay, but this has attained a more mature stage of topography, in which the drainage is complete and many streams lead down to the Missouri. Near this river the dissection of the upland is marked, and the "breaks of the Missouri" is a characteristic topographic feature. Missouri River occupies a broad, flat valley 1 to 3 miles wide, which has steep slopes on both sides.

GEOLOGY AND GROUND WATER

The drift supplies most of the wells in McLean County, as over a large part of the area it is very thick. Water is found either in gravel or sand at shallow depths or at the base of the drift immediately above the bedrock. The drift is everywhere underlain by the Fort Union formation, which contains water in the sandstone and lignite beds that lie between the layers of shale. These beds also give rise to a number of strong springs in the breaks of the Missouri and along its main tributaries.

The Minneapolis, St. Paul & Sault Ste. Marie Railway Co. put down a well at Max to a depth of 2,500 feet, without obtaining a satisfactory supply of water. This hole is the deepest ever drilled in the State for water. The work was done by the S. Swenson Artesian Well Co., of Minneapolis, whose foreman, Mr. Nels Christianson, has furnished the following incomplete log:

Log of Minneapolis, St. Paul & Sault Ste. Marie Railway well at Max

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface deposits	50	50	Shaly sandstone	45	765
Soft blue-gray shale	85	135	"Flint rock," hard and very heavy	3	768
Coal; little water	8	143	Shale, blue streaked with light	297	1,065
Blue-gray shale	107	250	"Flint rock," coarse, gray, sandy	2	1,067
Coal; little water	9	259	Shale, with "flint rock" layers	23	1,090
Shale	41	300	Sandy clayey shale	100	1,190
Fine gray sandy shale	100	400	Blue-gray shale	290	1,480
Coal	10	410	"Slate"	298	1,778
Shale, some light streaks	160	570	Shale	124	1,902
Soft gray sandstone	1	571	"Slate"	68	1,970
Shale	129	700	Shale	342	2,312
Fine gray shaly sandstone and shale	20	720	Not specified	188	2,500

The only water reported by the driller was "a small vein" at 140 and another at 250 feet. The thick beds of shale in the lower part of the hole are probably all of Pierre age.

A hole 2,000 feet deep has been drilled by the Washburn Lignite Coal Co. at Wilton, but no record of this hole was obtained.

Springs are well distributed throughout McLean County but especially along the bluffs that face Missouri River and in the many side valleys that lead back into the upland from the river. Outcrops of lignite give rise to most of these springs, as at the spring 2 miles north of the great cut bank known as "The Slides," where the Indians have dug through 10 feet of lignite to give freer vent to the water that flows from this bed. Another area of good springs occurs in the northeastern part of the county about Dogden, where the hills of the eastward facing Missouri escarpment break down into the lower prairie plain. A small stream of fairly good water flows from the lignite into a small coulee that heads back into the hill that faces Dogden Butte on the south. This is the same lignite bed that is entered by the Rose Hill mine which is not far distant. Between these two general areas lies the hilly belt of the Altamont moraine, which contains many gravel deposits that yield small springs and seepages in considerable numbers. Springs are therefore rather extensively used for domestic supplies and especially for water for stock in this county.

QUALITY OF GROUND WATER

Analyses of four waters from McLean County and of others from adjoining counties indicate that waters obtained in this county may differ considerably in quality. Wells supplied by the drift yield hard water, which differs in mineral content but is generally suitable for most uses. (See analyses Nos. 85, 94, and 95.) The alluvium of the valleys yields similar water, as shown by analyses 97, 98, and 99. Water from the sandstones and lignite beds of the Fort Union formation is softer than the water from the drift but commonly contains more dissolved matter. (See analyses 93 and 96.) Both the deep wells of the uplands and the springs along the bluffs yield water that is suitable for general use. The spring water contains less dissolved solids, probably owing to greater movement of the water or to leaching of the rocks by waters of earlier geologic times.

Typical wells of McLean County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
P. B. Torgerson	SW. ¼ sec. 18, T. 150, R. 89.	114	4		10	
Ole Torgerson	NW. ¼ sec. 19, T. 150, R. 89.	105	4	Blue sand	15	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Max	55	120		2	Small supply in dry season.
Village	do	15	48	Gravel		
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	2,400				Abandoned. Test hole.
Do	Ruso	407	10			Clay. No water.
Do	Dogden	197	10	Sand		Good well. Clay 183 feet, sand and water 14 feet.
B. L. Gage	SW. ¼ sec. 23, T. 149, R. 89.	140	5	Blue sandstone.	112	
J. J. Snipper	NW. ¼ sec. 13, T. 149, R. 87.	60	24	Sand, gravel	38	
Bert Johnson	SW. ¼ sec. 18, T. 149, R. 86.	142	24	Yellow sandstone.	125	
E. Bjornholtz	SE. ¼ sec. 26, T. 149, R. 86.	78	5	Coal	61	
L. J. Hoefer	NW. ¼ sec. 28, T. 149, R. 86.	147	5	Yellow sandstone.	105	

Typical wells of McLean County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
W. Walters	SE. ¼ sec. 7, T. 148, R. 87.	78	24	Yellow sandstone	62	
E. F. Hodges	NW. ¼ sec. 14, T. 148, R. 87.	37	24	Blue sand	14	
E. Krantz	NE. ¼ sec. 15, T. 148, R. 87.	130	24	Coal	30	Soft water.
D. Kitts	SW. ¼ sec. 24, T. 148, R. 87.	54	24	do	24	"Soft but poor."
A. K. Barrow	NE. ¼ sec. 33, T. 148, R. 87.	244	5	Gray sandstone.	201	"Soft but poor." Heavy bed of coal.
John Holst	NE. ¼ sec. 7, T. 148, R. 86.	147	5	Coal	120	"Soft and good." Heavy bed of coal.
Lars Lee	NE. ¼ sec. 9, T. 148, R. 86.	156	5	do	126	Do.
Matt Hagg	NE. ¼ sec. 19, T. 148, R. 86.	152	5	Gravel	42	
A. J. Londenbeck.	SE. ¼ sec. 22, T. 148, R. 86.	186	5	Sand, gravel	40	Yellow clay, gravel and sand, hard yellow sand, yellow sandstone 4 feet, shale with layers of coal 60 feet, "slate rock" 1½ feet, coal 2½ feet, coal and very hard clay 10 feet, hard blue sand 33 feet, hard sandstone 7 feet.
George Bidlack	NW. ¼ sec. 30, T. 148, R. 86.	40	24	Lignite	20	
G. L. Robinson	SW. ¼ sec. 8, T. 148, R. 85.	111	5	Sand, gravel	84	
Fritz Giffey	SW. ¼ sec. 10, T. 148, R. 85.	250				
J. Pahl	SW. ¼ sec. 17, T. 148, R. 85.	361	5			Dry. Soil and yellow clay; blue clay with some sand 110 feet; sand, silt, and coal 84 feet.
J. H. Runkel	NW. ¼ sec. 17, T. 148, R. 85.	115	24	Gray sandstone.	58	
E. H. Tank	SE. ¼ sec. 28, T. 148, R. 85.	108	24	Blue sandstone.	86	
City of Garrison	SW. ¼ sec. 8, T. 148, R. 84.	125	6		60	
Mrs. A. Parkratz.	do	35	24	Gravel	25	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Garrison	180	6			40 gallons a minute. Fine sand below shale gives trouble.
J. B. Peterson	NE. ¼ sec. 34, T. 148, R. 79.	350				
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Underwood	110	8	Coal	25	Water from coal bed 13 feet thick. Well is pumped 20 gallons a minute.
Northern Pacific Ry.	Mercer	23	192			Brick curb.
Mr. Messon	Sec. 32, T. 146, R. 78.	335				
J. H. Davidson	Sec. 5, T. 145, R. 78.	330				
P. M. Maloney	W. ½ sec. 27, T. 145, R. 82.	360	2			Dry hole.
Gus Fahlgren	SW. ¼ sec. 10, T. 144, R. 83.	200				
W. Wolitarsky[a]	SE. ¼ sec. 14, T. 144, R. 82.	60	4			
W. Stone	NW. ¼ sec. 15, T. 144, R. 80.	78	24	Gravel	9	
S. B. Jennings	SE. ¼ sec. 20, T. 144, R. 80.	130	24	Coal	110	
Jacob Falk	5 miles north of Wilton.	68	24	Sand	4	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Wilton	325	10	do		Clay 300 feet, sand and little water 25 feet.
Bartrom & Johnson.	do	225				

[a] See table of analyses.

Typical wells of McLean County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. J. Schmidt	SE. ¼ sec. 31, T. 143, R. 80.	42	2	Sand below coal.	68	Satisfactory well.
Do	NW. ¼ sec. 35, T. 143, R. 80.	192	2	Sand	40	Do.
Alex Stenquist	E. ½ sec. 17, T. 143, R. 80.	64			49	Bored well; brown water
J. O'Shea	SE. ¼ sec. 15, T. 140, R. 87.	80	24	Coal	36	Soft water.

Water supplies of towns in McLean County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Benedict	195	Drilled			175			
Coal Harbor	150	do	30	200	75	Drift	Sandstone	Good small springs.
Dogden	252	do	25	60	50	do		
Garrison	714	do	100	375	110	do	Sandstone	Town wells not over 100 feet; country wells 100 to 375 feet.
Max	473		100	250	100	do	do	Wells in town 100 feet, in country 100 to 250 feet.
Mercer	269	Bored, drilled	30	120				Lakes common.
Ruso	120	Dug, drilled	40	60	50			
Turtle Lake	395	Drilled, bored	10	300	100	Drift	Coal	Small springs. Shallow wells yield hard water; deep wells soft water.
Underwood	453	Bored, drilled	25	100	30	Sand	Sand	Springs.
Washburn	558	do	40	400		Drift	Coal	Bored wells 40 to 80 feet. Many deeper wells abandoned.
Wilton	1,026	do	20	1,000	180	Sand	Sand	

MERCER COUNTY

TOPOGRAPHY

Missouri River borders Mercer County on the north and northeast, and Knife River, one of its larger tributaries, passes entirely across the county from west to east and with its many tributaries has dissected the plateau so thoroughly that the drainage is remarkably perfect and large areas approach the badlands in roughness. Broad, rolling divides between the main streams are covered with flat-topped buttes and irregular mesas.

GEOLOGY AND GROUND WATER

The clay, sandstone, and coal beds of the Fort Union everywhere underlie the thin surficial deposits of drift and alluvium and crop out in every stream valley. Water is found in abundance in the alluvial deposits in the bottoms of the stream valleys, and springs flow from outcrops of sandstone and lignite on the sides. Wells on the uplands generally find fairly good water at some considerable depth in the coal and sandstone layers of the bedrock, though a number of dry holes are reported. Near the valleys these veins are dry owing to the drainage from the outcrops.

In the valleys of Spring Creek and Knife and Missouri Rivers a few flowing wells have been obtained. These wells have a small yield and slight head and owe their flow to the narrow-valley type of artesian condition. These flowing wells range in depth from 250 to 500 feet and have for their aquifers the sandstone and lignite beds of the Fort Union formation. The strongest of these wells is reported from the farm of Peter Buckler, in sec. 26, T. 143 N., R. 90 W. It is 260 feet in depth and 2 inches in diameter and yielded, when drilled, 15 gallons a minute under a head of 20 feet.

Mercer County is well supplied with good springs, owing to the deep valley carving of Missouri River on the north, Knife River and its many tributaries on the south, and Spring Brook across the middle of the county. Wherever these valleys cut through beds of sandstone or lignite, springs are found and because of the porous character of these beds and their thickness and general extent in this region, many of the springs yield good flows very valuable to stockmen. Such outcrops of lignite in thick seams occur in sec. 31, T. 145 N., R. 87 W., and good springs flow from them in abundance.

QUALITY OF GROUND WATER

The shallow wells in the alluvial deposits in Mercer County yield hard water of variable mineral content, most of which is satisfactory for general use. (See analyses 97, 98, and 99.) Wells in the drift yield hard water, moderately to highly mineralized, which is generally satisfactory for most uses. (See analyses 94 and 95.) Deeper wells draw on the sandstones and lignite beds of the Fort Union formation and yield moderately mineralized soft water, most of which is satisfactory for general use. (See analyses 93, 101, and 102.) Some of the waters of the lignite are slightly colored and therefore may be objectionable for drinking. The springs of the valley walls draw their supply from the Fort Union beds and yield water similar to that from the deep wells of the upland (analyses 91 and 92) but generally lower in dissolved mineral constituents.

Typical wells of Mercer County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
O. Bauman	S. ½ sec. 8, T. 146, R. 90	425	2	Coal	60	3 barrels an hour. Poor water.
W. M. Mueller	SW. ¼ sec. 14, T. 146, R. 90	220	2	Sand	140	4 barrels an hour.
J. Riegel	S. ½ sec. 32, T. 145, R. 89	160	4	do	80	
Adam Wagner	SW. ¼ sec. 22, T. 145, R. 89	300	2	Shale		No water.
G. Lang	Sec. 35, T. 145, R. 89	120	2	Coal	40	3 barrels an hour. Soft water.
A. Headquist	N. ½ sec. 34, T. 145, R. 88	300	2			Dry hole.
A. Wiege	N. ½ sec. 27, T. 144, R. 90	80	4	Sand		Good, hard water.
Jack Hanck	Sec. 37, T. 144, R. 89	320	2			Adequate supply.
H. A. Alds [a]	Sec. 6, T. 144, R. 84	8	48	Sand	12	
J. Maxie	3 miles south of Broncho	350				No water.
H. C. Loy [a]	Sec. 6, T. 144, R. 84	31	48	Sand	31	
Mrs. H. Gibbs [a]	do	31	48	do		
F. Martin	N. ½ sec. 13, T. 142, R. 90	100				

[a] See table of analyses.

Water supplies of towns in Mercer County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Beulah	552		20	225	100	Sand	Sandstone, lignite.	Springs in river valley.
Golden Valley	369	Bored, drilled	20	50	40			
Hagen	520		20	45	30	Sand	Gravel	Village supply from driven well.
Krem	100	Dug, drilled	40	100		Coal	Sand, coal	
Stanton	325	Driven, drilled	10	400	25	Sand	Coal	Good springs.

MORTON COUNTY

TOPOGRAPHY

Missouri River borders Morton County on the east and Cannonball River on the south. Heart and Little Heart Rivers flow through it from west to east and are joined within its borders by numerous large creeks. Both the Missouri and its chief tributaries occupy broad valley floors separated from the uplands on each side by rather steep slopes that change in places to abrupt bluffs. The upland of Morton County is a vast rolling plateau cut deeply by the valleys of its chief streams and broken to a greater or lesser degree near these streams. That this plateau is the result of long-continued erosion is evident from the fact that above it in places rises a remnant of the higher plateau, as Little Heart Butte, not far from the confluence of Little Heart River with the Missouri.

GEOLOGY AND GROUND WATER

Morton County lies entirely within the area occupied by the earlier drift. This drift sheet, though modifying the topography of the uplands, has so far been removed by erosion that drainage is completely developed and the bedrock is exposed in practically every valley wall and on the steep slopes of the buttes. Over a large portion of the area the drift is represented only by scattered boulders. It is therefore of little value as a source of ground-water supply. The alluvial deposits in the valleys yield much water, and the residual and wash material on the low slopes of the uplands yield small supplies to shallow wells. Over a large part of the county the sandstone and shale of the Lance formation lie at or near the surface. Moderate supplies of water are found in the sandstone beds at moderate depths. In the western part of the county the Fort Union formation overlies the Lance formation, and its beds of sandstone and lignite would probably yield most of the supply here.

Deep wells have been sunk at both Mandan and Sims by the Northern Pacific Railway Co. The well at Mandan, which is one of the deepest holes in the State, is 2,000 feet deep; the well at Sims is 1,311 feet deep. No log is preserved, but the Mandan well was not sufficiently deep to reach the Dakota sandstone, which was sought. A flow of 3 gallons a minute was found at 470 feet. From this point to the bottom the material was mainly shale. In the Sims well no flow whatever was obtained. The last coal and sandstone, at 710 feet, appeared to be at the base of the Lance formation. The underlying rock is a very uniform mass of pyritiferous clay which extends nearly 600 feet to the bottom of the well and apparently belongs to the Pierre shale. The presence of the Fox Hills sandstone was not recognized.

Log of Northern Pacific Railway well at Sims, Morton County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Drift	10	10	Coal	5	330
Coal	8	18	Very soft sandstone	42	372
Sandstone and shale	42	60	Hard bed sandstone	3	375
Coal	5	65	Shale, with sulphur	260	635
Sandstone and shale	60	125	Soft sandstone	75	710
Coal	5	130	Good coal	6	716
Soft sandstone	195	325	Shale, with sulphur	594	1, 310

Springs from the sandstone and lignite of the Lance formation occur along many of the deep valleys of the tributaries of Heart River, Sweetbriar Creek, and Curlew Creek, and are valuable sources of water for stock during the summer. The presence of large amounts of water in the lignite beds makes it difficult to mine the lignite when the structure is unfavorable for drainage. An old opening on the opposite side of the coulee from the Burton mine, half a mile south of Sims, affords a good illustration. This opening is not now operated, but a stream that fills a 2-inch pipe flows from the entry. The dip of the coal away from the coulee on this side makes it difficult to arrange for draining and developing these workings, whereas those on the opposite side of the coulee are not so handicapped because they have a natural drainage down the entry to the coulee.

QUALITY OF GROUND WATER

Shallow wells in the alluvial and surface deposits in Morton County yield hard water which differs in mineral content, though most of it is suitable for general use. (See analyses 100 and 104.) The best water analyzed in the county (analysis 100) contained 321 parts per million of total solids, which is representative of many waters from the alluvial deposits. The waters of the drift are similar to those from the alluvium, though more highly mineralized. Most of the deep wells of the eastern part of the county draw on the Lance formation and those of the western part on the Fort Union formation. Both formations contain soft water that has quite a range in the amount of dissolved constituents, as shown by analyses 101, 102, 103, 105, and 106. The principal constituents of the dissolved mineral matter in the waters are sodium and bicarbonate. Most of the water is suitable for general use.

Typical wells of Morton County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Theodore Bolke	Hebron	183	2	Sand	0	Flows into basement. Not pumped. Water at 100 feet and at bottom.
Eugene Weigel	do	320	2			Poor water at 20 and 100 feet (in quicksand). Water at 300 to 320 feet, not clear. Well abandoned.

Typical wells of Morton County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Hebron Brick Co.	Hebron	310	4½	Blue sand	30	No water below 80 feet. Well is pumped at 6 gallons a minute. Gumbo and blue clay 25 feet, quicksand 10 feet, soft gray clay 23 feet, coal 2 feet, clay 12 feet, fine sand 8 feet, clay, shale, and coal seams to 310 feet.
Northern Pacific Ry.	do	18	96			Near Knife River. Satisfactory water.
Mining experiment substations.[a]	NE. ¼ sec. 32, T. 140, R. 90.	110	5½	Sand		
Fredrick Mische	E. ½ sec. 27, T. 139, R. 90.	200				
George Schantz	Glen Ullin	70	2		20	
Charles Horst	do	95	2			Dark-brown water.
City	do	100	3		30	
Do	do	150		Sand		Satisfactory well. Sand bed, 7 feet thick, at 130 feet; under clay shale.
Creamery well	do	150	2			
Northern Pacific Ry.	do	1, 100				
Joseph Gust	do	65	2		10	
Martin Schmidt	1 mile east of Glen Ullin.	350		Shale		
E. F. Green	SW. ¼ sec. 17, T. 139, R. 88.	210				Four wells. No water. Mostly clay or shale.
William Engelter	NE. ¼ sec. 14, T. 139, R. 85.	80	3	Blue sand		
Dakota Coal Products Co.	NW. ¼ sec. 22, T. 139, R. 85.	463	4	Sand		Roils before storm.
Fredrick Weigmann, sr.	New Salem	395	4	Blue sand	208	Soft water.
Doctor Bodenstab.	do	245		Sand	170	Coal vein below 27 feet.
Northern Pacific Ry.	Sweetbriar	24	192			Near Sweetbriar Creek. Brick curb.
Charles Keidel	½ mile south of Mandan.	280	2	Sand, clay	Flow.	2 gallons a minute. Gravel and sand 70 feet, quicksand 14 feet, black sand and clay 140 feet.
C. C. Atkinson	Mandan	260		do	Flow.	½ gallon a minute. Gray sand 60 feet, dark sticky clay 60 feet, water-bearing sand and clay 140 feet.
Northern Great Plains Field Station.[a]	SW. ¼ sec. 33, T. 139, R. 81.	330	4		80	
Northern Pacific Ry.	Mandan	26	192			Near Missouri River. Concrete curb.
State training school.	NW. ¼ sec. 33, T. 139, R. 81.	22	1¼	Sand	12	
Northern Pacific Ry.	Mandan	16	192			Near Hart River. Satisfactory water.
Mandan Steam Laundry.[a]	Sec. 27, T. 139, R. 81.	450	2½		Flow.	
Northern Pacific Ry.	Sunny	25	300			Near Heart River. Brick curb.
Northern Great Plains Field Station.[a]	Sec. 16, T. 138, R. 81.	318	3	Fine sand	200	
N. Johnson	NW. ¼ sec. 12, T. 135, R. 84.	200	4	Blue sand		
A. C. Lindblom	SE. ¼ sec. 12, T. 135, R. 84.	205	4	Black sand	80	Soft water.
Lorenz Gustin	SE. ¼ sec. 14, T. 135, R. 84.	360	2½	do	100	Do.
O. E. Cole	SE. ¼ sec. 30, T. 135, R. 84.	185	4	do		Never pumped dry.

[a] See table of analyses.

Typical wells of Morton County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. H. Hoffman	NE. ¼ sec. 32, T. 135, R. 84.	300	2	Blue sand		Never pumped dry.
Northern Pacific Ry.[a]	T. 135, R. 79	35	48	Gravel, sand	20	
F. G. Boettcher	New Leipzig	180	2	Gravel	120	Water at 40, 75, and 120 feet, and bottom.
G. H. Seilman	do	165	2	Blue sand		Water at 45 feet and bottom.
Brown Land Co.	do	190	2	do		Never pumped dry.
Buch Bros	Flasher	146	2	do		
Dr. G. Speilman	do	164	2	do		
J. G. Karhoff	do	177	2½	Quicksand		Soft water.
E. T. Burke	SW. ¼ sec. 15, T. 134, R. 84.	172	4	Blue sand	100	Do.
E. R. Wallace	SE. ¼ sec. 17, T. 134, R. 84.	203	2¼	do	90	Do.
John Martin	NE. ¼ sec. 18, T. 134, R. 84.	224	2¼	do	60	Do.

[a] See table of analyses.

Water supplies of towns in Morton County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Almont		Dug, bored	10	50	25	Red sand, coal.	Sand, coal.	Hillside springs from coal. Well water of rather poor quality.
Flasher	287	Driven, bored	30	175	125			Water in shallow wells hard and alkaline, deep wells soft. Small springs of good water. Bedrock at 35 feet.
Glen Ullin	875		60	150				Sand layers at 60 to 95 feet.
Hebron	1,374	Dug, bored, drilled.	20	400				Shallow wells yield poor water; deep wells soft water.
Judson	90	Dug, bored	10	65	15	Sand		
Mandan	4,336		20	470				Railway uses five 10-inch wells about 200 feet deep.
New Salem	711	Drilled	30	420	50	Coal		Deep water soft, shallow water hard.
Sims		Dug	30	60	40			Large springs in vicinity.

MOUNTRAIL COUNTY

TOPOGRAPHY

The Missouri escarpment barely cuts the northeast corner of Mountrail County, and Missouri River forms its southwestern boundary. The county therefore lies almost entirely on the Coteau du Missouri and slopes very gently southwestward. Most of the northeast half is within the broad irregular zone of morainal hills which roll in seemingly endless confusion and constitute the terminal Altamont moraine of the later or Wisconsin ice sheet. The rest of the county lies in the drift-covered area of the earlier ice sheet, but as it is so close to the great master stream, the region is well drained and for a distance of several miles back from the Missouri bluffs is much dissected by the tributaries of that stream, so that it forms a part of the breaks of the Missouri. White Earth and Little Knife Rivers and Shell Creek resemble Missouri River in this respect and contribute their share to the broken topography west of the moraine.

GEOLOGY AND GROUND WATER

The mantle of glacial drift is so heavy in the younger drift area that most of the water supplies in this region come from the gravel of the drift. A few wells penetrate the lignite and sandstone beds of the Fort Union formation for a larger supply. Many of the upland wells in the southwestern half also draw supplies from the drift, particularly the base of the older drift immediately above the bedrock. Owing, however, to the perfection of the drainage the drift in many places lies above the water table, and a large number of wells must be drilled into the underlying Fort Union formation and draw their supply from the sandstone and lignite of this formation. In the valleys of Missouri River and its chief tributaries these beds yield many springs, but there are also shallow wells that end in the alluvium of the valley floors. The water from the alluvium and sandstone is of satisfactory quality; that from the lignite is brown and has an unpleasant taste.

Strong springs flow from the bluffs and hills along the north side of the Missouri Valley in southwestern Mountrail County and from the valley sides of its tributaries, White Earth River, Little Knife River, and Shell Creek. These springs form an excellent source of water for the ranches and stock farms of the region. One of these springs on the Gibbs ranch, in sec. 34, T. 152 N., R. 92 W., forms a stream 2 feet across and 2 or 3 inches deep, yielding approximately a million gallons daily. This spring is believed to be the largest in North Dakota. In the northern part of the county the gravelly hills of the Altamont moraine yield many spring-fed streams which flow into the undrained depressions and help to form the numerous lakes of the region.

QUALITY OF GROUND WATER

The quality of ground water obtained from different sources of supply in Mountrail County varies between wide limits. Shallow wells in the alluvium of the valleys yield hard water that contains small to moderate amounts of dissolved solids. Where the drift is not drained it yields hard water that contains from 300 parts per million of total solids to several thousand parts. Most of these waters do not contain over 1,500 parts per million of solids and many of them much less. Analysis 183, which represents a sample from Ward County, shows the kind of water generally obtained from the drift in Mountrail County. Deep wells that enter the sandstones and lignite beds of the Fort Union formation yield water which is generally soft and moderately or highly mineralized. Analysis 107 shows considerably more mineral matter than is contained in most of the waters from the Fort Union formation. Waters from this formation are better represented by analyses 182 and 194. Analyses 91 and 92 are representative of the spring waters that flow from the sandstone and lignite seams where they are exposed in the river valleys.

Typical wells of Mountrail County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Adolph Krause	SE. ¼ sec. 11, T. 158, R. 93.	176	5	Sand	130	
Martin Peterson	NE. ¼ sec. 14, T. 158, R. 93.	182	5	Clay	110	All reddish clay.
Nels Johnberg	NE. ¼ sec. 15, T. 158, R. 93.	154	5	Gravel	114	Clay 50 feet, sandstone 99 feet, then coarse gravel.
Lena Jenson	NW. ¼ sec. 27, T. 158, R. 89.	98	2	Sand	72	
Olaf Rustad	NE. ¼ sec. 29, T. 158, R. 89.	105	18	do	85	
Great Northern Ry.	White Earth					12 by 12 by 24 feet; 150,000 gallons a day.
Public school	do	126	3	Coal	12	Plenty; black color.
Pete Nerseth	do	99	3	Blue sand	49	Plenty; soft and good.
Samuel Norstedt	SE. ¼ sec. 9, T. 157, R. 93.	167	3	Quicksand		
John Fossaa	SW. ¼ sec. 9, T. 157, R. 93.	96	3	Yellow sand	70	
Paul Tessum	SE. ¼ sec. 1, T. 157, R. 93.	69	3	Blue sand	43	Plenty; good.
Erick Anderson	NW. ¼ sec. 14, T. 157, R. 93.	183	3	Sand	105	Do.
O. S. Lee	SE. ¼ sec. 15, T. 157, R. 93.	108	3	Gravel	80	Do.
Sigurd Bakke	SW. ¼ sec. 15, T. 157, R. 93.	194	2	Coal	104	Do.
Alfred Anderson	NW. ¼ sec. 23, T. 157, R. 93.	243	2	do	130	Black, but used for stock.
Anton Feiring	NE. ¼ sec. 25, T. 157, R. 93.	203	2	do	180	Plenty; good.
N. G. Evans	NE. ¼ sec. 2, T. 157, R. 92.	263	3	Shale	130	
Christ Anderson	SE. ¼ sec. 3, T. 157, R. 92.	73	3	Coal	58	
J. A. Monson	SW. ¼ sec. 3, T. 157, R. 92.	86	3	do	66	Small yield.
Halvor Siberg	NW. ¼ sec. 5, T. 157, R. 92.	63	3	Blue sand	38	Adequate supply.
Hans Colbrenson	NE. ¼ sec. 6, T. 157, R. 92.	112	3	Fine sand	40	Do.
A. Roise	NE. ¼ sec. 8, T. 157, R. 92.	90	2	Quicksand	70	
M. Grove	NE. ¼ sec. 9, T. 157, R. 92.	98	3	Coal	78	
Do	SE. ¼ sec. 9, T. 157, R. 92.	90	3	Quicksand	70	
Edward Enger	SW. ¼ sec. 17, T. 157, R. 92.	158	3	Fine sand	130	
Ole P. Nordby	NW. ¼ sec. 18, T. 157, R. 92.	146	3	Quicksand		
Ole J. Hauglie	NE. ¼ sec. 18, T. 157, R. 92.	125	4	Blue sand	130	Do.
Oscar Olson	E. ½ sec. 21, T. 157, R. 90.	160	2	Coal	80	
B. Holte	E. ½ sec. 6, T. 156, R. 93.	146	3	do	86	
Peter Blicher	SE. ¼ sec. 8, T. 156, R. 93.	96	3	Yellow sand	86	
Willis Butterfield.	NE. ¼ sec. 10, T. 156, R. 93.	233	3			
John Wales	NW. ¼ sec. 14, T. 156, R. 92.	200				Dry.
Adolph Olson	6 miles northwest of Stanley.	150			135	Bored.
Great Northern Ry.	Palermo					Size, 12 by 12 by 26 feet, 100,000 gallons a day.
Do	do	24	120			300,000 gallons per day.
M. Olson	Tagus	150				
Ole S. Biekke	½ mile north of Tagus.	250				
H. G. Naigle	Tagus	230				
City of Stanley[a]	SW. ¼ sec. 21, T. 156, R. 91.	216	4½	Shale and sand.	100	

[a] See table of analyses.

Typical wells of Mountrail County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
John Cronin	NW. ¼ sec. 9, T. 155, R. 91.	126			110	
Henry Bolfe	E. ½ sec. 20, T. 155, R. 90.	119			93	
George E. Allen	SE. ¼ sec. 9, T. 154, R. 94.	114	3	Quicksand	109	
Peter Olson	SE. ¼ sec. 13, T. 154, R. 94.	107			55	Adequate yield.
Tom Hargrade	S. ½ sec. 26, T. 154, R. 91.	71			50	
Oscar Schafer		85		Sand	75	All sand.
J. Purcell		136				Dry.
Torvold Luvaar	NW. ¼ sec. 19, T. 154, R. 90.	105		Sand	110	Plenty hard water.
R. W. Patten	SW. ¼ sec. 26, T. 153, R. 89.	282	5			5 gallons a minute.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Plaza	72	120	Sand		Small yield in dry season.
M. H. Malloy	SW. ¼ sec. 22, T. 153, R. 88.	430	6		230	Poor water.
H. A. Karlson	SE. ¼ sec. 33, T. 153, R. 88.	65	6	Lignite	35	Fair water.
C. L. Holt	SW. ¼ sec. 4, T. 152, R. 91.	452	4¼	Sand		Not completed at time record was obtained.
Do	do	618	4			Dry hole.
N. L. Hobson	Parshall	45	6	Gravel, sand	33	
Theodore Lee	SW. ¼ sec. 35, T. 151, R. 91.	67	4¼	Gravel	30	
Charles Frank	SE. ¼ sec. 8, T. 151, R. 88.	270	4¼	Sand, coal	160	Dark water.
M. W. Swenson	SW. ¼ sec. 9. T. 151, R. 88.	125	4¼	Clay	10	

Water supplies of towns in Mountrail County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Blaisdell	300	Dug	20	120	20			
Coulee	84	Drilled	10	200	20	Drift	Coal	
Palermo	179	Dug	10	65	15			Small springs.
Plaza	345	Drilled	40	100	60			
Ross	300	Dug, bored	15	35	25			
Tagus	133	Drilled	150	300			Sandstone, lignite.	Railway uses water from creek.
White Earth	247	Dug, bored	20	40		Gravel	Gravel	Springs.
Parshall	376	Bored, drilled	10	75	30	do	Sand	Deeper drilled wells on some farms.
Wabek	40	do	10	350		do	Coal	

NELSON COUNTY

TOPOGRAPHY

The surface of Nelson County is a gently rolling till plain characteristic of the Drift Prairie. It is, however, modified in the southwest corner by the great valley of the Sheyenne with its many small stream-carved tributary valleys. Another noteworthy topographic feature is Stump Lake, the second largest lake in the State.

The till plain is morainic in character, as it is crossed by at least four of the 10 recessional moraines formed at the retreating front of the Wisconsin ice sheet in North Dakota. Each of these four moraines is divided into several belts and loops that produce a remarkable confusion of morainal topography, which is perhaps best seen south of Stump Lake, where several of these belts unite. Associated with the morainic belt in this locality is a most remarkable outwash plain of gravel and sand which borders the south side of the hills and descends in remarkably even and graceful slopes to the valley of Sheyenne River. The hills are dotted with an accumulation of boulders, and gravel and coarse sand form the upper slopes of the outwash plain, but the lower, more level parts are formed of finer sand and alluvium. These beds have a considerable thickness, as shown by the watercourses, which have channeled into them 50 and even 100 feet without disclosing the till.

Stump Lake is second in size and in interest only to Devils Lake, with which it shares an interior drainage basin that lies within the Red River Basin in northeastern North Dakota. These two lakes have a common origin in a partly filled pre-glacial valley. They were formerly connected by a large river that flowed from the east end of Devils Lake at Jerusalem into the north end of Stump Lake and were drained by another equally large stream that passed out by Dissmore through Big Stony Coulee into Sheyenne River. They are to-day both brackish, owing to their present lack of outlet. At the time of the Government land survey in 1883 the area of Stump Lake was approximately 16 square miles, and its shore line was about 35 miles in length, owing to its great irregularity of form. The present area is somewhat less, and the depth is about 35 feet. Popular interest in Stump Lake is divided between the group of islands in West Bay that constitutes the national bird reserve, inhabited by thousands of ducks, gulls, tern, and other wild waterfowl, and the remains of an ancient forest, the stumps of which still stand at the south end of East Bay where they were until recently submerged. As these stumps are rooted in lake silt they indicate that the waters of the lake stood for a long period of years at least several feet lower than at present, and if the report of other submerged stumps is true the bed was probably free from water. This condition points to a much lower ground-water level and therefore to a much drier climate during some very recent period of geologic time.

The chief interest in Sheyenne River lies in the great valley through which the present stream winds between terraces of glacial gravel and sand, a small misfit on the broad alluvial floor. The greater Sheyenne, which was formed by the drainage from the front of the ice sheet, first carved the valley and then with its waning strength filled it with the deposits of a glacial valley train until, when it was relieved of its load from the ice front, the clearer stream began to recarve its valley. This cutting has continued until the present inner valley has been sunk to a depth of 150 to 200 feet below the upland through the gravel and deep into the original bedrock, the dark blue-gray Pierre shale.

GEOLOGY

The deep alluvial deposits that floor the valley of Sheyenne River, the coarse gravel terraces on its walls, the broad, thick outwash that leads from the moraines in the north to the very edge of the valley, and the large deposits of sand and gravel in the morainal ridges, all add variety to the drift deposits and interest to the ground-water relations of this region. The bedrock geology, however, is very simple. The Pierre shale crops out on both sides of the inner Sheyenne

Valley and occasionally in the lower valley sides of its main tributaries, notably on Big Stony Coulee, where it is crossed by the wagon road half a mile east of Tolna. Elsewhere it lies immediately below the glacial drift. All the outcrops reveal dark blue-gray shale, somewhat mottled with yellow, which breaks into small flaky fragments on weathering.

GROUND WATER

The waters utilized in Nelson County come from the alluvial gravel of the Sheyenne, the outwash and morainal sand and gravel, the till of the drift, and sandy layers of the Pierre shale.

Drive points and open wells find an abundance of water at very shallow depths in the alluvial gravel of the Sheyenne Valley.

In the area south and west of Hamar, Tolna, Pekin, McVille, and Kloten the thick deposits of outwash generally provide satisfactory water at comparatively shallow depths, and similar water may be procured at many points in the hilly morainal areas. The gravel forms very good storage reservoirs for the rain water, which is readily absorbed and is retained free from the excessive mineral salts of the till and shale.

The till sheet of the drift furnishes water for the great majority of farm wells, but these supplies differ greatly in quality and quantity. The best supplies come from sandy layers or the gravelly deposits that immediately overlie the shale. The drift is everywhere present except where it is replaced in the Sheyenne Valley by alluvium. It is therefore not necessary to drill into the underlying rocks, except rarely for a larger supply than the till affords where the gravel is absent.

Water is found in the sandy and gravelly layers of the Pierre shale, but this water generally contains mineral salts that render it unsatisfactory for domestic use though it is satisfactory for stock. In some places, however, the shale is devoid of sandy layers and here dry holes of great depths may result, as the 744-foot hole on the Edgar Gutormson farm near Aneta.

The southwest corner of the county probably lies within the area of artesian flow of the Dakota sandstone, but the wells would have to be sunk to a depth of 1,200 to 1,500 feet and the water would be highly mineralized. Very deep wells could be obtained from the same formation in the northwest half of the county, including Aneta and Lakota, but such wells would have to be pumped from a considerable distance below the surface.

Springs are common in the Sheyenne Valley along the contact of the till and the overlying outwash or valley-train gravel, particularly at the base of the drift immediately above the shale. A number of excellent springs also emerge about Stump Lake, one of which determined the location of the first settler's home in the county. The house still stands near the spring on the south shore of the lake, surrounded by a fine grove.

QUALITY OF GROUND WATER

The alluvial deposits in Nelson County yield hard water that contains small to moderate amounts of dissolved mineral matter. The drift yields similar water with a more variable mineral content, depending on local conditions, but most of it is suitable for general use. (See analyses 109 and 111.) The sandy layers of the Pierre shale yield mineralized waters of variable hardness. Analyses 108 and 110 represent waters from this formation that contain small to average amounts of dissolved solids.

Typical wells of Nelson County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Whitman	716	10	Shale		Not enough water for railroad use.
W. C. Hagler	SE. ¼ sec. 36, T. 154, R. 58.	89			15	
City	Lakota	66	8	Gravel	30	Prospect hole for city; yields 7 gallons a minute. Supply from gravel overlying shale.
Great Northern Ry.	do					Size 24 by 32 by 38 feet. 25,000 gallons daily.
City [a]	do	18		Fine sand	15	
H. B. Licknor	do	128	4		11	Bedrock at 45 feet.
S. H. John	do	85	4	Sand	20	
K. A. Anderson	do	80	8	do		
F. C. Schaible	do	132	4	Sand, gravel	20	Water at 110 feet in shale, poor; water also at base of drift at 58 feet.
E. Rebillard	do	209	5	Shale	15	Water beds at 150 feet and 60 feet. Salty. Very small supply. Bedrock at 60 feet.
Mr. Cummings	do	108		Gravel	18	Gravel in shale. Bedrock at 60 feet.
Gus Appleman	do	103	4	Shale		Bedrock at 40 feet.
J. G. Gunderson	do	65			10	
Nelson Kelly	do	172	4	Fine sand	83	Clay 10 feet, sand and gravel 35 feet, blue clay 35 feet, shale 83 feet, sand 9 feet.
Abe Thale [a]	Sec. 27, T. 153, R. 60.	136	4	Shale	55	
W. F. Swanston	Michigan	97	6	Sand	72	Bedrock at 80 feet.
M. C. Hagler	NE. ¼ sec. 4, T. 153, R. 58.	126	5	do	20	Water at 30 and 60 feet, and at bottom.
R. L. Wright [a]	Sec. 7, T. 153, R. 58.	101	4	Shale		
Erick Hansen	SE. ¼ sec. 20, T. 152, R. 57.	135	4	do	30	Water at 120 feet, soft and salty. Water also at 60 feet. Bedrock at 58 feet.
S. R. W. Pickard	Sec. 14, T. 152, R. 57.	106	6	do	15	Bedrock at 32 feet.
Do	Niagara	215				Dry hole. Soil 3 feet, sand and gravel 36 feet, blue clay 2 feet, shale 174 feet, white clay at bottom.
C. Hendrickson	NW. ¼ sec. 24, T. 151, R. 60.	117		Shale	26	Bedrock at 40 feet.
J. W. Biss	SE. ¼ sec. 3, T. 150, R. 60.	66	5			Strong well.
W. C. Fairbanks	W. ½ sec. 11, T. 150, R. 60.	115	6	Shale	50	Bedrock at 66 feet.
Tom Anderson	SW. ¼ sec. 2, T. 150, R. 57.	320				All drift.
Tom Field	NW. ¼ sec. 33, T. 149, R. 57.	167	6	Shale		Soft but salty. Small yield.

[a] See table of analyses.

Water supplies of towns in Nelson County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Aneta	662	Dug, bored, drilled.	35	600	40			Spring water for city reservoir.
Kloten	75	Bored, drilled	20	50	40			
Lakota	959		80	160	115	Gravel	Gravel	
McVille	546	Dug, bored	40	100	50	Sand		
Michigan City	491	Bored, drilled	15	100	90	Gravel		Small spring.
Pekin	197	Dug, bored			25	Quicksand		Several small springs of good water in vicinity.
Petersburg	367	Dug, drilled	30	100	40			
Sheyenne		Driven	10	25		Sand	Gravel	
Tolna	199	Bored	10	25	15			

OLIVER COUNTY

TOPOGRAPHY

Oliver County is bordered on the northeast and east by Missouri River and lies for the most part on the high upland slope west of the stream and between its large tributaries, Knife and Heart Rivers. It is therefore a typical plateau region, somewhat dissected by the tributaries of the rivers on both sides and by Square Butte Creek, which passes southeastward from Center.

GEOLOGY AND GROUND WATER

Although the older drift overlies the county, it is so thoroughly dissected and worn away that only scattered boulders and patches of till remain on the uplands. These are of little importance as sources of ground-water supply. The sandstone beds interstratified with the shale of the Fort Union formation, which underlies all except the southeast corner of the county are the chief reliance for the wells of the region, but springs and shallow wells in the alluvium and surficial deposits of the valleys are common sources of water. The Lance formation, which underlies the Fort Union, also supplies water to the deeper wells. A few small flows are reported to come from wells in the valley of Square Butte Creek in the region east of Center. These are probably the result of local artesian conditions of the narrow-valley type.

QUALITY OF GROUND WATER

Shallow wells in the alluvium and surficial deposits in Oliver County yield hard water suitable for general use. (See analyses 97, 98, and 99.) Most of it contains less than 1,000 parts per million of dissolved mineral matter. The sources of supply of the deep wells are the Fort Union and Lance formations, which yield soft, moderately to highly mineralized water generally acceptable for most uses. (See analyses 112 and 113.)

PEMBINA COUNTY

TOPOGRAPHY

Pembina, the northeasternmost county of North Dakota, lies wholly within the Red River Valley save for a few square miles where the Pembina Mountain escarpment crosses the southwest corner of the county. The Pembina delta, occupies an area equivalent to about two townships on the west side south and west from Walhalla. The remainder of the county is on the very level floor of the old bed of Lake Agassiz. The north half of the county is drained eastward through Pembina and Tongue Rivers, and the southwest corner is well drained by the northern branches of Park River. The southeastern part is so level that it affords little slope for run-off, and salt marshes are numerous.

GEOLOGY

The lacustrine and alluvial silt of Lake Agassiz underlies the valley to a considerable depth in the eastern half of the county. In the delta region the silt is overlain by the heavy bed of coarse gravel and sand deposited by Pembina River in the western margin of the lake when it was fed by the heavily loaded waters from the retreating front of the ice. The till sheet that was deposited directly by the glacial ice underlies the lake deposits and overlies the bedrock throughout the county, except where it has been cut through on the top and in the face of the escarpment by swiftly flowing streams as they pass from the upland out upon the valley floor.

In the valley of Pembina River occur the best exposures of the thick Cretaceous shales to be found in the entire State. Pierre, Niobrara, and Benton shales are all represented in a section hundreds of feet in thickness. No evidence of the Dakota sandstone is found even in the deepest wells of the county, but the records of the wells at Grafton and Hamilton reveal the thickest Ordovician and the only Cambrian sedimentary rocks recorded in the State. The Archean basement was reached at a depth of 960 feet at Hamilton.

GROUND WATER

Several ground-water horizons are drawn upon by the wells of Pembina County. The lacustrine deposits, including silt, delta gravel, and beach sand, the drift sheet, and the underlying bedrocks are all utilized. The best water is undoubtedly that which comes from the wells and springs of the delta and beaches in the western portion of the county.

The waters of the sand and gravel beaches formed on the western margin of Lake Agassiz at successive stages in the lake history are usually ample and of satisfactory quality. Though somewhat hard these waters are quite free from alkaline matter such as is contained in the waters of the region that come from clay silt or the bedrock shale. The waters of the Pembina delta have the same general quality but are found at considerably greater depths except on the margins. The depth of 100 to 135 feet is reached in some places before the water table in the basal portion of the formation is reached. Along the front of the delta, on the banks of streams which have cut through the delta deposits, this water issues in springs.

The shallow waters from the delta gravel and silt and the underlying drift in the western part of the county and from the lacustrine and alluvial silt in the central and eastern parts make the best obtainable supply. Where these waters are unsatisfactory the careful conservation of rain water in cisterns and use of the proper filtration is strongly urged for this region. The supply of rain water will no doubt be ample for drinking, and much may usually be had for household use and perhaps some for stock. The general use of good cistern water would mean longer life, better health, and greater comfort and prosperity throughout this region.

The waters of the drift are under pressure and generally rise nearly to the surface from depths of 100 to 250 feet. They are generally brackish, and though in many places they are used for stock they are unfit for domestic use. Exception, however, is found in the drift of the waters that lie near the surface in the western part of the county at depths not greater than 80 to 90 feet. The bedrock has been reached in only a few wells. The Cretaceous shales that occur just below the drift in the western portion of the county do not generally yield water, though a meager supply may in a few places be found in sandy layers in the higher portions of the Pierre shale. The lower shales (Niobrara and Benton), found for instance underneath the First Mountain, west of Walhalla, have been penetrated to a depth of several hundred feet without results.

The waters of the Paleozoic formations are reached in but few wells, including the Hamilton well and the mill well at St. Thomas. They are under artesian pressure but are so strongly mineralized as to be unfit for domestic use. The well, 1,560 feet deep, at Hamilton is supplied by the St. Peter or older (?) sandstone, and the well 450 feet deep at St. Thomas is probably supplied by the St. Peter sandstone.

The artesian waters of the Red River Valley in Pembina County come from two distinct horizons, the drift and the Paleozoic sandstones. The drift waters are not all artesian in character, for though water commonly rises to the surface or a few feet above it, other wells from the same or similar beds stand a few feet below the surface and others rise but little. Flowing waters in the drift are generally obtained at depths that range from 100 to 250 feet, though this depth differs greatly within short distances. The waters come from layers of granular sand in the drift and have probably fallen as rain upon the higher land not far to the west and followed the thin porous layers to the lower valley where they are inclosed with the body of boulder clay and thus obtain the head which causes them to rise to the surface when an opening is made by the drill. The waters of the drift artesian wells in the lower portion of the Red River Valley are unfortunately saline, probably through upward seepage from the aquifers of underlying bedrock, which are highly mineralized. The bedrock yields artesian waters at two places in the county. The salty water of the 450-foot roller mill well at St. Thomas probably comes from 60 to 80 feet below the top of the bedrock, and though the formation is unknown it is presumably older than the Cretaceous. The water is so salty that its use has been long abandoned except for fighting fires. It is permitted to flow into a cistern from which it is pumped in case of fire by a steam fire engine. Probably the most remarkable feat of drilling on record in the State is that of the Hamilton deep well. The total depth, 1,560 feet, is considerably less than that of several other holes reported, but the fact that a hard rock reported as granite was struck at 897 feet and drilling was continued through 663 feet of this rock is of considerable interest. The following account of the Hamilton well, taken from the Fifth Biennial Report of of the Geological Survey of North Dakota, is the most complete obtainable:

Located in sec. 35, T. 162 N., R. 53 W., town of Hamilton, county of Pembina. Owned by the Hamilton Artesian Well Co. Commenced November, 1887; completed August, 1889. Drilled by W. B. Clements, Hamilton, N. Dak. Depth, 1,560 feet. Cost, $10,150 or $6.50 per foot. Flow, 26 gallons per minute. Pressure, 27 pounds per square inch when flow is shut off. Temperature of water 41½° F. Elevation above sea level, 824 feet.

Driller's log of well at Hamilton

	Thickness (feet)	Total (feet)		Thickness (feet)	Total (feet)
Soil	10	10	Blue shale, main flow saline	7	307
Blue clay	122	132	Gray limestone	277	584
Coarse sand (surface water) saline and alkaline	42	174	Pink limestone	25	609
Hardpan (cemented gravel)	15	189	Gray limestone (very soft)	153	762
Quicksand	4	193	Blue shale (caving)	130	892
Red shale	32	225	White sandstone	5	897
Blue shale	20	245	Blue granite	344	1,241
Red shale	43	288	"White sand"	1½	1,242½
Gray limestone	12	300	Blue granite	1½	1,244
			"White sandstone"	315	1,560

This hole was put down for a test well, and with the hope of obtaining a supply of water for city purposes. Two small flows of salt water were struck—one at 300 feet, which flowed 80 gallons a minute, the other at 1,241 feet, which at first flowed 45 gallons of brine a minute. The water contains about 35,000 parts per million of salt. The well is cased with 6-inch casing to 350 feet. Inside of this is a string of 897 feet of 4-inch casing, which starts from the top. There are 600 feet of drill poles, and a drill in the bottom of the hole. An oak log 2½ feet thick, stained black, was reamed out at 120 feet to let the drill pass. The lower 663 feet is in what is supposed to be Laurentian granite. The bottom of this hole is 736 feet below sea level.

A number of strong springs that furnish excellent water are found along the margin of the Pembina delta and in the walls of the valleys but through the delta to the drift beneath. Within these valleys also smaller springs flow from the gravel immediately above layers of clayey silt that crop out some distance up the sides of the walls. Farther up these valleys other springs issue at the contact of the drift with the underlying shale. The best of these springs are those in a large district about Concrete and southward, in the vicinity of Mountain and Gardar. Here strong springs of good water issue from the contact of the drift with the underlying Niobrara formation, which is hard, compact, and impervious to the water that it carries down its gentle eastward slope to the outcrop in the face of the escarpment. A few small seepage springs occur in the valley walls of Red River and its tributary, the Pembina, but they flow from the porous upper layers of the lacustrine silt and are of little note.

QUALITY OF GROUND WATER

All ground waters in Pembina County are hard, but they differ widely in the content of dissolved mineral matter. The best water in the eastern and central part of the county comes from the shallow wells in the lacustrine silt. This water is satisfactory for domestic and other purposes. (See analyses 116 and 117.) The underlying drift yields some satisfactory water, but most of it is too highly mineralized for general use. In the western part of the county some waters from the drift are similar in quality to those from the lacustrine silt in the eastern part of the county and others are too highly mineralized for general use. The underlying bedrock yields very highly mineralized water, which is unsuitable for anything but extinguishing fires or diluting sewage. (See analyses 114 and 115.)

Typical wells of Pembina County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
C. W. Andrews	SE. ¼ sec. 32, T. 164, R. 56.	300				Salty; abandoned.
Cyrus Briggs	4 miles west of Neche.	200				
Minnesota & Northern Elevator Co.	Neche	175				Salty; unfit for use.
J. P. Hicks	1½ miles northeast of Neche.	133	2		Flow.	
T. Marsacer	1 mile east of Neche	40			Flow.	
Great Northern Ry.	Walhalla					6 by 16 by 20 feet. Near Pembina River; 5,000 gallons a day.
City	do	195		Gravel	Flow.	Salty.
Do	do	16	10	Gravel		Fire protection.
Walhalla Roller Mill.	do	16		do		Satisfactory boiler water.
J. Kitchen	do	50		Gravel over lake silt.		On edge of delta.
Carl Banta	NE. ¼ sec. 16, T. 163, R. 56.	302			14	Soil 3 feet, yellow clay to 108 feet, blue clay to 289 feet; a little water at 111 feet on top of blue clay.
Joseph Hoese	T. 163, R. 56	500				No water. Gas at 95 feet. Boulders interfered at 100 feet. Blue clay, blue shale, and black shale to 400 feet. Hard material at 500 feet.
J. P. Hicks	NE. ¼ sec. 19, T. 163, R. 53.	133	2			
Joseph Martindale.	S. ½ sec. 27, T. 163, R. 53.	135			4	Strongly mineralized water.
Charles Tittes	3 miles north of Bathgate.	160			Flow.	Strongly mineralized water. Flow has ceased.
William Steele	SE. ¼ sec. 30, T. 163, R. 53.	120			Flow.	
A. J. McFadden	SW. ¼ sec. 30, T. 163, R. 53.	100		Fine sand		Flows into dug well. Salty.
Louis McFadden	NW. ¼ sec. 30, T. 163, R. 53.	115		do	4	Flows into dug well.
J. La Moure	S. ½ sec. 25, T. 163, R. 52.	151		Sand	Flow.	Fair water.
H. Huston	S. ½ sec. 30, T. 163, R. 52.	162			Flow.	Strongly mineralized.
Alexander McConnell.	NE. ¼ sec. 3, T. 162, R. 54.	8			Flow.	Salty.
Harry O'Brien	SE. ¼ sec. 29, T. 162, R. 54.	219	2	Sand	12	5 gallons a minute.
Henry O'Brien	NW. ¼ sec. 29, T. 162, R. 54.	180			Flow.	Salty.
Minnesota & Northern Elevator Co.	Hamilton	179				Do.
Rand & Norton	do	175				Do.
Mr. Knight	1 mile north of Hamilton.	163	2	Sand	0	Do.
Hamilton Artesian Wells Co.	Sec. 35, T. 162, R. 53.	1,560	6	White sand	0	Do.
Minnesota & Northern Elevator Co.	Bathgate	143			6	Do.
Joseph O'Hara	NE. ¼ sec. 11, T. 162, R. 52.	160		Sand		Do.
H. J. A. Youmana.	N. ½ sec. 23, T. 162, R. 51.	150		do	Flow.	Strongly mineralized.
D. Cleary	SW. ¼ sec. 31, T. 161, R. 56.	40	4	Clay		Satisfactory water.
Great Northern Ry.	Cavalier	22	72			Near Pembina River; 6,000 gallons a day.
C. H. Assettine	1 mile south and 2 miles east of Cavalier.	150			Flow.	Salty.
Mr. Miller	SW. ¼ sec. 31, T. 161, R. 52.	201	2	Gravel	0	Yellow clay 8 feet, blue clay 125 feet, soft blue clay 35 feet, limestone 30 feet, sand and gravel 3 feet.

Typical wells of Pembina County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Joseph McCabe	SW. ¼ sec. 35, T. 161, R. 52.	187	2	Sand	12	Yellow clay 6 feet, blue clay 124 feet, soft blue clay 30 feet, limestone 25 feet, sand 2 feet. Water at 130 feet and at bottom.
John Whelan	NE. ¼ sec. 34, T. 160, R. 54.	365	2	do	Flow.	Salty. 1,500 barrels a day.
Minnesota & Northern Elevator Co.	Glasston	200			2	Salty.
Great Northern Ry.	Crystal	22	84			
Whelan farm	do	300				
John Whalen	NE. ¼ sec. 4, T. 159, R. 54.	360		White sand		Satisfactory water.
Robert Baird	NE. ¼ sec. 23, T. 159, R. 54.	235		do		Bitter; not used.
Roller Mill Co.	St. Thomas	450	6	Sand	Flow.	Heavy flow. Salty.
Minnesota & Northern Elevator Co.	do	175			do	Salty.
Terry Kelly	N. ½ sec. 3, T. 159, R. 53.	225	2	Sand	do	⅔ gallon a minute. Salty.
Dobbing & Bennett.		150	2			Mineralized.
Great Northern Ry.	St. Thomas	22	96			Three wells alike.
Do	do	32	48			Total capacity of five wells is 10,000 gallons a day.
Ale Roe [a]	NE. ¼ sec. 3, T. 159, R. 53.	18	12	Lake silt	10	
Great Northern Ry.	St. Thomas	150	5			
E. T. Thompson	SE. ¼ sec. 2, T. 159, R. 53.	450	4, 2			
John Holler	SW. ¼ sec. 19, T. 159, R. 51.	145	2	Gravel	Flow.	Salty. Unfit for use. Very small flow.

[a] See table of analyses.

Water supplies of towns in Pembina County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Backoo	100		10	25				
Bathgate	352	Dug, drilled	15	200	20	Sand, clay	Sand	Shallow water "alkaline." Saline flows.
Bowesmont	150	Surface	10	20	15			
Canton	101	Dug	10	40				
Cavalier	819	Dug, drilled	10	150	25	Gravel	Shale, gravel	Shallow water. Considered satisfactory. Saline flows at 150 feet.
Concrete	225	Dug	15	20		Shale		Water considered satisfactory. Springs in hills.
Crystal	349	Dug, drilled	15	250		Sand	Sand	Alkaline. Deeper water salty.
Drayton	647	do	10	250	15	Sandy clay	do	Hard and alkaline. Deeper water salty.
Gardar	60	Dug	10	20	15	Gravel	Shale, gravel	
Glasston	75	Dug, bored	10	20	15			
Hamilton	200	Dug, drilled			15	Lake silts	Sandstone	See record of deep well, p. 183.
Hensel	300	Dug	10	20				

Water supplies of towns in Pembina County—Continued

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Joliette	125	Dug	10	25				Some alkali in shallow wells. Flows are salty. None used.
Leroy	220	do	10	25	15	Sand	Sand	
Mountain	200	Bored	10	25	20			Bedrock at 20 to 25 feet.
Neche	528	Dug, drilled	10	145	15	Sand	Sand	Alkaline. Flows as saline.
Pembina	802	do	10	200	20			All wells deeper than 50 feet yield salty water. Springs in valley.
St. Thomas	500	Dug, bored, drilled.	15	200	150		Sand	Saline flows at 200 feet. Bored wells 100-150 feet deep.
Walhalla	634		10	150	15	Gravel	do	Springs yield good water.

PIERCE COUNTY

TOPOGRAPHY

Pierce County lies high on the divide between the Devils Lake and Sheyenne River drainage basin on the east and the Souris River drainage basin on the west. Three evenly spaced morainal belts cross the southern part of the county from northwest to southeast, and the northern part is one confused area of recessional moraine. In its extreme morainal topography it is exceeded only by Benson County, which joins it on the east. Among rolling hills lie many meadows, marshes, and ponds, the late stages of glacial lakes that formerly filled the almost innumerable irregular depressions left in the drift cover on the retreat of the ice. Many of these depressions are connected by broad, shallow, winding coulees now entirely grassed over, but none of the streams is permanent and little rainfall escapes from the region. The only valleys that lead outward are those formed by glacial drainage between the southern moraines that lead to Sheyenne River through which once flowed the drainage from Lake Souris, Assiniboine, and Saskatchewan Rivers, and the ice front far to the northwest. Portions of these channels of ancient rivers are occupied by elongated lakes and marshes to-day, as Girard, Buffalo, Antelope, and Alkali Lakes.

An area in the northwest corner that extends almost to Rugby and comprises about one-fifth of the county was covered by the waters of Lake Souris during its highest stage. The morainal drift is here somewhat modified and covered by beach ridges and lake sand. A number of shallow lakes and meadows remain and form a confusion of morainal and lacustrine topography. The surface is sandy throughout the area.

GEOLOGY

The drift mantle laid down by the glacial ice is undoubtedly very thick in Pierce County and reaches a maximum of possibly 300 feet in the moraine north of Pleasant Lake. In this heavy drift the sand and gravel deposited by the glacial waters form a very large part not only at the surface but within the till, thus indicating many advances and retreats of the ice front during which part of the water-laid deposits were covered deeply with ice-laid materials.

The bedrock immediately beneath the drift is the blue-gray Pierre shale.

GROUND WATER

In Pierce County water is obtained from the drift and the Pierre shale.

Owing to the thickness and the morainal character of the drift, most of the wells of the region draw from the gravel and sand of this surficial deposit. Many of the gravel deposits occur at the surface of the rougher portions of the moraines in the form of kames. In front of the ridges of morainal hills and in the lower lands lie extensive outwash deposits, and where these do not occur gravel beds and lenses are generally found in the body of the boulder clay at different depths or at the base of the drift immediately above the bedrock shale. These waters, when found beneath the kame or outwash gravel, are generally fair, though the supply may be meager. To this class of water belongs the supply of the city plant at Rugby. The waters from the gravel buried in the boulder clay are more commonly poor because of the presence of mineral salts in the clay, with which the water comes into intimate contact, and a strongly mineralized water results unless the surface drainage is good. Where there is good circulation in the waters through the buried gravel good water is the rule.

A growing number of the stock wells that fail to find an ample supply in the drift enter the Pierre shale, which contains a few sandy porous layers that yield a moderately mineralized water to wells 150 to 500 feet in depth. Some holes that enter the shale are reported dry, and a few others are abandoned because of the difficulty in keeping out the mixture of clay and exceedingly fine sand that flows into the well, but most of them result in successful wells.

QUALITY OF GROUND WATER

Hard waters that range from 250 to several thousand parts per million are obtained from the drift in Pierce County. Analyses 118 and 14 are representative of the better waters obtained from the drift. The sandy lenses of the bedrock yield moderately to highly mineralized water, which ranges in hardness from soft to moderately hard. (See analyses 6, 11, and 15.) The Dakota sandstone lies very deep and yields water that is generally rather highly mineralized and usually soft, though some of it is hard. (See analyses 7 and 191.)

Typical wells of Pierce County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
John Soude	S. ½ sec. 19, T. 158, R. 74.	90			Flow.	
A. D. Phelps	SE. ¼ sec. 32, T. 158, R. 74.	25		Sand		Sand points used.
W. H. Huff	SE. ¼ sec. 28, T. 158, R. 73.	126	2			
Charles Beck	4½ miles northwest of Wolford.	125		Sand		Strong well. Slightly salty.
O. A. Bryn	NE. ¼ sec. 31, T. 157, R. 74.	130	4	Gravel	12	Gas in well. May be ignited.
Elling Ellingson	SW. ¼ sec. 3, T. 157, R. 73.	190	2	Quicksand		Water at 50 feet. Dry blue clay (shale) below.
L. A. Larson	NW. ¼ sec. 21, T. 157, R. 73.	230				Water at 50 feet; poor.
Hans Hendrickson.	S. ½ sec. 29, T. 157, R. 73.	50				Dug well.
L. A. Larson	NW. ¼ sec. 32, T. 157, R. 73.	405	2	Quicksand		Water at 120 feet, blue clay (shale) below, Abandoned.
Great Northern Ry.	Rugby	34	2			21 driven sand points. 200,000 gallons a day.
Do	do	65				12 sand screens, driven. 25,000 gallons a day.

Typical wells of Pierce County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
George Watson	SE. ¼ sec. 21, T. 157, R. 71.	160	4	Shale	65	White sand 18 feet, blue clay, quicksand at 87 feet.
R. S. Smith	SE. ¼ sec. 34, T. 157, R. 69.	84	4		17	Steam pump, strong well.
Garvin Jacobson	NE. ¼ sec. 2, T. 156, R. 74.	112	2			Probably in blue clay.
Henry Paul	SE. ¼ sec. 20, T. 156, R. 74.	1,302	4			Abandoned.
H. J. Tjon	Sec. 18, T. 156, R. 73.	75		Quicksand		Water in fine sand at 40 feet.
Henry Gunderson	NW. ¼ sec. 25, T. 156, R. 73.	400				No water.
City [a]	Rugby	52		Gravel	40	8 feet by 2 feet.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Orrin	30		Sand		100 gallons a minute.
Steve Vetter	E. ½ sec. 34, T. 152, R. 73.	95		Gravel	30	
Do	do	400				Drift all the way. Abandoned. No water.
Peter Goldada	N. ½ sec. 35, T. 152, R. 73.	79	2	Sandstone	12	
Mrs. S. A. Pratt	NW. ¼ sec. 36, T. 151, R. 73.	92	2	Fine sand	30	Coarse gravel at 85 feet.
Lenwig Leismester.	Sec. 22, T. 151, R. 73.	195	2	Sandstone	40	

[a] See table of analyses.

RAMSEY COUNTY

TOPOGRAPHY

Ramsey County lies in the north-central portion of the Drift Prairie and includes the most notable part of what is known as the lake region of North Dakota.

The topography of the county is characteristic of the young drift type and has a strongly marked morainal character. The surface is a rolling plain that slopes gently southward to Devils Lake, which forms most of the southern border of the county. Several ranges of the Itasca moraine (of Upham) cross the county and give a hilly aspect to some areas, particularly about the east end of the lake. Pans are exceedingly common over the gentle slopes between the morainal ridges, and the landscape is plentifully dotted with these depressions, which are partly filled with water during the spring and seasons of abundant rainfall. Some of these pans are dry in summer and incrusted with a thin layer of white alkali salts, which at a distance has the appearance of water. Many have permanently dried and now form excellent hay meadows or are occupied with clumps of small trees, of which the poplar is perhaps most common.

The entire county lies within the theoretical drainage basin of Devils Lake, yet the region is almost unmarked by drainage lines save a few shallow winding coulees through which little or no water flows to-day but some of which were prominent channels of glacial drainage. Of these Mauvais Coulee is the largest, though but a very small part of it lies in this county. The lakes which it connected, however, largely lie within the county. These lakes form the Sweetwater group, which constitutes an extensive chain of lakes, including Sweetwater Lake, Dry Lake, Twin Lakes, Lac aux Mortes and Lake Irvine, all formerly connected by a series of coulees but now usually disconnected and dry in part. From this group Mauvais Coulee drained a considerable volume of water into Devils Lake. Of such volume was this stream in the early history of the region that a wagon ferry was maintained at Churchs Ferry.

Devils Lake is a very irregular body of water that occupies remnants of the drift-filled valleys of a preglacial river and its tributaries. The area of the lake when surveyed in 1883 was 125 square miles, and on account of its numerous bays and long slender arms the shore line exceeded 180 miles in length. The geologic as well as historic evidence shows that it was once even much larger than this, but to-day, owing to the rather rapid lowering of the lake level since cultivation of this region began, the area has been greatly reduced. The lake is relatively shallow, and at no point is more than 18 feet in depth.

Devils Lake is of interest here chiefly in its relation to the ground-water level of the region. As there is now no natural inlet the lake must receive its water from three sources: The rainfall upon the surface of the lake; the run-off from the small, uncertain, and very irregular area that slopes toward the lake and immediately surrounds it; and the ground water that comes into the lake, chiefly in the form of seepage. No considerable springs are known to feed the lake.

The amount of rainfall in the Devils Lake region is known from long-continued observations at several stations by the United States Weather Bureau. The records of these stations show that the normal annual rainfall is approximately 18 inches.

The inflow by run-off from the land immediately about the margins of the lake is small, uncertain, and very irregular. Comparatively little water enters the lake in this way because of the morainal character of the land that immediately surrounds it. Sags, pans, kettles, and other undrained depressions are common among the hills and on the prairies. The subsoil of glacial drift contains much gravel and sand and is relatively porous, and over a considerable portion of the area extends a forest cover. All these conditions favor evaporation or absorption of the rain water and decrease in the run-off. When we remember that "the total run-off for the entire year as found at river stations of this State is rarely more than 2 inches, and often only a fraction of 1 inch,"[28] we realize that very little of the run-off can reach Devils Lake under the conditions mentioned.

The chief source of the water of Devils Lake is undoubtedly the ground water. The surface of the lake is but a continuation of the water table that extends underneath the shores of the lake and gradually rises into the surrounding plains and hills. Water that falls in rain upon the lands percolates downward through the soil and subsoil until it reaches a horizon below which there is saturation or an impervious rock stratum. Owing to capillarity this water table, as the upper surface of the ground water is called, is higher under the hills and lower under the depressions, such as lake basins and valleys, but where these are so low as to pass below the water table the water seeps down along the table into these open areas until they are partly filled. In this way the level of the lake is maintained, subject to variations from evaporation and rainfall.

As there is no visible outlet to the lake, the only way that the water can pass from the lake is by evaporation into the air or by outflow in the form of ground water. The ground-water level is in general higher than the lake level, and the lake is the lowest part of this inland drainage basin, so it is exceedingly improbable that water actually flows out from the lake underneath any part of the surrounding country. The lake rather occupies the bottom of the basin into which the ground water from the surrounding country drains, particularly from the great prairie area that slopes from the north. The escape of water from Devils Lake

[28] Chandler, E. F., Surface Water Supply of the United States, 1907-8, Pt. V, U. S. Geol. Survey Water Supply Paper 245, p. 51, 1910.

to-day is therefore entirely by evaporation, and in times of normal rainfall the evaporation slightly exceeds precipitation and inflow and thus accounts for the gradual lowering of the lake since the earliest settlement in this region. The amount of water in the lake to-day therefore depends chiefly on the altitude of the water table on the one hand and evaporation on the other. Both of these factors depend to a large degree upon rainfall and the humidity of the atmosphere. We therefore see that the lake level is dependent primarily upon climatic control. It is subject to many fluctuations that are directly or indirectly associated with the weather and to some significant modifications that are the result of human agencies, such as drainage and the cultivation of the soil, but in general the size, depth, and permanency of the lake depends on climate.

An idea which has found rather wide credence among the inhabitants of the State is that the artesian wells are in some way connected with Devils Lake, that the head of the wells is maintained by this lake, and, further, that the flow of these wells has been the cause of the lowering of the lake level through drainage. This conclusion to some people seems to be verified by analysis of the waters, which shows the surface and the artesian waters to have some salts in common and therefore a similar taste. This theory has been most frequently advanced by those who reside in the vicinity of the lake and who are therefore familiar with both the water of the lake and that of the artesian well which supplies the city of Devils Lake.

It has evidently not occurred to those who have advanced this theory that the curb of the Devils Lake artesian well is approximately 40 feet above the present level of the lake and that the artesian pressure will carry the head of the water several feet higher. The holders of this belief are evidently not aware that the Dakota sandstone, the immediate source of the well water, is approximately at sea level—1,446 feet below the curb—and therefore over 1,400 feet below the bottom of Devils Lake, from which it is separated by that thickness of shale—the most impervious kind of rock known.

GEOLOGY

The surface deposits of glacial origin are so thick and so uniformly distributed over Ramsey County that no natural exposures of the underlying strata are known. From the samples and records of the deeper wells, particularly the log of the Devils Lake artesian well we have the essential facts. The bedrock is Pierre shale, and this shale, together with the Niobrara and Benton shales, underlie the region to the depth of 1,400 feet, where they are succeeded by the Dakota sandstone at approximately sea level. All these formations are of Upper Cretaceous age.

GROUND WATER

The well waters of Ramsey County are drawn from three distinct horizons—the drift, sand, layers of the Pierre shale, and the Dakota sandstone.

Most of the wells are shallow and draw their supply from the drift, which is chiefly a homogeneous boulder clay that ranges in thickness from 10 to 125 feet, though in few places does it exceed 60 feet, and is found throughout the county. Water occurs in small pockets of sand, beds, and seeps throughout the boulder clay and almost invariably in a sandy layer at the base of the drift, where it rests upon the shale. In the rolling morainal areas deposits of gravel and sand lie directly upon the surface and in these deposits water is usually found in considerable amount at their base, above the till. The water of the drift is generally of good or fair quality, particularly the waters of the morainal gravel and those in well-defined gravel beds in or below the till. Water from the smaller seeps and veins has usually been in such close contact with the débris of the shale, which constitutes a very large part of the boulder clay, that it is in many places strongly alkaline. Wells placed in low undrained depressions are usually very unsatisfactory because of the concentration of salts from surface drainage. The quantity of the drift waters is highly variable; it is large in thick beds of gravel but very meager in the till. It is generally inadequate for the larger farms.

The Pierre shale contains numerous fairly thick sandy layers in this region which may be commonly reached by wells 125 to 300 feet in depth and which furnish ample water for the ordinary farm well. These waters are, however, strongly impregnated with mineral salts, which render them rather undesirable for domestic use, though only a few are unfit for use by stock.

The third horizon is the Dakota sandstone, the aquifer of the Dakota artesian basin. Owing, however, to the depth of drilling required, the low pressure, and the poor quality of the water it is not practicable for individual well owners in this region. There are no shallow flowing wells of note in Ramsey County and but one deep artesian well that reaches the Dakota sandstone. The Devils Lake well is owned by the city but is operated by the Western Utilities Co., the owner of the waterworks system, near whose plant it is located. The well was completed in July, 1889, for use as a city supply. The curb is 1,470 feet above sea level, and the diameter of the well ranges from 8 inches at the top to 3½ inches at the bottom. When completed the well supplied 40 gallons a minute, but this quantity is said to have decreased until a centrifugal pump became necessary to increase the yield. The stream flows white and is rendered turbid by the extremely fine particles of white sand carried in suspension. The water is not generally considered potable but is used for fighting fires, flushing sewers, and other general purposes. The beds penetrated in the well are shown in the following log:

Log of Devils Lake well, Devils Lake [29]

	Feet
Glacial drift, till as on the surface	25
Dark shale, nearly alike through its whole thickness, including Pierre and Benton shales, with no noticeable calcareous beds at the intermediate Niobrara horizon	1, 403
Gravel, of granite pebbles up to half an inch in diameter, firmly cemented with nodular pyrite	3
Dakota sandstone, or rather a bed of loose sand, very fine, white or light gray, the base of which was not reached	80
	1, 511

The 1,403 feet of dark-gray shale beneath the drift and above the Dakota sandstone was not differentiated by the driller, but it undoubtedly included the Pierre, Niobrara, and Benton shales. In outcrops in the Pembina escarpment near Walhalla, Pembina County, both the Niobrara and the Benton are well shown. The Niobrara is somewhat lighter in color than either of the others and very calcareous. The Benton is dark, almost jet-black in large part, and in many places contains nodules of pyrite and crystals of gypsum. The lowest formation of this section is the Dakota sandstone, which was reached at a depth of 1,431 feet and which at 1,470 feet, just at sea level, yielded a strong flow of brackish water that carried much fine white sand in suspension. All the formations below the drift shown in this well log, which extends 41 feet below sea level, belong to the Cretaceous system. The artesian water from the sandstone at a depth of 1,470 feet had a pressure of 22 pounds to the square inch, but the pipe soon filled with sand and checked the flow. The drilling was continued 40 feet deeper, but no stronger flow was obtained below.

[29] Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, p. 529, 1895.

QUALITY OF GROUND WATER

The drift in Ramsey County yields hard water that ranges in mineral content from 300 to several thousand parts per million, though most of it is suitable for general use. (See analyses 13, 109, and 164.) The Pierre shale yields a better water in Ramsey County than in most places where it is resorted to for supplies. The water is moderately to highly mineralized and usually soft, though some hard water is obtained from this formation. (See analyses 120 and 165.) The Dakota sandstone yields water which is usually soft, though too highly mineralized for drinking and domestic uses. (See analysis 119.)

WATER SUPPLIES AT DEVILS LAKE

There are three possible sources of ground water supply for the city of Devils Lake—the Dakota sandstone, the Pierre shale, and the drift gravel.

The artesian waters of the Dakota sandstone are now in use as a source of supply by the city. This water is highly mineralized and is especially undesirable because of the amount of sulphates and common salt contained therein. It must be classified as poor for domestic use, though it is not a hard water. This sandstone will yield to pumps ample water for the use of the city for an indefinite future period, but the artesian flow will probably not continue for more than a few years, and the amount of pumping required will gradually increase.

Water may be obtained in small quantity in thin, fine, sandy layers of the Pierre shale at depths that range from 50 to 500 feet. This shale is drawn upon for the supply at the biological station and on many farms and a few city residences by tubular wells in which the water stands within easy pumping distance of the surface.

Shallow wells in boulder clay yield but little water, some of which is highly alkaline in character, but wells that draw their supplies from the drift gravel yield water superior to all others in this vicinity in quality. The water of the drift gravel is not ideal as a laundry or boiler water, but it is excellent water for drinking and for domestic uses in general. There are no wells which have given an adequate test as to quantity, but topographic and geologic conditions warrant further investigation on this point.

Typical wells of Ramsey County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
W. C. Faucett	SE. ¼ sec. 22, T. 159, R. 64.	367	6	Shale		
T. J. Dougherty	NE. ¼ sec. 31, T. 159, R. 63.	73	4¼	do	15	Satisfactory well.
Tom Rudser	SE. ¼ sec. 3, T. 158, R. 62.	135	4	do	14	Soft and salty.
Rielson Bros	NW. ¼ sec. 3, T. 158, R. 64.	125	4½	do	20	Soft. Drift 35 feet, shale 90 feet.
John Boulgers	NW. ¼ sec. 28, T. 158, R. 63.	68	4¼	Gravel		Satisfactory water.
James Hunt	SW. ¼ sec. 17, T. 158, R. 63.	98	6		20	Water at 15 and 26 feet and at the bottom.
Do	do	110	4½	Shale	25	Drift 40 feet, shale 70 feet.
Fred Anderson	SE. ¼ sec. 22, T. 158, R. 63.	107	4½	Gravel	20	
C. Hermens	SW. ¼ sec. 28, T. 158, R. 63.	170		Shale	12	Drift 60 feet, shale 110 feet.
William Ramboth.	NW. ¼ sec. 31, T. 158, R. 63.	80	4½	do		25 gallons a minute. Satisfactory water.
John Carroll	NE. ¼ sec. 4, T. 158, R. 62.	178	6	do	50	Salty water below shale.

Typical wells of Ramsey County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
O. O. Knudson	NE. ¼ sec. 6, T. 158, R. 62.	162	4	Gravel, clay	20	Soft but salty.
E. L. Beaverstad	4 miles northwest of Garske.	210				Satisfactory water.
E. Lee	W. ½ sec. 13, T. 157, R. 64.	116	4½	Shale	16	Soft. Drift 108 feet, shale 8 feet.
Do	do	125	5	do	12	Soft. Drift 90 feet, shale 35 feet.
Peter Traynor	SW. ¼ sec. 15, T. 157, R. 64.	74	4¼	do		Scant supply; salty.
Charles Burkett	SW. ¼ sec. 4, T. 157, R. 63.	81	4¼	do		Abundant but poor.
Gus Dahlstrom	SW. ¼ sec. 8, T. 157, R. 63.	79	4½	do	20	Soft. Drift 40 feet, shale 39 feet.
Gottlieb Otto	SE. ¼ sec. 20, T. 157, R. 63.	137	4½	Gravel	25	
J. W. Wheeler	NW. ¼ sec. 22, T. 157, R. 61.	186	5	Shale	45	Salty. Drift 30 feet, shale 156 feet.
A. T. Baker	SW. ¼ sec. 35, T. 157, R. 60.	95	66	do	21	Salty. Otherwise a good well.
Mrs. Kildahl	NW. ¼ sec. 3, T. 156, R. 66.	242		Dark sand	22	Salty.
R. J. Walker	NW. ¼ sec. 5, T. 156, R. 66.	45	4	Gravel	28	
C. A. Studness	NW. ¼ sec. 18, T. 156, R. 66.	153	140		22	
Erick Lysne	SW. ¼ sec. 23, T. 156, R. 66.	190	6	Gravel	20	
John Anderson	SE. ¼ sec. 23, T. 156, R. 66.	336	6	Sand in shale	20	Strong well. Water slightly mineralized.
E. Enger	NW. ¼ sec. 31, T. 156, R. 66.	190	4		25	
Garske Mercantile Co.	Garske	70		Shale		
Gus Garske	do	40		do		
W. D. Miller	Webster	140	4	do	18	Soft and salty.
Roy Ellis	NE. ¼ sec. 16, T. 156, R. 64.	140	4¼	do	30	Abundant but salty.
Rasmus Serson	SW. ¼ sec. 35, T. 156, R. 64.	300		do	18	Soft.
Peter Regan	NE. ¼ sec. 36, T. 156, R. 64.	111	6		17	Do.
William Belford	NW. ¼ sec. 7, T. 156, R. 63.	196		Shale	30	Soft. Drift 96 feet, shale 100 feet.
L. A. Frogner	NE. ¼ sec. 16, T. 156, R. 63.	150	4	do	12	Soft. Drift 40 feet, shale 110 feet.
John Zettler	NE. ¼ sec. 18, T. 156, R. 63.	169	4	do	20	Soft. Drift 80 feet, shale 89 feet.
John Maxwell	NW. ¼ sec. 20, T. 156, R. 63.	88	4	do	20	Soft. Drift 60 feet, shale 28 feet.
Ed. Regan	NW. ¼ sec. 31, T. 156, R. 63.	146				Salty.
Ray Rice	NW. ¼ sec. 8, T. 156, R. 62.	140		Soft shale	18	Drift 65 feet, shale 75 feet.
H. G. Hermenson	NW. ¼ sec. 10, T. 156, R. 62.	202	4	Shale	20	Salty, soft. Drift 60 feet, shale 142 feet.
John Steward	NW. ¼ sec. 16, T. 156, R. 62.	115	4	do	15	Soft and a little salty. Drift 59 feet, shale 56 feet.
E. S. Eich	NE. ¼ sec. 21, T. 156, R. 62.	130	4		30	
Lars Aberz	SW. ¼ sec. 22, T. 156, R. 62.	153	4	Shale	15	Salty, soft. Drift 50 feet, shale 103 feet.
R. Vilandre	SE. ¼ sec. 32, T. 156, R. 62.	125	4½	do	18	Soft. Drift 25 feet, shale 100 feet.
A. Kalhagen	SW. ¼ sec. 24, T. 156, R. 62.	140	4	do	18	Salty and soft. Drift 65 feet, shale 75 feet.
Louis Bratt	SE. ¼ sec. 19, T. 156, R. 61.	82	4	Sand, gravel		Satisfactory water from base of drift.
Great Northern Ry.	Penn					12 by 26 by 62 feet. Capacity 150,000 gallons a day.
Mr. Hausmann	Churchs Ferry	149	4	Shale	14	
Public school	do	140				
W. A. Howsman	do	140				
Henry Doyle	NE. ¼ sec. 1, T. 155, R. 66.	153	76		22	
Henry Gessner	SW. ¼ sec. 24, T. 155, R. 66.	178	4	Shale	25	

Typical wells of Ramsey County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
R. Stenke	SE. ¼ sec. 24, T. 155, R. 66.	227	4	Shale	28	
J. M. Litchenberger.	SW. ¼ sec. 27, T. 155, R. 65.	156	4	do	25	
Ole Leet	NE. ¼ sec. 9, T. 155, R. 64.	136	4½	do	25	Soft but slightly salty.
Charles Melson	SE. ¼ sec. 14, T. 155, R. 63.	81	4	do	20	
Hagen Bros	SW. ¼ sec. 3, T. 155, R. 62.	207	4	do	20	Salty. Drift 70 feet, shale 130 feet.
Ray Cunningham.	SE. ¼ sec. 33, T. 155, R. 61.	98	4	do	20	At 55 feet passed through 2 or 3 feet of coal.
J. J. Smith	SE. ¼ sec. 6, T. 155, R. 60.	51	4	Gravel	25	Satisfactory water above bedrock.
J. Johnson	SW. ¼ sec. 12, T. 155, R. 60.	304	4			45 feet to soft blue shale. Dry hole.
Hans Olson	SW. ¼ sec. 15, T. 155, R. 60.	77	4	Shale	58	Water at 33 feet and at bottom.
Vactow Pisek	SW. ¼ sec. 2, T. 155, R. 59.	130	4	do		
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Darby	70				Very little water.
Do	Devils Lake	225		Shale	20	Salty.
County [a]	Sec. 34, T. 154, R. 64.	136	6-4	do		
S. Merrill	NW. ¼ sec. 19, T. 156, R. 64.	198	4	Clay	35	Salty.
E. Gunn	SE. ¼ sec. 26, T. 154, R. 64.	116	4	do	26	
N. A. Halgren	SE. ¼ sec. 5, T. 154, R. 63.	116	4	do	30	
John Wolf	NE. ¼ sec. 11, T. 154, R. 63.	250				A little water at 50 feet. Abandoned.
V. Walters	NW. ¼ sec. 12, T. 154, R. 63.	300				Dry hole.
M. K. Lee	W. ½ sec. 26, T. 154, R. 63.	123	4		28	
Even Evenson	SE. ¼ sec. 28, T. 154, R. 63.	153	4		35	
C. Ashland	W. ½ sec. 2, T. 154, R. 62.	120			20	
John R. Shand	SE. ¼ sec. 3, T. 154, R. 62.	136	4	Shale	35	Water at 60 feet and at bottom. Drift 90 feet, shale 46 feet.
T. Kavana	Sec. 6, T. 154, R. 64.	208		do	18	Drift 120 feet, shale 88 feet. Abandoned.
Tom Lennon	SE. ¼ sec. 11, T. 154, R. 62.	190				
John Mather	Sec. 26, T. 154, R. 62.	112	4		20	
Kalinowski Bros.	NW. ¼ sec. 28, T. 154, R. 62.	120				Drift 60 feet, shale 60 feet.
A. R. Kalinowski	SW. ¼ sec. 28, T. 154, R. 62.	140				
Anton Rutten	NE. ¼ sec. 28, T. 154, R. 62.	190				Plenty but salty.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Southam	60		Shale		20 gallons a minute.
Village	Crary	225		Fine sand		Water at 165 feet.
Herman Rutten	do	250		Blue clay		Poor water.
James Dean	do	149		Sand in shale	30	
D. C. McCloud	E. ½ sec. 11, T. 153, R. 62.	120		do	18	
Do	W. ½ sec. 12, T. 153, R. 62.	120				Soft and slightly salty. Drift 60 feet, shale 60 feet.
T. W. Morrisey	1½ miles northwest of Crary.	130				
Lambert H. Rutten.	NW. ¼ sec. 16, T. 153, R. 62.	223	4	Sand	35	Soft.
K. H. Smith	NE. ¼ sec. 29, T. 153, R. 62.	300		Shale		Ample yield of salty water.
Great Northern Ry.	Doyon					12 by 24 by 20 feet. 150,000 gallons a day.
H. A. Nicholson	NW. ¼ sec. 14, T. 152, R. 63.	156			50	

[a] See table of analyses.

Water supply of towns in Ramsey County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bartlett	98	Bored			160		Shale	Shallow water somewhat alkaline, deeper slightly salty.
Brocket	240	Dug, bored	10	110	25			Shallow water hard and alkaline, deep salty.
Churchs Ferry.	353	Drilled	30	120	40			
Crary	307	Dug, drilled	25	40	35	Drift		
Devils Lake	5,140	do	20	140	130	Drift, gravel	Sand in shale.	Shallow water hard, artesian water soft but strongly mineralized.
Doyon	150	Bored, drilled	25	150	45	Sand	Shale	
Edmore	501		30	65	50	Clay	do	
Garske		Dug, drilled	20	150	30	Drift	do	Few slight flows.
Hampden	199	Drilled	80	175	130	Blue clay		Deep water salty, shallow better but hard.
Lawton	227	Dug, drilled	10	175	20	Gravel	Shale	
Penn	325	do			30			Deep water soft, shallow hard.
Starkweather	302	do	60	165	100	Gravel	Shale	Shallow waters alkaline, deep soft and salty.
Webster	100	Drilled	15	175	160	Drift	do	Deeper waters somewhat salty.

RANSOM COUNTY

TOPOGRAPHY

The Pembina escarpment separates Ransom County into two topographic provinces. The eastern province, which comprises only about one-third of the total area, belongs to the Red River Valley plain, and the western province lies in the higher Drift Prairie. The topography of the valley portion is not typical of the old lake floor, as the area lies entirely within that part of the southwestern margin on which was laid down the sand brought into the lake by Sheyenne River and deposited in a large delta. These delta deposits have been extensively worked upon by the waves, which have heaped them into beaches and in places so far removed them that the drift is exposed over considerable areas. In other places the wind has heaped the sand into dunes of considerable height.

The drift portion of the county lies 200 to 400 feet above the valley floor and has the uneven topography that is characteristic of the ground moraine in North Dakota. Two recessional moraines of the later or Wisconsin ice sheet cross this portion of the county—one along the western margin and the other diagonally from northwest to southeast. Each of these moraines forms fairly well defined ranges of rounded irregular hills that are more conspicuous than those of the ground moraine but of much the same character.

Probably the most striking topographic feature of the county is the valley of Sheyenne River. This river enters the county from the northwest, forms a great loop southeast of Lisbon, retires northward along the face of the escarpment for a distance, and then crosses the delta to the northeast. The portions of the valley above and below the escarpment present very striking contrasts. In the upland prairie the river has excavated a valley 200 feet in depth and three-fourths of a mile in breadth, which is out of all proportion to the small stream that now meanders widely upon the flood plain. In front of the escarpment the valley is much shallower and smaller. The contrast is explained only by reference to the origin and history of the stream. The upper valley was carved by the heavily laden waters that flowed southward from the front of the retreating ice sheet when it lay in the vicinity of Devils and Stump Lakes. The mouth of the stream was then at the margin of Lake Agassiz, near the face of the escarpment, and the coarse sand carried by the stream was being laid down on the delta while the finer silt was carried farther out into the deeper waters and deposited as lake silt. On the retreat of the lake water the river extended its course across the delta and ultimately to the axis of the valley, where it joined with the waters of Otter Tail, Wild Rice, and other rivers to form Red River.

GEOLOGY

The youngest formations of Ransom County are the gravelly alluvium of the flood plain and terraces of the Sheyenne Valley and the sand of the Sheyenne delta. Beneath the delta sands and forming the surficial deposits of the upland prairie lies a thick sheet of glacial drift, which is composed chiefly of till, or boulder clay, and more or less water-assorted sand and gravel. The rock on which the drift rests is probably of Cretaceous age throughout the county. Pierre shale is the country rock of the higher plain, but this undoubtedly ends at the escarpment, as it was eroded away over the area of the Red River Valley in preglacial time.

The Niobrara shale crops out beneath the Pierre shale in the Sheyenne Valley both above and below Fort Ransom, and the Benton shale is probably present underneath the delta. Below these shales lies the Dakota sandstone. Under the sandstone lies the granite in the Soldiers' Home well at Lisbon, and this probably forms the basement rock in the county.

GROUND WATER

Ransom County is well supplied with ground water, which comes from four distinct formations—the valley and delta sand and gravel, the drift sheet, the Pierre shale, and the Dakota sandstone.

The waters of the alluvial and lake gravel and sand are undoubtedly the best in quality. Wells not exceeding 30 feet in depth yield large supplies of water, particularly in the delta region, where the water is obtained in the fine gravel and sand immediately above the boulder clay. The water that falls on the surface as rain or snow percolates downward through a sand filter to the impervious clay beneath. Owing to the level surface of the clay the water is held in the base of this sand as in a reservoir.

The drift consists of yellow clay mingled with boulders, gravel, and sand above, passing into a more compact blue boulder clay below. The upper portion is stained yellow by the oxidized iron compounds and the blue is the unaltered and unoxidized drift. The water supply in the upland portion of the county for common household and domestic uses is procured from dug or bored wells that enter sand pockets or small veins in the clay. There is, however, at the base of the drift and immediately above the shale a porous sandy layer, which supplies many of the wells.

The Pierre formation is composed chiefly of shale that in places contains thin, porous sandy layers. The shale is of no value as a water bearer, but the sandy layers yield a small slightly brackish supply. Most bedrock wells, however, draw their supply from the artesian waters below.

As the entire county lies within the area of artesian flow of the Dakota sandstone, deep flowing wells are common, except in the portion covered by the delta sand, where better water is obtained at slight cost in shallow wells. The Dakota is a white friable sandstone interbedded with a few layers of shale and limestone that have a total thickness of about 200 feet. It lies not more than 400 feet below the surface at the eastern edge of the county, and because it dips westward whereas the surface rises toward the west, the depth increases to about 900 or 1,000 feet at the western margin of the county. Large flows under considerable pressure were found in all parts of the county, but the amount of flow depends on the size and location of the wells. The history of the decline in pressure and yield of the artesian wells of Lisbon (see below) is the history of all artesian wells in this county. In general, however, the pressure and flow are sufficient to make excellent farm wells, and relatively few wells have ceased to flow in this county. If, however, the waste of water from these wells is permitted to continue unabated the loss will begin to be seriously felt within the next decade, as it is now in counties on the margins of the area of artesian flow.

Most of the springs of Ransom County flow from the sides of the Sheyenne Valley, which enters the northwest corner, makes a great bend through the south-center, and leaves near the northeast corner. As the surface of this county is deeply covered with drift few large springs occur elsewhere.

QUALITY OF GROUND WATER

The valley and delta sand and gravel of Ransom County yield hard water of low to moderate mineral content and are suitable for general use. (See analysis 123.) The drift yields hard water that differs in mineral content but is usually acceptable for most uses. (See analysis 121.) The Pierre shale yields moderately to highly mineralized water of variable hardness. Many wells yield water that is satisfactory for domestic and other uses. The Dakota sandstone yields highly mineralized water, most of which is hard. (See analyses 122, 124, and 125.) It is used a great deal, but water from the shallow wells is preferred for drinking and domestic supplies.

WATER SUPPLIES AT LISBON

There are three possible sources of ground-water supply for Lisbon—the Dakota sandstone, the alluvial deposits of the Sheyenne Valley, and the drift gravel of the high-level terrace on the west side of this valley.

The artesian waters of the Dakota sandstone are now in use as a source of public supply for the city, the water being supplied by several wells, from which it has been until recently forced into the standpipe and distributed through the mains by direct pressure. Owing, however, to the decrease in pressure in the artesian basin, it has been found necessary to cut off the artesian wells from direct connection with the mains and to install a pump to lift the water from the strongest well into the standpipe, from which it is now distributed by gravity. The artesian waters are soft but highly mineralized and are therefore not entirely satisfactory as a city supply. The sandstone will yield to the pump ample water for the use of the city for an indefinite time, but the decrease in head, which in Lisbon amounts to at least 4 feet a year, will necessitate heavier pumping in the future. Three wells, known as the Martin (depth 890 feet, diameter 3 inches), Marsh (depth 751 feet, diameter 2 inches), and Standpipe (diameter 2 inches), have furnished the city supply. The Martin well alone will just about supply the city with its present flow of 200 gallons a minute when fully open. The Marsh and Martin wells are about on a level with each other, and though of different depths draw from approximately the same horizon, 840 and 770 feet, respectively. The pressure at the surface from this horizon has decreased from 65 pounds in 1908 to 50 pounds in 1915, 38 pounds in 1917, and 32 pounds in 1921, a decrease of about 2½ pounds a year. This decrease in pressure results in a decrease in head of water of about 5 feet a year. At this rate all three wells will cease to flow in about 12 years from the date of the last test.

Analyses of the waters of the terrace gravel show that they are superior in quality to all other available waters. As yet there has been no adequate test of the quantity of these waters available, but topographic and geologic indications are favorable on this point.

The waters found in the alluvial deposits that underlie the Sheyenne River Valley are fed by rainfall upon the uplands of the river basin and enter the alluvium through innumerable seepages along the valley sides. They therefore do not come from the river, as many suppose, except possibly to a slight extent in high water, but, on the other hand, are the source of much of the water which drains away through the river channel. These waters resemble the river waters in composition, though they are generally harder. They are usually thoroughly sand filtered and are not polluted, except from local sources. The depth of this alluvium and the character of the deeper deposits is not definitely known, and therefore the quantity has not yet been proved. There is, however, little doubt that the quantity is ample and that they would afford a good supply second only to the terrace-gravel waters above mentioned and probably more abundant.

Typical wells of Ransom County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Fred Budke	Sec. 26, T. 139, R. 54.	700				Dakota sandstone underlies drift. Water from bed at 450 feet rises outside of casing, causing damage.
Herman Oehlke	W. ½ sec. 21, T. 137, R. 55.	678	1¼	Sandstone	Flow.	
E. K. Aus	NE. ¼ sec. 6, T. 136, R. 57.	1,025	2½	do	Flow.	
J. L. Birklid	NW. ¼ sec. 29, T. 136, R. 57.	967	2½	do	Flow.	
A. Aasheim	Sec. 3, T. 136, R. 56.	800				Small flow at 500 feet; another flow at 600 feet; main flow not reached.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Enderlin	24	180	Gravel		2 wells of same size connected.
Do	do	613	10	Sandstone	Flow.	Original pressure 120 pounds. Original flow 1,000 gallons a minute. Salty.
George Olsen	SE. ¼ sec. 30, T. 136, R. 55.	702	1¼	do	Flow.	
Ole Christianson	NW. ¼ sec. 30, T. 136, R. 55.	745	1¼	do	Flow.	
Village [a]	Sheldon	633	3	do	Flow.	600 gallons a minute. Former pressure 60 pounds. Upper flow at 540 feet.
D. H. Olney	NW. ¼ sec. 9, T. 135, R. 57.	1,313	1¼			
William Casey	NE. ¼ sec. 5, T. 135, R. 56.	880	1¼	Sandstone	Flow.	Casing perforated 10 feet at bottom.
Northern Pacific Ry.	Butzville	50	4			Driven well.
Henry Behrend	NE. ¼ sec. 10, T. 135, R. 54.	476	1¼			
Minneapolis, St. Paul & Sault Ste. Marie Ry.	McLeon	50	2			Many sand points, 72 inches long. Satisfactory water.
Thomas Anderson.	Sec. 1, T. 135, R. 53.	550	3	Sandstone		First flow at 290 feet; second flow at 340 feet; third flow at 380 feet. Water in loose sand, with hard rock at bottom.

[a] See table of analyses.

Typical wells of Ransom County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Thomas Anderson.	Sec. 1, T. 135, R. 53.	182		Gravel	Flow.	10 rods from first well. Water from gravel at base of drift.
George H. Loomer.	NW. ¼ sec. 15, T. 134, R. 57.	925	1¼	Sandstone	Flow.	Perforated 13 feet at bottom.
J. A. Pietz	NE. ¼ sec. 21, T. 134, R. 57.	1,087	1¼	do	Flow.	
Northern Pacific Ry.	Engelvale	33	192			Brick curb; satisfactor water.
City	Lisbon	850			Flow.	Soft and salty.
M. Knapp	do	900				
Northern Pacific Ry.	do	14	96			Brick curb near Sheyenne River.
North Dakota Soldiers' Home.	do	960	4½			First flow at 540 feet; second flow at 650 feet; third at 700 feet. Granite at bottom.
Do	do	785		Sandstone	Flow.	
Do	do	655	2	do	Flow.	Perforated 6 feet at bottom in second flow.
Do	do	785	2	do	Flow.	Perforated 4 feet at 716 feet (third flow), 4 feet at 646 feet (second flow).
R. S. Adams [a]	NW. ¼ sec. 11, T. 134, R. 56.	30	30	Gravel, alluvium.	26	
J. W. Patterson	SW. ¼ sec. 1, T. 134, R. 55.	637	1¼	Sandstone	Flow.	Perforated 3 feet at bottom.
Jesse Sellman	11 miles east of Lisbon.	600	2	do	Flow.	Formerly used with water motor and dynamo for power and light for farm.
A. Nachtegall	NE. ¼ sec. 6, T. 134, R. 54.	475	1¼	do	Flow.	Perforated 49 feet at bottom.
L. M. Bixby	4 miles northeast of McLeod.	456	1¼		Flow.	
John Allen	E. ½ sec. 19, T. 134, R. 50.	515			Flow.	
C. C. Arndts	N. ½ sec. 9, T. 133, R. 55.	800	1¼	Sandstone	Flow.	Perforated 3 feet at bottom.

[a] See table of analyses.

Water supplies of towns in Ransom County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Anselm		Dug, drilled	20	500	25	Drift	Sandstone	Artesian wells yield salty water.
Buttzville		Bored, drilled	30	800	60	Gravel		Do.
Elliott	150	Drilled		1,100			Sandstone	Do.
Enderlin	1,919			800			do	Do.
Engleville	200	Dug, bored	20		25	Gravel	do	Do.
Lisbon	1,855	Drilled	25	950		Sand, gravel	do	Do.
McLeod	195	Driven	10	20		Sand	Sand	
Sheldon	321	Driven, drilled	15	600		do	Sandstone	Public supply from artesian well.

RENVILLE COUNTY

TOPOGRAPHY

The most striking topographic feature of Renville County is the deep narrow valley of Souris River, which traverses it from northwest to southeast. The area lies, therefore, within the Souris River Basin, yet because of its high altitude, no part of it save the extreme southeast corner was submerged by glacial Lake Souris. To the west of the Souris Valley the upland is morainal; whereas to the east it is fairly well drained by small shallow coulees that lead down to the margin of old Lake Souris. On the whole the county is a nearly level portion of the Drift Prairie.

GEOLOGY AND GROUND WATER

Small amounts of water for household and farm use are commonly procured from the sandy or gravelly portions of the drift. The Fort Union formation, which underlies the drift in all of the northern Missouri Plateau region in this State, thins out greatly in the Missouri escarpment and finally disappears near the eastern edge of Renville County, where it has been eroded away, and there the underlying Pierre shale becomes the bedrock. Throughout most of the county, however, drilled wells may draw water from the sandstone and lignite of the Fort Union, but the shale which predominates in the lower part of this formation and which almost entirely constitutes the Pierre is nearly or quite barren of available water. In the Pierre area wells have to be drilled deeper to obtain a supply in the porous sandy layers, and many of these wells contain a considerable amount of gas which, in some places, lifts the water in such a way as to cause it to jet out rather than flow in the normal way. A number of these wells occur in the eastern part of the county.

GAS WELLS

Along a line that extends southeastward from a point west of Sherwood to a point east of Glenburn, which marks the axis of a slight anticline, several gas wells have been obtained. In the well on the Kaasa farm, 3 miles west of Mohall, a pressure of 107½ pounds to the square inch has been recorded, and in the one on the Jesse Powell farm, 6 miles northwest of Mohall, an original pressure of 156 pounds has been reported. The gas from the Kaasa well is used for light and heat on the farm of the owner and that of one neighbor. All wells in this vicinity over 150 feet in depth show at least traces of gas. In some the gas is sufficient to interfere with the working of the cylinder in the pump, and in others it has been known to blow the drilling tools out of the well.

QUALITY OF GROUND WATER

Most of the shallow-dug wells in the drift in Renville County yield hard water that is generally low in mineral content. (See analyses 24, 126, 178, and 183.) The sandstone and lignite of the Fort Union formation in the western part of the county furnish soft, moderately to highly mineralized waters suitable for general use. (See analyses 25 and 182.) Where these beds thin out or completely disappear in the eastern part of the county, the sandy lenses of the Pierre shale yield water that differs from place to place both in mineral content and hardness. Much of this water is rather highly mineralized, and some of it contains enough mineral matter to make it unsuitable for general use.

WATER SUPPLIES AT MOHALL

The public water supply for the city of Mohall is taken from a well only 8 feet deep, 2½ miles northeast of the city, on the western side of a broad, shallow coulee. The water originally stood in spring and early summer about 5 feet below the surface in this well, and a pumping test shows the inflow to be about 150 gallons a minute. This coulee reaches far to the northwest, past Sherwood and into Canada, and to the southeast past Lansford and Glenburn and probably drains into a branch of Cutbank Creek, a tributary of Souris River. At a point a mile or two northwest of the well this coulee is apparently entered by a short branch of Cutbank Creek, and the upper portion is at least partly drained eastward by a short cut into Cutbank Creek. The present drainage area of this coulee is therefore rather small and may not extend more than a mile or two north of the well site. This coulee is evidently one of those streamways formed by the waters that flowed southward from the front of the glacial ice during its retreat in the closing stage of the glacial epoch and is partly filled with the coarse gravel and sand that was deposited by a stream of considerable size but of short duration. The surface drainage of this coulee is to-day limited to a very slight flow over the frozen ground with the melting of the waters from the rolling uplands on both sides during the early spring. This flow is slight because most of the drainage that formerly passed through this coulee is deflected to the Cutbank Creek in a more direct course by the short tributary mentioned above.

Most of the water of this coulee comes as slow seepage through the coarse sand and gravel that underlies the coulee floor to a depth of 12 to 14 feet. This underground drainage flows down the valley in the same direction as the surface water and is known as the underflow. The amount of underflow and therefore the depth of the ground-water level below the surface varies with the season; it is greatest in June, July, and August and is probably least in the late winter after the additions from the surface have been shut off by the frozen ground for several months and the water has been finding its way gradually to lower levels in the ground.

The water that occurs as underflow in valley gravel of this type comes directly from the rainfall of summer and to a less degree from the melting snows. It has percolated directly into the loose porous soil of the region and has neither been deep in the group nor traveled far underground. Its course has been through sand and gravel, from which it has dissolved little mineral matter, and it is therefore soft and wholesome and is undoubtedly the best obtainable water in the region.

Typical wells of Renville County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Ole Johnson	NE. ¼ sec. 34, T. 164, R. 85.	380		Sand		Gas.
John Volk	SE. ¼ sec. 9, T. 163, R. 86.	700				No gas; 2 other wells 600 feet deep. Dry.
C. H. Laisko	NW. ¼ sec. 12, T. 163, R. 86.	652				Little gas near 300 feet. Coal present.
Ed. Fods	NW. ¼ sec. 17, T. 163, R. 86.	718			40	
John Walstrom	NE. ¼ sec. 21, T. 163, R. 86.	805			150	No gas.
Pat J. Dalton	NE. ¼ sec. 23, T. 163, R. 86.	695				Some gas. Coal near 300 feet. Blue shale below.
A. W. Fenberg	SE. ¼ sec. 25, T. 163, R. 86.	400				Gas.

Typical wells of Renville County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
U. G. Beito	NE. ¼ sec. 25, T. 163, R. 86.	375	3	Gas		Gas.
Frank J. Harris	SW. ¼ sec. 4, T. 163, R. 85.					No gas. 21-foot coal bed at 400 feet.
G. Grengo	NW. ¼ sec. 9, T. 163, R. 85.	400		Sand	30	Water in sand below shale.
Alex Chapdeline.	NW. ¼ sec. 10, T. 163, R. 85.	385		do		Gas occurs a little above bottom in salty water. Coal at about 230 feet.
Mrs. Newbaue	NE. ¼ sec. 12, T. 163, R. 85.	337		Gravel	20	Plenty of salty soft water. Clay 285 feet, coal 6 feet, "hardpan" 35 feet, sand and gravel 10 feet.
City	Sherwood	340		Sand		Weak water well. Gas at 270 feet in blue sand. 8-foot coal bed at 280 feet; 11-foot coal bed at 300 feet.
Electric light plant.	do	372		do		Water in fine sand. Very little gas. 8-foot coal bed at 350 feet. Pumps down to 100 feet below curbs.
M. Reisling	1½ miles of Sherwood.				8	Trace of gas. Pumps down to 80 feet. 4 to 8-foot coal at about 230 feet.
Tom Rowan	SW. ¼ sec. 31, T. 163, R. 85.	396				Gas with water. Coal present.
Oscar Hammerberg.	SW. ¼ sec. 34, T. 163, R. 85.	380	3	Sand		Gas in fine sand at 300 feet. Coal bed at 340 feet beneath hard brownish shale.
Charles Sanderson.	NW. ¼ sec. 7, T. 163, R. 84.	370	3	do	2	Drift probably.
William Flath	NW. ¼ sec. 11, T. 163, R. 84.					Coal at 230 feet.
Ben Harvey	NW. ¼ sec. 13, T. 163, R. 84.	425	3	Sand, gravel.	30	Light gas above salty water. Coal at 200 feet.
T. A. Sloan	SW. ¼ sec. 21, T. 163, R. 84.	298	3	Sand		A little gas. First coal bed at 260 feet, second coal bed separated from water by thin layer of "hardpan."
Louis Backerdal.	1½ miles south and 1 mile east of Sherwood.	356	3		Flow.	Trace of gas.
J. W. Brown	NW. ¼ sec. 22, T. 163, R. 84.	300				Little gas.
R. A. Newbauer.	NW. ¼ sec. 26, T. 163, R. 84.	283	3	Coal, sand		Some gas with water. Streaks of coal between 80 and 100 feet; coal at about 200 feet.
L. L. Goheen	W. ½ sec. 26, T. 163, R. 84.	275		Sand	12	Gas at 260 feet in dark-blue sand. Gas sand passes into coarser water sand below. Coal present.
Frank C. Baska	NW. ¼ sec. 27, T. 163, R. 84.	580	3	do		Water salty. Gas with water at 320 feet in fine dark sand. Very coarse sand 2 feet at 123 feet, coal 2 feet, shale 4 feet, muddy sand 40 feet, hard white layer 10 inches at 290 feet, shale at 300 feet, muddy sand layer 10 inches at 320 feet, hard layer at 321 feet, coal 3 feet at 321 feet, coal 3 feet at 330 feet, very sandy white shale 2 feet at 334 feet, hard layer 4 inches at 347 feet, white limerock 4 inches at 350 feet, dark-gray shale (Pierre?) at 444 feet.

Typical wells of Renville County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
George Baker	NW. ¼ sec. 28, T. 163, R. 84.	340				Trace of gas.
John T. McCampbell.	SE. ¼ sec. 31, T. 163, R. 83.	235	2	Gravel	Flow.	Gravel 11 feet, boulder clay, gravel, shale, and coal 5 feet.
L. E. Zimmer	SE. ¼ sec. 3, T. 162, R. 87.	900				Dry.
Johanna Jensen	NE. ¼ sec. 27, T. 162, R. 87.	545	3	Sand	60	
Carl A. Olson	NE. ¼ sec. 10, T. 162, R. 86.	417		do		Gas. Sand at 124, 224, and 247 feet, soft shale at 283 feet, hard shale at 288 feet, little sand and coal at 310 feet, sandy streak at 386 and 396 feet, sandy shale at bottom, water bearing.
Marcus Johnson	SE. ¼ sec. 14, T. 162, R. 86.					Gas.
Ralph Taute	NW. ¼ sec. 15, T. 162, R. 86.	400		Sand		Trace of gas. Sand a 386 feet.
Emil Nelson	NE. ¼ sec. 24, T. 162, R. 86.	400		Sandy shale		Gas causes water to flow after pumping. Gas and water in shale.
H. J. Deverman (William Budke farm).	SW. ¼ sec. 2, T. 162, R. 85.	438	3	Sand	Gas lift.	Drift 400 feet, shale, sand 20 feet. Gas at 390 feet.
Ben Armstrong	SE. ¼ sec. 4, T. 162, R. 85.	425				Gas at about 400 feet. Coal present.
B. Godfrey	NE. ¼ sec. 9, T. 162, R. 85.	400	3	Sandy shale	30	Gas. Shale at 260 and 290 feet, sandy shale at 346 feet, coal at 355 feet, very fine sand at 362 feet, sandy shale at 372 feet, little coal at 387 feet, sandy shale, water bearing, at 392 feet.
Paddy Mullins	SW. ¼ sec. 23, T. 162, R. 85.			Shale		Trace of gas. Bedrock at 242 feet, shale at 285 feet, hard layer at 302 feet.
John Steffes	SE. ¼ sec. 23, T. 162, R. 85.	444	2	Sand	Gas lift.	Gas at about 300 feet. Salty water. Sand 3 feet at 70 feet, 2 feet at 80 feet, and 3 feet at 169 feet; fine gravel 2 feet at 266 feet; gas sand at 347 feet; sand at 440 feet.
J. P. McCrary	NW. ¼ sec. 23, T. 162, R. 85.	346		Sandy shale		Small cobbles at 75 feet, hard layer at 285 feet, hard shell at 306 feet, gravel at 326 feet, hard layer at 327 feet. Coarse sand and fine gravel, clean, white to brownish red, at 329 feet, muddy sand and shale at 346 feet.
J. A. Lorenzen	SE. ¼ sec. 34, T. 162, R. 85.	560		do		Drift about 250 feet, Fort Union 100 feet, Pierre 210 feet.
P. A. Jones	NW. ¼ sec. 5, T. 162, R. 84.	430				Gas at 260 feet.
Do	do	413				Water well.
N. O. Nelson	NW. ¼ sec. 8, T. 162, R. 84.	390	3	Sand	Gas lift.	Gas at 268 feet. Yellow and blue clay, white soapstone, coarse sand and gravel with water, white shale.
Village	Lorraine	420	3	do	Gas lift.	Gas.
Great Northern Ry.	do			Drift		12 by 24 by 18 feet. Dry in winter. Capacity 6,000 gallons in summer.

Typical wells of Renville County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
W. W. Schumaker.	SE. ¼ sec. 9, T. 162, R. 84.	420		Sandy shale		Gas with water in shale at bottom of well.
F. E. Bohn	NE. ¼ sec. 10, T. 162, R. 84.	440	3	Sand	35	Gas at about 300 feet. Hard layer of shale at 360 feet followed by blue-gray shale and quicksand containing gas at about 300 feet. Coal bed above or very near gas, also at about 140 feet.
P. Sheridan	NW. ¼ sec. 14, T. 162, R. 84.	416		do		Gas with water at bottom.
C. C. Snyder	SW. ¼ sec. 14, T. 162, R. 84.	410		do	Gas lift.	Gas in water at bottom.
A. D. Ketchem	NW. ¼ sec. 15, T. 162, R. 84.	426		do	Gas lift.	"Lorraine gas well."
Giles Ketchem	SW. ¼ sec. 15, T. 162, R. 84.	350		do		Gas. Also water.
L. E. Gates	SE. ¼ sec. 19, T. 162, R. 84.	495	3	do	Gas lift.	Coal bed at about 300 feet. Other small veins at 256 feet. Gas at about 400 feet in green sand.
Julius Larson	SW. ¼ sec. 21, T. 162, R. 84.	415		do		Shale at 285 feet; coal at 340 feet; sandy shale, gas, and water; sand 2 feet at 380 feet; sandy shale 318 to 415 feet; coal at 394 feet; little sand at 398 feet.
Jesse Powell	SE. ¼ sec. 24, T. 162, R. 84.	428	3	do	60	
Charley Burke	NW. ¼ sec. 21, T. 162, R. 84.	289½		do		Gravel 4 feet at 80 feet; 1 foot at 100 feet, and 1 foot at 120 feet; sand 2 feet at 125 feet, and 1½ feet at 130 feet; yellow sand 4 feet at 217 feet; a little water; sandy blue clay; soft shale at 283 feet.
Toutchek & Trentuva.	SE. ¼ sec. 23, T. 162, R. 84.	365		do		Gas at 310 feet. Shut off by drilling deeper and getting water at 365 feet. Probably drilled to 446 feet.
J. Moberg	NW. ¼ sec. 33, T. 162, R. 84.			do		Gas.
H. J. Lee	S. ½ sec. 34, T. 162, R. 84.	308				No gas.
Eric Johnson	SW. ¼ sec. 21, T. 161, R. 87.	360			40	
E. P. Polly	SE. ¼ sec. 13, T. 161, R. 86.	378		Sandy shale		Gas; some coal.
J. S. Johnson	NE. ¼ sec. 8, T. 161, R. 85.	518		Sand		Gas.
Herman Butts	NW. ¼ sec. 8, T. 161, R. 85.	468		Sandstone		Do.
K. Haarsager	NW. ¼ sec. 10, T. 161, R. 85.	326	1¼	Sand		Water that carries gas. Sand at 250 and 307–390 feet.
F. Dietz	NW. ¼ sec. 12, T. 161, R. 85.	414		Sandy shale		Gas. Probably finished at 360 feet.
John Harrold	NW. ¼ sec. 13, T. 161, R. 85.	270				Little gas.
E. Johnson	SW. ¼ sec. 14, T. 161, R. 85.	354		Sand		Gas in water sand.
G. Sundby	NW. ¼ sec. 15, T. 161, R. 85.	375		do		"Hardpan" at 360 feet, above gas and water in sand. Salty water.
G. E. Schroeder	NE. ¼ sec. 15, T. 161, R. 85.	315		do		No gas noted. Water not very salty. Sand at 65, 80, and 140 feet, soft blue clay, shale at 283 feet.
A. J. Cook	SE. ¼ sec. 18, T. 161, R. 85.	358		do	Gas flow.	

Typical wells of Renville County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
A. Johnson	NE. ¼ sec. 23, T. 161, R. 85.	319				Gas. Water soft and salty.
M. F. Johnson	SW. ¼ sec. 24, T. 161, R. 85.	400				
R. D. Johnson	NW. ¼ sec. 24, T. 161, R. 85.	290		Sandy shale		Little gas.
Fred Johnson	NW. ¼ sec. 26, T. 161, R. 85.	320				Gas. Water not salty.
S. A. Wilcox	NW. ¼ sec. 29, T. 161, R. 85.	580	3	Sand		Sand, muddy, 2 feet at 25 feet; sand, muddy, at 36 feet, sand at 40, 60, 71, and 90 feet; sand, muddy, 1½ feet at 173 feet; sand, yellow, 8 inches at 188 feet; sand 6 inches at 194 feet; sandy clay 15 feet at 200 feet; sand 20 inches at 256 feet; chalk rock 18 inches at 257½ feet; coal 8 inches at 309 feet; sand, muddy, 10 feet at 340 feet; sandy brown shale to bottom. Well finished later at 580 feet.
G. O. Wilcox	NE. ¼ sec. 29, T. 161, R. 85.	380		do		Trace of gas only. Much sand.
L. T. Stromsvold	SW. ¼ sec. 7, T. 161, R. 84.	410		Sandy shale		Blue clay 60 feet, sand 10 feet at 250 feet, shale 270 feet.
T. Bennett	NE. ¼ sec. 9, T. 161, R. 84.	312	3	Sand	12	Gas.
Martin Johnson	SW. ¼ sec. 12, T. 161, R. 84.	300	3	Sandy shale	Gas lift.	Gravel, hard layer, 4 feet at 260 feet; gravel 2 feet, layer of blue clay, gas sand, 3 or 4 feet at 268 feet; water to 296 feet; black shale at 300 feet; some chalky sand near hard layer of cap rock.
William Clifford	Mohall	350	2	Sandstone	60	
Village	do	350	4	do	60	Drift 270 feet to shale. Water in soft sandstone. Water salty.
O. E. Allen	SW. ¼ sec. 17, T. 161, R. 84.	352		Sand		Gas.
Frank Bowen estate.	SW. ¼ sec. 18, T. 161, R. 84.	393	3	do	28	Trace of gas. Water-bearing sand at 393 feet.
H. R. Kaasa gas well.	NE. ¼ sec. 20, T. 161, R. 84.	257	3	do		Dry gas well.
H. R. Kaasa	NE. ¼ sec. 20, T. 161, R. 84.	390	3			Water well. Sand with water and gas at 330 feet.
A. B. Stromsvold	NW. ¼ sec. 20, T. 161, R. 84.	462		Sand		Gas at 290 feet. Sand at 70, 80, and 90 feet; sand 13 feet at 266 feet, shale at 279 feet; sand at 317 feet. This hole was probably drilled to 462 feet with gas sand at 430 feet.
Mr. Gerringer	NE. ¼ sec. 21, T. 161, R. 84.	350		do		Test well for gas; Great American Gas & Oil Co. well No. 5. Drift to 263 feet; gravel, sand, and shale, 19 feet, to 281 feet; gas-bearing sand 13 feet at 282 feet; water-bearing sand with shale at 290 to 350 feet; coal 2 feet at 342 feet.

Typical wells of Renville County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
W. A. Overing, McNaught well.	NE. ¼ sec. 33, T. 161, R. 84.		3	Sand	Gas lift.	Gas at 282 feet.
Do	do	414	3	do		Attempt for water well. Gas, found at 276 feet, came up about casing and cracked ground under drilling rig. Well abandoned. No water.
City [a]	Mohall	8		Gravel	5	
Tom Newbeck	SW. ¼ sec. 36, T. 160, R. 86.	612	3	Sand	175	Several small water-bearing beds below 500 feet.
O. E. Peterson	SE. ¼ sec. 20, T. 160, R. 85.	396		do		Hard layer 5 feet at 321 feet, red sand 240 feet, streaks of sand 380 feet.
James King	SW. ¼ sec. 23, T. 160, R. 85.	486		do	100	Trace of gas in water-bearing sand.
N. Williamson	NE. ¼ sec. 3, T. 160, R. 84.	306				First and only hard cap rock 16 inches thick at 290 feet. Strong flow of gas with water under this cap. Test well for gas.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Grano	634	10	Shale		Yields 25 gallons a minute to pump. Clay 250 feet, shale 384 feet.
Do	do	735	10	Sandstone		Drift 90 feet, blue-gray shale at 402 feet, gray sandstone with salt water at 500 feet. No water below. Abandoned.
J. A. Randolph	SE. ¼ sec. 17, T. 159, R. 84.	408		Fine sand	60	Water at 250 to 260 feet.
M. J. Undlion	NW. ¼ sec. 25, T. 159, R. 84.	416	4–2½	do	40	Soft water.
Peter Hanson	NE. ¼ sec. 8, T. 158, R. 85.	500		Sand		Quicksand.
Henry Jevne	W. ½ sec. 12, T. 158, R. 84.	495	3	Sandy shale		Soft water.
Ed. Schelling	NW. ¼ sec. 15, T. 158, R. 84.	463	2½	Fine sand	150	
Great Northern Ry.	Glenburn					14 by 24 by 16 feet. 25,000 gallons daily in winter, 50,000 gallons in summer.
Village	do	407	6	Sand	40	Salty water; gas at 265 feet. 7 feet of coal near 260 feet. Gas interferes with pumping.
A. B. Shattuck	NE. ¼ sec. 14, T. 158, R. 82.	405		Gravel	25	Affected by weather. 365 feet to bedrock.
S. A. Haveland	NE. ¼ sec. 1, T. 158, R. 81.	200		Sand	Gas lift.	Flowed 24 hours probably due to gas.
George A. Walter	SW. ¼ sec. 3, T. 158, R. 81.	238	4		26	Drift 155 feet. Sandy shale at 232 feet. Gas.
Chris Broderson	NW. ¼ sec. 4, T. 158, R. 81.	196	2	Sand	Gas lift.	Blew water and gas for 2 weeks.
O. T. Thompson	SE. ¼ sec. 7, T. 158, R. 81.	309	3	Sandy shale	22	Drift 160 feet. Gray and brown sandy shale to 309 feet. Gas.
E. McIlroy	SE. ¼ sec. 9, T. 158, R. 81.	250–300			Gas lift.	Gas flowed for days. When engine stops water is forced out of top of well by gas. Coal present.
R. C. Barrett	NW. ¼ sec. 20, T. 158, R. 81.	325			Gas lift.	Gas. Plenty of water. 9-foot vein of coal at about 200 feet.
Ole Harringan	SW. ¼ sec. 28, T. 158, R. 81.	140	5		30	Water well.
Do	do	135	5			Strong gas well. Dry gas followed by water and sand.

[a] See table of analyses.

Water supplies of towns in Renville County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Glenburn	228	Dug, drilled		410	20 200	Gravel	Sand in shale, coal.	Deeper waters somewhat mineralized.
Grano	112	Bored, drilled	20	580	80	do	Sandstone	
Loraine	74	do	20			Drift		Shallow, water satisfactory; deep well, water salty. Natural gas lifts water without pumps.
Mohall	651	Dug	15	285	25	Clay	Sandstone	Water hard in shallow and soft in deep wells.
Sherwood	423	Dug, drilled	10	600	25	Drift	Shale	Water in shallow wells somewhat mineralized; in deep wells salty. A little gas in all deep wells.
Tolley	325	Dug	15	285	25	Clay	Sandstone	Water hard in shallow and soft in deep wells.

RICHLAND COUNTY

TOPOGRAPHY

Richland is the southeasternmost county of the State and belongs to two physiographic divisions—the Red River plain and the Drift Prairie. It has, however, a third distinct topographic division in the Sheyenne delta which must be differentiated from the other two in a study of the ground waters.

The lacustrine silt that was deposited on the bed of Lake Agassiz occupies the eastern part of the area in a belt 10 to 15 miles in width that parallels Bois de Sioux and Red Rivers. The silt is so thinly distributed in this portion of the lake bed, however, that the modified morainal topography of the underlying till sheet and the sand beach ridges thrown up by the waves produce a somewhat more undulating surface than is characteristic of the Red River Valley. The delta formed by the deposits of Sheyenne River in the southwestern margin of the lake rests on the lake bed in the northwestern and major part of Richland County. The surface of this delta differs greatly, from nearly level to rolling and even rough where the wind has formed hills of sand so choppy and irregular that driving among them is difficult.

The southwest corner of the county is occupied by morainal deposits, which for the most part are rough and hilly, with many sloughs and depressions between the hills. The division between the drift and lake areas is here formed by the Herman beach line, the highest level attained by Lake Agassiz. This beach lies along the high morainal range of hills, which confined the lake on the south. The escarpment probably lies west of the county border but is so low and so buried under morainal débris as not to be clearly distinguishable.

Over the drift-covered area drainage is very imperfectly developed. Small marshes, sloughs, and lakes occur in considerable numbers. Water that does not sink below the surface drains from the surface into the sloughs and there stands until absorbed by the soil or evaporated into the air. Sheyenne River in the north and Wild Rice River in the south cross the delta plain, but neither may be said to drain this area. The surface soil is so porous that practically all water that falls as rain enters the ground, and drainage is chiefly of the subsurface type. Some of this water enters the streams as seepage and springs.

The county is bordered on the east by Red River and its tributary, the Bois de Sioux, and Wild Rice River, where it emerges from the eastern margin of the delta upon the plain of the lacustrine silt, turns northward and parallels the master stream at a distance of only 2 or 3 miles until it enters Red River in Cass County.

GEOLOGY

So thick is the mantle of lacustrine deposits and glacial drift over the region that the only knowledge obtainable regarding the bedrock comes from the reports and drillings of the deeper wells. Owing to the prevailing use of the jetting process the results are very unsatisfactory.

The Cretaceous shale and sandstone extend eastward for a considerable distance underneath the county, probably entirely across the southern end, and they overlie granite of a rather gneissic sort in the eastern portion. In the northeast corner the till probably rests directly upon the decayed surface of the granite basement.

GROUND WATER

Several formations contain supplies of ground water in Richland County, including the lacustrine silt, delta gravel, drift gravel and sand, Cretaceous sandy shale, and Dakota sandstone.

Shallow wells in the eastern division, which is covered by lacustrine and alluvial silt, may find a scanty supply of water within this soft clay, but it is not generally satisfactory. In places the lower layers that overlie the till are sandy and contain a considerable amount of fair water.

An excellent supply for shallow wells is found in the sand and gravel of the delta deposits and in the beach ridges of the northwestern part of the county. On these areas wells 10 to 20 feet in depth generally furnish large supplies of water, chiefly from the base of the sand formation immediately above the underlying clay. This water has fallen upon the surface as rain or snow and percolated downward as through a sand filter until it has been checked by the impervious bed of clay, where it is held in the base of the sand as in a reservoir. So effectively was the shore sand washed by the waters of the lake that it contains very little soluble salts in solution, such as impregnate the waters of the drift and country rock.

The drift consists of yellow clay mingled with boulders, gravel, and sand, which passes below into a more compact blue boulder clay. The upper portion is stained yellow by the oxidation of the iron compounds, whereas the blue portion is the unoxidized drift. Beneath the lacustrine silt and sand the oxidized zone in the drift is generally absent. The water that supplies most of the homes of the county for domestic uses is procured from dug or drilled wells that enter this drift. In the morainal portion of the region the upper part of the till generally contains much gravel and sand, and these materials commonly supply the shallowest wells. Other wells find pockets of sand and sandy layers in the body of the till, in which the water is fair and the quantity variable but commonly abundant. The strongest wells of this horizon probably come from the gravelly layers at the base of the drift immediately above the bedrock. Many of these drift wells are artesian. The pressure is slight and the flow not strong, though considerable variation may occur in a small area. These artesian wells are commonly 50 to 150 feet in depth, but some of them are as much as 200 feet deep. Wells of this type are most common in the northeast quarter of the county, but a few have been obtained among the morainal hills of the southern part.

Cretaceous shales are not good water carriers, but in many places in the southwestern part of the county they contain thin porous beds of sandstone that yield a fair supply to a few of the wells. Most wells that do not find water in the drift are carried through to the Dakota sandstone for a flow or to granite before abandonment.

The Dakota sandstone probably underlies all the western half of the county, and in patches at least extends beneath Red River into Minnesota. Few if any wells have been drilled into this formation in the northeast quarter of the county, for excellent water can be obtained at shallow depths in the sand and gravel of the Sheyenne delta of the ancient beaches of glacial Lake Agassiz. Many wells have been drilled to the Dakota sandstone in the southwest quarter, and they obtain a moderate flow at depths of 300 to 600 feet. The water comes from a fine-grained loose gray sand of the Dakota formation. Both the pressure and the depth of these wells increase toward the west. The flow is decreasing on account of the loss of head through waste. It is hoped that the conservation of artesian water now being undertaken will check this decrease.

The springs of Richland County occur chiefly about the margin of the Sheyenne delta, where the waters that have fallen on the delta sand have percolated downward until they reached the drift or lake silt below and have moved along this clay surface until at the margin of the delta they emerge in the form of springs. In the morainic area in the southern portion of the county other springs flow from the sand and gravel deposits of the drift. One of this type is Crystal Spring, which is owned by A. J. Barkee and is situated in the NW. ¼ sec. 27, T. 130 N., R. 50 W., 3 miles southwest of Hankinson. The flow of 1 gallon a minute comes from the base of a high morainal hill that lies immediately west of Lake Elsie and enters the lake. Water from this spring is hauled to Hankinson and sold for household use. The water is reported to be hard but otherwise excellent.

QUALITY OF GROUND WATER

Analyses 127–136 indicate that the waters obtainable in Richland County differ greatly in quality. Shallow wells that draw on the delta deposits yield hard, moderately mineralized water that is suitable for general use. (See analysis 130.) Deeper wells that enter the drift sand and gravel yield hard water, much of which has less than 1,000 parts per million of total solids, though a few of these waters are too highly mineralized for general use. Water from the Cretaceous shales is acceptable for most uses, though it is usually hard and moderately to highly mineralized. The Dakota sandstone yields soft, moderately to highly mineralized water that contains less mineral matter than water from the same formation in counties farther west. (See analyses 134 and 136.) If a well penetrates one of the limestones concretions the water is hard and commonly contains more mineral matter.

Typical wells of Richland County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Village [a]	Christine	115	3	Sand	25	
John Kaufman	Walcott	196	3-2	Gravel		No flow found.
Do	SW. ¼ sec. 26, T. 135, R. 50.	724	3	Sandstone		724 feet to granite. No flow.
A. A. Moe	NE. ¼ sec. 10, T. 135, R. 49.	120			100	
A. A. Barboe	NW. ¼ sec. 26, T. 135, R. 49.	135	2	Gravel	Flow.	
L. M. Bixby	SW. ¼ sec. 6, T. 134, R. 52.	456	1¼	Sandstone	Flow.	

[a] See tables of analyses.

Typical wells of Richland County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
H. I. Moe	Abercrombie	150	2	Gravel, sand	Flow.	
A. K. Tweto	do	318	2	Fine sand	Flow.	
Mrs. F. Bauer	1¼ miles south of Abercrombie.	465		Sandstone		
Lars Samfer	SE. ¼ sec. 5, T. 134, R. 48.	132	2	Coarse gravel	Flow.	
W. T. Scoville	NW. ¼ sec. 8, T. 134, R. 48.	112	2	Sand, gravel	Flow.	
Rasmus Tverdahl.	NW. ¼ sec. 17, T. 134, R. 48.	165	2	Gravel	Flow.	
Mrs. A. K. Twete [a]	SW. ¼ sec. 4, T. 134, R. 48.	318	2	Fine sand		
A. Bidgood	SW. ¼ sec. 26, T. 133, R. 52.	565	2	Sandstone	Flow.	Soft water.
A. Read	SW. ¼ sec. 29, T. 133, R. 52.	583	2	do	Flow.	Do.
D. G. Hoxie	SW. ¼ sec. 24, T. 133, R. 51.	480	2	do	Flow.	
John McLeod	SW. ¼ sec. 8, T. 133, R. 50.	520				No water.
Paul Tibeau	NE. ¼ sec. 20, T. 133, R. 50.	450		Sandstone	Flow.	4 holes 400-500 feet deep. Struck granite two places. Little water, no pressure. Water at 280-300 feet.
E. Farub	SW. ¼ sec. 28, T. 133, R. 50.	566	1¼	do	Flow.	Salty water.
William Wumpful.	SW. ¼ sec. 11, T. 132, R. 52.	530	1¼	Sand	Flow.	Do.
D. Hanson	NE. ¼ sec. 15, T. 132, R. 52.	530	1¼	do	Flow.	Do.
A. Olson	NW. ¼ sec. 16, T. 132, R. 52.	300	2	do	Flow.	Drift; shallow flow.
A. Starin	NW. ¼ sec. 22, T. 132, R. 52.	285	2	do	Flow.	
George Blake	E. ½ sec. 25, T. 132, R. 52.	515				
A. L. Bailey	NE. ¼ sec. 27, T. 132, R. 52.	456	1¼	Gravel	Flow.	Water also at 280 feet.
Do	do	300			Flow.	
Village	Wyndmere	515	2	Sandstone		
J. H. Spohn	NE. ¼ sec. 8, T. 132, R. 51.	464	2	Sand	Flow.	
C. H. Kehrberg	NE. ¼ sec. 8, T. 132, R. 50.	470			Flow.	Into blue shale, little water; said to overlie granite.
Elizabeth Heilkamp.	NW. ¼ sec. 9, T. 132, R. 50.	520				No water.
A. Schwam	NW. ¼ sec. 11, T. 132, R. 50.	170	3	Sand	6	
Adam Stan	NW. ¼ sec. 22, T. 132, R. 50.	280				
Gust Lelland	E. ½ sec. 22, T. 132, R. 50.	280				
H. M. Bailey	N. ½ sec. 31, T. 132, R. 50.	470	2			470 feet to granite, no water.
A. Aspinwall	Wahpeton	270	2½	Sandstone	20	
City	do	450	10	do	Flow.	420 feet to water-bearing bed. Pumped with air lift.
S. Swenson	do	390	8	do	Flow.	Water rose practically to surface. Pumped with air lift at rate of fully 300 gallons a minute, which is reported to lower the water level in well about 200 feet.
City	do	470	4-2	do	Flow.	Water at 370 to 420 feet. Well extends to granite. Water rose practically to surface.
Northern Pacific Ry.	do	20	96	do		
Star Roller Mill	do	273	3	Sand	6	Principal water-bearing bed, 25 feet thick, at 248 feet.

[a] See table of analyses.

Typical wells of Richland County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
North Star Roller Mill.[a]	SE. ¼ sec. 8, T. 132, R. 47.	283	3	Coarse white sand.	12	
George W. Carey	NE. ¼ sec. 3, T. 131, R. 52.	501				
A. E. Otterburn	W. ½ sec. 22, T. 131, R. 52.	680	1¼	Sandstone	Flow.	
Charles Mittag	SW. ¼ sec. 13, T. 131, R. 50.	136	2	Sand	Flow.	
George Warner	W. ½ sec. 4, T. 131, R. 49.	163	2	do	Flow.	
Herman Zeitlow	T. 131, R. 49	150	2	do	3	Pumped 20 gallons a minute.
Berthold Zeitlow	SE. ¼ sec. 10, T. 131, R. 49.	238	2	do	Flow.	
George Woner	SW. ¼ sec. 14, T. 131, R. 49.	160	2	do	4	
Mrs. R. Newman	SW. ¼ sec. 15, T. 131, R. 49.	136	3	do		Pumped about 60 gallons a minute.
William Neitzel	NW. ¼ sec. 20, T. 131, R. 49.	80	3	do		Runs into reservoir; 3 gallons a minute.
William Weiss	NE. ¼ sec. 32, T. 131, R. 49.	180	3	do		Pumped 5 gallons a minute.
Herman Prochenow.	NW. ¼ sec. 32, T. 131, R. 49.	80	3	do		Do.
Alfred Ambach	NE. ¼ sec. 5, T. 131, R. 48.	70	3	do		Pumped 10 gallons a minute.
Rudolph Kreuger	SW. ¼ sec. 8, T. 131, R. 48.	127	3	do		Pumped 5 gallons a minute.
Herman Mitzel	NE. ¼ sec. 17, T. 131, R. 48.	137	2	do		Flows in reservoir; 3 gallons a minute.
Louis Stoltenow	NW. ¼ sec. 19, T. 131, R. 48.	42	3	do		Pumped 10 gallons a minute.
J. D. Holthusen	NE. ¼ sec. 20, T. 131, R. 48.	230	3	do		Flows 3 gallons a minute into reservoir;
H. A. Seana & Son.[a]	Fairmount	263	8	Red sand	30	
William Clark	Lidgerwood	697	2½-1¼	Sandstone	Flow.	20 gallons a minute. Perforated 5 feet at 622 feet.
Movius Land Co.	do	556	2	do	Flow.	
Lidgerwood Mill Co.	do	600	2	do	Flow.	
Jake Zimmerman	do	95	2		60	
City, first well	do	760	2	Sandstone	Flow.	Former pressure, 92 pounds. Flows also at 600 feet.
City, second well	do	640	3		Flow.	Former pressure 80 pounds; first flow at 490 feet, light second flow at 631 feet. Drift 100 feet, blue sand with little water 65 feet, blue shale 35 feet, dark-gray shale 100 feet, blue shale 325 feet, white sandstone 15 feet. Lower shale containing sandstone and pyrite few inches thick.
Lidgerwood Mill Co.	do	635	3-2	Sandstone	Flow.	Former pressure 65 pounds. Used for city supply.
J. H. Movius	SE. ¼ sec. 14, T. 130, R. 52.	670	3-2	do	Flow.	Former pressure 93 pounds. Yield 60 gallons a minute; flows at 490 and 631 feet. Used in city water system. Yellow clay 35 feet, blue clay 130 feet, sand and gravel, blue clay 135 feet, blue shale 100 feet, slate rock 20 feet, gray shale 80 feet, sandrock with hard layers 170 feet.
Lidgerwood Roller Mill.[a]	NE. ¼ sec. 13, T. 130, R. 52.	960	2			

[a] See table of analyses.

Typical wells of Richland County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. H. Movius	NW. ¼ sec. 15, T. 130, R. 52.	720	2	Sandrock	Flow.	Cloudy water in storm. Part of Lidgerwood water system.
Theodore Haas [a]	NW. ¼ sec. 13, T. 130, R. 52.	22	16	Gravel, drift	19	
Movius Land & Loan Co.	4 miles south of Lidgerwood.	675	1¼	Sandstone		8 gallons a minute.
Great Northern Ry.	Stiles	45	120			2 wells; 75 gallons a day.
Do	do	168	8			
City	Hankinson	140		Sand	Flow.	Hard rock at bottom.
Phillips & Courtenay Elevator Co.	do	130	3	do	Flow.	Fine sand 60 feet, coarse white water sand 5 feet, soft blue clay 10 feet, fine dark quicksand 45 feet, blue shale 4 feet (including lignite 3 inches), water sand 5 feet. Water sand also at 65 feet.
Krim Bros	do	162		do	Flow.	Sand 90 feet, soft blue clay 20 feet, clay and sand 30 feet, sand with water 20 feet.
A. H. Melcher [a]	NE. ¼ sec. 13, T. 130, R. 50.	12	36	Drift	4	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Hankinson	331	6	Sand		Pumped for boiler use.
Jaszkowich & Son [a]	NW. ¼ sec. 13, T. 130, R. 50.	170	2	Gravel and sand.	Flow.	
Matt Kenn	SW. ¼ sec. 1, T. 130, R. 49.	110	3	Sand		
Peter Wirtz	SE. ¼ sec. 3, T. 130, R. 49.	100	3	do		Pumped 3 gallons a minute.
G. Hulberg	N. ½ sec. 9, T. 130, R. 49.	326	2	do	10	Soft and salty. Sand 60 feet, till 140 feet, shale 108 feet, hard rock 2 feet, coarse sand 16 feet.
Great Northern Ry.	DeVillo	45	120			2,000 gallons a day.
Do	do	150	2½			3,000 gallons a day.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Fairmount	120	3	Coarse gravel	Flow.	
Continental Land Co.	6½ miles southwest of Fairmount.	130	2		Flow.	Strong artesian flow from drift. Strong flow of gas.
Robert Boetcher	NW. ¼ sec. 4, T. 130, R. 48.	158	2	Sand		Flows into reservoir 2 gallons a minute.
J. Richards	E. ½ sec. 14, T. 130, R. 48.	300	3			Dry.
H. Nelson	SE. ¼ sec. 24, T. 130, R. 48.	140	5	Gravel	20	
Dr. J. Greeman	W. ½ sec. 34, T. 130, R. 48.	135	3	Sand, coal	Flow.	
J. G. Johnson	SW. ¼ sec. 17, T. 130, R. 47.	276	4	Gravel	26	Pumped 30 gallons a minute.
Creamery	SE. ¼ sec. 20, T. 130, R. 47.	220	6	do	30	Pumped 55 gallons a minute.
Burt Kurtz	NW. ¼ sec. 33, T. 130, R. 47.	75	5	do	2	Pumped 50 gallons a minute.
Daniel Taylor [a]	Fairmount	1,624	36	Lake silt		

[a] See table of analyses.

Water supplies of towns in Richland County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Abercrombie	266	Drilled	60	400	250	Clay, sand	Gravel, sand	Many flowing wells.
Christine	175	Bored, drilled	30	100			Gravel	Bored wells 30 feet, drilled wells 100 feet.
Colfax	120	Drilled	80	150	90			85 to 100 foot artesian wells yield 5 to 30 gallons a minute, head 5 to 15 feet.
Dwight	139	do	80	160	100-150	Sand	Sand	Some flow with head 10 to 20 feet.
Fairmount	706	Dug, drilled	15	240	225	Clay	do	
Great Bend	142	Drilled	40	250	130	Sand, gravel	Sand, gravel	No flow. Small springs.
Hankinson	1,477	Bored, drilled	65	175	135	Sand	Gravel	Few small springs.
Lidgerwood	1,065	Drilled	20	700		Clay, sand	Rock	
Mantador	200	do	90	500	125		Sandstone	Artesian flow slight.
Moorton	123	do	150	280	225	Sand	Sand	Artesian head 20 feet.
Wahpeton	3,069		200	420		do	do	Flowing wells.
Wolcott		Drilled	100	450				
Wyndmere	570	Dug, drilled	10	525		Sand	Sand	Artesian head 10 feet.

ROLETTE COUNTY

TOPOGRAPHY

Rolette is a county of contrasts in topography, for it includes portions of the Turtle Mountains outlier of the Missouri Plateau, the Drift Prairie plain, and the Souris River Valley.

The Turtle Mountains consist of a moraine-covered table-land that occupies the northwestern part of the county. In the distance they appear to rise mesa-like above the surrounding plains to an altitude of 400 to 600 feet. Their margin is a gently sloping escarpment that merges rather gradually into the plain. The mountainous character is suggested not only by the height of the plateau above the surrounding country but also by the rough morainal character of its surface. The upland is covered with considerable timber but is poorly drained. Lakes are plentiful, and the clear, sweet waters are the home of many game fish and the resorts of numerous wildfowl.

The Drift Prairie slopes gently down toward the south and east and this, too, is quite strongly morainal in character. The numerous streams that rise in the foothills of the "mountains" lead southward into the headwaters of Willow Creek, a tributary of Souris River and eastward through shallow grassy coulees to the Mauvais Coulee, formerly occupied by a stream of considerable size. A broad strip in the southwestern part of the county, equivalent to about two townships, lies within the area covered by the waters of Lake Souris at its highest stage. This strip is not markedly different from the Drift Prairie except in the slightly modified drift hills and the marginal deposits of sand that cover portions of the surface of the former lake bed.

GEOLOGY

The Turtle Mountains form an isolated outlier of the Missouri Plateau and are capped, like the main part of the plateau, by the Fort Union formation, which consists mainly of shale and sandstone with a few thin beds of coal. The

Souris River Valley is a lake plain that resembles the Red River Valley in origin, as it was covered by the waters of Lake Souris. The shore sands here thinly cover the drift, which elsewhere forms a thick mantle over the entire region. The bedrock of the southern half of the county is the Pierre shale. No beds deeper than the Pierre crop out nor are any reached by wells in the county.

GROUND WATER

The Turtle Mountains may be considered a ground-water province distinct from the Drift Prairie. Very few wells have been sunk through the drift, and therefore little is known of the character of the waters of the Fort Union formation here except what may be inferred from wells in adjacent counties. The beds of sandstone and lignite that are common in the Fort Union formation are both good water bearers, though the water from the lignite has a brown color and a somewhat unpleasant taste. Owing to the heavy mantle of drift over the horizontal sedimentary beds that form the Turtle Mountains, the forest cover, and the lack of well-developed drainage, the rain which falls on the surface largely enters the ground, and much returns to the surface about the margins in the form of hillside springs.

Nearly all wells in the county draw their supply from the drift, which in this vicinity yields a somewhat better quality of water than that from the more level tracts because of the large number of gravel beds and layers of sand contained and the excellent subsurface drainage that results. Some of these gravel beds form widespread outwash deposits on the surface, as about Dunseith, where the Great Northern Railway has an extensive gravel pit. Others lie deeply buried at the base immediately above the bedrock. The waterworks at Rolla are supplied by two wells 35 and 104 feet deep.

In the Drift Prairie the sandy layers of the bedrock are drawn upon for a considerable number of wells, and many of those immediately about the foot of the slope of the escarpment flow, owing to the hydrostatic pressure that is developed in the higher head of waters in the adjacent upland. An illustration of this condition is found on the farm of John Dunlap, jr., in the SE. ¼ sec. 14. T. 161 N., R. 70 W., where a slight flow has been developed.

A stronger flowing well was obtained at the State sanitarium, 7 miles northeast of Dunseith, where a 12-inch well was sunk to a depth of 172 feet through glacial drift. The water-bearing bed ranges in texture from fine sand to coarse gravel. The well was finished in the coarse gravel without a screen. The flow was 250 gallons a minute and the head at least 29 feet above the surface. The temperature of the water was 42° F. This flowing well is undoubtedly of the artesian-slope type and obtains its head from the thick layers of gravel and sand that overlie the surface and upper slopes of the Turtle Mountain mesa. It is therefore no doubt closely akin to the strong springs that flow from the slopes in the vicinity of the sanitarium and of Dunseith.

As is characteristic of most escarpments in which horizontal beds of sedimentary rock crop out, particularly if overlain by a porous mantle of drift, hillside springs are common about the margin of the Turtle Mountains and in the sides of the valley that leads down from the hills and yield flows uncommonly large for North Dakota. In the early settlement of the region, before the virgin forest cover was removed from the hills, spring-fed streams from the hills were sufficiently strong to operate small gristmills. The mineral springs, a few miles northwest of Dunseith, are perhaps best known. Like all spring water of this region the water of these springs is high in mineral content. The deposition of the mineral content on exposure of the water to the air is aided very materially by the vegetable matter that grows profusely in the waters, and the result is the upbuilding of travertine or tufa domes and terraces of considerable area and height on the hillsides and in the heads of valleys. These terraces are, however, to-day heavily masked by vegetation, probably on account of the decreased activity in building that has resulted from the lessening flow of the waters since the destruction of a large part of the forest cover. At a somewhat similar group of springs on the mountain side 7 miles northeast of Dunseith the State sanitarium has been established. It has a healthful location, a beautiful outlook, and an abundant supply of pure water.

QUALITY OF GROUND WATER

Both shallow wells that enter the sandy layers near the surface and deeper wells that enter the base of the drift in Rolette County yield hard and moderately to highly mineralized water, most of which is satisfactory for general use. (See analyses 137–140.) Soft water that contains moderate to large amounts of mineral matter is obtained from the sandstone and lignite veins of the Fort Union formation. Analyses 18 and 20 indicate that water from this formation would be satisfactory for general use.

Typical wells of Rolette County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Charles Bryant	N. ½ sec. 31, T. 164, R. 70.	360		Shale		Abundant supply of hard water.
Eugene Conture	NW. ¼ sec. 4, T. 163, R. 70.	45	1½	Sand, gravel	Flow.	"Strong flow." Pressure 5 pounds.
Great Northern Ry.	Dunseith					150,000 gallons a day.
Samuel Watkins	10 miles north of Dunseith.	160				Dry hole.
Sanitarium [a]	NW. ¼ sec. 30, T. 162, R. 72.	190	12	Gravel	Flow.	
Indian agency	Belcourt	140			16	Filled with sand.
Charles Menciur	2 miles south and 3 miles west of Rolla.	380			25	Yellow and blue clay 120 feet, gravel 1 foot, blue clay 27 feet, gravel 2 feet, soft shale 30 feet, harder shale 100 feet, hard dark shale 20 feet, light-blue shale 80 feet.
John Dubois	1 mile south and 6½ miles west of Rolla.	98		Sand, gravel		
K. L. Turcott	NE. ¼ sec. 17, T. 162, R. 70.	340				Clay 240 feet, soft shale 60 feet, hard shale 40 feet.
R. H. Butterwick.[a]	NW. ¼ sec. 16, T. 162, R. 69.	16	36	Gravel		
Herman Shaver	SE. ¼ sec. 3, T. 162, R. 69.	130		Sand, gravel	48	
Doctor Lemmen	N. ½ sec. 4, T. 161, R. 73.				Flow.	Shallow flow.
D. C. Barnard	5 miles west of Dunseith.	102	4½		30	Soft but mineralized.
Harry Williams	NE. ¼ sec. 11, T. 161, R. 70.	96	18	Sand	46	Slightly salty water in white sand and gravel.
F. Bush	SW. ¼ sec. 12, T. 161, R. 70.	65			10	
John Dunlap, jr.	SE. ¼ sec. 14, T. 161, R. 70.	100		Sand, gravel	Flow.	Slightly mineralized.
Great Northern Ry.	Rolette					12 by 14 by 11 feet; 15,000 gallons a day.
Minneapolis, St. Paul & Sault Ste Marie Ry.	do	20	120			30 gallons a minute. Satisfactory water.

[a] See table of analyses.

Water supplies of towns in Rolette County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Mylo	140		20	100	60	Sand	Sand	
Rolette	409	Dug, driven	10	35	20	do	do	Abundant water in drift sands.
Rolla	675	Dug			15-35	Drift		
St. John	460	Dug, drilled	10	250	20	do		
Thorne	78	do	40	60	60	Clay	Sand	

SARGENT COUNTY

TOPOGRAPHY

Sargent County presents two rather distinct topographic divisions. The largest covers about seven-eighths of the area of the county and has the rolling topography of the ground moraine that is characteristic of the prairies of the State. Two prominent hilly moraines cross the county, one of which follows the western border and enters the county just east of Milnor and the other crosses the northeast corner, just west of Milnor, Ransom, and Cayuga and turns abruptly eastward past Geneseo. These moraines are for the most part belts of well-defined irregular hills.

The second topographic division, which constitutes about one-eighth of the county, is a portion of the Sheyenne delta, formed in the margin of Lake Agassiz, and therefore belonging to the Red River Valley province. The surface is very gently rolling and the slope quite uniform, except in patches where the delta sand has been blown up into dunes that present a very broken and choppy surface, difficult even to drive over.

The escarpment that separates the prairie and valley provinces crosses the county from north to south about one-fourth of the way from the eastern side. It is here so low and gentle that it is almost obliterated by the heavy glacial deposits, and although the Herman beach, the highest level of Lake Agassiz, follows it in the northern half it swings eastward along the middle line of the county, deflected by the high range of morainic hills already mentioned.

Wild Rice River drains the eastern part of the county, but over most of the area drainage is very imperfectly developed, small marshes and sloughs occur, and a number of morainal lakes remain, the largest of which is Skunk Lake, near the southeast corner. Water that falls as rain is either absorbed into the ground or runs through shallow grassy coulees into sloughs from which it is largely evaporated.

GEOLOGY

A heavy mantle of glacial drift forms the surficial deposit of the entire county, except in the northeast corner, where the drift is overlain by the gravel and sand of the Sheyenne delta of Lake Agassiz. All the rock beneath the drift is of Cretaceous age, probably Pierre shale. This rock, however, thins out rapidly in the eastern part, where the Niobrara and Benton shales may possibly be the bedrock formation, though these have not been differentiated. The Benton shale rests on the Dakota sandstone, and this in turn rests on the granite.

GROUND WATER

Four horizons are recognized in Sargent County as marked by water-bearing beds—the delta sand, the drift deposits, the Pierre shale, and the Dakota sandstone.

The water table stands high in the sands throughout the Sheyenne delta, held up by the nearly impervious boulder clay beneath, so that dug or driven wells 10 to 20 feet deep obtain an abundance of water in this formation. Low places and blown-out depressions among the wind-built hills are usually moist or contain pools of water, so near to the surface does the water table lie. The upper portion of the drift usually contains much gravel and sand in this locality, and these materials supply sufficient water for many shallow wells. A few wells find sand pockets in the body of the till; the water from these sands is variable both in quality and in quantity and frequently fails in dry seasons. Water is also found in thin beds of sand and gravel at the base of the drift, immediately above the bedrock shale. This water usually lies at depths of 75 to 200 feet, but both its depth and occurrence are uncertain.

The compact blue Pierre shale below the drift is not a good water carrier. It does not yield water except in sandy layers that are sufficiently porous to contain and carry water. Its supply is small and strongly mineralized from intimate contact with the shales, which contain much soluble salts. The character of this water is such that when insufficient water is found in the drift, it is advisable to drill for the artesian supply.

The entire county lies within the area of artesian flow of the Dakota sandstone, and strong flowing wells may be obtained at depths that range from 500 to 800 feet. The water is obtained from this loose white sandstone, which overlies the granite and underlies the heavy Cretaceous shales. The water is generally salt, though it is everywhere used for stock and many prefer it for drinking. It is commonly softer than the waters of the drift. Owing to the occurrence of layers of shale interbedded with the sandstone, three water-bearing beds are generally recognized, known as the first, second, and third water beds. The two most productive beds are here about 60 to 80 feet apart. Although this county is probably the most favored one in the State in the number of artesian wells and in the present pressure and flow of these wells owing to its favorable location near the axis of the area of artesian flow of the Dakota sandstone, the decline in pressure and flow are very noticeable. Few wells have ceased to flow in this county, and it is hoped through conservation of the water to prevent the loss of this valuable resource of this part of the State.

QUALITY OF GROUND WATER

The delta sands of Sargent County yield hard water of generally low mineral content and suitable for general use. (See analyses 47 and 48.) The drift yields hard water that differs in mineral content, but most of it is not so highly mineralized as to be objectionable for ordinary use. (See analyses 44 and 144.) The Pierre shale yields water which differs in different places both in amount of dissolved constituents and in hardness. Most of this water can be used, but some of it is too highly mineralized for satisfactory use. The artesian water from the Dakota sandstone is generally soft but highly mineralized. (See analyses 141, 142, 143, and 145.) Much of this water is usable but objectionable for drinking. Where it is not too highly mineralized one may become accustomed to the taste.

Typical wells of Sargent County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Village	Crete	960	1½	Sandstone		
Henry Orn	NW. ¼ sec. 31, T. 132, R. 58.	950	1¼	do	Flow.	Perforated 5 feet at bottom.
Village	Milnor	650	2	do	Flow.	Former pressure 70 pounds, 64 gallons a minute.
Northern Pacific Ry.	do	20	180			
Jens Pederson	Sec. 9, T. 132, R. 54	725	2	Gravel	Flow.	
F. V. Phelps	W. ½ sec. 15, T. 132, R. 54.	710	2	do	Flow.	
Peter Christianson.	NW. ¼ sec. 20, T. 132, R. 54.	630	1¼	do	Flow.	Pressure formerly 60 pounds.
H. A. Hendrickson.	SE. ¼ sec. 5, T. 132, R. 53.	620	1¼	do	Flow.	
Mrs. Eliza Kolbert.	SW. ¼ sec. 32, T. 132, R. 50.	169	2			8-foot screen at bottom.
P. E. Peterson [a]	SW. ¼ sec. 17, T. 131, R. 58.	1,120	2			
C. R. Bowen	SW. ¼ sec. 31, T. 131, R. 55.	740	1¼	Sandstone	Flow.	
D. J. Jones	SW. ¼ sec. 31, T. 131, R. 55.	840		do	Flow.	Pressure formerly 25 pounds.
Joseph Lanxon [a]	NE. ¼ sec. 30, T. 131, R. 55.	220	2		80	
H. L. Green	SW. ¼ sec. 19, T. 130, R. 59.			Gravel		
Village	Straubville	1,075	2	Sandstone		
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Nicholson	176	6			40 gallons a minute.
Village	Cogswell	1,060	1¼	Sandstone	Flow.	Pressure 80 pounds when well was drilled.
Richard McCarten.	NW. ¼ sec. 1, T. 130, R. 57.	830	1¼	do	Flow.	Slight pressure. Affected by weather.
D. J. Jones [a]	NE. ¼ sec. 1, T. 130, R. 56.	940	1½	do	Flow.	
Movius Land Co.	S. ½ sec. 25, T. 130, R. 54.	620	2½	do	Flow.	Pressure formerly 95 pounds; first flow at 520 feet, second flow at 590 feet. Yellow clay 20 feet, sand and gravel (dry) 50 feet, blue clay 20 feet, water, sand, and gravel 20 feet, blue clay 55 feet, sand and gravel 15 feet, blue shale 120 feet, shale rock 20 feet, gray shale 200 feet.
Do	do	630	2½	do	Flow.	Flowed 100 gallons a minute. Used to supply Lake Tewaukon. Loam 5 feet, dry sand and gravel 175 feet, red sand 15 feet, water, sand, and gravel 10 feet, blue shale 195 feet, "slate-rock" 20 feet, gray shale 210 feet.
J. H. Movius	Sec. 36, T. 130, R. 54.	620	2	do	Flow.	Pressure formerly 60 pounds.
Do	do	630	2	do	Flow.	Pressure formerly 90 pounds.
Great Northern Ry.	Rutland	178	96			
Village	do	600	2			
Do	do	685				
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Ransom	79	86			
Do	do	79	10	Coarse gravel		70 gallons a minute. Satisfactory water.
Village	Havana	960	1½	Sandstone	Flow.	Pressure formerly 80 pounds. Flowed 35 gallons a minute.
Movius Land Co.	SW. ¼ sec. 5, T. 129, R. 53.	675	1¼		Flow.	Pressure formerly 60 pounds.

[a] See table of analyses.

Water supplies of towns in Sargent County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Cayuga	182	Drilled	100	675	100	Gravel	Sandstone	Artesian flows from deep wells.
Cogswell	445	Bored, drilled	200	900		Drift	do	Do.
Crete	225	Driven, drilled	20	1,100			do	Do.
De Lamere	300	Dug, drilled	10	700		Sand	do	Do.
Forman	402	Drilled		1,000	850		do	Do.
Geneseo	175	do		130	110			
Milnor	680	Dug, drilled	20	725		Gravel	do	Do.
Rutland	291	Drilled	150	700			do	Do.
Stirum	150	Dug, drilled	15	1,200		Sand	do	Do.

SHERIDAN COUNTY

TOPOGRAPHY

The chief topographic feature of Sheridan County is the Missouri escarpment, which enters the county at the northwest corner and passes out near the southeast corner, making such a bend within the county that but a small marginal area lies to the north and east of the escarpment and therefore belongs to the Drift Prairie. The principal part of the county therefore lies on the Missouri Plateau, on the broad, flat, glaciated margin between the steep escarpment to the north and east and the gentle slope to Missouri River on the south and west.

This area was almost wholly covered by the last glacial invasion, the terminal moraine of which extends in a broad band 20 to 30 miles wide across the southwest corner. This portion is therefore strongly morainal. Rolling hills separated by irregular depressions that are filled with marshes and the alkaline remnants of glacial lakes characterize the landscape. The area between the moraine and the escarpment is more gently rolling but has all the characteristics of a young glaciated country. The only drainage of note is that through broad grass-grown coulees, which lead to the east over the face of the escarpment and which have the appearance of ancient glacial rather than present or recent waterways.

GEOLOGY

With the possible exception of the extreme northeast corner of the county the bedrock which underlies the heavy mantle of glacial drift is the Fort Union formation. Its horizontal beds may be so far eroded away to the northeast of the escarpment that the Pierre shale lies at the base of the drift in the immediate vicinity of Martin, but all bedrock is so deeply covered with surficial deposits that no outcrops are known in the county.

GROUND WATER

The ground waters used in Sheridan County come almost exclusively from the drift and are good, fair, or poor, largely according to the amount of gravel present in the beds tapped by the individual well and to the natural drainage facilities, both surface and subsurface. Plenty of porous water-bearing gravel means an abundance of fairly good water, whereas the absence of the porous beds and the undrained condition of the surface means alkaline water. So variable are these drift waters that no forecast may be made of them except the probability of finding a fair bed of sand and gravel at the base of the drift immediately above the bedrock.

A considerable number of wells have in recent years been drilled into the Fort Union formation, which lies below the drift. Beds of sandstone that yield water generally occur in this formation at no great depth below the surface.

A few strong springs are present near Denhoff, Lincoln Valley, and Skogmo, where the headwaters of Sheyenne River take their rise among the hills of the Missouri escarpment, which forms the eastern edge of the Great Plains. Elsewhere the county is largely covered with morainal hills, many of which contain extensive gravel deposits and yield small springs that flow into the pans, kettles, and potholes of the moraine and assist in the formation of many small lakes and ponds.

QUALITY OF GROUND WATER

Hard water of varying mineral content is obtained from the drift in Sheridan County. Analyses 147, 189, and 190 are representative of the better waters obtained from the drift. The wells in poorly drained places yield waters that are too highly mineralized for general use, and some contain as much as 5,000 or 6,000 parts per million total solids. Soft, moderately to highly mineralized water is obtained from the beds of sandstone and lignite in the Fort Union formation. Some of the waters from the lignite are slightly colored and may be objectionable for drinking, but they are usually suitable for other domestic uses. Analyses 93 and 94 are representative of the waters from the Fort Union formation in Sheridan County.

Typical wells of Sheridan County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Milo Good	SW. ¼ sec. 8, T. 147, R. 75.	25	1¼	Sand	6	Satisfactory well.
Northern Pacific Ry.	Denhoff	20	192			Brick curb.
J. E. McClusky	Sec. 9, T. 146, R. 77.	300	2			Dry hole. Sandy, hard clay.
City [a]	McClusky	30	156	Fine sand	24	
Fred C. Heitzmann.	NW. ¼ sec. 35, T. 146, R. 76.	644	2	Sand	40	
Rev. Bitner	S. ½ sec. 3, T. 146, R. 74.	450	2			Dry hole.
Jacob Axt	NE. ¼ sec. 7, T. 146, R. 74.	445	2	Sand, coal		Satisfactory well.

[a] See table of analyses.

Water supplies of towns in Sheridan County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Denhoff	525	Dug, drilled.	10	700	25	Gravel	Shale	Small springs.
Goodrich	476	Drilled	100	750	365 500		Sand in shale.	Some good springs. Public supply from well 486 feet deep.
Martin	525	Dug, bored, drilled.	20	140	30	Drift		Few small springs.
McClusky	646	Dug, drilled.	15	465	200			

SIOUX COUNTY

TOPOGRAPHY

Sioux County lies on the southern boundary of the State immediately west of Missouri River and is on the whole a fairly typical portion of the Great Plains. As it is bounded on the east by Missouri River and on the north and west largely by Cannonball River and its main tributary Cedar Creek, its drainage through the large valleys of these streams and their immediate tributaries is complete. Owing to this fact also its topography is mature, and many of the tributaries of these larger streams have trenched deeply into the plateau. The Missouri Valley is a remarkable lowland that is separated from the upland on the west by steep slopes so that the flood plain in the bottom of this trough-like valley resembles a flat floor 2 or 3 miles wide and 200 to 300 feet beneath the upland. This flood plain, which is but a few feet above normal water level, is bordered by grassed terraces, the principal one of which is about 40 to 45 feet above the river. This terrace is covered for the most part with a grassy meadow, whereas the flood plain contains considerable timber, chiefly cottonwood.

GEOLOGY AND GROUND WATER

The entire county, with the exception of the extreme west part, was covered by the older ice sheet during the glacial epoch. Erosion has been so rapid, however, in this region that most of the material deposited during this advance of the ice has been removed and the drift is of little value as a source of water supply.

QUALITY OF GROUND WATER

The bedrock of Sioux County is made up chiefly of the Lance formation, which consists of dark sandy shale, yellow shaly sandstone, and thin beds of lignite. The more sandy phases of this formation, together with the lignite, contain considerable amounts of water at relatively shallow depths. On the eastern edge of the county the Lance formation has been removed for a distance of several miles back from Missouri River, and the Fox Hills sandstone crops out both in the bluffs on the west side of the Missouri Valley and for some distance back in its tributary valleys. This formation consists chiefly of yellow sandstone with some thin shaly layers. It is therefore a good water-bearing formation, though few wells have yet been drilled into it in this county. In the southern half of the Missouri Valley as it borders this county the Fox Hills sandstone is entirely cut away, exposing the Pierre shale beneath. This rock is the dark blue-gray shale that is impervious to water and is therefore not used as a ground-water supply. As Sioux County has been open to settlement for but a short time and as the chief industry in that county at present is grazing, few wells have been drilled, and most of the ranchers and settlers depend upon surface waters, springs, and shallow wells. There is little doubt, however, that an abundance of water may be had from the wells that penetrate the Lance and Fox Hills formations, though drilling should not pass below these formations, as they are underlain by several hundred feet of impervious shales, and it is inadvisable to drill through these to procure the artesian waters in the Dakota sandstone below, except perhaps in the immediate valley of Missouri River. There is no assurance that a flowing well might be obtained from the Dakota, even in this location, though the pumping distance would not be great.

So many water-bearing beds of sandstone and lignite of both the Lance and Fox Hills formations crop out along the sides of the many deep valleys in this region that springs are numerous. The flow from these springs is of great value to the ranchers and settlers who are still largely interested in grazing.

QUALITY OF GROUND WATER

The two sources of water supply for Sioux County are the shallow wells in the alluvial drift of the valleys and surface deposits of the upland and the deep wells that draw on the Lance and Fox Hills sandstones. The shallow wells yield hard water that is generally acceptable for most uses. (See analyses 100, 104, 146, and 147.) The deep wells yield soft, moderately to highly mineralized water, most of which is usable. Analyses 148, 149, and 150 represent average waters from the Fox Hills sandstone; a few waters contain much more dissolved mineral matter, and others contain much less. Springs are used to some extent and generally furnish fair water, though it may be hard.

SLOPE COUNTY

TOPOGRAPHY

Slope County is the second county from the southwest corner of the State on the Montana line, entirely outside of the drift area. Its surface in the eastern part is characteristic of the broad, rolling topography of the Missouri Plateau. It has, however, several conspicuous buttes that rise above the general plateau level as remnants of the higher formations now nearly removed by erosion. Most conspicuous among these is Black Butte, the summit of which, 3,468 feet above sea level, is the highest point in the State of North Dakota.

Little Missouri River crosses the county from south to north in the western half. Its valley is a deep, broad, steep-sided trench bordered on either side and for some distance back along the tributary streams by belts of buttes and mesas known as "the badlands of the Little Missouri." These elevations approach the general level of the upland from which they have been carved largely by stream erosion. Running water has etched the soft formations found here into a picturesque chaos of topographic forms. The dull colors of these beds are banded with black lignite seams of considerable thickness, and over large areas these have been altered to colorful scoria by the burning out of some of the coal beds. At one locality between Black Butte and the Little Missouri the fires of hundreds and perhaps thousands of years are still burning, and the phenomenon is known far and wide as "the burning mine." Wind also plays a part on the dry flats and slopes between the times of irregular rainfall in adding picturesqueness to the topography.

GEOLOGY AND GROUND WATER

The surficial deposits of Slope County consists of residual soil on the upland and of alluvium on the valley floors. The alluvium yields a considerable amount of water to shallow wells. The youngest bedrock formation in this State is the small area of Oligocene sandstone and limestone (White River formation), which caps the summit of the Black Buttes, but because of its small area and topographic location it is valueless as a source of any water supply.

The bedrock on the uplands in most of the county is of Fort Union (Eocene) age and consists largely of shale with a number of sandstone beds and numerous beds of lignite. The sandstone and lignite beds bear a considerable quantity of water, and the lignites especially yield at their outcrops numerous strong springs in the valley sides.

In the badlands in the western part of the county the beds of the Fort Union formation have been eroded away, and the Lance formation (Eocene ?) lies immediately under the surface deposits and crops out on the hill and valley sides. These beds consist largely of shale with interbedded sandstone and lignite. The shale and lignite both contain water where they lie well below ground-water level. Some of the deeper wells in the valley of the Little Missouri probably penetrate the Fox Hills sandstone, which underlies the Lance formation, and obtain an abundant supply of water from the yellow sandstone of which the Fox Hills is largely composed.

Many drilled wells in the valleys of the Little Missouri and its larger tributaries yield artesian flows from the sandstone and lignite layers of the Lance formation and from the Fox Hills sandstone beneath. These flows are not strong and are representative of the narrow-valley type of artesian conditions, as the higher ground-water level and adjacent uplands give sufficient head to bring the water of the lowlands to the surface. Possibly artesian slope conditions are also present. These artesian waters are very valuable to the stock-raising interests of this region, especially in winter, when the streams are frozen over, as they yield a constant flow of relatively warm water.

In the deeply trenched valleys of the Little Missouri and its tributaries there are many springs. The numerous porous beds of sandstone and lignite yield copious springs wherever they crop out below the ground-water level. These springs are of great value in this region, which is largely used for the grazing of cattle and horses, and they generally supply the stock, except in winter, when they are supplemented by artesian wells. The constant flow of the fresh water of these springs is a great aid in keeping the stock in good condition throughout the warm summer.

QUALITY OF GROUND WATER

Hard water that contains a small to moderate amount of dissolved mineral matter is obtained from the alluvial deposits of the valleys and from a few wells in the surface deposits of the uplands. The sandstones and lignite of the Fort Union formation and the Lance formation generally yield soft water that is moderately to highly mineralized. Most of this water is suitable for general use, though some is too highly mineralized. The sandstone beds near the surface of the bedrock may yield hard water. Springs from the Fort Union and Lance beds, where they are exposed in the river valleys, yield soft water that is generally satisfactory for most uses.

Typical wells of Slope County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Bert Sargent	Ranger	285	2	Fine sand	Flow.	Dark soft water.
Junge Lebo	N. ½ sec. 10, T. 136, R. 102.	360	2	Heavy rock	Flow.	Clear soft water.
Annie Carpenter	S. ½ sec. 34, T. 136, R. 102.	200	2	Bedrock		Dark soft sater.
John McMahon	W. ½ sec. 14, T. 135, R. 104.	112	6	Coal, sand	30	Good hard water.
Charley Lang	SE. ¼ sec. 8, T. 135, R. 102.	240	2	Sand rock		Clear good water.
William Reger	SW. ¼ sec. 28, T. 135, R. 102.	400	2½	Hard rock		Dark soft water.
E. H. Erickson	SE. ¼ sec. 24, T. 135, R. 98.	154	6	Sand	25	Water also at 24 and 40 feet.
Joe Hamsted	SE. ¼ sec. 2, T. 134, R. 98.	64	6	do	18	Soft and colored.
C. Ballweber	SW. ¼ sec. 12, T. 134, R. 98.	87	6	do	45	Soft and clear.
Ole Bakke	NE. ¼ sec. 12, T. 134, R. 98.	107	6	do	95	Do.

Typical wells of Slope County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
S. O. Gronen	NW. ¼ sec. 12, T. 134, R. 98.	93	6	Sand	65	Soft and clear.
Ed. Wallner	NW. ¼ sec. 33, T. 134, R. 98.	149	5	do	86	Do.
F. N. Rose	NE. ¼ sec. 34, T. 134, R. 98.	125	6	Quicksand	80	Do.
H. L. Kelly	Marmarth	200				
George H. Sult	do	437		Sand	Flow.	Flow at 425 feet, now only one-eighth gallon. More before a rain. Water from horizon at 210 feet stood 1 foot below surface.
O. C. Jenks	do	310	3		Flow.	Flowed 6 gallons a minute. Now pumped. Flows also at 80, 210, and 310 feet. "Good water."
J. E. Phelan	do	173	3		Flow.	Flowed 2 gallons a minute. Now pumped into compressed-air tank.
City [a]	do	200	12	Blue sandstone.	Flow.	
G. Hawkins	Sec. 33, T. 133, R. 98.	85	2		Flow.	5 gallons a minute.

[a] See table of analyses.

STARK COUNTY

TOPOGRAPHY

Stark County is a typical portion of the Missouri Plateau. Though the advance of the early ice sheet may be traced by a few scattered boulders as far west as Gladstone the area is practically free from glacial drift. Its topography is therefore almost entirely the result of stream erosion that acted on nearly horizontal sedimentary formations, generally soft but in some places containing bands of more durable rock that form high square-topped mesas and buttes.

The drainage system is fully mature, and the surface of the uplands is generally moderately rolling but becomes more broken near the larger stream valleys. Heart River crosses the county from east to west and is joined near the center by Green River from the north. Along both streams lie extensive deposits of alluvium and low terraces which extend throughout the county.

GEOLOGY AND GROUND WATER

The older glacial drift is represented by scattered boulders and possibly small patches of till on some of the broad uplands. Alluvium underlies the valleys to a considerable depth, and the water-washed waste covers all of the lower slopes. Beneath these surficial deposits the Fort Union formation is everywhere present, as shown by outcrops along the upper slopes of every valley and in the sides of the steeper buttes and mesas on the upland divides. This formation consists chiefly of soft clay, sandstone, and lignite. Abundant opportunity for the storage and movement of ground water is found in the sandstone and lignite. Many strong perennial springs issue from these beds, particularly from the lignite, where it crops out in the sides of the valleys, and these springs governed to a large degree the location of ranches and the early settlement of the region. Shallow wells in the alluvium of the valleys yield satisfactory water in abundance. As yet there are comparatively few wells on the uplands, but these may obtain a fairly good supply by reaching the same beds that yield the spring waters in the valleys.

For stock there is generally sufficient water in the pools in the bed of the streams at all seasons, though there is no flow in the summer. These pools are supplied by springs and by the underflow through the alluvial deposits, but evaporation is too great to permit water to flow at the surface. Attention has been called to the curious fact that in the autumn, though no rain may have fallen, the water in the stream beds increases in volume until there is a considerable flow. This increase is undoubtedly due to the decrease of loss through evaporation and the continued discharge from springs and seeps of water which has fallen long before and perhaps at long distances from the outflow.

A few wells in low places that enter the Fort Union formation yield small flows under slight pressure. Attempts have been made by both the Northern Pacific Railway Co. and the city of Dickinson to procure deep artesian waters at that place, but without success. The railroad well was carried to a depth of 1,800 feet, and the city well to a depth of 1,600 feet. Both wells were drilled by J. F. McCarthy, of Minneapolis, who has kindly furnished a detailed log of the diamond-drill hole sunk for the railroad. Water was not reported in the railroad well in any considerable quantity before the depth of 1,325 feet was reached and there is no record of any having been found in the remaining 475 feet. Much water was, however, reported in the city well at 500 feet, and this well has been pumped at 150 gallons a minute.

Log of Northern Pacific Railway well at Dickinson

	Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*
Soil, clay, and débris	31	7	31	7
Clay shale	2		33	7
Lignite		5	34	
Clay shale	8		42	
Sandstone		5	42	5
Clay shale	6	7	49	
Lignite	4		53	
Blue clay shale	8		61	
Lignite		6	61	6
Blue clay shale	11	6	83	
Quicksand		8	83	8
Blue clay shale	15	4	99	
Hard sandstone	4	6	103	6
Clay and shale bands	19	6	123	
Very hard sandstone	6		129	
Sand	4		132	
Sand and clay bands	27	6	159	6
Lignite	2	8	162	
Soft clay shale	17		179	
Sandstone	6		185	
Coal	2		187	
Clay shale	10		197	
Sandstone	2		199	
Hard clay shale	14		213	
Coal	2		215	
Clay shale	45		260	
Sand shale	24		284	
Soft sandstone	19		303	
Clay shale		6	303	6
Coal		1	303	7
Sand shale	1	5	305	
Coal	5		310	
Do	2		312	
Sand shale		8	312	8
Coal	1		313	8
Sand shale	12	4	326	
Soft sandstone	17		343	
Sand shale	22		365	
Clay shale	1	6	366	6
Sand shale	5	6	372	
Clay shale	12		384	
Coal	1	6	385	6
Hard sandstone	7	6	393	
Clay shale	33	6	426	6
Coal		6	427	
Clay shale	7		434	
Coal	3	2	437	2
Clay shale	2	8	439	
Clay and sand (mixed)	11		450	
Sand shale	11		461	
Clay shale	4		465	
Sand shale	10		475	
Clay shale	8		483	
Coal	1	6	484	6
Sandstone	1	6	486	
Fine sand	14		500	
Sandstone	6		506	
Clay shale	2		508	
Coal	3		511	
Sand shale	9		520	
Coal	3		523	
Sandstone	4		527	
Clay and sand shale	5		532	
Hard sandstone	3		535	
Sand shale	18		553	
Sandstone	11		564	
Clay shale	9		573	
Sandstone	7		580	
Soft sandstone	16		596	
Clay shale	4		600	
Coal		6	600	6
Clay shale	2	6	603	
Coal	1	6	604	6
Clay shale	8	6	613	
Soft sand and shale	20		633	
Clay shale	29		662	
Coal	1		663	
Clay shale	33		696	
Slate	2		698	
Clay shale	10		708	
Sandstone	40		748	
Coal	5		753	
Clay shale	50		803	
Quicksand	10		813	
Hard slate	2		815	
Coal	4		819	
Clay shale	5		824	
Soft sandstone	7		831	
Hard slate	3		834	
Very hard slate	4		838	

Log of Northern Pacific Railway well at Dickinson—Continued

	Thickness	Depth		Thickness	Depth
	Ft. in.	*Ft. in.*		*Ft. in.*	*Ft. in.*
Coal	2	838 2	Clay shale	6	1,098
Slate	8 10	847	Sandstone and iron pyrites	4	1,102
Coal	3	850	Sand	26	1,128
Clay shale	2	852	Clay shale	3	1,131
Coal	1	853	Lignite	4	1,134
Shale	5	858	Gumbo or soapstone	29	1,163
Soft sandstone	10	868	Hard fine sandstone	5	1,168
Sand	10	878	Sandstone and soapstone	82	1,250
Clay shale	10	888	Soapstone	40	1,290
Sandstone	5	893	Soft sandstone	5	1,295
Coal	9	902	Soft soapstone	80	1,375
Sandstone	16	918	Soft sandstone	5	1,380
Sand shale	3	921	Soapstone	50	1,430
Sandstone	7	928	Soft soapstone and sandstone	12	1,442
Clay shale	2	930	Lignite coal	3	1,445
Coal	1	931	Soapstone	33	1,478
Clay shale	44	975	Lignite coal	2	1,480
Sandstone	5	980	Soapstone	18	1,498
Slate	14	994	Lignite	2	1,500
Clay shale	22	1,016	Soapstone and sand	15	1,515
Slate	5	1,021	Fine sand and soapstone	35	1,550
Clay shale	10	1,031	Soapstone	25	1,575
Coal	1	1,032	Soft sandstone	15	1,590
Clay shale	8	1,040	Hard sandstone	5	1,595
Slate	10	1,050	Soft sandstone	50	1,645
Coal	1	1,051	Stiff soapstone	50	1,695
Soft sandstone	22	1,073	Soapstone and sandstone	45	1,740
Hard slate	8	1,081	Hard sandstone	5	1,745
Clay shale	9	1,090	Soft sandstone and soapstone	52	1,797
Sandstone	2	1,092	Hard rock	3	1,800

A well was also drilled by the Northern Pacific Railway at South Heart for a boiler supply but without success. The record as supplied by J. F. McCarthy, of Minneapolis, driller, is as follows:

Log of Northern Pacific Railway well at South Heart

Shale	42	Shale	130
Coal	12	Rock	3
Shale	15	Shale	15
Coal	4	Rock	40
Shale	100	Coal	1
Coal	2	Shale	17
Shale	28		
Sand	15		424

Heart River and its many tributaries, of which Green River is chief, are fed perennially by springs which issue abundantly from the lignite seams that crop out on the valley sides. On account of evaporation in summer there are times when the water stands in the creek channels only in pools that are slightly connected by underflow. Wherever openings are made into the valley sides to mine lignite springs appear, and many strong springs at places not yet developed indicate the presence of lignite.

QUALITY OF GROUND WATER

The alluvium of the river valleys in Stark County yields hard water that may contain from 400 to 2,000 parts per million of total solids. Similar water is obtained from a few shallow wells in the surface deposits. The Fort Union formation yields hard water moderately to highly mineralized. (See analyses 152–154.) Wells over 250 feet deep may draw soft water of varying mineral content from the lower beds of the Fort Union or underlying formations. The springs of the valleys yield hard, moderately mineralized water from the Fort Union formation.

WATER SUPPLIES AT DICKINSON

The city of Dickinson obtains its public supply from a series of wells which draw their water from sand and gravel, presumably of Fort Union age, at depths that range from 95 to 200 feet. The reported logs of these wells differ greatly but in general resemble the detailed log of the Northern Pacific Railway Co.'s drill hole for similar depths. As the wells range from 6 inches to 2 feet in diameter, a considerable amount of water may be obtained from a relatively thin water-bearing bed. The head of water in these wells has ranged from 15 feet below the surface in the oldest wells, when first dug, to 60 feet below the surface in the present wells under the heavier pumping conditions that now exist. These wells show typically the ground-water conditions of the area underlain by the Fort Union

STEELE COUNTY

TOPOGRAPHY

Steele County presents two varieties of topography. The Pembina escarpment passes southward through it, separating the four northern townships of the eastern tier from the remainder of the county. These townships lie in the Red River Valley plain and have the topography of a wave-washed shore of a retreating lake. This area was covered with the waters of Lake Agassiz during its highest stage and was gradually uncovered as the lake receded. Well-marked ridges of sand and gravel formed by the action of the waves at successively lower stages cross the area from north to south, and sandy patches of reworked drift mingle with the fine lacustrine silt of the extreme southern end of the Elk Valley delta.

The remaining four-fifths of the county lies on the higher upland west of the escarpment, and the surface here has the rolling and undulating topogrpahy that characterizes a young drift plain. The northern and western margins are particularly morainic, whereas the eastern part of the upland is deeply eroded by the streams that flow down over the steep escarpment to Goose River on the valley floor. The drainage from the southwestern part passes southward into Maple River.

The escarpment itself is the most notable topographic feature of the county, as it forms a distinct step between the two plains, whose difference in altitude is 200 to 300 feet.

GEOLOGY

The surface deposits of Steele County consist of glacial drift and lake beds. The entire region is covered by the till sheet deposited by glacial ice. In the northeast corner this till was covered by the waters of Lake Agassiz immediately on the retreat of the ice sheet and was rewashed by the action of waves and currents, which produced characteristic beach forms of sand and gravel. Most of this area is also covered by a bed of fine sandy lake silt and the extreme southern extension of the Elk Valley delta.

Beneath the drift is rock of Cretaceous age. In the area west of the escarpment this bedrock is formed by the Pierre shale. In the lower face of the escarpment and eastward the Niobrara and Benton shales may be exposed, but this is uncertain. Probably in no part of the county does the Dakota sandstone lie immediately below the drift, though the shales thin out so rapidly in and east of the escarpment that it approaches this position within a short distance.

GROUND WATER

The water-bearing beds of the county consist chiefly of lenses of sand and gravel included within the drift sheet, beds of sand and gravel that rest directly upon the shale at the base of the drift, and porous sandy layers of the Pierre shale. The beds of the first named class supply the shallow drift wells common throughout the region at depths that range from 15 to 50 feet with a supply of water, variable as regards both quality and quantity but commonly of poor quality. Somewhat better and larger supplies come from the sand and gravel at the base of the drift at depths that average about 60 feet. Wells that penetrate the shale reach depths of 100 to 300 feet, and one well is reported to have been sunk into shale to a depth of 800 feet. Many dry holes that end in shale are reported, and those that obtain a supply are likely to yield poor water. The supply from the base of the drift is, on the whole, the one to be commended in this region.

The southwestern half of Steele County undoubtedly originally lay within the area of artesian flow of the Dakota sandstone. The depth at which this formation could be reached is probably between 1,000 and 1,500 feet, but no attempt to reach this aquifer has been reported. In view of the rapid decline of head within this formation an attempt to procure a flowing well from it is not advisable. One flowing well in the Goose River Valley east of the Pembina escarpment, in the northeast corner of the county, probably draws its supply of water from the Dakota sandstone, though it is in the Red River Basin. This well is 2 inches in diameter and 590 feet in depth and belongs to K. K. Pladson. It is in the SE. ¼ sec. 24, T. 148 N., R. 54 W. A few other flowing wells might be obtained in the Goose River bottoms in this township, but not many.

Owing to the position of Steele County on the escarpment the numerous small valleys of the headwaters of Goose River have been deeply cut into the drift and in some places into the shale beneath. This condition gives rise to a number of small springs on the valley sides, where the drift is in contact with the shale, and some of these springs are used as a supply for stock pastures. The same is true of the deeper tributaries of Sheyenne River on the west, some of which contain permanent streams that have their source in these springs. Among those best known is one in sec. 16, Finley Township, and another in sec. 8, Euston Township. No very large springs have, however, been reported.

QUALITY OF GROUND WATER

Wells that draw from the different layers of the drift yield moderately to highly mineralized hard water, most of which is satisfactory for general use. (See analyses 156–160.) A few wells draw a hard, highly mineralized water from the sandy layers of the Pierre shale. (See analysis No. 69.) Most of this water is usable but objectionable for drinking. The Dakota sandstone yields highly mineralized water, which is soft if it comes from the upper sand and hard if it comes from the lower sand.

Typical wells of Steele County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Thomas Porter	NW. ¼ sec. 5, T. 153, R. 53.	212	2	Sand	5	Salty water.
William Nagle	SE. ¼ sec. 12, T. 153, R. 51.	182	3-2		Flow.	Water also at 150.
L. J. Zimmer	NW. ¼ sec. 15, T. 153, R. 51.	130	2	Rock	Flow.	Water rose 6 feet above surface.
County poor farm	NE. ¼ sec. 12, T. 151, R. 54.	140	6-3		40-70	
	11 miles southwest of Northwood.	652	2	Sand	60	Drift 150 feet below which is shale, except 10 feet of fine sand at bottom. Slightly salty water.

Typical wells of Steele County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Jacob Vig	Finley	800	4	Sand		Hard water. Drift 140 feet (water at base of drift); shale 290 feet; soft white shale 250 feet; shale 120 feet. No sand or gravel in shale.
O. Cummings [a]	NW. ¼ sec. 32, T. 147, R. 56.	52		Gravel, clay	16	
B. F. Wade	NE. ¼ sec. 3, T. 147, R. 56.	60	6	Gravel	25	
G. O. Johnson [a]	NW. ¼ sec. 32, T. 147, R. 56.	46	24	do		
W. W. Archer	SW. ¼ sec. 14, T. 146, R. 57.	490				No water.
Mr. Mierchard	N. ½ sec. 6, T. 146, R. 56.	807	4			Do.
Great Northern Ry.	Luverne	356		Clay		Very little water.
M. B. Cassell	Hope	30	Dug.		27	
J. C. Wamberg [a]	NW. ¼ sec. 1, T. 144, R. 56.	45	48		35	
B. T. Kraabel [a]	do	30	12	Drift	Flow.	Water rose 2 feet above surface.
N. B. Cassel	do	30	30	Sand, gravel	Flow.	Water rose 4 feet above surface.

[a] See table of analyses.

Water supplies of towns in Steele County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Blabon	150	Bored, drilled	25	600	25	Sand		Water mineralized.
Colgate	375	Dug, drilled	15	60	30	do		Water scanty. Several wells drilled to 100 feet without results.
Finley	599	Bored, drilled	25	800	60	Sand, gravel	Sand, gravel	In town water of fair quality at 60 feet. Many deep wells in country.
Hope	699	Dug, bored, drilled.	10	75		Drift		Shallow waters alkaline. Deeper waters better.
Luverne	225	Bored, drilled	50	200	120	Gravel	Sand	Shallow waters scanty.
Sharon	362	Bored	60	95	90	Drift		Small springs in valleys.
Sherbrooke	60	Drilled	20	25	30			Fairly good water.

STUTSMAN COUNTY

TOPOGRAPHY

Stutsman County lies partly in the Missouri Plateau and partly in the Drift Prairie. It is crossed somewhat west of the center by the Missouri escarpment, nearly 400 feet high. The entire county lies well within the area covered by the last invasion of glacial ice and therefore presents the morainal features characteristic of a drift-covered region. That portion east of the escarpment is a rolling plain that has a gentle southward and eastward slope across which runs James River parallel to the escarpment at a distance of 12 to 15 miles, its course undoubtedly influenced by this relation. The valley of the James, though somewhat less deep and steep-sided than that of Sheyenne River, has a similar origin. It was excavated by the waters that flowed from the front of the melting ice sheet when it stood to the north and east of this valley, but so great was the flood of waters that only the coarsest materials were deposited in its bed and it contains practically no valley-train gravel, but its broad, flat bottom is boulder strewn and thoroughly covered with alluvium, through which the present stream meanders widely when carrying sufficient water to flow. During the summer season its bed contains only detached ponds and lakes connected by a trickling stream, which may be seen only where it passes over riffles formed by the massive boulders in its bed. Lateral valleys of somewhat similar form enter at intervals and give to the adjacent plain a trenched appearance as these wide troughs of ancient glacial spillways cross the broad and gently rolling plains from the morainal ridges. Chief among the tributaries is Pipestem Creek, which closely parallels the escarpment from the north and enters James River below Jamestown.

The western portion of the county rises by a moderately steep slope 300 feet and more to the eastern margin of the Missouri Plateau. This slope is broken by numerous deep, dry coulees that were carved chiefly by streams of former days and give the landscape a somewhat rugged appearance.

On the more level portions of both the Missouri Plateau and the Drift Prairie the surface drainage is very incomplete. Among the rough and irregular hills of morainal type are many small irregular lakes, ponds, and marshes, and in the deeper channellike valleys of the glacial streams there remain many elongated lakes. The most beautiful of these is Spiritwood, which lies high in the moraine north of the village of that name, and the largest is Arrowhead, a deep and enlarged portion of James River near the northern border of the county.

GEOLOGY

So thickly is the surface of Stutsman County covered with glacial drift that the underlying rocks are known only through records and samples from deep wells and by outcrops in the sides of the deep valley trenches of James River and its tributaries, and the places where these are not entirely obscured by talus and wash are extremely rare. The difference between the jettings of blue boulder clay of the drift and the bedrock beneath is so slight that the line of demarkation is frequently not recognized by the drillers, but the difference is clear to the geologist who is looking along the valley sides for outcrops. The bedrock everywhere, so far as known, is the fissile blue Pierre shale, though it is possible that younger formations may extend out over the plateau past the southwest border of the county.

Below the Pierre there undoubtedly lie the Niobrara and Benton shales, but they are rarely identified by drillers, and beneath them lies the Dakota sandstone, which consists of beds of sandstone alternating with shales, and which supplies the deep artesian wells.

The Jamestown Asylum well ended in a limestone that has been penetrated to a depth of 19 feet. It has been suggested that this limestone is Carboniferous because of the presence of numerous plant remains, but the evidence of limestone cores that contain similar remains taken in places farther south in the State leads to the conclusion that this is but one phase of the Cretaceous, which in places is distinctly carbonaceous in character.

GROUND WATER

Water comes from four horizons in the wells of Stutsman County, though these are not always easily distinguishable. Glacial stream deposits and other alluvium that occupy the valleys of James River, Pipestem Creek, and Sevenmile Creek yield considerable water. The extent and depth of these deposits is not so great, nor is there so large a proportion of sand and gravel as in the similar deposits of the Sheyenne Valley, yet they may generally be relied on for a water supply for domestic or farm use.

The waters of the drift are the almost universal source throughout the county, and the supply comes generally from the base of the drift, immediately above the shale. In some places, however, a gravel layer or lens occurs in the body of the drift, and in other places gravel and sand was deposited on the tops of ridges and hills. On the tops of the ridges and hills the water is good; in the other places it is generally palatable, though commonly brackish and alkaline from long standing in contact with the shale or with drift clay derived from the shale both of which contain a high percentage of soluble mineral salts. The great variation is almost entirely due to differences in conditions of subsurface drainage.

A few wells penetrate the shale or soapstone, as the drillers term it, and are supplied by porous layers at depths of 100 to 300 feet. In some places a layer of sand is found and then a fair supply of mineralized water. In other places the shale yields little or no water.

Stutsman County is probably everywhere underlain by the Dakota sandstone, which is overlain by a thick body of shale and dips gently toward the west. The depth to the sandstone is about 1,300 feet in the southeastern part of the county and 1,500 feet in the northeastern part. Owing to the westward dip of the sandstone and the rise of the land in the same direction the depth gradually increases to the foot of the escarpment, where it lies 1,600 to 1,800 feet below the surface or practically at sea level. The head of the water is sufficient to afford flows throughout that part of the county east of the escarpment, but on the plateau to the west the pressure is insufficient to bring the water to the surface. A number of wells that range in depth from 1,224 to 1,570 feet have been drilled, and nearly all obtain flows.

A more complete account of the geology and ground-water resources of the southeast quarter of Stutsman County is given by Willard,[30] and from this account the writer has taken some of the material here presented.

Log of the asylum well, sec. 6, T. 139 N., R. 63 W., Jamestown

[Diameter 3½ inches]

	Feet
Blue clay	42
Fire clay, impure	49
Quicksand	20
Shale and limestone fragments	100
Light-colored shale	150
Dark shale	200
Light and dark shale with limestone layers	398
Sandy shale	40
Sand	10
Blue shale with hard limestone layers	290
Quicksand with shale and limestone	175
Hard sandrock	7
Sandrock with 4-gallon flow	24
Limestone (Carboniferous?)	19
	1,524

[30] Willard, D .E., U. S. Geol. Survey Geol. Atlas, Jamestown-Tower folio (No. 168), 1909.

Log of Jamestown city well

[Altitude of surface, 1,400 feet. Original flow, 460 gallons. Original pressure, 97 pounds]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, clay, and gravel	120	120	Sandrock with small flow	10	1,395
Light shale	905	1,025	Shale and pyrite	55	1,450
Blue shale with pyrite	275	1,300	Hard sandrock	8	1,458
Sandy shale	85	1,385	Soft sandrock	18	1,476

QUALITY OF GROUND WATER

The alluvium of the river valleys in Stutsman County yields hard water, most of which contains a small amount of mineral matter and is satisfactory for domestic purposes. (See analysis 161.) The drift yields hard water similar to that from the river valleys, though some of it is highly mineralized. Analysis 162 is typical of the better water from the drift. The Dakota sandstone yields highly mineralized water that is generally soft, though the lower sands yield hard water. (See analysis 163.)

WATER SUPPLIES AT JAMESTOWN

There are two possible sources of ground water for the city of Jamestown—the water of the alluvial deposits of the James and Pipestem Valleys and the water of the Dakota sandstone.

Beneath the floor of the valleys of James River and Pipestem Creek alluvium extends to a maximum depth of more than 100 feet. Most of this material was deposited by glacial flood waters in the older and deeper valleys and filled them to the level of the present floor. The material is largely coarse sand and gravel, with layers of clay, the whole covered with a thick layer of fine silt and alluvium. Through these relatively coarse deposits ground water is percolating. This underflow water is generally relatively independent of the water in the river, from which it is sealed off by the fine mud and silt that have been deposited by the stream itself. The depth and volume of the shallow ground water of the James River Valley insures an abundance of water for the city.

Jamestown lies within the area of artesian flow of the Dakota sandstone, and flowing wells may be obtained from this bed at a depth of about 1,300 to 1,400 feet. The artesian water is very highly mineralized and is therefore unsuited for city use. One well of this type was formerly used by the city and was abandoned. Another has been drilled, and the flow is weak. Several wells operated by air lifts would probably be required to yield a sufficient supply, and there would be danger of loss of the wells by sand clogging or corrosion of the casing. The artesian supply can not be recommended for city use.

The bedrock that underlies Jamestown and overlies the sandstone of the Dakota basin is 1,000 to 1,200 feet thick and consists chiefly of a dense blue-gray shale which in places contains layers of fine sand. No considerable amount of water can be obtained from the bedrock above the Dakota sandstone.

Typical wells of Stutsman County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
A. Wenquist	NE. ¼ sec. 28, T. 144, R. 68.	335	2½	Fine sand	35	
G. H. Thorson	SW. ¼ sec. 34, T. 144, R. 68.	400				Dry hole.
Northern Pacific Ry.	Edmunds	25	144			Brick curb.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Kensel	136	10	Sand		
Nels Hohme	SW. ¼ sec. 15, T. 144, R. 63.	152	4½	Shale	35	
D. W. Gerber	S. ½ sec. 24, T. 143, R. 69.	90	2	Sand	40	
B. Bakken	NW. ¼ sec. 4, T. 143, R. 68.	400	2½	Fine sand	100	
Will Homriet	NW. ¼ sec. 30, T. 143, R. 68.	145	3	Sand	105	
C. Williams	S. ½ sec. 31, T. 143, R. 68.	135	2½	Coarse sand	110	
H. J. Hansen	NW. ¼ sec. 33, T. 143, R. 68.	175	3	Sand	155	
H. W. Larson	NW. ¼ sec. 32, T. 143, R. 65.	147	3	Shale	13	
Village	Woodworth	750				Dry hole.
Do	do	350	3	Sand	60	
A. G. Hoofman	NE. ¼ sec. 4, T. 142, R. 68.	125	2½	Gravel	10	
G. W. Nilson	W. ½ sec. 8, T. 142, R. 68.	400	2½	Sand	40	
Peter Hotchkiss	W. ½ sec. 10, T. 142, R. 67.	150	2½	do		Very little water.
Frank Norley	SE. ¼ sec. 12, T. 142, R. 65.	112	3	Sand, gravel	10	
Peter Johnson	SE. ¼ sec. 15, T. 142, R. 65.	129	45	Shale, drift	40	
L. Hopplin	SE. ¼ sec. 18, T. 142, R. 66.	148	3	Gravel	60	
Wells & Dickey	8 miles southeast of Woodworth.	250	3	Coarse sand		
J. A. Buchanan	Buchanan	280	2½	Shale		
William Stage	W. ½ sec. 29, T. 140, R. 68.	750	2	Sand	60	
Northern Pacific Ry.	Medina	25	196			Wood curb; goes dry.
E. Grover	2 miles north of Cleveland.	720	2	Shale		
Northern Pacific Ry.	Windsor	457	10		110	100 gallons a minute to pump.
Village	do	562	2	Sand, gravel		
Do	do	541	2	do		
H. Nichols	S. ½ sec. 14, T. 140, R. 64.	280	3	Shale		
City	Jamestown	113		Sand, gravel		
Do	do		10, 12		15	4 wells in battery yield 300 gallons a minute to centrifugal pump. Hard water for boiler. Precipitates iron. Well No. 1 is 75 feet deep and well No. 2 is 85 feet deep.
Do	do	1,476	6, 2	White sand	Flow.	First public supply, 1888–1890. Salty water. Original flow 460 gallons a minute. Original pressure 98 pounds.
Do	do	1,470	8, 4		Flow.	Warm water for Young Men's Christian Association pool. Insufficient flow.
Do	do	31	84	Gravel	22	Curbed well. Best for boiler and laundry use. 700 gallons a minute.
Western Electric Co.[a]	do	1,494	4½, 3	Sandstone	Flow.	Pressure 40 pounds. Perforated 40 feet at bottom. 18 gallons a minute.
City [a]	do	30	25	Gravel	14	

[a] See table of analyses.

Typical wells of Stutsman County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Northern Pacific Ry.	Jamestown	102	6		9	With the pipe cut at 19 feet below surface the two wells in 1908, flowed 50,000 gallons an hour. Sand to 24 feet, hardpan and stone to 34 feet, gravel to 35 feet, quicksand to 46 feet, fine sand to 47 feet, gravel and water to 66 feet, blue clay to 85 feet, sand, gravel, and water to 104 feet, blue shale to 105 feet.
Do	do	105	10		10	
Do	do	104	12		10	300 gallons a minute for 16 hours.
Do	do	108			Flow.	
Do	do		144			Old well. Dug 1883.
Do	do	17	300	Quicksand		Old well.
State hospital	do	70	12		10	Came to surface but is now pumped at 250 gallons a minute, which draws water level down to 50 feet. Soft and only trace of iron.
State asylum	do	1,542	6, 3	Sandstone	Flow.	Perforated 33 feet at 1,473 feet and 3 feet at 1,519 feet. 140 gallons a minute. Sandstone at 1,472 feet but no flow. Flow at 1,300 feet with gas.
Do	do	1,536	3, 2	do	Flow.	Perforated 4 feet at bottom.
Do	do	250	6			Pumps 170 gallons a minute.
C. F. Still	304 Nutton Avenue, Jamestown.	46	2	Sand		Dug 21 feet driven 18 feet. "Excellent water."
W. L. Hall	S. ½ sec. 23, T. 140, R. 64.	22			10	Driven and dug; satisfactory water.
Do	do	16	36		6	Shop well. Satisfactory water.
Charles Kruth	NW. ¼ sec. 24, T. 140, R. 64.	35			20	Driven in valley floor. Satisfactory water.
Henry Peters	NE. ¼ sec. 10, T. 140, R. 63.	22		Sand		Driven. Satisfactory water.
P. Kelly	W. ½ sec. 5, T. T. 140, R. 63.	187	3		137	On upland.
F. V. Steele	NW. ¼ sec. 34, T. 139, R. 69.	210	2	Sand	10	
Cleveland State Bank.	Cleveland	290	3	Sand, gravel		
H. Slot	4 miles south of Cleveland.	500	2	Shale		Salty water.
W. Bohlig	3 miles southeast of Cleveland.	330	2	do		Do.
State hospital [a]	NE. ¼ sec. 12, T. 139, R. 64.	100	3		80	
Dakota Meat Co.	NE. ¼ sec. 5, T. 139, R. 63.	1,510	3, 2	Sandstone	Flow.	Formerly flowed 60 gallons a minute, 25 gallons in 1915; 73-foot perforation at bottom. Also flow at 1,300 feet. Pressure formerly 60 pounds, probably 20 pounds in 1915. Temperature about 70° F.
Northern Pacific Ry.	Spiritwood	41	192			
T. C. Peterson	SW. ¼ sec. 22, T. 138, R. 69.	338	2	Shale	40	
John Dickster	NW. ¼ sec. 25, T. 138, R. 69.	404	2	do	80	
P. L. Hays	SE. ¼ sec. 26, T. 138, R. 69.	195	2	Sand	60	

[a] See table of analyses.

Typical wells of Stutsman County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
William Kohloff	SE. ¼ sec. 8, T. 138, R. 68.	175	2	Sand	50	
Albert Bast	NE. ¼ sec. 18, T. 138, R. 68.	350	2	Shale	60	
R. Sucks	N. ½ sec. 20, T. 138, R. 66.	11	4	Sand		
Mike Tooy	N. ½ sec. 11, T. 138, R. 64.	340	2	Shale		Salty water.
S. F. Corwin	SW. ¼ sec. 4, T. 138, R. 63.	1,358	3, 2	Sandstone	Flow.	Formerly pressure 50 pounds and flow 18 gallons a minute. Perforated 1,300-1,330 feet.
Northern Pacific Ry.	Streeter	21	216			Brick curb; satisfactory water.
Gottlieb Clundt	SE. ¼ sec. 1, T. 137, R. 69.	380	2	Shale	40	Slightly salty.
C. Fondrick	SW. ¼ sec. 2, T. 137, R. 69.	385	2	do	50	
John Schnake	NW. ¼ sec. 8, T. 137, R. 69.	480	2	do	10	Do.
Oley Nelson	NE. ¼ sec. 9, T. 137, R. 69.	375	2	do	60	
Jacob Remick	NE. ¼ sec. 13, T. 137, R. 69.	180	2	Sand	10	
Citizens State Bank of Edgeley.	NW. ¼ sec. 30, T. 137, R. 65.	270	4	do	10	Satisfactory water.
Fred E. Lee	NW. ¼ sec. 21, T. 137, R. 63.	1,300	2	Sandstone	Flow.	Salty water.

Water supplies of towns in Stutsman County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Cleveland	341	Drilled	20	400		Sand	Blue clay	Small springs.
Courtenay	490	Dug, bored	20	220		Drift		
Edmunds	501	Dug	25	50		do		Small springs. Many cisterns.
Kensal	415	Dug, drilled	20	130	120	Clay, gravel		
Medina	415	Dug, bored	15	70		Gravel, sand	Clay	Small springs. Hard water in wells.
Montpelier	186		15	1,350		Drift	Sandstone	Deep wells, artesian.
Pingree	286	Dug, bored, drilled.	10	120	25	do		
Spiritwood		Bored, drilled	15	150	30	do		
Woodworth	297		10	368	150			

TOWNER COUNTY

TOPOGRAPHY

Towner County is a typical Drift Prairie region. It is crossed from northwest to southeast, north of Cando, by the middle range of the Itasca moraine (of Upham), and the last of this series cuts the northeast corner. The whole county is characterized by gently rolling sag and swell topography, and the deeper pans were filled with ponds and marshes in the earlier days but now chiefly by marsh and meadow.

The entire county also lies within the inland drainage basin of Devils Lake and is crossed from north to south through the middle by Mauvais Coulee, at one time a large tributary to Devils Lake. Probably no other county in the State has less run-off than Towner County. Only a small fraction of 1 per cent of the rainfall leaves the county through streams, and this only in the early thaws through the shallow, winding southward-flowing coulees, now entirely grassed over.

GEOLOGY

The geology of Towner County is simple. The heavy drift mantle is everywhere underlain by the thick Pierre shale, through which no drill has passed in this county. The drift is commonly reported to reach 150 to 200 feet in thickness, and the greatest thickness reported is 254 feet in Dr. J. G. Lamont's well, in the NE. ¼ sec. 19, T. 161 N., R. 67 W. The shale here contains a few beds of porous sand.

GROUND WATER

Water is present at two horizons, and at each of them beds that have considerable thickness are drawn upon. The drift is exceptionally thick and contains at its base, and even at some distance above its base, thick layers of sand and gravel. These and the shallow surface materials supply most of the wells. Deep wells that extend into the underlying shale are, however, common. In the western central part of the county they are particularly deep and reach 300 or even 500 feet. Heavy sandy and even gravel layers are reported in the shale which contains considerable water. This region is unfavorably situated for deep artesian wells, but in a few places a weak flow may be had from horizons in the deeper drift or bedrock. One of these flows is on the C. E. Hanwalt farm, 2½ miles south of Cando. Others are obtained on the Frank Knutt farm, in the SW. ¼ sec. 6, T. 160 N., R. 66 W., and the Carl Johnson farm, in the SW. ¼ sec. 28, T. 158 N., R. 67 W., from depths of 165 and 115 feet respectively.

QUALITY OF GROUND WATER

Wells that draw upon the different gravel beds of the drift in Towner County yield hard water of variable mineral content, most of which is suitable for general use. Analyses 139, 140, and 164 represent waters that contain from 400 to 1,200 parts per million of total solids. Some waters contain more dissolved mineral matter, but samples of these were not collected. The sandy layers of the Pierre shale yield waters that may be hard or soft and moderately to highly mineralized. (See analysis 165.) Most of these waters are acceptable for general use. Better water is obtained from the Pierre shale in this county than in most of the other counties.

Typical wells of Towner County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
H. Gilbert	NW. ¼ sec. 5, T. 163, R, 68.	178	4	Shale	18	Soft.
Ed. Lentz	SE. ¼ sec. 10, T. 163, R. 68.	70	4	do		Do.
W. B. Underwood	SW. ¼ sec. 12, T. 163, R. 68.	96	4	Gravel		
Hugo Gailfuse	SW. ¼ sec. 20, T. 163, R. 68.	420	2½	Fine sand		Pumps 6 gallons a minute.
Joseph Agarand	SW. ¼ sec. 25, T. 163, R. 68.	121	4	Gravel		
W. A. Stadens	Hansboro	80				
James Brown	SW. ¼ sec. 5, T. 163, R. 67.	22				

Typical wells of Towner County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Armourdale	20	120			Near creek.
John Matison	W. ½ sec. 1, T. 162, R. 68.	208				
Marlin Johnson	W. ½ sec. 9, T. 161, R. 68.	320		Sandy shale	50	Slightly salty.
John Hartson	NW. ¼ sec. 21, T. 161, R. 68.	412	4	Shale	140	Salty, soft.
James Taylor	NW. ¼ sec. 27, T. 161, R. 68.	498			100	Salty.
Do	NE. ¼ sec. 28, T. 161, R. 68.	498		Shale	100	Soft, salty.
Dr. J. G. Lamont	NE. ¼ sec. 19, T. 161, R. 67.	343		Sand	40	Very salty. Quicksand above the water.
C. A. Simpson	SW. ¼ sec. 33, T. 161, R. 67.	208	4	Shale	70	Soft.
Mr. Eller	Rock Lake	132			100	Slightly salty.
E. A. Rimel	NW. ¼ sec. 3, T. 161, R. 66.	158	4½	Shale	28	Salty. Water also at 100 feet.
N. P. Mills	SE. ¼ sec. 4, T. 161, R. 66.	110	6	do	1	Soft. Affected by southeast wind. A "breathing well."
Village	Perth	443				Yellow clay 80 feet, blue clay 200 feet, shale. Salty.
Ole Kulberg	NE. ¼ sec. 1, T. 160, R. 68.	175			50	Yellow clay 80 feet, blue clay 40 feet, sand and gravel. Good yield.
H. H. Haskins	NE. ¼ sec. 10, T. 160, R. 68.	315	4	Gravel, sand	130	Soft.
J. C. Bonawitz	NE. ¼ sec. 11, T. 160, R. 68.	250		Sand	60	Good yield.
Christ Moen	NW. ¼ sec. 32, T. 160, R. 68.	305			50	Salty. Good yield.
Paul Scherf	SE. ¼ sec. 1, T. 160, R. 67.	204		Sand, gravel	25	
John Vooge	SE. ¼ sec. 4, T. 160, R. 67.	355	4	Sandy shale		Soft. Water also at 65 feet.
H. J. Larson	SW. ¼ sec. 17, T. 160, R. 67.	226		Sand		
James McCanna	NE. ¼ sec. 20, T. 160, R. 67.	120		do	60	Yellow clay, gravel, and sand.
Carl Haas	E. ¼ sec. 24, T. 160, R. 67.	266			40	
Ed. Nelson	N. ¼ sec. 28, T. 160, R. 67.	172		Sand		
Harvey Mentzer	SE. ¼ sec. 24, T. 160, R. 66.	115		Shale	20	
Robert Martin	SW. ¼ sec. 24, T. 160, R. 66.	130			20	Bitter and salty. Drift 80 feet.
C. J. Lord	NE. ¼ sec. 31, T. 160, R. 65.	165			20	Slightly salty.
J. M. Gary	Bisbee	208		Shale	40	Yellow clay 40 feet, blue clay 98 feet, sand 50 feet, shale 20 feet. Mineralized.
L. O. Wattling	do	197		Sand	80	Water in sand below shale.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	300	10			Drift 290 feet, shale. Abandoned; insufficient water.
C. J. Lord	Sec. 4, T. 159, R. 68.	350				Slightly salty.
Ole Lein	NE. ¼ sec. 6, T. 159, R. 68.	305			60	200 feet to bedrock.
D. F. McLaughlin.	W. ½ sec. 23, T. 159, R. 68.	150			20	Salty.
John Kelly	E. ½ sec. 25, T. 159, R. 68.	234			40	130 feet to bedrock.
Dinehart & Weck	W. ½ sec. 28, T. 159, R. 68.	185			40	Salty. 150 feet to bedrock.
Henry Castor	Arndt	124		Gravel	20	
Ben Jones	N. ½ sec. 22, T. 159, R. 67.	260	4	Shale	Flow.	Water rose 20 feet above surface.
R. M. Fargriarson.	SE. ¼ sec. 25, T. 159, R. 67.	204		Sand		
K. L. Palmerlee	N. ½ sec. 32, T. 159, R. 67.	130		do	Flow.	Soft water.

Typical wells of Towner County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
C. C. Reinert	SW. ¼ sec. 36, T. 159, R. 67.	232		Gravel	12	No shale.
F. F. Vaughn	SW. ¼ sec. 8, T. 159, R. 66.	239	4		7	Salty water.
O. N. Lundberg	SE. ¼ sec. 29, T. 159, R. 66.	173	6	Shale	Flow.	Soft water. Flowed 3½ gallons a minute. Water rose 5 feet above surface.
J. W. Crope	Newville	84			20	Drift 77 feet.
Village	do	120		Sand		
W. H. Folkrud	Egeland	136			20	
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	75	120			Poor.
Do	do	83	4			Small supply.
Fred C. Paulsen	SE. ¼ sec. 4, T. 159, R. 65.	150		Shale		Salty.
Pete Odegard	NW. ¼ sec. 8, T. 159, R. 65.	185	4	do		
Fawcett & McHenry.	W. ½ sec. 23, T. 159, R. 64.	210	4¼			Blue clay. No water.
William Schultz	SW. ¼ sec. 2, T. 158, R. 67.	196				Hard water at 18 feet.
Great Northern Ry.	Cando	24	192			150,000 gallons a day. Twelve 2-inch drive points 20 feet in bottom of well.
City	do	65		Sand		6 drive points in 40-foot open concrete well.
City hall	do	212	3		20	Corrodes iron, foams in boiler, muddy when pumped hard.
Elius Stubblefield	SE. ¼ sec. 10, T. 158, R. 66.	124		Sandy shale	21	"Fair water;" drift 72 feet.
Robert McTavish	SW. ¼ sec. 11, T. 158, R. 66.	120		do	21	"Fair water;" drift 68 feet.
D. F. McLaughlin.	S. ½ sec. 28, T. 158, R. 66.	217	4	Sand in shale		
C. J. Lord [a]	SE. ¼ sec. 20, T. 158, R. 66.	198	2	Shale		
Do	SW. ¼ sec. 29, T. 158, R. 66.	198			20	Soft.
Do	W. ½ sec. 30, T. 158, R. 66.	350		Shale	20	Salty.
Do	S. ½ sec. 9, T. 158, R. 65.	154		do	20	Soft, slightly salty. Good yield. Drift 75 feet.
City [a]	Cando	95		Quicksand	27	
John McPike	E. ½ sec. 18, T. 158, R. 65.	100				Soft.
Lord & Thompson.	NW. ¼ sec. 17, T. 158, R. 65.	175				Salty.
A. L. Straub	SE. ¼ sec. 22, T. 158, R. 65.	145	4	Shale	20	Salty water.
Do	S. ½ sec. 27, T. 158, R. 65.	214	4	Gravel	20	
Doctor Smith	SE. ¼ sec. 29, T. 158, R. 65.	194	4			Salty. Good yield. Drift 90 feet.
A. Currie	SE. ¼ sec. 36, T. 158, R. 65.	432	4½			Drift 43 feet. No water.
S. L. King	NW. ¼ sec. 4, T. 157, R. 66.	178	4	Gravel	20	5 gallons a minute.
E. E. Priest	NE. ¼ sec. 10, T. 157, R. 66.	196	4	Shale	7	Soft and little salty.
D. F. McLaughlin.	NW. ¼ sec. 18, T. 157, R. 66.	80				Soft.
Farmers Elevator	SW. ¼ sec. 32, T. 157, R. 66.	255	4	Sand	20	4 gallons a minute.
J. Gilberg	SE. ¼ sec. 1, T. 157, R. 65.	180	4½	Shale	30	Small supply. Drift 45 feet.
Do	do	60	4½	do	30	Small supply. Drift 50 feet.
A. J. McLartne	NE. ¼ sec. 2, T. 157, R. 65.	470	2	do		Small supply.
George Copeland	SE. ¼ sec. 20, T. 157, R. 65.	80			25	Slightly salty and bitter. Good yield.
A. S. Gibbens	SW. ¼ sec. 31, T. 157, R. 65.	100	4	Shale		8 gallons a minute. Soft.

[a] See table of analyses.

Water supplies of towns in Towner County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bisbee	500	Drilled	80	210	200	Drift sand	Drift gravel	Shallow alkaline, deeper better.
Cando	1,111	Dng, drilled	25	200				
Crete			20	100	30			Shallow wells satisfactory.
Egeland	306	Dug, drilled	10	450		Drift		Deeper water somewhat salty.
Hansboro	218	Bored	40	125	60			
Maza	125	Bored, drilled	20	255	30	Drift	Drift	Shallow water alkaline, deep water salty.
Olmstad			40	175	50	do		
Perth	218	Drilled	150	4,500		do	Drift	
Rock Lake	236	Bored, drilled	15	300		Sand	Shale	

TRAILL COUNTY

TOPOGRAPHY

Traill County lies almost wholly in the Red River Valley, and only a small area of not more than 5 square miles lies outside of the Herman beach—the highest shore line of Lake Agassiz. Two topographic divisions of the valley might be made, but the Elk Valley delta, which occupies perhaps two townships in the northwest corner, thins out both eastward and southward so gradually at its borders that it blends into the lacustrine silts that occupy the main floor of the valley plain without distinct boundary. The county therefore has the simplest topography in the State. The surface is that of a lake plain from which the waters have receded in very recent geologic time—so recent, in fact, that the few streams have hardly had opportunity to develop and scarcely any of the work of erosion has been done. It is a region in youth, a plain in its very infancy. Near the axis of the valley, along Red River, the slope is not greater than 1 foot to the mile toward that stream. Westward it increases to 4 and even 6 feet to the mile before the delta formation is reached. Here it is higher, perhaps 6 to 8 feet, but there are only very gradual slopes in Traill County.

On the western border of the county this even surface is slightly broken by a series of gravel and sand ridges that run in a general north and south direction. These ridges are the beaches that mark the several levels of Lake Agassiz. The highest one, which barely touches the southwest corner of the county, is the Herman beach and was formed at the maximum stage of the lake. Although the drainage is still immature, the region is so nearly level that little water remains on the surface; temporary ponds and springs in slight depressions are numerous in spring and after heavy rainfall. Goose River, the chief drainage line, is formed by the junction of several tributaries in the west and central parts of the county.

GEOLOGY

Lacustrine deposits everywhere cover the surface of Traill County except in the small area in the southwest corner where the drift is at the surface. Beneath the lacustrine deposits lies a heavy sheet of glacial drift consisting of clay, sand, gravel, and boulders. Beneath the drift there is a series of shale and sandstone of Cretaceous age. Along the eastern margin the Cretaceous series is thin and rests on the granite.

GROUND WATER

Shallow wells in the sand and silt of the delta and beaches obtain water in small amounts at depths of only a few feet. The sand and silt rest directly on the impervious clay base of the drift.

Throughout the eastern part of the county a small amount of water is procured by shallow wells in the lacustrine silt, particularly at the base, where it overlies the more compact clay of the till. These waters are not generally very palatable, as they come only by slow seepage through the clay and dissolve out much mineral material through long standing.

Traill County lies almost completely within the area of artesian flow of the Red River Valley Basin. There are probably more than 400 flowing wells widely distributed in the county. These wells represent at least two artesian horizons—the drift gravel of the Red River Valley and the sandstone of the greater Dakota artesian system. The waters of the gravel and sandy layers of the drift at depths of less than 100 feet are in many places under artesian pressure owing to the fact that they lie upon the western slope of the old preglacial valley once occupied by Red River, so that they rise to the west and may even extend underneath the upland beyond the Pembina escarpment, which nearly parallels the western border of the county. These wells differ in the quality of their water as well as in the depth at which it occurs. The western portion of Traill County is underlain by the Dakota sandstone, in which the water is under sufficient head to bring it to the surface in wells that range from 200 to 600 feet in depth. The water occurs in a fine-grained loose sand, and though somewhat saline it is used for stock and by many people for domestic supplies as well. It is also reported to be softer than the shallower waters of the drift. A more complete statement of similar artesian conditions is given under Cass County. (See p. 97.)

There are a few large springs in the Red River Valley because of the uniformly porous character of the lake silts. Among the low hills and slopes of the Manitoba escarpment along the margin of the western edges of the county emerge numerous springs, particularly about Portland in the valley of Goose River, along the North Branch of Goose River, and in the headwaters of Elm River, in the southwest corner of the county.

QUALITY OF GROUND WATER

The delta and beach sands in Traill County yield hard water that contains 250 to 500 parts per million total solids. (See analysis 167.) The lake silt yields moderately to highly mineralized hard water, most of which, however, is suitable for general use. (See analysis 168 and 173.) Wells 50 to 300 feet deep in the drift yield hard water, moderately to highly mineralized. Analyses 30, 36, 37, 169, 172 show that most of these waters are too highly mineralized for general use. The alluvial deposits of the valleys yield similar water. The Dakota sandstone yields water that differs in hardness in different places and is usually moderately to highly mineralized. (See analyses 168 and 170.) Many of these waters are not so highly mineralized as those farther north in the valley.

Typical wells of Traill County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
A. H. Stevens	NW. ¼ sec. 19, T. 148, R. 53.	714	3½			Drift 120 feet, sand 3 feet, blue clay 100 feet, fine blue sand, roily water, head 20 feet, shale 96 feet, muddy blue sand and shale 45 feet, hard shale with very hard streaks 349 feet.
C. O. Gorder [a]	NW. ¼ sec. 1, T. 148, R. 51.	135	42	Sand layer in clay.	6	
Village [a]	Reynolds					
Do. [a]	Buxton	16	96	Beach gravels.	8	
E. R. Nestoss	SW. ¼ sec. 29, T. 148, R. 50.	365	2	Sand	10	
S. H. Hogelie	NE. ¼ sec. 30, T. 148, R. 50.	360	2	do	30	Rusty water.
City	Portland	560		Gravel	Flow.	175 gallons a minute.
Nels Amundson	SE. ¼ sec. 34, T. 147, R. 53.	484	2	Sand	Flow.	Hard and salty. Water formerly rose 20 feet above surface.
J. E. Quam	NE. ¼ sec. 36, T. 147, R. 53.	500			9	Salty.
Northern Pacific Ry.	Mayville	395		Sand	Flow.	Pressure formerly 8 pounds. Yield formerly 60 gallons a minute.
Farmers Grain & Milling Co.	do	362	2	Sandstone	Flow.	Soil and clay 20 feet, blue clay and silt 60 feet. Till 120 feet, blue clay nearly black (Benton?) coarse white sand with water. Water level now 10 feet below surface.
E. E. Ellertson	do	365		do	Flow.	Ceased to flow. Now abandoned.
Mrs. Morstad	W. ½ sec. 26, T. 147, R. 52.	510				Blue clay 150 feet, gravelly clay and shale 25 feet, rock containing pyrite 100 feet.
J. L. and E. B. Grandin.	SW. ¼ sec. 31, T. 147, R. 52.	406	3	Sandstone	Flow.	
J. Cliasson	NW. ¼ sec. 11, T. 147, R. 51.	433	2	Fine red sand	8	Salty.
Joseph Johnson	SW. ¼ sec. 25, T. 146, R. 51.	330		Gravel		2,000 barrels a day.
Martin Johnson	NW. ¼ sec. 25, T. T. 146, R. 51.	330		do		3,000 barrels a day. Water in gravel below blue sandy clay.
F. E. Kindred	NW. ¼ sec. 5, T. 146, R. 50.	356	2	Sand	Flow.	Mineralized.
A. Steeson	SW. ¼ sec. 6, T. 146, R. 50.	215	2	do	Flow.	Salty.
City	Clifford	542		Sandstone	Flow.	Salty. Small yield.
J. E. Williams	NE. ¼ sec. 25, T. 145, R. 52.	199	2	White sand	Flow.	Salty.
Village	Blanchard	394	2	Gravel, coarse sand.	Flow.	Water rose 20 feet above surface.
Mrs. John Nelson.	NW. ¼ sec. 6, T. 145, R. 50.	200		Fine gray sand.	Flow.	
S. A. Sundby	SW. ¼ sec. 34, T. 145, R. 51.	260	2	Sand	Flow.	Salty.
City	Hillsboro	93		Fine sand	48	12 by 75 feet.
Great Northern Ry.	Galesburg	70	144			Sand points at bottom.
Do	do	300	6			
C. C. Dalrymple	Kelso	145	2½		Flow.	
W. G. Safford	NE. ¼ sec. 4, T. 144, R. 50.	150	2	Gravel, sand	Flow.	
Arthur Aby	SE. ¼ sec. 6, T. 144, R. 50.	150	3		0	
St. Anthony & Dakota Elevator. [a]	SW. ¼ sec. 32, T. 147, R. 52.	20	18	Alluvium		Delta deposit.

[a] See table of analyses.

Typical wells of Traill County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Martin Spellman	NE. ¼ sec. 12, T. 147, R. 51.	397	2	Gravel	Flow.	Salty, 2,000 barrels a day.
Andrew Johnson	SW. ¼ sec. 21, T. 147, R. 51.	330	2		3	
P. Johnson	NW. ¼ sec. 22, T. 147, R. 51.	268	2	Coarse gravel	10	Salty.
A. Sundby	NW. ¼ sec. 24, T. 147, R. 51.	80	3	Quicksand	16	Soft water.
L. O. Gibson	NE. ¼ sec. 26, T. 147, R. 51.	280	2	Sand	Flow.	Salty.
Mrs. A. Pudell	SW. ¼ sec. 26, T. 147, R. 51.	100	2	do	11	Soft.
E. Webjornson	SE. ¼ sec. 13, T. 147, R. 50.	220	1¼	Rock	11	Good hard water.
Jorstad farm	NE. ¼ sec. 16, T. 147, R. 50.	280	2	Sandstone	6	Slightly salty.
J. Lilleberg	SW. ¼ sec. 22, T. 147, R. 50.	315	1¼	Sand		
B. M. Johnson	S. ½ sec. 36, T. 147, R. 50.	215	1¼	do	6	
O. P. Pederson	W. ½ sec. 11, T. 147, R. 49.	584	1¼	Shale	15	Soft but not very good.
O. M. Berg	SW. ¼ sec. 15, T. 147, R. 49.	215	2	Gravel	10	
Charles Abentroth.	NE. ¼ sec. 21, T. 147, R. 49.	342	2	Shale	12	Salty water.
A. M. Berg	NW. ¼ sec. 22, T. 147, R. 49.	148	1¼	Gravel	Flow.	
A. Folsby	S. ½ sec. 24, T. 146, R. 53.	352	3	do	Flow.	3,000 barrels a day.
City [a]	Mayville	365		Sandstone	Flow.	

[a] See table of analyses.

Water supplies of towns in Traill County

Town	Population, in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Blanchard	95	Drilled	90	400		Clay		Deep water is salty.
Buxton	400	Dug, drilled	10	260		do	Sand	Some deep wells flow.
Caledonia	150	do	20	200		do	Sand, gravel	Chiefly shallow wells.
Cummings	100	do	10	370	15	Gravel, clay.	Sandstone	Shallow wells yield alkaline water. Artesian well 370 feet deep flows 1 gallon in 10 minutes.
Galesburg	250	Dug, bored, drilled.	25	550	25	Clay		Bored wells 15 to 50 feet deep yield relatively good water. Artesian wells 550 feet deep yields salty water.
Hatton	828	Dug	10	30	20	Sandy clay		All shallow well; water fairly good.
Mayville	1,218	Dug, driven	20	400	20	Clay and sand.	Sandstone	
Portland	623	Bored, drilled	15		20			Bored wells are 15 to 30 feet deep. Deep artesian wells yield salty water.

WALSH COUNTY

TOPOGRAPHY

Walsh County is divided by the Pembina escarpment, so that the eastern part lies in the Red River Valley and the western third is on the Drift Prairie. Not only are the resulting upland and lowland plains separated by the steep escarpment that runs north and south just west of Edinburg and Medford but a second "mountain" or ridge runs from Edinburg southward across the county, separated from the escarpment by a broad, shallow valley without a continuous stream. This ridge is the interlobate moraine formed between the two lobes of the great Wisconsin ice sheet, which were produced by the deflecting influence of the Pembina escarpment. The eastern or Minnesota lobe occupied the Red River Valley, and the western or Dakota lobe moved down the great prairie between this valley and the Missouri escarpment. Where these lobes came together a long ridge of débris was built up after the fashion of the medial moraines seen where the alpine glaciers meet to-day. The valley between this interlobate moraine and the escarpment was occupied toward the close of the glacial epoch, when the front of the ice was gradually retreating northward across the State, by a large river that flowed from the front of the ice lobes and entered Lake Agassiz just north of Larimore. This river, which no longer exists, is known as Elk River and the valley through which its waters flowed as the Elk Valley. The valley floor is well filled with the débris washed from the ice, much of which was carried southward to form the Elk Valley delta above the western margin of Lake Agassiz.

The higher western part of the county is marked by long loops of hills that belong to the Itasca moraine and represent the accumulation of débris formed in the last long pause of the ice front in North Dakota. The whole topography here is rolling and morainal.

The eastern part of the county has the very level surface that is characteristic of the lake plain and slopes gently eastward to Red River. Park and Forest Rivers flow into Red River after draining almost the entire county. These streams were early known as Little Salt and Big Salt Rivers owing to the saline character of their waters, caused by the rise of the salt and bitter ground waters through springs and lakes in the eastern part of the county. So marked is this characteristic that the waters of some of these numerous salt springs and lakes were evaporated by the earliest explorers and settlers in this region and used for the curing and preservation of the meat of the buffalo, which was then plentiful.

Small lakes and ponds dot the morainal district in the west end of the county, but these are not saline.

GEOLOGY

The surface deposits of the valley consist of a thick layer of yellow and blue clay and the silt and mud deposited in quiet waters on the lake bottom. These deposits overlie the heavy gravelly till deposited directly by the ice, and this till forms the surface deposit of the Drift Prairie. Well-defined ridges of beach gravel that mark the several stages in the level of the lake cross the western margin of the valley, and much outwash and waterlaid drift in places overlies the till. The blue-gray Pierre shale underlies the till in the escarpment and westward, and Ordovician limestones are noted in the records of the deep well at Grafton. Several other wells undoubtedly enter these limestones, but the Grafton well passes through the Ordovician and Cambrian formations and penetrates the Archean granite or gneiss a distance of 12 feet at a depth of 903 feet.

GROUND WATER

The wells of Walsh County are supplied with water from a number of horizons. The lacustrine deposits, including the beach gravel and the silt, undoubtedly furnish the most satisfactory water in the valley. (See analysis 176.) These deposits are reached by shallow wells, and the people who are fortunate enough to live on a well-defined beach ridge may procure water from the base of the gravel at little cost. All underlying rock waters are salty and bitter and generally unfit for use. (See analyses 174, 175, and 177.) This bad water rises to the surface in the eastern part of the county, thoroughly impregnating the soil over large areas and making all the water salty, including the surface lakes and streams.

The shallow drift artesian syncline of the Red River Valley is better developed in Walsh County than in any other county in the valley. There are about 500 flowing wells in a circle with a radius of 30 miles that centers in Grafton. These wells range in depth from about 50 to 300 feet. The shallower ones are supplied probably from some sandy phases of the Lake Agassiz silt; those 100 feet or more in depth yield waters from the sandy and gravelly beds of the glacial drift. A few 300 feet or more in depth pass through the drift and procure their supply from the underlying bedrock. The deepest and only notable well that draws its supply from bedrock is the Grafton city well, referred to below.

The central depression is the old preglacial valley that opens toward the north. Over this valley was spread a thick layer of glacial drift and later a thick bed of lake silt, in both of which, but especially in the drift, occur layers and beds of sand and gravel which slope from the margins of the valley on the east and west toward the axial line along which Red River now flows. The waters from the shallower silt wells are generally somewhat alkaline, whereas those from the sandy and gravelly portions of the drift are somewhat saline, and the bedrock water are salty.

The Red River Valley contains but few springs of note because of the character of the lake silt, which deeply underlies the floor of the valley. Most of such springs occur in the valleys of the chief streams and are unimportant seepages. One, however, owned by Mrs. H. J. Edwards, in the eastern part of Grafton, is used in the manufacture of carbonated waters. The farther west one goes in the valleys of Park and Forest Rivers the larger and more numerous become the springs until in the headwaters of both streams among the hilly margin of the Pembina escarpment many fairly strong springs occur.

Some of the largest springs in this county are strongly saline, more so than would be expected if their minerals were derived from the drift or the lake silt. Upham has shown that these strongly mineralized waters probably rise under pressure from the eastern edge of the Dakota sandstone, from which the overlying shales have been removed, by the erosion of the valley, so that the more permeable drift and lake silt formations rest on the sandstone.

The salt springs near Cashel, in the northern part of the county, form several small salt lakes. Another salt lake northeast of Ardoch is similarly formed, and both Park River and Forest River receive the waters of several springs of this type.

WATER SUPPLIES AT GRAFTON

The city of Grafton procures its public supply from an artesian well 915 feet in depth. The water, however, is too salty for general use. The water is taken from the St. Peter sandstone, which is here 93 feet in thickness and is reached at a depth of 435 feet according to the log furnished by the mayor, Mr. J. Toombs, to Warren Upham.[31]

[31] Upham, Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.

This log was also published by the Commissioner of Immigration for Dakota Territory,[32] who says:

Water was obtained from this stratum [St. Peter sandstone] but the pressure not being deemed sufficient, the bore was continued nearly 400 feet farther to the underlying bed of granite. A small flow of very salt water was struck in the sandstone [Dresbach?] first above the granite. The pipes were withdrawn, the bore filled up to the first water-bearing stratum [base of St. Peter sandstone at 528 feet], from which the flow is now taken.

The brine rising from this bed [Dresbach?] was analyzed by Prof. Henry Montgomery, of the University of North Dakota, and was found to be more saline than sea water.[33]

The log above referred to follows:

Log of Grafton artesian well

	Feet
Black loam	3
White clay	25
Blue clay	250
Hardpan	20
Limestone	137
Quicksand	20
White coarse sand	45
"Slate"	3
Sandstone yielding a copious flow of brackish water	25
Red shale	60
Blue shale	16
Pink shale	11
Gray gravel	49
Red shale	49
"Soapstone" (clayey shale)	188
Sandstone, yielding a very small flow of very salt water	5
Granite	12
	915

These formations were interpreted by Upham as follows:

Drift	298
Lower Silurian [Ordovician]	137
St. Peter	93
Lower Magnesian	87
Upper Cambrian:	
Jordan	49
St. Lawrence	234
Dresbach	5
Archean	12
	915

Samples of the borings in the lowest 12 feet were submitted to Prof. N. S. Shaler, who pronounced them to be granite or gneiss, being the Archean bed of the ocean in which the overlying Paleozoic strata were deposited.

The only record of the pressure of this well is given by McClure [34] as 15 pounds, though elsewhere he says:

At Grafton an iron bar 8 feet long and 2 inches in diameter was inadvertently dropped into the artesian well, causing a serious decrease in flow. But suddenly the water rushed forth with great power and threw out the iron bar with such force as to break the elbow of the main pipe, and the flow is since unabated.[35]

According to the table above referred to this well was begun March 15, 1886, and completed July 1, 1886. The temperature of the flowing water was 48° F., and the original flow was given as 1,000 gallons a minute.

[32] McClure, P. F., Resources of Dakota, p. 188, Pierre, 1887.

[33] Upham, Warren, op. cit., p. 78.

[34] McClure, P. F., op. cit., p. 186 (table).

[35] Idem, p. 181.

New light is thrown upon the geologic formations penetrated by the Grafton well in a log written in the office of the contracting drillers, W. E. Swan & Sons Andover, S. Dak., and bearing the initialed signature of the firm. This log was received from Dr. Henry Montgomery, professor in the University of Toronto and formerly of the University of North Dakota, in a letter dated October 23, 1916, in which he presented it to the geological department of the University of North Dakota because of the local geologic interest contained therein. In a later letter dated November 28, 1916, Professor Montgomery said:

> The company's report and a sample of the lowest formation were sent to me with the object of settling a dispute between the contractor and the town authorities as to whether they had struck granite or not. I was unable to tell whether the pulverized sample was granite or gneissoid rock, and I reported accordingly. Soon thereafter they informed me that my report was similar to those received from two other professors, I think of Harvard and Wisconsin, but that one other authority disagreed.

A copy of the log above referred to follows:

	Feet
Soil	3
Yellow clay	10
Blue clay	90
Gravelly clay	30
Quicksand	22
Hardpan	40
Sand and gravel	30
Sand	20
Red shale	20
Limerock	2
Red shale	30
White sandrock	60
Blue shale	3
Red shale	3
Limerock	4
Red shale and lime	23
Limerock	310
Red shale and lime	45
Gray slate	40
Greenish-blue shale	95
Dark-red shale, gritty	20
White sandrock	3
Gray granite	9
	912

WATER SUPPLIES AT PARK RIVER

There are three possible sources of ground-water supply in Park River—the waters of the sand deposits of the shore lines of the former glacial Lake Agassiz and those of the Park River Valley; the waters of the drift; the deeper waters of the bedrock.

The shallow waters of the sand deposits have long been used for the city supply at the most available point. Their quantity has sometimes been insufficient, both during the late winter and the late summer. They can not therefore be relied upon for a full supply. In quality they are, however, the best waters obtainable, being relatively soft and free from any considerable mineral matter. If properly obtained through a battery of wells of small diameter, furnished with suitable screens or strainers, no danger from surface pollution may be anticipated. It is therefore advisable to use these waters to the fullest extent possible.

The city well is 25 feet in depth and 3 feet in diameter and is curbed with brick. The water level changes greatly but averages about 12 feet below the surface. It supplies about 29,000 gallons a day to a steam pump, except during periods of low water above mentioned. (See analysis No. 176, pp. 302–303.)

Beneath the drift lies a compact shale, which is underlain by sedimentary rocks, including sandstone and limestone of much older age, and beneath these sedimentary rocks lies the granite. Wells 300 to 500 feet or more in depth have been drilled in the vicinity of Park River, and most of them draw their supply from a fine sand. They are quite strongly impregnated with mineral matter and are therefore not satisfactory as potable waters. Their yield is, however, uniform at all seasons. A typical well to this horizon is one owned by the city of Park River which was drilled to a depth of 496 feet with a diameter of 4 inches at the top and 2½ inches at the bottom, and the chief water-bearing bed is a fine sand between 474 and 494 feet. The water level is about 90 feet below the surface, and it is pumped, when the shallow waters are inadequate for the city supply, by an air lift. (See analysis 177.)

Typical wells of Walsh County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Henry L. Jasters	4½ miles southwest of Ambrose.	200				"Good water."
G. McGrager	Fairdale	30	48	Gravel, sand	8	
Bert Suland	2 miles southeast of Edinburg.	80		Gravel	77	Soil 2 feet, gravel 7 feet, sand and gravel 71 feet.
John Hughes	S. ½ sec. 4, T. 158, R. 54.	175			Flow.	
M. Jolsem	SW. ¼ sec. 9, T. 158, R. 54.	335	2	Shale	3	Salty.
K. Oaland	W. ½ sec. 5, T. 158, R. 54.	248	2	do	13	
R. S. Johnson	E. ½ sec. 36, T. 158, R. 53.	207	2	White sand	Flow.	Flow also at 170 feet, 30 to 40 barrels a day, and not salty. Flows now about 1,700 barrels a day, salty.
Do	do	915	8			
T. Langton	1 mile east of Auburn.	204		Dark sand	Flow.	Yellow clay 8 feet, blue clay 194 feet, sand.
J. De Schermsashel.	T. 158, R. 52.	118		do	½	Small flow into dug well, salty and bitter.
John Slomens	Cashel	144	2	Sand	Flow.	Slightly salty.
Ole Omlie	N. ½ sec. 14, T. 158, R. 52.	400	2	do	Flow.	
Deyden	1 mile south and 1½ miles east of Cashel.	156		do		Pumped from dug well. Fairly good water.
C. F. Bookwalter.	Adams	285	6	Shale		Salty.
J. E. Loftus	do	106	5	do	15	
John Omath	do	500				
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	345	10			No water.
City [a]	Park River	25	36	Gravel	12	
Flour mill	do	507		Sand	200	
City [a]	do	496	4, 2½	Quicksand	90	
Duncan White	SW. ¼ sec. 29, T. 157, R. 54.	340			30	
State Institute	Grafton	345	6	Sand	Flow.	Small flow; bitter and salty.
Grafton Roller Mill.	do	312	2	White sand		
Do	do	317		Coarse gravel.	Flow.	Formerly flowed 90 gallons a minute. Pressure 15 pounds.
Do	do	303		Sand	Flow.	
Do	do	320		do	Flow.	
Northern Pacific Hotel.	do	235		Gravel	Flow.	Small flow.
Creamery	do	313	2	Limestone	Flow.	Pressure was 30 pounds. Strong flow.
Courthouse	do	300				

[a] See table of analyses.

Typical wells of Walsh County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
T. H. Sprague	Grafton	240	2		Flow.	Slightly salty. Temperature 43° F. Fair water.
City [a]	do	915	6		Flow.	800 gallons a minute. Salty.
J. E. Gray	do	208	2	Sand	Flow.	Salty.
W. W. Reyleck	do	250	2		Flow.	Bored, alkaline.
James McDonald	do	258				Water at 60 and 200 feet.
William Listico	do	400		Sandstone	Flow.	Three distinct flows.
S. McLain	5 miles east of Oakwood.	150			Flow.	
Doctor Food	1 mile west of Oakwood.	244			Flow.	
Henry Sampson	2 miles east of Oakwood.	166		Coarse dark sand.	Flow.	800 barrels a day.
Mary Bina	SW. ¼ sec. 8, T. 155, R. 54.	222	6	White sand	19	Salty.
F. J. Schanilec	NW. ¼ sec. 11, T. 155, R. 54.	280	5	do	45	Do.
Daniel Hobbs	SW. ¼ sec. 21, T. 155, R. 43.	263	5	do	35	Do.
John Fisher	6 miles northwest of Forest River.	215	2	do		
William Johnson	2 miles west of Forest River.	230		Sand	Flow.	Slightly salty.
William Wilson	NE. ¼ sec. 20, T. 155, R. 52.	192		Dark sand	Flow.	Dark salt water.
M. Muir	SW. ¼ sec. 27, T. 154, R. 54.	258	5	White sand	35	
William Lambies	NW. ¼ sec. 13, T. 154, R. 54.	240	5	do	5	
Charles Burke	SE. ¼ sec. 18, T. 154, R. 53.	103	5	Gravel	20	Fresh water.
A. V. Eastman	SW. ¼ sec. 19, T. 154, R. 53.	242	5	White sand	5	Salty.
E. C. Krueger	N. ½ sec. 28, T. 154, R. 53.	198	5	do	Flow.	
D. B. Eastman	SW. ¼ sec. 30, T. 154, R. 53.	233	5	do	3	
Joe Gounde	NW. ¼ sec. 11, T. 157, R. 52.	304	2	Red sand	20	Reddens water before strong west winds.
Med. French	N. ½ sec. 12, T. 157, R. 52.	148		Light sand	Flow.	
A. Campbell	SE. ¼ sec. 16, T. 157, R. 52.	280	2	White sand	Flow.	Water rose 16 feet above surface.
A. C. Shrenk	NE. ¼ sec. 36, T. 157, R. 52.	110			Flow.	Bitter.
Power	1 mile east of Pisek	400		Sand	40	
A. D. Cross	S. ½ sec. 1, T. 156, R. 55.	345	1¼	White sand	50	Salty.
Village	Veselyville	310	2	Sand	2	Do.
Matt Houska	E. ½ sec. 17, T. 156, R. 54.	290	2½	do	25	Do.
Frank Sindlaw	SW. ¼ sec. 28, T. 156, R. 54.	287	2½	do	50	Do.
John Loset	5 miles southeast of Grafton.	180		do		
Guy Miller	S. ½ sec. 25, T. 156, R. 53.	200			Flow.	Somewhat salty.
Arch. McDeavitt	¼ mile north of Minto.	190	2	Rusty sand	Flow.	
O. M. Omlie	NE. ¼ sec. 3, T. 156, R. 51.	156	2			
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Fordville	32	120			Small supply of "good" water.
Village	Conway	428		Sand	50	Salty.

[a] See table of analyses.

Water supplies of towns in Walsh County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet): Shallow	Deep	Most common	Water-bearing materials: Shallow	Deep	Remarks
Adams	404	Bored, drilled						Water in shallow wells alkaline; in deeper wells salty.
Ardock	153	Bored	20		25	Clay		Deeper artesian water salty.
Auburn				240				Deep wells yield fair water.
Cashel	100			400				First water very bad. Salt springs.
Conway	148	Dug, drilled	10	428	15	Clay	Sand	
Edinburg	278	do	15	300	25	Gravel, blue clay.	Drift	Dug wells, 15 to 40 feet deep, yield satisfactory water. Many springs of alkaline water along river. Wells 110 to 166 feet deep yield poor bitter water. Wells 300 feet deep yield salty and bitter water.
Fairdale	192	Bored, drilled	15	130	50	Sand	Shale	Water from deep wells salty.
Fordville	320	Dug, drilled	10	20		do		Water of fair quality.
Forest River	226	Drilled	10	230	15		Drift	230-foot wells flow.
Grafton	2,512	Dug, drilled	10	500	250	Gravel	Sand	Water from deep wells salty.
Hoople	250	do	15	200	20			
Lankin	334	Dug, bored, drilled.	10	290	30	Sand	Quicksand	
Mandt								Most farms have small flows.
Minto	602	Dug, drilled	10	60		Sand	Sand	River water used. Artesian wells 30 to 60 feet deep. Shallow wells yield poor water.
Park River	1,114	do	10		20	Clay	Clay, sand	Small springs of good water.
Pisek	300		10	400	20			
Veseleyville	60	Dug, drilled	15	310		Sand	Sand	Artesian water salty.
Warsaw	100	Dug	10	265	15			Flowing wells 140 to 265 feet deep.

WARD COUNTY

TOPOGRAPHY

The Missouri escarpment divides Ward County into two nearly equal but very irregular portions. The valleys of Souris River and Des Lacs Lake are the only exceptions to the generally level surface of the northeastern part. There are few tributary streams, and outside of these valleys the topography is that of the ground moraine, a rolling prairie marked here and there with sloughs. A small area from Minot eastward was covered by the waters of Lake Souris.

The Altamont moraine covers, in a broad belt 15 to 20 miles in width, most of the plateau area southwest of the escarpment. The roughness of this part of the moraine is remarkable. Knobs and kettle holes mingle in a confusion as monotonous and bewildering as are buttes and valleys in the badlands, though the knobs and kettle holes are the result of deposition by the ice, whereas the buttes and valleys are the result of erosion by running water. In this area sloughs and marshes and undrained areas are common.

The escarpment, which lies between these two topographic regions, is cut by numerous coulees, which are dry throughout most of the year. In no portion of the escarpment are the coulees so active and erosion so vigorous at the present day as in this region. This area is the only well-drained part of the county.

GEOLOGY AND GROUND WATER

Ward County presents a large variety of surficial deposits, including the alluvium of the valley, the sand and silt of the bed of Lake Souris, the younger drift of the Altamont moraine and the ground moraine to the east, and the older drift of the extreme southwest corner. The alluvium and lake sediments are so thin and so small in extent as to be of little value for the supplies of ground water. The drift deposits, on the other hand, constitute the chief source of supply. Shallow wells are numerous throughout the area and draw water from drift gravel at different depths, some at the surface, some in the body of the drift, and some, particularly in the area of the older drift, at the base of the drift and immediately above the bedrock.

The country rock of the area belongs to the Fort Union formation, except in the extreme northeast corner, where the Fort Union has probably been removed by erosion and the underlying Pierre shale is the bedrock. The Lance formation is represented in the southwest corner of the county by about 380 feet of beds. Drilled wells obtain moderate supplies in the sandstone and lignite beds of the Fort Union formation at different depths down to 500 feet.

The driller's log of the well drilled by the Minneapolis, St. Paul & Sault Ste. Marie Railway at Ryder indicates the general character of the Fort Union and possibly the Lance formation and the distribution of water-bearing beds, none of which yielded a very satisfactory supply.

Log of the Minneapolis, St. Paul & Sault Ste. Marie Railway well at Ryder

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Drift (?)	54	54	Coal and water	5	408
Clay and boulders	27	81	Shale	4	412
Coal	2	83	Coal	2	414
"Slate"	42	125	Shale	6	420
Coal and water	12	137	Coal	1	421
"Slate"	31	168	Shale	16	437
Shale	39	207	"Slate"	31	468
Coal	5	212	Hard rock	5	473
"Slate"	22	234	Shale	3	476
Rock	2	236	Coal	6	482
"Slate"	9	245	Shale	1	483
Coal	1	246	Shale and coal	2	485
"Slate"	18	264	"Slate"	5	490
Shale	18	282	Shale	6	496
Coal	6	288	Coal	2	498
Shale	8	296	Shale	7	505
Coal and water	3	299	"Slate"	27	532
Shale	2	301	Sand and shale	11	543
Coal and water	2	303	Coal	1	544
Shale	35	338	Shale	1	545
Sandy shale	23	361	Sand and shale	16	561
Shale	9	370	Coal and water	4	565
Coal	6	376	Shale	3	568
Shale	27	403			

The record of the well of the Des Lacs Western Oil Co., drilled in the SW. ¼ sec. 4, T. 155 N., R. 85 W., in Ward County, has given valuable information as to the thickness and character of the Upper Cretaceous formations in the northwestern part of the State. The record was based upon the driller's log and a fairly complete set of drill cuttings from the well submitted by the author to the United States Geological Survey. The cuttings were examined by W. T. Thom, jr., and the fossils contained therein were studied by J. B. Reeside, jr. Though the well caved extensively and no samples of some parts of the log could be obtained, the following table shows with fair accuracy the thickness and the general character of the formations penetrated by the drill. This record is of especial interest because the well is the deepest ever drilled in North Dakota for any purpose. Some information was obtained regarding the occurrence of water, but the conclusions on this point were not highly satisfactory—first, because water was not the object of the investigation, and, second, because of numerous difficulties with the casing which permitted the mingling of waters from different horizons. The first water was found at 214 feet immediately below a layer of sand containing gas at 210 feet. The location of the second water-bearing stratum is not indicated. The third water-bearing stratum occurred at approximately 400 feet, and a fourth at about 800 feet. The fourth stratum was reported, however, to yield but little water. The sandy formation near the base of the well, thought by the driller to be of Dakota age, had the highest head of water in the well except that of the first water reached by the ordinary farm wells in the vicinity. It stood at approximately 300 feet below the surface. An interesting series of temperature tests were made in this well by C. E. Van Orstrand, of the United States Geological Survey, when the hole was at a depth of 3,965 feet and was filled with water within 925 feet below the surface. The estimated temperature at the bottom was 126° F., or an increase of approximately 1° for every 45 feet in depth, starting approximately 50 feet below the surface, at which depth the temperature is practically constant and not affected by seasonal changes.

Generalized record of the Des Lacs Western Oil Co.'s well

Age	Formation	Character of strata penetrated	Depth (feet)
Pleistocene.	Glacial drift.		0-50
Tertiary (Eocene).	Fort Union formation.	Gray, rather calcareous sandy clay, with streaks of limestone, sandstone, and lignite. Hard layer, with show of gas beneath, reported by driller at 210 feet.	60-590
		Lignite	590-598
		Sandy clay, in part calcareous	598-900?
		Fine quartz sand, reported by driller to show oil	900?-920
Tertiary(?) (Eocene?).	Lance formation.	Dark sandy calcareous shale, containing lignite and fragments of limestone.	920-960
		Gray muddy shale	960-1,050
		Gray sandy clay, with some carbonaceous matter	1,050-1,075
		Gray gumbo, with fragments of light-colored limestone	1,075-1,125
		Gray fine-grained shaly sandstone	1,125-1,160
		Gray soft sticky shale	1,160-1,300
Upper Cretaceous.	Fox Hills sandstone.	No cuttings; reported by driller as sandstone, with good show of oil and gas.	1,300-1,340
	Pierre shale.	Light-gray shale, with calcareous layers	1,340-1,900?
		No cuttings; reported by driller as "limestone, with good show of oil."	1,900?-1,905
		Gray shale	1,905-1,960
		Light-gray shaly limestone, with fragments of fossils	1,960-1,980
		Gray shale, with calcareous layers	1,980- ?
		Whitish clay	? -2,165
		Gray, rather calcareous shale	2,165-2,300
		Gray, calcareous shale and limestone. According to driller's report there is sandy shale and sandstone, showing 1 to 10 barrels of oil a day, between 2,300 and 2,310 feet, which may correspond to the gas sand of the gas field at Glendive, Mont.	2,300-2,320
		Gray calcareous shale; fragments of fossils at 2,650 feet	2,320-2,800
		Gray shaly limestone, with *Ostrea* and *Inoceramus*	2,820-2,830
		Whitish shaly limestone	2,830-2,833
		Gray crumbly shale	2,833-2,878
		Blue limestone with *Inoceramus* and *Ostrea congesta*; probably corresponds to Eagle formation.	2,878-2,900

Generalized record of the Des Lacs Western Oil Co.'s well—Continued

Age	Formation	Character of strata penetrated	Depth (feet)
Upper Cretaceous—Contd.	Pierre shale—Continued.	Dark crumbly calcareous shale. Blue limestone containing pyrite and fossils at 2,995–3,030 feet. Driller reports sandstone showing 1 to 10 barrels of oil a day at 3,040–3,043 feet. This unit probably corresponds to Telegraph Creek formation of southern Montana.	2, 900–3, 133
	Niobrara formation.	Blue limestone with *Baculites, Inoceramus*, and *Ostrea*	3, 133–3, 140
		Dark-blue to black calcareous shale and limestone, with *Ostrea congesta* and abundant fragments of thick-shelled *Inoceramus*.	3, 140–3, 400
	Benton shale.	Dark gummy, somewhat calcareous shale	3, 400–3, 476
		Dark-gray, rather splintery shale; fragments of fossils	3, 476–3, 500
		Dark, rather gummy shale. According to driller, limestone and limy shale at 3,460–3,560 feet.	3, 500–3, 650
		Dark hard massive, fairly calcareous shale	3, 650–3, 856
		Gray limestone	3, 856–3, 860
		Dark massive shale	3, 860–3, 880
		Massive gray limestone	3, 880–3, 890
		Dark hard shale and limestone with *Inoceramus*	3, 890–3, 909
		Quartz sand; may correspond to Muddy sand or Newcastle sandstone of Wyoming; called Dakota sandstone by driller.	3, 909–3, 924
		Hard dark, rather calcareous shale, with Inoceramus	3, 924–3, 980

A number of the wells east of the escarpment, both in drift and in bedrock, yield flows under slight pressure, the head of which is due to the higher ground-water level in the plateau back of the escarpment, the water-bearing beds being nearly horizontal and continuous westward. A number of these wells occur southwest of Minot. Two on the farm of James M. Schofield, in the NE. ¼ sec. 29, T. 154 N., R. 83 W., are only a few hundred feet apart. In one the water-bearing bed lies at a depth of 122 feet, in the other at 502 feet. A third well 493 feet in depth was abandoned because only a slight amount of water was found in the base of the drift at 142 feet. Similar wells are present in front of the foot of the escarpment southwest of Kenmare, where flows from coal veins occur at depths of 78 feet on the farm of Wendel Ackerman, in the NE. ¼ sec. 35, T. 160 N., R. 89 W., and at 97 feet on the farm of Louis de Mass, in the SE. ¼ sec. 25 of the same township. The temperature of the water from the Ackerman well was 43°, taken in July at the mouth of the pipe 3 inches above ground. This temperature is the lowest noted in artesian waters in the State. A more notable group of flowing wells occurs at Kenmare in the bottom of Des Lacs Valley. There are several of these wells, and they range from 320 to 350 feet in depth, depending on location, and furnish 1 to 140 gallons a minute.

Springs are numerous in Ward County, particularly in the coulees that lead into the Missouri escarpment and in the deeper valleys of Souris and Des Lacs Rivers. The horizons commonly represented are those at the base of the drift and the outcropping edges of the sandstone and lignite of the Fort Union formation. The waters are on the whole of good quality, though some of them are slightly alkaline. The best known of these springs is probably that of A. B. Cary & Son, of Kenmare, which flows about 45 barrels a day from a stratum of fine sand and is used by the Kenmare Bottling Works for their supply. Another region in which springs are common is that of the front of the Missouri escarpment, which is so deeply trenched by the tributaries of Souris and Des Lacs Rivers as to appear from the eastward to be a range of hills. In the heads and sides of these valleys numerous springs flow from the contact of the base of the gravelly drift with the underlying impervious shale and from the outcropping edges of seams of l

QUALITY OF GROUND WATER

The alluvial deposits in Ward County yield hard water that contains small to moderate amounts of dissolved constituents. (See analyses 184 and 186.) The drift yields hard water moderately to highly mineralized. Analyses 178, 183, 185, and 187 represent waters with different amounts of dissolved mineral matter and indicate that most of the waters from the drift are satisfactory for general uses. Analyses 179, 180, 181, and 182 are fairly representative of the quality of water obtained from the Fort Union formation. The upper sandstone and lignite beds of this formation generally yield hard water, and the lower beds yield water that is soft but usually more highly mineralized. Water from the lignite beds may be colored brown to almost black with organic matter leached from the lignite. Analyses 180 and 181 represent very dark waters.

WATER SUPPLIES AT MINOT

Four possible sources of ground water may be considered in a study of water supply for Minot—the Puritan and other springs in the margin of the valley; the underflow of the river valley, obtained by means of shallow wells or collecting galleries; drilled wells, not exceeding 800 feet in depth; deep artesian wells that reach the Dakota sandstone.

So far as now known there is but one spring worthy of consideration as a source of any considerable water supply—the Puritan Spring, about half a mile northwest of the normal school. This water is harder than the river water and is therefore only a fair water for boilers, but its purity commends it as a drinking water. The present flow is small, yet it would make an excellent supply for the normal school or a good supplementary supply for the city. Possibly a somewhat larger amount could be developed from the spring by use of tunnels or collecting galleries, but this can be determined only by prospecting.

A large amount of water gradually flows beneath the surface of the river valley through the sand and gravel of the alluvium, which overlies the bedrock in which the valley is carved. The movement, though very slow, is downstream, and the volume is considerable in many valleys of the glaciated region where thick beds of coarse sand and gravel are common. Coarse sand and fine gravel occur in the Souris River Valley in considerable abundance, as is shown by their appearance in many places upon the surface, notably in the vicinity of the stockyards, where seepage springs are numerous, and many wells are also reported in the main and upper portions of the city as drawing water from this source. Some of these wells furnish a scanty amount, but at least one known as the "Granite Spring" yields several hundred gallons a day from a 3-inch hole without showing any signs of failure. The quality of this water, when taken from the up-valley side of the city and kept free from surface contamination, is probably superior to all others that are available for domestic supplies, though like all the shallow waters of the region it is somewhat hard and therefore only fair for boiler use. This water could be procured by batteries of driven points, drilled wells with screens, or, if necessary, with collecting galleries. If quality and quantity are both considered, it is probably superior to that of any other available source.

Wells drilled to depths of 100 to 500 feet would undoubtedly yield water from sandy layers or beds of lignite in the shale. They might flow at the rate of a few gallons a minute, like those of the city of Kenmare and those on the Scofield farm, a few miles south of Minot. The flow would probably not be strong even if obtained, and it would probably be necessary to pump the wells. A maximum yield of not more than 40 or 50 gallons a minute per well could be expected, and it would probably be far below that. This water, though soft, would be inferior in quality to the shallow waters because of the presence of considerable quantities of sodium sulphates and other alkalies. The quality could not be rated better than fair and would probably be poor or even bad. The quantity is uncertain but probably very inadequate.

Minot probably lies outside the Dakota sandstone area of artesian flow, from which many flowing wells are obtained in the southeastern part of the State. As the Dakota sandstone dips westward it would probably not be reached at Minot within 2,500 feet of the surface, and it may lie at much greater depths. The head would probably be insufficient to bring the water to the surface. The water would be strongly mineralized, with salty taste, and might carry fine white sand when pumped, resembling in these respects the 1,900-foot well at Carrington, now abandoned. Drilling for deep artesian water is not therefore advised.

Until October, 1916, the city of Minot had taken its supply of water from Souris River, but this had been unsatisfactory because of its hardness, impurity, and inadequate quantity, and it was decided to investigate the possibility of ground-water supply. To ascertain the quality of water and the character of the overlying strata a series of test wells was drilled across the valley from south to north in the upper portion of the city, as the writer believed that coarse gravel and sand in considerable quantities would be found in the bed of the old valley near the base of the alluvium that now fills the Souris River Valley at this point to a depth of more than 100 feet. Gravel and sand were encountered in these wells at a depth of about 120 feet and continued to the base of the alluvium, which at the deepest point was 142 feet from the surface. The gravel in the valley is of glacial origin and was deposited during the closing stage of the glacial epoch and later covered by the sand and clay brought down from the upper courses of the river as the glaciers retreated.

In the test well located farthest north of all these wells the thickest gravel was found, and it was determined to put down a 10-inch well 90 feet to the north of this last test well. The new well indicated a coarse vein of gravel and sand from a depth of 85 to 132 feet below the surface. The water in the well rose within 10 feet of the top, 12 feet higher than the water level in the river. A Johnson brass well screen, 9 inches in diameter and 40 feet long, was installed and the well on pumping yielded 890 gallons a minute, or about 1,500,000 gallons a day, one of the largest yields ever obtained from any well in North Dakota. A pump test that was made covered a period of 48 hours at the rate of 890 gallons a minute. The water at the end of that time was lowered only 7½ feet, and this level was quickly restored when the pumping was stopped. For a period of half an hour 1,400 gallons a minute were pumped, but as the pump was not capable of maintaining a very high speed it was not attempted to continue pumping at that rate. The drilling of the well, the placing of the screen, and the conducting of the pumping test were done under a contract with the McCarthy Well Co., of Minneapolis.

After the pumping test was completed the city installed a 7-inch centrifugal pump and pumped the new water directly into the city mains, under a temporary arrangement to allow the water users to sample the water. During the summer the pump was operated for periods of 12 hours continuously and pumped approximately 1,500 gallons a minute.

The water is very soft and has a slight color from organic stain, but this color has decreased somewhat since the initial pumping. Bacteriologically the water is pure, and it is suitable for boiler use, for which purpose it far surpasses the filtered river water. For permanent supply a 12-inch well was drilled in Oak Park about 200 feet north of the 10-inch well, during the summer of 1918, and an artistically designed pumping station was constructed at the site, so arranged that it is also used as a park pavilion. A 4-stage, electrically operated centrifugal pump, designed for a head of 300 feet and equipped with an auxiliary gasoline engine for emergency, was installed to furnish the main water supply for the city. Included in the new system is a concrete reservoir of 3,000,000 gallons capacity, located on the uplands south of the city. A new pipe line from the wells delivers water directly to the reservoir. Water is supplied to the residences on the hill from the reservoir by auxiliary pumps, which lift it into an elevated tank that maintains a pressure for that district only. (See analysis 186.)

Typical wells of Ward County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
A. Wagner	S. ½ sec. 21, T. 160, R. 89.	60		Coal	5	Soft water.
J. A. Anderson	Sec. 24, T. 160, R. 89.	465	3		110	Yellow clay 35 feet, blue clay 355 feet, shale, sand. Soft water.
Louis DeMarr	SW. ¼ sec. 25, T. 160, R. 89.	97	5	Black sand	Flow.	Temperature 44° F. Strong flow of brown water from sand and gravel below smooth blue clay.
Wendel Ackerman.	NE. ¼ sec. 35, T. 160, R. 89.	78	6	Sand	Flow.	Temperature 43° F. Probably ends in drift. Soft water.
H. Ackerman	SW. ¼ sec. 35, T. 160, R. 89.	130	5	Coal	60	Thick bed of quicksand. Coal at 130 feet.
John Thalen	SE. ¼ sec. 35, T. 160, R. 89.	40		do	15	Brown water.
T. E. Rohe	Kenmare	416	3	Sand	70	Shale at 275 feet, gravel and sand at 400 feet.
Matthew Welch	do	328			Flow.	Dairy well. 9 gallons a minute.
City	do	326	10	Gravel	Flow.	45 gallons a minute with water level 4 feet below surface. Pumped by centrifugal pump.
Do	do	328			Flow.	Slight flow. Abandoned.
Des Lacs Milling Co.	do	320	3		Flow.	
E. J. Brown	do	308		Coarse sand	Flow.	Temperature 48° F.
E. C. Tolley	do	320			Flow.	Now plugged. Water stands below surface.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	320	10	Gravel	Flow.	Formerly flowed 140 gallons; now 100 gallons a minute.
Hotel Martin	do	340	3		Flow.	Unused.
City	do	447	6	Fine sand	20	Water bed at 456 feet; another water bed above. Gas.
Kenmare Light & Power Co.	do	450		do	Flow.	Former head reported as 80 feet.
Hard Luck mine	do	457	2		Flow.	Gas. Former flow 5 gallons a minute; stopped by sand.
Kenmare Briquetting Co.	do	420			20	Gas.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	425	12		Flow.	Air-lift used. Gas.
National Briquetting Co.	do	512			20	Test hole. Gas.
L. M. Sommerville.	3 miles southeast of Kenmare.	447	2	Coarse sand	Flow.	On valley floor; slight flow. Gas.
R. Gissell	SE. ¼ sec. 16, T. 160, R. 88.	508				Hard gray sand.
E. Kleinschmidt	SE. ¼ sec. 24, T. 160, R. 88.	280	2	Coal, sand	230	Soft water.
City of Kenmare[a]	SW. ¼ sec. 20, T. 160, R. 88.	313	12			
E. Durrell	SW. ¼ sec. 8, T. 160, R. 87.	510	1¼	Shale	440	Do.
N. Larson	Donnybrook	72	18	Coal	Flow.	Slight flow.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	27	132			Poor water.

[a] See table of analyses.

Typical wells of Ward County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
J. M. Thompson	SW. ¼ sec. 14, T. 158, R. 87.	600	2	Dark-blue sand.	Flow.	Flowed 1 gallon a minute. Also flow at 400 feet. Brown water in coal down to 300 feet.
Jens Matson [a]	¾ mile northwest of Minot.	30	2¼	Fine sand		
Joseph Johnson	NW. ¼ sec. 14, T. 158, R. 87.	250			Flow.	Slight flow.
P. A. Johnson	SW. ¼ sec. 14, T. 158, R. 87.	115	3	Coal	Flow.	2 gallons a minute. Brown water.
D. M. Nelson	SE. ¼ sec. 3, T. 157, R. 87.	230	2	Light shale	180	Soft water.
C. Erickson	NE. ¼ sec. 14, T. 157, R. 87.	295	2	Shale	250	Do.
T. L. Leegraden	NE. ¼ sec. 14, T. 157, R. 86.	200				Gas in water.
Frank Leslie	NW. ¼ sec. 26, T. 157, R. 86.	287		Sand		Blue clay; 10 feet of gravel at 160 feet; shale and sand.
Gilbert Skimmengsrud.	SE. ¼ sec. 27, T. 157, R. 86.	200			10	
E. O. Rostad	SW. ¼ sec. 11, T. 157, R. 85.	550			250	
Joseph Makins	SW. ¼ sec. 29, T. 157, R. 85.	207		Sand	Flow.	Very weak flow. Pumped. Gas.
Anton Johnson	SW. ¼ sec. 14, T. 157, R. 81.	312	2	do	100	
J. Salsag	Sec. 5, T. 157, R. 81	200				Gas.
Howard Woods	NE. ¼ sec. 17, T. 157, R. 81.	215	5		30	Do.
C. J. Perring	NE. ¼ sec. 30, T. 157, R. 81.	160			65	Do.
Peter Johnson	NE. ¼ sec. 25, T. 156, R. 87.	267		Sand		Blue clay, shale, and sand.
John Williams	4 miles northeast of Berthold.	225	5	White sand-sandstone.	Flow.	75 barrels a day.
O. Able	NW. ¼ sec. 3, T. 156, R. 86.				Flow.	Flowed 2 years, then became plugged by sand; was cleaned and is again pumped.
Charles Quamen	SW. ¼ sec. 7, T. 156, R. 86.	398		Sand		Blue clay to 250 feet; then clay, shale, and sand.
Bank of Berthold	SE. ¼ sec. 13, T. 156, R. 86.				Flow.	
George Erdale	do	234	5	Coal	Flow.	¼ gallon a minute. Slightly brown. Roily with change of weather.
L. R. Colvert	SW. ¼ sec. 15, T. 156, R. 86.	407		Sand	50	Yellow clay 40 feet, blue clay 140 feet, shale 130 feet, sand 13 feet, shale 77 feet, coal 1 foot, sand and gravel 6 feet.
Village	Berthold	570				Blue clay, sand with black water at 250 feet, coal and shale to 560 feet, hard material with much water.
Frederick Finger	Sec. 34, T. 156, R. 86.	242		Coal		
L. F. Walstad	NE. ¼ sec. 25, T. 156, R. 86.	295		do		Low ground. Water in coal mixed with clay.
Howard Miller	SW. ¼ sec. 29, T. 156, R. 86.	500				Blue clay, sand, fire clay, and shale.
W. J. Myers	NW. ¼ sec. 34, T. 156, R. 86.	408		Sand		Blue sand at 240 feet, black water at 260 feet.
C. G. Larson	E. ½ sec. 34, T. 156, R. 86.	750		Muddy sand	70	Water at 540 feet in sandy clay. Could not clear. Coal 16 feet at 650 feet, coal 5 feet between 500 and 600 feet. Gas flowed from bed near bottom.

[a] See table of analyses.

Typical wells of Ward County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Charles Stevenson.	SE. ¼ sec. 8, T. 156, R. 85.	420		Sand	150	Yellow clay 80 feet, blue clay 120 feet, shale 190 feet, clay, sand, and gravel.
John Williams	S. ½ sec. 18, T. 156, R. 85.	235		Coal	Flow.	
William Brown	SE. ¼ sec. 19, T. 156, R. 85.	224		White shale	Flow.	160 barrels a day.
G. A. Luke	NW. ¼ sec. 19, T. 156, R. 85.	235	3	Sand		Water rises nearly to surface and overflows to reservoir. Water in sand under 4-foot vein of coal.
Ralph Fegley	SW. ¼ sec. 19, T. 156, R. 85.	215		do	Flow.	Very slight flow.
Do	do	483		do	12	On hill. Water at 285 feet in 6 inches of sand; 4-foot vein of coal at 258 feet, water in coal cased out. Gas. Yellow clay 11 feet, blue clay 149 feet, shale 68 feet, hard soapstone 3 feet, white shale 36 feet, coal 4 feet, shale and sand 213 feet.
Charles Barton	NE. ¼ sec. 27, T. 156, R. 85.	568				Dry hole. Coal at 190, 300, and 562 feet.
S. W. Nelson	NW. ¼ sec. 29, T. 156, R. 85.	244	3	Coal	Flow.	½ gallon a minute. Brown water. Blue clay 200 feet, shale 35 feet, coal.
M. A. Warning	NE. ¼ sec. 29, T. 156, R. 85.				Flow.	Flowed slightly.
E. L. Griffin	NW. ¼ sec. 35, T. 156, R. 85.	206	4		170	Coal 12 feet at 180 feet.
T. J. Horton	SW. ¼ sec. 36, T. 156, R. 85.	213		Coal	70	Clay, sand, and water 50 feet, blue clay 130 feet, limestone 8 feet, soapstone, coal, water.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	Foxholm	34				Size 10 by 12 feet. Good water, but scanty supply.
Jorgen Olson	NW. ¼ sec. 26, T. 156, R. 84.	570	3	Black shale	120	
E. Hestekine	S. ½ sec. 36, T. 156, R. 81.	284	4	Shale	30	Shale at 134 feet.
H. K. Olson	E. ½ sec. 1, T. 155, R. 86.	600		Sand		Blue clay, soapstone, coal, and fire clay to 306 feet; quicksand 8 feet at 306 feet; fire clay, limestone, hard shale, gravel, and sand.
John Linster	NE. ¼ sec. 5, T. 155, R. 86.	584	3	Fine sand	160	Roily mineralized water. Clay 150 feet, shale; coal 3 feet at 355 feet, shale; coal and gravel 14 feet at 458 feet, shale; sand 18 feet at 538 feet.
P. L. Weatherwax.	N. ½ sec. 2, T. 155, R. 85.	248	3	White shale	25	
William Fisher	NW. ¼ sec. 8, T. 155, R. 86.	530				Blue clay, fire clay at 300 feet; coal 15 feet at 350 feet; hard white material with sand and shale.
J. W. McCahan	SW. ¼ sec. 15, T. 155, R. 85.	165		Coal	Flow.	Trace of gas (oil?). Brown water. Blue clay, fire clay, soapstone, and coal.
Albert Spicker	SE. ¼ sec. 15, T. 155, R. 85.	200	4		Flow.	Clay and gravel, coal bed. ¼ gallon a minute. Reddish brown water.
W. G. Varnes	N. ½ sec. 15, T. 155, R. 85.				Flow.	¾ gallon a minute. Pressure formerly 21 pounds. Water also at 80, 120, and 165 feet in sand or coal.

Typical wells of Ward County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
George McKee	SW. ¼ sec. 17, T. 155, R. 85.	185	6	Coal	Flow.	¾ gallon a minute. Bubbles of gas.
John McIsaacs	NW. ¼ sec. 17, T. 155, R. 85.	173			Flow.	¼ gallon a minute. Pressure less than 2 pounds. Light-brown water.
John Kassens	NE. ¼ sec. 18, T. 155, R. 85.	164	5		Flow.	Slight head.
J. H. Burkhart	NW. ¼ sec. 19, T. 155, R. 85.	237		Sand		Blue clay, coal at 135 feet with black water, shale, and coal and sand.
J. R. Waterman	NE. ¼ sec. 20, T. 155, R. 85.				Flow.	1 gallon a minute. Light brown.
H. W. Gunther	S. ½ sec. 21, T. 155, R. 85.	175		Coal	Flow.	Trace of gas. Strong flow; blue clay, soapstone 85 feet, fire clay, coal.
Do	SE. ¼ sec. 21, T. 155, R. 85.				Flow.	13 gallons a minute. Pressure 5 pounds. Very brown water.
C. E. Dickerson	NE. ¼ sec. 21, T. 155, R. 85.	265			Flow.	Light brown. Pressure 4 pounds.
J. W. Hussey	E. ½ sec. 22, T. 155, R. 85.	210	5		Flow.	½ gallon a minute. Pressure 3 pounds. Light brown.
A. J. Bridges	NE. ¼ sec. 23, T. 155, R. 85.	186			Flow.	Yellow clay, blue clay to 176 feet, shale, coal 3 feet.
Frank Groniger	NW. ¼ sec. 24, T. 155, R. 85.	180			Flow.	1¼ gallons a minute. Slight pressure.
A. McCormack	SW. ¼ sec. 24, T. 155, R. 85.	200		Sand	Flow.	Trace of gas. Pressure 2 pounds. Blue clay, white material 3 feet with water. Light-colored water.
S. B. Cassin	NW. ¼ sec. 24, T. 155, R. 85.				70	
W. White	SE. ¼ sec. 25, T. 155, R. 85.	153		Sand	Flow.	1¾ gallons a minute. Pressure 3 pounds. Slightly brown. Yellowish clay and blue clay to sand at 127 feet. First flow in drift, weak. White clay 25 feet, sand; second flow.
City school[a] (Des Lacs)	SE. ¼ sec. 11, T. 155, R. 85.	30	18	do		
M. Salts[a]	Do	340	5	Shale	60	
H. W. Gunther[a]	SE. ¼ sec. 21, T. 155, R. 85.	175	3	Lignite	Flow.	
George McKee[a]	SW. ¼ sec. 17, T. 155, R. 85.	185	6	do		
C. H. Weatherwax.	NW. ¼ sec. 26, T. 155, R. 85.	186		Sand	Flow.	1 gallon a minute. Pressure 6 pounds. Light brown. Water in sand at 124,144, and 186 feet. White shale above each. Larson, driller.
W. C. Price	NE. ¼ sec. 26, T. 155, R. 85.				Flow.	½ gallon a minute. Formerly stronger. Sand filled.
J. E. Clark	SE. ¼ sec. 26, T. 155, R. 85.	176	4	Coal	Flow.	5 gallons a minute. Pressure 3 pounds. Flow at 130 feet; brown water in coal at 166 feet; strong flow.
L. B. Weatherwax.	NW. ¼ sec. 27, T. 155, R. 85.	136	4		Flow.	5 gallons a minute. Pressure 9 pounds. Very dark brown.
E. L. Waterman	SE. ¼ sec. 27, T. 155, R. 85.	125		Coal	Flow.	Trace of gas.
W. J. Fey	NW. ¼ sec. 28, T. 155, R. 85.	165	4	do	15	
Malay Chaffel	NW. ¼ sec. 29, T. 155, R. 85.	190	5	Shale	Flow.	Dark water. Head formerly 20 feet.

[a] See table of analyses.

Typical wells of Ward County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
L. Waterman	NW. ¼ sec. 35, T. 155, R. 85.	220			Flow.	1½ gallons a minute. Pressure 3 pounds. Light-brown color.
W. C. Tunstall	SE. ¼ sec. 35, T. 155, R. 85.	176		Coal		Yellow clay, blue clay, coal.
A. J. Schmidt	SW. ¼ sec. 36, T. 155, R. 85.	286		Coarse sand		Yellow clay, blue clay, coal, shale, coal, soapstone, coarse sand.
W. L. Groninger	SW. ¼ sec. 31, T. 155, R. 84.	115	5		Flow.	Originally flowed 32 gallons a minute. Throws a little fine sand. Brown water. Pressure 22 pounds. Strongest pressure in basin.
William Marshall.	NW. ¼ sec. 33, T. 155, R. 84.	200		Coal, sand		Trace of gas. Blue clay at 25 feet, quicksand at 75 feet, clay, sand and coal to 200 feet.
Great Northern Ry.	Minot					Yard well near Souris River. 18 by 20 by 10 feet. 15,000 gallons a day.
Troy laundry	do	115	4	Sand	20	Yellow clay to 35 feet, blue clay to 100 feet, fine gray sand to 115 feet. Not used because of iron content.
Minot laundry	do	121	4	do	40	Blue clay to 100 feet, medium fine gray sand to 127 feet. Rusty on standing.
Consumers Power Co.	do	126				
Herman Titus	do	110	2		4	24 hours pumping at 3,500 gallons an hour. Good domestic water.
Fair ground	do	300				
Ole Knudson	do	76			43	Drift 65 feet, hardpan 8 feet, sand and gravel 3 feet.
City	do	120	4	Sand	10	Test well at old filter plant. Gravel and coarse sand 35 feet thick. Pumping test: 8 gallons a minute with water level drawn down to 12 feet; 12 gallons, 15 feet, 14 gallons, 20 feet; and 20 gallons, 30 feet below surface.
Do	do	120	3		20	Test well at old filter plant (No. 2). Pumped out in few strokes when well was 20 feet deep. Better yield at 60 feet and 80 feet below surface. Yielded 3½ gallons a minute when finished. 3-inch Cook strainer used.
Do	do	330	5	Sand	12	Test well at old filter plant. 9-foot bed of sand at 126 feet.
State normal school. [a]	NE. ¼ sec. 14, T. 155, R. 83.	200	6	Gravel	29	
City [a]	Minot	132	12	do	15	
Darby & Peterson.	do	110	4		4	
C. A. Nichols	SE. ¼ sec. 1, T. 154, R. 87.	82	4	Gravel	60	Drift well.
Jacob Peterson	SE. ¼ sec. 3, T. 154, R. 87.	252	3	Sand	70	Blue clay, shale and coal to sand under coal.
J. C. Cogdill	SW. ¼ sec. 1, T. 154, R. 85.			Gravel	Flow.	¼ gallon a minute. Water becomes rusty after standing.

[a] See table of analyses.

Typical wells of Ward County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
T. M. Williams	E. ½ sec. 9, T. 154, R. 85.	313				Yellow clay, blue clay at 35 feet, quicksand at 140 feet, fine clay 30 feet at 240 feet, coal 6 feet at 270 feet, clay, coal 3 feet at 310 feet.
William Moyer	NE. ¼ sec. 12, T. 154, R. 85.	180		Drift	10	Water becomes rusty after standing.
Shannon Wagoner.	SW. ¼ sec. 21, T. 154, R. 85.	339				Yellow clay, blue clay at 35 feet, coal 3 feet at 245 feet, fine white clay at 336 feet, coal at 339 feet.
C. H. Groninger	NW. ¼ sec. 6, T. 154, R. 84.	177			Flow.	15 gallons a minute. Pressure 15 pounds. Light-brown color. Temperature 41° F. One of the strongest flows in the basin. Coldest artesian water in North Dakota. Blue clay, soapstone, coal, and water.
J. F. Moyer	SW. ¼ sec. 6, T. 154, R. 84.	140	5	Coal	Flow.	3¾ gallons a minute. Pressure 9 pounds. Dark-brown water.
George Miller	SW. ¼ sec. 11, T. 154, R. 84.	165	5	Shale	Flow.	Pressure formerly 13 pounds.
Do	SW. ¼ sec. 14, T. 154, R. 84.	180	5	Gravel	6	
J. E. McKoane	SW. ¼ sec. 16, T. 154, R. 84.					
Ward County farm.	NE. ¼ sec. 11, T. 154, R. 83.	575	2		160	Gas.
F. J. Willman	S. ½ sec. 13, T. 154, R. 83.	250				
Henry Auslander.	S. ½ sec. 21, T. 154, R. 83.	197		Sand	Flow.	Pressure formerly 10 pounds. Reported flow 35 gallons a minute. Sand plugged and abandoned.
Do	do	157			Flow.	Slight flow. Drill struck rock, which is probably in drift.
Hart Swalstead	SE. ¼ sec. 26, T. 154, R. 83.	192	3	Sand	30	
Joseph Scofield	NE. ¼ sec. 29, T. 154, R. 83.	175	3	do	Flow.	Water bed at 122 feet. Throws some fine dark sand.
J. H. Scofield	do	502		Blue sand	Flow.	
Do	do	493	4			A little water at base of drift only. Abandoned.
George Kingstad	SE. ¼ sec. 32, T. 154, R. 83.	116	4	Gravel	16	
Anker Sundne	S. ½ sec. 10, T. 154, R. 82.	333	3	Sand	35	
T. Tompson	SE. ¼ sec. 17, T. 154, R. 82.	460	3			Dry hole.
Fremont Cook	S. ½ sec. 23, T. 154, R. 82.	302	3	Black shale	25	
John Weber	W. ½ sec. 30, T. 154, R. 82.	165	3	Sand	30	
Thomas Histed	Sec. 16, T. 154, R. 82.	265	2	do	115	
E. Nordquist	NW. ¼ sec. 4, T. 153, R. 83.	75	4	do		
Alfred Jylen	SE. ¼ sec. 4, T. 153, R. 83.	96	4	do		
E. R. Smith	SE. ¼ sec. 24, T. 153, R. 83.	125	3	do	80	
Dave Vannett	NW. ¼ sec. 26, T. 153, R. 83.	217	3	do	160	
Carl Swenson	NE. ¼ sec. 17, T. 153, R. 82.	310	2	do	110	

Typical wells of Ward County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
George Benchler	NE. ¼ sec. 1, T. 153, R. 81.	520				Dry. Hard rock at bottom.
G. J. James	SE. ¼ sec. 30, T. 153, R. 81.	431	2	Sand	181	
P. N. Coklin	NW. ¼ sec. 30, T. 153, R. 81.	220	2	do	70	
Mr. Shilling	SE. ¼ sec. 7, T. 153, R. 80.	142	3	Black shale	15	
Henry Myers	W. ½ sec. 18, T. 153, R. 80.	172	3	do	12	
Hugh McCuster	E. ½ sec. 24, T. 153, R. 80.	135	2	Sand	10	
Andy Anderson	SW. ¼ sec. 34, T. 153, R. 80.	118	3	do	35	
Walter Jensen	NW. ¼ sec. 21, T. 152, R. 80.	90	3	Gravel	30	
George Benchler	SE. ¼ sec. 22, T. 152, R. 82.	175	2	Coal	145	
Mr. Werstner	Ryder	585	6		12	
Creamery	do	315				Coal at 140 and 270 feet.

Water supplies of towns in Ward County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Aurelia	100	Bored, drilled	20	150	125	Clay	Gravel, coal	
Berthold	498			570			Sandstone	Few slight flows at 225 to 235 feet.
Carpio	244	Driven	15	325	30 300	Gravel		
Des Lacs	188	Bored	20		30	Drift	Coal	
Donnybrook	267	do	15	75			do	Slight flows.
Douglas	284	Bored, drilled	10		25	Gravel, sand	do	Water rises nearly to surface.
Foxholm	150	Dug	15	60	20			
Grano	112		95	135		do	Blue clay	
Hartland		Dug, drilled	15	200		Sand	Sand	Shallow wells hard; deep wells soft. Small springs.
Kenaston	20	do	16	276	125	Drift		Many drilled wells, some closed with quicksand.
Kenmare	1,446		20	500			Sand, gravel	
Ryder	483	Bored, driven, drilled.	10	585	20	Sand		
Sawyer	241	Dug, driven, bored, drilled.	15	180		Gravel, sand	Sand	Springs flow from 1 to 20 gallons a minute. Deep wells yield soft water; shallow wells hard.
Surrey	136	Dug, bored	15	75				Shallow waters good, deep waters salty.

WELLS COUNTY

TOPOGRAPHY

Wells County is divided into two distinct topographic regions by the Missouri escarpment, which crosses the southwest corner. The larger portion, including about four-fifths of the entire county, is a gently undulating drift prairie which slopes gradually to the east.

The southwest corner lies on the high front of the Missouri Plateau immediately west of the escarpment and is also covered with drift. This part of the county is considerably dissected by the many small valleys that lead down to the lower plain, whence they find their way across the county into James River. The northern part of the county is drained by Sheyenne River.

GEOLOGY

The larger part of the county east of the escarpment is underlain with the Pierre shale, but the escarpment is probably formed by the edges of the Fort Union formation, which underlies all the plateaus to the west.

The drift mantle here reaches the maximum reported anywhere in the State. In a 520-foot well in the SW. ¼ sec. 28, T. 147 N., R. 73 W., the remarkable thickness of 500 feet of drift is reported to overlie the shale. In the NE. ¼ sec. 35, T. 150 N., R. 72 W., 405 feet of drift overlies the shale, and the town well of Bowdon is reported to penetrate 415 feet of drift clays.

Although it is possible that soft clay of the Fort Union, which overlies the Pierre shale, may have been mistaken for drift by drillers unaccustomed to drilling in this formation, the evidence all points to a very heavy mantle of drift in this region.

GROUND WATER

The sandy lenses and the veins and seeps of the till are relied upon generally to supply the wells of this region. The drift is not strongly morainal in character, and the gravel and sand of the drift are so well mixed with the boulder clay that but a small supply of water is obtained. The depth of the drift ranges generally from 100 to 500 feet, so that only deep wells reach the horizon at the base of the drift and this also is not prolific. Many of the drilled wells of the northern and eastern parts of the county penetrate the bedrock and obtain a fair supply in the sandy layers of the shale, but a large percentage of the holes are dry. Those that obtain water range in depth from 150 to 500 feet. The deep well at Harvey was drilled to the Dakota sandstone. (See pp. 304–305.)

Springs are common in a rather broad zone which extends from southeast to northwest across the county and which is occupied by the hills of the eastern edge of the Missouri escarpment. As Wells County contains the sources of two large streams—James River and Pipestem Creek—and as Sheyenne River passes through from its headwaters farther west in Sheridan County, many springs emerge where the porous formations of the escarpment are cut through by these streams. The flow of these streams is materially affected by the flow of the springs of this region.

QUALITY OF GROUND WATER

The different horizons of the drift in Wells County yield hard water that ranges from 300 to 5,000 or more parts per million of total dissolved solids. (See analyses 188, 189, and 190.) The Fort Union and Pierre formations yield moderately to highly mineralized water that differs in the amount of hardness from place to place. Most of this water is suitable for general use. The Dakota sandstone yields to flowing wells highly mineralized water that is usually soft. (See analysis 191.)

Typical wells of Wells County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Mrs. Sarah Dolan [a].	SE. ¼ sec. 31, T. 150, R. 72.	18	96	Gravel, sand	12	
Krenik, Peterson & Jorgenson.[a]	do	60	60	Gravel	35	
City [a]	Harvey	2,235	1¼	Sandstone	Flow.	Original pressure 24 pounds; in 1917, 18 pounds. Flow 2½ gallons; diminished to 1 gallon a minute. Soft but mineralized water.
L. L. Goldberg	do	700				Chiefly shale below 200 feet. Dry except in drift in upper part.
Minneapolis, St. Paul & Sault Ste. Marie Ry.	do	277	8	Sand and shale.		Small yield.
John Leetum	SE. ¼ sec. 24, T. 150, R. 72.	220		Gravel and sand.	16	Yellow and blue clay 70 feet, rusty gravel 20 feet, blue clay 110 feet, gravel and sand 20 feet. Strong well.
A. D. Frost	NE. ¼ sec. 35, T. 150, R. 72.	410				Drift 405 feet, soft shale 5 feet. A little water in quicksand. Abandoned.
Ole Rodne	SE. ¼ sec. 35, T. 150, R. 71.	140	5	Sand	30	
Great Northern Ry.	Heimdahl					12 by 3 by 23 feet.
David Schinke	SE. ¼ sec. 31, T. 149, R. 72.	160	5	Shale	30	
Nels Hovey	SE. ¼ sec. 10, T. 149, R. 71.	230	5			Small supply of good water.
Ole Hedahl	NW. ¼ sec. 22, T. 149, R. 71.	486		Sand		Blue clay 43 feet, sand to 45 feet, shale to bottom. Finished in sand at 45 feet.
S. M. Willborg	SW. ¼ sec. 31, T. 149, R. 71.	644	5	Shale	90	Clay 70 feet, shale to 644 feet. Gas at 533 feet. Water slightly salty.
Great Northern Ry.	Bremen					12 by 24 by 17 feet. 264,000 gallons a day.
City [a]	Fessenden	148	6	Sand	68	Red clay 15 feet, gravel with many boulders 30 feet, blue clay 88 feet, gravel and sand 15 feet. Satisfactory water.
Mr. Hunt	do	908	4			Caved below 800 feet. Abandoned.
S. Neuenschwander.	Sec. 1, T. 148, R. 70.	95	2	Sand		
Jacob Pepple	SW. ¼ sec. 5, T. 148, R. 70.	135	2½			Blue clay 122 feet, sand 13 feet. Strong well at first; now weak.
Do	do	500	5½			Drift 164 feet, sand 1 foot, soft shale 235 feet, hard shale 100 feet. Well was to be drilled deeper.
Richard Pritchard.	NW. ¼ sec. 17, T. 148, R. 70.	150	2½	Sand	44	Drift well.
Albert Ranky	SE. ¼ sec. 21, T. 148, R. 70.	186	2½	do	16	Boulder clay 145 feet, sand 1½ feet, shale. Strong well.
David R. Jones	NW. ¼ sec. 20, T 148, R. 70.	180				Dry hole. Drift 160 feet, shale 20 feet.
Carl Brockat	NW. ¼ sec. 26, T. 148, R. 69.	115	2	Fine blue sand.	20	
Eugene A. Rolph	E. ½ sec. 32, T. 148, R. 70.	147	2½	Sand	15	Water at 135 feet.

[a] See table of analyses.

Water supplies of towns in Wells County

Town	Population in 1920	Kinds of wells	Common ranges in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Bowdon	306	Drilled	35	300				One good spring.
Cathay	185	Bored	10	40	20	Drift	Drift	
Fessenden	731	Dug, bored, drilled.	20	150		Gravel	Sand	Satisfactory water at 150 feet in drift sand.
Harvey	1,590							See records on pp. 304–305. One good valley spring.
Heaton	275				30	Sand		Many cisterns.
Hurdsfield	425	Dug, drilled.	10	550		Drift		Some flowing wells. Deep water soft.
Sykeston	367	Dug, bored	20	45	30			

WILLIAMS COUNTY

TOPOGRAPHY

Williams County is a characteristic portion of the Missouri Plateau within the area covered by the older drift. The major topographic features are the broad expanse of rolling plateau country deeply trenched on the south by the Missouri Valley and dissected for many miles back along the Little Muddy and other tributaries. The minor features are largely the work of the glacier modified by stream erosion.

GEOLOGY AND GROUND WATER

The bedrock is exposed in many places along the bluffs of Missouri River and in the valley walls of the larger creeks, and is found everywhere to be composed of the gray shale and sandstone and thick beds of lignite coal composing the Fort Union formation. These beds of sandstone and lignite contain considerable water and yield springs of considerable strength of flow where they crop out on the sides of the valleys unless heavily covered with surficial material. On the uplands they generally afford ample supplies of water to the wells, which have been drilled in considerable numbers to depths of 150 to 500 feet. Drilled wells in the lowlands occasionally yield weak flows from similar sources.

The drift is the source of water in many shallow wells on the upland and these wells generally draw the strongest and best supplies from the base where it overlies the bedrock. In the lower valleys shallow wells in alluvium gather the underflow and seepage which enters from the upland.

The Pioneer Oil & Gas Co. drilled a test hole on the Missouri River flats east of Williston, in the SW. ¼ sec. 29, T. 154 N., R. 100 W., in 1920 to a depth of 2,107 feet, which was started with a 14-inch casing and finished with 4-inch. Several artesian horizons were penetrated, and the first one, at 560 feet, was probably in the Fort Union formation. The casing was partly pulled, and no log has ever been given out by the company, so that nothing is known as to the source of the considerable flow of warm water which flows from the casing head. A number of other flowing wells of the narrow-valley type are scattered all along the Missouri River bottoms, especially just below the city of Williston. These wells all yield a moderate supply of mineralized water at slight pressure. A typical well is that of the Bueger Mercantile Co., in the SW. ¼ sec. 29, T. 154 N., R. 100 W., which was drilled to a depth of 640 feet and is 4 inches in diameter. This well yields 15 gallons a minute at 50° F. The water is used both for domestic supplies and for stock. (See analysis 194.) Similar but smaller flows are found in the valleys of Stony and Little Muddy Creeks, and in the vicinity of Wild Rose a few shallow artesian wells have been obtained in the drift at depths of 50 and 65 feet. One of these wells on the farm of Fred A. Johnson, in the NW. ¼ sec. 6, T. 159 N., R. 96 W., is 50 feet deep and 2 inches in diameter and yields about 4 gallons a minute.

In no part of this State are good springs more common than in Williams County. They are largest and most numerous in the deeper tributary valleys of the Missouri for a distance of 30 miles or more back from the main valley. The Little Muddy, Sand, Painted Woods, Stony, and Beaver Creeks all receive large supplies from these springs. The Little Muddy, the main tributary of the Missouri from the north and east in North Dakota, is fed by several perennial springs, which with ground water seepage give it a steady flow throughout the summer. J. F. Brother's spring, 6 miles east of Williston, in sec. 25, T. 154 N., R. 100 W., supplies much bottled water to Williston and the surrounding territory. The waters flows from the springs in a clear stream at the rate of 3 gallons a minute, and the temperature when taken in August was 49° F., which is approximately the temperature of most of the springs in this region. Lignite beds furnish the source of most of these springs. At a point 3 miles north of the Dahl mine, in the bed of Crazy Mans Creek, a spring issues from a lignite bed, of which 3 feet are exposed, and fills a 3-inch pipe with a strong stream of good drinking water. On Deer Coulee, a tributary of Beaver Creek, at the Marmon ranch, 4 miles from Nesson post office, a 10-foot seam of lignite yields a strong spring. North Tobacco Garden Creek, which unites with the Missouri at Nesson post office, is also fed by strong springs. Crusak Springs, at the source of its west fork in sec. 12, T. 154 N., R. 98 W., are perennial and flow 3 second-feet even in midsummer. During the summer the creek suffers loss of volume because of evaporation and the porous nature of its bed, so that the total flow at its mouth is less than that of its several spring sources. Nelson Creek is also spring-fed, though the springs are weak. There are many other valuable springs in the county which were formerly the chief sources of water for the cattle on the open ranges and determined the location of many of the ranch houses. Notable among these springs was that on the Ole Young place, 3 miles west of Williston, where many cattle from a large area watered. Having played a notable part in the early settlement of the region, though the country is now largely in fence, they are still of great value to the stock farmers and ranchmen on whose places they are now located.

QUALITY OF GROUND WATER

The drift in Williams County yields hard, moderately to highly mineralized water, most of which is suitable for general use. (See analysis 196.) The alluvium of the valleys yields similar water, though some of it is not so highly mineralized. Shallow wells that enter the upper sandstone and lignite beds of the Fort Union formation yield hard water that differs in mineral content from place to place. Deeper wells that draw on the lower beds of the Fort Union and also on those of the Lance formation yield soft water moderately to highly mineralized. (See analyses 192, 194, and 195.)

WATER SUPPLIES AT WILLISTON

The city of Williston contains dug, driven, bored, and drilled wells that range in depth from 30 to 250 feet. Sand points driven into the alluvial deposits of the river valley are common and make the most satisfactory of the shallow wells. Drilled wells that draw their supplies from the sandstones and lignite beds of the Fort Union formation yield more strongly mineralized water but are used where larger supplies are needed. A number of flowing wells indicate the possibilities of obtaining a supply of soft though highly mineralized water at depths of several hundred feet. The public waterworks are supplied from a dug well, 10 feet in diameter and 46 feet deep; the consumption of water ranges between about 300,000 and 750,000 gallons a day.

Typical wells of Williams County

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
Great Northern Ry.	Wildrose					18 by 24 by 44 feet; 150,000 gallons daily.
E. Lindquist	SE. ¼ sec. 27, T. 160, R. 95.	154	5	Sand	60	
Nilo Samdahl	NW. ¼ sec. 28, T 159, R. 95.	172	5	do	70	
August Nelson	NE. ¼ sec. 2, T. 158, R. 95.	130	5	do	75	
T. Holden	SE. ¼ sec. 30, T. 158, R. 85.	100	5	Gravel	20	
H. Hawkinson	NW. ¼ sec. 33, T. 158, R. 95.	245	5	Coal	120	
C. H. Borstad	SE. ¼ sec. 34, T. 158, R. 95.	132	5	Sand	20	
Clarence Hough	SE. ¼ sec. 20, T. 157, R. 103.	100				
Nick Nelson	NE. ¼ sec. 4, T. 157, R. 102.	162				
Oscar Strand	SE. ¼ sec. 23, T. 157, R. 103.	40				
A. Anderson	NE. ¼ sec. 25, T. 157, R. 102.	84				
J. F. Borstad	SW. ¼ sec. 31, T. 157, R. 102.	180				
W. B. Scott	SE. ¼ sec. 27, T. 157, R. 97.	217	2	Sand	98	
Oscar Peterson	NE. ¼ sec. 2, T. 157, R. 96.	215	6	do	100	
Ole Harstade	SE. ¼ sec. 27, T. 157, R. 96.	336	2	Blue clay	140	Roily.
C. Hemsing	SE. ¼ sec. 9, T. 157, R. 95.	156	5	Sand	30	
N. W. Simon	NW. ¼ sec. 18, T. 157, R. 95.	154	5	do	75	
Ed. Hilsted	SE. ¼ sec. 3, T. 156, R. 103.	86				
John Elton	Sec. 7, T. 156, R. 103.	128				
L. O. Higly	W. ½ sec. 25, T. 156, R. 102.	166				
Herman Schoughberg.	SW. ¼ sec. 34, T. 156, R. 102.	100				
L. Bear	SE. ¼ sec. 34, T. 156, R. 101.	135				
J. G. Gujjedal	S. ½ sec. 3, T. 156, R. 99.	362	3	Coal	100	
Otto Hough	E. ½ sec. 19, T. 156, R. 98.	311	3	do	125	
H. Redlich	SW. ¼ sec. 23, T. 156, R. 98.	145	2	Sand	49	
P. LaBarge	NE. ¼ sec. 26, T. 156, R. 98.	145	2	Coal	96	
W. Burington	S. ½ sec. 8, T. 156, R. 98.	265	2	Sand	100	
R. H. Everson	NE. ¼ sec. 3, T. 156, R. 97.	219	4	do	25	Soft.
R. Schmeider	SW. ¼ sec. 7, T. 156, R. 97.	164	2	do	80	
Wingate Charlson.	SW. ¼ sec. 9, T. 156, R. 97.	175	2	Gravel	75	
William O'Brien	SW. ¼ sec. 26, T. 156, R. 97.	95	2	Coal	60	Coal at 40 feet.
C. J. Sanders	S. ½ sec. 28, T. 156, R. 97.	186	2	Sand	40	
A. J. Sorlie	NE. ¼ sec. 32, T. 156, R. 97.	196	2	Coal, sand	2	
B. J. Foss	SW. ¼ sec. 8, T. 156, R. 96.	171	2	Sand	85	

Typical wells of Williams County—Continued

Owner	Location	Depth of well (feet)	Diameter (inches)	Source of supply	Water level below surface (feet)	Remarks
T. M. Moe	SW. ¼ sec. 2, T. 156, R. 95.	238	2	Coal	50	
J. K. Hanson	SE. ¼ sec. 23, T. 155, R. 103.	104				
Dave Mahoney	SE. ¼ sec. 2, T. 155, R. 102.	110				
Martin Jensen	NE. ¼ sec. 12, T. 155, R. 102.	306				
Roy Ashville	SW. ¼ sec. 31, T. 155, R. 101.	35				
Do	do	255				No water.
	7 miles northwest of Williston.	203	6	Gravel	125	Coal beds present.
	do	291	6	do	125	Do.
F. E. Davis	NW. ¼ sec. 35, T. 155, R. 101.	103				
W. A. Palmer	NW. ¼ sec. 32, T. 155, R. 100.	40		Coal, gravel		Strong well. Temperature 48° F.
S. Haney	NE. ¼ sec. 3, T. 155, R. 99.	40	4	Coal	12	
Otto Wannagat	NW. ¼ sec. 29, T. 155, R. 99.	97	4	do	50	
Jack Daily	do	34	4	Gravel	12	1 gallon a minute.
Hendrum Strand	SW. ¼ sec. 33, T. 155, R. 99.	110	4	Coal	12	
Anton Holman	NE. ¼ sec. 3, T. 155, R. 97.	135	2	do	65	
R. M. Grove [a]	SE. ¼ sec. 36, T. 155, R. 97.	883	6	Sandstone	Flow.	Water rose 20 feet above surface.
Ralph Holler	Williston	70				Bored.
Mike O'Neill	do					Do.
August Boud	Sec. 4, T. 154, R. 101.	113	4¼	Coal		Slightly salty.
Leonard Logan	SE. ¼ sec. 9, T. 154, R. 101.	105				
Cliff Hardacie	6 miles east of Williston.	110				
United States irrigation station.	5 miles northeast of Williston.	30		Gravel	10	2-inch drive points in 10-foot well. Centrifugal pump at 15 feet below surface.
Bruegger Mercantile Co.[a]	SW. ¼ sec. 29, T. 154, R. 100.	640	4			
H. P. Hendrickson.[a]	do	2,100	14 4	Sandstone	Flow.	Water rose 20 feet above surface.
E. Evans	NW. ¼ sec. 1, T. 154, R. 99.	136	4	Sand	70	
L. Kirkpatrick	W. ½ sec. 3, T. 154, R. 99.	202	4	do	28	
Thomas Gabert	NE. ¼ sec. 26, T. 154, R. 99.	126	4	do	10	
Joe Shamon	SE. ¼ sec. 18, T. 154, R. 98.	200	4	do	6	

[a] See table of analyses.

Water supplies of towns in Williams County

Town	Population in 1920	Kinds of wells	Common range in depth of wells (feet)			Water-bearing materials		Remarks
			Shallow	Deep	Most common	Shallow	Deep	
Buford	150	Drilled	125	180	150			
Epping	116	Bored, drilled	35	70	40			Small springs.
Grenora	358	Dug, drilled	20	200	150	Clay	Sand	Flowing wells in the river valley.
Ray	563	do	25	200	100			Many springs.
Springbrook.	93							Springs from coal seams in Springbrook Valley.
Tioga	320	Bored, drilled	40	250	60	Drift, sand.	Sandstone.	
Trenton		Dug, bored, drilled.	25	200		Sand	Gravel	Some farm wells 350 feet deep. Springs in coulees.
Wheelock		Drilled	75	200	150	Clay	Sand, coal.	Springs.

PUBLIC WATER SYSTEMS

Public water systems of cities and villages with waterworks

[Revised to June 1, 1927]

Town	County	Population in 1920	Source of water	Reservoirs	Capacity of reservoirs (gallons)	Length of mains (miles)	Number of taps	Number of fire hydrants	Percentage of population supplied	Estimated average daily consumption (gallons)	Capacity of pumps (gallons a minute)
Abercrombie	Richland	266	Artesian well	Air-pressure tank	1,800			9			
Anamoose	McHenry	586	Well	Elevated tank	50,000	1.9		18	32	10,000	45
Ayr	Cass	[a] 150	Rain water	do	15,000			1			50
Beach	Golden Valley	1,100	4 wells	do	125,000	5.5	50	39			250
Berlin	La Moure	130	Artesian wells			.1					
Bismarck	Burleigh	7,122	Missouri River	3 concrete tanks	3,000,000	18		94	50	500,000	1,000
Bottineau	Bottineau	1,172	Spring; 4 wells	Elevated tank and cistern	192,000	3.5	30	29			160
Bowbells	Burke	643	Well	do	50,000	.6	1	13		Small.	30
Bowman	Bowman	787	2 wells	do	75,000	4.3		25		28,000	100
Cando	Towner	1,111	do	do	170,000	2.0		24			30
Carrington	Foster	1,420	Well	Standpipe	143,000	6.6	80	29	60	25,000	250
Casselton	Cass	1,538	2 artesian wells	Standpipe and cisterns	280,000						
Cooperstown	Griggs	1,112	2 wells	Elevated tank and 2 reservoirs	250,000	4.5	80	28	25	35,000	250
Crosby	Divide	1,147	Artesian well	Gravity tank, reservoir, and cistern.	219,000	4.5		52			
Devils Lake	Ramsey	5,140	Artesian wells	Reservoir and elevated tank	180,000	6.6		109	50	250,000	1,760
Dickinson	Stark	4,122	Wells	Cisterns and elevated tank	1,040,000	7.6	280	68	65	175,000	1,730
Drake	McHenry	517	3 artesian wells	Elevated tank	50,000	3.6		25			90
Edgeley	La Moure	803	Wells	Cistern	47,000	.2		4			750
Elgin	Grant	429	Artesian well	Elevated tank	50,000	1.0		10			
Ellendale	Dickey	1,334	Artesian wells	Tank and reservoir	110,000	2.4		38			100
Enderlin	Ransom	1,918	Well	Elevated tank and cistern	85,000	4.0		47	70	50,000	
Fairmont	Richland	706	Artesian well	Elevated tank and reservoir	72,000	2.1		19			
Fargo	Cass	21,961	Red River (filtered)			35	3,000	400	80	2,300,000	7,000
Fessenden	Wells	731	2 artesian wells	Tank and reservoir	40,000	1		15			60
Fullerton	Dickey	202	Well			4.0		5			
Garrison	McLean	714	2 wells	Elevated tank	50,000	2.8		16	83		
Glen Ullin	Morton	875	Wells and lake	Reservoir and railway tank	97,000	.6		7		150	
Grafton	Walsh	2,512	4 artesian wells			2.5		36			1,200
Goodrich	Sheridan	476	Artesian well	Elevated tank	50,000	1.0	40	12	66⅔		30
Grand Forks	Grand Forks	14,010	Red Lake River (filtered)	Reservoir	1,000,000	26	2,350	253	90	900,000	3,100
Hankinson	Richland	1,477	Artesian wells	Tank and reservoir	300,000	4.5		29		175	
Hannaford	Griggs	431	Creek	Reservoir and tank	30,000			1		200	
Harvey	Wells	1,590	2 wells	2 elevated tanks	181,000	6.0	135	44	25	60,000	250
Hazen	Mercer	520	do	Elevated tanks	50,000	.3		6	10		50
Hebron	Morton	1,374	Pond	Elevated tanks and reservoir	140,000			2		150	

[a] Estimated.

Public water systems of cities and villages with waterworks—Continued

Town	County	Population in 1920	Source of water	Reservoirs	Capacity of reservoirs (gallons)	Length of mains (miles)	Number of taps	Number of fire hydrants	Percentage of population supplied	Estimated average daily consumption (gallons)	Capacity of pumps (gallons a minute)
Hettinger	Adams	817	Wells	Elevated tank	50,000	3.5	150	30	45	10,000	100
Hillsboro	Traill	1,183	do	Reservoir	114,000	4.0	102	31	20	6,500	
Jamestown	Stutsman	6,627	Well	Standpipe	135,000	7.0		72	75	450,000	
Kathryn	Barnes	289	Artesian well			.5		6			
Kenmare	Ward	1,446	Wells	Elevated tank and reservoir	225,000	4.0		41	100		500
Killdeer	Dunn		Well	Elevated tank	50,000	.5		6			250
Lakota	Nelson	959	2 wells	Tank and cistern	50,000	3.7		30			300
La Moure	La Moure	1,014	Well	Tank	50,000	8.1		27	95	50,000	
Langdon	Cavalier	1,228	2 wells	Tanks	160,000	2.1		18	75	37,000	550
Larimore	Grand Forks	1,089	Well	2 reservoirs	220,000						
Leeds	Benson	704	Artesian well	Elevated tank and reservoir	75,000	1.4		12			100
Lidgerwood	Richland	1,065	Artesian wells	do	190,000	1.7	140	17	75		
Linton	Emmons	1,011	2 wells	Elevated tank	50,000	2.0	85	28	33⅓	25,000	120
Lisbon	Ransom	1,855	Artesian wells	do	12,500	4.8		53	80	30,000	
Litchville	Barnes	528	Artesian well	Cistern		.1		5			75
Ludden	Dickey	132	do			.6		3			
McClusky	Sheridan	646	Well	Elevated tank	50,000	1.3		16			144
McVille	Nelson	546	do	Reservoir and cisterns	30,000	1.8		17			100
Mandan	Morton	4,336	Missouri River	2 reservoirs and 2 tanks		10.0	300	56	75	133,000	1,830
Marmarth	Slope	1,318	2 wells	Reservoir tank	130,000	3.1		16	65	20,000	
Mayville	Traill	1,218	Goose River	Elevated tank	75,000	2.4			50	70,000	780
Minot	Ward	10,470	2 wells	Elevated tank and reservoir	100,000	18.0		180	70	600,000	1,000
Mohall	Renville	651	Wells	Elevated tank and cistern	100,000	4.5		30			125
Monango	Dickey	231	Artesian well			.3					
New England	Hettinger	613	2 wells	Elevated tank	50,000	.8		12			100
New Rockford	Eddy	2,111	4 wells	Elevated tank and cistern	150,000	7.5		47	40	50,000	230
Nome	Barnes	267	Artesian well		60,000	.3	5	5			
Oakes	Dickey	1,637	18 shallow wells			3.0		37	95	166,000	350
Park River	Walsh	1,114	2 wells	Elevated tank and reservoir	90,000	2.3		19			250
Rhame	Bowman	302	Well	Elevated tank	100,000	.4		19			100
Richardton	Stark	626	Reservoir	do	50,000	.5		4			
Rolla	Roletta	625	2 wells	do	50,000	1.5	20	14			70
Rugby	Pierce	1,424	Well	do	52,000	2.2	75	28	50	52,000	215
Sheldon	Ransom	321	Artesian well			1.0		17			
Stanley	Mountrail	591	2 wells	Elevated tank	50,000	2.0		19			
Sykeston	Wells	367	Lake	do	50,000	1.1		11			110
Towner	McHenry	610	Wells	do	60,000	2.5	38	28	35	8,000	200

Valley City	Barnes	4,686	Well	do	75,000	11.0	360	70	75	265,000	1,300
Velva	McHenry	836	do	Cistern and elevated tank	100,000	3.3		31	83	30,000	300
Wahpeton	Richland	3,069	Well and Ottertail River (filtered).	Elevated tank	100,000	6.6	575	38	100	300,000	10,000
Walhalla	Pembina	634	Well			.5		5			550
Washburn	McLean	558	Missouri River	Elevated tank	50,000	1.2	50	12	50	15,000	400
Williston	Williams	4,178	Dug well	3 reservoirs and 1 elevated tank	900,000	12.0	750	75	95	500,000	1,100
Wilton	Burleigh and McLean.	1,026	5 wells	Elevated tank	50,000 55,000	2.5		23			

QUALITY OF THE WATERS OF NORTH DAKOTA

By Harry B. Riffenburg

GENERAL FEATURES

The waters of North Dakota range in quality from excellent waters that carry less than 300 parts per million of dissolved solids to those that contain more than 10,000 parts per million. Most of those that are low in mineral content are entirely satisfactory for all ordinary uses, whereas some of those that are high in mineral content are wholly unfit for domestic or industrial use or for stock. The 196 samples collected for analysis were chosen to represent the different geologic formations and the different parts of the State. The analyses given in the accompanying table are discussed with reference to the geologic formations and in connection with the discussion of the occurrence of water in each county. The analyses show only the mineral constituents and do not indicate the sanitary condition of the waters. The purity of a water as regards the sanitary conditions must be determined by inspection of the source and its surroundings and by bacteriologic examination of the water. The condition of a water as regards pollution may change so quickly that the results of an examination at one time do not necessarily bear any relation to the quality of the water at another time. The mineral constituents, on the other hand, are fairly constant in water from a given source unless the source is a river that carries different quantities of dissolved material at different stages.

Most of the waters of this area are of meteoric origin and have replaced the connate waters contained by the rocks after sedimentation.[36] Ordinary ground water is of the calcium-carbonate type that contains from 20 to about 700 parts per million of total solids dissolved from the materials with which it has been in contact. Waters in which calcium and sulphate, sodium and sulphate, or sodium and carbonate are the predominating radicles have undergone alteration in chemical character. The different forms of alteration are concentration, base exchange, absorption of both basic and acid radicles, and a loss or gain in concentration by oxidation, reduction, or precipitation of certain constituents in either the waters or the rocks with which they came in contact. The various types of water are discussed more in detail under the heading of the different formations. (See p. 35.)

ANALYSES

The analyses were made by the methods regularly used in the laboratory of the Geological Survey, which are substantially the same as those described in standard texts on water analysis. The quantities of the following constituents were determined: Total dissolved solids, silica, iron, calcium, magnesium, sodium and potassium, carbonate, bicarbonate, sulphate, chloride, nitrate, and in a few samples hydrogen sulphide. Hardness was calculated by multiplying the quantities of calcium and of magnesium by 2.5 and 4.1, respectively.

The analyses are given in parts per million—that is, in parts by weight of the constituents in 1,000,000 parts by weight of the water. Analyses are sometimes reported in grains per United States gallon; 1 grain per gallon is equivalent to 17.12 parts per million.

The analyses in this report show the quantities of the elements or radicles determined and do not attempt to indicate the possible combinations of these radicles as salts. It is certain that the radicles are not combined in ordinary

[36] Riffenburg, H. B., Chemical Character of Ground Waters of the Northern Great Plains: U. S. Geol. Survey Water-Supply Paper 560, pp. 31-52, 1925.

waters, and where a considerable number of basic and acid radicles are present at the same time it is not possible to pair them off. If, however, the dissolved solids consist almost wholly of two radicles, as sodium and chloride or sodium and sulphate, the water is for all practical purposes a solution of sodium chloride or of sodium sulphate, and it is therefore permissible to use the name of the salt in describing the character of the water.

TOTAL DISSOLVED SOLIDS

The total quantity of dissolved solids is determined by evaporating a given quantity of water and weighing the residue after it has been heated for an hour at 180° C. This quantity may serve as a basis for a rough classification of waters, although it is evident that the composition of the dissolved material is of equal significance with its quantity in determining the suitability of a water for different uses.

It is generally considered that waters that have less than 1,000 parts per million of dissolved solids are suitable for ordinary uses. Some such waters contain material that makes them unfit for special uses, but many of the waters in North Dakota that contain as much as 1,000 parts per million of dissolved solids are entirely satisfactory. Nearly all waters that contain more than 1,000 parts per million of total solids have a taste that is due to the dissolved mineral matter. Those accustomed to the waters may use those that have more than 2,000 parts per million of dissolved solids without marked inconvenience, although most persons not used to highly mineralized water would find such waters decidedly objectionable.

MINERAL SUBSTANCES PRESENT

Silica.—Silica (SiO_2) is dissolved from practically all rocks and therefore is found in every natural water. Although some waters contain enough to cause them to be classed as sodium silicate waters, the quantity in most waters, including the majority of ground waters in North Dakota, is from 10 to 30 parts per million. Silica has little effect on the usefulness of water except as it contributes to the formation of boiler scale.

Iron.—Iron (Fe) is dissolved from many rocks and also from well casings, water pipes, and other fixtures. More than 0.1 part per million of iron in solution or suspension in colloidal state may settle out as a red precipitate when oxidized by exposure of the water to the air. It is not unusual to find 2 or 3 parts per million of iron in ground waters and sometimes as much as 20 parts. Water that contains as much as 1 part per million of iron may be considered good, 1 to 3 parts fair, and more than 3 parts bad. Much iron in water will stain porcelain, enameled ware, and clothing and other fabrics washed in it and in addition may affect the appearance of substances cooked in it if they contain tannin. Iron is generally removed by aerating the water.

Calcium and magnesium.—Calcium (Ca) and magnesium (Mg) are dissolved from practically all rocks but in larger amounts from limestone, dolomite, and gypsum. Calcium and magnesium impart hardness to water and are similar in their effects on the industrial use of water. They may cause a water to be corrosive, especially where magnesium occurs in large amounts with chlorine and sulphates. Calcium and magnesium, together with carbonates, sulphates, and other weak acid radicles, are precipitated from solution in some of the waters from the Fox Hills sandstone, the Fort Union and Lance formations, and the Dakota sandstone. Other waters from these formations show a base exchange where the rocks have exchanged sodium for calcium and magnesium of the waters and reduced the quantities of calcium and magnesium in solution as low as 4 and 1.6 parts per million, respectively. However, there are also very hard waters, where the quantities may be 500 and 200 parts per million, respectively.

Sodium and potassium.—Sodium (Na) and potassium (K) are dissolved from practically all rocks and soils. Waters generally contain nearly equal amounts of each up to about 6 parts per million, above which quantity the ratio of sodium to potassium increases rapidly as the total amount of the two increases. Salts of sodium and potassium are the most soluble of the ordinary mineral constituents and make up the greater part of the dissolved material in highly mineralized waters.

Clarke [37] refers to a number of reports which point out that potassium is absorbed more readily than calcium, magnesium, or sodium by soils and rocks, which hold it tenaciously. Sodium is exchanged by most of the lower formations of the State for calcium and magnesium in the migrating waters. Many waters, both from deep and from shallow wells over the State, contain sodium as the principal basic radicle, which with its salts, principally sulphate, makes the waters unfit for domestic use. Salts of sodium are the cause of the injury to crops by the so-called "alkali" waters.

Carbonate and bicarbonate.—Carbon dioxide occurs in water both free and in combination in the form of carbonate (CO_3) and bicarbonate (HCO_3). Most natural waters do not contain carbonate, though many waters from the deeper horizons in North Dakota contain variable amounts. Practically all natural waters contain bicarbonate, and in the waters of North Dakota the quantity ranges from 95 to 2,152 parts per million. It has been pointed out that the larger quantities of carbonate appear to have been formed at the expense of the sulphate. Clarke [38] quotes three theories that have been advanced to account for the formation of carbonates in natural waters and soils. First, by direct derivation from volcanic rocks. Second, by reduction of alkaline sulphates. Third, by double decomposition between calcium bicarbonate and alkaline sulphates or chlorides.

The bicarbonate as such has comparatively little effect, although a large quantity may make water unsatisfactory for drinking and other domestic uses as well as for irrigation.

Sulphate.—The range in quantity of sulphate (SO_4) in the samples of water analyzed is greater than that of any other constituent. Several waters contain less than 10 parts per million of sulphate (SO_4), and a number contained over 2,000 parts per million. Deposits of gypsum and sodium sulphate are comparatively easily leached, and waters from these deposits usually contain large quantities of sulphates. Large quantities of sodium sulphate in water are less objectionable than the same quantities of sodium chloride or carbonate, but some waters contain so much sodium sulphate that they are not safe to use for irrigation.

Chloride.—Chloride (Cl) is dissolved in small quantities from rocks throughout most of the country. Some waters contain comparatively small quantities, whereas others that come from certain sedimentary rocks may contain several hundred parts per million of chloride. In moderate quantities chloride has little effect on the value of a water. If the quantity is much over 400 parts per million the water may have a salty taste.

Nitrate.—Nitrate (NO_3) is present in few ground waters in sufficient quantities to have any effect on the use of the water.

[37] Clarke, F. W., The Data of Geochemistry, 5th ed.: U. S. Geol. Survey Bull. 770, p. 212, 1924.
[38] Clarke, F. W., op. cit., pp. 241-243.

HARDNESS

Hardness of water is generally recognized by the difficulty of obtaining a lather with soap. Calcium and magnesium compounds cause practically all the hardness of most waters, and the hardness is expressed as the quantity of calcium carbonate ($CaCO_3$) equivalent to the calcium and magnesium in the water. Hardness of water is barely noticeable up to 50 parts per million, and up to 150 parts it does not seriously interfere with the use of the water for most purposes. Whipple [39] estimates that 1 pound of soap is required to soften 24 gallons of water that has a total hardness of 200 parts per million. Soap will not lather until the hardness has been precipitated, and hence it means a large saving in laundries to soften waters that have more than 200 parts per million of hardness. The constituents that cause hardness also form scale in steam boilers, and the softening of water for use in boilers generally adds greatly to the efficiency of a steam plant.

[39] Whipple, A. C., Value of Pure Water, p. 26, New York, 1907.

Analyses of waters in North Dakota

No.	Location: Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
	Adams County												
1	Hettinger	NW.	13	129	96	City	Drilled well	400	6 in	Sand	Fort Union formation.	−150	Municipal supply.
2	do	NW.	13	129	96	O. T. Peterson	Dug well	30	3 ft	do	do	−22	Domestic.
	Barnes County												
3	Enderlin	NW.	13	137	56	J. Janz	Dug well	44	2 ft	Drift and alluvium.	Quaternary drift	−20	Domestic and stock.
4	Valley City	SE.	21	140	58	P. G. Davidson	Drilled well	985	4½ in	Sandstone	Dakota sandstone	Flows [a]	Sprinkling streets.
5	do		21	140	58	City	Dug well	30	15½ ft	Gravel	Alluvium	−28	Municipal supply.
	Benson County												
6	Leeds	NE.	31	156	68	City	Bored well	90	18 in	Shale	Pierre shale		Domestic and stock.
7	do	NE.	31	156	68	do	Drilled well	2,100	6 in., 3 in	Sandstone	Dakota sandstone	Flows [b]	Municipal supply.
8	Maddock		27	152	69	Northern Pacific Ry	Dug well	12	32 ft	Fine sand	Quaternary drift	−8	Boilers.
9	do	NE.	26	152	70	Martin Solberg, Lake Park, Minn.	do	20	4 ft	do	do	−8	Domestic and stock.
10	do	NW.	29	152	69	Public school	Dug and drilled well.	[c] 62½	12 ft., 6 in	Shale	Pierre shale		Drinking and boilers.
11	do	NW.	29	152	69	H. J. Rice	Drilled well	153	4 ft	do	do	−25	Domestic.
12	do	SE.	23	152	70	D. A. Hill	Dug and driven well.	26	3 ft., 2 in	Fine sand	Quaternary drift	−12	Do.
13	Oberon	SW.	2	151	67	A. Baldwin	Dug well	21	2½ ft	Sand and gravel	do		Domestic and stock.
14	Pleasant Lake	SW.	4	156	71	C. Geibel	Pleasant Lake Springs.			Fine sand	Base of Quaternary drift.		Do.
15	York	SE.	19	156	69	School district No. 8	Drilled well	100	6 in	Sand	Pierre shale		Domestic.

[a] 320 gallons a minute.
[b] 150 gallons a minute.
[c] Dug 6 feet, drilled rest of depth.

Analyses of waters in North Dakota

[Parts per million]

Adams County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_3)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted).
1	City of Hettinger	July 23, 1921	854	19	1.3	12	6.1	316	0	849	42	12	2.0	55	
2	O. T. Peterson	do	274	18	.20	56	30	7.7	0	307	14	2.0	3.1	263	
	Barnes County														
3	J. Janz	June 24, 1921	1,601	34	0.80	252	81	135	0	403	856	14	2.5	962	
4	P. G. Davidson	June 13, 1921	3,584	28	.20	29	13	1,361	0	727	64	1,740	Trace.	126	C. S. Howard.
5	Valley City	do	724	24	.13	110	37	79	0	383	187	48	2.9	427	Do.
	Benson County														
6	City of Leeds	May 14, 1921	1,858	13	0.10	147	77	359	0	500	782	174	Trace.	683	C. S. Howard.
7	do	do	[a] 4,310	14	.12	27	12	1,545	0	878	1,251	1,046	Trace.	117	
8	Northern Pacific Ry	June 4, 1921	317	32	.40	18	26	37	0	95	143	6.0	Trace.	152	
9	Martin Solberg	do	722	29	Trace.	73	43	115	0	454	225	8.0	2.0	359	
10	Public school, Maddock	do	1,781	31	.12	33	11	609	0	1,000	396	180	2.6	128	
11	H. J. Rice	do	1,706	30	Trace.	8.6	4.6	670	0	947	2.8	507	Trace.	40	Do.
12	D. A. Hill	do	388	27	.45	53	24	60	0	362	42	3.0	Trace.	231	Do.
13	A. Baldwin	do	539	28	Trace.	89	47	4.1	0	259	90	39	60	415	
14	C. Geibel	May 13, 1921	230	27	.27	57	14	9.3	0	237	14	1.0	1.0	200	
15	School district No. 8, York.	do	1,378	25	.06	163	40	234	0	586	550	20	4.7	572	Do.

[a] Hydrogen sulphide (H_2S) 4.8 parts per million.

Analyses of waters in North Dakota—Continued

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
Billings County													
16	Medora	NE.	27	140	102	G. R. Osterhout	Drilled well	300	1¼ in	Sand	Fort Union formation.	+10	Domestic.
17	do	NE.	27	140	102	Northern Pacific Ry.	do	505	4 in	do	do	Flows	Railroad and domestic.
Bottineau County													
18	Bottineau	SW.	30	162	75	F. M. Woodward	Drilled well	135	2½ in	Sand	Fort Union formation.		Boilers and domestic.
19	do	SW.	15	162	75	J. J. Scully	Bored well	14	4 in	Gravel	Quaternary drift	Flows	Stock.
20	do	NW.	30	162	75	State school of forestry.	Drilled well	150	2½ in	Sand	Fort Union formation.	do	Drinking.
21	Lansford	NE.	3	159	83	City	do	254	4 in	Gravel	do	−3	Fire protection, stock, and washing.
Bowman County													
22	Bowman	NW.	11	131	102	Village	Dug well	48	16 ft	Blue sand	Fort Union formation.	−34	Municipal supply.
23	do	SE.	11	131	102	George Seibert	do	10	3 ft	Sand	do	−7	Domestic and stock.
Burke County													
24	Bowbells	NW.	3	161	89	N. C. Aukerman	Dug well	12	5 ft	Gravel	Quaternary drift	−9	Domestic.
25	do	NW.	5	161	89	City	Drilled well	155	8 in	Lignite	Fort Union formation.	−21	Fire protection and stock.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Billings County														
16	G. R. Osterhout	July 20, 1921	1,294	8.6	0.33	4.0	2.9	456	38	522	506	8.0	Trace.	22	
17	Northern Pacific Ry	do	1,308	12	.27	5.2	2.2	470	34	810	294	16	3.4	22	
	Bottineau County														
18	F. M Woodward	May 16, 1921	1,269	31	0.13	6.0	1.7	478	12	764	10	306	Trace.	22	C. S. Howard.
19	J. J. Scully	do	1,648	14	.67	49	19	492	0	688	656	12	Trace.	200	Do.
20	State school of forestry	May 17, 1921	1,159	21	.10	4.4	1.5	428	31	644	150	166	3.8	17	Do.
21	City of Lansford	May 18, 1921	2,651	9.8	1.9	14	4.3	1,026	0	848	12	1,135	Trace.	53	Do.
	Bowman County														
22	Village of Bowman	July 23, 1921	365	16	0.20	54	32	39	0	342	50	6.0	2.0	266	
23	George Seibert	do	814	15	1.4	186	27	64	0	400	93	76	181	576	
	Burke County														
24	N. C. Aukerman	May 20, 1921	223	19	0.10	41	15	9.9	0	193	23	2.0	5.1	164	
25	City of Bowbells	do	1,472	12	.10	16	6.6	585	0	1,530	11	36	2.0	67	

Analyses of waters in North Dakota—Continued

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers		Water level above (+) or below (−) surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T. N.	R. W.					Character of material	Geologic horizon		
	Burleigh County												
26	311 Front Street, Bismarck.			139	80	Capital Steam Laundry.	Drilled well	400	6 in., 3 in.	Gravel	Fox Hills sandstone.	Flows	Laundry.
27	Fourth Street and Broadway, Bismarck.			139	80	Grand Pacific Hotel	do	200	4 in.		do		Hotel use.
28	Bismarck	NW.	4	138	80	George Gassner	do	75	3 in.		do		Industrial.
29	McKenzie	SW.	28	139	77	H. Turner	do	125	2½ in.		do	−40	Domestic.
	Cass County												
30	Argusville	SW.	6	141	49	Village	Drilled well	149	2 in.		Quaternary drift		Domestic and stock.
31	Casselton	SW.	35	140	52	Public school	do	70	4 in.	Drift	do		Domestic.
32	do	NE.	35	140	52	Mrs. Grovenor, "roller mill."	do	430	2 in.	Sandstone	Dakota sandstone	+30 originally; +1 July, 1921.	Domestic and stock (formerly industrial).
33	Fargo	NW.	7	139	48	Red River (raw water).							Filtered for municipal supply.
34	203 Sixteenth Street, South Fargo.					H. A. Older	Drilled well	175	4 in., 2½ in.	Sand	Quaternary drift	−8	Domestic, stock, and municipal supply.
35	Fargo	NW.	6	139	48	S. B. Steeves, 1316 Eighth Street, North Fargo.	Bored well	22.5	16 in.	Sandy clay	Lake Agassiz silt	−12½	Domestic and stock.
36	Gardner	NE.	2	142	50	Village	Drilled well	135	2 in.	Fine gray sand	Quaternary drift	+2	Do.
37	Grandin	NW.	3	143	50	do	do	230	do	do	do		Do.
38	Hickson	NE.	24	137	49	do	do	80	3 in.		do	−15	Do.
	Cavalier County												
39	Langdon	SW.	14	161	60	City	Dug well	36	13 ft.	Shale	Quaternary drift	−20 to −30	Domestic.
40	do			161	60	C. J. Bone	Drilled well	75	6 in.	do	Pierre shale	−45	Stock.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Burleigh County														
26	Capital Steam Laundry	June 16, 1921	2,441	37	0.27	9.6	2.8	951	0	1,174	5.9	824	Trace.	35	C. S. Howard.
27	Grand Pacific Hotel	do	1,776	13	Trace.	7.4	2.3	659	0	1,035	491	66	1.7	28	Do.
28	George Gassner	do	1,509	17	.15	15	2.4	540	0	1,015	323	64	3.0	47	Do.
29	H. Turner	June 15, 1921	13,807	19	4.0	476	814	2,362	0	1,188	7,838	386	7.2	4,530	Do.
	Cass County														
30	Village of Argusville	June 24, 1921	1,194	35	1.4	51	15	363	0	390	193	328	7.1	189	
31	Public school, Casselton	July 1, 1921	915	30	1.6	126	30	148	0	464	301	40	1.5	438	
32	Mrs. Grovenor, "roller mill."	do	2,767	12	.48	12	7.3	938	0	344	1,091	492	9.5	60	
33	Red River at Fargo	June 25, 1921	361	20	Trace.	50	34	[b] 21	0	261	83	6.0	1.6	264	
34	H. A. Oder	do	772	26	.30	40	14	215	0	334	175	122	5.7	157	
35	S. B. Steeves	do	1,340	27	.27	186	145	46	0	644	244	110	272	1,060	
36	Village of Gardner	June 24, 1921	2,298	32	.53	83	24	710	0	212	410	890	15	306	
37	Village of Grandin	do	3,116	34	1.8	135	53	880	0	276	876	930	13	555	
38	Village of Hickson	June 25, 1921	534	31	1.1	60	21	96	0	300	132	46	2.8	236	
	Cavalier County														
39	City of Langdon	May 2, 1921	429	26	Trace.	37	11	87	0	149	168	20	2.4	138	
40	C. J. Bone	do	3,088	28	0.67	67	29	1,050	0	780	449	1,048	1.0	287	

[b] Calculated.

Analyses of waters in North Dakota—Continued

Dickey County

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
41	Clement	SE.	18	131	60	M. J. Morgan	Drilled well	950	2 in.		Dakota sandstone		Domestic and stock.
42	Ellendale	SW.	12	129	63	City	do	1,087	8 in., 3¾ in.	Sandstone	do	+335	Laundry and fire protection.
43	do	SW.	12	129	63	do	do	1,385	8 in., 3 in.	do	do	+460	Municipal supply.
44	do	NW.	12	129	63	D. E. Greer	Dug well	22	2 ft.	Drift	Quaternary drift		
45	Monango	SE.	8	131	63	Village	Drilled well	1,230	4 in., 2½ in.	Sandstone	Dakota sandstone	Originally +135; June, 1922, +20.	Domestic and stock.
46	do	SE.	8	131	63	Public school	Bored well	38	34 in.	Gravel	Drift gravel	−16	Domestic.
47	Oakes	NE.	29	131	59	City	Driven wells [d]	40–48	([d])	Alluvium	Alluvium		Municipal supply.
48	do	NW.	18	131	59	H. J. Johnson	"The Springs"			Drift	do		Not used.
49	do	SW.	8	131	59	Henry Gemeer	Drilled well	1,145	3 in., 2¼ in.	Sandstone	Dakota sandstone		Stock.

Divide County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
50	Crosby	SE.	29	163	97	City	Drilled well	407	6 in., 4 in.		Fort Union formation.	−6	Fire protection, stock, and washing.
51	do	SW.	29	163	97	do	Dug well	30	3 ft.	Gravel	Quaternary drift	−16	Domestic.
52	do	SE.	6	163	97	Robert Brewis	Drilled well	253	6 in.		Fort Union formation.	+32	Domestic and stock.

Dunn County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
3	Killdeer	NW.	23	145	95	Motor Inn	Drilled well	73	6 in.	Black sand	Fort Union formation.	−50	Domestic.
54	do	NE.	9	145	95	Jim Scholmeyer	Sand Springs			Sand and gravel	do	Flows [e]	Stock.

[d] Composite sample—6 wells 3 inches diameter; 8 wells 1½ inches diameter.

[e] 500 gallons a minute.

Analyses of waters in North Dakota—Continued

[Parts per million]

Dickey County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
41	M. J. Morgan	June 19, 1921	2,618	16	0.47	17	4.6	928	0	476	560	812	Trace.	61	
42	City of Ellendale	June 28, 1921	2,700	19	2.0	30	13	990	0	495	236	1,150	Trace.	128	
43	do	do	[c] 2,079	17	2.3	204	64	320	0	171	1,200	70	Trace.	772	
44	D. E. Greer	do	1,443	30	.13	233	72	107	0	403	537	166	2.0	878	
45	Village of Monango	June 29, 1921	2,588	23	3.2	30	14	954	0	720	95	1,075	Trace.	132	
46	Public school, Monango	do	1,487	32	.10	49	27	440	0	647	479	126	1.6	233	
47	City of Oakes	June 19, 1921	723	32	.24	115	38	74	0	364	184	80	6.7	443	
48	H. J. Johnson	June 20, 1921	658	38	Trace.	65	20	145	0	476	105	48	1.2	244	
49	Henry Gemeer	June 19, 1921	4,313	19	2.4	68	19	1,345	0	285	1,989	608	Trace.	248	

Divide County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
50	City of Crosby	May 21, 1921	1,721	21	0.07	5.6	3.6	700	0	1,405	52	274	Trace.	29	
51	do	do	856	25	.17	200	57	14	0	569	226	36	12	734	
52	Robert Brewis	do	1,620	33	.27	22	8.0	617	0	1,464	85	100	3.8	88	

Dunn County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
53	Motor Inn	June 22, 1921	348	16	0.48	27	17	77	0	303	55	6.0	0.2	137	
54	Jim Scholmeyer	do	1,017	18	.14	16	15	342	0	615	320	2.0	.50	102	C. S. Howard.

[c] Hydrogen sulphide (H_2S) 3.4 parts per million.

Analyses of waters in North Dakota—Continued

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
Eddy County													
55	New Rockford	W.	6	148	66	City	Drilled wells	(f)	5 in.	Gravel in river bed.	Quaternary drift	−14	Municipal supply.
56	do	NE.	34	149	66	D. Nevin	Nevins Spring			Gravel	do		Not used.
Foster County													
57	Carrington	NE.	6	146	66	City	Dug well	55		Gravel	Quaternary drift		Domestic.
58	McHenry	SE.	5	147	62	J. H. Hancher	do	14	3 ft.	Gravel and sand	do	−12	Do.
59	do	SE.	5	147	62	E. P. Eide	do	16	4 ft.	Sand and gravel	do	−11	Do.
Golden Valley County													
60	Beach			140	106	City	Dug and drilled well.	g 110	20 ft., 6 in. (4 holes).	Gravel	Fort Union formation.	−25	Municipal supply.
61	Beach, lot 1, block 4.			140	106	J. H. Schroeder	Bored well	26	6 in.	Blue-gray shale	do	−16.5	Domestic.
62	Sentinel Butte	NW.	8	139	104	J. Grimm	Spring				do		Stock.
63	do	SW.	5	139	104	do	do			Probably lignite	do		Do.
Grand Forks County													
64	Grand Forks	NW.	3	151	50	Ole Hippe	Dug well	20	4 ft.		Lake Agassiz silt	−19.5	Domestic.
65	do	NW.	15	151	50	R. B. Griffith	Drilled well	322	4 in.	Fine white sand	Dakota sandstone (?).	−6	Domestic and stock.
66	do	NE.	22	151	50	O'Connor Bros.	do	135	2 in.	do	do	Flows	Domestic, stock, and dairy.
67	Larimore	SE.	12	151	55	City	Dug well	28	12 ft.	Beach sand	Lake Agassiz silt	−24	Domestic.

f 4 wells, three 90 feet deep and one 140 feet deep.

g Dug 30 feet, drilled 80 feet.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Eddy County														
55	City of New Rockford	June 10, 1921	1,222	36	1.6	107	29	288	0	883	190	70	4.0	386	
56	Nevins Spring	do	278	26	.14	36	15	23	0	168	55	6.0	8.1	152	C. S. Howard.
	Foster County														
57	City of Carrington	June 2, 1921	356	34	0.79	52	24	35	0	322	45	4.0	Trace.	228	C. S. Howard.
58	J. H. Hancher	June 9, 1921	757	25	.16	120	48	29	0	285	171	.68	48	497	
59	E. P. Eide	do	1,694	28	.80	268	138	40	0	400	430	228	250	1,240	
	Golden Valley County														
60	City of Beach	July 21, 1921	579	13	0.60	66	45	78	0	434	145	8.0	8.6	350	
61	J. H. Schroeder	do	696	12	.27	75	78	35	0	405	233	12	12	507	
62	J. Grimm	July 20, 1921	256	36	.14	36	13	35	0	244	21	2.0	Trace.	143	
63	do	do	1,963	27	.70	44	24	645	0	1,274	537	4.0	2.7	208	
	Grand Forks County														
64	Ole Hippe	July 11, 1921	742	23	Trace.	178	46	23	0	644	111	34	4.4	631	
65	R. B. Griffith	July 18, 1921	10,484	16	7.2	736	164	2,670	0	90	2,158	4,240	Trace.	2,512	
66	O'Connor Bros	do	5,786	30	9.9	402	149	1,440	0	207	1,211	2,350	Trace.	1,616	
67	City of Larimore	Apr. 28, 1921	470	32	Trace.	101	30	7.9	0	339	88	16	6.4	376	

Analyses of waters in North Dakota—Continued

Griggs County

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
68	Cooperstown	SW.	24	146	59	City	Dug well	21	8 ft	Gravel	Quaternary drift	−15	Municipal supply.
69	do	SW.	24	146	59	Louis Berg	do	42	3½ ft	Blue shale	Pierre shale	−12	Stock.
70	Hannaford	NW.	8	144	59	Hannaford Hotel	Drilled well	100	5 in	Gravel	Quaternary drift		Domestic.
71	do	SW.	5	144	55	Mrs. Mabel Thorson.	do	80	6 in	do	do		Do.

Hettinger County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
72	Mott	SW.	35	134	93	Brown Hotel	Dug well	21	3 ft		Fort Union formation.		Domestic.
73	do	SW.	35	134	93	do	Drilled well	177	3 in	Lignite	do		Hotel use.

Kidder County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
74	Steele	SE.	17	139	73	R. L. Phelps	Drilled well	120	4 in	Brown sandstone.	Fox Hills sandstone.	−60	Domestic.
75	do	SE.	17	139	73	City	do	110	2½ in		do		Do.

La Moure County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
76	Edgeley	SW.	3	133	64	Fred Thome	Drilled well	96	4 in	Blue hard shale	Pierre shale	−40	Domestic and stock.
77	La Moure	NW.	6	133	60	City	do	1,440	3 in	Sandstone	Dakota sandstone	Originally +165; June 1921, +150.	Stock.
78	do	NW.	6	133	60	do	Dug well	20	16 ft	Gravel	Quaternary drift	−17	
79	do	NW.	6	133	60	do	Drilled well	875	2½ in	Sandstone	Dakota sandstone	Early +127; June, 1921, +92.	Fire protection and stock (formerly municipal supply).
80	Verona	NW.	2	133	59	do	do	1,100	1½ in	do	do	Originally +50.	

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Griggs County														
68	City of Cooperstown	June 9, 1921	2,691	31	0.08	198	112	475	0	476	1,418	104	Trace.	954	
69	Louis Berg	do	2,748	14	.80	184	56	600	0	346	1,551	71	4.0	690	
70	Hannaford Hotel	June 10, 1921	772	35	.80	94	38	112	0	451	241	16	4.8	391	
71	Mrs. Mabel Thorson	do	612	27	.40	110	34	47	0	425	152	7.0	1.8	414	
	Hettinger County														
72	Brown Hotel	June 28, 1921	846	12	0.20	156	74	26	0	561	219	36	8.9	693	
73	do	do	1,208	14	.80	7.6	4.3	430	34	590	400	6.0	2.0	37	
	Kidder County														
74	R. L. Phelps	June 15, 1921	1,038	46	0.72	150	62	101	0	561	366	6.0	Trace.	629	C. S. Howard.
75	City of Steele	do	1,059	45	Trace.	193	65	55	0	554	389	4.0	0.33	749	Do.
	La Moure County														
76	Fred Thome	June 29, 1921	1,394	31	Trace.	22	6.1	516	0	586	30	484	2.9	80	
77	City of La Moure	do	2,071	18	1.4	120	34	495	0	171	1,164	94	7.7	439	
78	do	do	459	36	.70	90	29	40	0	412	66	16	Trace.	344	
79	do	do	2,151	16	1.1	56	19	635	0	242	1,074	194	Trace.	218	
80	City of Verona	do	2,552	17	1.4	23	4.6	836	0	364	1,073	366	Trace.	76	

Analyses of waters in North Dakota—Continued

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers		Water level above (+) or below (−) surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T. N.	R. W.					Character of material	Geologic horizon		
	Logan County												
81	Burnstad	SW.	29	134	71	Mrs. Roth	Dug well	12	5 ft	Drift alluvium	Alluvium	−9	Domestic and stock.
82	do	SE.	29	134	71	C. P. Burnstad	Drilled well	132	2 in		Fox Hills sandstone (?).	−30	Do.
83	do	SE.	34	134	71	Jake Hoirup	Spring			Drift	Quaternary drift		Stock.
	McHenry County												
84	Towner	NW.	11	156	76	City	Dug well	18	20 ft	Gravel and sand	Quaternary drift	−14	Municipal supply.
85	Velva	NE.	26	153	80	do	do	10	3 by 36 ft	Sand	do	−9.8	Do.
	McIntosh County												
86	Ashley	W.	31	130	69	Jacob Doerr	Bored well	70	2 ft		Quaternary drift	−50	
87	do	W.	31	130	69	Reinhold Schaber	do	30	do		do	−22	
88	Venturia	NE.	15	129	71	A. A. Sayler	do	146	do		Fox Hills sandstone.	−122	Stock.
89	do	SE.	3	129	71	August Dockler	do	80	do		Quaternary drift	−3½	Domestic.
90	do	NE.	15	129	71	Jacob Schepp	do	23	do		do	−11	Do.
	McKenzie County												
91	Schafer	SW.	23	150	98	C. E. Shafer	Shafer Spring (west).			Lignite	Lignite in Fort Union formation.	(h)	Stock.
92	do	SE.	23	150	98	do	Shafer Spring (east).			do	do	(i)	Do.

h 1,200 gallons a minute.

i 1,800 gallons a minute.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Logan County														
81	Mrs. Roth	June 26, 1921	320	25	0.10	78	20	6.9	0	266	24	14	24	277	
82	C. P. Burnstad	do	592	26	.80	57	28	120	0	500	97	4.0	Trace.	258	
83	Jake Hoirup	do	795	27	1.2	107	44	126	0	622	189	4.0	6.0	448	
	McHenry County														
84	City of Towner	May 17, 1921	390	23	0.97	75	29	23	0	337	63	6.0	4.5	306	C. S. Howard.
85	City of Velva	May 31, 1921	357	26	.09	54	25	36	0	322	55	2.0	2.4	238	Do.
	McIntosh County														
86	Jacob Doerr	June 20, 1921	2,405	28	Trace.	412	140	87	0	537	1,236	27	2.0	1,600	
87	Reinhold Schaber	do	432	26	Trace.	106	24	30	0	488	12	4.0	3.0	363	
88	A. A. Sayler	do	1,905	37	0.80	168	76	346	0	671	848	16	3.0	732	
89	August Dockler	do	1,524	38	3.6	135	52	296	0	549	669	42	3.8	551	
90	Jacob Schepp	do	797	30	.40	145	53	33	0	356	93	70	200	580	
	McKenzie County														
91	Shafer Spring (west)	May 26, 1921	533	27	1.5	77	41	59	0	420	131	1.0	0.67	361	C. S. Howard.
92	Shafer Spring (east)	do	883	30	.48	56	28	210	0	551	248	2.0	1.2	255	

Analyses of waters in North Dakota—Continued

McLean County

No.	Location: Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
93	Garrison	SW.	8	148	84	City	Drilled well	125	6 in.		Fort Union formation.	−60	Municipal supply.
94	do	SW.	8	148	84	Mrs. A. Pankratz	Bored well	35	2 ft.	Gravel	Quaternary drift	−25	Domestic.
95	Max	SE.	9	150	83	Village	Dug well	15	4 ft.	Gravel and clay	do	−13½	Do.
96	Washburn	SE.	14	144	82	W. Wolitarsky	Drilled well	60	4 in.		Fort Union formation.		Stock.

Mercer County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
97	Stanton, lots 14 or 15, block 6.		6	144	84	H. A. Olds	Dug and driven well.	14	4 ft., 1¼ in.	Sand	Alluvial deposit	−12	Domestic.
98	Stanton, lots 5 or 6.		6	144	84	H. C. Loy	do	37	4 ft.	do	do	−31	Do.
99	Stanton, lot 7, block 29.		6	144	84	Mrs. A. Gibbs	do	31	4 ft., 1¼ in.	do	do		Do.

Morton County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
100	Fort Rice			135	79	Northern Pacific Ry.	Dug well	35	4 ft.	Gravel and sand	Alluvial deposit	−20	Domestic and stock.
101	Hebron	NE.	32	140	90	Mining experiment substation.	Drilled well	110	5½ in.	Sand	Fort Union formation.		Domestic and industrial.
102	do	NW.	33	140	90	Hebron Fire & Press Brick Co.	do	215	4½ in.	Blue sand	do	−25	Boiler, tempering clay.
103	Mandan lot 14, block 6.		27	139	81	Mandan Steam Laundry.	do	400–500	2½ in.		Lance formation	Flows	Laundry use.
104	Mandan	NW.	33	139	81	State training school	Driven well	22	1¼ in.	Sand	Alluvial deposit	−12	Domestic.
105	do	SW.	33	139	81	Northern Great Plains field station.	Drilled well	330	4 in.		Lance formation	−80	Stock and laundry.
106	do		16	138	81	do	do	318	3 in.	Fine sand	do	−200	Stock.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	McLean County														
93	City of Garrison	June 18, 1921	1,386	27	3.0	47	24	437	0	922	368	10	1.1	216	C. S. Howard.
94	Mrs. A. Pankratz	do	1,052	31	.20	187	78	26	0	490	422	10	2.6	788	
95	Village of Max	June 17, 1921	961	29	.20	165	80	59	0	688	278	4.0	.36	740	C. S. Howard.
96	W. Wolitarsky	do	752	21	Trace.	36	20	213	0	634	136	4.0	.55	172	Do.
	Mercer County														
97	H. A. Olds	June 21, 1921	2,176	13	4.1	235	118	417	0	625	59	996	1.5	1,070	Margaret D. Foster.
98	H. C. Loy	do	789	25	Trace.	135	66	40	0	573	74	114	12	609	
99	Mrs. A. Gibbs	do	338	24	Trace.	62	31	14	0	350	32	2.0	1.0	282	
	Morton County														
100	Northern Pacific Ry., Fort Rice.	June 27, 1921	321	20	1.3	15	10	101	0	317	27	2.0	0.30	78	C. S. Howard.
101	Mining experiment substation, Hebron.	June 23, 1921	924	18	1.0	22	14	302	0	520	302	2.0	2.0	112	Do.
102	Hebron Fire & Press Brick Co.	do	1,874	19	.68	8.4	7.2	691	58	1,139	510	5.0	2.6	51	Do.
103	Mandan Steam Laundry	June 20, 1921	2,059	28	.20	18	7.6	795	16	1,271	4.9	533	Trace.	76	Margaret D. Foster.
104	State training school, Mandan.	do	1,396	18	.59	188	56	207	0	609	464	113	16	700	Do.
105	Northern Great Plains field station, Mandan.	do	1,427	15	.40	5.6	2.7	575	0	1,220	11	208	Trace.	25	
106	do	do	1,272	14	.07	4.0	3.1	520	41	1,200	22	66	2.7	23	

Analyses of waters in North Dakota—Continued

Mountrail County

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
107	Stanley	SW.	21	156	91	City	Drilled well	216	4½ in.	Shale with sand	Fort Union formation.	−100	Municipal supply.

Nelson County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
108	Lakota		27	153	60	Abe Thal	Drilled well	136	4 in.	Shale	Pierre shale	−55	Domestic.
109	do	SE.	32	153	60	City	Dug well	18	20 ft.	Fine sand	Glacial drift, Quaternary	−15	Municipal supply.
110	Michigan			153	58	K. L. Wright	Drilled well	101½	4 in.	Shale	Pierre shale		Domestic.
111	do	NW.	6	151	58	J. W. Cecka	Gordon Springs				Glacial drift, Quaternary.		Stock; formerly bottled.

Oliver County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
112	Fort Clark	NW.	6	143	83	Northern Pacific Ry.	Drilled well	130	4 in.	Sand	Lance formation	−100	Domestic.
113	do	NW.	6	143	83	Village	do	200	2 in.	do	do	Flows	Do.

Pembina County

No.	Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Character of material	Geologic horizon	Water level (feet)	Use of water
114	Hamilton	SE.	35	162	53	Hamilton Artesian Well Co.	Drilled well	1,560	6 in., 4 in.	White sand	St. Peter or older (?) sandstone.	Flows	Fire protection.
115	St. Thomas	SE.	2	159	53	E. T. Thompson	do	450	4 in., 2 in.	Sand	St. Peter (?) sandstone.	do	Do.
116	do	NE.	3	159	53	Ole Roe	Bored well	18	12 in.		Lake Agassiz silt	−10	Domestic.
117	Walhalla	NE.	31	163	56	Miss E. Mager	Sand-pit spring				do	Flows	Stock.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Mountrail County														
107	City of Stanley	May 25, 1921	4,386	14	0.09	18	7.4	1,499	0	1,227	2,185	30	4.5	75	C. S. Howard.
	Nelson County														
108	Abe Thal	May 4, 1921	2,107	26	3.0	8.4	6.1	753	0	788	606	273	Trace.	46	
109	City of Lakota	do	2,261	29	4.5	254	115	288	0	517	1,174	40	3.6	33	
110	K. L. Wright	Apr. 30, 1921	1,233	27	.13	29	14	416	0	664	206	210	4.5	130	
111	J. W. Cecka	do	571	27	Trace.	109	33	42	0	410	154	2.0	1.0	408	
	Oliver County														
112	Northern Pacific Ry., Fort Clark.	June 22, 1921	1,925	11	0.69	6.4	4.9	765	72	1,674	145	56	4.0	36	
113	Village of Fort Clark	do	1,610	15	.40	7.2	2.6	670	82	1,444	11	112	Trace.	29	
	Pembina County														
114	Hamilton Artesian Well Co.	Apr. 23, 1921	[d] 20,290	10	10	1,285	517	Na 8,970 K 177	0	174	3,714	15,050	4.0	5,330	Margaret D. Foster.
115	E. T. Thompson	Apr. 25, 1921	[e] 42,345	9.4	6.6	1,385	556	Na 13,450 K 327	0	223	2,557	23,370	--------	5,740	Do.
116	Ole Roe	do	827	15	1.6	151	68	Na 9.1 K 5.9	0	394	255	31	48	656	Do.
117	Miss E. Mager	Apr. 26, 1921	414	32	.04	93	31	6.8	0	366	76	4.0	Trace.	360	Do.

[d] Specific gravity, 30°/30°, 1.020.

[e] Specific gravity, 30°/30°, 1.028.

Analyses of waters in North Dakota—Continued

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
	Pierce County												
118	Rugby	NW.	1	156	73	City	Dug and driven well.	52	8 ft., 2 in.	Gravel	Quaternary drift	−40	Municipal supply.
	Ramsey County												
119	Devils Lake		34	154	64	City	Drilled well	1,514	8 in., 4½ in.	Sand	Dakota sandstone.	Flows part of time.	Municipal supply.
120	do		34	154	64	County	do	136	6 in., 4 in.	Shale	Pierre shale		Domestic and public use.
	Ransom County												
121	Enderlin					City	Spring			Drift	Quaternary drift		Municipal supply.
122	do					Minneapolis, St. Paul & Sault Ste. Marie Ry.	Drilled well	613	10 in.	Sandstone	Dakota sandstone.	Flows [i]	Railroad.
123	Lisbon	NW.	11	134	56	R. S. Adams	Dug well	30	30 in.	Gravel	Alluvial deposit	−26	Domestic and stock.
124	do	SW.	12	134	56	State Soldiers' Home.	Drilled well	785	3 in., 2 in.	Sandstone	Dakota sandstone.	Flows	Domestic.
125	Sheldon	SE.	17	136	54	City	do	633	3 in.	do	do	Originally +138 [k].	Municipal supply.

[i] 1,000 gallons a minute.

[k] Flows 600 gallons a minute.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Pierce County														
118	City of Rugby	May 16, 1921	510	25	9.1	94	31	32	0	298	145	18	0.50	362	C. S. Howard.
	Ramsey County														
119	City of Devils Lake	May 4, 1921	3,835	15	Trace.	13	9.1	1,390	22	825	1,091	885	Trace.	70	
120	County	do	967	33	0.20	8.4	4.7	357	29	727	107	32	7.2	40	
	Ransom County														
121	City of Enderlin	June 24, 1921	930	35	2.4	152	50	74	0	425	350	22	1.0	585	
122	Minneapolis, St. Paul & Sault Ste. Marie Ry., Enderlin.	do	3,448	23	4.8	136	35	960	0	249	1,263	734	7.5	484	
123	R. S. Adams	June 30, 1921	1,297	33	.20	164	112	69	0	190	510	178	80	869	
124	State Soldiers' Home	June 29, 1921	2,663	10	.30	26	6.1	890	0	278	1,184	390	2.0	90	
125	City of Sheldon	do	2,671	16	.80	132	35	702	0	195	1,254	372	4.5	474	

Analyses of waters in North Dakota—Continued

Renville County

No.	Location: Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
126	Mohall	SW.	6	161	83	City	Dug well	8	12 by 20 ft	Gravel	Quaternary drift	−5	Municipal supply.
	Richland County												
127	Abercrombie	SW.	4	134	48	Mrs. A. K. Tweto	Drilled well	318	2 in	Fine sand	Quaternary drift	Flows	Domestic, stock, and municipal supply.
128	Christine	SE.	23	136	48	Village	do	115	3 in	Sand	do	−25	Domestic and stock.
129	Fairmount	SE.	20	130	47	do	do	263	8 in	Red sand	do	−30	Municipal supply.
130	do	SE.	20	130	47	Daniel Taylor	Dug well	16–24	3 ft	Lake silts	Lake Agassiz silt		
131	Hankinson	NW.	13	130	50	City	Drilled well	170	2 in	Sand and gravel	Quaternary drift	+3	Do.
132	do	NE.	13	130	50	A. H. Melcher	Dug well	12	3 ft	Drift	do	−4	Domestic and stock.
133	do	NE.	27	130	50	Henry Foeltz	Crystal Springs			Glacial gravel	do		Domestic and stock (also sold).
134	Lidgerwood	NE.	13	130	52	Lidgerwood Roller Mill.	Drilled well	960	2 in		Dakota sandstone	Flows	Industrial.
135	do	NE.	13	130	52	Theodore Haas	Bored well	22	16 in	Gravel	Quaternary drift	−19	Domestic and stock.
136	Wahpeton	SE.	8	132	47	North Star Roller Mill.	Drilled well	283	3 in	White sand (coarse).	Dakota sandstone (?).	−12	Domestic and industrial.
	Rolette County												
137	Dunseith	NE.	22	162	73	William Gottbright	Mineral Spring			Gravel	Quaternary drift	Flows [l]	Stock.
138	do	NW.	30	162	72	State Sanitarium	Drilled well	190	12 in	do	do	do	Domestic.
139	do	SW.	25	162	72	M. Ohmer	Holy Springs				Base of Quaternary drift.	Flows [m]	Stock.
140	Rolla	NW.	16	162	69	R. H. Butterwick	Dug well	16	3 ft	Gravel	Quaternary drift	−12	Domestic.

[l] 150 gallons a minute.

[m] 200 gallons a minute.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Renville County														
126	City of Mohall	May 18, 1921	359	21	0.11	71	28	11	0	281	66	4.0	1.0	292	C. S. Howard.
	Richland County														
127	Mrs. A. K. Tweto	June 25, 1921	830	33	1.0	61	25	194	0	320	248	112	6.8	255	
128	Village of Christine	do	940	31	1.1	122	40	128	0	320	366	60	4.0	469	
129	Village of Fairmount	June 27, 1921	1,678	11	.75	20	9.2	578	0	378	374	472	10	88	
130	Daniel Taylor	do	1,659	30	.27	303	117	16	0	376	273	236	400	1,240	
131	City of Hankinson	do	884	35	2.4	121	60	82	0	459	334	12	2.4	548	
132	A. H. Melcher	do	1,207	37	1.2	189	86	60	0	410	453	72	33	825	
133	Crystal Springs	do	647	38	.60	130	42	17	0	403	193	2.0	Trace.	497	
134	Lidgerwood Roller Mill	do	3,140	9.2	.30	17	6.5	1,046	0	498	1,235	482	Trace.	69	
135	Theodore Haas	do	1,310	23	.08	232	97	12	0	410	517	62	40	978	
136	North Star Roller Mill	do	1,056	17	.48	6.8	4.1	394	0	739	147	102	5.3	34	
	Rolette County														
137	Wm. Gottbright	May 12, 1921	1,068	30	0.07	192	65	79	0	529	428	5.0	1.5	746	
138	State Sanitarium	do	1,102	31	Trace.	196	60	63	4.8	522	417	6.0	2.0	736	
139	M. Ohmer	May 11, 1921	1,227	35	.06	169	19	220	0	481	533	8.0	3.4	500	C. S. Howard.
140	R. H. Butterwick	May 6, 1921	1,055	30	Trace.	159	40	152	0	493	296	98	39	562	

Analyses of waters in North Dakota—Continued

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers		Water level above (+) or below (−) surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T. N.	R. W.					Character of material	Geologic horizon		
	Sargent County												
141	Cogswell	NE.	2	130	57	Village	Drilled well	1,060	1¼ in.	Sandstone	Dakota sandstone	Originally +184.	Municipal supply.
142	Forman	NE.	1	130	56	do	do	840	3 in.	Sandstone (grayish white).	do	Flows	
143	do	NE.	1	130	56	D. J. Jones	do	940	1½ in.	Sandstone	do	+95	Stock.
144	do	NE.	30	131	55	Joseph Lanxon	do	±220	2 in.		Quaternary drift	−80	Domestic and stock.
145	Oakes	SW.	17	131	58	P. E. Peterson	do	1,120	do	Sandstone	Dakota sandstone		Do.
	Sheridan County												
146	McClusky	NE.	11	146	77	City	Dug well	30	13 ft.	Sand	Quaternary drift	−24	Municipal supply.
	Sioux County												
147	Cannonball	NW.	23	134	79	Northern Pacific Ry.	Dug well	26	20 ft.	Gravel	Alluvial deposit	−8	Boiler and stock.
148	Solen	SW.	30	134	80	Dr. P. F. Rice	Drilled well	67	3 in.	Blue sand	Fox Hills sandstone.	−40	Domestic.
149	do	SW.	30	134	80	Frank K. Welch	do	65	do	do	do	−40	Do.
150	do	SW.	30	134	80	Village	do	65	4 in.		do		Domestic use.
	Slope County												
151	Marmarth lot 6, block 19.		31	133	105	City	Drilled well	200	12 in.	Blue sandstone	Fort Union formation.	Just flows	Municipal supply.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Sargent County														
141	Village of Cogswell	June 28, 1921	2,471	9.6	0.07	24	7.8	800	24	256	1,146	292	Trace.	92	
142	Village of Forman	do	2,568	16	.40	19	6.5	861	0	390	954	456	4.0	74	
143	D. J. Jones	do	2,559	14	.16	16	6.3	864	0	415	932	464	2.9	66	
144	Joseph Lanxon	do	1,650	28	1.4	175	43	301	0	520	763	44	2.9	614	
145	P. E. Peterson	June 19, 1921	3,542	16	1.1	36	11	1,130	0	344	1,666	430	4.4	135	
	Sheridan County														
146	City of McClusky	June 3, 1921	727	31	0.14	110	48	65	0	400	242	14	Trace.	472	C. S. Howard.
	Sioux County														
147	Northern Pacific Ry. Co.	June 27, 1921	396	23	1.3	64	30	38	0	405	40	2.0	2.5	283	
148	Dr. P. F. Rice	do	1,367	17	.63	8.0	2.6	520	0	1,039	227	60	10	31	
149	Frank K. Welch	do	1,539	21	Trace.	12	4.6	580	0	1,078	346	47	7.4	49	
150	Village of Solen	do	1,168	16	.20	46	32	350	0	903	200	45	24	246	
	Slope County														
151	City of Marmarth	June 22, 1921	1,673	17	0.69	9.6	3.3	570	38	566	729	11	3.0	38	

Analyses of waters in North Dakota—Continued

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers		Water level above (+) or below (—) surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T. N.	R. W.					Character of material	Geologic horizon		
	Stark County												
152	Dickinson	NW.	3	140	96	City	Drilled well	202	6 in	Gray sand	Fort Union formation.		Municipal supply.
153	do	NW.	3	141	96	do	do	185	8 in	do	do		Do.
154	do	NE.	4	141	96	Dickinson Ice Co	do	130		Sand	do		Industrial.
155	Taylor	SE.	34	140	93	H. R. Hutchinson	Bored well	80	18 in	Clay	do	—40	Stock.
	Steele County												
156	Finley	NW.	32	147	56	O. Cummings	Bored well	52	12 in	Gravel and clay	Quaternary drift	—16	Domestic.
157	do	NW.	32	147	56	G. O. Johnson	Dug well	46	2 ft	Gravel	do		Do.
158	Hope	NW.	1	144	56	J. C. Wamberg	do	45	4 ft	Drift	do	—35	Stock.
159	do	NW.	1	144	56	B. T. Kraabel	Bored well	30	12 in	do	do	—28	Domestic.
160	do	NW.	1	144	56	N. B. Cassel	Dug well	30	30 in	Sand and gravel	do	—26	Do.
	Stutsman County												
161	Jamestown lots 17–20, block 20.			140	64	City	Dug well	30	25 ft	Gravel	Alluvial deposit	—14	Municipal supply.
162	Jamestown	NE.	12	139	64	State hospital	Drilled well	100	3 in	do	do	—80	Drinking water.
163	do	SE.	28	140	64	Western Electric Co.	do	1,487	do	Sandstone	Dakota sandstone.	Flows	Industrial.
	Towner County												
164	Cando	SE.	20	158	66	City	Dug and driven well.	95		Quicksand	Glacial drift	—27	Municipal supply.
165	do	SE.	20	158	66	C. J. Lord and Harry Lord.	Drilled well	198	2 in	Shale	Pierre shale		Domestic.

Analyses of waters in North Dakota—Continued

[Parts per million]

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
	Stark County														
152	City of Dickinson	June 25, 1921	913	20	1.8	46	52	205	0	508	324	2.0	1.5	328	C. S. Howard.
153	do	do	892	16	Trace.	47	40	206	0	503	304	3.0	1.6	282	Do.
154	Dickinson Ice Co.	do	948	16	1.0	49	40	217	0	505	347	4.0	.39	286	Do.
155	H. R. Hutchinson	June 24, 1921	4,980	16	.80	429	415	424	0	593	2,994	8.0	2.8	2,770	Do.
	Steele County														
156	O. Cummings	June 9, 1921	2,522	30	0.30	408	187	30	0	547	998	213	80	1,787	
157	G. O. Johnson	do	2,339	30	.53	302	165	141	0	464	1,232	42	10	1,431	
158	J. C. Wamberg	June 8, 1921	2,752	37	2.4	500	176	100	0	398	1,600	120	1.0	1,972	
159	B. T. Kraabel	do	1,164	34	.74	228	79	19	0	437	422	94	24	894	
160	N. B. Cassel	do	1,700	37	.40	341	111	38	0	408	720	210	Trace.	1,310	
	Stutsman County														
161	City of Jamestown	June 14, 1921	740	32	0.97	94	34	123	0	476	212	26	0.67	374	C. S. Howard.
162	State hospital, Jamestown.	do	476	28	.46	97	21	45	0	405	85	2.0	Trace.	329	Do.
163	Western Electric Co., Jamestown.	do	2,372	19	1.5	57	23	707	0	378	1,048	276	Trace.	237	Do.
	Towner County														
164	City of Cando	May 6, 1921	448	31	11	85	28	22	0	303	79	26	7.2	327	
165	C. J. Lord and Harry Lord.	May 7, 1921	1,090	33	Trace.	34	14	363	0	673	71	220	Trace.	142	

Analyses of waters in North Dakota—Continued

Traill County

No.	Location: Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
166	Blanchard	NE.	25	145	52	Village	Drilled well	394	2 in.	Coarse sand, gravel.	Dakota sandstone	+20	Domestic and stock.
167	Buxton	SW.	25	148	51	do	Dug well	16	8 ft.	Beach gravels	Lake Agassiz beach deposit.	−8	Domestic.
168	Hillsboro	NE.	6	145	50	City	do	93	12 by 75 ft.	Fine sand	Lake Agassiz silt	−48	Domestic, stock, municipal, and industrial.
169	do					Mr. Nelson	Artesian well	200			Quaternary drift		
170	Mayville	NE.	6	146	52	City	Drilled well	365 (?)	2 in.	Sandstone	Dakota sandstone	Flows	Stock.
171	do	SW.	32	147	52	St. Anthony & Dakota Elevator Co.	Bored well	20	18 in.	Delta alluvium	Alluvial deposit	Flows	Domestic and stock.
172	Reynolds	NW.	1	148	51	Village	Drilled well	162	2 in.		Quaternary drift		Stock.
173	do	NW.	1	148	51	C. O. Gorder	Dug well	13½	3½ ft.	Sand layers in clay.	Lake Agassiz silt	−6	Domestic.

Walsh County

No.	Location: Nearest post office	Quarter	Sec.	T. N.	R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
174	Grafton			157	53	City	Drilled well	915	6 in.		St. Peter or older (?) sandstone.	Flows [a]	Sewer and fire protection.
175	do	NE.	13	157	53	Grafton Roller Mill	do	312	2 in.	White sand	Dakota sandstone (?).	Flows	Industrial.
176	Park River	SE.	28	157	55	City	Dug well	25	3 ft., 20 ft.	Gravel	Glacial drift and beach gravel.	−12	Municipal supply.
177	do	SE.	28	157	55	do	Drilled well	494	4 in., 2½ in.	Quicksand	Dakota sandstone (?).	−90	Boilers.

[a] 800 gallons a minute.

Analyses of waters in North Dakota—Continued

[Parts per million]

Traill County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
166	Village of Blanchard	July 1, 1921	3,262	15	1.2	72	18	1,042	0	276	1,200	734	Trace.	254	
167	Village of Buxton	June 24, 1921	250	34	Trace.	56	18	6.9	0	232	24	2.0	2.0	214	
168	City of Hillsboro	do	805	36	.80	132	36	90	0	383	224	72	8.0	478	
169	Mr. Nelson	do	3,431	37	1.6	142	54	929	0	305	1,241	760	Trace.	576	
170	City of Mayville	July 18, 1921	3,369	14	2.2	177	70	867	0	254	1,227	790	15	730	
171	St. Anthony & Dakota Elevator Co., Mayville.	do	2,206	29	.20	436	126	26	0	451	1,020	82	144	1,607	
172	Village of Reynolds	June 23, 1921	3,660	36	1.5	168	62	982	0	290	1,270	860	Trace.	674	
173	C. O. Gorder	do	2,092	33	Trace.	155	201	212	0	703	412	304	285	1,210	

Walsh County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
174	City of Grafton	Apr. 25, 1921	4,560	24	0.40	44	22	1,640	0	881	605	1,720	9.0	200	
175	Grafton Roller Mill	Apr. 26, 1921	4,799	7.6	.70	43	26	Na 1,710 K 28	0	900	603	1,882	Trace.	227	Margaret D. Foster.
176	City of Park River	Apr. 29, 1921	739	28	.10	29	9.1	228	0	337	173	116	1.7	110	
177	do	do	4,575	14	.50	29	17	1,637	0	866	988	1,420	Trace.	142	

Analyses of waters in North Dakota—Continued

Ward County

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
178	Des Lacs	SE.	11	155	85	Public school	Bored well	30	18 in.	Sand	Quaternary drift		Drinking.
179	do	SE.	11	155	85	M. Soltz	Drilled well	340	5 in.	Shale	Fort Union formation.	−60	Stock.
180	do	SE.	21	155	85	H. W. Gunther	do	175	3 in.	Lignite	do	+12	Domestic and stock.
181	do	SW.	17	155	85	Geo. McKee	do	185	6 in.	do	Lignite in Fort Union.	−4	Do.
182	Kenmare	SW.	20	160	88	City	do	313	12 in.		Fort Union formation.		Municipal supply.
183	do	SW.	20	160	88	A. N. Cary & Son	Kenmare Springs.			Fine sand	Quaternary drift		Bottled for commercial use; drinking.
184	¾ mile northwest of Minot.					Jens Matson, route 5.	Driven well [a]	30	6 in., 2¼ in.	do	Alluvial deposit		Domestic (sold in Minot for drinking).
185	Minot	NE.	14	155	83	State Normal School	Drilled well	200	6 in.	Gravel	Quaternary drift (?).	−29	Boilers, irrigation, and domestic.
186	do	SW.	14	155	83	City	do	132	12 in.	do	Alluvial deposit	−15	Municipal supply.
187	do	NW.	14	155	83	E. D. Kelley	Puritan Springs			Glacial drift	Quaternary drift		Domestic.

Wells County

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T. N.	Location: R. W.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers: Character of material	Aquifers: Geologic horizon	Water level above (+) or below (−) surface (feet)	Use of water
188	Fessenden	SE.	7	148	70	City	Drilled well	148	6 in.	Sand	Quaternary drift		Domestic.
189	Harvey	SE.	31	150	72	Mrs. Sarah Dolan	Dug well	18	8 ft.	Gravel and sand	do	−12	Do.
190	do	SE.	31	150	72	Krenik, Peterson & Jorgenson.	do	60	5 ft.	Gravel	do	−35	Domestic and stock.
191	do	SW.	31	150	72	City	Drilled well	2,235	5 in., 1¼ in.	Sandstone	Dakota sandstone	+55	Domestic (slight use).

[a] Called "Crystal Springs."

Analyses of waters in North Dakota—Continued

[Parts per million]

Ward County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
178	Public School, Des Lacs	May 24, 1921	2,548	19	0.11	406	158	105	0	403	1,465	26	1.5	1,660	C. S. Howard.
179	M. Soltz	do	2,244	16	1.7	10	3.4	920	0	1,954	2.6	294	Trace.	39	Do.
180	H. W. Gunther	July 5, 1921	2,345	15	.75	16	4.8	882	29	2,152	31	110	Trace.	60	
181	George McKee	do	2,300	14	-----	-----	-----	-----	55	1,920	[f] 30	106	1.3	-----	
182	City of Kenmare	May 19, 1921	1,433	32	.58	30	16	515	0	1,186	100	134	4.4	141	Do.
183	A. B. Cary & Son	do	875	17	.20	133	56	81	0	510	246	50	3.0	562	
184	Jens Matson	May 23, 1921	332	25	.12	73	23	15	0	312	43	.20	2.7	277	
185	State Normal School, Minot.	do	1,454	29	3.2	125	56	320	0	742	291	232	Trace.	542	
186	City of Minot	do	1,135	29	2.6	56	27	353	0	799	68	200	Trace.	251	Do.
187	E. D. Kelley	June 17, 1921	1,093	35	Trace.	173	58	79	0	537	365	6.0	Trace.	670	

Wells County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
188	City of Fessenden	June 1, 1921	1,321	32	0.59	59	27	378	0	651	309	170	Trace.	258	C. S. Howard.
189	Mrs. Sarah Dolan	May 31, 1921	324	17	.05	62	28	9.4	0	239	50	10	12	270	Do.
190	Krenik, Peterson & Jorgenson	do	965	32	.43	151	59	88	0	500	338	16	2.0	619	Do.
191	City of Harvey	June 12, 1921	3,400	33	3.2	5.6	2.4	1,248	48	1,025	764	710	Trace.	22	

[f] By turbidity.

Analyses of waters in North Dakota—Continued

Williams County

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifers		Water level above (+) or below (−) surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T. N.	R. W.					Character of material	Geologic horizon		
192	Ray	SE.	36	155	97	R. M. Grove	Drilled well	833	6 in	Sandstone	Lance formation	+20	Domestic and stock.
193	Williston	SE.	23	154	101		Missouri River (raw water).						Filtered for municipal supply.
194	do	SW.	29	154	100	Bruegger Mercantile Co.	Drilled well	640	4 in		Fort Union formation.		Domestic and stock.
195	do	SW.	29	154	100	H. P. Hendrickson	do	(?)2,100	14 in., 4 in		Lance formation	+20	Stock.
196	do	NE.	26	154	100	J. F. Brothers	Medicine Lodge Spring.			Sedimentary rock.	Quaternary drift		Stock; formerly bottled.

Analyses of waters in North Dakota—Continued

[Parts per million]

Williams County

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na, K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (H. B. Riffenburg unless otherwise noted)
192	R. M. Grove	June 22, 1921	2,124	39	0.24	10	3.4	832	34	1,479	8.7	422	1.9	39	
193	Missouri River (raw water).	May 28, 1921	[a]426	11	.15	64	17	49	0	164	190	6.0	1.0	230	
194	Bruegger Mercantile Co.	do	1,936	15	Trace.	5.2	4.5	796	29	2,089	7.1	2.2	Trace.	31	
195	H. P. Hendrickson	June 22, 1921	1,580	21	.31	4.8	3.4	640	0	1,332	6.6	236	Trace.	26	
196	J. F. Brothers, Medicine Lodge Spring.	May 29, 1921	1,130	25	1.1	52	33	290	0	568	428	2.0	1.8	265	

[a] Suspended matter 3,920.

INDEX

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DIAGRAM SHOWING PRECIPITATION, TOTAL RUN-OFF, GROUND-WATER RUN-OFF, TEMPERATURE, AND FLUCTUATION OF THE WATER TABLE IN THE POMPERAUG BASIN, JULY, 1913, TO DECEMBER, 1916