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GROUND WATER IN THE KINDRED AREA CASS AND RICHLAND COUNTIES, NORTH DAKOTA

BY

P. E. DENNIS, P. D. AKIN, AND SUZANNE L. JONES

NORTH DAKOTA GROUND WATER STUDIES NO. 14

PREPARED IN COOPERATION BETWEEN THE GEOLOGICAL SURVEY
U.S. DEPARTMENT OF THE INTERIOR, THE NORTH DAKOTA STATE
WATER CONSERVATION COMMISSION, AND THE NORTH DAKOTA STATE
GEOLOGICAL SURVEY

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ABSTRACT

The area covered by this report includes the four townships nearest the town of Kindred, which is in south-central Cass County about 25 miles southwest of Fargo. It lies entirely within the area of Pleistocene Lake Agassiz and includes a part of the northeast margin of the Sheyenne delta, which was built by the ancestral Sheyenne River during the earlier periods of the lake history.

Information regarding the geologic formations in the area was obtained chiefly from 23 test holes drilled by the U. S. Geological Survey during the investigation in 1947 and 1948. They revealed the formations in the area to be as follows: the surficial Lake Agassiz deposits, which consist of a single unit of fine sand comprising the delta and two units (a basal clay unit and an overlying silt unit) elsewhere; till and associated glacioaqueous deposits; Cretaceous shale of older Pleistocene lake clay; and pre-Cambrian crystalline rocks, which are locally called "granite."

The clay unit and the delta unit of the Lake Agassiz deposits are thought to be different facies of the same time interval, deposited during the earlier and deeper phases of the lake. In the Kindred area and elsewhere along the delta margin the clay and delta sands are interfingered. The silt unit was deposited during a later flooding of the lake, and it completely covers the clay unit.

Because the lake rose high enough only to lap the margin of the delta, the silt unit is not present landward from the delta escarpment. The total thickness of the Lake Agassiz deposits ranges from about 100 to 200 feet.

Two aquifers, the most important in the area, are contained in the Lake Agassiz deposits: (1) delta sand, rather generally distributed throughout the delta area, and (2) sand beds at the base of the silt unit. In all that part of the delta included within the area, farm wells yield water from the delta sand at depths ranging from 10 to 70 feet. The waters from this aquifer are generally less mineralized than the waters from other aquifers in the area. The wells are generally adequate for farm use, and in some areas moderate supplies for municipal, industrial, and other purposes could possibly be developed.

Water is obtained from wells in the sandy basal portions of the silt unit in Kindred and in scattered areas throughout the lake plain. Wells are most common in front of the delta escarpment and along the Sheyenne River. On the basis of information obtained from the test holes, the town completed two supply wells in this aquifer. Pumping tests made on these wells indicate a transmissibility of about 4,500 gallons a day per foot for the materials of the aquifer in the vicinity of the wells. Specific capacities of the wells averaged about 1.0 gallon per minute per foot after 1 day of pumping at the rate of about 30 gallons a minute. This amount is very low, considering the transmissibilities involved, and probably is caused by head loss through the fine screen. It is not serious, however, in view of the fact that the wells will ordinarily be pumped at rates of less than 30 gallons a minute. Estimates of storage based on the available, rather incomplete, data regarding the areal extent of the aquifer suggest that the sands contain an adequate amount of stored water to supply the town through several seasons of dry weather without benefit of normal recharge. Records of water-level fluctuations in wells in the Kindred area do not yet cover a sufficient length of time to demonstrate the exact character and magnitude of the recharge, but from the records that have been obtained and from analogy with similar aquifers in the Fargo area it is clear that recharge to the aquifer is chiefly from local precipitation, which reaches the sand beds by percolation through the relatively thin overlying silt beds.

Till and associated glacioaqueous deposits underlie the Lake Agassiz deposits and range from 100 to 190 feet in thickness in this area. The till itself will not effectively transmit water, but the associated glacioaqueous deposits constitute the second most important source of ground water in the region. About 75 or 80 percent of the farm wells beyond the delta margin derive their water from them. The glacioaqueous beds generally are small, and in the immediate vicinity of Kindred only one bed appears to be thick enough to merit consideration as a possible source of municipal supply. This bed in USGS test 23 consisted of about 50 feet of clayey, bouldery gravel between depths of 223 and 275 feet. Available information from other test holes and wells suggests that the aquifer is not very extensive, although Kindred well 1 probably is in it, and USGS test 24 penetrated 5 feet of gravel which probably should be correlated with it. Special interest might be attached to the aquifer because of the possibility of obtaining a stand-by well in it as insurance against an extended period of dry years.

The till and associated glacioaqueous deposits are underlain at Kindred and presumably throughout the eastern part of the area by "granite," but at the locations of USGS tests 1R and 2R and probably throughout the western part of the area they are underlain by clay, siltstone, and shale. On the basis of present information it does not seem possible to determine if a part or all of this material is to be correlated with the older Pleistocene lake clay found in the Fargo area, or if a part or all of it is of Cretaceous age. So far as is known, it is not water bearing in the Kindred area.

The basement rock of the area consists of igneous and metamorphic rocks that locally are called granite. The upper part of the "granite" is highly decomposed, and it is generally considered useless to drill deeper when this zone is reached.

In general the waters from aquifers in the Lake Agassiz deposits are somewhat less mineralized than are those from the glacioaqueous aquifers.

INTRODUCTION

Scope and purpose of the investigation

This is a progress report covering a part of the study of the geology and ground-water resources of Cass and Richland Counties, being made by the U. S. Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the State Geological Survey, as a part of a series of investigations of different counties in the State. The purpose of these general studies is to determine the occurrence, movement, discharge, and recharge of the ground water, and the quantity and quality of such water available for all purposes, including municipal, domestic, irrigation, and industrial. At present, the most critical need is for adequate and perennial water supplies for many towns and small cities throughout the State wishing to construct municipal water-supply and sewage disposal systems. For this reason, the county-wide studies are being started in the vicinity of those towns requesting the help of the State Water Conservation Commission and the State Geologist in locating suitable ground-water supplies. Progress reports, such as this one, are being released before the completion of the general studies so that the data may be available as soon as possible for use in connection with immediate problems. The area described in this report comprises chiefly the four townships nearest the Village of Kindred, because that area is of the most immediate interest to the Village in its search for an adequate water supply.

Acknowledgments

The investigation was made in 1947 and 1948 under the general supervision of A. N. Sayre, Geologist in Charge of the Ground Water Branch, Water Resources Division, of the Federal Geological Survey. The field work and test drilling were done under the direct supervision of P. E.

Dennis, District Geologist. Most of the well-inventory work was done by Robert Aaker and H. K. Wold. In addition, well records obtained by the county assessors in 1939 as part of a State-wide well inventory under the Works Projects Administration were available, and many of them are included in this report. Test drilling was done by Ray Danielson, George McMaster, Keith Hanson, and Gilbert Rupp. Work was facilitated by the excellent cooperation of all residents and particularly by the interest and assistance of Mayor C. O. Trom and the members of the Village Council. Carl Owen assisted in making the pumping tests and in making water-level measurements in the observation wells.

Previous investigations

No intensive investigation of the geology and occurrence of ground water has ever been made in the Kindred area. Upham's description 1/ of the various features of Lake Agassiz that are present in the area includes also brief mention of the wells of the area.

A general discussion of the geology and occurrence of ground water in the area, as well as topographic, geologic, and artesian-water maps, is included in Hall and Willard's report 2/ on the Casselton and Fargo quadrangles.

General information concerning the geology and ground water of Cass and Richland Counties, is included in a report by Simpson. 3/ More specific data are given only for wells in the town of Davenport (see Fig. 3). Simpson made a short special investigation of the water supply of

1/ Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.
2/ Hall, C. M., Willard, D. E., Description of the Casselton and Fargo quadrangles: U. S. Geol. Survey Geol. Atlas Casselton-Fargo folio no. 117, 1905.
3/ Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey water-Supply Paper 598, pp. 97-108, 208-214, 1929.

Kindred in 1933 and a report was submitted to the Mayor and Village Council. The report lists data from a number of wells in the area and also a number of chemical analyses of well waters.

Location and general features of the area

The area covered by this report includes the following four townships: T. 136 N., Rs. 50 and 51 W., in Richland County, and T. 137 N., Rs. 50 and 51 W., in Cass County. There are three villages in the area: Walcott, Kindred, and Davenport. Kindred is in the north-central part, about a mile north of the Richland County line, which is followed by State Highway 46. The village is 18 miles south and about 10 miles west of Fargo. According to the United States Bureau of the Census, the population of Kindred in 1940 was 450. Walcott is in the southeastern corner of the area, about 4 miles east and 6 miles south of Kindred. Its population in 1940 was 375. The altitude of both Kindred and Walcott is about 950 feet above sea level. Davenport is on the northwestern edge of the area, about 4½ miles north and 2 miles west of Kindred. The 1940 population was 147. The altitude there is 922 feet above sea level.

The Mayville line of the Great Northern Railroad serves all three villages, and Davenport is served also by the Fargo and Southwestern Branch of the Northern Pacific Railroad.

Farming is the main occupation in the area, with corn and wheat as the major crops. The villages serve as trading and shopping centers for the surrounding farm areas.

The climate is one of extremes. During the summer temperatures may reach 100° F. and higher and during the winter temperatures

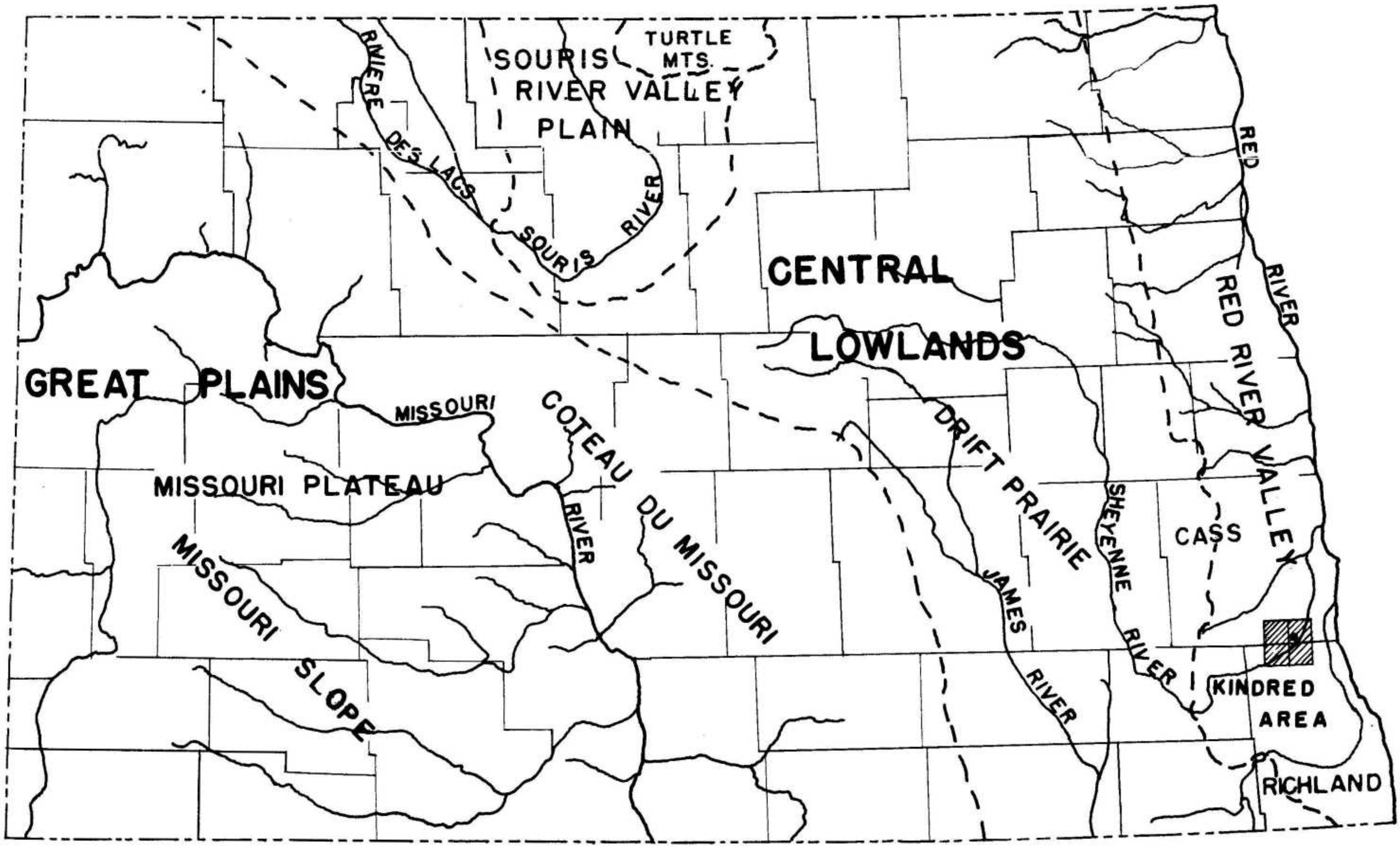


FIGURE I.–MAP SHOWING LOCATION OF THE KINDRED AREA WITH RESPECT TO THE PHYSIOGRAPHIC FEATURES IN NORTH DAKOTA (AFTER SIMPSON) of 30° or more below zero are not uncommon. According to the Weather Bureau, the mean annual temperature at Fargo is 40° F., and the mean annual precipitation is 22 inches. About 80 percent of the precipitation occurs as rain during the months of April through September.

Physiographic features

The area is part of the Western Young Drift section of the Central Lowland province 4/ and is in the Red River Valley area of Simpson 5/ (see fig. 1). The Red River Valley is a broad, flat glacial-lake plain modified chiefly by low beach ridges and deltas. The Kindred area includes a part of the northeastern edge of one of the larger deltas, known as the Sheyenne delta (see fig. 2).

The Sheyenne delta is one of the largest formed in the lake and covers an area of about 800 square miles. The surface is an almost featureless plain sloping gently eastward. Its northern and eastern margins are marked by a steep slope or escarpment that rises as much as 75 feet above the lower part of the Red River Valley plain. The escarpment is very prominent in the Kindred area but decreases in height to the south and is almost indiscrenible along the highway between Wyndmere and Wahpeton. It has been variously interpreted as an ice-contact face 6/ and as a wave-cut slope. 7/

Beach ridges, which are generally the most common features marking successive shore lines of Lake Agassiz, are not conspicuous

4/ Fenneman, N. M., Physiography of the eastern United States, p. 559, McGraw-Hill Book Co., Inc., 1938.
5/ Op. cit., p. 4.
6/ Leverett, Frank, Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, pp. 126-127, 1932.
7/ Upham, Warren, op. cit., p. 316.

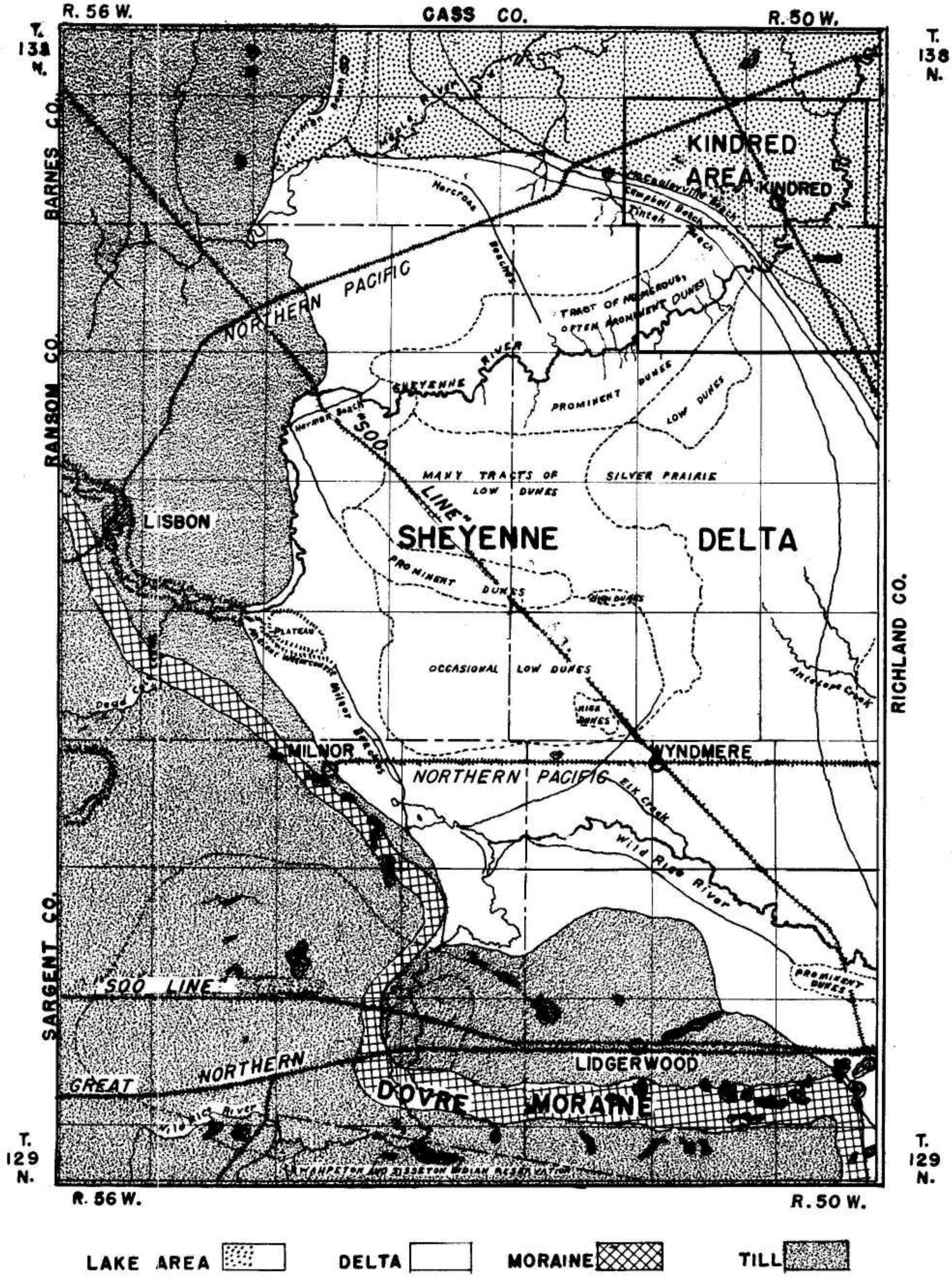


FIGURE 2.—MAP SHOWING GENERAL GEOLOGY IN THE VICINITY OF THE KINDRED AREA (AFTER UPHAM).

in the Kindred area. It seems likely that the 50- to 75-foot escarpment that marks the margin of the Sheyenne delta southwest of Kindred owes a part of its prominence to wave cutting at the Campbell stage of the lake. A series of beach ridges parallel to and lakeward from the escarpment are best developed south of the Sheyenne River and north of Walcott (see fig. 2). Upham 8/ correlates the lowest of these ridges with the McCauleyville beach, and it is so designated on figures 2 and 3. The Tintah beach, which is next higher than the Campbell, is a wave-cut feature crossing the delta, and the materials underlying it are identical with the delta materials elsewhere. It has been obscured by wind erosion and deposition near the Sheyenne River and has a relief of only a few feet elsewhere.

All drainage in the area is youthful. The master stream is the Sheyenne River, which crosses the area diagonally from the southwest corner of T. 136 N., R. 51 W., to the northeast corner of T. 137 N., R. 50 W. Its source is southwest of Devils Lake near the great southeastern bend of the Souris River (see fig. 1). From there it flows 180 miles southeastward, entering the valley of the Red River, where it turns northeastward and flows in a tortuous course 40 miles to enter the Red River.

According to Upham, 9/ the deposition of the Sheyenne delta took place largely during the period of formation of the Herman beaches, but it began as early as the Milnor stage and continued to the Campbell stage of the lake. As the lake waters receded, the

8/ Op. cit., pl. 27, p. 316.
9/ Op. cit., p. 316.

river began to flow across its newly formed delta, and the present valley was initiated. The valley has an average depth of about 100 feet and a maximum width of about three-fourths of a mile. There is a distinct terrace at an altitude of 1,000 feet above sea level. The present stream occupies a channel cut below this terrace to a depth of about 40 feet and a width of rarely more than 300 feet.

Outside the delta area the Sheyenne River ranges from 50 to 75 feet in width and from 1 to 3 feet in depth 10/ and has incised its channel an average of 20 to 30 feet below the general level of the lake plain. The course of the Sheyenne is tortuous and meandering, both through the delta and on the lake plain. A belt of meander scars on both sides of the river averages about half a mile in width and is a much as a mile wide in some places. Accretion scars showing the growth and development of the meanders are well developed in T. 136 N., R. 51 W. (sec. 32).

The high absorptive capacity of the silts and sands composing the surface materials of the delta, combined with the low gradient, retards the development of a well-integrated system of surface drainage. A few tributaries, mainly intermittent, occupy gullies eroded into the valley walls of the Sheyenne River. These occur mainly in the delta area and rarely exceed 2 miles in length. Consequently, the area directly adjacent to the stream is well drained, but the greater part of the interfluvial area has no surface drainage. Some gullies are present also along the steep northeastward-facing escarpment of the delta. The gullies carry water only during times of heavy

10/ Upham, Warren, op. cit., p. 57.

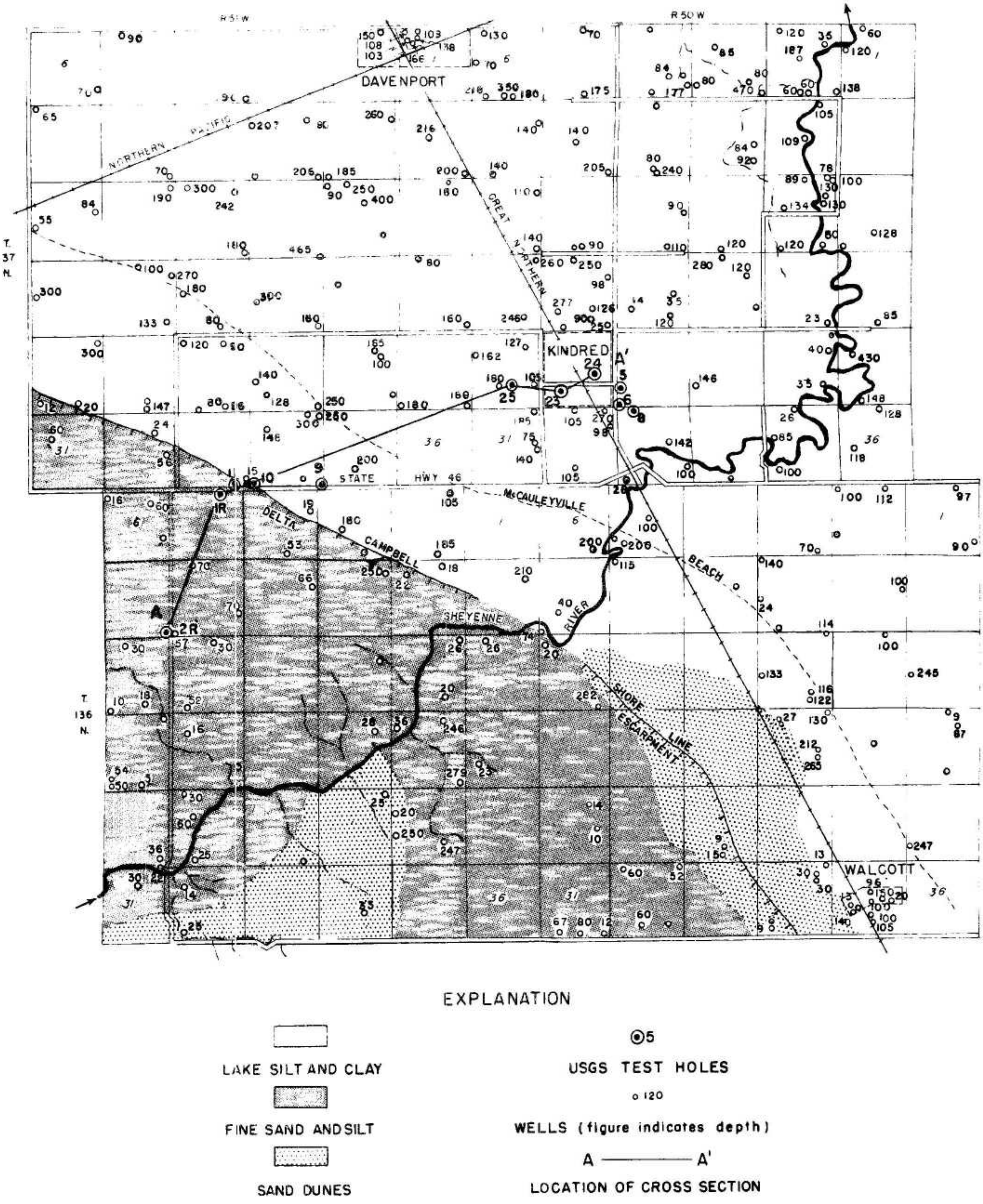


FIGURE 3.—MAP SHOWING GEOLOGIC AND HYDROLOGIC FEATURES OF THE KINDRED AREA

precipitation of melting snow. They begin suddenly along the top margin of the delta slope and end just as suddenly at the foot of the slope. Some of them have formed small alluvial fans. Typical examples may be seen in T. 136 N., R. 51 W., secs. 3, 4, and 5, and in T. 137 N., R. 51 W., secs. 32 and 33.

Many small temporary springs are reported to occur in the valley of the Sheyenne River, particularly throughout the delta area, as well as at the base of the delta escarpment southwest of Kindred and near Walcott. During the spring and early summer the Sheyenne River probably gains some water from these sources, but the springs may dry up in dry seasons, and the Sheyenne River has been known to become completely dry in this area.11/

Much of the surficial material of the area has been reworked by the wind, and prominent sand-dune areas are present along the Sheyenne River and east of the delta escarpment south of the river. The two largest areas of sand dunes are shown on figure 3.

Present water supply and future needs

Water supplies for stock and domestic purposes in the Kindred area are obtained largely from wells. Where the well water is highly mineralized or inadequate in quantity, rain water caught on the roofs of buildings and stored in cisterns is used as a supplemental supply. Records of available data concerning most of the wells in the area are given on pages 48-60. Locations of the wells and their depths are shown on figure 3.

11/ Hall, C. M., and Willard, D. E., U. S. Geol. Survey Geologic Atlas, Casselton-Fargo folio (no. 117), p. 1, 1905.

Before the new municipal wells were drilled in 1948 as a result of the present investigation, the public water supply at Kindred was obtained from three wells of intermediate depth (nos. 2, 3, and 4), one deep well (no. 1), and one shallow well (no. 5). The wells of intermediate depth were drilled in 1935, but the water obtained was inadequate in quantity and of very poor quality. The deep well was drilled in 1936, and it is reported to have been the principal source of supply for the town until the shallow well (no. 5) was drilled in 1944. Although the quality of the water from well 5 is considered satisfactory, the maximun yield is reported to be only about 6 gallons a minute. A number of shallow wells, most of them 15 to 20 feet deep, had been dug and drilled at various times by home owners, but the amount of water obtained was rarely adequate even for a single family. However, the no. 5 city well, drilled in 1944 to a depth of 40 feet, yielded as much as 15 to 20 gallons a minute.

Thus, the town officials, in making plans in 1946-47 for a municipal water-supply system, were confronted with considerable evidence indicating a dearth of ground water at all depths in and near Kindred. Most of the wells in the shallow sand has very small yields, and water levels in them had dropped very low in the drought years of the thirties. The sand and gravel bodies at intermediate depth, which supply most of the farm wells in the area, had yielded only small supplies of highly mineralized water. The Dakota sandstone, which supplies artesian water to many wells west and south of Kindred and which Simpson had recommended as the most likely source of supply, 12/

12/ Simpson, H. E., Ground-water resources of Kindred. Manuscript report filed with the State Geologist, Grand Forks, N. Dak., 1933.

had proved to be absent at Kindred. Unsuccessful attempts to obtain the artesian water from wells drilled for the Rustad Estate, to a depth of 600 or 700 feet in Kindred and to a depth of 300 feet 4 miles east of town, are reported by Simpson.13/ A number of deep "dry" holes are reported to have been drilled in that area since that time.

The estimated minimum water requirement for a feasible municipal water-supply and sewage system in Kindred is said to be of the order of 30,000 to 40,000 gallons a day. In order to provide a margin of safety, it would be highly desirable to develop two or more wells capable of yielding 30 to 40 gallons of water per minute. The two wells developed in 1948 (nos. 6 and 7) appear to meet at least the minimum water requirements.

13/ Op. cit., p. 5.

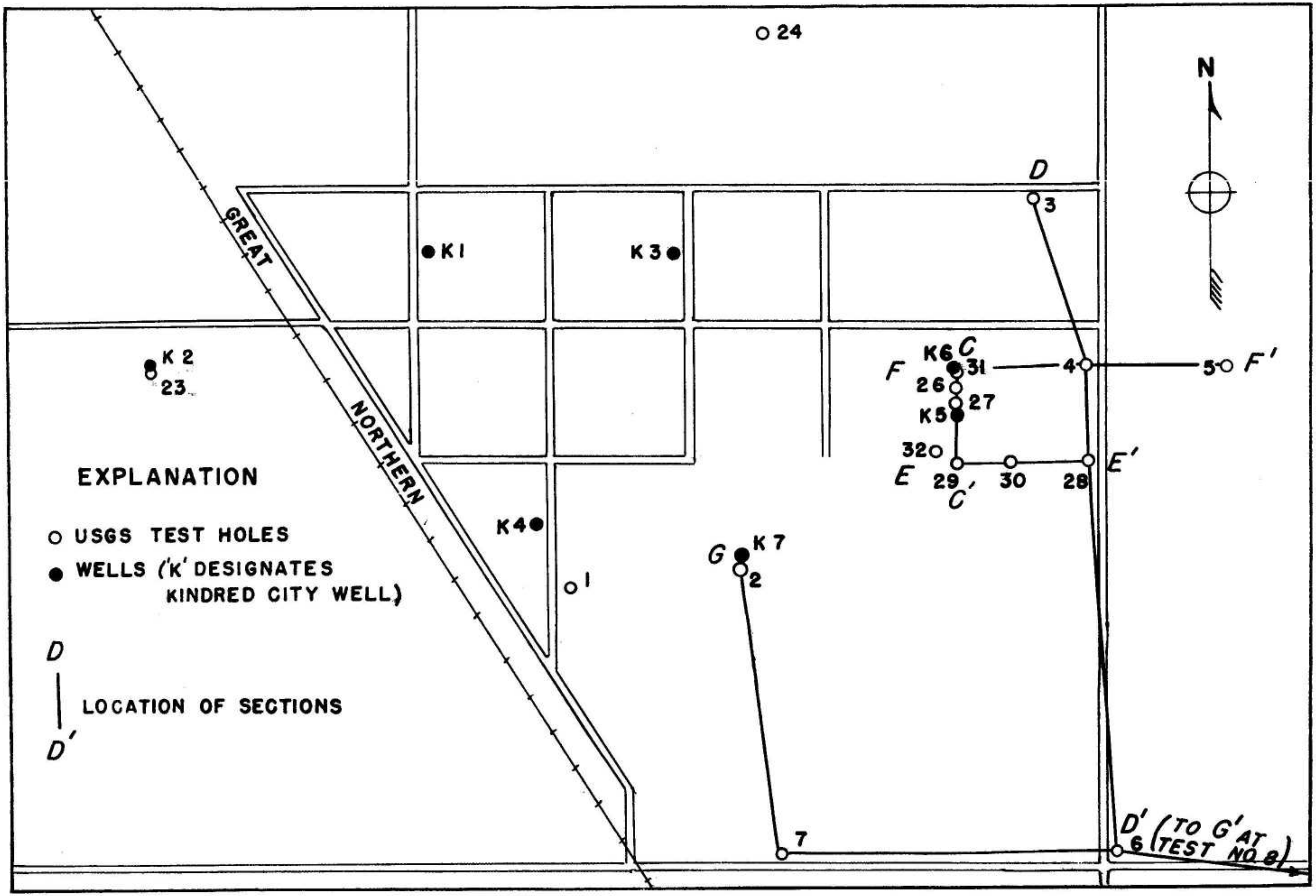


FIGURE 4.— MAP OF KINDRED SHOWING LOCATION OF WELLS AND TEST HOLES.

GEOLOGY AND OCCURRENCE OF GROUND WATER

General

Stratigraphic units

Information concerning the geologic formations in the Kindred area was obtained principally from 23 test holes drilled by the U. S. Geological Survey during the course of the investigation and from logs of a few city-owned and privately owned wells. Eighteen holes ranging in depth from 30 to 77 feet were drilled to obtain information concerning the shallow sand of the Lake Agassiz deposits. The other five holes were drilled through the full section of sedimentary rocks to obtain information in regard to the deeper water-bearing beds. Locations of the test holes drilled in the general area are shown in figure 3, and locations of test holes and town wells in Kindred are shown in figure 4. Logs of all test holes and 19 other available logs are given on pages 61-75.

Stratigraphic nomenclature used in this report conforms generally to that established by Dennis, Akin, and Worts 14/ for Cass and Clay Counties, North Dakota and Minnesota. Following is the stratigraphic section for the Kindred area:

QUATERNARY	Pleistocene	Wisconsin stage	Lake Agassiz deposits Silt unit Clay unit and deposits of the Sheyenne delta Till and associated glacioaqueous deposits.
QUATERNARY OR CRETACEOUS	Pleistocene or Upper Cretaceous		Older Pleistocene lake clay and drift or Benton (?) shale.
PRE-CAMBRIAN			"Granite"

14/ Dennis, P. E., Akin, P. D., Worts, G. F., Jr., Geology and ground-water resources of parts of Cass and Clay Counties, N. Dak. and Minn., U. S. Geol. Survey mimeographed report, pp. 16-17, 1949.

The surficial sediments in the Kindred area are the Lake Agassiz deposits, which may be conveniently divided into a clay unit, a silt unit, and a delta unit. The clay unit and the delta unit are thought to be different facies of the same time interval, deposited during the earlier and deeper phases of the lake when the shore line was at the Herman and other high-level beaches. The delta sediments, which are coarser and thicker than either of the other units, occur in the area south and west of the delta escarpment (see fig. 3). The clay unit was formed lakeward from the delta, and in the Kindred area and elsewhere along the delta margin the clay and delta sands are interfingered. The silt unit was deposited during a later flooding of the lake, and it completely covers the clay unit. As the lake that deposited this unit rose high enough only to lap the margin of the delta, the silt unit is not present landward from the delta escarpment. The Lake Agassiz deposits are generally slightly less than 100 feet thick in the area lakeward from the delta but may be from 150 to 200 feet thick in the delta area.

The Lake Agassiz deposits are underlain by till and associated glacioaqueous deposits. The till consists largely of clay and silt mixed with varying proportions of shale pebbles. Interbedded with the till and lenticular and, usually, small bodies of poorly to moderately well assorted glacioaqueous sand and gravel. The formation ranges in thickness from about 100 to 190 feet in the Kindred area.

At Kindred and presumably in most of the eastern part of the area the till and associated glacioaqueous deposits are underlain by "granite," but at the location of USGS test 1R and 2R and probably in most of the western part of the area the deposits are underlain by

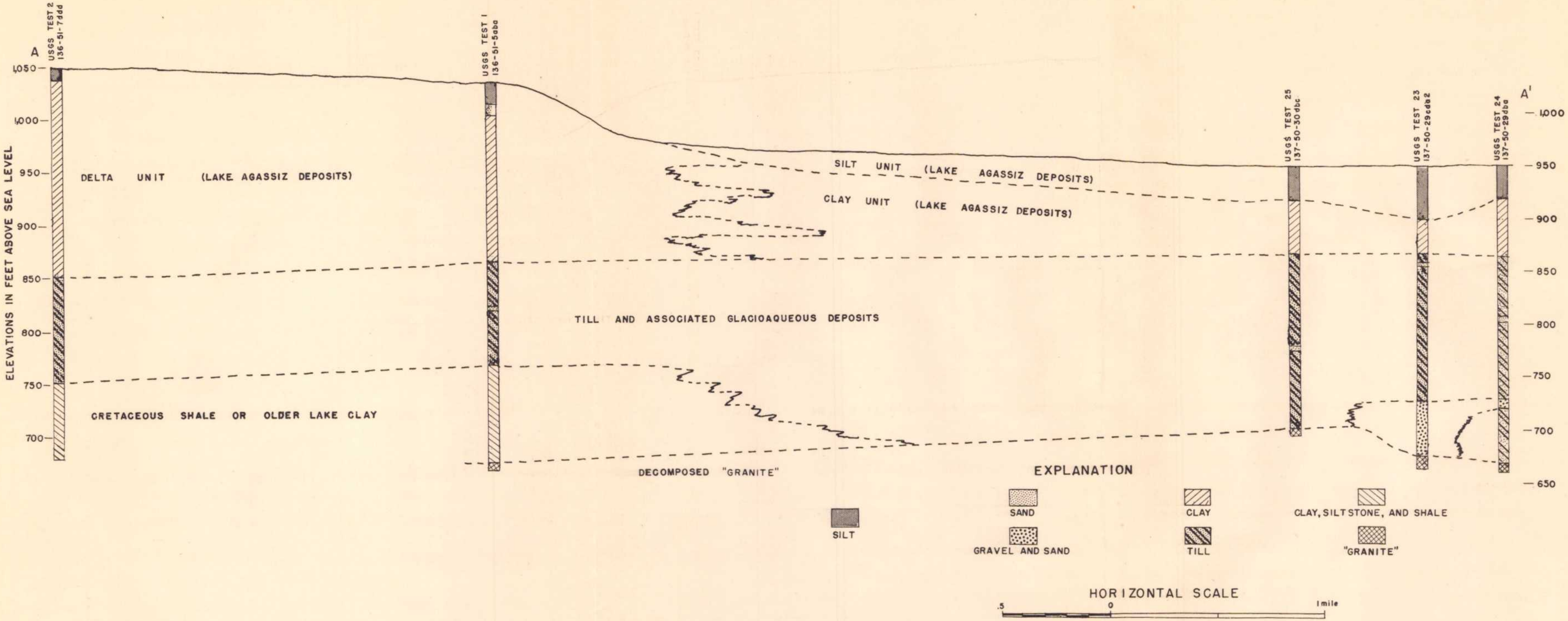


FIGURE 5.–GEOLOGIC SECTION SHOWING GENERAL CHARACTER OF THE ROCK MATERIALS IN THE KINDRED AREA.

Interior—Duplicating Section, Washington, D. C.

clay, siltstone, and shale. These materials, which had been removed by erosion from the eastern part of the area before the deposition of the till, may represent an older Pleistocene lake clay or remnants of a shale of Cretaceous age or both. About 92 feet of clay, siltstone, and shale was present in USGS test 1R. If of Cretaceous age, the material may represent the Benton shale.

Underlying the till and associated glacioaqueous deposits in the eastern part of the area and the clay, siltstone, and shale in the western part of the area is highly decomposed crystalline rock locally referred to as granite.

Figure 3 is a geologic section in the Kindred area showing the general character of the rock materials and the relationships of the stratigraphic units.

Hydrologic concepts

An "aquifer" is any rock formation or stratum that will yield water in sufficient quantity to be of importance as a source of supply. 15/ The amount of water that can be stored in an aquifer is measured by the porosity of the rock material. The unconsolidated rocks such as clay, sand, and gravel are generally more porous than consolidated rocks such as sandstone and limestone, although in some areas the consolidated rocks are highly porous. The "specific yield" (effective porosity, or water-yielding capacity) of a rock is somewhat less than its total porosity--much less in the finer-grained materials--because some water is held in the pore spaces by molecular forces and will not flow out by gravity.

15/ Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, p. 52, 1923.

If the water in an aquifer is not confined by impervious strata above, the water is said to occur under water-table conditions. In this case water may be obtained from storage in the aquifer by lowering the water level, which results in gravity drainage, and the specific yield is some large fraction of the porosity; in coarse-grained materials it may approach very closely the total porosity. If the water is confined in the aquifer by an overlying impermeable stratum, however, so that the water rises above the top of the aquifer under hydrostatic pressure, the water is said to occur under artesian conditions. In this case, water will be yielded as the water level in a well is lowered, but the aquifer remains saturated and the water is yielded because of its own expansion and the compression of the aquifer due to lowered pressure, rather than by gravity drainage. The water-yielding capacity is called the "coefficient of storage" and is generally very much smaller than the specific yield of the same material when drained by gravity.

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

There are, then, two fundamental physical properties of an aquifer that largely control the movement of water through it, the specific yield or coefficient of storage and the permeability. The specific yield may be defined as the amount of water, expressed as a fraction of a cubic foot, that will drain by gravity from a cubic foot of saturated material. The coefficient of storage is defined as the amount of water in cubic feet that will be released from storage in each vertical column of the aquifer having a base 1 foot square when the water level falls 1 foot. For nonartesian aquifers the coefficient of storage is, for all practical purposes, identical with the specific yield.

The permeability of a rock is expressed as the "coefficient of permeability" or by the "coefficient of transmissibility," which is the average permeability multiplied by the thickness of the aquifer. The coefficient of transmissibility is expressed in gallons per day per foot and is defined as the number of gallons of water that will pass in 1 day through a vertical strip of the aquifer 1 foot wide under a unit hydraulic gradient (1 foot per foot - 5,280 feet per mile). Likewise, inasmuch as the flow of ground water normally is directly proportional to the hydraulic gradient, it may be thought of as the number of gallons of water that will pass in 1 day through a vertical strip of the aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile.

Essentially all ground water is derived from precipitation. The water may enter the ground by direct penetration from rain or from melting snow, and by percolation from streams that cross the area if the water in the streams is higher than the water level in the ground-water body. In some areas a part of the ground water comes from adjacent regions, entering the ground at higher elevations and moving slowly to lower elevations.

Essentially all ground water of economic importance is in process of movement through the ground from a place of intake or recharge to a place of disposal or discharge. Velocities of a few tens or a few hundreds of feet a year probably are most common in aquifers under natural conditions. Ground-water discharge may occur by direct evaporation from the soil surface and by transpiration by plants in areas where the water table is very near the surface, or by seepage to streams or to other ground-water bodies where the physical situation is suitable.

As ground water moves through an aquifer it dissolves a part of the more soluble mineral constituents of the rock particles. The amount of mineral matter dissolved by the water is dependent upon the kind of soluble materials present in the aquifer, and the length of time the water is in contact with them. Therefore, the waters that have been underground longest and have traveled the greatest distances are commonly more highly mineralized than those relatively near the recharge areas.

In the Kindred area, the delta unit and the sandy portions of the silt unit of the Lake Agassiz deposits, and the glacioaqueous deposits associated with the till, are the only aquifers of importance. These aquifers and the occurrence of ground water in them are discussed in the following sections.

Lake Agassiz deposits

Geologic aspects

During the waning stages of the Wisconsin glaciation, a marginal glacial lake known as Lake Agassiz was formed in the northward-sloping Red River Valley. Sediments derived mainly from glacial till were deposited in this lake directly from the melting ice front and by streams fed by glacial meltwater. The deposits in the deeper part of the lake consist mainly of clay, whereas coarser material was concentrated along the shores to form the present beach ridges, bars, deltas, and other shore features. Irregularities of the former land surface were partly or completely obscured by this blanket of sediment. The Kindred area lies near the northeastern edge of one of the largest of the deltas formed in the lake, and the character and water-bearing properties of the lake deposits can best be understood in the light of the lake history, insofar as it has been worked out.

The history of Lake Agassiz has been studied and described by Upham, 16/ Tyrell, 17/ Johnston, 18/ Leverett, 19/ and Nikiforoff. 20/ These authors are not in complete agreement concerning the history of the lake, and much additional work will have to be done before the complete story is known. The following brief summary utilizes factual data and interpretations from all these authors, coordinated in the light of data obtained during the present study.

The ice appears to have melted first around the thin edges of the lake that occupied the Red River Valley. Thus the first lakes to form were small isolated bodies around the margins of the valley. One of these small lakes occupied the extreme southwestern part of the area of the Sheyenne delta (see fig. 2) and formed the Milnor beaches at an altitude of 20 to 25 feet above the highest (Herman)

16/ Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.
17/ Tyrell, J. B., The genesis of Lake Agassiz, Jour. Geology, vol. 8, pp. 811-815, 1896.
18/ Johnston, W. A., The genesis of Lake Agassiz: Jour. Geology, vol. 24, pp. 625-638.
19/ Leverett, Frank, Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, 1932.
20/ Nikiforoff, C. C., The life history of Lake Agassiz: Alternative interpretation: Am. Jour. Sci., vol. 245, pp. 205-239, 1947.

beaches that extend completely around the lake. The northeastern shore of this small ancestor of Lake Agassiz was formed by the ice, and its exact extent is not known, although it probably extended beyond Wyndmere. According to Upham, 21/ the formation of the Sheyenne delta began at this stage. As the ice melted and the lake occupied a larger part of the valley, the water stood at the height of the Herman beaches and found an outlet to the Mississippi drainage. Cutting down of the outlet channel caused the lake waters to drop by successive stages to the level of the Campbell shore line. As the ice front retreated northward, the lake waters also receded northward until the lake was very nearly or completely drained. Subsequently, a readvance of the ice again blocked the northward-flowing drainage, and a final lake was formed in the Red River Valley. It rose only to the level of the outlet (Campbell beach) and then receded.

Below the Campbell shore line two distinct units have been identified as corresponding to the two stages of lake flooding. 22/ The lower and thicker unit is thinly laminated blue-gray clay; the upper and thinner unit is a more coarsely laminated buff to yellow silt. The Campbell shore line cuts the eastern (lakeward) margin of the Sheyenne delta (see fig. 2), and the waters of the last lake flooding never covered the delta.

Upham 23/ described the formation of the Sheyenne delta as resulting largely from the sediment carried into the lake by the glacial Sheyenne River, although he recognized the possibility of large

21/ Op. cit., p. 212.
22/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., op. cit., p. 18.
23/ Op. cit., p. 316.

contributions of sediment directly from the melting ice front. Leverett 24/ was concerned about the absence of similar deltas at the mouths of larger rivers, such as the Red Lake River, and believed that the greater part of the material was contributed directly by the melting ice. The fine-grained character and excellent assortment of the sediments, together with the almost total lack of pebbles, boulders, and unassorted blocks and balls of clayey material, which one would expect to find in ice-laid deposits, lead the present authors to favor Upham's theory of a deltaic origin for the Sheyenne delta at least. Evidence for the moraine deposited in water, which Leverett 25/ shows along the margin of the Sheyenne delta southwest of Kindred, was not found during the present investigation. On the contrary, instead of a few feet of sand covering "a highly calcareous, somewhat pebbly clay," as described by Leverett, 26/ the test holes drilled just above the escarpment encountered silt, find sand, and silty lake clay to a depth of approximately 150 feet.

On the map (fig. 3) three types of surficial materials are distinguished. The fine sand and silt of the delta are in general coarser, lighter-colored, and less compacted than the yellow lake silt. However, there is considerable intergradation and interlensing of the two types of sediment in the area adjacent to the delta, perhaps chiefly because the delta sands were washed down and irregularly distributed over the lake floor during the interval between the two lake floodings and during the Campbell stage of the last flooding.

24/ Op. cit., pp. 126-127.
25/ Op. cit., fig. 17, p. 124.
26/ Op. cit., p. 127.

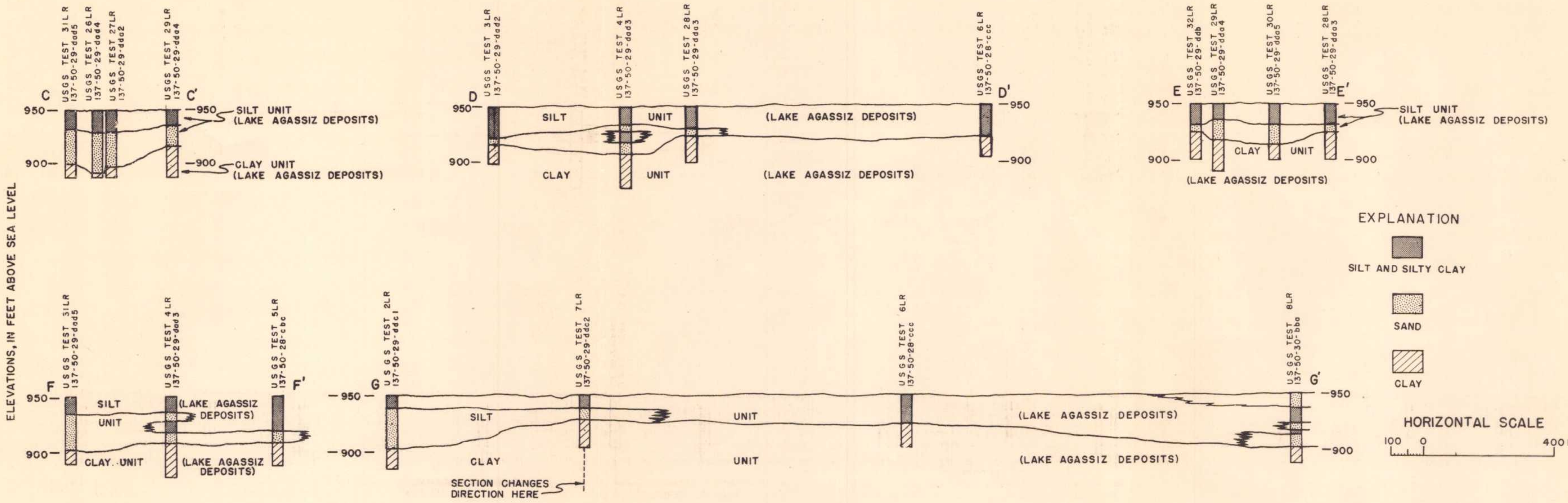


FIGURE 6.—GEOLOGIC SECTIONS SHOWING THE DISTRIBUTION OF THE SANDS IN THE LAKE AGASSIZ DEPOSITS AT KINDRED.

Interior—Duplicating Section, Washington, D. C. 82387

Areas of prominent sand dunes are mapped as a third type of surficial material. In general the materials of the sand-dune areas are coarser and better sorted than the delta sediments elsewhere. Most of the delta surface shows some evidence of reworking by wind, and only the most prominent sand-dune areas were mapped. The dunes are, at present, more or less stabilized by a growth of grass and other vegetation. Most of them are low, but some attain heights of 20 to 40 feet.

The delta sediments are dominantly fine sand and silt. Considerable clay is interbedded with some of the silt; on the other hand, some medium sand occurs locally with the fine sand. Altogether the unit is less compacted, even at depth, than are the clay and silt units. The total thickness of the delta sediments appears to be about 150 to 200 feet, although they may be considerably thinner locally. The contact between the Lake Agassiz deposits and the till and associated glacioaqueous deposits in the delta area is much more difficult to determine than is the same contact elsewhere. The contact was picked at the depth at which pebbles and gravel were first found in the silt and clay. The silt and clay with contained shale pebbles may have been pebbly lake clay rather than till in some cases, and the boundary between the formations (see fig. 5) is only approximate.

Lakeward from the delta the Lake Agassiz deposits consist of an upper silt unit and a lower clay unit. The silt unit consists largely of silt and sand with only minor amounts of clay. It is generally yellow to buff in color and in many places is sandy at the base. In the Kindred area it is generally 30 to 50 feet thick (see fig. 6). The clay unit consists largely of clay and silt with only minor amounts of sand. It is generally bluish gray in color and thinly laminated. In the Kindred area it appears to be about 50 feet thick (see fig. 5).

The Lake Agassiz deposits contain some of the most important aquifers of the area. Practically all the farm wells in the delta portion of the area obtain their water from these deposits at depths ranging from 10 to 70 feet (see fig. 3). Many of the wells are driven sand-point wells equipped with hand pumps or windmills. It appears likely that moderate supplies of water for municipal, industrial, or other purposes could be developed in this area. Not much detailed work was done on the delta unit during the present investigation, but considerable test drilling and other work was done on it in the nearby Wyndmere area. 27/

Wells similar to those in the delta unit are obtained in the sandy parts of the silt unit in scattered areas throughout the lake plain. Most of them are in front of the delta escarpment and along the Sheyenne River but there are a few elsewhere. In most places they are about 15 to 20 feet in depth. So far as known, no wells obtain water from the clay unit of the Lake Agassiz deposits.

The probable distribution of the sandy parts of the silt unit in the vicinity of Kindred is shown in the sections of figure 6, which are based on data from test holes (see Fig. 4). If these sandy beds are to serve as a source of municipal water supply for the town, it is important to know as much as possible about their extent and continuity so that an estimate of the storage capacity

27/ Dennis, P. E., Akin, P. D., and Jones, Suzanne L., Ground water in the Wyndmere area, Richland County, N. Dak.: U. S. Geol. Survey mimeographed report, 1950.

of the aquifer may be obtained. A comparison of the logs of the test holes in the vicinity of Kindred with those in the Fargo area 28/ indicates that the silt unit contains a much higher percentage of sand in the Kindred area than in the Fargo area. However, the stratigraphic position of the sand generally near the base of the unit is similar to that in the Fargo area and elsewhere. Furthermore, only in an occasional test hole, such as USGS 6, are the sand beds absent. The eight private wells in Kindred are all developed in shallow sand aquifers. Thus all the available evidence indicates the general presence of the sand beds in and near the town and their probable continuity and interconnection as indicated in figure 6. That the sand beds are probably present and perhaps thicker in the area between the town and the delta is suggested by their probable mode of origin. The clay unit of the Lake Agassiz deposits was being formed in relatively deep water while the Sheyenne delta was growing northeastward toward the Kindred area. However, when the lake waters fell to the Campbell stage, some of the sandy delta sediments were probably eroded and redistributed lakeward by the lake waters, and during the interval between lake floodings streams probably spread additional quantities of delta sand upon the adjacent portions of the lake plain. As the waters of the second lake flooding again reached the area, near-shore sand deposits may have formed near Kindred until the water became so deep and the shore moved farther away so that silt rather than sand was deposited.

28/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., op. cit., pp. 134-177.

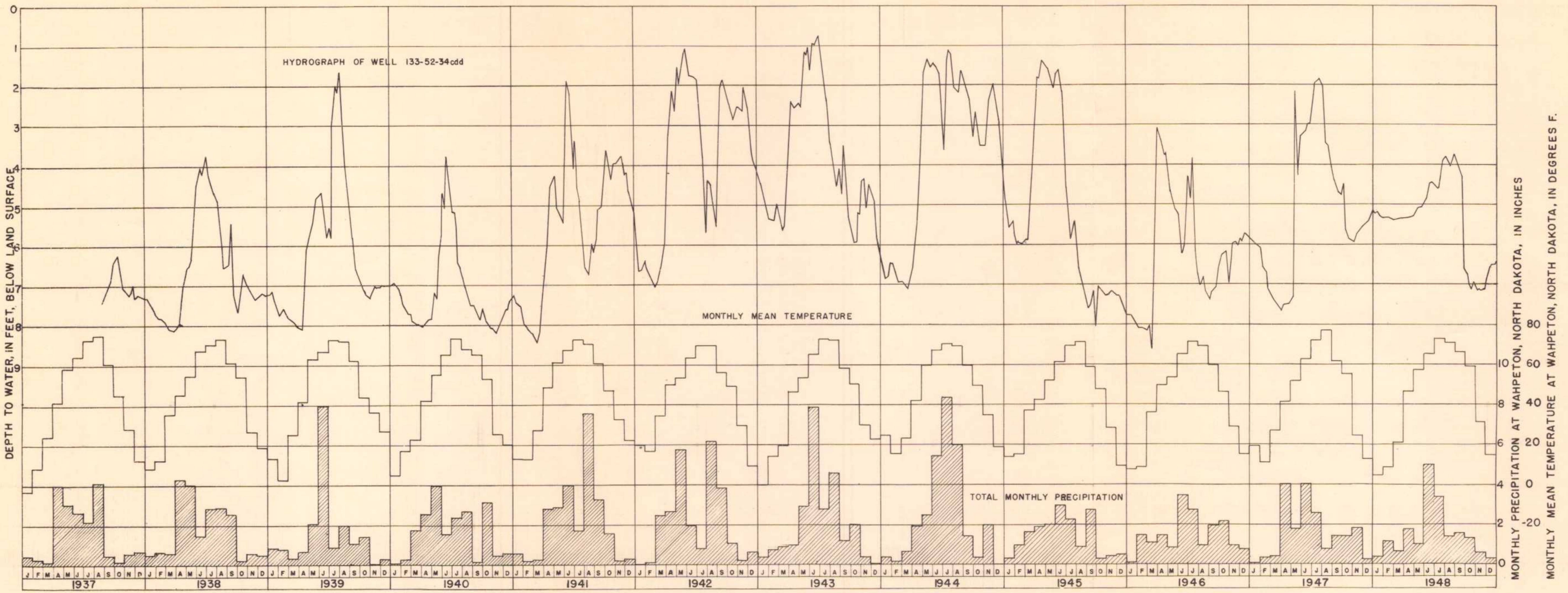


FIGURE 7.– HYDROGRAPH OF SHALLOW WELL WEST OF WYNDMERE AND GRAPH OF MONTHLY MEAN TEMPERATURE AND MONTHLY PRECIPITATION AT WAHPETON, NORTH DAKOTA.

Interior—Duplicating Section, Washington, D. C.

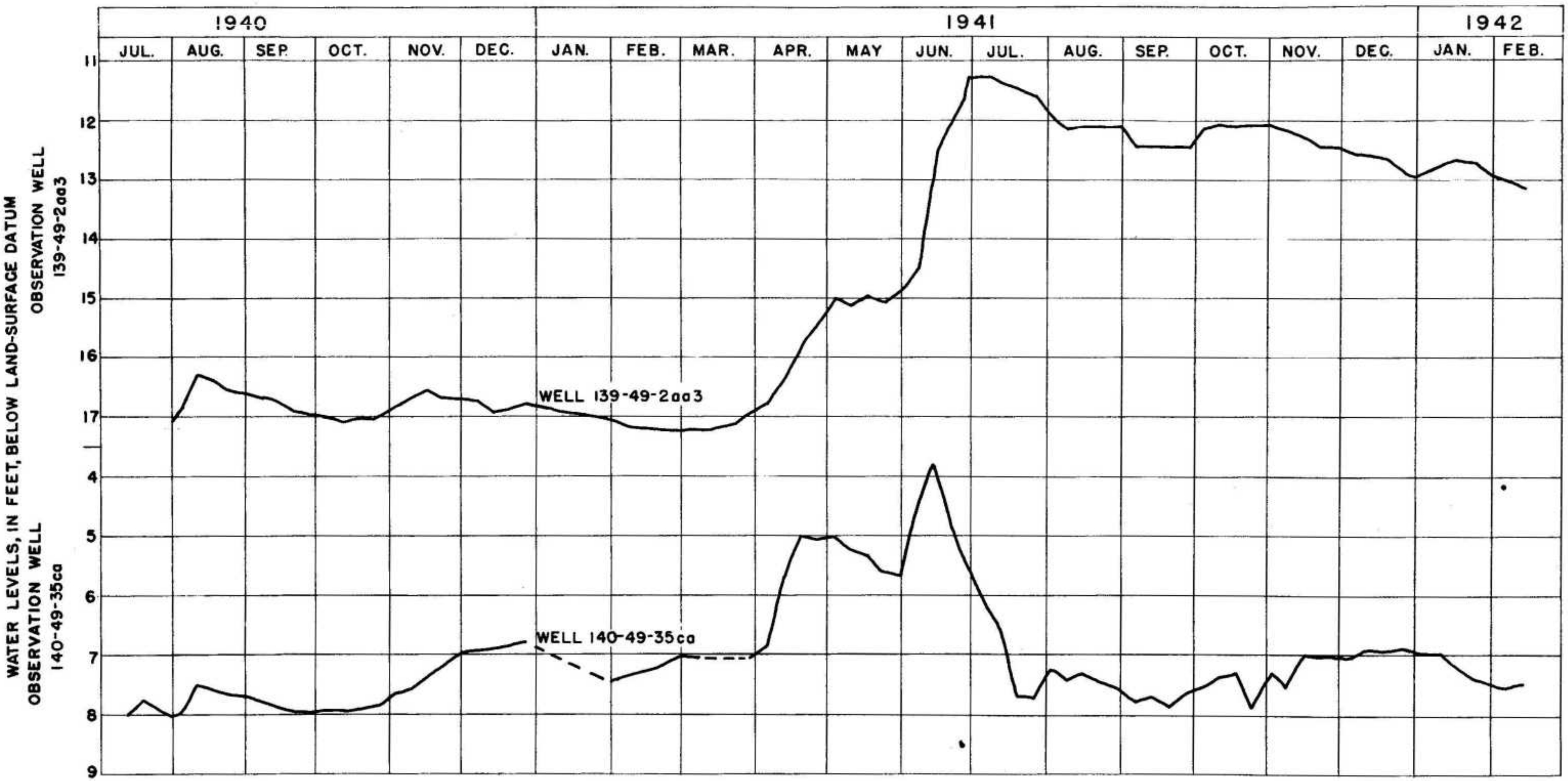
Water-level Fluctuations in aquifer of the Lake Agassiz deposits

Records of water levels in observation wells in the Kindred area have not been obtained for a sufficient length of time to demonstrate the exact character and magnitude of the natural water-level fluctuations. However, fluctuations have been observed in a shallow well on the Sheyenne delta near Wyndmere for a number of years, and it seems likely that the natural water-level fluctuations in wells in the delta near Kindred may be analogous to the fluctuations in that well, although the magnitude of the fluctuations may not be comparable. Figure 7 is a hydrograph of an observation well which is located 1 mile north and 5½ miles west of Wyndmere.

Recharge to the delta sands is a complex function of precipitation, temperature, and other climatic factors. In general, the greatest amount of recharge occurs in the spring after the spring thaw. During this time the water from the melting snow collects in undrained or poorly drained areas and gradually seeps into the sands, together with the water from melting frost. Also, evaporation from the soil and from open water surfaces at this time takes place at a comparatively slow rate because of the low temperatures. Rainfall during this season augments the water from the melting snow and thus increases the amount of water available for recharge.

As a result of recharge during this period, water levels ordinarily reach their highest stages during the late spring or early summer and may be very near the land surface throughout most of the area. With the advent of warmer, drier weather in the early summer, natural discharge of water from the sands is accelerated by increased evaporation from the soil and open water areas, as well as by underground drainage to the streams in the area.

FIGURE 8.—HYDROGRAPHS SHOWING WATER-LEVEL FLUCTUATIONS IN TWO SHALLOW WELLS NEAR FARGO.



Recharge occurs also as a result of rainfall during the summer and fall, but much of this precipitation is held in the soil zone for a time and evaporates from the soil surface or is transpired by plants without reaching the water table. For this reason, only heavy or sustaind precipitation during the summer and fall seasons effectively adds to the ground-water storage.

Little or no recharge occurs during the winter season while the ground is frozen and there is little or no melting of snow.

During the spring and summer when the water level is very near the land surface the sands may be considered as overfull, and much water is lost by evaporation. This rejected recharge would be available as actual recharge if the water levels were lowered by pumping or from other causes. The rises in water level probably are much greater than they would be if the water table were a greater distance below the land surface, because the capillary fringe may extend some distance above the water table and probably is effective in keeping the sands partly saturated almost to the land surface most of the time.

Similar data on water-level fluctuations in two wells in the silt unit of the Lake Agassiz deposits near Fargo are available for a period of approximately 20 months during 1940-42. These data are shown in figure 8.

The hydrographs of these wells illustrate clearly the response of the water levels in the shallow aquifers to recharge. Recharge to shallow aquifers in the area during the spring thaw is common. As the ground thaws, the water from melted snow that collected in poorly drained areas has ample opportunity to soak into the ground and seep down to the water table. Fluctuations due to recharge of this type are illustrated by the water-level rise that began about the middle of March 1941 in well 139-49-2aa3 and during the first part of April in well 140-49-35ca. The rises continued until the last part of April in the latter well and until the first part of May in the former well. During the first part of June the water levels in both wells began to rise as a result of recharge from rains during that period. This rise continued until about the last of June in well 139-49-2aa3 but only until about the middle of June in well 140-49-35ca.

After the full effects of the recharge were culminated, the water level in well 140-49-35ca declined rather steadily until it reached a level lower than that preceding the rise in April. The water level in well 139-49-2aa3 began to decline after reaching a peak in June, but the decline took place at a much slower rate, and the water level at the end of 1941 was still several feet higher than before the spring rise began. Also, the total fluctuation in 1941 at well 140-49-35ca was considerably less than at well 139-49-2aa3. The difference in the magnitude of the fluctuations was due principally to the difference in depth to water in the two wells and is explained as follows: The water level in well 140-49-35ca ranged from 3.8 to 8 feet below the land surface, so that in this area much of the ground water was disposed of by capillary movement upward from the water table and subsequent transpiration by plants and evaporation from the soil surface. On the other hand, the water level in well 139-49-2aa3 was never less than 11 feet below the surface,

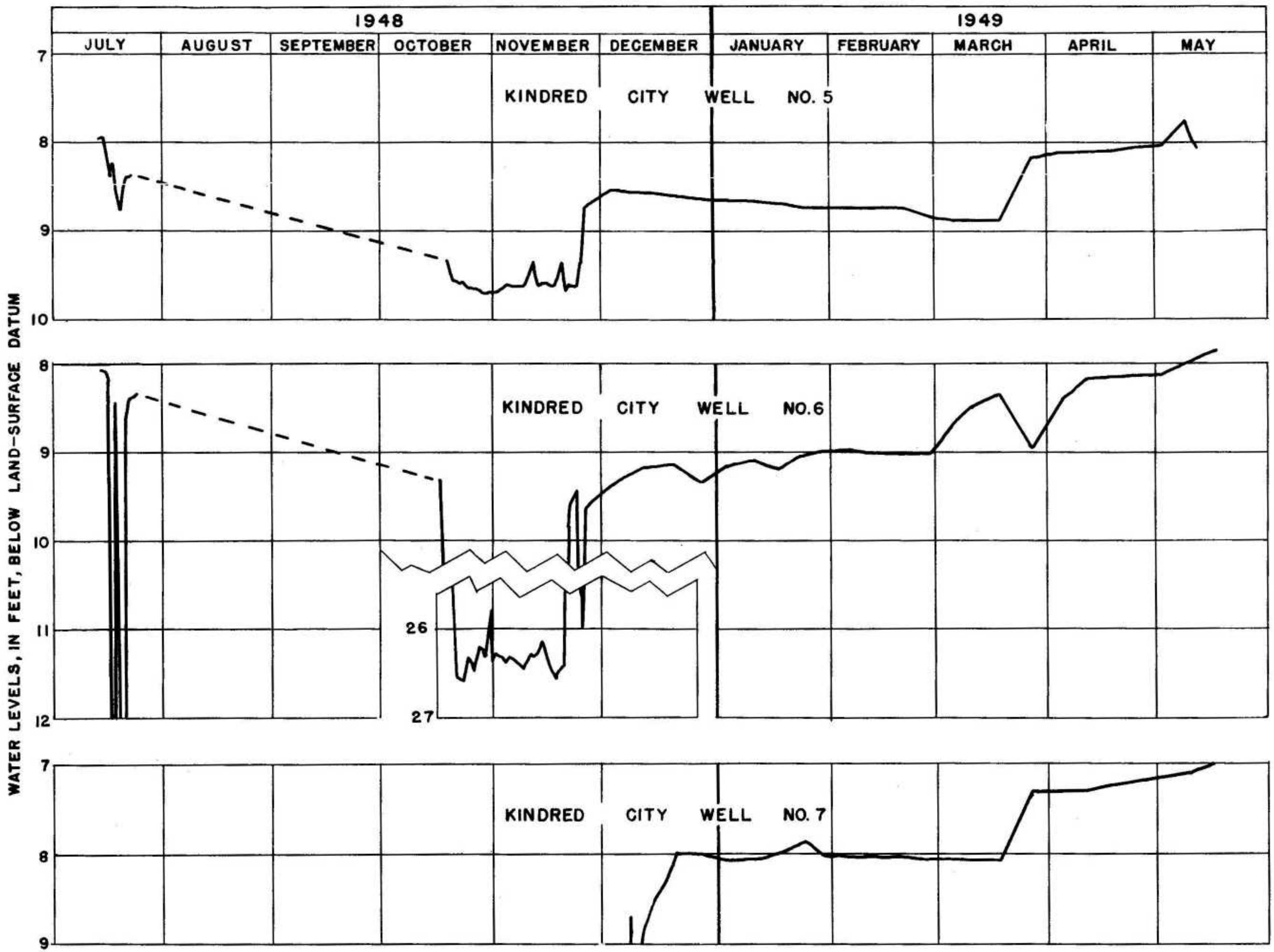


FIGURE 9-HYDROGRAPHS SHOWING WATER LEVEL FLUCTUATIONS IN THREE SHALLOW WELLS AT KINDRED, NORTH DAKOTA.

and therefore was deep enough to escape, for the most part, surface discharge by transpiration and evaporation.

Figure 9 shows available data on water-level fluctuations in three wells in the Kindred area. The records are short and the levels were somewhat affected by pumping. However, a general water-level rise during the latter part of March is shown, indicating recharge to the silt unit of the Lake Agassiz deposits in the area during the spring thaw. The rise in this instance amounted to only about 1 foot, which is much smaller than the rises in the shallow wells near Wyndmere and Fargo for comparable seasons in other years. It is possible that the particular season for which records are available was an unusual one and the water-level fluctuations not of the magnitude ordinarily experienced. However, the discussion given for the water-level fluctuations in the Wyndmere and Fargo areas doubtless applies in general to the shallow aquifer in the Kindred area.

Pumping tests on shallow wells at Kindred

Between July 13 and 28, 1948, pumping tests were run on Kindred City well 6, and well 5, 86 feet south, was used as an observation well. Several pumping periods were involved in this test. The first period, of only a few hours' duration, was principally to determine at what rate the well could be pumped. The second period lasted for about 24 hours, and water-level measurements were made during this pumping period and for approximately 24 hours following it. At the end of the 24-hour recovery period, it was felt that the data obtained were not sufficient for interpretive purposes and another pumping period was begun. The pump was run for approximately 48 hours, and water-level measurements were continued over an extended recovery period.

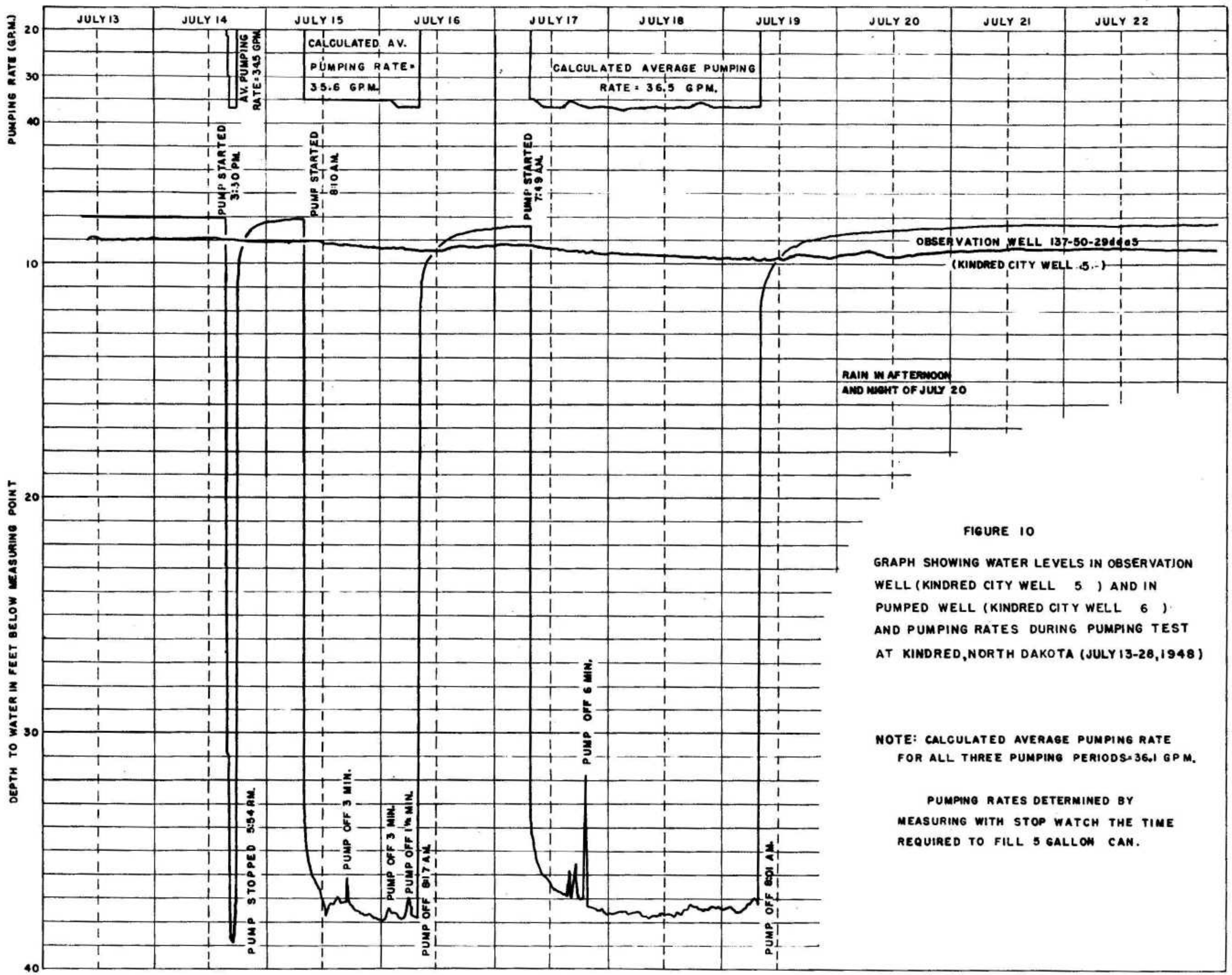


FIGURE 10

GRAPH SHOWING WATER LEVELS IN OBSERVATION WELL (KINDRED CITY WELL 5) AND IN PUMPED WELL (KINDRED CITY WELL 6) AND PUMPING RATES DURING PUMPING TEST AT KINDRED, NORTH DAKOTA (JULY 13-28, 1948)

NOTE: CALCULATED AVERAGE PUMPING RATE FOR ALL THREE PUMPING PERIODS = 36.1 GPM.

PUMPING RATES DETERMINED BY MEASURING WITH STOP WATCH THE TIME REQUIRED TO FILL 5 GALLON CAN.

Figure 10 shows the water levels in the pumped well and in the observation well, and the pumping rates during the period involved.

Computations of transmissibility were made from data on the recovery of the water level in the pumped well after the last pumping period and data on the water levels in the observation well during the last pumping period. In making the computations, corrections were made only for the effects of the previous pumping periods. No corrections were attempted for partial screening of the aquifer at the pumped well, for the effects of natural water-level fluctuations, or for other factors that might introduce small errors, because it was felt that insufficient data were available to justify the procedures necessary, and also because the preliminary results obtained did not indicate **that** the refinements could increase the accuracy of the computations.

Figure 11 is a semilog plot of the residual drawdown in Kindred City well 6 after the last pumping period against

$$\frac{t_1 \cdot t_2 \cdot t_3}{t_1' \cdot t_2' \cdot t_3'}$$

, where t = time since pumping started, t' = time since pumping stopped, and the subscripts **refer** to the respective pumping periods used in the calculations. For certain ideal conditions, this plot would approach a straight line passing through the origin as values of t_3' become sufficiently large.

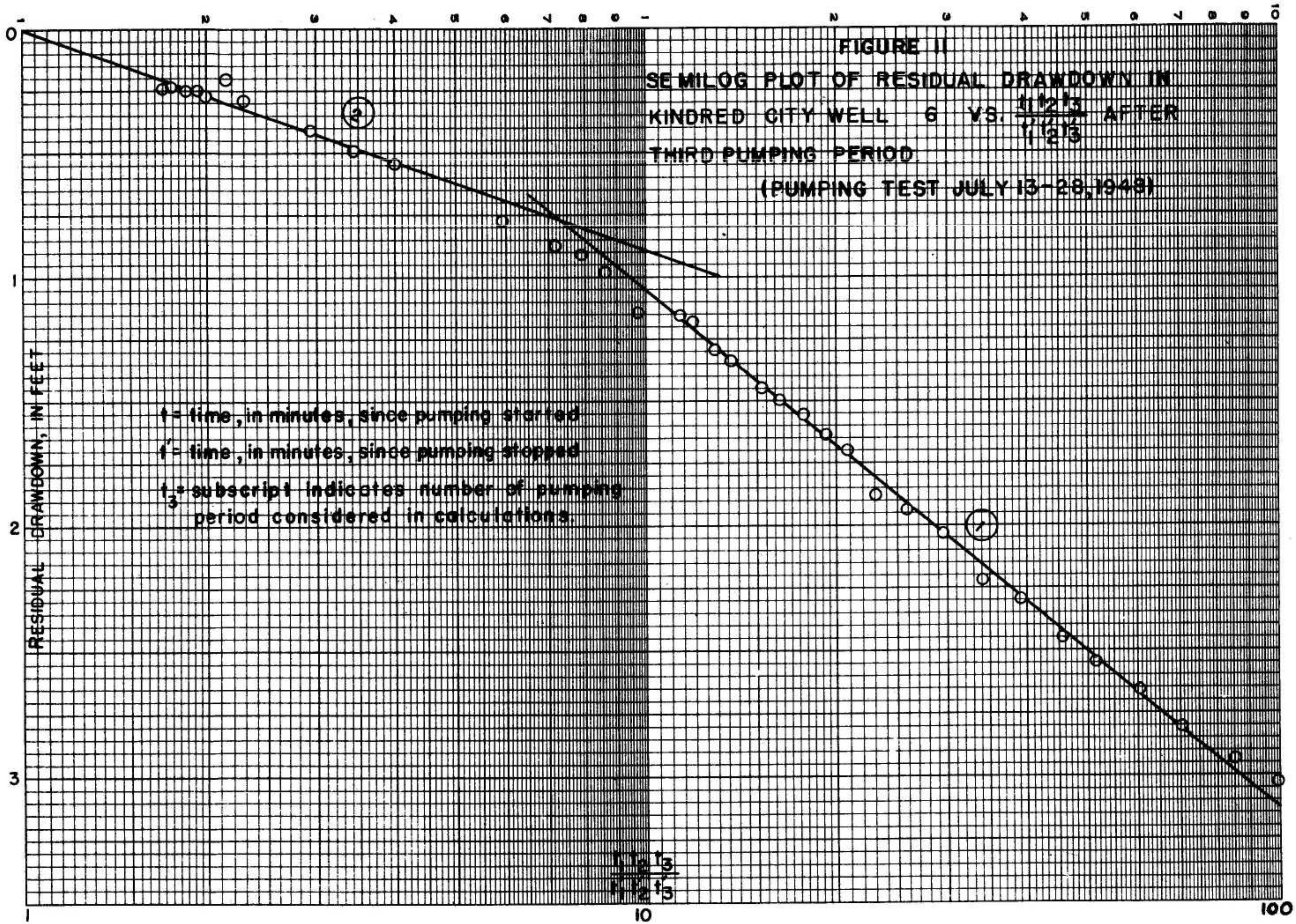


FIGURE 11
SEMILOG PLOT OF RESIDUAL DRAWDOWN IN KINDRED CITY WELL 6 VS. $\frac{t_1 t_2 t_3}{t'_1 t'_2 t'_3}$ AFTER THIRD PUMPING PERIOD
(PUMPING TEST JULY 13-28, 1948)

The transmissibility could then be computed by the equation

$$T = \frac{264\ Q}{\Delta s'}$$

where T = coefficient of transmissibility, gpd/ft.

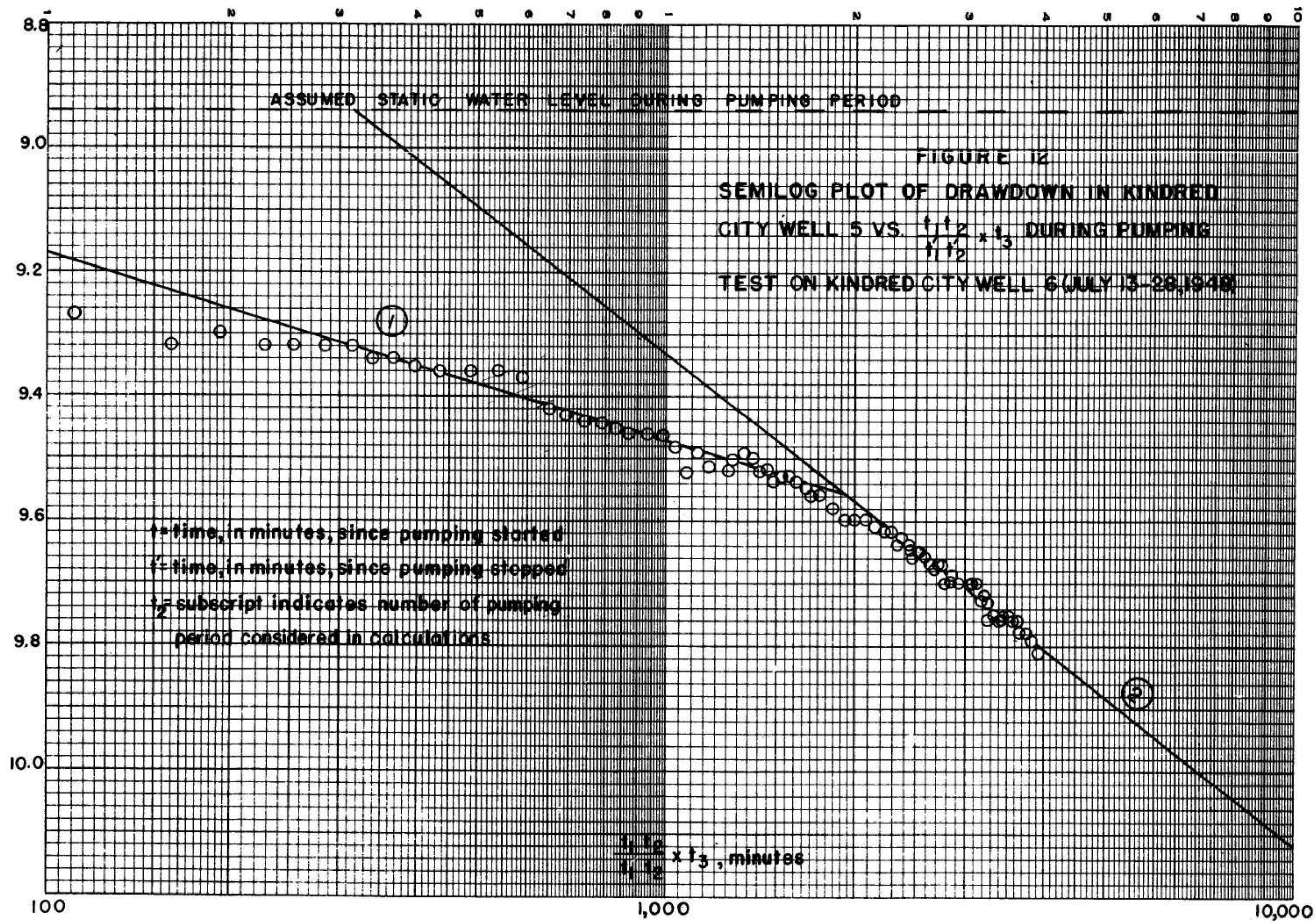
Q = pumping rate, gallons per minute

$\Delta s'$ = change in residual drawdown over 1 log cycle.

The plot in figure 11 does not form one straight line as would happen under the ideal conditions upon which the formula is based, and it is possible to draw two straight lines as indicated. It is believed that the nature of the plot is the result of slow draining of the water-bearing materials during recovery. The material composing the aquifer is fine to very fine sand and silt, and very slow drainage and refilling of the materials would be expected. Examples of the type of recovery curve to be expected under these conditions have been described by Jacob. 29/

On the assumption that the reason for the failure of the data to plot as a straight line is as stated above, the coefficient of transmissibility should be computed from line 1 of the graph, or $T = \frac{264 \times 36.1}{2.07} = 4,604$, or T = 4,600 gpd/ft approximately. Line 2 is based upon scanty data, and it is likely that if additional data were at hand the points would form a curved line into the origin instead of the straight line as drawn. It is shown here only as a possible interpretation of the available data.

29/ Jacob, C. E., Recovery method of determining permeability, empirical adjustment for, U. S. Geol. Survey mimeographed report, 1945.



ASSUMED STATIC WATER LEVEL DURING PUMPING PERIOD
FIGURE 12
SEMILOG PLOT OF DRAWDOWN IN KINDRED CITY WELL 5 VS. $\frac{t_1 t_2}{t'_1 t'_2} \times t_3$ DURING PUMPING
TEST ON KINDRED CITY WELL 6 (JULY 13-28, 1949)
t = time, in minutes, since pumping started
t' = time, in minutes, since pumping stopped
t_2 = subscript indicates number of pumping period considered in calculations
$\frac{t_1 t_2}{t'_1 t'_2} \times t_3$, minutes
8.8
9.0
9.2
9.4
9.6
9.8
10.0
100
1,000
10,000

Figure 12 is a semilog plot of drawdown in the observation well (Kindred City well 5) during the last pumping period against $\frac{t_1 \times t_2}{t_1' \times t_2'} \times t_3$, where the symbols and subscripts have the same meaning as in the previous example. This plot may also be interpreted to consist of at least two straight lines. The possibility that this plot could represent the influence of an impermeable boundary 30/ was considered but was discounted in view of the results obtained from the recovery curve (see fig. 11) and the observed geologic conditions. The coefficients of transmissibility and storage as computed by the usual methods 31/ from line 1 are T = 30,742 gpd/ft and S = 0.0147, respectively.

This computed value of T seems much too high for the material composing the aquifer and the results obtained from the recovery curve. Also, the value of S appears to be much too low for water-table conditions and much too high for artesian conditions. Similar computations from line 2 give T = 12,218 gpd/ft and S = 0.107.

Although more nearly the expected values, the coefficient of transmissibility is still not compatible with that computed from the recovery curve.

It is believed that the plot of figure 12 shows the result of slow drainage of the materials during the pumping period, especially in the area between the observation well and the pumped well. This would cause the water level in the well to fall more rapidly during

30/ Ferris, John G., Ground-water hydraulics as a geophysical aid: Michigan State Dept. Cons. Tech. Rept. 1, 1948.
31/ Jacob, C. E., Drawdown test to determine effective radius of artesian well: Am. Soc. Civil Eng. Trans., pp. 1047-1064, 1947.

the very early part of the pumping period than if instantaneous and complete drainage occurred. Also, after the first rapid lowering had occurred, the continued addition of water through delayed drainage would tend to cause the subsequent rate of lowering to be less than would occur with instantaneous, complete drainage. This would cause the computed values of T to be too high and the values of S to be too low, as they are believed to be in this case. Values of T as computed from figure 12 are therefore discredited in favor of that computed from the recovery curve, and the computed values of S are also discredited as being too low, at least for ultimate values of this coefficient.

Another possible explanation for the behavior of the water levels and a condition that might yield comparable results was considered, as follows:

The upper part of the silt unit in the vicinity of the wells is composed of clayey silt that is less permeable than the underlying fine sand and therefore would produce a partly effective confining bed. At the time of the pumping test the water level was somewhat above the bottom of the silty material. When pumping began, the water level near the well would be drawn below the silt, and water would be yielded to the well largely by rapid drainage of the sands in the immediate vicinity of the well. At some distance from the pumping well, and at the observation well, the water level would still be in the silts, which would be yielding water more slowly. As pumping continued, the cone of depression would deepen and expand so that the contact between the cone of depression and the confining silt would be continually moving outward from the well.

An artesian, or at least a semiartesian, condition would exist at the beginning of the pumping, and there would be a change from artesian to water-table conditions as pumping continued, thus producing an ever-increasing effective coefficient of storage.

If the process were exactly reversed during the recovery period, however, the effective average coefficient of storage would be ever diminishing until the water level in the pumped well reached the bottom of the confining bed, after which it would remain constant at its initial value, provided, of course, that other complicating factors were not present. This condition, however, would produce a curve that would approach the origin with a curvature opposite that shown in figure 11. It seems most likely, therefore, that the failure of the curves in figure 12 to give results compatible with the other data and the failure of the plot in figure 11 to yield a straight line passing through the origin are due principally to slow drainage of the unwatered materials during pumping and to correspondingly slow refilling of the materials during the recovery period, although some effects of partial confinement may also be included.

The final pumping test on well 6 was made over an extended period of time. The pump was started on October 18 with a pumping rate of 25 gpm. On October 20 this pumping rate was reduced to about 23 gpm., and pumping at this rate was continued without interruption until November 19. Daily water-level measurements were made in the pumped well and in the observation well during this period, and the results are shown in figure 9.

During the interval from December 8 to 11, 1948, a pumping test was made on the newly constructed city well 7. The well was pumped

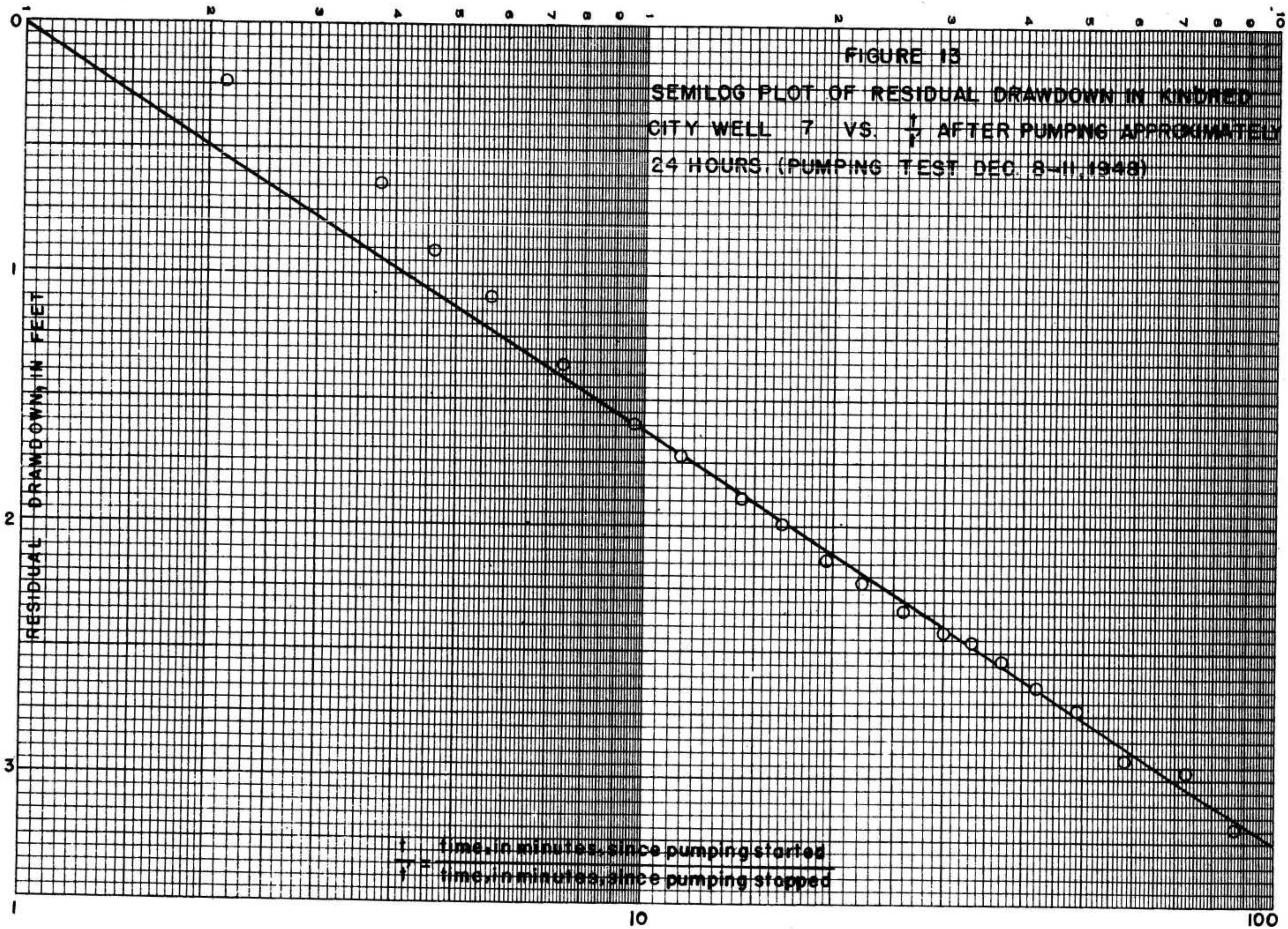


FIGURE 13
SEMILOG PLOT OF RESIDUAL DRAWDOWN IN KINDRED CITY WELL 7 VS. t/t' AFTER PUMPING APPROXIMATELY 24 HOURS. (PUMPING TEST DEC. 8-11, 1948)
RESIDUAL DRAWDOWN, IN FEET
0
1
2
3
1
10
100
t/t' = time, in minutes, since pumping started / time, in minutes, since pumping stopped

approximately 24 hours at an average rate of 26.1 gpm., and water-level measurements were made during the pumping and the ensuing recovery period. No observation wells in the vicinity of the pumped wells were available for measurement during this test. The recovery curve plotted on semilog paper is shown in figure 13. The coefficient of transmissibility computed from this plot is 4,250 gpd/ft, which is in reasonably good agreement with the value of 4,600 gpd/ft obtained from the computation from figure 11 for the test on city well 6.

Specific capacities of Kindred wells

The "specific capacity" of a well is its yield per unit of drawdown of the water level in the well, generally expressed as gallons a minute per foot of drawdown. Thus, the specific capacity of a well that yields 100 gallons a minute when the water level in the well is lowered 20 feet is $\frac{100 \text{ gpm}}{20 \text{ ft}} = 5$ gpm/ft. Because the drawdown in a well increases as pumping continues, the specific capacity is only an approximate quantity, and it is convenient for comparative purposes to use the drawdown after a 1-day pumping period in computing the specific capacity.

The 1-day specific capacity for well 6 is computed to be approximately 1.2 gpm/ft pumping 55.3 gpm., and that for well 7 is computed to be approximately 0.84 gpm/ft pumping 26.1 gpm at the time the pumping tests were made.

The specific capacities of the wells are very low, considering the transmissibilities involved. This probably is due to the head loss through the fine screens, which were necessary in the construction of the well, and other hydraulic head losses; therefore it would be expected that the specific capacities would be somewhat higher for lower pumping rates.

Storage

The test drilling was not extensive enough to outline exactly the areal extent of the shallow-sand aquifer of the silt unit near Kindred. However, from the apparent mode of origin of the sands and from the data obtained from the test holes, it seems likely that they are quite widespread in the area from Kindred south to the delta escarpment. The sands are not everywhere present, but it is estimated that they are present in perhaps three-quarters of this area. The sands should also be present north of Kindred, but they would be finer and siltier and less general in occurrence at greater distances from the delta margin.

The following calculation may be helpful in estimating the amount of water stored in the sands. Assuming an effective long-term specific yield of 0.20 for the sands, it is computed that the amount of recoverable water stored in each foot of thickness of the sands over a 40-acre tract would amount to 43,560 x 40 x 7.5 x 0.20 = 2,613,600 gallons. If the water requirements of Kindred are about 40,000 gallons a day, the total annual use would amount to 40,000 x 365 = 14,600,000 gallons, which is equivalent to the amount of water obtained by unwatering about 5.6 feet of sands over a 40-acre tract. Inasmuch as the areal extent of the sands greatly exceeds 40 acres, the water stored in them would be correspondingly larger. It is believed, therefore, that the sands contain adequate stored water to supply the city through several seasons of dry weather without benefit of normal recharge.

Till and associated glacioaqueous deposits

Till and associated glacioaqueous deposits underlie the Lake Agassiz deposits throughout the area. In the three test holes that penetrate these deposits in and near Kindred they were about 160 to 190 feet thick. In the two test holes drilled near the margin of the delta they were only about 100 feet thick. There appears to be considerable variation in the elevation of the bottom of the deposits, probably resulting from an uneven land surface upon which the till was deposited.

The till consists largely of light- to dark- gray calcareous clay mixed with varying proportions of sand, pebbles, and boulders. The coarser materials consist of shale, limestone and dolomite, and crystalline rocks. Sand and gravel intimately associated with the till represent deposits of glacial meltwaters (glacioaqueous), generally of glacial streams (glaciofluvial), but perhaps also of glacial ponds and lakes (glaciolacustrine). These glacioaqueous deposits vary widely in degree of assortment, some of them containing 20 or 30 percent or more of silt and clay and others being relatively free of fine materials. They are found at the top and at the base of the till and at various horizons within it. The bodies are in general small, lenticular, and discontinuous, and it is very difficult to determine the presence or absence of any particular aquifer at a given spot in advance of drilling. Nevertheless, one or more aquifers are generally encountered throughout the area, and many of the farm wells are developed in these deposits.

The glacioaqueous aquifers may be quite permeable, especially where composed essentially of coarse sand and gravel, and wells tapping these aquifers may have very high yields. However, the materials composing the aquifers may be entirely encased in impermeable materials so that essentially no recharge can reach the aquifer, or at best it can enter very slowly. As a consequence, if the areal extent of the aquifer is small and the pumping rate high, water levels will fall rapidly, and the well may fail within a short time. The larger the aquifer, of course, the longer it will take to unwater it at a given pumping rate, and the better the chance that it will be accessible to recharge at a substantial rate.

It has been demonstrated through water-level records that the aquifers associated with the till in the Fargo area 32/ are interconnected so that the till and associated glacioaqueous materials as a unit have a transmissibility of about 1,000 gpd/ft. If the glacioaqueous materials in the Kindred area are interconnected as they apparently are in the Fargo area, it would be expected that supplies from wells on the order of 50,000 to 70,000 gallons a day would be supported for many years, provided that wells were spaced sufficiently far apart to avoid local overdevelopment. On the other hand, available evidence from the test holes and from wells in the area suggests that interconnection of the glacioaqueous materials is not so well developed in this area as in the Fargo area, and that the aquifers are much smaller. For these reasons the aquifers might be unwatered quite rapidly, and wells producing heavily from them might fail within a comparatively short time.

32/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., Geology and ground-water resources of parts of Cass and Clay Counties, N. Dak. and Minn., U. S. Geol. Survey mimeographed report, pp. 70-84, 1949.

It seems unlikely that wells of capacities of several hundred gallons a minute could be obtained in any of the glacioaqueous aquifers encountered during the test drilling.

Glacioaqueous beds of sand or gravel sufficiently well assorted to yield adequate water supplies for farm wells were encountered in four of the five test holes that penetrated the till and associated glacioaqueous deposits in the Kindred area (see fig. 5). However, only one bed appears to be thick enough to merit consideration as a possible source of municipal supply. It was about 50 feet thick and was penetrated in USGS test 23 at the base of the formations, between 225 and 275 feet below the land surface. Considerable clay was mixed with the sand and gravel, and several large boulders were encountered in the lower half of the bed. Nevertheless, the pebbles were moderately well rounded and made up largely of hard rock fragments rather than shale, indicating that the material was transported considerable distances by water. This means that the chances are good that the deposit is rather extensive and that on the whole it is well sorted.

In USGS test 24 the 5 feet of gravel containing considerable clay, from 220 to 225 feet below the surface, may represent the same bed. It seems likely that Kindred well 1, which is reported to be 235 feet deep, obtains its water from this aquifer. USGS test 25, a quarter of a mile west of Kindred, did not encounter a glacioaqueous bed below a depth of 180 feet, and it appears that the aquifer is not present there. The only information available concerning the quantity of water that might be available from the aquifer is from well 1, which is said to yield a maximum of only 6 gallons a minute.

However, the aquifer appears to be much thinner at the location of the village well than it is at the location of USGS test 23, and a much higher yield might be obtained at the latter location. Special interest might be attached to the aquifer because of the possibility of obtaining a stand-by well in it. Because the two village supply wells (nos. 6 and 7) are in the shallow aquifer in which water levels fluctuate rather quickly in response to changes in local precipitation, a stand-by well in the deeper aquifer would be especially valuable in the event of an extended period of dry years.

Cretaceous shale or older Pleistocene lake clay

The till and associated glacioaqueous deposits are underlain at Kindred and presumably throughout the eastern part of the area by "granite," but at the locations of USGS tests 1R and 2R (see fig. 3) and probably throughout the western part of the area they are underlain by clay, siltstone, and shale. The material was completely penetrated only in USGS test 1R, where it is about 92 feet thick. The clay seems to be interbedded with the siltstone and shale, but occurs chiefly in the upper part of the unit. It is light to dark gray in color, plastic, noncalcareous, and thinly laminated. The siltstone and hard fissile clay or shale are interbedded in thin layers. The coarser particles consist largely of angular quartz grains, with minor amounts of mica, gypsum, dolomite, and pyrite. One section of a core about 3 inches thick was argillaceous dolomite. Bedding planes show secondary cyrstals of dolomite, pyrite, and gypsum. Secondary dolomite and ankerite are rather abundant, but there is little or no calcite, and niether core nor drill cuttings effervesce with dilute hydrochloric acid. The siltstone and shale resemble the material encountered at Wyndmere that was questionably correlated with the Benton formation of Cretaceous age. 33/ However, no fish scales were found in the material near Kindred, and plant fragments were the only fossils found. The plastic clay, although apparently interbedded with the siltstone and shale near Kindred, is unlike any of the Benton (?) formation at Wyndmere. On the basis of present information it does not seem possible to determine whether a part or all of this formation is to be correlated with the older Pleistocene lake clay found in the Fargo area, 34/ or with the Cretaceous shale.

So far is known, the formation is not water bearing in the Kindred area.

<u>Dakota sandstone</u>

The Dakota sandstone, of Upper Cretaceous age, is one of the most widespread aquifers in the world. It is present in parts of nearly a dozen States. So far as is known, it underlies the entire State of North Dakota, except in the Red River Valley area where it has been at least partly removed by erosion or modified by glacial activity. It is a fine-grained, grayish-white to buff sandstone, which may be interstratified with clay or shale. It is famous for the high pressures under which water occurred in it in the early years of its development and for the relatively large flows obtained. It is not a highly permeable formation, however, and only small flows are obtained where the artesian pressure is low.

33/ Dennis, P. E., Akin, P. D., Jones, S. L., Ground water in the Wyndmere area, Richland County, N. Dak., Manuscript rept. to be mimeographed as North Dakota Ground-Water Studies No. 13.
34/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., op. cit., pp.26-29.

As an aquifer in North Dakota the Dakota sandstone is of most importance in the south-central part of the State. Elsewhere in the State it is so deeply buried and the water is so highly mineralized that drilling to it is generally impractical.

The Dakota sandstone is certainly absent at Kindred and in the eastern part of the area described in this report. Whether it is present in the western part is not known. At the present time there are no known flowing wells in the area, although Hall and Willard 35/ and Simpson 36/ reported some flowing wells, chiefly in the western part of the area. These wells have now ceased to flow and probably no others are obtainable anywhere within the area.

"Granite"

The basement rock of the area consists of undifferentiated crystalline igneous and metamorphic rocks locally termed "granite." Little is known of their composition except what can be learned through the examination of well cuttings, as the rocks do not crop out in or near the area.

A zone of decomposition exists at the surface of the "granite," and drilling in this zone in the test holes was stopped before fresh rock was reached. Drilling usually progressed a maximum of 20 feet in this zone. The decomposed material derived from the "granite" is reddish brown, greenish gray, or white. It consists of a greasy-feeling clay and fine to coarse angular quartz crystals. The presence

35/ Hall, C. M., Willard, D. E., Description of the Casselton and Fargo quadrangles: U. S. Geol. Survey Geol. Atlas Casselton-Fargo folio no. 117, p. 7, 1905.
36/ Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 8, 1929.

of fragments of shale, granite, and basic igneous rock in some of the well cuttings from the "granite" contact suggests that the upper part of this zone was reworked by the glacier and some glacial material was incorporated within the decomposed zone.

Only four of the test holes in the Kindred area entered the "granite," nos. 23, 24, 25, and 1R.

Zones of fracture within or at the surface of the "granite" have yielded small supplies of water in some areas. However, no wells in this area derive their water from the "granite," and it is generally considered useless to drill deeper when the zone of decomposed "granite' is reached.

QUALITY OF GROUND WATERS IN THE KINDRED AREA

Chemical analyses of waters from 20 wells in the Kindred area are given in the following table. Of these the Alsage, Echre, Morgan, and Alsager wells are in the vicinity of Walcott, the Melvin Simmons well is 8 miles west of Kindred, and the other wells are in or within a mile of Kindred.

The waters are of moderate to high concentration and differ considerably in chemical composition. The dissolved solids range from 302 to 3,260 parts per million; the total hardness as $CaCO_3$ ranges from 82 to 832 parts per million. Some of the waters were of the calcium sulfate type; in others the mineral matter was largely sodium chloride or bicarbonate.

In general, the waters from aquifers in the Lake Agassiz deposits are less mineralized than waters from the glacioaqueous aquifers. The dissolved solids in waters from these shallow wells (20 to 54 feet deep) range from 302 to 1,070 parts per million, the total hardness from 82 to 470, sulfate from 78 to 363, chloride (if present) from a trace to 32, bicarbonate from 310 to 515, calcium and magnesium from 111 to 116, and sodium and potassium from 147 to 159 parts per million. Iron is rather high in some of these waters.

Waters from wells in the glacioaqueous deposits in the till are generally more highly mineralized. However, the dissolved solids in most of the waters were less than 2,000 parts per million. These well waters would be acceptable for most domestic uses even though they are generally very hard.

CHEMICAL ANALYSES OF GROUND WATERS
(PARTS PER MILLION. ABBREVIATIONS: T,

Location number	Owner	Date of analysis	Source of analysis	Depth of Well (feet)	Dissolved solids	Iron (Fe)
136-50	Ole Alsage	2-24-47	a/	...	998	0.2
136-50-	Albert Eckre	4-18-46	c/	...	537	0.1
136-51-19ccl	Ken Morgan	2-22-47	a/	54	302	0.2
136-51-29baa	Delmar Alsager	2-22-47	a/	30	649	6
137-50-20	Eric Erickson	11-33	b/	95	1350	....
137-50-28cbc	Public School	..do..	b/	20	475	0.1
137-50-29aca	Kindred No. 3	11-17-47	a/	78	3260	1.9
137-50-29cac	..do.. No. 4	11-17-47	a/	70	2960	2.7
137-50-29dcal	..do.. No. 2	11-17-47	a/	95	2650	0.2
137-50-29dad4	..do.. No. 6	3-25-49	b/	45	1070	3.2
137-50-29dad4	..do.. No. 6	7-15-48	b/	45	660	1.9
137-50-29dbdl	..do.. No. 1	11-17-47	a/	235	1780	1.5
....do....	..do.. No. 1	11-33	b/	235	1640	0.1
137-50-29dda5	..do.. No. 5	1-29-47	a/	40	886	0.1
137-50-30cda	Herman Olson	11-17-47	a/	180	2040	0.6
137-50-30dad	A & S Grangaard	11-33	b/	105	1300	....
137-51	Albert Piper	12-31-47	c/	...	1020	0.3
137-51-11aad	B. J. Sather	10-10-47	c/	260	1140	3.5
137-51-16a	Ronice Bros.	6-25-48	c/	242	1530	4.5
137-51-25ddd	Peter Boresen	8-17-48	d/	180	....	....
137-51-28	Melvin Simmons	11-33	b/	805	1720	....

a/ State Laboratories Department, Bismarck, N. Dak.
b/ North Dakota State Department of Health, Bismarck, N. Dak.
c/ Refinite Sales Co., Omaha, Nebr.
d/ Water Softener Service, St. Paul, Minn.

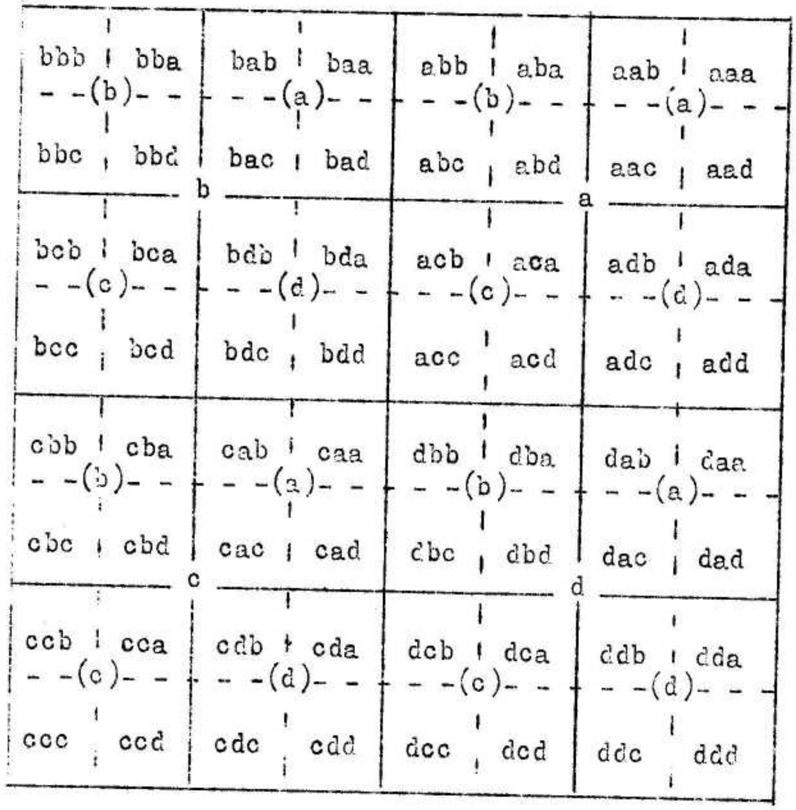
IN THE KINDRED AREA
TRACE: M, MODERATE: H, HEAVY)

Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (C_1)	Nitrate (NO_3)	Total hardness as $CaCO_3$
....	....	....	....	....	340	0	....	271
....	....	....	....	....	142	....	....	....
....	....	....	....	....	0	0	....	135
....	....	....	....	....	78	0	....	249
M	....	....	....	290	T	190	....	350
..do..	....	....	....	350	M	32	....	470
174	101	481	72	615	683	399	....	852
68	47	720	91	307	1340	97	....	362
249	55	398	86	163	1180	157	....	850
57	54	159	0	515	274	4.4	4.4	368
52	49	55	7.2	332	152	7.4	4.3	330
207	55	370	46	159	484	493	....	745
H	0.1	....	....	214	H	510	....	640
82	34	147	19	310	363	0	....	82
56	21	646	0	380	529	562	....	234
M	....	....	0	328	H	170	....	150
....	....	....	....	....	....	....	....	488
....	....	....	....	....	....	....	....	344
....	....	....	....	....	....	....	....	360
....	....	....	....	....	....	....	....	428
M	0.1	....	....	250	H	333	....	310

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based upon the location of the well with respect to the land-survey divisions used in North Dakota. The first number is that of the township north of the base line running along the Kansas-Nebraska State line. The second number is that of the section within the designated township. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections. If more than one well occurs within a 10-acre tract (quarter-quarter-quarter section), consecutive numbers are given to them as they are scheduled. This number follows the letters. Thus, well 137-50-29dad4 is in Township 137 North, Range 50 West, section 29. It is in the southeast quarter of the northeast quarter of the southeast quarter of that section and was the fourth well scheduled in that 10-acre tract. Similarly well 136-51-7ddd (see USGS test 2R, fig. 3) is in the southeast quarter of the southeast quarter of the southeast quarter of sec. 7, T. 136 N., R. 51 W. Numbers for wells not accurately located within the section in the field may contain only one or two letters after the section number, indicating that the locations of such wells are accurate only to the quarter section or the quarter-quarter section, respectively.

The following diagram, showing the method of numbering the tracts within the section, may be helpful to the reader in determining locations of wells shown in the illustrations.



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

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

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
136-50-1aba	Andrew Johnson	97	3	Drilled	1944
136-50-1dda	Christ Olerud	90	3	Jetted	1917
136-50-2aba	Sophus Grinaker	112	2	..do..	1910
136-50-2bbb	Karl Toppen	100 +	3	Driven	Old
136-50-2cbc	Nipstad Bros.	....	2	Drilled	Old
136-50-3ddc	M. A. Severson	70 +	18	Bored	1929
136-50-5acc	Chris Erickson	100 +	....	..do..	1926
136-50-5cbc	Mrs. Sorrbel	....	3	Drilled	Old
136-50-5cca	Theodore Erickson	200	3	...do...	1942
136-50-6ddc	Melvin Erickson	200	3	Jetted	1938
136-50-7cac	John Blomlie	40	12	Bored	Old
136-50-7ccc	Graff Bros.	74	18	..do..	1946
136-50-8bbb	Ted Lee	113	3	Jetted	1935
136-50-9acd	Ole Osgard	....	3	.....	.....
136-50-10bbb	A. P. Hertzgaard	140	....	Drilled	.....
136-50-10cbb	Palmer Ellingson	24	48 x 48	Dug	1934
136-50-10cdc	Bernard Bakke	Deep	2	Drilled	1933
136-50-11add	Joe Ronning	100 +	3	...do...	.....
136-50-13cbb 1/	....	245	....	....	.....
136-50-14aba	Ole Keene	100	3	Jetted	Old
136-50-15aaa	E. B. Anderson	114	3	..do..	1888

Use of water: U, used, D, domestic;
S, stock; M, municipal.

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
22	9-47	DS	Water reported good, hard.
....	....	DS	Aquifer reported as sand from 85 to 90 feet; water reported good, hard.
4	9-47	DS	Water reported good, hard.
15	9-45	S	Do.
....	....	DS	Water reported very hard; turns red on standing.
....	....	S	Aquifer reported fine to medium sand at 70 feet; well pumped dry easily.
....	....	DS	Water reported very hard, unfit for laundry use; well pumped dry easily.
....	....	....	Water reported good, hard.
....	....	DS	Water reported good, not too hard; adequate for watering 75 head livestock.
10	7-11-46	DS	Water reported medium hard, good; adequate.
26	9-11-47	D	Reported inadequate during drought years.
10.97	9-11-47	D	Sand reported from 0 to 20 feet. Water reported good, hard. See log.
30	9-47	DS	Aquifer reported as sand and gravel from 110 to 115 feet. Water reported good, hard; adequate for watering 200 head livestock.
....	....	DS	
30	9-12-47	DS	Water reported good; adequate for 80 head livestock.
9.15	9-12-47	S	Aquifer reported as shale gravel from 20 to 24 feet.
....	....	DS	Water reported good, soft; adequate for 50 head livestock.
....	....	DS	Water reported hard, turns brown on standing; adequate for 75 head livestock.
8	....	....	Water reported hard.
10	9-12-47	DS	Water reported good, hard; adequate for 90 head livestock.
35	9-12-47	DS	Water reported good, hard; adequate for 32 head livestock.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches	Type	Date completed
136-50-15dbb	Hjelmer Toppen	155	3	Jetted	1935
136-50-15dca1	P. O. Eckre	116	3	...do...	1890
136-50-15dca2	.....do.....	122	3	...do...	1920
136-50-18bbb	Albert Olson	20	36 x 36	Dug	....
136-50-18ddc	Marcus Lee	282	3	Drilled	1940
136-50-22aaa	Fred Flaa	130	2	Jetted	Old
136-50-22bbd1	Theodore Goldberg	26.8	40	Dug	1930
136-50-22bbd2	.....do.....	.....	....	..do..	1911
136-50-22dab1	Hugo Anderson	212	3	Jetted	1944
136-50-22dab2	.....do.....	265	3 to 2	..do..	1922
136-50-23acc	Clayton Blilie	....	2	Drilled	Old
136-50-24abb	Arnold Lahren	9.3	36 x 36	Dug	....
136-50-24abd	.....do.....	87	2	Jetted	1944
136-50-24dcb	....	....	2	Drilled	....
136-50-25ccb	B. Goldberg	247	2	Jetted	1942
136-50-28dcb1	Ted Amundson	8.7	48 x 48	Dug	1941
136-50-28dcb2	.....do.....	14.7	48 x 48	..do..	1930
136-50-29dcc	Dolman Alsaker	.....	....	Driven	....
136-50-30abd	Pete Kaind	15.9	48	Dug	1935
136-50-30dab	Andrew Strand	10	....	..do..	1937
136-50-31cdc	A. H. Bakke	67	1½	Driven	1916
136-50-31dcc	Nels Bakke	80	1½	...do...	1917?

Depth to water (feet below land surface	Date of measurement	Use of water	Remarks
30	1947	DS	Aquifer reported as gravel from 130 to 135 feet. Water reported good, hard; adequate for 130 head livestock.
12	1946	DS	Water reported good, hard; adequate for 140 head livestock during drought years.
12	1938	D	Screen in bottom. Water reported good. See log.
3	9-19-47	D	Water reported good, soft.
....	....	DS	Water reported good, soft, no iron; adequate for 70 head livestock.
....	....	DS	Aquifer reported as sand from 128 to 130 feet. Water reported good.
25.4	9-11-47	S	Water reported good, hard; inadequate.
10	9-11-47	U	
15	1947	S	Aquifer reported as sand from 209 to 212 feet.
24.30	9-11-47	DS	Aquifer reported as sand. Water reported good, hard.
3.77	9-12-47	S	Water reported good.
4.68	9-11-47	U	
5	9-12-47	DS	Aquifer reported as gravel from 85 to 87 feet. Water reported good.
Flow	9-11-47	....	
5.86	9-11-47	....	Aquifer reported as sand from 240 to 247 feet. Water reported to have alkaline taste; adequate for 70 head livestock.
3.86	9-10-47	DS	Water reported good, soft.
11.45	9-10-47	S	Sand from surface to bottom of well. Hit clay at bottom. Water reported hard.
....	....	DS	Water reported good, hard. See water analysis.
8.59	9-10-47	DS	Well in sand. Water reported good. Always adequate supply.
8.27	9-10-47	S	Well in sand. Water reported good, hard.
6	9-10-47	DS	Water reported good, hard; scaler sandpoint. Adequate for about 2,000 gpd. during threshing season.
....	....	DS	Do.

(see footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
136-50-31ddd	Sigrud Winger	12.3	40 x 40	Dug	1903
136-50-32aaa	D. P. Thue	52	2	Driven	1947
136-50-32bba	Ole Jordheim	60	2	..do..	1947
136-50-32cda	Carl Erickson	60	2	Drilled	1946
136-50-32ddb	Peterson	....	1¼	....	....
136-50-34aaa	Oscar Tingen	12.7	40 x 40	Dug	Old
136-50-34aac1	.....do.....	30	1¼	Driven	1947
136-50-34aac2	.....do.....	30	1¼	..do..	1947
136-50-34cca1	Rockstad	....	....	....	....
136-50-34cca2	...do...	8.35	....	....	....
136-50-35acc	Albert Bakko	96	3	Jetted	1946
136-50-35cac1	J. C. Nelson	173	3	Drilled	Old
136-50-35cac2	C. F. Turmo	140	3	Jetted	....
136-50-35cac3	Town of Walcott	....	96	Drilled	Very old
136-50-35cbd	Julius Turner	13.4	40	Dug	....
136-50-35dab	William Oestriech	20	48 x 48	..do..	....
136-50-35dba	School	150	3	Jetted	Old
136-50-35dbb	Town of Walcott	100	....	Drilled	Old
136-50-35dbc1	Albert Rockstad	100 +	....	...do...	1935
136-50-35dbc2	Stevens	105	2	Jetted	1944
136-51-aaab	Norris Hogan	105	3	..do..	1943
136-51-2ccc	Julius Offerson	....	48 x 48	Dug	Old
136-51-2dcc	Peter Overboe	183	3	Jetted	1940
136-51-3cac	Fred Judisch	180	3	..do..	Old

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
4.5	9-10-47	DS	Well in sand. Clay at bottom. Water reported good.
11.95	9-10-47	DS	Sand from 0 to 12 feet. See log to 19 feet.
6.19	9-10-47	DS	Aquifer reported as sand. Water reported good, hard.
....	....	DS	Aquifer reported as sand from 50 to 60 feet. Water reported good, hard, See log.
10.15	9-10-47	....	
8.00	9-10-47	DS	Water reported good; inadequate for all farm uses.
....	....	S	Water reported good.
....	....	D	Water reported good. (Sufficient) Adequate supply for domestic use.
....	....	S	
6.35	9-10-47	....	
....	....	D	Reported inadequate; unfit for laundry use.
....	....	D	Water reported good, soft.
....	....	DS	Water reported good, hard; turns brown on standing. Adequate for 10 head livestock.
4.25	9-11-47	S	
7.55	9-11-47	S	
15	9-11-47	S	Aquifer reported as sand from 0 to 20 feet. Water reported alkaline; unfit for laundry use; adequate for 18 head livestock.
10	9-11-47	D	Water reported hard.
6	9-8-47	M	Water reported good, hard. Used to flow.
....	....	DS	Reported inadequate; turns brown on standing.
6	9-11-47	D	Aquifer reported as sand from 100 to 105 feet. Water reported good, hard.
85	1945	DS	Water reported good; supply adequate
11.4	9-17-47	DS	Water reported good, hard.
Flow	9-17-47	DS	Water reported good, soft.
....	9-18-47	DS	Water reported good, soft; supply inadequate.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches	Type	Date completed
136-51-3dcb	Paul Wise	....	48 x 48	Dug	Old
136-51-4adb	George Lee	19	48 x 48	..do..	1944
136-51-4dcc	Carl Lybeck	35	2	Jetted	1947
136-51-5aba	USGS test 1R	363	5	Drilled	1947
136-51-6aac	Albert Hasson	60	2	Jetted	1946
136-51-6bbb	G. Dukek	13.9	36	Dug	Old
136-51-6dad	John Sweggan	....	2	Jetted	....
136-51-7ddd	USGS test 2R	370	3	Drilled	1947
136-51-8baa	Clifford Vengsness	70	2	Driven	Old
136-51-8ccc	Mabel Fjelstad	57	2	Jetted	1943
136-51-8daa	Julian Reistad	70	2	..do..	1946
136-51-9ada	Melvin Grant	66	2	......	1946
136-51-10aad	Bernhard Lee	250	3	Jetted	1938
136-51-11abb	Neilus Iverson	18	36	Dug	1937
136-51-11bbd	Oscar Otterson	22	48 x 48	..do..	1922
136-51-12adc	Tilmonson Estate	210	3	Jetted	1930
136-51-13bba	Oliver Grant	26	....	Dug	Old
136-51-14aaa	Sven Graff	26	36 x 36	..do..	Old
136-51-14dca	Ed Eckre	20	36 x 36	..do..	....
136-51-15ada	Ester Twedt	....	36 x 36	..do..	Old
136-51-17abb	Thomas Hagen	30	2	Driven	Old
136-51-17ccd	George Nettum	52	2	Jetted	1945
136-51-18baa	Graff Bros.	30	36 x 36	Driven	Old
136-51-18ccc	Clarence Anderson	10	....	..do..	Old
136-51-18dbb	Irving White	18	2	Jetted	....
136-51-19aaa	Avery Anderson	....	36	Dug	1945
136-51-19cc1	Ken L. Morgan	54	....	Drilled	1946
136-51-19cc2	.....do.....	30	....	...do...	1947
136-51-19dcc	Gordon Olson	4.5	36 x 36	Dug	....
136-51-20bca	Mrs. Albert Anderson	13.6	36 x 36	..do..	Old
136-51-20daa	H. R. Morgan	....	2	Driven	....
136-51-22aac	J. L. Sandquist	28	24	Bored	Old

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
6.39	9-47	S	Water reported of very poor quality; aquifer reported sand.
10.93	9-13-47	DS	Aquifer reported to be delta sand.
4	5-47	DS	Water reported to be good, soft.
....	....	U	Hole refilled. See log.
....	....	DS	Aquifer reported to be sand.
14.2	9-18-47	S	Water reported good, soft.
....	....	DS	Water reported to be of good quality.
....	....	U	See log.
....	....	DS	Water reported good, medium soft.
12.22	9-18-47	....	Aquifer reported to be sand from 40 to 57 feet.
8	9-46	DS	Aquifer reported to be sand. Water reported good, soft.
6	8-46	DS	Aquifer reported as sand. Water reported good, soft.
....	....	DS	Water reported good, hard.
10	9-47	DS	Water reported good, hard.
6	9-47	DS	Water reported good; adequate supply.
20	1942	DS	Aquifer reported to be medium fine sand from 175 to 210 feet.
12	9-47	DS	Water reported good, hard.
16	9-47	DS	Do.
14	9-47	DS	Water reported poor, hard.
12.4	9-19-47	D	Aquifer reported as sand. Water is good, soft.
....	....	DS	Aquifer reported as sand.
....	....	D	Aquifer reported as quicksand. Water is good, hard.
Dry	9-18-47	U	Dry well; formerly good, soft water reported.
....	....	DS	Water reported good, soft.
....	....	DS	Water reported good, fairly soft.
....	....	D	Adequate supply.
14	1946	D	Water reported good. See water analysis.
10	1947	S	Water reported good.
2.05	9-18-47	DS	Do.
13.75	9-18-47	S	Water reported hard; supply adequate.
....	....	DS	Water reported hard, good; supply adequate.
20	9-19-47	U	Aquifer reported as dirty sand.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
136-51-23abd	Oscar Braaten	246	....	Jetted	1940
136-51-23bbc	Ingwald Otterson	36	36	Dug	Old
136-51-23ddd	Iver Braaten	279	3	Jetted	1941
136-51-24cbc	S. H. Berg	23	36 x 36	Dug	Old
136-51-26adc	I. E. Graff	250	2	Jetted	1941
136-51-26bcb	Knute Eckre	20	2	Driven	Old
136-51-26cbb	Andrew Otterson	230	2 to 1¼	Jetted	6-1943
136-51-26dbd	Miles Johnson	247	2	..do..	1943
136-51-27aaa	John Braaten	23	2	Driven	1922
136-51-28ddc	Dan Alsager	....	....	..do..	....
136-51-29bba	Delman Alsager	30	1¼	..do..	....
136-51-29bdb	Irvin Swenson	60	2	..do..	Old
136-51-29cdc	E. J. Halbjornis	25	2	..do..	Old
136-51-30ddc	Clarence Hovelson	7.6	36	Dug	....
136-51-31aaa	H. Ulsaker	22	2	Driven	1946
136-51-31abc	Gordon Hagen	30	....	..do..	....
136-51-32bca	Albert Eckre	14	36 x 36	Dug	Old
136-51-32ccc	Henry G. Graff	23	2	Driven	1943
136-51-34dbd	Slemer Jordheim	35	....	..do..	Old
137-50-1bab	Albert Perhus	60	3	Drilled	Old
137-50-1bcb	Mrs. Oliva Perhus	120	3	..do..	1933
137-50-2adb	Knute Stenberg	35	....	Bored	Old
137-50-2b 2/	Alfred Johnson	120	24 to 3	..do..	1932
137-50-2bdd	Mrs. Alfred E. Johnson	187	3	Drilled	1941
137-50-2cdd	Magnus Simonson	60	....	Bored	1941
137-50-2dcc	Harland Thoen	60	18	..do..	Old
137-50-2ddd	Melford Mickleson	138	3	Jetted	1921
137-50-3bdb	Mrs. Emma Bundtzen	85	18	Bored	Old
137-50-3ccb	Harold Hedland	80	12	..co..	1924

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
....	....	....	Aquifer reported as coarse gravel; water reported good.
28.2	9-19-47	DS	Water reported good, medium hard.
....	....	DS	Water reported good, soft.
18	9-19-47	DS	Aquifer reported as quicksand.
20	11-41	DS	Aquifer reported as gravel from 235 to 250 feet.
....	....	DS	Water reported good, hard; supply adequate.
40	6-45	DS	Water reported slightly salty, hard; supply adequate.
15	11-45	....	Aquifer reported as coarse white sand from 245 to 247 feet.
10	9-18-47	DS	Aquifer reported as sand. Water reported good, hard.
....	....	U	Well caved in.
....	....	DS	Water reported good; see analysis.
....	....	DS	Supply adequate.
....	....	DS	Water reported good, soft; supply adequate.
4	9-18-47	DS	
....	....	DS	Water reported good, hard.
....	....	DS	Water reported good; supply adequate.
12.34	9-18-47	U	Water reported good, hard.
2	9-45	D	Do.
....	....	S	Water reported fair; supply adequate.
20	1945	D	Water reported good, soft; supply inadequate.
....	....	DS	Water reported hard.
12	1947	DS	Water reported good, hard.
30	1932	....	Reported inadequate.
30	1946	DS	Aquifer reported as sand. Water reported hard, good.
20	1941	DS	Aquifer reported as medium gravel with fine sand from 55 to 60 feet. Water reported good. See log.
55	1947	D	Reported inadequate.
15	9-11-47	DS	Water reported good, hard.
29.10	9-16-47	U	
....	....	S	Water reported hard; turns brown on standing.

(See footnotes at end of table)

Location number	Owner or Name	Depth of well (feet)	Diameter (inches	Type	Date completed
137-50-3d 2/	M. A. Severson	80	18	Bored	1934
137-50-3ddd 1/	....	470	....	.....	....
137-50-4baa	Ben Lehren	.....	18	Bored	Old
137-50-4cdd	John Eiben	.....	12	..do..	Old
137-50-4dd1 2/	B. M. Grangaard	84	14	..do..	1934
137-50-4dd2 2/	Carl Lohren	177	3	Drilled	1904
137-50-4dda	Clarence Grangaard	.....	12	Bored	Old
137-50-5abb	Jasper Flaa	70	48 x 48	Dug	Old
137-50-5dcc	Carl Lehren	175	3	Drilled	1932
137-50-6bba	August Haugen	130	24	Bored	Old
137-50-6bcc	Bill Plath	70	36	Dug	1917
137-50-6ccd	John Brosell	218	3	Drilled	1936
137-50-6cdd 1/	....	350	.....	....	....
137-50-6dcc	Clarence Jermstad	180	3	Drilled	1938
137-50-7ada	Herman Gust	140	4	Jetted	1917
137-50-7cdd	John Ottis	140	4	..do..	1917
137-50-8caa	Strehlow Estate	140	4	..do..	1917
137-50-8ddd	Richard Braalten	205	3	..do..	1910
137-50-9abb	William Moon	.....	18	Bored	....
137-50-9dcc1	Alvin Sorbel	80	16	..do..	....
137-50-9dcc2	Ingval Sorbel	240	3	Jetted	1914
137-50-10d 2/	Carl Simonson	84	16 to 6	Bored	1932

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
.....	....	S	Reported inadequate.
.....	....	...	No water.
.....	....	S	
.....	....	DS	Water reported good, hard; adequate for 25 head livestock.
27	1939	DS	
24	1904	DS	
33.40	9-16-47	DS	Water reported hard; unfit for laundry use; supply inadequate.
33.40	9-16-47	S	Turns brown on standing; unfit for domestic use.
24	1932	DS	Aquifer reported as sand from 170 to 175 feet. Water reported good, hard; adequate for 125 head livestock.
6	1942	DS	Water reported good, soft.
10	1947	DS	Water reported good, hard; adequate for 75 head livestock.
35	1943	DS	Aquifer reported as gravel from 200 to 218 feet. Water reported good, medium hard.
.....	....	...	White soapstone mixed with sand at 300 to 310 feet. Hardpan above soapstone.
27	1938	DS	Water reported good, medium hard.
20	1917	DS	Aquifer reported as fine gray sand from 136 to 140 feet. Water reported good, medium hard.
20	1917	S	Water reported good, hard; adequate supply.
18	1917	DS	Aquifer reported as fine gray sand from 136 to 140 feet. Water reported good, soft.
6	1943	DS	Water reported good, soft.
14.97	4-16-47	DS	Water reported very hard; unfit for human consumption.
25	1944	S	Aquifer reported as coarse sand from 79 to 80 feet. Water reported hard; unfit for human consumption.
10	1914	D	Aquifer reported as fine sand from 234 to 240 feet. Water reported good, soft. See log.
29	1939	S	Aquifer reported as sand.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)		Type	Date completed
137-50-10d 2/	Carl Simonson	92	16 to 6	Bored	1931
137-50-11abc	Olaf Perhus	105	3	Drilled	1928
137-50-11dbb	W. O. Perhus	109	3	...do...	1928
137-50-13S½ 2/	Henry Trangsrud	128	18 to 5	Drilled and Bored	1933
137-50-13ccc	Lanford Spelhaugh	....	2	Drilled	Old
137-50-14a1 2/	Mota Trangsrud	78	18	Bored	1937
137-50-14a2 2/	....,do.....	100	3	Drilled	1934
137-50-14abb	H. G. Kruse	89	3	..do..	1931
137-50-14adb1	Andrew Anderson	130+	3	..do..	Old
137-50-14adb2	.....do.....	130	3	..do..	Old
137-50-14bdc	H. H. Bjorke	134	.....	..do..	1932
137-50-14ccd	Christ Erickson	120	3	Jetted	1922
137-50-14ddc	Chris Stenberg	30	.....	Dug	....
137-50-15cdd	Henry Folstad	120	3	Jetted	1936
137-50-16add	Ole Braaten	90	4	..do..	1914
137-50-16dcd	Dahlen Bros.	110	3	..do..	1929
137-50-17cdd	John Dahlen	.....	6	..do..	1900
137-50-17dcc	Wm. Desmond	90	3	..do..	1941
137-50-18aad	Strohlow Estate	110	3	..do..	1932
137-50-18ddd	Henry Severson	140	3	..do..	....
137-50-19aaa	Anderson	260	3 to 2	..do..	....
137-50-19ddd	Christ Frosaker	246	3	..do..	1936

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
20	1939	D	Aquifer reported as sand. Supply reported inadequate.
16	1945	DS	Aquifer reported as sand. Water reported good, hard.
20	1945	DS	Do.
30	1935	S	Aquifer reported as sand and gravel.
3.52	9-11-47	DS	Water reported good; uses pail on standing; adequate for 40 head livestock
18	1939	S	Aquifer reported as gravel.
12	1934	D	Aquifer reported as sand.
4.50	9-16-47	DS	Water reported good, hard.
.....	....	S	Reported unfit for drinking.
.....	....	D	Water reported good, very hard.
15	9-16-47	DS	Aquifer reported as blue sand from 130 to 134 feet. Sand also reported from 80 to 84 feet. Water reported good, hard.
20	1931	S	Water reported good, hard.
.....	....	S	Water reported hard.
12	7-11-46	DS	Aquifer reported as fine gravel from 115 to 120 feet. Water reported good, hard.
20	7-11-46	DS	Aquifer reported as coarse sand from 87 to 90 feet. Water reported good, hard.
16	7-12-46	DS	Aquifer reported as fine sand. Water reported good, hard.
....	....	DS	Water reported good, hard.
20	1941	DS	Aquifer reported as fine gravel from 89 to 90 feet. Water reported as good, hard.
20	7-12-46	DS	Aquifer reported as black and gray, medium coarse sand from 106 to 110 feet. Water reported good, hard.
18	7-12-46	DS	Aquifer reported as fine sand from 138 to 140 feet. Water reported good, hard. See log.
20	7-12-46	DS	Water reported good, hard.
12	1936	DS	Aquifer reported as sand and gravel. Water reported slightly salty; adequate.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)		Type	Date completed
137-50-20ada	Ed. Overbee	98	4	Jetted	1936
137-50-20baa	Marie Jensen	250	2	..do..	1946
137-50-20c 2/	Ted M. Lee	277	3 to 2	Drilled	1935
137-50-20cdc	Henry Boreson	...	....	Jetted	....
137-50-20d1 2/	E. F. Erickson	126	3	Drilled	1938
137-50-20d2 2/	K. F. Thompson	90	18 to 12	Bored	1935
137-50-20ddd	Edwin Overbee	25	....	..do..	1946
137-50-21c 2/	Peter Lykken	14	42	Dug	1930
137-50-21d 2/	Om M. Huseby et al.	120	18 to 6	Bored	1931
137-50-21dab	Gilbert Overbee	35	16	..do..	1946
137-50-22adb	M. O. Sternberg	120	3	Jetted	1920
137-50-22baa	Ed. Kjos	280	3 to 2	..do..	1940
137-50-22bba	Milton Myhre	180	3	Drilled	Old
137-50-22dad	Kermit Hertsgaard	...	3	..do..	1939
137-50-23ddd	John Swenson	23.23	16	Bored	1930
137-50-24dcc	Wm. Nelson	85	3	Drilled	1938
137-50-25bca 1/	....	430	...	.....	...
137-50-26aaa	Grant Smeby	....	30	Dug	Old
137-50-26ada	Peter Edwardson	40	30	Dug and bored	Old
137-50-26dad	E. F. Brakke	35	36	Dug	Very old
137-50-27ccb	M. C. Sand	146	3	Jetted	Old
137-50-28cbc	USGS test 5 LR	62	4	Drilled	1948
137-50-28ccc	USGS test 6 LR	47	4	..do..	1948

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
20	1936	U	Aquifer reported as coarse sand. Well was drilled to 240 feet, finished at 98 feet.
19	7-1-46	DS	Aquifer reported as fine gravel from 247 to 250 feet. Water reported good, medium hard. See log.
20	1939	DS	Aquifer reported as shale.
....	....	DS	Water reported good, hard.
20	1939	DS	Supply reported inadequate.
....	....	DS	Aquifer reported as sand. Supply reported inadequate.
....	....	....	
8.5	1939	DS	Aquifer reported as sand.
80	1939	S	Supply reported inadequate.
15	7-12-46	....	
....	....	S	Aquifer reported as gravel. Water reported as good, hard.
....	....	D	Aquifer reported as fine sand. Water reported as good, hard.
6	9-17-47	DS	Water reported good, medium hard; inadequate supply.
....	....	DS	Water reported as good, hard.
16.65	9-15-47	U	Aquifer reported as quicksand from 20 to 24 feet. Water reported as good, hard.
16	9-47	S	Aquifer reported as sand and gravel from 82 to 85 feet. Water reported as good, hard.
7	....	....	Hardpan at 75 feet; some stones, water below hardpan; 7 feet green stuff (shale) at 400 feet; stopped in hard rock at 450 feet.
....	....	DS	Water reported hard; adequate for house and chickens.
....	....	D	Water reported to turn brown on standing; supply reported inadequate.
20	1940	DS	Water reported hard; turns brown on standing.
50	9-47	DS	Water reported medium hard; supply inadequate.
....	....	U	Hole refilled. See log.
....	....	U	Do.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)		Type	Date completed
156-50-29 2/	Tolloff Braaton	16	60	Dug	1934
157-50-29aca	Kindred No. 3	78	16	Bored	1935
157-50-29cac	Kindred No. 4	70	16	..do..	1935
157-50-29cda1	Kindred No. 2	95	16	..do..	1935
157-50-29cda2	USGS test 23	286	5	Drilled	1947
157-50-29d 2/	Gust Bratong	28	12	Bored	1939
157-50-29dab	USGS test 24	290	5	Drilled	1947
157-50-29dad1	USGS test 4	72	4	..do..	1948
157-50-29dad2	USGS test 26	60	4	..do..	1947
157-50-29dad3	USGS test 31	60	4	..do..	1947
157-50-29dad4	Kindred No. 6	45	8	..do..	4-48
157-50-29dad5	USGS test 3	52	4	..do..	1948
157-50-29dbb1	Solvick No. 1	102	....	......	....
157-50-29dbb2	Solvick No. 2	175	....	......	....
157-50-29dbc1	2/ Alfred Elstad	18	12	Bored	1936
157-50-29dbc2	2/ Andrew Olerud	18	12	..do..	1931
157-50-29dbc3	2/ H. H. Bjorke	20	12	..do..	1934
157-50-29dbd1	Kindred No. 1	235	4	Jetted	1936
157-50-29dbd2	Evingson Estate	....	3 to 2	..do..	....
157-50-29dca1	2/T. N. Hagen	22	12	Bored	1934
157-50-29dca2	2/Ole Tappen	16	12	..do..	1915
157-50-29dca3	USGS test 1	67	4	Drilled	1948
157-50-29dcd	2/Fred E. Russell	15	12	Bored	1914
157-50-29dda1	USGS test 27	60	4	Drilled	1947
157-50-29dda2	USGS test 28	50	4	..do..	1947
157-50-29dda3	USGS test 29	60	4	..do..	1947
157-50-29dda4	USGS test 30	30	4	..do..	1947
157-50-29dda5	Kindred No. 5	40	16	Bored	1944
157-50-29ddb	USGS test 32	50	4	Drilled	1947
157-50-29ddc1	USGS test 2	67	4	..do..	1948
157-50-29ddc2	USGS test 7	47	4	..do..	1948
157-50-29ddc3	Kindred No. 7	47	8	..do..	1948
157-50-30aac	Oscar Erickson	127	3	Jetted	1952

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
7.5	1939	DS	
11.33	10-23-47	M	Aquifer reported as gravel. Water reported hard; well condemned. See water analysis.
8.87	10-23-47	M	Water reported hard; well condemned. See water analysis.
20	7-12-46	M	Aquifer reported as sand. Water reported hard. See water analysis.
....	....	U	Hole refilled. See log.
10	1939	S	Aquifer reported as sand.
....	....	U	Hole refilled. See log.
....	....	U	Do.
....	....	U	Do.
....	....	U	Do.
8.3	4-19-48	M	See water analysis.
....	....	U	Hole refilled. See log.
....	....	...	See log.
....	....	...	Do.
9	1939	D	Aquifer reported as sand.
16	1939	D	Do.
12	1939	S	Do.
9.78	10-23-47	M	Aquifer reported as fine sand from 229 to 235 feet. Water reported good, hard. See analysis.
....	....	DS	Water reported good, medium hard.
15	1939	S	Aquifer reported as sand.
10	1939	S	Do.
....	....	U	Hole refilled. See log.
13.5	1939	D	Aquifer reported as sand.
....	....	U	Hole refilled. See log.
....	....	U	Do.
....	....	U	Do.
.....	....	U	Do.
10	1944	M	Water reported hard. See water analysis. See log.
....	....	U	Hole refilled. See log.
....	....	U	Do.
....	....	U	Do.
9.32	12-3-48	M	
14	7-11-46	DS	Aquifer reported as fine sand from 126 to 127 feet. Water reported good, hard. See log.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)		Type	Date completed
137-50-30bcb	O. C. Olson	162	3	Jetted	1928
137-50-30cad	Herman Olson	180	3	..do..	1938
137-50-30dad	A. & S. Grangaard	105	3	..do..	1937
137-50-30dbc	USGS test 23	255	5	Drilled	1947
137-50-31aaa	Rudolph Homry	185	3 to 2	Jetted	1932
137-50-31daa1	Evingson Estate	140	6 to 2½	..do..	1932
137-50-31daa2	.....do.....	75	16	Bored	....
137-50-32aab	Norris Swenson	270	3	Jetted	1938
137-50-32ada	Edwin Overboe	98	4	..do..	1936
137-50-32baa	Iver Lokken	105	16 to 8	Bored	1942
137-50-32cda	Elder Erickson	105	3	Jetted	1934
137-50-33acd	Andrew Ulsaker	142	3	..do..	1933
132-50-33bba	USGS test 8 LR	62	4	Drilled	1948
137-50-33ccd	James Barfuss	28	...	..do..	....
137-50-33dda	L. A. Perhus	100	15	Bored	....
137-50-34dcc	....	....	...	Drilled	....
137-50-35baa	Oscar Ulsaker	26.30	18	Bored	Old
137-50-35bcc	C. Stenberg	85	6 to 5	Jetted	....
137-50-35cca	Joe Fjelstad	100	3	Drilled	1945
137-50-36abb	Bernt J. Traaa	128	3 to 2½	..do..	1908

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
7	7-11-46	DS	Aquifer reported fine sand from 160 to 162 feet. Water reported good, medium soft. See log.
14	7-11-46	DS	Aquifer reported as sand and gravel. Water reported good, medium soft. See water analysis.
10	1937	S	Aquifer reported as coarse sand from 102 to 105 feet. Water reported good, medium soft. See log. See water analysis.
....	....	U	Hole refilled. See log.
40	1932	S	Aquifer reported as fine dirty sand from 184 to 185 feet. Water reported good, hard. Well drilled to 257 feet; finished at 185 feet. See log.
0.75	1932	U	.
20	7-11-46	S	Water reported hard; unfit for human consumption.
20	1938	DS	Water reported good, hard.
20	1936	D	A quifer reported as fine sand from 95 to 98 feet. Water reported good, hard. See log.
10	7-11-46	DS	A quifer reported as fine sand from 100 to 105 feet. Water reported good, hard.
20	7-11-46	DS	Aquifer reported as coarse sand from 103 to105 feet. Water reported good, medium hard. See log.
50	7-12-46	DS	Water reported hard.
....	....	U	Hole refilled. See log.
....	....	D	Water reported good, hard; adequate supply.
15.1	9-15-47	D	Aquifer reported as sand from 90 to 100 feet. Water reported good, hard. See log.
....	....	S	
19.26	9-15-47	D	Water reported hard; supply inadequate.
35	1944	DS	Water reported good, hard; supply inadequate.
15	1945	DS	Well pumps dry easily.
2	1947	DS	A quifer reported as sand from 124 to 128 feet. Water reported good, soft; adequate for 50 head livestock.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)		Type	Date completed
137-50-36cba	Einar Ersted	118	3	Drilled	1924
137-51-1	S. Severson	108	...	Jetted	....
137-51-1	A. P. Heuer	103	2	..do..	....
137-51-1	P. F. Fredrickson	166	2	..do..	....
137-51-1	......do......	138	2	..do..	....
137-51-1	W. Knobel	109	2	..do..	....
137-51-2aab	Clarence Steinburgh	150	3	Drilled	Old
137-51-4ddd	R. J. Schroeder	190	36 to 3	..do..	Very old
137-51-5bab	Milton Hans	90	36	Dug	....
137-51-6dda	Floyd Plath	70	3	Dug	1917
137-51-7bbb	August Plath	65	36	..do..	1917
137-51-8ddd	Fred Kellerman	70	36	..do..	Old
137-51-10aac	Wm. Rohde	90	3	Jetted	1945
137-51-10bcb	Olson Bros.	207	3	Drilled	1917
137-51-10ccc	Oliver Vangsness	...	18	Bored	Old
137-51-10ddd 1/	....	206	...	.....	....
137-51-11aad	B. J. Sather	260	3	Jetted	1922
137-51-11ccc	Edwin Simonson	185	3	..do..	....
137-51-12bdd	Mickleson	216	...	..do..	....
137-51-12ddd	Mrs. Josie Jensvor	200	3	..do..	Old
137-51-13aba	Ingvald Broff	180	3	..do..	....
137-51-14acb	Norman Liudahl	400	4	Drilled	....
137-51-14bab	Melvin Enger	250	3	Jetted	1909
137-51-14bbb	Herman Appel	90	36 to 2	Dug	1917
137-51-14dac	Ingolf Sandbeck	...	2	Jetted	1940

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
8	1924	D	Water reported good, hard; supply inadequate.
20	9-16-47	D	Water reported good, hard; adequate supply.
15	9-16-47	D	Aquifer reported as gravel. Water reported good, hard.
16	9-16-47	D	Aquifer reported as sand.
24	9-16-47	D	A quifer reported as gravel. Water reported good, adequate.
18	9-16-47	D	Aquifer reported as gravel. Water reported good, adequate.
8	9-16-47	DS	Water reported good.
2.66	9-16-47	DS	Water reported hard; turns brown on standing. Used to flow.
12	1947	DS	Water reported good, hard; adequate for 150 head livestock.
10	9-16-47	DS	Water reported good, hard.
30	1947	DS	Water reported good, hard; supply inadequate.
45	9-17-47	S	Water reported poor; very hard.
...	....	DS	Water reported good, soft.
3	9-47	DS	Water reported good, hard; adequate for 50 head livestock. Used to flow.
7.69	9-17-47	U	
Flow	When drilled	...	Water reported salty.
25	9-47	DS	Water reported good, medium hard. See water analysis.
6	9-47	DS	Water reported good, hard; turns red on standing. Used to flow.
12	....	U	
5	9-47	DS	Water reported good, hard.
30	7-11-46	DS	Do.
15	9-47	DS	Water reported good, soft.
5	9-47	DS	Aquifer reported as sand. Water reported good, medium hard; adequate for 50 head livestock. Used to flow.
16	1945	DS	Aquifer reported as sand from 85 to 90 feet. Water reported as good, hard; turns brown on standing; unfit for laundry use.
....	....	DS	Water reported good, hard.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)		Type	Date completed
137-51-15ddd 1/	....	465	....	......	....
137-51-15ddd	Alfred Simonson	...	3	Drilled	1933
137-51-16a 2/	J. and O. T. Ronico	242	2	..do..	1936
137-51-16bba	Ervin Johnson	300	2	Jetted	Old
137-51-16ddd	John E. Myhre	180	3	..do..	1920
137-51-17aaa	Fred Kellerman	190	1½	Drilled	Old
137-51-18add	.....do.....	84	18	Bored	1935
137-51-18cbb	Reinhold Groell	55	40 x 40	Dug	....
137-51-19bcc	Edwin Nygaard	300	2	Jetted	Old
137-51-20aad 1/	....	270	....	......	....
137-51-20baa	Morris Lohren	100	18	Bored	1930
137-51-20d 2/	Ed and H. H. Nygaard	133	3	..do..	1939
137-51-20ddd	Ed Nygaard	....	3	Jetted	Old
137-51-21bcc	Conrad Nygaard	180	2	..do..	Old
137-51-21dcc1	Irvin Johnson	80	2	..do..	1947
137-51-21dcc2	.....do.....	90	18	Bored	1931
137-51-22cbb	Floyd Nygaard	300	3	Jetted	Old
137-51-22ddd	W. C. Nettum	160	6	..do..	Old
137-51-23bca	A. N. Luidahl	....	3	Drilled	Old
137-51-24bab	Peter Fredrickson	80	6	Jetted	1900
137-51-24ddd 1/	....	160	....	......	....
137-51-24ddd	Peter Boreson	180	3	Jetted	Old
137-51-25ccc	Conrad Trom	180	2	..do..	....
137-51-25ddd	Peter Boreson	180	2	..do..	1905
137-51-26abd	Ole Jordet	165	3 to 2	..do..	1930
137-51-26adb	John Nettum	100	2	Jetted	....
137-51-26dda	Tom Nelson	...	3	..do..	1935
137-51-27c 2/	Arthur Sand	128	3	Drilled	1939
137-51-27cbc	....do....	140	3	Jetted	1938
137-51-27ddd	M. L. Vangarud	250	3	..do..	Old

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
....	....	...	No flow. Hardpan at 82 feet.
16	9-17-47	DS	Water reported good, medium hard.
Flow	When drilled	DS	See water analysis.
..do..	9-17-47	DS	Water reported soft, salty.
..do..	9-17-47	DS	Aquifer reported as gray sand; water reported salty, hard.
1.5	9-17-47	DS	Well reported to have flowed formerly.
50	9-17-47	S	Water reported poor, hard; supply inadequate.
15	9-17-47	LS	Water reported good; supply adequate.
Flow	When drilled	DS	Water reported good, hard.
..do..	.....do.....	...	Light flow.
14	9-17-47	DS	Water reported fairly soft, good.
10	....	DS	
5.4	9-17-47	DS	Water reported good, medium hard.
Flow	When drilled	DS	Water reported good, hard; supply adequate
2	9-17-47	D	Aquifer reported as coarse sand and gravel from 70 to 80 feet.
5	9-17-47	S	Aquifer reported as sand from 87 to 90 feet.
Flow	When drilled	DS	Water reported salty, fairly soft; adequate flow.
....	....	U	Water reported good, soft.
8	9-17-47	DS	Well reported to have flowed formerly.
....	....	DS	Water reported as good, hard.
....	....	...	Hardpan at 84 feet.
15	9-47	DS	Well reported to have flowed formerly.
6	1936	DS	Water reported as good, hard.
14	7-11-46	DS	Water reported good. See analysis.
6	1930	DS	Aquifer reported as medium coarse sand from 162 to 165 feet. Water reported as good, soft. Well drilled to 400 feet; finished at 165 feet. See log.
5	7-11-47	DS	Water reported good, hard.
....	....	DS	Do.
0	1939	...	
32	1938	DS	Water reported good, hard; adequate supply.
1	9-47	DS	Water reported good, medium hard; adequate supply.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)		Type	Date completed
157-51-28abb	Clarence Johnson	90	36	Bored	....
157-51-28bba1	Mrs. A. Vigen	120	6	Jetted	Old
157-51-bba2	.....do.....	120	18	Bored	....
157-51-28bbb 1/	....	120	...	.....	....
157-51-28cdc 1/	John Anduik	80	2	Jetted	Old
157-51-28dcc	Melvin Anderson	96	2	..do..	1914
157-51-29dcb	Delman Alsager	...	2	Driven	Old
157-51-29dcc	John Taylor	147	3	Jetted	1926
157-51-30aaa	Fred Heidenreich	300	2	..do..	Old
157-51-30ccb	Ed Hans	12	36 x 36	Dug	Old
157-51-30dcc	Raymond Thompson	20	1½	Driven	....
157-51-31bdb	Lester Olson	60	3	Jetted	1947
157-51-32aca	Edwin Lunder	24	36	Dug	....
157-51-32daa	Eric Swiggum	56	2	Jetted	1946
157-51-33dcd	USGS test 11 LR	42	4	..do..	1948
157-51-33ddd	Melvin Stenseth	14.9	36 x 36	Dug	....
157-51-34aaa	Alvin Simons	230	3	Jetted	Old
157-51-34aab 1/	....	300	...	......	....
157-51-34bbd 1/	....	148	...	......	....
157-51-34bbd	Alvin Tweet	135	3	Drilled	Old
157-51-34c 2/	Erick Lee	...	...	..do..	1939
157-51-34ccc1	....do....	343	3	Jetted	1938
157-51-34ccc2	USGS test 10 LR	52	4	Drilled	1948
157-51-34ddd1	USGS test 9 LR	62	4	..do..	1948
157-51-34ddd2	Kermit S. Johnson	126	2	Jetted	1946
157-51-35cdd	Thoraal Andruck	200	2	..do..	Old

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
2.85	9-17-47	DS	Water reported good, hard; adequate supply.
Flow	When drilled	DS	Water reported slightly salty, soft.
10.7	9-17-47	S	Water reported poor, hard.
Flow	When drilled	...	Small flow. Hardpan at 80 feet. Very hard just above water.
..do..	.....do.....	DS	Water reported good, hard.
..do..	.....do.....	DS	Water reported of good quality.
....	....	DS	Water reported good, hard; adequate supply.
2	1926	DS	Water reported good, medium hard.
Flow	9-17-47	DS	Water reported fairly salty, hard.
6	9-47	S	Aquifer reported to be sand. Water reported poor.
7	9-47	DS	Aquifer reported to be fine sand. Red substance precipitates from water.
25	9-47	DS	Water reported fair, hard.
8.5	9-17-47	DS	
15	9-47	DS	Water reported good, medium hard.
....	....	U	Hole refilled. See log.
12.82	9-17-47	S	Supply reported inadequate.
4	9-47	DS	Water reported good, hard.
Flow	When drilled	...	
..do..	....do....	...	Small supply
6	9-17-47	U	
16	1939	...	Aquifer reported as sandstone.
75	9-47	DS	Water reported fairly soft and salty.
....	....	U	Hole refilled. See log.
....	....	U	Do.
10	9-46	U	Sand reported in water; supply inadequate.
20	9-47	DS	Water reported soft, salty.

1/ Hall, C. M., Willard, D. E., Description of the Casselton-Fargo quadrangle: U.S. Geol. Survey Geologic Atlas, Casselton-Fargo folio (no. 117), p. 7, 1905.
2/ From well inventory made by county assessors in 1939 as part of State-wide well inventory under Works Projects Administration.

LOGS OF WELLS AND TEST HOLES IN THE KINDRED AREA

136-50-7ccc
Graff Brothers

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand	20	20
	Clay	54	74

136-50-15dca2
P. O. Eckre

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand..........................	3	3
	Clay..........................	49	52
	"Quicksand"........................	1	53
Till and associated glacioaqueous deposits (?):			
	Clay and rocks..................	67	120
	Sand..........................	2	122

136-50-32aaa
D. P. Thue

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand..........................	7	7
	"Quicksand"........................	5	12
	Clay, blue......................	7	19
	No log..........................	33	52

136-50-32dca
Carl Erickson

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand..........................	10	10
	Clay..........................	40	50
	Sand..........................	10	60

136-51-5aba
USGS test 1R

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Clay, cream, silty	19	20
	Sand, very light-gray, fine	10	30
	Silt, very light-gray, clayey, little very fine sand	70	100
	Clay, light-gray, silty, compact at base........................	68	168
Till and associated glacioaqueous deposits:			
	Clay, medium light-gray, sandy, gravelly, mostly clay and shale.	43	211
	Sand, coarse to medium, and gravel, fine to medium, shale pebbles, and a little coal	3	214
	Clay, very light-gray, sandy, gravelly	21	235
	Clay, dark-gray, sandy, gravelly..	30	265
Cretaceous shale or Pleistocene lake clay (?):			
	Clay, very dark-gray, little sand and gravel	77	342
	Clay, dark-gray, shaly	4	346
	Clay, streaked gray, gypsiferous..	5	351
	Clay, dark-gray, sandy, gravelly..	6	357
"Granite":			
	"Granite," white, decomposed	8	365

136-51-7ddd
USGS test 2R

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black or brown	2	2
	Silt, yellow to buff, clayey, sandy	10	12
	Clay, light-gray, silty, sandy ...	186	198
Till and associated glacioaqueous deposits:			
	Clay, medium gray, sandy, gravelly.	99	297
Cretaceous shale or older Pleistocene lake clay (?):			
	Clay, medium-gray, gypsum crystals, sandy, gravelly	73	370

157-50-2cdd
Magnus Simonson

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand, fine	20	20
	Clay	35	55
Till and associated glacioaqueous deposits (?):			
	Gravel, medium, with some fine sand	5	60

157-50-9dcc2
Ingval Sorboll

Formation	Material	Thickness	Depth
Lake Agassiz deposits and drift, undifferentiated:			
	Clay, with some hardpan	234	234
	Sand, fine	6	240

157-50-18ddd
Henry Severson

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, blue	120	120
Till and associated glacioaqueous deposits:			
	Hardpan	18	138
	Sand, fine	2	140

157-50-20baa
Marie Jenson

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, blue	2-	20
	Clay, yellow	15	35
	Clay, blue	50	85
Till and associated glacioaqueous deposits:			
	Hardpan	35	120
	Clay, gray	115	235
	Sand, fine	9	244
	Hardpan	3	247
	Gravel, fine	3	250

137-50-28dbc
USGS test 5

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay, black, sandy.......	2	2
	Silt and clay, light grayish-brown, sandy, shell fragments; coal flakes from 27 to 32 feet..	30	32
	Sand, light-gray, silty, snail shells at 37 feet...............	10	42
	Clay and silt, light-gray, sandy, some gravel, snail shells.......	5	47
	Clay and silt, light-gray, sandy, shell fragments.................	10	57
	Clay, light-gray, silty..........	5	62

137-50-28ccc
USGS test 6 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay, gray to black, silty.........................	2	2
	Clay, light-brown, silty, sandy, few shell fragments............	15	17
	Clay and silt, yellowish-brown, slightly sandy, very few shell fragments.....................	10	27
	Clay and silt, light-gray, sandy..	20	47

137-50-29cda2
USGS test 23

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black....................	2	2
	Clay, buff, silty, occasional gypsum crystals; iron concretions at 45 feet..........................	48	50
	Clay, light-gray, silty..........	33	83
Till and associated glacioaqueous deposits:			
	Clay, gray, sandy, gravelly.......	9	92
	Gravel, gray, clayey.............	2	94
	Clay, gray, sandy, gravelly.......	129	223
	Gravel, gray, sandy, clayey.......	50	273
"Granite":			
	"Granite," white, decomposed......	13	286

137-50-29dab
USGS test 24

Formation-	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black....................	2	2
	Sand, light-brown, medium to coarse, clayey, gravelly...............	5	7
	Clay, buff, silty, sandy, shell fragments......................	25	32
	Clay, light-gray, silty, sandy....	54	86
Till and associated glacioaqueous deposits:			
	Clay, gray, silty, sandy, gravelly	60	146
	Gravel, gray, fine to medium, clayey.........................	2	148
	Clay, gray, sandy, gravelly.......	72	220
	Gravel, gray, clayey..............	5	225
	Clay, gray, sandy, gravelly.......	52	277
"Granite":			
	"Granite," very light gray, decomposed........................	13	290

137-50-29dad2
USGS test 3

Formation-	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay and silt, gray.......	2	2
	Clay, buff to light olive-gray, silty.........................	25	27
	Sand, light-gray, very fine, very silty.........................	5	32
	Clay, gray, silty, sandy..........	10	42
	Clay, light olive-gray, slightly silty.........................	10	52

157-50-29dad3
USGS test 4

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay grayish-black, sandy	2	2
	Clay and silt, light-brown, sandy, a little gravel at 12 feet.......	15	17
	Sand, light-brown, silty..........	5	22
	Silt, light grayish-brown, very sandy.........................	10	32
	Sand, light-gray, very fine, silty, many coarse sand-size rounded shale pebbles from 37 to 42 feet	10	42
	Silt and clay, light-gray, sandy, shale as above, coal fragments; pelecypod shells at 52 feet.....	20	62
	Clay, light-gray, silty, sandy....	10	72

157-50-29dad4
USGS test 26

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black....................	2	2
	Clay, buff, sandy, silty..........	18	20
	Sand, light-brown to gray, very fine to coarse, very silty; less silt and coarser sand from 40 to 45 feet......................	35	55
	Clay, gray, silty, sandy..........	5	60

157-50-29dad5
USGS test 31

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black....................	2	2
	Clay, buff, silty, sandy, calcareous.....................	15	17
	Sand, light-brown, fine, silty....	19	36
	Sand, gray, fine, interbedded with clay.........................	4	40
	Sand, gray, fine to medium........	7	47
	Clay, gray, silty................	13	60

157-50-29dbb1
Solvick No. 1

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, light olive-gray............	15	15
	Clay, tannish-gray; some selenite.	7	22
	Clay, tan, sandy..................	8	30
	Clay, light-gray..................	45	75
	Clay, light-gray; small amounts of gravel and sand.................	5	80
Till and associated glacioaqueous deposits:;			
	Clay, gray, sandy, gravelly.......	18	98
	No sample	2	100
	Sand, bluish-gray, composed mainly of shale, dolomite, and/ or limestone,......................	2	102

157-50-29dbb2
Solvick No. 2

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, light-gray, selenite flakes, some limonite nodules near surface, few shell fragments.......	45	45
	Sand, grayish-white, gravelly.....	5	50
	Clay, light-olive-gray, selenite flakes, shell fragments.........	20	70
	No sample........................	5	75
	Clay, light olive-gray, small amount coarse sand and fine gravel.........................	5	80
Till and associated glacioaqueous deposits:			
	Clay, light-gray, silty, sandy, gravelly, coal flakes...........	20	100
	Sand, white, fine to very coarse, mostly medium, gravelly.........	5	105
	Clay, gray, silty, sandy, gravelly, coal chips............	15	120
	Sand, mostly fine with some coarse silty, gravelly.................	5	125
	Clay, gray, silty, sandy, gravelly, coal chips.....................	5	130
	Clay, gray, silty, sandy, coal chips..........................	25	155
	Sand, gray, mainly shale and limestone, clayey, gravelly, many wood and coal fragments.........	5	160
	Sand, light-gray, fine to very coarse, few pebbles.............	5	165
	Sand, tan, very fine to very coarse, mostly fine to medium...........	3	168
	Sand, tan to gray, fine, much shale, coarse sand to fine sand........	2	170
	Clay, gray, silty, gravelly, sandy	5	175

157-50-29dca
USGS test 1

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay, black, sandy.......	2	2
	Silt, grayish-buff to buff, clayey, sandy..........................	20	22
	Clay, light olive-gray, silty, sandy..........................	10	32
	Clay and silt, light olive-gray...	35	67

157-50-29dda1
City of Kindred No. 5

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay..............................	14	14
	Sand, red.........................	4	18
	Sand, gray, coarser from 28 to 29½ feet..........................	17	35
	No log............................	5	40

157-50-29dda2
USGS test 27

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black....................	2	2
	Clay, buff, silty, sandy, very calcareous......................	18	20
	Sand, buff to gray, very fine, very silty......................	30	50
	Clay, gray, silty, sandy..........	10	60

157-50-29dda3
USGS test 28

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black....................	2	2
	Clay, yellow, silty, sandy, gravelly........................	17	19
	Sand, yellow, very fine to fine, silty..........................	6	25
	Clay, gray, silty, sandy..........	25	50

157-50-29dda4
USGS test 29

Lake Agassiz deposits:		
Topsoil, black....................	2	2
Clay, buff, silty, sandy,.........	12	14
Sand, fine, clayey................	6	20
Sand, gray, fine..................	12	32
Clay, gray, sandy, silty..........	28	60

157-50-29dda5
USGS test 30

Lake Agassiz deposits:		
Topsoil, black....................	2	2
Silt, grayish-brown to buff, clayey, sandy..................	17	19
Sand, light-brown, fine to medium, some small rounded shale pebbles, some coal.......................	11	30
Sand, light-brown, fine to very fine, silty......................	5	35
Clay, light-gray, silty...........	15	50

157-50-29ddb
USGS test 32

Lake Agassiz deposits:		
Topsoil, black....................	2	2
Clay, buff, sandy, silty..........	17	19
Sand, fine, silty.................	6	25
Clay, gray, sandy.................	10	35
Clay, gray........................	15	50

157-50-29ddc1
USGS test 2

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, silt and clay, black, sandy	2	2
	Silt and clay, buff, sandy, shell fragments at 7 feet	10	12
	Sand, buff, very fine, silty	20	32
	Sand, light-gray, fine to medium, silty	5	37
	Sand, whitish-gray, very slightly silty	5	42
	Sand, light-gray, silty	5	47
	Silt and clay, light-gray, sandy	20	67

157-50-29ddc2
USGS test 7

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay and silt, grayish-black, sandy	2	2
	Clay and silt, grayish-brown, sandy, shell fragments	10	12
	Sand, yellowish-brown, very fine, silty, shell fragments	10	22
	Silt and clay, gray, sandy, shell fragments from 22 to 37 feet	25	47

157-50-30aac
Oscar Erickson

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay	90	90
Till and associated glacioaqueous deposits:			
	Hardpan	10	100
	Clay, blue	26	126
	Sand, fine	1	127

137-50-30bcb
Ole Olson

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay..............................	90	90
Till and associated glacioaqueous deposits:			
	Hardpan..........................	65	155
	Clay..............................	5	160
	Sand, fine........................	2	162

137-50-30dad
A. and S Grangaard

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, blue........................	102	102
Till and associated glacioaqueous deposits:			
	Sand, coarse......................	3	105

137-50-30dbc
USGS test 25

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black....................	2	2
	Clay, buff, silty, sandy, gypsiferous....................	31	33
	Clay, light-gray, silty, sandy....	51	84
Till and associated glacioaqueous deposits:			
	Clay, gray, sandy, gravelly.......	87	171
	Gravel, gray, clayey, sandy, mostly shale....................	2	173
	Clay, gray, sandy, gravelly, well indurated......................	75	248
"Granite":			
	"Granite," very light gray, decomposed......................	7	255

137-50-31aaa
Rudolph Henry

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, blue	140	140
Till and associated glacioaqueous deposits:			
	Hardpan	20	160
	Hardpan and clay, blue	24	184
	Sand	1	185
	Clay	72	257

137-50-32ada
Edwin Overboe

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay	70	70
Till and associated glacioaqueous deposits:			
	Hardpan	25	95
	Sand, fine	3	98

137-50-32cda
Elder Erickson

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, blue	102	102
	No log	1	103
Till and associated glacioaqueous deposits:			
	Sand, coarse	2	105

157-50-33bba
USGS test 8

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay and silt, black, sandy, shell fragments..........	2	2
	Sand, gray, very fine to fine, silty, shell fragments................	10	12
	Silt, light-brown, clayey, shell fragments from 12 to 17 feet and 22 to 27 feet................	15	27
	Sand, light-gray, silty, shell fragments......................	5	32
	Silt, light brownish-gray, clayey, very sandy, shell fragments, snail shells at 32 feet.........	5	37
	Sand, light-gray, fine, silty, shell fragments.................	10	47
	Silt, light-gray, sandy, few shell fragments, flat snail shell at 47 feet.........................	15	62

157-50-33dda
L. A. Porhus

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand............................	10	10
	Clay............................	80	90
Till and associated glacioaqueous deposits:			
	Sand............................	10	100

157-51-26abd
Ole Jordet

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, blue.......................	85	85
Till and associated glacioaqueous deposits:			
	Hardpan.........................	35	120
	Clay, blue.......................	30	150
	Hardpan.........................	12	162
	Sand, medium to coarse...........	3	165

137-51-33dcd
USGS test 11

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Silt, yellowish-brown, clayey, sandy	7	7
	Silt, yellowish-brown, clayey	5	12
	Sand, yellowish-brown, very fine, very silty	10	22
	Silt, tannish-brown to light-gray, clayey	15	37
	Clay, light olive-gray, silty	5	42

137-51-34ccc
USGS test 10

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand, yellowish-brown, very fine to fine, silty	12	12
	Silt, light-gray, sandy, large gravel, one large pebble, snail shells from 22 to 27 feet	15	27
	Silt, light-gray, shells	15	42
	Clay, light olive-gray, silty	10	52

137-51-34ddd
USGS test 9

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay and silt, black, sandy	2	2
	Sand, tannish-brown, very fine, silty, shell fragments	10	12
	Clay and silt, yellowish-brown, sandy, very few shell fragments, none from 22 to 27 feet	20	32
	Silt, creamish-brown, clayey	5	37
	Silt, light olive-gray, clayey	25	62

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